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Master’s Thesis

INTERCONNECTING MALTA’S ISOLATED ELECTRIC POWER SYSTEM TO THE EUROPEAN MARKET – INSTITUTIONAL CHALLENGES AND IMPLICATIONS FOR MALTESE ELECTRICITY CONSUMERS

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I AUTHORIZATION FORM

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III EXECUTIVE SUMMARY

In light of European electricity market liberalization this master's thesis addresses the envisaged grid interconnection – a high voltage subsea cable with 200 megawatt transmission capacity – between the two EU member states Malta and Italy. So far, Malta's electric power system has been isolated and therefore electricity supply in the small European island state has heavily relied on imported fossil fuels. Consequently, Malta's exposure to volatile fossil fuel prices inherently impedes to reliably predict electricity generation costs. This motivates to investigate whether and to what degree the vulnerability to distinct oil price scenarios can be overcome with the new interconnector that is expected to be operational as of 2014/2015.

Generally, an isolated power system like in Malta implies peculiarities. This master paper thoroughly examines whether the interconnection cable to Sicily breaks up the Maltese market and potentially threatens the privileges of the incumbent utility Enemalta. It presents the drivers that have forced the small EU member state to radically revise its hitherto energy policy. Primarily our Malta-Sicily case study i.) discusses the cable's qualitative implications – in particular institutional challenges – and ii.) numerically determines potential consequences for Maltese electricity consumers.

Our numerical sensitivity analysis defines the merit order for both Malta's isolated and the future generation setup differentiating between three distinct oil price scenarios. Based on the constructed marginal cost curves, we then simulate the interconnection case. Malta's quantity imports and the cable's total capacity utilization indicator are two key findings. Moreover, the algorithm enables to determine the average electricity spot price with interconnector and the computation of rents for both the supplier and cable owner. Our analysis demonstrates that the submarine interconnector does not inherently reduce the electricity price level for Maltese consumers. It thus renders whether and in which of the presented generation setups and distinct oil price scenarios Malta's interconnected power system benefits. The study concludes that the cable's impact significantly depends on the considered generation setup, the oil price scenario and the market design.

In sum, this thesis simulates how the theoretical concept of market liberalization practically applies to the EU island's micro power system. Its added value originates from both a qualitative and quantitative analysis which shows that the cable's impact for Maltese end consumers is importantly co-determined by Enemalta's future positioning. Although the link will certainly promote the creation of a single European electricity market, this paper suggests to thoroughly rethink infrastructure projects such as the submarine cable installation between Malta and Sicily.

IV ACRONYMS

Acronym	Meaning
AC	alternating current
ACER	Agency for the Cooperation of Energy Regulators
AEEG	Autorità per l'Energia Elettrica e il Gas
AGCM	Autorità Garante della Concorrenza e del Mercato
a.m.	ante meridiem
AU	Acquirente Unico
bn	billion
BOT	Build-Operate-Transfer
BOOT	Build-Own-Operate-Transfer
BOPS	base oil price scenario
CCDE	combined cycle diesel engine
CCGT	combined cycle gas turbine
CEER	Council of European Energy Regulators
CESI	Centro Elettrotecnico Sperimentale Italiano
cf.	confer/compare
DAM	day ahead market
DC	direct current
DPS	Delimara power station
DSO	distribution system operator
EAC	Electricity Authority of Cyprus
EC	European Commission
EEPR	European Energy Program for Recovery
e.g.	for example/ex generali
EMIN	Erasmus Mundus Joint Master in Economics and Management of Network Industries
ENTSO-E	European Network of Transmission System Operators for Electricity
EPC	Engineering-Procurement-Construction
EPS	Electric Power System
ERGEG	European Regulators' Group for Electricity and Gas
etc.	et cetera
ETSO	European Transmission System Operators
EU	European Union
ff.	and the following

Fig.	Figure
GDP	Gross Domestic Product
GENCO	generation company
GME	Gestore Mercati Energetici
GO	gas oil
GSE	Gestore Servizi Energetici
GW	gigawatt
HFO	heavy fuel oil
HHI	Herfindahl-Hirschman-Index
HOPS	high oil price scenario
HVAC	high voltage alternating current
HVDC	high voltage direct current
ibid.	in the same place/ibidem
ICAI	Escuela Técnica Superior de Ingeniería
i.e.	that is/id est
IEA	International Energy Agency
IED	Industrial Emissions Directive
IEM	internal electricity market
Ifri	Institut français des relations internationales
IMF	International Monetary Fund
IPEX	Italian power exchange
IT	Italy
kg	kilogram
km	kilometer
kV	kilovolt
kWh	kilowatt hour
LCPD	Large Combustion Plant Directive
LNG	liquified natural gas
LOPS	low oil price scenario
m.	million
M&A	merger and acquisition
MC	marginal cost
MEPA	Malta Environment and Planning Authority
MJ	mega joule
MLP	Malta Labor Party
MPS	Marsa power station

MRA	Malta Resources Authority
MRRA	Ministry for Resources and Rural Affairs
MSD	Mercato Servizi di Dispacciamento
MT	Malta
MVA	megavoltampere
MW	megawatt
n.a.	not available
n.d.	no date
NG	natural gas
NSO	National statistics office
OCGT	open cycle gas turbine
OPEC	Organization of the Petroleum Exporting Countries
OTC	over the counter
PD	Partito Democratico
PEX	power exchange
PIP	priority interconnection plan
p.m.	post meridiem
PN	Partit Nazzjonalista
PPA	power-purchase agreement
PPP	public private partnership
PUN	prezzo unico nazionale
PURPA	Public Utilities Regulatory Policies Act
PV	photovoltaic
R&D	Research and Development
RES	Renewable Energy Sources
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SoS	Security of Supply
SPV	special purpose vehicle
Tab.	Table
TEN-E	trans-European energy networks
TPA	Third Party Access
TSO	transmission system operator
TWh	Terawatt hour
T-YNDP	Ten-Year Network Development Plan
UK	United Kingdom

U.S.	United States
vs.	versus

V LIST OF FIGURES

Figures that are not explicitly marked with footnotes/references represent illustrations by the author of this thesis.

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Tables that are not explicitly marked with footnotes/references represent illustrations by the author of this thesis.

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Abstract Chapter 1

The first part of chapter one specifies the general framework for this master paper. It introduces the main European policy ideas for electricity market liberalization, in particular the vision of one single internal European electricity market; it therefore stresses exemplarily some of the various existing arenas of international scope, at present, for instance, the market coupling and the prerequisites for a European wide electricity market. Additionally, the general introduction gives a broad historical overview of principal events/ changes in the European electricity industry. Furthermore, the term of energy import dependency is introduced since it will help to easier understand the vision of an integrated European electricity market using the example of the Malta-Sicily interconnector.

In the following, the initial situation is described, i.e. Malta‘s status of a small isolated electricity system and the planned submarine interconnection with Italy. Besides Malta‘s vulnerability to high oil prices, the section highlights the island‘s privileges regarding some EC directives. It will be particularly interesting to investigate whether the interconnection of two separated fully independent electric power systems will challenge Malta‘s derogations from these directives. Moreover, Malta‘s case study is especially appropriate to give a clear and holistic overview of a small scale isolated EPS. Other examples of isolated electricity systems like Cyprus prove that this hot topic requires more research. Most important to investigate are the interconnector‘s impact on Enemalta‘s – the sole electricity supplier in Malta – predominant monopoly position and related consequences for Maltese electricity consumers.

Breaking down the research question enabled to find five main master‘s thesis objectives. In a top-down logic, firstly, characteristics particularly for interconnections and isolated systems on the European electricity policy agenda are to be presented. Then, more specifically the work should establish an objective viewpoint for the Malta-Sicily interconnection‘s framework, before identifying qualitative challenges of the EPS interconnection by analyzing systematically key drivers in both independent systems, and lastly simulating quantitative impacts for Maltese electricity consumers focussing on the spot price as a textbook example indicator.

1. INTRODUCTION

1.1 GENERAL FRAMEWORK

For this master‘s thesis the general framework is given by the European Commission‘s (EC) policy initiatives seeking to enhance electricity market liberalization across the member states. The European Union (EU) attaches major importance to the field of energy as it is the crux to ensure short and long term security of supply, at an affordable price, for both domestic and industrial customers, always with respect to defined environmental standards.

Energy policy and in particular the creation of one single integrated electricity market in which power can be traded through an organized form of energy exchange represents today a topic of utmost importance from a European perspective. Various arenas of international scope, such as the most recent market coupling in North Western Europe in February 2014, promote the idea of a single integrated market to establish a coordinated price mechanism while favoring transnational competition especially in the electricity generation business.[1] First, however, as a prerequisite for this aimed internal European electricity market a sound individually developed energy market place within the 28 member states must be assured. Certainly the degree of market opening in European countries today still differs significantly (cf. chapter 2.1.4 on *Divergence in market opening across Europe*). Differences in pace and approach determine how each particular state has practically transposed the EC‘s directives into national law.

The aforementioned aspects highlight where the framework for this paper originates from. In order to be able to properly analyze the Malta-Sicily electricity interconnection a clear vision of both electric systems affected by the market opening process is needed. It will be relevant to investigate whether both countries have established any sort of competitive electricity market, and if so, how they achieved this goal successfully.

Connecting both electric power systems with a submarine cable of course appears to be a step forward in the perception of a single European electricity market, but first it remains to be seen whether the predominant systems‘ elements are in line with this policy direction. For instance by just looking at the commissioned market coupling mechanism, we find that neither Italy (logically nor Malta as an isolated electricity system) are presently part of this initiative.

[1] Cf. Merino (2014), p. 1
North West European market coupling includes 15 countries: Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Great Britain, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland and Sweden

As studied along this master's thesis, a certain type of liberalized market can be noticed in the first third of the 20th century, in which spontaneous growth of private companies took place and the state (solely) adopted the role of an observer of the electricity industry. [2] However, a first major restructuring of the electric power industry due to technical and economical developments, for instance reduced investment capacity as a consequence of the Second World War, shifted the electricity business to become state responsibility in nearly all European countries, so that until the 1980s the entire power sector, i.e. all necessary power supplying activities, were considered to be regulated.

This is mainly due to the following two reasons:

- The existence of economies of scale (competition in the electricity generation business was not likely to appear because of the dominance of large scale power supplying units)

- The nature of the service (it is not economically viable to build multiple distribution/ transmission networks)

By the end of the 20th century, new factors made a change from state driven monopolies towards a liberalized and more competitive electricity market possible (especially differentiating between activities that are competitive from those that are not). A significant reduction of economies of scale can be seen as the main driver for this development. The entry of new generation technologies such as combined cycle gas turbines (CCGT), rapid volume growth on the demand side and the overall increase in transmission capacity favored this process.

In total three energy packages were successively introduced by the EC in order to set the policy framework for a gradual market opening. Relevant directives from these energy packages for the paper concern primarily the creation of an internal European electricity market and the legislation on interconnection (cf. more in detail chapters on the *European policy framework* (2.1) and *EU specific policy for interconnection* (2.2)).

Within these directives the topic of energy import dependency plays a major role, and since it strongly relates to the security of supply issue which is of fundamental relevance for Malta's isolated electric power system, it is hence of particular interest for this research paper. To give a first insight into the energy dependency evolution on European level Fig. 1. shows the EU-27 energy import dependency between 1995 and 2010 by types of fuel in percent.

[2] Cf. Batlle (2012), p. 2 ff.

Interestingly, we observe that the EU-27‘s energy import dependency increased to a total of over 50 percent in the displayed period. Moreover, the EU member countries are most dependent on importing oil from non-member states (more than 80 percent in 2010) followed by gas and coal, but it is noteworthy that this fuel reliance varies significantly among member countries and depends solely on certain suppliers (mainly OPEC, Russian Federation and Norway).[3] In isolated electricity systems, like those of the European island states Malta and Cyprus, where fuel import dependency is largest, i.e. close to 100 percent, an interconnection with the European mainland (cf. envisaged Malta-Sicily interconnector) should reduce such dependency and therefore improve the countries‘ security of supply.

Yet, without interconnecting isolated EPSs these island states run the risk of not being able to satisfy the demand in situations when external fuel import is disrupted. Both historically and at present, political events like the dispute between Russia and the Ukraine (e.g. March 2014) demonstrate that EU energy supply might be endangered when Russia, for instance, as one of the major fuel exporting nations, would restrict to export through Ukrainian transit gas pipelines to EU member states. Already little disruption could have tremendous consequences for EU countries, as, for example, in Germany, about one third of all crude oil and gas imports are from Russia.[4] Hence, for the case of isolated electric systems where a country‘s energy supply depends entirely from its import, there exists a significant vulnerability to any disturbance in fuel provision.

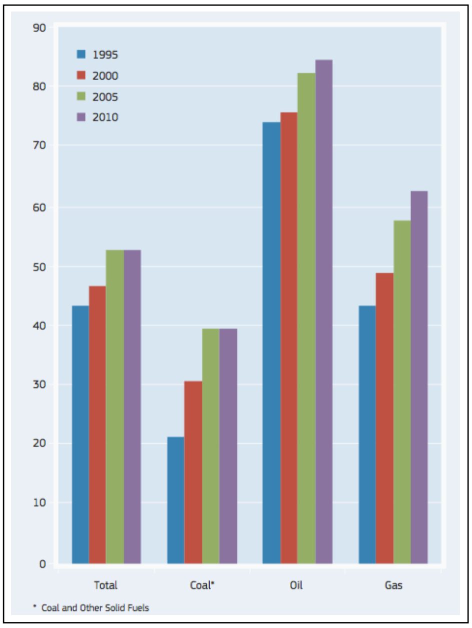

Fig. 1. EU-27 energy import dependency (1995-2010) by Fuel (%)[5]

[3] Cf. Directorate – General for Energy EC (2011a), p. 8

[4] Cf. Allé (2014)

[5] European Commission (2012c), p. 20

In summary, the addressed subsea interconnection between Malta and Sicily in this master paper serves as an excellent example to understand and illustrate the vision of an integrated European electricity market and gives a lot of room for analyzing potentially occurring institutional challenges which are likely to appear when merging two independent electric power systems. With respect to the European perspective it is also interesting to investigate the future implications of the gigantic interconnection undertaking for a small European island state like Malta which joined the EU in 2004.

1.2 INITIAL SITUATION AND MOTIVATION

A key issue to start with is to highlight that energy supply in Malta depends completely, in fact close to 100 percent, on imported fossil fuels, i.e. no other relevant domestic primary energy source exists. The current situation raises, at least in the long term, many question marks regarding the system‘s security of supply and reflects both in short and long term Malta‘s vulnerability when oil prices are high.

„*Every $10 increase in the price per barrel consumes approximately 1 percent of Malta‘s GDP*“ (quote by Maltese economist Gordon Cordina).[6]

Referring to the prescribed directives by the EC, it must be emphasized that Malta has at present the status of a small isolated system, which lets it benefit from certain privileges, for example, no need to unbundle the distribution system operator, no existence of third party access (TPA) to the distribution system and no establishment of a competitive electricity market. However, this thesis focusses not solely on the Maltese EPS but on the planned submarine interconnection cable between Malta and Sicily in Italy which can change the rules of the game significantly.

Fig. 2. Planned subsea interconnection between Malta and Italy[7]

[6] Ghirlando (2013), p. 17

[7] Malta News (2013)

This subsea link connects Malta to the Italian or, in a broader dimension, to the European electricity market so that the aforementioned derogations for Malta from the EC directives can be challenged: what do these scenarios look like, what are the prerequisites that Malta has to fulfill and what might be the impact on Maltese electricity consumers? In Malta all electricity services are provided by Enemalta, a single vertically integrated state owned authority.

It is not the aim of this introduction to list the diversity of reasons given by Enemalta for the submarine interconnection with Sicily, but rather to scrutinize the scenario of merging the two separated fully independent electric power systems of Malta and Italy. From a first broad literature review it seems that there is relatively little research carried out about the institutional challenges this project implicates.

The participation of various stakeholder groups in such a large scale international project is enormous. Regulators, energy service providing facilities and additionally the political landscape both on a national and European level codetermine the success of the aimed interconnection project. Official reports often highlight the interconnection‘s well-known advantages such as an improved security of supply and the possibility of integrating renewable energy sources (RES) for the island state, but at present too little attention is paid to the possible negative outcomes the governance between Malta and Italy – two EPS of a completely different dimension – might imply.

The motivation to study the particular problem of interconnecting the Maltese EPS with the Italian one in Sicily – the largest Mediterranean island – stems from different facets. Firstly, Malta‘s small, isolated and 100 % fuel dependent system represents an excellent textbook example in which technological characteristics, the landscape of domestic stakeholders and economical peculiarities can be studied from a micro perspective. Compared to the dimension of much larger electric power systems, Malta‘s case study is especially appropriate to give the reader a clear and holistic overview of a small scale isolated EPS. Moreover, it is particularly interesting to analyze how Malta as an example of an EU island member state is implementing the current European policy framework and what challenges they could face once the interconnection is in place. As mentioned earlier in this introduction, Enemalta is the only entity in charge of providing electricity related services on the island, so it might be relevant to discuss to what extent the interconnector can break up Enemalta‘s predominant monopoly position. A necessary requirement to discuss any implication for the Maltese system is to analyze both Malta‘s and Italy‘s EPS evenhandedly.

Furthermore, being isolated from other electricity systems is a hot topic that increasingly provokes interest on political agendas. Malta is not the only case (in the EU), where electricity generation depends almost 100 percent on external provision of fossil fuels. In Cyprus, for instance, we observe a similar situation, i.e. an EPS in which 98.2 % of gross electricity production is based on crude oil and petroleum products.[8] Without going into detail we can easily identify other similarities between the two EU island member states: the Electricity Authority of Cyprus (EAC) is the counterpart to Malta's entity Enemalta providing as a single vertically integrated state owned organization all electricity related services, and additionally, Cyprus's status of a small isolated system allows them to derive from certain EC directives. In the course of the Eurozone crisis[9] the Cypriot banking industry got into heavy difficulties, especially favored by Cyprus's close connections to the Greek financial sector, so that rating agencies downgraded Cyprus's credit-worthiness. In 2011 an explosion on a military base destroyed the largest Cypriot electricity generation power plant, a negative climax which had threatened security of supply for Cypriot electricity consumers since it accounted for more than 50 percent of consumption needs in the south of the island and resulted, besides the economical difficulties, in a political crisis, i.e. as a consequence of this incident the whole Cypriot government resigned from its responsibilities. The aforementioned aspects are the major reasons why Cyprus got assured financial support from the EU and the International Monetary Fund (IMF). In this agreement, the EU and IMF grant Cyprus funds of ten billion euro while obligating them to privatize state owned authorities like EAC and the port authority until 2018. Recently however, massive protests of EAC employees against the government's privatization initiatives in form of scheduled blackouts throughout different regions of the island jeopardized electricity supply. These rigorous actions should demonstrate EAC's power or, in other words, the incumbent's ability as a publicly ruled enterprise to significantly influence the Cypriot society in many areas. But Cyprus's government has to fulfill the agreed privatizations, otherwise EU and IMF could retain the following payment rate of 236 million euro.[10]

By having briefly introduced the example of Cyprus we see that an isolated electric power system implicates peculiarities and that these specific system characteristics might have negative consequences when changes are envisaged. In Malta the situation seems different, no mandatory privatization of state authorities is planned, however, the interconnection project can entail similar, more negative results than foreseen, since the link to Italy breaks up the Maltese market and might threaten the incumbent's privileges. This motivates further investigation of isolated electricity systems in the context of current politico-economic developments.

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[8] Cf. European Commission (2011a)

[9] Cf. more in detail Eurokrise and Eurozone crisis, Wikipedia (2014)

[10] Cf. more in detail Tagesschau (2014)

And lastly, a main driver to investigate this particular problem of linking two independent EPSs is to analyze the potential consequences for consumers. This thesis will deliver an objective view of the present situation (this might be of interest for different stakeholders) where both systems are separated while giving insights on future scenarios by analyzing for example expected price changes for Maltese electricity customers when the interconnector will be in place.

Fig. 3. summarizes the initial situation of the Malta-Sicily interconnection project. It systematically displays the elements of major interest to be analyzed in both electric power systems and emphasizes Malta‘s peculiarities. One principal reason among others to commission a submarine cable between Malta and Italy addressed by the Maltese state owned authority Enemalta is that the interconnector would support in developing an internal European energy market.[11] One might easily accept this argument and others, but this thesis seeks to adopt a critical perspective, mainly to assess uncertainties in the possible outcomes for Malta‘s citizens as shown in the following scheme.

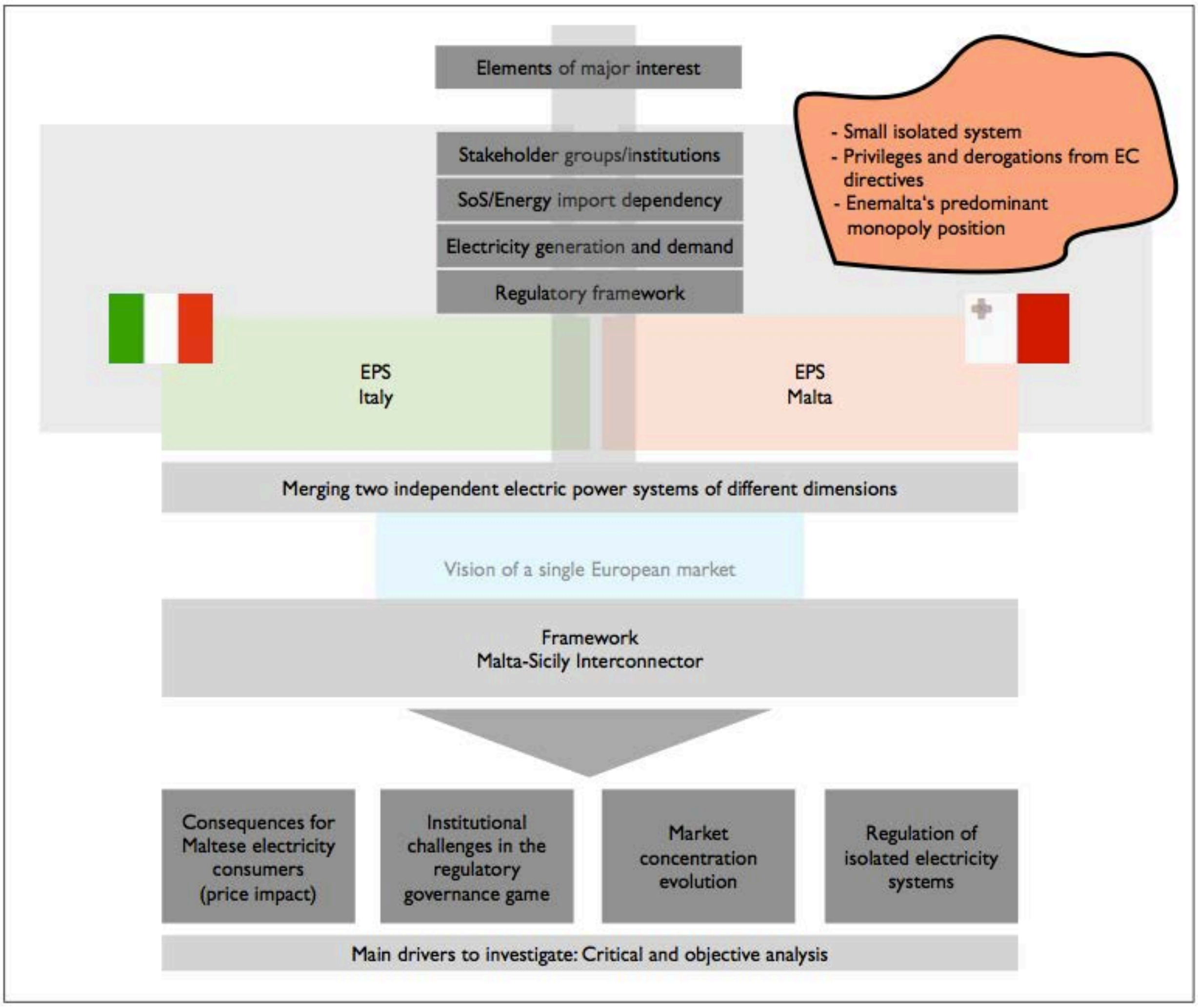

Fig. 3. Elements and drivers of the Malta-Sicily interconnector

[11] Cf. Darmanin (2007), p. 2

1.3 MASTER‘S THESIS OBJECTIVES

1.3.1 Break down of the research question

After having introduced the context of connecting the Maltese with the Italian EPS and having identified some major drivers that justify to investigate this particular research question, the following section discusses more specifically the master‘s thesis objectives. Fig. 4. gives an overview of the defined objectives this paper is expected to provide an answer for.

OBJECTIVE CATEGORY	OBJECTIVE SUB-CATEGORY	PROPERTY	PRIORITY
European electricity market liberalization	European policy framework	Highlighting characteristics especially for interconnections and isolated systems like Malta	MUST
	Regulatory framework	Deriving/Discussing potential consequences from the particular case of Malta for regulation (of isolated systems) in Europe	Desired/Option
Malta-Sicily interconnector	Fundamentals	Establishing an objective point of view for the interconnection's project framework	MUST
	Institutional challenges	Identifying qualitative challenges of the EPS interconnection by analyzing systematically key drivers in both independent systems	MUST
	Electricity consumer impact in Malta	Quantitative impact simulation for Maltese electricity consumers focussing on price as a textbook example indicator	MUST

Fig. 4. Master‘s thesis objectives

These objectives are structured around two main categories and follow a top-down approach in a way that firstly, from a more general perspective, the European electricity market liberalization is presented, and secondly, the peculiarities of the Malta-Sicily interconnection project will be analyzed. To allow an easier classification of the goals this paper aims for, objectives are divided into five sub-categories. For each sub-category an exact objective property is assigned (followed by a prioritization).

It is clear that to start with and before entering the specific interconnection context between Malta and Italy, the characteristics of the European policy framework with special attention to legislation on interconnection and the situation of isolated systems must be presented. In a second step, the paper should establish an objective viewpoint of the interconnection‘s project framework, since presently existing literature is strongly influenced by the interests of involved stakeholders and lacks to provide a more neutral representation.

The core of this thesis is built around the objective sub-categories *Institutional challenges* and *Electricity consumer impact in Malta*. A systematic analysis of the chief elements in both to date independent electric systems should be developed to derive first qualitative implications, i.e. to discuss especially institutional challenges which may arise due to the coexistence of Maltese and Italian authorities and their potential conflicting interests.

Finally, the master‘s thesis has to quantitatively assess the future consequences the subsea link can entail for Maltese electricity consumers. By the time this introduction is written we could think of different options of how to simulate the interconnector‘s impact. Undoubtedly this part seeks to provide a regulatory outlook of the Malta-Sicily submarine cable by looking at concrete indicators.

To get a clear vision of how the end consumer in Malta (both domestic and industrial) is affected, it seems appropriate to concentrate on simulating electricity prices while comparing the scenarios with and without interconnection cable. To complete this thesis, the obtained results for the specific case of Malta enable to redirect the discussion towards a broader European perspective in which regulatory implications for isolated electricity systems might be identified.

Substance for this master paper comes from the aimed Malta-Sicily submarine interconnection. As stated the core of the thesis is structured around two distinctive parts. That is 1.) to qualitatively derive implications of the Malta-Sicily interconnection project by particularly highlighting institutional challenges that are likely to arise because of the multiplicity of involved actors and 2.) to quantitatively determine potential consequences for Maltese electricity consumers the interconnector might entail.

1.3.2 Methodology

- System Analysis

To derive qualitative implications of the interconnector this paper should follow a holistic analysis of the key elements in both independent electricity systems. Here we could think of a systems engineering approach (e.g. Daenzer, 1982) for which it is necessary to examine Malta‘s and Italy‘s EPS evenhandedly. Systems engineering methodology requires a detailed investigation of each system‘s main ingredients to identify substantial drivers and risk factors for the scenario of one single interconnected power system.

And finally, this analysis should lead from the qualitative evaluation of possible outcomes for Maltese consumers, for instance performing a semi-quantitative analysis by looking at quality of supply indicators such as SAIDI/SAIFI,[12] to the more in depth quantitative impact simulation. The applied top-down logic sets up a systematic structure to break down the Malta-Sicily interconnection case into its single elements to give the reader a critical but objective reflection of the project's difficulties.

- Simultaneous Hourly Price Simulation in Malta and Italy

The quantitative impact simulation for Malta's electricity consumers aims to numerically demonstrate the possible outcomes the interconnector might implicate. First, this part reviews literature on existing approaches to assess impacts on electricity consumers (with particular interest in interconnection schemes). From a preliminary literature study it seems that authors do focus on the interconnection problem, e.g. Cartea and González-Pedraz (2011) „How much should we pay for interconnecting electricity markets?", but the crucial factor that differentiates this thesis from other papers is Malta's peculiarity of a small isolated electricity generation system. Other authors emphasize the latter, e.g. Perez and Ramos Real (2008) „How to make a European integrated market in small and isolated electricity systems?", but remain silent about the interconnection issue.

