Co-funded by the Intelligent Energy Europe
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Contract N°: IEE/11/845/SI2.616378

Bringing Europe and Third countries closer together through renewable Energies

BETTER

WP3: North Africa Case Study Final Report

Project Coordinator: ***CIEMAT***

*Work Package **3** Leader Organization:* ***DLR***

*Contributions from**: CIEMAT, JR, OME, PIK***

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PREFACE

BETTER intends to address RES cooperation between the EU and third countries. The RES Directive allows Member States to cooperate with third countries to achieve their 2020 RES targets in a more cost efficient way. The core objective of BETTER is to assess, through case studies, stakeholders involvement and integrated analysis, to what extent this cooperation *can help Europe achieve its RES targets in 2020 and beyond, trigger the deployment of RES electricity projects in third countries and create win-win circumstances for all involved parties.*

The case studies focusing on **North Africa, the Western Balkans and Turkey** will investigate the technical, socio-economic and environmental aspects of RES cooperation. Additionally, an integrated assessment will be undertaken from the "EU plus third countries" perspective, including a quantitative cost-benefit evaluation of feasible policy approaches as well as strategic power system analyses. Impacts on the achievement of EU climate targets, energy security, and macro-economic aspects will be also analysed.

The strong involvement of all relevant stakeholders will enable a more thorough understanding of the variables at play, an identification and prioritisation of necessary policy prerequisites. The dissemination strategy lays a special emphasis on reaching European-wide actors and stakeholders, well, beyond the target area region.

PROJECT PARTNERS

N°	Participant name	Short Name	Country code
CO1	Centro de Investigaciones Energéticas, Tecnológicas y Medioambientales	CIEMAT	ES
CB2	German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt e.V.)	DLR	DE
CB3	Energy Research Centre of the Netherlands	ECN	NL
CB4	JOANNEUM RESEARCH Forschungsgesellschaft mbH	JR	AT
CB5	National Technical University of Athens	NTUA	GR
CB6	Observatoire Mediterranéen de l'Energie	OME	FR
CB7	Potsdam Institute for Climate Impact Research	PIK	DE
CB8	Vienna University of Technology	TUWIEN	AT
CB9	United Nations Development Program	UNDP	HR

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1. Executive Summary

This final report describes the results of the North-Africa case study within the BETTER analysis framework. The goal of BETTER Work Package 3 is to assess the potential of the 4th cooperation mechanism in helping Europe to achieve its renewable electricity (RE) targets and to trigger the faster implementation of RE projects in North Africa (NA) by 2020 and beyond (www.better-project.net).

Within Chapter 1 we present an executive summary of our findings from the North Africa Case Study. Chapter 1.1 is related to RES-E expansion in North Africa, while Chapter 1.2 is related to RES-E exports from North Africa to Europe.

Later in this report in Chapter 2 we provide our findings regarding RES-E expansion in North Africa and how to achieve high renewable energy shares in the region in the medium and long term. Chapter 3 provides our findings concerning RES-E exports from North Africa to Europe and how barriers can be overcome to realize related infrastructures. The report is completed by Chapter 4 on socio-economic and environmental impact assessment and by Chapter 5 about the role of Article 9 for RES-E expansion.

1.1. SUMMARY AND CONCLUSIONS FOR RES-E EXPANSION IN NA

All North African countries have an outstanding potential for domestic RES-E generation. As an average, only about 1% of the existing potential would be needed even in the long term for satisfying own demands, leaving more than enough room for potential exports to other regions. RES-E resources, mainly wind and solar power, are characterized by being relatively cost effective. Solar resources based on easily storable solar thermal energy as used by Concentrating Solar Thermal Power technology (CSP) have particularly high added value because of being able to provide flexible power on demand without causing fluctuating input to the electricity grid.

At present, Morocco is the most appealing country for RES-E investment in North Africa, with fairly good infrastructure, a well-diversified economy, a well-developed banking sector, stable policy and strong GDP growth. Moreover, Moroccan RES-E policy and regulatory framework can even serve as good example for other countries for successful renewable energy deployment in the region.

According to our findings the following factors are key for successful RES-E implementation in North Africa:

- a fundamental recognition of the socio-economic benefits of RES-E as motivation for durable political and civil support;
- the ability to afford RES-E investments, either from national income, foreign aid or – preferably – from savings induced by the introduction of RES-E;

- a predictable and attractive national RE expansion plan;
- a reliable legal environment and streamlined permit procedures;
- establishment of efficient RE authorities;
- a national RES-E resource assessment program;
- identification of concrete sites for RES-E project development;
- establishment of a public core instrument for RE investment, like e.g. feed-in tariff system or tendered PPAs;
- a reduction of capital cost by public entities taking the risks out of RES-E projects, converting them in the best case into AAA investment opportunities. This can be achieved by reliable power purchase agreements backed by national and international guaranties (financial de-risking), by a reliable policy and legal framework (policy de-risking) and by the participation of public institutions in equity or other kinds of support (direct incentives). Short loan periods also help to reduce investment risks and capital cost;
- capacity building for RE in all sectors like technical, legal, finance etc.;
- financial and technical international cooperation.

As mentioned before, Morocco is at present the country that has realized most of the key success factors named above, and is on a good way of achieving its goals for solar and wind energy expansion, aiming at 40% RES-E share in 2020. Next important countries in North Africa for RES-E deployment are Egypt and Tunisia, followed by the oil and gas exporting countries Algeria and Libya.

1.2. SUMMARY AND CONCLUSIONS FOR RES-E EXPORTS FROM NA TO EU

There has been a certain confusion that has dominated the discussion about RES-E imports in the past years. The concept followed in the past years by some initiatives did not follow the original idea published in the frame of the TRANS-CSP study of the German Aerospace Center (DLR) in 2006, that recommended the installation of dedicated point-to-point High-Voltage-Direct-Current (HVDC) interconnections for the transfer of flexible power from concentrating solar power plants (CSP) commssioned specifically for that purpose and directly connected to European centres of demand.

On the contrary, past years developments were inspired by some kind of “supergrid” vision that resembled an almost ideal “copperplate” interconnection between all national electricity grids in Europe and North Africa that would allow for a compensation of almost any kind of fluctuating power input from cheap wind and solar energy sources.

However, some studies on that concept finally revealed that present electricity grids would have to be expanded by orders of magnitude between 8 (Germany) and 55 times (Spain) in order to allow for such transitions, seriously questioning the desirability and acceptability of such a concept. Finally, the idea of RES-E exports itself was abandoned because of such frustrating results.

Therefore, the original, more resilient concept of flexible solar electricity imports from CSP plants connected to European demand centers via point-to-point HVDC links must be re-established before significant advances in the frame of the 4th cooperation mechanism with respect to North Africa can be expected. Except oil and gas, North Africa simply has no other RES-E source with similar quality and added value like flexible power from CSP.

The striking similarity of such CSP-HVDC links with gas pipelines shows both the opportunities and the challenges of such large scale infrastructures (Figure 1). The Nord Stream gas pipeline project over the Baltic Sea, touching the interests of about ten different countries with different cultures and languages has been analyzed as a successful example for the implementation of such large scale infrastructure, and major key factors for success were identified.

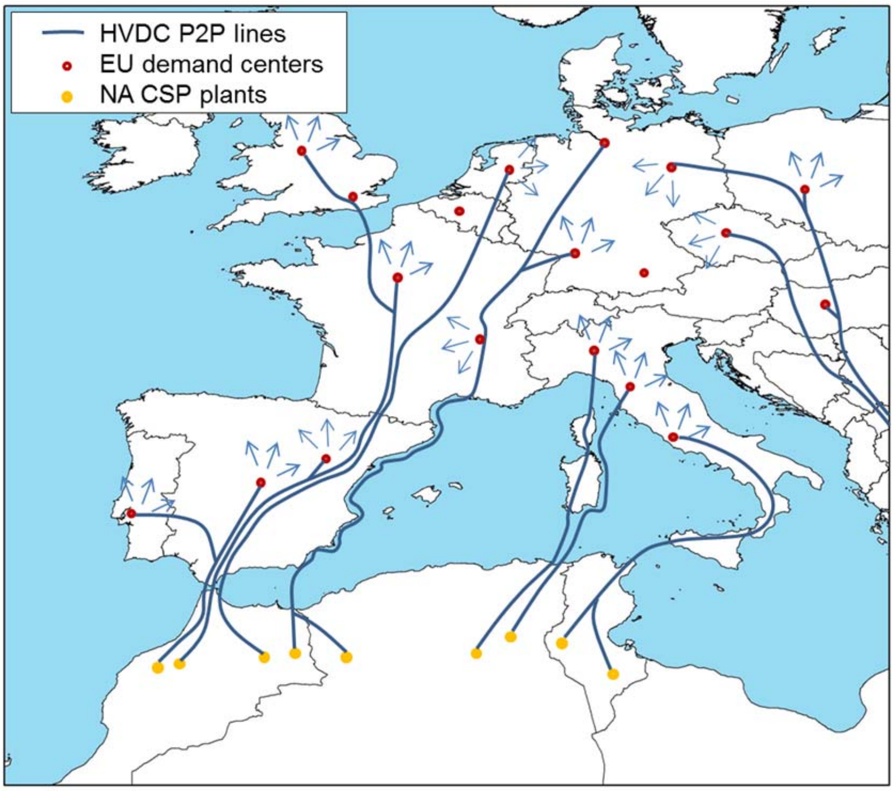


Figure 1: Draft illustrating the possible role of CSP-HVDC plants in the EU electricity network elaborated during the REACCESS project. The fat lines do not represent any planning results, but are only for illustration of the concept of point-to-point HVDC links connecting dedicated export CSP plants in North Africa to European centres of demand. The concept does not require any "supergrid" infrastructure but is fully additional to and compatible with the conventional electricity grid. For final results of the REACCESS study, please refer to (Trieb et al., 2009 and Trieb et al., 2012).

One of those success keys was the formation of a completely independent project company that on one side had full responsibility for the project, but on the other side could not be influenced by the specific interests of the related founding consortium members.

Another key was the existence of a very strong founding consortium accepting such an independent project company but at the same time willing and able to support it by equity investment and a strong technical support in the construction phase.

Finally, a reliable “power purchase agreement” (in that case a gas transport agreement) from creditable off-takers was the essential trigger to start the project and bring it into the real world.

Public involvement in form of a continuous and transparent dialogue with any kind of public and private stakeholders and visible reactions to public concerns, together with thorough environmental and socio-economic impact analysis and monitoring was another major key to success.

Success of such project will require major private engagement and public support in form of de-risking measures and must rely on a team of exceptional international experts capable of managing the extremely demanding communication and logistic challenges of such large scale international infrastructure projects.

Also financial participation of the public must be organized, that could take place in the frame of cooperative structures that would have to cope with the challenge of being international rather than regional or even local organizations as usual in cooperative finance.

Due to their intrinsic large scale, such projects cannot be demonstrated by small pilots (which by the way was another misconception that led to failure in the past years). The only way to demonstrate the feasibility of such enterprise before building it is an in-depth feasibility study that resiliently shows it’s technical, geographic, socio-economic and environmental implications. Such feasibility (pilot) study has been recommended within this report to be supported by the European Commission as an immediate action to be started latest in the year 2016.

Altogether it can be summarized that CSP-HVDC links from North Africa to Europe can become an important element of European power supply due to their high quality in terms of flexible and at the same time sustainable solar power. They are an important means to reduce the effort required to achieve high RES-E shares in Europe, by avoiding surplus generation and the related storage, grid expansion and backup capacity otherwise produced by volatile RES-E.

The extremely high investment for such a Euro-North African infrastructure of 16-25 billion Euro per unit is a significant challenge, as well as the question of acceptance. However it is also a big opportunity for an economic and cultural partnership of those regions. Citizen participation both in decisions and finance will be crucial for a successful implementation.

2. PROSPECTS FOR RES-E DEPLOYMENT IN NORTH AFRICA

All North African countries Morocco, Algeria, Tunisia, Libya and Egypt face rapidly rising energy demand, so that investments in energy infrastructure especially in the power sector are urgently needed. Depending on the stage of liberalization and regulation these investments are to be done either by the private sector or by governmental or public organizations. All North African countries have adopted renewable electricity targets, ranging from 10% in Libya to 42% percent in Morocco for the year 2020, indicating that are significant portion of the new capacity are to be covered by investments in renewable electricity generation.

Morocco, Algeria, Tunisia and Egypt have implemented renewable energy policies at different levels of ambition and with different levels of success. Especially in Morocco, significant advancements have been made resulting in 16 projects with an installed capacity of 1,727 MW currently in planning. In most countries, some kind of financial or regulatory support schemes are in place either to allow a direct feed-in of RE power into the grid or to directly invest in RE projects mainly by applying tendering schemes.

Yet, in the other North African countries only few large-scale projects have actually been realized. Stakeholders identified a lack of available capital as a major barrier for RE deployment across all countries. This is partly due to the fact that electricity prices in all North African countries are politically defined and in most cases highly subsidized. As these prices are not sufficient to cover the costs for RE electricity generation, RE support policies are needed, but their implementation has not always been effective. Thus, the second, closely related, main barrier identified by most stakeholders is the regulatory and bureaucratic uncertainty and inefficiency deterring investors and project developers from RE deployment. In some cases, a lack of knowledge concerning renewables and their system integration was reported to be an additional barrier to local investments in RE projects.

Chaper 2 gives an inventory on the present grid (Chapter 2.1) and power plant infrastructure (Chapter 2.2) and provides an overview of the existing renewable energy potential in North Africa (Chapter 2.3). After discussing the presently existing (Chapter 2.4) and the future required framework for RES-E expansion in the region (Chapter 2.5), long term scenararios for RES-E deployment from the year 2000 to 2050 are presented (Chapter 2.6) for each country, under the assumption that the requirements are fulfilled. Chapter 2.7 presents an analysis of strengths, weaknesses, opportunities and threads (SWOT) for RES-E deployment in the region.

2.1 GRID INFRASTRUCTURE

The electricity transmission systems and cross-border interconnections across the Mediterranean are very important elements for establishing physical cooperation in renewable energy between the North and South shores of the Mediterranean. The Euro-Mediterranean grid can be justified based on several factors: provides for mutual support in emergencies (imbalance between generation and load) through importing back-up energy, increases electricity exchanges especially among countries with different load profiles, mitigates market power of incumbent utilities in generation and supply and better managing intermittency with the introduction of renewable energy. Thus, all these drivers characterize the Euro-Mediterranean region, especially between the Northern and Southern countries (OME-MEDGRID, 2013).

Despite such drivers, obstacles to transmission infrastructure development exist, however. In the Mediterranean countries, for example, the main challenges are related to environmental impacts, land-use conflicts and social acceptance. In the North (Europe), for instance, the under-construction interconnection between Spain and France has suffered from delays because, in part, of NIMBY (Not-In-My-Backyard) issues. In the South (North Africa), however, the major challenges have been investment financing and need for strengthening and extending the transmission network because of the increasing load growth (OME-MEDGRID, 2013).

In the frame of the BETTER Project WP 3.1 a very comprehensive and up-to-date dataset on the power plant and electricity grid inventory existing in the year 2012 for Morocco, Algeria, Tunisia, Libya and Egypt has been created on the basis of DLR's information system for the MENA region. The database contains name, location, power plant type, capacity, fuel and cooling type, commissioning year, power plant efficiencies, status, name, geographic location, voltage of substations, etc. for over one thousand power plants, and 400 converter stations and power line units.

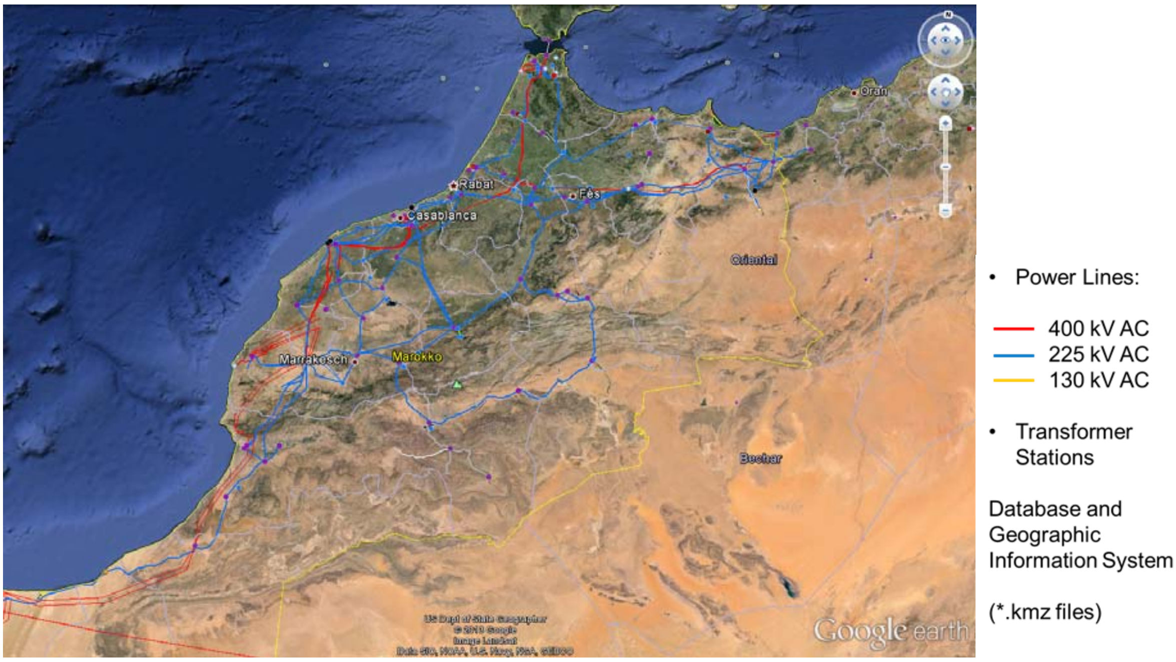
On the basis of this dataset, a condensed dataset for each country specifically to be used for the modelling within WP6 has been created according to the requisites of the WP6 leader. For the modelling of the RES-E perspectives in 2020 and beyond, the installed capacity from the 2012 inventory expected to be still online in 2020, 2030, 2040 and 2050 has been derived according to the commissioning years and the expected lifetime of the different power plant types. Average efficiencies of the different power plant types have also been estimated.

From the detailed electricity grid and converter station inventory, the existing net transfer capacity in the year 2012 of each NA country to its neighbor countries has been assessed.

While only the aggregated condensed data is published here, the project has created a very valuable update of the existing database for further in-depth assessment of the NA power sector.

Existing Grid Infrastructure

Within this analysis data sets with more than 400 geo-referenced transformer stations and high voltage transmission lines were developed and analyzed (Figure 2). Main data sources have been "Grid Maps (2010)" from the AUE, information provided within the project "Paving the Way for the Mediterranean Solar Plan", and various annual reports from the respective authorities in the North African countries. For the modelling within WP6 each North African country will be treated as only one single node. For this purpose, an aggregated data set was derived for each country showing the net transfer capacities and number of connecting lines between countries (**Table 2**).



Data ID	Country	Subject	Name (Long)	Name (Short)	ADM1 Level	Name of Location/nearest City	Status	Voltage in kV
1	Algeria	Substation	AIN BEIDA SUBSTATION	BEI-SUB	Oum el Bouaghi	Ain Beida	OPR	400
2	Algeria	Substation	AIN EL KEBIRA SUBSTATION	KEB-SUB	SÚtif	Ain El Kebira	OPR	225
3	Algeria	Substation	AIN M'LILA SUBSTATION	LIL-SUB	Oum el Bouaghi	Ain M'Lila	OPR	225
4	Algeria	Substation	AIN NAGA SUBSTATION	ANA-SUB	Biskra	Ain Naga	OPR	
5	Algeria	Substation	AIN OULMENE SUBSTATION	OUL-SUB	SÚtif	Ain Oulmane	OPR	225
6	Algeria	Substation	AIN OUSSERA SUBSTATION	OUS-SUB	Djelfa	Ain Oussera	OPR	225
7	Algeria	Substation	AIN SALAH SUBSTATION	ASA-SUB	Tamanghasset	In Salah	OPR	225
8	Algeria	Substation	ALGIER SUBSTATION	ALG-SUB	Alger	Kouba	OPR	225
9	Algeria	Substation	ANNABA SUBSTATION	ANN-SUB	Annaba	Annaba	OPR	
10	Algeria	Substation	AOULEF SUBSTATION	AOU-SUB	Adrar	Tit	OPR	225
11	Algeria	Substation	BARIKA SUBSTATION	BAR-SUB	Batna	Bitam	OPR	225
12	Algeria	Substation	BATNA 1 SUBSTATION	BAT1-SUB	Batna	Batna	OPR	
13	Algeria	Substation	BATNA 2 SUBSTATION	BAT2-SUB	Batna	Ouyoun El Assafir	OPR	225
14	Algeria	Substation	BATNA 3 SUBSTATION	BAN2-SUB	Batna	Batna	OPR	225
15	Algeria	Substation	BECHAR SUBSTATION	BEC-SUB	BÚchar	Bechar	OPR	400
16	Algeria	Substation	BEN BADIS SUBSTATION	BBA-SUB	Sidi Bel AbbÞs	Sidi Ali Boussidi	OPR	225
17	Algeria	Substation	BERKINE 1 SUBSTATION	BER-SUB	Ouargla	El Borma	OPR	225
18	Algeria	Substation	BERKINE 2 SUBSTATION	BEK-SUB	Ouargla	El Borma	OPR	225

Figure 2: Examples of DLR's numerical and geographic database for power lines and transformer stations

The Euro-Mediterranean power system is characterized by four separate synchronous blocks:

- The Northern (European) Mediterranean countries are interconnected within the Synchronous Continental Region of the European Network of Transmission System Operators for Electricity (ENTSO-E/SCR). They are also synchronously connected with Morocco, Algeria and Tunisia through an alternating current (AC) submarine cable between Morocco and Spain,which was commissioned in 1997 (and a second cable in 2006).

- Turkey requested a synchronous connection to the ENTSO-E/SCR in 2000 with the aim of benefiting from synchronous (or parallel) operation and integration into the European Union's Internal Electricity Market (IEM). Measures to improve the dynamic performance of the Turkish system are being undertaken to ensure full compliance with ENTSO-E/SCR standards. In this regard, ENTSO-E recently required one more year of trial operation for security reasons until autumn 2013.[2]
- The Mashreq-Libya system is composed of Libya, Egypt, Jordan, Lebanon, Syria, Saudi Arabia, Iraq and part of the Palestinian Territories.
- Israel and part of the Palestinian Territories.

Transmission systems in the Mediterranean countries feature several voltage levels:

• Extra-high voltage (EHV): 500 kilovolts (kV) only in Egypt; 400 kV and 220 kV in almos tall the other countries.

• High voltage (HV): 161 kV only in Israel; 154 kV only in Turkey; 150 kV; 132 kV; 110 kVand 90 kV.

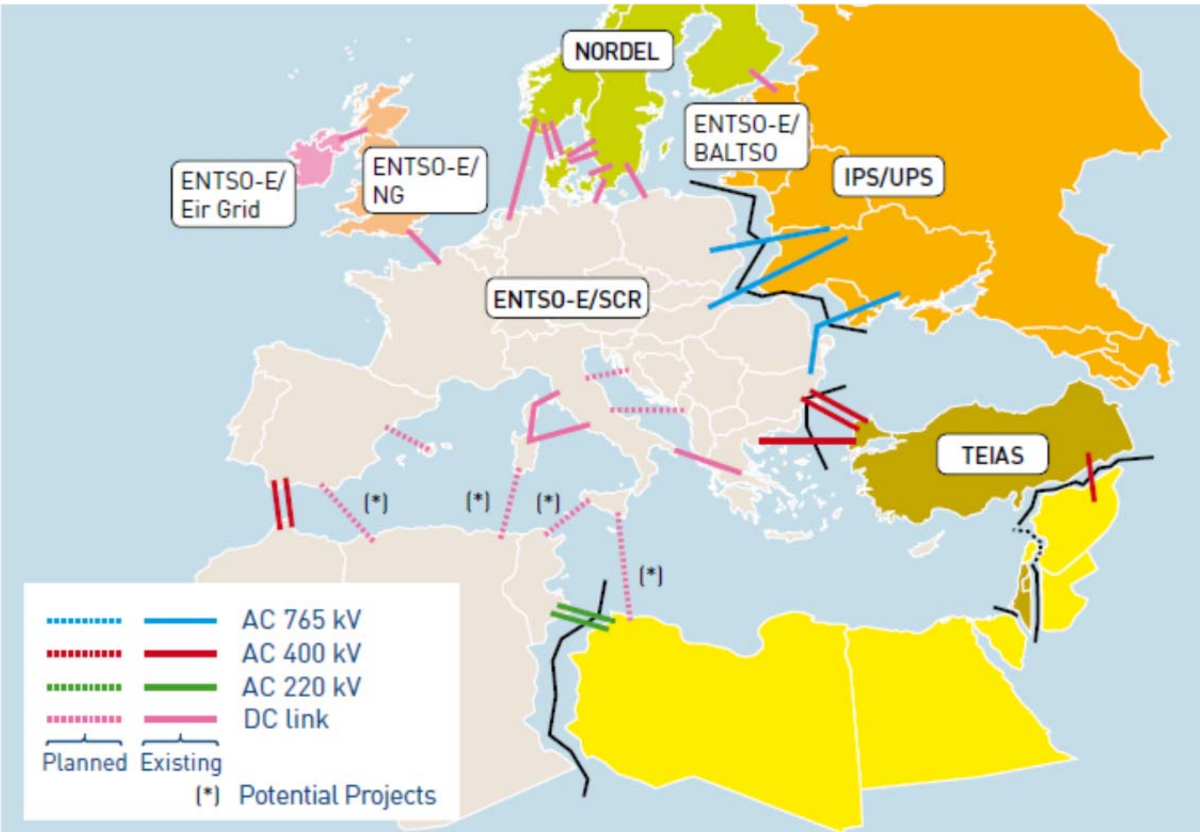


Figure 3: Europe and Mediterranean Synchronous Power Systems. Source: MEDRING, Update Study, 2010.

In terms of submarine transmission infrastructure, several links already exist under the Mediterranean Sea. The table below summarizes the existing interconnectors in the Mediterranean.

[2] https://www.entsoe.eu/news-events/announcements/newssingleview/article/third-phase-of-the-trial-parallel-operation-of-teias-prolonged-until-autumn-2013/?tx_ttnews%25255BbackPid%25255D=28&cHash=df9e31f081ee148ee8bdd6c7135b7622

Table 1: Existing Interconnectors in the Mediterranean

Name of the existing submarine interconnector	Voltage (kV)	Capacity (MW)	Max. depth (m)	Commissioning date	Under water length (km)
Spain (Mallorca Menorca)	132 AC	50	90	1973	120
Spain (ROMULO-Cometa)	250 DC	400	1 500	2011	237
Morocco - Spain 1	400 AC	700	630	1997	30
Morocco - Spain 2	400 AC	700	630	2006	30
Italy - France (SACOI 1)	200 DC	200	450	1965	118
Italy - France (SACOI 2)	200 DC	100	450	1992	118
Italy (SAPEI) 1	500 DC	500	1 650	2009	420
Italy (SAPEI) 2	500 DC	500	1 650	2011	420
Greece - Italy (GRITA) 1	400 DC	500	1 000	2001	163

Source: MEDGRID

The only existing interconnection linking North and South West Mediterranean is the one between Spain and Morocco. Some are operated in “island mode” (i.e. connecting a limited set of generation units and/or load in one system to the other system), whereas others are not in operation because of some technical issues. The main interfaces are (OME-MEDGRID, 2013):

Interconnections operating in “island mode”:

- Libya-Mashreq // Turkey: one 400 kV single-circuit line, Aleppo-Birecik (completed in 2003) supplied power from Turkey to Syria between 2006 and 2010. However, the corresponding generating units in Turkey were disconnected from the rest of the Turkish system. Power transfers to Syria are in isolated mode.
- Palestinian Territories // Jordan: one 132 kV line connects Jericho to Suweimeh, but operates at 30 kV to feed load in Jericho in islanded operation mode.

Interconnections not operating due to technical issues:

- ENTSO-E/SCR-Western Maghreb // Libya-Mashreq: two 225 kV lines between Libya and Tunisia, the Abou Khamesh-Medine double-circuit line and the Rowis-Tataouine single circuitline (completed in 2002). However, these lines are not in operation due to technical problems with synchronizing the two systems. Synchronization tests withENTSO-E/SCR have failed so far, with the most recent test conducted in April 2010.
- Turkey // ENTSO-E/SCR: three 400 kV lines interconnect Turkey with Bulgaria (Hamitabat-Maritsa 3 and Babaeski-Maritsa 3, both single-circuit lines) and Greece (Babaeski-NeaSanta-Filippi, single-circuit line to Nea Santa and then double-circuit line to Filippi).Currently, and for another year (2013), these lines will be operated for trial synchronous operation with ENTSO-E, supporting no electricity exchanges.

Table 2: Existing electricity grid net transfer capacity (NTC) in Morocco in 2012

	Thermal capacity in MVA	Net transfer capacity in MW	Number 380-400kV links	Number 220-225kV links	Number 150kV links	Number 90kV links
to Spain	1,400	700	2	0	0	0
to Algeria	2,500	800	2	2	0	0

Table 3: Existing electricity grid net transfer capacity (NTC) in Algeria in 2012

	Thermal capacity in MVA	Net transfer capacity in MW	Number 380-400kV links	Number 220-225kV links	Number 150kV links	Number 90kV links
to Morocco	2,500	800	2	2	0	0
to Tunisia	1,200	300	1	1	1	2

Table 4: Existing electricity grid net transfer capacity (NTC) in Tunisia in 2012

	Thermal capacity in MVA	Net transfer capacity in MW	Number 380-400kV links	Number 220-225kV links	Number 150kV links	Number 90kV links
to Algeria	2,500	800	2	2	0	0
to Libya (failed)	1,470	0	0	3	0	0

Table 5: Existing electricity grid net transfer capacity (NTC) in Libya in 2012

	Thermal capacity in MVA	Net transfer capacity in MW	Number 380-400kV links	Number 220-225kV links	Number 150kV links	Number 90kV links
to Tunisia	1,470	0	0	3	0	0
to Egypt	490	180	0	1	0	0

Table 6: Existing electricity grid net transfer capacity (NTC) in Egypt in 2012

	Thermal capacity in MVA	Net transfer capacity in MW	Number 380-400kV links	Number 220-225kV links	Number 150kV links	Number 90kV links
to Libya	490	180	0	1	0	0
to Jordan	NA	450	1	0	0	0

Planned interconnections

In perspectives, several studies are on-going for possible future interconnections in the Mediterranean. The table below summarizes the projects foreseen and the projects that have been studied or still under study.

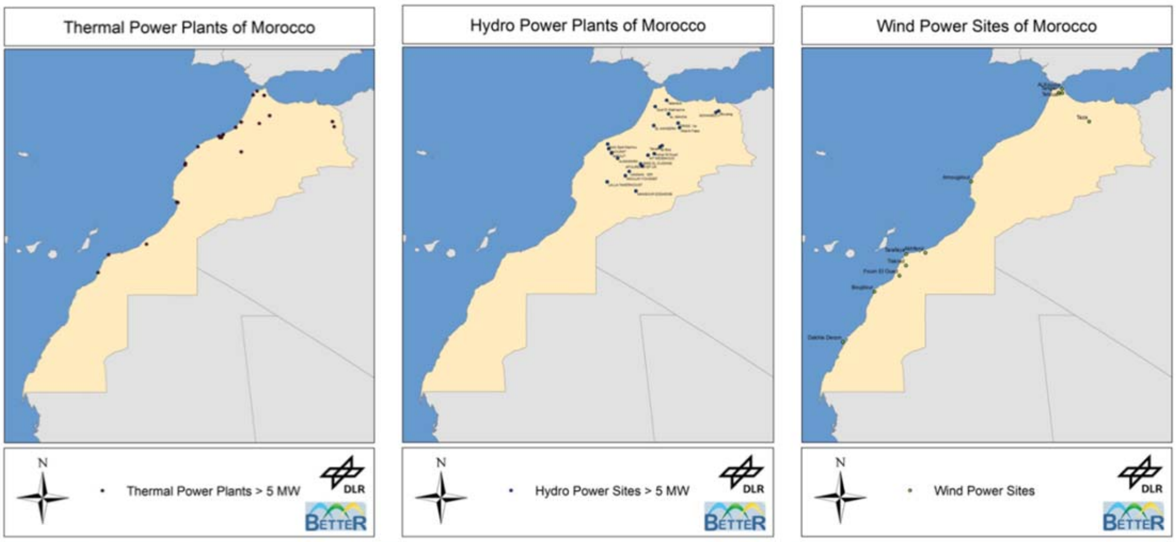
Table 7: Interconnection projects in the Mediterranean (decided in light blue and under study in yellow).

Name of the project	Voltage (kV)	Capacity (MW)	Max. depth (m)	Commissioning date	Under water length (km)
Morocco - Spain capacity increase	400 AC	700 - 3 000[7]	630	Before 2025[8]	30
Italy - Sicily	400 AC			2013	90
Italy - Croatia	400 DC	1 000	200	2020	200
Italy - Montenegro	500 DC	1 000	1 200	2015	375
Italy - Albania	400 DC	500		2014	290
Greece - Italy (GRITA) 2	400 DC	1 000	1 000	2020	163
Italy Malta 1	132 AC	400	160	2015	100
Italy Malta 2	220 AC	600	160	2020	100
Italy (Elba island)	132 AC			2015	40
Italy (Islands : Capri, Ischia, Procida)	150 AC			2015	95
Tunisia - Italy (TUNITA 1)	400 DC	1 000	670	2015	194
Libya - Italy (LIBITA)	500 DC	1 000	600	2020	550
Algeria - Italy (1)	500 DC	500	2 000	2016	330
Algeria - Italy (2)	500 DC	500	2 000	2020	330
Algeria - Spain	500 DC	2 000	1 900	2018	240
France - Spain (Biscay Bay)	320/500 DC	2 000	30-1 500 m	2018-2020	- 350
France - Spain (other)	320/500 DC	1 000-2 000	30-1 000 m	→2020	- 500

Source: MEDGRID.

2.2. POWER PLANT INFRASTRUCTURE

The main data sources for assessing the existing power plant infrastructure in North Africa have been the “World Electric Power Plants Database (2010)” from PLATTS and the “Power Plant Database (2012)” of the Arab Union of Electricity (AUE). Both data sets containing units which are already operating or are currently under construction. The two data sets, containing together more than 1000 single units in North Africa, were merged and checked on contingency. In a second step, the developed data set was updated by an extensive desktop research for the case that units were connected to the grid in 2012 and were not included in both data sets. Besides of the installed nominal capacity and partially the utilized cooling technology, both data sets provided no unit specific technical data such as net efficiency / heat rate, minimum load rate, auxiliary power, etc. or geographic coordinates. Thus, the developed data set was completed with technology type specific technical characteristics (e.g. for Combined-Cycle Gas Turbine) available form literature and sent to regional stakeholders for review. However, feedback from stakeholders about this specific and sensitive data was rather low.



Data ID	Country	Subject	Name (Full)	Name (Short)	ADM1 Level	ADM2 Level	Status	Technology	Fuel	Number of Blocks	Installed Gross Turbine Capacity in MW	Installed Gross Pumping Capacity in MW
1	Morocco	Powerstation	AFOURER	AFOU-HP-ROR	Tadla - Azilal	Azilal	OPR	HP-ROR	HYDRO	2	93.6	0
2	Morocco	Powerstation	AIT MESSAOUD	AITM-HP-R	Tadla - Azilal	Béni Mellal	OPR	HP-R	HYDRO	2	6.4	0
3	Morocco	Powerstation	AL WAHDA	ALWA-HP-R	Gharb - Chrarda - Béni Hssen	Sidi Kacem	OPR	HP-R	HYDRO	3	240.0	0
4	Morocco	Powerstation	Allal Al Fassi	ALLA-HP-R	FÞs - Boulemane	Sefrou	OPR	HP-R	HYDRO	3	240.0	0
5	Morocco	Powerstation	ALMASSIRA	ALMA-HP-R	Marrakech - Tensift - Al Haouz	El Kelaâ des Sraghna	OPR	HP-R	HYDRO	2	128.0	0
6	Morocco	Powerstation	BINE EL OUIDANE	BINE-HP-R	Tadla - Azilal	Azilal	OPR	HP-R	HYDRO	3	135.0	0
7	Morocco	Powerstation	Bouareg	BOUA-HP-R	Oriental	Berkane Taourirt	OPR	HP-R	HYDRO	2	6.4	0
8	Morocco	Powerstation	DAOURAT	DAOU-HP-R	Doukkala - Abda	El Jadida	OPR	HP-R	HYDRO	2	17.0	0
9	Morocco	Powerstation	Dchar El-Oued	DCHA-HP-R	Tadla - Azilal	Béni Mellal	OPR	HP-R	HYDRO	1	98.0	0
10	Morocco	Powerstation	El Borj	ELBO-HP-ROR	MeknÞs - Tafilalet	Khénifra	OPR	HP-ROR	HYDRO	2	26.0	0
11	Morocco	Powerstation	Tanafnit	TANA-HP-ROR	MeknÞs - Tafilalet	Khénifra	OPR	HP-ROR	HYDRO	2	18.0	0
12	Morocco	Powerstation	EL KANSERA	ELKA-HP-R	Rabat - Salé - Zemmour - Zaer	Khémisset	OPR	HP-R	HYDRO	2	14.4	0
13	Morocco	Powerstation	HASSAN 1ER	HASS-HP-R	Marrakech - Tensift - Al Haouz	El Kelaâ des Sraghna	OPR	HP-R	HYDRO	1	67.0	0
14	Morocco	Powerstation	IDRISS 1er	IDRI-HP-R	Taza - Al Hoceima - Taounate	Taounate	OPR	HP-R	HYDRO	1	40.0	0
15	Morocco	Powerstation	IMFOUT	IMFO-HP-R	Marrakech - Tensift - Al Haouz	El Kelaâ des Sraghna	OPR	HP-R	HYDRO	2	31.2	0
16	Morocco	Powerstation	LALLA TAKERKOIUST	LALLA-HP-R	Marrakech - Tensift - Al Haouz	Al Haouz	OPR	HP-R	HYDRO	2	12.0	0
17	Morocco	Powerstation	MANSOUR EDDAEHBI	MANS-HP-R	Souss - Massa - Draâ	Ouarzazate	OPR	HP-R	HYDRO	2	10.0	0
18	Morocco	Powerstation	MOHAMED V	MOHA-HP-R	Oriental	Berkane Taourirt	OPR	HP-R	HYDRO	1	23.0	0
19	Morocco	Powerstation	MOULAY-YOUSSEF	MYOUS-HP-R	Marrakech - Tensift - Al Haouz	Al Haouz	OPR	HP-R	HYDRO	2	24.0	0
20	Morocco	Powerstation	Quel El Makhazine	MAKA-HP-R	Tanger - Tétouan	Larache	OPR	HP-R	HYDRO	1	36.0	0
21	Morocco	Powerstation	Sidid Said Machou	SIDI-HP-R	Chaouia - Ouardigha	Settat	OPR	HP-ROR	HYDRO	1	20.8	0
22	Morocco	Powerstation	STEP UR	AFOU-HP-PUMP	Tadla - Azilal	Azilal	OPR	HP-PUMP	HYDRO	4	464.0	0
23	Morocco	Powerstation	Talambot	TALA-HP-R	Tanger - Tétouan	Chefchaouen	OPR	HP-R	HYDRO	3	5.7	0

Figure 4: Examples of the comprehensive numerical and geographic power plant data set of DLR.

Due to the data input needs of the modelling team of WP6, the data provided in this MS Excel file contains only an aggregated version of the developed power plant data set. For each country the development of technology specific installed capacities (accounting only units > 10 MW) of the inventory of 2012 for the years 2020, 2030, 2040, and 2050 is shown, assuming a technology specific life-time for each power plant unit according to **Table 8**. Furthermore, the data set contains a table with the development of technology specific weighted average net efficiencies of the existing inventory over the years 2020 – 2050.

Table 8: Expected operational life time of different power plant types in NA.

Conventional Plants:	40	years
Wind:	25	years
CSP:	40	years
PV:	25	years
Hydro:	No decommissioning	

Additionally to the aggregated country specific generation capacities tables, the data set at hand contains a table showing all hydro power plant units in North Africa with an installed capacity larger than 10 MW including several technical parameters which are necessary for an adequate modelling of hydro units within WP6 (Chapter 4).

The data resulting from the inventory (D3.1. Part A) is contained in the EXCEL File: D31_Part A-Inventory_NA.xlsx. It is summarized in the following:

MOROCCO

Table 9: Installed gross capacity (MW) of power plants in Morocco from the 2012 inventory that are expected to be still online in 2020, 2030, 2040 and 2050, respectively.

Year	2020	2030	2040	2050
ST-COAL	1,620	1,320	660	-
ST-GAS/HFO	300	-	-	-
CCGT	852	852	852	-
OCGT	1,143	1,143	714	315
Diesel Engines	225	199	199	80
Hydro-Pump	464	464	464	464
Hydro-Reservoir	1,154	1,154	1,154	1,154
Hydro-Run-off-River	114	114	114	114
Onshore-Wind	280	230	-	-
CSP	-	-	-	-
Utility-scale PV	-	-	-	-
Total	**6,152**	**5,476**	**4,157**	**2,127**

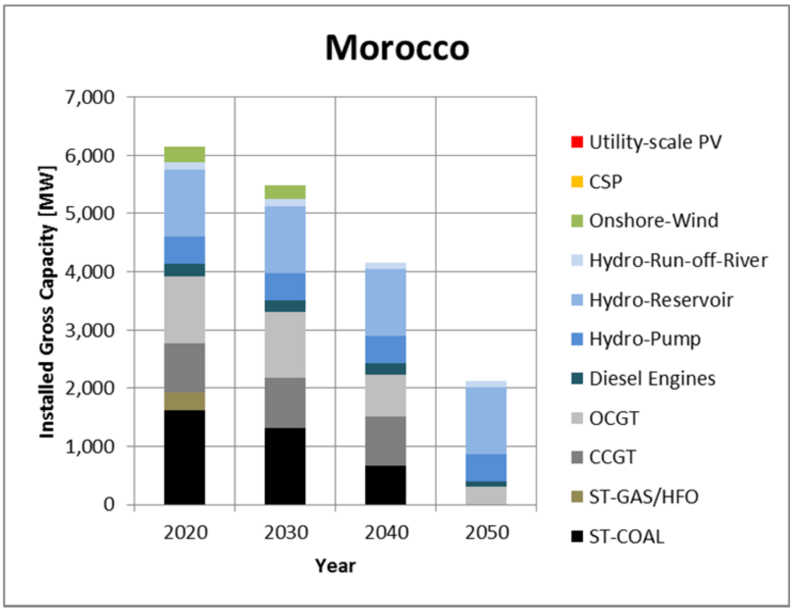


Figure 5: Installed gross capacity (MW) of power plants in Morocco from the 2012 inventory expected to be still online in 2020, 2030, 2040 and 2050, respectively

Table 10: Weighted average net efficiency of existing units in Morocco

Year	2020	2030	2040	2050
CCGT	51.00%	51.00%	51.00%	-
OCGT	31.50%	31.50%	33.00%	33.00%
ST-COAL	37.50%	38.50%	39.50%	-
ST-GAS/HFO	31.00%	-	-	-
Diesel Engines	42.00%	44.00%	44.00%	44.00%

ALGERIA

Table 11: Installed gross capacity (MW) of power plants in Algeria from the 2012 inventory that are expected to be still online in 2020, 2030, 2040 and 2050, respectively.

Year	2020	2030	2040	2050
ST-COAL	-	-	-	-
ST-GAS/HFO	2,100	924	-	-
CCGT	4,575	4,575	4,575	2,550
OCGT	6,043	4,567	4,221	2,361
Diesel Engines	-	-	-	-
Hydro-Pump	-	-	-	-
Hydro-Reservoir	219	219	219	219
Hydro-Run-off-River	-	-	-	-
Onshore-Wind	10	10	-	-
CSP	-	-	-	-
Utility-scale PV	-	-	-	-
Total	**12,947**	**10,295**	**9,015**	**5,130**

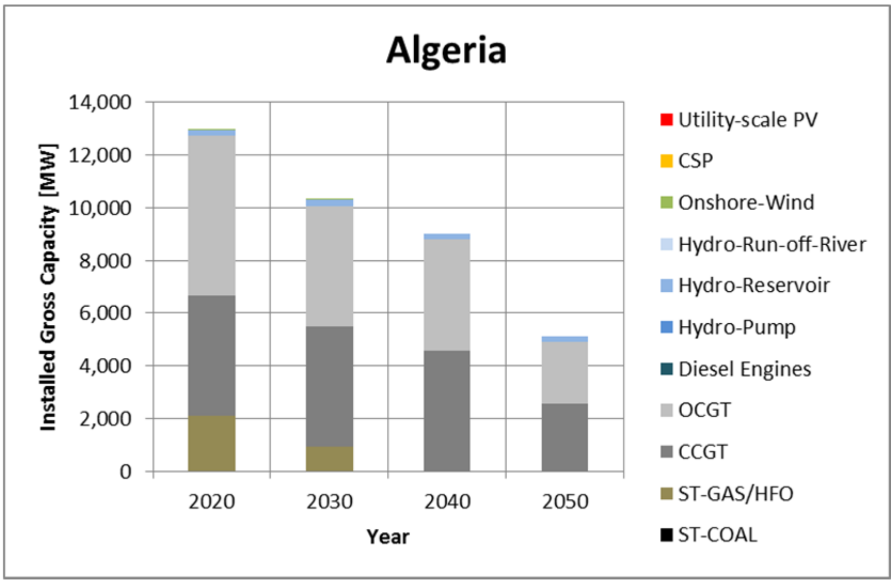


Figure 6: Installed gross capacity (MW) of power plants in Algeria from the 2012 inventory expected to be still online in 2020, 2030, 2040 and 2050, respectively

Table 12: Weighted average net efficiency of existing units in Algeria

Year	2020	2030	2040	2050
CCGT	53.50%	53.50%	53.50%	54.00%
OCGT	33.00%	34.00%	34.50%	34.50%
ST-COAL	-	-	-	-
ST-GAS/HFO	34.50%	35.50%	-	-
Diesel Engines	-	-	-	-

TUNISIA

Table 13: Installed gross capacity (MW) of power plants in Tunisia from the 2012 inventory that are expected to be still online in 2020, 2030, 2040 and 2050, respectively.

Year	2020	2030	2040	2050
ST-COAL	-	-	-	-
ST-GAS/HFO	700	-	-	-
CCGT	2,630	1,780	1,780	-
OCGT	1,760	1,060	590	-
Diesel Engines	-	-	-	-
Hydro-Pump	-	-	-	-
Hydro-Reservoir	56	56	56	56
Hydro-Run-off-River	-	-	-	-
Onshore-Wind	242	189	-	-
CSP	-	-	-	-
Utility-scale PV	-	-	-	-
Total	**5,388**	**3,085**	**2,426**	**56**

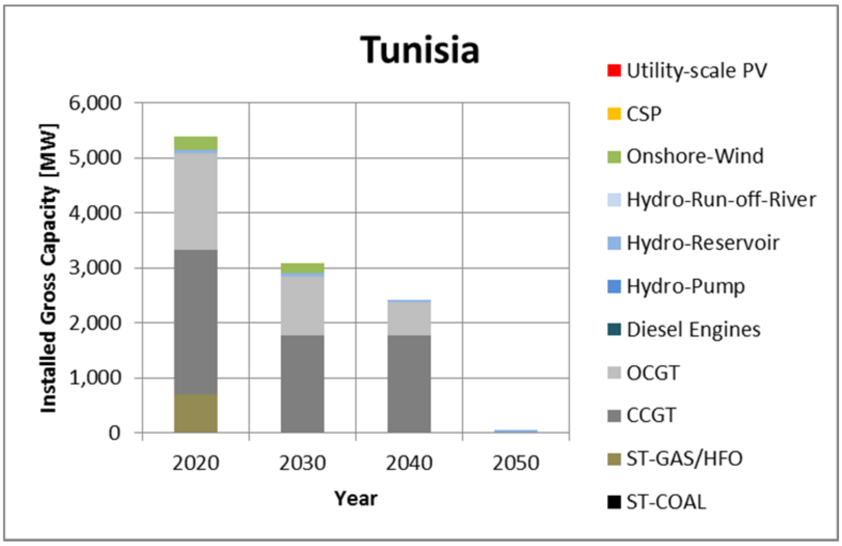


Figure 7: Installed gross capacity (MW) of power plants in Tunisia from the 2012 inventory expected to be still online in 2020, 2030, 2040 and 2050, respectively

Table 14: Weighted average net efficiency of existing units in Tunisia

Year	2020	2030	2040	2050
CCGT	52.50%	54.50%	55.50%	-
OCGT	31.50%	34.00%	34.00%	-
ST-COAL	-	-	-	-
ST-GAS/HFO	36.00%	-	-	-
Diesel Engines	-	-	-	-

LIBYA

Table 15: Installed gross capacity (MW) of power plants in Libya from the 2012 inventory that are expected to be still online in 2020, 2030, 2040 and 2050, respectively.

Year	**2020**	**2030**	**2040**	**2050**
ST-COAL	-	-	-	-
ST-GAS/HFO	3,537	2,557	2,050	1,400
CCGT	4,080	4,080	4,080	825
OCGT	2,718	2,539	1,194	570
Diesel Engines	-	-	-	-
Hydro-Pump	-	-	-	-
Hydro-Reservoir	-	-	-	-
Hydro-Run-off-River	-	-	-	-
Onshore-Wind	-	-	-	-
CSP	-	-	-	-
Utility-scale PV	-	-	-	-
Total	**10,335**	**9,176**	**7,324**	**2,795**

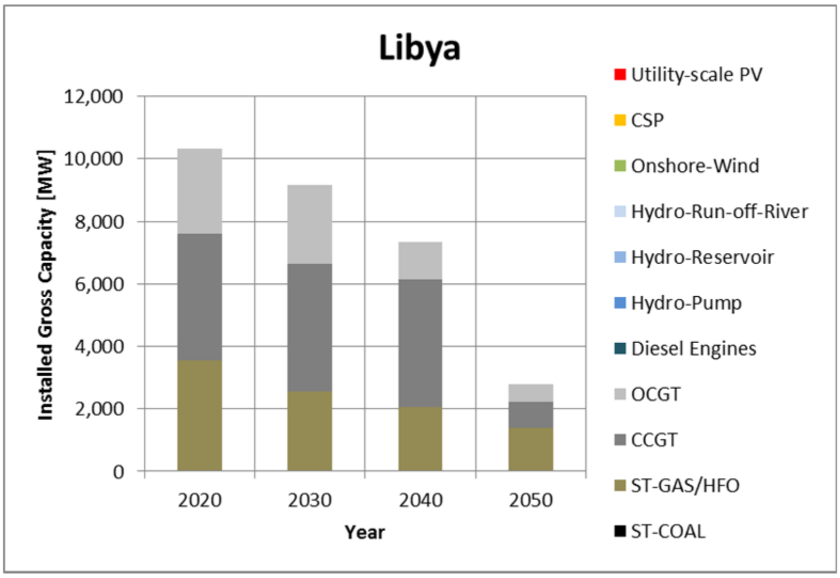


Figure 8: Installed gross capacity (MW) of power plants in Libya from the 2012 inventory expected to be still online in 2020, 2030, 2040 and 2050, respectively

Table 16: Weighted average net efficiency of existing units in Libya

Year	**2020**	**2030**	**2040**	**2050**
CCGT	53.50%	53.50%	53.50%	55.50%
OCGT	32.50%	33.00%	35.00%	55.50%
ST-COAL	-	-	-	-
ST-GAS/HFO	36.50%	39.00%	41.00%	41.00%
Diesel Engines	-	-	-	-

EGYPT

Table 17: Installed gross capacity (MW) of power plants in Egypt from the 2012 inventory that are expected to be still online in 2020, 2030, 2040 and 2050, respectively.

Year	2020	2030	2040	2050
ST-COAL	-	-	-	-
ST-GAS/HFO	12,223	8,423	4,728	1,400
CCGT	10,218	9,478	7,640	890
OCGT	2,747	2,227	2,036	1,939
Diesel Engines	-	-	-	-
Hydro-Pump	-	-	-	-
Hydro-Reservoir	2,650	2,650	2,650	2,650
Hydro-Run-off-River	150	150	150	150
Onshore-Wind	550	405	-	-
CSP	-	-	-	-
Utility-scale PV	-	-	-	-
Total	**28,538**	**23,333**	**17,204**	**7,029**

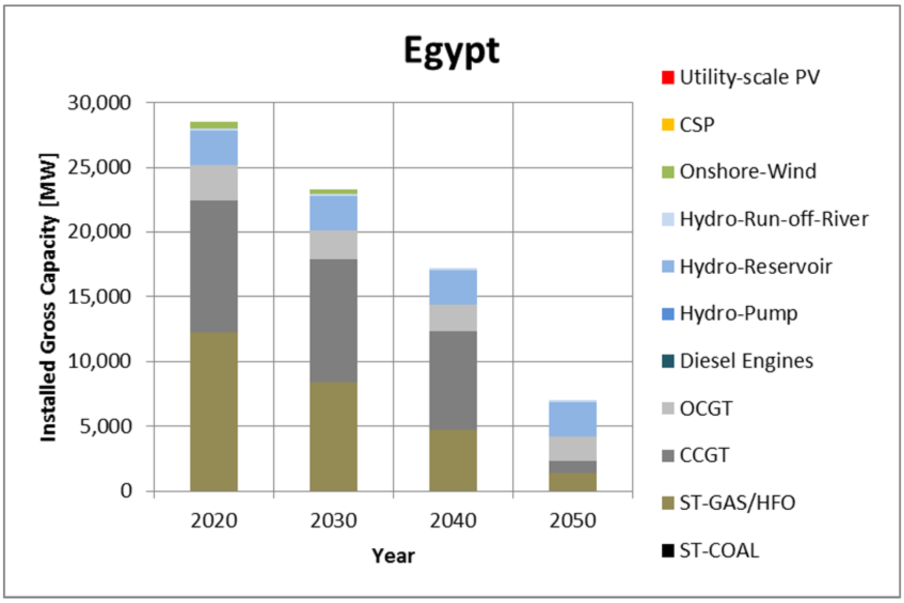


Figure 9: Installed gross capacity (MW) of power plants in Egypt from the 2012 inventory expected to be still online in 2020, 2030, 2040 and 2050, respectively

Table 18: Weighted average net efficiency of existing units in Egypt

Year	2020	2030	2040	2050
CCGT	52.50%	53.00%	54.50%	54.50%
OCGT	27.00%	27.50%	29.00%	-
ST-COAL	-	-	-	-
ST-GAS/HFO	37.00%	39.00%	40.00%	41.00%
Diesel Engines	-	-	-	-

2.3 RENEWABLE ENERGY POTENTIAL IN THE MEDITERRANEAN

The renewable energy resources in NA were assessed on the basis of the results of MED-CSP 2005 and MENA Water Outlook 2011. We have taken into consideration the following renewable energy resources for power generation:

1. Direct Solar Irradiance on Surfaces Tracking the Sun (Concentrating Solar Thermal Power Plants - CSP)
2. Direct and Diffuse (Global) Solar Irradiance on a Fixed Surface tilted South according to the Latitude Angle (Photovoltaic Power)
3. Wind Speed (Onshore and Offshore Wind Power Plants)
4. Hydropower Potentials from Dams and River-Run-Off Plants
5. Heat from Deep Hot Dry Rocks (Geothermal Power)
6. Biomass from Municipal and Agricultural Waste and Wood

In the MENA Water Outlook 2011 both the technical and economic potentials were defined for each renewable energy resource and for each country. The technical potentials are those which in principle could be accessed for power generation by the present state of the art technology. The economic potentials shown here are those with a sufficiently good performance that will allow new plants in the medium and long term to become competitive with other power sources, considering their potential technical development and economies of scale.

The renewable energy potentials for power generation differ widely in the countries analyzed within this study. Altogether they can cope with the growing demand of the developing economies in MENA. The economically feasible potentials are given in Table 19. For wind power, biomass from municipal and agricultural waste, geothermal energy and hydropower together they amount to about 362 TWh/y. Those resources are more or less locally concentrated and not available everywhere, but can be distributed through the electricity grid, which will be enforced in the future in line with the growing electricity demand of this region.

The by far biggest resource in NA is solar energy from PV and CSP, with a potential of 288,000 TWh/y that is much larger than the present global electricity demand. The solar energy irradiated on the ground in North Africa equals 1 - 2 million barrels of fuel oil per square kilometer and year. This magnificent resource can be used both in distributed photovoltaic systems and in large central solar thermal power stations.

The accuracy of a global resource assessment of this kind cannot be better than ± 30 % as it depends on many assumptions and simplifications. However it gives a first estimate of the order of magnitude of the renewable energy treasures available in NA.

Comparing the solar energy potential to the demand expectations we find that for solar energy, the potential is not at all a limiting factor, as it is several orders of magnitude larger then local demand even in the far future, which supports the idea of exploiting part of it for export. On the other hand, all the other RES-E sources are smaller than demand, not supporting a business case for exports.

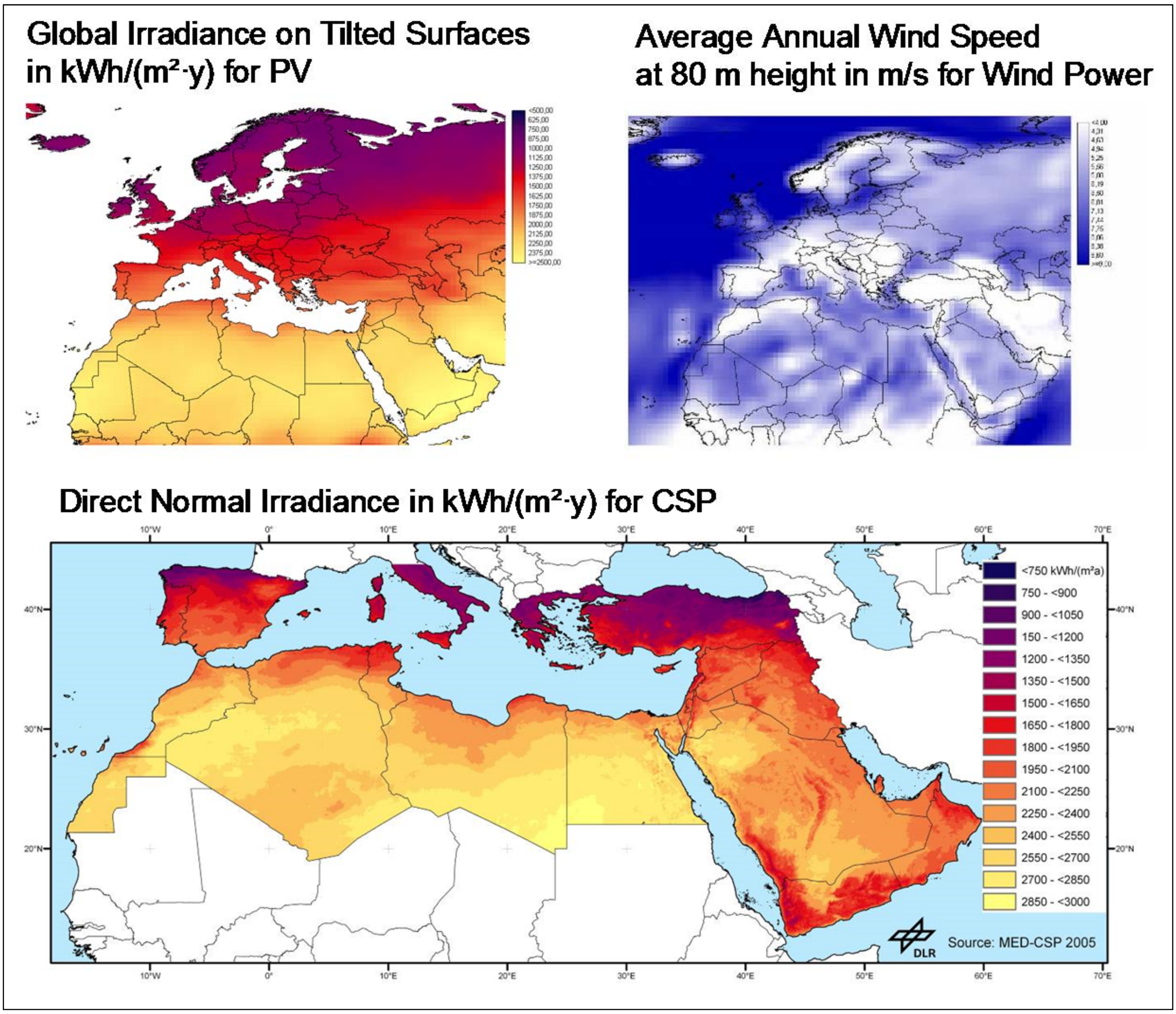


Figure 10: Mapping renewable energy sources in MENA (MED-CSP 2005 and MENA Water Outlook 2011)

Table 19: Economic potential (TWh/y) of renewable sources for power generation in North Africa according to MENA Water Outlook 2011 and updated information. Note: other sources like e.g. Dii 2013 give higher theoretical wind potentials. However, in our bottom-up scenarios we have used the more conservative values given here, as they are also confirmed by national assessments.

	Hydro	**Geo**	**Bio**	**Solar (CSP & PV)**	**Wind**
Algeria	0.5	4.7	12.3	135000	38.0
Egypt	15.0	25.7	14.1	57000	125.0
Libya	0.0	0.0	1.8	82000	15.0
Morocco	4.0	10.0	14.3	8400	38.0
Tunisia	0.5	3.2	3.2	5700	9.0

2.4 EXISTING FRAMEWORK FOR RES-E EXPANSION IN NA

The near term economic outlook for North Africa's economy is not very optimistic. There are difficult political transitions related to the Arab Spring, leading to significant regional uncertainties. Those uncertainties combine with high unemployment, low living standards and a general trend to negative national and especially fiscal account balances, especially in the oil-importing countries, creating a difficult environment for foreign and internal equity investment. High and increasing governmental debt relates unfavourably to high energy subsidies that are difficult to remove due to the already existing social strife. The region is trapped in a vicious cycle of economic stagnation and persistent socio-political unrest, creating an urgent need for policies that increase confidence, economic growth and job opportunities (IMF 2013).

The highest per capita GDP can be found in the two oil and gas exporting countries Libya and Algeria, while the per capita GDP in the other NA countries is much lower. While GDP growth rates have been lately increasing in the energy exporting countries, they have been slightly decreasing in the others. Actually, real GDP growth rates range between 2-4%/yr. Libya shows the strongest fluctuations of annual GDP growth from one year to the other, with high positive and high negative values, indicating a relatively unstable economy, although the overall trend might be positive.

Public deficits and debt are high and increasing. The general government fiscal balance is negative in all countries, with a clear trend to higher negative values. As a consequence, total government gross debt is quickly increasing in the oil-importing countries, while kept stable at low values in the energy producing countries. This indicates that in Algeria and Libya, the negative fiscal balance is largely compensated by exploiting the national resource of fossil fuels. The higher public deficits have been the result of increasing subsidies and wage bills since 2011 that were provided in order to soothe political and social unrest and the pressure from increasing food and fuel prices on the world market.

From an external point of view, the major challenges in the NA countries can be summarized as high unemployment, shrinking economic growth rates and lack of predictability of the political and economic environment. To this add internal risks related to a high subsidization of energy paired with low national reserves and a high public debt rate.

External and fiscal buffers are rather small, foreign exchange reserves are low, while national and fiscal account deficits remain high. Increasing public debt driven by persistently large fiscal deficits is especially high in the oil-importing countries, while exporters try to maintain equilibrium at the cost of exploiting their national wealth including that of future generations. Although countries are realizing the need for consolidation, fiscal deficits are still rising, due to strong pressures for subsidies and other social spending amid high unemployment. In this environment, characterized by significantly increased risks due to high political uncertainty and regional tensions, policy goals are threefold according to IMF 2013:

(1) **Create jobs** to help sustain socio-political transitions. Governments play a key role in reviving economic activity over the near term. With limited room for widening fiscal deficits in many countries, subsidies need to be re-oriented towards growth-enhancing public investment, while improving protection of vulnerable groups through well-targeted social assistance. External partners

could support this priority by providing additional financing for public investment spending and basic services based on the existence of adequate policy frameworks.

(2) **Start fiscal consolidation** to restore debt sustainability and rebuild buffers protecting the economy from unanticipated shocks. Consideration needs to be given to supporting fiscal consolidation through greater exchange rate flexibility, which can help to soften the short-term impact of fiscal consolidation on growth and help to rebuild international reserves.

(3) **Start structural reforms** that will improve the business climate and governance and enhance equity by improving business regulation and governance, expanding access of businesses and consumers to finance, enacting labour market policies that support job creation and employment opportunities, and protecting the vulnerable through well-targeted social assistance.

High public debt and increasing fiscal deficits are directly related to energy subsidies, especially in those countries that do not have domestic fossil fuel resources. For decades, countries in the region have relied heavily on generalized price subsidies - overwhelmingly on energy products but also on food - as the main tool to provide social protection and, in oil exporters, share hydrocarbon wealth with citizens. The lately increasing deficit has been largely the result of increases in generalized subsidies and public wage bills since 2011 that were intended to soothe political and social unrest and easy the burden of elevated international food and fuel prices. While Morocco and to some extent Tunisia have been able to limit subsidies in spite of being energy importers, Egypt has not, running into an increasingly critical situation in terms of fiscal balance.

According to the International Monetary Fund (IMF 2013), “subsidies are expensive and inefficient as a social protection tool because they benefit mainly the wealthy, whose energy consumption is usually higher than that of the poor. By encouraging higher energy consumption, subsidies increase pollution and damage health. Subsidies may also lead to overinvestment in capital-intensive activities, limiting job creation, and underinvestment in energy production, which, in turn, may cause poor service quality and shortages. Finally, subsidies promote smuggling and corruption.”

Several MENA countries have recently taken steps to lower energy subsidies. In the past few years, Egypt, Morocco and Tunisia initiated subsidy reform by increasing energy prices while mitigating the impact on the poor. Reforms have been part of a strategy to reduce fiscal deficits and free resources for social projects and infrastructure, in order to boost growth and reduce poverty and inequality. Reforms have often been supported by international stakeholders, including technical assistance and financial support.

Managing the political economy of subsidy reform is crucial in the current difficult political situation. Policymakers and international partners must move carefully and choose the reform mix that balances fiscal returns against social opposition to price increases. They should strive to mitigate the impact of price increases and strengthen confidence that the resulting savings will be put to good use. To this end, they should avoid abrupt price shocks, and should communicate effectively to the public the costs of subsidies and the benefits of reform. But, to gain crucial support for reform, subsidy removal should be accompanied by the introduction, or, if already existing, the scaling up of well-targeted social safety nets to compensate those who will be hardest hit by higher prices. Targeted cash transfers or vouchers, especially if based on need, are particularly effective." The IMF gives a series of recommendations to reduce subsidies and achieve the three major goals described above, that are based on a package of internal reforms and external financing (IMF 2013).

At present, Morocco appears to be the most appealing country for foreign investment in North Africa, with fairly good infrastructure, a well-diversified economy, a well-developed banking sector, stable policy and strong GDP growth. Although current account and budget show a negative balance since 2009, foreign exchange reserves are still healthy. With 9.3% Morocco has the lowest unemployment rate in NA paired with moderate socio-economic development. The fairly good conditions in Morocco are also reflected by an OECD country rating of 3, that compares e.g. to that of the Russian Federation. This is particularly important to note when arguing e.g. that a dependency on solar electricity imports from North Africa would considerably increase the dependencies and risks in Europe.

In terms of OECD country rating, Morocco (3) is followed by Algeria (3), which has a similarly low unemployment (10%) and medium to high socio-economic development. The country has substantial foreign exchange reserves and a current account surplus, achieved by significant oil and gas exports that balance the budget deficit of the government. Infrastructure is below average, the banking sector is under-developed and there is opacity in policy making paired with restrictive laws that makes foreign investment rather difficult.

The next country in the ranking would be Tunisia with an OECD risk classification of 4 that is still suffering from the uprising in 2011 with its detrimental consequences on economic growth, foreign exchange reserves and political stability. On the positive side, Tunisia offers good infrastructure, economic diversity, although a fragile banking sector. Socio-economic development is high although paired with a high unemployment rate of almost 16%.

Egypt shows a rather unfavourable OECD country rating of 6, representing a critical situation that definitely requires help from outside to get under control. Recently Egypt has obtained significant financial aid from Saudi Arabia, UAE and other Arab neighbour countries after the end of the presidency of Mohammed Morsi and can build on a fairly good infrastructure, a well-diversified economy and a well-developed banking sector. Although GDP growth is still slow, it is expected to accelerate in 2014 and beyond, especially if political stability is achieved and foreign investment and tourism can be revived. The major challenges can be found in the political development towards a balance of powers in the country and sufficient foreign help to overcome the difficult economic situation.

The biggest problem in the otherwise rich country Libya with an OECD country rating of 7 is a total breakdown of political stability and continuity that must be resolved in order to foster economic progress. Extremely high unemployment of almost 20% and severe damages on infrastructure during the civil war require external logistic help for their removal, while national account and budget balances can be stabilized by oil and gas exports.

It can be summarized that in all NA countries, the political climate for RES-E is rather friendly, but the challenges are numerous, making a big difference between targets and planning on one side and acting and the capability of bringing things to reality on the other side.

Morocco is clearly the country with the best perspectives for dynamical growth of RES-E in the short, medium and long term, being already under way since 2010 and pursuing rather ambitious goals for RES-E expansion in the future. Morocco has a fairly good investment climate for RES-E.

If the political situation remains stable, Egypt would be the next important place for RES-E expansion in North Africa, being the country with the largest potential and the largest electricity demand as well. To overcome the present critical situation and get rid of subsidies and a negative fiscal balance, Egypt will require foreign financial aid. However, once RES-E are in place in a large scale, running cost will be rather low, as no fuels are burned, and thus, funds may be released and the subsidy problem may be resolved in a socially compatible manner. While subsidies into fossil fuel are burned in the same moment they are provided, aid for RES-E infrastructure investment will last 20, 30 or even 40 years, providing energy from renewable sources all that time.

Tunisia will require strong external aid as well, but RES-E do not yet have a high priority in national policy, while other issues, political stability on top, are much more pressing. However, along with political stabilisation, a good investment environment for RES-E and fair ground for European support may appear. RES-E in Algeria and Libya will be mainly driven and financed by the government, with foreign support probably focusing on cooperation in R&D and know-how transfer.

2.5 REQUIRED FRAMEWORK FOR RES-E EXPANSION IN NA

In order to find recommendations for a set of framework conditions required for RES-E expansion in North Africa, we have tried to identify the keys for success in Morocco and to see if the other NA countries could profit from that experience.

Being the largest energy importer of the MENA region, and in view of a strongly increasing demand, Morocco has tried to diversify its energy mix by establishing a policy and regulatory framework for promoting RES and energy efficiency. This means that Morocco has good own reasons behind its RES strategy, other than climate change and other environmental considerations or foreign (like e.g. European) policies building up pressure into that direction. Good reasons and the real need behind them makes Morocco go seriously for RES, recognizing that this will bring tangible benefits to the national economy and society, besides of participating in the global task of climate protection.

This ***fundamental political recognition of the socio-economic benefits of RES*** in fact is the first and most important pre-condition for any successful RES policy. Only if the benefits are clear, the related extra effort and investment makes sense. If such a basis is not given, RES policy may change with any major global or regional event or with any change of minister or government party. National RES industry, RES production and RES job creation will only gain a foothold, if the national long-term goal is clear, credible and reliable. The sporadic RES-E investment of most NA countries, often induced by incentives from foreign international cooperation, clearly shows that RES-E are not yet fully recognized there as being beneficial for the national economies, other than by appeasing the international community with respect to climate change issues. Therefore, a major task to be achieved is to explain why RES are in fact a good idea for NA economies, even for those who have fossil fuel resources in place, and what real world experiences confirm this assumption, learning from those who are already one step ahead. A clear sign of such recognition is **the founding of powerful institutions responsible for RES introduction and expansion** and the setup of concrete national targets, like in the case of MASEN and the Moroccan Solar Plan, that are backed by a **robust legal framework installed by the government** (MASEN 2013).

Another important pre-condition is that ***a country must be able to afford the relatively large investment*** related to RES. A fundamental difference between RES and fossil fuels is the point in time when one has to pay for it: RES are paid mainly on the first day in form of an investment (capital good) while energy from fossil fuels is bought as required during the whole production period that may be up to 40 years or more. Even if the life-cycle cost of RES would be lower than the equivalent life-cycle cost of fossil fuel, the initial high investment presents a significant barrier by itself.

In Algeria and Libya the decision on RES-E investment will fully depend on the government that in principle would easily be able to afford the necessary investments, as long as enough national income can be generated by selling fossil fuels (and later eventually by selling solar energy). In this context it must be noted that investment in RES-E should take place as long as income and monetary reserves from fossil fuel sales are available.

However, in the course of time, the availability of income from fossil fuel sales can be reduced by several reasons:

a) if national fossil fuel resources are depleted,
b) if domestic fossil fuel consumption increases due to growth of economy and population,
c) if the international fossil fuel market is saturated because of over-supply or reduced demand.

It is therefore essential for NA energy exporting countries to start RES-E investment as long as sufficient funds from fuel exports are available, instead of waiting for a decrease of fossil fuel incomes. The worst case – a rather quick and unexpected depletion of national fossil fuel resources like in the recent case of natural gas in Egypt – will eliminate the financial means for investing in alternatives in a relatively short time, and may even lead to a need for international aid to overcome such a situation. A transition from energy exporter to energy importer usually means such a heavy burden for national budgets, that investments in RES-E will be difficult to realize, even though they might be the only way out of the dilemma.

While energy exporting countries can rely on their foreign sales, energy importing countries must free financial resources from their running budget in order to finance RES-E. In energy-importing countries like Morocco, Tunisia and Egypt both the current account balance and the fiscal budget balance already show deficits that would be increased by any governmental aid for RES-E financing. **Sustainable support for RES-E can only be achieved, if the overall savings induced by RES-E deployment are larger than or equal to the financial effort to introduce them**.

Again here, Morocco is a leading country in the region because it is following a strategy exactly approaching that goal. As an example, the Ouarzazate CSP plant is designed to provide solar power during peak load hours, replacing to a great extent power from peaking gas turbines operated with rather low efficiency and consuming significant amounts of fuel oil or Diesel that are bought on the world market. In this context it becomes clear that such an approach makes absolutely sense, even if fossil fuels or power would be subsidized for consumers, because at the end of the day, the relatively high cost for solar power (in this specific case around 0.187 US$/kWh) is compensated by savings from high fossil fuel cost and related subsidies in the same order of magnitude. In this concrete case electricity is sold to Moroccan consumers at an average of around 0.08 US$/kWh, but MASEN is willing to buy solar electricity from the plant at the price mentioned above and paying for the difference, knowing that savings will be in the same order of magnitude or even higher (Frisari and Falconer 2012, Frisari and Falconer 2013).

Obviously, if a country can afford paying for or subsidizing power from expensive fossil fuel, it will likewise be able to afford RES-E under the condition that they substitute an equally expensive segment of power supply. This can be the case for flexible peak load CSP plants with storage as in the Ouarzazate case. However, also wind power and PV can induce fuel savings, although not as flexible and on-demand like a CSP plant with storage, but rather in the less expensive base load and medium load segment that may be powered by cheaper natural gas or coal. Being cheaper than CSP, wind and PV may be competitive with cheaper fuels as well, eventually leading to a well-balanced mix of cheaper, but volatile RES-E and more expensive, but flexible CSP that together can effectively reduce fuel consumption at lower or at least equal cost. The threshold for calculating the affordability of RES-E is therefore not the average cost of electricity paid by consumers – no matter if subsidized or not – but the real production cost of power that is directly substituted by the respective RES-E, that may be either cheap base load power from coal steam cycles or high-cost peaking power from oil-fired gas turbines. The concept of financing flexible CSP plants by selectively substituting expensive fossil fuels for peaking purposes has been described in Trieb et al. (2011).

A key barrier of RES-E deployment is the large investment involved and the related high cost of capital induced by interest rates from loans and equity. Therefore, **an effective measure to reduce the financial effort of RES-E deployment is the reduction of capital cost, namely by reducing interest rates**. Unfortunately, interest rates are usually even higher in NA than e.g. in the EU, because of additional investment risks involved. Therefore, the clue of reducing interest rates and thus, capital cost for RES-E investment, lies in the reduction of all kinds of risks related to that investment.

A short loan period is in itself an effective measure to reduce investment risk and interest rates with respect to a reference case with longer loan period. This is simply because the lender gets his money back in shorter time. On the other hand, reducing the loan period may be limited by the capacity of the debtor to pay for the annual capital return that becomes higher if the loan period becomes shorter. Therefore, the loan period should always be as short as possible, according to the maximum annual payments the debtor can afford. A loan period that is significantly shorter than the operational lifetime may be especially interesting for RES-E investment in NA, as the longer golden end – the operation period after the loan has been paid back – will be free of capital cost and in case of RES-E also free of fuel cost and will clearly lead to a stabilization or even reduction of the average electricity cost in the country.

Further to reducing the loan period and providing preferential finance, there are other possible measures of de-risking renewable energy investment as has been shown by UNDP (2013). **Figure 11** summarizes some actions that can be taken for reducing the risk and thus the capital cost of RES projects in developing countries in general.

The key of this concept is the **identification of a public instrument mix that will reduce the risk of RES-E projects**, particularly for private investments into the RE sector, in order to activate private capital and to provide a reliable and sustainable framework for RE deployment especially in countries where the risk perception is high and a special barrier for RE. **A specific public core instrument may be complemented by political and financial de-risking instruments and eventually also by direct financial incentives.**

A **public core instrument** may e.g. be a project-specific Power Purchase Agreement (PPA)-based bidding process, as e.g. the one applied for the Ouarzazate project in Morocco, or a feed-in tariff system like e.g. in Germany. A long-term power purchase agreement – especially one guaranteed by the state – reliefs the investor from the risks of volatile market prices and sales volumes, which is particularly important for RES-E: while the consumption of fossil fuel can easily be adapted to volatile market prices and demand, the production from RES-E is defined by the design and the site of the respective plant, leaving the investor alone with the full risk of selling the generated RES-E electricity or not, a fact that usually drives interest rates up to high levels. This risk can directly be taken off the investment by a long-term PPA, “long-term” meaning just as long as the loan period, because after that, a considerable part of the cost will be gone and new tariffs can be agreed upon (Trieb et al. 2011). The key of a feed-in tariff system also is a long-term PPA guaranteed by law, but not based on a project-specific bidding process, but based on technology-specific, fixed tariffs. The major disadvantages of this method with respect to the bidding process is that the amount of RES-E installed per year is not per se limited and the related tariffs are not found and defined by competitive bidding. The advantage of this method is that permits and approval processes are valid for a large number of projects and can therefore be very efficient.

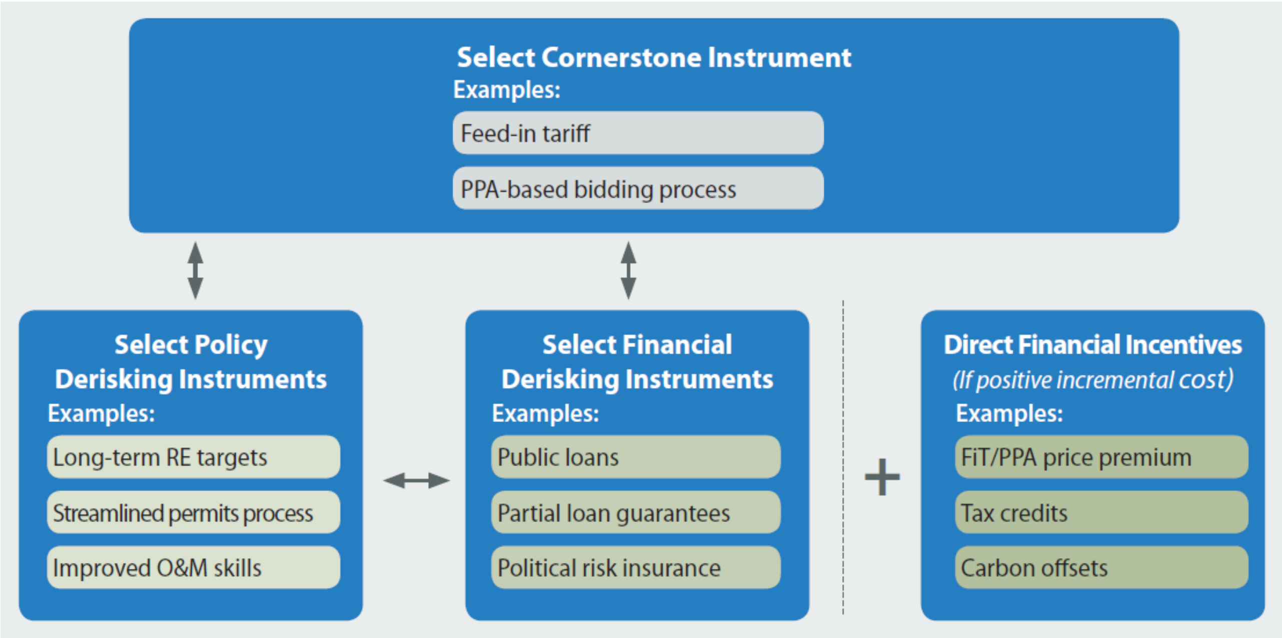


Figure 11: Action for de-risking renewable energy investment proposed by UNDP (2013)

According to UNDP (2013) **policy de-risking instruments** would address and try to remove the underlying political reasons for investment risks. These instruments would rely on policy and programmatic interventions like the establishment of long-term RE targets, streamlining permit and approval procedures, clarifying institutional responsibilities and providing capacity building programs for administration and technical support. Also the implementation of a strong, efficient and transparent authority responsible for RE expansion is part of such political risk mitigation measures.

Financial de-risking instruments do not directly address the underlying barriers, but instead transfer the related investment risks to public actors, such as development banks. These instruments can include public loans, soft loans and guarantees, political and force majeure risk insurance and public equity co-investments. If e.g. the credit worthiness of a power purchase agreement (PPA) is a concern to lenders, a partial loan guaranty from an international development bank can provide local banks with the security to lend to project developers, thereby motivating the local financial sector to finance renewable energy projects.

Finally, **direct financial incentives** like price premiums, tax credits or carbon offsets can be provided that eventually cover part of the incremental cost of RES-E technologies, especially if they are at the beginning of their cost learning curve as described in prior chapters. A RES-E specific character of such incentives is that they usually can be reduced with time, while the specific technology runs through its learning curve and becomes cheaper due to economies of scale. If this is the case, the related incentives may rather be considered as a public investment required to tap a certain technology option, than a subsidy in the common sense (which is usually required forever and in the worst case even increases with time like in the case of fossil fuels).

Instead of spending scarce public money to pay for higher electricity tariffs, it may be advantageous to first reduce and manage the related risks in order to achieve a lower necessary rate of return (UNDP 2013).

The best measure to reduce risks and related capital cost is the establishment of a **long-term, reliable, credible, transparent and predictable RE policy framework** that strictly avoids drastic changes of rules, insecurity of investment perspectives and volatility of RE expansion targets. Such stability is an indispensable requisite for the settlement of a productive domestic RE industry. Moroccan policy is a good and successful approach, as it combines clear long-term RES-E expansion goals with a transparent and effective project-wise bidding process resulting in reliable PPAs backed by international development organizations that allows for considerable de-risking of the involved investments.

The **Moroccan approach can serve as an example of a successful implementation of a legal framework for RES-E deployment**. The main pillars of the Moroccan solar energy strategy are the following:

1. **Predictable RES-E market perspectives**
   The establishment of long-term targets for RES-E expansion e.g. in the frame of the Moroccan Solar Plan (2009) and the Moroccan Integrated Wind Energy Project (2010) is a major requisite of RES-E industry to become actively involved in a regional market, as only this opens a real perspective for replicable business cases. Such plans should be reliable, credible and achievable, and good reasons should be visible that justify and confirm a strong support by the government. Such good reasons can be identified by analyzing the main objectives of the Moroccan energy strategy which are to secure energy supply and availability in front of quickly growing demand by tapping domestic resources, to keep energy prices affordable and to protect the environment. These are rather good reasons that speak for the long-term stability of the respective legal and political framework.

2. **Reliable legal environment**
   a. ***Decree 1-06-15***
      Decree 1-06-15 obliges public institutions to employ competitive calls for tender in the award of projects. This law gives a legal framework to municipalities that wish to contract with RES-E providers.

   b. ***Law 16-08***
      Law 16-08 raised the threshold for self-generation by industrial sites from 10MW to 50MW. The law was initially conceived to support wind power, but also applies to other technologies.

   c. ***Renewable Energy Law 13-09***
      The Renewable Energy Law 13-09 aims to promote energy production from renewable sources for the domestic market and for export either by public or private entities. Before that the state owned utility Office National de l'Electricité ONE

(responsible for power supply and the transmission system) had the monopoly for the production of electricity. Law 13-09 permits electricity to be produced and exported also by private entities. However, the supply of electricity must still be undertaken through the national electricity network. Any renewable power producer – either public or private – has the right to be connected to the medium, high and very high voltage national electricity grid. The law gives the possibility to any developer to build a direct electric distribution line operated separately from the transmission network if the electricity produced is aimed to be exported or the operator has entered into a formal agreement with ONE. The law also introduces an authorization scheme for renewable energy projects through ADEREE.

3. Efficient RE authorities

a. ***Law 16-09 Establishment of ADEREE***

"Moroccan Renewable Energy & Energy Efficiency National Development Agency" (ADEREE) was established after Renewable Energy Law 13-09. ADEREE is in charge of implementing Morocco's national plan for renewable energy and energy efficiency. ADEREE seeks to do this by:

i. proposing national and regional plans and incentive measures for renewable energy and energy efficiency;
ii. the development of programs for renewable energy and energy efficiency within the framework of Morocco's national energy strategy;
iii. the identification, evaluation and realization of the cartography of renewable energy resources and ideas for energy efficiency as well as proposing development zones for solar and wind energy;
iv. developing standards in the fields of renewable energy and energy efficiency as well as supporting research and development and training;
v. the follow-up and co-ordination at national level of energy audits;
vi. ensuring participation at national and international level of technical and financial co-operation in the achievement of ADEREE's objectives.

b. ***Law 57-09 Establishment of MASEN***

The Moroccan Agency for Solar Energy (MASEN) is a public-private agency dedicated to implementing the Moroccan Solar Plan and the promotion of solar energy by:

i. developing solar power projects including studies, project financing
ii. contributing to the development of national expertise and R&D
iii. proposing and implementing regional and national plans on solar energy

MASEN has invited expressions of interest in the design, construction, operation, maintenance and financing of the first of the five planned solar power stations in Morocco.

4. **Resource assessment and identification of project sites**
In-depth assessment of the available solar energy, wind energy and land resources is an essential requisite for RES-E project development. It includes mapping of long-term average annual availability for site identification and the provision of representative annual hourly time series of the different RE resources for performance modelling. A resource assessment program is a most effective measure to trigger RES-E investment, because the lack of knowledge about the available renewable energy sources and their temporal and geographical availability is a major barrier for project development. On the basis of national assessment programs, focal areas for project development can be identified and the resource information can be used for technical and economic performance modeling. In the case of Morocco sites for large scale solar power projects and sites for large scale wind power projects have been identified by the authorities mentioned above. This opens the way for concrete project development in the related areas that will be started by a bidding process.

5. **National funding background**
Société d'Investissements Énergétiques (SIE) is a Moroccan investment fund created in 2010 for developing and promoting renewable energy and energy efficiency in Morocco. The fund was created in 2010 with MAD1 billion of capital from the Energy Development Fund (FDE). FDE was created to support the national energy strategy and strengthen Morocco's energy independence. The FDE has also received US$1 billion in grants provided by the Kingdom of Saudi Arabia, the United Arab Emirates and the Hassan II Fund for Economic and Social Development. SIE's investment policy is to take a minority shareholding interest in companies with "viable and concrete projects whose feasibility has been proven." These stakes are managed within a formal partnership agreement where areas of responsibility and cash flow are clearly outlined.

6. **Capacity building**
The Institut de Recherche en Energie Solaire et Energies Nouvelles (IRESEN) was created in 2011 as a foundation within the initiative of the Moroccan ministry of energy, mines, water and environment, and supported by several Moroccan institutions: ADEREE, CNESTEN, MASEN, OCP, ONE, ONHYM and SIE, in order to carry technological and applied R&D at the national level in the area of renewable energies, to define research axis, to coordinate and reinforce research efficiency and to push innovation and development in one of the most promising fields in Morocco.

7. **International cooperation**
Renewable energy projects commissioned or in the pipeline in NA indicate that concessionary finance involving long-term, low-interest loans remain an important source for many renewable energy projects. KfW, the European Investment Bank (EIB), the Agence Française de Développement (AFD), and the World Bank group and the Abu Dhabi Fund for Development participate in RES-E financing in the region. The World Bank also has been active in analysis and advisory work. Climate finance, the United Nations Development Programme (UNDP), and the African Development Bank also play a significant role (Bryden et

al. 2013). E.g. the Clean Technology Fund (CTF) is one of four Climate Investment Funds administered through the regional development banks. Algeria, Egypt, Morocco and Tunisia together with Jordan plan to use 750 USD million from the CTF in conjunction with other funding sources to support the deployment of about 1 GW of CSP capacity. Another emerging carbon market mechanism is the Nationally Appropriate Mitigation Actions (NAMAs). A NAMA specifies voluntary activities to mitigate greenhouse gas emissions in developing countries that are not subject to mitigation commitments, and these actions can be supported by industrialized countries through financing, technology transfer, or capacity building.

Summarizing the findings mentioned above, we can now formulate the **general requisites of an appropriate political and legal framework for RES-E in North Africa**:

- a fundamental recognition of the socio-economic benefits of RES-E as motivation for durable political and civil support;
- the ability to afford RES-E investments, either from national income, foreign aid or – preferably – from savings induced by the introduction of RES-E;
- a predictable national RE expansion plan;
- a reliable legal environment and streamlined permit procedures;
- establishment of efficient RE authorities;
- a national RES-E resource assessment program;
- identification of concrete project sites;
- establishment of a public core instrument for RE investment, like e.g. feed-in tariff system or tendered PPAs;
- a reduction of capital cost by public entities taking the risks out of RES-E projects, converting them in the best case into AAA investment opportunities. This can be achieved by reliable power purchase agreements backed by national and international guaranties (financial de-risking), by a reliable policy and legal framework (policy de-risking) and by the participation of public institutions in equity or other kinds of support (direct incentives). Short loan periods also help to reduce investment risks and capital cost;
- capacity building for RE in all sectors like technical, legal, finance etc.;
- international financial and technical cooperation.

2.6 SCENARIOS FOR RES-E EXPANSION IN NA

It has been commonly accepted in the past years that the introduction of renewable energy in the power supply sector of the North African countries will be beneficial for their economic and industrial development, and will also contribute to the solution of environmental concerns like climate change and pollution.

However, the extent of RES-E shares and the type of RES-E technologies applied is still under controversial discussion. Some electricity authorities claim that renewable shares should not exceed 10% of annual power generation, as the fluctuating character of wind and PV systems would destabilize the rather week and unstable electricity grids in the region. Others say that least cost generation by wind power and photovoltaic power (PV) should have a priority on more expensive concentrating solar thermal power (CSP) production in order to avoid overloading national economies with subsidies for renewables.