The second section deals with data representation. Since the electricity price is a sound indicator to assess the interconnection cable's impacts on Maltese consumers we should identify this data first. Moreover, additional data (demand, efficiency, assumptions on fuel prices, etc.) are needed in order to simulate/compare hourly prices in Malta and Italy. Once the historical data is in place, we can build the hourly marginal cost curves for both systems. That is the base case from which we can derive historical mutual price differentials. With this simultaneous hourly price simulation in Malta and Italy we can conduct a sensitivity analysis which takes into consideration the interconnection case. From these price scenarios for the Malta-Sicily interconnector major consequences for Maltese consumers may be found (note that the key assumption here is that the interconnector can only influence Malta's electricity prices as due to the sufficient Italian market size the price would unlikely to be influenced by one additional competitor, i.e. Enemalta). The core is to analyze supply-demand-scenarios for which assumed parameters – since Malta's generation units are completely fossil fuel dependent and prices of natural resources may change – should be varied, and therefore the result interpretation for Malta's consumers depends on the particular considered case.

Remarkable price volatility through spikes/drops in Italy depending on the Maltese electricity price level might impact consumers significantly in the short term, i.e. possibly

[12] System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI)

make them pay more for electricity than without interconnection cable to cover both the investment of the submarine cable plus the fixed costs of installed capacity in Malta, and additionally to reduce state enterprise Enemalta‘s large level of debt. At present, electricity prices are tremendously state subsidized whereof consumers are not explicitly aware (lack of demand response), so that it seems they pay relatively little for their supply. Thus the interconnector‘s commissioning could appear as a price shock for Malta‘s citizens. However, in the long term Maltese population could benefit from the interconnection but it might not be obvious today and obliges for further investigation.

Another approach when assessing impacts for Malta‘s electricity consumers is to concentrate on analyzing market power, i.e. to discuss the degree of monopoly position Malta‘s single electricity service providing entity exercises. Our numerical cable simulation allows to comment on the prospective market evolution in both scenarios with and without interconnection to the Italian system. Within the European electricity market liberalization context it is crucial to evaluate to what extent the Malta-Sicily interconnector enables the Maltese market to take off. A final discussion should lead the focus from the specific Maltese Islands‘ case to the broader European perspective to comment on regulatory implications for isolated electricity systems.

1.4 STRUCTURE

The master‘s thesis consists of five chapters: 1.) *Introduction*, 2.) *European Electricity Market Liberalization*, 3.) *Institutional Challenges Of The Malta-Sicily Subsea Link*, 4.) *Impact Simulation For Malta‘s Electricity Consumers* and 5.) *Conclusions*. Fig. 5. shows the exact structure of this report. The first part of this paper is dedicated to introduce the main ideas related to the research question. General framework, initial situation and motivations have previously been presented. Within the section *Master‘s Thesis Objectives* five goals which this paper is expected to find results for have been defined. Moreover, it discusses potential approaches which might be useful in order to tackle the addressed problems. The second chapter details the European framework on electricity market liberalization. Since isolated electricity systems are at the core of this work, chapter two highlights not only specific policies on interconnection but also more specifically the peculiarities of these isolated systems by giving some example cases.

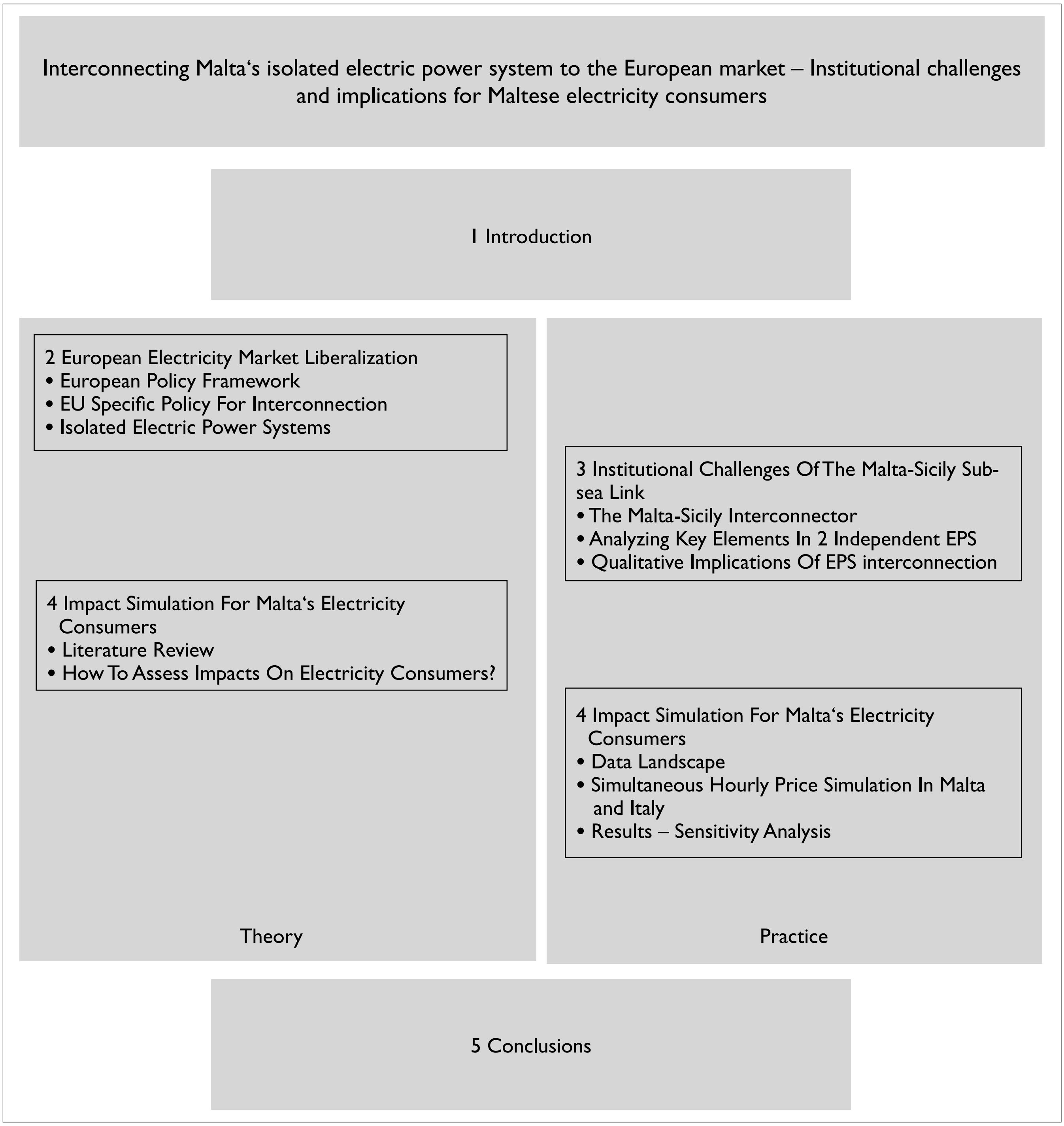

Fig. 5. Master‘s thesis structure

Chapter three first describes practically the problem setting of the Malta-Sicily interconnection project. By analyzing the key elements in both Malta‘s and Italy‘s electric power system this section identifies primarily qualitative implications of the interconnector, in particular it identifies institutional difficulties that may arise as a consequence of interconnecting the small EU island state Malta with Italy‘s electric system. Chapter four aims to simulate impacts for Maltese electricity consumers. First, this section reviews literature on existing approaches on how to assess impacts on electricity consumers. Then, it focuses on simulating hourly prices, i.e. marginal costs in Malta and Italy.

A sensitivity analysis takes into account the interconnection and details corresponding price scenarios as well as market concentration evolution. The last part of this chapter serves to comment on the regulation of isolated electricity systems from a broader perspective, i.e. this section adopts a European viewpoint and considers not solely the Malta-Sicily context. Finally, chapter five concludes this master‘s thesis and highlights the lessons learnt from the specific Malta-Sicily case study.

Abstract Chapter 2

Chapter two explicitly addresses developments within the European framework for electricity market liberalization. First, it details how the paradigm of vertically integrated state monopolies has changed in network industries since the late 1980s. Major (economical) reasons for the introduction of competition in network, and then more specifically for the electricity industry, are introduced. Moreover, the part on EU legislation deals with the main elements of the binding directives. The last part of this section highlights the status quo of the market opening process and its remaining obstacles. Second, the chapter discusses the EU‘s specific policy for interconnection. It illustrates the complexity of the European institutional design and summarizes the relevant legislative regulations on interconnection. Third, we analyzed specificities of small sized EU island power systems. In particular, we emphasized their challenges. Furthermore, we gave some examples of small isolated EU islands. And lastly, we concluded this chapter with a section on the necessity to interconnect isolated electricity systems.

2. EUROPEAN ELECTRICITY MARKET LIBERALIZATION

2.1 EUROPEAN POLICY FRAMEWORK

Electricity business belongs to one of the major network industries. Detailing the evolution towards market liberalization for all principal network industries, i.e. air, sea and rail transportation, postal services and telecommunications would be outside the scope of this thesis. However, before shedding light on the particular case of electricity, from a broader perspective main developments and drivers that motivated European policy makers in the past to set off initiatives to restructure network industries as a whole are presented.

According to specific literature on network industries[13] they importantly affect prevalent, mostly purely economical EU targets such as „economic growth" and „competitiveness".[14] That is why a turnaround in the fundamental economic principles of network industries – mainly the introduction of competition – has taken place since the 1980s, and consequently has put into question incumbent practices in operating them.

„*In The Wealth of Nations,* ***Adam Smith*** *(1776) contended that a free market economy is* ***more productive*** *and* ***more beneficial*** *to society. Smith noted that individuals, in the pursuit of their individual self-interests, interact on the market place guided by an „****invisible hand****" that inadvertently leads them to reach in the end* ***socially optimum results****. In a way, the* ***market price*** *acts as this "invisible hand" that drives the activity and ensures the* ***efficient allocation of resources****".*[15]

In summary, following the „father's of economics" reasoning who claims that competition in a free market environment is most beneficial to society and results in the maximum social welfare since the market forces participants to carry out transactions efficiently, technological progress linked together with rapid demand growth is one of the vehicles which enabled to shift from vertically integrated, usually state-owned, monopolies where one incumbent performs activities of the whole value chain to a significantly antithetic situation, namely network industries open to competition and thus allowing multiple entities to provide services. Nevertheless, these developments should not belie that at present both extremes exist in parallel, i.e. a predominant monopoly position as opposed to a well-developed competitive market environment.

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[13] Cf. in the following more in detail Bergman et al. (1999), p.1 ff.

[14] Hence, other motivations besides these pure economical intentions will be discussed in connection with the electricity market reform in different countries subsequently.

[15] Batlle (2013a), p. 1

We have to consider that, for network industries, European market liberalization is a gradual process. A vast time can elapse from EU policy propositions and their ratification until the final step of implementing them into national law of a member state. So, this market liberalization process must be seen as an evolution in which first monopoly solely, and then monopoly together with competition coexists (with the final aim to achieve entirely competitive industries).[16] Hegemony of incumbent enterprises often demonstrates a barrier for other, smaller players to access markets and prevents them to genuinely take off. It is therefore the EC‘s role to design adequate regulation in favor of a free and competitive market environment. In the following Tab. 1. introduces major obstacles to competition in network industries plus corresponding remedies. These obstacles also apply in electric power industries and build the framework for the course of this work.

Obstacles	Remedy
Legacy of monopoly	Sector specific regulation
Slow transposition of European legislation	Penalties, guidelines
Ineffective regulation, regulatory capture	Auditing, transparency
Unwieldy European procedures	EU reform
Public ownership	Privatization
Standards	Coordination through negotiation and standards bodies
Public service objectives	Transparency in accounting
Environmental concerns	Taxation, quotas, tradable permits
Interconnection and interoperability	Sector specific regulation, guidelines
Badly designed market institutions	Trials, experimentation

Tab. 1. Obstacles to competition in network industries and remedies[17]

2.1.1 Electricity sector evolution: key drivers to restructure the industry

This thesis agrees with Dr. Carlos Batlle‘s statement that „it is very possibly true ... that no two countries anywhere in the world have taken the same approach to the regulation of the power sector“.[18] Other standard literature on electric power sector regulation confirms that a diversity of practices in implementing the European legislation on market opening

[16] Cf. Bergman et al. (1999), p.3

[17] Cf. ibid.

[18] Batlle (2013a), p. 6

exists and highlights the discordance for a standard electricity market design (cf. for example Pérez-Arriaga (2013), Meeus et al. (2005) and Bergman et al. (1999)).

As stated earlier in this paper the power industry in the second half of the 20th century is characterized through heavy state intervention, in essence, the electricity service providing facilities being regulated as monopolies by their governments. Moreover, large public electricity utilities started to serve as political leverages for politicians, for instance, in order to prompt their electoral campaigns or to promote job opportunities. The 1973 oil crisis provoked strong financial difficulties for power industries, so that governments had to provide immense subsidies to avoid their breakdown and to ensure countries' security of supply. Political initiatives such as the Public Utilities Regulatory Policies Act (PURPA) in the United States were precipitated in response to reduce energy import dependency from foreign countries and opened the door to primarily small, alternative RES generation units.[19]

Towards the end of the 20th century a sectoral reform also in Europe seems ineluctable. Different motives in electric power systems all over the world favored the transition from state driven monopolies to liberalized market places. First, however, beyond the orthodox factors to liberalize electricity industries a fundamental prerequisite was the mitigation of scale economies. In general, the electricity industry had reached a sufficiently large size altogether in generation (new technologies), transmission (market expansion) and demand (fast volume increase) to allow private firms to challenge prevalent structures.

Following reasons count as universal key drivers to liberalize the industry:[20]

- Efficiency promotion in operation, planning and expansion
- Improved risk allocation (particularly for investment decisions; in a competitive market environment agents have to make investment decisions themselves as opposed to the traditional system in which they are monitored centrally, therefore the decisions of the agents are likely to be more accurate but tend also to be more risky since no investment recovery is guaranteed)
- Fast adaptation to technological developments/changes (more efficient technologies are rapidly adopted in a competitive market environment whereas in the traditional context firms have to take into consideration already made investments, i.e. „sunk“ costs)

In large parts the predominate paradigm of vertically integrated state monopolies has changed in many states worldwide today. It is well-known that Chile was first to reform its

[19] Cf. Batlle (2013a), p. 4

[20] Cf. Batlle (2012)

power sector in 1981. Some years later in the beginning of the 1990s the United Kingdom, Norway and Argentina among others followed the Chilean example.[21]

In addition to the aforementioned factors, also other, more country specific drivers characterize the reform process in establishing electricity markets, for instance, in the UK the renunciation from the coal industry (miner‘s strike 1984/85), abnormally high electricity prices in California caused particularly by environmental policies[22] and the Spanish case with a large state budget deficit are three striking examples that boosted electricity market liberalization efforts. However, this market reform in Europe is also a result of political enforcement since the prescribed EC directives (see in the following chapter 2.1.2 *EU energy packages*) have obliged member states to implement the features of market competition. Yet, political pressure does not necessarily mean that member countries show large interest in achieving committed targets being on the EC‘s agenda, therefore it does not surprise that the degree of market opening differs to some extent significantly among them (see chapter 2.1.4 on *Divergence in the market opening across* Europe).

2.1.2 EU energy packages

According to literature provided by the EC „to create a genuine internal market for energy is one of the European Union‘s priority objectives. The existence of a competitive internal energy market is a strategic instrument in terms both of giving European consumers a choice between different companies supplying gas and electricity at reasonable prices, and of making the market accessible for all suppliers, especially the smallest [...]“.[23]

The essential step in advancing the idea of an internal European market for energy has been to eliminate obstacles to competition, majorly to set off binding legislation for all member states concerning common rules for the internal market in electricity and gas in order to abrogate potential barriers as previously highlighted in Tab. 1. In total legislation comprises three so called European „energy packages“. In short, the basic elements are as follows:[24]

- Unbundling of activities to distinguish between competitive and non-competitive parts of the industry (generation and retailing are open to competition; transmission and distribution networks remain regulated natural monopolies; diverse models for system and market operation)

[21] Cf. Batlle et al. (2013d), p. 7

[22] Cf. amongst others Sweeney (2002) and Battle (2012)

[23] EU legislation (n.d.)

[24] Batlle (2012) and European Commission (2012a)

- Decentralization of operation and investment planning

- Establishment of independent regulatory bodies

- Establishment of electricity wholesale and retail markets enable end consumers to freely choose suppliers

- Obligation for operators of non-competitive parts of the industry to allow third parties to have access to the infrastructure (TPA)

Fig. 6. displays the three principal directives (96/92/EC, 2003/54/EC, 2009/72/EC) of the European Parliament and of the Council concerning common rules for the internal market in electricity. Binding legislation was primarily introduced by means of the first liberalization directive for electricity which entered into force in 1997 and had been transposed in member states‘ law by 1999.

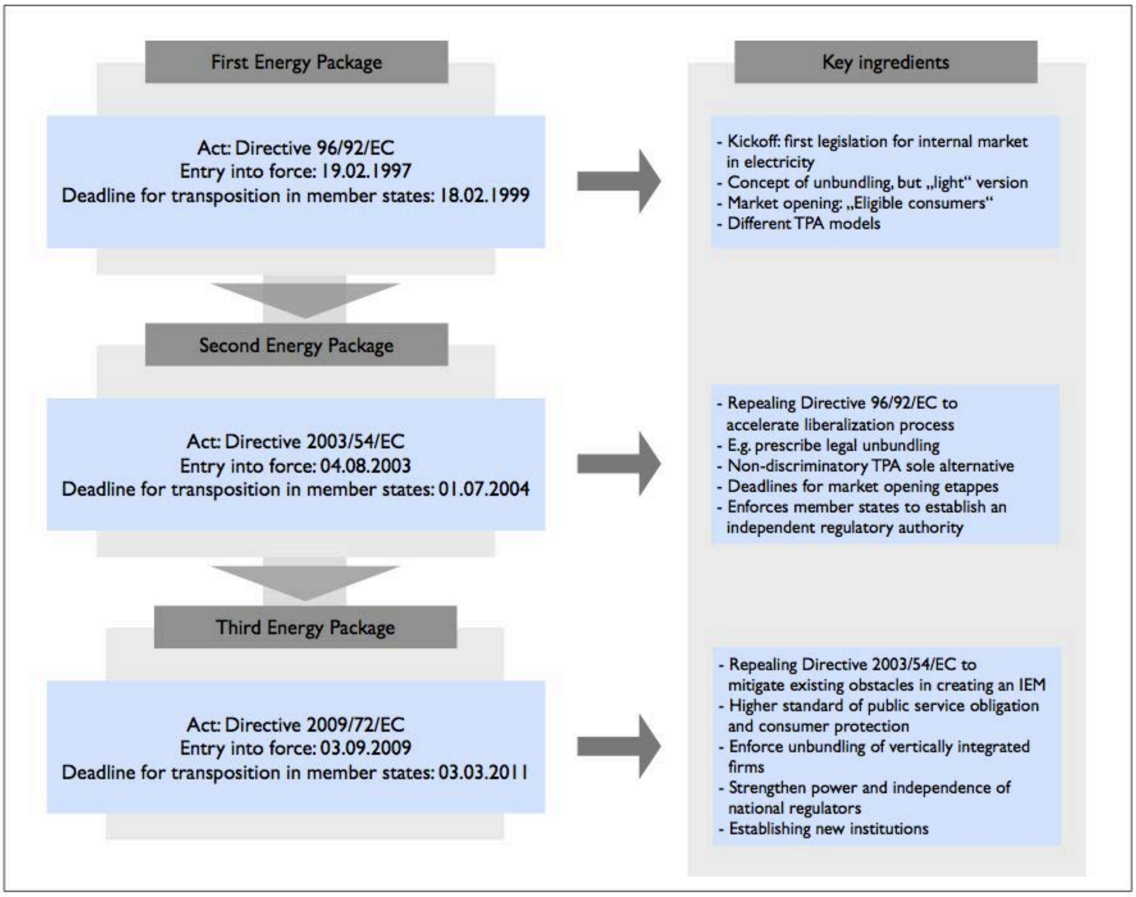

Fig. 6. EU energy packages and key ingredients[25]

Directive 96/92/EC was repealed by directive 2003/54/EC which came into effect in 2003. Member states had a time horizon of one year to transpose the directive into national law

[25] Illustration is based on Directorate – General for Energy EC (2011b), Domanico (2007), Durán (2010) and Meeus et al. (2005); Note that the EU energy packages not only concern electricity but also the gas market, for the scope of this work the illustration of the electricity directives is assumed as sufficient.

by 2004. The latest electricity liberalization directive 2009/72/EC from the third energy package reversing directive 2003/54/EC became legally valid in 2009 and its deadline for transposition in member states was in 2011.

It is not the aim of this thesis to present the in-depth details of each EU energy package, that is why it rather points out their key ingredients as shown in Fig. 6. For the purpose of this paper it is most important to underline the evolution of the market opening process since it is relevant in the discussion for interconnecting isolated power systems like Malta. The gradual process of successively updating the existent liberalization directives demonstrates that advances in opening the electricity market to competition had been achieved, though it shows concurrently that it has been a tedious endeavor which has not come to an end yet.

In essence, the directives all contain similar elements to satisfy the previously mentioned basic features to competition. While the first directive gave large discretion in the practice how member states could implement it into national law, the second and third directive aimed to accelerate the market opening. They were composed of elements that sought to better oblige member states, for instance, with shorter temporal deadlines for transposition and the establishment of an independent regulatory authority to progress in liberalizing their electricity markets as opposed to the „light" version from which followed that competition rather took off slowly. As a result to observed flaws in the implementation of the first and second liberalization directive – markets staying largely national, being highly concentrated and little cross border trade taking place – the EC initiated a sector inquiry in 2005 to designate the main drivers of the slow wholesale market development exhibiting high electricity prices and limitations in choosing suppliers for consumers.[26] To summarize, the third EU energy package from 2009 is the latest update for legislation on electricity market liberalization being launched in response to the Commission's sector inquiry with the goal to reinforce a common European standard that allows competition for those parts of the industry which are not regulated as natural monopolies.

2.1.3 Today's European electricity market architecture

The previous sub-chapter highlighted the European legislative framework on electricity market liberalization. Since the legislation does not stipulate exact means in order to implement the directives' single elements, member states have large freedom in designing the specifications for their national electricity markets. For this reason, today's electricity market architectures not only differ worldwide but also significantly between EU nations.

[26] Cf. European Commission (2012a)

Regardless the details in member states' market designs in the following we discuss how European electricity wholesale markets are generally organized as it is at the core of the market opening process. National electricity acts determine the functioning and regulation of electricity wholesale markets, i.e. in principal, laws and regulations define specific rules for the many dimensions wholesale markets incorporate (the most salient concern allowed transactions, system and market operation, functioning of the spot market, price mechanisms, allocation of operating reserves, network access and charges, RES, etc.).

Essentially, establishing a wholesale market stands for different ways of selling generated electricity quantities. We differentiate ways to sell electricity by dividing them into three temporal sequences:[27] long term markets, day ahead markets and intraday plus balancing markets. Fig. 7. evinces the basic European electricity wholesale market architecture.

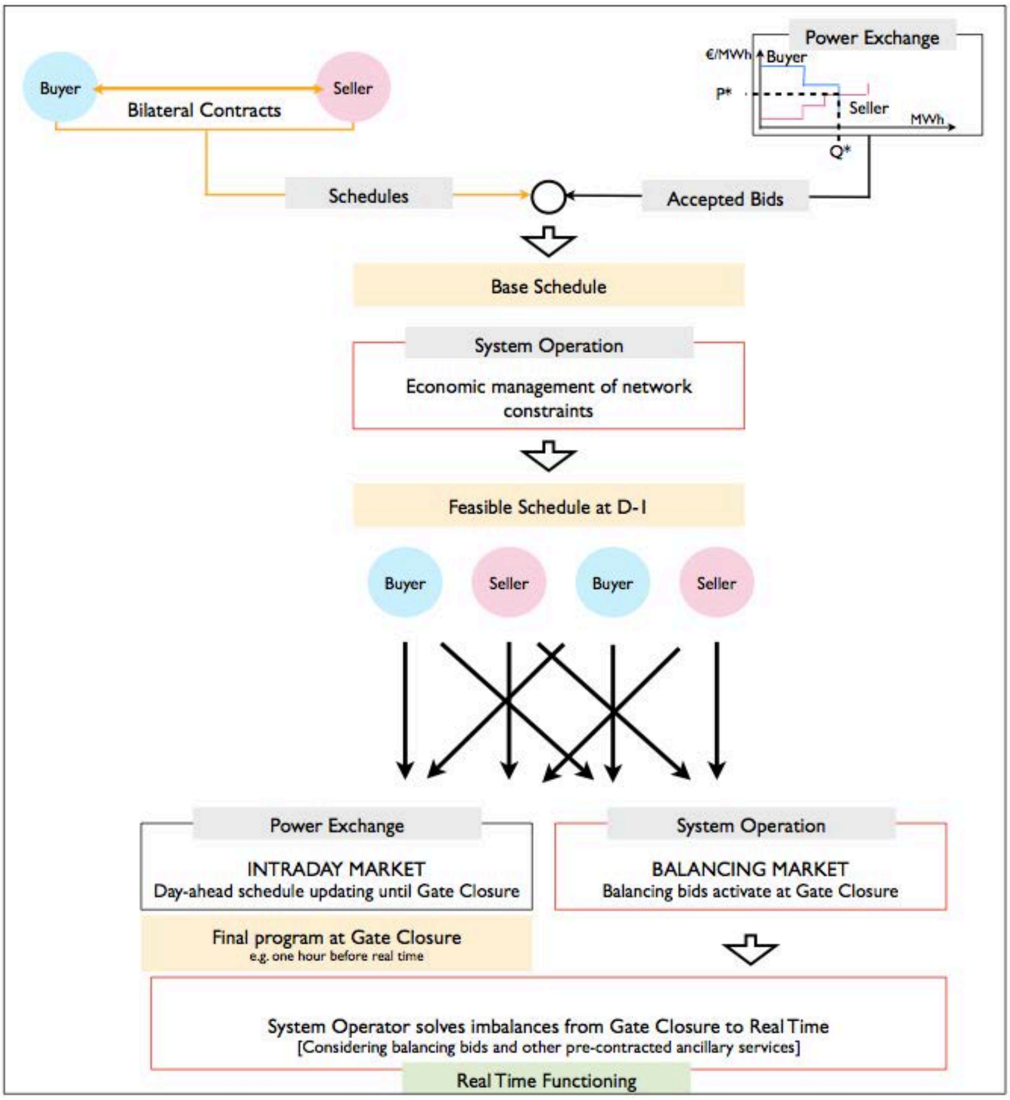

Fig. 7. European electricity wholesale market architecture[28]

[27] Cf. Batlle (2013a), p. 15

[28] Illustration modified from ibid., p. 17

To comment on Fig. 7., we can say that long term markets are characterized as over the counter (OTC) transactions, for instance, a bilateral physical or financial forward contract between a seller and a buyer with a fixed agreement about the desired quantity to trade and its corresponding price. OTC trading takes place outside the organized trading platforms. Brokers also coordinate buyers and sellers, but as opposed to the OTC alternative and power exchanges, they do not hedge risk in case any of the trading partners cannot meet its obligations (power exchanges require a collateral from both parties).

In addition to long term markets, a vital activity in electricity wholesaling is the day ahead market (DAM) place. In a DAM, trading occurs through the organized form of a power exchange where buyers and sellers submit their bids based on marginal cost pricing one day before the physical power delivery to the clearing house which determines the price by matching the tendered bids.[29] The detailed functioning of trading platforms, for example, the price computation for every hour of the following day and the bid formats can vary from one country to another.[30]

As Fig. 7. demonstrates, market operation is being performed by the power exchange, and together with bilateral contract agreements from these two resources the base schedule for next day‘s electricity supply is defined. The transmission system operator (TSO) manages in a second step possible network constraints and releases a feasible schedule one day in advance of the electricity delivery (Day – 1).

Once the feasible schedule is generated by the TSO, the day ahead schedule can be updated bilaterally through the market operator (power exchange) until a defined deadline before real time (called gate closure), that is what is called the intraday market. From gate closure to real time the system operator is responsible for solving potential imbalances. For this reason TSOs consider balancing bids and other pre-contracted ancillary services.

It is important to highlight that balancing and reserve capacities are not traded through the power exchange since it is the system operator‘s responsibility to procure these operating reserves. The procurement of the reserve capacities is often structured around an internet based competitive bidding procedure and requires the purchase of three different operating reserves, i.e. primary, secondary and tertiary control. Seperate markets with different auctioning mechanisms for each of the three mentioned reserves may exist.

[29] In Europe the submitted bids in simple auctions do not include unit constraints whereas in the U.S. complex auctions consider technical unit constraints within the bids.

[30] Unlike the majority of the European countries, the U.S. has a centralized electricity pool model; System and market operation is both performed by one system operator; An optimization algorithm, a so called security constraint economic dispatch, solves any infeasibility, i.e. no intraday market exists.

Since it is hardly possible for TSOs to determine in advance the necessary capacity of operating reserves, so called qualified balancing parties bid a certain amount of operating reserve being instantaneously capable to generate electricity. Balancing parties are remunerated according to their availability to deliver reserves and get an extra compensation when they actually produce.

In summary, reviewing the key elements in the European electricity wholesale market architecture serves to show exemplarily one possible approach of how selling electricity is organized. As stated, other practices like in the U.S. exist because, for instance, responsibilities in performing market respectively system operation and temporal sequences are arranged differently.