On the other hand, RES-E fans claim that only a decided expansion of RES-E capacity to 100% will allow for a sustainable supply of electricity in the region and worldwide. The fluctuating character of wind power and PV should be compensated by a strong expansion of electricity storage technologies and electricity grid transfer capacity (super grid, smart grid and super-smart-grid) combined with demand side management, combined heat and power and smart metering, assuming in their expansion strategy a series of several technological break-throughs that may be achieved in the future or perhaps not.

In view of the controversial discussion on RES-E expansion that is going on even in Europe and – as a country leading European RES-E development – also in Germany, we have decided to develop "bottom-up" scenarios for RES-E expansion in North Africa that will not require any technological break-through, no grid expansion beyond the level that is needed anyway to cope with the growing electricity consumption, no extra electricity storage technologies and no overloading of the electricity grid with significant fluctuating capacities from wind power and PV.

The result of this approach are scenarios for Algeria, Egypt, Libya, Morocco and Tunisia from the year 2000 to 2050, that are based on historical development (until 2010), short-term national planning (until 2020) and further scenario development (until 2050) that takes into account the existing RES-E potentials, defined sustainability targets and – among others – the natural limitations mentioned above.

All scenarios are characterized by a well-balanced mix of about 30-40% fluctuating renewables (wind and PV), 50-60% flexible renewables (mainly CSP, but also hydropower, biomass and geothermal power, where available) and 10-20% ideally stored energy in form of fossil fuels or eventually, renewable fuels that may become available in the long-term, like hydrogen or synthetic natural gas from renewable sources.

We found that all countries analyzed in the North Africa case study can achieve sustainable supply in terms of supply security, cost stability and environmental as well as social compatibility.

Electricity exports to and imports from neighboring countries are assumed to take place through the AC electricity grid just as needed to satisfy the frame conditions mentioned above. As all NA countries have enough natural resources for their own supply, we have assumed that imports and exports through the power grid will be balanced over the year, so no net import or net export takes place through the AC grid interconnectors, but occasional transfers in both directions. This will allow making use of synergies and compensation effects of power demand and production between neighbor countries. The net transfer capacity (NTC) of the grid is assumed to be symmetrical in both directions. The NTC of the conventional alternating current (AC) grid between the NA countries is expanded in our model proportionally to the growing demand of the North African countries, taking German annual generation (600 TWh/y) and German NTC (8 GW) as reference values for a well-developed electricity scheme. As an example, if the Egyptian electricity demand would expand to 600 TWh/y in 2050, by that time its AC grid would have the same NTC as Germany has today. Further expansion of the AC grid beyond what is required by the growing electricity consumption is not necessary in our scenario, as the fluctuating renewable energy sources are designed in a way that does not lead to significant surplus capacity that would have to be balanced by extra grid capacity.

In addition to national domestic supply, the scenarios foresee the export of highly flexible power from CSP plants explicitly built for that purpose to different centers of demand in Europe according to a European scenario described in /Trieb and Müller-Steinhagen 2007/, that follows the same principles as described before. By separating the infrastructure needed for export and the infrastructure needed for national supply, national electricity supply on demand will be guaranteed at any time independently from any export scheme, and vice versa. Any conflicting situations between import and export countries are thus avoided, because both schemes will be completely independent from each other. Another advantage of this approach is that the electricity exported to Europe will be clearly and verifiably solar. Another important aspect of separating national supply and export schemes is that export electricity in some cases may be in the same order of magnitude as national supply. If both structures would be dependent on each other, severe conflicts about the access to the electricity produced could arise in the future.

On the other hand, structures for export and local supply could be connected in a way that avoids conflicts on firm capacity by guaranteeing firm capacity on each side, but at the same time allows sharing surplus energy in order to minimize curtailment losses. This would constitute a higher complexity of the system, but would allow for synergies and more efficient overall system design. Nevertheless, for simplicity and as a conservative point of view, we have assumed here that export and domestic supply would be based on completely separated infrastructure.

The former studies and scenarios of DLR for the MENA region like /MED-CSP 2005/ and /TRANS-CSP 2006/ have often been criticized because of their high share of CSP compared to the share of wind power and photovoltaic power on the annual electricity production. **Figure 12** shows that this is not a result of CSP lobbying but a consequence of a sound design of the total electricity supply system. On the top left of **Figure 12** we can appreciate a series of days showing the varying load curve and how it is covered by wind and PV capacity that is slightly lower than peak load, and firm capacity composed of hybrid CSP plants and fuel-fired peaking plants, that together make up for a little more than peak load. There is only little surplus, and over the year, only 10% of the electricity must be supplied by hybrid operation of CSP with fuel and by fuel-fired residual peaking plants that will only work occasionally in summer during peak load. In this example, the annual power production is composed of 56% CSP, 17% PV, 17% wind power and 10% fossil fuel (**Figure 12**, top right). The total installed power plant capacity amounts to 170% of peak load.

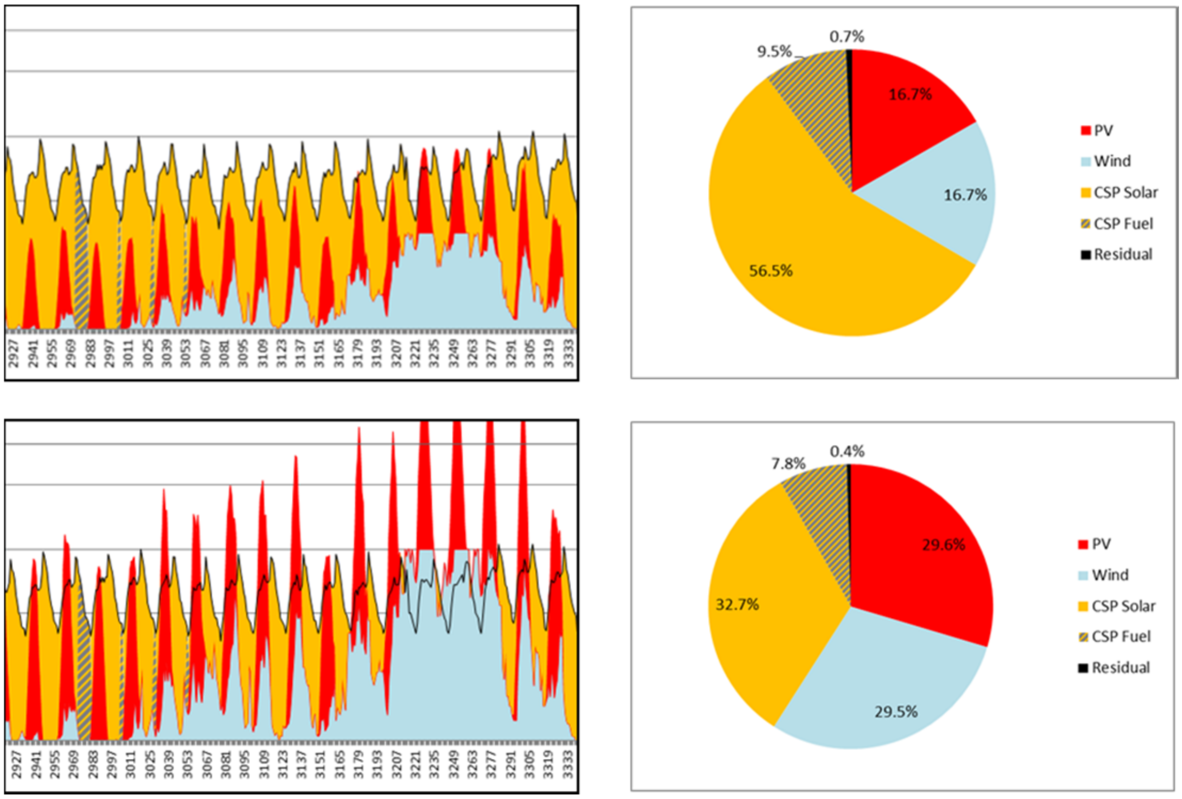


Figure 12: Hourly time series (left) and annual composition (right) of a well balanced mix of wind, PV and hybrid CSP plants (top) and a mix resulting from doubling the wind and PV capacity with respect to the first case (bottom). Substituting flexible CSP electricity by wind and PV leads to considerable increase of unused surplus from 0.7% to 14%, while fossil fuel consumption is only reduced marginally from 10% to 8%.

On the bottom left of **Figure 12** we can see the same time series, but now the installed capacity of wind power and PV was doubled with respect to the top figure, providing much higher wind and PV shares on annual basis (bottom right). However, we can see that there is a considerable unused surplus of wind and PV power, while the gaps that have to be filled by fossil fuel still remain. The total installed capacity amounts to 240% of peak load. This second approach leads to capacity surpluses in the order of magnitude of the maximum load itself, requires much more installed capacity, and only leads to a marginal reduction of fuel consumption of about 2%. Another issue is the balancing of the electricity grid, which is much more difficult in the second case, as the grid must be operated for long periods without any flexible / reliable power plants being online. The only "positive" issue is that shares of wind, PV and CSP are more or less equal. However, this is not a criteria that would be important for achieving sustainability.

The bottom-up scenarios developed here will follow the first (top) approach, trying to achieve a well-balanced mix of renewable power technologies and sources that will lead to a secure, sustainable supply, without creating imponderability regarding technical feasibility, external costs or public acceptance of the required power infrastructures.

A simple thumb rule resulting from this approach that can be applied to almost every country worldwide is that the installed capacities of fluctuating sources would be limited to just below peak load, while flexible and firm power capacity will be at least extended to slightly over peak load demand, thus resulting more or less the same installed capacities for both categories, with slightly higher values for flexible power. Depending on the natural productivity of the different renewable resources, the annual electricity mix will then be composed of about 50% flexible renewables, about 40% fluctuating renewables and 10% ideally stored forms of energy that can be fossil fuels or synthetic fuels originating from renewable sources.

Such a development of RES-E will require considerably less installed power capacity and will not require a dramatic expansion of grid and storage capacities except those that will be needed anyway to satisfy growing demand. Because it requires much less infrastructure, in technical terms, but also in economic and environmental terms, the impact and footprint of such a scenario will be considerably lower than for scenarios mainly relying on fluctuating RES-E.

In the past 5 year planning period, all North African countries have set goals for the development and expansion of their domestic renewable energy resources. In terms of renewable energy development, Morocco is the leading country in the region, with a well-balanced and timely expansion of all available renewable energy sources, mainly solar and wind power. All other countries could accelerate their expansion of RES-E, particularly Tunisia and Libya, which are still far behind their actual potential.

A balanced mix of fluctuating (wind, PV) and flexible renewable energy sources (CSP, biomass, geothermal, hydropower with dam) will be particularly important in order to be able to cope with the growing peak demand and to substitute the consumption of ideally stored fossil fuels. CSP, in spite of being more expensive than PV or wind power, will clearly achieve the highest RES-E shares in North Africa being the resource with the largest potential and being able to deliver firm capacity and flexible power on demand, both crucial for the economic development of the NA countries.

The advantage of CSP over conventional fossil fuels, that would be the alternative to provide firm and flexible power on demand, is that its cost will be reduced while fuel prices will stay at a high level or even increase in the future.

The lack of hydropower dams and pump storage in the NA region – that could act as natural storage for fluctuating sources like wind and PV – limits the expansion of fluctuating sources to an installed capacity that would be more or less in the order of the national peak load. This strategy will avoid the need for extra storage and net transfer capacities and the related energy losses and cost.

By achieving a well-balanced mix of renewable and fossil, variable and flexible, fluctuating and firm power generation all countries will be able to reach a sustainable supply by the middle of the century in spite of strongly growing consumption and peak load, under the condition that they immediately start with the introduction and expansion of RES-E.

Especially in Egypt and Tunisia, but also in Algeria, the long-term availability of national fossil fuels is not secured under the assumption that presently growing demand would be covered by fossil fuels in a business as usual way. All countries except Libya are already or will become net energy importers in the short and medium term, if they continue or even increase their present consumption of fossil fuels.

Following our scenarios for NA would lead to the following implications:

1. ALL countries can achieve sustainable electricity supply. The available renewable energy potential is much larger than electricity demand will ever be, leaving enough room for self-supply and for export to Europe.
2. All countries can become net solar electricity exporters, as only a few percent of the potential is required for domestic supply. The export HVDC infrastructure must be separated from national AC supply structures in order to avoid supply conflicts.
3. The availability of fossil fuels – mainly in Libya and Algeria – would be prolonged for many decades and could be shared in the region as ideally stored form of energy.
4. Fossil fuel-fired power plants will remain for a long-time as firm backup capacity and reserve, but their fuel consumption will be reduced significantly. In the very long-term, they may be applied as “silent” reserves.
5. The RES-E expansion strategy shown here will lead to an overall reduction and stabilization of electricity cost without creating external costs of electricity storage, grid transfer and backup plants. Thus, it is an important option of getting rid of present energy subsidies.
6. The development of the electricity grid in North Africa will be proportional to the growing electricity consumption. In the long-term, a similar grid transfer capacity between countries will be achieved as the one existing today in Europe, because power consumption will also be on a similar level. However, as today in Europe, only small amounts of energy will be exchanged over the borders, and transfers will be balanced in both directions.
7. Renewable electricity shares between 80% and 90% can be achieved by 2050, leading to a considerable relief in terms of greenhouse gas emissions and other pollutants related to power generation that otherwise would occur if fossil fuel consumption would continue at present levels.

Our scenarios are not considered as predictions of the future, but rather as consistent pathways towards a long-term target defined by a set of criteria that describe a sustainable supply of electricity. The scenarios will not happen spontaneously, but will require political will and socio-economic effort. The main pillars of a sustainable electricity scenario are affordability, security of supply and compatibility with society and environment. Each scenario leads to a mix of supply options that fulfills the sustainability criteria applied and respects eventual limiters.

The pathway towards sustainability described by such a scenario must be free of contradictions and inconsistencies and is narrowed down by technical, economic, social and environmental constraints, so called guard rails. A limited portfolio of electricity supply options is available to follow those guard-rails towards a sustainability target.

The sustainability target function is defined by the following parameters:

1. Affordability
2. Supply security
3. Environmental compatibility
4. Social compatibility

The methodology and the guardrail assumptions for the modelling are given in detail in the report "D3.2.2 Criteria and guidelines for sustainable electricity scenarios" published on the BETTER website www.better-project.net.

2.6.1. Algeria

The Algerian power market experienced a massive increase in demand and a corresponding expansion of the generation capacities of 51% within the last decade (MEM 2013). The electricity generation sector is characterized by the presence of domestic natural gas resources: 97% of electricity produced in 2011 was fueled by natural gas (CREG 2011). In 2002, the power market was restructured and liberalized through the creation of an independent regulator, *Algerian Electricity and Gas Regulation Commission* (CREG), safeguarding fair grid access and the opening of the generation market for Independent Power Producers (IPPs). Despite the liberalization, the power market is still dominated by the state-owned energy companies, Sonatrach and Sonelgaz, which produce 55% of the electricity in Algeria (MEM 2011a). In 2011, Sonelgaz generated 26.4 TWh while IPPs were responsible for 21.9 TWh and self- producers generated 2.3 TWh of the 50.7 TWh of total electricity production. 74.7 % of the total 11,300 MW installed capacity in 2011 was owned by the Sonelgaz affiliate SPE. In 2010 the installed capacity of solar PV in Algeria was reported to be 7.1 MW, CSP capacity in 2012 was 25 MW and hydro capacity was 228 MW (REN21 2013). As for projects in pipeline the installation of 195 MW from mostly solar energy are reported (REN21 2013).

Although the electricity market has been formally liberalized and non-discriminatory grid access is to be ensured by the regulator, only joint ventures with the main public energy company Sonelgaz have successfully entered the Algerian power market (Supersberger et al. 2010). Due to abundant and cheap domestic gas, the electricity prices in Algeria are much lower than in other power markets and are still defined and regulated by CREG. The regulator is obliged to develop a 10-year program for energy generation prospects every two years (MEM 2002).

With the opening of the power generation market, the government intended to trigger a stronger deployment of renewable energy to diversify the electricity and energy supply in Algeria. These plans for a rapid expansion of renewables have not been implemented yet, although financial support schemes for renewable energy are legally in place since 2004 (MEM 2004a). In 2011, the Algerian government renewed its RE strategy, aiming for 40% of RE installed capacities in 2030. In 2011, Algeria's first combined CSP power plant with an installed capacity of 150 MW in total in solar capacity of 25 MW began operations in Hassi R'Mel. This project is planned to be followed by three more CSP plants with installed solar capacities of 70 MW each in the years 2014, 2016 and 2018 (NEAL 2013).

To finance the renewable energy plans, the "Fonds national pour les énergies renouvelables et la cogeneration" (FNER) was established in 2011. This fund is, in turn, financed by a 1% of oil royalties and other contributions (MEM 2011a). Until now, only very few RE projects planned were successfully implemented.

2.6.1.1 Demand Expectations

In the past decade, an electricity consumption of approximately 1.9 TWh/y has been added every year in Algeria, reaching an annual demand of 45 TWh/y in 2010 (DLR 2013). The growth rate of demand in 2010 was 12%/y. If the linear trend would continue in the future Algeria would consume about 65 TWh/y by 2020 and 120 TWh/y by 2050 (**Figure 13**). According to AUE 2011 the national expectations are higher, indicating a demand of 95 TWh/y by 2020. Extrapolating this expectation linearly after 2020, Algeria would consume about 240 TWh/y by 2050.

Our model predicts a demand that is well in line with the national outlook and its linear extrapolation almost until 2040. Starting with 45 TWh/y in 2010, our model predicts about 87 TWh/y in 2020. After that, the model shows a linear growth and a beginning saturation after 2040, leading to a value of 200 TWh/y in 2050. As Algeria today is a country with relatively high per capita income among the NA countries, the model function shows a beginning saturation effect that can be expected in the long term.

Per capita electricity consumption will increase from 1.3 MWh/cap/y in 2010 to around 4.3 MWh/cap/y in 2050.The result of our demand modelling shows that Algeria will face significant challenges with respect to its growing electricity demand, and dependency of fossil fuel would increase significantly if no additional domestic sources would be developed.

An hourly load curve for Algeria for the year 2010 was provided by AUE 2012. This load curve was scaled for all consecutive years until 2025 for detailed scenario modelling of the electricity mix (**Figure 14**). Scaling was done in a way that maintains the relation of annual electricity demand and peak load just as scheduled by the national outlook data provided by AUE 2011. The load curve shows two peaks during summer and smaller peaks during the winter season.

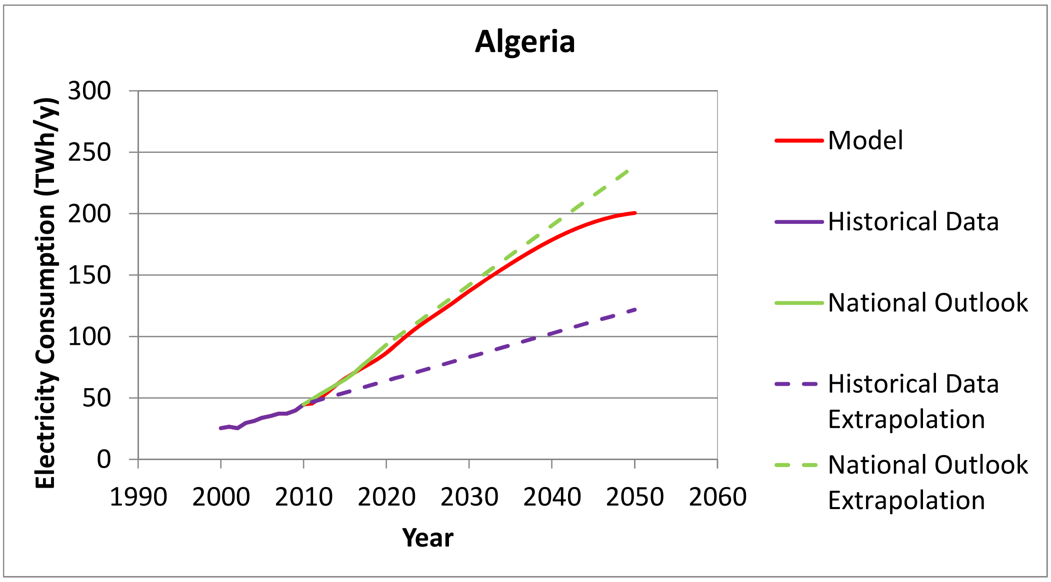


Figure 13: Gross electricity consumption in Algeria: Model result, historical data until 2010 with linear extrapolation after 2010, national outlook from 2010 to 2020 with linear extrapolation after 2020.

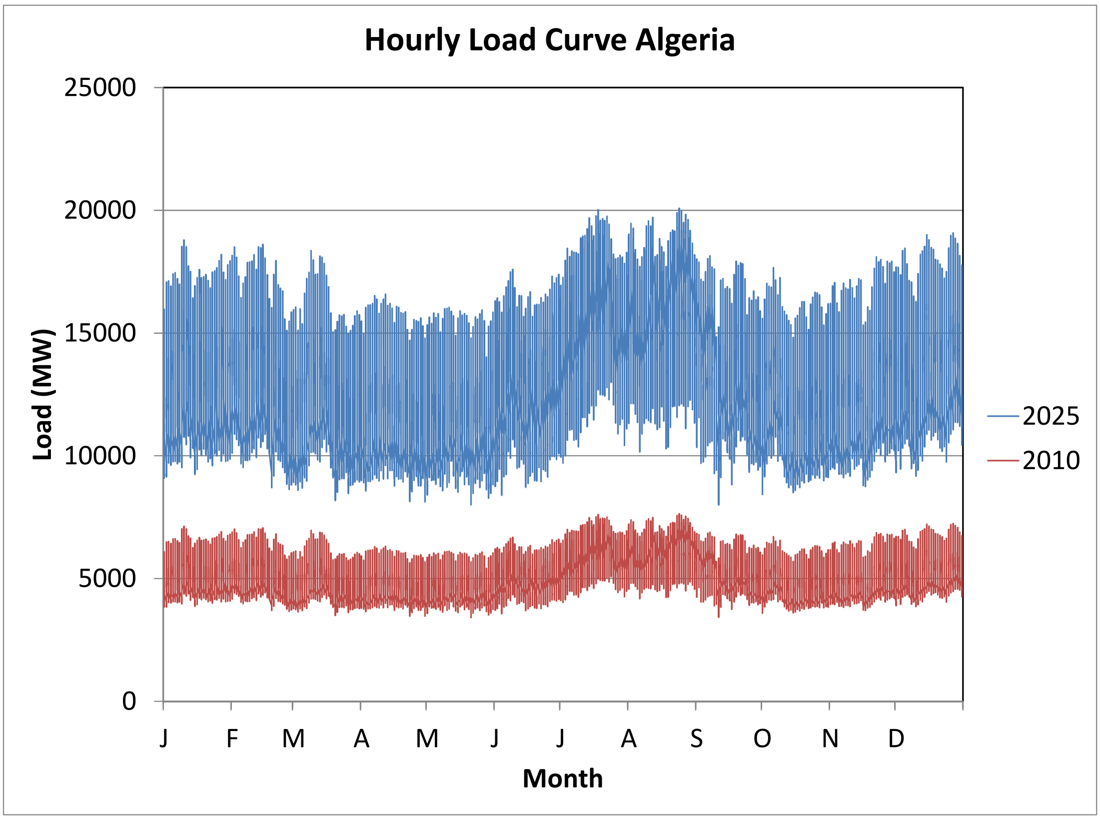


Figure 14: Hourly load curve for the years 2010 and 2025 for Algeria

2.6.1.2 RE Targets and Policy Framework

Algeria has a target of 6% share of renewables in electricity generation by 2015, 15% by 2020 (REN21 2013) and as announced 2011 in a governmental program a renewable energy share of installed capacities of 40% by 2030 (MEM 2011b). These 40% are projected to consist of 12,000 MW RE capacities for domestic demand and 10,000 MW for exports. The bulk of the RE deployment is planned to be solar power mainly from CSP power plants which is intended to account for 37% - i.e. almost the entire renewables target – of the Algerian production in 2030. The remaining 3% are projected to come from wind power. The program is structured into three phases of deployment:

1 The installation of 110 MW RE capacities in 2013 and 650 MW until 2015.

2 Deployment of 2,600 MW by 2020 for domestic use and 2,000 MW for exports (of which 800 MW is planned to come from solar PV installations and 1,200 MW from CSP plants).

3 The large scale deployment of 12,000 MW for domestic consumption and 10,000 MW for exports until 2030. From 2020 until 2030, 200 MW of solar PV and between 500 and 600 MW of CSP is planned to be installed every year.

The equipment and operation of the power stations, including those for export, are planned to be done mainly by Algerian companies: the aim within the RE program is to achieve an “integration factor” of the Algerian industry of 80% in 2030 (MEM 2011b).

The implementation of the renewable energy program is slow: Despite the targets, the 10 year-indicative program of the CREG foresees a maximum of 8% of the electricity generation coming from renewable energies in 2020 (CREG 2010). There are no renewable energy expansion plans beyond 2030.

REGULATORY FRAMEWORK

A general framework for the deployment of renewable energies was created in 2004 with the renewable energy law (MEM 2004b). The core of the law is a feed-in premium support scheme, intended to remunerate the additional costs for renewable energy deployment (MEM 2004a).

The legal framework for the feed-in premium mechanism already exists. Nevertheless, new developments have been recently made. This has been reinforced by the two inter-ministerial decrees passed October 2012 and published in the official gazette (entered into force) in May 2013. One determines the conditions of access for private producers to feed-in tariffs for electricity produced from renewable energy sources. The other one provides for the establishment of a guarantee certificate of origin[3] for equipment and facilities for the production of electricity from renewable energy sources.

[3]The certificate scheme is under the law 04-09 of 18 August 2004 on the promotion of renewable energy. This certification is to be issued by CREG to facilities of electricity produced from renewable energy sources.

With the reformulation of the renewable energy program in 2011 and the creation of the National Renewable Energy Fund, further financial incentives to foster private investments in RE in Algeria such as VAT reduction, tax exemptions, guaranteed loans and reduction of custom duties were backed by public funding (MEM 2011b). Cooperation mechanisms with EU or renewable energy related carbon credits are not in place yet.

Algeria ratified the Kyoto Protocol in 2005. The DNA is the Ministry of Territorial Planning and Environment. Regarding carbon credits, the table below lists registered CDM projects in the chemical industry for NOx reductions.

Taking advantage of opportunities that could be offered under NAMAs could be interesting as a complementary source of revenue. Therefore, carbon projects for the voluntary market could be another alternative. No NAMAs have been submitted yet to the UNFCCC by Algeria. A feasibility study for NAMAs in the area of CSP and building is ongoing.

The extra costs for renewable electricity transmission under the special regime are regulated by CREG and are to be covered by the funding of the cost of diversification as defined by law (MEM 2004a, 2006). Thus, the national TSO, *Société Algérienne de Gestion du Réseau de Transport de l'Electricité* (GRTE) a subsidiary of Sonelgaz, is responsible for grid connection to the transmission network for projects less than 50 km from a suitable grid connection point, while the distribution companies are obliged to connect projects within a limit of 5 km. Beyond these distances, the grid connection – and the costs arising – lay in the responsibility of the generator. RE projects which were subject to a public tendering by CREG are exempted from this regulation: In these cases production sites have to be connected and the additional costs should be covered by the costs of diversification as defined for the *National Fund for Renewable Energy,* FNER (MEM 2006). RE facilities under the special regime of renewable energy do have priority grid access (MEM 2006).

The Algerian power market is legally unbundled, following the restructuring of the former state-owned monopolist Sonelgaz in 2002. Since then, the Sonelgaz group consists of seven different state-owned companies: one in generation, one in transmission, one in system operation and four in the distribution domains (Sonelgaz 2013).

Although the generation sector is formally liberalized, foreign investors must cooperate with Algerian companies for a market entry: no more than 49% of the joint venture can be held by a foreign investor, whereas the majority shares must be held by Algerian entities (Government of Algeria 2009). The Sonelgaz group thus was still responsible for the production of 83% of electricity produced in 2011 (CREG 2011).

The transmission of electricity is seen as a natural monopoly and as such only the assigned transmission operator is allowed to operate and invest in transmission capacities. The Algerian TSO, GRTE is regulated by CREG since its establishment in 2005 (CREG 2013). The regulation commission has the power to intervene in transactions such as exporting electricity when the satisfaction of national demand is endangered (MEM 2002).

Concessions to regional distribution companies are legally allowed but until now, only the four Sonelgaz group companies have been established as distribution entities.

Given the high targets of RE by 2030, the regulatory framework is evolving, and thus allowing for a faster penetration of renewable energy in the market. For this to be realized, two decrees are currently under preparation and discussion:[4]

- an executive decree on the promotion of electricity generation from renewable energy sources and co-generation system;
- a decree on certification of origin of electricity.

Within the framework of the national industrial integration strategy, two solar PV module factories are under construction in Algeria. Recently, Condor Electronics, an Algerian electronics manufacturer, announced the opening of a 50 MW photovoltaic module production facility in Bordj Bou Arreiridj by July 2013. The second solar module factory under construction, with a 140 MW production capacity, is owned by Rouiba Eclairage (a subsidiary of Sonelgaz), and is planned to be commissioned by early 2014.[5]

INSTITUTIONAL FRAMEWORK

The institutional framework in Algeria has been characterized by the creation of several agencies for the promotion of renewable energy in the country. The Ministry of Energy and Mining (MEM) is the main institution responsible for energy policy design and implementation. Its main functions are detailed in the Executive Decree No. 07-266 of 9 September 2007. The main institutions dealing with renewable energy are the New *Energy Algeria (NEAL)*, *Institute for Renewable Energy and Energy Efficiency* (IAER),[6] the *Agency for the Promotion of the Rationalization of the Use of Energy* (APRUE), the *Algerian Electricity and Gas Regulation Commission* (*CREG)* and the *Renewable Energy Development Centre* (CDER-under the authority of the Ministry of higher education and scientific research) as well as the *Centre de Recherche de Développement de l'Electricité et du Gaz* (CREDEG).

New Energy Algeria (NEAL) is the agency responsible for the promotion of renewable energy. NEAL is a joint stock company held by Sonatrach, Sonelgaz and SIM Group (private agribusiness group). Its strategic orientations are: identification and the realization of projects related to new and renewable energy; definition, drafting and implementation of the strategies for development and organization of industrial and commercial activities; and take stakes in companies in the field of production, transport and distribution of new and/or renewable energy.

The *Agency for the Promotion and the Rationalization of the Use of Energy* (APRUE) is important especially in energy efficiency and awareness raising. It was created in 1985 with a mission of promoting energy conservation and energy efficiency. Its main objectives are: coordination of

[4] Presentation of Djamila Mohammedi, Director of Strategy, Sonelgaz, at the 5th conference of COMELEC , 13 November 2012
[5] http://www.maghrebemergent.info/actualite/breves/fil-maghreb/item/24343-algerie-condor-compte-produire-des-panneaux-photovoltaiques-des-le-mois-de-juillet.html
[6]Mainly for conducting training activities. More details are under the social development framework.

national policy related to energy conservation; putting in place and follow-up of the National Programme for Energy Conservation; awareness raising; and implementation of programs in partnership with relevant sectors (industry, construction, transport, etc,.).

The *Renewable Energy Development Centre* (CDER-under the authority of the Ministry of higher education and scientific research) is responsible for developing and implementing programs of scientific and technological research and development in renewable energy including solar, wind, geothermal and biomass.[7]

The *Centre de Recherche de Développement de l'Electricité et du Gaz (CREDEG)* is a subsidiary company of Sonelgaz group. It was created in January 2005 and its missions are : advice and assistance in the industrial sector, approval of electrical and gas appliances, testing of electrical gas equipments, certification, introduction of new techniques and technologies in education, tesing and applied research and management, monitoring and dissemination of technical and technological references (standards, technical guides, newsletters, etc).[8]

Given the increasing complexity of the electricity sector, an important step towards institutional consolidation has been the establishment in 2002 of an independent regulator, *Algerian Electricity and Gas Regulation Commission* (CREG). Among its roles are setting tariffs, guaranteeing grid access and liberalizing the generation market for Independent Power Producers (IPPs), which are very important elements in inducing competition, especially at the generation level.

Regardless of such institutional advancements, further framework conditions are needed to achieve the RES policy targets. Further institutional consolidation is needed, especially at the ministry level, for example, a dedicated division on renewable energy with enough human resources expertise would be very important, especially in policy coordination among the other actors involved in the promotion and development of renewable energy. In addition to electricity, gas and nuclear, renewable energy and energy conservation are under the scope of the "Direction Générale de l'Energie." So, even though one of MEM's attributions are conducting studies related to the promotion of renewable energy, further steps would be the establishment a dedicated division as is the case of "*Direction Générale des Hydrocarbures*.

Given that several institutions are involved in renewable energy and energy efficiency in the country, clear mandates of each actor should be further clarified to avoid any potential conflicts. Clear responsibilities should be, in particular, further reinforced for APRUE, NEAL and CREG. This should, thus, constitute a significant advancement towards more institutional consolidation.

CREG could be a suitable institution to facilitate the implementation of the cooperation mechanisms between Algeria and Europe. This role would entail i) administration of the provided remuneration, ii) facilitation of an oversight over the implementation and iii) proof of renewable energy transfers (Frieden *et al*., 2012).

[7] Renewable Energy and Energy Efficiency Program, March 2011,http://www.mem-algeria.org/francais/uploads/enr/Programme_ENR_et_efficacite_energetique_en.pdf
[8] CREDEG, http://www.sonelgaz.dz/article.php3?id_article=235

INFORMATION POLICY AND CAPACITY BUILDING

Several RE research and training agencies and institutions have been created such as the *Institute for Renewable Energy and Energy Efficiency* (IAER), the *Agency for the Promotion of the Rationalization of the Use of Energy* (APRUE) and the *Renewable Energy Development Centre* (CDER).

Awareness raising is very important in promoting renewable energy. APRUE, for example, has already held several campaigns related to energy conservation, including TV and radio spots. CDER also plays an essential role in disseminating information related to renewable energy. On its website,[9]regular news on all aspects of renewable energy and energy efficiency are published. The Ministry of Energy and Mines (MEM), also has information on its website, in particular, renewable energy atlas.

Regarding education and training, several university degrees are offered at the master's and Ph.D levels. In addition to many specific training/workshops on renewable energy, some of the other university level education degrees are: *Master Systèmes Energétiques Industriels* (Université Mentouri de Constantine), *Master en Systèmes Frigorifiques et Energies Renouvelable* (Univeristé Mentouri de Constantine) and a "*Master pro (M2) Génie Electrique, Energétique et Energies Renouvelable* (GEER)."[10] Another joint partnership of different research institutions and universities is the "*Ecole Doctorales Energies Renouvelables*" established (CDER).

The *Institute for Renewable Energy and Energy Efficiency* (IAER) is, in particular, targeting training activities and ensuring quality development of renewable energy. The main fields of training to be provided by the institute include engineering, safety and security, energy auditing and project management.[11]

Awareness raising at the level of the finance sector is one of the barriers for scaling up large deployment of renewable energy in Algeria. Regardless of the efforts done in terms of information and awareness raising on renewable energy, specific campaigns should be tailored to specific audiences, including the finance sector given its importance in the widespread of the technology.

In terms of training needs, the target group identified is mainly the "RES and EE system designers/technicians/researchers" and then followed by RES system installers. On the level of content, impact on the grid of the RE system development followed by CSP technology themes were identified. For consultants and the national regulatory services categories, the scope and elaboration of the RES and EE project feasibility studies and the tender specifications and tender evaluation themes were identified (PWMSP 2013).

Regarding local manufacturing and further employment, within the framework of the national industrial integration strategy, two PV module units are under construction. One is Condor Electronics (Algerian electronics manufacturer with a production capacity of 50 MW) in Bordj Bou Arreiridj was opened by July 2013 and the first PV panel was produced in October 2013[12] and

[9] http://portail.cder.dz/spip.php?rubrique13
[10] GEER established in a partnership with l'AgenceUniversitaire de la Francophonie (AUF) and the European Commission (EC) through the ACP-EU Energy Facility and the
[11] Renewable Energy and Energy Efficiency Program, March 2011.http://www.mem-algeria.org/francais/uploads/enr/Programme_ENR_et_efficacite_energetique_en.pdf
[12] http://portail.cder.dz/spip.php?article3552

another one is under construction (200 MW production capacity) owned by Rouiba Eclairage (a subsidiary of Sonelgaz) and is expected to be opened in early 2014.[13] Another project for manufacturing PV panels with 500 MW is also expected to be built at Larbaa by Cevital (Noureddine 2013). Once in place, these would have positive socio-economic impact in the country.

BARRIERS[14]

Despite the relatively ambitious Algerian RE targets, the present deployment of RE projects is very limited. The most important barriers for a large scale deployment of RE in Algeria as identified by stakeholders are:

- The restrictions for foreign investors in RE projects in Algeria, in particular the compulsory association with national partners that hold 51% of the investment;
- The low and subsidized energy prices and the subsidized electricity from fossil fuels create market distortions and discourage investments in RE as long as RES-E are not subsidized equally;
- The relative lack of awareness and information of the financial sector on RE, leading to a low interest of banks in financing renewable energy projects;
- The limited success of the 2002 electricity law in terms of private sector development of RE.

Specific barriers directly linked to the export of RE electricity from Algeria to Europe have also been identified:

- The regulatory challenges to access the European market, which is subject to the “rigid” provisions of Article 9 of the European Directive, constitutes a major obstacle to export 10,000 MW to Europe envisaged under the national strategy for 2030.
- Lack of interconnections capable of transmitting electricity and the time horizon of building new interconnections. Marine interconnections, which are expensive and may be complicated and take time to realize, are needed to strengthen the only Euro-Maghreb existing electrical interconnection linking Spain and Morocco. Currently, this interconnection is not sufficient to export Algerian electricity to Europe. Even with sufficient interconnections, the export of Algerian RE electricity through Moroccan grid would need specific legal rules to be implemented.

[13] http://www.maghrebemergent.info/actualite/breves/fil-maghreb/item/24343-algerie-condor-compte-produire-des-panneaux-photovoltaiques-des-le-mois-de-juillet.html
[14] This section is based on interviews and contributions of experts from Sonelgaz

2.6.1.3 Scenario for the power sector

Scenario analysis reveals two aspects of electricity supply that will be shown for a possible transition towards a sustainable electricity scheme: the installed capacity and the annual electricity production and their development as function of time.

In terms of installed capacity, the most important target to be achieved is that the firm capacity of all power plants is always larger than the peak load that occurs once a year. Our scenario in **Table 20** shows how peak load will increase almost linearly between 2010 and 2040, and as a consequence firm power capacity from gas fired power stations also will have to increase in line with that growing demand. However, after 2030, CSP plants step-by-step will take over firm capacity supply, because by then the CSP industry will have grown sufficiently to cover the increasing demand for firm renewable power capacity. According to national planning, by 2020 about 600 MW of wind power, 1200 MW of PV and 2500 MW of CSP capacity could be installed. Also hydropower capacity could be extended to about 500 MW.

By 2030 about one third of the installed capacity will be covered by renewable sources, and CSP exports to Europe will also be implemented. The strongest growth of renewable power capacity will take place between 2030 and 2040. In 2050, the largest part of the power park will already be renewable, with hybrid (solar/fossil) CSP taking over the job of providing firm and flexible power capacity on demand, and major wind and PV capacities that will act as fuel savers every time the sun shines and the wind blows.

Table 20 shows how this condition is maintained at any time in the future. It can also be appreciated how the relation of installed capacity and peak load increases with time due to the introduction of fluctuating renewables like wind power and PV. While in the year 2000, the relation of installed capacity to peak load is equal to 7.7/4.8 = 1.6, this relation increases to 108.2/35.5 = 3.0 in the year 2050. An almost doubling of this relation means that the average utilization (capacity factor) of the total power park is reduced by about 50%.

In our scenario, the total installed capacity of about 11 GW in 2010 would increase to about 23 GW in 2020 and to 108 GW in 2050. Under this condition, the mix of fluctuating and flexible power plants would allow for a guaranteed production of electricity on demand at any time, without requiring major additional electricity storage devices or an expansion of the electricity grid beyond the natural growth of the AC grid assumed here.

Our scenario in Figure 15 shows how peak load will increase almost linearly between 2010 and 2040, and as a consequence firm power capacity from gas fired power stations also will have to increase in line with that growing demand. However, after 2030, CSP plants step-by-step will take over firm capacity supply, because by then the CSP industry will have grown sufficiently to cover the increasing demand for firm renewable power capacity. According to national planning, by 2020 about 600 MW of wind power, 1200 MW of PV and 2500 MW of CSP capacity could be installed. Also hydropower capacity could be extended to about 500 MW.

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Table 20: Installed power capacity (GW) in Algeria for each technology and firm capacity of all plants compared to the peak load as function of time between the years 2000 and 2050. Import / Export refers to the Net Transfer Capacity (NTC) of the conventional AC grid.

Year	2000	2010	2020	2030	2040	2050
Peak Load	4.8	7.6	15.3	24.2	31.6	35.5
Firm Capacity	6.8	9.5	19.2	30.3	39.5	44.4
Installed Capacity	7.7	10.8	23.4	45.6	88.4	108.2
Wind Power	0.0	0.0	0.6	2.0	12.8	14.2
Photovoltaics	0.0	0.0	1.2	2.8	11.7	14.2
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	0.0	0.0	0.0	0.0	0.2	0.6
CSP Plants	0.0	0.0	2.5	7.2	28.6	40.6
Wave / Tidal	0.0	0.0	0.0	0.0	0.0	0.0
Hydropower	0.2	0.3	0.5	0.5	0.5	0.5
Oil	1.0	0.9	0.8	0.7	0.0	0.0
Gas	6.0	9.0	16.6	23.4	10.9	3.3
Coal	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Import / Export NTC	0.5	0.6	1.2	1.8	2.4	2.7

Figure 16 shows a comparison of the firm power capacity from flexible sources and the variable capacity from fluctuating sources and their relation to the national peak and base load demand. It can be seen that the fluctuating capacity from wind and PV can become larger than base load demand, but not larger than the peak load of the country. This simple strategy will lead to power surpluses from time to time when demand is low that however can be partially compensated by exporting electricity via the AC grid and by using the existing – rather scarce – options for electricity storage. Due to the fact that wind power and PV power will not often be fully available at the same time, surpluses will not occur very frequently. Also the surplus power capacity – which would dictate the necessity for an equivalent conversion capacity of related electricity storage devices like pump storage or batteries – will be rather low.

The simple strategy followed here assumes that fluctuating power capacity will be limited to slightly lower values than peak load and flexible power capacity will be at least expanded to 125% of peak load. This way, surpluses can be effectively avoided and security of supply is maintained at any moment in time. In the medium and long term, wind and PV power will be least cost sources of energy and installed preferentially until reaching the peak load limit. Flexible power sources like CSP, being more expensive, will be used to fill the remaining gaps.

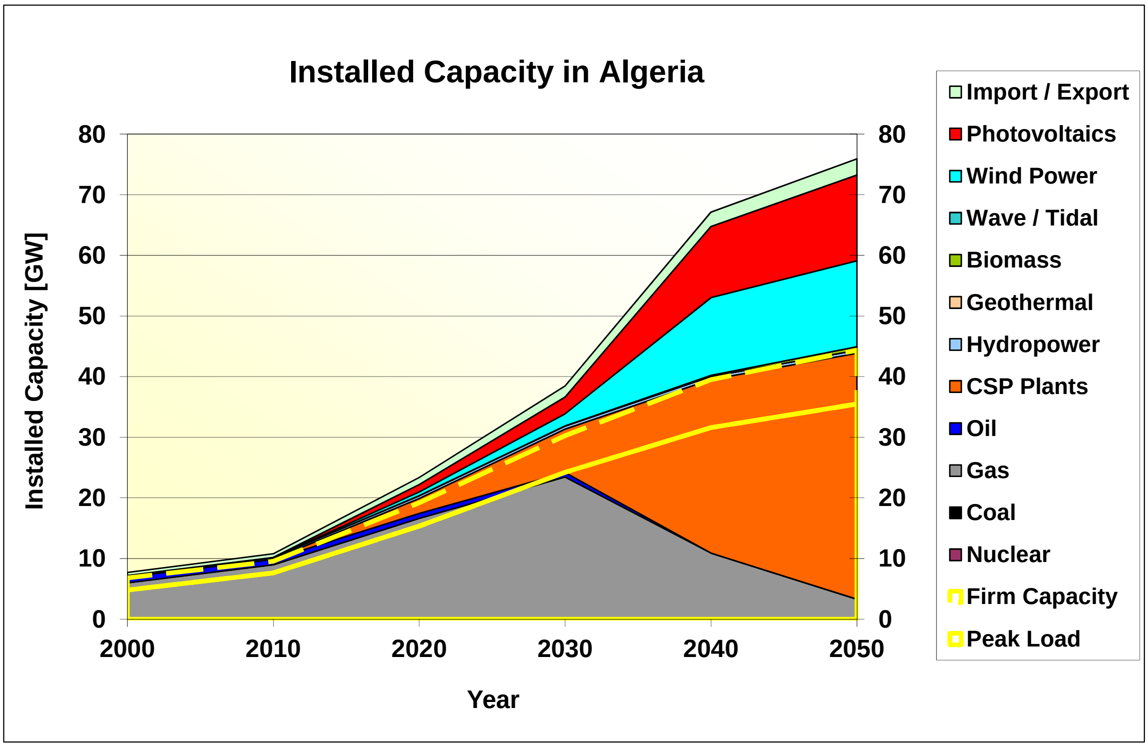

Figure 15: Installed power capacity in Algeria for each power plant technology and firm capacity of all plants compared to the peak load of the country as function of time between the years 2000 and 2050. Import / Export refers to the Net Transfer Capacity (NTC) of the AC grid.

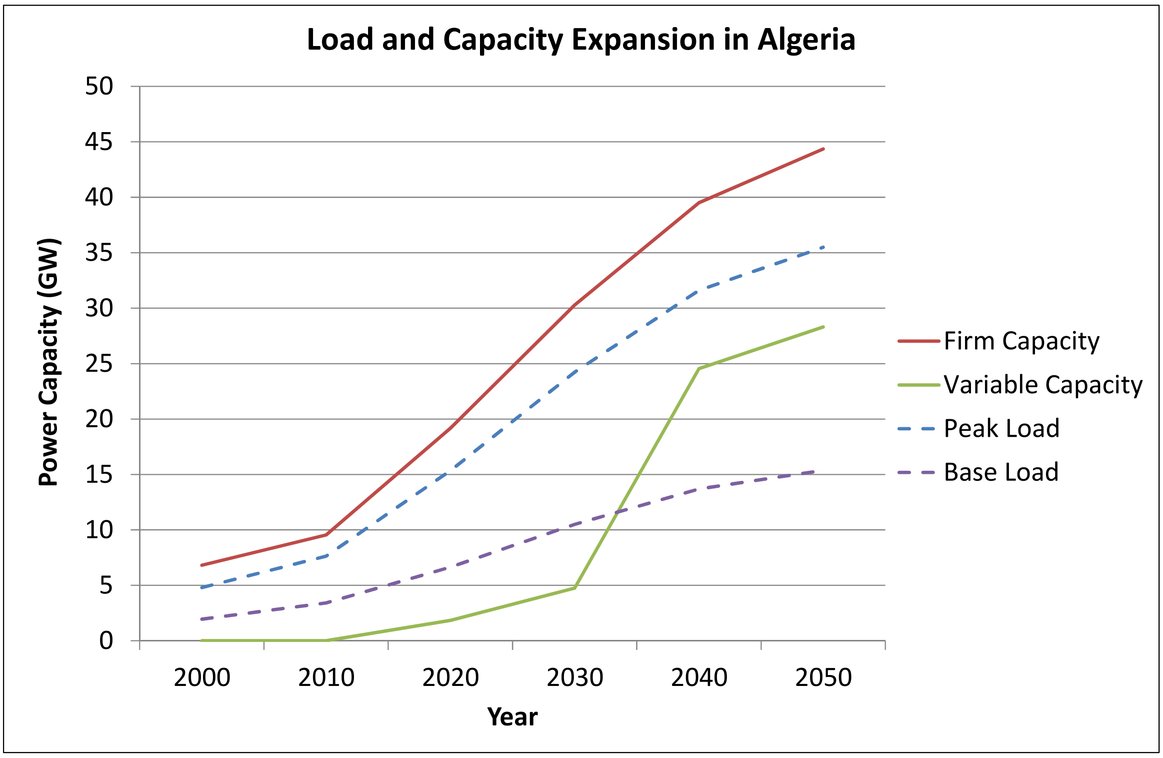

Figure 16: Comparison of firm capacity, variable capacity from fluctuating sources and export capacity of CSP plants with peak load and base load in Algeria

Electricity production and import through the AC grid will cover the gross electricity consumption analyzed before plus eventual export through the AC grid. Import and export through the AC grid will increase with time and in line with the growing net transfer capacity of the grid. In our model, it is assumed that annual import and export streams will be balanced in both directions.

As consumption will almost double between 2010 and 2020, there will be a tremendous pressure on fossil fuel resources that can only be relieved by quickly introducing cost-effective fuel savers like wind and PV power (Table 21). This will prolong the availability of fossil fuels and stabilize the cost of power generation.

The option of additionally exporting solar electricity to Europe would be in line with the tradition of Algeria as energy exporter, while at the same time prolonging the availability of natural gas for own use and export.

Table 21: Annual electricity production (TWh/y) in Algeria by each technology, exports to and imports from neighbour countries via the AC electricity grid as function of time between the years 2000 and 2050.

Year	2000	2010	2020	2030	2040	2050
Consumption	25.4	44.7	86.7	136.9	178.6	200.5
Export via Grid	0.2	0.3	1.0	1.7	2.3	3.0
Wind Power	0.0	0.0	1.3	4.3	29.2	34.0
Photovoltaics	0.0	0.0	2.4	5.5	23.4	28.3
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	0.0	0.0	0.0	0.2	0.8	2.7
CSP Plants	0.0	0.1	8.2	43.1	124.7	135.2
Wave / Tidal	0.0	0.0	0.0	0.0	0.0	0.0
Hydropower	0.2	0.3	0.5	0.5	0.5	0.5
Oil	0.6	0.5	0.5	0.5	0.0	0.0
Gas	24.6	43.8	73.8	82.9	0.0	0.0
Coal	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Import via Grid	0.2	0.3	1.0	1.7	2.3	3.0

Peak load will increase in line with increasing consumption, and therefore, there is a compulsive need for sufficient firm and flexible power capacity and reserve. Only fossil fuel fired power plants and renewable power plants using biomass or concentrating solar thermal power can provide this type of high quality supply. As biomass is rather scarce in North Africa, hybrid (solar/fossil) concentrating solar power stations are the only alternative to fossil fuel plants, being able to deliver the same quality of supply with much lower fossil fuel consumption. Therefore, their short term introduction and expansion is crucial for achieving sustainable supply in the medium and long term, as the natural gas reserves are limited and expected to achieve its maximum exploitation rate around 2020.

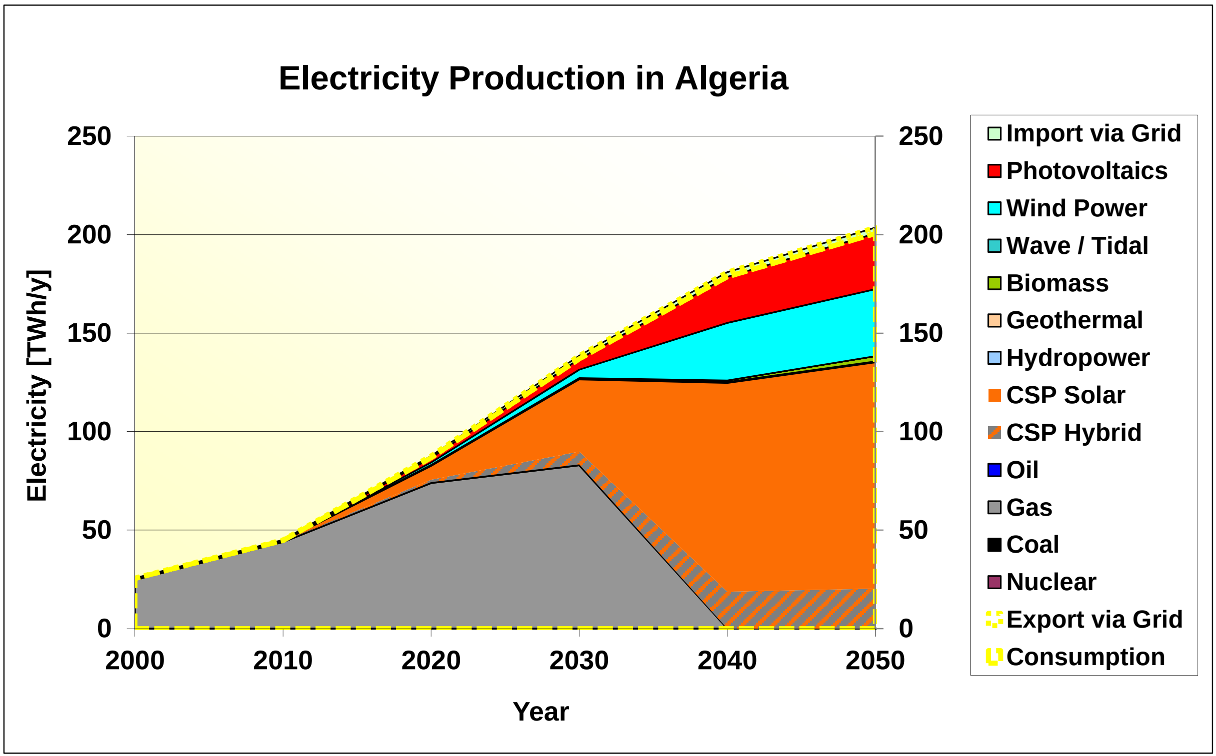

Figure 17: Annual production of RES-E and conventional power plants in Algeria compared to the gross electricity consumption plus export to neighbours through the AC grid. Hybrid CSP operation is assumed to be achieved by natural gas backup for steam generation within the CSP plants. In the long-term, only marginal amounts of electricity will be produced in fossil fuel plants for back-up and emergency purposes.

Our scenario reflects this strategy, by massively increasing the share of RES-E until achieving about 90% in 2050 (Figure 17). By then, wind power and PV would make up for 31% of the annual power production for national supply. In order to provide sufficient firm power capacity and RES-E production, CSP plants are extended to provide 66% of annual production, of which 59% will be solar. About 10% (20 TWh/y) of annual production in Algeria will stem from hybrid CSP operation with natural gas. There will still be a significant capacity of pure natural gas plants installed for reserve and emergency purposes in 2050, but their power production will be limited to extreme situations and thus will be almost negligible. The use of natural gas in CSP plants is more cost effective and efficient than solar only operation of CSP plants and balancing by gas plants. Firstly, hybrid CSP plants will have less part-load losses and thus higher efficiency for solar power generation. Secondly, gas plants would have rather low efficiencies just filling the few supply gaps (10% of power consumption) that would be left by wind, PV and solar only CSP plants.

A well-balanced mix of the available RES-E resources in Algeria can lead to a scenario that satisfies all the sustainability criteria described before. The national potential of wind power of about 35 TWh/y will be exploited by over 99%, while less than 1% of the solar energy resource potential will be needed to satisfy the national demand and in addition provide significant amounts of flexible solar electricity exports for Europe.

At present power production in Algeria is almost fully dependent on natural gas. It is clear that the availability of gas would be reduced significantly if the quickly growing demand would only be satisfied by this limited resource. In fact this cannot be avoided, as the consumption of natural gas still doubles in our scenario until 2030. According to the BP Statistical Review of World Energy 2013 the ratio of natural gas reserves and present exploitation in Algeria amounts to about 55 years. A significant increase of exploitation – not only for domestic use but also for export – would reduce this time accordingly. Another aspect of fossil fuel consumption is the importance of natural gas for the Algerian international trade balance. It is clear that gas burned for power generation today cannot be sold on the market tomorrow. On the other hand, using gas only for hybrid operation in CSP plants as in our scenario would reduce its consumption and almost double its availability for the future.

Biomass and hydropower are available to a small extend, but do not achieve a significant importance for sustainable supply. CSP, PV and wind power are the major domestic sources of energy for power generation, while natural gas is the most important ideally stored form of energy available in the country. An intelligent combination of ideally stored and free flowing forms of energy will allow Algeria to achieve a sustainable power supply by the mid of the century. In technical and economic terms, the transition to renewable power could by slightly faster than foreseen here on the basis of national planning. Therefore, Algeria could consider accelerating its transition towards renewable power sources in order to save its most valuable form of energy, natural gas, and prolong its availability for future generations.

It is important to note that ideally stored forms of energy like fossil fuels will be required for a long time. Even in a desert country like Algeria with one of the largest solar energy potentials worldwide, the availability of solar power over the whole year is not 100%, so CSP plants will have to operate in hybrid mode with natural gas in order to cover the load at any time on demand. The substitution of these last 10% of fossil fuel consumption will be a special challenge, which may be overcome in the long-term by innovations such as power-to-gas or power-to-liquid fuel conversion. As research and development of such technologies is already under way, our scenario must not be understood as if those technologies would not be implemented before 2050. On the contrary, in the best case, the 10% hybrid operation of CSP plants in our scenario could eventually already be provided by synthetic natural gas or synthetic fuel oil derived from renewable sources, in that case effectively leading to a 100% RES-E share in 2050.

Synthetic natural gas production from renewable sources would require additional RES-E infrastructure that has not yet been included in our scenario and would have to be assessed and designed separately. An important frame condition for any hydrocarbon synthesis process is its operation near to steady state conditions, which is required to achieve the equilibrium needed for an efficient chemical conversion process. Such a steady state operation will be very difficult to achieve by (cheap) wind and PV input, but is easily achieved by (more expensive) CSP plants with thermal energy storage. As there is still not enough information and experience available for a reliable modeling and comparison of such solutions, we have assumed that the need for ideally stored energy in our scenario until 2050 will be covered by fossil natural gas.

2.6.2 Egypt

The Egyptian power market is, just as the other North African power systems, marked by a strong increase of energy demand. Peak load within the Egyptian electricity market increased from 13,300 MW in 2001 to 25,700 MW in 2012 resulting in several power shortages during peak load in the summer season in the last decade (EEHC Annual Report 2011/2012). Egypt is about to become a net importer of energy as oil exports have been decreasing since 1996 and the increasing gas production was mostly used to satisfy the vast increase of demand in electricity (AfDB 2012). In 2011/2012 the installed capacity of the power sector in Egypt was 29,074 MW of which 2,800 MW were hydropower, 550 MW wind, 140 MW solar capacities and 25,584 MW of conventional thermal power plants mainly fueled by gas (EEHC Annual Report 2011/2012). Eight RE projects with a total installed capacity of 1,208 MW are in the pipeline according to REN21 (REN21 2013).

The power sector is organized mainly by the Egyptian Electricity Holding Company (EEHC) which consists of sixteen affiliated companies (six production, nine distribution and the Egyptian Electricity Transmission Company EETC) owned and governed by the Ministry of Electricity and Energy (MOEE).

Egypt adopted a diversification and energy efficiency strategy in the 1980s, with the aim to meet the growing demand in face of the limited supply of domestic oil resources. Steps towards liberalization and unbundling were taken to attract sufficient investments in the energy sector, also including private capital. Ambitions, however, remained limited in terms of infrastructure modernization and technology diversification and the main effects of this strategy were investments in gas explorations and the installation of some wind power capacities.

To monitor a fair and effective functioning of the electricity market the Egyptian *Electric Utility and Consumer Protection Regulatory Agency* (EgyptERA) was created in 1997. The EgyptERA is responsible for the regulation of electricity system, including PPAs, and issues licenses for new constructions, management, operation and maintenance of all power generation, transmission and distribution projects (EgyptERA 2013). Despite the opening of the market, the electricity price is still determined by the government (the Supreme Council for Energy, which includes all concerned Ministers and the Prime Minister (AfDB 2012)). Current electricity prices[15] for households are depending on the total consumption of the specific household and range from 5 PT to 48 PT/kWh[16] (EgyptERA 2013).

The *New and Renewable Energy Authority* (NREA) was established in 1986 with the mandate to promote and implement renewable energy projects in Egypt. In 2010, the reorganization of the electricity sector was announced, and these changes are to be implemented following a still pending parliamentary approval of a new electricity bill. This initiative aims at increasing investor protection, thus making private actor participation more attractive. As of today (April 2013), the Egyptian parliament has not adopted the bill, and final decisions concerning a number of institutional and regulatory amendments to the electricity bill, initially prepared by the former government, are still pending.

[15] The IEA estimates a subsidy rate for Egyptian fossil fuel consumption of 54.2% (http://www.iea.org/subsidy/).
[16] Exchange rate on 2013/04/17: 1.00 EUR = 9.02495 Egyptian pound (EGP), 1 EGP = 100 PT

In October 2014 the Egyptian government introduced a renewable energy feed-in tariff system (EGYPTERA 2014).

2.6.2.1 Demand Expectations

In the past decade, an electricity consumption of approximately 6.6 TWh/y has been added every year in Egypt, reaching an annual demand of 145 TWh/y in 2010 (DLR 2013). The growth rate of demand in 2010 was 6.2%/y. If the linear trend would continue in the future Egypt would consume about 200 TWh/y by 2020 and 400 TWh/y by 2050 (**Figure 18**).

According to AUE 2011 the national expectations are much higher, indicating a demand of 295 TWh/y by 2020. Extrapolating this expectation linearly after 2020, Egypt would consume about 750 TWh/y by 2050.

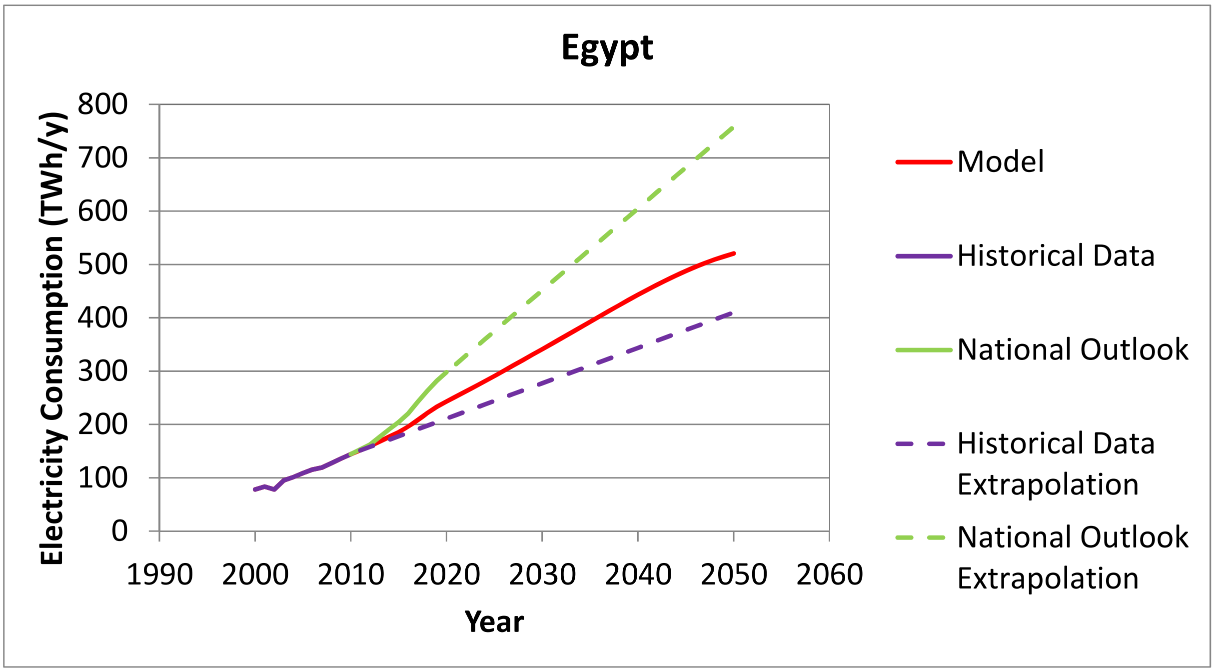

Figure 18: Gross electricity consumption in Egypt: Model result, historical data until 2010 with linear extrapolation after 2010, national outlook from 2010 to 2020 with linear extrapolation after 2020.

Our model predicts a demand that is lower than current expectations but higher than extrapolating the linear trend of the past decade. Starting with 145 TWh/y in 2010, our model predicts about 240 TWh/y in 2020 and 520 TWh/y in 2050, respectively. As Egypt is a country with still relatively low per capita income and low per capita electricity demand, the demand grows steadily and a beginning saturation effect can only be seen in the very long term future around 2050.

Per capita electricity consumption will increase from 1.8 MWh/cap/y in 2010 to around 4.1 MWh/cap/y in 2050, which would be the lowest value among the NA countries analysed. Certainly, there is a possibility that the effects of the political changes in Egypt may cause a temporary decline of GDP and electricity demand. Therefore, the relatively low prediction of the model compared to the expectations seems justified, if not still optimistic.

The result of our demand modelling shows that Egypt will face significant challenges with respect to its growing electricity demand, moreover if at the same time the availability of natural gas for power generation would be reduced.

An hourly load curve for Egypt for the year 2010 was provided by AUE 2012. This load curve was scaled for all consecutive years until 2025 for detailed scenario modelling of the electricity mix (**Figure 19**). Scaling was done in a way that maintains the relation of annual electricity demand and peak load just as scheduled by the national outlook data provided by AUE 2011. The load curve shows a clear peak in summer and lower demand during the winter season.

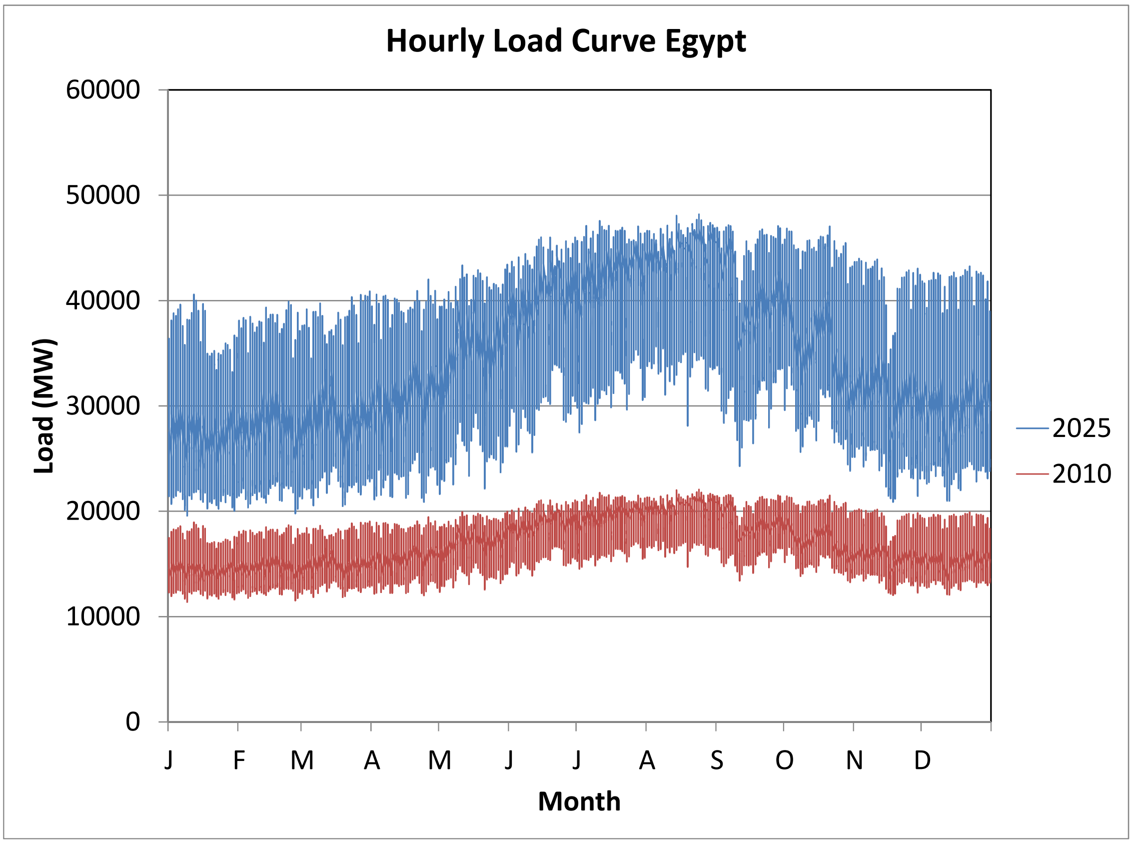

Figure 19: Hourly load curve for the years 2010 and 2025 for Egypt

2.6.2.2 RE Targets and Policy Framework

In 2008, the Supreme Council of Energy adopted a target of 20% renewable energy in the electricity production by 2020. Of this, 12% is intended to be wind power and 8% hydro and solar power. In absolute terms, the plan includes the target of the installation of 7,200 MW installed wind power capacity (NREA 2013). For solar power, the five-year plan from 2012 to 2017 foresees the installation of 100 MW of CSP capacities in Kom Ombo City and 20 MW of solar PV installations (NREA 2013). In July 2012, the Egyptian solar Plan was approved by the Cabinet and targets to install 3,500 MW (2,800 CSP & 700 PV) by 2027 with a private investment share of 67%.

The recent political developments and the instable political system, including all parliamentary processes, cause uncertainty concerning the future strategy of the Supreme Council for Energy and the Ministry MOEE. The new electricity bill, which was brought into the parliamentary process by the former Minister, has not yet been adopted. The new law would provide a new framework for private investments in the energy market with regulatory and financial support for the deployment of renewable energy in Egypt. However, until now it is not clear if the law will be approved or if further amendments will be made.

In April 2013 EETC has already tendered the first 250 MW BOO wind farm at Gulf of Suez to the short-listed bidders. The pre-bid meeting for that project was held in May 2013, while the bid submission is scheduled in September 2013. This is a major milestone due to the approval of the Central Bank of Egypt for the Sovereign guarantee for this project and is a concrete step towards implementing the plans of the Energy Supreme Council. Moreover, EETC is expected to launch a tender for the second project under the same mechanism by the end of 2013. Secondly, NREA had issued a tender for 6 pieces of land at the Gulf of Suez area on the basis of direct contract between producers and consumers. Tender documents have been published and the bid submission date is due in June 2013.

REGULATORY FRAMEWORK

Until today, the main support system for third party investments in RE in Egypt is tendering for new capacities of more than 50 MW per project. New renewable energy projects are planned and implemented mainly with the financial support of European development agencies and within the EU NIF (EC 2013).

The tendering scheme has been the main support mechanism for renewable energy in Egypt. A new electricity bill under discussion is expected to include new mechanisms for attracting private investments in RE. NREA, ERA and MOEE have announced a new energy strategy focusing on wind energy and to be partly financed through different sources, including public funds, development aid and carbon credits from CDM. In terms of carbon credits, Egypt has already an advanced market, and thus renewable energy projects have benefited from extra revenues the CDM provides. Egypt has ratified the United Nations Framework Convention on Climate Change in 1994. The Egyptian Environmental Affairs Agency has been assigned as the DNA. The table below summarizes the registered projects, the avoided CO2 emissions and the EU countries with which Egypt has sold carbon credits to meet some EU countries' targets.

Land for renewable energy is owned by the government. In 2010, the Cabinet decision (of 26/5/2010) has led to the allocation of 7600km² of desert land for future siting of RE projects under the responsibility of NREA (NREA, 2010).It is allocated to investors on a usufruct basis. The land is provided for private investors and it is to be compensated based on predetermined price between the government and private investors.

Given the shortage of enough funds to finance new investments in the electricity transmission and generation infrastructure, the achievements of the RES targets will very much depend on how enough funds are mobilized for such new investments. Involving the private sector will require more investment incentives sufficient for making renewable energy investments viable. A sovereign guarantee for the first Build Own and Operate (BOO) RE project is worth highlighting as a first step towards encouraging private investments. Nevertheless, more funding would be required to achieve a wide scale deployment of renewable energy projects.

To cover the difference between the cost of electricity generation from RE and the selling tariff, MOEE has established an RE fund to finance such difference. In addition to financing the gap, the Renewable Energy Fund will address the risk for foreign currency exchange, contribute in financing RE pilot projects, support R&D in RE and enhance local manufacturing of RE equipments (Amin, 2012). Also, RE equipments would be exempted from custom duties and VAT. To further give a push for renewable energy deployment, the Central Bank of Egypt with guarantee some financial obligations under the PPAs and long-term BOOT contracts should be signed with private investors. To reduce investment risks and thus attract foreign investors, the PPA for RE power is expected to be transacted partly in foreign currency. A very important item is also the licensing and tariff setting powers are to be granted to EgyptERA (EgyptERA 2013).[17]

In October 2014 the Egyptian government introduced a renewable energy feed-in tariff system (EGYPTERA 2014). The electricity transmission company (EETC) or distribution companies are committed to purchase the produced electricity from RE power plants at the prices announced by the Cabinet of Ministers through Power Purchase Agreements (PPA) for 25 years for the PV projects, and 20 years for wind projects. Accordingly, the Egyptian Electricity Utility and Consumer Protection Regulatory Authority (EgyptERA) has set the required regulations and procedures for executing the Renewable Energy Feed-in Tariff (RE - FiT) projects for wind and PV projects. CSP is not included in that regulation.

The proposed electricity bill, which is yet to be adopted, holds a new mechanism for attracting private investments in RE (AfDB 2012). The new energy strategy as announced by NREA, EgyptERA and the MOEE is focused on wind energy and is to be financed partly by a public fund, partly by development aid and carbon credits from CDM closing the gap between the selling and the production price. This strategy includes the application of a two-phase process. In the first phase, 1,250 MW wind capacities will be installed on the basis of competitive bids as PPA under a *Build, Own and Operate* (BOO) regime. The second phase, in contrast, sees the introduction of feed-in-tariffs orientated at the PPA price levels from the first phase (NREA 2010). In addition to this, the Egyptian state plans to install another 1,750 MW with public funding.

As foreseen by the still pending electricity bill, the custom duties and VAT for all RE equipment should be released. Furthermore, the Central Bank of Egypt will guarantee some financial obligations under the PPAs and long-term BOOT contracts should be signed with private investors. The PPA for RE power is intended to be transacted partly in foreign currency to lower investment risks for foreign investors. The licensing and tariff regulation is planned to be in the responsibility of the EgyptERA (EgyptERA 2013).

The cost of grid connection is fully allocated to the generation facility, whereas the costs of the maintenance and reinforcement of the grid is in the responsibility of the respective distribution or transmission company (Paving the Way for the MSP 2012). The IPP has to make a contract with the

[17] More information is discussed in Ellenbeck S., Lillistam J. and Battaglini A. 2013: Energy Policy, Targets, Present Discussions and Barriers in RE deployment in Morocco, Algeria, Tunisia, Libya and Egypt, BETTER Project, June 2013.

EETC and pay a fee for the grid usage (MOEE 2013). The new electricity bill foresees the establishment of an independent TSO, as well as new regulations to safeguard third party access to the grid instead of the case-by-case agreements between EETC and the IPP (NREA 2013). A grid code to integrate large wind parks into the power system in the final stage for approval is planned. There is a general priority access for RE electricity in place (Paving the Way for the MSP 2012).Transmission is under the responsibility of the Egyptian Electricity Transmission Company EETC and until now the grid operation is not opened for third parties.

The electricity market is legally unbundled, but as the EEHC acts as a public holding of the former vertically integrated utility under the ownership and supervision of the MOEE, the independence of the different companies might not be fully functional.

The generation market is open for IPPs, which however have to be approved by EgyptERA. Until now, no direct contracts between producers and consumers can be made. However, the first direct contact is coming soon through EECT as a wheeling entity for generated electricity. (NREA 2013).

INSTITUTIONAL FRAMEWORK

The institutional arrangement for energy is under the Supreme Energy Council (SEC) that plays the role of the overall coordinator of energy strategy at the national level. The energy sector is under two ministries; the Ministry of Electricity and Energy (MOEE) and the Ministry of Petroleum (MoP). As the main responsible body for the electricity sector, the Ministry of Electricity and Energy sets plans for generation, transmission and distribution.

The power sector is organized mainly by the Egyptian Electricity Holding Company (EEHC) which consists of sixteen affiliated companies (six production, nine distribution and the Egyptian Electricity Transmission Company EETC) owned and governed by the Ministry of Electricity and Energy (MOEE).

The *New and Renewable Energy Authority* (NREA) was established in 1986 under the auspices of MOEE with the mandate to promote and implement renewable energy projects in Egypt. In 2010, the reorganization of the electricity sector was announced, and these changes are to be implemented following a still pending parliamentary approval of a new electricity bill. This initiative aims at increasing investor protection, thus making private actors' participation more attractive.

The Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA) was created in 1997 to regulate the electricity market. It is responsible for the regulation of electricity system, including Power Purchase Agreements (PPAs), and issues licenses for new constructions, management, operation, and maintenance of all power generation, transmission and distribution projects (EgyptERA 2013). However, tariffs setting power is still in the hand of the Supreme Council for Energy (AfDB 2012).[18]

For further institutional framework conditions needed to achieve the RES policy targets, it will very much depend on whether the institutional and regulatory framework will be able to evolve and thus

[18] More information is discussed in Ellenbeck S., Lillistam J. and Battaglini A. 2013: Energy Policy, Targets, Present Discussions and Barriers in RE deployment in Morocco, Algeria, Tunisia, Libya and Egypt, BETTER Project, June 2013.

attract the required capital (MEP, 2011). Moreover, having two ministries dealing with energy issues might create some responsibilities' overlap and eventually conflicts, thus necessitating the need to carefully study the potential to merge the two ministries, yet with clear defined roles of each division/department to be created.

Moreover, given the limited scope and mandates of EgyptERA as a regulator of the electricity sector, it could be very useful to enlarge its mandate to include all the energy sector. Further developments would entail increasing its independence and empowering it to have a final say on tariffs, yet with the suggestions of the other stakeholders involved such as MOEE and NREA.

EgyptERA could be a suitable institution to facilitate the implementation of the cooperation mechanisms. This role would entail i) administration of the provided remuneration, ii) facilitation of an oversight over the implementation and iii) proof of renewable energy transfers (Frieden et al., 2012).

INFORMATION POLICY AND CAPACITY BUILDING

An extensive wind atlas has been compiled by NREA with detailed information about potential generation sites (NREA 2013). In addition, a solar atlas has been developed. Several institutes for the promotion and research for renewable energy technology have been established including the *Regional Center for Renewable Energy and Energy Efficiency* RCREEE,[19] the *Industry Modernization Center* and the *Energy Research Center* at Cairo University's Faculty of Engineering.

Several institutes for the promotion and research for renewable energy technology have been established, including the *Industry Modernization Center* and the *Energy Research Center* at Cairo University's Faculty of Engineering.

In terms of capacity building, NREA has played an important role in training. It has provided training locally and to other neighboring countries, alike. NREA has organized several specialized trainings in renewable energy (wind, solar, PV, energy conservation, etc) for regional and local organizations. Other trainings were also held upon request of other countries[20] in the region. Besides, summer course in RE is organized for university students (Ismail Amin, 2012).

In addition to government agencies, other NGOs play also an important role in promoting renewable energy and raising awareness. The Consumer and Energy Organization (CEO), for example, In addition to being involved in a research study in 2009 with the Industry Modernization Centre to explore methods for reducing harmful emissions, CEO is conducting an awareness campaign on energy conservation as well as setting up a small grants program to promote renewable energy and energy conservation in poor communities. Besides, seminar and workshops to raise awareness have been conducted by CEO in this regard. In the same context, Egypt Green Energy Association (EGEA) also promotes renewable energy use.[21]

[19] Although the RCREEE is not focused specifically on Egypt the technology and policy knowledge of the Center might also have positive effects for the Egyptian case.
[20] Trainees attended from the following countries: Syria, Jordan, Lebanon, Yemen, Oman, Saudi Arabia, Palestine and Kuwait.
[21] http://www.egyptoil-gas.com/read_article_issues.php?AID=654

Despite the efforts made in terms of capacity building, further training programs would need to be put in place. Tailored capacity building programs could be designed for policy makers and administrative officers dealing with renewable energy projects.

Despite the advancements made regarding awareness raising, extra efforts would be much needed, as is highlighted by the chairman of the EGEA that Egypt has "to raise awareness and changing attitudes and behavior towards energy consumption."[22]

BARRIERS[23]

Investments in the Egyptian electricity sector face various difficulties and especially the RE deployment that is slowly advancing. The current unstable regulatory, financial and political frameworks are major barriers for a large scale RE deployment. Further important barriers include:

- The lack of firm and stable regulations for RE. The electricity bill has not been adopted by the parliament yet, and until the regulations are adopted there is great uncertainty about how RE will be advanced in Egypt in the future.
- One of the main issues in reforming the electricity sector in Egypt is the current organizational conflicts. As stated earlier, EEHC is the holding company with 16 affiliated companies for generation, transmission, and distribution. There is no clear borders between these companies and they are not completely independent. This creates conflicts and delays, especially in decision making.
- Egypt suffers a huge shortage of funds to finance new electricity generation and transmission projects. However, the government is trying to overcome these barriers by encouraging private investments in the sector. The sovereign guarantee for the first BOO RE project has been issued recently, and this will continue for the coming projects.
- The tariffs of the electricity were modified recently on two stages, one in December 2012 and one in January 2013. These modifications included almost all the tiers of consumers. Moreover, the subsidization was completely removed from the heavy industry users, but some other subsidies still remain in the market. As a result, the difference between the cost of generating electricity from RE and the tariff of selling this energy to the consumers is very high. The MOEE has established a RE fund to finance this difference, however, this fund is in its formulation stage and is not yet fully functional.

2.6.2.3 Scenario for the power sector

Scenario analysis reveals two aspects of electricity supply that will be shown for a possible transition towards a sustainable electricity scheme: the installed capacity and the annual electricity production and their development as function of time.

[22] http://www.egyptoil-gas.com/read_article_issues.php?AID=654
[23] This section is based on interviews and contributions of experts from the Egyptian Electricity Transmission Company (EETC)

In our scenario, the total installed capacity of about 18.4 GW in 2010 would increase to about 63 GW in 2020 and to 191 GW in 2050. Under this condition, the mix of fluctuating and flexible power plants would allow for a guaranteed production of electricity on demand at any time, without requiring major additional electricity storage devices or an expansion of the electricity grid beyond the natural growth of the AC grid assumed here.

Our scenario in **Figure 20** shows how peak load will increase almost linearly between 2010 and 2050, and as a consequence firm power capacity from gas fired power stations also will have to increase in line with that growing demand. However, after 2030, CSP plants step-by-step will take over firm capacity supply, because by then the CSP industry will have grown sufficiently to cover the increasing demand for firm and renewable power capacity. According to national planning, by 2020 about 7200 MW of wind power, 1400 MW of PV and 500 MW of CSP could be installed. Hydropower capacity at the Nile River could be extended to about 2900 MW.

By 2030 about 30% of the total installed capacity will be covered by renewable sources, and CSP exports to Europe will also be implemented. The strongest growth of renewable power capacity will take place between 2030 and 2050. In 2050, over 75% of the power park will be renewable, with hybrid (solar/fossil) CSP taking over the job of providing firm and flexible power capacity on demand, and major wind and PV capacities that will act as fuel savers every time the sun shines and the wind blows. The total installed capacity of wind and PV plants will be considerably larger than that of CSP.

In terms of installed capacity, the most important target to be achieved is that the firm capacity of all power plants is always larger than the peak load that occurs once a year.

Table 23 shows how this condition is maintained at any time in the future. It can also be appreciated how the relation of installed capacity and peak load increases with time due to the introduction of fluctuating renewables like wind power and PV. While in the year 2000, the relation of installed capacity to peak load is equal to 18.4/13.0 = 1.4, this relation increases to 191.1/86.5 = 2.2 in the year 2050. The increase of this ratio means that the average utilization (capacity factor) of the total power park is reduced accordingly.

Table 22: Installed power capacity in Egypt (GW) for each technology and firm capacity of all plants compared to the peak load of the country as function of time between the years 2000 and 2050. Import / Export refers to the Net Transfer Capacity (NTC) of the conventional AC grid.

Year	2000	2010	2020	2030	2040	2050
Peak Load	13.0	22.1	40.4	56.6	73.6	86.5
Firm Capacity	16.2	27.6	50.5	70.8	91.9	108.1
Installed Capacity	18.4	31.6	63.3	106.5	166.3	191.1
Wind Power	0.1	0.6	7.2	9.9	20.6	27.8
Photovoltaics	0.0	0.0	1.4	13.3	38.6	40.8
Geothermal	0.0	0.0	0.1	0.5	2.0	3.1
Biomass	0.0	0.0	1.6	3.3	4.1	4.3
CSP Plants	0.0	0.0	0.5	2.5	15.2	52.0
Wave / Tidal	0.0	0.0	0.0	0.0	0.0	0.0
Hydropower	2.8	2.8	2.9	3.1	3.1	3.1
Oil	2.0	1.8	1.6	1.5	0.0	0.0
Gas	13.0	25.3	44.7	61.0	66.5	42.8
Coal	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Import / Export	0.5	1.0	3.2	4.5	5.9	6.9

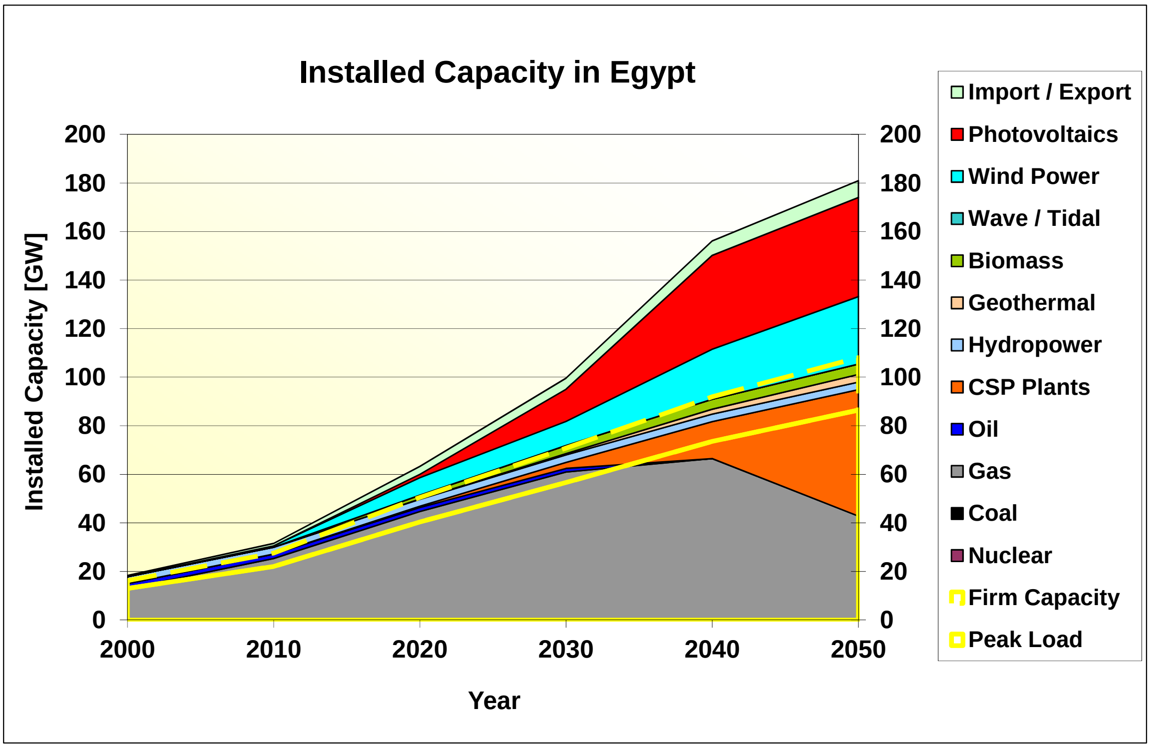

Figure 20: Installed power capacity in Egypt for each power plant technology and firm capacity of all plants compared to the peak load of the country as function of time between the years 2000 and 2050. Import / Export refers to the Net Transfer Capacity (NTC) of the AC grid.

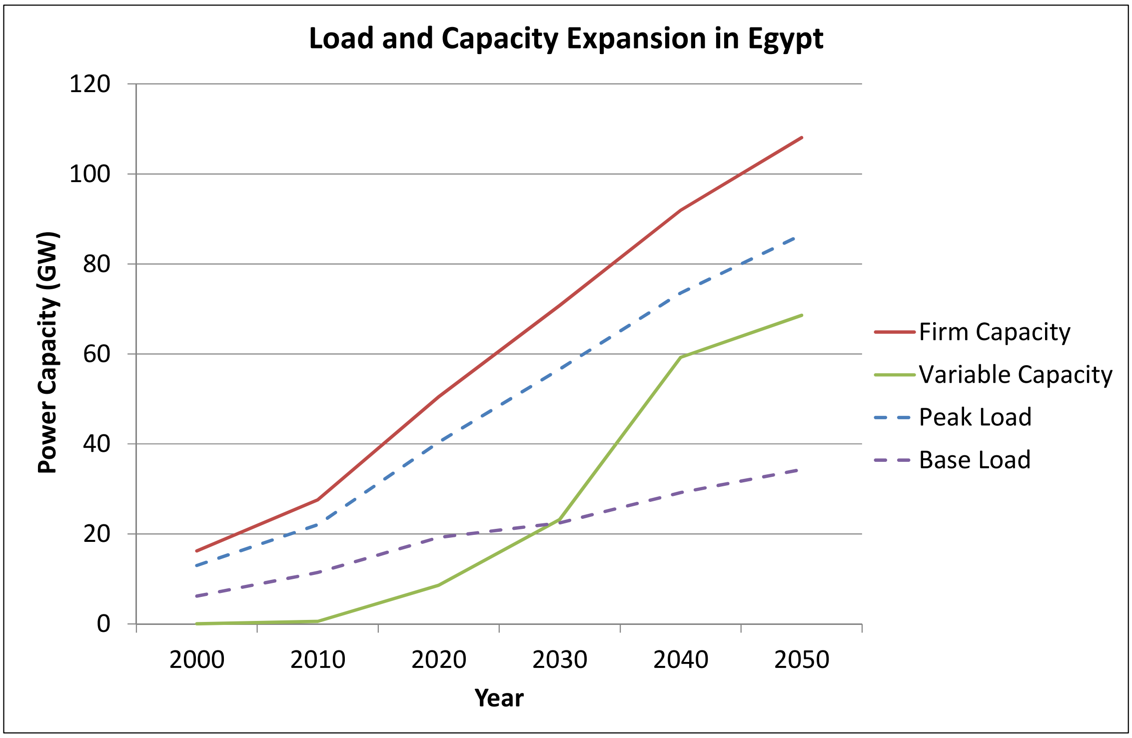

Figure 21: Comparison of firm capacity, variable capacity from fluctuating sources and export capacity of CSP plants with peak load and base load in Egypt

It can be seen in Figure 21 that the fluctuating capacity from wind and PV can become larger than base load demand, but not larger than the peak load of the country. This simple strategy will lead to power surpluses from time to time when demand is low that however can be partially compensated by exporting electricity via the AC grid and by using the existing – rather scarce – options for electricity storage. Due to the fact that wind power and PV power will not often be fully available at the same time, surpluses will not occur very frequently. Also the surplus power capacity – which would dictate the necessity for an equivalent conversion capacity of related electricity storage devices like pump storage or batteries – will be rather low.

The simple strategy followed here assumes that fluctuating power capacity will be limited to slightly lower values than peak load and flexible power capacity will be at least expanded to 125% of peak load. This way, surpluses can be effectively avoided and security of supply is maintained at any moment in time. In the medium and long term, wind and PV power will be least cost sources of energy and installed preferentially until reaching the peak load limit. Flexible power sources like CSP, being more expensive, will be used to fill the remaining gaps.

Electricity production and import through the AC grid will cover the gross electricity consumption analyzed before plus eventual export through the AC grid and via HVDC interconnections to Europe. Import and export through the AC grid will increase with time and in line with the growing net transfer capacity of the grid. In our model, it is assumed that annual import and export streams through the AC grid will be balanced.

Table 23: Annual electricity production in Egypt (TWh/y) by each technology, exports to and imports from neighbour countries via the AC electricity grid as function of time between the years 2000 and 2050.

Year	2000	2010	2020	2030	2040	2050
Consumption	78.1	144.5	243.3	341.1	443.0	520.7
Export via Grid	1.0	1.0	1.0	1.5	2.0	2.5
Wind Power	0.2	1.7	23.8	34.3	74.3	104.2
Photovoltaics	0.0	0.0	2.8	27.3	80.5	85.0
Geothermal	0.0	0.0	0.6	4.1	15.0	23.4
Biomass	0.0	0.1	5.6	11.6	14.5	15.1
CSP Plants	0.0	0.1	2.6	14.0	79.7	251.2
Wave / Tidal	0.0	0.0	0.0	0.0	0.0	0.0
Hydropower	13.7	13.7	14.1	15.0	15.2	15.3
Oil	9.3	7.4	7.4	7.4	0.0	0.0
Gas	55.0	121.4	186.2	227.3	163.8	26.5
Coal	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Import via Grid	1.0	1.0	1.0	1.5	2.0	2.5

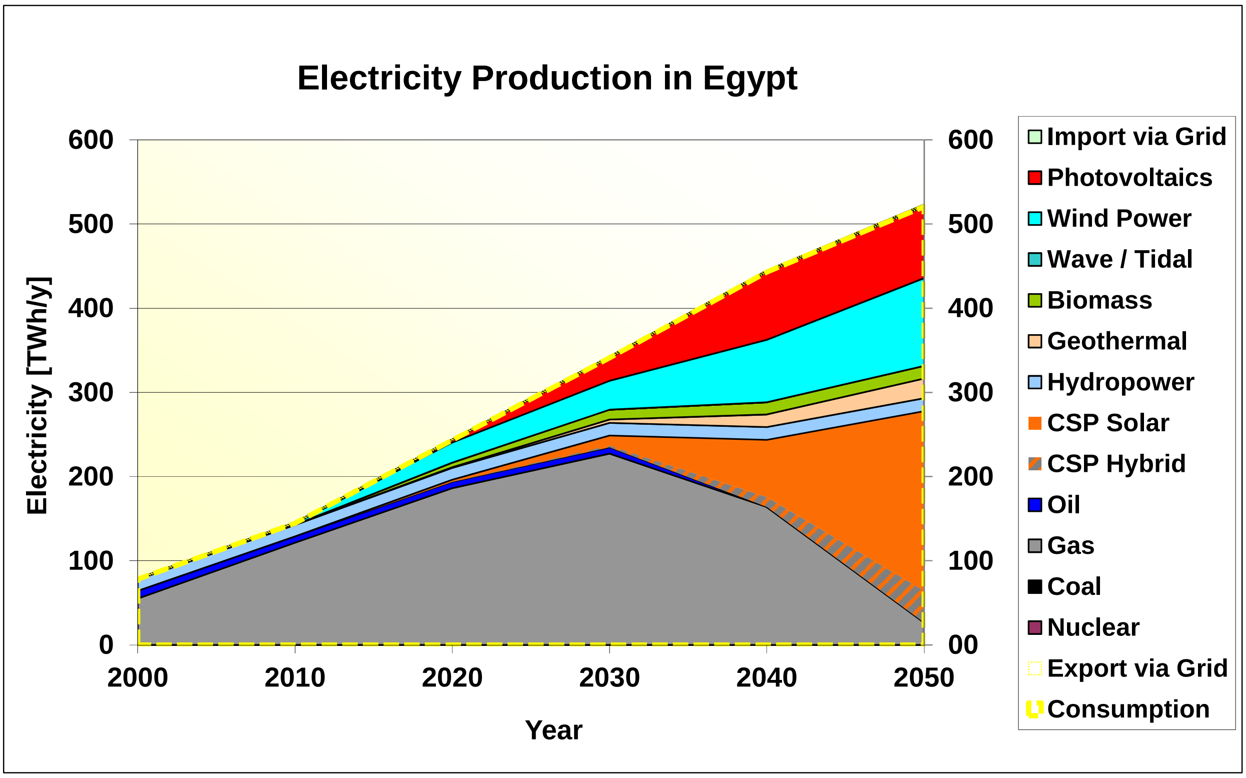

Figure 22: Annual production of RES-E and conventional power plants in Egypt compared to the gross electricity consumption plus export to neighbors through the AC grid. Hybrid CSP operation is assumed to be achieved by natural gas backup for steam generation within the CSP plants. In the long-term, only marginal amounts of electricity will be produced in fossil fuel plants for back-up and emergency purposes.

As consumption will almost double between 2010 and 2020, there will be a tremendous pressure on fossil fuel resources that can only be relieved by quickly introducing cost-effective fuel savers like wind and PV power (Table 23). This will prolong the availability of fossil fuels and stabilize the cost of power generation.

The option of additionally exporting CSP electricity to Europe via HVDC links would be in line with the tradition of Egypt as energy exporter, while at the same time prolonging the availability of natural gas for own use and export.

Peak load will increase in line with increasing consumption, and therefore, there is a compulsive need for the installation of sufficient firm and flexible power capacity and reserve. Only fossil fuel fired power plants and renewable power plants using biomass or concentrating solar thermal power can provide this type of high quality supply. As biomass is rather scarce in North Africa, hybrid (solar/fossil) concentrating solar power stations are the only alternative to fossil fuel plants, being able to deliver the same quality of supply with much lower fossil fuel consumption. Therefore, their short term introduction and expansion is crucial for achieving sustainable supply in the medium and long term, as the natural gas reserves are limited.

Our scenario reflects this strategy, by massively increasing the share of RES-E until achieving about 87% in 2050 (Figure 22). By then, wind power and PV would make up for 36% of the annual power production for national supply. In order to provide sufficient firm power capacity and RES-E production, CSP plants are extended to provide 48% of annual production. About 7% (35 TWh/y) of annual production in Egypt will stem from hybrid CSP operation with natural gas and further 5% (25 TWh/y) from natural gas peaking plants. There will still be a significant capacity of natural gas plants installed for reserve and emergency purposes in 2050, but their power production will be limited to backup purposes and thus will be rather low. The use of natural gas in CSP plants is more cost effective and efficient than solar only operation of CSP plants and balancing by extra gas plants. Firstly, hybrid CSP plants will have less part-load losses and thus higher efficiency for solar power generation. Secondly, gas plants would have rather low efficiencies just filling the few supply gaps that would be left by wind, PV and solar only CSP plants.

A well-balanced mix of the available RES-E resources in Egypt can lead to a scenario for 2050 that satisfies all the sustainability criteria described before. The national potential of wind power of about 120 TWh/y will be exploited by 87%, while less than 1% of the solar energy resource potential will be needed to satisfy the national demand and in addition provide significant amounts of flexible solar electricity exports for Europe. In Egypt, export electricity will make up for only 10% of the total generation. This is due to the very high domestic demand that will bind most of the production industry and to the relative remoteness of Egypt with respect to access to continental Europe. Nevertheless, although the relation of export and domestic supply is less critical than in the other North African countries, infrastructures for national supply and for export should be separated in order to avoid utilization conflicts.

At present power production in Egypt is almost fully dependent on natural gas. It is clear that the availability of gas would be reduced significantly if the quickly growing demand would only be satisfied by this limited resource. In fact this cannot be avoided, as the consumption of natural gas still doubles in our scenario until 2030. According to the BP Statistical Review of World Energy 2013 the ratio of natural gas reserves and present exploitation in Egypt amounts to about 33 years. A significant increase of exploitation – not only for domestic use but also for export – would reduce this time accordingly. Another aspect of fossil fuel consumption is the importance of natural gas for the international trade balance. It is clear that gas burned for power generation today cannot be sold on the market tomorrow. On the other hand, using gas mainly for hybrid operation in CSP plants as in our scenario would reduce its consumption and almost double its availability for the future.

Biomass (3% in 2050), geothermal power (4% in 2050) and hydropower (3% in 2050) are available, but will not achieve major importance in the long term, as Egypt will experience a strong growth of demand. CSP, PV and wind power are the major domestic sources of energy for power generation, while natural gas is the most important ideally stored form of energy available in the country. CSP would provide about 50% of domestic supply in 2050. An intelligent combination of ideally stored and free flowing forms of energy will allow Egypt to achieve a sustainable power supply by the mid of the century. In technical and economic terms, the transition to renewable power could by significantly faster than expected on the basis of present national planning. Therefore, Egypt could consider accelerating its transition towards renewable power sources in order to better conserve its most valuable form of energy, natural gas, and prolong its availability for future generations. The strong increase of natural gas consumption until 2030 that is related to the present tentative RES-E integration policy suggests that Egypt will become a net importer of natural gas in the short and medium term. The only alternative would be an accelerated introduction of all available forms of renewable energy.

It is important to note that ideally stored forms of energy like fossil fuels will be required for a long time. Even in a desert country like Egypt with one of the largest solar energy potentials worldwide, the availability of solar power over the whole year is not 100%, so CSP plants will have to operate in hybrid mode with natural gas in order to cover the load at any time on demand. The substitution of the last 12% of fossil fuel consumption will be a special challenge, which may be overcome in the long-term by innovations such as power-to-gas or power-to-liquid fuel conversion. As research and development of such technologies is already under way, our scenario must not be understood as if those technologies would not be implemented before 2050. On the contrary, in the best case, hybrid operation of CSP plants in our scenario could eventually be provided by natural gas derived from renewable sources, in that case effectively leading to a 100% RES-E share in 2050.

Synthetic natural gas production from renewable sources would require additional RES-E infrastructure that has not yet been included in our scenario and would have to be assessed and designed separately. An important frame condition for any hydrocarbon synthesis process is its operation near to steady state conditions, which is required to achieve the equilibrium needed for an efficient chemical conversion process. Such a steady state operation will be very difficult to achieve by (cheap) wind and PV input, but is easily achieved by (more expensive) CSP plants with thermal energy storage. As there is still not enough information and experience available for a reliable modeling and comparison of such solutions, we have assumed that the need for ideally stored energy in our scenario until 2050 will be covered by fossil natural gas.

2.6.3 Libya

The Libyan energy market was shaped by the organizational structure of the Gaddafi-era political system "Jamahiriya". In accordance to the socialist People's Republic ideology of Gaddafi almost the whole economic sector was nationalized. This national strategy applied strongly for the energy sector, which was and still is the main source of income for the Libyan economy as well as for the public budget. The electricity company, *General Electric Company of Libya* (GECOL), and the Renewable Energy Authority of Libya (REAOL) were under the direct supervision of the General Peoples' Committee for Electricity, Water and Gas. International companies are active only in joint ventures with the National Oil Company (NOC) in the oil and the gas sectors (EIA 2012) and private engagement in the electricity sector remains limited to contracted work in specific projects.

In 2010, an installed capacity of 6,300 MW produced 32,560 GWh of electricity mainly from oil (62%) and gas (38%) (GECOL 2013). Only very few solar PV stations with a total installed capacity of 4.8 MW were installed in 2012 (REN21 2013) mainly for communication uses (690 kW), for cathodic protection (650 kW) and more than 300 off-grid installations existed in remote areas (RCREEE 2010).[24] REN21 reports 5 wind projects currently in planning, with an installed capacity of 610 MW (REN21 2013). Electricity prices are highly subsidized,[25] resulting in high residential consumption and a vast increase in demand of 7% per year (Grant /Wahab 2012).

After the war, a new government was appointed in 2012 and a new constitution was planned to be drafted until December 2013. The present situation is thus marked by on-going restructuring of the governance structures including the uncertainty related to the legislative, regulatory and institutional framework (EIA 2012).

2.6.3.1 Demand Expectations

In the past decade, an electricity consumption of approximately 1.8 TWh/y has been added every year in Libya, reaching an annual demand of 33 TWh/y in 2010 (DLR 2013). The growth rate of demand in 2010 was almost 9%/y. If this trend would continue linearly in the future Libya would consume about 50 TWh/y by 2020 and 100 TWh/y by 2050 (**Figure 23**).

According to AUE 2011 the national expectations are much higher, indicating a demand of 90 TWh/y by 2020. Extrapolating this expectation linearly after 2020, Libya would consume over 250 TWh/y by 2050. As these expectations are rather unrealistic, the linear extrapolation of the past decade was also used as outlook.

[24] Abdulwahab Misherghi, Ministry of Electricity and Renewable Energies, Berlin, 26/06/2012
[25] The IEA estimates a subsidy rate for Libyan fossil fuel consumption of 76.9% (http://www.iea.org/subsidy/).

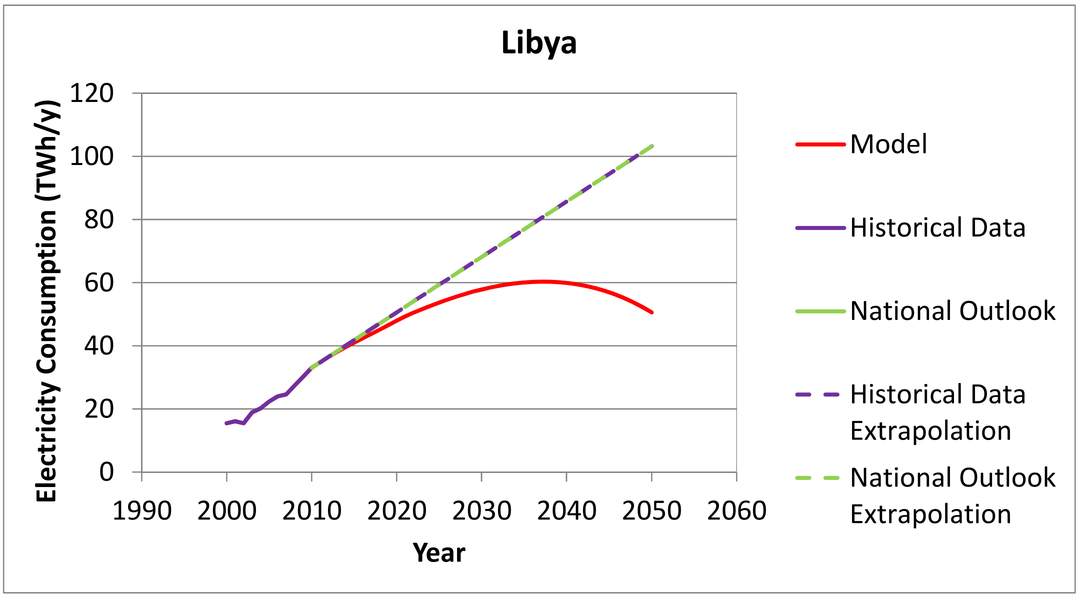

Figure 23: Gross electricity consumption in Libya: Model result, historical data until 2010 with linear extrapolation after 2010, national outlook from 2010 to 2020 with linear extrapolation after 2020.

Our model predicts a demand that is much lower than expectations prior to the Libyan revolution but well in line with the linear extrapolation until 2020. Starting with 33 TWh/y in 2010, our model predicts about 48 TWh/y in 2020, a peak around 60 TWh/y around 2035 and 51 TWh/y in 2050. As a country with relatively high per capita income and high per capita electricity demand, Libya's growth of demand is steadily reduced and a clear saturation effect can be after 2030. As the growth of population is rather low, there could be even a reduction of electricity demand, especially if efficiency measures are introduced in the power sector. The gap between the model and national outlook may look too big, but considering the high per capita demand already assumed, the model at hand seems to be more realistic than this outlook.

Per capita electricity consumption will increase from 5.2 MWh/cap/y in 2010, reach a maximum of 7.4 in 2035 and in the long term 5.8 MWh/cap/y in 2050, which would be the highest value among the NA countries analysed here. Certainly, there is a possibility that the effects of the recent political changes in Libya may cause a temporary decline of GDP and electricity demand in the short term. Therefore, the relatively low consumption predicted by the model compared to the national expectations seems justified. The result of our demand modelling shows that Libya may soon enter a phase of stabilizing electricity demand at around 60 TWh/y by 2030.

An hourly load curve for Libya for the years 2007 and 2010 was provided by AUE 2012. The 2010 load curve was scaled for all consecutive years until 2025 for detailed scenario modelling of the electricity mix (Figure 24). Scaling was done in a way that maintains the relation of annual electricity demand and peak load just as scheduled by the national outlook data provided by AUE 2011. The load curve shows a clear peak in summer and smaller peaks in the winter season.

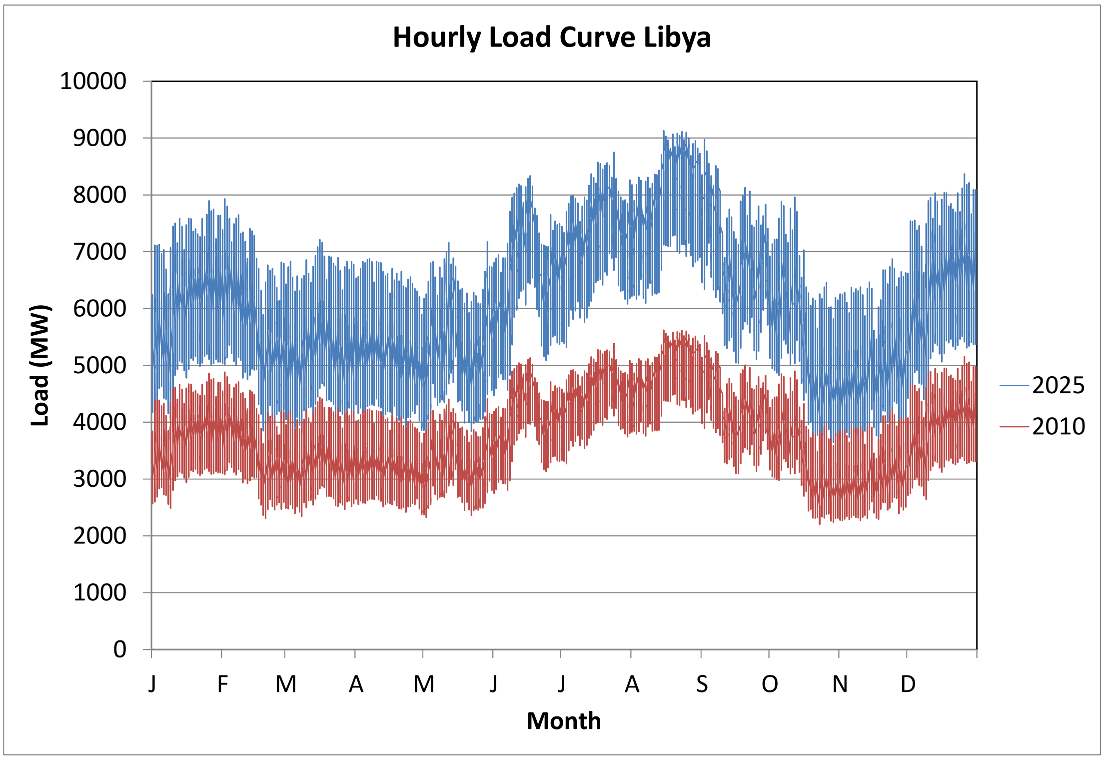

Figure 24: Hourly load curve for the years 2010 and 2025 for Libya

2.6.3.2 RE Policy and Targets

The Renewable Energy Authority of Libya (REAOL), founded in 2007, has adopted – before the war – a renewable energy road map with the targets of 10% renewable electricity generation by 2020 and 30% renewables share in the energy supply in 2030. This plan was approved by the former Ministry of Electricity and Energy (Reegle 2012) and technology specific targets were indicated for 2015 and 2020. An open tender to finance the first 100 MW capacity of CSP was issued by REAOL in 2011. This process was disrupted by the war, but may be issued again in 2013 (Reuters 2013).

A road map for developing renewable energy in Libya was adopted by the Renewable Energy Authority of Libya (REAOL), with specific targets of 6% share in 2015 and 10% in 2020 of total electricity installed capacity. A target of 30% of renewable energy share in the energy supply is envisaged for 2030.

A new target of 20% RE share in electricity generation by 2020 was announced by the Energy minister Ali Mohammed Muhairiq in April 2013 (Reuters 2013).

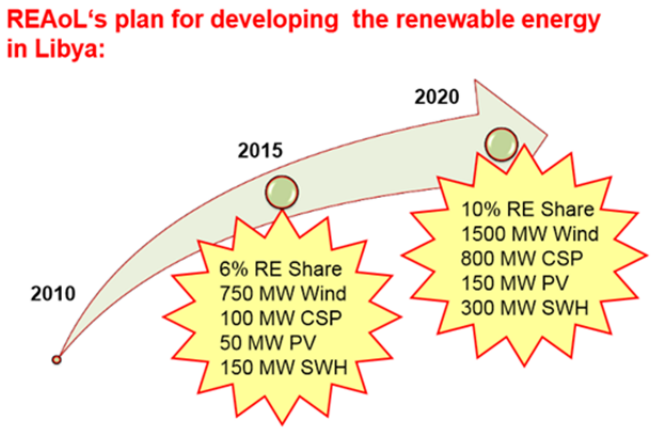

Figure 25: Technology specific targets adopted by REAOL26, 27

The mid-term plan of REAOL envisions several concrete projects, but none of them has been implemented as of today. This is primarily due to the present Libyan political situation, but already in the pre-war period a disagreement within the different governmental institutions and ministries were reported to hamper the RE deployment (RCREEE, 2010).

REGULATORY FRAMEWORK

Development of renewable energy is not governed by any legislative framework. Public funds have been allocated for investments in renewable energy. In terms of private sector investments, there is no framework governing the investments.

The policy and regulatory framework is not well developed and thus need further reforms. Adopting a comprehensive law pertaining to renewable energy could give an impetus for a wide scale development and deployment of renewable energy in Libya. This regulatory and legislative framework should entail clear targets, transparent rules, grid access, non-licensing of small installations, etc. The National Energy Master Plan could be a very important step towards overcoming the regulatory and institutional framework hurdles.

There is no legislation covering financial support for renewable energy and addressing the issue of how additional costs of renewable energy compared to the least cost alternative should be financed. Former investments in RE projects have been financed directly by public funds. Moreover, there is no clear legislative basis for the participation of private capital in the power sector (RCREEE 2010).

There is no regulation for third party access to the grid in place.

In the pre-war period, the Libyan power sector did not experience any actual liberalization or opening for IPPs. A law comprising a legal unbundling and a regulatory framework for IPPs was

[26] Abdulwahab Misherghi, Ministry of Electricity and Renewable Energies, Berlin, 26/06/2012
[27] However, these technology specific targets as reported by Abdulwahab Misherghi in June 2012 do not reflect the targets as defined in the REN21 MENA report published in May 2013. REN21 reports that Libya has a solar PV target of 129 MW by 2015, 344 MW by 2020 and 844 MW by 2025. The CSP target is reported to be 125 MW by 2020 and 375 MW by 2025, while the wind energy target is 260 MW by 2015, 600 MW by 2020 and 1,000 MW by 2025 (REN21 2013).

drafted, but never adopted. Thus, the vertically integrated public electricity company, GECOL, is responsible for power generation, transmission and distribution in Libya, owning and operating 100% of the transmission grid and 90% of the distribution grid (Reegle 2012).

No regulatory framework exists in terms of providing incentives to renewable energy in Libya. Renewable energy projects have been financed by public funds, and the private sector involvement is inexistent.

Libya ratified the UNFCCC in June 1999 and the Kyoto Protocol in 2006. The DNA in Libya is the Environment General Authority (EGA). The table below summarizes the registered projects, the avoided CO2 emissions and the EU countries with which Libya has sold carbon credits to meet some EU countries' targets. The table below summarizes the registered CDM projects in Libya.

No NAMAs have been submitted yet in Libya.

INSTITUTIONAL FRAMEWORK

The electricity sector in Libya is under the control of the state-owned company GECOL (*General Electric Company of Libya), a* vertically-integrated monopolistic company. The electricity company GECOL and the Renewable Energy Authority of Libya (REAOL) which was established in 2007,were under the direct supervision of the General Peoples' Committee for Electricity, Water and Gas. International companies were active only in joint ventures with the National Oil Company (NOC) in the oil and the gas sectors (EIA 2012) but the private engagement in the electricity sector remains limited to contracted work in specific projects. Several institutions exist, yet with slow implementation process.

In 1978, the Center for Solar Energy Research and Studies (CSES) was established under the Ministry of Higher Education and Scientific Research. The Center conducts studies and research in solar energy, proposes plans for a large scale deployment and provides a better understanding of the field. Some of the activities it has performed or supervised are: field project for solar water heaters, solar desalination projects, experimental wind farm project in Zawara, the wind and solar radiation atlas in cooperation with the GECOL and the use of cell for electrical energy generation, etc.[28]

Established in 2007, the Renewable Energy Authority of Libya (REAOL), is a public entity whose objectives are implementation of renewable energy projects, increase the share of RE in the energy mix, encourage and support industries in the renewable energy sector, and propose legislation needed to support renewable energy (Misherghi, 2012).

Recent developments have seen the establishment of the Ministry of Electricity and Renewable Energy in 2011; a very important step for promoting renewable energy technologies in the country. In this regard, the Ministry is drafting a new electricity law and is considering renewable energy legislation.[29]

In terms of further institutional framework conditions needed to achieve the RES policy targets and given the inexistence of a regulatory body, it is very important to establish an independent regulatory agency. The independence of the regulatory authority is very important. Some of the competencies of an independent regulatory authority are; it should have adequate human and

[28]REEGLE, http://www.reegle.info/actors/2703/centre-for-solar-energy-studies.htm.
[29]John Hamilton, the sun will not shine automatically on Libya's renewable plans, April 2013, http://www.libyaherald.com/2013/04/17/the-sun-will-not-shine-automatically-on-libyas-renewable-plans/

financial resources; capacity to guarantee a fair and transparent remuneration of networks (tariff setting); have a role in energy markets monitoring (opening up to competition, settlement of disputes); and be able to enforce customers' rights and customer empowerment (Gallèpe, 2013).

Likewise, the Ministry of Electricity and Renewable Energy needs further consolidation. As a new entity, consolidation at all levels, human and financial resources will play a very important role in the success of an energy strategy in the country, including renewable energy.

Once in place, a regulatory body to be established could be a suitable institution to facilitate the implementation of the cooperation mechanisms. This role would entail i) administration of the provided remuneration, ii) facilitation of an oversight over the implementation and iii) proof of renewable energy transfers (Frieden *et al*., 2012).

INFORMATION POLICY AND CAPACITY BUILDING

A wind atlas has been drafted but not yet published. There is no comprehensive assessment of the solar energy potential in Libya (RCREEE 2010). Libya has no strong awareness and information policy or capacity building programs. There is lack of awareness and information related to RE technologies among policy makers, energy planners and potential users of the technology. Capacity building programs are also of need.

Nevertheless, the Center for Solar Energy Research and Studies (CSES) is worth highlighting in this respect. Some of the main objectives of the center are: transfer of abstract renewable energy research to applied research, promoting RE technology transfer, adaptation of RE technology systems for the local environment, and improving performance, and participating in establishing industrial base for local manufacturing of RE systems. In terms of measurements and testing facilities, the center has calibration facilities for climate sensors, testing of PV and thermal conversion technologies, and other supporting facilities such as electronic and mechanical workshops. Some current projects are worth mentioning, namely operating an experimental distillation unit with solar collectors, pilot project of using PV systems for electrification of two remote villages, performance of evaluation of PV water pumping systems and performance evaluation of grid connected PV system.[30]

Awareness raising is particularly interesting in bridging social acceptance barriers. Conducting such national awareness campaigns would be very necessary. Another important element would be to facilitate access to information through posting all related information about renewable energy including resources, strategy, targets, and incentives on the websites of important stakeholders such as the Ministry of Electricity and Renewable Energy and the Renewable Energy Authority of Libya (REAOL).

Regarding education, putting in place educational programs about renewable energy at the university level is of paramount importance in preparing the required skills for the development and deployment of renewable energy technologies in the country. Vocational training programs to qualify technicians are also needed.

[30] Alaref, Abdelmula, 2013: Promoting Renewable Energy and Energy Efficiency in Libya, Workshop on Renewable Energy and Energy Efficiency, Tripoli, 16-17 April 2013.

For further research activities, several initiatives are envisaged by CSES. Some of the projects planned are: development of center research facilities, determination of technical and economic potential of solar ration and wind energy in Libya, installation and evaluation of experimental renewable energy systems and seeking accreditation for testing and certification of solar collectors and PV modules.[31]

Capacity building for all governmental levels, including public agencies, is very important. Skills development of personnel related to all the aspects of renewable energy projects, starting from administrative to legal, managerial, development, engineering and any other aspects of renewable energy.

In this framework, CSES is putting in place a qualification and training program for engineers in the year 2013. Two programs are worth emphasizing in this perspective; post graduate study for both masters and Ph.D degree and other training in different fields related to the center activities abroad and local trainings alike. [32]

BARRIERS

The Libyan renewable energy sector faces several serious barriers, in particular related to the current unstable regulatory and political framework. The main barriers can be summarized as follows:

- Libya lacks a stable institutional and regulatory framework for RE;
- Large fossil resources and discoveries in recent years continue to strengthen the fossil fuel energy path of the Libyan energy strategy. Abundant conventional resources and absence of environmental constraints in policy are thus major barriers for a large scale RE deployment;
- Furthermore, as electricity prices are subsidised and there is no official cost calculation within GECOL, it is not even possible to identify the cost gap between renewables and conventional electricity generation;
- The lack of awareness and information about RE technologies among policy makers, energy planners, and potential users of the technology hinders the creation of a domestic RE sector;
- Lack of capacity building programmes in the field of RE in the country and for different actors (especially decision makers, consultants, within energy companies).

2.6.3.3 Scenario for the power sector

Scenario analysis reveals two aspects of electricity supply that will be shown for a possible transition towards a sustainable electricity scheme: the installed capacity and the annual electricity production and their development as function of time. In terms of installed capacity, the most important target to be achieved is that the firm capacity of all power plants is always larger than the peak load that occurs once a year.

[31] Alaref, Abdelmula, 2013: Promoting Renewable Energy and Energy Efficiency in Libya, Workshop on Renewable Energy and Energy Efficiency, Tripoli, 16-17 April 2013.
[32] Alaref, Abdelmula, 2013: Promoting Renewable Energy and Energy Efficiency in Libya, Workshop on Renewable Energy and Energy Efficiency, Tripoli, 16-17 April 2013.

Table 24 shows how this condition is maintained at any time in the future. It can also be appreciated how the relation of installed capacity and peak load increases with time due to the introduction of fluctuating renewables like wind power and PV. While in the year 2000, the relation of installed capacity to peak load is equal to 4.3/2.9 = 1.5, this relation increases to 29.5/8.6 = 3.4 in the year 2050. The increase of this ratio means that the average utilization (capacity factor) of the total power park is reduced accordingly.

In our scenario, the total installed capacity of about 4.3 GW in 2010 would increase to about 13 GW in 2020 and to 30 GW in 2050. Under this condition, the mix of fluctuating and flexible power plants would allow for a guaranteed production of electricity on demand at any time, without requiring major additional electricity storage devices or an expansion of the electricity grid beyond the natural growth of the AC grid assumed here.

Our scenario in **Figure 26** shows how peak load will increase between 2010 and 2050, showing a saturation point around 2040 and a slight reduction afterwards. As a consequence firm power capacity from gas and oil fired power stations also will have to increase in line with that growing demand. However, after 2030, CSP plants step-by-step will take over firm capacity supply, because by then the CSP industry will have grown sufficiently to cover the increasing demand for firm and renewable power capacity. According to national planning, by 2020 about 1500 MW of wind power, 200 MW of PV and 800 MW of CSP could be installed. There is no hydropower or any reported geothermal power potential in Libya. Due to the high cost of fuel oil, oil fired power stations will be phased out after 2030.

Table 24: Installed power capacity in Libya (GW) for each technology and firm capacity of all plants compared to the peak load of the country as function of time between the years 2000 and 2050. Import / Export refers to the Net Transfer Capacity (NTC) of the conventional AC grid. Export CSP capacity is assumed to be totally independent from national supply and will be discussed later.

Year	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Peak Load	2.9	5.6	8.2	9.8	10.2	8.6
Firm Capacity	3.9	7.0	10.2	12.3	12.7	10.8
Installed Capacity	4.3	7.8	12.8	22.9	28.1	29.5
Wind Power	0.0	0.0	1.5	3.3	3.6	3.5
Photovoltaics	0.0	0.0	0.2	2.6	3.5	3.5
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	0.0	0.0	0.1	0.3	0.4	0.5
CSP Plants	0.0	0.0	0.8	1.4	4.7	7.4
Wave / Tidal	0.0	0.0	0.0	0.0	0.0	0.0
Hydropower	0.0	0.0	0.0	0.0	0.0	0.0
Oil	3.2	2.9	2.6	1.9	0.0	0.0
Gas	0.8	4.5	7.1	8.9	7.8	3.1
Coal	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Import / Export NTC	0.3	0.4	0.6	0.8	0.8	0.7

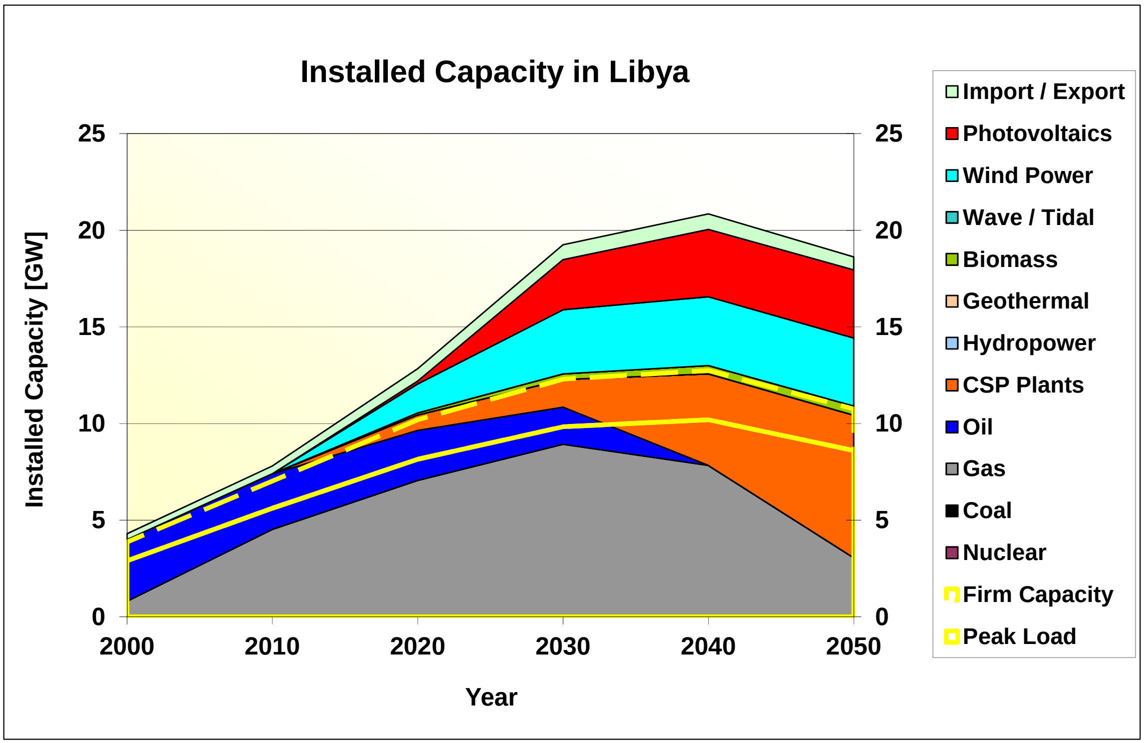

Figure 26: Installed power capacity in Libya for each power plant technology and firm capacity of all plants compared to the peak load of the country as function of time between the years 2000 and 2050. Import / Export refers to the Net Transfer Capacity (NTC) of the AC grid.

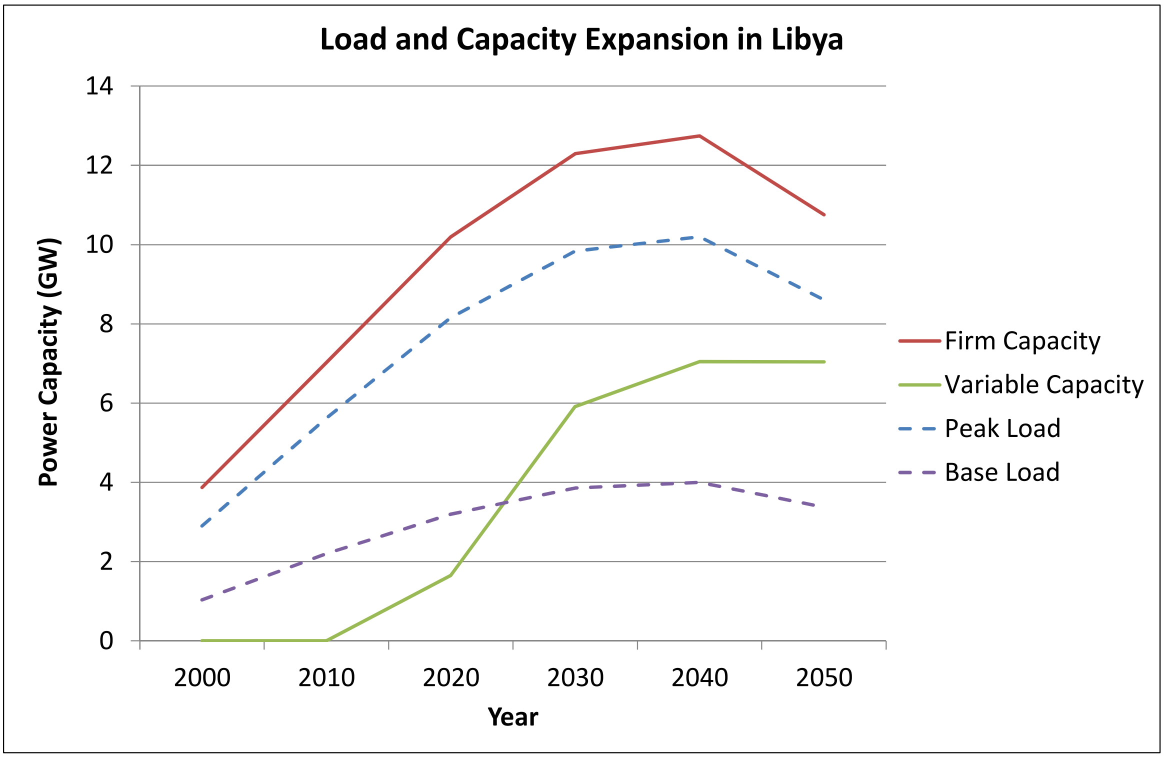

Figure 27: Comparison of firm capacity, variable capacity from fluctuating sources and export capacity of CSP plants with peak load and base load in Libya.

By 2030 about 30% of the total installed capacity will be covered by renewable sources, and CSP exports to Europe will also be implemented for the first time. The strongest growth of renewable power capacity will take place between 2030 and 2050. In 2050, over 75% of the power park will already be renewable, with hybrid (solar/fossil) CSP taking over the job of providing firm and flexible power capacity on demand, and major wind and PV capacities that will act as fuel savers every time the sun shines and the wind blows. The total installed capacity of wind and PV plants will be almost equal to that of CSP.

Figure 27 shows a comparison of the firm power capacity from flexible sources and the variable capacity from fluctuating sources and their relation to the national peak and base load demand. It can be seen that the fluctuating capacity from wind and PV can become larger than base load demand, but not larger than the peak load of the country. This will lead to power surpluses from time to time when demand is low that however can be partially compensated by exporting electricity via the AC grid and by using the existing – rather scarce – options for electricity storage. Due to the fact that wind power and PV power will not often be fully available at the same time, surpluses will not occur frequently. Also the surplus power capacity – which would dictate the necessary rated power of related electricity storage devices like pump storage or batteries – will be rather low.

Within the simple approach followed here fluctuating power capacity will be limited to slightly lower values than peak load, and flexible power capacity will make up for at least 125% of peak load. This way, surpluses can be effectively avoided and security of supply is maintained at any moment in time. In the medium and long term, wind and PV power will be least cost sources of energy and installed preferentially until reaching the peak load limit. Flexible power sources like CSP, being more expensive, will be used to fill the remaining gaps and cover peak load reliably at any time.

Electricity production and import through the AC grid will cover gross electricity consumption plus eventual export through the AC grid and via HVDC interconnections to Europe. Import and export through the AC grid will increase with time and in line with the growing net transfer capacity of the grid. In our model, it is assumed that annual import and export streams will be balanced.

As consumption will more than double between 2010 and 2020, there will be a tremendous pressure on fossil fuel resources that can only be relieved by quickly introducing cost-effective fuel savers like wind and PV power (Table 25). This will prolong the availability of fossil fuels and stabilize the cost of power generation.

The option of additionally exporting solar electricity to Europe would be in line with the tradition of Libya as energy exporter, while at the same time prolonging the availability of fossil fuels for own use and export.

Table 25: Annual electricity production in Libya (TWh/y) by each technology, exports to and imports from neighbor countries via the AC electricity grid as function of time between the years 2000 and 2050.

Year	2000	2010	2020	2030	2040	2050
Consumption	15.5	33.0	48.0	57.8	60.0	50.6
Export via Grid	0.0	0.1	0.3	0.6	0.8	1.0
Wind Power	0.0	0.0	3.0	6.7	7.3	7.4
Photovoltaics	0.0	0.0	0.3	4.8	6.5	6.6
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	0.0	0.0	0.4	1.0	1.5	1.7
CSP Plants	0.0	0.0	3.8	7.3	22.4	32.1
Wave / Tidal	0.0	0.0	0.0	0.0	0.0	0.0
Hydropower	0.0	0.0	0.0	0.0	0.0	0.0
Oil	12.1	9.7	9.7	7.2	0.0	0.0
Gas	3.4	23.4	30.9	30.9	22.2	2.8
Coal	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Import via Grid	0.0	0.1	0.3	0.6	0.8	1.0

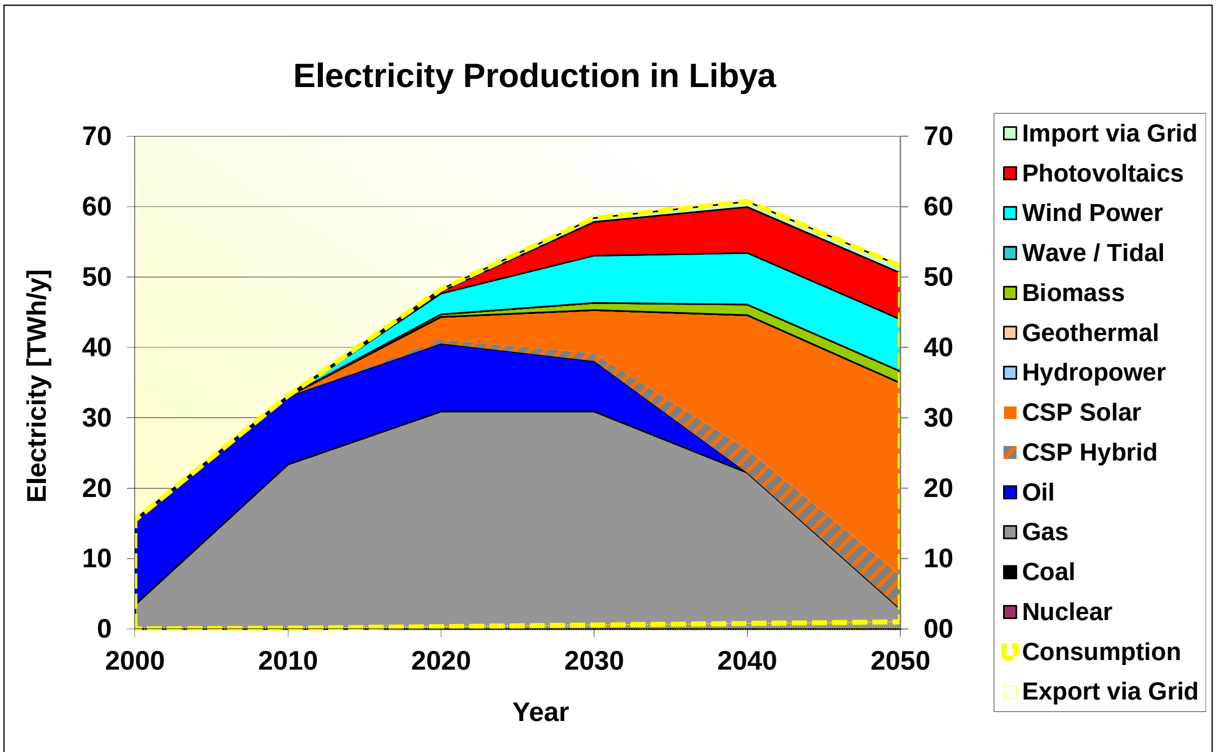

Figure 28: Annual production of RES-E and conventional power plants in Libya compared to the gross electricity consumption plus export to neighbours through the AC grid. Hybrid CSP operation is assumed to be achieved by natural gas backup for steam generation within the CSP plants. In the long-term, only marginal amounts of electricity will be produced in fossil fuel plants for back-up and emergency purposes.

Peak load will also increase in line with increasing consumption, and therefore, there is a compulsive need for the installation of sufficient firm and flexible power capacity and reserve. Only fossil fuel fired power plants and renewable power plants using biomass or concentrating solar thermal power can provide this type of high quality supply. As biomass is rather scarce in North Africa, hybrid (solar/fossil) concentrating solar power stations are the only alternative to fossil fuel plants, being able to deliver the same quality of supply with much lower fossil fuel consumption. Therefore, their short term introduction and expansion is crucial for achieving sustainable supply in the medium and long term, as the natural gas and oil reserves are limited.

Our scenario reflects this strategy, by massively increasing the share of RES-E until achieving about 83% in 2050 (Figure 28). By then, wind power and PV would make up for 27% of the annual power production for domestic supply. In order to provide sufficient firm power capacity and RES-E production, CSP plants are extended to provide 62% of annual production. About 10% (5 TWh/y) of annual production in Libya will stem from hybrid CSP operation with natural gas and further 5% (2.8 TWh/y) from natural gas peaking plants. There will still be a significant capacity of natural gas plants installed for reserve and emergency purposes in 2050, but their power production will be limited to backup purposes and thus will be rather low. The use of natural gas in CSP plants is more cost effective and efficient than solar only operation of CSP plants and balancing by extra gas plants. Firstly, hybrid CSP plants will have less part-load losses and thus higher efficiency for solar power generation. Secondly, gas plants would have rather low efficiencies just filling the few supply gaps that would be left by wind, PV and solar only CSP plants.

A well-balanced mix of the available RES-E resources in Libya can lead to a scenario for 2050 that satisfies all the sustainability criteria described before. The national potential of wind power of about 25 TWh/y will be exploited by 30%, while less than 1% of the solar energy resource potential will be needed to satisfy the national demand and in addition provide significant amounts of flexible solar electricity exports for Europe.

At present power production in Libya depends on natural gas and fuel oil. It is clear that the availability of gas would be reduced significantly if the quickly growing demand would only be satisfied by those limited resources. Consumption of natural gas and oil will remain at a high level until 2030 and then will be slowly reduced. According to the BP Statistical Review of World Energy 2013 the ratio of natural gas reserves and present exploitation in Libya amounts to over 100 years. A significant increase of exploitation – not only for domestic use but also for export – would reduce this time accordingly, but there will be no critical situation in the medium term future. Another aspect of fossil fuel consumption is the importance of natural gas for the international trade balance. It is clear that gas burned for power generation today cannot be sold on the market tomorrow. On the other hand, using gas mainly for hybrid operation in CSP plants as in our scenario would reduce its consumption and increase its availability in the future.

Biomass will have minor importance, while there is no significant potential for geothermal power and hydropower. CSP, PV and wind power are the major domestic sources of energy for power generation, while natural gas and to some extent fuel oil are the most important ideally stored forms of energy available in the country. CSP would provide about 60% of domestic supply in 2050. An intelligent combination of ideally stored and free flowing forms of energy will allow Libya to achieve a sustainable power supply by the mid of the century. In technical and economic terms, the transition to renewable power could by significantly faster than expected on the basis of present national planning. Therefore, Libya could consider accelerating its transition towards renewable power sources in order to better conserve its most valuable forms of energy, fuel oil and natural gas, and prolong their availability for future generations.

It is important to note that ideally stored forms of energy like fossil fuels will be required for a long time. Even in a desert country like Libya with one of the largest solar energy potentials worldwide, the availability of solar power over the whole year is not 100%, so CSP plants will have to operate in hybrid mode with natural gas in order to cover the load at any time on demand. The substitution of the last 17% of fossil fuel consumption by renewable sources will be a special challenge, which may be overcome in the long-term by innovations such as power-to-gas or power-to-liquid fuel conversion. As research and development of such technologies is already under way, our scenario must not be understood as if those technologies would not be implemented before 2050. On the contrary, in the best case, hybrid operation of CSP plants in our scenario could eventually be provided by natural gas derived from renewable sources, in that case effectively leading to a 100% RES-E share in 2050.

Synthetic natural gas production from renewable sources would require additional RES-E infrastructure that has not yet been included in our scenario and would have to be assessed and designed separately. An important frame condition for any hydrocarbon synthesis process is its operation near to steady state conditions, which is required to achieve the equilibrium needed for an efficient chemical conversion process. Such a steady state operation will be very difficult to achieve by (cheap) wind and PV input, but is easily achieved by (more expensive) CSP plants with thermal energy storage. As there is still not enough information and experience available for a reliable modeling and comparison of such solutions, we have assumed that the need for ideally stored energy in our scenario until 2050 will be covered by fossil natural gas

2.6.4 Morocco

From 2002 to 2011 the total Moroccan energy consumption increased with an average rate of 5.7 % per year with a greater part of it coming from the rapid increase of electricity demand (Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement - MEMEE 2012). The Moroccan electricity market is mainly controlled by the public company, Office National de l'Electricité et de l'Eau potable (ONEE), which has the exclusive right to buy and transmit electricity and to assign concessions to Independent Power Producers (IPP) for conventional generation sites with a capacity of 10 MW or higher. ONEE owns and runs 4507 MW of the installed 6,377 MW of thermal and hydroelectric capacities in 2011 (including 464 MW of pump storage capacity). In 2011, thermal electricity production capacities were mainly fueled by coal (4553 kilo tons), fuel oil (1605 kilo tons) and natural gaz (745 Million m3) (MEMEE 2013) which led to an electricity production of 11679 GWh by coal-fired power plants, 6578 GWh by oil-fueled production sites, 4051 GWh by gas-fired plants and 2005 GWh of hydroelectricity output (IEA 2011). In the same year, ONEE produced almost 40% of the electricity consumed in Morocco while 43% was generated by independent power producers under concessions from the ONEE (Paving the Way for the MSP 2012; MEMEE 2013; ONEE 2013). The remaining 17% were imports mainly from Spain and a very small part of 0.7% generated by self-producers. The largest privately owned electricity production facility is a coal-fired power plant with a total capacity of 1,356 MW run by Jorf Lasfar Energy Company (JLEC) held by the Abu Dhabi National Energy Company (PJSC) and is in expansion to reach a total installed capacity of 2,056 MW in 2013/2014 by the construction of two new units of 350 MW each (JLEC 2013).

Private entities such as industrial consumers are allowed to generate electricity for their own consumption, if the installed capacity is lower than 50 MW. Special purchasing terms for electricity surpluses supplied to the national grid can be agreed on with ONEE offering special tariffs in case of renewable electricity generation. In 2011, 2.4% of the consumed electricity was produced by wind power33 and 7% by hydropower (MEMEE 2013). Installed capacity in 2012 for solar PV was 15 MW, for CSP 20 MW, for wind 291 MW and for hydro 1,745 MW according to REN21 (REN21 2013). RE projects in pipeline were reported as a total of 1,727.37 MW (REN21 2013).

Morocco is a net importer of electricity with a total import of 4,509 GWh in 2011 from Spain (ENTSO-E 2013). With the renewable energy law of 2009 (Royaume du Maroc 2010) and a new RE strategy (MEMEE 2013), Morocco has introduced incentives for the deployment of renewable energy for the domestic market, while also opening the regulatory possibility of exporting RE electricity. For the implementation of the renewable energy program the company, *Société d'Investissement Energétique* (SIE), and a new agency, *Moroccan Agency For Solar Energy (MASEN),* for the solar energy deployment were created. In 2012, the tendering for a solar plant in Ouarzazate was accomplished, so that the first 160 MW of CSP capacities (NOOR 1) are operational since 2015. The tendering scheme of Ouarzazate included a local content valued at 30 percent of the plant capital costs requirement (Falconer et al. 2012). The second round of tendering lead to offers for solar energy at less than 14 €cents/kWh (MASEN 2013-1, Reuters 2014).

[33] The French company Theolia runs a 50 MW wind farm close to Tétouan. This farm is being repowered at date to reach a capacity of 300 MW (Theolia 2013).

2.6.4.1 Demand Expectations

In the past decade, an electricity consumption of approximately 1.2 TWh/y has been added every year in Morocco, reaching an annual demand of 27.5 TWh/y in 2010 (DLR 2013). The growth rate of demand in 2010 was 6.2%/y. If this trend would continue linearly in the future Morocco would consume about 40 TWh/y by 2020 and 80 TWh/y by 2050 (Figure 29).

According to AUE 2011 the national expectations are higher, indicating a demand of 50 TWh/y by 2020. Extrapolating this expectation linearly after 2020, Morocco would consume about 115 TWh/y by 2050.

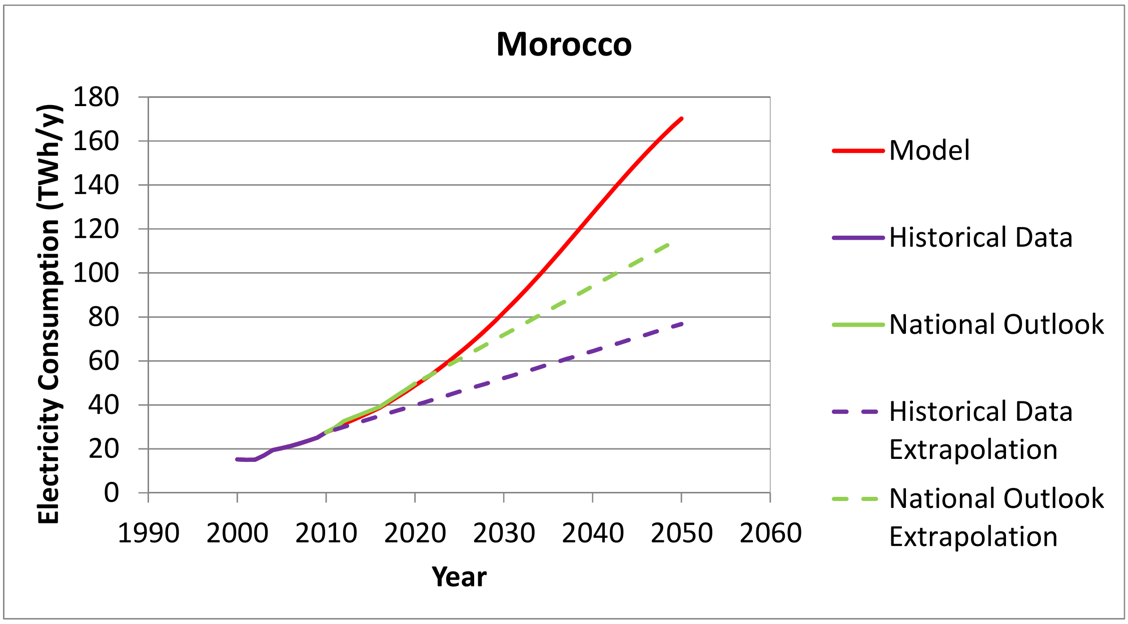

Figure 29: Gross electricity consumption in Morocco: Model result, historical data until 2010 with linear extrapolation after 2010, national outlook from 2010 to 2020 with linear extrapolation after 2020.

Our model predicts a demand that is perfectly in line with the national outlook until 2020. Starting with 27.5 TWh/y in 2010, our model predicts about 50 TWh/y in 2020 followed by an exponential growth of demand that leads to a value of 170 TWh/y in 2050. As Morocco today is the country with lowest per capita income and lowest per capita electricity demand in North Africa, the demand grows steadily and a saturation effect cannot be seen even in 2050. However, from 2010 to 2050, the growth of demand changes from exponential to linear to sub-linear.

Per capita electricity consumption will increase from 1.8 MWh/cap/y in 2010 to around 4.1 MWh/cap/y in 2050, which would be the lowest value among the NA countries analysed.

The result of our demand modelling shows that Morocco will face significant challenges with respect to its growing electricity demand, and dependency of fossil fuel imports would increase dramatically if no domestic sources would be developed.

An hourly load curve for Morocco for the year 2010 was provided by AUE 2011. This load curve was scaled for all consecutive years until 2025 for detailed scenario modelling of the electricity mix (Figure 30). Scaling was done in a way that maintains the relation of annual electricity demand and peak load just as scheduled by the national outlook data provided by AUE 2011. The load curve shows a clear peak in summer and lower demand in the winter season.

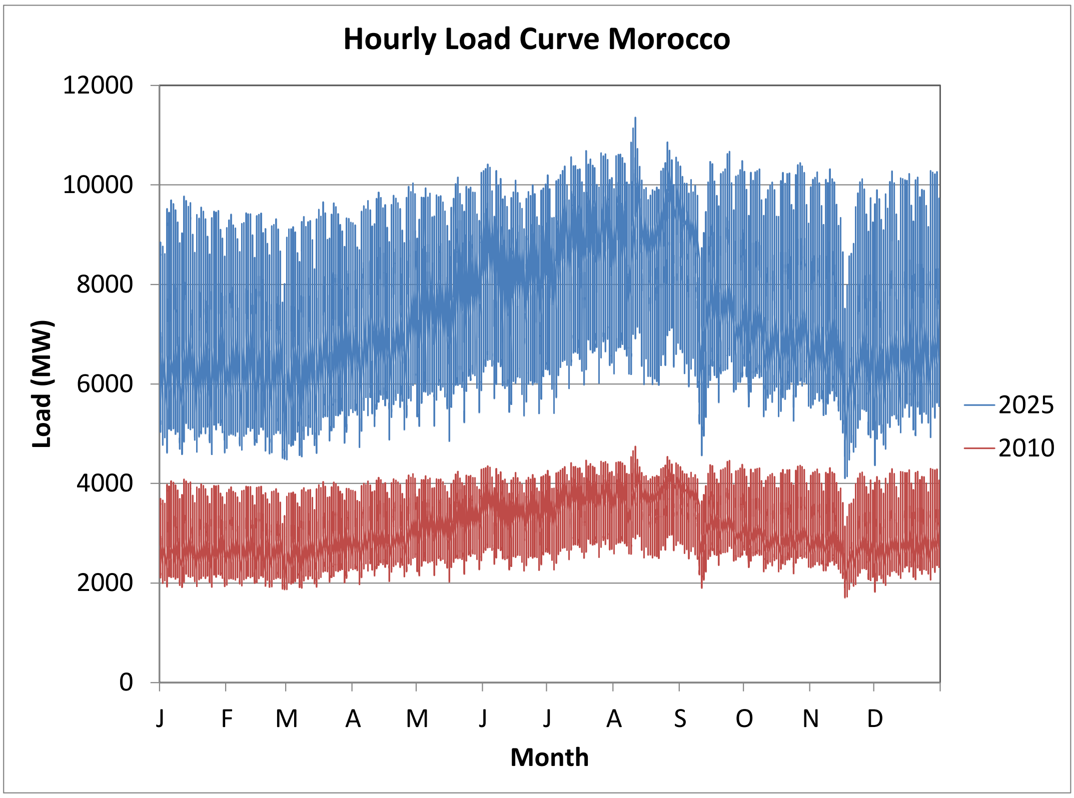

Figure 30: Hourly load curve for the years 2010 and 2025 for Morocco

2.6.4.2 RE Policy and Targets

The overall target for installed RE capacity share is 42% by 2020, with an installed capacity of 6,000 MW, consisting of 2,000 MW hydro, 2,000 MW solar and 2,000 MW wind power contributing equal 14% shares. In 2009, the Moroccan government announced a solar plan, targeting the planned 2,000 MW PV and CSP capacity in 2020. The solar power stations are planned to be built at five sites: Ouarzazate, Ain Bni Mathar, Foum Al Oued, Boujdour and Sebkhat Tah and with a financial volume of 9 Billion US$ (MASEN 2013-2).

The specific wind power capacity target for 2020 (14%) foresees the installation of 1,720 MW of new wind energy facilities (ONEE 2013). Of these, 720 MW are currently under development and projected to be operational in 2014[34] and another 1000 MW are planned to be operational latest in 2020[35] (Moroccan Investment Development Agency 2013). The tenders for wind power capacity implementation included a local content requirement so that Moroccan manufacturing companies

[34] These projects are Tarfaya (300 MW), Akhfenir (200 MW), Bab El Oued-Laayoune (50 MW), Haouma (50 MW) and Jbel Khalladi (120 MW).
[35] These are Tanger 2 (100 MW), JBEL LAHDID (200 MW), Midelt (150 MW), Taza (150 MW), Tiskrad Laayoune (300 MW) and Boujdour (100 MW).

would directly benefit from the RE deployment.36 In addition to the public wind program administered by ONEE, independent actors are planning to install wind farms for their own consumption. A new hydropower plant in M'dez - El Menzel with 170 MW installed capacity is projected to be operational in 2016. In Abdelmoumen, close to Agadir, a 350 MW pumped hydro storage plant is planned and is expected to be operational by 2016 (ONEE 2013). Renewables targets for the time beyond 2020 are still under study.

REGULATORY FRAMEWOK

Morocco provides several non-sector specific financial support mechanisms for investments through public funds and tax exemptions as a 5-10% investment subsidy and import duty and VAT omissions in the first 36 months of investment (IEA 2011; Moroccan Investment Development Agency 2013). Furthermore, free zones for RE deployment are being developed where taxes and duties are omitted.

Small scale RE deployment has been funded by international donors like the installation of PV systems at the household level through the Global Rural Electrification Program (PERG) or by concessional loans of development banks. Furthermore, carbon financed projects have been developed under the clean development mechanism as a wind farm in Tétouan.[37]

However, the most important financing institution for RE deployment was established by the renewable energy law of 2009 (Royaume du Maroc 2010) and as a fund for energy development "Fonds de Développement Energétique" (FDE) intended to finance the implementation of the Moroccan RE targets by the *Société d'Investissement Energétique* (SIE)[38].

The main tool to implement the large scale RE targets in Morocco is tendering. For the wind projects, the private project developer winning the specific tender is responsible for the implementation of the project together with ONEE. For each of the tenders, a 20-year power purchase agreement is instated between the project developer and ONEE. Some projects like the the Taza 150 MW windproject received strong financial support from international donors and banks (KfW, EIB and AfDB).

Private project developers winning the specific tender are responsible for the implementation of solar power projects together with MASEN. For each of the tenders, a 25-year power purchase agreement is instated between the project developer and MASEN, which is obliged to buy the produced electricity at a fixed tariff and sell the electricity to ONEE. The difference between the fixed tariff and the electricity price[39] will be covered by the energy development fund. The installation of the first 160 MW of the 500 MW solar power plant in Ouarzarzate received strong financial support from international donors as European development agencies and international banks.[40]

[36] http://www.one.org.ma/FR/pages/AO_SP40311_En.asp.
[37] http://cdm.unfccc.int/Projects/DB/DNV-CUK1123244454.33
[38] With the establishment of the fund external capital was mobilized representing about 1 mio. US-Dollars with contributions from the Kingdom of Saudi Arabia (U.S. $ 500 million), UAE (U.S. $300 million) and the contribution of the Hassan II Fund for Economic and Social Development (200 million U.S.)
[39] The residential electricity prices are between 0.9010 MAD and 1.4407 MAD depending on the volume of consumption (exchange rate 2013/04/17: 1 EUR = 11.1245 Moroccan Dirham (MAD).
[40] given as a grant from the EU (EUR 30m) and as loans from AFD (EUR 100m), EIB (EUR 100m), KfW/BMZ (EUR 100m), KfW /BMU (EUR 15m), the Worldbank and the AfDB (USD 197m).

Grid access and the option to agree on fixed power purchase agreements with the single buyer, ONEE, for electricity from RE sites larger than 2 MW are regulated by the renewable energy law of 2009 (Royaume du Maroc 2010). RE power generation sites up to 50 MW for self-production for industrial uses can also be connected to the national grid and transmitted to the consumer facility by the ONEE transmission grid through the "EnergiePro" program. Surpluses can be sold to ONEE at agreed rates. ONEE also assists self-producers along the different stages of project development. Depending on the tariff these power purchase agreements between ONEE and the generator can work in a similar way as feed-in tariffs (Paving the Way for the MSP 2012). Furthermore, it is explicitly allowed to export RE electricity and sell it to (foreign) third parties.

All RE generation projects larger than 2 MW must be connected to the high voltage transmission grid (Royaume du Maroc 2010). There is no priority dispatch guarantee in place, but it can be agreed on with the grid operator. Special regulations govern the transmission of renewable power for export via the Moroccan domestic grid. This allows both: dedicated agreements between grid operators and the production facility to transmit RE power through the national grid (Article 27-30 Royaume du Maroc 2010) and the construction of new transmission lines if the existing grid capacity is insufficient. In both cases the cost allocation is defined by the grid operator (ONEE) on a case-by-case basis based essentially on the type of investment to be done and the distance between grid and the generation site.

Morocco has laid down the main energy objectives and targets to be achieved. To that end, a wide range of policy instruments has been put in place, including a national energy strategy that was adopted in March 2009, which is clearly supported by political will. In the Throne Speech of July 2010, the king emphasized the major axes of such strategy, particularly energy efficiency and development of renewable energy sources, especially wind and solar.

Tendering is the main support scheme in Morocco. Both wind and solar programs are, thus, implemented through an international competitive process. Whereas ONEE administers the wind integrated program, MASEN coordinates the solar integrated program.[41]

Morocco has already trade cooperation with Europe in non-renewable electricity. Morocco has been importing electricity from Spain since 2000 to meet its growing domestic electricity demand. In terms of physical renewable energy exchange, no cooperation mechanisms are in place yet. Only non-physical trade cooperation exists so far under carbon credits terms.

Regarding carbon credits, Morocco is well advanced and thus has benefited from several Clean Development Mechanisms (CDM) revenues through the sale of Carbon Credits (CERs) to European countries. Morocco has ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995. The *Secrétariat d'Etat chargé de l'Eauet de l'Environnment* of the Ministry of Energy, Mines, Water and Environment is the Designated National Authority (DNA). The table below summarizes the registered CDM projects in Morocco.

[41] More details about support incentives are discussed in Ellenbeck S., Lillistam J. and Battaglini A. 2013: Energy Policy, Targets, Present Discussions and Barriers in RE deployment in Morocco, Algeria, Tunisia, Libya and Egypt, BETTER Project, June 2013.

Land allocation is another incentive measure for promoting investments in renewable energy. In Morocco, for both the solar and wind programs, the government designates land of the renewable energy projects. Land is acquired through ONEE's "*Division de la Gestion du Patrimoine et des Affaires Immobilières.*" Whereas it is granted by ONEE directly to wind developers, land is granted by MASEN after its acquisition by ONEE.

The Nationally Appropriate Mitigation Actions (NAMAs) could also provide another incentive for developing renewable energy. Despite the fact that the concept of NAMAs is not yet fully developed, Morocco submitted the Morocco Solar Plan as NAMA. The NAMA includes the following main activities:[42]

- Installation of concentrated solar power plants
- Capacity building
- Promotion of an integrated solar industry

The initiative has already received support from international donors. For the first phase of the Ouarzazate solar plant, the German Government (BMU) is providing a grant of 15 million euros under the International Climate Initiative (ICI) to equity capital share of MASEN within this project. The BMZ also is offering low-interest loans in the amount of 100 million euros from the Special Facility "Initiative for Climate and Environmental Protection."[43]

RE targets are set for 2020 only. For more clear signals for investors of the country's orientations in terms of the energy mix, it would be necessary to set up further targets beyond 2020. This would entail amending the 2009 energy strategy. Further regulations would also be needed, especially in terms of determining cooperation mechanisms and the conditions for electricity export to North.

ONEE has the monopoly on medium and high voltage transmission and is responsible for the electricity distribution to 55% of the Moroccan consumers (ONEE 2013). Further distribution is organized by concessions to local distribution companies, including foreign investors. As of early 2013, no independent grid regulator was in place, but the establishment of a new regulatory authority – *Autorité nationale de régulation de l'énergie* (ANRE) – is envisaged for 2014 (Brahim 2013).

ONEE is still the major player in generation, transmission and distribution of electricity in Morocco. In the generation sector, ONEE is accompanied by several IPPs producing electricity. Concessions for IPPs are issued by ONEE and have the obligation to sell the electricity exclusively to ONEE under PPAs terms. Industrials are allowed to generate electricity for their own use and sell the surplus to ONEE. ONEE is the only grid operator for medium, high and very high voltage transmission grids. For the distribution system, special concessions are given to local distribution companies, as well as international companies or municipalities.

INSTITUTIONAL FRAMEWOK

The institutional framework for the promotion of renewable energy in Morocco is evolving. In the past the Moroccan institutional arrangement suffered from lack of a dedicated agency for the

[42] http://www.namadatabase.org/index.php/Morocco_solar_plan
[43] http://www.international-climate-initiative.com/en/media-centre/news-archive/news-detail/article/german-government-supports-worlds-largest-solar-power-plant/?cHash=a8227e024734b6d7e2e20eb775912d38

promotion and development of renewable energy projects, with the exception of ONEE taking charge of promoting and developing wind energy, especially under concessional terms. However, the institutional framework has been improved, and the success of the renewable energy programs much depends on how such institutions are consolidated and how joint efforts are developed for a better coordination of the overall policies related to the promotion of renewable energy.

The Ministry of Energy, Mines, Water and Environment (MEMEE) is responsible for developing and implementing government policies in the areas of its jurisdiction as well as the oversight of sectors under its supervision, including public institutions and companies such as ONEE, ADEREE, MASEN and IRESEN. In addition to chairing the National Nuclear Energy Council, the Directorate of Electricity and Renewable Energy is the department in charge of the electricity sector. The institutional arrangement has been, thus, reinforced by restructuring and creating further institutions.

L'Office Nationale de l'Electricité (ONE) has been merged with *l'Office National de l'Eau Potable* (ONEP)[44] in 2012, what becomes later as l'Office National de L'*Electricité* et de l'Eau Potable (ONEE) that has been created by law 40-09.Created by Decree No.1-63-226 on 5 August 1963, ONE has been responsible for production, transmission and distribution of electric energy. Under the Decree, ONE had an exclusive development of means of production of electricity with a power greater than 300 kW. In 1994, the decree law n.2-94-503 (September 23, 1994) amended the Decree No. 1-63-226 (August 5, 1963) establishing ONE allowing private investors with an installed capacity of 10 MW to supply electricity to ONE. The law grants ONE the right to pass, after competitive bidding, conventions with legal persons under private law, for power production greater than 10 MW and that production should be sold exclusively to ONE, thereby resulting in a single buyer model. ONEE is also in charge of coordinating the wind integrated program. It has also developed expertise in the bidding process, especially for wind generation.

The Centre for Renewable Energy Development (CDER) has been restructured to include energy efficiency, becoming the Agency for Development of Renewable Energy and Energy Efficiency. ADEREE has been created by law 16-09 replacing law 26-80 establishing CDER in 1982. The law maintains ADEREE as a public institution with legal personality and financial autonomy and extends its mandate to include energy efficiency. ADEREE[45] is subject to foresight and financial control of the state. The aim of ADEREE is to contribute to the implementation of the state's policy on renewable energy and energy efficiency. ADEREE is also empowered to participate in the creation of economic interest groups and it may take stakes in any other group or company whose mission goes along with that of ADEREE. It can also develop public/private partnerships in renewable energy and energy efficiency.

The Moroccan Agency for Solar Energy (MASEN)[46]is exclusively designed for solar energy. It has been created by law 57-09 and is entitled with the overall management of the Integrated Solar Plan launched in 2009, starting from design and choice of operators to overall implementation phase. The objective of the creation of MASEN is to take charge of the Moroccan integrated solar plan with a minimum installed capacity of 2000 MW. For that purpose, MASEN is in charge of the design of solar energy projects (mainly grid connected electricity generated from solar energy) with installed capacity greater than or equal to 2 megawatts. MASEN will be a stakeholder in the project companies to be established for carrying out the projects (25% stake in Solar Power Company to develop the

[44] http://www.onep.ma/historique.htm
[45] Prior to the creation of ADEREE, CDER responsibilities were limited in such areas: evaluating the potential and publication of an atlas of renewable energy in Morocco as well as elaborating plans in collaboration with municipalities and ministries; managing the off-grid rural electrification programme and promoting SWH through the Promasol programme; and disseminating information about renewable energy.
[46]MASEN is a public agency whose shareholders are the State, ONEE, Hassan II Fund for Economic and Social Development and the Energy Investment Company (SIE).

first 160 MW phase of Ouarzazate). Energy produced from solar plants is intended primarily to supply the domestic market. Electricity produced is fully sold to ONEE or any other party, public or private in accordance with the terms and conditions established by agreement between the state and ONEE or this organization. Part of electricity, however, can be exported. MASEN is empowered to have partners either public or private. It may, in accordance with Article 8 of Law No. 39-89 authorizing the transfer of public enterprises to the private sector, create subsidiaries or take stake in companies doing business within its purpose. It can also acquire any assets necessary for its work, including private assets of the state, land, any immovable or real estate whatever its legal regime is including through expropriation and has the right of temporary utilization of private property.

Research and development in the renewable energy sector has also been reinforced through the establishment of IRESEN (*Institut de Recherche en Energie Solaire et en Energies Nouvelles*). IRESEN is, in particular, responsible for identifying areas of research, realizing, financing and managing R&D projects. R&D will cover a wide range of issues, including solar and wind energy, storage and grid as well as other renewables such biomass and marine. IRESEN's success will very much depend on its effectiveness in creating links with industry, ministries and research institutions.

Established in February 2010, *Societé d'Investissement Energétique* (SIE) is a public corporation with a starting capital of MAD 1 billion by the Energy Development Fund (FDE), to support renewable energy projects. The FDE was endowed with USD 1 billion from grants by Saudi Arabia, the United Arab Emirates and the Hassan II Fund. SIE's strategic goals are providing support to national energy programs, reinforcing local energy resources, anticipating trends and identifying investment opportunities. With regards to its contribution, SIE enters with other partners as a minority shareholder of companies operating in renewable energy. All the generated revenues are expected to be reinvested into other projects. This is very important element in the sustainability of the company and therefore the continuation of such projects. SIE has a 25% stake in the capital of MASEN.

Whereas the wind program is under ONEE, the solar program is coordinated by MASEN. Despite the fact that the roles and responsibilities of developing the two renewable energy integrated programs are clear, one of the main issues to be avoided, however, is overlap of responsibilities. Having several actors responsible for renewable energy related tasks is more likely to make coordination increasingly difficult.

Thus, policy coordination of the national energy strategy is essential for a successful implementation of renewable energy projects. MEMEE is well positioned to play the coordination role as the overall policy coordinator. This coordination could take the form of a joint platform or working groups that bring regularly all the stakeholders involved in promoting renewable energy, thereby avoiding any overlap of responsibilities. Therefore, the success of the Moroccan renewable energy program will very much depend on how these institutions coordinate their activities.

In light of this evolving institutional structure as several institutions have been created, thereby make the energy sector and electricity market, in particular, more complex. Given the number of institutions and agencies to be involved in renewable energy promotion and development, it is very crucial to establish an independent energy regulator (*Autorité nationale de régulation de l'énergie* - ANRE), which is foreseen to be created in 2014. This authority should be in charge of licensing and setting tariffs, overseeing the electricity market, and enforcing regulations.

Once in place, the ANRE could be a suitable institution to facilitate the implementation of the cooperation mechanisms between Morocco and EU countries. The role of such entity would entail i) administration of the provided remuneration, ii) facilitation of an oversight over the implementation and iii) proof of renewable energy transfers (Frieden *et al.,* 2012).

INFORMATION POLICY AND CAPACITY BUILDING

With the creation of MASEN, the national RE and energy efficiency agency ADEREE and the research and development agency IRESEN, the Moroccan government focuses on dissemination of knowledge about renewable energy and is financing trainings in this sector. A solar, biomass and wind atlas[47] supports this information strategy (ADEREE 2013).

In terms of the social development framework, the basic infrastructure for research and development, training and awareness raising exist. As far as the legal framework for Research and Development (R&D), it is not governed by any legal text for its own. It is rather treated in several other legislations, including Decree No. 2-96-793 of February 1997 (post-secondary teacher-researchers); decree No. 2-96-804 of 19 February 1997 (management training institutions); law No. 1-76-500 creating the *Centre National de Coordination et de Planification de la Recherche Scientifique (CNCPRS)*- responsible for development and coordination of scientific and technical research; decree No. 2-91-683 of February 1993, determining the powers of the *Ministère de l'Enseignement Supérieur de la Formation des Cadres et de la Recherche Scientifique (OME, 2012)*.

As for the institutional arrangement, the CNCPRS (established on 5 August 1976) to develop and coordinate scientific and technical research) was replaced by the *Centre National pour la Recherche Scientifique et Technique* (CNRST) in 2001. Hassan II Academy of Science and Technology, created in the 1990s, was among the first institutions carrying out R&D activities. In addition, a permanent inter-ministerial committee for scientific research centers among which is the *Centre d'Etude et de Recherche sur l'Eau et l'Energie* at the Faculty of science in Marrakech (OME, 2012).

Regarding research in renewable energy, this has been strengthened by the establishment of a new institution. In addition to the *Centre de Développement des Énergies Renouvelables* (CDER), which became later ADEREE, the institutional gap has been recently filled with the establishment of the IRESEN (*Institut de Recherche en Energie Solaire et en Energies Nouvelles*), which is responsible, in particular, for identifying areas of research, realizing, financing and managing R&D projects. R&D will cover a wide range of issues, including solar and wind energy, storage and grid as well as other renewables such as biomass and marine. IRESEN's success will very much depend on its effectiveness in creating links with industry, ministries and research institutions (OME, 2012).

ADEREE has also played an important role in providing training in renewable energy and energy efficiency. More than 100 cadres and more 1000 other cares and technicians received trainings at the center. 5 specialized training platforms have been put in place. ADEREE has also held several trainings at the regional level (Sembene, 2013).

Awareness raising plays an important role in social acceptance for new technologies, in general, and for renewable energy, in particular. In this regard, it is worth mentioning the renewable energy resources atlas being recently launched by ADEREE, which will play an important role for a wide dissemination of information related to renewable energy.

Regarding research and development, albeit a newly established institution, IRESEN is creating the suitable R&D environment through, in particular, building partnerships with international renowned

[47] www.aderee.ma/atlas-ER

R&D institutions including HELMHOLTZ Berlin, DLR and Fraunhofer CSP[48] and devoting financial resources for R&D projects open to researchers. The success of establishing a strong R&D infrastructure would very much depend on establishing links with industry and other players involved in renewable energy in Morocco. Another aspect to be further developed would be the number of the permanent personnel at the institution. Likewise, enough financial resources would be also important in a sustainable functioning of IRESEN.

In terms of further training needed, some training needs, especially for government administrative officers engaged in the national regulatory services and decision/policy makers might be needed. The main needs for training identified are: development of feed-in-tariff schemes, tariff setting and revision; economic impact assessment of EE and RE support schemes, assessment of economic costs and benefits; RE and EE programs and RE and EE action plans; and tender specification and tender evaluation. For research and technicians, the training needs are the impact on the grid of the renewable energy system development, photovoltaic and CSP. For bank/governmental/private consultants, needs are elaboration of the RES and EE project feasibility studies (PWMSP, 2013).

In this same context, capacity building will be further strengthened with the foreseen establishment of a new center on renewable energy and energy efficiency in Morocco by the UNESCO. The center will be based on the Green Platform of ADEREE and will provide training on renewable energy and energy efficiency at the national, regional and international levels. The objectives of the center are strengthening capacity building for different actors involved in renewable energy, contributing in putting in place the Global Renewable Energy Education and Training (GREET). It will also allow for exchange of information and practices and promote South-South and North-South cooperation on renewable energy and energy efficiency, help African countries putting in place renewable energy and energy efficiency policies and strategies, and will also offer awareness raising on sustainable development, environment protection and climate change mitigation (Sembene, 2013).

Under the framework of re-inforcing training and after the launching of the integrated solar and wind programs, several actions have been taken in this regard. A number of specialties have been created at the engineering schools and technology institutes. Three specialized training institutions on renewable energy and energy efficiency are foreseen to be created in Oujda, Ouarzazate and Tangier (Sembene, 2013).

For social acceptance, further awareness raising is also needed. Tailored campaigns should be designed targeting different categories of audience. These categories could include the private sector banks, regional investment agencies, local authorities and the wider public.

BARRIERS[49]

Investments in renewable energy projects in Morocco still face several barriers. These barriers can be differentiated into barriers for RE deployment for local consumption and barriers for exports of renewable electricity to Europe. Among the most important barriers for the RE deployment for domestic consumption as identified by stakeholders are:

- The subsidies allocated to electricity generated from fossil fuels create market distortions and thus make investments in renewable energy less appealing and less competitive in the market;

[48] http://www.iresen.org/index-1.html
[49] This section is based on interviews and contributions of experts from the Office Nationale de l'Electricité et de l'Eau Potable (ONEE) and from the Ministry of Energy, Mining, Water and Environment (MEMWE).

- The medium voltage level is not yet included in the implementing decree of the law 13-09 on renewable energy
- Regarding solar technologies: the technology costs, the lack of access to financing and the required share of local content of the projects which influences the results in bids;
- Regarding wind energy: the required share of local content, thus influencing the results of bids. The last tenders launched for wind farms by ONEE (and particularly the 150 MW wind farm of Taza) have attracted interest of many consortia with a strong decrease of wind electricity prices offered compared to previous tenders.
- The limited capacity of the electrical system to integrate RE (system security, reliability of the grid) and the lack of investments needed in terms of reinforcement of the domestic grid as well as the construction of new international interconnections.

2.6.4.3 Scenario for the power sector

Scenario analysis reveals two aspects of electricity supply that will be shown for a possible transition towards a sustainable electricity scheme: the installed capacity and the annual electricity production and their development as function of time. In terms of installed capacity, the most important target to be achieved is that the firm capacity of all power plants is always larger than the peak load that occurs once a year. Table 14 shows how this condition is maintained at any time in the future. It can also be appreciated how the relation of installed capacity and peak load increases with time due to the introduction of fluctuating renewables like wind power and PV. While in the year 2000, the relation of installed capacity to peak load is equal to 4.7/2.4 = 1.95, this relation increases to 92.5/27.2 = 3.4 in the year 2050. The increase of this ratio means that the average utilization (capacity factor) of the total power park is reduced accordingly.

In our scenario, the total installed capacity of about 7.5 GW in 2010 would increase to about 14.4 GW in 2020 and to 93 GW in 2050. Under this condition, the mix of fluctuating and flexible power plants would allow for a guaranteed production of electricity on demand at any time, without requiring major additional electricity storage devices or an expansion of the electricity grid beyond the natural growth of the AC grid assumed here.

Our scenario in **Figure 31** shows how peak load will increase linearly between 2010 and 2050. As a consequence firm power capacity from coal and gas fired power stations also will have to increase in line with that growing demand. However, after 2020, CSP plants step-by-step will take over firm capacity supply, because by then the CSP industry will have grown sufficiently to cover the increasing demand for firm and renewable power capacity. According to national planning, by 2020 about 2000 MW of wind power, 500 MW of PV and 1500 MW of CSP could be installed. Hydropower (2000 MW) and geothermal power (10 MW) plants can also be installed in Morocco until 2020. Due to the high cost of fuel oil, oil fired power stations will be phased out after 2020. Morocco is the only country in NA that uses coal for power.

By 2020 about 40% of the total installed capacity will be covered by renewable sources. CSP exports to Europe will be implemented for the first time between 2020 and 2030. The strongest growth of renewable power capacity will take place between 2020 and 2050. In 2050, about 90% of the power park will already be renewable, with hybrid (solar/fossil) CSP taking over the job of providing firm and flexible power capacity on demand, and major wind and PV capacities that will act as fuel savers every time the sun shines and the wind blows. The total installed capacity of wind and PV plants will be slightly larger than that of CSP.

Figure 32 shows a comparison of the firm power capacity from flexible sources and the variable capacity from fluctuating sources and their relation to the national peak and base load demand. It can be seen that the fluctuating capacity from wind and PV can become larger than base load demand, but not larger than the peak load of the country. This will lead to power surpluses from time to time when demand is low that however can be partially compensated by exporting electricity via the AC grid and by using the existing – rather scarce – options for electricity storage. Due to the fact that wind power and PV power will not often be fully available at the same time, surpluses will not occur frequently. Also the surplus power capacity – which would dictate the necessary rated power of related electricity storage devices like pump storage or batteries – will be rather low.

Table 26: Installed power capacity in Morocco (GW) for each technology and firm capacity of all plants compared to the peak load of the country as function of time between the years 2000 and 2050. Import / Export refers to the Net Transfer Capacity (NTC) of the conventional AC grid.

Year	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Peak Load	2.4	4.3	7.9	13.5	20.8	27.2
Firm Capacity	3.8	5.7	9.9	16.9	26.0	34.1
Installed Capacity	4.7	7.5	14.4	45.3	75.8	92.5
Wind Power	0.0	0.3	2.0	8.9	11.7	12.6
Photovoltaics	0.0	0.0	0.5	2.6	6.5	10.2
Geothermal	0.0	0.0	0.0	0.1	0.3	0.7
Biomass	0.0	0.0	0.1	0.4	1.2	3.0
CSP Plants	0.0	0.1	1.5	6.4	14.4	21.2
Wave / Tidal	0.0	0.0	0.0	0.0	0.0	0.0
Hydropower	0.7	1.4	2.0	4.0	4.0	4.0
Oil	0.6	0.5	0.5	0.0	0.0	0.0
Gas	1.0	0.9	2.6	5.7	6.9	7.3
Coal	1.9	3.2	4.3	2.1	1.1	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Import / Export NTC	0.5	1.0	1.0	1.0	1.2	1.5

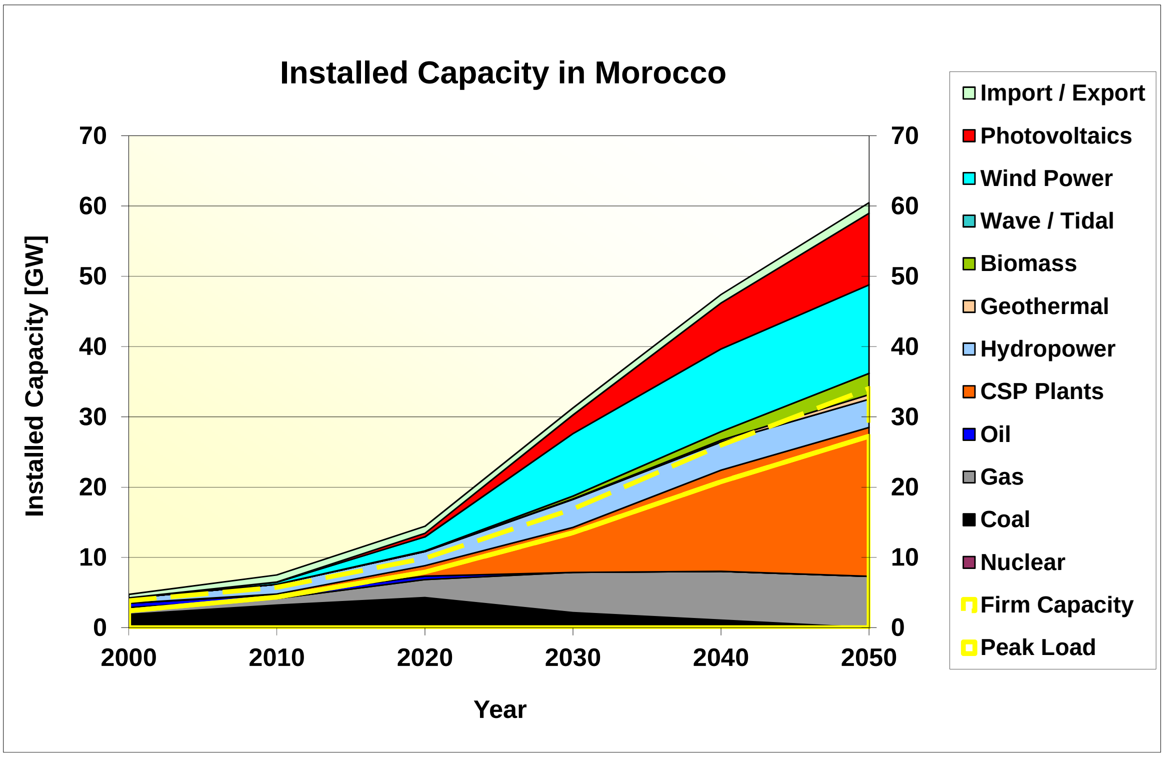

Figure 31: Installed power capacity in Morocco for each power plant technology and firm capacity of all plants compared to the peak load of the country as function of time between the years 2000 and 2050. Import / Export refers to the Net Transfer Capacity (NTC) of the AC grid.

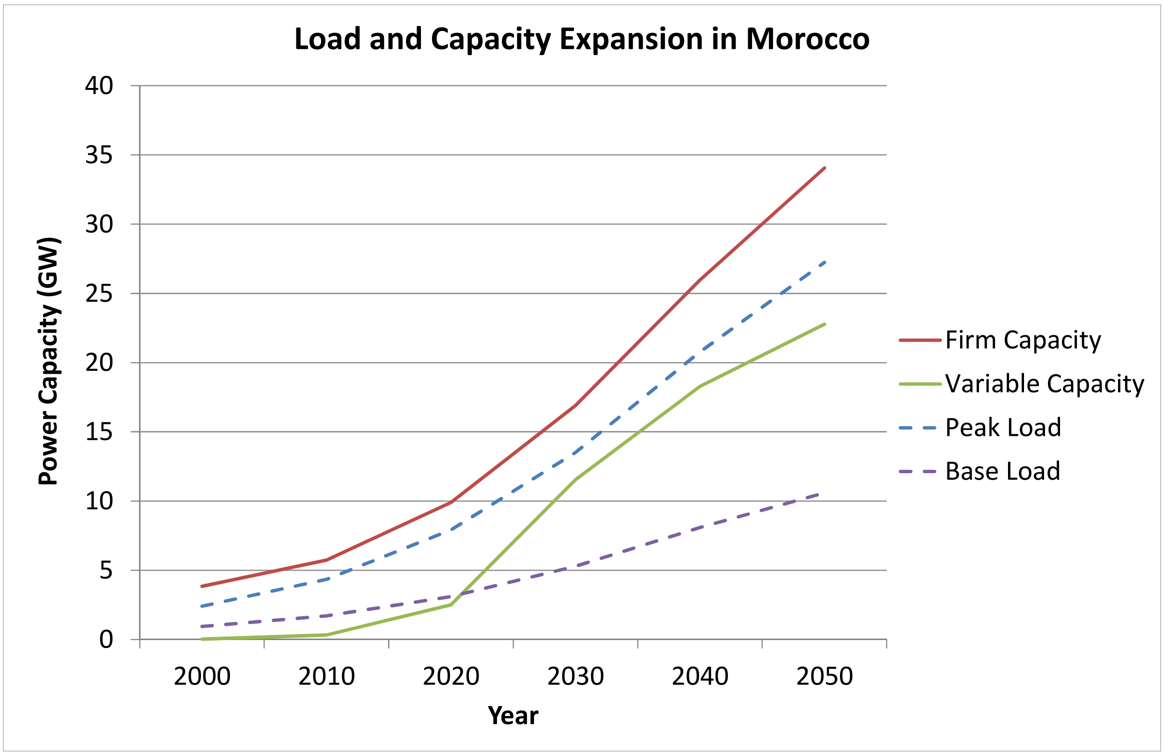

Figure 32: Comparison of firm capacity, variable capacity from fluctuating sources and export capacity of CSP plants with peak load and base load in Morocco.