Finally, Meeus et al. (2005) point out that two market categories exist „[...] those being the entire market and its component submarkets".[31] This is what the EU strives for: establishing an entirely liberalized electricity market by interconnecting the national member states' submarkets. Yet, the sub wholesale market designs differ and that is why it must be taken into account when analyzing Malta and Italy, in particular the interconnection of two markets with significantly different architectures and dimensions.

2.1.4 Divergence in market opening across Europe

To finish the section on the European policy framework, this last subchapter surveys the divergence in the electricity market opening across Europe. In theory, as demonstrated by sub chapters 2.1.2 and 2.1.3, unbundling activities distinguishing competitive and non-competitive parts of the industry in order to establish electricity wholesale and retail markets to comply with European legislation seems evident, but reality reveals another picture. Differences in the member states' history, electricity sector evolution and the respective political will have been key drivers in enabling European governments to select distinct policy approaches regarding the market opening.

Both research literature, for instance, Newbery (2002) „Problems of liberalising the electricity industry"[32], and latest official working papers of the EC like the „2009-2010 Report on progress in creating the internal gas and electricity market" conclude that, in general, advances in opening national markets to competition could have been achieved, however, the ultimate goal of an entirely developed single European electricity market is far from being accomplished. In EU member states at present too many impediments which hamper truly competitive market designs exist.

[31] Meeus et al. (2005), p. 28

[32] See also Meeus et al. (2005) and Bergman et al. (1999)

According to the EC these major obstacles are as follows:[33]

- Insufficiently developed interconnection capacity between member states results in power system isolation for some regions/countries
- Bottlenecks in Central European electricity networks hinder steady transmission within and between countries
- Lack of harmonization of market rules in different member countries results in higher transaction costs
- Absence of regulatory power prevents from correctly enforcing/applying EU legislation
- Low switching rates in electricity retail
- In most member states national energy markets continue to be highly concentrated with little evidence of new entrants attempting to challenge incumbent suppliers

Tab. 2. reveals the degree of market concentration in some EU member states using the Herfindahl Hirschman Index (HHI). By definition the HHI is the sum of squares of market shares of each individual firm.[34] The HHI can adopt values between 0 and 10,000, i.e. low HHI values imply a well developed competitive market environment with many small firms, whereas the maximum HHI value indicates a monopoly position with one single supplier. The HHI is one possible indicator to measure divergence in the market opening process across Europe.

HHI	Member State
Very highly concentrated [HHI above 5000]	BE,FR,LU,LV,SK,GR
Highly concentrated [HHI 1800-5000]	ES,LT,PT,RO,SI
Moderately concentrated [HHI 750-1800]	DE,GB,HU,IT,NL,NO,PL

Tab. 2. Degree of market concentration in some EU member states[35]

[33] Cf. European Commission (2011d, 2011e and 2011f), p.1 ff.

[34] Cf. European Commission (2011d), p. 7

[35] European Commission (2011e), p. 12

As shown in Tab. 2. member states are ranked in three categories according to their HHI magnitude. It underlines the hypothesis that in the majority of member countries national energy markets remain very highly or highly concentrated, thus this situation inherently demonstrates divergence in how member states have yet succeeded in enabling not only incumbents but also newcomers to access markets.

Even though the third energy package has claimed full European market opening, the different pace in transposing mandatory EU legislation into national law has resulted to some extent in market fragmentation and partial liberalization. In many cases we observe few large suppliers, those often being the ancient vertically integrated monopolists who still rule the sector. Infringements against the legislative framework make true competition rare. So far, smaller players are often exposed to significant entry barriers. Enforced regulatory commitment is necessary to further enhance the restructuring process. We will further discuss the degree of market liberalization when simulating the interconnector's impacts for Malta's electricity consumers. In this chapter the HHI presentation serves as a first classification for electricity market opening. For a better understanding of the status quo also other indicators, for example, the electricity price convergence in wholesale and retail markets[36] should be considered.

2.2 EU SPECIFIC POLICY FOR INTERCONNECTION

2.2.1 Unsatisfactory institutional framework

Reviewed literature on institutional design and its corresponding regulation in EU network industries, for instance, Thatcher (2002) and Coen/Doyle (1999), along with papers that concentrate more specifically on the institutional framework in European energy markets, exemplarily, Hancher/De Hautecloque (2010) and Egenhofer/Gialoglou (2004), scrutinize the existent patchwork of authorities concerning the European electricity market liberalization process.

There exists consensus that since the late 1980s, when member states have started to gradually open their electricity markets to competition, „different regulatory philosophies and approaches have prevailed [...] and have in some cases led to asymmetric development of the framework as well as implementation“.[37] The too large number of actors participating in the regulatory governance game, namely regulatory bodies, competition authorities, judiciary, industrial players and both national governments and interfering EU level institutions, significantly hamper harmonization.

[36] Cf. Penados (2008), p. 11

[37] Egenhofer/Gialoglou (2004), p. 37

A weak institutional framework thus results from 27 individual and to some extent fundamentally distinct electricity market designs. Essentially, the basic prerequisite for enhancing the market opening is an institutional design without inconsistencies and flaws, else it might be difficult to achieve satisfactory outcomes particularly in interconnection projects.

In the following we will examine the proposed „*Patchwork of institutions in the implementation of the internal energy market*" by Egenhofer and Gialoglou closer (Fig. 8.).

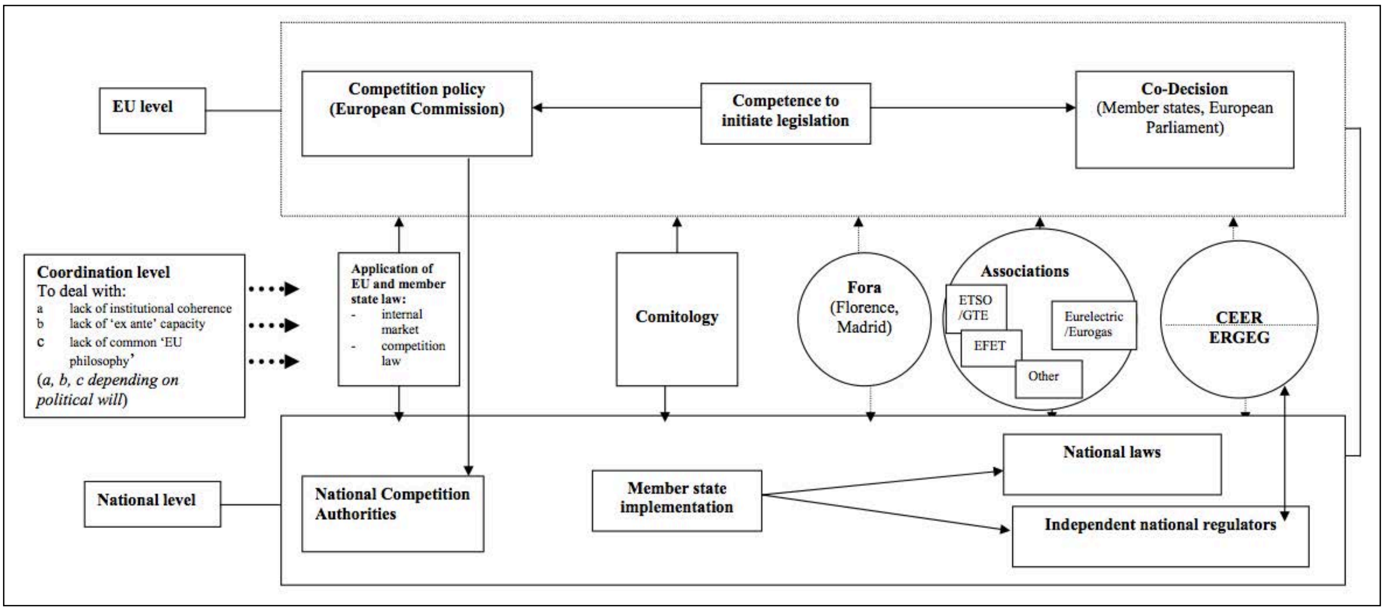

Fig. 8. Patchwork of institutions in the implementation of the internal energy market[38]

In principal, Fig. 8. displays institutions on two distinctive levels, European and national. Competence to initiate legislation stems from the EU level where the European Commission is responsible to design competition policy. Moreover, the European Council of Ministers and the European Parliament have the power to challenge the decisions of the EC (See in detail EC (2013d) „How the European Union works"). On national level the ECs counterpart is the respective national competition authority, and additionally, member states have been obliged to establish independent national regulators.

So far, the game remains simple, however, the design complicates when considering the coordination level. Since the first directives on market liberalization have entered into force, many different European entities have been set up. First, in 1996, the EC initiated the Florence and Madrid Fora for electricity and gas in which member country delegates of industry, national regulators and the European Parliament are represented to reflect on issues related to the creation of a single European electricity market.[39]

[38] Egenhofer/Gialoglou (2004), p. 39; Note that since 2004 new institutions have been set up which are not shown in the figure.

[39] Cf. Hancher/De Hautecloque (2010), p. 2

The establishment of the Council of European Energy Regulators (CEER) as a non-profit organization in 2000 served to further encourage cooperation between member states' regulators and between them and EC.[40] Then, in 2003, the EC officially instituted the European Regulators' Group for Electricity and Gas (ERGEG) to formally establish a regulatory body similar to CEER in the Florence and Madrid Fora whose competencies were to advise the EC, particularly in harmonizing the regulatory activities between member states.[41] ERGEGs successor is the Agency for Cooperation of Energy Regulators (ACER).

ACER has been created in response to the third EU energy package (cf. section 2.2.2 *EC regulation on interconnection* for additional information on ACER*).* Also other associations like the European Network of Transmission System Operators for Electricity (ENTSO-E, formerly ETSO) have been appointed to foster cross-border collaboration among TSOs.

In general, these institutions are key instruments to enhance the electricity market opening. This paper does not criticize their creation, but as they represent interfaces between European and national level and therefore adopt a fundamental role in cross-border projects, difficulties at the coordination level as listed in Fig. 8., such as missing institutional coherence among countries and lacking motivation to follow EU policy ideas, for example, due to national history and political regime, decelerate the liberalization process.

So, the success of the European institutional framework, i.e. the interaction of the different entities largely depends on the degree of consensus[42] between themselves and each member state's willingness to adapt to enacted legislation. Yet, past experiences have shown that the electricity market liberalization is a European controversy. This study agrees with Egenhofer and Gialoglou who identified shortcomings in the internal energy market as a result of the institutional context being insufficient rules, late implementation, inconsistencies and weak coordination between member states[43] and predicates that this unsatisfactory institutional patchwork framework especially impedes in interconnecting countries. In other words, the network of institutions and its functioning are critical factors of success in the development of cross-border electricity trading.

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[40] Cf. ibid.

[41] Cf. Hancher/De Hautecloque (2010), p. 3

[42] Cf. Egenhofer/Gialoglou (2004), p. 38

[43] Cf. ibid., p. 40

2.2.2 European Commission's regulation on interconnection

In the following we will shed light on EC specific regulations on interconnection laid out in the market liberalization policy.

Contrary to a **directive**,

„a law that binds the member states, or a group of member states, to achieve a particular objective. Usually, directives must be transposed into national law to become effective. Significantly, a directive specifies the result to be achieved: it is up to the member state individually to decide how this is done".[44]

a **regulation**

„is a law that is applicable and binding in all member states directly. It does not need to be passed into national law by the member states although national laws may need to be changed to avoid conflicting with the regulation".[45]

In chapter 2.1.2 this thesis addressed the directives on electricity market liberalization. Moreover, it highlighted that EU member states have large discretion in implementing them since the EC solely specifies little tools and measures. As shown, different market designs among member states are one major consequence.

Similarly, the directives remain silent about how to regulate cross-border electricity trade.[46] Therefore specific regulations – EC 1228/2003 repealed by EC 714/2009 – on conditions for access to the network for cross-border exchanges in electricity have been designed. The first regulation dealing specifically with interconnection (EC 1228/2003) entered into force in 2004. This is another proof of slow progress in opening the market to competition, only several years after the liberalization process had started the essential topic of cross-border exchange in creating an internal European electricity market was legally set up by regulation EC 1228/2003.

A key ingredient to enhance competition in a European electricity market is not only to foster competition within national power market places but also to promote cross-border trade. EC regulation 1228/2003 introduced necessary rules with the goals of i.) harmonizing national and cross-border transmission charges, i.e. to organize payment flows between TSOs for electricity transit, and ii.) allocating accessible interconnection volumes, i.e. to establish a coordination procedure in managing congestions to guarantee

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[44] European Commission (2013d), p. 5

[45] Ibid.

[46] Cf. Roggenkamp (2013), p. 13

network security.[47] EC regulation 1228/2003 on conditions for access to the network for cross-border exchanges in electricity was a result of the 1990s in which „[...] member states each had different export, import and transit electricity tariffs which led to so-called ‘pancaking‘, namely cross-border trade was subjected to as many tariffs as member states involved, and did not reflect the actual costs incurred.[48]

To summarize, article 1 of EC Regulation No 1228/2003 of the European Parliament and of the Council defines the legislative scope as following:

„This regulation aims at setting fair rules for cross-border exchanges in electricity, thus enhancing competition within the internal electricity market, taking into account the specificities of national and regional markets. This will involve the establishment of a compensation mechanism for cross-border flows of electricity and the setting of harmonized principles on cross-border transmission charges and the allocation of available capacities of interconnections between national transmission systems.“[49]

To further enhance the internal electricity market harmonization process additionally to the liberalization directives of the third energy package, the two main EC regulations on interconnection are EC 714/2009 repealing EC 1228/2003 on conditions for access to the network for cross-border exchanges in electricity and EC 713/2009 establishing an Agency for the Cooperation of Energy Regulators (ACER).

A major novelty in EC 713/2009 compared to EC 1228/2003 consisted of the creation of the European Network of Transmission System Operators for Electricity (ENTSO-E). ENTSO-Es primary responsibility is to biannually disclose a Ten-Year Network Development Plan (T-YNDP).[50]

European legislation on interconnection outlines that ACER‘s role is „to assist the regulatory authorities [...] in exercising, at Community level, the regulatory tasks performed in the member states and where necessary, to coordinate their action“.[51] However, ACERs power is limited. The agency has advisory responsibility and spans an intermediary between national regulators, TSOs and European bodies.

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[47] Cf. Roggenkamp (2013), p. 14

[48] Cf. Hancher/De Hautecloque (2010), p. 3

[49] Eur-Lex (2003)

[50] Cf. ENTSO-E (n.d.); The T-YNDP is designed to increase information and transparency regarding the investments in electricity transmission systems which are required on a pan-European basis and to support decision-making processes at regional and European level.

[51] Cf. Craig/Búrca (2011), p. 776

In summary, EC regulations on interconnection show the significance of institution building. Latest legislation demonstrates that initiating institutions like ENTSO-E and ACER can particularly help to improve cross-border electricity trade. Though, even if these organizations have already proved to be valuable in fostering the creation of an internal electricity market, their institutional power is weak. Hancher and De Hautecloque claim that institutional power in the third energy package is larger than compared to the second, but then they emphasize contrarily that institutions like ACER miss the ability to enforce legally binding decisions and lack enforcement power.[52] Therefore, member states still exhibit too many options to bypass/neglect binding legislations.

2.2.3 Background on EU interconnection activities

In the EC's report „Interconnecting Europe – New Perspectives for trans-European Energy Networks" from 2008, aspects relevant for this thesis are presented. In essence, it underlines the main EU energy policy targets and discusses how a harmonized European wide transmission network eases to achieve them. Furthermore, the authors reveal the priority interconnection plan (PIP) – EC act of 2007 establishing an overview of the interconnection projects of European interest – and highlight the necessary steps and challenges to move forward in the creation of an internal European electricity market.

EU energy policy targets

As briefly stated in the introduction of this paper, the EU's energy policy seeks to i.) enhance the EU's security of supply by decreasing energy import dependency, ii.) foster consumption and generation from RES reducing negative environmental influences and iii.) safeguard affordable electricity prices as a prerequisite for competition. The well-known 2020 targets[53] concretize the aforementioned policy directions. The EU member states' energy networks have a key role in achieving the defined goals which is to provide the infrastructure for domestic and industrial energy delivery. In the context of an internal European electricity market the functioning of the existing national network infrastructure and more importantly the establishment of new interconnection lines is essential.

The priority interconnection plan (PIP)

Both national and cross-border network interconnections between member states are crucial to the maturation of a truly competitive internal market design.

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[52] Cf. Hancher/De Hautecloque (2010), p. 3/5

[53] Cf. Directorate – General for Energy EC (2008), p. 4; The 2020 targets are as follows: 20 % reduction of greenhouse gas emissions by 2020 compared with 1990 levels; 20 % share of RES in overall energy consumption by 2020; 20 % increase in energy efficiency by 2020, i.e. saving 20 % of EU energy consumption.

Therefore, the EC established the PIP in 2007. Its five principal elements are as follows:[54]

- Identification of most significant parts of missing infrastructure
- Appointment of European coordinators to pursue the most important priority projects
- Agreeing a maximum of five years within which planning and approval procedures must be complemented for projects that are defined as being of European interest
- Examination of funding needs
- Establishment of ENTSOs

The trans-European energy network (TEN-E) guidelines build the legislative fundament (decision 1364/2006/EC) for the PIP. Over 40 projects of European interest, primarily those with large influence on trans-border transmission capacity bottlenecks, have been predicated on these guidelines. Interestingly, for the scope of this work referring to the additional criteria for identifying projects of common interest decision, 1364/2006/EC – developing electricity connections between the member states needed for the functioning of the internal market and in order to ensure the reliability and dependability of the operation of electricity networks[55] – addresses the submarine electricity connection to link Malta and Sicily.

Remaining difficulties

At present it is questionable whether existing EU energy transmission grids enable to adequately achieve the three main EU goals. According to the EC most critical are aging infrastructure, insufficient investments in new installations, the danger of temporary blackouts and missing transmission capacities. Another obstacle the majority of EU interconnection projects exhibits and which thus prevents from properly pursuing the defined targets is delay in commissioning. Planning complexity and authorization are frequent factors, however, also strong citizen opposition to project propositions and shortcomings in cooperation between different actors (regulatory authorities, TSOs, suppliers, etc.) can provoke delays in commissioning. [56]

Firstly chapter 2.2 on *EU specific policy for interconnection* introduced the peculiarities the institutional framework for European electricity market liberalization entails. Secondly it highlighted the relevant legislative regulations on interconnection. And lastly background information on EU interconnection activities was provided.

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[54] Cf. Directorate – General for Energy EC (2008), p. 9

[55] Eur-Lex (2006)

[56] Cf. Directorate – General for Energy EC (2008), p. 10

2.3 ISOLATED ELECTRIC POWER SYSTEMS

2.3.1 Isolated EPS peculiarities and key challenges

Compared to the total EU-28 population in 2014 (505,665,739),[57] the share of citizens living on EU islands is small. In sum, they account for only two percent of the displayed number, i.e. approximately ten million people reside as EU islanders.[58] Circumstances for Europeans on islands regarding energy provision are distinct from those living on the EU mainland. The singularities of small scale electricity supply, in particular EU islands which are isolated electric power systems without interconnection to remote networks, have thus increasingly aroused policy makers‘ interests.

Not surprisingly, small EU islands subject to confined EPS dimensions as opposed to electric systems on the mainland suffer from difficulties to satisfy their energy requirements according to the three main EU energy policy targets highlighted in the previous sub chapter. In the following the thesis will point out the mutual characteristics of these small sized island EPSs.

The electricity sector association Eurelectric states that 286 islands exist across the EU territory.[59] Many of them have in common the status of an isolated electricity system. Since interconnections with the mainland do rarely exist, EU islands have to establish alternative ways to ensure energy provision to island inhabitants. However, their options are limited, therefore energy supply typically is heavily – in many cases over 90 percent – fossil fuel based and hence interferes with chief EU energy policy aims. We do not speak about electricity markets when addressing small-sized EU island power systems as competition does inherently not take place, i.e. electricity services are usually provided by a vertically integrated monopolist. Due to the nature of these micro systems, electricity market places are insignificant, their physical size is a critical barrier and consequently do not boost to invest in other/new technologies.

Moreover, it is noteworthy that tourism plays a crucial role in many EU island economies, yet this dependency is two-fold: for many EU islands tourism represents a lion‘s share in economical activity, e.g. employment, but also tremendously impacts environment because large power needs are supplied by unsustainable energy sources.

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[57] Eurostat (2014b)

[58] Cf. Eurelectric (2012), p. 7

[59] Cf. ibid., p. 8/9; Additional information: „According to EUROSTAT, an island is defined as an area of at least 1km², located at a distance of at least one kilometer from the continent, that has a permanent resident population of at least 50 people, has no permanent link with the continent and does not host an EU capital. On the basis of this definition the European Commission‘s DG REGIO has identified 286 EU islands. [...] While islands within the the territory of EU member states are included in the definition, island member states such as Malta and Cyprus are not. Nevertheless, they are also very much affected by the challenges islands face in terms of power systems“.

Regulatory frameworks of EU islands differ. In EU island member states like Malta and Cyprus the situation may be different from those islands appertaining to other EU countries.[60] Often it is not only a question of the applied European legislative framework, rather the rigorousness and ability of the islands to enforce rules. Obviously, the European liberalization policy framework is in large parts inappropriate for small islands, though derogations from the market opening directives have been granted. So, EU island electricity market design depends first on how the mainland has implemented EU legislation and second on the degree of its transfer to appendant islands. This makes regulation distinct between EU islands belonging to a EU member country and from those being independent member states.

Although we have highlighted some attributes that many small isolated EU islands share, dissimilarities exist, for instance, in power demand. Generally, power needs mainly depend on island size, residential density, geographical area and economic activities. The economical crisis in the eurozone has led to a drop in electricity demand in EU member states including respective islands. Yet, according to an internal survey Eurelectric found that island power needs will rise by an average of 24 percent in the period from 2009 to 2020 (see Fig. 9.). Considering the discussed EU islands' specificities, this large demand increase may significantly challenge small islands' capabilities to meet energy needs.

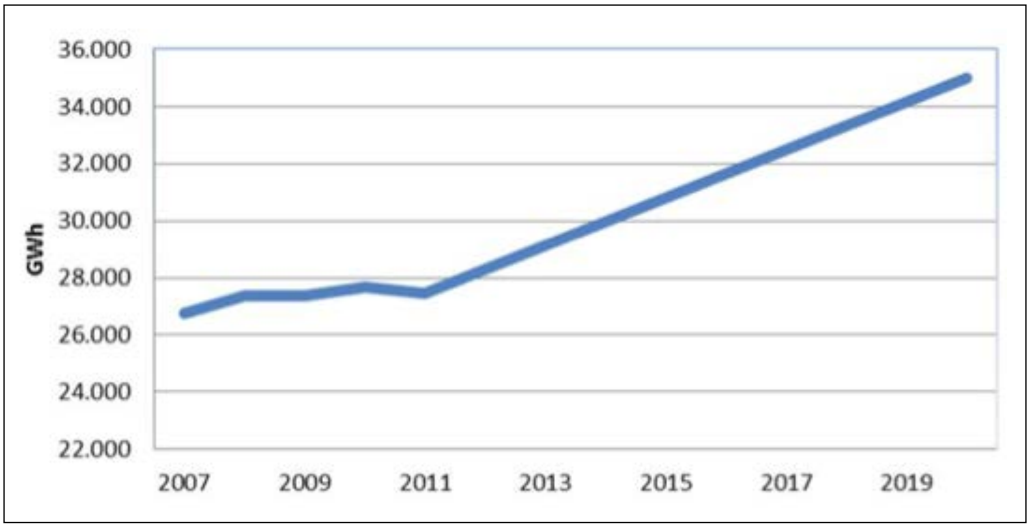

Fig. 9. Island power demand outlook 2020[61]

Often the principal resource for EU island electricity generation technologies is heavy fuel oil. So, EU islands' technology mix is dominantly based on fossil fuel driven power units. Two key drivers to use fuel oil as a primary energy source are the versatility of generation units with a typically relative high degree of reliability/efficiency to satisfy despite high

[60] Cf. Eurelectric (2012), p. 9; Note that „the 286 islands belong to eleven EU countries, with five member states accounting for over 75 % of the islands".

[61] Ibid., p. 13

demand volatility both peak and base loads as well as the simple procurement plus distribution procedure as opposed to other commodities like liquified natural gas (LNG). For SoS reasons EU islands bunker reserve capacities, i.e. their supply margins are significantly higher than on the mainland. To reduce vulnerability to unit failures in most cases the electricity mix is predicated on a number of small generators.

But flaws do exist. Next, we will survey more specifically the shortcomings isolated power systems on EU islands implicate. We refer to Eurelectric‘s report „EU islands: towards a sustainable energy future“ when pointing out the five economical and ecological key challenges that make policymakers overhaul the present situation on European islands.

5 key challenges for EU island electricity systems:[62]

Market failure

In contrast to large scale power systems in which big suppliers benefit from economies of scale, i.e. as they increase their electricity production level up to a certain point, their average cost per megawatt hour generated will decrease, small-sized isolated electricity systems do not render this effect. Energy needs are inherently too little. This also hinders them to establish distinct generation alternatives. Therefore, fuel driven power plants often represent the only viable solution.

Regulatory framework and market design

The divergence in the market opening process across Europe has led to different approaches how electricity regulation is implemented, likewise for EU islands the regulatory framework differs from one country to another. Regulatory models that are exercised in mature electricity markets might not be suitable for isolated small-sized power systems. Exemption rules from the third energy package mainly concerning the introduction of competition to the generation and retailing business, TPA and separation of system operation are necessary. The isolation of small islands innately provokes elevated costs, thus islands typically exhibit relatively high electricity prices.

SoS

The insularity of European islands challenges their system‘s security and stability of energy supply. For this reason supplementary actions in form of power generation reserves are needed. On the European mainland, where networks are usually heavily meshed and well interconnected, SoS represents a less significant challenge. For distant islands however, missing interconnection lines represent a risk.

[62] Cf. Eurelectric (2012)

To offset the danger of not being able to meet required energy needs, according to Eurelectric, EU islands have generation capacity reserves of 30 to 40 percent compared to significantly smaller margins of 15 to 20 percent on the mainland. SoS for European islands increasingly awakens interest on political agendas. Too little evidence is shown on how islands can shift from heavy fuel dependent power systems to significantly less impacting RES technologies.

Emissions

EU islands' reliance on fuel oil fired generation technologies substantially hampers them in pursuing a more sustainable energy production approach and disfavors EU regulation. Fossil fuel driven power plants strongly impact the environment by emitting, for example, sulphur dioxide, carbon dioxide and nitrogen oxide. These generation units are characterized by high pollution levels so that emission limits set by directives, e.g. the Industrial Emissions Directive (IED), often cannot or only with support of huge investments in abatement technologies be met. Today, derogations authorize small isolated island EPSs to generate with emission limitations of the former, less strict Large Combustion Plant Directive (LCPD) until the end of 2019.

Import dependency

Power production for isolated EU islands significantly relies on fossil fuel import. The main challenge is that power systems are overdependent on external fuel provision. Fig. 10. reveals the fuel price volatility between 2008 and 2012.

Fig. 10. Fuel price volatility 2008-2012[63]

[63] Eurelectric (2012), p. 23

The observed high fuel price volatility in the displayed period impacts isolated European islands more than countries on the mainland, because the latter can easier diversify their power generation portfolios. Accordingly, islands' small power systems – up to 100 percent fossil fuel reliant – represent a large handicap to such price developments. Despite this over-dependency on external resources, fuel driven generation technologies persist being dominant. Alternative primary energy sources and interconnection lines to reduce the dependence are yet more costly than the procurement of foreign raw materials.

Drivers for the fuel price volatility are manyfold: e.g. political instability in exporting nations, the shift away of the petroleum industry from strongly environmental unfriendly fuels resulting in reduced offers for pure heavy fuel oil products, and the simultaneously enhanced needs for low-sulphur products in the Japanese power sector consequently to the Fukushima nuclear catastrophe are some of the major causes exposing European islands to high fuel price scenarios consistently in recent years. Fuel price volatility is also fostered due to islands' physical sizes, since space limitations inherently imply little bunkering abilities.

In sum, both island specific characteristics such as insularity including its related difficulties, and additionally the shift towards more sustainable generation technologies make small isolated power systems particularly vulnerable to external resource price increases and raise many open questions regarding their current fuel dependent production.

2.3.2 Example cases of European islands and their isolated power systems

Tab. 3. summarizes general and power industry relevant key figures for some European islands with isolated EPS. This thesis solely considered power systems without interconnector to the mainland as it is more conform to this sub chapter dealing with the principal of insularity. In essence, Tab. 3. approves the findings of the previous section, for instance, we notice significant dominance of fossil fuel based generation technologies. Islands exhibiting a fuel generation indicator lower than 90 percent, have integrated small amounts of RES technologies in their systems.

	Azores	Canary Islands	Cyprus	Faroe Islands	Guadeloupe	Malta	Martinique	La Réunion
Population	246,000	2,127,000	804,435	48,372	404,000	417,000	403,000	824,000
GDP (€ bn)	3.7	40.34	17.8	1.7	7.75	4.7	7.9	14.7
Unemployment (%)	11.7	32.2	8.5	1.3	22.6	6.8	21.9	29.5

Demand (GWh)	772	8862	5305.8	273.8	1692	2046	1576	2750
Generation (% fuel)	69.9	93.3	97	60.7	87.9	99.8	96.6	69.7
Emissions (tons)	395,933	6,134,019	4,417,081	114,256	n.a.	1,943,212	n.a.	n.a.