Within the simple approach followed here fluctuating power capacity will be limited to slightly lower values than peak load, and flexible power capacity will make up for at least 125% of peak load. This way, surpluses can be effectively avoided and security of supply is maintained at any moment in time. In the medium and long term, wind and PV power will be least cost sources of energy and installed preferentially until reaching the peak load limit. Flexible power sources like CSP, being more expensive, will be used to fill the remaining gaps and cover peak load reliably at any time.

Electricity production and import through the AC grid will cover gross electricity consumption plus eventual export through the AC grid and via HVDC interconnections to Europe. Import and export through the AC grid will increase with time and in line with the growing net transfer capacity of the grid. In our model, it is assumed that annual import and export streams will be balanced.

Morocco imports almost all fossil fuels for power generation. As consumption will almost double between 2010 and 2020, there will be a strong pressure on fossil fuel imports that can only be relieved by quickly introducing cost-effective fuel savers like wind and PV power (Table 27). This will reduce import dependency of fossil fuels and stabilize the cost of power generation. Introducing renewable energy in Morocco means in a first place replacing imported forms of energy by domestic ones.

Table 27: Annual electricity production in Morocco (TWh/y) by each technology, exports to and imports from neighbor countries via the AC electricity grid as function of time between the years 2000 and 2050.

Year	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Consumption	15.2	27.5	49.9	84.9	130.1	170.3
Export via Grid	0.0	0.0	0.1	0.5	1.3	2.0
Wind Power	0.1	0.7	4.9	23.5	33.1	37.8
Photovoltaics	0.0	0.1	0.8	4.4	11.1	17.3
Geothermal	0.0	0.0	0.1	0.5	2.0	4.9
Biomass	0.0	0.1	0.3	1.4	4.3	10.6
CSP Plants	0.0	0.6	7.3	33.7	70.6	95.6
Wave / Tidal	0.0	0.0	0.0	0.0	0.0	0.0
Hydropower	0.7	1.4	2.0	4.0	4.0	4.0
Oil	5.6	4.5	4.5	0.0	0.0	0.0
Gas	0.0	5.3	10.0	7.4	0.0	0.0
Coal	8.8	15.0	20.0	10.0	5.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Import via Grid	0.0	0.0	0.1	0.5	1.3	2.0

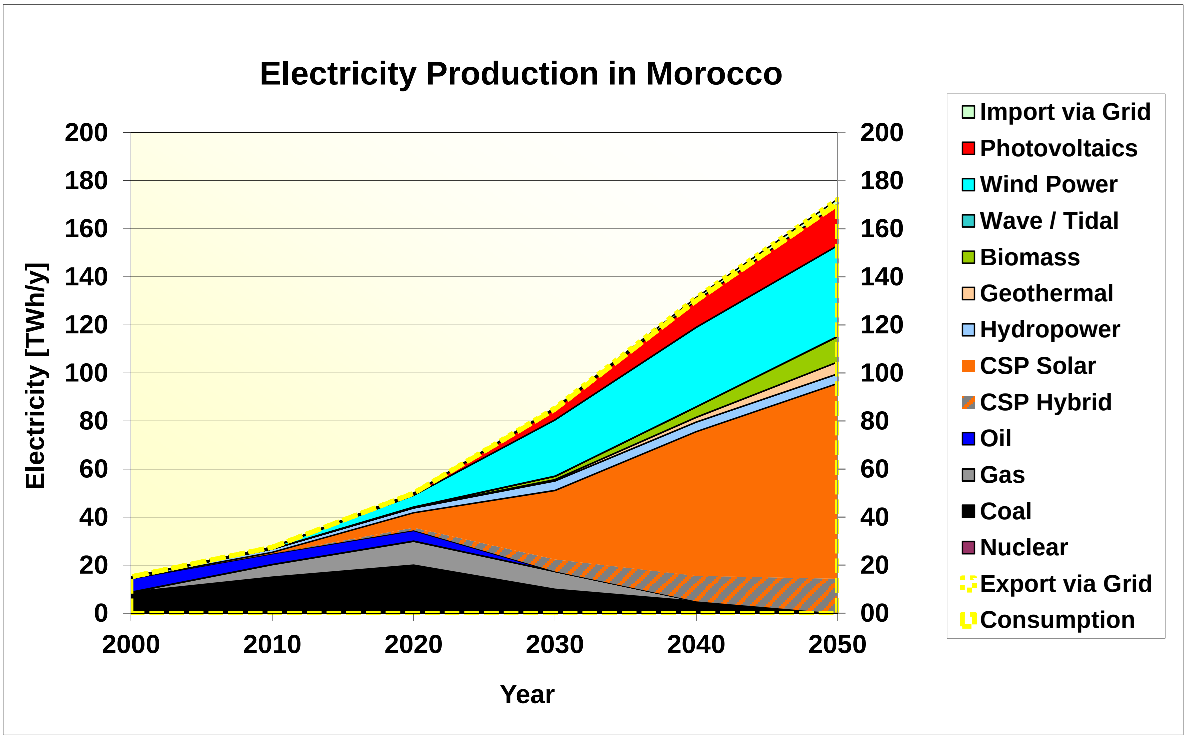

Figure 33: Annual production of RES-E and conventional power plants in Morocco compared to the gross electricity consumption plus export to neighbours through the AC grid. Hybrid CSP operation is assumed to be achieved by natural gas backup for steam generation within the CSP plants. In the long-term, only marginal amounts of electricity will be produced in fossil fuel plants for back-up and emergency purposes.

The option of additionally exporting solar electricity to Europe represents a dramatic change of paradigm for Morocco, as it would change from energy importer to energy exporter. This would have a very positive effect on the international trade balance of the country, as the amount of electricity exported would be in the same order of magnitude as domestic power consumption.
Peak load will increase in line with increasing consumption, and therefore, there is a compulsive need for the installation of sufficient firm and flexible power capacity and reserve. Only fossil fuel fired power plants and renewable power plants using biomass or concentrating solar thermal power can provide this type of high quality supply. As biomass is rather scarce in North Africa, hybrid (solar/fossil) concentrating solar power stations are the only alternative to fossil fuel plants, being able to deliver the same quality of supply with much lower fossil fuel consumption. Therefore, their short term introduction and expansion is crucial for achieving sustainable supply in the medium and long term, as global natural gas and oil reserves are limited and their prices may heavily escalate at the world market place.

Our scenario reflects this strategy, by massively increasing the share of RES-E until achieving about 90% in 2050 (Figure 33). By then, wind power and PV would make up for 32% of the annual power production for domestic supply. In order to provide sufficient firm power capacity and RES-E production, CSP plants are extended to provide 56% of annual production. About 10% (14 TWh/y) of annual production in Morocco will stem from hybrid CSP operation with natural gas. Less than 1% will be produced by natural gas backup plants. There will still be a significant capacity of natural gas plants installed for reserve and emergency purposes in 2050, but their power production will be limited to backup purposes and thus will be rather low. The use of natural gas in CSP plants is more cost effective and efficient than separating solar only operation

of CSP plants and balancing by extra gas plants. Firstly, hybrid CSP plants will have less part-load losses and thus higher efficiency for solar power generation. Secondly, gas plants would have rather low efficiencies just filling the few supply gaps that would be left by wind, PV and solar only CSP plants.
A well-balanced mix of the available RES-E resources in Morocco can lead to a scenario for 2050 that satisfies all the sustainability criteria described before. The national potential of wind power of about 7900 TWh/y will be exploited by only 0.5%, and less than 1% of the solar energy resource potential will be needed to satisfy the national demand and in addition provide significant amounts of flexible solar electricity exports for Europe.

At present power production in Morocco depends on coal, natural gas and fuel oil. It is clear that the cost of fuel imports would increase significantly if the quickly growing demand would only be satisfied by those limited resources. Consumption of coal and natural gas will remain until 2030 and then will be slowly reduced. Morocco at present imports almost all fossil fuels for power generation. Using gas mainly for hybrid operation in CSP plants as in our scenario would reduce its consumption and increase its availability in the future.

Biomass will also have some importance, while there is also a potential for geothermal power and hydropower. However, CSP, PV and wind power are the major domestic sources of energy for power generation, while the use of coal and natural gas will remain for some time as they are ideally stored forms of energy. CSP would provide about 56% of domestic supply in 2050. An intelligent combination of ideally stored and free flowing forms of energy will allow Morocco to achieve a sustainable power supply by the mid of the century. In technical and economic terms, the transition to renewable power planned at present is well balanced.

It is important to note that ideally stored forms of energy like fossil fuels will be required for a long time. Even in a country like Morocco with a very large solar energy potential, the availability of solar power over the whole year is not 100%, so CSP plants will have to operate in hybrid mode with natural gas in order to cover the load at any time on demand. The substitution of the last 10% of fossil fuel consumption will be a special challenge, which may be overcome in the long-term by innovations such as power-to-gas or power-to-liquid fuel conversion. As research and development of such technologies is already under way, our scenario must not be understood as if those technologies would not be implemented before 2050. On the contrary, in the best case, hybrid operation of CSP plants in our scenario could eventually be provided by natural gas derived from renewable sources, in that case effectively leading to a 100% RES-E share in 2050.

Synthetic natural gas production from renewable sources would require additional RES-E infrastructure that has not yet been included in our scenario and would have to be assessed and designed separately. An important frame condition for any hydrocarbon synthesis process is its operation near to steady state conditions, which is required to achieve the equilibrium needed for an efficient chemical conversion process. Such a steady state operation will be very difficult to achieve by (cheap) wind and PV input, but is easily achieved by (more expensive) CSP plants with thermal energy storage. As there is still not enough information and experience available for a reliable modeling and comparison of such solutions, we have assumed that the need for ideally stored energy in our scenario until 2050 will be covered by fossil natural gas.

2.6.5 Tunisia

The Tunisian energy market is marked by a rapid increase of electricity demand, just like the other North African markets. The electricity consumption grew by some 5% per year over the last decades (ANME 2011). The Tunisian market distinguishes itself from its neighbors, as the Tunisian fossil resources are very limited (IEA 2011). Consequently, with the increase of demand the Tunisian energy import dependency is steadily growing – Tunisia is a net importer since 2000 (ANME 2012). The first framework for energy saving, efficiency and renewable energy promotion was already adopted in the 1990s, but the Tunisian power sector is still consisting mainly of gas turbines and combined cycled power plants.

The energy market is dominated by the public utility *Société Tunisienne d'Electricité et du Gaz* (STEG), which is the sole distribution and transmission operator and owns and operates most of the electricity production capacities. In addition to STEG, two Independent Power Producers (IPPs) supplied about 20% of the electricity and several self-consumers produced 6% of the Tunisian electricity in 2010 (ANME 2012). Only 1.1% of the 15.3 TWh electricity produced in 2011 were generated from renewable sources (ANME 2012). At the end of 2012, 250 MW of RE (mainly wind 245 MW and solar PV 5 MW), 560 000 m² of solar thermal collectors were installed, primarily to supply households in rural and remote areas (GIZ 2012, ANME 2012). A total of 105 MW were reported to be in the pipeline in 2013 (REN21 2013).

The *Agence Nationale pour la Maîtrise de l'Energie* (ANME) is the national energy agency under the mandate of the Trade and Industry Ministry. ANME implements the governmental energy policy and provides scientific advice in the area of energy saving, energy efficiency and renewable energy. The institution was established in 1985 but its mandate was extended with the introduction of the energy law in 2004 (ANME 2012).

2.6.5.1 Demand Expectations

In the past decade, an electricity consumption of approximately 0.4 TWh/y has been added every year in Tunisia, reaching an annual demand of 15 TWh/y in 2010 (DLR 2013). The growth rate of demand in 2010 was 3.5%/y. If this trend would continue linearly in the future Tunisia would consume about 20 TWh/y by 2020 and 30 TWh/y by 2050 (Figure 34).

According to AUE 2011 the national expectations are higher, indicating a demand of 25 TWh/y by 2020. Extrapolating this expectation linearly after 2020, Tunisia would consume about 55 TWh/y by 2050.

Our model predicts a demand that is perfectly in line with the national outlook until 2020. Starting with 15 TWh/y in 2010, our model predicts about 25 TWh/y in 2020. After that, the model predicts a slightly stronger growth than the national outlook and leads to a value of 60 TWh/y in 2050. As Tunisia today is the country with relatively high per capita income and per capita electricity demand, the demand grows steadily and a beginning saturation effect can clearly be seen in 2050.

Per capita electricity consumption will increase from 1.4 MWh/cap/y in 2010 to around 4.9 MWh/cap/y in 2050. Certainly, there is a possibility that the effects of the political changes in Tunisia may cause a temporary slight decline of GDP and electricity demand.

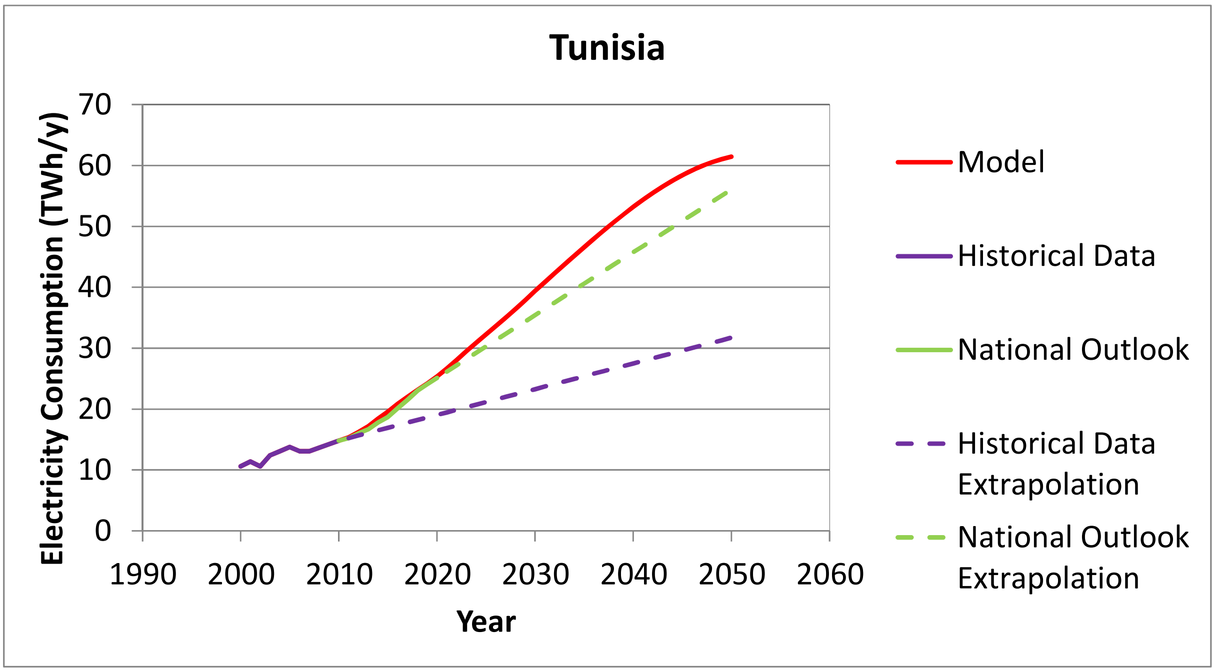

Figure 34: Gross electricity consumption in Tunisia: Model result, historical data until 2010 with linear extrapolation after 2010, national outlook from 2010 to 2020 with linear extrapolation after 2020.

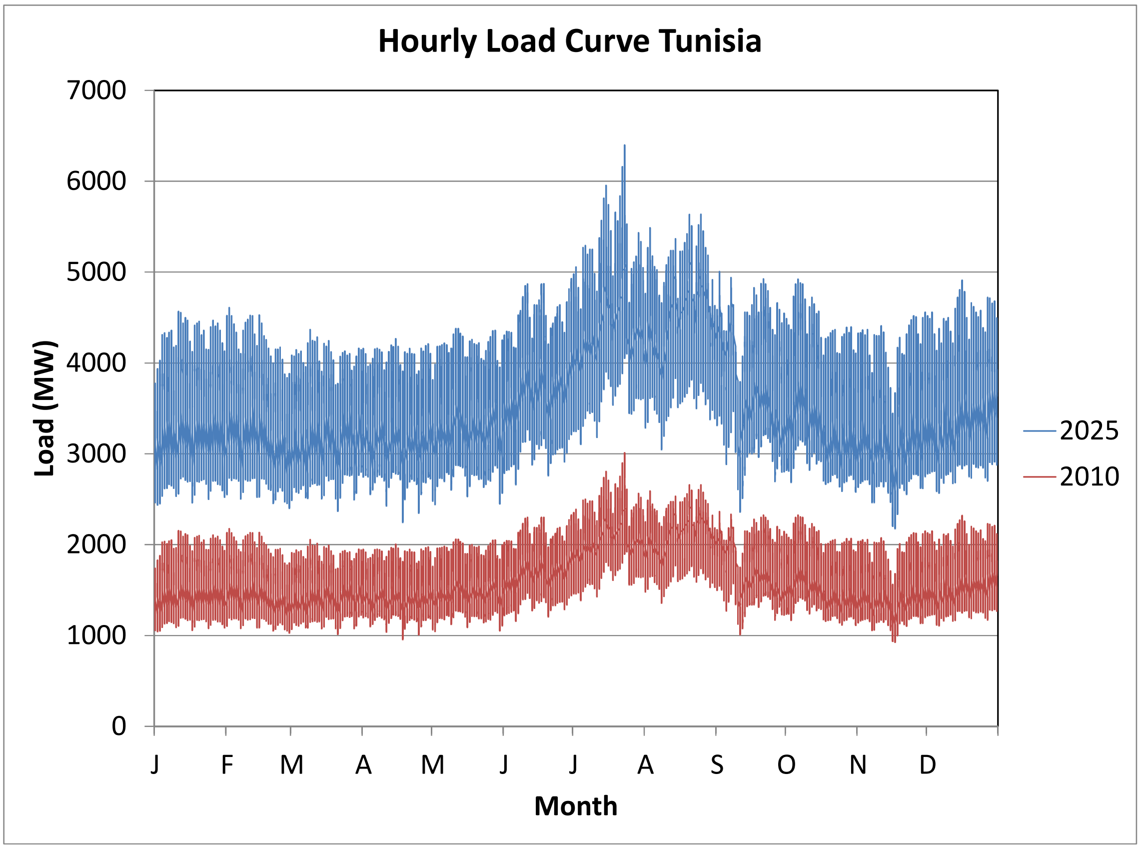

Figure 35: Hourly load curve for the years 2010 and 2025 for Tunisia

The result of our demand modelling shows that Tunisia will face significant challenges with respect to its growing electricity demand. Dependency on fossil fuel imports would increase significantly if no additional domestic sources would be developed.

An hourly load curve for Tunisia for the year 2010 was provided by AUE 2012. This load curve was scaled for all consecutive years until 2025 for detailed scenario modelling of the electricity mix (Figure 35). Scaling was done in a way that maintains the relation of annual electricity demand and peak load just as scheduled by the national outlook data provided by AUE 2011. The load curve shows a clear peak in summer and smaller peaks in the winter season.

2.6.5.2 RE Policy and Targets

Tunisia has adopted a target of 10% of renewable energy in primary energy consumption by 2016 (OME 2011). To achieve this, the Tunisian government announced the implementation of a renewable energy program,the Tunisian Solar Plan („le *Plan Solaire Tunisien* (PST)) in 2009. This included more than 40 projects in the area of wind and solar electricity production, solar heating and energy efficiency. Until 2016, 1,000 MW of wind, solar energy and biomass was planned to be deployed and until 2030 the installed capacity of wind and solar electricity was intended to reach 4,700 MW. The share of RE in total generating capacity was thus aimed to reach 16% in 2016 and 40% in 2030 (Paving the Way for the MSP 2012b). According to IRENA this translates into a target of 11% of electricity generation from renewables by 2016 and 25% in 2030 (IRENA 2011). The Tunisian Solar Plan launched in 2009 is under revision since 2012. In terms of renewable energy, the new plan foresees now an installed capacity of about 4,200 MW in 2030, corresponding to around 30% of the electrical mix. The plan will be accompanied by the establishment of an appropriate regulatory framework and the development of local manufacturing industry for components and equipments. Several projects are currently under study: a CSP plant of 50 MW by 2016, a PV plant of 10 MW by 2018 in Oued El Melah.

REGULATORY FRAMEWORK

The financial incentives include the reduction of custom duties from 18 to 10% for those RE goods and components that are not locally manufactured and the VAT for all RE equipment and resources is omitted (Government of Tunisia, 1995). Moreover, investments in specific programs and sectors are eligible for direct subsidies. For example, installations of pilot projects in the areas of renewable energy, energy efficiency or conservation can be covered by 50% (to a limit of 100.000 Dinars[50]) by the ANME (Government of Tunisia 2004).

In 2005, the *National Fund for Energy Saving* (FNME) was established as the main financing mechanism for different support schemes given to projects or households in the specific sectors and domains as declared by law (Government of Tunisia 2004). The 40 projects of the 2009 PST are to be financed by the FNME, as well as by public and private investors and international and multi-lateral institutions (ANME 2013). For the financing of RE electricity facilities, the fund might also provide the financial resources to include a mechanism to cover the gap between the electricity price paid by STEG and the *Levelised Cost of Energy* (LCOE) for a specific RE technology.

[50] Exchange rate 2013/04/15: 1 EUR = 2.09606 Tunisian Dinar (TND), 1 Cent are 20.9606 Millimes,

Some of the financial incentives provided for renewable energy are: reduction of custom duties from 18 to 10% for imported RE equipments; Value Added Tax(VAT) for all RE equipment and resources; and direct subsidies for specific programs and sectors. The incentives are financed through the National Fund for Energy Saving (FNME) set up in 2005. Up to now, no feed-in tariff system exists in Tunisia. However, the new energy strategy under discussion might provide for some sort of feed-in tariff schemes.

Regarding other economic conditions, no cooperation mechanisms with EU in terms of renewable energy are in place yet, except carbon credits. However, some discussions have been conducted to implement the ELMED project between Italy and Tunisia, related to the development of TunisianItalian underwater electrical interconnection (GSE, 2012). Under the ELMED[51] project, in February 2012, the Tunisian Ministry of Industry and the Italian Ministry of the environment, the earth and the sea signed a technical agreement, providing for the development of an institutional, legal and regulatory roadmap for the export of renewable energy.[52] The project's goals are opening new markets and promoting renewable energy sources and the diversification of sources and of supply areas, as well as the integration of markets of the European and Mediterranean areas.[53] Thus, once in place, the ELMED project would be a very important step towards establishing cooperation in renewable energy.

Tunisia ratified the Kyoto Protocol in 2003 and entered into force in 2005. The DNA is the *Ministère de l'Environment et du Développment Durable/Direction Générale de l'Environment et de la Qualité de la Vie*. In terms of carbon credits financing, Tunisia has several registered CDM projects, thus allowing for extra revenues. The table below summarizes the registered CDM projects in Tunisia.

For further economic framework conditions needed to achieve the RES policy targets, other incentives should be put in place. First, putting in place some sort of a feed-in tariff or feed-in premium scheme could help in wide dissemination of renewable energy. In particular, financial conditions of the National Fund for Energy Saving (FNME) should be further consolidated through sustainable financial resources.

The new solar plan is expected to give an impetus for a wide scale deployment of renewable energy. Some of its main characteristics are guarantees for different categories of investors, a correct but not excessive return on investments and scalable incentive system so as to integrate the downward trend in production costs closer to reality (Laponche and Missaoui, 2012).

The Tunisian Solar Plan was submitted as NAMA entailing the implementation of 40 individual projects to promote wind and solar energy, biogas and the introduction of energy efficiency measures in the transport and building sector.[54] The project document is under conception to be submitted to GEF in early 2014. Another NAMA submitted relates to reduction of methane emissions from biodegradable waste (agricultural waste, waste products from food production and sewage sludge).

An innovative aspect of the proposed project is to develop a framework of Nationally Appropriate Mitigation Actions (NAMAs) to enable the TSP to play its potentially transformative role. This derives from the recognition that a project-based approach will not be sufficient and that a coordinated, scaled-up approach is required. The TSP NAMA is far more than the implementation of specific measures, but the creation of the enabling environment as thus is called a "transformative " NAMA. The project will revise existing regulatory structures and will establish secondary laws for promoting private investment (e.g. a Public-Private

[51] http://www.medrec.org/fr/download/Executive-Summary-ELMED-CESI.pdf
[52] Tunisia prepares to export its renewable energy to Europe, December 2012, http://www.revolutiontunisia.com/tunisia-news/tunisia-prepares-to-export-its-renewable-energy-to-europe/
[53] http://www.terna.it/default/home_en/the_company/about_terna/terna_group_abroad/growth_abroad/elmed_project.aspx
[54] http://www.namadatabase.org/index.php/Plan_Solaire_Tunisia_NAMA

Partnership, PPP, Act). PPPs can be a vital modality for attracting private investment since the public partner can absorb certain risks such as access to the grid, setting up of sub-stations for interconnections, establishing transmission lines, etc. A grid code will be developed that renewable energy technologies must meet. This will provide transparency in the technical standards requirements for renewable electricity interconnection to the national grid. The project will examine different financial/economic instruments that will provide project developers with the long-term visibility required to take risks and invest in renewable energies. It will put in place the institutional and policy frameworks necessary to coordinate and support the up-scaling of renewable electricity in Tunisia, as well as developing an architecture for developing these NAMAs. Besides these two technical assistance components, the project also encompasses an investment component to support two baseline investment projects to enhance their mitigation potential and to be framed as supported NAMAs (the 10 MW Tozeur solar plant and the 24 MW Gabesse wind farm). (See Project Information, NAMA Support for the Tunisian Solar Plan, GEF 2013.

The deployment of renewable energy and energy conservation measures is regulated by a law from 2004. Since its adoption the law was revised several times, in order to better incentivize the deployment of RE production facilities and energy efficiency measures and to attract private investments in the energy sector in general (Government of Tunisia 2004). Until 2009, these RE policy incentives focused mainly on solar heating, electrification and energy savings. With the adoption of the Tunisian Solar Plan in 2009, the RE strategy was extended to include also medium- and large-scale electricity production from renewable energies with the option of exporting parts of it (ANME 2013).

Self-consumers have the opportunity to sell their surplus electricity to STEG via power purchase agreements (PPAs) and thus generate additional income and increase their investment security. All IPPs connected to the grid have to be approved by the grid operator and the ANME (Government of Tunisia 2009). A guaranteed purchase of maximum 30% of total surplus power and the guaranteed access to the transmission network for facilities are in place. Biomass power plants are exempted from the 30% limit, if the installed capacity is less than 15 MW (Government of Tunisia 2009). The purchasing price for self-production fed into the grid depends on the connection to the grid. In case of a connection directly to the transmission grid the selling price is defined by the electricity tariffs for high voltage customers of STEG and metered against the respective consumption. In case of feeding into the distribution grid the electricity tariffs of the respective consumer electricity price is paid. The tariff for the transmission is set to be 5 Millimes/kWh (STEG 2013). The VAT is 18% except for electricity used at the household level and for irrigation uses where the VAT is 12% (STEG 2013).

Conditions for transport, congestions mechanisms and distribution are to be defined by decree as stated in the energy law of 2009, but until now only specifications for surplus electricity from self-producers have been made. The costs for grid access and for additional reinforcement measures of the grid due to the connected renewable energy facility have to be covered by the RE operator. Self-consumers have the right to use the transmission network for their electricity at a defined price of 5 Millimes/kWh (STEG 2013) but no priority dispatch is in place (Paving the Way for the MSP 2012a).

The Tunisian market is not unbundled: almost 75% of the electricity is generated by STEG, which also owns and operates the transmission and distribution networks (STEG 2013). Since 1996, the generation sector is legally open for IPPs, and special amendments were made for self-generation, especially for RE deployment or cogeneration in 2004 and 2009.

Renewable energy and energy conservation are governed by law of 2004-72,[55] which has been amended several times since its adoption, especially by law N 2009-7.[56] Prior to 2009, RE incentives targeted mainly solar heating, electrification and energy savings. The Tunisian Solar Plan of 2009, however, extended the scope to include medium-and large-scale deployment of production of electricity from renewable energy sources, including solar and wind.

A new solar plan[57] is expected to provide further incentives for renewable energy. Some of the main characteristics of the new plan is to open the electricity generation market for different investors including households, companies, etc especially in terms of small scale PV installations

INSTITUTIONAL FRAMEWORK

Tunisia has provided a favourable institutional framework for the promotion of renewable energy since the early 1980s (MEP, 2011). Energy policy design and overall oversight of energy related issues is under the auspices of the Ministry of Industry and Commerce at which there is a specific division on energy; *Direction Générale de l'Energie*. The *Agence Nationale pour la Maîtrise de l'Energie* (ANME) is the national energy agency. It implements the governmental energy policy and provides scientific advice in the areas of energy saving, energy efficiency and renewable energy. The institution was established in 1985 but its mandate was extended with the introduction of the energy law in 2004 (ANME 2012).

STEG-ER[58] is worth highlighting given its importance in developing renewable energy in Tunisia. It is a prívate company whose stakeholders include STEG (Tunisian Company of Electricity and Gas) with a share of 35% of other shareholders such as engineering firms, bansk and industrial companies, etc. Its main objective is to contribute to the leadership and the development of the Tunisian Solar Plan (TSP). It engages in developing public-private partnerships in renewable energy and energy efficiency.

Regarding further institutional framework conditions needed to achieve the RES policy targets and given the inexistence of a regulatory body, it is of paramount importance to establish an independent regulatory agency. This would result in reducing the scope of the Ministry of Industry and Commerce in terms of regulations, and thus move these roles to the regulator. Policy coordination should be further strengthened by the Ministry of Industry and Commerce through special committees for policy coordination in terms of renewable energy aspects in the country.

A new regulatory body could be a suitable institution to facilitate the implementation of the cooperation mechanisms. Alternatively, this could also be ensured by ANME. This role would entail i) administration of the provided remuneration, ii) facilitation of an oversight over the implementation and iii) proof of renewable energy transfers (Frieden *et al*., 2012).

[55] http://www.anme.nat.tn/fileadmin/user1/doc/fr/lois/Loi_2004_72_fr.pdf
[56] http://www.anme.nat.tn/fileadmin/user1/doc/fr/lois/Loi_2009_7_fr.pdf
[57] More information is under the "further economic development framework" section.
[58] http://www.steg.com.tn/en/ser/presentation.html

INFORMATION POLICY AND CAPACITY BUILDING

Several trainings and academic courses are established at universities and research institutions to develop and strengthen the domestic expertise in renewable energy deployment. Especially ANME plays an important role in compiling information and advising governmental and private actors towards RE target implementation.

Tunisia has already established training activities related to renewable energy. Several trainingand academic courses are established at universities and research institutions to develop and strengthen the domestic expertise in renewable energy deployment. In particular, the Research and Technology Centre of Energy (CRTEn) was launched in 2005. It is a structure of Research & Development (R&D) operative under the supervision of the Ministry of Higher Education and Scientific Research (MESRS) and located in EcoparkBorjCedria in Tunisia. The CRTEn is a technological platform where pilot R&D actions play a significant role in the development of the innovating companies working in the various energy sectors, particularly renewable energy. The CRTEn also contributes in an effective way to post-graduate education (Ellenbeck, 2012).

Awareness raising campaigns have been also conducted in Tunisia, but almost all of them are related to energy efficiency/energy conservation, namely labeling, low consumption lumps and solar water heating technologies. Regardless of the efforts in terms of awareness raising for the financial sector that has been involved in the solar water heating initiative, more awareness raising would be needed especially engaging banks in utility scale renewable energy projects.

BARRIERS[59]

Barriers that are currently limiting the expansion of renewable electricity in Tunisia were identified by stakeholders. The most important ones for the development of domestic renewables are:

- The risks and uncertainty related to projected income, implementation delays, administrative procedures, permissions and feasibility studies;
- The instable political framework, including the risk of discontinuation of policies and legislation, and insufficient policy transparency;
- insufficient laws and decrees to support self-producers continuing their investments in that field;
- The high costs and long-term investments needed for RE deployment;
- The technical limitations for the integration of renewables in the Tunisian electrical system;
- The lack of local technological expertise to install or maintain facilities including skilled workers to develop a local industry;
- A deficient assessment of available renewable energy resources;
- A possible lack of social acceptance of projects related to renewables in Tunisia due to the environmental impacts.

[59] This section is based on interviews and contributions of experts from CRTEn.

The main barrier identified related to the export of RE electricity from Tunisia to Europe is the weakness of the national grid infrastructure and lack of interconnections with Europe as well as the weak interconnections with neighboring Maghreb countries. Reinforcements both of the national grid and the interconnections are needed in order to improve absorptive capacity and enable export.

2.6.5.3 Scenario for the power sector

Scenario analysis reveals two aspects of electricity supply that will be shown for a possible transition towards a sustainable electricity scheme: the installed capacity and the annual electricity production and their development as function of time.

In terms of installed capacity, the most important target to be achieved is that the firm capacity of all power plants is always larger than the peak load that occurs once a year. **Table 28** shows how this condition is maintained at any time in the future. It can also be appreciated how the relation of installed capacity and peak load increases with time due to the introduction of fluctuating renewables like wind power and PV. While in the year 2000, the relation of installed capacity to peak load is equal to 2.8/1.6 = 1.75, this relation increases to 37.5/12.2 = 3.0 in the year 2050. The increase of this ratio means that the average utilization (capacity factor) of the total power park is reduced accordingly.

In our scenario, the total installed capacity of about 4.5 GW in 2010 would increase to about 8.5 GW in 2020 and to 37 GW in 2050. Under this condition, the mix of fluctuating and flexible power plants would allow for a guaranteed production of electricity on demand at any time, without requiring major additional electricity storage devices or an expansion of the electricity grid beyond the natural growth of the AC grid assumed here.

Our scenario in **Figure 36** shows how peak load will increase almost linearly between 2010 and 2050. As a consequence firm power capacity from gas fired power stations will have to increase in line with that growing demand. However, after 2030, CSP plants step-by-step will take over firm capacity supply, because by then the CSP industry will have grown sufficiently to cover the increasing demand for firm and renewable power capacity. According to national planning, by 2020 about 800 MW of wind power, 690 MW of PV and 250 MW of CSP could be installed. Hydropower (200 MW) and geothermal power (10 MW) plants only have minor potentials in Tunisia. Due to the high cost of fuel oil, oil fired power stations will be phased out after 2030.

By 2020 about 24% of the total installed capacity will be covered by renewable sources. CSP exports to Europe will be implemented for the first time between 2020 and 2030. The strongest growth of renewable power capacity will take place between 2030 and 2050. In 2050, about 70% of the power park will be renewable, with hybrid (solar/fossil) CSP taking over the job of providing firm and flexible power capacity on demand, and major wind and PV capacities that will act as fuel savers every time the sun shines and the wind blows. The total installed capacity of wind and PV plants will be larger than that of CSP for domestic use. The capacity of CSP exports to Europe would in the long-term achieve about 30% of total installed capacity.

It can be seen in Figure 37 that the fluctuating capacity from wind and PV can become larger than base load demand, but not larger than the peak load of the country. This simple strategy will lead to power surpluses from time to time when demand is low that however can be partially compensated by exporting electricity via the AC grid and by using the existing – rather scarce – options for electricity storage. Due to the fact that wind power and PV power will not often be fully available at the same time, surpluses will not occur very frequently. Also the surplus power capacity – which would dictate the necessity for an equivalent conversion capacity of related electricity storage devices like pump storage or batteries – will be rather low.

Table 28: Installed power capacity in Tunisia (GW) for each technology and firm capacity of all plants compared to the peak load of the country as function of time between the years 2000 and 2050. Import / Export refers to the Net Transfer Capacity (NTC) of the conventional AC grid.

Year	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Peak Load	1.6	3.0	5.0	7.8	10.5	12.2
Firm Capacity	2.5	3.8	6.3	9.8	13.2	15.2
Installed Capacity	2.8	4.5	8.5	18.3	30.4	37.5
Wind Power	0.0	0.2	0.8	1.8	3.6	4.7
Photovoltaics	0.0	0.0	0.7	1.9	5.1	5.3
Geothermal	0.0	0.0	0.0	0.0	0.1	0.2
Biomass	0.0	0.0	0.0	0.1	0.3	0.7
CSP Plants	0.0	0.0	0.3	0.6	3.1	7.6
Wave / Tidal	0.0	0.0	0.0	0.0	0.0	0.0
Hydropower	0.0	0.1	0.2	0.2	0.2	0.2
Oil	0.2	0.2	0.2	0.1	0.0	0.0
Gas	2.6	3.9	6.1	9.3	10.1	7.1
Coal	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Import / Export NTC	0.0	0.1	0.3	0.5	0.7	0.8

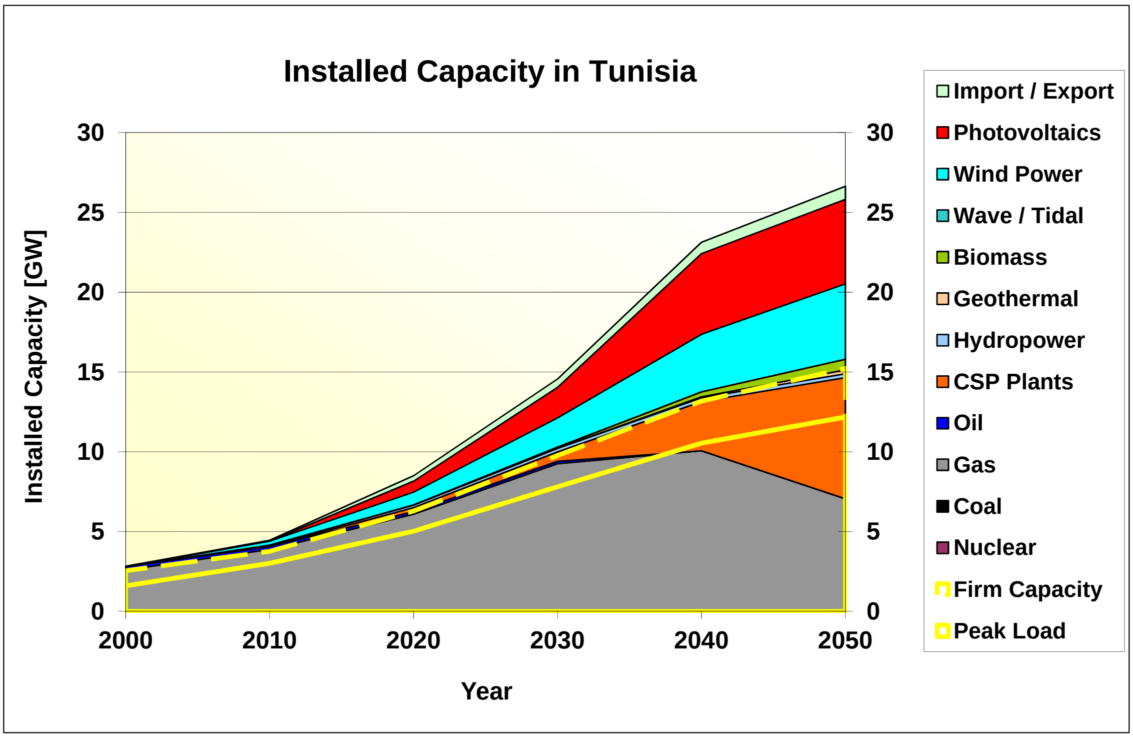

Figure 36: Installed power capacity in Tunisia for each power plant technology and firm capacity of all plants compared to the peak load of the country as function of time between the years 2000 and 2050. Import / Export refers to the Net Transfer Capacity (NTC) of the AC grid.

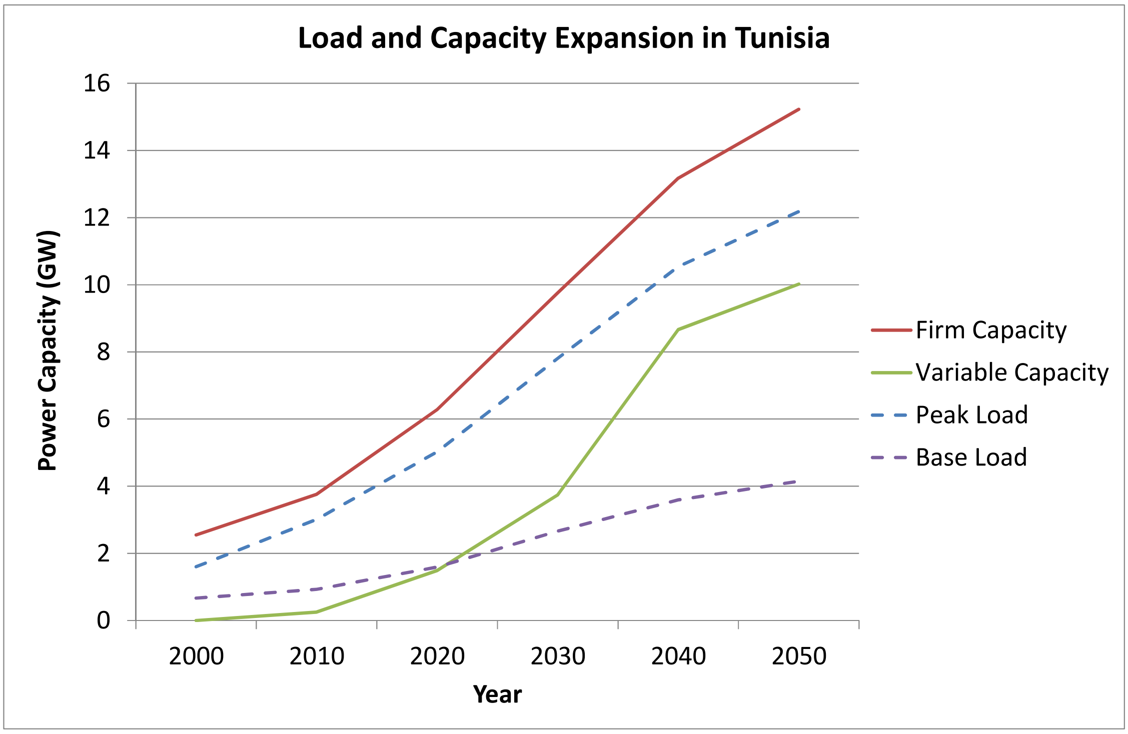

Figure 37: Comparison of firm capacity, variable capacity from fluctuating sources and export capacity of CSP plants with peak load and base load in Tunisia.

The simple strategy followed here assumes that fluctuating power capacity will be limited to slightly lower values than peak load and flexible power capacity will be at least expanded to 125% of peak load. This way, surpluses can be effectively avoided and security of supply is maintained at any moment in time. In the medium and long term, wind and PV power will be least cost sources of energy and installed preferentially until reaching the peak load limit. Flexible power sources like CSP, being more expensive, will be used to fill the remaining gaps.

Electricity production and import through the AC grid will cover the gross electricity consumption analyzed before plus eventual export through the AC grid. Import and export through the AC grid will increase with time and in line with the growing net transfer capacity of the grid. In our model, it is assumed that annual import and export streams will be balanced.

As consumption will almost double between 2010 and 2020, there will be a strong pressure on fossil fuel resources that can only be relieved by quickly introducing cost-effective fuel savers like wind and PV power (Table 29). This will prolong the availability of fossil fuels and stabilize the cost of power generation. The option of additionally exporting solar electricity to Europe would open the possibility of Tunisia becoming an energy exporter, while at the same time prolonging the availability of natural gas for own use in the country.

Table 29: Annual electricity production in Tunisia (TWh/y) by each technology, exports to and imports from neighbor countries via the AC electricity grid as function of time between the years 2000 and 2050.

Year	2000	2010	2020	2030	2040	2050
Consumption	10.6	14.8	25.4	39.4	53.2	61.5
Export via Grid	0.0	0.0	0.1	0.2	0.5	1.0
Wind Power	0.0	0.3	1.2	3.5	7.1	9.4
Photovoltaics	0.0	0.0	0.1	3.4	9.0	9.5
Geothermal	0.0	0.0	0.0	0.1	0.5	1.8
Biomass	0.0	0.0	0.1	0.3	1.1	2.4
CSP Plants	0.0	0.1	0.4	2.8	13.5	30.7
Wave / Tidal	0.0	0.0	0.0	0.0	0.0	0.0
Hydropower	0.0	0.1	0.2	0.2	0.2	0.2
Oil	1.3	1.0	1.0	1.0	0.0	0.0
Gas	9.3	13.2	20.3	28.1	21.8	7.5
Coal	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
Import via Grid	0.0	0.0	0.1	0.2	0.5	1.0

Peak load will increase in line with increasing consumption, and therefore, there is a compulsive need for the installation of sufficient firm and flexible power capacity and reserve. Only fossil fuel fired power plants and renewable power plants using biomass or concentrating solar thermal power can provide this type of high quality supply. As biomass is rather scarce in North Africa, hybrid (solar/fossil) concentrating solar power stations are the only alternative to fossil fuel plants, being able to deliver the same quality of supply with much lower fossil fuel consumption. Therefore, their short term introduction and expansion is crucial for achieving sustainable supply in the medium and long term, as the natural gas reserves are limited.

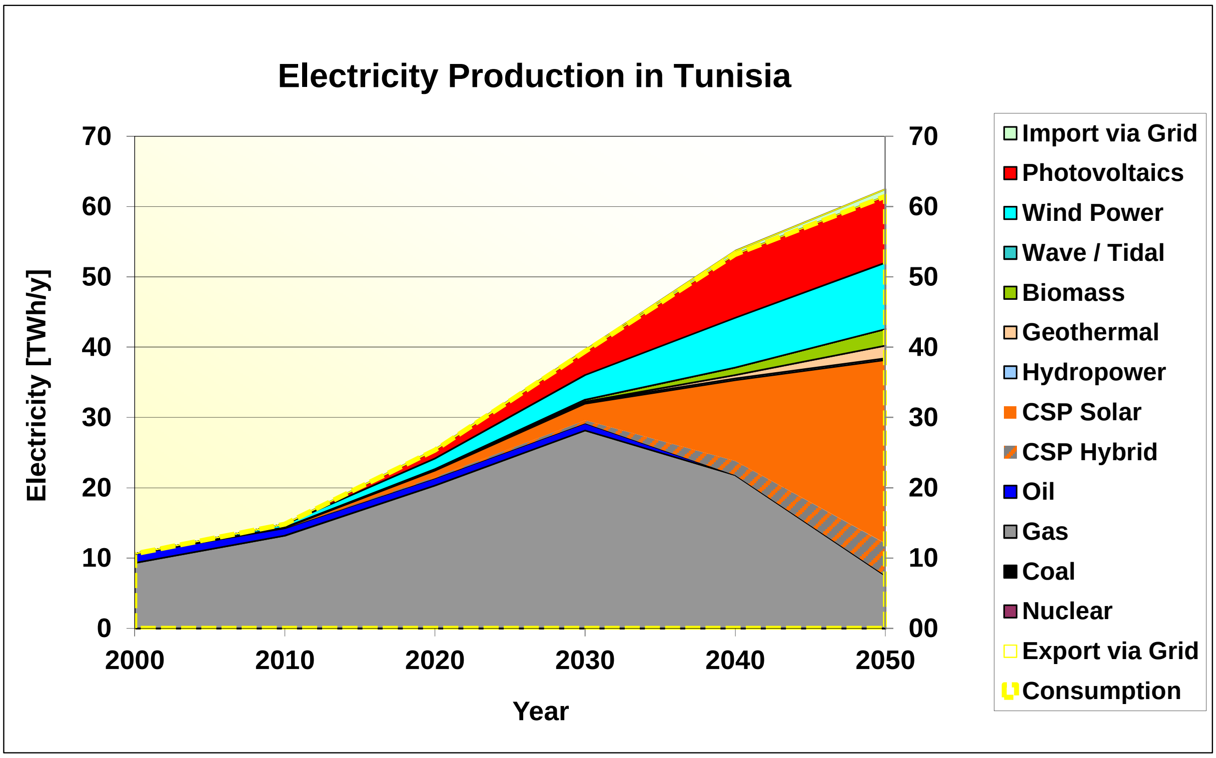

Figure 38: Annual production of RES-E and conventional power plants in Tunisia compared to the gross electricity consumption plus export to neighbours through the AC grid. Hybrid CSP operation is assumed to be achieved by natural gas backup for steam generation within the CSP plants. In the long-term, only marginal amounts of electricity will be produced in fossil fuel plants for back-up and emergency purposes.

Our scenario reflects this strategy, by massively increasing the share of RES-E until achieving about 79% in 2050 (Figure 38). By then, wind power and PV would make up for 30% of the annual power production for local supply. In order to provide sufficient firm power capacity and RES-E production, CSP plants are extended to provide 50% of annual production. About 7% (4.6 TWh/y) of annual production in Tunisia will stem from hybrid CSP operation with natural gas and further 12% (7.5 TWh/y) from natural gas peaking plants. There will still be a significant capacity of natural gas plants installed for reserve and emergency purposes in 2050, but their power production will be limited to backup purposes and thus will be rather low. The use of natural gas in CSP plants is more cost effective and efficient than solar only operation of CSP plants and balancing by extra gas plants. Firstly, hybrid CSP plants will have less part-load losses and thus higher efficiency for solar power generation. Secondly, gas plants would have rather low efficiencies just filling the few supply gaps that would be left by wind, PV and solar only CSP plants.

A well-balanced mix of the available RES-E resources in Tunisia can lead to a scenario for 2050 that satisfies all the sustainability criteria described before. The national potential of wind power of about 15 TWh/y will be exploited by 63%, while less than 1% of the solar energy resource potential will be needed to satisfy the national demand and in addition provide significant amounts of flexible solar electricity exports for Europe.

At present power production in Tunisia is almost fully dependent on natural gas. It is clear that the availability of gas would be reduced significantly if the quickly growing demand would only be satisfied by this limited resource. In fact this cannot be avoided, as the consumption of natural gas still doubles in our scenario until 2030. According to the /indexmundi 2013/ statistics the ratio of natural gas reserves of 65 billion cubic meters and present exploitation in Tunisia above 5 billion cubic meters per year would lead to a static availability of only 13 years. A significant increase of exploitation for domestic use would reduce this time accordingly. On the other hand, using gas mainly for hybrid operation in CSP plants as in our scenario would reduce its consumption and prolong its availability for the future.

Biomass (4% in 2050), geothermal power (3% in 2050) and hydropower (less than 0.1% in 2050) are available, but will not achieve major importance in the long term, as Tunisia will experience a strong growth of demand. CSP, PV and wind power are the major domestic sources of energy for power generation, while natural gas is the most important ideally stored form of energy available in the country. CSP would provide about 50% of domestic supply in 2050. An intelligent combination of ideally stored and free flowing forms of energy will allow Tunisia to achieve a sustainable power supply by the mid of the century. In technical and economic terms, the transition to renewable power could by significantly faster than expected on the basis of present national planning. Therefore, Tunisia should consider strongly accelerating its transition towards renewable power sources in order to better conserve its most valuable form of energy, natural gas, and prolong its availability for future generations. The strong increase of natural gas consumption until 2030 that is related to the present tentative RES-E integration policy suggests that Tunisia will become net importer of natural gas in the short and medium term. The only alternative to remain self-sufficient in the future would be an accelerated introduction of all available forms of renewable energy.

It is important to note that ideally stored forms of energy like fossil fuels will be required for a long time. Even in a desert country like Tunisia with a large solar energy potential, the availability of solar power over the whole year is not 100%, so CSP plants will have to operate in hybrid mode with natural gas in order to be able to cover the load at any time on demand. The substitution of the last 25% of fossil fuel consumption by renewable sources will be a special challenge, which may be overcome in the long-term by innovations such as power-to-gas or power-to-liquid fuel conversion. As research and development of such technologies is already under way, our scenario must not be understood as if those technologies would not be implemented before 2050. On the contrary, in the best case, hybrid operation of CSP plants in our scenario could eventually be provided by natural gas derived from renewable sources, in that case effectively leading to a 100% RES-E share in 2050.

Synthetic natural gas production from renewable sources would require additional RES-E infrastructure that has not yet been included in our scenario and would have to be assessed and designed separately. An important frame condition for any hydrocarbon synthesis process is its operation near to steady state conditions, which is required to achieve the equilibrium needed for an efficient chemical conversion process. Such a steady state operation will be very difficult to achieve by (cheap) wind and PV input, but is easily achieved by (more expensive) CSP plants with thermal energy storage. As there is still not enough information and experience available for a reliable modeling and comparison of such solutions, we have assumed that the need for ideally stored energy in our scenario until 2050 will be covered by fossil natural gas.

2.7 STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREADS – A SWOT ANALYSIS FOR RES-E DEPLOYMENT IN NORTH AFRICA

2.7.1 INTRODUCTION

SWOT stands for **S**trength, **W**eakness, **O**pportunities and **T**hreats and is a method often applied in strategic business planning to address the complexity of a situation by reducing the information to improve decision-making (Helms and Nixon, 2010). Favorable and unfavorable issues are listed in the four quadrants of the analysis grid. This allows for a quick qualitative overview as well as an understanding of how to better capitalize on strengths and opportunities or to overcome weaknesses and meet upcoming challenges. Weaknesses and strengths are related to a company's internal qualities and characteristics whereas threats and opportunities relate to possible external influences. However, use of the method has expanded beyond the company level and today, SWOT is used to assess the situation of whole industry sectors in different countries.

Within the North African case study of the BETTER project, we used the SWOT analysis to **assess the exporter country situation as conducive to implement RE projects under Article 9** of the RED. The aim is to identify factors that are favorable (Strengths, Opportunities) and unfavorable (Weaknesses, Threads) to the use of Article 9.

Our approach differs slightly from how SWOT is typically applied to companies. Instead of internal factors we assess the current host country's situation and, instead of external factors, we assess possible future (internal and external) developments in the ability to change the current situation. This comprises the dynamic character of the subject. In others words: strengths and weaknesses manifest themselves in the present but cannot be limited to the host country alone, opportunities and threats are related to the future but cannot be limited to external developments alone.

Building on deliverable D2.4 of the BETTER project, macroeconomic and microeconomic as well as acceptance issues have to be examined to understand cooperation or non-cooperation, so we follow a three-level framework. The macro-level places emphasis on the economy and puts the focus on associated political representation such as national governments. Without any perceived economic or political benefits from possible international cooperation, policy-makers will simply not be willing to support it. While the energy importer country may seek a cheaper, cleaner or more secure way of meeting its energy demand, the energy exporter country might be looking for added value in the form of additional revenues, the attraction of Foreign Direct Investments (FDI), access to new technologies and knowhow, job creation or more energy security.

These macro-level benefits must be present in exporter, importer and transit countries and then be translated into microeconomic business cases to attract investors and bring in actual projects. Microeconomic factors include all factors that make possible investments in RES-E projects attractive such as financial stability, clear and stable rules for grid access and long-term political support schemes or market designs for RES-E imports/exports. If macro-level policy makers are supportive and micro-level business cases are present a third level of factors has to be taken into account to assess favorable and non-favorable conditions in North Africa: the acceptance factors.

The acceptance dimension takes into account relevant questions related to civil society, social and environmental issues as possible sources of support for, or resistance towards, Article 9 projects. Experience within Europe indicates that low public acceptance is one of the reasons for the extremely long permission times for transmission projects in Europe (ENTSO-E, 2010).These factors are highly dependent on discursive processes taking place in media and political debates in science, policy and civil society. The Arab Spring has shown a great potential for civil society activation and protests against top-down governance structures (Schellekens et al., 2011). Thus, although social acceptance factors are hard to assess, they nevertheless play a pivotal role for a successful implementation of article 9 of the RE Directive.

Within this three level structure we identified 13 pivotal factors that have to be looked at to assess the favorable and non-favorable conditions for joint projects in the five North African countries. These factors were presented to experts and stakeholders and a qualitative analysis using the SWOT structure was carried out based on the responses received.

The macrolevel factors are: energy system strategy and energy outlook, RES industry development and energy security. The micro level factors are: market structure of energy system, grid and Interconnections, RE regulatory and policy framework, institutional framework for RES-E deployment, financial risks and uncertainty, investment facilitation and RES-E capacity and potential. The acceptance factors are: public acceptance, environmental effects and social effects.

Data sources

Data sources are the qualitative results of several deliverables of the BETTER project, including a quantitative social and environmental impact assessment of Article 9 projects in North Africa (Caldés et al., 2014). The findings were substantiated with desktop research using documents from relevant energy related initiatives, international organizations and research institutes, active in the North African Region (Paving the way for the Mediterranean solar plan, Medgrid, RCREEE, Germanwatch, WTO, World Bank, UNEP, REN21, DIE, DII), as well as publicly available data from national authorities. With feedback from a consultation workshop with 24 stakeholders in Rabat on October 28th, 2013, and 16 qualitative responses to a questionnaire sent to stakeholders from all five North African countries the findings were complemented and validated. After the SWOT was drafted it was circulated again amongst selected stakeholders and we received five qualitative responses.

How to read the SWOT's

At first, it is important to note and at the same time one of the outcomes of the data analysis that there are different storylines included in the results, so to say different (ideological) perspectives from which the SWOT's can be read. Many stakeholders and also many European and International researchers suggested strengths, weaknesses, opportunities and threats rather from a liberalized market perspective. In this view for example the existence of publicly controlled incumbents and energy subsidies are barriers to new market entrants, foreign direct investment and competition, i.e. business cases for cooperation projects. Successful cooperation seems to be a function of the level of liberalization. From a political-pragmatic, mere cooperation implementation point of view, however, it might be more realistic to implement RE projects in the short- to mid-term via high-level agreements with public authorities and public national companies and if the public goal (RE deployment for domestic use or export) is reached directly with public investments. Given the current market and political structure of the five NA countries this opportunity is thus also mentioned in the SWOT's next to the liberalized, private investments approach.

Second, there are direct and indirect drivers to energy cooperation. A direct driver would e.g. be an existing export regulation/framework or interconnector projects. Because to date there is no successful example for Art.9 cooperation between the EU and North Africa many factors are derived from national conditions for

RES-E. It is not only assumed that the domestic supply with RES-E in the North African countries is a parallel goal next to RES-E exports, it is seen as an important indirect driver for cross-border-cooperation. Therefore we also included factors influencing domestic RE deployment.

Third, it has to be noted that two different possible pathways for physical electricity transmission between the north and south shores of the Mediterranean exist that are often not clearly separated. The 'business-as-usual' interconnection of national grids via AC or HVDC interconnectors and power-lines sometimes referred to as 'Supergrid'. And the concept of point-to-point HVDC lines from central RES-E plants in North Africa to central European demand centres, as highlighted as Trans-CSP-concept by DLR in this report. These lines are not connected to the host countries electricity grid and can be seen as a parallel structure. This concept brings about different political, economic, technical and acceptance implications than an interconnected 'Supergrid'-scenario.

2.7.2. SWOT ANALYSIS OF NORTH AFRICAN COUNTRIES

2.7.2.1. SWOT Analysis Morocco

	Strengths (current)	**Weaknesses (current)**	**Opportunities (future)**	**Threats (future)**
Energy system strategy and energy outlook	• Very ambitious targets for domestic RE deployment (42% RES-E capacity by 2020) provide a stimulating environment also for export projects • High costs and high price volatility of imported energy fuels low comparative cost for new RE capacities	• Rapid growth of electricity demand decreases the attractiveness to export • Import of grey electricity (mainly from Spain) to meet demand • High domestic price of electricity is favoring imports	• Very high increase in electricity demand[60] might call for international cooperation on construction of new energy infrastructure • Large scale deployment might lower the cost for additional RE capacities and thus create incentives to produce for domestic consumption and export	• Overcapacities in Spain might reduce the attractiveness of importing electricity from Morocco and could at the same time appear as a measure to cover rising domestic demand in Morocco • Low comparative prices for fossil fuels (e.g. due to the boom of unconventional sources) might slow down the push for renewables
RES Industry development	• Huge share of the value chain of RE installations can be manufactured or performed by domestic companies first solar technology cluster was founded in 2014 • Extensive training and knowledge diffusion campaigns by ADEREE, SIE and others also in cooperation with European research institutes have taken place	• Local content share requirements in current and past (large scale) RE tenders was and can be perceived as barrier as local manufactures might not be as developed as needed • Limited financing options and projects for SMEs in domestic RES-E sector • Low R&D investment capacities	• Local content share requirement might stimulate further development of RE industry and thus make their bids competitive • Potential regional first mover advantage (especially CSP) as Morocco has an industry base to build on selling components and know how to other MENA countries and the EU	• Decreasing world market prices for RE components might threaten the Moroccan RE industry development • Licensing problems with advanced RES-E manufacturers might deter know-how transfer for parts higher in the value chain
Energy security	• Very high dependency on imported fossil fuels, partly from geopolitically unstable countries, is leading the Moroccan government to push for domestic RES-E generation capacity • Rel. low import country diversity in energy sector triggers government to aim at more energy independency	• Low grid operating expertise with fluctuating RE integration	• A more interconnected market of Europe and North Africa might increase system stability, grid reinforcements and could trigger more cooperation in other areas • RE imports from Morocco to Europe would actually lower the risks of an outage due to more diversification and increased interconnection	• A more interconnected electricity market between Europe and North Africa is increasing the complexity and challenges for grid operation • Energy related interdependencies between Morocco and Europe might affect political relations, but coercion is not likely as possible income losses of exporter country exceed damages in

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See D3.2.2: DLR 2013 “*Demand Development Scenarios”* of the BETTER project

				European importer country due to available back-up generation capacities
Market structure of energy system	• Public, vertically integrated utility ONEE is pushing for RES-E deployment • New intermediary entities as MASEN push for financial attractiveness of RE projects • Only North African country among the Top40 of EY's Renewable Energy Country Attractiveness Index (rank 31 in 2/2014) • Private ownership of IPPs is allowed	• ONEE is responsible for determining prices and concessions with IPPs in case to case negotiations (single-buyer model) → no independent regulator in place that sets tariffs	• If new financial constructs with risk sharing and risk management to attract RE projects are successful this might have spill-over effects and reduces financial barriers for investments • Development of market structure to be more compatible with EU market to facilitate electricity trade • Independent regulator to be created in 2014 could lead to more market transparency	
Grid and Interconnections	• 2 direct connections to EU (1400 MW maximum capacity to Spain) • 4 interconnections with Algeria • Merchant power lines are allowed under a concession scheme • ONEE as operator in the Spanish market and the possibility of exchange contracts with the Spanish operators • High general and rural electrification rate • Low rate of electricity transmission and distribution losses (2011: 6.2 %)	• Connection to Spain is limited • Access to interconnection capacity by RES-E projects is unregulated and depends on ONEE • No coherent grid regulation and planning between Morocco and EU (ENTSO-E) • Domestic grid not sufficient to transport big quantities of export electricity • Little experience with integration of decentralized produced electricity into the grid	• Reinforcement/expansion of the 400 kV grid connecting Spain with Morocco, Algeria and Tunisia is planned → opportunity to export (independent of possible Trans-CSP lines) • Reinforcement of the internal 400 kV grid is targeted (in the Maghreb electricity transmission master plan) • Independent regulator to be created in 2014 could guarantee IPPs access to interconnectors	• If interconnections to wider Europe are not expanded, physical transmission to demand countries on a larger scale is impossible • Financing issues and the appropriate allocation of costs and benefits to stakeholders remain unsolved
RE Regulatory & Policy Framework	• Regulation for PPAs with ONEE for RE projects is in place and already used • RE pilot projects are tendered and financed by intermediary entities • Export of RE electricity through the grid is allowed • Private ownership of solar and wind power plants is allowed	• The case to case negotiations for PPAs with ONEE can hamper a transparent and beforehand investment calculation for project developers and financers • No priority grid access for renewables • No system for Guarantees of Origin for RES-E	• Independent regulator to be created in 2014 might attract private investment • The renewable energy grid code in preparation might strengthen the investment environment	• In case regulation of the transmission system gives no incentive to ensuring security of supply, grid instability due to insufficient investments of ONEE might occur while new generation capacities are connected by IPPs
Institutional Framework for	• MASEN, SIE, ONEE, ADEREE and other institutional support to implement governmental targets is present	• No detailed technical specification of the regulation exists → rests on bureaucracy and specific actors and	• Free trade agreement between EU and Morocco could stimulate RE investments and further integration of energy markets	• Possible overlaps of responsibilities between MASEN, SIE, ONEE, ADEREE and others could produce inefficiencies

RES deployment	• Experience with CDM and carbon finance • UfM member, ENP partner and partner in the German Moroccan energy partnership	people to take decisions	• A new center on renewable energy and energy efficiency in Morocco by the UNESCO is planned to be established and might push for more technical expertise	
Financial risks and uncertainty	• Currently significant RES-E investments with international support are being made ⇒ that might decrease risk perceptions • Low prices for land acquisition thanks to specific regulation under the Moroccan Solar Plan • General country risk is low (3 in OECD index)[61] • Continuity in economic policy	• Grid access cost have to be borne by RE project owner • Transaction costs for land acquisition due to bureaucratic barriers and unclear ownership in remote regions • Lack of market visibility (size and predictability) • Uncertainty about the EU post 2020 regime reduces the attractiveness of RES imports from Morocco (Uncertainty about the RES electricity European demand)	• Free trade agreement between Morocco and EU, further cooperation within the UfM and the implementation of the Energy Charter Treaty might lower risk perceptions • Framing big pilot projects as development projects could help to acquire international (multilateral) aid (like Quarzazate) • Clear technology roadmap by MASEN could improve market visibility	• Currency risks and European financial crisis might lead to higher security requirements for investments of banks and other RE investors • Low land prices and governmental purchase strategy could be perceived as unfair und evoke resistance
Investment facilitation	• Tax and duty exemptions for RE projects • Access to finance facilitated by SIE (e.g. SIE acts as direct investor or third party investor) • Well-developed banking sector • Substantial foreign investment • Increasing interest by private funds in Moroccan RE sector	• Local content share might increase costs for RE project implementation • Information on incentives not easy to access by smaller investors	• Free trade agreement between Morocco and EU, further integration within the UfM, and the recently set up Moroccan Investment Development Agency (in 2009) might accelerate foreign investments in Morocco • Potential inclusion of interconnectors/transmission lines in/to NA into the ENTSO-E PCI framework • Green climate fund and Carbon market financing like NAMA's might open possibilities to access financial support	• A lack of coordination between different investment services and poor service governance could produce inefficiencies
RES capacity/ potential/ Available Technology Options	• Solar radiation of 5 kWh/m2/day • Average wind speed is more than 6m/s and in very good areas 9-11m/s • Experience in the installation of wind farms (several hundred megawatts installed and under construction) • Rank 7 out of 40 for CSP in EY's	• Land and territory (secession) conflicts (e.g. Western Sahara) are still present ⇒ reduces attractiveness for RES investors in these regions • Land for large-scale solar and wind projects not yet allocated for private development	• CSP could be a highly valuable technology as it can provide flexible electricity on demand to the European market • In the longer term PV and wind with meshed grids might also be suitable • Large-scale deployment of pilot CSP	• Land and territory (secession) conflicts in resource rich regions (e.g. Western Sahara) might further escalate and reduce available land for RES projects • PV becomes the preferred option for RES-E developers as it is currently more economically attractive, but less suitable

[61] See OECD 2013: http://www.oecd.org/tad/xcred/crc.htm

	Renewable Energy Country Attractiveness Index (2014)		projects (e.g. Ouarzazate) might trigger cost-reductions and show feasibility for new projects	for export (inflexible)
Public awareness/ acceptance	• Wide public and political support for RE deployment • With RES-E projects currently under construction government shows commitment towards RE goals	• Some complaints about limitation only to either large scale projects or off-grid RE installations • Some concerns regarding the local benefits of large scale RES/CSP projects	• International cooperation might increase acceptance if exporter country benefits (including positive externalities associated to RES deployment) reach large parts of the population and are communicated	• Top-down planning of large-scale RE projects (especially for exports) might produce local resistance[62] • If benefits associated to exports do not reach local populations (and only benefit a small fraction of the population), public acceptance might be jeopardized
Environmental effects	• Less pollution due to cleaner energy production In almost all of the impact categories CSP plants perform better than coal, oil and gas technologies	• Landscape impacts in case of wind energy • Maybe new transmission lines are needed • Water scarcity in some regions • In some impacts categories such as human toxicity, ionizing radiation, fresh water toxicity and eutrophication and resource depletion, natural gas power plants perform better than CSP plants	• Average environmental impacts of the electricity mix per kWh are reduced (in almost all the categories) in future scenarios due to the penetration of renewable technologies and the gradual substitution of coal, natural gas and oil plants	• Environmental impacts of CSP exports have a significant share of the total environmental impacts of the electricity generation sector in many of the impact categories
Social effects	• Technical jobs and vocational training are relatively fast available for local workers • Good social conditions compared to other countries of the region (SHDB[63])	• Further training, expertise as well as RES industrial development are needed to capture the socio-economic benefits of RES deployment associated to large shares of local content • The high upfront costs of large-scale RES-E investments require capital and correspondingly repayments of credits, thus having a negative effect on national income	• RES deployment for exports might create synergies with national RES deployment and the associated socio-economic and environmental benefits • Increasing national income in the mid-term due to less fossil fuel imports • If social safeguards (similar to Gold Standard) are put in place for RES exports, that might also lead to local benefits for rural communities • High local content shares might promote the socio-economic benefits associated to RES deployment	• More transmission capacity to Europe may increase average domestic electricity price level and cause resistance • Welfare losses in touristic areas when landscape damages are present

[62] As experienced with the 72 MW oil-fired power plant in Ait Melloul/Tiznit that was delayed for 2 years as local concerns have not been included into the siting procedure as reported by the SocialCSP project of Germanwatch and the Wuppertal Institute for Climate, Environment and Energy in 2014.
[63] See http://socialhotspot.org/

2.7.2.2. SWOT Analysis Algeria

	Strengths (current)	Weaknesses (current)	Opportunities (future)	Threats (future)
Energy System strategy and energy outlook	• Ambitious RE targets (40% RES-E share in 2030, 22 GW capacity in 2030, including 10 GW dedicated for export) • Shrinking conventional domestic gas resources • Access to huge financial resources due to gas exports • High vulnerability to changing world market prices for exported fossil fuels as motivation to diversify energy mix	• Strong path dependency on gas as energy source • Increasing domestic electricity demand decreases the attractiveness to export • Domestic grid challenged by increasing demand, outages occur especially in peak times	• High increase in electricity demand[64] might push for new RE generation capacities Algeria could save gas resources in domestic consumption and thus be able to export more gas (and longer)	• Unconventional gas resources and new techniques to tap them might strengthen the gas energy path and lower interest in RE deployment • If conventional fossil fuel reserves deplete earlier than expected (like in the recent case of natural gas in Egypt), space for investing in RES-E might be restricted
RES Industry development	• Some solar heating and CSP companies have been developed • Extensive national programs to strengthen RE knowledge (through IAER, NEAL, APRUE and CDER)	• Foreign investors have to be in joint ventures with national companies (max. 49% share of a foreign investor) • Aside from mining and fossil fuels weakly developed industry base, most industrial goods are imported	• 80% of local content share in RE targets for 2030 might push for a quick development of the local RE industry • The lack of a world market of CSP products might support the potential success of an Algerian CSP industry	• Domestic market prices for RE components etc. might not be competitive, so that the local content share duty might be suspended
Energy security	• Low diversity of energy sources (97% usage of natural gas for electricity production in 2011) is leading the Algerian government to push for construction of domestic RES-E generation capacity	• Relatively high domestic fossil fuel resources, unconventional shale gas potential is seen as large[65]	• A more interconnected market of Europe and North Africa might increase system stability and could trigger more cooperation in other areas • RE imports from Algeria to Europe would actually lower the risks of an outage due to more diversification and increased interconnection	• A more interconnected electricity market between Europe and North Africa increases the complexity and challenges for grid operation • Further interdependencies between Algeria and Europe might affect political relations, but coercion is not likely as possible income losses of exporter country exceed damages in European importer country due to available back-up generation capacities • Terrorist attacks on infrastructure can occur as single events but only pose a more severe threat when coordinated

64 See D3.2.2: DLR 2013 "*Demand Development Scenarios*" of the BETTER project
65 See http://www.iea.org/aboutus/faqs/gas/ (8/7/2014)

				across the region
Market structure of energy system	• The electricity market is partly liberalized and legally unbundled with strong public utilities who are able to implement governmental targets directly • IPPs, selling RE to 3rd parties – including exports - are allowed	• Energy sector is still closely related to (regulated or owned by) governmental institutions and thus political interests might interfere • Export regime needs still to be fully developed	• Market opening to external companies and investors within the energy sector through RE cooperation National strategy to export RE electricity to EU • Direct agreements with public utilities on export projects	• Renationalisation of energy infrastructure and companies due to political changes
Grid and Interconnections	• Regulation for grid connection of RE sites in place • Independent grid regulator • High general and rural electrification rates	• No interconnection with Europe • Weak interconnection with Morocco (800 MV) and Tunisia (300 MV) • High rate of electricity transmission and distribution losses (2011: 19.5 %) • Merchant power lines are not allowed	• Two HVDC underwater cables to EU under study (Spain and Italy)	• Prohibitive costs for direct transmission lines to EU • Grid instability due to a lack of knowledge and sufficient investments in Algerian transmission and distribution grid
RE Regulatory & Policy Framework	• FiTs as premiums exist for all technologies • New FiTs for ground-mounted PV and wind introduced in 2014, also eligible for projects >5 MW[66] • The national TSO and regional distribution company are obliged to connect RE sites to the grid	• Support schemes have not been used by private companies yet • Weak implementation due to non-transparent bureaucracy • No system for Guarantees of Origin for RES-E	• International demand could foster national implementation of targets and support schemes	• General political instability
Institutional Framework for RES deployment	• APRUE, NEAL and CREG as institutional entities to support RE deployment • Independent regulator CREG is in place to formally guarantee fair access, regulate prices and organize tenders • ENP partner, UfM member	• Regulator is responsible for highly subsidized electricity prices • Non-transparent bureaucracy and no clear mandates of different institutions • Concern about corruption in the electricity sector	• Project implementation and funding of projects can be done by Algerian energy companies using financial resources from gas exports no need for international investments to develop a RES-E project	• Institutional path dependencies in favor of the gas industry might be informal barriers to further RE deployment
Financial risks and uncertainty	• FiTs as guaranteed tariffs lower investment risks and can create investment stability concerning possible income flows • National Fund for Renewable Energy	• Costs for investments are uncertain due to bureaucracy, opacity in policy making, unclear timing and low experience • Land access might be difficult in remote areas where ownership is unclear	• Large scale implementation of the ambitious governmental targets might stimulate efficient procedures and a better knowledge at administrative and business level	• Financial crisis in Europe and economic instability in import countries might decrease demand for RE imports from NA

66 See CDER 2014: http://www.cder.dz/IMG/pdf/arrete_tarifs_achat_garantis_photovoltaique_eolien.pdf

	and Co-generation established • Investments can also be made by Algerian public companies due to high incomes from gas exports (cross-subsidizing) • General country risk is low (3 in OECD index)[67] • Positive current account balance	• Unfavorable business climate[68] low rate of FDI • High total tax rate (72% of profits) • Uncertainty about the EU post 2020 regime reduces the attractiveness of RES imports from Algeria (Uncertainty about the RES electricity European demand)		
Investment facilitation	• Membership in WTO (accession status), MEDREG • Cooperation already in place within the gas industry	• Only joint-ventures with Algerian companies are currently allowed • State-controlled, under-developed banking sector • Foreign investment constrained by restrictive laws	• Project implementation and funding of projects can be done by Algerian energy companies using financial resources from gas exports no need for international money to develop RE projects	• Path dependencies and bureaucracy in governmental agencies in favor of the gas industry
RES capacity/ potential/ Available Technology Options	• Large deserts not densely populated • Huge solar energy potential of >6 kWh/m2/day on average • Some experience with a small CSP combined cycle power plant • Good wind resources: wind speed in the south is 4-6m/s • Cooperation of Algerian and European research institutes and companies to develop CSP power plants and grid issues is under development	• Almost no installed RES-E capacity • Low experience with the integration of high shares of fluctuating RE sources into the grid • Maintenance costs and limited technical knowledge in remote areas can be barriers	• CSP could be a highly valuable technology as it can provide flexible electricity on demand to the European market • In the long-term PV and wind with meshed grids might also be suitable • Large scale deployment of CSP does include the potential of huge cost savings • Synergy effects when combining RES-E plants with seawater desalination	• CSP technology learning curves might be flatter than expected and thus costs remain high; the economic potential would decrease • PV becomes the preferred option as it is currently more economically attractive, but less suitable for export (inflexible)
Public awareness/ acceptance	• As for now, no public acceptance problems have been communicated, but fears towards stability and availability of RE resources exist	• Political acceptance is challenged by national gas industry interests	• International cooperation might increase acceptance if exporter country benefits (including positive externalities associated to RES deployment) reach large parts of the population and are communicated • Domestic RES deployment could save gas for domestic use, thus expanding the period of possible gas exports and	• If benefits are perceived by crucial actors to not be fairly distributed between EU and Algeria arguments of "neo-colonization" might further emerge • If benefits associated to exports do not reach local populations (and only benefit a small fraction of the population), public acceptance might be jeopardized

67 See OECD 2013: http://www.oecd.org/tad/xcred/crc.htm
68 See World Bank 2014: http://www.doingbusiness.org/rankings

			generation of income	
Environmental effects	• In many of the impact categories CSP plants perform better than natural gas (main electricity technology in Algeria).	• Water scarcity • Landscape impacts in case of wind energy • Maybe new transmission lines are needed • In some impacts categories such as human toxicity, ionizing radiation, fresh water toxicity and eutrophication and resource depletion, natural gas power plants perform better than CSP plants	• Average environmental impacts of the electricity mix per kWh are reduced (with the exceptions shown before) in future scenarios due to the penetration of renewable technologies and the gradual substitution of natural gas plants	• Water reserves for cooling and cleaning CSP plants might be a limiting factor (if not dry cooled systems) • Environmental impacts of CSP exports have a significant share of the total environmental impacts of the electricity generation sector in many of the impact categories
Social effects	• Technical jobs and vocational training are relatively fast available for local workers	• Current insufficient industrial development might jeopardize the possibility to tap socio-economic benefits associated to further RES deployment under a high local content scenario	• Creation of a new industry and jobs • RES deployment for exports might create synergies with national RES deployment and the associated socio-economic and environmental benefits • If social safeguards (similar to Gold Standard for CDM) are put in place for RES exports, RES deployment for exports might lead to local benefits for rural communities	• Top-down approach in large scale projects might strengthen neopatrimonial elements in governance • More transmission capacity to Europe may increase average domestic electricity price level and cause resistance • Bounded (medium) local content shares might limit the socio-economic benefits (job creation and economic activity stimulation in a wide range of sectors) associated to RES deployment

2.7.2.3. SWOT Analysis Tunisia

	Strengths (current)	**Weaknesses (current)**	**Opportunities (future)**	**Threats (future)**
Energy System strategy and energy outlook	• Ambitious RES-E targets (PST aims at 25% RES-E generation in 2030) provide a stimulating environment also for export • High costs and high price volatility of imported energy fuels low comparative cost for new RES-E capacities • First Desertec pilot project TuNur is in planning	• Limited financial resources to support the high upfront costs of large-scale RES-E deployment • Rapid growth of electricity demand[69] decreases the attractiveness to export	• RE deployment would slow down depleting domestic fossil resources • Technology and knowledge transfer can stimulate large scale RE deployment and lower marginal costs	• Financial setback due to political and economic crisis in both regions Europe or Tunisia • Government might strengthen the role of nuclear energy and warm up the pre-revolution plan to build a nuclear power plant in cooperation with France • Lower prices for fossil fuels (e.g. due to the boom of unconventional gas) might slow down the push for renewables
RES Industry development	• Large experience with solar heating, energy auditing, wind and decentralized solar PV installations and manufacturing of certain RE components (e.g. small PV module assembly line operating since mid-2014)	• Limited knowledge about grid integration of decentralized production and balancing of fluctuating RES-E feed-in	• Large scale investments in centralized and decentralized RES-E production sites could strengthen local RE companies and thus generate income and create jobs • Tunisia could develop a pioneer market for solar seawater desalination with CSP given its urgent need for freshwater[70]	• The political and economic turmoil might produce a roll-back within the just developing RE industry sector
Energy security	• 90% reliance on gas in electricity sector; growing share is imported from Algeria leading Tunisian government to diversify energy mix		• A more interconnected market of Europe and North Africa might increase system stability and could trigger more cooperation in other areas • RE imports from Tunisia to Europe would actually lower the risks of an outage due to more diversification and increased interconnection	• A more interconnected electricity market between Europe and North Africa increases the complexity and challenges for grid operation • Further interdependencies between Tunisia and Europe might affect political relations, but coercion is not likely as possible income losses of exporter country exceed damages in European importer country due to available back-up generation capacities

69 See D3.2.2: DLR 2013 “*Demand Development Scenarios”* of the BETTER project

70 See Schmidt, Lilliestam, Battaglini 2013: Tunisian electricity futures – a comparison of the implications of renewable and nuclear power

Market structure of energy system	• One large vertical integrated public utility STEG that is able to implement governmental targets directly • IPPs are possible (shares in Tunisian companies >49.9% need prior approval)	• STEG is mainly experienced with centralized fossil fueled power plants • STEG is not unbundled so that IPPs have to cooperate with STEG for transmission and distribution although STEG is a theoretical competitor	• Further liberalizing of the market due to increasing electricity demand and limited financial resources of STEG • A more active civil society might call for unbundling of STEG and an independent regulator • Direct agreements with STEG on export projects	• Investments in new fossil fueled power plants by IPPs, satisfying the demand and not challenging the grid stability, as they fit into a centralized system
Grid and Interconnections	• One 400 kV interconnection to Algeria, more in planning • Connection to Libya exists but is not in use • High general and rural electrification rates • Moderate rate of electricity transmission and distribution losses (2011: 12.3 %)	• Weak grid capacities • Lack of investments in the past • No interconnections to Europe • RES-E producers have to bear the additional costs of grid access and transmission • No merchant lines allowed	• Past lack of investment opens up a window of (investment) opportunity to reinforce the grid in coherence with RES-E targets • New interconnections to Italy are under study (1000 MW capacity, 200 MW reserved for RES-E in Elmed project) • New RE law might allow direct lines for export (not connected to domestic grid)	• Interconnection between Tunisia and Italy might be related to new fossil fuelled power plants • Financing issues and the appropriate allocation of costs and benefits to stakeholders remain unsolved
RE Regulatory & Policy Framework	• Pilot projects and project of the public RE program (PST) are partly funded by governmental subsidies	• No direct feed-in tariff for IPPs • No priority grid access for RES-E • Grid access costs have to be borne by project owner • No regulatory framework for large-scale RE deployment yet • No system for Guarantees of Origin for RES-E	• More incentives for IPPs through attractive PPAs might stimulate private investments in RES-E and lower costs for the electricity system in total • New RE law (in preparation) could allow for export to 3rd countries	• No interconnections and weak grid infrastructure might limit the potential to produce RE electricity for domestic use and exports
Institutional Framework for RES deployment	• Governmental subsidiaries to implement PST are created (ANME, STEG-ER) and training and knowledge diffusion is provided by CRTEn and others • UfM member, ENP partner	• No independent regulator in place • Long and complex administrative procedures	• Increasing electricity demand might push for a more efficient allocation of resources to implement the PST and approve claims	• Political turmoil might affect institutional settings
Financial risks and uncertainty	• 50% direct subsidies for pilot projects, VAT reductions, PST as long-term program • Creation of a public fund to finance projects of the PST (FNME) • Relatively good business climate (Rank 51 of 189 in World Bank's Ease of Doing Business Ranking in April 2014, highest	• Grid access costs • No feed-in tariffs • Long and complex procedures • Currency risks • Rel. high level of total tax rate (63% of profits) • FNME so far only supports solar water	• Financial stability through long-term agreements via PPAs with electricity consumers (such as European countries) • Extension of FNME also for bigger projects • Framing big pilot projects as development projects could help to	• Political and financial instability

	rank of the region)	heaters, small-scale PV and biogas • Prior to land purchase government approval is necessary • Uncertainty about the EU post 2020 regime reduces the attractiveness of RES imports from Tunisia (Uncertainty about the RES electricity European demand) • Deteriorated continuity of economic policy after uprising	acquire international development aid money • New RE law (in preparation) foresees priority zones for RES-E projects • A new free trade agreement between Tunisia and EU might lower risk perceptions	
Investment facilitation	• Omitted VAT and decreased custom duties for RE components that are not manufactured locally • Rel. high foreign ownership allowed in electricity sector (WB Foreign ownership index 71.4) • Usually strong foreign investment	• Instable policy and political framework • Delays in approval processes and administrative complexity • Fragile banking sector	• Civil society activation and democratic movements might lead to more efficient governance structures in the mid- or long-term	• Political conflicts might delay administrative and institutional reforms to attract investments
RES capacity/ potential/ Available Technology Options	• Solar irradiation from 2 kWh/m2/day in the north to 6 kWh/m2/day in the areas of the south • Good sites for wind farms with 6- more than 8 m/s at 60m above sea level[71] • Some installed wind capacity • Small-scale PV installations mostly in rural areas • Skilled workforce in RE project implementation	• For the siting of large scale RE facilities there might be potential land use conflicts in touristic or agricultural areas	• CSP could be a highly valuable technology as it can provide flexible electricity on demand to the European market • In the longer term PV and wind with meshed grids might also be suitable for export • Synergy effects when combining RES-E plants with seawater desalination	• PV becomes the preferred option as it is currently more economically attractive, but less suitable for export (inflexible)
Public awareness/ acceptance	• Public support is largely present if benefits are apparent and communicated • Political support is present due to increase in energy consumption and high costs for imported fossil fuels • With (few) wind and PV projects currently under construction the government is showing commitment towards its RES-E goals	• Call for environmental impact assessment and local participation in project siting etc. delaying projects	• A more active civil society might call for more decentralized and clean energy infrastructure • If social safeguards are put in place for RES exports, social acceptance both in Tunisia as well as in Europe might increase • International cooperation might increase acceptance if exporter country benefits (including positive externalities	• Renationalization and centralization ideology of conservative political groups • Centraliztic, large scale RE projects that were promoted by autocratic regimes or elites might be perceived as threat to a more democratic decentralized socio-economic system • If RE deployment is associated with liberalization and liberalization leads to

71 http://www.uneca.org/publications/renewable-energy-sector-north-africa-1

			associated to RES deployment) reach large parts of the population and are communicated	rising prices, resistance might arise from industry and residents • If benefits associated to exports do not reach local populations (and only benefit a small fraction of the population), public acceptance might be jeopardized
Environmental effects	• In almost all of the impact categories CSP plants perform better than coal, oil and gas technologies	• Water scarcity • In some impacts categories such as human toxicity, ionizing radiation, fresh water toxicity and eutrophication and resource depletion, natural gas power plants perform better than CSP plants	• Average environmental impacts of the electricity mix per kWh are reduced (with the exceptions shown before) in future scenarios due to the penetration of renewable technologies and the gradual substitution of natural gas plants	• Water reserves for cooling and cleaning CSP plants might be a limiting factor (if not dry cooled systems) • Environmental impacts of CSP exports have a significant share of the total environmental impacts of the electricity generation sector in many of the impact categories
Social effects	• Job creation due to the inclusion of local companies for installation and O&M • Technical jobs and vocational training are relatively fast available for local workers • Good social conditions compared to other countries of the region (SHDB[72])	• For the siting of large scale RE facilities there might be potential land use conflicts in touristic or agricultural areas • Further training, expertise as well as RES industrial development are needed to capture the socio-economic benefits of RES deployment associated to large shares of local content	• Jobs in manufacturing industry for RE components, in installation and O&M could help solving the unemployment problem • Increasing national income in the mid-term due to less fossil fuel imports • RES deployment for exports might create synergies with national RES deployment and the associated socio-economic and environmental benefits • If social safeguards (similar to Gold Standard) are put in place for RES exports, RES deployment for exports might lead to local benefits for rural communities • Improvement of economic diversity (EDI)	• More transmission capacity to Europe may increase average domestic electricity price level and cause resistance • Medium local content shares might limit the socio-economic benefits (job creation and economic activity stimulation in a wide range of sectors) associated to RES deployment

72 See http://socialhotspot.org/

2.7.2.4. SWOT Analysis Libya

	Strengths (current)	**Weaknesses (current)**	**Opportunities (future)**	**Threats (future)**
Energy System strategy and energy outlook	• Targets for RE deployment (10% RE share in energy supply in 2025) • Potential access to huge financial resources due to gas and oil exports	• Huge domestic oil and gas resources strong path dependency • Highly subsidized electricity prices render renewable electricity for domestic demand unprofitable	• Insufficient generation capacity and 7% increase in demand per year might push for new generation capacities Libya could save domestic gas and oil resources and thus be able to export more (and longer)	• Major (national and international) energy players might only be interested to invest in tapping new gas and oil resources path dependency • Fossil fuel reserves might deplete earlier than expected (like in the recent case of natural gas in Egypt), thus leaving less space for investing in energy transition
RES Industry development	• Experience with large-scale engineering projects (e.g. Great man-made river project)	• Lack of capacity building programs in the field of RE • Lack of technology transfer and know-how • Weakly developed industry base	• REAoL is studying the possibility of using silicon available in Libya for the PV solar cell industry	
Energy security	• Low diversity of energy sources (62% usage of oil, 38% of natural gas for electricity production in 2010) motivation to reduce dependency on depleting fossil resources (long-term) and replace aging generation capacities	• Focus currently rather on restoring and controlling oil infrastructure that was damaged in internal conflict than on RE	• A more interconnected market of Europe and North Africa might increase system stability and could trigger more cooperation in other areas • RE imports from Libya to Europe would actually lower the risks of an outage due to more diversification and increased interconnection	• A more interconnected electricity market between Europe and North Africa increases the complexity and challenges for grid operation • Further interdependencies between Libya and Europe might affect political relations, but coercion is not likely as possible income losses of exporter country exceed damages in European importer country due to available back-up generation capacities • Terrorist attacks on infrastructure might occur as single events but only pose a more severe threat when coordinated across the region
Market structure of energy system	• The vertical integrated public utility GECOL can directly implement governmental targets and agreements concerning RE deployment and	• No third party access to the electricity market/to the grid • No transparent information about costs, prices and weaknesses in the electricity	• An international agreement for RES-E exports might lead to a partial market opening (as for IPPs etc.) • Direct agreements with public utilities	• Renationalisation actions towards foreign and privately owned companies due to political events might prevent market liberalization

	cooperation	sector • No independent regulator • Highly subsidized electricity prices rendering production and supply of RES-E financially unattractive	on export projects • High national income for gas and oil exports might facilitate financial means to invest in RES-E capacities cross-subsidization	
Grid and Interconnections	• 180 MV capacity interconnection to Egypt (synchronous connection to the Egyptian grid) • High general and rural electrification rates	• No interconnections to Europe • 220 kV Interconnection to Tunisia not in operation due to synchronization problems • Rel. high level of transmission and distribution losses (2011: 15.9 %) • Several outages reported in the southern part of Libya caused by fights between rival groups	• A potential Libya-Italy connection was under study in 2007 • Libya-Tunisia and Libya-Algeria 400 kV lines are in discussion	• Further destabilization of Libya as a nation state possible secession conflicts affecting energy infrastructure planned by national authorities • Prohibitive costs for direct transmission lines to EU
RE Regulatory & Policy Framework	• Due to the publicly owned and integrated utility, RE targets can be implemented directly no need for regulatory framework	• No private investments in RE deployment and civil society engagements possible • No formal official regulatory and support framework in place	• The dismissal of Gaddafi and his system "Jamahiriya" have opened up space for a new regulatory framework to be determined by a new legitimized government	• The dismissal of Gaddafi and his system "Jamahiriya" have opened up space for a further destabilization of the country with huge political conflicts that might deter a new policy formulation
Institutional Framework for RES deployment	• The public utility GECOL is responsible for project development, financing, connecting to the grid and maintenance of RE sites • The Renewable Energy Authority of Libya REAoL is responsible for mapping RE potential, implementing RE targets and projects, industry and policy advice	• Currently, non-operative institutions due to the civil unrest • Very weak integration and participation of Libya in international agreements • Lack of experience with RE support and projects • Concern about corruption in the electricity sector	• REAoL might introduce PPAs to promote RE deployment in a larger scale to reach RE targets • A new government might strengthen Libya`s effort to join and actively take part in international agreements to build up trust for potential project developers	• A new government might keep up following the fossil fuel path, neglecting RE institutions
Financial risks and uncertainty	• Bilateral RE agreements between governments can be implemented directly due to the not liberalized and integrated electricity sector selling prices (RE electricity export prices) could be agreed on in advance • Positive current account balance (but diminishing)	• These high level RE agreements would be strongly dependent on political decisions • Unfavorable business climate (rank 187 of 189 in World Bank's Ease of doing business ranking in April 2014)[73] low rate of FDI and high financial costs • Grid connection costs have to be borne	• The political situation might stabilize and a legitimized government might take over	• The political situation might destabilize even further

73 See World Bank 2014: http://www.doingbusiness.org/rankings

	• Low total gross external debt (5.9% of GDP)	by investor • Land ownership is unclear in regions where government has no or weak control • Continuity of economic policy broken down since civil war • Uncertainty about the EU post 2020 regime reduces the attractiveness of RES imports from Libya (Uncertainty about the RES electricity European demand)		
Investment facilitation		• No private investments in the electricity market are allowed at the moment • Under-developed banking sector • Low foreign investment	• A new political and regulatory framework might include market opening and investment facilitation in RE projects • International oil companies with RE know-how willing to invest in Libya could be asked to invest parallel in RE deployment (as they already do in the UAE and Saudi Arabia)[74]	• Renationalization strategies of specific political groups • Path dependencies and bureaucracy in governmental agencies in favor of the gas and oil industry
RES capacity/ potential/ Available Technology Options	• Large deserts not densely populated • Solar irradiation of 7.5 kWh/m2/day with 3000 -3500h of sun per year • Average wind speed is 6-7.5 m/s[75] • A first 14 MW ground-mounted PV plant under the CDM framework is due to start operating in 2014 near the city of Hun (Al-Jofra) • A 60 MW wind farm at Dernah is under construction	• Almost no installed solar and wind capacity • Low experience with the integration of high shares of fluctuating RE sources into the grid • Maintenance costs and limited technical knowledge in remote areas can be barriers	• CSP could be a highly valuable technology as it can provide flexible electricity on demand to the European market • In the longer term PV and wind with meshed grids might also be suitable	• PV becomes the preferred option as it is currently more economically attractive, but less suitable for export (inflexible)
Public awareness/ acceptance		• Extremely high subsidized electricity prices in the past and large domestic fossil resources do not support the perception of the need for RE deployment • Low awareness and information about RE technologies among policy-makers	• International cooperation might increase acceptance if exporter country benefits (including positive externalities associated to RES deployment) reach large parts of the population and are communicated	• RE might be seen as a threat to the established conventional sources and low energy prices, thus causing opposition • If benefits associated to exports do not reach local populations (and only benefit a small fraction of the population), public

74 See http://www.geopoliticalmonitor.com/is-libyas-energy-future-green-4800/
75 http://www.uneca.org/publications/renewable-energy-sector-north-africa-1

		• Some public opposition reported as there is low knowledge about RE compared to the conventional sources	• Domestic RES deployment could save gas and oil for domestic use, thus expanding the period of possible gas and oil exports and generation of income • If social safeguards are put in place for RES exports, social acceptance both in Libya as well as in Europe might increase	acceptance might be jeopardized
Environmental effects	• In almost all of the impact categories CSP plants perform better than oil and gas technologies	• Water scarcity • In some impacts categories such as human toxicity, ionizing radiation, fresh water toxicity and eutrophication and resource depletion, natural gas power plants perform better than CSP plants	• Average environmental impacts of the electricity mix per kWh are reduced (in almost all the categories) in future scenarios due to the penetration of renewable technologies and the gradual substitution of natural gas and oil plants	• Water reserves for cooling and cleaning CSP plants might be a limiting factor (if not dry cooled systems) • Environmental impacts of CSP exports have a significant share of the total environmental impacts of the electricity generation sector in many of the impact categories
Social effects		• Regional tribes and informal land acquisition structures might conflict with centralized planning of RE sites • Limited human capital and industrial development to be able to capture all potential socio-economic benefits associated to RES exports	• Job creation • RES deployment for exports might create synergies with national RES deployment and the associated socio-economic and environmental benefits • If social safeguards (similar to Gold Standard) are put in place for RES exports, RES deployment for exports might lead to local benefits for rural communities	• Job losses due to reduction of subsidies in fossil-fuel industry • Low local content share which could arise from the current situation might limit the socio-economic benefits (job creation and economic activity stimulation in a wide range of sectors) associated to RES deployment

2.7.2.5. SWOT Analysis Egypt

	Strengths (current)	**Weaknesses (current)**	**Opportunities (future)**	**Threats (future)**
Energy System strategy and energy outlook	• Ambitious target of 20% RE in electricity production until 2020 provides a stimulating environment also for export projects • Energy diversification strategy since 1980ies already experienced in wind, hydropower and solar electricity installations	• Power outages due to grid instability • Water scarcity • RE targets include a private investment share of 67% • Rapid growth of electricity demand decreases the attractiveness to export • Subsidies on fossil fuel use	• Insufficient generation capacity and very high increase in electricity demand[76] might call for international cooperation • Depleting national resources and subsidy reduction on fossil fuels might push for RE deployment	• The RE energy strategy was approved by the former government and thus might change depending of the future energy policy preferences of the governing parties • New potential explorations of unconventional gas might slow down the push for renewables
RES Industry development	• Already some experience in installation, grid access and maintenance of wind sites in cooperation with international companies • Several local supply-chain manufacturers in the wind, PV and CSP sector (e. mirror industry)	• Infrastructure, knowledge and expertise for maintenance in remote areas might not be present • Subsidies on fossil fuels are barrier for local RE industry offtake	• National targets, training centers and civil society activation might push for a development of a domestic RE industry including manufactures and project implementation companies • Possible creation of jobs in the Egyptian glass industry after building up know-how in the production of components for CSP plants • Energy subsidy reform might make domestic RE sector more competitive	• Decreasing world market prices and lack of import restrictions (or local content obligations) might deter the development of RE component manufacturing capacities • International, experienced companies might be able to implement targets more cost-efficient (including easier access to investment capital)
Energy security	• Low diversity in the power generation mix; mainly natural gas and oil fueled power plants and some hydro (Aswan Dam) and little wind power motivation to reduce dependency on by trend depleting fossil resources		• A more interconnected market of Europe and North Africa might increase system stability (in Europe and exporter country) and could even trigger more cooperation in other areas • RE imports from Egypt to Europe would actually lower the risks of an outage due to more diversification and increased interconnection	• A more interconnected electricity market between Europe and North Africa increases the complexity and challenges for grid operation • Further interdependencies between Egypt and Europe might affect political relations, but coercion is not likely as possible income losses of exporter country exceed damages in European importer country due to available back-up generation capacities • Terrorist attacks on infrastructure might

76 See D3.2.2: DLR 2013 "*Demand Development Scenarios*" of the BETTER project

				occur as single events but only pose a more severe threat when coordinated across the region
Market structure of energy system	• Formally unbundled and liberalized (IPPs are allowed and operate under BOOT regime to the single buyer EETC) • Third party access to the grid can be agreed on with the grid operator	• The formerly vertical integrated public utility is still merged under the umbrella of a public holding under the supervision of the ministry • Power market is rather unregulated	• Further opening of the market through tenders and IPPs (due to a lack of public investment resources) • Direct agreements with public holding on export projects • An independent grid operator might ensure guaranteed third party access to the grid	• Lack of public investment due to socio-economic crisis and lack of private investment due to instability
Grid and Interconnections	• 180 MW capacity interconnection to Libya (synchronous connection to the Libyan grid) • 450 MW capacity (400 kV) interconnection to Jordan • High general and rural electrification rates	• No interconnection to Europe • Grid instability in some regions • Merchant power lines are not allowed • Private access to interconnectors not clearly regulated	• Potential interconnection to Europe via Libya and Tunisia	• Prohibitive costs for direct transmission lines to EU • Potential HVDC on-land connection to Turkey is in discussion but unlikely in the near term due to regional instability and armed conflicts • Persisting grid instability due to rapid and highly volatile demand
RE Regulatory & Policy Framework	• Tenders and BOO or BOOT regimes are the main tools for RE deployment	• No private direct proposals for RES-E installations are currently allowed • Lengthy public bidding process • No system for Guarantees of Origin for RES-E	• FiTs are foreseen in the planned new energy law and might stimulate private RE and network investments	• Instable political situation could deter implementation of policies
Institutional Framework for RES deployment	• NREA has already gathered experience and expertise in RE installations • Research and cooperation institutes providing knowledge and support are based in Egypt like RCREEE	• Main institution to control and plan energy market developments is the governmental Supreme Energy Council (SEC) together with the Egyptian Electricity Holding Company (EEHC) ⍰ no independent regulator (except EgyptERA that is the technical regulator)	• The role of EgyptERA could be strengthened towards energy market development including tariff setting etc. and EgyptERA could work as an independent regulator ensuring Third Party Access and facilitating cooperation projects	• Political instability could produce also institutional instability
Financial risks and uncertainty	• Tendering schemes for specific RE projects reduce financial risks • RE financing has already been successfully done via CDM, international carbon funds and development aid	• Grid connection costs have to be borne by RE project owner and grid usage is financed by a fee to the grid operator • Delays and drawbacks in project implementation (e.g. Kom Ombo CSP	• Green climate fund or other international carbon financing might increase experiences with RE financing and decrease risk and uncertainty related barriers	• Downgrading of Egypt in risk and investment security indices might deter investors because of restrictions in own regulations (banks, pension funds, etc.)

	• RE Fund, supported with USD 50 Million from the Clean Technology Fund • High rating in Arab Future Energy Index (3rd of 13 countries)	project) and administrative uncertainty due to internal turmoil • General country risk is high (6 in OECD index)[77] • Increasingly negative current account balance (higher % of GDP) • Uncertainty about the EU post 2020 regime reduces the attractiveness of RES imports from Egypt (Uncertainty about the RES electricity European demand)	• Framing big RE pilot projects as development projects could help to get (multilateral) institutional donors on board (e.g. Worldbank and IBRD in planned CSP plants at Kom Ombo and Kureimat) • Improvement of balance of payments due to CSP exports	
Investment facilitation	• Land acquisition is taken care of by authorities (7,600 square kilometers, allocated to date for wind) • No custom duties and VAT on RE components • Extended investment protection regulations and incentives to invest for foreign companies • UfM member, ENP partner • Full foreign ownership is allowed in the electricity sector • Well developed banking sector	• Delays and drawbacks of policy implementation and administrative uncertainty due to internal turmoil • Low foreign investment after uprising	• Democratization and civil society activation within the Arab Spring movements might stimulate positive investment climate in the long term	• Governance instability might deter foreign investors to invest
RES capacity/ potential/ Available Technology Options	• Large deserts not densely populated • Potential of >20,000 MW of wind capacity • Highest wind capacity in the region with several hundred MW installed • Solar irradiation level of 5.5 to 8.8 kWh/m2/day[78]	• Knowledge and expertise for maintenance in remote areas might not be present	• 7,600 square kilometers for RE deployment and the implementation of national targets might lead to cost-reductions and technology development (including increasing number of skilled and trained staff) to increase economic potential • CSP could be a highly valuable technology as it can provide flexible electricity on demand to the European market • In the longer term PV and wind with	• Delays in foreign and national investments might increase costs for new projects due to insufficient technology and trained worker supply at the local level • PV becomes the preferred option as it is currently more economically attractive, but less suitable for export (inflexible) Government announcement in April 2014 to invest 1 bn US-Dollar in (mostly rooftop) PV[79]

77 See OECD 2013: http://www.oecd.org/tad/xcred/crc.htm
78 http://www.uneca.org/publications/renewable-energy-sector-north-africa-1
79 http://www.eversheds.com/global/en/what/articles/index.page?ArticleID=en/Energy/Egyptian_government_invest_in_solar_energy_projects_140521

			meshed grids might also be suitable • Synergy effects when combining RES-E plants with seawater desalination	
Public awareness/ acceptance	• RE technologies (especially wind) are generally accepted as there have been early actions and thus experiences already exist • Egyptian Government seeks to attract FDI in RE sector	• Due to the electricity crisis in Egypt international cooperation for export of RES-E is currently not very high on the political agenda • Awareness of RES-E other than wind is not widespread	• Civil society activation might lead to aspirations for more decentralized, more private engagements in energy projects in in the long-term • International cooperation might increase acceptance if exporter country benefits (including positive externalities associated to RES deployment) reach large parts of the population and are communicated	• Political acceptability of small-scale RES-E deployment might be harmed due to centraliztic ideologies of specific policy-makers ⍰ neo-patrimonial aspirations • Resistance by industry and residents against lifting of energy subsidies • If benefits associated to exports do not reach local populations (and only benefit a small fraction of the population), public acceptance might be jeopardized
Environmental effects	• Egypt has strict environmental regulations on ESIA's in conjunction with large infrastructure projects and each ESIA undertaken needs formal approval by the Egyptian Environmental Affairs Agency (EEAA) • In almost all of the impact categories CSP plants perform better than oil and gas technologies	• Water scarcity • In some impacts categories such as human toxicity, ionizing radiation, fresh water toxicity and eutrophication and resource depletion, natural gas power plants perform better than CSP plants	• Average environmental impacts of the electricity mix per kWh are reduced (with the exceptions shown before) in future scenarios due to the penetration of renewable technologies and the gradual substitution of natural gas and oil plants	• Water reserves for cooling and cleaning CSP plants might be a limiting factor (if not dry cooled systems) • Environmental impacts of CSP exports have a significant share of the total environmental impacts of the electricity generation sector in some impacts categories
Social effects	• Technical jobs and vocational training are relatively fast available for local workers	• Land allocation conflicts in the past • Welfare losses in touristic areas due to landscape damages • Further training, expertise as well as RES industrial development are needed to capture the socio-economic benefits of RES deployment associated to large shares of local content	• RES deployment for exports might create synergies with national RES deployment and the associated socio-economic and environmental benefits • If social safeguards (similar to Gold Standard) are put in place for RES exports, that might lead to local benefits for rural communities	• More transmission capacity to Europe may increase average domestic electricity price level and cause resistance • Job losses due to reduction of subsidies in fossil-fuel industry • Bounded (medium) local content shares might limit the socio-economic benefits (job creation and economic activity stimulation in a wide range of sectors) associated to RES deployment

2.7.3 SWOT SUMMARY

2.7.3.1. Energy System strategy and energy outlook

As a favorable political framework and a specific energy outlook are necessary conditions for public and private investments in the RE facilities, most of the stakeholders pointed to the ambitious plans for RE deployment in all North African countries. Especially the investment needs due to old inefficient capacities and a fast growing electricity demand are seen as pivotal drivers for new RE capacities and thus can be perceived as an opportunity to follow the RE path. Especially Morocco, Tunisia and to some extent also Egypt could significantly lower their public spending for imported fossil fuels when deploying large amounts of RE production facilities. If this opportunity might also lead to exports of RE electricity to Europe strongly depends on the energy strategy of the respective government. Experiences made with projects for domestic supply might form a valuable base for later exports, both technically and from an institutional capacity building point of view. Moreover, large-scale deployment of domestic RES-E might lower the overall costs for installing additional capacities and therefore increase the comparative cost advantage. For gas and oil exporting countries as Algeria and Libya, domestic renewable build-up could save fossil fuels and thus extend the period of high world market price exports of those fuels.

2.7.3.2. RES Industry development

An important argument for North African policy makers for supporting renewables are expected socio-economic benefits due to an RE Industry development. Up till now only limited RE manufacturing and O&M capacities exist especially in rural areas but might be established when suitable measures are implemented like the facilitation of licensing, joint ventures, research exchange and local content obligations. These measures might be hampered as free trade agreements and world market prices of RE components might deter the development of a local RE industry. Still, RE connected services and local value added might still have a positive effect on local jobs and income.

2.7.3.3. Energy security

A possible future interconnected electricity market bears security concerns on both exporter and importer country side. Thus new regulation mechanisms and joint institutions are needed to meet the additional technical and economical complexity, to secure security of supply and avoid manipulations. The use of export electricity as an 'energy weapon' by NA countries is not likely as possible income losses exceed the damages in European importer countries due to the available back-up generation capacities. The energy security assessment (opportunities and threats) was based on the ENERGEO scenario developed and used by DLR. For the conceptualization of vulnerability of electricity imports from North Africa to Europe related to terror attacks see Lilliestam 2013 (Deliverable 3.4 of the BETTER project). For a conceptualization of political impacts of interdependence due to RE electricity imports between Europe and North African countries see Lilliestam and Ellenbeck 2011.

2.7.3.4. Market structure of energy system

The (non-) market structure of the energy sectors in North African countries does not play a clear–cut role for the prospects of energy cooperation projects with Europe. All North African countries energy systems are characterized by a very strong role of the state – be it publicly owned companies in the energy sector as in Algeria with a formerly regulated market or be it the single public buyer with private IPPs as in Morocco. Whether this state dominated scheme is a threat or an opportunity to possible cooperation projects depends on the ideological and pragmatically perspective taken. Cooperation projects agreed on directly with NA governments and public institutions might be a viable way to circumvent some internal risks, investments, governance and regulation challenges but lowers European investments opportunities and a transparent implementation from an European perspective. This might be critical especially in regard to monitor social and ecological safeguards, but on the other hand might deter perceptions of neo-colonialism. In contrast to that when a liberalized unbundled market approach is followed private investments could be made but would need public support schemes and a regulated and open market. Depending on the capital available by the state and by private actors and their willingness to invest in RE facilities both ways could offer cooperation possibilities.

2.7.3.5 Grid and Interconnections

Until now only one direct transmission line between North-Africa and Europe exists between Morocco and Spain, mainly used to export electricity from Spain to Morocco due to solar overcapacities in Spain and a growing demand in Morocco. In between the North African countries only weak connections exist and national grid development is currently mostly not adjusted to the challenges posed by the integration of large amounts of renewable energy into the system. Intra-regional electricity trade in NA could help establishing a robust electricity network which could also be used for exports. Although some connections between Italy and Tunisia and Libya were planned, no further steps have been taken so far and no common grid regulation is in place. Building new connections between NA and Europe would also bear the risk of carbon leakage by exporting electricity from fossil fuels from the EU to NA and importing RE electricity from NA to the EU via these new transmission lines.

2.7.3.6. RE Regulatory & Policy Framework

All NA countries do have some kind of policy, strategy or support scheme to foster RE deployment in place. But to effectively deploy these clean technologies, dedicated legislation, regulation, institutions and financing is needed. Many countries still face big implementation deficits. Not least, these stem from strong dependencies on the fossil fuel path existing in net oil/gas exporting countries like Algeria or Libya. Here, due to the interdependencies of the traditional oil and gas industry and the supporting governmental institutions together with consumers used to heavily subsidized low energy prices, (informal) barriers to RES-E deployment appear to be comparably high. Governance structures and a lack of knowledge were reported to inhibit the full exploitation of support schemes in some countries but some institutions for knowledge generation and RE capacity development were created in the last years.

2.7.3.7. Institutional Framework for RES deployment

Several institutions for training and capacity building in the RE sector are in place in all countries but with different mandates and expertise. Some stakeholders also reported confusion about different roles and responsibilities of the different institutions and authorities. A clear mandate and responsibilities are mostly lacking. Especially in Egypt and Libya the governance structure and functioning of public intuitions is also limited due to instable political developments.

2.7.3.8. Financial risks and uncertainty

Stakeholders of all NA countries reported difficulties in assessing risks and procedural barriers due to non-transparent governance and bureaucracy structures although to different extent in the countries. For foreign investors this uncertainty is seen to prohibitively high when public and political support is lacking. Measures to circumvent risks due to bureaucracy are high-level political agreements and support by local stakeholders. Nevertheless until now, mostly public or semi-public institutions invested directly in RE facilities (e.g. in the Ouarzarzate project in Morrocco). An exception to this are tenders where a clear assignment is agreed on also with foreign companies. With specific look on the export framework, there is currently a wide regulatory gap producing uncertainty for investors in most project host countries and on EU side. Closing this gap in terms of grid and interconnector access, capacity allocation rules, traceability of green electricity, etc. could reduce risk premiums for export projects and thus raise the economic attractiveness of such projects. A 'Trans-CSP'-concept as proposed by DLR in this report could also circumvent some of these risks as it would establish a parallel grid structure but would bring its own risks which were not considered here

2.7.3.9. Investment facilitation

In Egypt, Morocco and Tunisia some measures to facilitate foreign investments in RE facilities exists but as no open, unbundled and regulated market for electricity exits in these countries investments are mostly restricted to tenders and clear assignments of private companies by public authorities. Only the possibility to generate RE electricity as IPP, e.g. in a Build Operate and Transfer-regime (BOT), may attract private investors until now in cases when electricity prices agreed on with the buyer are sufficiently high. New investment schemes as currently tested in Morocco might trigger further development of investment facilitation strategies that lower risks and give transparent business opportunities. In the long-term reducing bureaucracy, raising transparency of permission processes/access to RES-E support, and fighting corruption would also lower investment barriers and could also effectively facilitate foreign engagement.

2.7.3.10. RES capacity/potential/ Available Technology Options

For most regions in North Africa extensive RE potential assessments exist or are currently carried out. In Morocco, Algeria and Egypt very good wind sites are present and in all countries solar irradiation is very good. In some areas land use conflicts with touristic, agriculture or nomadic uses are possible but in general comparatively unlikely. The technical potential is in some regions restricted by transmission and grid weaknesses and lacking grid extensions.

2.7.3.11. Public awareness/acceptance

Until today only very few public acceptance problems have been reported towards renewable energy projects in NA. In Algeria and Libya political acceptance of RE policies might be an issue as interdependencies and path dependencies with the gas and oil industry exists. The export option has not yet been implemented so far so that possible future acceptance problems can be hardly predicted but the promotion of RES-E deployment for domestic use might raise public acceptance for exports. Clear benefits for local communities from RES-E projects are likely to generate a supportive environment, starting from renting or selling the project land, job creation, over project co-ownership to the dedication of taxes derived from the project to the local (social) infrastructure. Projects should be accompanied with transparent participation processes in local communities. The participation of NGOs in project planning could also raise acceptance. In the long-term, if large scale RE deployment comes alongside with liberalization and lower subsidies and thus higher electricity prices political acceptance might be hampered.

2.7.3.12. Environmental effects

Environmental effects are directly dependent on the specific technology deployed, the siting and the size of a project. Thus, only parameters that might stress or ease impacts of RE deployment can be mentioned here. For a comprehensive overview of possible environmental impacts of RE installations see Annex 1 of D2.5 of the BETTER project (Caldés, Rodríguez, de la Rúa, López-Dóriga and Lilliestam 2013: Indicators and Methodologies to Assess Key Issues for the Implementation of the Cooperation Mechanism.) Environmental concerns could be met with site-specific Environmental Impact Assessments (EIA), ensuring the identification of environmental issues and proposing measures to minimize the environmental consequences of the proposed project or plan. Central here are the investigation and implementation of long-term solutions for the large water use of CSP and PV projects in desert areas (cooling, cleaning), e.g. through application of seawater desalination, dry cooling (Heller) towers and advanced cleaning procedures. Up to date regional climate projections should also be considered when estimating water availability. It is important that social and environmental regulation is streamlined over the entire region, otherwise a 'a race to the bottom' in standards to attract investors might be the consequence.

2.7.3.13. Social effects

To meet fears regarding higher electricity prices, social safeguard programs attached to RES-E export projects, energy subsidy reductions and RES-E support programs might help reducing the burden for the poorer part of society in host countries and guarantee that fundamental human rights are met. Dedicated policies and measures such as local content obligations and small scale RE deployment are pivotal to generate the expected positive socio-economic effects. Further training, capacity transfers as well as RES industrial development are needed to capture these welfare effects. In the long-term large shares of RE electricity can ensure low energy prices and lower public spending for fossil fuels (either through substitution of costly imports as in Morocco, Tunisia and Egypt or by savings for high price exports as in Algeria and Libya).

2.7.4 SWOT Conclusion

As a result of the stakeholder input to the SWOT analysis several conclusions can be drawn.

First of all, a country specific approach is needed. Although some conditions and factors are valid for all five NA countries, most issues are country specific and possible cooperation opportunities have to be adjusted to the national context. Especially a distinction between energy importer and exporter countries has to be made as the political and economical context for RE investments differs significantly. But also depending on specific barriers and challenges decisions about technology and knowledge transfer, development cooperation projects, investment supports etc. have to be complementary to the national context. European approaches to foster cooperation projects should thus take this country specific perspective into account.

Secondly, at least two different approaches to generate investments in RE facilities in NA could be identified and these two ways have to be explicitly differentiated from each other. Either a public, governmental actor's driven approach is followed or the liberalized market and private investment approach. Both ways could lead to investments but are attached to different strategies, policies and measures. For the short time-frame a public investment approach seems to be more realistic whilst in the long-term the liberalization of North African energy sectors might be possible, depending on the specific national political preferences and developments.

Thirdly, this SWOT analysis only looked at exporter country conditions and thus left the European dimension of cooperation projects out. This is of course a major constraint as North African stakeholders reported that the lacking of demand for RE electricity in the EU is currently one of the most important barriers to cooperation.

Fourthly, social and political acceptance of possible policies and projects are seen to be crucial for a successful implementation of cooperation projects. Especially the satisfaction of domestic demand is seen to be a necessary condition for the political and social acceptance for exports. Thus, also RE investments for domestic use can be seen as a way towards possible exports at a later stage.

3. Prospects for renewable energy exports from NA to EU

In the past years there have been a significant number of activities related to RES-E exports from North Africa to Europe via High Voltage Direct Current (HVDC) on a theoretical level, but no practical implementation has been achieved in any concrete project so far. The idea was presented to the European Parliament for the first time by the Trans-Mediterranean Renewable Energy Cooperation (TREC) in November 2007, based on the analysis of DLR and partners from Europe, North Africa and the Middle East in the frame of the study TRANS-CSP (2006).

After that event in late 2007, significant attention was given to the option of RES-E imports from NA to EU, resulting in a number of policy initiatives like the Mediterranean Solar Plan (MSP) launched in 2008 (UfM 2011), the European project Paving the Way for the Mediterranean Solar Plan PWMSP (2010), the German North African Energy Partnerships BMWi (2012) and BMWI (2013), and industrial initiatives like DESERTEC (2009), Dii (2013) and Medgrid (2010) to mention only a few, while the European Commission has put in place several articles to regulate such cooperation with third countries in the frame of the fourth cooperation mechanism which is the objective of the BETTER project at hand (EC 2009, EC 2013a, EC 2013b).

The TRANS-CSP scenarios have been developed on the basis of a set of pre-defined sustainability criteria that must be achieved in the model without compromise, in order to lead to the target of sustainability (Table 30). This has been described in more detail in D3.2.1 of the BETTER project. The criteria do not represent sharp, quantified values, but rather qualitative indicators. However, we have introduced values that define the goals of sustainability of the target function (e.g. energy cost level of the year 2000, carbon emissions of 1 ton/capita/year, firm capacity of 125% of peak load, etc.).

Interpreting the political focal points resulting from that study from Table 31 in a superficial way, one could understand that wind and solar power might be gathered in NA at a lower cost than in EU, and in spite of the need of a "supergrid" to interconnect both regions, it would be cheaper than tapping less abundant European sources. This rather common point of view contains however a series of misunderstandings:

1. European RES-E from wind power and PV have experienced significant cost reduction and are particularly cost-effective today. This has lately eliminated the argument of "cheaper" RES-E from North Africa, because possible profit margins with respect to domestic production have become too small to finance a transport to the EU.

2. TRANS-CSP study details reveal that the "best" RES-E are not necessarily the cheapest, but a well-balanced mix of cheap, but volatile sources like wind and PV power and more expensive, but flexible sources like biomass (BIO), hydropower (HYDRO), geothermal power (GEO) and concentrating solar thermal power (CSP). RES-E sources can be distinguished by the storability of their primary energy source (**Fehler! Verweisquelle konnte nicht gefunden werden.**). If the primary energy source cannot be stored easily, surplus electricity will have to be produced and stored in order to provide power on demand. E.g., while photons cannot be stored, directly producing electricity in a PV cell, high temperature heat from a concentrating

solar thermal collector field can easily be stored, enabling a CSP plant with heat storage to produce electricity on demand just like a coal-fired power station.

3. According to TRANS-CSP, RES-E exports/imports are not "technology-open", but are restricted to high quality electricity capable of producing power on demand with firm capacity whenever required, in order to complement volatile domestic European RES-E sources and to justify the large effort for transport. This clearly limits exports from North Africa to CSP, while hydropower imports from Norway and Iceland may also be considered as possible source of flexible power. It is not an option to import wind or PV power from North Africa because e.g. importing PV power from Tunisia to Italy would simply add to the local PV production peaks in summer and increase surplus and the need for electricity storage in Italy, thus not creating any business case but on the contrary, an additional problem.

4. An HVDC "Supergrid" is a long-term option that cannot yet be realized today, because state-of-the art HVDC technology is not yet ready to be interconnected in form of a loop or grid (van Hertem 2010). The TRANS-CSP concept therefore starts with simple point-to-point HVDC links (electricity highways) that connect very good CSP production sites in North Africa to large centers of demand in Europe. In the beginning, each center of demand would be the only point of interconnection of the HVDC links to the existing AC grid, just as if the CSP plant itself would be virtually placed at that site in Europe, but performing with high Northern African availability of solar power, which can be up to 8000 hours per year (Trieb et al. 2009). Using e.g. former sites of decommissioned nuclear or coal plants in Europe to connect the CSP-HVDC links, an adequate grid infrastructure for distributing the large amounts of solar electricity to the consumers would already be in place, avoiding the need for any further expansion of the grid or storage, as solar power will be generated on demand.

5. TRANS-CSP predicts that fossil-fuel fired base-load plants will subsequently disappear because of low utilization when introducing RES-E. Ideally stored fossil fuels will be used in the long-term exclusively for very high value, flexible backup power supply. This means that a well-balanced mix of RES-E will also have to take over grid services formerly provided by fossil-fuel-fired base load plants, like firm capacity, black start capacity, spinning reserve, secondary reserve capacity, reactive power, balancing power, etc. This will be the task of flexible RES-E like BIO, GEO, HYDRO and CSP plants. If not available locally, those electricity sources may be imported from the distance via point-to-point HVDC links, if the related effort is justified by their high value.

Since 2009, China has installed ten point-to-point HVDC links over about 2000 km distance each, with a total 30 GW of capacity, aiming to finalize 270 GW by 2020 (Retzmann 2013). For comparison, the total HVDC capacity scheduled in the original TRANS-CSP scenario for Europe until 2050 was only 100 GW, aiming to provide 15-20% of the annual European electricity demand.

Chapter 3.1 explains the presently existing framework for RES-E exports from North Africa to Europe and the reasons for the unsucessful development of the past years since 2009. Chapter 3.2 then describes the requirements that are needed to overcome present stagnation. Chapter 3.3 highlights the role of RES-E imports from the European, German and regional perspective of the Federal State of Baden-Württemberg, which is considered one of the motors of economy in Europe. Chapter 3.4 provides a first rough technical and economic picture of a CSP-HVDC import scheme from Morocco to Central Europe. Chapter 4 provides a socio-economic and environmental impüact assessment of such infrastructures. The report concludes with the role of Article 9 and other mechanisms of RES-E expansion in Chapter 5.

Table 30: Sustainability criteria applied for the target function of the TRANS-CSP scenarios

1. **Affordability**
   - Low cost
   - Low subsidies
   - Low structural effort
2. **Security**
   - Diversification of supply
   - Power on demand and redundancy
   - Sustainable energy resources
   - Available technology
3. **Environmental compatibility**
   - Low pollution, climate protection
   - Low risks for health and nature
   - Low land use and structural impacts
4. **Social compatibility**
   - Fair access to energy
   - Balance of dependencies and interdependencies
   - Flexibility during transition
   - Unproblematic replication

Table 31: Energy policy focal points as recommended by the TRANS-CSP study in the frame of a presentation of results to the European Parliament in Brussels, November 2007 and a publication from Trieb and Müller-Steinhagen (2007).

Five Focal Points for Sustainable Energy Policy

The timely realization of a scenario that meets all criteria of sustainability will require determined political support and action. Five focal points for national and international policy for all countries in Europe, the Middle East and North Africa (EUMENA) result from our studies:

1. **Increase support for research and development and for the market introduction of measures for efficient supply, distribution and use of energy (*efficiency focus*).**
2. **Increase support for research and development and provide a reliable framework for the market introduction of renewable energy technologies based on best practice experience (*renewable energy focus*).**
3. **Initiate a EUMENA-wide partnership for sustainable energy. Provide European support to accelerate renewable energy use in MENA (*interregional cooperation focus*).**
4. **Initiate planning and evaluation of a EUMENA High Voltage Direct Current super-grid to combine the best renewable energy sources in this region and to increase diversity and redundancy of supply (*interconnection focus*).**
5. **Support research and development for shifting the use of fossil fuels from bulk electricity supply to a source of balancing power for volatile renewable sources, including necessary structural changes (*balancing power focus*).**

3.1. EXISTING FRAMEWORK CONDITIONS FOR RES-E EXPORTS

The basic idea of RES-E exports from North Africa to Europe was developed since 2003 by an international network of politicians, academics and economists, the Trans-Mediterranean Renewable Energy Cooperation (TREC). The ground laying studies - MED-CSP 2005, TRANS-CSP 2006 and AQUA-CSP 2007 - were led by the German Aerospace Centre (DLR) with participants from Morocco (CDER), Algeria (NEAL), Libya (CSES), Egypt (NREA), Jordan (NERC) and Yemen (Universities of Sana'a and Aden). The results of the studies as well as proposals for action regarding RES-E implementation in the EU-MENA region (Europe, Middle East and North Africa) were summarized in a White Book, which was presented to the European Parliament in November 2007 by HRH Prince El Hassan bin Talal (Trieb and Müller-Steinhagen (2007).

The idea found its way into the concept of the Mediterranean Solar Plan (MSP) of the Union for the Mediterranean (2008) and got a strong push forward with the foundation of the DESERTEC Foundation (DF) and the DESERTEC Industrial Initiative (later Dii GmbH) in 2009 (DF 2014 and Dii 2014). Those were followed by several other initiatives like Transgreen and later MedGrid in 2010. As mentioned before, the Moroccan Renewable Energy Law from 2009 includes the option of RES-E exports to Europe, also considering the construction of the necessary transmission lines that should be physically separated and independent from the national grid infrastructure. In 2011, Algeria launched its Renewable Energy and Efficiency Program that includes 10 GW of RES-E capacity scheduled for export to Europe. Also in 2009, the RES-Directive 2009/28/EC was published, who's Article 9 about the 4th cooperation mechanism is subject to our analysis at hand within the BETTER project. No projects have been realized under this framework up to now.

Current post-2020 EU policy and targets do not provide much incentive for RES-E imports. As has been stated e.g. by The Economist (2013), Europe might “not really want North African solar power at the moment, with infrastructure costs, an unstable regional security situation, an improved business environment for European solar production and a net decrease in European energy demand all being contributing factors.” These would in fact be serious arguments against RES-E imports from North Africa, if the only point speaking for them would be a lower cost of production than in Europe. Recent cost reductions of domestic RES-E in Europe have been quite promising and the added risks related to such imports would easily justify a slightly higher cost of domestic production, reducing dependency on foreign supply. However, as has been described before, the true reason for such long-distance transfer is not a low cost, but the high quality of flexible CSP, which is similar to that of power from fossil fuels but stemming from a very large, renewable and distant source: solar energy in the desert. This fundamental – and probably the only good – reason for solar electricity imports from NA to Europe has not been recognized yet, even more than one decade after its publication by TREC.

This is particularly surprising when comparing the original TRANS-CSP concept with the “Supergrid” concept that has been pursued in the past years by several industrial, scientific and also political organizations in Europe (**Table 32**). The value of “surplus” import electricity peaks from North African wind and PV plants that would have to be compensated by flexible European sources would clearly be inferior to that of flexible power from CSP that would even be able to compensate the fluctuating

European sources, and the transmission via dedicated point-to-point HVDC links would clearly be advantageous over a continental grid expansion in terms of transfer bottlenecks, source traceability and structural effort for an expansion of grid and storage capacity.

Table 32: Comparison of TRANS-CSP (2006) and the Supergrid concept (Dii 2012, PWC 2010)

TRANS-CSP Concept	**"Supergrid" Concept**
flexible solar power on demand from dedicated CSP plants in NA with thermal energy storage	surplus from technology-open production from wind, PV and CSP in NA
transport of flexible power via point-to-point HVDC lines to the European centres of demand with the purpose to compensate local fluctuations from variable RES-E	transport via "super-grid", a combined AC-DC high voltage grid and storage infrastructure that is supposed to be able to compensate all fluctuations from variable RES-E input
full traceability and physical accountability of CSP generated on demand in the EU	no traceability or physical accountability of fluctuating RES-E from NA in EU
high cost of initial projects but also high quality of flexible energy supply from CSP	low cost but also low quality of energy supply from occasional wind and PV surplus peaks
no transfer bottlenecks due to dedicated HVDC links designed for nominal export capacity	bottlenecks within weak grids in transfer regions like e.g. Andalusia, Southern Spain & Pyrenees
dedicated CSP-HVDC plants for export, in-dependent from national grid and power supply	RES-E plants produce for domestic demand and occasionally provide surplus for export
surplus electricity is avoided by a balanced mix of variable and flexible sources	surplus electricity is stored and distributed through a "supergrid"

By leaving the original TRANS-CSP concept and substituting it by a "Supergrid" vision, the original reasons for solar electricity imports from NA to Europe – flexibility, traceability, physical accountability, quality of supply, additionality to domestic demand in NA, additionality to domestic RES-E production in EU, technical feasibility and structural efficiency – were lost on the way. Moreover, a state-of-the art technology option – point-to-point HVDC links of which 30 GW were commissioned in China in the past five years and over 100 GW are already installed world wide – was substituted by an unclear, un-defined picture of some super-infrastructure under undefined responsibility that to a great extent still would have to be invented in the future. Moreover, new barriers were erected: electricity surplus in NA is not visible in view of strongly growing demand; current technology is not yet ready to form an HVDC grid, but only point-to-point HVDC interconnections; questions remain without answer, like e.g. who would have to extend the regional grid to avoid bottlenecks and who would be in charge of compensating fluctuating imports; if plants produce partially for domestic demand and partially for export, then who would get the power in case of a simultaneous shortage or emergency in both regions?

Among the different applications of HVDC links, there are two related to exports (ABB 2014):

1. The first application of HVDC is **connecting remote power generators to large centres of demand by point-to-point interconnectors**. This is in principle the basis for the TRANS-CSP concept. Such interconnections exist world wide, e.g. in Brasil and China connecting large

hydropower plants to the Megacities, and in the Philippines and New Zealand to bring geothermal and hydropower from one island to the centres of demand on the other. In this case the HVDC transfer capacity is directly related to the production capacity at the starting point and to the net supply capacity at the feed-in point.

2. Another application of HVDC is the **interconnection of AC grids that are separated e.g. by large water bodies**, like e.g. the Baltic Cable in the Northern Sea and the connection of Italy and Greece in the Mediterranean. Several such HVDC links are planned at present to interconnect the electricity grids of Italy and Tunisia, Algeria and Spain, etc. This is an important element of conventional grid expansion and interconnection which is motivated by a better synergetic utilization of power capacity when sharing demand and supply, higher flexibility and compensation effects of demand and RES-E supply. In this case the HVDC capacity is designed to increase the Net Transfer Capacity (NTC) between neighbours in order to allow for a higher capacity to exchange power in both directions.

Unfortunately, during the discussion about RES-E imports from NA to Europe in the past years, these two concepts have been mixed up, resulting in a rather unclear picture of some kind of Supergrid being composed of AC and DC technology somehow approximating a kind of virtual copperplate that would ideally interconnect all countries in EUMENA without any restrictions of power exchange capacity, creating an infrastructure that would be capable of compensating any fluctuations from wind and PV power in the total EU-MENA region. As an example, the Dii in its 2050 roadmap proposes an NTC of 66 GW for Germany towards its neighbours, about 140 GW NTC for France and 160 GW for Spain, being a major transit country (Dii 2012, pp.71). Looking however at realities, todays NTCs are about 9 GW for Germany, around 10 GW for France and 3 GW for Spain (entso-e 2010), meaning that the existing electricity grids in those countries, that already are among the strongest world-wide, would have to be expanded by a factor of 6, 14 and 55 times respectively, in order to achieve the "copperplate" requirements for realizing such scenario. Such an enormous grid expansion would eventually not be desirable in terms of the related technical and economic effort and limited public acceptance.

Another severe drawback of the copperplate assumption is that under such condition, fluctuating capacities from wind and PV can be installed almost without limit, because they are assumed to be completely compensated within the Supergrid. As a consequence, least-cost electricity generation in the related scenarios depends mostly on wind and on photovoltaic energy, while all the other RES-E and fossil fuel options together account for a small rest, resulting in a poor diversification of supply and major dependence on fluctuating sources. Under such a scenario, power from RES-E over-capacity on local level would frequently exceed the actual load by a factor of two or more. It is quite natural that under those conditions, no physical project for RES-E exports from NA to EU has been realized to date. Up to now, the right questions about the design of a favourable political, legal and economical framework have yet not even been asked, because the correct target was not yet set. Although political support for the general idea of RES-E imports was strong from the beginning, the reason for such imports was lost on the way and unnecessary new barriers were erected. Public opinion about RES-E imports from NA to EU today is certainly not better or maybe even worse than in the year 2009, when the RES-Directive 2009/28/EC was released (euractiv 2013, CSP World 2013, Reuters 2014).

The realization of long-distance point-to-point CSP-HVDC links is without doubt a big technical, economic and social challenge, but it is a clear picture that can be brought to reality step-by-step and project-by-project, while the "Supergrid" assumption is a rather un-tangible, diffuse vision of some distant future. Therefore, a major requisite for successfully introducing physical RES-E exports from NA to EU is the correction of the concept to be followed and the beginning of concrete project planning for the first CSP-HVDC links, as will be shown in the following.

3.2. REQUIRED FRAMEWORK CONDITIONS FOR RES-E EXPORTS

3.2.1. Potential Business Case for RES-E Exports/Imports

It is in the nature of import / export that two points of view must be satisfied in order to succeed. A fundamental requisite for the realization of RES-E exports from North Africa to Europe is a convincing argument to do so for both sides. The standard argument for RES-E exports used up to now – an expected lower cost of generation than in Europe - is not sufficient and not even resilient. North Africa would not profit from a strategy that would export its cheapest energy options to other places, while leaving the region behind to cover its own demand with the more expensive ones.

The best reason for the import of electricity like for any other import product is that one doesn't get it nearby, that it has a special quality that is difficult – or expensive – to get from national/regional sources. Such a product should be plentiful in the country of origin in order to avoid social conflicts related to its consumption, and it should be scarce in the country to be imported to in order to avoid market disruptions because of destructively competing with national products, or at least it would be little competitive. It should definitely have an added value on both sides.

Table 33: Quality and availability of RES-E and fossil fuel resources in Europe and North Africa and opportunities for a possible business case for exports from North Africa to Europe

Source	Type	Quality	North Africa	Europe	Business Case
Biomass	renewable	flexible	scarce	available	no
Hydropower	renewable	flexible (lim.)	scarce	available	no
Geothermal	renewable	flexible (lim.)	scarce	scarce	no
CSP	**renewable**	**flexible**	**plentiful**	**scarce**	**yes**
PV	renewable	fluctuating	plentiful	plentiful	no
Wind Power	renewable	fluctuating	available	plentiful	no
Coal / Lignite	fossil	flexible	n.a.	available	no
Natural Gas	fossil	flexible	available	scarce	yes
Mineral Oil	fossil	flexible	available	scarce	yes
Nuclear	unclear	flexible (lim.)	n.a.	available	no

There is e.g. a business case for gas and oil that in fact are exported to Europe from North Africa, while nobody in NA would reasonably think about exporting scarce resources like biomass or hydropower to a place where they are fairly available. When looking for an energy "commodity" that at the same time is renewable, of high quality like fossil fuel, plentiful in North Africa but scarce in Europe, then only CSP remains as natural candidate for exports (**Table 33**).

Certainly two neighbour countries may think about helping each other by increasing the Net Transfer Capacities of their interconnecting electricity grid in order to better cope with fluctuating wind and PV power, compensating fluctuations in both directions. They might achieve this by interconnecting their electricity grids via HVDC links over a sea barrier, like Norway and the Netherlands have recently done. But nobody would invest significant amounts of money in order to just "import" fluctuations from whatsoever source there may be. It becomes clear from the table above, that the only "high quality" sources of energy that North Africa could reasonably offer to Europe for export are fossil fuel and flexible solar power from CSP. North Africa could also offer to export cheaper fluctuating power surplus from its national wind and PV production, but most probably, nobody in Europe would be interested in paying money for that. On the other hand, there is significant interest on both sides of the Mediterranean to interconnect grids, for the reasons and synergies already mentioned above, which is a completely different story and is considered here as business as usual.

Like explained before, the only good reason for physical RES-E exports from North Africa to Europe is a high quality of the product supplied, and the only available source with that high quality is flexible solar power from CSP. Unfortunately, this reason has been completely lost on the way during the discussions of the past years, and must finally be re-established before the two regions will be able to proceed with the 4th cooperation mechanism.

3.2.2 Resilient Concept for RES-E Exports/Imports

Following the arguments shown above, the picture of RES-E exports/imports from NA to Europe achieves a clearer contour: flexible power from CSP plants dedicated specifically to export, generating power just as required by European centres of demand that are directly connected to the CSP production plants via a point-to-point HVDC links.

Figure 39 (top) shows how flexible power generation is usually obtained from ideally stored fossil fuels: firstly, primary energy like coal, oil or gas is obtained by exploiting a natural reservoir, and transported via ship, railway, truck or pipeline over long-distance routes to the power plants that are usually located near the centres of demand. There, electricity is generated just as required by the respective load, and transmitted via AC lines to the next closest feed-in point of the local electricity distribution grid. On the other hand, **Figure 39** (bottom) shows how flexible power generation is obtained from solar energy that is collected in a concentrating solar collector field, then stored via molten-salt thermal energy storage tanks and transported over a short distance to the power block of the CSP plant, where electricity is generated just as required by the load. After that, long-distance HVDC power transmission brings the electricity to a distant centre of demand, where the power is fed into the local electricity distribution grid.

The fossil and the solar systems are completely analogous and provide almost the same quality of supply: power on demand just as required by the load. All other functions are also similar, like spinning reserve, black start capacity, reactive power control, etc. A major difference is that in the case of the fossil supply chain, the transport of primary energy takes place over a long distance and that of electricity over a short distance, while in the CSP supply chain the transport of the generated electricity takes place over a long distance and that of the primary energy, solar heat, over a short distance within the CSP plant.

One could say that the electricity links of the TRANS-CSP concept are analogous to pipelines for renewable energy (Nold 2014). The infrastructure required for that is definitely not an expansion or reinforcement of the existing electricity grid towards a supergrid, but a simple long-distance HVDC link connecting a solar power plant with a feed-in point close to a centre of demand, preferably a point where a conventional power plant of the same size, e.g. an old nuclear reactor, has recently been decommissioned and the infrastructure for electricity distribution already is in place.

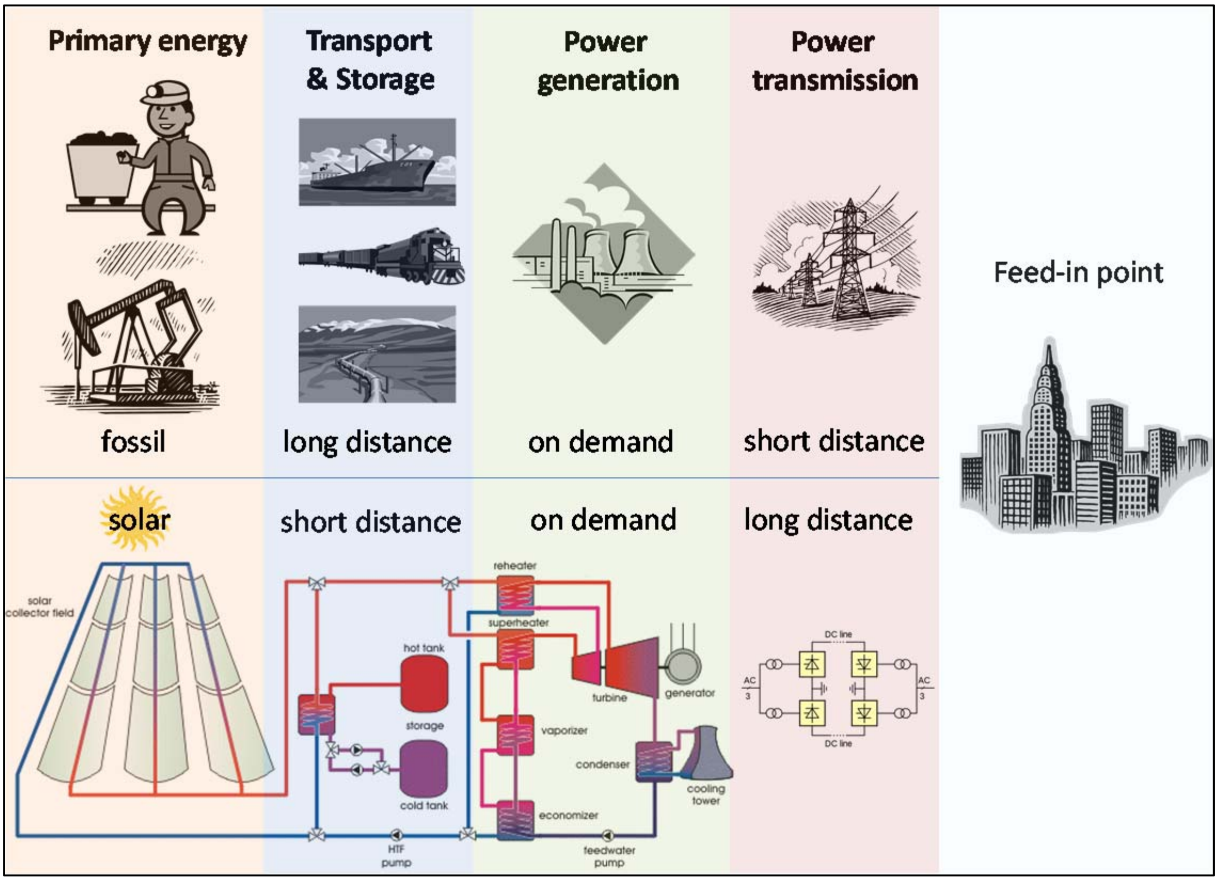


Figure 39: Exploitation, transport and conversion of storable forms of energy for flexible power generation from conventional sources (top) and from solar energy (bottom). While power from solid and liquid biomass would be analogous to the fossil supply chain (top), hydropower and geothermal power would be similar to the CSP supply chain (bottom).

Another major difference of fossil and solar power supply chains is the significant amount of material transported over long distances required for the fossil fuel scheme. Astoundingly, the majority of people today still find it much easier to move billions of tons of material all around the globe than just moving electrons through a cable. However, the substitution of long-distance material transport by long-distance electricity transport is a major inherent change of paradigm of RES-E based electricity supply, and will certainly dominate the energy future of the planet.

Long-distance electricity transport is something completely different from the task of electricity grid expansion and eventual reinforcement: the latter will be helpful to cope better with higher demand and with increasing fluctuating supply, but will not provide flexible power to complement local fluctuations. While grid expansion is a natural process during operation and management of the electricity supply schemes of growing economies, the infrastructure proposed here is analogous to energy pipelines that are needed to tap remote sources of flexible / storable solar energy. Having this concept in mind, we can finally start to think about the required frame conditions for its successful implementation, as described in the following.

3.2.3 The Nord Stream Experience

At this point it must be underlined that the CSP-HVDC infrastructure drafted later in this report, connecting a large CSP-plant in Morocco with a German center of demand, is a scientific model. Future real world installations will certainly look different and could include other and even more off taker and supplier countries. Real planning of such infrastructure has not yet started. Among others, the following questions are still open:

1. Which European country will recognize the necessity of flexible solar power imports from North Africa as an element of its domestic power supply system?
2. Which North African country will be ready to facilitate solar energy exports to Europe?
3. Will transit countries agree to such an infrastructure?
4. Who will be the players who can start such an international project?
5. How will the significant barriers of such a project be overcome?

China has installed about 30 GW of point-to-point HVDC links interconnecting large hydropower plants with several megacities, and is planning to commission a total of 270 GW in form of about 40 long-distance HVDC power lines by 2020 (Retzmann 2013). However, this cannot serve as a blueprint for our purposes, because in our case interconnection does not take place on the national territory of one state, but within five states, of which at least one will not even be European. Moreover, while power generation in China is organized by one company operated by the government, a multitude of private and governmental players from different nations would be involved in the European case.

However, there is one recent success story about a long-distance energy transport infrastructure for a major central European economy including oversea transport and touching several transit countries: the Nord Stream gas pipeline from Russia over the Baltic Sea to Germany, that was realized within a time-span of only six years between the first announcement in 2005, when a letter of intent of the founding consortium was signed with two major off-taker companies in Germany, and start of operation in 2012 (Nord Stream 2013).

As has been stated before, the infrastructure proposed here for flexible solar electricity imports is very similar to that needed for the exploitation and transportation of natural gas

Figure 40). In the case of natural gas, usually a consortium composed of companies from the provider and off-taker countries takes the venture of developing the production and long-distance transport infrastructure, while local distribution companies take over the retail of the energy commodity to consumers.

A key success factor of the gas pipeline in the Baltic Sea was an independent company (Nord Stream AG) with headquarters in Switzerland set up by shareholders from a consortium of leading European companies like OAO Gazprom, Russia (51%), E.ON Ruhrgas AG, Germany (15.5%), BASF SE / Wintershall Holding GmbH, Germany (15.5%), N.V. Nederlandse Gasunie, the Netherlands (9%) and GDF SUEZ SA, France (9%).

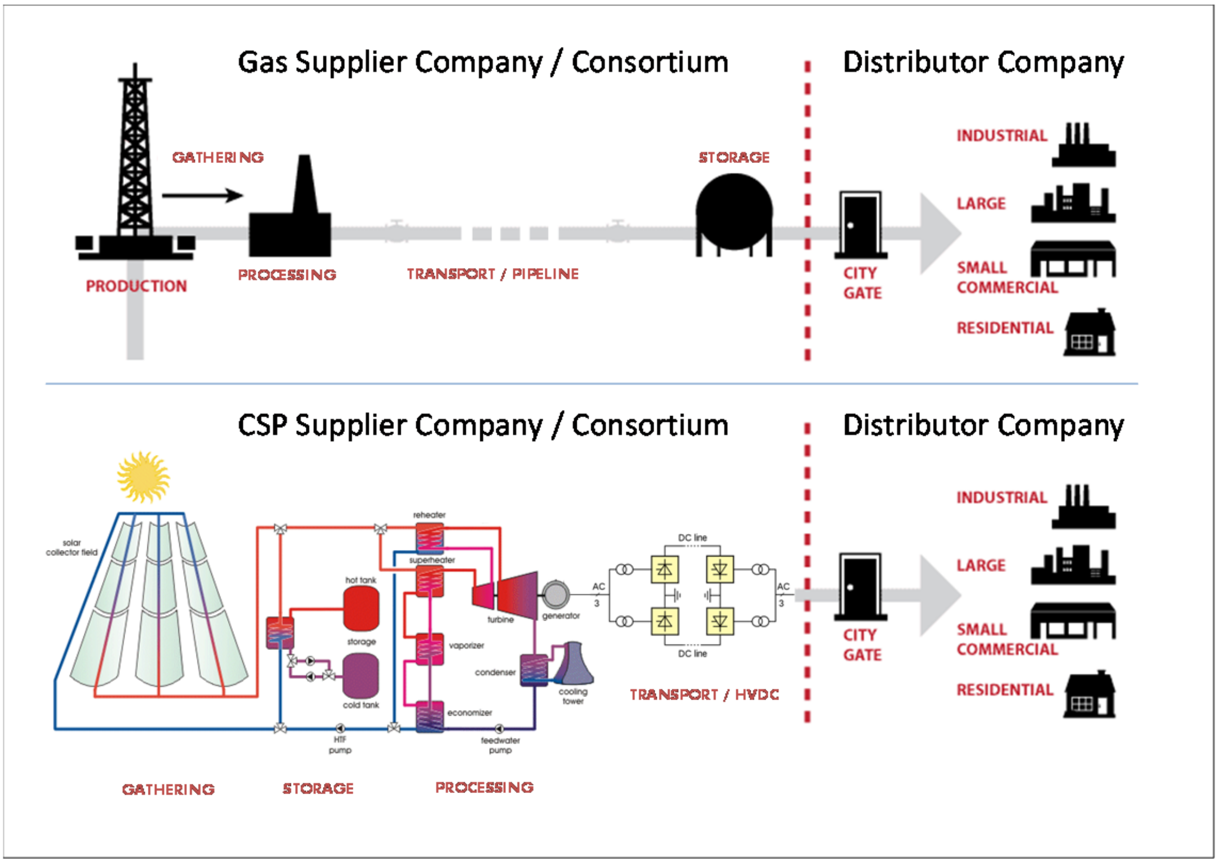


Figure 40: Supply and distribution infrastructures for natural gas and CSP, showing also the analogy to possible related enterprise structures (top figure adapted from ACE 2014).

By November 2006, all nations had been officially notified of Nord Stream's intention to build the pipelines. The permitting process started at that early stage. At that point the planned pipelines were upgraded to "a Project of European Interest" within the revised Trans-European Network for Energy (TEN-E) guidelines, which gave the project a strong position on European level.

Internationally acknowledged companies were hired to carry out the related socio-economic and environmental impact assessment and to help in the permitting process. Part of the information had been gathered in early Pre-Feasibility and Environmental Impact Assessment studies already in the late 1990ies, while about 100 million Euros were spent for new and additional study work. Environmental issues played a major role in the permitting procedure. Special concerns were about the Natura 2000 network of protected areas, shipwrecks and munitions scattering the sea floor, areas of polluted sediment and commercial fisheries, all these factors influencing the selection of the final route.

Already at a very early stage, just after starting the project in 2006, numerous consultation meetings with local authorities and stakeholders in all countries around the Baltic Sea took place, in order to explain the concept and to provide and discuss the results of the investigations and seriously considering the concerns of affected stakeholders. Constant communication between the environmental permitting team and the construction engineering team was crucial to absorb the results of the public consultation process and translate it to action in form of an iterative planning process involving survey, engineering and authority consultation. Detailed survey of the sea bed including potential impacts was performed, including fishery, wildlife, cultural sites and the risk related to munitions, which led to several changes of the original route and to the introduction of a series of mitigation measures.

A key success factor during the permitting phase was the commissioning of well-acknowledged companies capable of technically doing the environmental and socio-economic surveys and impact assessment and also having close contact to the national authorities in the region in order to maintain a constant dialogue with them and the company. Questions with a solution at hand were answered within one day, and those that could not be answered immediately triggered a related investigation. A specific challenge was the provision of information in all languages involved, which were ten.

"The optimal route was selected on the basis of in-depth research, and alternatives were measured against three main criteria, with safety being a constant, overarching concern. The first criterion was environmental and focused on avoiding areas designated as protected or sensitive, or areas with ecologically sensitive species of animal or plant life." Every effort was made to minimize work on the seabed that might disrupt its natural composition, preferring the construction of support structures for the pipeline over the detonation of obstacles. The field studies included analysis of water and soil samples as well as observation of the behavior of fish, marine mammals, and birds.

"The second criterion looked at socio-economic factors to minimize any contact with shipping, fishing, dredging, the military, and tourism – and with sea installations, such as existing cables or wind turbines. Avoiding known areas with discarded conventional and chemical munitions was also a top priority in the route selection process.

The third criterion covered technical considerations, such as minimizing construction time, and therefore any disruptions, as well as reducing the technical complexity of the operation to keep the use of resources as low as possible. These criteria were applied to each of the main routing choices" (Nord Stream 2013).

Information was published in a transparent and open way, which was a major factor to achieve credibility and acceptance of the project in the affected countries, even in those that did not benefit directly from the infrastructure. Finally, the installation corridor for the pipelines was selected. Nord Stream cooperated with the five countries (Parties of Origin) through whose territorial waters or Exclusive Economic Zones (EEZ) the pipelines would pass – Germany, Finland, Denmark, Sweden and Russia – as well as with Estonia, Latvia, Lithuania and Poland, the other countries that might be affected.

"Nord Stream had to apply for permits from the five countries through whose territorial waters or Exclusive Economic Zones (EEZs) the pipelines would pass: Russia, Finland, Sweden, Denmark, and Germany. The permitting regulations in each country were based on UNCLOS – the United Nations Convention on the Law of the Sea, which regulates the utilization and exploitation of the oceans. This law gives developers the right to lay down pipelines, but also obliges coastal states to protect the marine environment. In other words, it gave the permitting countries the right to thwart the enterprise if environmental and safety requirements were not met. In addition, under a United Nations convention known as the Espoo Convention, neighboring countries also had to be consulted." According to Nord Stream, "EU was treated just like another concerned country", because many citizens petitions regarding the project were raised there and had to be answered in the same way as the others.

Apart from ensuring that the pipelines complied with the national legislation of all Parties of Origin, and with the terms of the 1991 Espoo Convention, it was essential to ensure that the relevant non-governmental organizations (NGOs) and other bodies were in agreement with the measures taken to avoid adverse environmental and economic impacts.

This process took three years, while the technical planning went in parallel to the consultations with authorities and the environmental permitting team. From 2006 onward, about 100 million Euros were spent on detailed and transparent environmental study work. Monitoring of the socio-economic and environmental impacts is ongoing since the commissioning of the pipeline.

In the early stages of the project, about 40 % of the press about the project had a negative tone. The communications department focused on rationalizing the initially highly political debates and started to monitor press coverage. Taking seriously all public concerns and through open and transparent communication, including an information tour all along the pipeline with a mobile exhibition installed in a truck, the company was able to gradually shift the style of the public debate towards a fact based discussion. Obtaining the last permit by the end of 2009 and by the start of construction in 2010, media coverage was over 90% neutral or positive. A key success factor to overcome criticism was that the project was adjusted many times in the light of new elements that were brought up either by the public consultation process, citizen requests or the technical studies, and that the company managed to explain the benefits of the project to opinion leaders, stakeholders, the media and the public in an on-going, two way information exchange.

The final investment cost of the pipeline project was 7.4 billion Euro which is in accordance to the initial budget plan. It is composed of € 1.7 billion for design, surveys, environmental assessments and monitoring, inspections, certifications and personnel, € 3 billion for the manufacture of pipes and pipeline materials, € 2 billion for pipe laying and € 0.7 billion for concrete coating and logistics.

Figure 41: Illustration of the Nord Stream Pipeline Project (Nord Stream 2008)

Projects related to energy infrastructure are usually attractive to financing, especially if a strong shareholder group is behind the equity investment. Such a constellation is normally related to low risk and thus very attractive to investors. In the Nord Stream case 30% of the investment was covered by equity and 70% by project financing from about 30 different banks. Such a success is not self-understanding, as financing took place in 2009 directly after – or better said in the middle – of the global financial crisis, when financial markets were in turmoil and credits not easily available.

In the case of Nord Stream, the completion risk was taken by the shareholders. A big part of the financial risk was covered by a long-term Gas Transportation Agreement (GTA) with two major German gas importers, based on the initial letter of intent already mentioned before.

A major success factor for financing was that the company organized a market sounding with the world's major project financing banks in one-by-one meetings before going out to call for tender. As expected at that time, the result of that hearing was highly negative. The only way out was "to offer the banks a risk-free deal". Nord Stream succeeded in obtaining business risk insurance in the order of 70-80 percent of the loans provided by several Export Credit Agencies (ECAs). Germany provided an "untied loan guarantee (UFK = Ungebundener Finanzkredit) that was modified in 2009 to cover political and also some commercial risks of the project by public institutions. Under this framework, the project became AAA standard, almost risk-free investment. Finally, it was oversubscribed by 60 %, with more than 30 project finance lenders participating.

There were also other success factors to the financing of Nord Stream:

1. A solid financing structure with a strong debt/equity ratio and a comprehensive shareholder support package during the construction period. A particularly innovative feature was a self-correcting cash flow under the GTA, which automatically adjusts to meet debt service.
2. The project was split into two consecutive phases, reducing the amount of investment needed per phase, providing a success story for the second phase and allowing for an integrated sharing of cash-flows.
3. Governance and procurement policy was established in the frame of a totally new, independent organization, Nord Stream AG, according to highest international standards and procurement guidelines at the cutting edge of international best practice, highly transparent and visible and without any preferences.
4. The bidding process was based on a pre-qualification process with very high technical standards and supervised by an independent consultant. Not only price, but mainly quality was a decisive factor.

Finally, the logistics of the project were an award-winning international venture, starting construction in 2009 and commissioning just on schedule in 2012, and could certainly be used as reference for future international energy projects of this type.

Learning from Nord Stream will be a major requisite for any RES-E imports related to the 4th cooperation mechanism. RES-E projects will be at the same time easier and also more challenging than Nord Stream: easier, because electrons flowing in cables are much easier to handle than natural gas and the required pipelines; more difficult, because in case of RES-E, the production sites – that were already in place in the case of Nord Stream – must still be built, adding significantly to the required investment.

3.2.4 CSP-HVDC Pilot Study

It must be noted that the Nord Stream AG was founded on the basis of several pre-feasibility and feasibility studies that already were available at that time, showing the rough picture of such a pipeline infrastructure through the Baltic Sea. Such studies are not yet available for the CSP-HVDC links between North Africa and Europe proposed here.

Since 2009, several initiatives proposed to establish “pilot” projects to demonstrate the 4th cooperation mechanism on a smaller scale. However, just like in the case of the Nord Stream Pipelines, a smaller scale demonstration prior to a real project is impossible, as the related effort would be almost as large as in a full size project and would not be justified by a smaller output. This and the erroneous concept that formed the basis of those considerations up to now has avoided the realization of concrete projects under the 4th cooperation mechanism, although, as has been shown in WP 3.3 of the BETTER report, flexible renewable energy imports will most probably be needed in Europe shortly after 2020, and planning should be started asap.

Therefore, it may be considered by the European Commission to release a call for a CSP-HVDC Pilot Study that may contain, among others, following topics to be described in reasonable detail:

GEOGRAPHICAL ASSESSMENT

- Demand side analysis of potential off taker regions in EU for flexible solar power imports
- CSP production site screening of potential supplier regions in NA
- Geographic analysis of potential HVDC corridors in pre-defined transit regions

TECHNICAL AND FINANCIAL ASSESSMENT

- Technical pre-design and performance study related to the prior demand side analysis
- Economic and financial pre-engineering study including de-risking opportunities, compensation payments and financial citizen participation
- Assessment of the necessary logistics and time schedule

IMPACT ASSESSMENT

- Environmental impact study
- Socio-economic impact study
- Social acceptance and citizen involvement study including a concept for a prior public visualization of the infrastructure and for citizen dialogue and participation
- Analysis of the replication potential of such projects

POLITICAL AND REGULATORY FRAMEWORK ASSESSMENT

- Analysis of existing and missing political framework requirements including the role of authorities at different levels
- Analysis of existing and missing regulatory framework requirements including the role and identification of permitting authorities

Such a study could be commissioned directly by the European Commission authorities or included in the HORIZON 2020 Call. It would help EC to evaluate the potential and assess the importance of such infrastructures for the EU’s future energy infrastructure.

3.2.5 Recommendations for RES-E exports from NA to EU

The infrastructure proposed here is analogous to pipelines that are used world-wide to tap remote sources of flexible / storable energy. A major requisite for successfully introducing physical RES-E exports from NA to EU is the correction of the concept to be followed and the beginning of concrete project planning for the first CSP-HVDC links, recognizing that the only “high quality” sources of energy that North Africa could reasonably offer to Europe for export are fossil fuel and flexible solar power from CSP. The original TRANS-CSP concept must be re-established in the minds of decision makers before NA and EU will be able to proceed with the 4th cooperation mechanism.

In order to provide a clear first picture of such infrastructure, a CSP-HVDC feasibility (pilot) study should be commissioned as soon as possible.

After finalizing such study, a first step into the real world would certainly be a letter of intent of a founding consortium with major off-taker companies for RES-E electricity in a target country. The founding consortium would ideally – but not compulsively – be composed of strong players from the provider, off taker and transit countries with strong long-term interest in exporting / importing solar energy.

The founding consortium should establish a project company as a totally independent organization with own budget in form of at least 30% shareholder equity, own staff and own governance and procurement policy following best practice international standards, and provide a comprehensive shareholder support package during the construction period.

Affected nations should be notified about the intentions of the company immediately after its foundation.

The project should be considered by the European Commission as potential Project of Common Interest (PCI) within the Trans-European Network for Energy (TEN-E) guidelines.

Internationally acknowledged companies with comprehensive experience in the respective project region should be hired externally to carry out independent socio-economic and environmental impact assessment and to help in the permitting process with regional authorities of the countries involved. Environmental, socio-economic and technical considerations should equally be considered for infrastructure planning, either modifying routes or providing technical solutions to mitigate impacts.

Directly after starting the project, a consultation process with local authorities and stakeholders should be initiated in all affected countries. The consultation process must be kept continuously alive between the company's planning, permitting and communication departments and public opinion leaders, stakeholders, the media, authorities, NGOs and the public in an on-going, two way information exchange. Transparent information on the project must be provided in all related languages. Requests and consultation should be seriously considered and become visible in the planning of the infrastructure. Press coverage about the project should be monitored, analyzed and responded in a way that leads to a rationalization of the public debates. A key to overcome criticism is a visible consideration of all types of concerns in the project planning.

Projects related to energy infrastructure are usually attractive to financing if a strong shareholder group capable of taking over the full completion risk is involved. Equity shares should solidly and conservatively cover at least 30% of the investment.
A long-term, project-specific power purchase agreement (PPA) between the project company and strong and credible off taker companies (electricity distribution companies and / or large consumers) is pivotal to such large RES-E infrastructures. Innovative features like self-correcting cash flow under the PPA that automatically adjusts to meet debt service could be introduced.

Large scale projects should be split into consecutive phases, e.g. starting with the full scale HVDC link plus only a part – let's say 30-40% of the CSP infrastructure, which will considerably reduce the initial investment. This will allow finalize the large CSP infrastructure in a second phase, build on a success story and combine cash flows in an optimal way. This is particularly interesting in combination with an accelerated loan period as proposed above. If the investment for the first phase is returned quickly, it can immediately be used in the financing of the second phase.

In terms of cost calculation of the project, it is particularly important to consider comprehensive compensation payments for the land requirements of the infrastructure, as described in WP 3.3 of the BETTER project. This will allow affected citizens and communities to choose between a higher compensation payment resulting from overhead lines and a lower visual impact of underground cables.

Before going out to call for tender it is recommendable to organize market sounding with the world's major project financing banks in one-by-one meetings. This will provide the necessary information required for the financial engineering of the project. Reserving a reasonable priority share for Cooperative Finance will allow affected citizens and communities to become shareholders of the project as described in WP 3.3 of the BETTER report.

The RES-E specific challenge of high initial investment cost can be addressed by PPAs that foresee two different tariffs: a high one adapted to the loan period including capital cost and a much lower one following the loan period that will be free of capital cost, but only includes O&M cost. An initially higher tariff caused by a short loan period can be advantageous because it reduces considerably the cost of finance. If the initially high tariff is shared by a large number of consumers, the short-term load for individual consumers will be small and the long-term low O&M cost will finally lead to the benefit of long-term stable electricity prices. Project finance should be free of public subsidization. Public contribution should be limited to sharing and reducing the investment risks of the project, applying several de-risking strategies as described before.

In general, it is recommended to address AAA investment standards for such projects in order to reduce capital cost to a minimum. This can be achieved if public institutions take over the political and some of the commercial risks by providing specific export and partial loan guarantees. Further risk mitigation measures like those for national RES-E expansion described in Chapter 2.2 of this report can also be applied. The reduction of the loan period as described above is also a very effective measure to reduce investment risk.

Tendering, pre-qualification and procurement should take place under highest international standards and independent supervision and should be fully visible and transparent.

The demanding logistics and other major challenges of such a project require a team of international top experts that must have full responsibility for the project but at the same time have full independence from any shareholder interests.

After analyzing the general socio-economic situation in the five North African countries we were able to identify existing political and regulatory framework conditions for national RES-E expansion as well as for RES-E exports to Europe, and derive some recommendations for action in order to remove existing barriers.

Morocco was identified as the most advanced country in terms of national RES-E expansion, possibly also serving as good example for the total region, with clear policy targets, a reliable legal framework, strong institutional support and first large scale projects already in place.

In terms of project finance we have identified the de-risking of RES-E investment by a series of political, institutional and international financial measures as key to successful expansion, as has also been recommended by the UNDP. Taking risks from private investors will reduce interest rates and thus the capital cost, which is by far the dominating cost item in all RES-E projects. Public guarantees, reliable power purchase agreements, streamlined permitting procedures and predictable RE policy are other core elements of successful national RES-E implementation.

3.3. ROLE OF RES-E IMPORTS

While China has understood that high-value RES-E can be tapped in the distance by interconnecting them to the centers of demand via HVDC links and decidedly pursues the implementation and expansion of this concept, Europe has not yet even started to develop such an option, which due to democratic limitations will take considerably longer than in China, although there is no doubt about the size and quality of the huge solar energy potential available in North Africa (MED-CSP 2005), MENAWATER (2011).

On the other hand, there have been attempts to export RES-E from North Africa to Europe via the existing AC grid, hoping that for first steps, no HVDC links would be necessary (Dii 2013). The only existing interconnection between Spain and Morocco has about 1 GW net transfer capacity (NTC). Up to now it is mainly used in a north-south direction, as Morocco's demand is quickly growing while Spain is suffering from over-capacities. In this case, it is difficult to detect a pilot character of this concept for future electricity exports, because it may take long time until Morocco would produce and Spain would be willing to accept and upgrade occasional electricity peaks from wind or PV surplus that would have no significant value, but may rather cause congestion in the Andalusian electricity grid.

In general it should be noted that transporting RES-E over an electricity grid (no matter if AC or DC) reduces considerably the traceability of the power source, so it would remain a question of believe if the electricity obtained is really stemming from renewable sources or not, while a point-to-point interconnection guarantees the traceability of the source. Having also in mind that the grid between the borders of NA and Europe can only transport 1 GW of capacity today, it is difficult to imagine a future "super grid" that would be able to transport 100 GW or more instead, and not only between borders, but interconnecting all consumers and power sources in EUMENA. Even a strong electricity grid like the one existing in Germany can only transport about 8 GW of power capacity to the neighbor countries (entso-e 2012).

It is rather unlikely that the EUMENA electricity grid will be expanded 100 times or more just because of RES-E deployment. It is much more likely that the electricity grid will simply grow in proportion to the growing electricity consumption, leading in the future to a similar net transfer capacity in Egypt as in Germany, at the moment when Egypt's annual consumption would approximate German demand. In the beginning, the HVDC links between NA and EU will not increase the transfer capacity of the grid, but will only bring flexible solar power to Europe's centers of demand. In the long-term they may be interconnected – again analogous to highways – to form a HVDC overlay grid in the far future, but this would not be a pre-condition for implementing our concept.

In the following we will focus on the original concept and the recent achievements of the TRANS-CSP approach and its implications for Europe and the NA region. We will show that a transformation of power supply towards more than 90% RES-E is possible without a significant RES-E-driven expansion of the electricity grid, electricity storage and fossil backup plants, if the principles of the TRANS-CSP concept are respected.

The original idea of the import of flexible solar energy from North Africa to Europe as initially presented to the European Parliament in 2007 but including latest research activities will be described in the following in order to explain and illustrate the potential role of RES-E imports at three different levels of detail:

1. a European long-term RES-E perspective (3.3.1),
2. a German long-term RES-E perspective (3.3.2),
3. a long-term perspective of the German Federal State of Baden-Württemberg (3.3.3).

The CSP power plant sites in North Africa, the feed-in points in Europe and the interconnecting HVDC corridors discussed here are first hypothetical model cases for a first visualization of such an infrastructure and are not meant to replace or anticipate the still necessary in-depth planning of real sites and corridors. Of course, such links are also possible for other flexible forms of RES-E as well as for other producer and off-taker countries.

3.3.1 Role of RES-E imports in Europe

For the bottom-up analysis of possible RES-E electricity exports from North Africa within WP3, electricity supply scenarios for each of the European countries were taken from an update of the TRANS-CSP study in the frame of the European ENERGEO project from the year 2012. In this study, each country scenario was updated according to the real development of the power sector between the years 2000 and 2010. The most recent National Renewable Energy Action Plans (NREAPS) were taken from Beurskens et al. (2011) as reference for further development until 2020. Electricity consumption of electric vehicles and electric heating was introduced as new demand drivers, considerably increasing electricity demand by 30% in comparison to the original TRANS-CSP scenario that only considered conventional power consumption patterns as the ones existing in the year 2000. From the three scenarios developed for ENERGEO, the one with about 80% RES-E share in 2050 and phase-out of nuclear power was taken as reference (Figure 43). The other two ENERGEO scenarios (100% RES-E and Nuclear Power Renaissance) were not considered here.

The results are in principle the same as for the original TRANS-CSP scenario with 30% lower demand, while only the quantities of energy supplied are different. This confirms that the TRANS-CSP principles are also valid for high-demand scenarios. The scenario is characterized by a strong diversification of supply and a clear reduction of import dependency, as most RES-E stem from domestic sources. Imports are limited in 2050 to fossil fuel (18% gas and coal) and 19% solar electricity from North Africa (hydropower from Norway is considered a domestic European resource). For comparison, today's European import dependency on fuels for electricity is higher than 50%.

The scenario is built in a way that at any time the firm capacity that can be delivered by all power plants is 25% larger than peak demand. This guarantees that at any time there is sufficient reserve capacity available even in case of a major failure.

Within the TRANS-CSP scenario, RES-E imports go from North Africa and Western Asia to about 15 different European countries that require such a flexible RES-E complement to their national electricity mix (Trieb et al. 2012). From those possible links, we have selected one for more detailed description that will be described later.

A particularly interesting and important result of the TRANS-CSP scenario is that there is no significant need for expansion of the electricity grid, electricity storage or fossil backup power capacity except that driven by increasing consumption, in spite of achieving RES-E shares of 80% and higher. According to our analysis, a "well-balanced" mix of volatile and flexible RES-E sources can lead to high RES-E shares without producing significant surplus from wind and solar power that would have to be stored or transported elsewhere.

"Well-balanced" simply means that the shares of volatile and flexible RES-E are kept more or less equal all the time (Figure 42) while growing simultaneously. A long-term share on annual production of 40-50% volatile RES-E (wind and PV) will be balanced by an equal share of 40-50% flexible RES-E (BIO, GEO, HYDRO and CSP) and complemented by fossil fuel backup usually not higher than 10%. A volatile RES-E share of 40-50% of annual production is usually achieved when the installed volatile capacity is slightly higher than peak load, which does not yet yield considerable surplus because of compensation effects. A maximum of only 50% of the installed volatile capacity will be operating simultaneously, thus not producing surplus most of the time.

On the other hand, firm capacity from flexible RES-E plus fossil backup must be larger than peak load in order to guarantee supply at any time, therefore, a capacity reserve of 25% is included. Following these principles, our scenarios for a long-term annual RES-E share of 80-100% usually lead to a total installed power capacity of more or less 250% with respect to peak load: approximately 125% volatile + 125% flexible power capacity with respect to peak load in terms of GW, leading to about 40-50% flexible + 40-50% volatile shares with respect to the total annual electricity supply in terms of TWh/a. A 10% contribution of ideally stored fossil fuel share may be tolerated if needed, and later substituted by synthetic fuels from renewable production. This composition can be appreciated in Figure 44 for the European power mix, but is also valid for each individual country, although exceptions may occur due to the difference of RES-E resources between different countries.

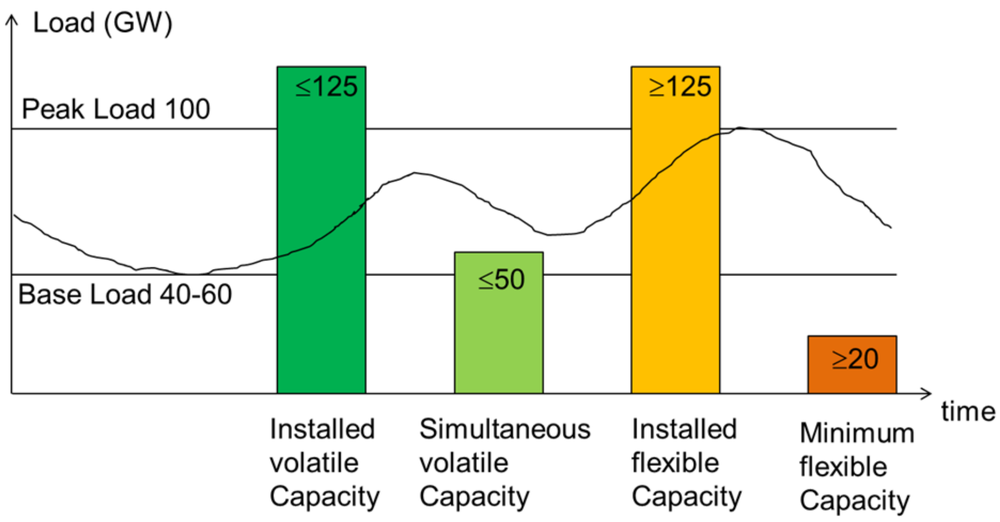


Figure 42: Visualization of the TRANS-CSP concept of a "well-balanced" mix of volatile and flexible power sources: with respect to peak load (set at 100 GW as an example) no more than 125 % volatile capacity is installed in order to avoid surplus. On the other hand, a minimum of 125% flexible capacity must be installed to guarantee supply at any time. Over the year, volatile and flexible RES-E deliver about 40-50% of electricity supply, each, leading to a 90-100% RES-E supply without producing considerable electricity surplus from volatile sources.

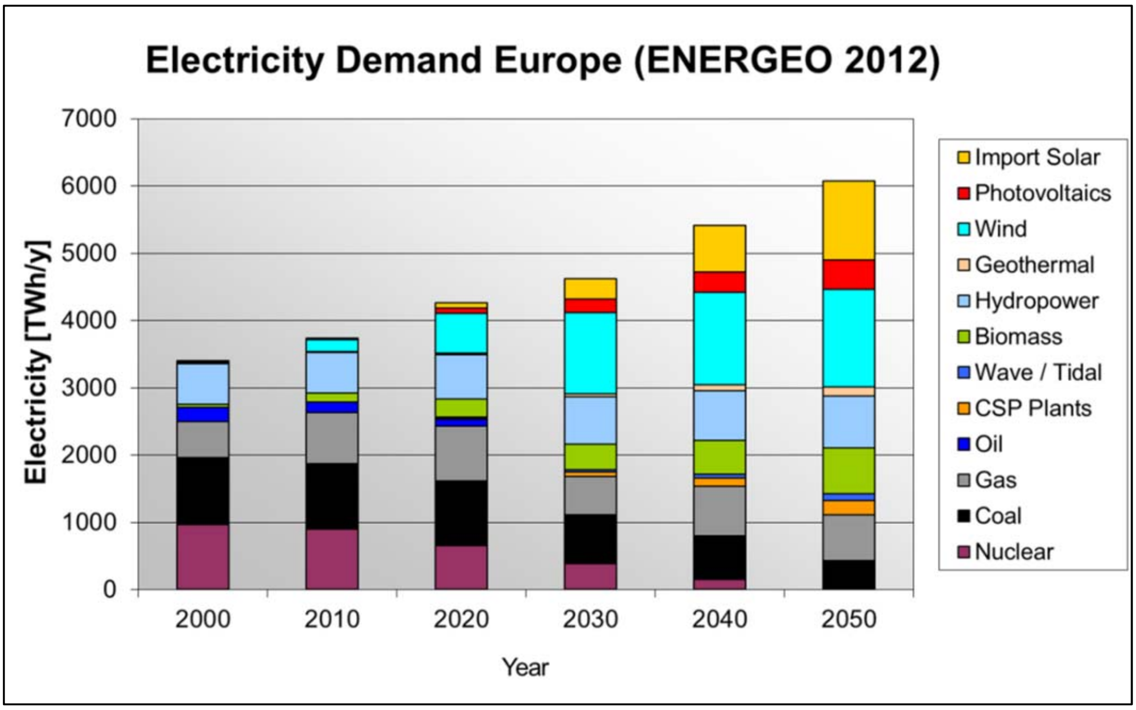


Figure 43: Electricity supply in TWh/y in the TRANS-CSP reference scenario for Europe (update for the ENERGEO project (Trieb and Stetter 2012). "Import Solar" is power from CSP plants in NA imported via HVDC point-to-point interconnections to European centers of demand.

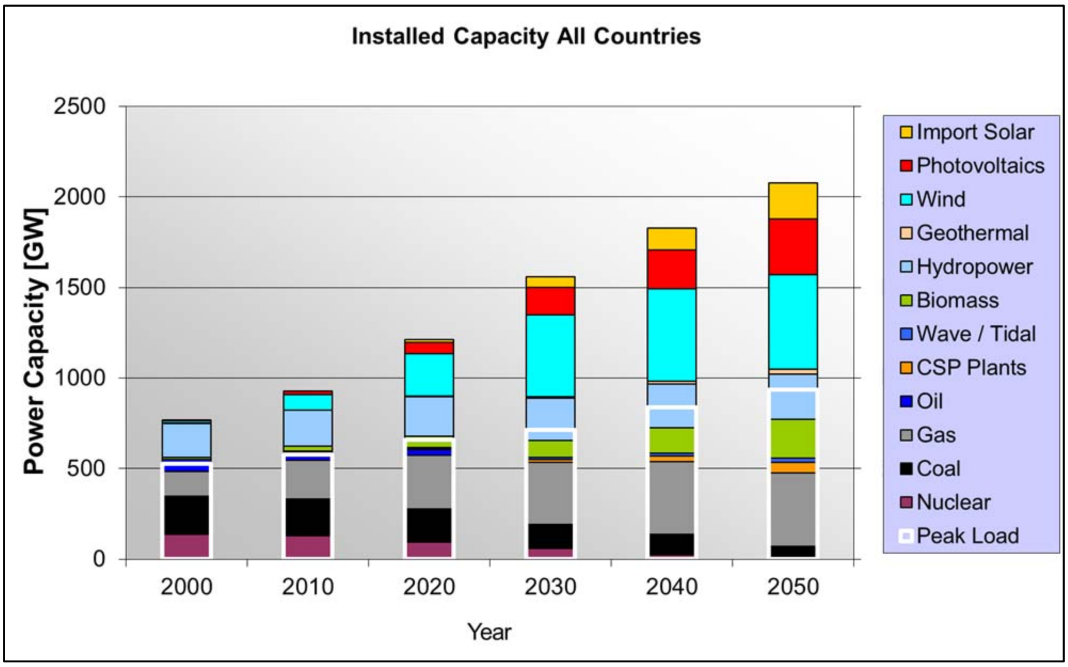


Figure 44: Installed capacity in GW in the TRANS-CSP reference scenario for Europe (update for the ENERGEO project Trieb and Stetter 2012). Import Solar is power from CSP plants in NA imported via HVDC point-to-point interconnections to European centers of demand.

This result was confirmed by an hourly time series modelling of the above mentioned power scenario for the interconnected European electricity grid using DLR's energy system modelling tool REMix-OptiMo (Stetter 2012). The system includes a simplified one-node-per-country model of the transfer capacities of the European AC grid according to data from entso-e (2012) (Figure 45) and all power stations installed in each country.

Hydropower, pump storage capacities and other future electricity storage options (compressed air and hydrogen) are also included. The linear optimization model calculates the least cost unit commitment and merit order for all power stations based on cost assumptions for each technology and the meteorological data input for renewable energy on an hourly basis for a one-year cycle.

CSP-HVDC imports were also considered. In the frame of the project REACCESS for the European Commission, a large number of potential import corridors for solar electricity from North Africa have been assessed (REACCESS 2009). Suitable corridors were identified using a geographic information system that selected the most economic and ecologically compatible pathways from 11 excellent CSP production sites in North Africa towards 28 large centers of demand within Europe.

From around 300 potential import corridors, 33 were selected as candidates for importing the amount of solar electricity required by the original TRANS-CSP scenario (Trieb et al. 2012). Stetter (2012) added further corridors to cope with the higher demand of the ENERGEO scenario as discussed above (Table 34). The resulting CSP-HVDC links were integrated into the REMix-OptiMo modelling as shown in Figure 46, integrating various centers of demand of each country in one single node of the simplified AC electricity grid model. It is particularly important to note that the aggregated capacity of the HVDC links (up to 13 GW) is in reality separated into smaller portions of around 3 GW or less distributed among several centers of demand in each country, in order to be conform with the entso-e rules of n-1 security (entso-e 2009).

As a result we obtain the annual electricity produced by each power plant category in each country and the electricity transported through the electricity grid between the countries involved. The analysis was done for the ENERGEO reference scenario described above for the years 2010, 2030 and 2050, while only the results for 2010 and 2050 are displayed in Figure 47.

Again it can be seen that there is a strong diversification of supply, and high shares of renewable energy are possible in each country in spite of a considerable growth of demand including electro-mobility and -heat.

The utilization of the power lines between countries is considerably reduced in most cases between 2010 and 2050 (Figure 48). This is due to the fact that the country scenarios are built in a way that avoids surplus from volatile RES-E and rather provides power on demand by combining volatile and flexible RES-E in an optimal way. This fully confirms the TRANS-CSP principles and scenario results.