Tab. 3. Some EU islands' isolated EPSs[64]

To sum up, the displayed indicators for European islands do not differ significantly. Indeed, dissimilarities exist because of distinct island dimensions, however, where islands dimensions coincide, exemplarily in Guadeloupe, Malta and Martinique, they render homogenous power necessities and thus prove that mutual singularities exist.

2.3.3 Conclusions and necessity to interconnect isolated electricity systems

To conclude, the part on isolated electric power systems raises the key question whether small European islands should switch from local entirely fossil fuel dependent electricity production to electric network interconnection. Today, the EC examines for many EU islands adjacent to the mainland the feasibility to link their power systems in order to mitigate precedent hurdles small isolated EPSs entail.

Isolated power generation systems' connection with electric grids on the mainland is usually realized by submarine cables. Whether to install alternating (AC) or direct current (DC) wire transmission is majorly determined by the interconnector's distance depending on the particular case. Installing connections between small sized EU islands and close mainland countries may add value for both systems, albeit effects for islands might be more significant.

Indeed, European islands will profit from enhanced security of energy supply combined with reduced dependency on external fossil fuel resources by repealing their insularity. Interconnection can also favor the EU energy policy goal to foster power consumption from RES. „Green" electricity may be then imported from neighboring systems to offset negative environmental impacts, a possible way to comply with EU regulations without large investments in RES technologies in the isolated island system itself. Moreover, the installation of interconnectors with the mainland reduces island needs to bunker large extra capacities of fossil fuel.

[64] Summary of tables from Eurelectric (2012), p. 50 - p.62; Data depending on availability of 08', 10', 11' and 2012.

Additionally, to interconnect two independent power systems also enables electricity trading. Competition for isolated EU islands can only arise when their EPSs are linked to the competitive power market places on the mainland. When integrating isolated small power systems into the European electricity market, the electricity spot price is the main indicator to which accordingly must be decided whether to import or export electricity, and should thus potentially reduce costs.

However, many interconnection undertakings have not exceeded the feasibility study phase because of the vast investment requirements. Cable interconnection costs can be severely high, for instance, „a 200 MW AC installation with a circuit length of some 100 km would be some 160 € million".[65] The analysis showed that fuel based generation technologies on islands heavily impact the environment, mainly through pollutant emission, but the construction of interconnection cables can likewise provoke environmental constraints. Interconnectors might impact submarine grounds, fish populations and other marine animals. For reasons of system security (e.g. n-1 criterion) back-up fuel driven generation reserves are needed. Economically, the commissioning of a second undersea cable is not viable.

To sum up, Fig. 11. shows main isolated island power system characteristics. The necessity to interconnect small European islands results from their EPS singularities. Their chief characteristics such as over-dependency on fossil fuel make EU islands vulnerable to external economical events. That is why many policy makers increasingly examine interconnection opportunities with countries on the mainland. In particular, connections with onshore countries shall enable small isolated EU islands to benefit from actively taking part in the European electricity market places. More specifically, the installation of interconnection cables is usually seen as a key to reduce electricity prices. So, interconnectors are expected to open the door for isolated systems to participate in competitive electricity markets which, according to economic theory, inherently should alleviate the revealed drawbacks of non-competitive market designs.

In summary, the striking benefits of interconnectors to isolated power systems can significantly improve their current situation. However, we do have to bear in mind that the establishment of subsea interconnection cables can also imply inconveniences. Following our top-down logic we will next shed light on the particular case of linking Malta and Sicily. The EC's priority interconnection plan lists the submarine electricity connection to link Malta and Sicily as a project of European interest (cf. sub chapter 2.2.3 *Background on EU interconnection activities*). Unlike this general discussion about isolated electric power systems, the analysis will focus exclusively on both the European island state Malta

[65] Eurelectric (2012), p. 33

including particularly its isolated power system singularities and the Italian power market. Our investigation will prove that besides well-known advantages of installing subsea interconnection cables, substantial challenges can arise.

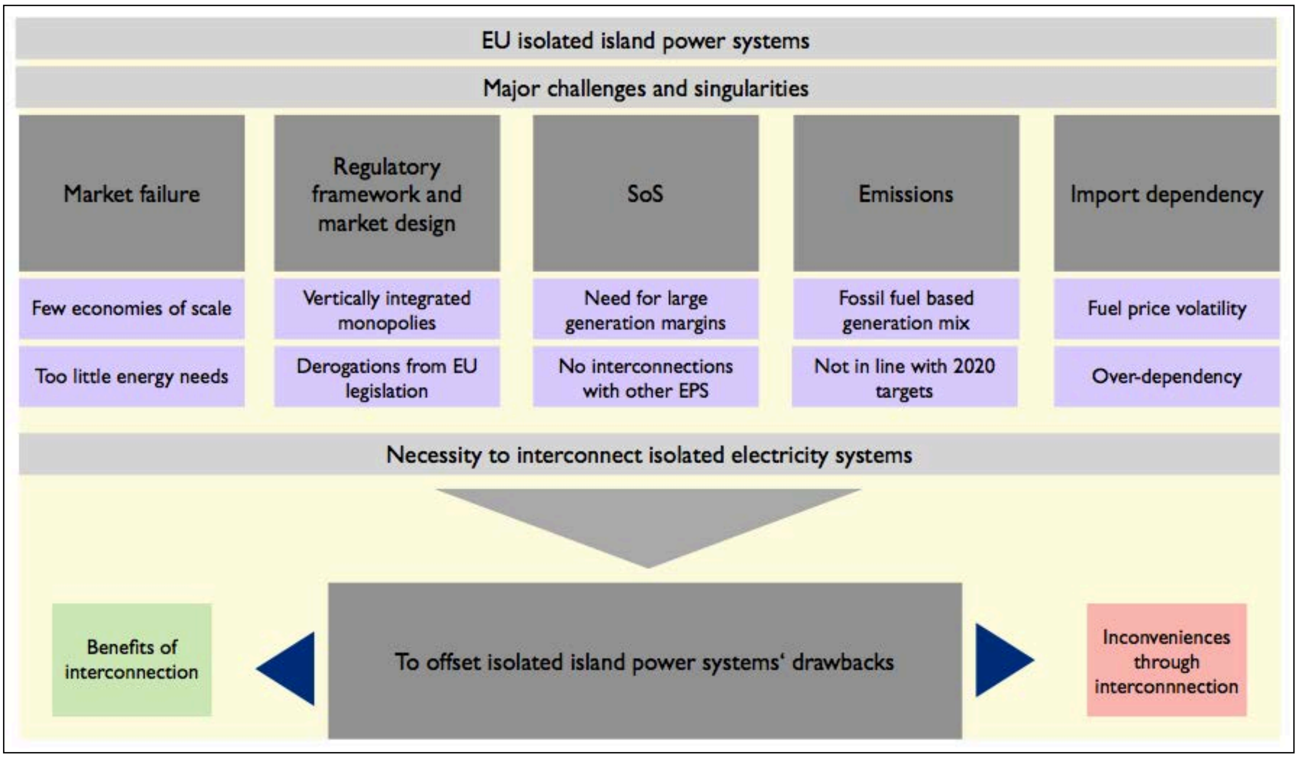

Fig. 11. Isolated island power system characteristics

Abstract Chapter 3

Chapter three is of more practical nature compared to the framework on European electricity market liberalization, it specifies first the most salient features of the Malta-Sicily submarine cable, in particular it discusses the main drivers that motivated for linking the Maltese archipelago to Italy. It also surveys the cable's technical characteristics and compares the project to other (undersea) interconnectors. Furthermore, an analysis about the possible interconnector's business model – merchant link, DSO implementation or special purpose vehicle – is carried out before detailing funding and the possible reasons for delay in commissioning, which was originally planned for 2012. The core of this chapter demonstrates the holistic review on both linked power systems in Malta and Italy with special attention to their stakeholders and institutions and market designs. Lastly, chapter three presents qualitative implications of the interconnector. It contrasts the key indicators found in the performed study on both EPSs and a systemic approach helps to develop a clear understanding of the cable's main benefits and drawbacks for Malta. One of the qualitative key findings – in case Malta has to entirely open its electricity market – is that the cable's utilization must be viewed in the light of both the shortfall of financial state aid for Enemalta and the cost of producing electricity with national resources compared to the power purchase price in Italy.

3. INSTITUTIONAL CHALLENGES OF THE MALTA-SICILY SUBSEA LINK

3.1 THE MALTA-SICILY INTERCONNECTOR

3.1.1 Interconnection project roots

Specific literature on electricity interconnection economics defines an interconnector as an asset in form of an underground, respectively subsea cable, or overhead transmission line whose purpose is to link and to enable electricity transfer between two individual electric power systems.[66]

EU regulations have forced the small European island state Malta to radically revise its hitherto energy policy. Previously, we highlighted the key challenges small isolated European islands often encounter. Thus, the initiated submarine interconnection between Malta and Sicily aims at offsetting these drawbacks.

The necessity to interconnect Malta's small sized grid with Sicily's network in Italy is precipitated due to political pressure from EU side. More specifically, the Maltese power infrastructure suffers from infirmity. Some power units require rapid mandatory shutdown as they approach technical lifetime limits and would not longer comply with EU directives (e.g. IED). The European „Energiewende" has obliged the Maltese government to set up measures against the island's unsustainable energy mix. Before European electricity market liberalization had started, incentives to invest in interconnection projects and other, more environmental friendly technologies for the indebted public electricity provider Enemalta did not exist. Consequently, a heavily fuel dependent electricity generation mix was the only alternative.

Malta's vertically integrated state-owned company Enemalta Corporation had launched a request for information regarding a submarine electrical interconnection between the Maltese and European grids in 2007 (cf. Darmanin 2007).

Enemalta lists the drivers to interconnect the Maltese and Sicily's grid as follows:[67]

- An interconnection with the European grid would help Malta **observe the target** stated in the Presidency Conclusions reached at the Barcelona European Council in March 2002, to **increase minimum electricity interconnection levels between member states to 10 % of their installed production capacities**.

[66] Cf. Turvey (n.d.), p. 1 and Cartea/González-Pedraz (2012), p. 14

[67] Darmanin (2012), p. 2 ff.

- Maltese consumers are currently served by **one vertically integrated** corporation for the **generation**, **distribution** and **supply** of electricity through a totally **isolated network**. An interconnection between Malta and the European mainland would help the **development** of an efficient **internal energy market**.
- Malta‘s efforts to **comply with EU directives** regarding emissions of pollutants [...] will be greatly aided by **purchasing electricity from the European grid**. Furthermore Malta would be able to **purchase electricity generated by renewable sources** [...].
- An interconnection to the European electrical network would be **instrumental** for the **integration of a large intermittent source of renewable energy** such as the proposed multi-megawatt offshore wind farms. With such wind farms in operation, any **excess power** generated can be **exported** as a renewable source.
- The new interconnection infrastructure will provide **shared spinning reserve** [...].
- The need to ensure that Malta‘s **supply of electricity is secure** requires a **change** in the current situation where the country‘s f**uel needs are provided solely through liquid fossil fuels imported from third countries rendering it particularly vulnerable to disruption** [...].
- The submarine interconnection introduces the possibility of additional optic-fibre telecommunication connections to mainland Europe.
- A Malta-European grid link could be the first phase of a project linking Europe with Libya as a part of a wider Euro-Mediterranean electricity ring.

This was to highlight Enemalta‘s motivations behind the project to connect Malta and Sicily with a submarine cable. Due to the historical evolution of the power sector in Malta, Enemalta Corporation represents as such the Maltese government and we know that the government had little options to ignore European orders. At first glance it seems that especially Malta‘s consumers may benefit from the subsea link. It agrees with the theory on isolated small sized power systems, namely that the interconnector might significantly more impact the Maltese rather than the Sicilian side. In fact, to identify added value for Italy‘s EPS is difficult, official documents address Malta‘s urgency for interconnection, but remain silent on Italy. Reports may detail future implications, but information on reasons for Italy to install an interconnector to Malta are hardly found. Enel, Italy‘s largest electricity supplier, states that current EU interconnection initiatives serve „to increase the international role of Italy in the electricity field“ providing more flexibility in importing and exporting electricity.[68]

[68] Enel (2014)

Enel‘s ambition is to create a „hub for renewable and nuclear energy to and from the Balkans, North Africa and Europe“.[69] For the objective reader the interconnector to link Malta with Italy hence appears as a prestige project for Italian electricity service providers. But we assume that the interconnector has importance that goes beyond pure prestige. It seems likely that large Italian electricity suppliers see the interconnector as a profit opportunity. Exact scenarios remain to be seen until the interconnector is commissioned.

Originally, the Maltese government wanted the interconnector to be commissioned by the end of 2012, an agreement on the submarine wire installation with the Norwegian based enterprise Nexans was signed in 2010. Maltese media reported the interconnector could foster to reduce electricity prices and would demonstrate a chance to purchase electricity from bigger European market places.[70] However, they also emphasized uncertainties and pointed out that future price scenarios „[...] depend on the contracts signed with electricity generation companies once the cable becomes operational“.[71]

In essence, the interconnector realization is indispensable to guarantee the island state a secure energy supply. Phase out of conventional fossil fuel driven power units (cf. more in detail chapter 3.2 when discussing Malta‘s EPS) necessitates replacement. Although the interconnector‘s project roots due to Malta‘s status as a small isolated power system seem obvious, the set up is somewhat questionable (cf. Lahmeyer‘s critical review on the feasibility study on electrical interconnection between transmission grids of Italy and Malta) and requires more investigation. We also raise the question if the interconnector is a result of political forces, and so potentially ill designed.

Commonly Maltese citizens belong to one of the two big national parties since Malta‘s independence from the UK in 1964, i.e. to either the conservative Partit Nazzjonalista (PN) or the Malta Labor Party (MLP). When the contract on the interconnector was signed the conservative PN was in power.[72] But parliamentary elections in 2013 stopped the 15 years‘ era of PN, since then the MLP has constituted the government. PN was accused by MLP to counterfeit national economic statistics. Malta‘s new prime minister Joseph Muscat has claimed to end corruption and to regulate lower electricity tariffs that were granted exclusively for large industrial consumers by the previous government.[73]

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[69] Enel (2014)

[70] Cf. Times of Malta (2010)

[71] Ibid.

[72] Cf. more in detail Malta, Wikipedia (2014); Result of parliamentary elections 2008: Partit Nazzjonalista (49.3 %), Malta Labor Party (48.8 %), Alternattiva Demokratika (1.3 %), Azzjoni Nazzjonali (0.5 %).

[73] Cf. EurActiv (2013)

Malta's hitherto energy policy shows that domestic electricity consumers have born the major burden of high electricity rates, government attached them little significance. In the same legislative period (2008-2013) the project to link Malta's and Sicily's power systems was fixed by the PN. We presume – following PNs former energy policy direction – the interconnector may not have a considerably positive effect for Malta's household electricity consumers. Our analysis in chapter four should give an answer to this question.

3.1.2 Technical features of the subsea cable and benchmark with similar undertakings

Although our analysis is not of technical nature, we will detail the most salient technical interconnector characteristics to provide the reader a holistic understanding. Fig. 12. reveals schematically the high voltage alternating current (HVAC) submarine cable installation between Malta (Pembroke) and Italy (Marina de Ragusa) in the Mediterranean Sea.

Fig. 12. Schematic illustration of the Malta-Sicily interconnector[74]

Technical specificities[75]

- Involved EU member countries: Malta and Italy

- Project promoter: Enemalta

- Total cable length: 120 km whereof 95 km are undersea

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[74] European Commission (2013b)

[75] Cf. ibid., European Commission (2013a), European Investment Bank (2010), Lahmeyer (2009) and Lauria/Palone (2012)

- Cable transmission technology: HVAC

- Rated cable capacity: 200 MW

- Rated voltage of interconnector: 220 kV

- Subsea cable terminals to be installed in Pembroke (MT) and Marina di Ragusa (IT); project requires to build a new substation in Malta to connect the Maltese electric distribution network operated at 132 kV to both the Italian grid and the local distribution center in Kappara; In Sicily 20 km underground cable are needed to connect to the main grid infrastructure in Ragusa (cf. Fig. 12.)

- Infrastructure appropriate to install a second subsea cable at a later stage

- Technical losses: 4 %

- Undersea cables have large reactive power requirements; Remedy: installation of reactors/inductances

At the moment the Malta-Sicily link becomes operational, it will be the world's longest subsea interconnection cable operated in HVAC technology.

Excursus – Characteristics of other, similar interconnection projects already in place

- Isle of Man-England Interconnector (HVAC)

Isle of Man has a submarine HVAC connection to the mainland in UK. Compared to the Malta-Sicily link the Isle of Man interconnector (rated capacity of 65 MW) is operated at a lower voltage level (90 kV) and its cable distance is shorter (104 km). It is noteworthy that Isle of man solely procures some 8 % of its energy needs from the interconnector, mainly to meet peak demand and emergency situations. Generally, the island's peak load of approximately 90 MW does not pose problems for national generation capabilities (179 MW). When we specify Malta's EPS characteristics (cf. chapter 3.2), we will observe a distinct scenario, i.e. the Maltese power system relies on larger generation margins and renders a significantly higher peak load.

- Estlink (HVDC)[76]

Estlink is the name for the two high voltage direct current subsea cables between Estonia and Finland (cf. Fig. 13.). While Estlink 1 became operational in 2007 (rated capacity of

[76] Cf. information on Estlink 2 (2014)

350 MW), Estlink 2 with a transmission capacity of 650 MW has been commissioned some months ago in 2014.

Fig. 13. Estlink interconnections between Estonia and Finland[77]

In total the Estlink 2 interconnection cable between Estonia and Finland measures 170 km whereof the submarine part represents the lion's share with 145 km. To complete the interconnection, 12 km underground cable on the Estonian and 14 km overhead transmission line on the Finnish side had to be installed. Estlink 2 is operated at a rated voltage of 450 kV. Converter stations are needed on both sides to transform AC to DC and vice versa. Both cables are owned equally by the Estonian and Finnish TSO. Main driver to commission a second connection cable was to raise the power transfer capacities within the Nordic-Baltic area.

- Murraylink (HVDC)[78]

Today's worldwide longest existing subterranean interconnection cable (180 km) is the high voltage direct current Murraylink connecting the electricity networks of two distinct states in Australia. The underground cable was commissioned in 2002 and exhibits a rated power transfer capacity of 220 MW at an operating voltage of 150 kV. Theoretically, the interconnector can assure the electricity demand of some 200,000 households and plays also an important role to control the system's voltage.

As demonstrated by the different interconnection projects, submarine electricity transmission is a question of two possible cable transmission technologies those being HVAC and HVDC. According to a research report by PikeResearch (2012) on submarine electricity transmission, the share of the two subsea cable technologies being presently operated is nearly equally distributed.

[77] Estlink, Wikipedia (2014)

[78] Cf. ABB (2014)

However, due to R&D progress in HVDC subsea cables, those increasingly become the prominent technology for large interconnection projects. Over very long distances HVDC affords electricity transfer with lower total costs compared to the HVAC alternative (cf. Fig. 14.).

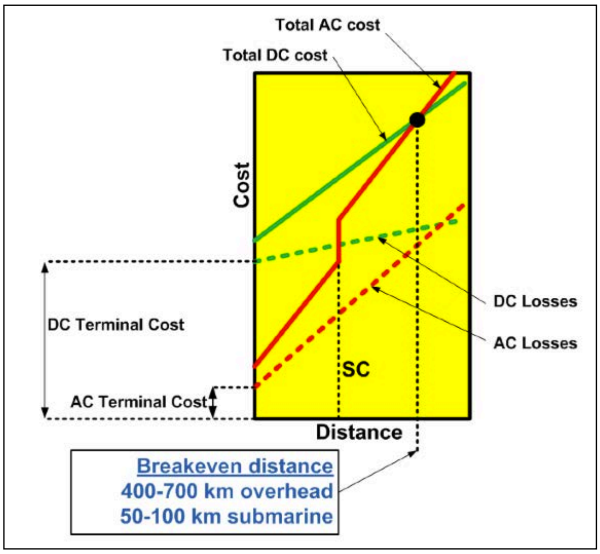

Fig. 14. HVAC vs. HVDC submarine cables[79]

Moreover, due to their nature HVDC cables do not exhibit reactive power losses, but necessitate more sophisticated thus costlier technologies to reconvert power back from DC to AC. In short, interconnectors like the Estlink reinforce the trend that subsea cables exceeding a distance of 100 km are commissioned in HVDC. As Lahmeyer (2009) pointed out the Malta-Sicily interconnector will be „an unprecedented scale of project“ launched in HVAC without having examined the DC alternative in detail.[80] The following Tab. 4. summarizes the main characteristics of the three discussed submarine interconnectors.

	Countries involved	Project promoted through	Transmission technology	Total cable length	Transmission capacity	Rated voltage
Malta-Sicily Interconnector	Malta and Sicily	Enemalta	HVAC	120 km	200 MW	220 kV
Isle of Man-England Interconnector	Isle of Man and England	Manx Electricity Authority	HVAC	104 km	65 MW	90 kV
Estlink 2	Estonia and Finland	Elering AS and Fingrid Oyj	HVDC	170 km	650 MW	450 kV

Tab. 4. Characteristics of selected interconnection projects

[79] Energy Development in Island Nations (2010), p. 4

[80] Cf. Lahmeyer (2009), p. 2-20

3.1.3 Analysis of possible implementation and operating mode scenarios[81]

So far, we stressed the key drivers which have triggered the construction of the Malta-Sicily submarine interconnection cable. Yet, we did not specify options that are likely to operate the interconnector nor did we discuss potential business models that endorse its implementation.

Although Enemalta had launched a request for information regarding a submarine electrical interconnection with a minimum transmission capacity of 200 MW between the Maltese and European grids in 2007 (cf. sub chapter 3.1.1), the explicit operational design of the link largely relies on its contribution to the Maltese energy supply. Accordingly, Lahmeyer (2009) found insufficient transparency in available official reports on whether the interconnector shall back up peak demand or rather secure the island's base load energy needs. Moreover, they add that in particular the feasibility study on the electrical interconnection between the transmission grids of Italy and Malta, for which Enemalta contracted the Italian TSO Terna together with the Centro Elettrotecnico Sperimentale Italiano (CESI) and the Roman university La Sapienza, undermines the interconnector's contribution/use to the island's electricity needs.

Within the European electricity market liberalization framework the connection cable between Malta and Sicily could implicate that the island state has henceforth to comply with binding market opening legislation presented in sub chapters 2.1.2 and 2.2.2. Undoubtedly, such an abrupt turnaround from being close to 100 percent dependent on external fuel provision to a complete market opening with third parties being authorized to enter the Maltese power sector can significantly challenge the small island. Malta's EPS has grown individually over many years, i.e. Enemalta, as such, has been inherently alone in charge of the Maltese power system development, maintenance and investment.

Enemalta thus has acquired a deep knowledge of the island's energy needs and power system characteristics. That is why the system largely depends on its expertise, but it also implicates that deviations, such as the entry of new players, from the „business as usual" – in the past those were unlikely – might jeopardize national SoS. If exemptions from electricity market opening directives are further granted for Malta will depend on how the interconnector is operated (cf. chapter 3.2 for details on Malta's derogations from EU electricity legislation).

At present, scenarios are many-fold since there prevails ambiguity on whether, given restricted TPA, the „national champion" Enemalta will continue to be the sole supplier, or in case the EC does not acknowledge derogations any longer, other players will participate in the Maltese market place.

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[81] Cf. more in detail Lahmeyer (2009) and Darmanin (2007)

Additionally, the fact that a large part to finance the interconnection project originates from EU funds may also end Malta's exclusive right to derogate from certain EU rules (cf. sub chapter 3.1.4 for project costs and financing).

As Michel Rivier pointed out in his lecture on regulation of electricity transmission (ICAI, 2013), there are distinct business models to prompt transmission investments. Accordingly, we survey the most probable alternatives of the Malta-Sicily subsea link realization.

Merchant link

A prominent implementation scheme for new transmission investments are so-called merchant lines. Essentially, this scheme implicates that a private merchant invests to install a new transmission line and subsequently owns it. Merchant line theory calls this an **unregulated** operating mode since the investment costs are not recovered by a fixed regulatory tariff, but through the congestion rent that results from the price differential between two interconnected markets. Merchant lines boost competition in transmission business which is inherently considered as a natural monopoly. However, implementing merchant lines bears risks. These risks are two-fold: firstly, merchants are exposed to uncertain revenues, and secondly, to counteract this risk exposure, they may be incentivized to abuse market power, i.e. in other words merchants could restrict electricity transfer to achieve greater price differences, and thus increase their potential remuneration.

Enemalta's request for information regarding a submarine electrical interconnection between Malta and Sicily (2007) indicates that „the preferred option [...] for the interconnector is to be operated as an unregulated merchant interconnector whereby Enemalta and other consumers may purchase or sell electricity using a power-purchase agreement (PPA) from the interconnector operator [...]".[82] In short, merchant lines demonstrate an opportunity for areas that suffer from systematic congestion. Reviewed literature scrutinize the merchant link implementation scheme as the latter is questionable, and additionally, one purpose of the link, to provide the island state electricity reserve margins in emergency situations, disagrees with the principle of maximum transmission capacity utilization the link operator strives for.

Interconnector implementation by distribution system operator (DSO)

In this scheme, for instance, Malta's DSO Enemalta is entirely responsible for the interconnector project implementation. As such, Enemalta would own the cable and hence be obliged to guarantee financial funding and its proper functioning.

[82] Darmanin (2007), p. 6

Contrary to the merchant link, this scheme represents a **regulated** operating mode scenario in which Enemalta's discretion is subject to regulatory approval. Consequently, the interconnector's investment costs are passed through to consumer electricity rates. For Malta's DSO it might be difficult to handle the entire project scope, so that it is likely to assign some activities such as construction by competitive bidding. This scheme often runs the risk of over-investment if regulators miss to cap investment expenditures (cf. Averch-Johnson effect).[83]

Special Purpose Vehicle

As opposed to both aforementioned implementation schemes, project financing in form of a special purpose vehicle (SPV) avoids to leave the interconnector realization to a single entity.

„Project finance involves the creation of a legally independent project company financed by non-recourse debt for the purpose of investing in a capital asset, usually with a single purpose and a limited life.“[84]

A SPV should include the most relevant stakeholders to the project. Compared to the two other alternatives, the goal of SPVs is to implement a major infrastructure project through a combination of public and private initiative. Primarily, these so-called public private partnerships (PPP) target to unbundle tasks and allocate risks usually under a long term contract.[85] Within SPVs distinct options of project finance exist. Two prominent schemes are i.) Build-Operate-Transfer (BOT) and ii.) Build-Own-Operate-Transfer (BOOT).[86]

For both schemes BOT and BOOT, public bodies transfer the task, e.g. construction and operation, to one or several private firms, which have thus the responsibility to fund the project and recover their costs through profits realized in response to the project commissioning within an agreed time framework. When the contract ends, the asset will be transmitted from private to public régime. Typically, BOT schemes are adopted in early project stages/first years, i.e. private entity's competencies are limited to construction and operation, they do not own the asset. Contrarily, BOOT schemes stronger foster investment recovery, in addition to construction and operation the private company owns on an interim basis the infrastructure asset.

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[83] Batlle/Ocaña (2013d), p. 134; „Lack of incentives for efficient management: keeping costs as low as possible calls for some effort from company managers. Under the traditional system of regulation, managers have no incentive to make this effort since, if costs grow, revenues are in principle automatically adjusted to absorb the difference".

[84] Esty (2004)

[85] Cf. Chong (2013)

[86] Cf. more in detail Prieto (2013) and Build-operate-transfer, Wikipedia (2014)

To set up a SPV for the subsea connection cable between Malta and Sicily appears to be a viable solution. It surely better evades potential flaws such as market power abuse that can arise when either of the grid operator has entire responsibility for the cable construction and functioning. A jointly owned SPV between the Italian TSO Terna and Maltese DSO Enemalta would bring together the principal actors to obviate potential conflicts of interest. Such a compulsory association between the two parties would significantly boost the commitment to the planned interconnection cable.

3.1.4 Interconnector's status quo in 2014

Recent literature states that the Malta-Sicily subsea interconnection cable requires an investment of some 180 € million by Enemalta.[87] As pointed out in the chapter *EU specific policy for interconnection* the TEN-E program serves to foster trans-border transmission grid development. Since the interconnector has been identified as a project of European interest to progress in creating a single European electricity market, in sum 200,000 € of the TEN-E budget were granted to finance the feasibility study on an electric subsea interconnection to link Malta and Sicily. [88] Detailed information on the actual interconnector funding are hardly found. According to the majority of authors the major financing instruments including their contributions are as follows:[89]

- Loans from the European Investment Bank (100 € million)

- European Energy Program for Recovery [90] (20 € million)

- Enemalta, respectively domestic banks (60 € million)

Lately, Enemalta announced on its homepage that the interconnector is supposed to reach completion in late 2014. This goes against to what the EC said, namely that the project will become operational by March 2014; other authors such as Weissenbacher claim that the interconnector will not be commissioned before the beginning of 2015. By now the cable has been fabricated and subsea construction works have started in December 2013. Our analysis shows how controversial the setup for such an ambitious, large scale project of high public interest between two European member states is.