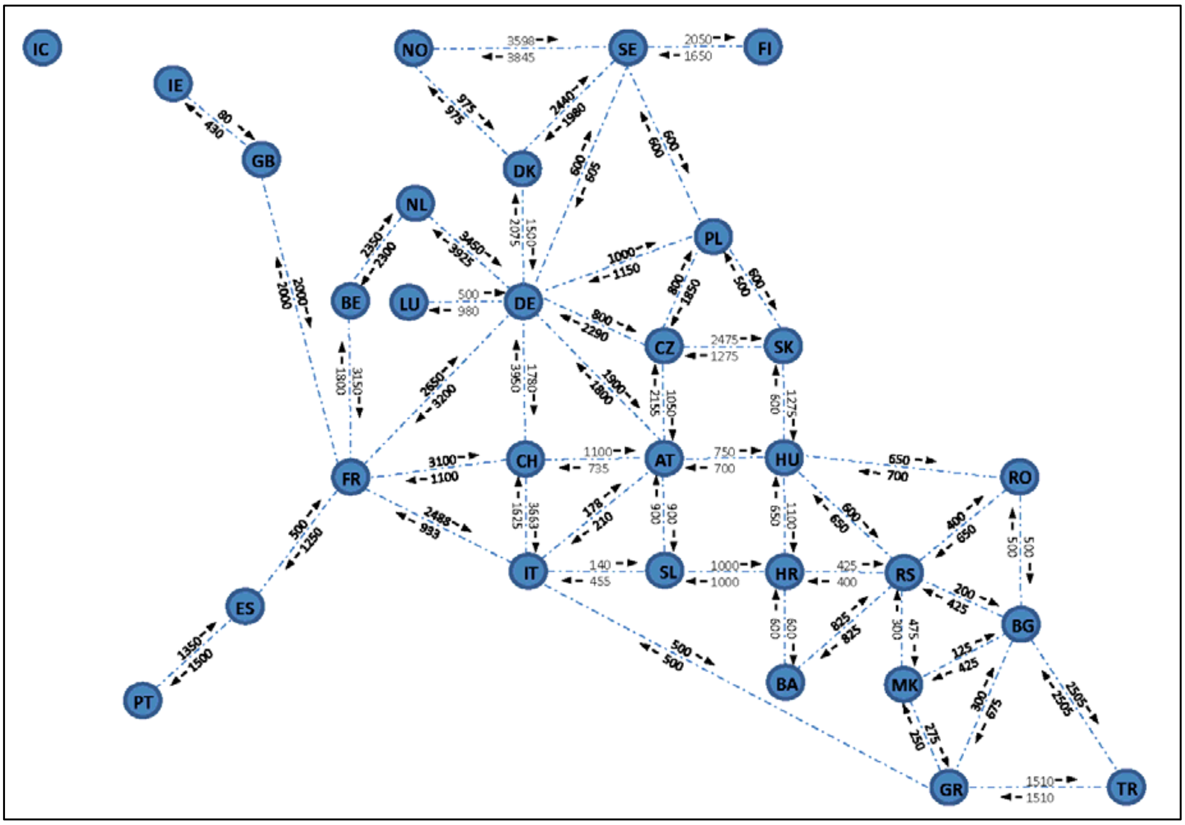


Figure 45: Mean net transfer capacities of the conventional European AC electricity grid according to ENTSO-E (Strachan 2012). Displayed values indicate the average of the Figures from summer 2010 and winter 2010/2011. All links are included in the model, the line lengths are approximated as the distances of the geographical centers (Stetter 2012). Each country is represented by one node.

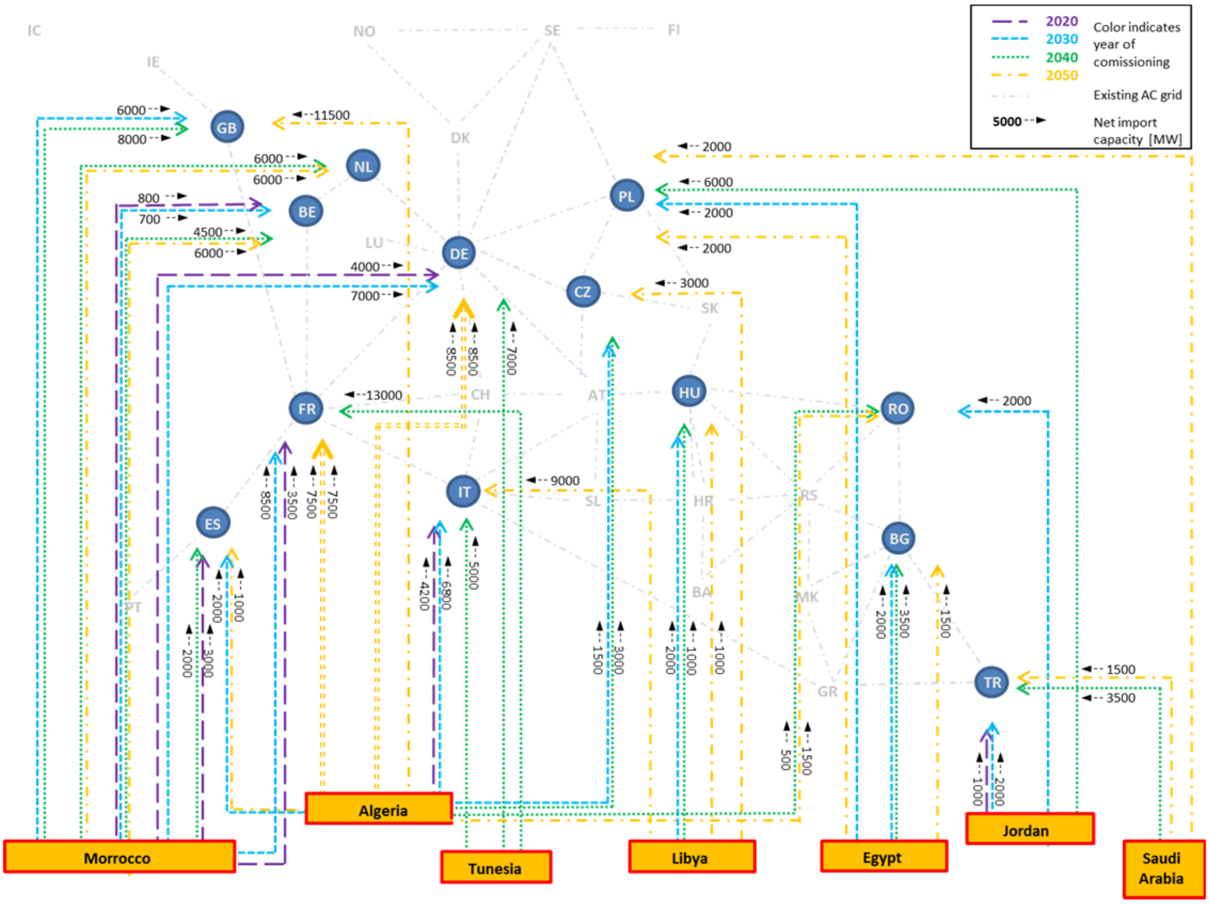


Figure 46: CSP import capacities implemented into the REMix OptiMo environment according to an updated framework of [TRANS-CSP 2006]. The different colors indicate the year of commissioning of the latest respective link. Values next to the lines represent the cumulated net import capacities [MW], i.e. net feed-in at the terminal node after power transmission loss. Dashed grey lines in the background show the existing European AC grid (Stetter 2012).

Table 34: Overview on all CSP-HVDC lines with more elaborate data on line end points, lengths, import capacities and loss based on (Trieb et al. (2012), REACCESS (2011). Values of net import capacities are derived within an update of TRANS-CSP. All power plants indicated in red are added to the original framework to meet the massive demand increase of the ENERGEO scenario (Stetter 2012).

Import Country	Start Point	End Point	Overhead Line Length [km]	Underground Cable Length [km]	Sea Cable Length [km]	Total Length [km]	Start Year [a]	Net Import Capacity [MW]	HVDC Loss [MW]	HVDC Loss [%]
Germany	Morocco #1	Karlsruhe, Germany	2506	278	132	2917	2020	4000	560	14
	Morocco #2	Jülich, Germany	2075	231	149	2455	2030	7000	836	12
	Tunisia #1	Mainz, Germany	1634	182	344	2160	2040	7000	722	10
	Algeria #1	Hannover, Germany	2384	265	202	2851	2050*	8500	1156	14
	Algeria #2	Munich, Germany	1427	159	413	1998	2050	8500	807	9
France	Morocco #1	Paris, France	1957	217	132	2306	2020	3500	396	11
	Morocco #2	Paris, France	1611	179	149	1939	2030	8500	823	10
	Tunisia #1	Paris, France	1666	185	344	2195	2040	13000	1361	10
	Algeria #1	Lyon, France	1480	164	202	1847	2050*	7500	689	9
	Algeria #2	Lyon, France	1805	201	202	2208	2050	7500	808	11
United Kingdom	Morocco #1	London, UK	2125	236	282	2643	2030	6000	753	13
	Morocco #2	London, UK	1835	204	265	2304	2040	8000	887	11
	Algeria #1	Newcastle, UK	2196	244	308	2748	2050	11500	1491	13
Spain	Morocco #2	Madrid, Spain	853	95	16	964	2020	3000	180	6
	Algeria #1	Zaragoza, Spain	879	98	202	1179	2030	2000	120	6
	Morocco #2	Madrid, Spain	853	95	16	964	2040	2000	112	6
	Algeria #1	Zaragoza, Spain	879	98	202	1178	2050	1000	62	6
Italy	Algeria #2	Milano, Italy	1057	117	413	1587	2020	4200	323	8
	Algeria #2	Milano, Italy	1057	117	413	1587	2030	6800	522	8
	Tunisia #1	Firence, Italy	980	109	344	1432	2040	5000	356	7
	Libya #1	Roma, Italy	1305	145	312	1761	2050	9000	776	9
Poland	Egypt #1	Warszaw, Poland	2574	286	665	3525	2030	2000	316	16
	Jordan #1	Warszaw, Poland	3053	339	108	3500	2040	6000	997	17
	Egypt #2	Warszaw, Poland	2837	315	665	3817	2050*	2000	341	17
	Saudi Arabia #1	Warszaw, Poland	3130	348	108	3586	2050	2000	340	17
Turkey	Jordan #1	Ankara, Turkey	2050	205	0	2255	2020	1000	113	11
	Jordan #1	Ankara, Turkey	2050	205	0	2255	2030	2000	227	11
	Saudi Arabia #1	Ankara, Turkey	2100	210	0	2310	2040	3500	405	12
	Saudi Arabia #1	Ankara, Turkey	2100	210	0	2310	2050	1500	174	12
Czech Republic	Algeria #2	Prague, Czech Republic	1635	182	413	2230	2030	1500	158	11
	Algeria #2	Prague, Czech Republic	1635	182	413	2230	2040	3000	315	11
	Libya #1	Prague, Czech Republic	1629	181	344	2154	2050	3000	309	10
Belgium	Morocco #1	Brussels, Belgium	2232	248	132	2612	2020	800	101	13
	Morocco #1	Brussels, Belgium	2232	248	132	2612	2030	700	89	13
	Morocco #1	Brussels, Belgium	2232	248	132	2612	2040	4500	570	13
	Morocco #1	Brussels, Belgium	2232	248	132	2612	2050	6000	760	13
Netherlands	Morocco #2	Appledorn, Netherlands	2082	231	149	2462	2040	6000	719	12
	Morocco #2	Appledorn, Netherlands	2082	231	149	2462	2050	6000	719	12
Romania	Jordan #1	Bukarest, Romania	2154	239	108	2502	2030	2000	244	12
	Algeria #2	Bukarest, Romania	2255	251	413	2918	2040	500	68	14
	Algeria #2	Bukarest, Romania	2255	251	413	2918	2050	1500	203	14
Bulgaria	Egypt #2	Sophia, Bulgaria	1974	219	655	2849	2030	2000	256	13
	Egypt #2	Sophia, Bulgaria	1974	219	655	2849	2040	3500	449	13
	Egypt #2	Sophia, Bulgaria	1974	219	655	2849	2050	1500	192	13
Hungary	Libya #1	Budapest, Hungary	1388	154	712	2254	2030	2000	202	10
	Libya #1	Budapest, Hungary	1388	154	712	2254	2040	1000	101	10
	Libya #1	Budapest, Hungary	1388	154	712	2254	2050	1000	101	10

* start year is 2045 in the original scenario, allocated to 2050 for the validation run.

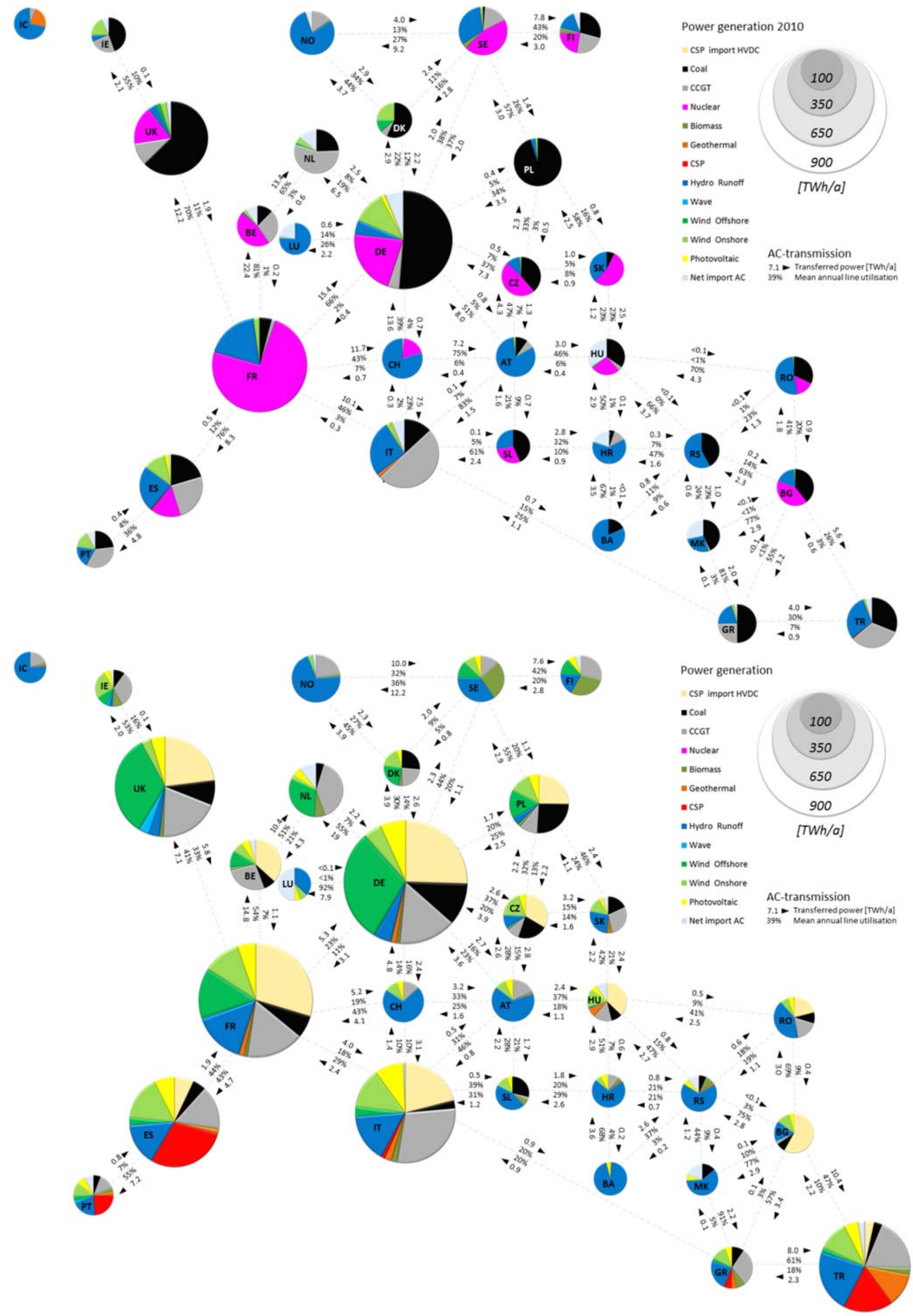


Figure 47: Shares of power generation, AC and CSP imports displayed for each country for the year 2010 (top) and 2050 (bottom) according to the reference scenario. Data on AC transmission between the countries is presented in terms of overall transferred annual power in TWh/a and the connection's mean annual line utilization [%] (Stetter 2012).

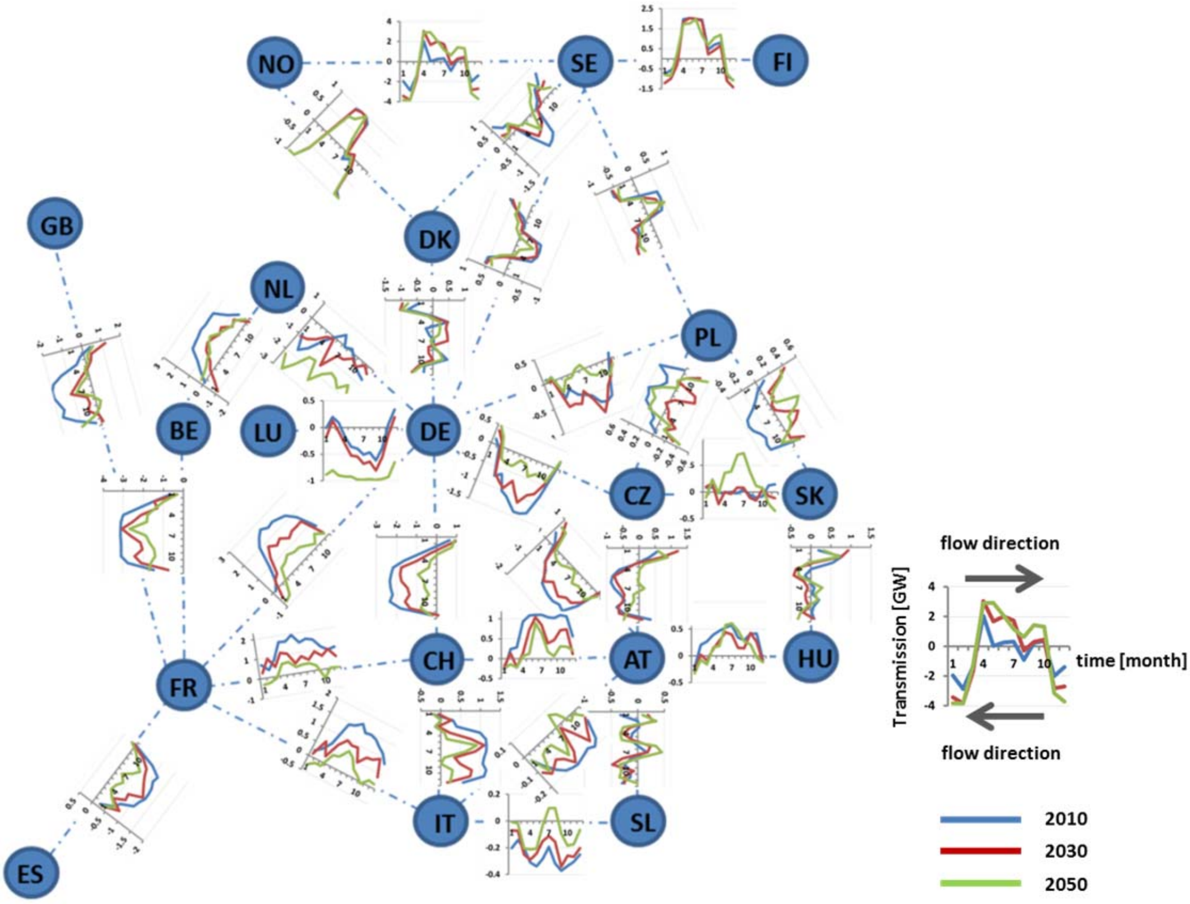


Figure 48: Mean monthly bi-directional power transmission [GW] resulting from the REMix-OptiMo validation simulations. Data for the years 2010, 2030 and 2050 is indicated in blue, red and green respectively. The presentation is limited to the second nearest neighbors of Germany for reasons of clarity (Stetter 2012).The load on the transmission grid is clearly reduced when introducing CSP-HVDC links from North Africa to Europe.

In view of present EU-wide discussions on RES-E -driven expansion of electricity grids and electricity storage this result may be rather surprising, but there is a simple explanation for it:

1. In TRANS-CSP, volatile RES-E like wind and PV are expanded in each EU country only until their installed capacity becomes slightly larger than maximum (winter) peak load in order to avoid surplus power (an installed volatile capacity larger than base load or summer peak load can be tolerated, because there is a significant compensation effect affecting PV and wind parks in a large area like a country that will reduce their simultaneous power production). Once the installed volatile capacity is larger than peak load, further expansion is stopped. In this way, the expansion of volatile RES-E is stopped before major surplus power is produced that cannot be consumed locally or at least nationally. This point will be reached in most countries approximately when about 40%-50% of the annual electricity demand will be covered by volatile RES-E. In this case, no significant RES-E driven expansion of grids or storage will be needed on international level. However, local concentration of volatile RES-E within a country may require adequate measures for regional grid enhancement, electricity storage and demand-side management for compensation on a local/regional level.

2. In addition, flexible RES-E like BIO, GEO, HYDRO and CSP plants are developed simultaneously and in parallel to the volatile RES-E in order to provide similar shares on power supply at any time. Flexible RES-E plants are operated like fossil fuel plants in order to fill the gaps left uncovered by volatile RES-E. At the point when volatile RES-E will have achieved 40%-50% of total annual production, flexible RES-E will have achieved similar shares, leading to a total 80-100% RES-E share. In case not enough flexible RES-E would be available nationally, they may be imported from outside.

A direct effect of this approach is a strong diversification of supply. Power supply scenarios that depend by 70% or more on single sources like wind energy or PV will not result from our approach. On the contrary, the clue of TRANS-CSP is to establish and maintain an optimal balance of volatile and flexible RES-E while reducing as much as possible the consumption of fossil fuels, without creating significant external costs and ecological footprints for storage, grid expansion or backup technology.

This principle can be applied to any country and any situation, with high or low RES-E share, with very good or less appropriate RES-E sites, with high or low electricity demand, with strongly or slowly growing demand, etc. Following this principle, 100% RES-E shares can be achieved in a very efficient and environmentally compatible way, without a need for creating significant changes of the electricity supply schemes or demand patterns, and especially without affecting security of supply.

After seeing the impact of point-to-point CSP-HVDC imports of flexible solar power in Europe as a whole, in the following we will look into more detail of such interconnections and their potential impact on a strong central European economy with significant energy demand like Germany.

3.3.2 Role of RES-E imports in Germany

The original TRANS-CSP framework has been taken as reference for the following analysis. From the 40-50 potential North-Africa-European CSP-HVDC links identified in the frame of the REACCESS (2009) study (Figure 49), five were selected for the modelling of CSP-HVDC imports from North Africa to Germany, summing up to a total of 16 GW net import capacity (Trieb et al. 2012). The other two (more northern) German sites were reserved for HYDRO imports from Norway. In Chapter 4, we describe one of the potential German CSP-HVDC links in more detail.

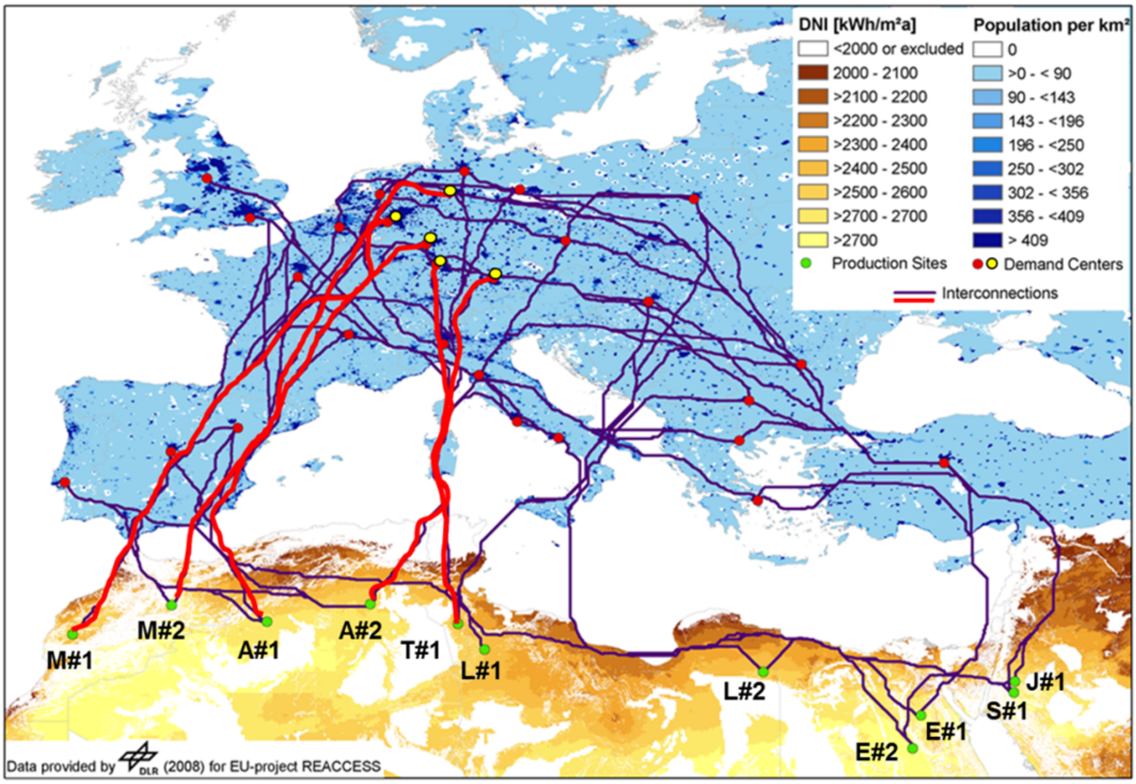


Figure 49: Geographic illustration of CSP plant sites located in North Africa and the Middle East interconnected via high voltage direct current power lines to various centers of demand in Europe (Trieb et al. (2012), REACCESS (2009), REACCESS (2011). High population densities corresponding to the centers of demand and advantageous sites in terms of solar irradiance are connected. Note that only point-to-point interconnections are displayed. The high number of potential corridors displayed (300) gives the impression of a grid structure, which however is not the case. Five potential links from NA to Germany are highlighted in red color.

Infrastructures for long-distance transport of solar electricity may look unfamiliar to most viewers, but there is a clear logic behind: while former access corridors for solid, liquid or gaseous fossil energy were composed of pipelines, shipping roots, railways and highways and the power plants burning fossil fuels were placed nearby the centers of demand, renewable energy - usually generated distant from demand centers - will mainly be transported there by power lines except only for biomass.

An expansion and reinforcement of the electricity grid within a country may be necessary if the best RES-E production sites are distant from the highly populated centers of demand, which in fact is often the case. An example for that is the interconnection of the Northern German wind parks to Southern Germany via special HVDC links (TENNET 2013a). It may also be worthwhile to extend the net transfer capacity of the electricity grid to neighbor countries if they posses particularly valuable RES-E sources that may be helpful to complement the domestic electricity mix, or to increase temporal compensation effects between national and international volatile RES-E resources. Interconnections between Norway and the Netherlands are partly due to that reason (TENNET 2013b). Finally, there is also the option to import flexible RES-E directly via HVDC point-to-point interconnections for very long-distance transport as proposed here, just like fossil fuel imports for flexible power generation.

Aiming at a long-term scenario for Germany with 90% RES-E share, two approaches can be followed:

1. Scenario 1 excluding CSP-HVDC imports from North Africa. This scenario will be mainly based on domestic, volatile RES-E and will require significant storage, grid expansion and backup capacity in order to cope with the fluctuating supply from wind and PV.
2. Scenario 2 including about 16 GW CSP-HVDC imports from North Africa and 4 GW HYDRO imports from Norway, closing the gaps that cannot be covered by domestic flexible RES-E from BIO and GEO plants that are also developed as far as possible.

For both scenarios, the winter peak load reaches about 90 GW while total annual consumption amounts to 560 TWh/a. Base load varies between 40 GW in summer and 60 GW in winter.

The results for Scenario 1 excluding CSP-HVDC imports are shown in Figure 50, top. From the hourly time series for a summer and a winter week large surplus capacity from volatile sources (wind power surplus mainly in winter and PV surplus mainly in summer) can be appreciated. In order to achieve a 90% RES-E share, a total of 375 GW of power generation capacity has to be installed, composed of 235 GW of volatile RES-E, 8 GW flexible RES-E, 90 GW natural gas backup plants, 20 GW generation capacity from pump storage and compressed air storage (CAES) and 20 GW hydrogen power generation capacity by fuel cells. To this massive expansion of power generation capacity add 40 GW of storage capacity composed of 20 GW pump storage and CAES plus 20 GW hydrogen electrolysis and storage facilities plus 40 GW of Net Transfer Capacity (NTC) of the electricity grid, in order to cope with relatively frequent power surpluses of up to 70 GW capacity (note that electricity storage systems are composed of converter/storage units and power generation units, thus counting in both categories).

Comparing those numbers to today's situation in Germany – about 180 GW installed power plant capacity, 6 GW pump storage and 8.5 GW net transfer capacity of the grid (NTC) – gives an impression of the massive additional impact and footprint that can be expected by following such a scenario.

In the bottom part of Figure 50, the results for Scenario 2 including 16 GW CSP-HVDC imports and 4 GW HYDRO imports from Norway can be appreciated: the total power park has an installed capacity of only 225 GW, being composed of 117 GW volatile RES-E (slightly higher than the peak load of 90

GW), 35 GW flexible RES-E including 20 GW imports via HVDC links, 65 GW gas-fired backup plants (together, the flexible capacity is slightly larger than peak load), 7.5 GW pump storage and 8.5 GW NTC grid capacity, reaching the same 90% RES-E share as Scenario 1. This considerably lower structural effort is achieved by avoiding large surplus capacities in summer as well as in winter, and instead filling the gaps left by volatile sources by flexible RES-E in a first place, and fossil backup after that.

In both scenarios, the gas-turbine backup plants could be fired with synthetic methane from power-to-gas conversion, leading in both cases to 100% renewable share. However, this would increase the necessary installed RES-E capacity accordingly, because the efficiency of power-to-gas processes is rather low around 30%.

Comparing the two scenarios for 90% RES-E, it can be seen that 16 GW flexible CSP-HVDC imports from North Africa and 4 GW hydropower imports from Norway would lead to:

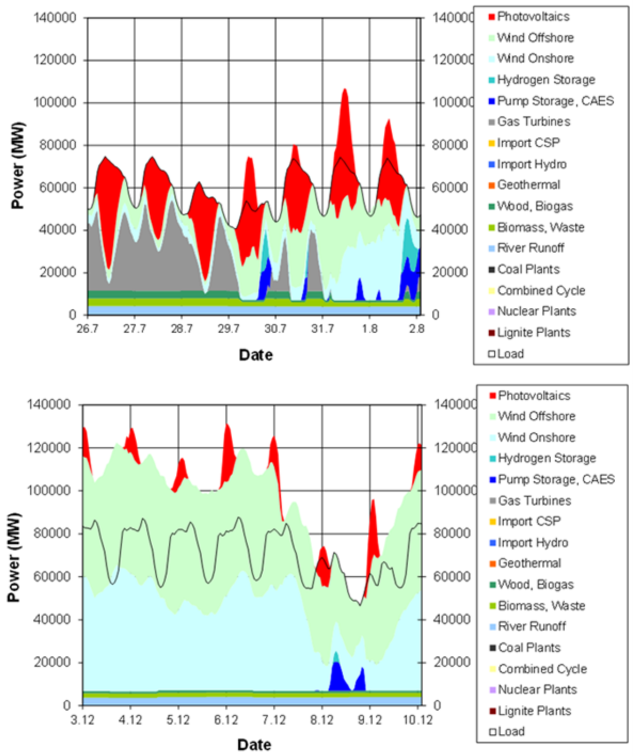
1. 150 GW less required power plant capacity for the German "Energiewende", a saving that would be equivalent to the total capacity of the German power park in the year 2010,
2. five times less grid capacity, as no significant expansion will be necessary except for some internal north-south balancing within Germany to integrate wind power,
3. five times less power storage, as no significant expansion of storage capacity will be necessary.
4. 90% RES-E can be achieved much faster and with much less effort, because the scheduled 117 GW volatile RES-E will already be installed in 2020, and the scheduled 35 GW flexible RES-E including 20 GW imports via HVDC links can in principle be realized within 10-15 years (e.g. installing 30 GW took 5 years in China).
5. TRANS-CSP provides a consistent strategy for all European countries that can follow a similar strategy without creating RES-E surplus and gaps to be balanced by neighbors.

A scenario for Germany including CSP-HVDC imports will not only have a much lower structural impact and ecologic footprint in terms of installed power, storage and grid capacity, but also will lead to a lower investment and electricity cost (Trieb 2013).

A 90% RES-E scenario for Germany without CSP imports:

375 GW + 40 GW NTC + 40 GW Storage

Energy source	Installed Capacity	Annual electricity yield	average utilization
	MW	TWh/a	h/a
Variable / renewable	235500	551.3	
Photovoltaics	100000	98.9	989
Wind Onshore	70000	156.4	2235
Wind Offshore	60000	257.7	4295
River Runoff	5500	38.2	6951
Flexible / renewable	8000	37.9	
Biomass, Waste	4000	22.1	5515
Wood, Biogas	4000	15.9	3964
Geothermal		0.0	0
Import Hydro		0.0	0
Import CSP		0.0	0
Fossile / Nuclear	90000	56.4	
Gas Turbines	90000	56.4	627
Coal Plants	0	0.0	0
Combined Cycle	0	0.0	0
Nuclear Plants	0	0.0	0
Lignite Plants	0	0.0	0
Storage and net transfer	80000	48.7	
Pump Storage, CAES	20000	15.7	785
Hydrogen Storage	20000	13.8	688
H2-Storage Capacity (days)	1		
Net Transfer Capacity (NTC)	40000	19.3	482
Total power park	**373500**	**579**	**1551**



A 90% RES-E scenario for Germany with CSP imports:

225 GW + 8 GW NTC + 20 GW HVDC + 8 GW Storage

Energy source	Installed Capacity	Annual electricity yield	average utilization
	MW	TWh/a	h/a
Variable / renewable	117500	288.1	
Photovoltaics	45000	44.5	989
Wind Onshore	40000	89.4	2235
Wind Offshore	27000	116.0	4295
River Runoff	5500	38.2	6951
Flexible / renewable	35000	220.2	
Biomass, Waste	4000	30.0	7502
Wood, Biogas	7000	49.8	7112
Geothermal	4000	30.2	7547
Import Hydro	4000	25.8	6462
Import CSP	16000	84.3	5271
Fossile / Nuclear	65000	54.4	
Gas Turbines	65000	54.4	837
Coal Plants	0	0.0	0
Combined Cycle	0	0.0	0
Nuclear Plants	0	0.0	0
Lignite Plants	0	0.0	0
Storage and net transfer	16000	3.1	
Pump Storage, CAES	7500	1.9	255
Hydrogen Storage	0	0.0	0
H2-Storage Capacity (days)	0		
Net Transfer Capacity (NTC)	8500	1.1	135
Total power park	**225000**	**561**	**2494**

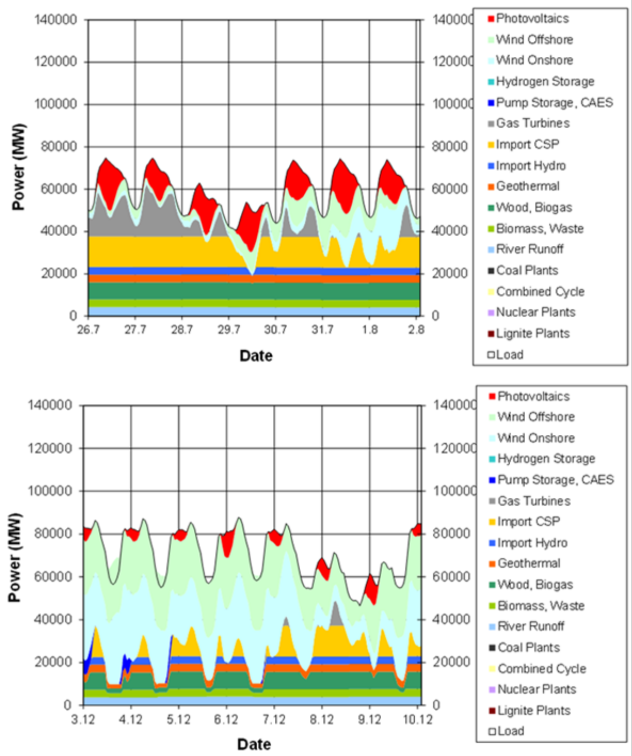


Figure 50: Comparing scenarios excluding (top) and including (bottom) CSP-HVDC imports from North Africa. Tables give installed capacity (GW), annual electricity generation (TWh/a) and full load hours (h/a) for each plant category. Graphs show hourly time series for a summer and a winter weak for each scenario, respectively.

3.3.3 Role of RES-E imports in the Federal State of Baden-Württemberg

Within this chapter we will describe the potential future role of flexible solar electricity imports from North Africa to the German Federal State of Baden-Württemberg, and present a techno-economic model of a first CSP-HVDC link between Morocco and South-Western Germany.

As a potential off-taker of solar electricity imports from NA, the German Federal State of Baden-Württemberg was chosen as model for a typical European balancing authority area with 10.8 million inhabitants and an electricity consumption of 80 TWh/y in the year 2012.

For the analysis two scenarios were designed and modelled by Hess (2013) on the basis of hourly time series for one year. Figure 51 shows the difference between scenario 1 building on strong national expansion of fluctuating renewable energies (photovoltaic, wind) and scenario 2 following a well-balanced approach combining domestic, volatile RES-E with flexible RES-E including 1.5 GW of CSP-HVDC imports from North Africa in the year 2025. In both scenarios offshore wind power will be imported additionally from the North Sea to Baden-Württemberg together with dispatchable hydropower from Norway by using the national north-south HVDC transmission lines scheduled for this purpose. The model is based on statistical data from the German Agency for the Electricity Grid (BNA 2012) for the year 2012 and on the "Integrated Energy and Climate Concept for Baden-Württemberg for the medium term perspectives until 2020 (IEKK 2012). The latter was presented in 2012 to the government of Baden-Württemberg as a proposal for its long-term implementation.

Germany plans to shut down all nuclear power plants in the year 2022. By that time about 35-40% RES-E share will be achieved. In both scenarios, considerable investment in new flexible gas turbine power plants will have to be undertaken before the year 2050 in order to cover the load securely at any time in case fluctuating energy resources will not be available. Gas turbines are very flexible and have the advantage of good economic performance even at a low average utilization. Coal plants are more expensive and less flexible than gas plants, although their fuel is cheaper. Lignite and nuclear power plants are not able to provide flexible power on demand in a short time and are therefore phased-out.

Figure 51 and Table 35 show the clear structural benefit of scenario 2 compared to scenario 1 with considerably less power plant, grid and storage capacity especially in the long term. There is lower surplus capacity and a higher annual average utilization of the power park if 1.5 GW CSP-HVDC imports are added before 2025 and expanded to 3 GW in the long-term. While scenario 1 shows an exponential growth of installed capacity towards 55 GW in the long-term in order to achieve 95% RES-E share, scenario 2 achieves the same RES-E share but shows a clear saturation of capacity at 35 GW in 2050. This confirms – now on a smaller, regional level – the results from the analysis of Europe and Germany described before.

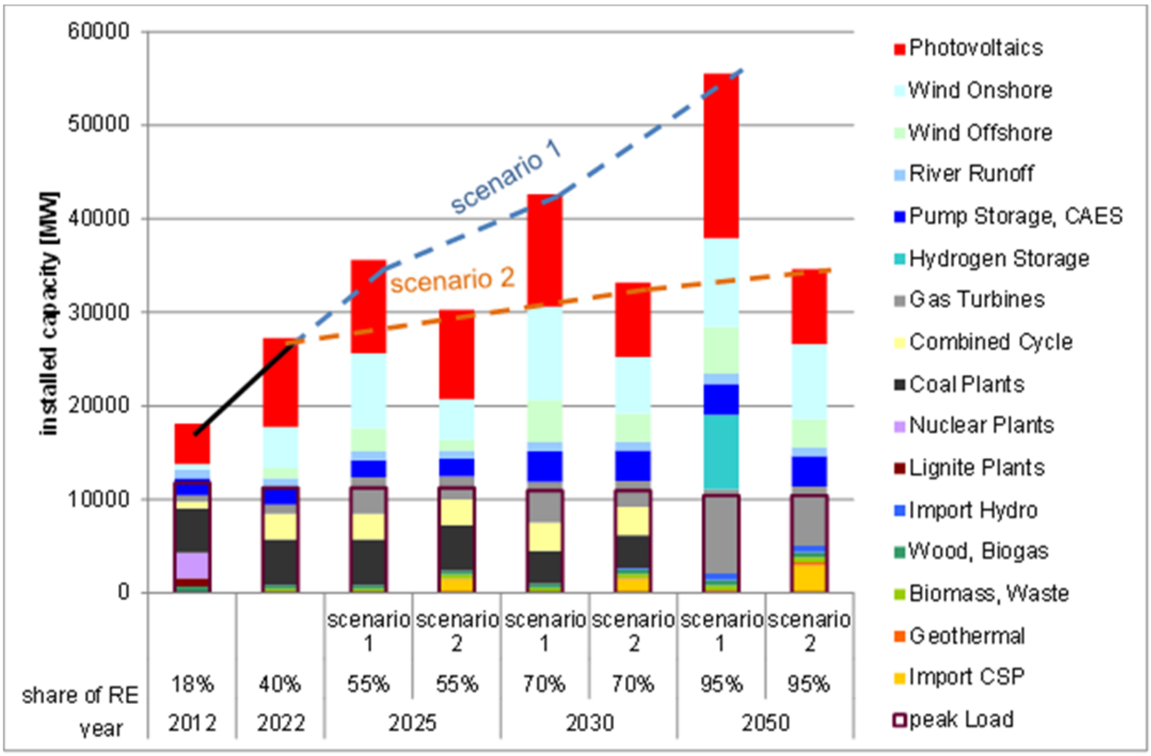


Figure 51: Two scenarios for Baden-Württemberg that follow different strategies after 2022 and reach 95% RES-E until 2050. They differ in the import of dispatchable solar imports from CSP plants in North Africa (Hess 2013).

Table 35: Installed capacity, annual electricity production and average utilization of the German power park for scenario 1 (left) and scenario 2 (right) in the year 2025 (Hess 2013)

Scenario 1 Year 2025 national, 55% RES-E	**Installed Capacity**	**Annual Electricity Generation**	**Average Utilization**	**Scenario 2 Year 2025 incl. import, 55% RES-E**	**Installed Capacity**	**Annual Electricity Generation**	**Average Utilization**
	MW	TWh/a	h/a		MW	TWh/a	h/a
Fluctuating / Renewable	21420	35,4	46%	**Fluctuating / Renewable**	15890	24,4	32%
Photovoltaic	10000	8,2	819	Photovoltaic	9500	7,8	819
Wind Onshore	8000	11,7	1461	Wind Onshore	4400	6,4	1461
Wind Offshore	2500	9,1	3651	Wind Offshore	1100	4,0	3651
River Runoff Hydropower	920	6,4	6951	River Runoff Hydropower	890	6,2	6951
Flexible / Renewable	895	6,3	8%	**Flexible / Renewable**	2395	19,1	25%
Biomass, Waste	415	3,0	7247	Biomass, Waste	415	3,1	7523
Wood, Energy Crops, Biogas	415	2,8	6761	Wood, Energy Crops, Biogas	415	3,0	7160
Geothermal	65	0,5	7269	Geothermal	65	0,5	7559
Import stored Hydropower	0	0,0	0	Import stored Hydropower	0	0,0	0
Import CSP-HVDC	0	0,0	0	Import CSP-HVDC	1500	12,5	8321
Fossil / Nuclear	11450	35,6	46%	**Fossil / Nuclear**	10100	33,0	43%
Gas Turbinens	3850	0,2	46	Gas Turbinens	2500	0,0	4
Steam Coal Plants	4850	25,8	5319	Steam Coal Plants	4850	24,4	5034
CC and CHP	2750	9,6	3484	CC and CHP	2750	8,6	3126
Nuclear Plants	0	0,0	0	Nuclear Plants	0	0,0	0
Lignite Plants	0	0,0	0	Lignite Plants	0	0,0	0
Speicher und Netztransfer	7470	0,9	1%	**Speicher und Netztransfer**	7470	0,1	0%
Pump Storage and CAES	1870	0,7	358	Pump Storage and CAES	1870	0,1	42
H2-Storage (Power)	0	0,0	0	H2-Storage (Power)	0	0,0	0
H2-Storage (Capacity) (days)	0			H2-Storage (Capacity) (days)	0		
Net Transfer Capacity (NTC)	5600	0,3	48	Net Transfer Capacity (NTC)	5600	0,0	0
Total Power Park	**35635**	**77**	**2154**	**Total Power Park**	**30255**	**77**	**2529**
Gross Consumption BW		**76,5**		**Gross Consumption BW**		**76,5**	

3.4. 1st DRAFT OF A RES-E IMPORT INFRASTRUCTURE

In the following we provide a first rough model of a point-to-point HVDC interconnection between a Moroccan CSP plant that would provide flexible solar power just as required at the demand side in the Federal State of Baden-Württemberg, Germany (Hess 2013). The analysis reveals that such infrastructure could be realised and commissioned around the year 2025 if started latest in 2016.

3.4.1. CSP Site and HVDC Corridor Selection

The CSP power plant sites in Morocco, the feed-in points in Germany and the interconnecting HVDC corridors discussed here are first hypothetical model cases for a first visualization of such an infrastructure and are not meant to replace or anticipate the planning of real sites and corridors.

CSP site selection in Morocco was based on technical, social and environmental exclusion criteria and on Direct Normal Irradiance (DNI) potentials from SOLEMI (2012) with the result of two exemplary sites in Marrakesh and Missour with about 2300 kWh/(m²·a) at a relatively short distance to Europe (Figure 52). This DNI enables up to 6200 h/y average utilization for CSP plants with a Solar Multiple of SM = 3.5 according to Trieb et al. (2009).

The required capacity of the concentrating solar power plant park was modelled reciprocally with about 2200 MW (17 x 130 MW) of gross capacity in Morocco, taking into consideration the losses of the HVDC transmission line and the internal own demand of the CSP plants, in order to achieve a net import capacity of 1500 MW at the feed-in point in Germany (Figure 53), as required according to the analysis of Baden-Württemberg presented before. With an average utilization of 6200 hours per year about 9.3 billion kWh of solar electricity per year would be delivered to Germany covering approximately 1.5% of Germany's electricity demand.

In this case an excessive dependence on energy imports is not visible. On the contrary, a diversification of resources by solar power imports leads to higher independence, higher flexibility and adds high value, dispatchable renewable energy to the domestic energy sources.

With Morocco as solar electricity provider, the risk of regional political instability is rather low, as Morocco is in a phase of modernization with intensive economic growth, expected to continue with over 4%/a, therefore also becoming increasingly attractive for international investment (KPMG 2012). A major change of paradigm would be involved in such a project, transforming the former almost 100% energy importer Morocco into an energy exporting country, significantly adding to the portfolio of possible energy supply corridors for Europe (REACCESS 2009 and REACCESS 2012).

The feed-in points at the end of the HVDC link in Daxlanden and Eichstetten in the South of the Federal State of Baden-Württemberg were selected on the basis of discussions with local grid operators that identified those sites as appropriate (Zeitler 2012).

The transmission route was calculated using a computer based algorithm according to May (2005) which includes cost criteria based on economic, environmental and social factors (Figure 54). Two exemplary routes over Morocco, Spain, France and Germany where identified as possible corridors for the HVDC link (Figure 55). While one route crosses the Pyrenees, the other one avoids that by taking a route along the sea shore. The limit for the sea cable was set at a depth of 1000 meters (ABB 2012) and can extend to up to 1450 meters (REE 2013).

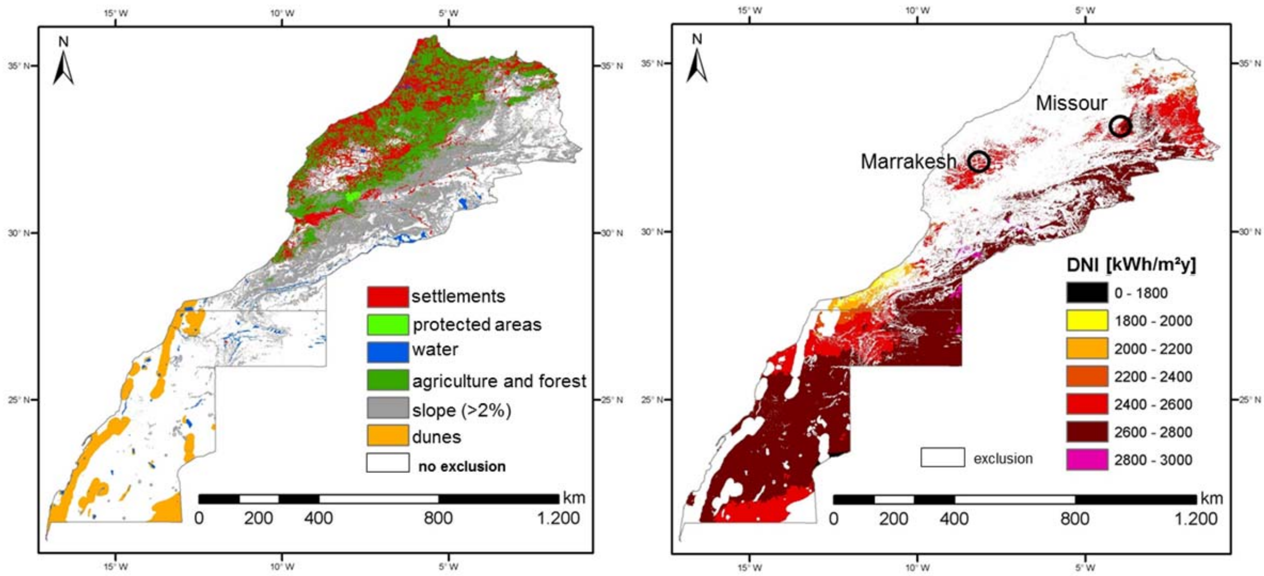


Figure 52: Site exclusion criteria for the CSP plants (left) and Direct Normal Irradiation (DNI) in Morocco (right). The sites of Marrakesh and Missour marked in the right figure were selected as CSP model sites for our analysis (Hess 2013).

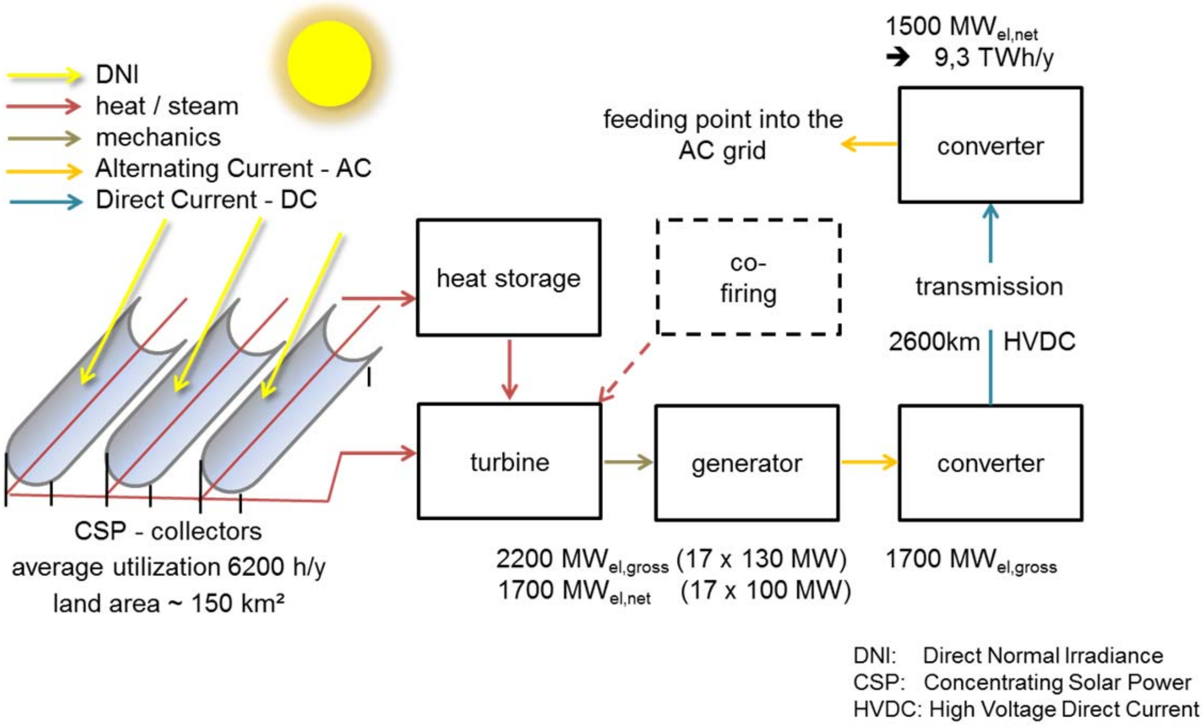


Figure 53: Sketch of a CSP-HVDC infrastructure for 1500 MW net power capacity at the feed-in point in Germany (Hess 2013)

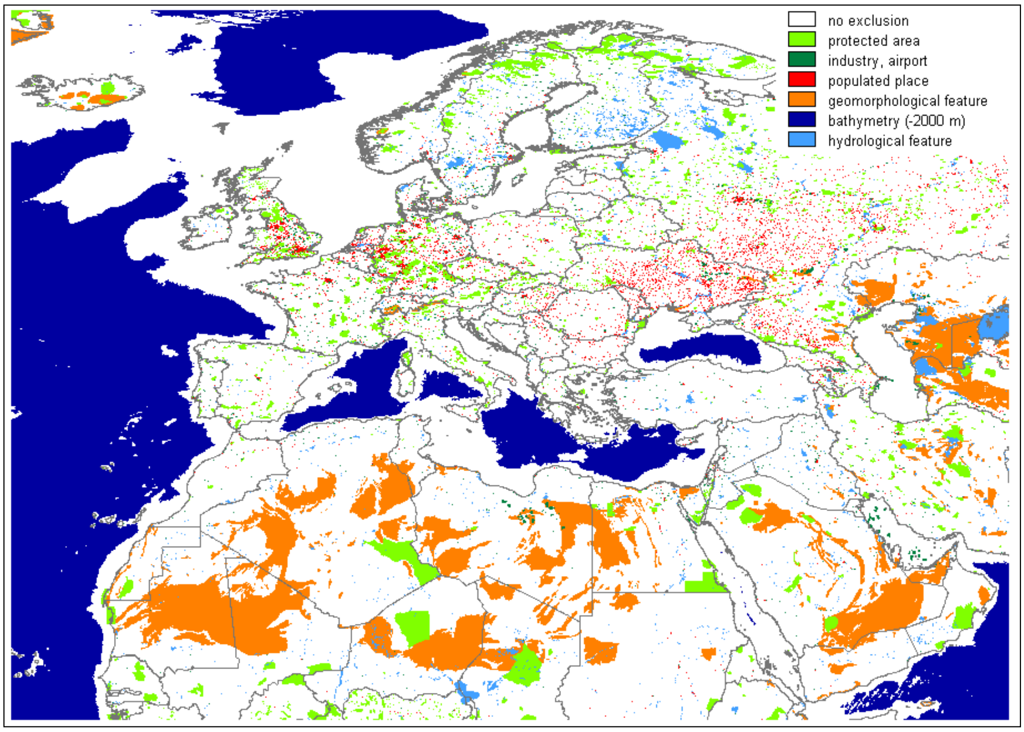


Figure 54: Site exclusion criteria for HVDC interconnections in Europe, the Middle East and North Africa (May 2005)

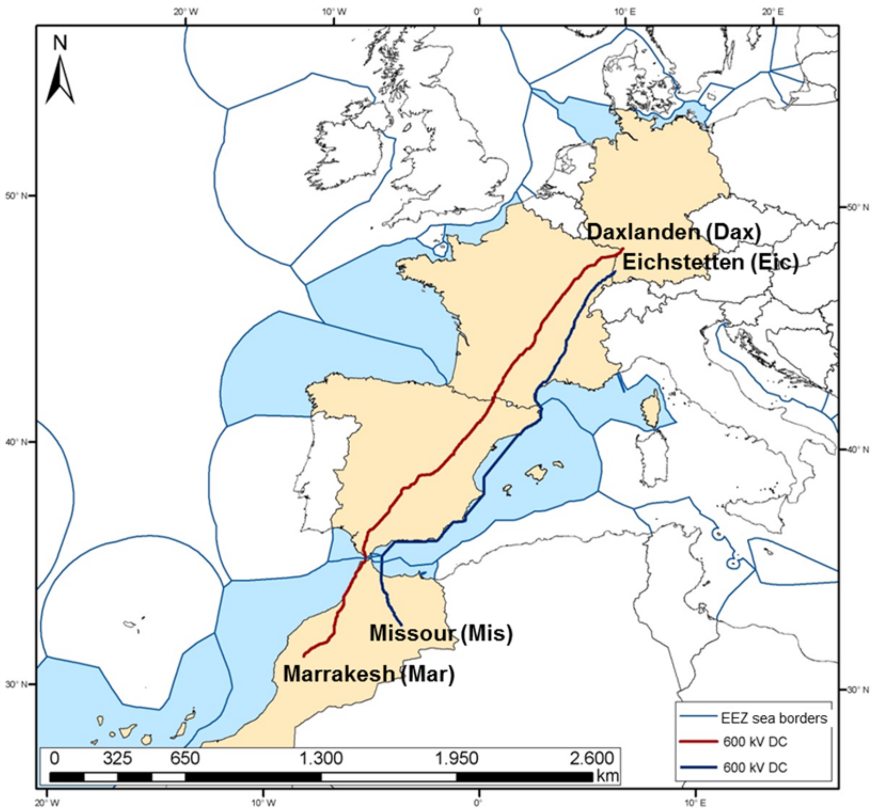


Figure 55: Two alternative HVDC corridors from Marrakesh and Missour, Morocco to Daxlanden and Eichstetten in the Federal State of Baden-Württemberg, South-Western Germany (Hess 2013).

3.4.2. Design model of the CSP plant units

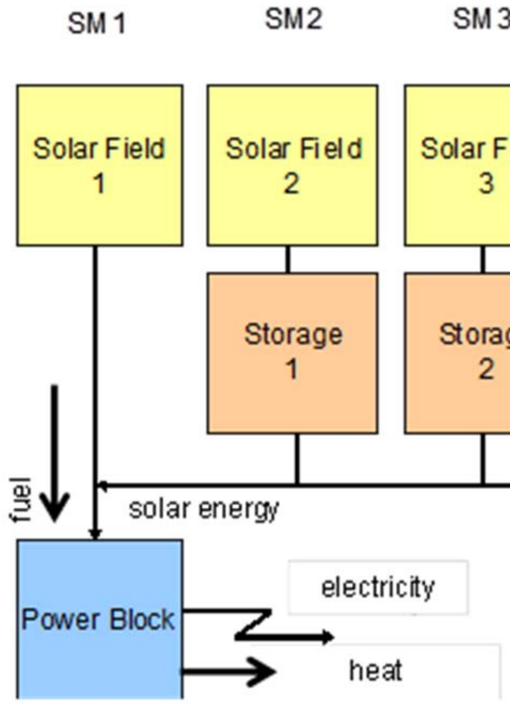
Concentrating solar power (CSP) plants are steam power plants using direct sunlight - Direct Normal Irradiance (DNI) - with concentrating solar mirrors to produce high temperature heat for a conventional steam turbine power block (Figure 56, top). Thanks to the possibility of storing heat in a simple storage tank with molten salt as storage medium, electricity can be produced just as required by demand (Trieb et al. 2014). Optionally a co-firing with fuels of all kinds can be used in case. Therefore, CSP plants can be considered as a source of dispatchable power. The turbine mechanically drives a generator, which produces alternating current (AC) that has to be converted to Direct Current (DC) before it can be fed into an HVDC link. The CSP plant has to compensate all losses of transmission of the HVDC line and own demand for the CSP plant operation.

For the performance modelling of the plant, time series of DNI and of the load to be covered are required. The Solar Multiple describes the number of additional solar fields with thermal storage (Figure 56, top) that are required to produce electricity also in times when the sun does not shine. For example, with a SM 2 the first solar field drives the turbine during the day, while the second solar field fills the thermal storage for later night-time operation. An integrated fossil-fuel-fired steam generator can provide additional thermal energy for power generation (hybrid mode). For the purpose of producing the amount of electricity required in Baden-Württemberg, we have chosen a solar multiple of SM = 3.5 which will yield about 6200 full load operating hours at the selected sites, producing 13.7 TWh/a gross electricity output at the selected sites in Morocco with DNI of 2300 kWh/m²/a (Figure 56 bottom).

In order to achieve an electricity input of 1700 MW at the beginning of the HVDC line in Morocco according to Figure 53, 17 CSP units with 100 MW_{net} power output each would be required. The reference concentrating solar power plant units are assumed to use parabolic trough mirrors of the type ANDASOL (ESTELA SOLAR 2012). This type of plant will have parasitic losses in form of electricity consumption of the solar field pumps, the storage pumps, the condensate feed-pump, the dry cooling tower and others. In order to cover the parasitic electricity demand of 29 MW for a 100 MW plant with Solar Multiple 3.5, the gross power of each CSP plant unit would have to be 129 MW_{gross} (Figure 57). Design details of the CSP plant units are given in (Table 36). Parasitic losses are particularly high for parabolic trough plants with high solar multiple, and can be reduced significantly using central receiver (solar tower) technology.

For the water needs of the CSP plant, a reverse osmosis plant at the seashore can be used (MENAWATER 2011). It turns sea water into fresh water by desalination. For 13.7 TWh/y gross electricity production the total CSP plant requires about 4.1 million m³ of water per year. Reverse osmosis has a power requirement of approximately 4-6 kWh/m³ and is dependent on the salinity of the water. At an average capacity utilization of solar thermal power plant of 6200 hours per year an installed capacity of 3-4 MW for the water desalination is needed. This represents about 0.2% of the total CSP power plant park of 2200 MW and can therefore be considered as a marginal loss.

The water could be transported at a flow rate of 130 l/s in a pipeline from the Atlantic or Mediterranean coast to the power plant park. As a synergy effect, the water pipeline could, depending on the dimensioning, supply surrounding settlements and agriculture and thus create habitat in the desert, stop the desertification and even gain back land that has been lost by desertification.



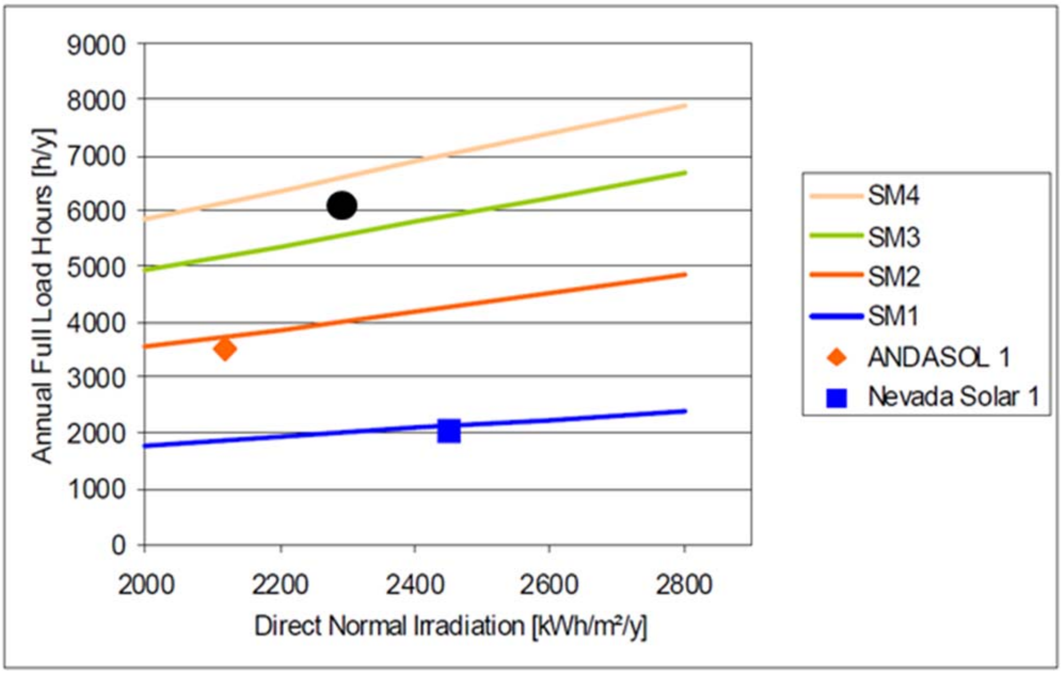


Figure 56: Definition of the Solar Multiple SM (top) and its impact on the annual full load operating hours of a CSP plant as function of DNI (bottom) according to Trieb et al. (2009). The black point in the lower graph indicates the design point of the selected CSP sites with a DNI of around 2300 kWh/m²/y and a Solar Multiple of 3.5.

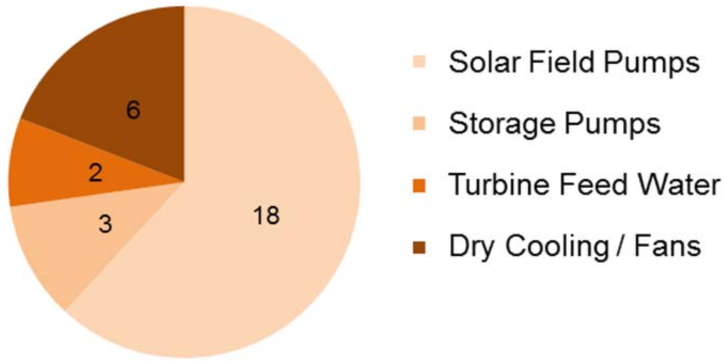


Figure 57: Parasitic own electricity demand (MW) of each CSP plant unit with a SM 3.5 and 129 MW gross output (Hess 2013)

Table 36: Pre-design dimensions of the 100 MW CSP power plant units

General CSP technology information:	
Building period (status of technology) year	~ 2020-2025
Solar field technology	parabolic trough
Power plant technology	steam cycle
Heat storage technology	molten salt
CSP design characteristics (per unit)	
Solar field collector aperture area per unit (million m²)	2.287
Solar Multiple (SM)	3.5
Nominal solar field output at DNI 800 W/m² per unit ($MW_{thermal}$)	986
Size of the molten salt heat storage per unit ($MWh_{thermal}$)	4225
Storage time at full load (h)	15
Nominal turbine heat input per unit ($MW_{thermal}$)	282
Nominal turbine gross electric output per unit ($MW_{gross, electric}$)	129
Nominal turbine net electric output per unit ($MW_{net, electric}$)	100
Total land requirement per unit (million m²)	8.693
Water requirement ($m^3/MWh_{gross, electric}$)	0.3
Minimum lifetime of all components (years)	40
Number of units per CSP-HVDC link	17

3.4.3. Design model of the HVDC Links

The first CSP-HVDC link in Baden-Württemberg was scheduled to replace one nuclear power block with a typical capacity of 1500 MW similar to the last one to be decommissioned in the year 2022. Therefore the losses of the sea cable, underground cable, overhead lines and converters (Table 37) where added in a reciprocal way to the net power at the feed-in point in Germany, yielding a gross capacity of 1700 MW at the beginning of the line in Morocco. The gross capacity of the transmission line equals the net capacity of the CSP plant.

For each of the two alternative corridors (Marrakesh – Daxlanden and Missour – Eichstetten), there are two possibilities for the HVDC connection over land resulting in a total of four different options for the realization of the CSP-HVDC links between Morocco and Germany (Table 38 and Figure 58).

1. an overhead line plus sea cable between Marrakesh and Daxlanden,
2. an underground cable plus sea cable between Marrakesh and Daxlanden,
3. an overhead line plus sea cable between Missour and Eichstetten,
4. an underground cable plus sea cable between Missour and Eichstetten.

Due to differences in distance and transmission technology that relate to different losses, the gross output of each CSP plant in Morocco will have to be different in order to compensate for those losses and yield in all four cases the same net input power in Baden-Württemberg.

Table 37: General transmission losses related to the nominal capacity of the HVDC link (Hess 2013).

losses overhead line ±600 kV HVDC [%/1000km]	4.3
losses sea cable ±600 kV HVDC [%/1000km]	2.6
losses underground cable ±600 kV HVDC [%/1000km]	3.4
losses of one converter station [%]	1.0

Table 38: Overall losses of the CSP-HVDC links (Hess 2013). The losses are added to the net import capacity of 1500 MW, yielding for each line and configuration the necessary gross power output of the respective CSP plant in Morocco.

route	technology	length	losses HVDC	own demand CSP	losses (MW)	Gross CSP capacity (MW)
Marrakesh-Daxlanden	overhead	2600 km	9.6 %	22.6 %	712	2212
Marrakesh-Daxlanden	cable	2600 km	7.9 %	22.6 %	658	2158
Missour-Eichstetten	overhead	2300 km	7.3 %	22.6 %	640	2140
Missour-Eichstetten	cable	2300 km	6.6 %	22.6 %	618	2180

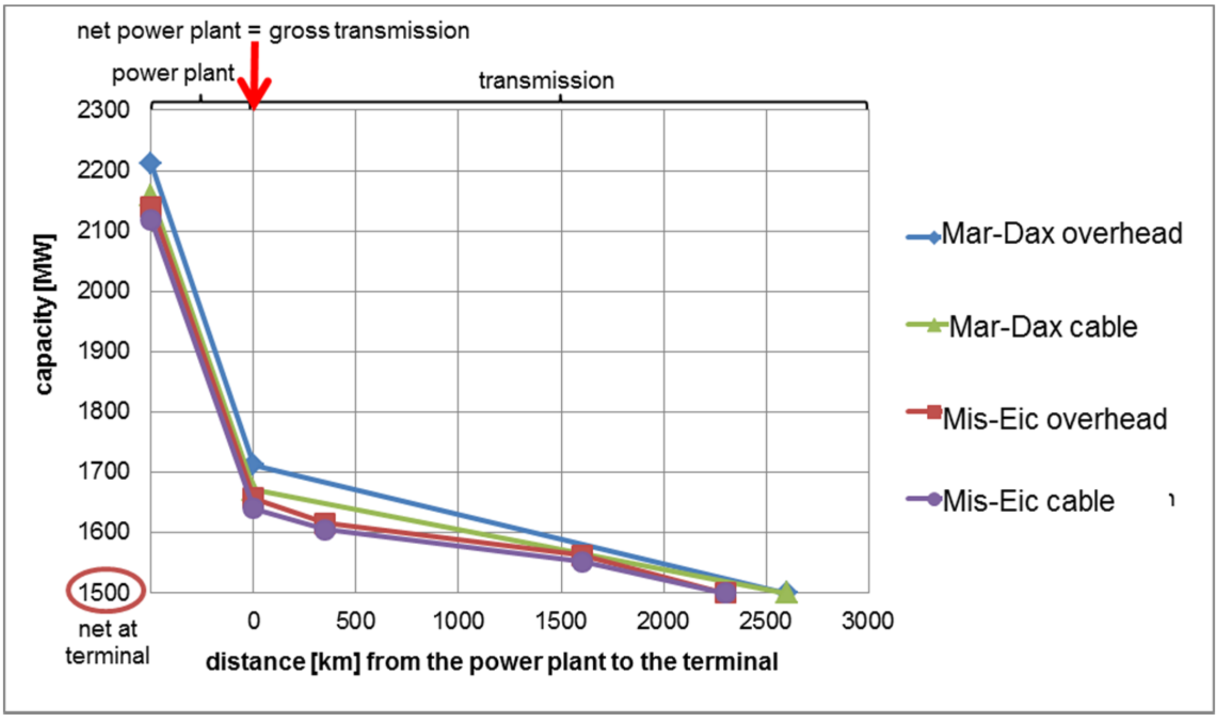


Figure 58: Gross capacity and capacity losses of the four analyzed CSP-HVDC alternatives dependent on distance and technology [16]

The maximum capacity for one symmetric bipolar HVDC system with a tension of ±600 kV and cable is about 1920 MW. The bipolar system consists of one plus pole and one minus pole. As safety conductor a metallic return (MTLR) is installed as third cable in case one of the pole cables has a defect. In case of a defect the system with the MTLR can transmit 50% of the active power (Westermann 2012).

Tension and current are the limits for the sea cable (ABB 2012) which is used to cross the Mediterranean Sea. The required gross capacity of about 1710 MW (Figure 58 at 0 km) for the transmission is hence within the capacity limits of the sea cable.

The characteristic losses of the technology are described in Table 37 and summarized for the four transmission route variants in Table 38. The losses of the analyzed CSP-HVDC sites are 29.2% to 32.2% of the gross capacity of the CSP plant. About 22.6% of the losses occur in the CSP plant.

The transmission line crosses predominantly agricultural and grassland. The demand of land for the four HVDC-variants is between 155 km² and 326 km² (Table 39). The reason for the remarkable difference is that the overhead line needs 70 m and the underground and sea cable only 4 m for its protective strip (Figure 59).

Table 39: Demand of land of the CSP-HVDC link depending on transmission technology

Element	Marrakesh-Daxlanden (~2600 km)	Missour-Eichstetten (~2300 km)
CSP plant park	149 km²	146 km²
share of sea cable (fix)	0.10 km²	5 km²
100% overhead transmission line	177 km²	78 km²
pylon bases	0.13 km²	0.05 km²
number of pylons	6300	2600
100% underground cable	10 km²	4 km²
∑ 100% overhead transmission line incl. CSP	~326 km²	~229 km²
∑ 100% underground cable incl. CSP	~159 km²	~155 km²

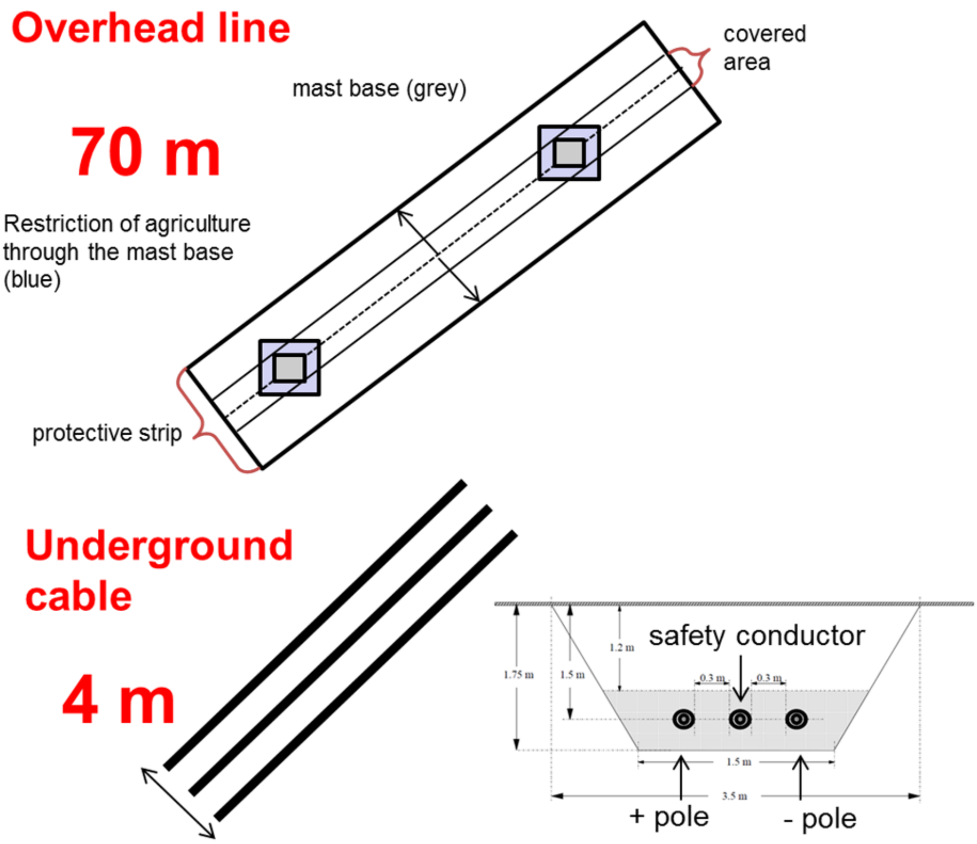


Figure 59: Safety width of a ±600 kV HVDC overhead line (top) and an equivalent underground cable (bottom) for 1700 MW nominal capacity (ECOFYS 2008).

3.4.4. Investment Cost Model

According to Table 41 the specific costs of a concentrating solar thermal power plant with a Solar Multiple of SM = 3.5 and 15 full load hours of storage capacity are calculated at about 5284 €/kW on the basis of an estimate of Trieb et al. (2012) for a worldwide installed capacity of 80 GW that could be realized between 2020 and 2025, including all material and construction costs. Prices are given in real constant monetary value of the year 2010. For nominal prices beyond 2020, inflation since the year 2010 must be added. Details of the CSP investment are given in Table 41, Table 43 and Figure 60 for the four CSP-HVDC alternatives. The total investment of the CSP plants amounts to 11.3 - 11.8 billion €, with the solar field making up for the largest part of it. The most expensive CSP plant is required for the Marrakesh – Daxlanden overhead link, the cheapest for the Missour-Eichstetten underground and sea cable.

While the CSP investment is more or less similar for all four variants, HVDC investment differs strongly between roughly 2 and 5 billion €. The cheapest version is the overhead line between Marrakesh and Daxlanden, while the most expensive version is the underground cable version on the same route (Figure 60 and Table 42). The cost of the variants on the route Missour-Eichstetten with a much larger share of sea cables lies in between those values.

Altogether, the total specific investment is lowest for the Marrakesh-Daxlanden overhead line alternative and highest for the underground cable on the same route (Table 40). This confirms the much higher impact of the CSP plant on the overall cost, which makes up for 70-85% of the total investment. The overall total investment for the CSP-HVDC links varies between 13.7 and 16.5 billion €. With respect to the net power capacity of each link of 1500 MW, this translates to a specific overall investment of the HVDC links of 9000 to 11000 €/kW_{net}.

Table 40: Total system cost of the four CSP-HVDC alternatives

Route	Technology	Length	CSP Cost	HVDC Cost	Total Cost
Marrakesch-Daxlanden	overhead HVDC	2600 km	11.7 billion €	2.0 billion €	13.7 billion €
Marrakesch-Daxlanden	underground cable HVDC	2600 km	11.4 billion €	5.1 billion €	16.5 billion €
Missour-Eichstetten	overhead HVDC	2300 km	11.3 billion €	3.7 billion €	15.0 billion €
Missour-Eichstetten	underground cable HVDC	2300 km	11.2 billion €	4.9 billion €	16.1 billion €

With around 9,000 - 11,000 €/kW, the total specific investment cost of the CSP-HVDC links lies in the same order of magnitude as the commissioning cost of the latest nuclear reactors in the UK, that amounts to approximately 10,000 €/kW, if the CSP-HVDC onfrastructure is designed for a comparable base load performance with over 7500 full load hours per year (European Commission 2014). Moreover, while the decommissioning cost of the existing nuclear plants in the UK is around 100 billion € for an installed capacity of 11 GW which makes up for 9,000 €/kW (NAO 2008), the decommissioning cost of CSP-HVDC links is near zero, as the rest value of the recyclable materials easily makes up for their decommissioning cost. In the long-term, old plants of both types will be decommissioned and new ones will be commissioned in order to replace them, adding both the commissioning and decommissioning cost in the same period of time. This makes CSP-HVDC imports clearly a less expensive solution (10,000 €/kW for commissioning + 0 €/kW for decommissioning) when compared to nuclear power (11,000 €/kW for commissioning + 9,000 €/kW for decommissioning), when talking about the moment old plants are replaced by new ones. This comparison does not take into account that future specific investment in CSP will be considerably lower due to the learning effects still ahead, while nuclear power has negative cost learning rates and tends to become more and more expensive (Neij 2008).

According to Trieb et al. (2012) the cost of CSP stations between 2020 and 2025 used here as reference could be achieved if by that time an installed power capacity of world wide 39 GW in 2020 and 95 GW in 2025 would be achieved. This involves the risk that less capacity might be installed on a global level until then, and learning effects would be lower. According to REN21 (2013), the average annual growth rate of CSP in the past five years was 43%/a, with an installed capacity of 2550 MW in 2012. If this average growth rate would be maintained constant, in 2020 about 44 GW could be achieved, and up to 104 GW by 2025. Therefore, as CSP growth rates have even been increasing during the past years, there is a good chance that our cost expectations could be achieved or even surpassed.

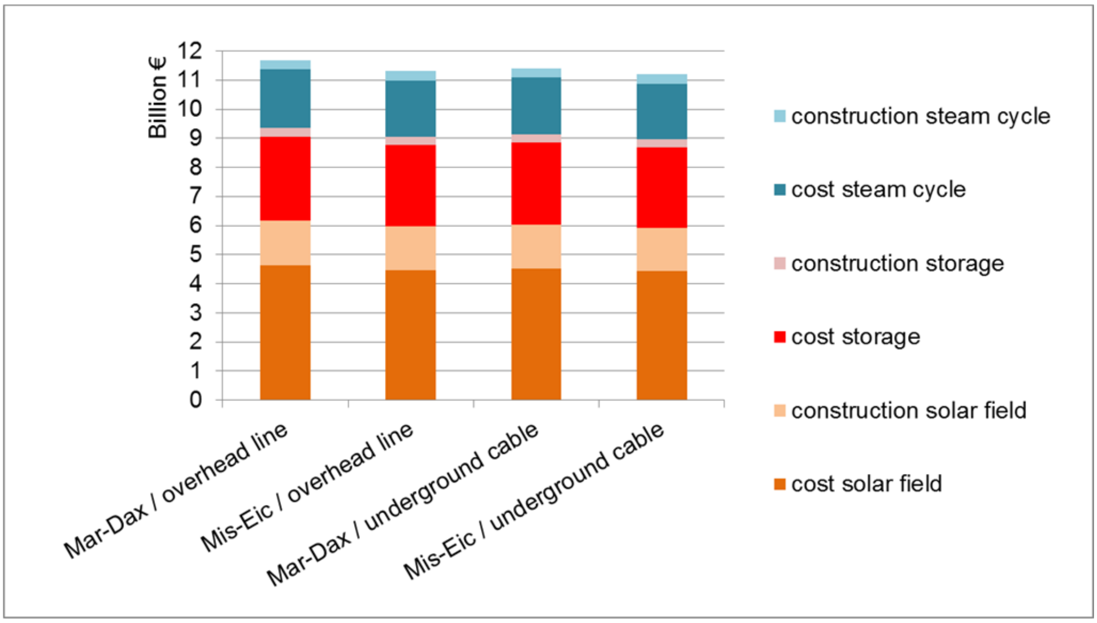
Our cost predictions for CSP are rather conservative when compared to other sources (Philibert 2010, Greenpeace 2009). Considering also, that other technologies than parabolic trough collectors might be used in future CSP plants, this also holds a considerable potential for cost reduction. Another cost reduction potential is related to the selected sites with a DNI of 2300 kWh/(m²a), considering that sites with higher DNI (up to 2700 kWh/(m²a)) are available in the region, allowing for a smaller solar field to produce the same amount of electricity over the year. In this context, we can assume a certain risk that our CSP collector field might be more expensive than expected in case of a much slower development of CSP technology world wide, although our estimate can be considered as conservative approach. This could lead to a total CSP-HVDC investment of roughly 23 billion € instead of 16 billion €.

Table 41: CSP cost model parameters (Trieb et al. 2012) and Moser (2013)

General CSP technology information:	
Building period (status of technology) year	~ 2020-2025
Solar collector field technology	parabolic trough
Power plant technology	steam cycle
Heat storage technology	molten salt
Cost of CSP elements (including construction):	
Solar field cost (€/m²)	156
Heat Storage Cost (€/$kWh_{thermal}$)	44
Power block cost (€/$kW_{gross, electric}$)	1056
Minimum lifetime of all components [y]	40
Construction cost (included in CSP element cost):	
Solar field (planning; construction; commissioning)	30 [%]
Heat storage (planning; construction; commissioning)	10 [%]
Power block (planning; construction; commissioning)	15 [%]

Table 42: HVDC cost model parameters (Hess 2013)

General HVDC technology information:	
Building period (status of technology) year	~ 2020-2025
Converter technology	VSC
Symmetrical bipolar HVDC with a tension of	±600 kV
HVDC material cost (excluding construction):	
Cost overhead line ±600 kV HVDC [€/ (MW km)] without construction	134
Cost underground cable ±600 kV HVDC [€/ (MW km)] without construction	791
Cost sea cable ±600 kV HVDC [€/(MW km)] without construction	930
Cost converter stations [€/MW]	130000
Minimum lifetime of all components [y]	40
Additional construction cost (in percent of material costs):	
Overhead line (planning; construction; commissioning)	5; 136; 3 [%]
Underground cable (planning; construction; commissioning)	5; 32; 3 [%]
Sea cable (planning; construction; commissioning)	5; 32; 3 [%]



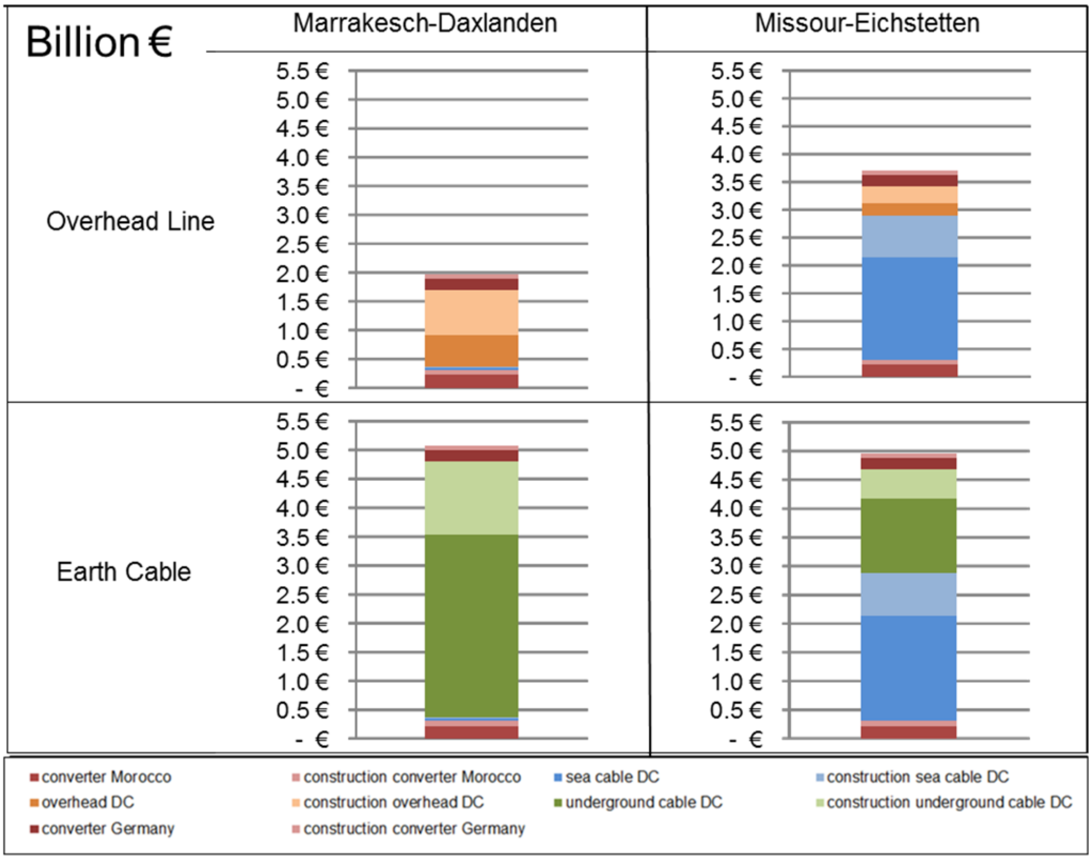


Figure 60: Investment cost for the CSP plant (top) and for the HVDC infrastructure (bottom) for the four CSP-HVDC link alternatives (Hess 2013)

Table 43: Investment cost of the four CSP-HVDC alternatives in numbers (Hess 2013)

Investment in Euro	Mar-Dax / overhead line	Mis-Eic / overhead line	Mar-Dax / underground cable	Mis-Eic / underground cable
cost solar field	4,627,032,212	4,477,467,346	4,515,117,763	4,431,752,274
construction solar field	1,542,344,071	1,492,489,115	1,505,039,254	1,477,250,758
cost storage	2,893,230,662	2,799,709,451	2,823,251,829	2,771,124,335
construction storage	286,143,692	276,894,341	279,222,708	274,067,242
cost steam cycle	2,009,302,705	1,944,353,710	1,960,703,518	1,924,501,802
construction steam cycle	327,095,789	316,522,697	319,184,294	313,290,991
converter Morocco	222,615,559	215,419,701	217,231,136	213,220,259
construction converter Morocco	89,046,223	86,167,880	86,892,454	85,288,104
sea cable HVDC	39,991,978	1,840,572,174	39,239,025	1,828,078,944
construction sea cable HVDC	15,996,791	736,228,869	15,695,610	731,231,578
overhead HVDC	544,397,230	220,467,426	-	-
construction overhead HVDC	783,932,011	317,473,094	-	-
underground cable HVDC	-	-	3,173,095,702	1,294,385,373
construction underground HVDC	-	-	1,269,238,281	517,754,149
converter Germany	196,950,000	196,950,000	196,950,000	196,950,000
construction converter Germany	78,780,000	78,780,000	78,780,000	78,780,000
Total CSP	**11,685,149,130**	**11,307,436,661**	**11,402,519,366**	**11,191,987,402**
Total HVDC	**1,971,709,791**	**3,692,059,144**	**5,077,122,208**	**4,945,688,407**
Total CSP-HVDC	**13,656,858,922**	**14,999,495,805**	**16,479,641,574**	**16,137,675,810**

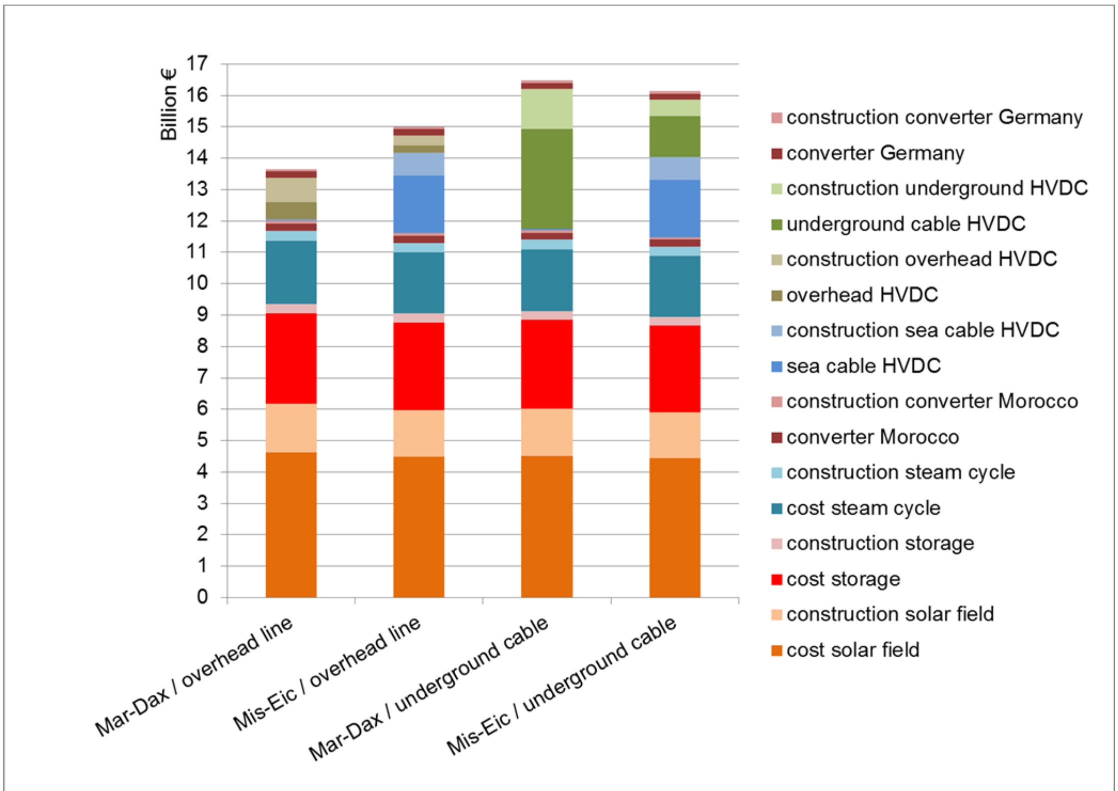


Figure 61: Total investment cost of the four CSP-HVDC alternatives for 1.5 GW net power import (Hess 2013)

3.4.5. Annual Operation Cost Model

The annual operation cost model for the CSP-HVDC links is composed of five components:

1. Operation and maintenance (O&M) cost including personnel of the CSP plant
2. Insurance cost of the CSP plant
3. Operation and maintenance cost (O&M) of the HVDC link including personnel
4. Insurance cost of the HVDC link
5. Compensation payment for the land use of the CSP-HVDC infrastructure

The parameters for the O&M cost model of the four CSP-HVDC alternatives are given in

Table 45 and Table 46. The annual operation cost estimate for the CSP infrastructure includes an O&M share of 2% and an insurance rate of 0.5% of the total investment per year. The annual operation cost for the HVDC infrastructure includes 1300 €/(MW a) for the AC/DC converters, 3000 €/(km a) for the power lines and an insurance rate of 0.5% of the total investment.

In addition to the O&M cost, the model assumes three categories of durable compensations which are related to the standard land value of each country shown in Table 44.

Table 44: Standard land value(EUROSTAT 2013)

agricultural crop land or desert	standard land value	highest standard land value	highest leasing fees
Morocco	0.1 €/m²	-	-
Spain	1 €/m²		
France	0.5 €/m²		
Germany	2 €/m²	18 €/m²	2.9 €Cent/m²

The first payment is a compensation for the devaluation of the affected land area. It is supposed to permanently compensate the decrease in value of the affected land for the total economic lifetime of the CSP-HVDC infrastructure:

$$\boldsymbol{devaluation\ payment} = \frac{\text{particular standard land value} \cdot 20\%}{9.32\ \text{TWh/y}} \left[\frac{\text{€Cent}}{\text{TWh} \cdot \text{m}^2 \cdot \text{y}}\right]$$

The devaluation payment varies from 0.29-0.83$\left[\frac{\text{€Cent}}{\text{TWh} \cdot \text{m}^2 \cdot \text{y}}\right]$ according to the standard land value in each country. It makes up for about 10-20% of the total compensation payment.

The second payment is the indemnity payment. This part of the compensation payment is equal for all needed land areas of the transmission line and power plant. It is meant to fairly and uniformly compensate for the impact of the CSP-HVDC infrastructure in all affected countries. The motivation payment goes to private landowners and to the municipalities. Municipalities will also profit from the taxes on the income of private landowners.

$$\boldsymbol{indemnity\ paym}\text{ent} = \frac{\text{highest standard land value} \cdot 2\%}{9.32\ \text{TWh/y}} \left[\frac{\text{€Cent}}{\text{TWh} \cdot \text{m}^2 \cdot \text{y}}\right]$$

The indemnity payment makes up for the largest part (80-90%) of the compensation payment. It would be in the order of magnitude of 3.92 $\left[\frac{\text{€Cent}}{\text{TWh} \cdot \text{m}^2 \cdot \text{y}}\right]$.

The third payment is the concession fee. This is a supplemental income for the municipality related to the highest leasing fees in each municipality.

$$\text{concession fee} = \frac{\text{highest leasing fees} \cdot 20\%}{9.32\ \text{TWh/y}} \left[\frac{\text{€Cent}}{\text{TWh} \cdot \text{m}^2 \cdot \text{y}}\right]$$

The concession fee is only a minor part of less than 2% of the compensation payment in the order of 0.06 $\left[\frac{\text{€Cent}}{\text{TWh} \cdot \text{m}^2 \cdot \text{a}}\right]$.

Figure 62 shows the annual compensation payments in absolute numbers in each country for the four CSP-HVDC alternatives. It can be noted that there is a considerable annual compensation payment for the large land area required for the CSP plants and the HVDC lines in Morocco summing up to about 70 million €/a, which is equivalent to the present annual German financial aid for this country.

As a result of the permanent payment dependent on the needed land area, overhead lines and underground cables can reach cost neutrality within their lifetime (Hess 2013). While overhead lines require a lower investment than underground cables, the latter need 17.5 times less land area and thereby cause less permanent expenses for compensation payments.

The maximum compensation for the CSP-HVDC Marrakesh-Daxlanden overhead line would be in the order of 145 million €/a equivalent to about 1.56 €cent/kWh and the minimum compensation would be in the order of 62 million €/a equivalent to about 0.67 €cent/kWh for the Missour-Eichstetten underground cable considering an annual production of 9.3 TWh/a.

With these model assumptions, the local income from compensation payments for the affected inhabitants and municipalities would amount to about 40 €cent/(m^2a) for the total operation time of the CSP-HVDC infrastructure of 40 years. As the transmission line runs in its majority over agriculture areas one may compare this value to the typical income from agriculture. E.g., the average typical income for land owners and farmers in agricultural areas in Baden-Württemberg is about 8 €cent/(m^2a).

The income per land area from compensation payments from the CSP-HVDC infrastructure would therefore be five times higher than from agricultural work, even in a high-income area like Germany, while in the desert area in Morocco, it would be particularly difficult to generate any income by agriculture at all. A high local income from compensation payments may thus considerably facilitate the acceptance of such a project and create numerous benefits for local development. On the other hand, it is not scheduled that the CSP-HVDC infrastructure would replace agriculture in any of the affected countries. In Morocco, desert areas are used for the CSP stations, while HVDC lines would be compatible with agricultural work in Europe.

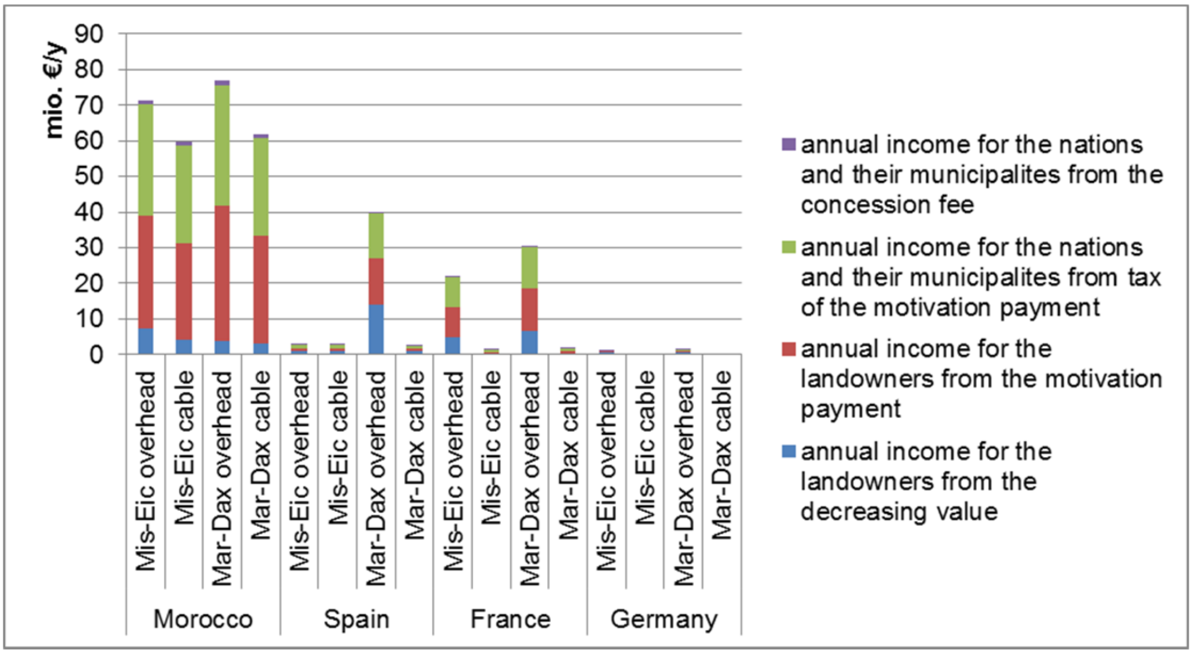


Figure 62: Annual compensation of the affected communities and landowners for the four CSP-HVDC alternatives (Hess 2013)

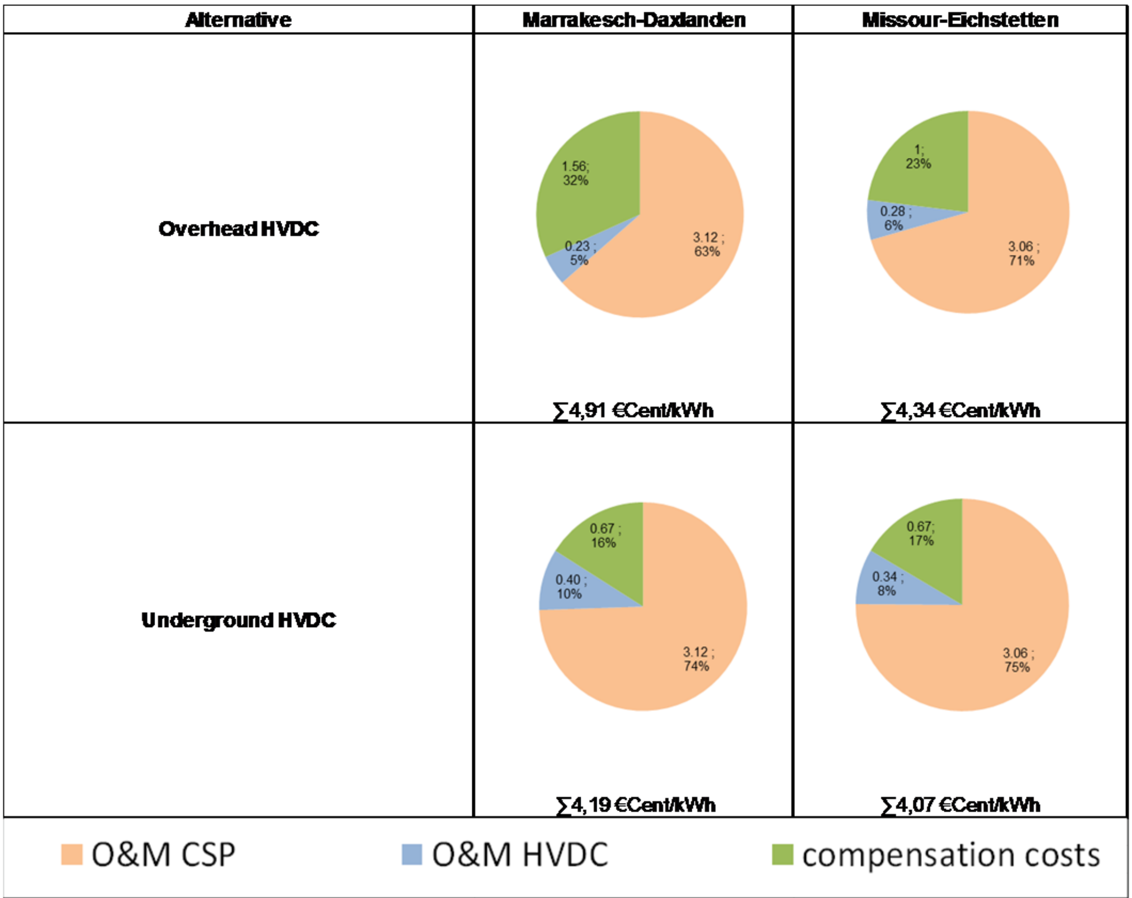


Figure 63: Annual operation cost model of the four CSP-HVDC alternatives including compensation cost for land use (Hess 2013). Cost of capital is not included.

The result for the total annual operation cost for all variants is given in Figure 63 in units of €/Cent/kWh related to the net electricity production. It is particularly interesting to note that the annual operation cost is highest for the Marrakesh – Daxlanden CSP-HVDC overhead line with a total of 4.91 €cent/kWh, which was the connection with the lowest overall investment cost. On the other hand, the CSP-HVDC underground link from Missour to Eichstetten, which had the highest investment cost, yielded the lowest annual operation cost of 4.07 €cent/kWh. This is due to the fact, that the underground cable requires much less land than the overhead line as shown in Figure 59 and Table 39 and moreover, the land use of the Missour-Eichstetten link is much lower due to the long sea cable used here. Therefore, compensation payments for land use are much lower for underground- and sea cables than for the other alternatives with overhead lines.

Table 45: Annual operation cost details of technology alternatives for the Marrakesh-Daxlanden route (Hess 2013)

Marrakesh-Daxlanden Overhead Line					
Cost item	Relative Cost	Annual cost (€)	Share	Cost per kWh [€/kWh]	Cost escalation
Compensation payment	4.75 [€cent/(TWh·m²·a)]	144,981,410	31.70%	**0.0156**	0.2%/a
O&M AC/DC converters	1300 [€/MW/a]	4,195,655	0.90%	0.0005	2%/a
O&M HVDC link	3000 [€/km/a]	7,602,000	1.70%	0.0008	2%/a
Insurance HVDC	0.5 [% of investment]	9,858,548	2.20%	0.0011	0%/a
Total annual cost HVDC				**0.0023**	
O&M CSP	2 [% of investment]	232,492,327	50.80%	0.0249	2%/a
Insurance CSP	0.5 [% of investment]	58,123,081	12.70%	0.0062	0%/a
Total annual cost CSP				**0.0312**	
Total annual cost CSP-HVDC		**457,253,024**	**100%**	**0.0491**	
Marrakesh-Daxlanden Underground Cable					
Cost item	Relative Cost	Annual cost	Share	Cost per kWh [€/kWh]	Cost escalation
Compensation payment	4.21 [€Cent/(TWh·m²·a)]	62,894,805	16.10%	**0.0067**	0.2%/a
O&M AC/DC converters	1300 [€/MW]	4,195,655	1.10%	0.0005	2%/a
O&M HVDC link	3000 [€/km]	7,602,000	1.90%	0.0008	2%/a
Insurance HVDC	0.5 [% of investment]	25,385,611	6.50%	0.0027	0%/a
Total annual cost HVDC				**0.004**	
O&M CSP	2 [% of investment]	232,492,327	59.50%	0.0249	2%/a
Insurance CSP	0.5 [% of investment]	58,123,081	14.90%	0.0062	0%/a
Total annual cost CSP				**0.0312**	
Total annual cost CSP-HVDC		**390,693,481**	**100%**	**0.0419**	

Table 46: Annual operation cost details of the technology alternatives for the Missour-Eichstetten route (Hess 2013)

Missour-Eichstetten Overhead Line					
Cost item	Relative Cost	Annual cost	Share	Cost per kWh [€/kWh]	Cost escalation
Compensation payment	4.38 [€Cent/(TWh·m²·a)]	93,312,335	24.60%	**0.01**	0.2%/a
O&M AC/DC converters	1300 [€/MW]	4,141,811	1.10%	0.0004	2%/a
O&M HVDC link	3000 [€/km]	3,147,000	0.80%	0.0003	2%/a
Insurance HVDC	0.5 [% of investment]	18,460,295	4.90%	0.002	0%/a
Total annual cost HVDC				**0.0028**	
O&M CSP	2 [% of investment]	228,199,673	60.10%	0.0245	2%/a
Insurance CSP	0.5 [% of investment]	57,049,918	15.00%	0.0061	0%/a
Total annual cost CSP				**0.0306**	
Total annual cost CSP-HVDC		**404,311,035**	**100%**	**0.0434**	

Missour-Eichstetten Underground Cable					
Cost item	Relative Cost	Annual cost	Share	Cost per kWh [€/kWh]	Cost escalation
Compensation payment	4.21 [€Cent/(TWh·m²·a)]	62,495,354	16.50%	**0.0067**	0.2%/a
O&M AC/DC converters	1300 [€/MW]	4,101,702	1.10%	0.0004	2%/a
O&M HVDC link	3000 [€/km]	3,147,000	0.80%	0.0003	2%/a
Insurance HVDC	0.5 [% of investment]	24,728,442	6.50%	0.0027	0%/a
Total annual cost HVDC				**0.0034**	
O&M CSP	2 [% of investment]	228,199,673	60.10%	0.0245	2%/a
Insurance CSP	0.5 [% of investment]	57,049,918	15.00%	0.0061	0%/a
Total annual cost CSP				**0.0312**	
Total annual cost CSP-HVDC		**379,722,091**	**100%**	**0.0407**	

3.4.6. Options for Finance

The implementation of an investment of 16 billion € for the CSP-HVDC infrastructure would generate an extremely high cost of capital for the financing of the system. E.g. a fix charge rate (annuity) of 10%/a, equivalent to a project interest rate of about 10%/a over a project period of 40 years, would lead to an annual repayment (liquidation plus interests) of 1.6 billion €/a, equivalent to a cost of 17 €cent/kWh for 40 years, not including the annual operation cost described before. This high cost for such a long period would not be attractive even considering the high quality of flexible solar power, and would mean a heavy burden on national economies.

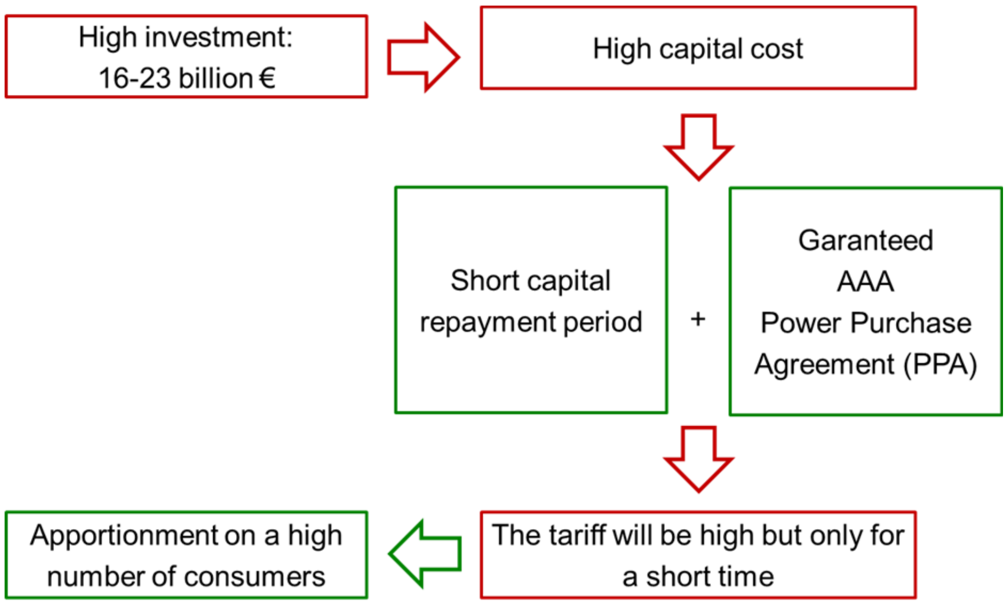


Figure 64: Principle approach to reduce the high capital cost induced by the large investment for the CSP-HVDC link by reducing the investment risk through a short payback period and a guaranteed AAA power purchase agreement

Therefore, it will be crucial to reduce the project interest rates for such large scale renewable energy projects, at least until the related technologies have run through their cost learning curves and can be considered economically mature (without considerable further potential for cost reduction). There are in principle two options to reduce the risk and with that the interest rates of such a project (Figure 64):

1. a short capital repayment period of 5 years or less,
2. a power purchase agreement guaranteed by strong national and international institutions which gives the project a very good (AAA) risk rating.

As an example, if we change the loan period from 40 to 5 years the fix charge rate or annuity would become 26%/a instead of 10%/a, and the annual repayment would amount to 4.2 billion €/a or 45 €cent/kWh, respectively, but in this case this high cost would only have to be paid for 5 years instead of 40. After 5 years, the total annual cost of the project would be reduced to its operation cost (around 4-5 €cent/kWh as shown before), thus considerably contributing to a cost stabilization of the European electricity mix.

However, shorter loan periods will lead to higher tariffs that will have to be paid for the electricity during that (shorter) period. Figure 65 shows the required tariffs for the CSP-HVDC underground cable from Missour to Eichstetten as function of the capital repayment period. For our example, we have assumed a project interest rate of 9.9%/a, a general discount rate of 1.3%/a and a project lifetime of 40 years. In this case, the highest tariff for the case of a one-year capital repayment period would amount to almost 2 €/kWh for that year. In spite of that, this would clearly be the least-cost solution, as it would lead to the lowest capital cost (9.9% for only one year) possible.

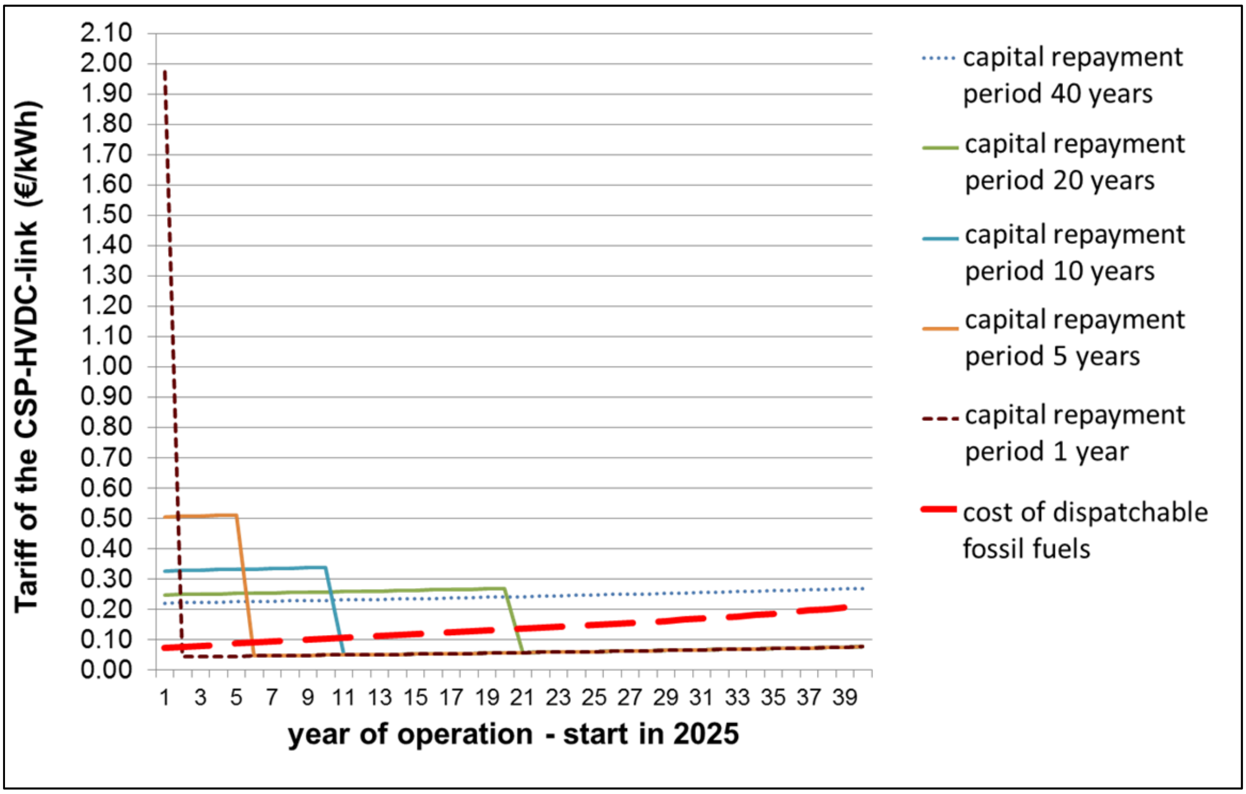


Figure 65: Required electricity tariff (€/kWh) for the CSP-HVDC link Missour-Eichstetten with underground cable as function of the capital repayment period (capital interest rate 9.9%/a). (Hess 2013)

The second measure to reduce capital cost would have to be assumed by national and international financial institutions capable of providing a guarantee on the related power purchase agreement between the electricity producer in Morocco and the off-taker in Germany. Such a guarantee could be designed in a similar way as the Partial Risk Guarantee (PRG) of the World Bank that is usually provided for power projects in developing countries in order to facilitate investment under critical frame conditions (Word Bank 2011).

Coming back to our example with 10% interest rate and 5 year payback period above, the availability of a guarantee that would turn the project into a AAA investment opportunity would easily reduce interest rates to 4% or less. This would translate into an annual payment of 3.6 billion €/a or 38.6 €cent/kWh, respectively. Thus, the repayment for the 16 billion € investment would amount to 18 billion € within 5 years, with a capital cost of only 2 billion €. After the repayment period of 5 years, the electricity tariff for the CSP-HVDC link could be reduced to its operation cost of 4.1 €Cent/kWh for the rest of its 40 year operation period.

The challenge of the temporarily high tariff could be solved by distributing the load on as many as possible electricity consumers. E.g. if all German electricity consumers would participate in the financing of the CSP-HVDC link, e.g. by introducing this option to the German Feed-in tariff system like all other RES-E sources, they would have to assume an additional payment of 0.7 €Cent/kWh on their electricity bill (Figure 66) in order to finance the full CSP-HVDC infrastructure within 5 years. If all European consumers would participate, their load would only amount to an additional 0.1 €Cent/kWh on their electricity bill for a five years period.

Thus, reducing the risk and loan period of such projects can lead to reduced interest rates, reduced capital cost and considerable cost savings (Figure 67). In this case, more money will go directly into the financing of the technology and infrastructure required, and less money will go to the profits of banks and investors. On the other hand, such an infrastructure will not be for free, and European citizens and governments will have to invest considerable amounts of money in order to obtain the related benefits, which are not only of environmental but also clearly of economical nature.

It will depend on a European consensus and the creation of an appropriate legal and political framework, if such large energy infrastructures can be realized and financed in a solidary, collaborative way. The size of such projects is too large for conventional private financing and conventional market schemes to be applied for its realization. It must be considered an important and sustainable part of the European energy infrastructure of the future.

A collaborative European participation in the finance of the CSP-HVDC infrastructure is clearly justified by the fact that all Europeans will benefit from this important element of a future sustainable electricity supply structure, which will facilitate the way towards high RES-E shares. This element will not be obtained by waiting for offers from industry or from North Africa, as those responsible for a sustainable European electricity supply system are those who are mostly in need of such an infrastructure, as has been shown in the previous chapters.

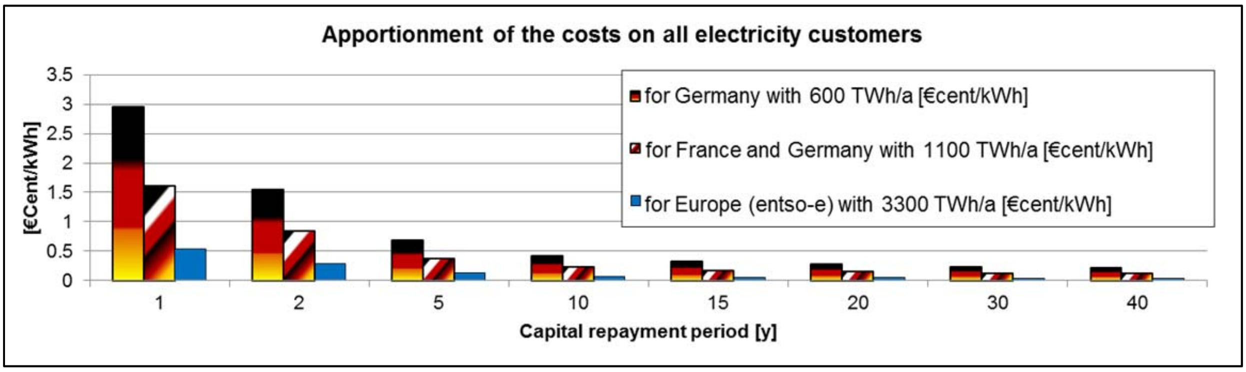


Figure 66: Example of the required tariff additions for the repayment of the CSP-HVDC capital cost as function of the capital repayment period if apportioned between German, German and French, or all European electricity consumers. E.g. assuming a capital repayment period of 5 years, German consumers would have to pay additional 0.7 €cents/kWh for that period, while the load distributed between all European consumers would be around 0.1 €cent/kWh. After the capital repayment period (in this case only 5 years), only the O&M cost that is around 4 €cent/kWh would have to be paid by the consumers, thus strongly contributing to a stabilization of electricity cost in Europe (Hess 2013).

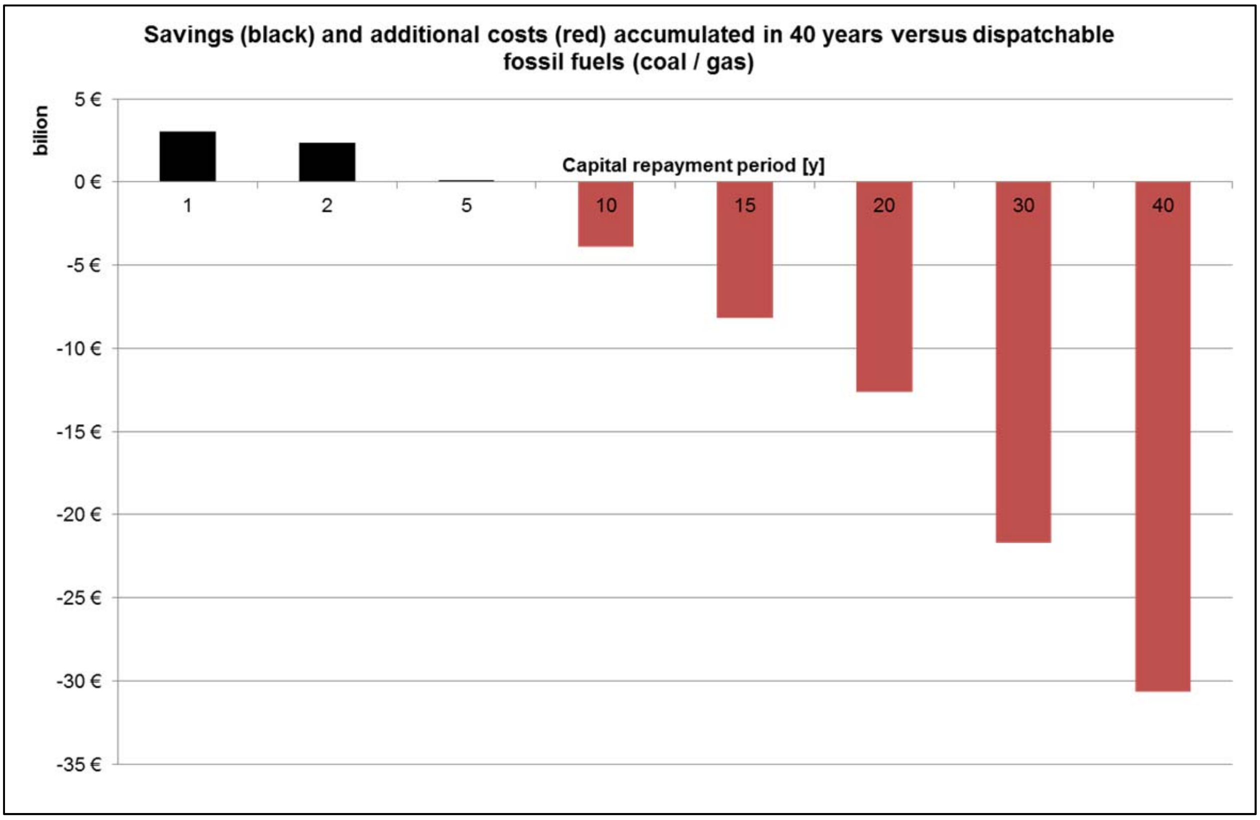


Figure 67: Savings of dispatchable solar power induced by CSP-HVDC investment versus fossil dispatchable power at a levelized cost of about 12.5 €cent/kWh after 2025 as function of the capital repayment period. Under the assumed conditions, a break-even with power from fossil fuel would occur for a capital repayment period of 5 years. Only the variant Missour-Eichstetten underground cable is displayed (Hess 2013).

3.4.7. Citizen Participation

The implementation of an electricity transmission project with four nations involved is an ambitious and interdisciplinary project that requires the participation of all stakeholders. This includes citizens, science, policy, industry and finance.

Languages, cultures, economies and even the understanding of democracy will be different for the different communities and citizens affected by the CSP-HVDC link. The project will only be successful if it achieves a win-win situation for everybody, and if the common “Not in my backyard (NIMBY)” attitude can be substituted by a “Please in my backyard (PIMBY)” perception.

There is no doubt that the project holds a fascinating potential for international and intercultural cooperation between different regions in Europe and the Mediterranean, but also numerous obstacles can be expected that may consume much more time for its realization than has been spent e.g. in China for a similar infrastructure.

Therefore, it will be crucial that strong citizen participation is an intrinsic characteristic of such a project. Citizen participation will reduce obstacles and show alternatives, e.g. if routes are discussed, if decisions on overhead lines versus underground cables must be taken, or when it comes to unavoidable environmental impacts.

Citizen participation should start as early as possible. Therefore, the best approach is to directly start such a project by citizens. A network of international cooperative civil societies, from communal to national to international level could provide an adequate framework to organize citizen participation in terms of process decisions and also in terms of financial participation in the project (Figure 68 and Figure 69). Any communal cooperative society involved could start the formation of such a network that will be finalized when it covers all the communities along the potential extension of the CSP-HVDC link.

Such a cooperative society framework will have three major tasks:

1. Start and organize the project and its implementation.
2. Organize citizen information and participation in the decision procedures including technical alternatives, route planning, environmental concerns, etc.
3. Organize citizen information and participation in the financing of the project including investment opportunities, compensation payments for land use, apportionment of electricity tariffs, etc.

The framework of cooperative societies will interact between the citizens and the involved specialists from policy, NGOs, science and industry and organize the exchange of information between those groups in order to facilitate an adequate framework for the realization of the project. Finally, after a successful decision phase, it will organize the project’s finance and EPC.

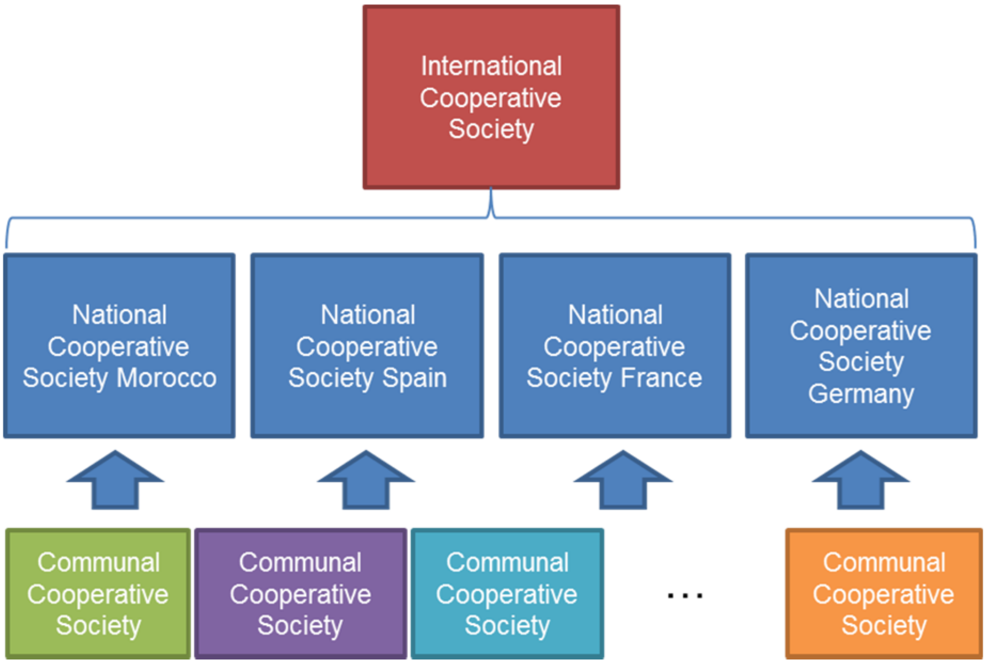


Figure 68: Structure of international cooperative societies for citizen participation (Genossenschaftsverband Bayern 2012).

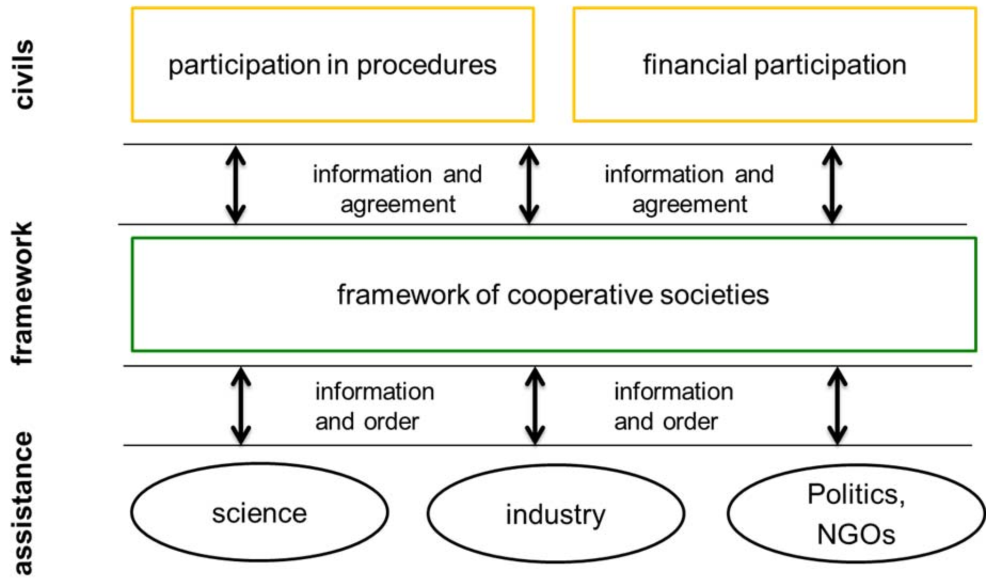


Figure 69: Potential international framework of cooperative societies for citizen participation in the procedures and in the finance of the CSP-HVDC link.

In sensitive natural areas people may be concerned by the impacts of the infrastructure. Therefore professional information is a precondition so that people can be involved in the decision process and make up for their own thoughts and ideas of a realization.

The early communication of the need of such a project is necessary to be able to weigh the pros and cons and enable an acceptance debate for the society and the affected people. If the overall benefit for society is greater, the individual interests will need to stand back and be compensated with attractive means. These issues must be discussed with the individuals to make acceptance achievable. Participation is a basis for this communication process. Today's usual procedure by only enabling "decisions on decisions" does not include the option of a basic participation in the target definition. It just involves the justification of decisions taken by a project consortium in front of the public, just before they are implemented.

One possible and maybe better way of citizen participation is the traffic light model in Figure 70. Its basic idea is to democratize the decision structure at different levels, starting from citizens over policy to the local affected people.

With the start of the information on the project idea through the media and the declaration of political intention to the public and during the formation of the international cooperative society described before, one is in the red phase. After the information through media by the mentioned international cooperative society has taken place, citizens can start to make petitions. Public decisions can take place on a multinational online communication platform and thus influence the representative democracy. In such a comprehensive, spatially diversified project modern information technologies such as social networks can assume the role of mediation and thereby prepare exchanges of arguments for an interactive decision process.

The project America Speaks (1995) can serve as a model for such a process at national level, by successfully advising U.S. citizens on public decisions in form of a congress. The topics for a decision congress consist e.g. of questions about technologies, opportunities, risks and aspects of financial participation of affected citizens. It is important to weigh general criteria, requirements and conditions for compensation benefits that are site-specific equally that can be discussed in local or regional participation processes. This congress can instruct the direct local and regional participation processes. Ultimately the elected representatives in parliament decide whether such a project is intended or not. This decision is still in the red traffic light phase. However it is only considered a framework decision rather than a dictation already concretized in details. The advantage is that such a decision cannot be influenced by minorities and would not allow overriding public interest. With a positive decision for the project one now enters the phase of the yellow light.

In the planning phase (yellow traffic light) of the project, affected citizens can play a role in the participatory democracy through deliberation (consultative decision) with the proposal of alternative solutions, especially in order to avoid conflicts. The limits of the decision are not primarily due to the construction costs, but rather rest with the technical and legal possibilities. These must be discussed with feedbacks in the population. For the communication, modern 3D interactive visualization technologies can be used with cadastral and cost data (Hess 2013).

If an agreement of the project is achieved it would be in the green phase of the traffic light - the implementation. Now there is legal certainty for the project executing organization and investors. This is important because large projects are often accompanied by private lawsuits against their local implementation.

During the project implementation an ongoing evaluation provides information to the affected citizens as a control option to obtain an evaluation of the entire project. Finally future projects can benefit from this.

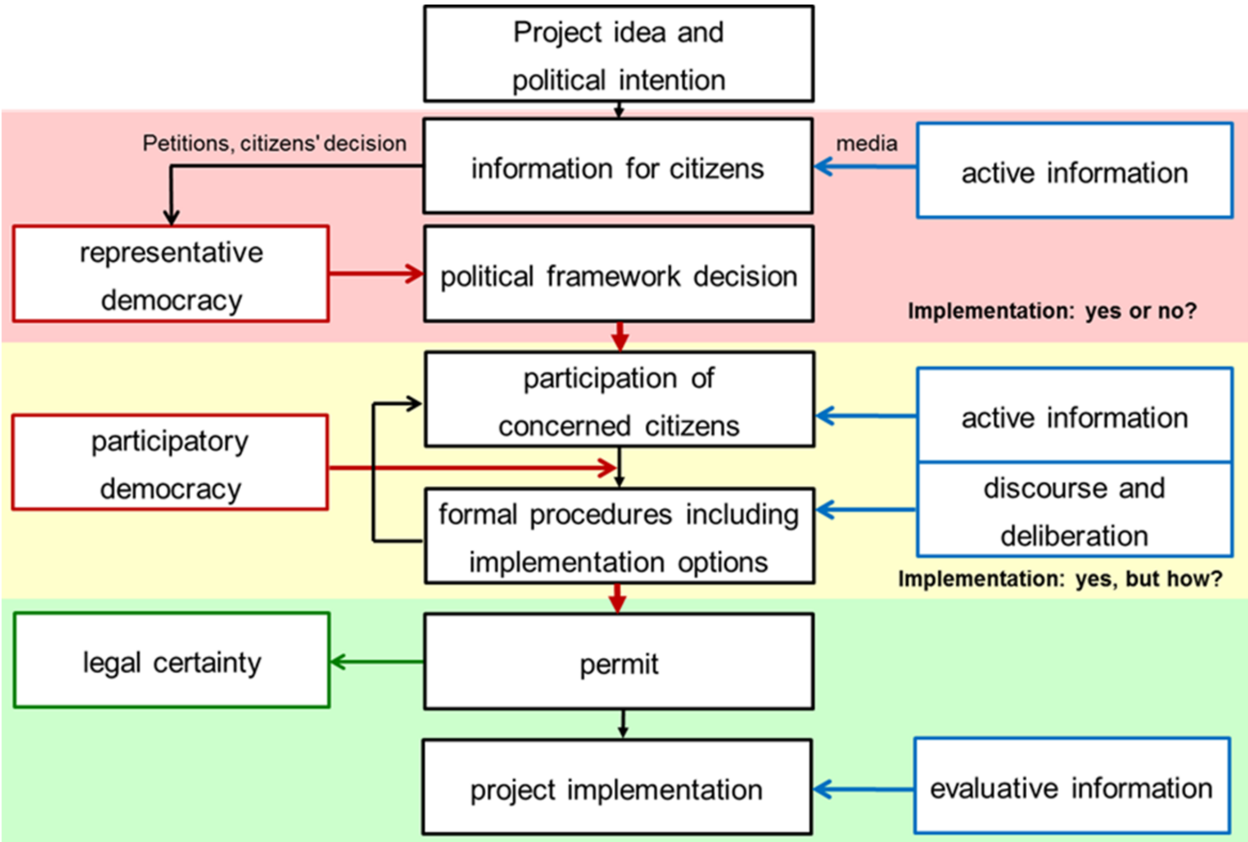


Figure 70: Traffic light model for citizen participation (Wörner 2011, Hess 2013)

3.4.8. Time Schedule

A time frame is needed for the planning and integration of the CSP plant in the power plant park of Baden-Württemberg to assess the need and the design of the power plant in time. Figure 23 describes the necessary requirements on the basis of the traffic model and the duration of the process. Here the total time schedule of decision-making, planning and building (traffic signals) extends to about 10-15 years. To start, there should be a clear political signal not later than 2014. Under optimistic assumptions the CSP plant could then provide electricity to Germany in earliest 2024. A delay of the decision of intent inevitably leads to time displacement of the entire process.

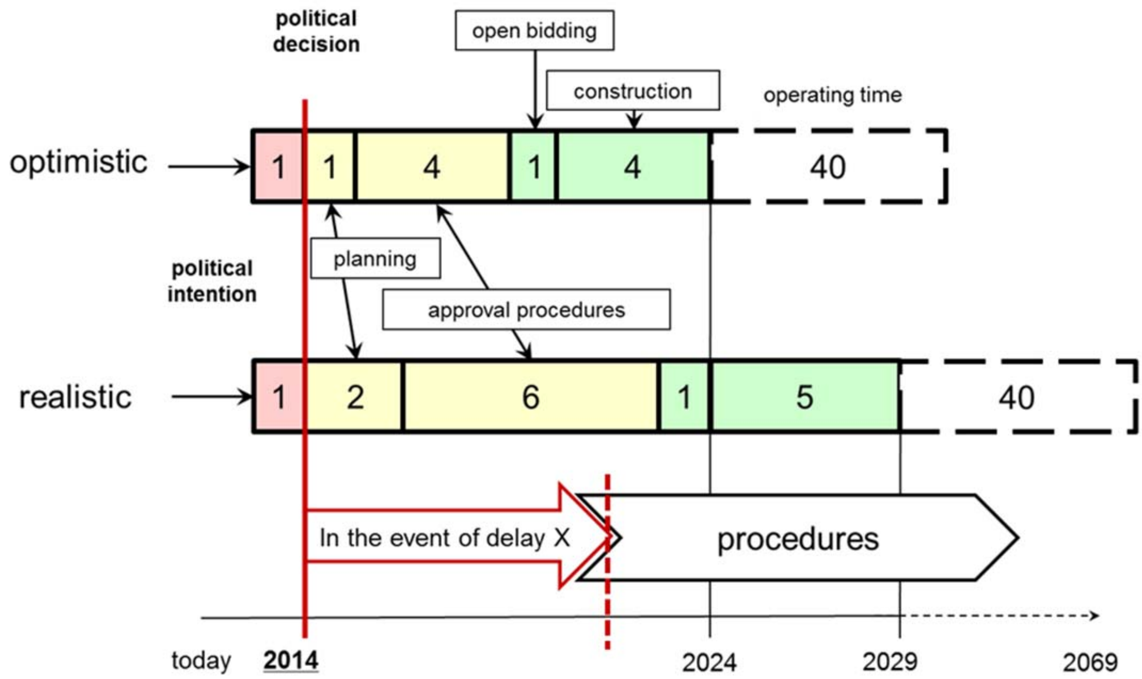


Figure 71: Time schedule considering the citizen participation model from Figure 70 (Hess 2013)

From the sheer technical point of view, it should be noted that the implementation of such a project would not necessarily take more than 5 years, as has been demonstrated in China. The reason that in Europe such a project would take much longer is its internationality and the scheduled citizen participation which will take considerable time for its organization. Although this is a considerable challenge, this type of project will be the first of its kind and will obviously have a pioneer character for similar future international RES-E projects.

4. Socio-Economic and Environmental Impacts Assessment

INTRODUCTION:

The potential socio-economic and environmental effects associated to RES deployment in North Africa are not negligible. In general, compared to conventional fossil fuel technologies, renewable technologies lead to larger socio-economic impacts and lower environmental impacts. Thus, if deployed under the right conditions, the quantification and dissemination of such benefits can be used as an additional argument to advocate in favor of RES deployment among policy makers as well as civil society.

However, the sign and the magnitude of such externalities should not be taken for granted as they depend on a wide range of factors. Once such potential socio-economic and environmental effects associated to RES deployment are identified, accompanying measures must be put in place to minimize negative co-effects and tap the positive co-effects.

In terms of environmental impacts, when considering a Life Cycle Thinking perspective and compared to conventional fossil fuel technologies, renewable energies lead to reductions in GHG emissions, local pollutants (PM, NOx, etc), water consumption, etc. However, the implementation of any large scale renewable energy project might cause other additional direct impacts, affection of the fauna migration, change in the runoff water regimes, loss of habitats and visual impacts, which should be further analyzed case by case and, to the extent possible, minimized.

In terms of the socio-economic impacts associated to RES deployment, North Africa could potentially benefit various socio-economic effects such as from job creation as well as increase in the demand of goods and services. Such co-effects associated to RES deployment would occur not only in those sectors directly related to the various phases of the life cycle (project planning, manufacturing, installation, grid connection, operation and maintenance and decommissioning) but would also indirectly have an impact in those other sectors that supply goods and services to the first. Nevertheless, the magnitude of such socio-economic effects is greatly dependent on the local content share of the goods and services involved in the value chain.In order to maximize value creation it is important that countries put in place a set of policies –tailored to country conditions and priorities- that stimulate deployment and aim at building a domestic industry by encouraging investment and technology transfer, strengthening capabilities, promoting education and training, as well as research and innovation.

Finally, like any other large-scale investment, utility scale renewable energy plants have the potential to transform communities at the project-level beyond the economic benefits of employment and income generation. Poorly planned and designed projects could hinder the pursuit of people´s traditional ways of life and thereby magnify the local vulnerability of already stressed region. For example, by restricting the usage of land and water resources and reducing the cohesion of community groups. Similarly, potential conflicts and social discontents could arise from distributional equity issues varying from verbal disagreement to sabotage to violent confrontation (Schinke et al. 2014).

This section of the report attempts to shed some light to the above mentioned issues by assessing potential environmental and socio-economic impacts associated to the deployment of RES technologies (CSP+HVDC) in North Africa under various possible local content scenarios.

4.1. ALTERNATIVE FUTURE SCENARIOS IN NORTH AFRICAN COUNTRIES:

As described in detailed in Deliverables 3.2.4 and 3.3 "*Technologically and Economically Feasible Pathways for RES-E Deployment* ", two possible future **scenarios** for which its environmental and socio-economic impact will be assessed are bottom-up scenarios for RES-E expansion in North Africa that will not require any technological break-through, no grid expansion beyond what is needed to cope with the growing electricity consumption, no extra electricity storage technologies and no overloading of the electricity grid with significant fluctuating capacities from wind power and PV (Trieb *et al*, 2013).

The results of this approach are scenarios for Algeria, Egypt, Libya, Morocco and Tunisia from the year 2000 to 2050, that are based on historical development (until 2010), short-term national planning (until 2020) and further scenario development (until 2050) that takes into account the existing RES-E potentials, defined sustainability targets and – among others – the natural limitations mentioned above. All scenarios are characterized by a well-balanced mix of about 30-40% fluctuating renewables (wind and PV), 50-60% flexible renewables (mainly CSP) and 10-20% ideally stored energy in form of fossil fuels or eventually, renewable fuels that may become available in the long-term, like hydrogen. All countries analyzed in the North Africa case study can achieve sustainable supply in terms of supply security, cost stability and environmental as well as social compatibility (Trieb *et al* 2013).

In terms of electricity produced, the only difference between the two future scenarios is the greater CSP production which could be exported to Europe through a HVDC line. Four possible alternatives CSP-HVDC lines are contemplated. The different alternatives CSP-HVDC lines as well as their investment costs can be consulted in Deliverable 3.3 (Trieb *et al* 2013).

Thus, to estimate the net socio-economic and environmental impact associated to the future "export" scenario, one must only consider and estimate the environmental and socio-economic effects derived from the additional CSP electricity produced in the "export" scenarios as the rest of the energy mix remains unchanged.

In the next section, data used and working main assumptions to estimate the impacts will be presented and the quantitative results will be presented for each country.

4.2 DATA SOURCES AND CONSIDERATIONS

4.2.1 LOCAL CONTENT SCENARIOS

Despite the first results will be estimated without assuming imports of goods and services, this is not the most likely scenario as it takes time, resources and political will. Certain framework conditions for the development of local industry need to be put in place (DIE, 2013). The impacts considered in this report (expenditures, economic activity, job creation, energy consumption, CO_2 emissions and other pollutants) will be assessed under three possible "local content scenarios", defined based on experts opinion and international literature review.

Background information to define local content scenarios:

According to a 2011 study commissioned by the World Bank, the status of local shares lies between 17% and 43%, which will have a local share of added value ranging from 23% in 2012 to 57% in 2025. For the period 2012 to 2025, there could be three possible future scenarios. Under a slow market development or low financial support (scenario A) the local share would be limited to about 24% of the total investment for construction. Under scenario B, there would be an increase of 28% local share. Under a large market demand (scenario C), the local share could increase up to 70%. Local mirror and receiver production as well as other components would be produced locally due to the large market size. After 2025, the local share is assumed to increase further due to a greater technology transfer and knowledge sharing (ESMAP, 2011). There are a few components (e.g.turbine and CSP generator) which, given their great complexity, are very unlikely to be produced locally. However, such components represent a not negligible share of the total capital investment of the plant (Dii, 2013). According to the same study, in the mid-term, it is possible that CSP receivers will be produced in many of the studied countries. For other CSP components (e.g. solar collector assembly, heat exchangers, mirrors and to some extent the HTF (heat transfer fluid)- it is more likely that, already in the short term, some MENA countries could produce them (Dii, 2013).

Similarly, a recent report by GIZ for South Africa identified the possible shares of local value under three possible scenarios: (i) Low capacity scenario where <50 MW installed capacity per year; (ii) Medium capacity scenario with 50 to 150 MW installed capacity per year and (iii) High capacity scenario with more than 150 MW installed capacity per year (GIZ, 2013).

Thus, three possible future localcontent scenarios (S1-high, S3-moderate and S2-high) for CSP are assessed. The shares of domestic components in each country are shown on Table 47.

Table 47: Local content scenarios

Scenarios	S1-Low	S2-High	S3-Moder
Share of domestic component in production (%)	10	80	50
Share of domestic component in installation (%)	20	90	60
Share of domestic component in maintenance (%)	40	100	80

Regarding environmental impacts, the following assumptions have been made (Dii, 2013):

- S1-Low scenario: only pipes and cables would be produced locally.
- S2-High scenario: only the turbine and CSP generator will be not produced locally.
- S3-Moderate scenario: cables, electronics, controls, pipes, heat exchangers and all the elements of the solar field will be produced locally.

Some impact categories will take place locally regardless the location of the production process. This is the case for example of the impacts on land use. On the contrary other impacts are global in nature and therefore independent on the actual location of the production process. This is the case of global warming impacts as well as ozone depletion impacts.

The following share of locally or regionally produced impacts in the different impact categories has been applied in the assessment (Table 48).

Table 48: Share of locally or regionally produced impacts

Impact categories	S1	S2	S3
Climate change	100	100	100
Ozone depletion	100	100	100
Human toxicity, cancer effects	1	98	91

Human toxicity, non-cancer effects	49	99	95
Particulate matter	20	98	73
Ionizing radiation HH	63	99	95
Ionizing radiation E (interim)	52	99	94
Photochemical ozone formation	27	99	72
Acidification	29	99	70
Terrestrial eutrophication	13	100	50
Freshwater eutrophication	8	98	90
Marine eutrophication	18	99	66
Freshwater ecotoxicity	8	98	90
Land use	100	100	100
Water resource depletion	79	100	98
Mineral, fossil & ren resource depletion	98	100	100

Despite that the results for the three scenarios will be estimated for each country, the likelihood of each type of CSP local content future scenario (S1, S2 and S3) will be different across countries as the different baseline situation and future development of each country.

Based on the literature and stakeholder consultation feedback, the most likely scenarios for the five analyzed countries are: Algeria (Moderate-S3), Egypt (Moderate-S3), Libya (Low-S1), Morocco (High S2) and Tunisia (Moderate-S3). Thus, a sensitivity analysis will be done comparing the scenario with no imports and the impact of the "most likely scenarios". The local content scenarios have a great deal of uncertainty so their associated results should be taken and interpreted with caution.

4.2.2 DATA FOR THE SOCIO-ECONOMIC IMPACTS OF CSP

a) Direct expenditures associated to RES exports

Techno-economic parameters of the CSP plants

In order to estimate the socio-economic impacts associated to CSP deployment for exports in the studied countries, the techno-economic characteristics of a 100 MW CSP plant -described in Deliverable 3.3- have been considered and are summarized in the table below.

Table 49: Techno-economic characteristics of a 100 MW CSP reference plant

General CSP technology information:	
Building period (status of technology) year	~ 2020-2025
Solar field technology	parabolic trough
Power plant technology	steam cycle
Heat storage technology	molten salt
CSP design characteristics (per unit)	
Solar field collector aperture area per unit (million m²)	2.287
Solar Multiple (SM)	3.5
Nominal solar field output at DNI 800 W/m² per unit ($MW_{thermal}$)	986
Size of the molten salt heat storage per unit ($MWh_{thermal}$)	4225
Storage time at full load (h)	15
Nominal turbine heat input per unit ($MW_{thermal}$)	282
Nominal turbine gross electric output per unit ($MW_{gross, electric}$)	129
Nominal turbine net electric output per unit ($MW_{net, electric}$)	100
Total land requirement per unit (million m²)	8.693
Water requirement ($m^3/MWh_{gross, electric}$)	0.3
Minimum lifetime of all components (years)	40
Number of units per CSP-HVDC link	17

Table 50 shows the economic parameters and Table 51 the investment breakdown of the reference plant. The experience curve parameter for CSP will be around 90% (ESMAP, 2011)

Table 50: Key economic parameters of the 100 MW CSP reference plant

Cost of CSP elements (including construction)	
Solar field costs (€/m2)	156
Heat storage cost (€/kwh thermal)	44
Power block cost (€/kwh thermal)	1056
Minimum lifetime of all components (y)	40
Construction cost (included in CSP element cost)	
Solar field (planning; construction; commissioning)	30%
Heat storage (planning; construction; commissioning)	10%
Power block cost (planning; construction; commissioning)	15%
Investment and Operation and Maintenance cost / Kw (in 2025 assum. 80 GW world installed capacity)	
Investment cost/ Kw	5,284 €/Kw
Operation and Maintenance cost / Kw	105.6 €/Kw

Table 51: Investment breakdown of the reference plant

Investment cost components:	€/kw
Investment cost solar field	2092
Construction cost solar field	688
Investment cost storage (15h)	1308
Construction cost storage	129
Investment cost steam cycle	908
Construction cost steam cycle	148
Sum	5273

Taking into account the above mentioned expected cost decline, the corresponding cost parameters for the 100 MW reference plant for the studied period (2020-2050) would be:

Table 52: Future evolution of costs of the reference plant

CAPEX and OPEX of 100 MW reference plant (real € 2010)	**2020**	**2030**	**2040**	**2050**
Investment costs (€/kw)	5280	4224	3801,6	3421,44
Investment	4308	3446,4	3101,76	2791,584
Construction	965	772	694,8	625,32
O&M costs (€/kw)/a	105,6	84,48	76,032	68,4288

Note: Cost decline assumptions as in Trieb *et al* 2012.

b) Total economic activity associated to RES exports

As described in deliverable 2.5, the total effects associated to any given RET project investment plan are greater than just the so called "direct effects". For each dollar spent in any RET project, the overall national economic activity will increase by more than one dollar. This "multiplier" effect is due to the combination of direct, indirect and induced effects:

- Direct effects are changes in sales, income or jobs associated with the on-site or immediate effects created by an expenditure or change in final demand.

• Indirect effects are changes in sales, income, or jobs in upstream-linked sectors within the region. These effects result from the changing input needs in directly affected sectors.

• Induced effects are changes in sales, income or jobs created by changes in households, business, or government spending patterns.

Table 52 presents the cost for the 100 MW reference plant. A CSP multiplier effect from the international literature have been considered: 2.15 for a 50 MW PT in South Africa in 2013(GIZ, 2013); 2.3 for a 17 MW PT in Spain in 2009 (Caldés *et al* 2009); 2.19 for a 110 MW CR in Chile in 2015 (Rodríguez *et al* 2014) and 1.6-2 for a 50 MW PT in MENA in 2020 (ESMAP, 2011). Based on this review, a **multiplier effect of 2** is assumed**.** Of the non-direct economic impact, 78% would be attributable to indirect effect and 22% to induced effect (GIZ, 2013).

Under such assumptions, Table 53 shows the total economic activity associated to the investment, construction as well as annual operation & maintenance phase of the plant.

Table 53: Economic activity generated by the 100 MW reference plant

CAPEX and OPEX of 100 MW reference plant (real € 2010)	2020	2030	2040	2050
Investment (€/kw)				
Direct	4308,00	3446,40	3101,76	2791,58
Indirect	3360,24	2688,19	2419,37	2177,44
Induced	947,76	758,21	682,39	614,15
Construction (€/kw)/year				
Direct	965,00	772,00	694,80	625,32
Indirect	752,70	602,16	541,94	487,75
Induced	212,30	169,84	152,86	137,57
O&M costs (€/kw)/a				
Direct	105,60	84,48	76,03	68,43
Indirect	82,37	65,89	59,30	53,37
Induced	23,23	18,59	16,73	15,05

In order to further analyze the direct, indirect and induced economic effects by economic sector, a recent study by Dii (2013) provided estimates for Morocco and Egypt regarding the split across economic sectors for both the direct and indirect effects of the CSP investments. Additionally, data on household expenditures shares for the studied countries from the African Development Bank were considered to estimate the distribution of the induced economic effects across economic sectors (ADB, 2011). The assumptions on the distribution of the economic effects are shown on Table 54.

Table 54: Assumptions on the distribution of the economic effects across sectors.

ECONOMIC SECTOR SHARE - DIRECT EFFECT	MOROCCO	TUNISIA	EGYPT	ALGERIA	LYBIA
Construction	24%	24%	28%	28%	28%
Minerals	16%	16%	9%	9%	9%
Metals	16%	16%	28%	28%	28%
Transport	24%	24%	11%	11%	11%
Electr. Equip	8%	8%	10%	10%	10%
machinery	6%	6%	0%	0%	0%
Business services	6%	6%	14%	14%	14%
ECONOMIC SECTOR SHARE - INDIRECT EFFECT	**MOROCCO**	**TUNISIA**	**EGYPT**	**ALGERIA**	**LYBIA**
Other services	50%	50%	25%	25%	25%
Other indirect	50%	50%	75%	75%	75%
ECONOMIC SECTOR SHARE - INDUCED EFFECT	**MOROCCO**	**TUNISIA**	**EGYPT**	**ALGERIA**	**LYBIA**
Food and non-alcoholic beverages	41%	26%	45%	42%	24%
Alcoholic beverages, tobacco & narc	4%	4%	2%	2%	1%
Cloting and footwear	5%	8%	5%	4%	5%
Housing, water, electricity, gas other fuels	16%	16%	18%	6%	28%
Furinsihg, hhd equipment and maintenance	5%	6%	4%	4%	0%
Helath	4%	5%	7%	5%	2%
Transport	10%	15%	5%	17%	25%
Communication	6%	4%	3%	8%	3%
Recreation and culture	4%	3%	2%	2%	1%
Education	2%	1%	4%	0%	0%
Restaurants & hotels	7%	14%	4%	3%	1%
Miscellaneous & goods/services	7%	7%	8%	4%	3%

Source; ADB, 2012

Note: Morocco and Tunisia on one side and Egypt, Algeria and Libyaon the other side were assumed to have a similar distribution of the direct and indirect effects on the economy.

Finally, the local share greatly influences the impact of the CSP investments on the local economic activity. Thus, as mentioned before, a sensitivity analysis is conducted considering the most likely local content shares scenario (low, moderate, high) by country.

c) Total job creation

There are different methodologies to assess the number of jobs created by renewable energies. Generally, the Input output methodology is consistent and it has a wide consent among the scientific community. Unfortunately, North Africa countries do not have updated IO tables so a revision of the existing literature was carried out.

The employment generated due to RE deployment is often divided into three categories: manufacturing, construction employment and operation and maintenance employment. Figure x shows the distribution of full-time job years between the categories in the plant's lifetime. Manufacturing accounts for 10% of total employment, Construction for 45% and Operation and Maintenance for 45% that will last longer than the rest of the jobs created.

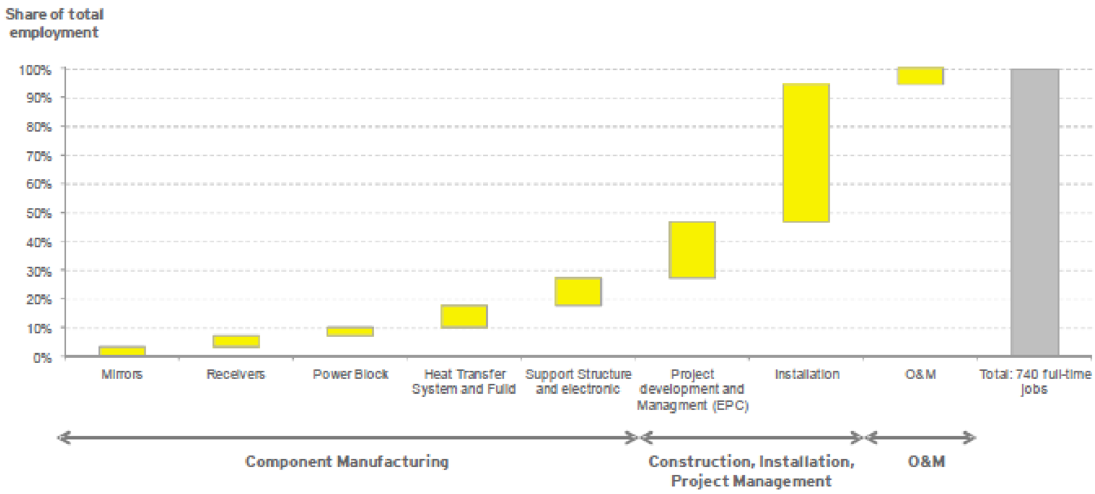


Figure 72: Distribution of full-time job years created by a CSP parabolic 50 MW reference plant over its 25-year life (Source: ESMAP 2011)

Over the 40-year life of the plant, manufacturing jobs are created over one year, construction jobs over two years and O&M jobs are needed every year of the plant's lifetime.

The indicator more often used to assess the impact of a RE technology on employment is direct employment. Table 9 compares direct job creation ratios (direct jobs/MW) of each study considered in this analysis for each of the employment categories mentioned above.

Table 55: Comparison of total direct job creation ratios for CSP (direct jobs/MW)

Study	GIZ	IDC study	RE IPPP	Spain 2008-2010	MENA study	Rutovitz et al.	Protermosolar
CSP technology	CSP parabolic trough with storage	Various	Parabolic trough and tower with storage	CSP with storage 70%, without storage 30%	CSP parabolic with storage	CSP parabolic with storage	CSP parabolic with storage
Country	South Africa	South Africa	South Africa	Spain	MENA region	South Africa	Spain
Manufacturing employment	4.00	14.40	-	-	3.50	7.20	23.31
Construction employment	10.00	21.60	9.13	17.00	8.70	10.80	-
O&M employment	0.80	0.54	0.60	-	0.90	0.54	0.47

The construction and O&M assumptions of the first study seem to be the most reasonable based on the data from Spain (considering that African countries have a lower labor productivity) and the results of the rest of the studies. As for the manufacturing data, the GIZ (GIZ, 2013) study has a lower result than the IDC studies, which is probably because the report from IDC (IDC, 2011) considers various CSP technologies; and is close to the MENA study result. All of this indicates that the first study could be the most accurate of the ones considered and it could be used for MENA countries since Industrial Performance is similar between MENA countries and South Africa according to UNIDO's Competitive Industrial Performance Index.

When assessing the impact of RE on direct, indirect and induced employments, the proportions vary across studies. In Caldés *et al* (2009), the ratio of indirect FTE jobs per direct FTE job for Spain is 0.73 whereas in GIZ (2013) is 0.9 for South Africa. Also the induced FTE jobs per direct or indirect FTE job in GIZ (2013) is 0.25. A consequence of a higher labor productivity is a lower impact on employment (Dii, 2013), this is why Spain's ratios are lower than South Africa's ones. Regarding impacts in North Africa, the GIZ ratios will be used.

The ratios used to calculate the employment generated by CSP are displayed on Table 56.

Table 56: Summary of employment ratios used (FTE jobs per MW)

Employment (FTE/MW)		
Manufacturing	Direct	4
	Indirect	3,6
	Induced	1,9
	Total	9,5
Construction	Direct	10
	Indirect	9
	Induced	4,75
	Total	23,75
Operation&Maintenance	Direct	0,8
	Indirect	0,72
	Induced	0,38
	Total	1,9

An additional detail that is important to describe is the occupations required for CSP development. The specific jobs for solar technologies are described in Table 11.

Table 57: Summary of specific occupations required for CSP technologies

Equipment Manufacture and Distribution	Project Development	Construction and Installation	Operations and Maintenance
– Researchers (chemists, physicists, engineers with specialization in electrical, mechanical, chemical, materials, system design or process engineering) (H) – Chemical laboratory technicians and assistants (M)	– Architects (H)	– Welders (M) – Pipe fitters – Electrician solar specialists (M) – Installers (M) – Project and installation evaluators (H,M)	– CSP maintenance specialists (M)

Where: H= High skilled, M=Medium skilled, Source: IRENA

Table 57 shows that all of CSP specific employments need training since they are medium or high skilled, this is an advantage for MENA region as it will be explained below.

Another aspect that is relevant to describe in this analysis is in which sectors the employment will be created. CSP creates the most direct jobs in the minerals, metals, transport equipment and construction sectors. The indirect jobs are created in other services and other indirect sectors (Dii, 2013).This will have as a result that more blue-collar than white-collar workers will be required, reaching between 80 and 90 % of the total workforce of manufacturing and construction and 30 to 40% for operation and maintenance. These technical jobs will require vocational training which in the case of the MENA region is an advantage because the training process for these technical jobs is relatively fast for local workers (Dii, 2013).

As for induced jobs, they result from the consumption of the newly employed workers. The sectors affected will be similar between the five countries: food and non-alcoholic beverages; Housing, water, electricity, gas other fuels and Transport (Dii, 2013). On top of all this, it is interesting to analyze the evolution of the ratios of employment creation. For this, three aspects have to be considered. First, a foreseeable higher labor productivity has a negative impact on job creation of 16,39% in 20 years. Second, an expected stronger industry capability allows countries to source more components domestically and can increase job effects in 29,51% in 20 years (Dii, 2013). Third, the technological improvement will have a negative impact on job creation. For 2010-2015, the employment factor decline rate will be 5.6; for 2015-2020 will be 5.1 and for 2020-2030 will be 2.8 (Rutovitz, 2010).

To determine the annual decline rates considering the three aspects mentioned above the next assumptions have been done. First, the three impacts have been determined for a period of 10 years. Second, the technology decline rate between 2000 and 2015 is considered zero since they were the first years of the technology development and from 2030 the rate is considered constant and equal to 2.8. For indirect jobs, it is assumed that the technology rate is the same that for direct jobs and for induced jobs, the assumption is that the proportion to direct and indirect jobs remains 0.25. The decline rates for each time period are shown in Table 58 for direct employment and Table 59 for indirect employment.

Table 58: Total direct employment variation rates

	2000-2010	2010-2020	2020-2030	2030-2040	2040-2050
Productivity	-8.2%	-8.2%	-8.2%	-8.2%	-8.2%
Industrial capability	14.8%	14.8%	14.8%	14.8%	14.8%
Technological improvement	0%	-10.7%	-2.8%	-2.8%	-2.8%
Total variation	6.6%	-4.1%	3.8%	3.8%	3.8%

Table 59: Total indirect employment variation rated

	2000-2010	2010-2020	2020-2030	2030-2040	2040-2050
Productivity	-8.41%	-8.41%	-8.41%	-8.41%	-8.41%
Industrial capability	23.37%	23.37%	23.37%	23.37%	23.37%
Technological improvement	0%	-10.7%	-2.8%	-2.8%	-2.8%
Total variation	14.96%	4.26%	12.16%	12.16%	12.16%

Finally, this analysis has been carried out assuming that all the jobs created by this plant are local. Since this is not likely to happen, a sensitivity analysis has been conducted.

d) Effects on the balance of trade

The introduction of renewable energies in the MENA region can have consequences that have positive effects on the balance of trade. Some of these consequences can be: the decrease of oil and gas imports for fossil fuel importing countries, the possibility to export electricity to Europe and the development of a local manufacturing industry and potential exports.

In this report, the electricity produced by the deployment of CSP would be intended only for exports to Europe so there would not be a decrease in oil and gas imports of the importer countries (Morocco, Tunisia and Egypt) due to this specific expansion of CSP. Nevertheless, the effects of the other two consequences mentioned above are interesting to be assessed.

First, electricity trade strongly increases export revenues which has a positive effect on the trade balance. This is especially relevant for countries with a negative trade balance such as Morocco, Tunisia and Egypt. Electricity exports from MENA have the potential to make up a high portion of overall exports (Dii, 2013), the amount of the economic output for each country will be based on the price of electricity of Europe, that will be the importer of the electricity, and on the production destined for exports of each country (Table 60).

Table 60: CSP production for exports

TWh/a	2030	2040	2050
Algeria	38,6	126,3	200,0
Egypt	40,4	62,5	62,5
Libya	20,6	45,3	64,3
Morocco	85,2	166,3	188,7
Tunisia	19,3	40,6	63,6

But these positive effects will take place only if sufficient FDI is attracted, interconnectors are built and a stable regulatory framework is in place. In this case it has been assumed that both first and second conditions will be met. Moreover FDI would increase the domestic capital stock and thus contribute to GDP growth (Dii, 2013).

Second, the possibility of developing a CSP manufacturing industry able to export the components produced would also be beneficial for the balance of trade, especially for fossil fuel importer countries. Trade growth of CSP components to external CSP projects can strongly increase if a national decision to promote CSP technologies is made at an early stage of the market development (Vidican et al. 2013). First movers, potentially based in the MENA region due to the established large local markets and attractive solar potential in North Africa, could supply the international market if the following key success factors are achieved: Stable home market as basis for export expansion, Large growing world market, Price competiveness to international competitors, International quality standards, Reduction of trade barriers between MENA and Europe, Creation of regional lead market players for different components and equipment and the existence of a local demand (ESMAP).

The study "Middle East and North Africa Region Assessment of the Local Manufacturing Potential for Concentrated Solar Power (CSP) Projects" carried out by Fraunhoffer and Ernst&Young for World Bank and ESMAP (ESMAP, 2011) attempts to assess the consequences of the development of a local RE manufacturing industry and the exports. In one of the scenarios, a demanded volume of 2 GW was included to show economic impacts in the MENA region. By 2025 over US$9.6 billion could be earned by exporting CSP components.

e) HVDC economic impact

Besides the socio-economic impact of the electricity produced, the impacts of the HVDC line are also worth mentioning taking into account that these impacts will be split between Morocco and Europe (for both importer and transit countries). There is scarce literature on these specific socio-economic impacts which makes difficult to compare results. A study commissioned by Rock Island Clean Line LLC carried out by Loomis Consulting (Carlson *et al,* 2011) assesses the economic impacts of an HVDC Transmission Line in the USA. To determine the impacts on the economy and the employment in North Africa, the results of the low case will be used since there is a lower labour productivity than in the other case considered (Illinois). Table 61 shows the ratios that were assumed to determine the impacts of HVDC.

Table 61: HVDC impact ratios

		Unit	Direct	Indirect	Induced	Total employment multiplier effect
Manufacturing and Construction	Employment (FTE)	Jobs/million €	8,59	5,75	7,78	22,11
	Economic Activity	Multiplier effect	1,00	1,02	0,93	2,95
O&M	Employment (FTE)	Jobs/million €/year	13,28	5,20	9,24	27,72
	Economic Activity	Multiplier effect	1,00	0,80	1,11	2,90

Note: Manufacturing and Construction will last five years and O&M 40 years

4.2.3 DATA USED FOR THE ENVIRONMENTAL IMPACTS OF CSP

a) Methodology

The potential environmental impacts have been estimated following the Life Cycle Assessment methodology (LCA). The LCA allows the assessment of potential environmental impacts associated with all the stages of a product's life from cradle-to-grave. For this analysis in North Africa, the disposal phase has not been considered.

This assessment is carried out based on the four phases of the ISO 14040 and 14044 standards:

1. Goal and scope: refers to the context of thework, the intended application and the target audience. The functional unit and system boundaries have to be defined.
2. Life Cycle Inventory (LCI): data are collected taken into account the goal and scope defined in the previous phase. Two types of data can be defined:
   a. Foreground data: describe elementary flows that are directly linked with the processes being analysis.

   b. Background data: describe flows that are indirectly linked with the processes being analysis, such as supply-chain and upstream processes. There are several life cycle databases that provide well recognized background data.

The LCI will list all the inputs and outputs from and to nature from the analyzed system. These flows will be expressed in relation to the functional unit.

3. Life Cycle Impact Assessment (LCIA): This phase of LCA is aimed at evaluating the significance of potential environmental impacts based on the LCI flow results. There are two mandatory stages – classification and characterization- and two optional stages –normalization and weighting

The mandatory phase is first performed by assigning the elementary flows from the LCI to one or more relevant categories of impact –climate change, acidification, etc.- which is called "Classification". Then, these flows have to be translated into potential environmental impacts. This step is known as "Characterisation", in which the environmental flows assigned to a particular impact category are quantified in terms of a common unit for that category (Guinée, et al 2002). These factors derive from characterisation models that consider dispersion models, damage functions, etc. Many LCA studies conclude with the characterization stage.

In normalization, the results obtained from the characterization are compared with a reference like the total impacts per category in the region of interest or by person per year.

In weighting, the environmental impacts are weighted relative to each other so they can be summed together and result in a single number. There are many weighting factors available for different regions, and it is possible to find also factors defined by different panels.

ISO 14044:2006 does not recommend the implementation of this last phase in the studies where there is a comparative assertion intended to be disclosed to the public.

4. Interpretation: This phase of LCA is aimed at analyzing the obtained results. The results will identify areas of improvement and hotspots of the analyzed system. Additional, sensitivity analysis could be conducted.

In this case study, the objective of the LCA **is to estimate the net environmental impacts associated to the electricity that might be exported in a scenario of cooperation compared to other scenario without cooperation between the EU** (Germany) and North Africa.

b) Environmental data

For the Life Cycle Inventory stage, the difficulties associated to the collection and treatment of data to estimate the environmental impacts make necessary the use of life cycle databases and other published data. Two different types of data have been used to conduct the assessment depending on the processes that are included:

-Foreground: it includes all processes that are directly involved in the system being analyzed. In order to model these processes it is recommended the use of primary data. In the case of North Africa, primary data are referred to the CSP technology that will produce the electricity.

-Background: it includes all processes that affect the system but are not directly link to it. Data from literature, databases or other references can be used as far as are well described. In this study, the well-recognized database ecoinvent (Frischknecht R., et al, 2007) has been used.

The both manufacturing and O&M phases as well as the CSP plant technical characteristics were mentioned before. In order to achieve the net import capacity at the feed-in points in Germany, the required capacity of each plant has been modeled with about 130MW of gross capacity. The main losses are due to the HVDC corridor and the energy that will be demanded by the reverse osmosis plant that supply the water needs to the CSP plant (D3.4).

As described before, the electricity surplus will be generated by CSP technology. Deliverable 3.4 has analyzed and pre-designed a CSP plant, taking into account the specificities of North Africa. The potential environmental impacts of the electricity production have been estimated based on the parameters considered in the design. Additional, detailed specification about the materials used for the manufacturing and operation and maintenance activities have been taken from a previous study conducted by CIEMAT (De la Rúa, 2009).

Using the software SimaPro7.3 [80], the following potential impacts,displayed in Table 26, have been estimated for the production of 1kwh of electricity considering the technical characteristics for North Africa (D3.4).

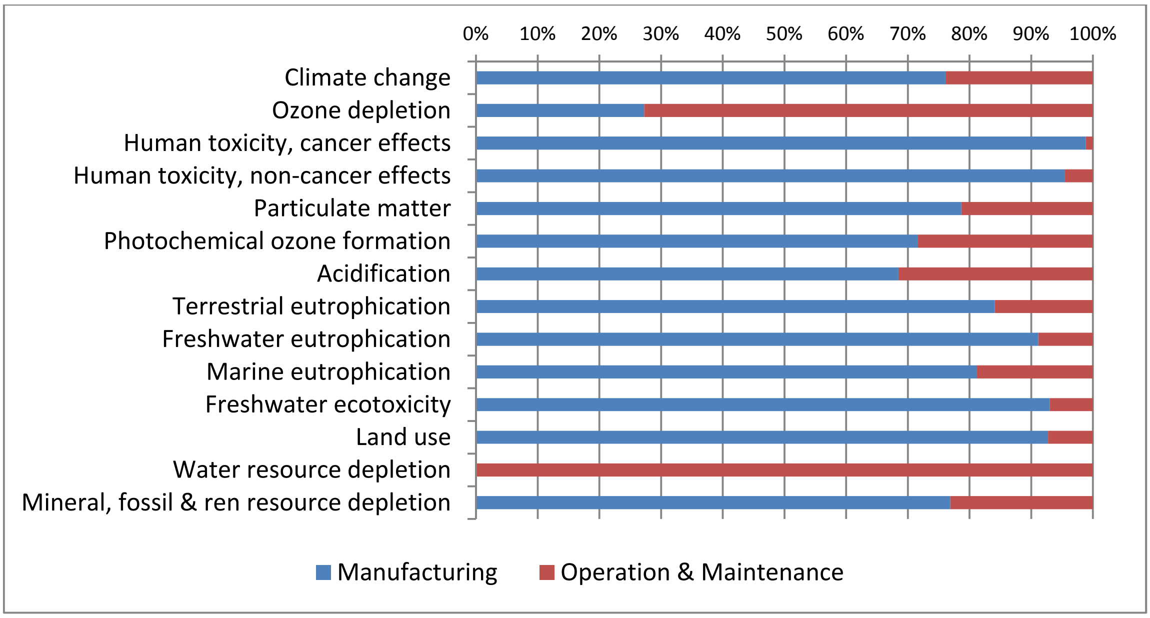
Table 62: Environmental impacts from producing 1kwh in a CSP plant in North Africa

Impactcategories	Units	Total
Climatechange	kg CO2 eq	0.0155
Ozone depletion	kg CFC-11 eq	2.12E-09
Human toxicity, cancereffects	CTUh	4.87E-09
Human toxicity, non-cancer effects	CTUh	3.60E-09
Particulatematter	kg PM2.5 eq	6.19E-06
Photochemical ozone formation	kg NMVOC eq	4.57E-05
Acidification	molc H+ eq	7.99E-05
Terrestrialeutrophication	molc N eq	1.75E-04
Freshwatereutrophication	kg P eq	3.82E-06
Marine eutrophication	kg N eq	1.37E-05
Freshwaterecotoxicity	CTUe	0.055
Land use	kg C deficit	0.749
Waterresourcedepletion	m3 watereq	0.049

[80] http://www.pre-sustainability.com/

Mineral, fossil &ren resource depletion	kg Sb eq	7.07E-08

In the following figure, the contribution of manufacturing and operation and maintenance to each environmental impact is shown. This information will be relevant when different scenarios of local content are considered, although some impact categories are referred to global impacts.



Note: Manufacturing stage includes in this case the construction phase.

Figure 73: Percentage of contribution of each stage to the total impact of 1kwh from CSP

The potential environmental impacts of the HVDC corridor have been also estimated, considering an average distance of 2600 km, being 2210 km of overhead cable and 390 km of sea cable. The impacts for each country have been calculated for 2030 and 2040 since the uncertainty for 2050 is too great.

Finally, the potential environmental impacts of producing 1kwh with other energy technologies have been also estimated through the life cycle assessment (Figure 73,Table 63)

Table 63: Potential environmental impacts of producing 1kwh with other energy technologies

Impactcategories	Units	1kwh lignite	1kwh oil	1 kwh natural gas
Climatechange	kg CO_2eq	1.08	0.97	0.51
Ozone depletion	kg CFC-11 eq	5.12E-09	1.17E-07	6.98E-08
Human toxicity, cancereffects	CTUh	1.44E-07	7.79E-09	3.01E-11
Human toxicity, non-cancer effects	CTUh	5.29E-08	1.73E-08	6.60E-10
Particulatematter	kg $PM_{2.5}$eq	1.84E-03	5.25E-04	2.11E-05
Photochemical ozone formation	kg NMVOC eq	5.29E-03	4.97E-03	5.94E-04
Acidification	molc H^+eq	3.80E-02	8.13E-03	4.06E-04
Terrestrialeutrophication	molc N eq	1.30E-02	1.83E-02	2.24E-03

Freshwatereutrophication	kg P eq	2.22E-03	2.63E-05	1.78E-07
Marine eutrophication	kg N eq	1.64E-03	1.68E-03	2.05E-04
Freshwaterecotoxicity	CTUe	2.26	0.45	4.40E-04
Land use	kg C deficit	-0.027	3.004	-8.17E-05
Waterresourcedepletion	m^3watereq	0.15	0.43	0.007
Mineral, fossil & renew. resource depletion	kg Sb eq	1.24E-07	3.16E-07	6.75E-08

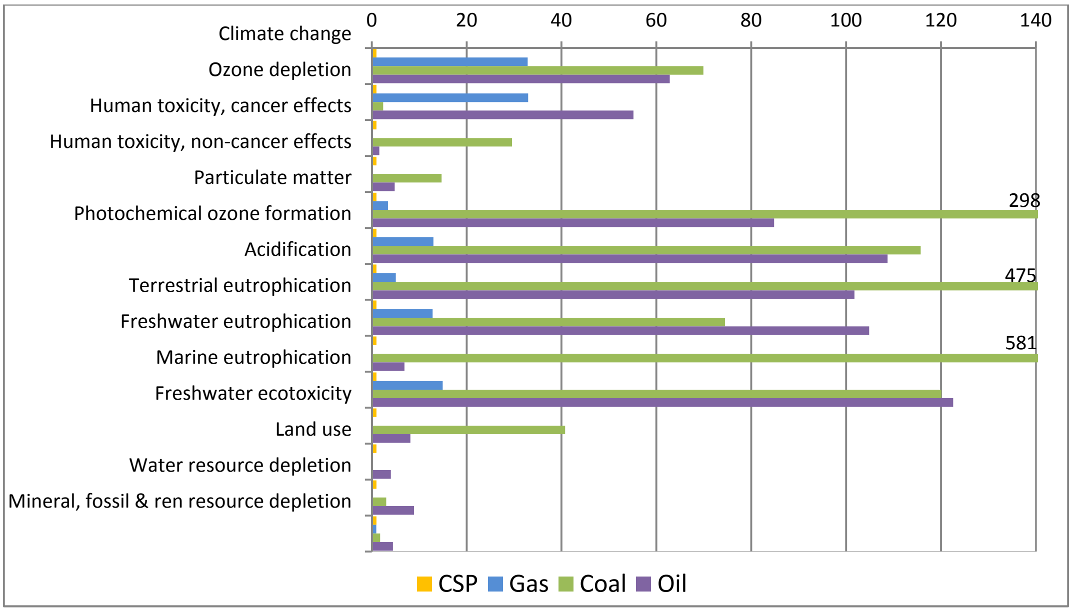


Figure 74: Potential environmental impacts of producing 1kwh with other energy technologies compared to those of CSP (1=impact of CSP technology in each category)

In many of the impact categories CSP plants perform better than the other prevailing technologies in the analyzed countries. The exceptions are some categories such as human toxicity, ionizing radiation and fresh water toxicity and eutrophization and resource depletion in which natural gas power plants perform better. According to our results, water resource depletion impacts of CSP plants are not higher than the other fossil technologies.