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[87] Cf. Weissenbacher/Muenchrath (2014), p. 5

[88] Cf. European Commission (2008) for TEN-E financed projects 1995-2012

[89] Cf. Lahmeyer (2009), p. 3-9, European Commission (2013b) and Stagno-Navarra (2013)

[90] Cf. European Commission (2013c) „A €4bn program was set up in 2009 to co-finance projects (59 so far), designed to make energy supplies more reliable and help reduce greenhouse emissions, while simultaneously boosting Europe's economic recovery".

While originally the project should be completed in 2012, delays provoked through Italian authorities refusing to award construction permissions have also hampered the interconnector‘s commissioning on schedule.[91] Finally, as discussed in sub chapter 3.1.1, the change of political power within Malta‘s government demonstrates another factor that potentially has restrained the submarine connection.

3.2 ANALYZING KEY ELEMENTS IN 2 INDEPENDENT ELECTRIC POWER SYSTEMS

3.2.1 Salient country/region characteristics

MALTA

The Republic of Malta, as such a south EU island member state, is centered in the Mediterranean Sea close to 100 kilometers distant from Sicily. Malta‘s archipelago consists of seven small Mediterranean islands of which the three largest – Malta, Gozo and Comino (cf. Fig. 15.) – with a total area of approximately 316 square kilometers are inhabited. Topographically, Maltese land can be characterized as a flat and rocky area that is surrounded by cliffs at the coast line. Mediterranean climate dominates in Malta, i.e. in principle winters are mild and humid, whereas summers are hot and dry.

Fig. 15. Malta‘s main islands[92]

[91] Cf. Micallef (2011)

[92] Malta, Wikipedia (2014)

Today the island's population totals some 400,000 citizens. Due to its small size Malta exhibits one of the world's highest population densities. British colonial rule ended in 1964, since 2004 Malta has been EU member state. Malta's political landscape was revealed in sub chapter 3.1.1.

According to the Maltese government's National Strategic Reference Framework (2007-2013) „Malta's socio-economic development rests on three main pillars: sustaining **economic growth** and **competitiveness** through the generation of a **knowledge-based** and **service-based** competitive economy; the **safeguarding** of the **natural** and **urban environment**; and **ensuring** continuous **investment** in **human capital** and **education** [...]".[93] In general, Malta's economical structure comprises an open import and export dependent market economy. The German Federal Foreign Office states that Malta's GDP in 2012 equaled around 6.8 € billion, that corresponds to a GDP per capita of 16,300 €. As measured by July 2013 Malta renders an unemployment rate of 6 percent, which ranks the island state lower than EU average. Moreover, it is noteworthy that global economic trends because of Malta's small isolated island status significantly more impact its national economy than in other countries. Malta's economy is particularly service oriented, i.e. financial services, the establishment of online gambling services, the tourism sector and technical service provision such as aircraft maintenance gain increasingly in importance. As we demonstrated in the previous chapter, EU subsidies/funds play a crucial role to enhance the island's (power system) modernization process.

ITALY

Italy – a founder member of the EU in 1952 – spans an area of some 300,000 square kilometers from the Alps in the north of the country to the Mediterranean Sea with Sicily in the south. Italy's topography is characterized by a mountainous inland with exception of the country's flat north. Climate largely depends on the respective region, Sicily e.g. has similarly to Malta a Mediterranean climate. Italy's population with approximately 60 million inhabitants is the fourth biggest in the EU-28. Italy's political system is based on a parliamentary democracy, currently ruled by Matteo Renzi as head of state.[94] Moreover, Italy is politically composed of 20 regions with own governments (regions are further split in 109 provinces and 8,094 communities). According to the German Federal Foreign Office Italy's economy still suffers from recession as, for instance, seen in the state budget deficit evolution. Statista data reveals that GDP in 2013 equaled $1,953.82 billion ($ 33,909 per capita; i.e. about 24,542 € per capita).

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[93] MT Government (2006), p. 1

[94] Cf. Italy, Wikipedia (2014); Renzi is partisan of the democratic Partito Democratico (PD) and became Italy's Prime Minister in February 2014 after the incumbent Enrico Letta resigned from his function.

What is more, for 2013 the Italian mean unemployment rate, 12.9 percent, was higher than EU average.[95] Since more than a decade economic growth in Italy is also lower than the average value for EU countries. For trading goods Italy's most important partner is Germany. Italy's national economy is primarily based on mechanical machine manufacturing, chemicals, automobile and food industry and the tourism sector.

In short, we also want to shed light on Sicily as the Italian autonomous region has crucial significance for the subsea interconnection cable with Malta. Sicily is the largest Mediterreaen Sea island that has no direct connection with the Italian mainland, the Strait of Messina separates Sicily from the Italian peninsula. Its area is about 25,000 square kilometers and Sicilian population accounts for some 5 million. The autonomous region Sicily as such composed of nine provinces gained its special status by the 1948 constitution, it primarily gives the regional government discretion in legislation and financial affairs (e.g. 100 percent tax retention). Beyond that Sicily is a striking example for Italy's regional disparities, it exhibits a rather weak economical performance with increased unemployment rates and organized crime.

3.2.2 Electricity generation mix

MALTA

Due to Malta's present status of a small isolated power system, so far electricity demand had to be secured with domestic, fossil fuel based generation capacity. The Maltese EPS consists of two power stations, namely Marsa (MPS) and Delimara power station (DPS). In recent years EU requirements have consistently obliged Malta to overhaul its generation portfolio, therefore many modifications within the infirm Maltese EPS have been undertaken.

MPS is located southeasterly on Malta's main island and was commissioned in the mid 1950s. Increasing energy needs on the island state led to gradual extension of this power station. However, since power units will soon or already exceed economic lifetime and thus do not comply, for instance, with the IED, entirely shut down of MPS is envisaged in late 2015 (once the interconnector is commissioned). In 2012, nominal installed generation capacity of MPS equaled 167 MW. DPS is situated some 10 kilometers south of MPS and was first inaugurated in the 1990s. Its nominal installed capacity increased from 304 to 453 MW by the end of 2012 due to the installation of new combined cycle diesel engines with a nominal capacity of 149 MW. Note that total installed generation capacity can be

[95] Cf. Auswärtiges Amt (2014)

significantly lower in summer, i.e. up to 10 percent may be unavailable because of temperature restrictions.

Tab. 5. reveals the installed nominal fossil fuel generation capacity by the end of 2012.

Technology	Installed nominal capacity in MW	Share of installed nominal capacity between MPS and DPS in MW	Fossil fuel
Steam Turbine	250	MPS (130) DPS (120)	Heavy fuel oil
Open Cycle Gas Turbine	111	MPS (37) DPS (74)	Gas oil
Combined Cycle Gas Turbine	110	DPS (110)	Gas oil
Combined Cycle Diesel Engines	149	DPS (149)	Heavy fuel oil
TOTAL	**620**		

Tab. 5. Installed generation capacity Malta 2012[96]

Furthermore, our review on the Maltese EPS identified that currently little RES potential in form of solar photovoltaic, micro wind and biogas plant generation exists. RES generation is increasingly dominated by domestic solar photovoltaic installations as Malta's government launched distinct support schemes and market prices fall. However, the share of RES in the Maltese EPS remains for now insignificant (cf. in the following the actual electricity generation mix). Fig. 16. depicts Malta's annual electricity generation between 2001 and 2012.

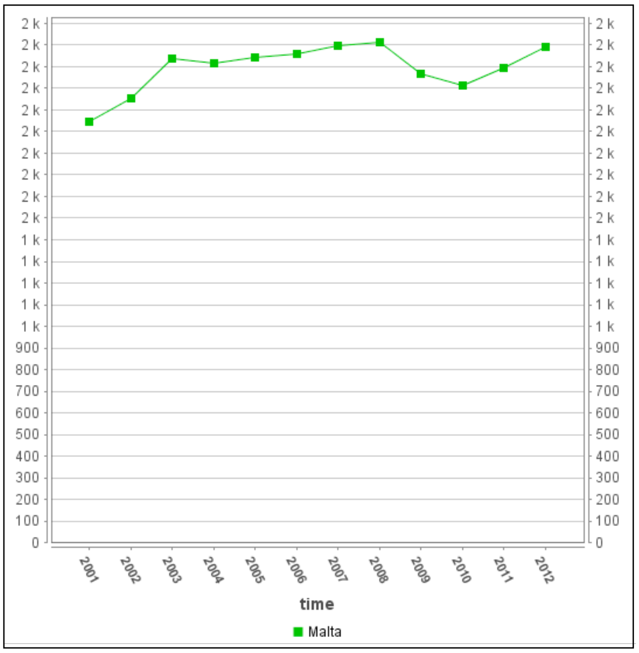

Fig. 16. Total annual production of electricity in Malta between 2001 and 2012 in GWh[97]

[96] Table modified from MRA (2013), p. 13

[97] Eurostat (2014c)

In 2012, total electricity supplied to the Maltese distribution network by both power stations MPS and DPS accounted for approximately 2.3 Terawatt hours (TWh). The actual generation mix in the year 2012 is illustrated in Fig. 17.

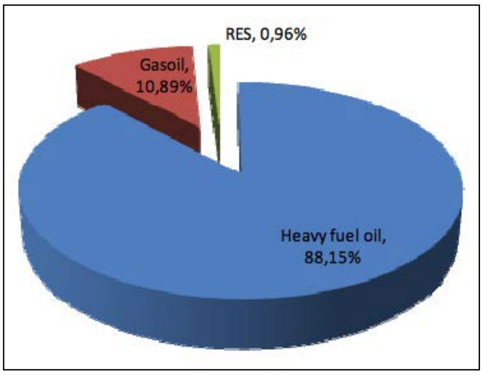

Fig. 17. Malta's electricity generation mix in 2012[98]

Moreover, our analysis confirms the main findings for isolated electric power systems of chapter 2.3., i.e. Malta's fossil fuel import dependency averages 100 percent, its CO2 emission per capita value (14,856 kg CO2/capita) nearly doubles EU average and for SoS reasons several new generation projects such as the mentioned Delimara extension aim to increase the island's supply margin (Malta's security margin in 2012 was 69.2 percent).[99]

ITALY

According to Monesi's chapter on Italy's energy regulation, Italian net power generation capacity in late 2010 was equal to some 107 GW knowing that 20 years ago in 1990 total net installed capacity of electricity generating power plants solely accounted for approximately 57 GW.[100] Italy's net installed generation capacity is particularly dominated by conventional thermal power plants, followed by RES technologies (headed by hydro power) and some geothermal.[101] Power generation plants are distributed all over Italy with a major share in the country's north (approximately 48 GW in 2008). Unlike other large EU economies such as Germany, France and the UK, Italy has no nuclear power plants. Fig. 18 depicts the evolution of Italy's annual electricity production between 2001 and 2012. Latest numbers of Italy's TSO Terna render a total generation of some 299 TWh in 2012. Natural gas is most important fossil fuel in the Italian generation portfolio, in 2010, for instance, it accounted for over 50 percent of electricity generated.[102]

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[98] MRA (2013), p. 14

[99] Cf. European Commission (2012c), p. 167; Figures provided for the year 2010.

[100] Cf. Eurostat (2007), p. 18

[101] Cf. Cariello (2008), p. 28; In 2007 installed generation capacity totaled about 94 GW whereof 74 % were thermal, 22 % hydro, 3 % other RES and 1 % geothermal capacity.

[102] Cf. European Commission (2011b); We calculated the security margin by dividing the annual peak demand by the installed generation capacity both in MW.

According to indicators of the EC (2009) Italy's fossil fuel import dependency totals 83.3 percent, in average 7,201 kg of CO2 per capita is produced and the country's security margin equals 52.3 percent (value from 2010).

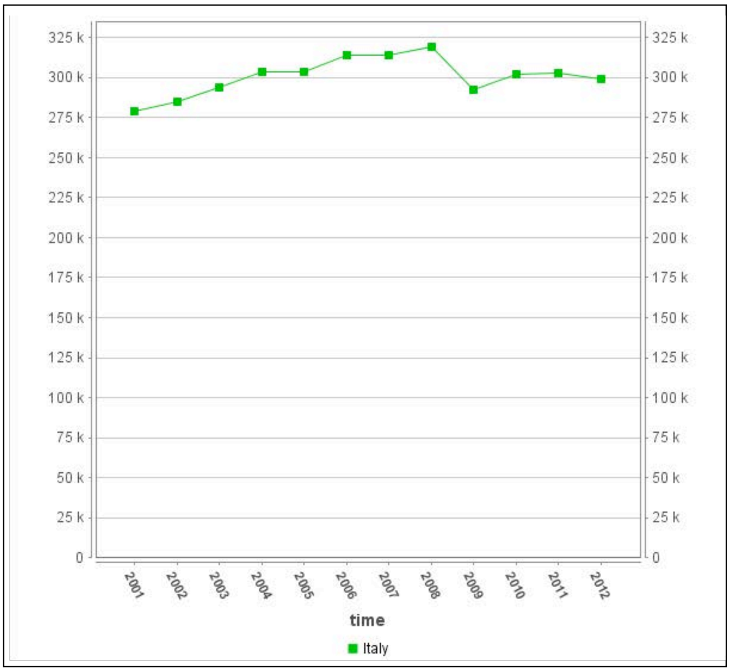

Fig. 18. Total annual production of electricity in Italy between 2001 and 2012 in GWh[103]

3.2.3 Electricity demand

MALTA

First, we classify the total Maltese electricity consumption into different sectors/user groups for the reviewed year 2010. In general, Malta's sectoral electricity demand is not strongly dominated by a certain sector. In Fig. 19. we observe that the commercial industry has largest electricity needs, followed in marginal distance by domestic and industrial consumers. „Lost and Unaccounted for" also achieves a notably high percentage.

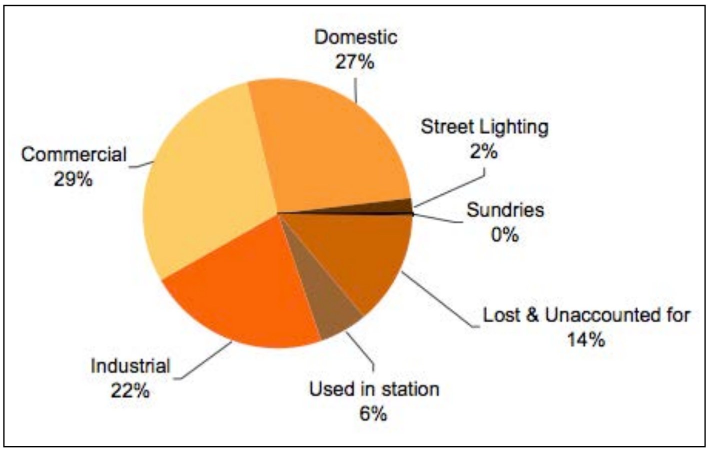

Fig. 19. Sectoral electricity consumption in Malta in 2010[104]

[103] Eurostat (2014c)

[104] NSO Malta (2012), p. 4

Malta renders a load profile that is representative for small isolated island power systems. Steam plants of MPS and DPS secure base load, whereas the more flexible gas turbines are connected to satisfy peak demand scenarios. Fig. 20. shows exemplarily Tuesday the 14th February 2012 as a typical dispatch for Malta‘s generation technologies.

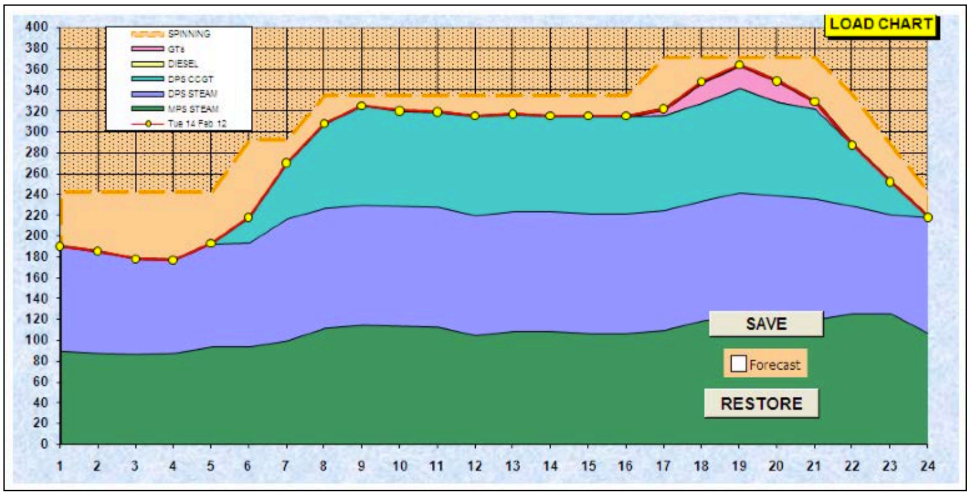

Fig. 20. Typical load shape in Malta[105]

As for many Mediterranean islands electricity demand in Malta is significantly characterized by seasonal variation. Typically, peak load appears to be different in summer (usually in the course of the afternoon) and winter (more likely in the evening hours) and is thus significantly influenced by the temperature fluctuation throughout the year. According to the MRA peak load in 2012 constituted 429 MW and is presumed to raise by 2 percent from 2012 forth.

ITALY

Among EU member states Italy exhibits the fourth highest electricity consumption. Classification by user group shows that the industrial sector has the highest electricity demand in Italy. Industrial consumers are followed by the commercial respectively residential sector, other industries such as transport and agriculture have significant lower consumption needs. Terna‘s figures on electricity demand in the period from 2002 to 2011 demonstrate little variation, i.e. demand ranged between 340 TWh in 2007 and 311 TWh in 2002. Italian electricity peak load is usually reached during the midday hours in the summer months, primarily in July, and equaled, e.g., in July 2011 56.5 GW (winter peaks tend to be lower). [106] Referring to the sub chapter on electricity generation, we find that Italy significantly relies on electricity imports to balance supply needs. The International Energy Agency (IEA) states that electricity imports from France and Switzerland secure the lion‘s share of the national generation shortage.

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[105] European Commission (2013e), p. 8

[106] Cf. Terna (2011) and IEA (2009), p. 75 ff.

3.2.4 Electricity network

MALTA

Most importantly, Malta's electricity network is a small isolated power system, i.e. at present the island's grid does not have a physical interconnection line with any other EPS. Malta therefore significantly relies on its own grid infrastructure. Technical failures represent a challenge in small grids and may jeopardize island inhabitants' electricity supply. Its physical size restricts Malta to a distribution network (circuit length about 1412 km) without high voltage transmission lines. As such, the distribution network is operated with 132 kV, 33kV and smaller power cables. Malta, Gozo and Comino are like the two principal power stations MPS and DPS interconnected. Although Malta has a micro grid, electric power losses as demonstrated in Fig. 19. are considerably high (in 2011 eleven percent according to the World Bank). In essence, system's security/reliability in Malta's distribution network is safeguarded due to the n-1 criterion. This standard would cover in an emergency situation the highest peak load which was ever registered in Malta.[107] To investigate the quality of supply of Malta's distribution network, we focus on two indicators – SAIDI and SAIFI – that relate to the continuity of electricity supply. The numbers were taken from the CEER benchmarking report on the continuity of electricity supply.

System Average Interruption Duration Index (SAIDI)

$$SAIDI = \frac{\Sigma U_i N_i}{\Sigma N_i} \quad U_i \text{ Annual interruption time} \quad N_i \text{ Number of consumers} \tag{1}$$

The SAIDI measures the overall minutes lost of electricity supply per customer per year.

2008	2009	2010	2011	2012
187	688	621	191	286

Tab. 6. Unplanned SAIDI in minutes per customer for Malta[108]

System Average Interruption Frequency Index (SAIFI)

$$SAIFI = \frac{\Sigma \lambda_i N_i}{\Sigma N_i} \quad \lambda_i \text{ Annual failure rate} \quad N_i \text{ Number of consumers} \tag{2}$$

The SAIFI measures the average number of interruptions that consumers experience per year.

2008	2009	2010	2011	2012
2.35	5.04	5.5	2.66	4.28

Tab. 7. Unplanned SAIFI in units of interruptions per customer for Malta[109]

[107] Cf. MRA (2013), p. 7; Malta's highest peak demand ever was recorded in the summer 2007 with 434 MW.

[108] CEER (2014), p. 17

[109] Ibid., p. 20

ITALY

For Italy's electricity network we differentiate between transmission and distribution system. Terna is the principal TSO which owns and operates Italy's high voltage transmission network (cf. more information on Terna in sub chapters 3.2.5 and 3.2.6). Italy's high voltage transmission grid is primarily composed of 380 kV and 220 kV lines. In principle, the northern part of Italy's transmission network is well meshed, the interconnections to the south are weaker (and often exhibit congestion). The country's large islands like Sicily and Sardinia are interconnected with the national transmission grid. According to the IEA Italy's transmission lines account for almost 40,000 km. Italy's transmission network is interconnected with Austria, France, Greece, Slovenia and Switzerland. World Bank data reveals that electric power transmission and distribution losses account for seven percent of the generation output. For electricity distribution we only highlight that there currently exist more than 100 DSOs. Distribution overall circuit length is more than one million km.

Continuity of electricity supply was like for Malta taken as a proxy for Italy's quality of supply. CEER's benchmarking report provides the SAIDI and SAIFI in the Italian grid as follows:

System Average Interruption Duration Index (SAIDI)

The SAIDI measures the overall minutes lost of electricity supply per customer per year.

2008	2009	2010	2011	2012
90	79	89	108	133

Tab. 8. Unplanned SAIDI in minutes per customer for Italy[110]

System Average Interruption Frequency Index (SAIFI)

The SAIFI measures the average number of interruptions that consumers experience per year.

2008	2009	2010	2011	2012
2.38	2.36	2.27	2.08	2.33

Tab. 9. Unplanned SAIFI in units of interruptions per customer for Italy[111]

[110] CEER (2014), p. 17

[111] Ibid., p. 20

3.2.5 Representing the landscape of domestic stakeholders and institutions

MALTA

European wide energy policies concerned the Maltese archipelago little before its official entry into the European Union in 2004. However, Malta‘s EU accession tremendously changed the game, from 2004 onwards the island state had to comply with EU imposed energy legislation. Although Malta is by far the smallest EU member country in terms of both area and population, it differs insignificantly in its state organization compared to other designs, i.e. the archipelago is ruled centrally and built up of 68 individually elected local councils.[112] Kotzbue entitles the Maltese network of players dealing within the energy business as a national multi actor governance structure, that „squeezes national, regional and local governance levels into one policy level“.[113] Due to its small size the Maltese micro state inherently has a governance structure affected by interpersonal relations between different domestic stakeholders and institutions that may hamper consistent decision making.

Traditionally, Malta‘s governance setup is organized top down whereby its national government has supreme authority to direct policy goals and implementation. Malta‘s Prime Minister represents the island member state and guides the principal ministries such as the Ministry of Finance and Ministry for Resources and Rural Affairs which are responsible to oversee the authorities in charge of energy. On state level in principle two key actors that significantly determine electricity regulation, policy making and implementation exist. That are first the Malta Resources Authority (MRA), the Maltese regulatory body, and second Enemalta Corporation, the national electricity provider (cf. in the following discussion). Malta‘s Environment and Planning Authority (MEPA) is not occupied with energy policy making, but represents the environmental supervisory body that intervenes e.g. in eco-political questions.

MRA is Malta‘s national regulator for energy (including electricity, petroleum and gas), water and mineral resources. Malta‘s public regulatory body was established by the MRA Act in 2000 and represents a small entity with eight officials, 46 employees and an about two million euro budget. In particular, MRA must monitor operations and activities in the addressed fields, guarantee fair competition, establish minimum quality standards and promote alternative energy sources.[114] In short, MRA holds a crucial role as overseer of Enemalta, the key actor in charge of the entire electricity business. Solely the enforcement

[112] Cf. Kotzbue (2012a), p. 5971

[113] Ibid., p. 5968

[114] Cf. Ghirlando (2013), p. 27

of a well designed regulatory framework by MRA can ensure secure electricity provision in Malta (see sub-chapter 3.2.6).

Energy service provision in Malta is dominated by a single utility. Enemalta Corporation is a vertically integrated 100 percent government owned enterprise that was instituted by parliamentary Act.[115] Its operation in the field of energy is three-fold, i.e. Enemalta has a division for electricity, petroleum and gas. With 1,700 employees Enemalta is one of Malta's biggest firms which achieved for the financial year 2011 – majorly provoked by high oil prices – an operating loss of 7,015,000 € for its electricity division.[116] Since the financial unbundling of the generation and distribution business units, Enemalta does no longer exhibit a legal monopoly position. However, the organization's strong interference with national government together with its role of being the single electricity supplier shift Enemalta far away from being acknowledged as a truly commercialized operator.

In particular, Malta's government grants the incumbent heavy financial support. Accordingly, the International Monetary Fund points out that „Enemalta's total debt in 2012 grew to 836 € million, 12.4 percent of Malta's GDP, of which 85 percent is guaranteed by the government" (cf. Fig. 21).[117] In summary, Enemalta's weak financial position results from the vulnerability to oil price increases, respectively its inability to counteract this exposure by putting them through to end consume rates, and additionally high inefficiency costs provoked e.g. by the country's aging distribution grid.

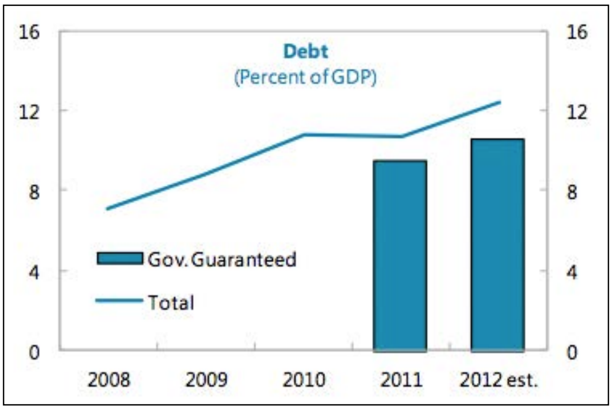

Fig. 21. Enemalta debt evolution in percent of GDP[118]

Beyond these presented key actors, also local councils, as such the link between government and citizens, partisans of the ruling MLP and the conservative opposition party PN, principal domestic industries like tourism, and potential external private investors co-determine electricity business in Malta.

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[115] Cf. Enemalta (2008), p. 1; Enemalta was established by „the Enemalta Act 1977 Chapter 272 of the Laws of Malta".

[116] Cf. Enemalta (2011), p. 1

[117] IMF (2013), p. 49

[118] Ibid.

Fig. 22. summarizes the Maltese regulatory governance framework and repeals the most relevant relationships between institutions that concern electricity business.

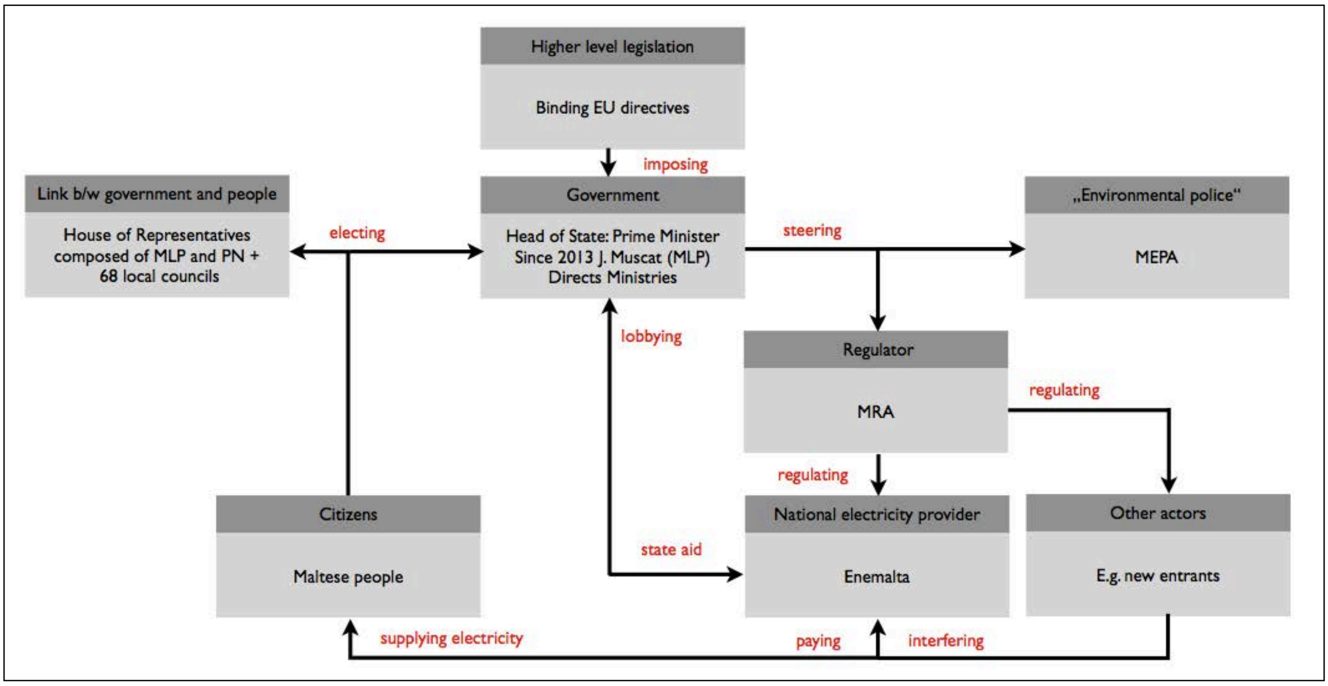

Fig. 22. Maltese regulatory governance framework

ITALY

Italy's landscape of institutions that determines the electricity industry is characterized by a patchwork composed of state authorities, private firms and hybrid companies owned by both public and private shareholders. On state level national energy policy is governed at the Ministry of Economic Development. It closely collaborates with other ministries such as the Ministry for Environment, Land and Sea concerning, for example, RES issues. As highlighted in the paragraph on Italy's country characteristics, Italy's regions – in particular autonomous ones like Sicily – benefit from large discretion in national state legislations. The IEA points out that regions „have now legislative powers for any matter not expressly reserved for the exclusive competence of the national Parliament".[119] For the specific case of energy (including electricity) legislative authority co-exists at state and regional level. Regions are competent to legislate, but only without interfering the higher electricity state norm. To authorize electricity infrastructure projects, regions have to obtain regulatory approval from the responsible state ministry.

Since 1997 (by virtue of Law no. 481 of 14 November 1995, cf. IEA) the Autorità per l'Energia Elettrica e il Gas (AEEG) has been the independent regulator for Italy's electricity and gas sector.

[119] IEA (2009), p. 18

According to the EC in 2011 AEEG had a total workforce of 168 employees and a budget of 39 € million. Interestingly, AEEG's financial funding is based on annual payments undertaken by industry stakeholders. Generally the Italian regulatory authority acts autonomously without government's interference. AEEG's main tasks comprise the appointment of tariffs for electricity retail, the establishment of quality targets for electricity supply and services, and the definition of a technic-economic framework regarding access requirements to national grids. In addition to AEEG whose actions are rather of an ex-ante nature, the Autorità Garante della Concorrenza e del Mercato (AGCM) – the Italian competition authority – officially enacted in 1990, investigates ex-post, for instance, potential market power abuses and M&As. Like AEEG the AGCM is an independent body that acts according to established law and thus (theoretically) obviates governmental influences.

In Italy's generation business distinct players are active. However, Enel – formerly vertically integrated monopolist – and today one of the national incumbent electricity operators produces the lion's share of electricity. In response to the electricity market opening Enel had to divest installed generation capacity in order to lower its market power. Literature points out that Enel's ownership is two-fold, i.e. both state (the Ministry of Economy and Finance) and private investors have stakes in Italy's largest power utility (status 2009).[120] Notwithstanding Enel's dominance other, smaller actors such as Edison, Eni, Endesa Italia and Edipower entered the electricity generation market in Italy. Fig. 23. thus renders the share of electricity output by these different generation companies (GENCOs).

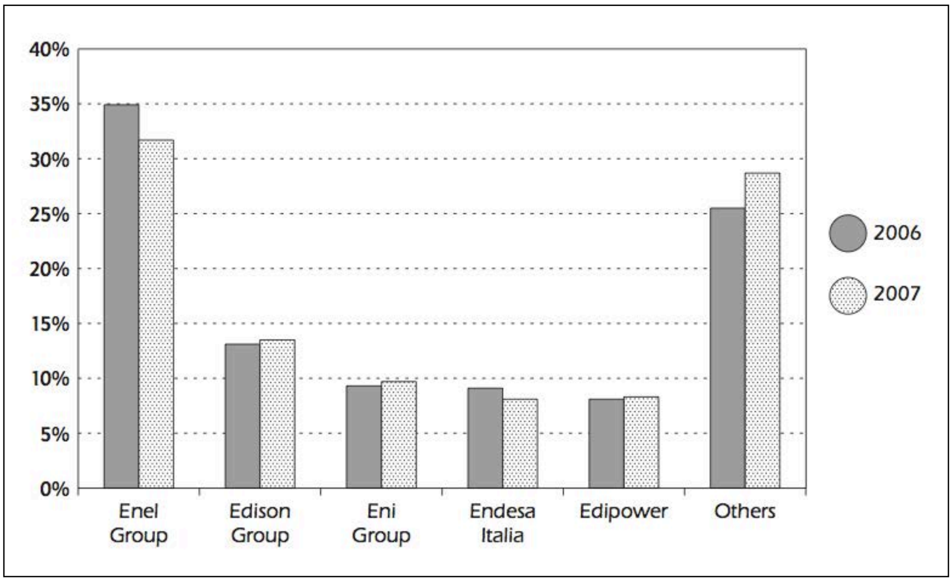

Fig. 23. Share of electricity output by generator in 2006 and 2007[121]

[120] IEA (2009), p. 79

[121] Ibid.

Other relevant players to this sub chapter concern electricity transmission and distribution. EU legislation forced Italy like other member states to unbundle its transmission activity. Ownership unbundling in 2005 resulted in Terna being both proprietor and Italy's responsible transmission system operator (although in some regions other very small other owners exist). Similar to Enel, the Italian state is among other national shareholders and international funds one of the principal stock owners. With regard to electricity distribution there exists significantly more players. According to 2009 EC data in Italy operate 144 DSOs. Despite this DSO fragmentation figures demonstrate that the former monopolist's distribution division still sends out the largest share of electricity, i.e. more than 85 percent among all DSOs in 2007.[122] To complete this overview of domestic stakeholders the Gestore Mercati Energetici (GME), that is the Italian electricity wholesale market operator, must be mentioned. As such GME is entirely owned by the Gestore Servizi Energetici (GSE).[123] GME fully operates since 2004 and is the fundamental platform for Italy's electricity trade. In essence, GME creates a market place for GENCOs and retailers (cf. sub chapter 3.2.6 for the functioning of the Italian power exchange).

Fig. 24. sums up the Italian regulatory governance framework and renders the most relevant relationships between institutions and players that concern electricity business.

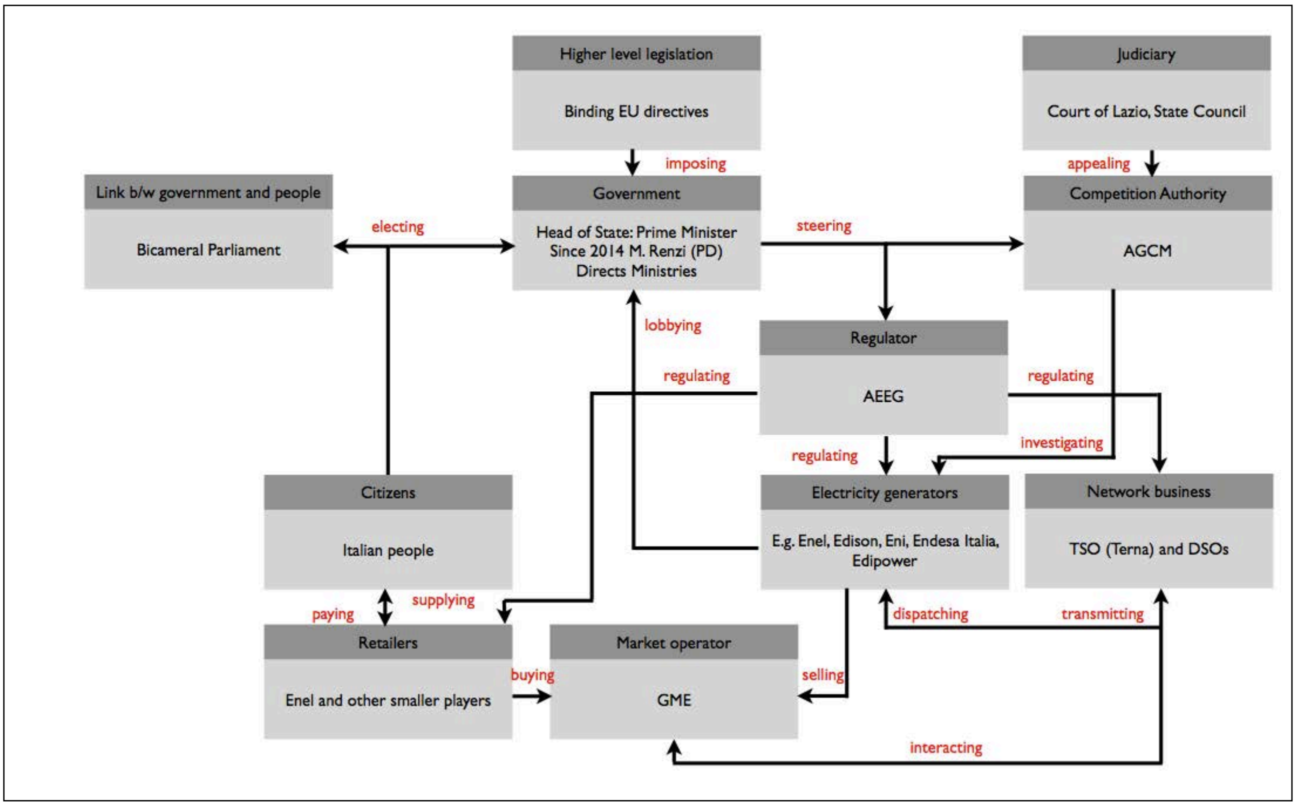

Fig. 24. Italian regulatory governance framework

[122] Cf. IEA (2009), p. 83

[123] Cf. Cariello (2008), p. 24; GSE is a state-controlled company which is fully owned by the Ministry of Finance.

3.2.6 Regulatory framework and market design

MALTA

The electricity market regulations **S.L.423.22** established by the the Enemalta Act lay down the principles and rules according to which electricity provision in Malta is organized. These regulations detail how supply-demand-balance should be met, services of practical nature such as meter reading are implemented and tariffs are set.

In the wording of the law it says:

„These regulations establish common rules for the generation, distribution and supply of electricity, together with consumer protection provisions, with a view to improving and integrating competitive electricity markets in the Community. These regulations also lay down:

(a) the rules relating to the organization and functioning of the electricity sector,

(b) open access to the market where applicable, the criteria and procedures applicable to calls for tenders and the granting of authorizations and the operation of systems;

(c) universal service obligations and the rights of electricity consumers and clarification of competition requirements.“[124]

For this master paper it is most important to highlight that Malta benefits due to its small isolated electricity system from certain derogations in directive 2009/72/EC concerning common rules for the internal market in electricity. Malta‘s electricity market regulations must be therefore viewed against the background of these exemptions granted under article 44 of directive 2009/72/EC that comprise i.) article 9 „unbundling of transmission systems and TSOs“, ii.) article 26 „unbundling of DSOs“ iii.) article 32 „TPA“ and iv.) article 33 „market opening“.[125]

Electricity business on the EU island state is composed of generation, distribution and retailing. Unbundling is realized at the level of accounting separation, i.e. liberalized – generation should be theoretically open to competition – and regulated activities – distribution represents a natural monopoly – are carried out both by Enemalta having distinct accounts for both businesses.[126] Enemalta‘s retail division also separates accounts from the other activities (cf. discussion in the following).

[124] MT Government (2011), p. 1

[125] Cf. MRA (2013), p. 4

[126] Cf. Enemalta (2014b) and Batlle/Ocaña (2013d), p. 138

In sub chapter 2.1.3 we specified the electricity wholesale market architecture today prevalent in many European countries. In Malta such a trading platform, i.e. a wholesale market for electricity including spot and intraday market, does not exist. As a result of absent market forces, Malta‘s government commissions the MRA to fix regulated electricity tariffs for consumers. Consumers do not purchase electricity at real costs since the government heavily subsidizes Enemalta, being the „national champion“ capable of offering affordable electricity prices to citizens. In other words Malta has yet no real electricity market place established, demonstrated e.g. with the absence of a market operator. We observe rather the traditional regulatory paradigm where the incumbent Enemalta covers the entire value chain under MRA‘s oversight.

Due to its small size there does not exist any transmission system respectively TSO. The core of the island‘s electricity grid is the distribution network for which Enemalta executes the role of distribution system operator (DSO). Although some independent electricity self generators, e.g. by means of roof top solar photovoltaic installations, do co-exist, Enemalta produces the lion‘s share of electricity needs and is the sole entity responsible for electricity retailing to consumers. That is also why the state enterprise performs balancing services and no distinct balancing/reserve market is established. In sum, Enemalta altogether carries out the DSO‘s role of „dispatcher“, „balancing responsible party“ and „ancillary service provider“. Distribution network tariffs are subject to MRA‘s approval. Moreover, network utilization tariffs for electricity producers different from Enemalta did not exist in 2012. National regulations would currently require other electricity producers being connected to the Maltese distribution grid to sell their capacities to the single national supplier.[127] In prospect of the planned subsea interconnection between Malta and Italy it is also the regulator‘s role, namely MRA, to monitor a non discriminatory entry to transnational grid facilities for other players than Enemalta, as until now this was never the case before.

Malta has no competitive electricity retail market, i.e. the incumbent Enemalta has a monopoly as sole licensee in electricity provision to end consumers. Therefore retailer switching for Maltese electricity consumers is infeasible. Both household and industrial consumers are under a regulated tariff scheme that includes a capacity charge (€/kWh) plus a fixed fee for services (€). In essence, the tariff scheme separates between primary residential, domestic and non-residential premises.[128]

[127] Cf. MRA (2013), p. 8

[128] Ibid., p. 12 and Enemalta (2014c); „Domestic tariffs are applicable for electricity consumed in premises intended for domestic use and which are not registered as a primary residence“.

In 2013 electricity retail prices for private households averaged 0.1615 € per kWh, and for industrial consumers 0.18 € per kWh.[129] (We will further elaborate on electricity prices in chapter four). From the consumer perspective the lack of an alternative to Enemalta implicates that retail contracts are valid for an unlimited period. Enemalta has established support mechanisms for vulnerable consumers, e.g. families with a minimum threshold income can obtain energy benefits, and an „eco reduction mechanism“ incentivizes Maltese people to lower their consumption.[130]

Lastly, we briefly address the role of RES in the Maltese EPS. Several reports by Malta‘s authorities such as the „2006 Draft Renewable Energy Policies published by the MRA, the 2008 National Energy Efficiency Action Plan of the Ministry for Resources and Rural Affairs (MRRA)“,[131] the 2012 MRRA‘s National Energy Policy for the Maltese Islands and Mott MacDonald‘s 2005 Strategy for Renewable Electricity Exploitation in Malta give a holistic overview of the RES potential in Malta. As pointed out in the sub chapter on Malta‘s electricity generation mix, RES do not play a significant role in the current electricity production portfolio. Although Malta‘s geographical location would inherently favor to generate electricity from RES such as wind and solar photovoltaic, its renewable share is small among EU member states. With a RES share lower than one per cent in 2012 (cf. Fig. 17. Malta‘s electricity generation mix in 2012) it is hard to believe that Malta can achieve the EU required ten per cent by 2020. The island‘s specificities (e.g. high population density) and natural boundaries (e.g. water depth) at present tremendously hamper the implementation of proposed RES projects such as a large scale offshore wind farm. The Maltese electricity market regulations were highlighted at the beginning of this sub chapter are the fundament for integrating RES in the Maltese EPS. Due to little RES significance at present, it is assumed to be sufficient for the scope of this thesis to emphasize that small independent electricity producers benefit from RES support mechanisms, i.e. grants for technology installation and feed in tariffs (different for domestic and industrial consumers; locational differences; cap of kWh per year and maximum period of years) are paid.

[129] Cf. Eurostat (2014a)

[130] Cf. MRA (2013), p. 12; „Households composed of two or more persons may benefit from a two tier eco reduction mechanism provided that the consumption per person does not exceed 1750 kWh per annum. A reduction of 25 % in the consumption bill is possible if the consumption does not exceed 1000 kWh per person for the first tier. The second tier consists of a reduction of 15 % in the bill on the next 750 kWh per person/household“.

[131] Kotzbue (2010), p. 5972

ITALY

In the late 1980s a national referendum in response to the Tchernobyl catastrophe resulted in Italy's exit of nuclear power. Intentions to re-introduce nuclear power plants in the Italian electricity generation mix as aimed by Berlusconi's cabinet in 2008 failed after the Fukushima reactor accident in 2011 and another referendum on Italy's re-entry in nuclear energy. As of 1990 the Italian government enacted multiple decrees for its energy sector to conform to higher level European legislation. The decree **no. 79 of 1999**, the so called **Bersani decree**, can be seen as the essential step in establishing an Italian electricity market, and hence enabled to transpose the first liberalization directive for electricity 96/92/EC into national law. As in many other EU member states the market opening process was gradual, i.e. while the regulatory authority AEEG has already become operative in 1997 (before being officially required by the EU), in 2004 the reform was followed by ownership unbundling of the TSO and the commissioning of the Italian power exchange (IPEX), before in 2007 full eligibility in supplier choice for consumers took place.

For Italy's wholesale market design we refer to Fig. 7. Italy's electricity wholesale market architecture is based on the IPEX where generators sell electricity quantities to retailers/ suppliers. The IPEX is operated by GME whose major responsibility is to determine the 24 hourly clearing prices resulting from submitted marginal cost priced bids by buyers and sellers. Once GME established a base schedule for the delivery of electricity for the following day, Terna ensures its technical dispatch feasibility. IPEX comprises two distinct electricity market places, one for electricity day ahead trade and another for ancillary services.

CESI highlights the different types of bids for buyers and sellers in the DAM as follows: i.) simple bids composed of a single quantity-unit price pair, ii.) multiple bids composed of a maximum of four quantity-unit price pairs and iii.) predefined bids.[132] The DAM further comprises an intraday market. Since 2009 the intraday market has repealed the former adjustment market by introducing four sessions in which market participants can bilaterally update the day ahead schedule until 11.45 a.m. the same day of physical electricity delivery. The second market place is the ancillary service market. It is the TSO's, namely Terna's responsibility to procure operating reserves in this market which is split into the so called ex-ante Mercato Servizi di Dispacciamento (MSD) to create reserve margins and the balancing market to solve real-time constraints.[133] Whats is more, zonal pricing is a singularity of the Italian electricity spot market.

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[132] Cf. CESI (2009), p. 79; Predefined bids are simple or multiple bids that each market participant may submit on a one-time basis and they are used for slots where GME has received no current bids.

[133] For the detailed functioning view https://www.mercatoelettrico.org/en/mercati/MercatoElettrico/MPE.aspx

Zonal prices result from transmission network congestions and divide the EU member state into six geographical zones, namely northern Italy, central-northern Italy, central-southern Italy, southern Italy, Sicily and Sardinia, i.e. depending on the grid capacity utilization there can exist six distinct zonal prices.[134] Generators are remunerated according to the respective zonal price, whereas the buyer side always pays the prezzo unico nazionale (PUN), that is a uniform national price without considering the particular zone from which power was withdrawn.[135]

Italy's retailing market was entirely liberalized in 2007. Since then all Italians and not only former eligible consumers, i.e. non-residential users, have been authorized to select any supplier. However, until recently competition in the Italian retail sector took off slowly as demonstrated by low supplier switching rates. This is majorly due to the survival of a default supplier which continued to provide electricity at controlled prices for most Italian household consumers (more than 70 percent in 2011). Default supply is usually performed by the local distribution system operator that purchases electricity from the Acquirente Unico (AU). The AU as such entirely hold by the government represents a single buyer that is in charge of acquiring wholesale traded power in order to satisfy power needs for the regulated market. In 2011 the three dominant retailers served approximately 50 percent of the Italian market. Eurostat 2013 energy statistics reveal that Italy's retail price level was considerably higher than EU-28 average (0.094 €/kWh) for both household some 60 percent (0.15 €/kWh) and industrial (0.112 €/kWh) consumers about 20 percent.

Finally, the master paper briefly introduces Sicily's role within Italy's power system. The hitherto discussion focussed on the Italian EPS as a whole, since the subsea cable links Malta not only to Sicily but the entire Italian system and in a broader sense to the European market. However, the Sicilian power system exhibits some particularities. Although a new two GW cable linking Sicily and the Italian mainland will be soon commissioned, up to now the interconnection capacity was weak (1000 MW). Transmission network congestions thus often result in significantly higher zonal wholesale market prices in Sicily than in other areas of the peninsula (according to Terna, e.g. up to 40 percent higher compared to the PUN in 2010).[136] Authors like the AGCM point out that missing competitiveness in the Sicilian wholesale market fosters incumbents' potential to abuse their dominant positions (cf. anti-competitive procedures against Enel and

[134] Cf. CESI (2009), p. 77

[135] Cf. Gianfreda/Grossi (2012), p. 7 ff.; „The accepted supply offers are evaluated at the clearing price of the zone. Hence the zonal market clearing prices are those prices observed on several zones or areas, and they can differ across zones if a proportion of the grid becomes congested. [...] Demand bids [...] are evaluated at the single national price which is the purchase price for end customers and it is computed as the average of the zonal prices weighted by zonal consumptions".

[136] Cf. Terna (n.d.)

Edipower) leading to increased market concentration as opposed to the country's rest and therefore higher prices.

3.3 QUALITATIVE IMPLICATIONS OF EPS INTERCONNECTION

3.3.1 EPS confrontation – Scenario of merging two independent systems

This sub-chapter juxtaposes the two independent electric power systems of Malta and Italy. Fig. 25. and Fig. 26. contrast the electricity key indicators for both EU member states the paper previously presented.

Electricity market key indicator juxtaposition

	MALTA	ITALY
Country characteristics		
Area [km²]	316	300,000
Population [millions]	0.4	60
GDP per capita [€]	16,300	24,542
Electricity generation and demand		
Installed capacity [GW]	0.62	107
Total electricity generated [TWh]	2.3	299
Peak load [GW]	0.429	56.5
Fossil fuel import dependency [%]	100	83.3
Emissions [kgCO_2/capita]	14,856	7,201
Security margin [%]	69.2	52.3
Electricity network		
Circuit length [km]	1412	>1m.
Transmission & distribution losses [%]	11	7
SAIDI [minutes per consumer]	286	133
SAIFI [interruptions per consumer]	4.28	2.33

Fig. 25. EPS confrontation – electricity market key indicators (a)

Electricity market key indicator juxtaposition

Market design	MALTA	ITALY
Number of companies representing at least 95 % of net power generation	1	217
Main generation companies (producing at least 5 % of national net electricity generation)	1	5
Market share of largest generation company [%]	100	27.5
Number of electricity retailers	1	342
Number of DSOs	1	144
HHI in power generation market	10,000	1,087

Fig. 26. EPS confrontation – electricity market key indicators (b)[137]

In essence, the selected electricity market key indicators show two fundamentally different electric power systems. The displayed numbers are the evidence for the heterogeneity of the Maltese and Italian prevalent architectures, they differ significantly in all four categories. Specific country characteristics reveal inherently distinct state dimensions, for instance, Malta‘s population being smaller than one percent of Italy‘s, and the Italian geographical area approximately 1000 times larger than the EU island state. Electricity generation and demand data renders an equivalent picture, i.e. while Malta‘s indicators exhibit significantly smaller magnitudes, for Italy the values of fossil fuel import dependency and security margin attract attention. Italy‘s fossil fuel import dependency is notably higher than EU average which is only marginal greater than 50 percent. The reason why mainland EPSs have smaller security margins than islands (52.3 percent (IT) as opposed to 69.2 percent (MT)) was highlighted in the sub chapter on small isolated

[137] Fig. 25. and Fig. 26. are developed by the author of this thesis. The sources for the figures were provided throughout chapter 3.2. The numbers displayed in Fig. 26. are taken from European Commission (2011b) and (2011c).

power systems. With regard to the electricity network both Malta and Italy suffer from high inefficiencies (cf. e.g. losses) and quality of supply, as demonstrated by their SAIDI and SAIFI values, is poor compared to the values of other member states in the CEER benchmarking report on the continuity of electricity supply. Furthermore, EPS inequality is proven by the results of the market design analysis. A striking example is the HHI in the power generation market that underlines on the one hand Malta's highly concentrated market in which Enemalta's dominance as single electricity producing utility is omnipresent, and contrarily, Italy's electricity market place exhibiting a moderately concentrated market.

In near future the interconnection cable will link both independent systems, thus it will change the game and it is most likely that the interconnector will impact more Maltese consumers than Italians. The reasons are many-fold, but most of them are related to the fact that the cable's transmission capacity will represent a large share of Malta's total installed generation capacity whereas for Italy it will not. To maintain the objective viewpoint, this thesis does not evaluate the cable's profitability as a whole (feasibility studies have done this), it rather discloses the impacts on the Maltese power market architecture. Primarily, the paper scrutinizes unexpected scenarios Maltese consumers are not aware off when merging both systems, for example, the development of electricity spot prices; the benefits such as a more flexible, i.e. less fossil fuel dependent generation portfolio are more obvious. This first part of chapter 3.3 served to oppose the key indicators of both power systems, sub chapter 3.3.4 summarizes concrete qualitative implications of the subsea interconnector.

3.3.2 System boundary definition

Daenzer's systems engineering approach (1982)[138] served as a guideline for the hereafter shown system boundary definition for the interconnection case (cf. Fig. 27.). The general scope of analysis is based upon the priority interconnection plan (PIP) established by the EC in 2007 which imposed an electrical connection to link Malta and Sicily as a project of European interest. The intervention system separates the Malta-Sicily subsea cable from other interconnection projects, explicit changes are likely to appear when commissioning one consolidated instead of two independent systems. The scope of effect further disentangles the system. It comprises the principal electric power system characteristics and shows the areas where modifications are expected. Lastly, the solution's scope precisely addresses the interconnection case. In case of compulsory interconnection to project the potential electricity price impact for Maltese consumers should be possible. The interconnection case must be viewed against the background of high electricity price levels (revealed by the analysis in chapter 3.2).

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[138] Cf. Daenzer (1982), p. 59 chapter 42.32 Abgrenzung von System und Umwelt

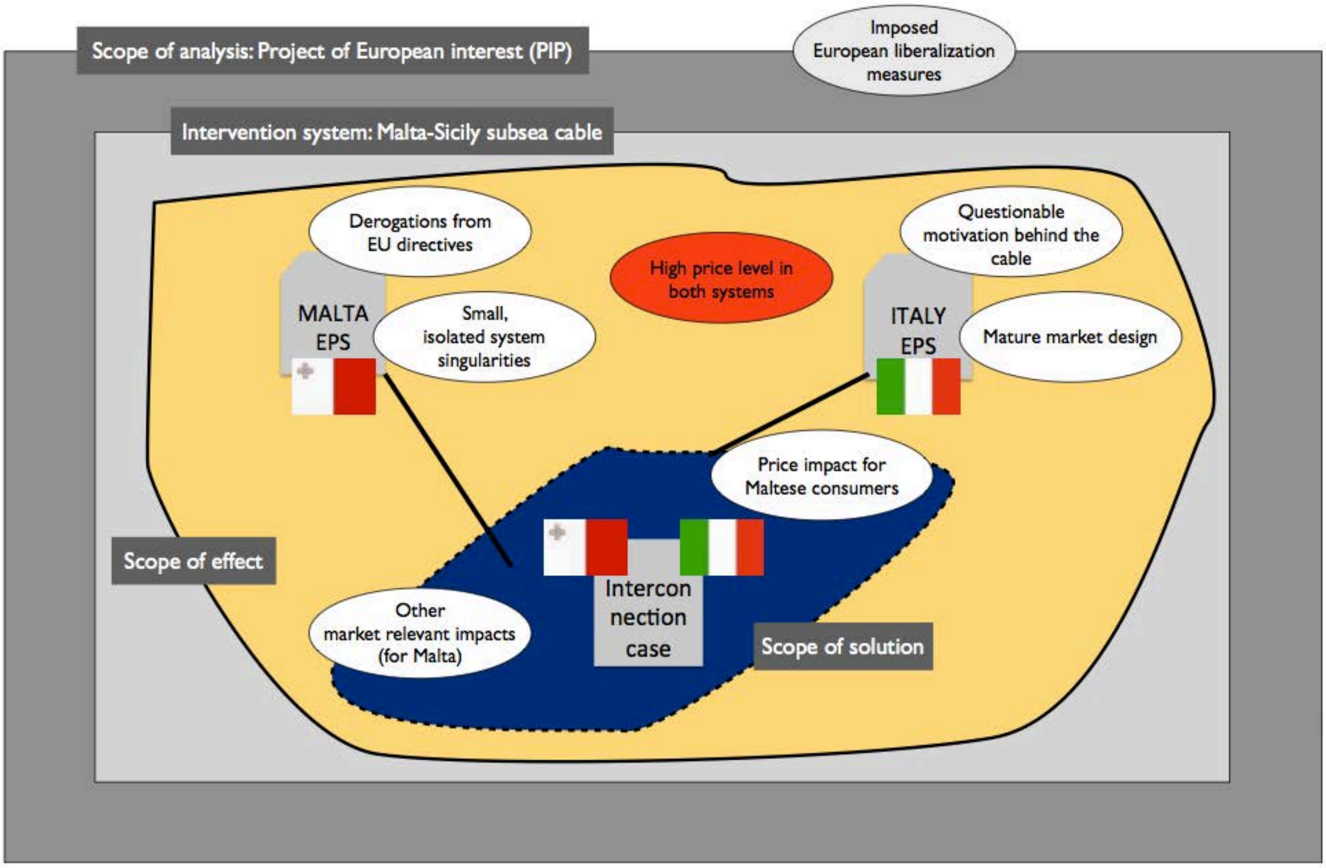

Fig. 27. System boundary definition for the interconnection case

3.3.3 Scenario analysis: Uncerntainty about possible outcomes in the interconnection case

Based on the systemic approach this thesis introduced beforehand, Fig. 28. outlines schematically price scenarios the interconnector can entail for Malta's consumers. The illustration follows Daenzer's methodology of non-quantitative, intuitive forecast techniques. Fig. 28. renders one qualitative textbook example for a potential outcome in case the connection cable linking Malta's and Italy's EPS will be commissioned.