4.3 –RESULTS

Table 64: Electricity in TWh/a

	2020	2030	2040	2050
Algeria	0,00	38,60	126,30	200,00
Egypt	0,00	40,40	62,50	62,50
Lybia	0,00	20,60	45,30	64,30
Morocco	0,00	85,20	166,30	188,70
Tunisia	0,00	19,30	40,60	63,60

Table 65: Installed Capacity (left) and new installed capacity (right) both in GW

	2020	2030	2040	2050		2020	2030	2040	2050
Algeria	0,00	7,17	21,30	32,24	Algeria	0,00	7,17	14,13	10,94
Egypt	0,00	6,86	10,18	10,18	Egypt	0,00	6,86	3,32	0,00
Lybia	0,00	3,65	7,25	10,84	Lybia	0,00	3,65	3,60	3,59
Morocco	0,00	14,00	28,39	31,99	Morocco	0,00	14,00	14,39	3,60
Tunisia	0,00	3,70	7,30	10,90	Tunisia	0,00	3,70	3,60	3,60

4.3.1 ALGERIA

a) Socio-economic

Table 66: Total expenditures in Algeria

CAPEX and OPEX (real Mio € 2010)	2020	2030	2040	2050	2020-2050
Investment expenditures	0,00	24724,47	43824,77	30537,14	99086,38
Construction expenditures	0,00	5538,33	9816,83	6840,38	22195,53
TOTAL INVESTMENT REQUIREMENTS	**0,00**	**30262,80**	**53641,60**	**37377,51**	**121281,91**
Operation & Maintenance costs/year	0,00	606,06	1619,71	2206,28	

Table 67: Total economic activity in Algeria

	2020	2030	2040	2050
Investment (million €)				
Direct	0,00	24724,47	43824,77	30537,14
Indirect	0,00	19285,09	34183,32	23818,97
Induced	0,00	5439,38	9641,45	6718,17
Construction (million €)				
Direct	0,00	5538,33	9816,83	6840,38
Indirect	0,00	4319,90	7657,13	5335,49
Induced	0,00	1218,43	2159,70	1504,88
O&M costs (million €/year)				
Direct	0,00	606,06	1619,71	2206,28
Indirect	0,00	472,73	837,92	583,86
Induced	0,00	133,33	356,34	485,38

Table 68: Economic activity stimulation by sectors in Algeria (million €)

ECONOMIC SECTOR SHARE - DIRECT EFFECT	shares	2020	2030	2040	2050
Construction	0,28	0,00	8643,28	15473,17	11083,46
Minerals	0,09	0,00	2778,20	4973,52	3562,54
Metals	0,28	0,00	8643,28	15473,17	11083,46
Transport	0,11	0,00	3395,57	6078,74	4354,22
Electr. Equip	0,10	0,00	3086,89	5526,13	3958,38
machinery	0,00	0,00	0,00	0,00	0,00
Business services	0,14	0,00	4321,64	7736,58	5541,73
ECONOMIC SECTOR SHARE - INDIRECT EFFECT					
Other services	0,25	0,00	6019,43	10669,59	7434,58
Other indirect	0,75	0,00	15477,64	27524,52	19356,92
ECONOMIC SECTOR SHARE - INDUCED EFFECT					
Food and non-alcoholic beverages	0,42	0,00	2852,28	5106,14	3657,54
Alcoholic beverages, tobacco & narc	0,02	0,00	162,99	291,78	209,00
Cloting and footwear	0,04	0,00	298,13	533,71	382,30
Housing, water, electricity, gas other fuels	0,06	0,00	427,84	765,92	548,63
Furinsihg, hhd equipment and maintenance	0,04	0,00	247,88	443,75	317,86
Helath	0,05	0,00	319,18	571,40	409,30
Transport	0,17	0,00	1154,50	2066,77	1480,43
Communication	0,08	0,00	550,08	984,76	705,38
Recreation and culture	0,02	0,00	141,94	254,09	182,01
Education	0,00	0,00	6,79	12,16	8,71
Restaurants & hotels	0,03	0,00	230,90	413,35	296,09
Miscellaneous & goods/services	0,04	0,00	292,70	523,99	375,33

Table 69: Total economic activity considering imports under the medium local share scenario (S3) in Algeria

	2020	2030	2040	2050
Investment (million €)				
Direct	0,00	6181,12	10956,19	7634,28
Indirect	0,00	4821,27	8545,83	5954,74
Induced	0,00	1359,85	2410,36	1679,54
Construction (million €)				
Direct	0,00	1993,80	3534,06	2462,54
Indirect	0,00	1487,09	647,73	0,00
Induced	0,00	223,17	198,10	177,80
O&M costs (million €/year)				
Direct	0,00	387,88	1036,61	1412,02
Indirect	0,00	289,30	386,38	347,75
Induced	0,00	43,42	77,61	104,44

EMPLOYMENT

Table 70: Total employment generation in Algeria

ALGERIA		2030	2040	2050
Manufacturing (FTE current jobs)	Direct jobs	29786	58664	45419
	Indirect jobs	28967	57050	44169
	Induced jobs	14688	28928	22397
	Total Jobs	73442	144641	111985
Construction (FTE current jobs)	Direct jobs	74466	146659	113547
	Indirect jobs	72417	142624	110423
	Induced jobs	36721	72321	55992
	Total Jobs	183604	361603	279962
O&M (FTE current jobs)	Direct jobs	5957	17690	26774
	Indirect jobs	5793	17203	26037
	Induced jobs	2938	8723	13203
	Total Jobs	14688	43617	66014

Table 71: Distribution of employment by sectors in Algeria

DIRECT JOBS	2030	2040	2050
Construction	30859	62444	52007
Minerals	9919	20071	16717
Metals	30859	62444	52007
Transport	12123	24531	20431
Electr. Equip	11021	22301	18574
machinery	0	0	0
Business services	15429	31222	26004
INDIRECT JOBS			
Other services	26794	54219	45157
Other indirect	80383	162657	135472
INDUCED JOBS			
Food and non-alcoholic beverages	22826	46188	38469
Alcoholic beverages, tobacco & narc	1304	2639	2198
Cloting and footwear	2386	4828	4021
Housing, water, electricity, gas other fue	3424	6928	5770
Furinsihg, hhd equipment and maintena	1984	4014	3343
Helath	2554	5169	4305
Transport	9239	18695	15571
Communication	4402	8908	7419
Recreation and culture	1136	2298	1914
Education	54	110	92
Restaurants & hotels	1848	3739	3114
Miscellaneous & goods/services	2342	4740	3948

Table 72: Results for Algeria under medium local share scenario (S3)

ALGERIA (S3-Molder)		2030	2040	2050
Manufacturing (FTE current jobs)	Direct jobs	14893	29332	22709
	Indirect jobs	14483	28525	22085
	Induced jobs	7344	14464	11198
	Total Jobs	36721	72321	55992
Construction (FTE current jobs)	Direct jobs	44680	87995	68128
	Indirect jobs	43450	85574	66254
	Induced jobs	22033	43392	33595
	Total Jobs	110163	216962	167977
O&M (FTE current jobs)	Direct jobs	4766	14152	21419
	Indirect jobs	4635	13763	20830
	Induced jobs	2350	6979	10562
	Total Jobs	11751	34893	52811

b) Environmental

Table 73: Environmental impacts in Algeria

Environmental impacts Algeria	Units	2030			2040		
		TOTAL	% Power plant	% HVDC	TOTAL	% Power plant	% HVDC
Climate change	kg CO2 eq	6.15E+08	96.93	3.07	1.97E+09	99.04	0.96
Ozone depletion	kgCFC-11 eq	9.24E+01	88.42	11.58	2.78E+02	96.15	3.85
Human tox. cancer eff.	CTUh	2.04E+02	92.18	7.82	6.31E+02	97.47	2.53
Human toxicity, non-cancer effects	CTUh	1.15E+04	1.20	98.80	1.18E+04	3.84	96.16
Particulate matter	kgPM2.5 eq	3.91E+06	6.11	93.89	4.45E+06	17.55	82.45
Ionizing radiation HH	kg U235 eq	1.37E+08	97.17	2.83	4.39E+08	99.12	0.88
Ionizing radiation E (interim)	CTUe	4.42E+04	0.72	99.28	4.49E+04	2.31	97.69
Photoch.$o_3$formation	kgNMVOCeq	1.90E+06	92.70	7.30	5.91E+06	97.65	2.35
Acidification	molc H+ eq	3.34E+06	92.20	7.80	1.04E+07	97.48	2.52
Terrestrial eutroph.	molc N eq	6.94E+06	97.26	2.74	2.23E+07	99.15	0.85
Freshwater eutroph.	kg P eq	1.76E+05	83.69	16.31	5.12E+05	94.38	5.62
Marine eutrophication	kg N eq	1.06E+08	0.50	99.50	1.08E+08	1.61	98.39
Freshwater ecotoxicity	CTUe	2.27E+09	94.20	5.80	7.12E+09	98.15	1.85
Land use	kg C deficit	2.89E+10	99.96	0.04	9.46E+10	99.99	0.01
Water depletion	m3 watereq	1.88E+09	99.997	0.003	6.14E+09	99.999	0.001
Mineral, fossil & ren resource depletion	kg Sb eq	3.58E+03	76.33	23.67	9.78E+03	91.34	8.66

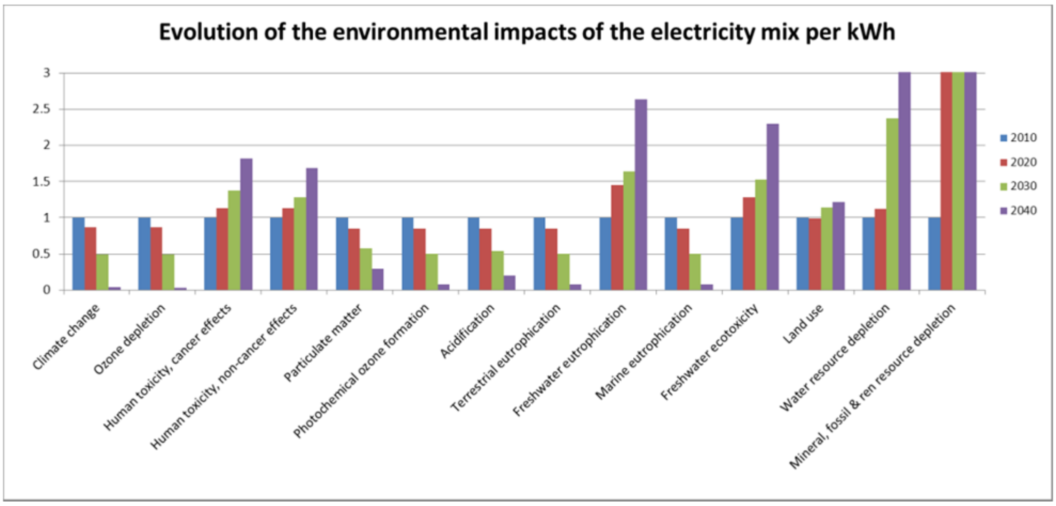


Figure 75: Evolution of the environmental impacts mix per kWh in Algeria

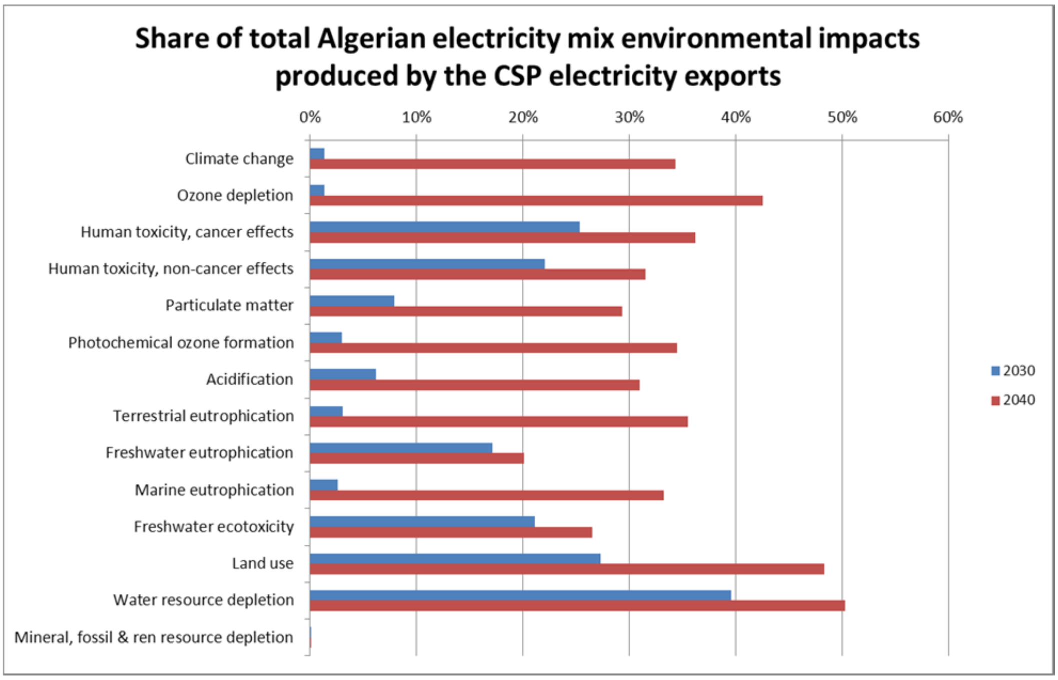


Figure 76: Share of total Algerian electricity mix environmental impacts produced by CSP electricity exports

Table 74: Environmental impacts in Algeria under medium local share scenario (S3)

Environmental impacts Algeria (S3)	Units	2030			2040		
		TOTAL	% Power plant	% HVDC	TOTAL	% Power plant	% HVDC
Climate change	kg CO2 eq	6.15E+08	96.93	3.07	1.97E+09	99.04	0.96
Ozone depletion	kgCFC-11eq	9.24E+01	88.42	11.58	2.78E+02	96.15	3.85
Human tox. Cancer eff.	CTUh	1.87E+02	91.46	8.54	5.76E+02	97.23	2.77
Human toxicity, non-	CTUh	1.15E+04	1.15	98.85	1.18E+04	3.65	96.35

cancer effects							
Particulate matter	kg PM2.5 eq	3.85E+06	4.54	95.46	4.24E+06	13.48	86.52
Photoch. O_3formation	kgNMVOCeq	1.41E+06	90.14	9.86	4.30E+06	96.77	3.23
Acidification	molc H+ eq	2.41E+06	89.20	10.80	7.30E+06	96.43	3.57
Terrestrialeutroph.	molc N eq	3.59E+06	94.70	5.30	1.13E+07	98.32	1.68
Freshwater eutroph.	kg P eq	1.61E+05	82.12	17.88	4.61E+05	93.76	6.24
Marine eutrophication	kg N eq	1.06E+08	0.33	99.67	1.07E+08	1.06	98.94
Freshwater ecotoxicity	CTUe	2.06E+09	93.62	6.38	6.44E+09	97.96	2.04
Land use	kg C deficit	2.89E+10	99.96	0.04	9.46E+10	99.99	0.01
Water resource depletion	m3 water eq	1.83E+09	99.996	0.004	6.00E+09	99.999	0.001
Mineral, fossil & ren resource depletion	kg Sb eq	3.57E+03	76.30	23.70	9.76E+03	91.33	8.67

4.3.2 EGYPT

a) Socio-economic

Table 75: Total expenditures in Egypt

CAPEX and OPEX (real Mio € 2010)	2020	2030	2040	2050	2020-2050
Investment expenditures	0,00	23642,30	10297,84	0,00	33940,15
Construction expenditures	0,00	5295,92	2306,74	0,00	7602,66
TOTAL INVESTMENT REQUIREMENTS	0,00	28938,22	12604,58	0,00	41542,80
Operation & Maintenance costs/year	0,00	579,53	774,01	696,61	

Table 76: Total economic activity in Egypt

	2020	2030	2040	2050
Investment (million €)				
Direct	0,00	23642,30	10297,84	0,00
Indirect	0,00	18441,00	8032,32	0,00
Induced	0,00	5201,31	2265,53	0,00
Construction (million €)				
Direct	0,00	5295,92	2306,74	0,00
Indirect	0,00	4130,82	1799,25	0,00
Induced	0,00	1165,10	507,48	0,00
O&M costs (million €/year)				
Direct	0,00	579,53	774,01	696,61
Indirect	0,00	452,04	603,72	543,35
Induced	0,00	127,50	170,28	153,25

Table 77: Economic activity stimulation by sectors in Egypt (million €)

ECONOMIC SECTOR SHARE - DIRECT EFFECT	shares	2020	2030	2040	2050
Construction	0,28	0,00	8264,97	3746,00	195,05
Minerals	0,09	0,00	2656,60	1204,07	62,69
Metals	0,28	0,00	8264,97	3746,00	195,05
Transport	0,11	0,00	3246,95	1471,64	76,63
Electr. Equip	0,10	0,00	2951,78	1337,86	69,66
machinery	0,00	0,00	0,00	0,00	0,00
Business services	0,14	0,00	4132,49	1873,00	97,52
ECONOMIC SECTOR SHARE - INDIRECT EFFECT					
Other services	0,25	0,00	5755,96	2608,82	135,84
Other indirect	0,75	0,00	17267,89	7826,47	407,51
ECONOMIC SECTOR SHARE - INDUCED EFFECT					
Food and non-alcoholic beverages	0,45	0,00	2889,79	1309,76	68,20
Alcoholic beverages, tobacco & narc	0,02	0,00	155,85	70,64	3,68
Cloting and footwear	0,05	0,00	344,18	155,99	8,12
Housing, water, electricity, gas other fuels	0,18	0,00	1168,90	529,79	27,59
Furinsihg, hhd equipment and maintenance	0,04	0,00	227,29	103,02	5,36
Helath	0,07	0,00	422,10	191,31	9,96
Transport	0,05	0,00	292,23	132,45	6,90
Communication	0,03	0,00	170,14	77,11	4,02
Recreation and culture	0,02	0,00	136,37	61,81	3,22
Education	0,04	0,00	227,29	103,02	5,36
Restaurants & hotels	0,04	0,00	266,25	120,67	6,28
Miscellaneous & goods/services	0,08	0,00	513,02	232,52	12,11

Table 78: Total economic activity with imports in the medium local share scenario (S3) in Egypt

	2020	2030	2040	2050
Investment (million €)				
Direct	0,00	11821,15	5148,92	0,00
Indirect	0,00	9220,50	4016,16	0,00
Induced	0,00	2600,65	1132,76	0,00
Construction (million €)				
Direct	0,00	3177,55	1384,04	0,00
Indirect	0,00	2478,49	1079,55	0,00
Induced	0,00	699,06	304,49	0,00
O&M costs (million €/year)				
Direct	0,00	463,63	619,20	557,28
Indirect	0,00	361,63	482,98	434,68
Induced	0,00	102,00	136,23	122,60

EMPLOYMENT

Table 79: Total employment generation in Egypt

EGYPT		2030	2040	2050
Manufacturing (FTE current jobs)	Direct jobs	28483	13785	0
	Indirect jobs	27699	13405	0
	Induced jobs	14045	6798	0
	Total Jobs	70227	33988	0
Construction (FTE current jobs)	Direct jobs	71207	34462	0
	Indirect jobs	69248	33513	0
	Induced jobs	35114	16994	0
	Total Jobs	175568	84969	0
O&M (FTE current jobs)	Direct jobs	5697	8453	8453
	Indirect jobs	5540	8221	8221
	Induced jobs	2809	4169	4169
	Total Jobs	14045	20843	20843

Table 80: Distribution of employment by sectors in Egypt

DIRECT JOBS	2030	2040	2050
Construction	29508	15876	2367
Minerals	9485	5103	761
Metals	29508	15876	2367
Transport	11592	6237	930
Electr. Equip	10539	5670	845
machinery	0	0	0
Business services	14754	7938	1183
INDIRECT JOBS			
Other services	25622	13785	2055
Other indirect	76865	41355	6166
INDUCED JOBS			
Food and non-alcoholic beverages	23126	12442	1855
Alcoholic beverages, tobacco & narc	1247	671	100
Cloting and footwear	2754	1482	221
Housing, water, electricity, gas other fue	9354	5033	750
Furinsihg, hhd equipment and maintena	1819	979	146
Helath	3378	1817	271
Transport	2339	1258	188
Communication	1362	733	109
Recreation and culture	1091	587	88
Education	1819	979	146
Restaurants & hotels	2131	1146	171
Miscellaneous & goods/services	4105	2209	329

Table 81: Results for Egypt under medium local share scenario (S3)

EGYPT (S3-Molder)		2030	2040	2050
Manufacturing (FTE current jobs)	Direct jobs	14241	6892	0
	Indirect jobs	13850	6703	0
	Induced jobs	7023	3399	0
	Total Jobs	35114	16994	0
Construction (FTE current jobs)	Direct jobs	42724	20677	0
	Indirect jobs	41549	20108	0
	Induced jobs	21068	10196	0
	Total Jobs	105341	50981	0
O&M (FTE current jobs)	Direct jobs	4557	6763	6763
	Indirect jobs	4432	6577	6577
	Induced jobs	2247	3335	3335
	Total Jobs	11236	16674	16674

b) Environmental

Table 82: Environmental impacts in Egypt

Environmental impacts Egypt	Units	2030			2040		
		TOTAL	% Power plant	% HVDC	TOTAL	% Power plant	% HVDC
Climate change	kg CO2 eq	6.43E+08	97.06	2.94	9.85E+08	98.08	1.92
Ozone depletion	kgCFC-11eq	9.63E+01	88.88	11.12	1.43E+02	92.51	7.49
Human tox. cancer eff.	CTUh	2.13E+02	92.50	7.50	3.20E+02	95.02	4.98
Human toxicity, non-cancer effects	CTUh	1.15E+04	1.26	98.74	1.16E+04	1.94	98.06
Particulate matter	kgPM2.5eq	3.92E+06	6.38	93.62	4.06E+06	9.53	90.47
Ionizing radiation HH	kg U235 eq	1.43E+08	97.30	2.70	2.19E+08	98.24	1.76
Ionizing radiation E	CTUe	4.42E+04	0.75	99.25	4.44E+04	1.16	98.84

(interim)							
Photoch. O3formation	kgNMVOCeq	1.99E+06	93.00	7.00	3.00E+06	95.36	4.64
Acidification	molc H+ eq	3.49E+06	92.53	7.47	5.25E+06	95.04	4.96
Terrestrialeutroph.	molc N eq	7.25E+06	97.38	2.62	1.11E+07	98.29	1.71
Freshwater eutroph.	kg P eq	1.83E+05	84.31	15.69	2.68E+05	89.26	10.74
Marine eutrophication	kg N eq	1.06E+08	0.52	99.48	1.07E+08	0.80	99.20
Freshwater ecotoxicity	CTUe	2.37E+09	94.45	5.55	3.59E+09	96.34	3.66
Land use	kg C deficit	3.03E+10	99.96	0.04	4.68E+10	99.97	0.03
Water depletion	m3 water eq	1.96E+09	100.00	0.00	3.04E+09	100.00	0.00
Mineral, fossil & ren resource depletion	kg Sb eq	3.70E+03	77.14	22.86	5.26E+03	83.93	16.07

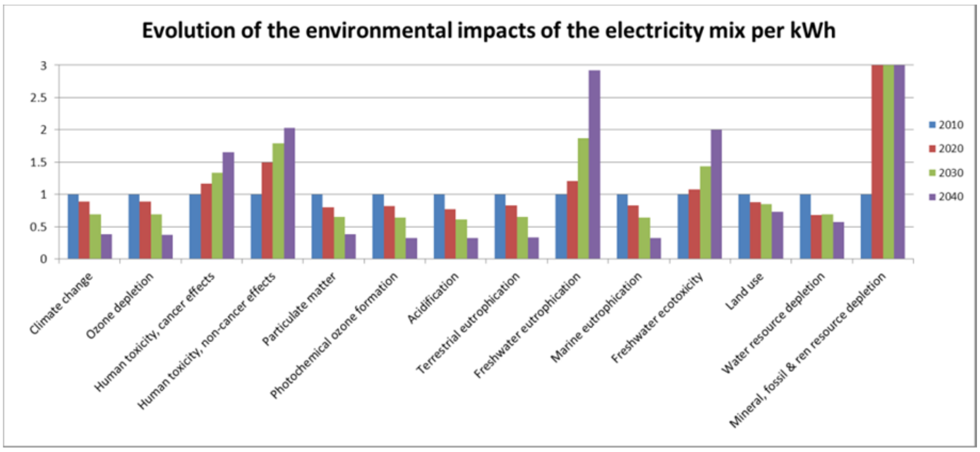


Figure 77: Evolution of the environmental impacts mix per kWh in Egypt

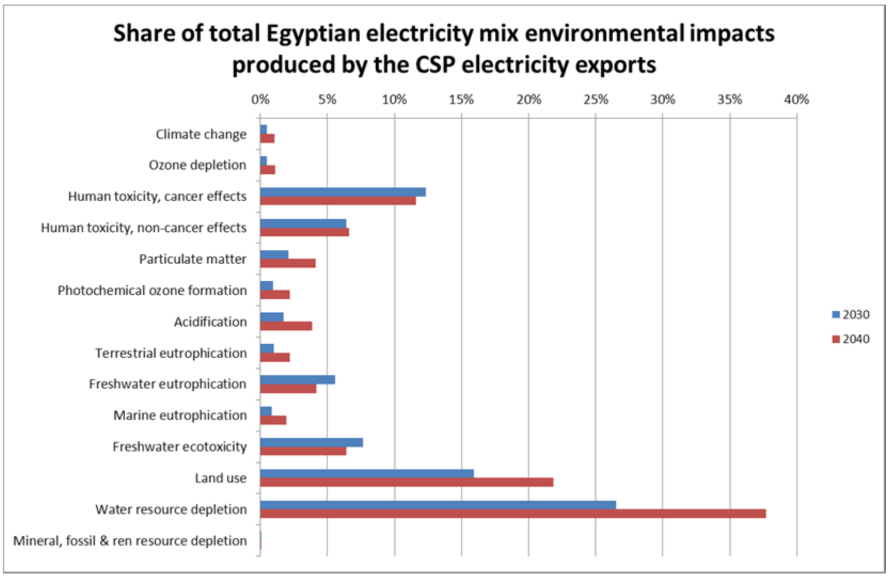


Figure 78: Share of total Egyptian electricity mix environmental impacts produced by CSP electricity exports

Table 83: Environmental impacts in Egypt under medium local share scenario (S3)

Environmental impacts Egypt (S3)	Units	2030			2040		
		TOTAL	% Power plant	% HVDC	TOTAL	% Power plant	% HVDC
Climate change	kg CO2 eq	6.43E+08	97.06	2.94	9.85E+08	98.08	1.92
Ozone depletion	kgCFC-11eq	9.63E+01	88.88	11.12	1.43E+02	92.51	7.49
Human tox., cancer eff.	CTUh	1.95E+02	91.81	8.19	2.93E+02	94.55	5.45
Human tox., non-cancer effects	CTUh	1.15E+04	1.20	98.80	1.16E+04	1.84	98.16
Particulate matter	kgPM2.5eq	3.85E+06	4.75	95.25	3.95E+06	7.16	92.84
Ionizing radiation HH	kg U235 eq	1.37E+08	97.17	2.83	2.09E+08	98.15	1.85
Ionizing radiation E (interim)	CTUe	4.42E+04	0.71	99.29	4.43E+04	1.09	98.91
Photochemical ozone formation	kgNMVOCeq	1.47E+06	90.54	9.46	2.20E+06	93.68	6.32
Acidification	molc H+ eq	2.51E+06	89.63	10.37	3.75E+06	93.04	6.96
Terrestrial eutrophicat.	molc N eq	3.75E+06	94.93	5.07	5.70E+06	96.66	3.34
Freshwater eutrophication	kg P eq	1.67E+05	82.78	17.22	2.43E+05	88.15	11.85
Marine eutrophication	kg N eq	1.06E+08	0.34	99.66	1.06E+08	0.53	99.47
Freshwater ecotoxicity	CTUe	2.15E+09	93.89	6.11	3.26E+09	95.96	4.04
Land use	kg C deficit	3.03E+10	99.96	0.04	4.68E+10	99.97	0.03
Water depletion	m3 water eq	1.92E+09	100.00	0.00	2.97E+09	100.00	0.00

Mineral, fossil & ren resource depletion	kg Sb eq	3.70E+03	77.12	22.88	5.26E+03	83.91	16.09

4.3.3 LIBYA

a) Socio-economic

Table 84: Total expenditures in Libya

CAPEX and OPEX (real Mio € 2010)	2020	2030	2040	2050	2020-2050
Investment expenditures	0,00	12579,36	11166,34	10021,79	33767,48
Construction expenditures	0,00	2817,80	2501,28	2244,90	7563,98
TOTAL INVESTMENT REQUIREMENTS	0,00	15397,16	13667,62	12266,69	41331,46
Operation & Maintenance costs/year	0,00	308,35	551,23	741,77	

Table 85: Total economic activity in Libya

	2020	2030	2040	2050
Investment (million €)				
Direct	0,00	12579,36	11166,34	10021,79
Indirect	0,00	9811,90	8709,74	7816,99
Induced	0,00	2767,46	2456,59	2204,79
Construction (million €)				
Direct	0,00	2817,80	2501,28	2244,90
Indirect	0,00	2197,88	1951,00	1751,02
Induced	0,00	619,92	550,28	493,88
O&M costs (million €/year)				
Direct	0,00	308,35	551,23	741,77
Indirect	0,00	240,51	429,96	578,58
Induced	0,00	67,84	121,27	163,19

Table 86: Economic activity stimulation by sectors in Libya (million €)

ECONOMIC SECTOR SHARE - DIRECT EFFECT	shares	2020	2030	2040	2050
Construction	0,28	0,00	4397,54	3981,28	3642,37
Minerals	0,09	0,00	1413,50	1279,70	1170,76
Metals	0,28	0,00	4397,54	3981,28	3642,37
Transport	0,11	0,00	1727,61	1564,07	1430,93
Electr. Equip	0,10	0,00	1570,55	1421,88	1300,85
machinery	0,00	0,00	0,00	0,00	0,00
Business services	0,14	0,00	2198,77	1990,64	1821,18
ECONOMIC SECTOR SHARE - INDIRECT EFFECT					
Other services	0,25	0,00	3062,57	2772,68	2536,65
Other indirect	0,75	0,00	9187,72	8318,03	7609,95
ECONOMIC SECTOR SHARE - INDUCED EFFECT					
Food and non-alcoholic beverages	0,24	0,00	829,25	750,76	686,85
Alcoholic beverages, tobacco & narc	0,01	0,00	17,28	15,64	14,31
Cloting and footwear	0,05	0,00	158,94	143,89	131,65
Housing, water, electricity, gas other fuels	0,28	0,00	967,46	875,88	801,32
Furinsihg, hhd equipment and maintenance	0,00	0,00	10,71	9,70	8,87
Helath	0,02	0,00	63,23	57,25	52,37
Transport	0,25	0,00	846,53	766,40	701,16
Communication	0,03	0,00	108,49	98,22	89,86
Recreation and culture	0,01	0,00	45,95	41,60	38,06
Education	0,00	0,00	13,82	12,51	11,45
Restaurants & hotels	0,01	0,00	25,91	23,46	21,46
Miscellaneous & goods/services	0,03	0,00	96,75	87,59	80,13

Table 87: Total economic activity with imports under the low local share scenario (S1) in Libya

	2020	2030	2040	2050
Investment (million €)				
Direct	0,00	1257,94	1116,63	1002,18
Indirect	0,00	981,19	870,97	781,70
Induced	0,00	276,75	245,66	220,48
Construction (million €)				
Direct	0,00	563,56	500,26	448,98
Indirect	0,00	439,58	390,20	350,20
Induced	0,00	123,98	110,06	98,78
O&M costs (million €/year)				
Direct	0,00	123,34	220,49	296,71
Indirect	0,00	96,21	171,98	231,43
Induced	0,00	27,13	48,51	65,28

EMPLOYMENT

Table 88: Employment generation in Libya

LIBYA		2030	2040	2050
Manufacturing (FTE current jobs)	Direct jobs	15155	14947	14906
	Indirect jobs	14738	14536	14496
	Induced jobs	7473	7371	7350
	Total Jobs	37366	36854	36752
Construction (FTE current jobs)	Direct jobs	37887	37368	37264
	Indirect jobs	36845	36340	36239
	Induced jobs	18683	18427	18376
	Total Jobs	93414	92135	91879
O&M (FTE current jobs)	Direct jobs	3031	6020	9002
	Indirect jobs	2948	5855	8754
	Induced jobs	1495	2969	4439
	Total Jobs	7473	14844	22194

Table 89: Distribution of employment by sectors in Libya

DIRECT JOBS	2030	2040	2050
Construction	15700	16334	17128
Minerals	5047	5250	5505
Metals	15700	16334	17128
Transport	6168	6417	6729
Electr. Equip	5607	5834	6117
machinery	0	0	0
Business services	7850	8167	8564
INDIRECT JOBS			
Other services	13632	14183	14872
Other indirect	40897	42548	44616
INDUCED JOBS			
Food and non-alcoholic beverages	6636	6904	7240
Alcoholic beverages, tobacco & narc	138	144	151
Cloting and footwear	1272	1323	1388
Housing, water, electricity, gas other fue	7742	8055	8446
Furinsihg, hhd equipment and maintena	86	89	94
Helath	506	526	552
Transport	6774	7048	7390
Communication	868	903	947
Recreation and culture	368	383	401
Education	111	115	121
Restaurants & hotels	207	216	226
Miscellaneous & goods/services	774	805	845

Table 90: Results for Libya under low local share scenario (S1)

LIBYA (S1-Low)		2030	2040	2050
Manufacturing (FTE current jobs)	Direct jobs	1515	1495	1491
	Indirect jobs	1474	1454	1450
	Induced jobs	747	737	735
	Total Jobs	3737	3685	3675
Construction (FTE current jobs)	Direct jobs	7577	7474	7453
	Indirect jobs	7369	7268	7248
	Induced jobs	3737	3685	3675
	Total Jobs	18683	18427	18376
O&M (FTE current jobs)	Direct jobs	1212	2408	3601
	Indirect jobs	1179	2342	3502
	Induced jobs	598	1188	1776
	Total Jobs	2989	5938	8878

b) Environmental

Table 91: Environmental impacts in Libya

Environmental impacts Libya	Units	2030			2040		
		TOTAL	% Power plant	% HVDC	TOTAL	% Power plant	% HVDC
Climate change	kg CO2 eq	3.37E+08	94.39	5.61	7.19E+08	97.37	2.63
Ozone depletion	kg CFC-11 eq	5.43E+01	80.29	19.71	1.07E+02	89.96	10.04
Human tox., cancer eff.	CTUh	1.16E+02	86.28	13.72	2.37E+02	93.26	6.74
Human tox., non-cancer effects	CTUh	1.15E+04	0.65	99.35	1.15E+04	1.41	98.59
Particulate matter	kg PM2.5 eq	3.80E+06	3.36	96.64	3.95E+06	7.09	92.91
Ionizing radiation HH	kg U235 eq	7.49E+07	94.83	5.17	1.60E+08	97.58	2.42
Ionizing radiation E (interim)	CTUe	4.40E+04	0.38	99.62	4.42E+04	0.84	99.16
Photoch. o3formation	kgNMVOCeq	1.08E+06	87.14	12.86	2.21E+06	93.71	6.29
Acidification	molc H+ eq	1.91E+06	86.33	13.67	3.88E+06	93.28	6.72
Terrestrialeutroph.	molc N eq	3.79E+06	94.98	5.02	8.11E+06	97.65	2.35
Freshwater eutroph.	kg P eq	1.08E+05	73.26	26.74	2.02E+05	85.76	14.24
Marine eutrophication	kg N eq	1.06E+08	0.27	99.73	1.06E+08	0.58	99.42
Freshwater ecotoxicity	CTUe	1.27E+09	89.66	10.34	2.64E+09	95.02	4.98
Land use	kg C deficit	1.54E+10	99.92	0.08	3.39E+10	99.96	0.04
Water resource	m3 water eq	1.00E+09	99.99	0.01	2.20E+09	100.00	0.00
Mineral, fossil & ren resource depletion	kg Sb eq	2.30E+03	63.25	36.75	4.05E+03	79.10	20.90

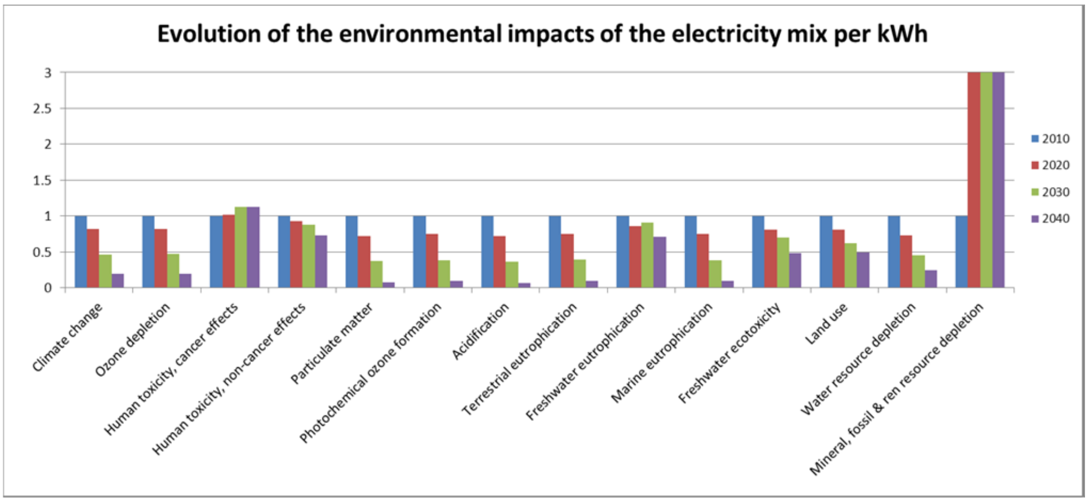


Figure 79: Evolution of the environmental impacts mix per kWh in Libya

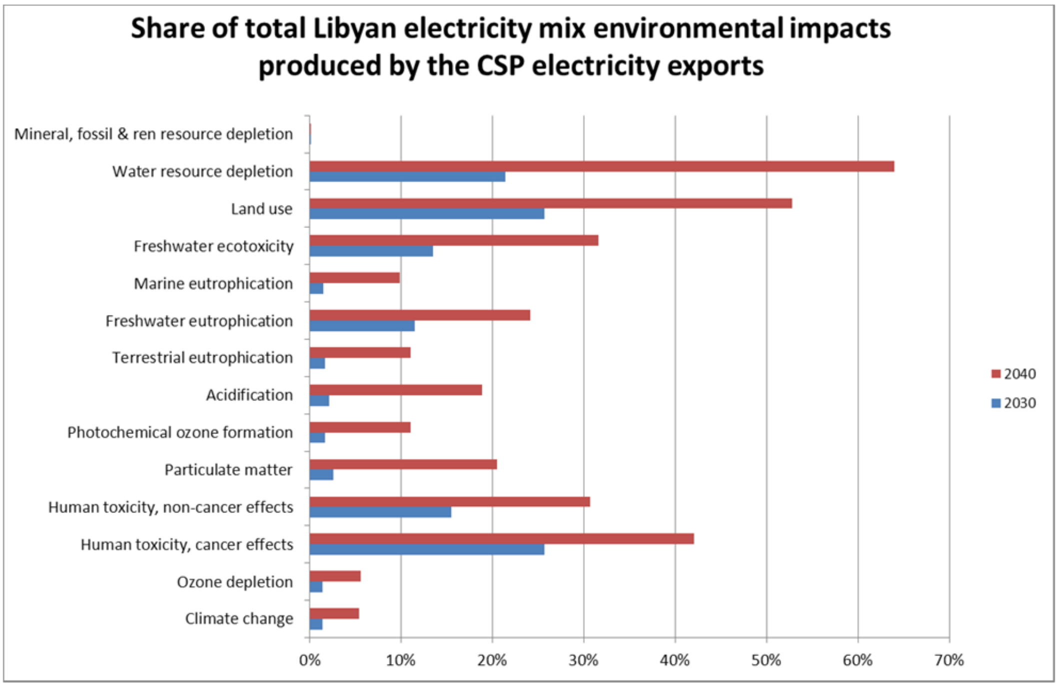


Figure 80: Share of total Libyan electricity mix environmental impacts produced by CSP electricity exports

Table 46: Environmental impacts in Libya under low local share scenario (S1)

Environmental impacts Libya (S1)	Units	2030			2040		
		TOTAL	% Power plant	% HVDC	TOTAL	% Power plant	% HVDC
Climate change	kg CO2 eq	3.37E+08	94.39	5.61	7.19E+08	97.37	2.63
Ozone depletion	kg CFC-11 eq	5.43E+01	80.29	19.71	1.07E+02	89.96	10.04

Human tox. Cancer effe.	CTUh	1.71E+01	6.41	93.59	1.84E+01	13.09	86.91
Human tox., non-cancer	CTUh	1.14E+04	0.32	99.68	1.15E+04	0.69	99.31
Particulate matter	kg PM2.5 eq	3.70E+06	0.70	99.30	3.73E+06	1.52	98.48
Ionizing radiation HH	kg U235 eq	4.88E+07	92.08	7.92	1.03E+08	96.23	3.77
Ionizing radiation E (interim)	CTUe	4.39E+04	0.20	99.80	4.40E+04	0.44	99.56
Photoch. O3formation	kgNMVOCeq	3.93E+05	64.66	35.34	6.98E+05	80.09	19.91
Acidification	molc H+ eq	7.42E+05	64.87	35.13	1.32E+06	80.24	19.76
Terrestrialeutroph.	molc N eq	6.74E+05	71.76	28.24	1.25E+06	84.82	15.18
Freshwater eutroph.	kg P eq	3.47E+04	17.13	82.87	4.18E+04	31.25	68.75
Marine eutrophication	kg N eq	1.06E+08	0.05	99.95	1.06E+08	0.10	99.90
Freshwater ecotoxicity	CTUe	2.22E+08	40.73	59.27	3.30E+08	60.18	39.82
Land use	kg C deficit	1.54E+10	99.92	0.08	3.39E+10	99.96	0.04
Water depletion	m3 water eq	7.91E+08	99.99	0.01	1.74E+09	100.00	0.00
Mineral, fossil & ren resource depletion	kg Sb eq	2.27E+03	62.80	37.20	3.99E+03	78.78	21.22

4.3.4 MOROCCO

a) Socio-economic

Table 92: Total expenditures in Morocco

CAPEX and OPEX (real Mio € 2010)	2020	2030	2040	2050	2020-2050
Investment expenditures	0,00	48249,60	44634,33	10049,70	102933,63
Construction expenditures	0,00	10808,00	9998,17	2251,15	23057,32
TOTAL INVESTMENT REQUIREMENTS	0,00	59057,60	54632,50	12300,85	125990,95
Operation & Maintenance costs/year	0,00	1182,72	2158,55	2189,04	

Table 93: Total economic activity in Morocco

	2020	2030	2040	2050
Investment (million €)				
Direct	0,00	48249,60	44634,33	10049,70
Indirect	0,00	37634,69	34814,77	7838,77
Induced	0,00	10614,91	9819,55	2210,93
Construction (million €)				
Direct	0,00	10808,00	9998,17	2251,15
Indirect	0,00	8430,24	7798,57	1755,90
Induced	0,00	2377,76	2199,60	495,25
O&M costs (million €/year)				
Direct	0,00	1182,72	2158,55	2189,04
Indirect	0,00	922,52	1683,67	1707,45
Induced	0,00	260,20	474,88	481,59

Table 94: Economic activity stimulation by sectors in Morocco (million €)

ECONOMIC SECTOR SHARE - DIRECT EFFECT	shares	2020	2030	2040	2050
Construction	0,24	0,00	14457,68	13629,85	3477,57
Minerals	0,16	0,00	9638,45	9086,57	2318,38
Metals	0,16	0,00	9638,45	9086,57	2318,38
Transport	0,24	0,00	14457,68	13629,85	3477,57
Electr. Equip	0,08	0,00	4819,23	4543,28	1159,19
machinery	0,06	0,00	3614,42	3407,46	869,39
Business services	0,06	0,00	3614,42	3407,46	869,39
ECONOMIC SECTOR SHARE - INDIRECT EFFECT					
Other services	0,50	0,00	23493,72	22148,51	5651,06
Other indirect	0,50	0,00	23493,72	22148,51	5651,06
ECONOMIC SECTOR SHARE - INDUCED EFFECT					
Food and non-alcoholic beverages	0,41	0,00	5453,56	5141,29	1311,77
Alcoholic beverages, tobacco & narc	0,04	0,00	524,81	494,76	14,31
Cloting and footwear	0,05	0,00	681,20	642,19	163,85
Housing, water, electricity, gas other fuels	0,16	0,00	2075,40	1956,57	499,21
Furinsihg, hhd equipment and maintenance	0,05	0,00	612,28	577,22	147,28
Helath	0,04	0,00	553,97	522,25	133,25
Transport	0,10	0,00	1375,65	1296,88	330,89
Communication	0,06	0,00	848,18	799,62	204,02
Recreation and culture	0,04	0,00	561,92	529,75	135,16
Education	0,02	0,00	273,01	257,38	65,67
Restaurants & hotels	0,07	0,00	861,44	812,11	207,21
Miscellaneous & goods/services	0,07	0,00	870,71	820,86	209,44

Table 95: Total economic activity with imports in the high local share scenario (S2) in Morocco

	2020	2030	2040	2050
Investment (million €)				
Direct	0,00	38599,68	35707,46	8039,76
Indirect	0,00	30107,75	27851,82	6271,01
Induced	0,00	8491,93	7855,64	1768,75
Construction (million €)				
Direct	0,00	9727,20	8998,35	2026,04
Indirect	0,00	7587,22	7018,72	1580,31
Induced	0,00	2139,98	1979,64	445,73
O&M costs (million €/year)				
Direct	0,00	1182,72	2158,55	2189,04
Indirect	0,00	922,52	1683,67	1707,45
Induced	0,00	260,20	474,88	481,59

EMPLOYMENT

Table 96: Total employment generation in Morocco

MOROCCO		2030	2040	2050
Manufacturing (FTE current jobs)	Direct jobs	58128	59747	14947
	Indirect jobs	56529	58103	14536
	Induced jobs	28664	29463	7371
	Total Jobs	143321	147313	36854
Construction (FTE current jobs)	Direct jobs	145320	149368	37368
	Indirect jobs	141322	145258	36340
	Induced jobs	71660	73657	18427
	Total Jobs	358302	368283	92135
O&M (FTE current jobs)	Direct jobs	11626	23575	26564
	Indirect jobs	11306	22926	25834
	Induced jobs	5733	11625	13100
	Total Jobs	28664	58127	65498

Table 97: Distribution of employment by sectors in Morocco

DIRECT JOBS	2030	2040	2050
Construction	51618	55846	18931
Minerals	34412	37230	12621
Metals	34412	37230	12621
Transport	51618	55846	18931
Electr. Equip	17206	18615	6310
machinery	12904	13961	4733
Business services	12904	13961	4733
INDIRECT JOBS			
Other services	104578	113144	38355
Other indirect	104578	113144	38355
INDUCED JOBS			
Food and non-alcoholic beverages	43643	47217	16006
Alcoholic beverages, tobacco & narc	4200	4544	1540
Cloting and footwear	5451	5898	1999
Housing, water, electricity, gas other fue	16609	17969	6091
Furinsihg, hhd equipment and maintena	4900	5301	1797
Helath	4433	4796	1626
Transport	11009	11910	4038
Communication	6788	7344	2489
Recreation and culture	4497	4865	1649
Education	2185	2364	801
Restaurants & hotels	6894	7458	2528
Miscellaneous & goods/services	6968	7539	2556

Table 98: Results for Morocco under high local share scenario (S2)

MOROCCO (S2-High)		2030	2040	2050
Manufacturing (FTE current jobs)	Direct jobs	46502	47798	11958
	Indirect jobs	45223	46483	11629
	Induced jobs	22931	23570	5897
	Total Jobs	114657	117851	29483
Construction (FTE current jobs)	Direct jobs	130788	134431	33631
	Indirect jobs	127189	130733	32706
	Induced jobs	64494	66291	16584
	Total Jobs	322472	331455	82921
O&M (FTE current jobs)	Direct jobs	11626	23575	26564
	Indirect jobs	11306	22926	25834
	Induced jobs	5733	11625	13100
	Total Jobs	28664	58127	65498

b) Environmental

Table 99: Environmental impacts in Morocco

Environmental impacts Morocco	Units	2030			2040		
		TOTAL	% Power plant	% HVDC	TOTAL	% Power plant	% HVDC
Climate change	kg CO2 eq	1.34E+09	98.58	1.42	3.33E+09	77.26	22.74
Ozone depletion	kg CFC-11 eq	1.91E+02	94.40	5.60	7.80E+02	45.12	54.88
Human tox. Cancer effe.	CTUh	4.31E+02	96.30	3.70	1.45E+03	55.93	44.07
Human toxicity, non-cancer effects	CTUh	1.17E+04	2.62	97.38	4.56E+05	0.13	99.87
Particulate matter	kg PM2.5 eq	4.20E+06	12.56	87.44	1.48E+08	0.70	99.30

Ionizing radiation HH	kg U235 eq	2.98E+08	98.70	1.30	7.28E+08	78.74	21.26
Ionizing radiation E (interim)	CTUe	4.46E+04	1.57	98.43	1.76E+06	0.08	99.92
Photoch. O3formation	kgNMVOCeq	4.03E+06	96.56	3.44	1.32E+07	57.77	42.23
Acidification	molc H+ eq	7.07E+06	96.31	3.69	2.37E+07	56.03	43.97
Terrestrial eutroph.	molc N eq	1.51E+07	98.74	1.26	3.67E+07	79.26	20.74
Freshwater eutroph.	kg P eq	3.55E+05	91.89	8.11	1.79E+06	35.60	64.40
Marine eutrophication	kg N eq	1.07E+08	1.09	98.91	4.23E+09	0.05	99.95
Freshwater ecotoxicity	CTUe	4.85E+09	97.29	2.71	1.45E+10	63.64	36.36
Land use	kg C deficit	6.38E+10	99.98	0.02	1.25E+11	99.60	0.40
Water depletion	m3 water eq	4.14E+09	100.00	0.00	8.09E+09	99.97	0.03
Mineral, fossil & ren resource depletion	kg Sb eq	6.87E+03	87.68	12.32	4.56E+04	25.78	74.22

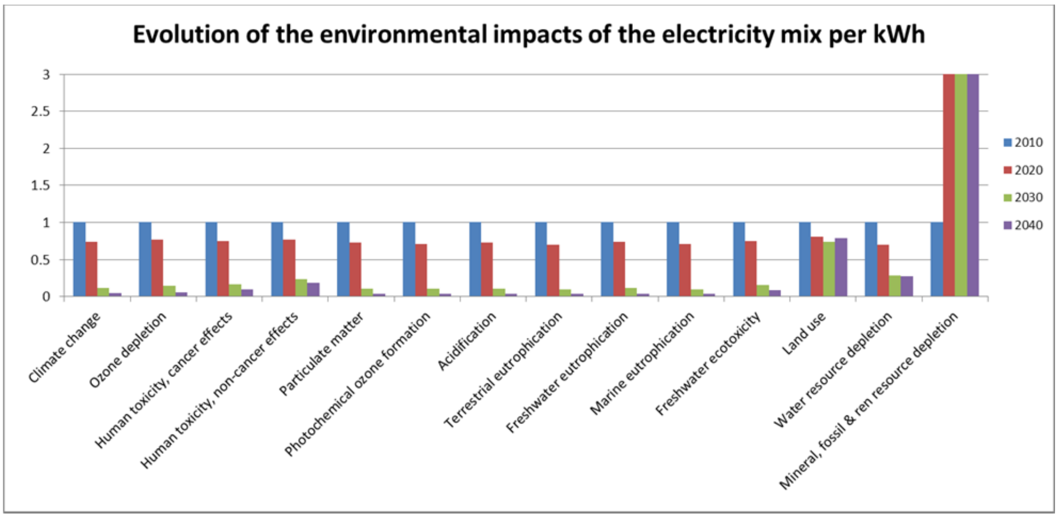


Figure 81: Evolution of the environmental impacts mix per kWh in Morocco

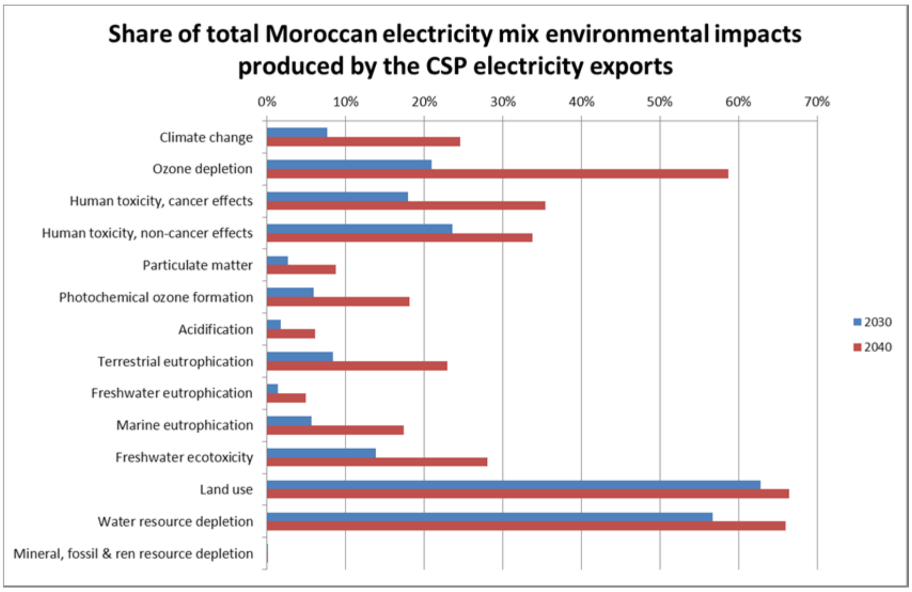


Figure 82: Share of total Moroccan electricity mix environmental impacts produced by CSP electricity exports

Table 100: Environmental impacts in Morocco under high local share scenario (S2)

Environmental impacts Morocco (S2)	Units	2030			2040		
		TOTAL	% Power plant	% HVDC	TOTAL	% Power plant	% HVDC
Climate change	kg CO2 eq	1.34E+09	98.58	1.42	3.33E+09	77.26	22.74
Ozone depletion	kg CFC-11 eq	1.91E+02	94.40	5.60	7.80E+02	45.12	54.88
Human toxicity, cancer effects	CTUh	4.23E+02	96.23	3.77	1.43E+03	55.44	44.56
Human toxicity, non-cancer effects	CTUh	1.17E+04	2.59	97.41	4.56E+05	0.13	99.87
Particulate matter	kg PM2.5 eq	4.19E+06	12.39	87.61	1.48E+08	0.69	99.31
Ionizing radiation HH	kg U235 eq	2.96E+08	98.69	1.31	7.24E+08	78.63	21.37
Ionizing radiation E (interim)	CTUe	4.45E+04	1.56	98.44	1.76E+06	0.08	99.92
Photochemical ozone formation	kg NMVOC eq	4.01E+06	96.54	3.46	1.31E+07	57.62	42.38
Acidification	molc H+ eq	7.03E+06	96.29	3.71	2.36E+07	55.87	44.13
Terrestrial eutrophication	molc N eq	1.50E+07	98.73	1.27	3.65E+07	79.18	20.82
Freshwater eutrophication	kg P eq	3.48E+05	91.73	8.27	1.77E+06	35.13	64.87
Marine eutrophication	kg N eq	1.07E+08	1.08	98.92	4.23E+09	0.05	99.95

Freshwater ecotoxicity	CTUe	4.76E+09	97.24	2.76	1.43E+10	63.20	36.80
Land use	kg C deficit	6.38E+10	99.98	0.02	1.25E+11	99.60	0.40
Water resource depletion	m3 water eq	4.13E+09	100.00	0.00	8.07E+09	99.97	0.03
Mineral, fossil & ren resource depletion	kg Sb eq	6.87E+03	87.68	12.32	4.56E+04	25.77	74.23

4.3.5 TUNISIA

a) Socio-economic

Table 101: Total expenditures in Tunisia

CAPEX and OPEX (real Mio € 2010)	2020	2030	2040	2050	2020-2050
Investment expenditures	0,00	12751,68	11166,34	10049,70	33967,72
Construction expenditures	0,00	2856,40	2501,28	2251,15	7608,83
	0,00	15608,08	13667,62	12300,85	41576,55
Operation & Maintenance costs/year	0,00	312,58	555,03	745,87	

Table 102: Total economic activity in Tunisia

	2020	2030	2040	2050
Investment (million €)				
Direct	0,00	12751,68	11166,34	10049,70
Indirect	0,00	9946,31	8709,74	7838,77
Induced	0,00	2805,37	2456,59	2210,93
Construction (million €)				
Direct	0,00	2856,40	2501,28	2251,15
Indirect	0,00	2227,99	1951,00	1755,90
Induced	0,00	628,41	550,28	495,25
O&M costs (million €/year)				
Direct	0,00	312,58	555,03	745,87
Indirect	0,00	243,81	432,93	581,78
Induced	0,00	68,77	122,11	164,09

Table 103: Economic activity stimulation by sectors in Tunisia (million €)

ECONOMIC SECTOR SHARE - DIRECT EFFECT	shares	2020	2030	2040	2050
Construction	0,24	0,00	3820,96	3413,44	3131,21
Minerals	0,16	0,00	3820,96	3413,44	3131,21
Metals	0,16	0,00	3820,96	3413,44	3131,21
Transport	0,24	0,00	3820,96	3413,44	3131,21
Electr. Equip	0,08	0,00	3820,96	3413,44	3131,21
machinery	0,06	0,00	3820,96	3413,44	3131,21
Business services	0,06	0,00	3820,96	3413,44	3131,21
ECONOMIC SECTOR SHARE - INDIRECT EFFECT					
Other services	0,50	0,00	6209,06	5546,83	5088,22
Other indirect	0,50	0,00	6209,06	5546,83	5088,22
ECONOMIC SECTOR SHARE - INDUCED EFFECT					
Food and non-alcoholic beverages	0,26	0,26	0,26	0,26	0,26
Alcoholic beverages, tobacco & narc	0,04	0,00	908,91	811,97	744,84
Cloting and footwear	0,08	0,00	908,91	811,97	744,84
Housing, water, electricity, gas other fuels	0,16	0,00	908,91	811,97	744,84
Furinsihg, hhd equipment and maintenance	0,06	0,00	908,91	811,97	744,84
Helath	0,05	0,00	908,91	811,97	744,84
Transport	0,15	0,00	908,91	811,97	744,84
Communication	0,04	0,00	908,91	811,97	744,84
Recreation and culture	0,03	0,00	908,91	811,97	744,84
Education	0,01	0,00	908,91	811,97	744,84
Restaurants & hotels	0,14	0,00	908,91	811,97	744,84
Miscellaneous & goods/services	0,07	0,00	908,91	811,97	744,84

Table 104: Total economic activity considering imports under the medium local share scenario (S3) in Tunisia

	2020	2030	2040	2050
Investment (million €)				
Direct	0,00	6375,84	5583,17	5024,85
Indirect	0,00	4973,16	4354,87	3919,38
Induced	0,00	1402,68	1228,30	1105,47
Construction (million €)				
Direct	0,00	1713,84	1500,77	1350,69
Indirect	0,00	1336,80	1170,60	1053,54
Induced	0,00	377,04	330,17	297,15
O&M costs (million €/year)				
Direct	0,00	250,06	444,03	596,70
Indirect	0,00	195,05	346,34	465,43
Induced	0,00	55,01	97,69	131,27

EMPLOYMENT

Table 105: Employment generation in Tunisia

TUNISIA		2030	2040	2050
Manufacturing (FTE current jobs)	Direct jobs	15362	14947	14947
	Indirect jobs	14940	14536	14536
	Induced jobs	7576	7371	7371
	Total Jobs	37878	36854	36854
Construction (FTE current jobs)	Direct jobs	38406	37368	37368
	Indirect jobs	37349	36340	36340
	Induced jobs	18939	18427	18427
	Total Jobs	94694	92135	92135
O&M (FTE current jobs)	Direct jobs	3072	6062	9051
	Indirect jobs	2988	5895	8802
	Induced jobs	1515	2989	4463
	Total Jobs	7576	14946	22317

Table 106: Distribution of employment by sectors in Tunisia

DIRECT JOBS	2030	2040	2050
Construction	13642	14011	14728
Minerals	9095	9340	9819
Metals	9095	9340	9819
Transport	13642	14011	14728
Electr. Equip	4547	4670	4909
machinery	3410	3503	3682
Business services	3410	3503	3682
INDIRECT JOBS			
Other services	27638	28385	29839
Other indirect	27638	28385	29839
INDUCED JOBS			
Food and non-alcoholic beverages	7274	7470	7853
Alcoholic beverages, tobacco & narc	1043	1071	1126
Cloting and footwear	2150	2208	2321
Housing, water, electricity, gas other fue	4605	4730	4972
Furinsihg, hhd equipment and maintena	1814	1863	1958
Helath	1334	1370	1440
Transport	4246	4361	4585
Communication	1096	1126	1183
Recreation and culture	849	872	917
Education	174	178	188
Restaurants & hotels	4003	4111	4321
Miscellaneous & goods/services	2021	2076	2182

Table 107: Results for Tunisia under medium local share scenario (S3)

TUNISIA (S3-Molder)		2030	2040	2050
Manufacturing (FTE current jobs)	Direct jobs	7681	7474	7474
	Indirect jobs	7470	7268	7268
	Induced jobs	3788	3685	3685
	Total Jobs	18939	18427	18427
Construction (FTE current jobs)	Direct jobs	23044	22421	22421
	Indirect jobs	22410	21804	21804
	Induced jobs	11363	11056	11056
	Total Jobs	56816	55281	55281
O&M (FTE current jobs)	Direct jobs	2458	4850	7241
	Indirect jobs	2390	4716	7042
	Induced jobs	1212	2391	3571
	Total Jobs	6060	11957	17854

b) Environmental

Table 108: Environmental impacts in Tunisia

Environmental impacts Tunisia	Units	2030			2040		
		TOTAL	% Power plant	% HVDC	TOTAL	% Power plant	% HVDC
Climate change	kg CO2 eq	3.17E+08	94.04	5.96	1.38E+09	45.34	54.66
Ozone depletion	kg CFC-11 eq	5.16E+01	79.24	20.76	5.14E+02	16.72	83.28
Human tox. Cancer effe.	CTUh	1.10E+02	85.49	14.51	8.36E+02	23.66	76.34
Human toxicity, non-cancer effects	CTUh	1.15E+04	0.61	99.39	4.55E+05	0.03	99.97
Particulate matter	kg PM2.5 eq	3.79E+06	3.15	96.85	1.47E+08	0.17	99.83
Ionizing radiation HH	kg U235 eq	7.04E+07	94.50	5.50	2.95E+08	47.49	52.51
Ionizing radiation E (interim)	CTUe	4.40E+04	0.36	99.64	1.75E+06	0.02	99.98
Photoch. O3formation	kgNMVOCeq	1.02E+06	86.39	13.61	7.41E+06	25.03	74.97
Acidification	molc H+ eq	1.80E+06	85.54	14.46	1.37E+07	23.72	76.28
Terrestrialeutroph.	molc N eq	3.56E+06	94.66	5.34	1.47E+07	48.26	51.74
Freshwater eutroph.	kg P eq	1.03E+05	71.96	28.04	1.31E+06	11.89	88.11
Marine eutrophication	kg N eq	1.06E+08	0.25	99.75	4.23E+09	0.01	99.99
Freshwater ecotoxicity	CTUe	1.20E+09	89.04	10.96	7.51E+09	29.94	70.06
Land use	kg C deficit	1.45E+10	99.91	0.09	3.09E+10	98.38	1.62
Water depletion	m3 water eq	9.38E+08	99.99	0.01	1.98E+09	99.87	0.13
Mineral, fossil & ren resource depletion	kg Sb eq	2.21E+03	61.72	38.28	3.67E+04	7.82	92.18

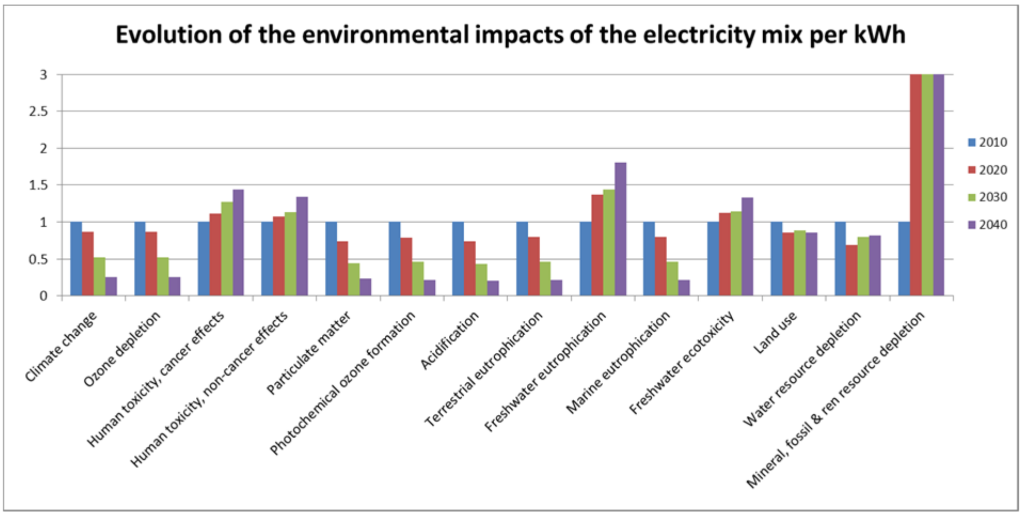


Figure 83: Evolution of the environmental impacts mix per kWh in Tunisia

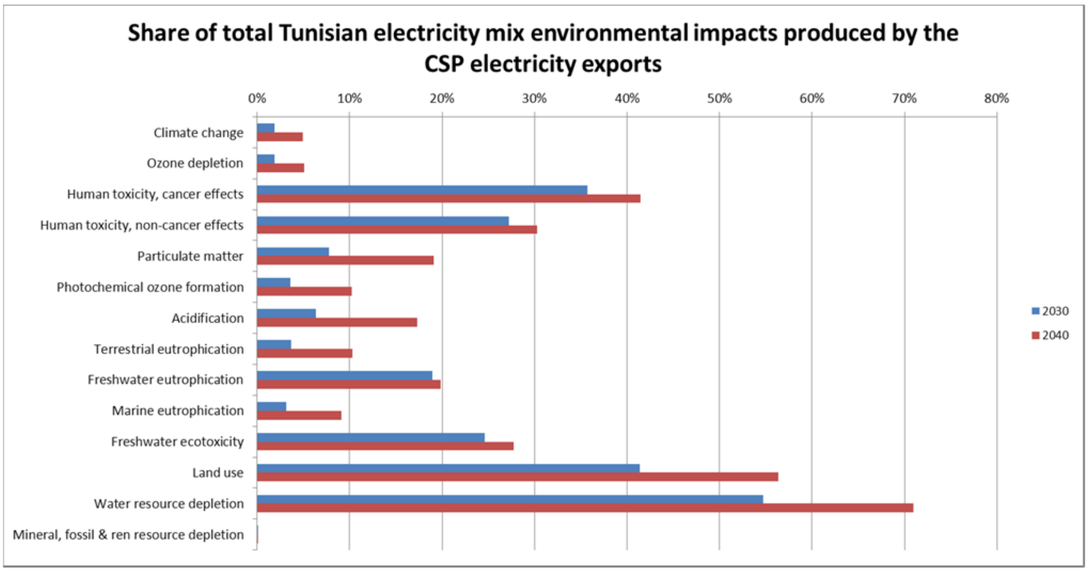


Figure 84: Share of total Tunisian electricity mix environmental impacts produced by CSP electricity exports

Table 109: Environmental impacts in Tunisia under medium local share scenario (S3)

Environmental impacts Tunisia (S3)	Units	2030			2040		
		TOTAL	%Powerplant	% HVDC	TOTAL	%Powerplant	% HVDC
Climate change	kg CO2 eq	3.17E+08	94.04	5.96	1.38E+09	45.34	54.66
Ozone depletion	kg CFC-11 eq	5.16E+01	79.24	20.76	5.14E+02	16.72	83.28
Human tox., cancer eff.	CTUh	1.01E+02	84.27	15.73	8.18E+02	21.98	78.02
Human tox., non-cancer	CTUh	1.14E+04	0.58	99.42	4.55E+05	0.03	99.97
Particulate matter	kg PM2.5 eq	3.76E+06	2.32	97.68	1.47E+08	0.13	99.87

Ionizing radiation HH	kg U235 eq	6.73E+07	94.25	5.75	2.88E+08	46.28	53.72
Ionizing radiation E (interim)	CTUe	4.40E+04	0.34	99.66	1.75E+06	0.02	99.98
Photoch. O3formation	kgNMVOCeq	7.74E+05	82.06	17.94	6.89E+06	19.39	80.61
Acidification	molc H+ eq	1.34E+06	80.50	19.50	1.27E+07	17.84	82.16
Terrestrialeutroph.	molc N eq	1.89E+06	89.94	10.06	1.12E+07	31.98	68.02
Freshwater eutroph.	kg P eq	9.48E+04	69.67	30.33	1.29E+06	10.78	89.22
Marine eutrophication	kg N eq	1.06E+08	0.16	99.84	4.23E+09	0.01	99.99
Freshwater ecotoxicity	CTUe	1.10E+09	88.01	11.99	7.29E+09	27.84	72.16
Land use	kg C deficit	1.45E+10	99.91	0.09	3.09E+10	98.38	1.62
Water depletion	m3 water eq	9.16E+08	99.99	0.01	1.93E+09	99.86	0.14
Mineral, fossil & ren resource depletion	kg Sb eq	2.21E+03	61.68	38.32	3.67E+04	7.81	92.19

4.3.6 HVDC LINE

Table 110: Employment and economic impacts of Overhead HVDC line

Overhead line		Unit	Direct	Indirect	Induced	Total employ.Mult.effect
Manufacturing and Construc.	Employment (FTE)	Jobs/million €	16926,32	11345,00	15329,69	43597,57
	Economic Activity	Million €	1971,41	2016,80	1837,02	5825,23
O&M	Employment (FTE)	Jobs/million €/year	287,64	112,56	200,10	600,30
	Economic Activity	Million €	21,66	17,28	23,96	62,90

Table 111: Employment and economic impacts of Underground HVDC line

Underground line		Unit	Direct	Indirect	Induced	Total employ. Mult. effect
Manufacturing and Construc.	Employment (FTE)	Jobs/million €	43591,64	29217,65	39479,72	112280,14
	Economic Activity	Million €	5077,12	5194,01	4731,03	15002,16
O&M	Employment (FTE)	Jobs/million €/year	493,87	193,26	343,56	1030,69
	Economic Activity	Million €	37,18	29,67	41,14	107,99

5. ROLE OF ARTICLE 9 AND OTHER MECHANISMS

5.1. Relevance of Article 9 for an EU-North Africa CHP cooperation

The cooperation mechanisms of the EU RES directive were primarily created to reach the 2020 renewable energy targets of EU Member States more cost-efficiently. Some initiatives have evolved (even though mostly not yet implemented) that follow the purpose of cost-efficiency in such a short- to mid-term way. In some cases, the cooperation mechanisms may become the prime driver of a RES investment.

For North Africa, flexible electricity supply from Concentrating Solar Power (CSP) stations connected directly to European centers of demand via dedicated point-to-point High-Voltage-Direct-Current (HVDC) links were identified as the only candidate that would provide sufficient added value in Europe to achieve a realistic business case for RES-E cooperation. As compared to other potential joint projects, this business case is not mainly determined by the value added of Article 9, article 9 however can be supportive. A major difference of the here presented approach to the majority of other cooperation projects that may evolve or are under development is that article 9 cannot be expected to be a sufficient driver for implementation as the long-term decarbonisation envisaged with the proposed concept is not fully consistent with Article 9. This also means that article 9 as it is currently in place does not provide for a planning security as its further existence is not guaranteed.

As compared to cost reductions that may be achieved by investment in, e.g., hydro and wind power, CSP, in particular in combination with the proposed HVDC link to the EU, is a comparably expensive technology and thus requires major investments. Importing CSP-based electricity from North Africa to the EU is therefore not cost-efficient in the short- to mid-term and long-term benefits are not taken into account by the current form of the RES cooperation mechanisms. National 2020 targets in the EU thus cannot be expected to be a sufficient trigger for a CSP-based North Africa – EU cooperation.

However, the high quality of the provided electricity importantly distinguishes CSP from other concepts for renewable energy cooperation that rather would lead to imports of volatile electricity. Instead of additionally requiring balancing capacity, imports of electricity from CSP may provide flexible supply themselves which is strongly needed in order to balance an increasing share of volatile renewable energy sources. This distinguishes the concept fundamentally from most other potential article 9 projects with the exception of pump storage plants or other electricity storage options that however cannot be considered an energy source like CSP. A CSP-based North Africa – EU cooperation can thus importantly contribute to a long-term cost-efficient transition of the energy system towards high RES-E shares and decarbonisation such as envisioned for 2050 (Fragkos et al. 2013) and thus corresponding priority should be given to it.

The prime feature that was introduced with the cooperation mechanisms is the possibility to transfer not only electricity but also its renewable characteristic between and to EU Member States. This feature may remain of interest for EU-NA CHP cooperation, even though the current Article 9 is unlikely to be applied. A comparable future mechanism that enables such recognition of the renewable characteristic in European statistics may provide an important additional incentive for cooperation. In addition, it may be used as one tool for the cost and benefit sharing within the EU as discussed below.

5.2. Implications and design options of Article 9 or a successor mechanism

5.2.1. Governmental involvement

Projects that primarily aim at a cost-efficient achievement of national renewable energy targets will typically be government-driven with bi- or multilateral governmental agreements being the basic element. Investments would be triggered by, e.g., the provision of a feed in tariff or premium from the buyer country to companies that implement the projects in the host country. The approach presented above puts companies in the centre of a potential initiative. The question thus may arise, how a governmental involvement would look like as this is required in order to transfer not only electricity but also its renewable nature that may ultimately show up in European energy statistics. Besides the establishment of the before mentioned inter-governmental agreements and corresponding notifications to the European Commission, importing governments would need to provide proof for the electricity actually imported to the EU. Being transmitted via point-to-point interconnections, electricity from CSP-HVDC imports would be easily traceable by simple metering at the power lines. An involvement of governments in the monitoring of electricity flows to the EU and the forwarding of this data to the countries that intend to account for the renewable energy in their statistics would additionally be required.

5.2.2. Attribution of the renewable characteristics

A more challenging effort may be the attribution of the renewable characteristics of the imported electricity to the EU countries. This is, decisions need to be taken on who (MS, clusters) would statistically account for the renewable energy. The most straightforward approach would be to attribute the renewable characteristic to the country to which the electricity is physically imported. If need arises, the physical renewable energy transfer could further be traded statistically between EU countries.

The current cooperation mechanisms provide some additional elements for this distribution among countries. For instance, agreements on distribution rules between Member States are suggested for both joint projects and joint support schemes. A distribution approach could take into account governments' involvement in risk reduction and possibly financing. Governmental guarantees that may be needed in order to provide for low-risk financing may be correlated to the interest of the involved countries to import electricity – both physically and statistically. This could also provide a basis for a statistical transfer of renewable energy including transit countries (that would not necessarily import electricity in physical terms). A group of off-taking and transit countries could also establish a common agreement including specific distribution rules. As discussed before, financing will require a PPA which would cover capital and operation costs. If such a PPA receives governmental support, e.g. via integration in a FIT, the distribution of the statistical renewable energy may be correlated to the relative height of the provided support. This may or may not be equivalent to the actual physical import and consumption of the involved electricity. In particular in multilateral agreements the sharing of the statistical distribution of renewable energy will need to be negotiated in addition to physical imports. In this context, Article 9 or a successor mechanism may provide an additional incentive for governments to co-finance such an initiative because it provides a framework for consideration of the renewable characteristics of the imported electricity in the national statistics. If still existent at the time of implementation, Article 9 or a successor mechanism may thus play a role in its implementation even if this will not be the prime driver.

5.2.3. Cost- and benefit-sharing

Another important challenge of the cooperation mechanism is the sharing of costs and benefits between the involved countries and a corresponding (financial) compensation. This includes physical costs for, e.g., grid expansion and transmission lines but also impacts on the environment, job creation (or its absence), security and diversification of supply, a potential “sell out” of low cost potentials and other. While in many cases an interference with local support schemes, electricity supply, grid capacities and own renewable energy targets in the host country exist, the approach presented here is different and simpler in several ways. The installed infrastructure would exclusively serve export purposes and would therefore be fully additional to local supply. This also includes dedicated transmission lines which would avoid negative interferences with the domestic grid in the host country. Another relevant aspect is that an abundant physical potential for CSP is present which means that no important potentials would be “taken away” from domestic supply. No infrastructure costs would be carried by the host country and no interference with a domestic support scheme and electricity prices would occur. The fact that CSP does currently not provide low-cost electricity (being at the beginning of its cost learning curve) further should exclude a competition with low cost energy supply in the host country. Compensation payments for land used for the HVDC power lines and CSP plants are considered as part of the operation cost and would be charged to consumers.

5.3. Potential combinations with other climate change related mechanisms

As mentioned earlier, reducing risks and thus the costs of capital is key for an EU-NA CHP cooperation. Experiences with CHP in the region, other existing energy cooperation, access to institutions and other may equally help to implement such a concept. The implementation of joint projects may thus benefit from other existing instruments. In some cases a direct combination may be possible, while other instruments may rather indirectly contribute to the implementation of joint projects. In particular, it should be guaranteed that joint projects do not negatively interfere with other instruments, such as domestic support systems in the host countries. As a general precondition for recognition of renewable energy from third countries under EU Member State targets, the RES directive requires the expansion of capacities explicitly for the purpose of import to the EU. This means that, this transfer needs to be foreseen in any financing set-up from the beginning, including when it is combined with one of the here discussed instruments. In addition, the production transferred must not receive production support (e.g. FITs) from the host country but may receive domestic investment support.

5.3.1. Domestic support schemes

The renewable energy directive states that the amount of electricity produced and exported to the EU under joint projects must not receive “support from a support scheme of a third country other than investment aid”. This is, no production support from the host country is possible for the electricity exported under joint projects. While this seems obvious given that the produced electricity does not contribute to domestic electricity supply, care needs to be taken in order not to negatively impact the electricity market of the host country. The presented concept is unique in the sense that point-to-point links avoid the integration in the grid and thus are fully kept separate from the domestic electricity system and market in the host country. Negative interferences can thus be excluded.

5.3.2. Official development assistance (ODA)

In countries where energy-related development cooperation is in place, this may assist the implementation of the cooperation mechanisms. However, a direct combination of ODA support with the cooperation mechanisms would be challenging, in particular because the objectives would not be easy to harmonize (development of renewable energy for the benefit of the ODA recipient vs. interests of the importer country, see discussion in deliverable D2.3 of the BETTER project[81]). Generally, development cooperation may to some extent prepare the ground for the use of the cooperation mechanisms by supporting, e.g., institutional capacity building and the creation of cooperation frameworks. Also, where the domestic supply of energy in ODA receiving countries is supported, this may facilitate energy exports at a later stage by improving energy security in the exporter countries. In North Africa, for instance, the German development agency GIZ (former GTZ) is engaged in the promotion of renewable energy in several countries. This includes a support of the implementation of the national Moroccan and Tunisian solar plans. It further supports the Mediterranean solar plan as well as activities aiming the integration of the Mediterranean energy market (Euro-Mediterranean Energy Market Integration Project, MED-EMIP)[82]. The latter is financed by the European Commission in the framework of the European Neighbourhood policy and provides a good example of an initiative which aims to benefit cooperation in general and which may thus also contribute to facilitate the implementation of the cooperation mechanisms.

5.3.3. The Clean Development Mechanism (CDM)

The functioning and potential interactions of the CDM with the cooperation mechanisms as well with ODA are discussed in deliverable D2.3 of the BETTER project. A direct combination with the cooperation mechanisms is unlikely because no new CDM projects can be expected in the region and electricity needs to remain in the host country/region under the CDM which is in contradiction with the idea of the cooperation mechanisms. However, existing CDM projects contributed to renewable energy generation in North Africa and thereby contribute to regional electricity supply which can be expected to be the first priority before important exports may occur. In addition, lessons may be drawn from their implementation.

Box 1: *CDM and NAMAs in North Africa*

The CDM in North Africa

The North African countries are non-Annex 1 countries under the United Nation Framework Convention on Climate Change, UNFCCC, and therefore eligible for the CDM. New project can hardly be expected in the region due to the limitation of the EU to new projects from least developed countries. However, CDM renewable energy projects were developed in Egypt (mainly fuel switching and wind energy), in Tunisia (wind power, biomass), Morocco (primarily wind energy, also CSP, photovoltaic and fuel switch) and Libya (photovoltaic).

Example: In Morocco the **Ouarzazate I Concentrated Solar Power Project** was registered as CDM project in 2012. The proposed project is the first stage of a 500 MW solar power complex, and

[81] http://better-project.net/sites/default/files/D2.3_Design%20Options%20of%20the%20Cooperation%20Mechanisms.pdf.pdf
[82] GIZ activity descriptions (German): http://www.giz.de/de/weltweit/340.html, http://www.giz.de/themen/de/31009.htm (access November 2012)

represents the first step of the Morocco Solar Plan launched in 2009 by the Moroccan Government, which aims at installing at least 2,000 MW of solar generation capacity by 2020. The Ouarzazate Power Station Project I will be a 120 to 160 MW project using concentrated solar power (CSP) and includes 3 hours of thermal energy storage. The project is expected to supply around 497.5 GWh per year to the Moroccan electricity grid. It is expected to result in a reduction of an average of 271,366 tonnes CO_2 per year and 2,713,663 tonnes CO_2 over the crediting period (Fujiwara *et al.*, 2012).

Source: Frieden *et al., 2012*

5.3.4. National appropriate mitigation actions (NAMAs) and fast start finance under UNFCCC

The term NAMA was first used in the Bali Action Plan as part of the Bali Road Map agreed at the climate change conference of the United Nations Framework Convention on Climate Change (UNFCCC) in Bali in December 2007 (Conference of the Parties, COP, 13). It also formed part of the Copenhagen Accord, the major outcome of the climate change conference in Copenhagen (COP 15) in December 2009. NAMAs refer to a set of policies and actions that countries undertake as part of a commitment to reduce greenhouse gas emissions. The term recognizes that different countries may take different nationally appropriate actions on the basis of equity and in accordance with common but differentiated responsibilities and respective capabilities. It also emphasizes financial assistance from developed countries to developing countries. Most developing countries seeking support for NAMAs submitted their NAMA proposals to UNFCCC under the Copenhagen Accord (NAMAs were added in an Annex to the Accord). NAMA proposals as well as available funding can also be submitted to the UNFCC NAMA registry which serves to match funders' and NAMA host countries' interests[83].

General discussion of the compatibility with the cooperation mechanisms

It cannot be expected that capacities for export will be financed under NAMAs because NAMAs, comparable to the CDM, aim an impact such as emission reductions in the country receiving the support. While this is not a stringent requirement because the international rules for NAMAs are not clearly defined, potential donors will most likely want to have a proof of the nationally achieved emission reduction. However, a combination of NAMAs for domestic renewable electricity consumption in combination with an export project might be possible. Such support will depend on the willingness of donors to support fractions of large projects or programmes (e.g. the Austrian NAMA initiative targets smalls scale installations) or several donors teaming up for larger projects. A potentially major benefit from NAMAs, similar to ODA, may be the support for creating suitable frame conditions such as regulations, risk reduction, tec-transfer mechanisms etc. as well as the establishment of cooperation frameworks. Where NAMAs focus on satisfying domestic demand in the NAMA host country, they may contribute to creating a basis for export by increasing the overall domestic electricity generation.

Donors – information of the NAMA registry so far

[83] http://www4.unfccc.int/sites/nama/SitePages/Home.aspx

The NAMA registry is still in its initial phase and information on financing agreements is still negligible. Individual donor countries that provided information on available support are the UK, Germany, Austria, and Japan. Corporate and regional donor information is provided by the GEF, the EU-Africa Infrastructure Trust Fund, and the EU including the Neighbourhood Investment Facility. While the EU-Africa Infrastructure Trust Fund focuses on sub-Saharan Africa, the Neighbourhood Investment Facility supports a number of energy projects in North Africa (see sections below). These projects receive grants from the facility in combination with loans from European IFIs or national development banks such as KfW or the French Agence Française de Développement (AFD). Unlike the joint German/UK NAMA facility, the Neighbourhood Investment Facility (NIF) also supports feasibility studies in addition to "ready to implement" projects. In addition to the national projects described below, the NIF finances the regional "Renewable Energy and Energy Efficiency Project Preparation Initiative in support of the Mediterranean Solar Plan" (MSP-PPI). As mentioned above, Germany supports the Tunisian solar plan as part of the German-Tunisian technical cooperation. An additional NAMA support is described below.

Tunisia

Tunisia submitted NAMA proposals to UNFCCC referring to the Copenhagen Accord. The country seeks financial support as well as technology transfer and capacity building. In the area of renewable energy it seeks support for its solar plan which is partly financed and implemented since 2009. It was developed by the national agency for energy conservation and endorses Tunisia's aim of becoming an international hub for energy production and exportation. The Plan Solaire includes 40 concrete public-private projects (energy efficiency, RES) of which parts are fully financed and have already been implemented. Responsible institutions as well as a timeframe are identified for each action. The latest project components shall be finalised in 2016 (MEDD 2010, RCREEE 2011). The individual projects shall promote wind and solar energy, biogas and the introduction of energy efficiency measures in the transport and building sector. The required financial means amount to total cost of EUR 1800 mln while the financing requested is EUR 371 mln. The Tunisian solar plan includes the interconnection to Italy which would facilitate exports of electricity to the EU and thus the establishment of joint projects. For reasons mentioned above, however, we do not anticipate such interconnection to be financed with NAMA support. Tunisia already receives support from GEF („NAMA Support for the Tunisian Solar Plan")[84] and Germany supports a NAMA on increased energy efficiency in the building sector under its International Climate Initiative[85]. In addition, Germany and the UK prepare NAMA support on renewable energy through their joint NAMA facility. This support will, however, aim at smaller scale and decentralized technologies and focus on „ready to implement" projects rather than on capacity building or readiness activities. The contribution of these NAMAs to a potential renewable energy export would thus mainly be to improve covering the domestic energy demand which would facilitate a surplus generation for export at a later stage. The EU Neighbourhood Investment Facility granted final approval to a feasibility study for a concentrated

[84] http://www.thegef.org/gef/project_detail?projID=5340
[85] http://www.international-climate-initiative.com/en/news/article/iki-continues-its-support-for-national-climate-change-mitigation-activities-by-partner-countries/ Access 23 July 2014

solar power plant[86]. As of 31 July 2013 the Akarit CSP project as well as two photovoltaic plants were under provisional approval[87].

Box 2: *GEF support for the Tunisian Solar Plan*

GEF NAMA Support for the Tunisian Solar Plan

The proposed GEF project will, support the implementation of the TSP using NAMAs pertaining to three technologies. It will put in place the institutional and policy frameworks necessary to coordinate and support the up-scaling of renewable electricity in Tunisia, as well as developing an architecture for developing these NAMAs. Besides these two technical assistance components, the project also encompasses an investment component to support two baseline investment projects to enhance their mitigation potential and to be framed as NAMAs receiving financial support (supported NAMA). GEF funding will be used incrementally to create the appropriate institutional, policy and capacity environment in which the identified (and enhanced) baseline projects can be embedded, thereby enhancing their probability of successful implementation as supported NAMAs; establishing the framework for a programmatic approach to NAMAs; and supporting the pre-conditions for replication in Tunisia and in the broader MENA region. In a first step one private-sector supported wind energy NAMA (Gabesse 24 MW grid-connected wind farm) and one public-sector supported PV NAMA (Tozeur 10MW PV) are implemented to validate the adopted framework and methodologies. The system design of the NAMA will specifically incorporate the international dimensions of the TSP that may play a role in the longer term – i.e. the fact that clean electricity may be exported to North African (Non-Annex 1) and European (Annex 1) countries.

Source: GEF 2013

Algeria

Algeria did not submit specific NAMAs to UNFCCC. Accordingly, at the moment no NAMAs exist but feasibility studies were undertaken. The feasibility studies refer to the development of concentrated solar power and energy efficiency in residential buildings[88]. The study on CSP includes activities from 2011 to 2030 and identified a total of 7200 MW that could be installed. The electricity generated would supply the domestic demand with a surplus to be exported. The program would have three phases:

(2011-2013) Pilot project of two solar power plants with a total capacity of 150 MW each. These are in addition to the hybrid power plant project of Hassi R'Mei with a total power capacity of 150 MW, which includes 25 MW from solar energy

[86] http://ec.europa.eu/europeaid/where/neighbourhood/regional-cooperation/irc/nif_tunisia_en.htm Access 24 July 2014
[87] http://ec.europa.eu/europeaid/where/neighbourhood/regional-cooperation/irc/documents/nif_list_of_projects_under_provisional_approval_august_2013_en.pdf
[88] http://www.nama-database.org/index.php/Algeria

(2016-2021) Construction of 4 solar thermal power plants with a total capacity of approx. 1200 MW.

(2021-2030) Installation of 500MW annually until 2023 and 600MW annually until 2030.

Egypt

Egypt has not made a NAMA submission under the Copenhagen Agreement nor under the UNFCCC NAMA registry. However, it submitted potential projects to the Ad Hoc Working Group on Long-term Cooperative Action (AWG-LCA) in 2012 in the areas of, e.g., fuel switching, energy efficiency and public lighting[89]. One feasibility study exists in relation to the target of 20% renewable electricity generation by 2020. A feed-in tariff was to be developed for several sources of renewable energy and a renewable energy support fund to be set up to back feed-in tariff payments. Activities include the reform of regulatory framework to fit a larger renewable energy share (e.g. guaranteed network access and preferential dispatch), support of the New and Renewable Energy Agency (NREA), and assistance for the integration of RE into the grid. The EU Neighbourhood Investment Facility (NIF) granted final approval to a number of projects[90]:

a 200 MW wind farm in the Gulf of El Zayt (NIF grant: €10M of €340M total cost),

a study aiming at the development of a Renewable Energy Framework for wind and solar power generation (Combined Renewable Energy Masterplan) including a feasibility study for a concentrated solar power plant (NIF grant: €3M),

an investment programme in the Egyptian 220-500 kV transmission network connecting new wind energy generation facilities to the grid as well as enabling future regional interconnections (NIF grant: €20M of €762M total cost),

technical assistance for the Implementation of a 20 MW photovoltaic grid connected power plant project (NIF grant: €0.8M of €100M).

Libya

Libya has not made a NAMA submission under the Copenhagen Agreement nor under the UNFCCC NAMA registry.

Morocco

Morocco submitted NAMAs under the Copenhagen Accord in the areas of Energy, industry, waste, agriculture and forestry, and housing. The submission relates to, e.g., the National Plan Against Global Warming (2009), the Moroccan Solar Plan and the Wind Plan. In the energy sector, the submission includes projects on hydropower, solar heat, concentrated solar power (CPS), energy efficiency, public lighting, and wind power. The NAMA support currently under development focuses on CSP. This includes the goal to install 2000 MW of CSP by 2020 based on the national Solar Plan. Specific activities foreseen for the period 2015-2020 are:

- Installation of concentrated solar power plants;

[89] http://unfccc.int/resource/docs/2012/awglca15/eng/misc02.pdf
[90] http://ec.europa.eu/europeaid/where/neighbourhood/regional-cooperation/irc/nif_egypt_en.htm Access 24 July 2014

- Capacity building;
- Promotion of an integrated solar industry.

Total cost would amount to US$ 6600 mln, the financing received to-date for the solar plan are US$ 110 mln according to the NAMA database91. NAMA financing thus directly contributes to installing CSP plants and gaining experience with this technology; the prime technology of interest for potential exports to the EU.

NAMA Morocco: installation of 2000 MW of concentration solar power (CSP) by 2020[92].
Activities: (2015-2020). This NAMA includes the following main activities: **Installation of concentrated solar power plants;** **Capacity building;** **Promotion of an integrated solar industry.**
Type of support needed: financial support

EU Neighbourhood Investment Facility provides support for the Ouarzazate solar power complex already mentioned under the CDM above. This initial project concerns the development of a 500 MW solar power complex thus contributing to the Moroccan solar plan. The NIF provides 30 mio € of estimated total costs of 800 mio €. The lead IFI is the EIB, other FIs are AFD and KfW. The NIF further supports the reinforcement of the high voltage transmission network including technical assistance (NIF grant: 15 mio € of 411 mio € total costs, further supported by the AFD, the EIB and KfW)[93].

5.4. Conclusions on the role of Article 9 and other instruments for an EU-North Africa cooperation on CSP

Electricity imports from North Africa to the EU based on CSP plants are highly desirable from the viewpoint of a long-term decarbonisation of the European electricity system due to the quality (flexibility and reliability) of the supplied electricity and increased diversity of supply. At the same time, the presented approach requires far higher upfront investments and a much longer lead-time than any other potential Article 9 option (hydro, wind, solar). This makes it unsuitable for short-term cost-efficient imports for 2020 RES target achievements which are the prime aim of Article 9. The presented concept may not be exploited before 2020 and before 2025 only if major steps to do so are taken very soon. Thus, the cooperation mechanisms as they are in place now do not match with the presented concept. On the other side CSP exports have a fundamental value added for the future European energy system and may thus benefit from support if these benefits are valued sufficiently. Article 9 or a similar future mechanism that enables the recognition of the renewable characteristic

[91] http://www.nama-database.org/index.php/Morocco_solar_plan Access 23 July 2014
[92] Ibid.
[93] http://ec.europa.eu/europeaid/where/neighbourhood/regional-cooperation/irc/nif_morocco_en.htm Access 24 July 2014

in European statistics may still provide an important additional incentive and may be used as one tool for the cost and benefit sharing within the EU. Complementary support may equally stem from another mechanisms type that does not necessarily need to be based on RES shares but may, for instance, be part of broader climate-finance mechanisms to meet, for instance, the EUs 2030 greenhouse gas targets. Such mechanisms have still to be established. A clear distinction between the different instruments is not always possible. For instance, NAMA support is often counted as ODA and ODA means are channelled through a variety of financing institutions and instruments such as the EU Neighbourhood Investment Facility. In many cases a direct combination of the discussed already existing instruments with exports to the EU is excluded or unlikely due to the focus of the instruments on domestic supply of electricity. However, synergies can be expected between these instruments and a potential implementation of joint projects. This includes in particular the different funding schemes for the Tunisian and Moroccan solar plans which already involve several of the discussed mechanisms (ODA, CDM, NAMAs). The existing and future initiatives can be expected to preparing the ground for cooperation by providing experiences with technologies such as CSP and by providing technical assistance and institutional frameworks for implementing RES projects. In addition, cooperation frameworks established by the different instruments so far may as well be built upon for the implementation of an Article 9 or comparable cooperation.

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