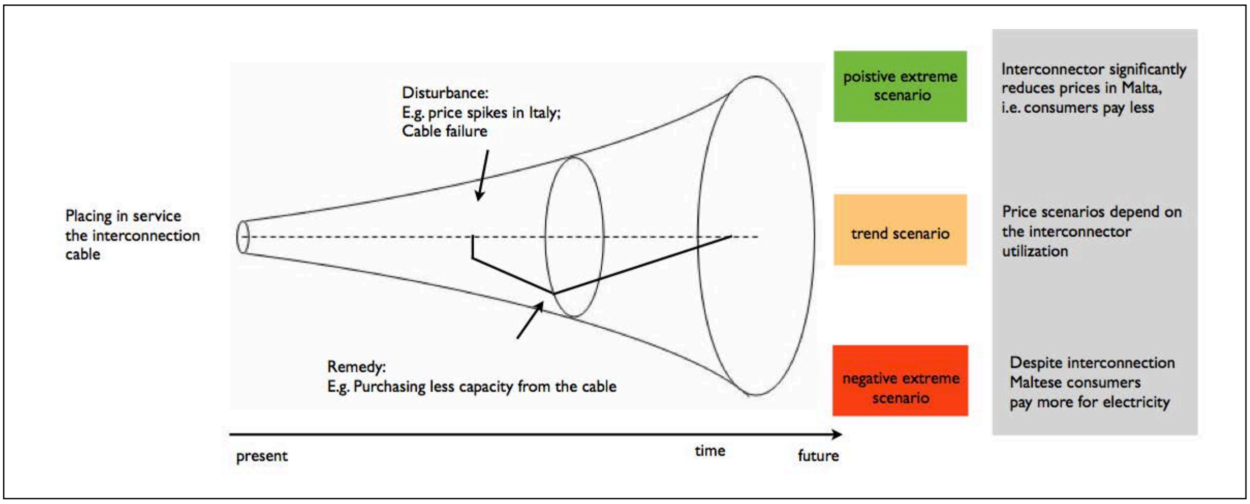

Fig. 28. Schematic price scenario analysis for the interconnection case

3.3.4 Vulnerability of a common EPS

Institutional challenges – Drivers of uncertainty in the regulatory governance game

So far, the conducted analysis showed that Malta‘s electricity business is heavily determined by the vertically integrated incumbent Enemalta benefiting from extensive governmental financial state aid. In recent years discontinuity regarding personnel policy, especially at management level, led to image deterioration and uncertainty in Enemalta‘s strategic positioning. Despite its significantly leveraged financial structure, Enemalta failed to adequately prompt investments in both electricity production and network assets. Existing power stations like Marsa and Delimara are aging and exhibit technical deficiencies. Moreover, Enemalta‘s activities are strongly co-determined by political influence, which is possibly unavoidable for the status quo Enemalta being state owned, but it hampers straightforward policy making. Malta‘s power system characteristics, in particular the exposure to unstable fossil fuel prices, inherently impede to predict prospective electricity generation costs. Past experiences have demonstrated that a raise in demand can challenge Malta‘s security of electricity supply (see evolution of SAIDI/ SAIFI indicators on continuity of electricity supply).

In Italy the negative dynamics in politics and economy impinge upon the member state‘s capability to render a precise, unambigous strategic energy direction. As Ifri pointed out (2012) the Italian energy policy encounters as a major challenge „administrative sluggishness“, i.e. decision power and legislation authority is split between the distinct administrative entities tied either directly to the state or regional level.[139] Constitutional amendment in 2001 empowered regional councilors‘ decision making authority regarding energy specific questions (concerning for example electricity infrastructure investment). This patchwork of state level and regional authorities can significantly decelerate the approval procedure for projects that are of national concern. Theoretically, the state has the opportunity to override regional proposals, but in practice this right is seldom exercised. Electricity network expansion always represents a hot topic on countries‘ agendas, however, what differentiates Italy from other EU member states is the entanglement of different national entities with binding decision making power.

Having analyzed both systems evenhandedly shows that political interference in electricity relevant questions in Malta and Italy is significant and thus can provoke institutional challenges. Literature proves that the submarine connection cable is much more than a physical asset. Politicians within both countries but also between them, make use of the interconnector for their election campaigns.

[139] Cf. Ifri (2012), p. 3 ff.

While in Malta the former governing PN was pro interconnection, the new government under prime minister Muscat values more other energy projects (e.g. expansion of gas infrastructure). From Italian politicians emanates even stronger opposition to the cable construction as of early 2013. With regard to local elections particularly Sicilian parties took into consideration to disrupt the subsea cable works on the grounds of its strong environmental impacts. From an operational point of view the two key actors are the grid operators, namely Terna and Enemalta. Since Italy has several interconnections to other countries, its grid operator has large expertise in this field. Yet, Enemalta lacks this experience, deviations from the „business as usual" can be a potential risk (e.g. how to react in case of cable outage?). Within the interconnection project framework one of the major concerns is/was the investment, i.e. since it is most likely/expected that the cable particularly contributes to Malta's EPS, the added value for Italy's EPS is questionable. Therefore funding must be exclusively provided by the small island state (in addition to the loans from the European Investment Bank and EEPR, cf. sub chapter 3.1.4).

Qualitative benefits and drawbacks of the interconnector for Malta's consumers

Tab. 10. lists the qualitative key findings of the interconnector with special attention to Malta's consumers.

BENEFITS
- Since the cable is installed undersea it is visually not perceived by Maltese consumers nor does it cause noise disturbance. The cable does not exhibit any atmospheric emmissions/pollution. - The interconnector strengthens Malta's security of energy supply in case of un unexpected event. - The cable makes new, extra fuel bunkers redundant. Given that the cable would not have been installed those storage capacities would be necessary with respect to new fossil fuel fired power plants (a problem because of Malta's limited space). - The subsea link will support Malta in complying with EU imposed energy requirements. Own poor RES generation capacity can be offset with purchasing „green" electricity from other countries. - If plans of implementing large RES, in particular an offshore wind farm, are followed, the commissioning of the submarine cable is mandatory to safeguard grid stability (i.e. to counteract RES intermittency).
DRAWBACKS
- The interconnection cable itself does not imply inherently a low electricity price for consumers. The analysis revealed that Italy has one of the highest electricity price levels among EU member states (Congestion!); Import through Italy's interconnected neighbouring systems such as France seems more viable. - Italy (specifically Sicily) and Malta exhibit a similar load/demand shape. Depending on the supply strategy, over dependency on the interconnector can cause problems because Italian electricity production capacity is poor with a relatively low security margin; This can especially pose problems when peak load in both countries coincides. - Cable impairment/breakdown will entail long, tedious and costly maintainance procedures. It is estimated to be about one month. - To offset the risk of a cable outage and being able to perform maintenance (SoS reasons), the N-1 criterion requires the installation of a second cable which implies large investment needs. - Disconnecting the submarine link from Malta's network can challenge its stability; This requires sufficient back-up/reserve generation capacity.

Tab. 10. Qualitative benefits and drawbacks of the interconnector

In conclusion, this master paper highlights again Malta‘s singularity of an electric island system. There exists no doubt about the interconnector‘s advantages. However, as stated in Tab. 10. over reliance on imported electricity can threaten SoS, in particular when peak loads of both EPSs coincide and national power plants run short. To prevent from such a scenario supplementary (conventional) electricity production capacity is needed.

Derogations and questionable electricity price evolution

A question mark is behind the derogations Malta has been granted from the EU due to its small, isolated system. The subsea cable will abrogate its isolation and therefore integrates Malta into the internal European electricity market place. While TSO unbundling will have no impact (as such Malta has no transmission system operator), DSO unbundling may require enforcement. Sub chapter 3.2.5 pointed out that unbundling is currently performed at accounting level. Ownership separation like it was the case for Italy‘s TSO, would obligate Enemalta to sell/auction its distribution grid to a third party in conjunction with the boost of a deeper independence between businesses that are open to competition and those that are regarded as natural monopolies. Furthermore, if an exemption from TPA is not chartered any longer with the commissioning of the cable, new entrants potentially will interfere Enemalta‘s monopoly position. If we think of the merchant link implementation scheme (see sub chapter 3.1.3), the cable would be operated by a private investor, and it thus raises the question whether the national electricity producer is still able to contest the private operator given that imported power has a significant cost advantage. Above all, one major key challenge for Malta would be the abrogation from its market opening privileges. Financial state aid infringes upon EU energy legislation,[140] i.e. assuming that the Maltese EPS must be entirely opened to competition, Enemalta can potentially not longer count on the enormous hitherto subsidies provided by the government.

„About 75 % of Enemalta‘s costs are fuel related and the company is not allowed to pass oil price increases to final consumer tariffs, as electricity prices for (industrial) consumers in Malta are among the highest in Europe. To avoid further tariff hikes, the government has been supporting Enemalta through subsidies“.[141]

The lack of the government‘s heavy financial support can lead to a scenario in which consumer bills tend to be higher than without interconnection cable. Although the remuneration from charged electricity rates was not enough in the past to cover costs, Enemalta has been significantly backed up by the Maltese government to avoid to pass on

[140] Cf. European Commission (2014); „A company which receives government support gains an advantage over its competitors. Therefore, the Treaty generally prohibits State aid [...]“.

[141] IMF (2013), p. 49

the real costs to consumers. In the new setup the absence of these subsidies might significantly impact citizens due to their unawareness of the interconnector's long term profitability.[142] The connection cable to link Malta and Sicily thus might be perceived by the public rather as a cost driver than an absolutely essential infrastructure project to diversify the island's generation mix. What is more, that Italy's high electricity wholesale market prices can offset the initial interconnector's advantage of cheap power imports (resulting in even higher prices for final consumers as is in the previous case where solely the fact of missing state subsidies was assumed). Therefore the use of the interconnector must be viewed in the light of both the abrupt shortfall of financial state aid and the cost of producing electricity with national resources compared to the power purchase price in Italy. Chapter four will further investigate the interconnector's impact for Malta's consumers to provide a more accurate conclusion.

Abstract Chapter 4

Chapter 4 builds the core of this thesis. It numerically assesses the interconnector's potential impacts on electricity prices for Maltese consumers. In a first step the marginal cost curves for electricity generation on the EU island state based on data of Maltese and Italian authorities are constructed. We establish the merit order for both Malta's isolated and the future generation setup differentiating between three distinct oil price scenarios. The obtained marginal cost curves enable to determine a first value of interest, namely the average electricity generation price in Malta – for all reviewed generation portfolios and oil price scenarios – without interconnector and, hypothetically 100 percent electricity import from Sicily. In the next step the interconnector is simulated. Quantity imports and the total capacity utilization are two first key findings. Moreover, the algorithm determines the average electricity generation price with interconnector and computes rents for both the supplier and cable owner. Our analysis revealed that the submarine interconnector does not inherently reduce the electricity price level for Maltese consumers. Furthermore, it renders whether and in which of the presented generation setups and distinct oil price scenarios Malta's interconnected power system possibly benefits the final consumer.

[142] Cf. Navarra (2013); Recent articles scrutinize whether Malta possibly might be obliged to repay funds granted from the EU in case the cable is poorly used, i.e. up to 20 percent capacity. This is due to a PPA for Malta's gas fired power station which requires the purchase of a certain electricity threshold through this agreement. It will be penalized by non compliance and potentially implicates a limited cable utilization.

4. IMPACT SIMULATION FOR MALTA‘S ELECTRICITY CONSUMERS

4.1 LITERATURE REVIEW

4.1.1 Approaches to assess impacts on electricity consumers

The quantitative impact simulation for Malta‘s electricity consumers aims to demonstrate in a more numerical way the possible outcomes the interconnector between the Maltese archipelago and Sicily might implicate. From a preliminary literature study it seems that authors do focus on the interconnection problem, e.g. Cartea and González-Pedraz (2011) „*How much should we pay for interconnecting electricity markets*?“, but the crucial factor that differentiates this thesis from other papers is Malta‘s peculiarity of a small isolated electricity generation system. Their principal research question focusses on how to „value an interconnector“.[143] The authors apply a financial approach based on real options theory that seeks to determine the interconnectors‘ valuation for five pairs of EU adjacent electricity markets. Despite the fact that our study will not use the financial real options methodology, the concept that „power plants that offer operational flexibility (like CCGTs) derive most of their value from the option to produce electricity when prices are high“[144] is coherent with our idea to start this part by modeling the Maltese generation setup for distinct oil price scenarios.

As stated in the hitherto analysis of this paper, we agree with the authors that „electricity prices are characterized by exhibiting extreme volatility and by undergoing abrupt changes [...]. This extreme behavior is also present in the difference between prices of two locations and explains why interconnecting two markets could be profitable“.[145] However, their assumption on the interconnection capacity is that the transferred capacities are likely to be small compared to the existing electricity market places the new line interconnects. In other words, this implies that the commissioning of the „interconnector does not alter the price dynamics in either market“[146] and thus disagrees with our hypothesis that the subsea link between Malta and Sicily will highly impact the electricity spot price on the small EU island power system.

Other authors write about the singularities of small isolated electricity generation systems, the majority concentrates on costs and reliability related aspects of integrating renewable

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[143] Cartea and González-Pedraz (2011), p. 14

[144] Ibid., p. 15

[145] Ibid., p. 14

[146] Ibid., p. 17

energy sources into the islands' electricity production setups as, for instance, Karki and Billinton „*Reliability/cost implications of PV and wind energy utilization in small isolated power systems*" (2001) and Chun-Lung et al. „*Optimal wind-thermal coordination dispatch in isolated power systems with large integration of wind capacity*" (2006). Perez and Ramos Real raise the question of „*How to make a European integrated market in small and isolated electricity systems*?" (2008). The latter idea is more in line with this thesis, i.e. to scrutinize to what extent the cable that links Malta and Sicily achieves to foster the vision/implementation of a single European electricity market, however, they remain silent on the distinct interconnection issue and do not carry out a quantitative analysis. Authors like Thakur et al. „*Impact assessment of the Electricity Act 2003 on the Indian power sector*" (2005) stress the revamping of the electricity industry in India and emphasize particularly its implications for the generation, transmission and distribution business, yet in their case study for the Indian power sector they also lack to propose a concrete quantitative methodology. The well-known paper „*Competition in the British Electricity Spot Market*" (1992) of Green and Newbery investigates the competitiveness within the British electricity „pool" by applying the Nash equilibrium. Their practical approach of modeling the British electricity spot market comprises to construct the supply function which is very similar to our envisaged method. However, these authors do not examine any interconnection project.

4.1.2 Conclusions for this work – Why are prices good indicators?

Kammen and Pacca developed a qualitative tutorial – „*Assessing the costs of electricity*" (2004) – to survey the distinct approaches utilized to define electricity prices. They especially underline „the impacts of price fluctuations, subsidies, concealed health, and environmental impacts that may be valued and considered by energy analysts".[147] Our approach is of practical nature and straightforward, but due to Malta's power system singularities it is not a standardized approach found in literature. At present, statistical data only reveals retail prices for Malta's final electricity consumers. The hitherto absence of marginal costs/electricity generation prices for the Maltese past and future generation setup will be overcome with this thesis. Batlle and Rodilla (2013) in their lectures pointed out that scarcity of generation capacity is the main indicator for high electricity prices. Hence, the paper firstly establishes the merit order for the Maltese generation mix to assess the prevalent electricity price level. Secondly, it goes one step further and simulates the interconnector. Lastly, the simulation will evaluate the cable's impacts on Malta's prices and examine whether these price differentials are also beneficial to Maltese consumers.

[147] Kammen/Pacca (2004), p. 339

4.2 DATA LANDSCAPE

4.2.1 Available data for Italy/Sicily

To assess the interconnector‘s impact for Malta‘s electricity consumers this master‘s thesis uses official data provided by the Italian market operator GME and the Maltese vertically integrated utility Enemalta. Raw data comprises both the average hourly *prezzo unico nazionale* (PUN) and the Sicilian hourly electricity wholesale market spot price from 2007 to 2010. As it is of fundamental relevance for this paper, namely that electricity transmission (import and export) will take place between Malta and Sicily, it must be emphasized that spot prices in Sicily are significantly higher compared to Italy‘s mainland prices (cf. Fig. 29.). According to our dataset Sicily‘s wholesale electricity price averages 89.71 €/MWh whereas the PUN equals 71.47 €/MWh, i.e. the average Sicilian price level exceeds the average PUN by almost 26 percent. Sicily is a well-known bottleneck inside the Italian transmission network, the large price differential is due to frequent congestion of the weak interconnection capacity between Sicily and the mainland. Additionally, Italy‘s TSO Terna points out that Sicily‘s electricity generation system (thermal capacity 7700 MW) is „less efficient compared to the rest of Italy thus determining a lack of competitive prices“[148] (see further information sub chapter 3.2.6 on Sicily‘s role in the Italian EPS).

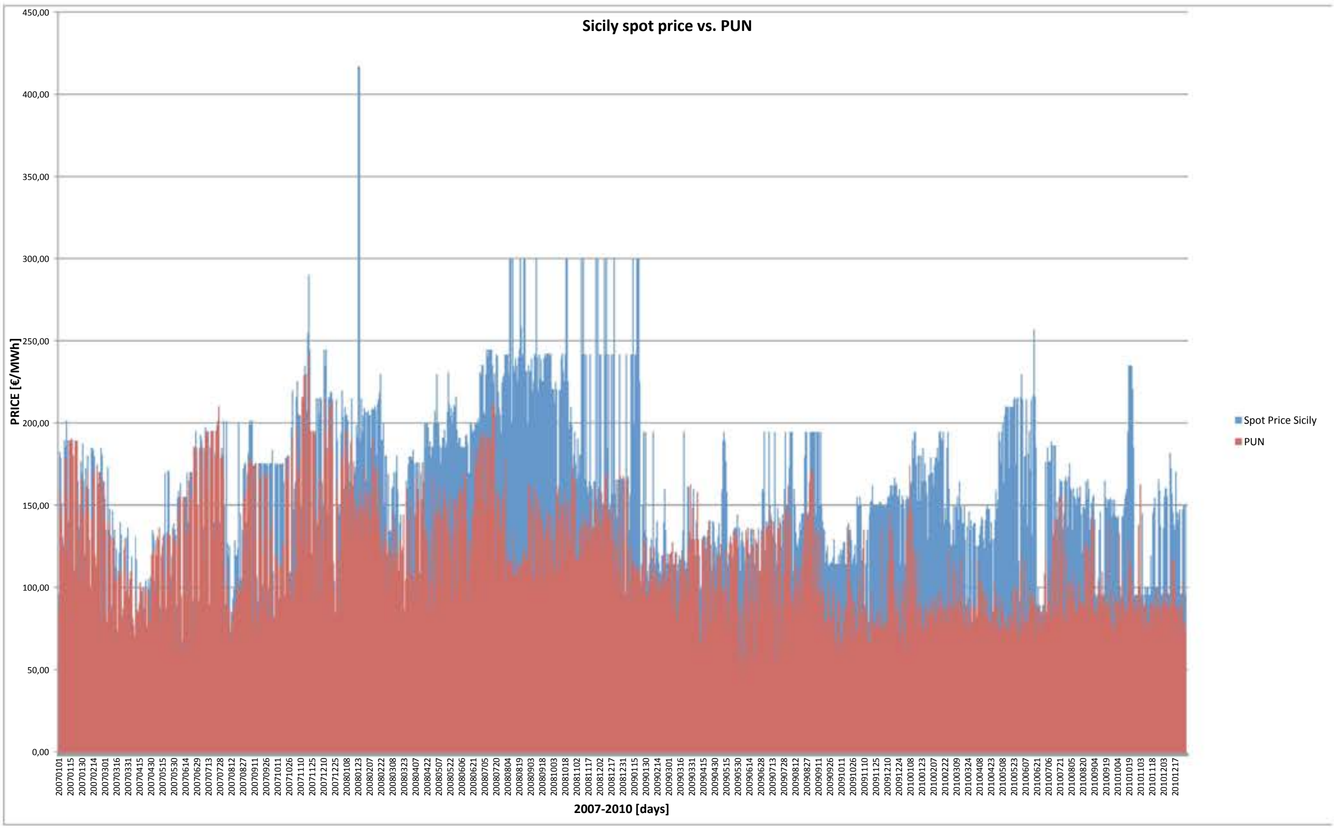


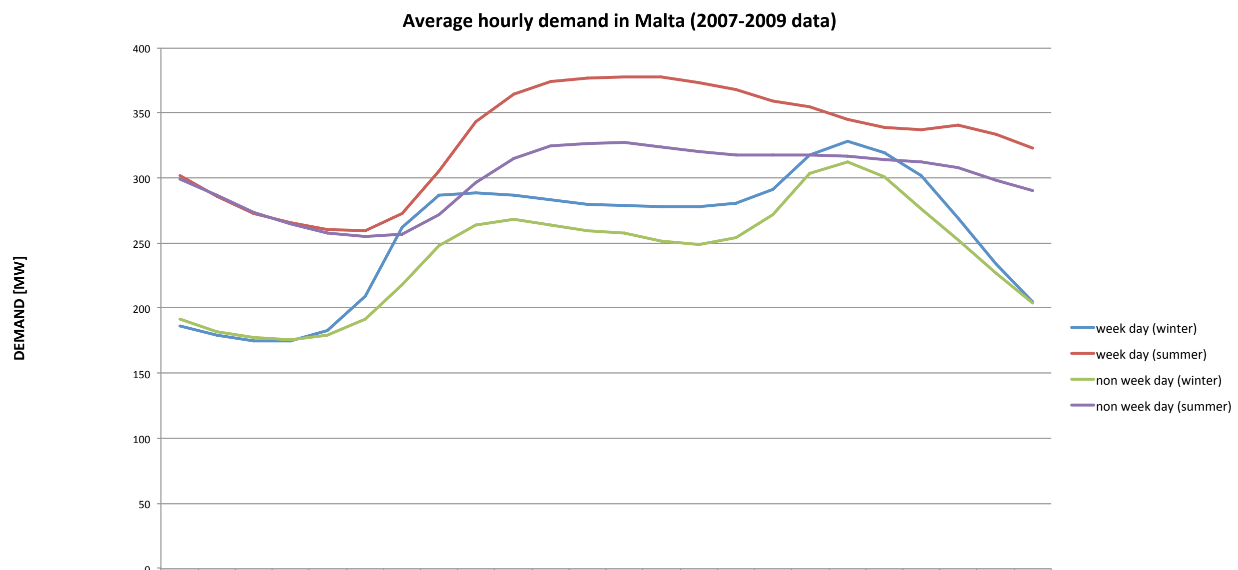
Fig. 29. Sicily spot price vs. PUN

[148] Cf. Terna (n.d.) and Enemalta (n.d.)

4.2.2 Available data for Malta

Demand data for Malta is established in a similar manner, i.e. the dataset contains the daily hourly demand for the period 2007 to 2010 in MW. Some preliminary data analysis was performed to obtain Fig. 30. It displays the average hourly demand differentiating between summer and winter, and week day respectively non week day. While for summer the data was taken from the months July and August, winter data was extracted from January and February (based on Malta's climate chart where July and August are the hottest and January and February the coldest months).

Week days are represented by Wednesdays, whereas non week day data is calculated on a Saturday basis. In short, the graph provides characteristic seasonal demand curves separating also between week days and non week days. The graphs show that demand is highest during week days in summer. Peak demand in summer occurs around 12 noon and 1 p.m. for both week and non week days (due to high cooling needs). Generally in winter the demand is lower, however, for some hours week day load can be higher than the demand on non week days in summer. This is typically around 9 a.m. and 7 p.m. the case when winter week days increasingly require heating. In winter peak demand is usually reached during the evening. Week day demand is predominantly higher than demand on non week days in summer and winter.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
week day (winter)	186	179	175	175	182	209	262	287	289	287	284	280	279	278	278	281	291	317	328	319	302	269	234	205
week day (summer)	302	286	273	266	260	259	273	305	343	364	374	377	378	377	373	368	359	354	345	339	337	341	334	323
non week day (winter)	192	182	177	176	179	192	218	248	264	269	264	260	258	252	249	254	272	304	312	301	276	252	227	204
non week day (summer)	299	287	274	265	258	255	256	272	296	315	325	327	327	324	320	318	317	318	317	314	312	308	298	291

HOUR [h]

Fig. 30. Representative hourly demand curves in Malta

Fig. 31. presents Malta's monthly demand calculated as the average demand from January to December by means of the 2007 to 2010 data. The summer months July and August exhibit the highest demand values, they exceed 300 MW and are followed by June

and September revealing values between 250 and 300 MW. Demand is lowest in April with 226 MW in average. For two-thirds of the displayed months demand goes below 250 MW.

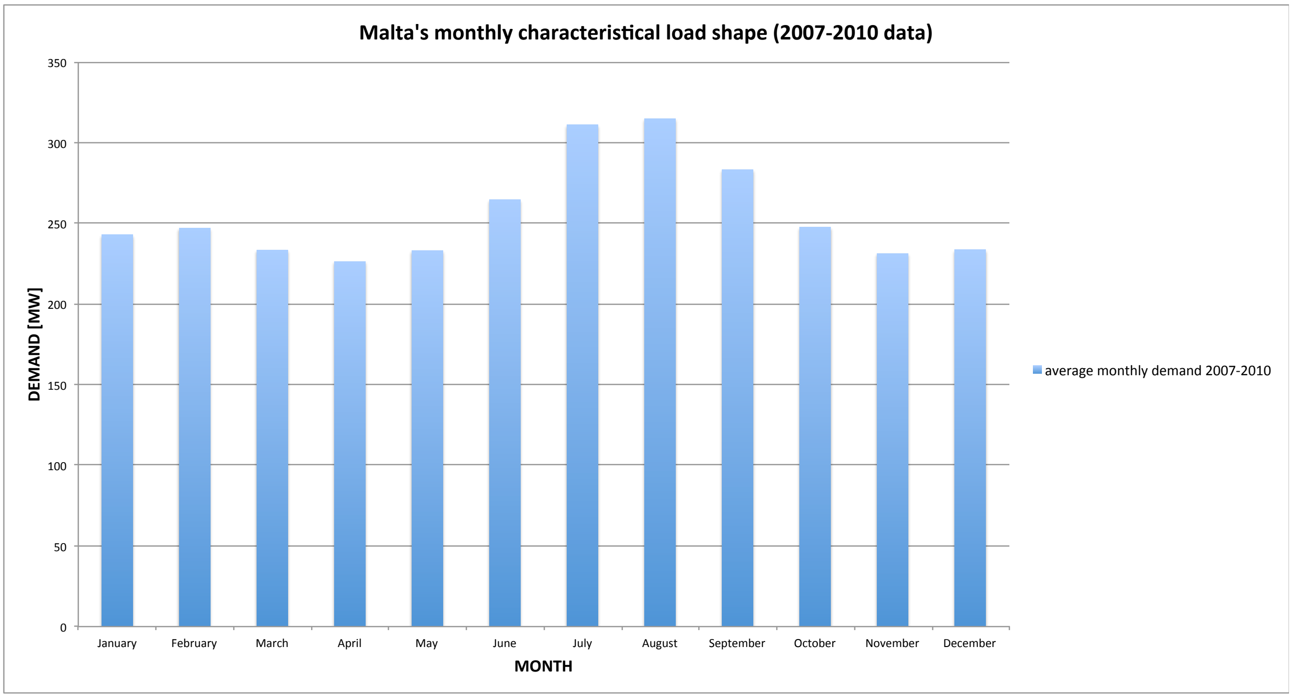


Fig. 31. Malta's monthly characteristical load shape

Eurostat statistics provide Maltese biannual electricity prices from 1991 to 2013 charged to domestic and industrial end consumers (retail tariffs). Hourly wholesale electricity price data (on a per hour basis as opposed to the data utilized for Sicily) for Malta is not available. The next chapter thus renders how to determine the marginal costs for electricity generation (equivalent to the electricity production price of each power plant) needed to assess whether and if so, to what degree importing electricity from Sicily is beneficial to Malta's citizens.

4.3 RESULTS – SENSITIVITY ANALYSIS

4.3.1 Simulation of marginal cost curves for electricity generation in Malta

Methodological approach and assumptions to determine supply curves

For Malta's marginal cost simulation this paper concentrates on two distinct electricity generation setups. The first setup reflects Malta's status of a small isolated system, it therefore comprises all power plants that were in operation in 2010. The second setting regards Malta's prospective electrical production capacities taking for granted that the interconnector is operational as of end 2014/2015. The latter considers both the complete shutdown of MPS and the installation of the new combined cycle diesel engines (CCDE) at DPS.

Tab. 11. lists the data to calculate the **electricity production prices/marginal costs** for the **isolated electricity generation setup of Malta's power system in 2010**. Data originates from Enemalta's official 2009 annual report.

Status 2010						
Technology	**Nominal capacity [MW]**	**Internal consumption / Losses [%]**	**Net capacity [MW]**	**Fuel rate [kg/kWh]**	**Thermal efficiency [%]**	**Fossil fuel**
DPS STEAM	120	5,50	113,40	0,27	31,12	HFO
DPS OCGT	74	5,50	69,93	0,36	23,32	GO
DPS CCGT	110	5,50	103,95	0,21	38,19	GO
MPS STEAM	230	5,50	217,35	0,32	26,12	HFO
MPS OCGT	37	5,50	34,97	0,40	20,71	GO
Total	571		539,60			

Tab. 11. Isolated electricity generation setup – Malta's EPS in 2010

- Technology

In 2010 three different types of generation technologies were installed in Malta, namely two steam driven plants one each at MPS and DPS, two open cycle gas turbines (OCGT) one each at MPS and DPS, and one combined cycle gas turbine (CCGT) at DPS. For this paper it is assumed to be sufficient to not further detail the composition of the respective plants.[149] Technical specificities of the plants differ as the following discussion shows.

- Nominal capacity [MW]

Nominal capacity is equivalent to nameplate, rated and installed capacity. As such the nominal capacity relates to the maximum programmed power output of the plant.[150] The installed capacity in 2010 totaled 571 MW.

- Internal consumption [%]

An official fuel optimization study to Enemalta states that power plants' internal electricity consumption (including losses) accounts in average for 5.5 percent.[151] Power plants usually utilize some of their own generated output to run the internal electric network. In other words, power plants generate a certain output of electricity that is not fed into the external grid.

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[149] For further information on the configuration of Malta's power plants consult for instance Enemalta (2009).

[150] Cf. e.g. U.S. Energy Information Administration (2014); „The maximum rated output of a generator under specific conditions designated by the manufacturer. Installed generator nameplate capacity is commonly expressed in megawatts (MW) and is usually indicated on a nameplate physically attached to the generator".

[151] Cf. IPA (2010), p. 12 and http://www.abb-conversations.com/2013/08/optimizing-power-plant-performance-for-energy-effiency/

- Net capacity [MW]

The column net capacity hence stands for the maximum electrical power each of Malta's power plants is able to send out to the (distribution) grid. Net capacity in megawatt is obtained by discounting the internal electricity consumption from the nominal installed capacity. For the isolated electricity generation setup in 2010 the net capacity totaled 539.60 MW.

- Fuel rate [kg/kWh]

The fuel rate for each power plant is given in kilogram per kilowatt hour. It specifies the quantity of fossil fuel needed to generate one kilowatt hour of electricity. Enemalta calculated the fuel rate using the 2010's overall fuel consumption value per power plant divided by the total amount of kilowatt hours electricity generated per plant.

- Thermal efficiency [%]

Thermal efficiency measures the degree of energy conversion which is always lower than 100 percent due to technological limitations. Values stem from Enemalta's 2009 annual report. It can be derived from the fuel rate which was presented beforehand. Generally, a higher fuel rate implies a lower thermal efficiency.

- Fossil fuel

In the 2010 generation setup, power plants either run on heavy fuel oil (HFO) or on gas oil (GO). Both HFO and GO are products obtained from processing crude oil. One major reason for GO being more expensive than HFO is due to its heating properties, i.e. GO has a higher calorific value than HFO and thus exhibits a higher energy value per kilogram of fuel (cf. fuel price calculation in the following).

Tab. 12. presents the data used to determine **the prices to produce electricity/marginal costs** for the **interconnected generation setup of Malta's power system as of 2014/2015**.

Status 2014/2015						
Technology	Nominal capacity [MW]	Internal consumption [%]	Net capacity [MW]	Fuel rate [kg/kWh]	Thermal efficiency [%]	Fossil fuel
DPS STEAM	120	5,50	113,40	0,27	31,12	HFO
DPS OCGT	74	5,50	69,93	0,36/0,31	23,32	GO/NG
DPS CCGT	110	5,50	103,95	0,21/0,19	38,19	GO/NG
DPS CCDE	149	3,89	143,20	0,18/0,15	46,70	HFO/NG
Total	453		430,48			
Malta-Sicily subsea cable	200	4,00	192,00			
Total with interconnector	653		622,48			

Tab. 12. Interconnected electricity generation setup – Malta's EPS as of 2014/2015

Assuming the commissioning of the subsea cable between Malta and Italy in late 2014 respectively during 2015 will change the previously presented 2010 generation setup (primarily the installed production capacity). While the mandatory shutdown of MPS reduces the nominal electric generation capacity down to 304 MW, the Delimara extension – a combined cycle diesel engine (CCDE) with a nominal capacity of 149 MW – and the interconnector with a rated capacity of 200 MW increase the total available capacity from former 571 MW to 653 MW. For DPS plants the internal consumption remains the same as in Tab. 11., solely the new CCDE displays a lower value with 3.89 percent.[152] In sub chapter 3.1.2 on the technical features of the subsea cable, the technical losses for the interconnector were listed with four percent. Malta‘s EPS net capacity as of 2014/2015 therefore equals 622.48 MW. Thermal efficiency is assumed unmodified. For the CCDE Enemalta specified a thermal efficiency of 46.70 percent which is significantly higher compared to the other power plants at DPS. For the OCGT, CCGT and CCDE this paper introduces two separate fuel rates since these technologies are technically capable and could prospectively be operated not only on GO (OCGT and CCGT) and HFO (CCDE) but also on natural gas (NG). Tab. 13. provides the calorific values for HFO, GO and NG. In this instance the fuel rate was approximated for the new installed CCDE considering a calorific value of 43 MJ/kg for HFO (cf. equation (3)). Accordingly, the NG fuel rates for the DPS OCGT and CCGT as listed in Tab. 12. were computed.

(3)
$$CCDE_{fuel\,rate\_HFO} = \frac{3.6\,\frac{MJ}{kWh}}{43\,\frac{MJ}{kg} \times 0.467} = 0.18\,\frac{kg}{kWh}$$

	Calorific values [MJ/kg]
HFO	43,00
GO	46,00
NG	50,00
	Conversion 1MWh=3600MJ

Tab. 13. Calorific values of fossil fuels[153]

Marginal cost scenarios for Malta‘s EPS in 2010

An essential requirement of this thesis is to calculate the marginal costs, i.e. the price to produce electricity, for the Maltese power plant portfolio. For this calculation the major indicator is the fossil fuel price. The significant fluctuation of oil prices has been revealed in the course of the analysis (cf. for example Fig. 10.). To incorporate such fuel price volatility in the marginal electricity production cost determination, this paper proposes three distinct oil price scenarios, namely the i.) **base oil price scenario (BOPS)**, ii.) **low oil prices scenario (LOPS)** and iii.) **high oil price scenario (HOPS)**. Tab. 14. renders the fuel prices in euro per megawatt hour for the different fossil fuels in each scenario that were postulated in an official fuel optimization study to Enemalta.

[152] Cf. Enemalta (2013)

[153] Kaye and Laby (2014); Calorific values of solid, liquid and gaseous fuels.

Once more the calorific values (cf. Tab. 13.) of HFO, GO and NG were needed to convert the fuel price unit from euro per megawatt hour into euro per kilogram. Hereafter, the fuel price calculation for HFO in the BOPS is shown exemplarily, prices for the other cases and fuel types were simulated correspondingly.

(4)
$$Fuel\ price_{BOPS\_HFO} = 35\frac{€}{MWh} \times 43\frac{MJ}{kg} = 35\frac{€}{3600MJ} \times 43\frac{MJ}{kg} = 0.42\frac{€}{kg}$$

		Fuel prices [€/kg]	Fuel Price [€/MWh]
BOPS	HFO	0,42	35,00
	GO	0,74	58,00
	NG	0,42	30,00
LOPS	HFO	0,24	20,00
	GO	0,41	32,00
	NG	0,28	20,00
HOPS	HFO	0,60	50,00
	GO	1,02	80,00
	NG	0,56	40,00

Tab. 14. Fuel prices for three different scenarios[154]

The data shown in Tab. 14. was the last ingredient needed to compute marginal costs, i.e. the prices to generate electricity for Malta's power plants. Mathematically the marginal cost scenarios for Malta's EPS in 2010 are expressed as the product of fuel rate (cf. Tab. 11.), fuel price (cf. Tab. 14.) and a factor to compensate the internal electricity consumption costs (see data Tab. 11.).

(5)
$$MC_{ijk} = fuel\ rate_i \times fuel\ price_{jk} \times (1 + internal\ consumption_i)$$
$$MC_{DPS\ STEAM\_BOPS\_HFO} = 0.27\frac{kg}{kWh} \times 0.42\frac{€}{kg} \times 1.055 = 0.12\frac{€}{kWh}$$
$$Where\ \ MC = Electricity\ generation\ price_{ijk}$$

Tab. 15. was completed accordingly. It reveals the marginal costs in euro per kilowatt hour for the five generators with regard to the BOPS, LOPS and HOPS.

	Marginal Costs [€/kWh]		
	BOPS	LOPS	HOPS
DPS STEAM	0,12	0,07	0,17
DPS OCGT	0,28	0,15	0,39
DPS CCGT	0,16	0,09	0,23
MPS STEAM	0,14	0,08	0,20
MPS OCGT	0,32	0,17	0,44

Tab. 15. Marginal cost scenarios for Malta's EPS in 2010

[154] Cf. IPA (2010), p. 18

By means of the calculated data, in particular the net generation capacity (x-coordinate) and the electricity production price (y-coordinate), we were able to construct the marginal cost curves (also known as supply curves) for Malta's EPS in 2010 with respect to the three distinct oil price scenarios.

Fig. 32. solely considers the BOPS. DPS and MPS steam plants together have a net generation capacity of over 330 MW. In the 2010 generation setup these plants exhibit the lowest marginal electricity production costs and are typical base load units. DPS's CCGT marginal generation costs are moderately above the two latter plants, whereas DPS's OCGT and MPS's OCGT electricity production prices are significantly higher, especially provoked due to the considerable price differential between HFO and GO, i.e. with regard to the BOPS, GO costs are some 76 percent higher compared to HFO. Fig. 33. includes altogether the BOPS, LOPS and HOPS into one single graph to account for possible fuel price volatility. Plants' net capacities remain as they were shown in Fig. 32. Marginal costs for each of the five plants are different depending on the calculated fuel price in the respective scenario. The stepwise supply curves for the LOPS and HOPS are thus shifted in the price axis, that implicates a downshifted curve for the first case and an upshifted curve for the latter (the colors used in Fig. 33. refer to Tab. 15.).

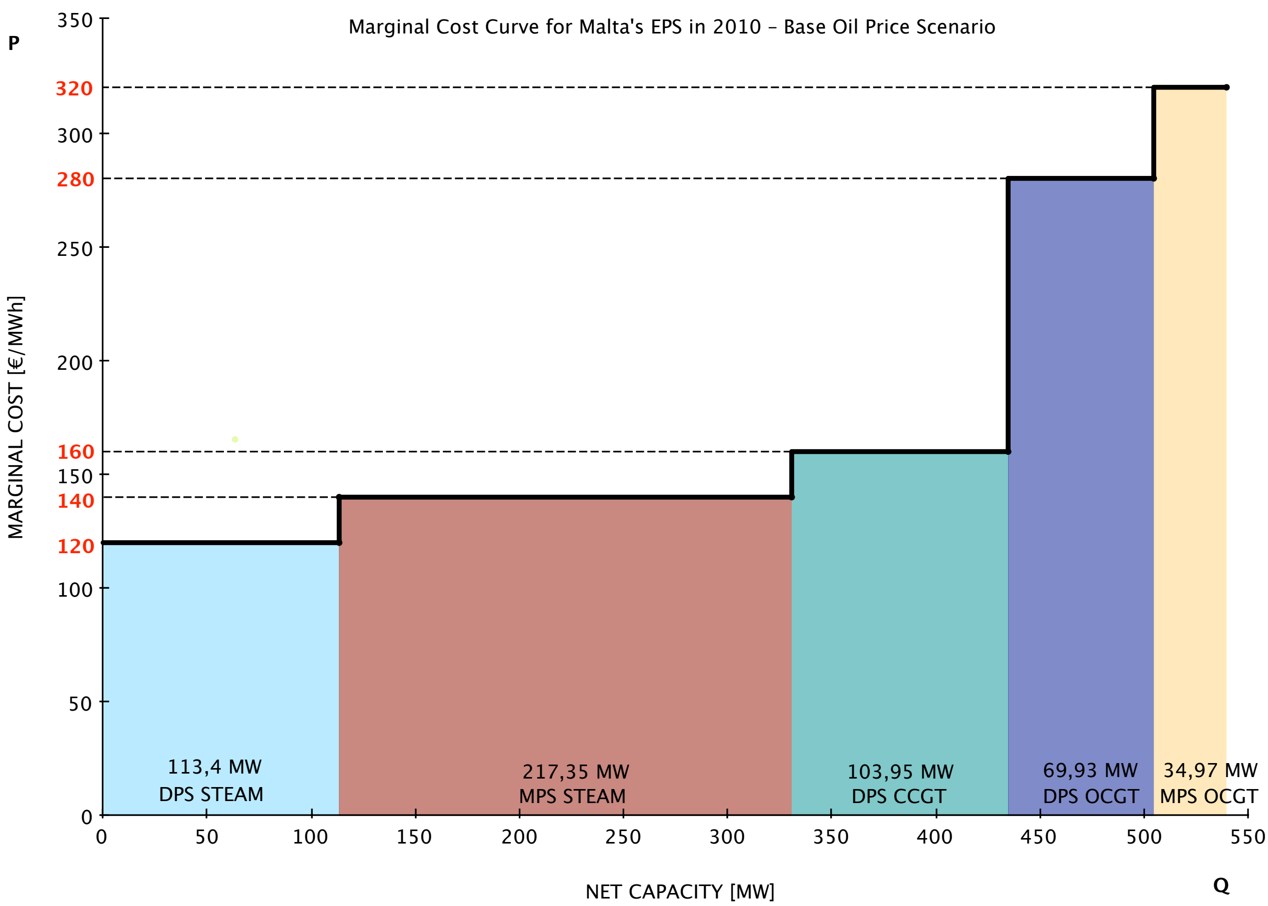

Fig. 32. Marginal cost curve for Malta's EPS in 2010 – BOPS

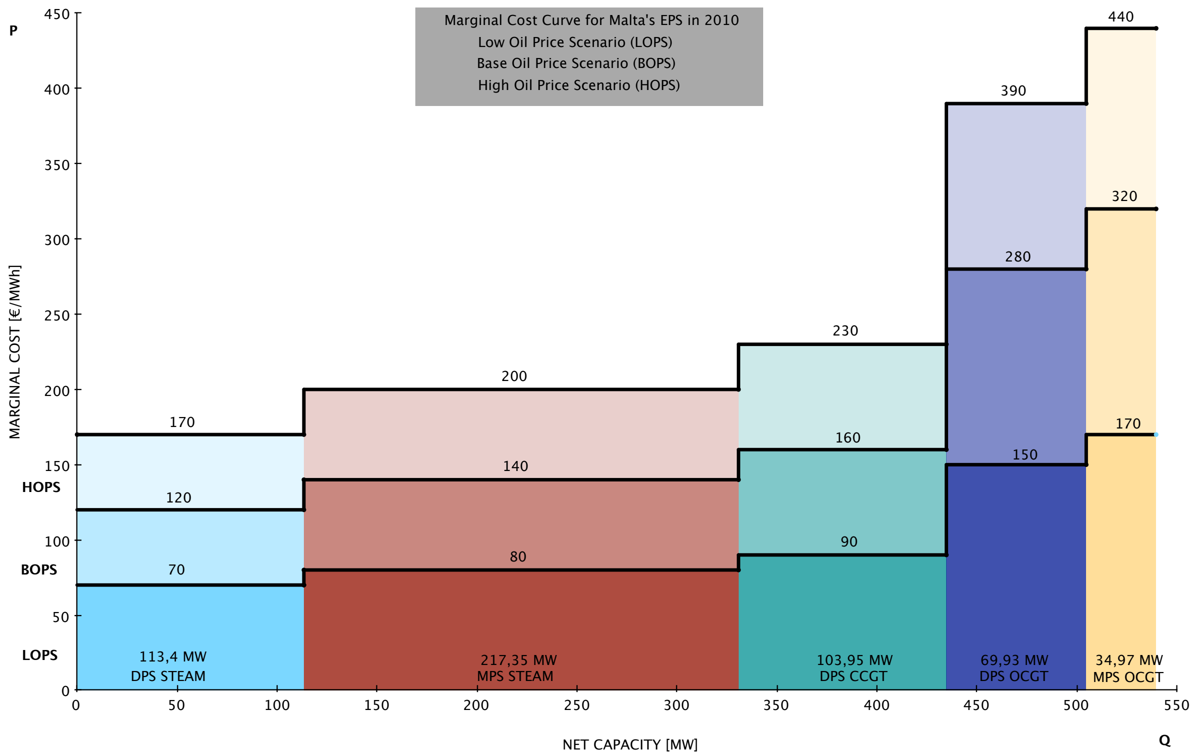

Fig. 33. Marginal cost curve for Malta's EPS in 2010 – BOPS, LOPS and HOPS

Marginal cost scenarios for Malta's EPS as of 2014/2015

The marginal cost calculation for Malta's EPS as of 2014/2015 refers to the data presented in Tab. 12. (fuel rates and internal electricity consumption compensation factors) and Tab. 14. (fuel prices for the three different scenarios). Tab. 16. therefore renders the electricity generation prices for the „updated" power plant mix including the Delimara extension and the shutdown of MPS. Calculations were carried out like in equation (5). Moreover, Tab. 16. not only lists the marginal costs for the BOPS, LOPS and HOPS, it also displays them for all three scenarios under the hypothetical assumption that the OCGT, CCGT and CCDE could prospectively run on natural gas.

	Marginal Costs [€/kWh]					
	BOPS	LOPS	HOPS	BOPS including NG	LOPS including NG	HOPS including NG
DPS STEAM	0,12	0,07	0,17	0,12	0,07	0,17
DPS OCGT	0,28	0,15	0,39	0,14	0,09	0,18
DPS CCGT	0,16	0,09	0,23	0,08	0,06	0,11
DPS CCDE	0,08	0,04	0,11	0,07	0,04	0,09

Tab. 16. Marginal cost scenarios for Malta's EPS as of 2014/2015

Equivalent to the hitherto existing generation setup the supply curves for Malta's EPS as of 2014/2015 for the i.) BOPS (cf. Fig. 34.), ii.) BOPS, LOPS and HOPS (cf. Fig. 35.) and iii.) BOPS including NG (cf. Fig. 36.) were developed. While the marginal cost and net capacity for DPS STEAM, DPS OCGT and DPS CCGT remain unchanged compared to the BOPS in Fig. 32., the DPS CCDE modifies the supply curve being the new cheapest unit.

Interestingly, when including natural gas in the base oil price scenario, the order of the marginal cost dispatch changes. As NG has a significant cost advantage compared to GO and an equal price compared to HFO in the BOPS (cf. Tab. 14.), the lower fuel rate of DPS's CCGT led it switch (with DPS STEAM) from the unit with the third highest electricity production price to the second lowest.

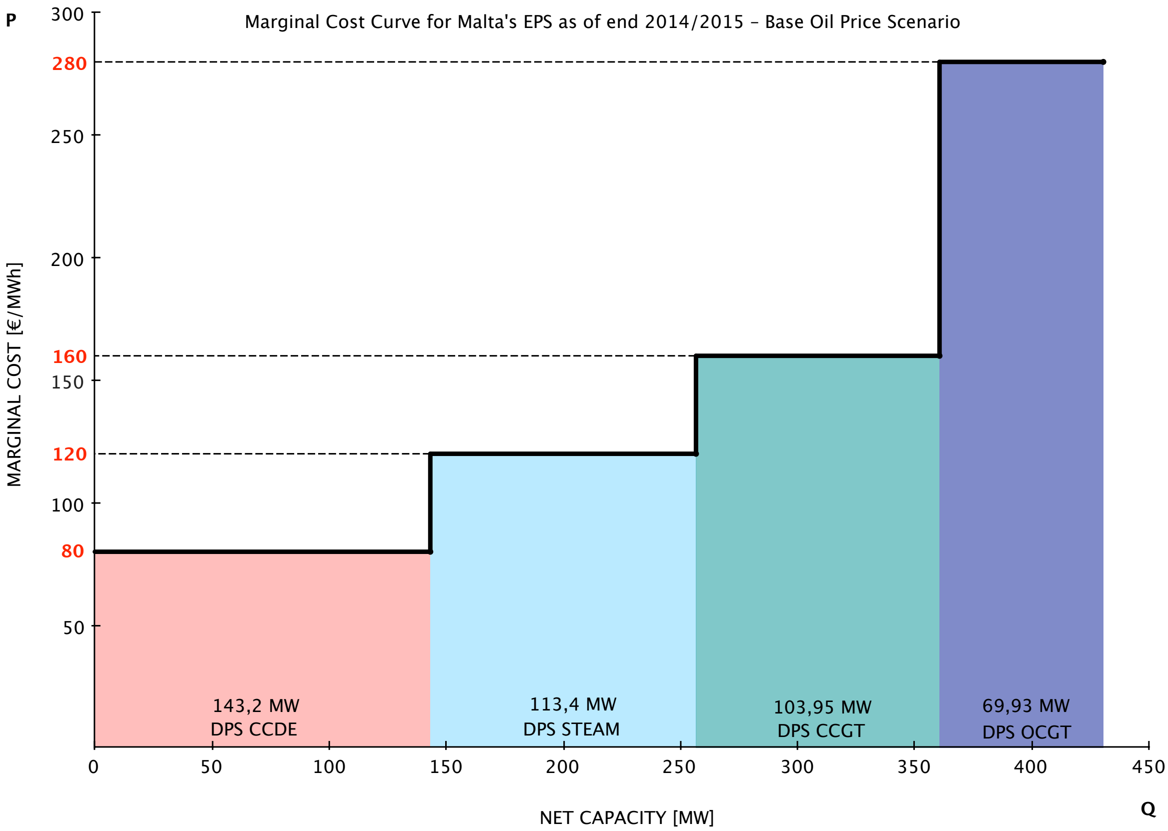

Fig. 34. Marginal cost curve for Malta's EPS as of 2014/2015 – BOPS

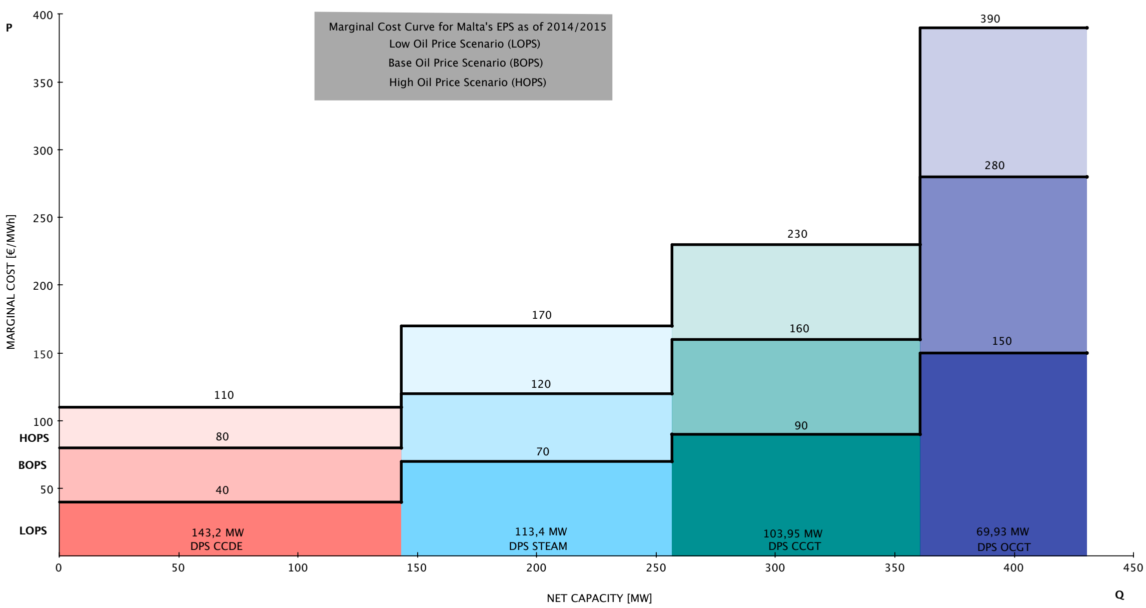

Fig. 35. Marginal cost curve for Malta's EPS as of 2014/2015 – BOPS, LOPS and HOPS

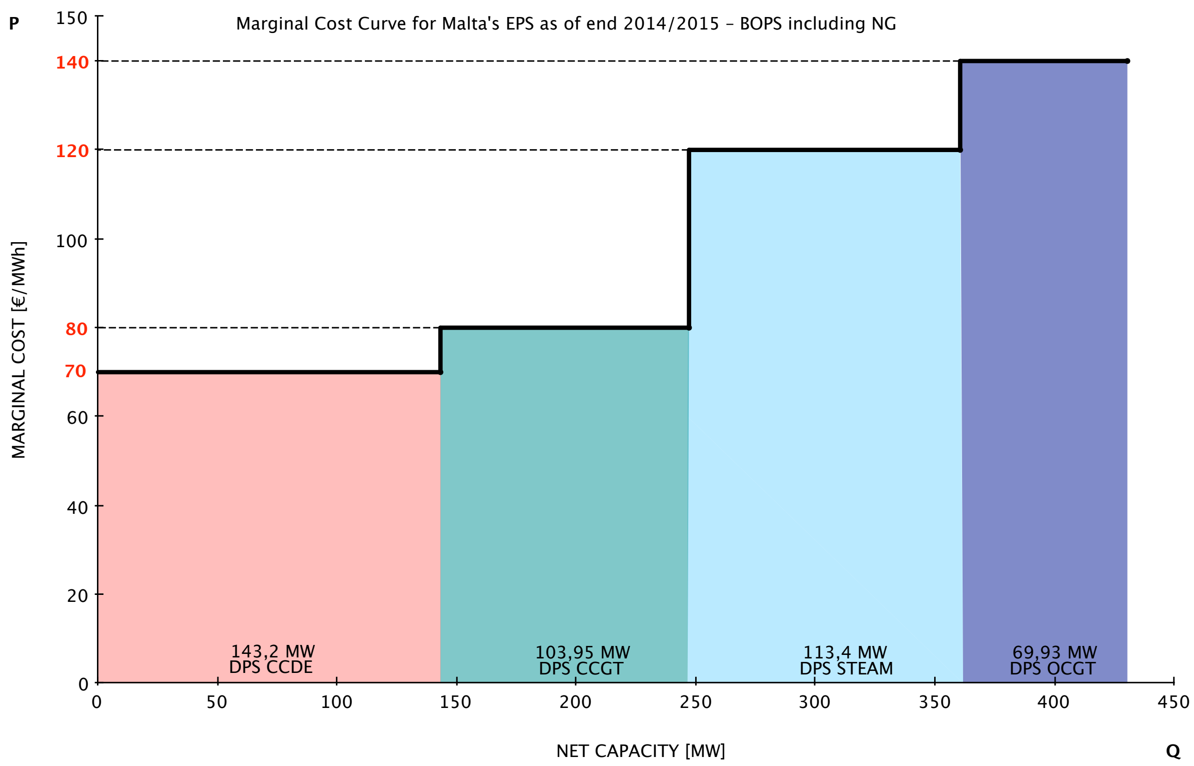

Fig. 36. Marginal cost curve for Malta's EPS as of 2014/2015 – BOPS including NG

4.3.2 Base case: Price scenarios without interconnector

Malta's average electricity generation price – Alternative 1: Malta's EPS in 2010

Malta's average electricity generation price was computed in Excel by means of the previously calculated marginal costs for the different power plants in Malta (cf. Tab. 15.) and the available demand data. However, the price determination corresponding to the respective hourly demand (in total more than 35,000 hours in four years) necessitated some intermediate steps. A key requirement to obtain the single electricity generation prices that correspond to the hourly demand values was to establish an algorithm that dispatches the plants like in Fig. 32. ff. according to ascending net capacity and marginal costs, i.e. the 35,064 demand values had to be matched with the marginal cost curve/ supply curve for Malta's EPS in 2010.

To be able to calculate the average electricity generation price for Malta's isolated EPS, first of all the electricity generation price for each hour for the considered dataset had to be determined. In Excel a sheet with the corresponding plant characteristics (in a first instance for the BOPS), i.e. their electrical net generation capacities, marginal costs (retrieved from the previously performed calculations) and cumulative generation capacities was established. An if-logic was written to decide whether – depending on the demand – the respective plant operates, and if so, to define the power plant‘s individual electricity generation price for the considered demand value. To determine the power plant‘s individual electricity generation price the if-loop checks first the power plant with lowest marginal cost and corresponding generation net capacity. If the cumulative generation capacity is lower than the hourly demand value, Excel runs until the demand value is met by the cumulative generation capacity and assigns the corresponding price/ marginal cost value of the last power plant in the merit order.

Equation (6) reveals how the Maltese average electricity generation price was computed. It is the sum of the product of Malta‘s hourly electricity generation prices and the referring demand values divided by the sum of the hourly demand between 2007 and 2010. With regard to our dataset in **alternative 1: Malta‘s EPS in 2010, the electricity generation price** for the **BOPS averaged 142.7 euro per megawatt hour.**

(6)

$$P_{MT} = \frac{\Sigma\,(P_{Malta} \times D_{Malta})}{\Sigma\, D_{Malta}}$$

Where

P_{Malta} *Maltese hourly electricity generation price in* $\frac{€}{MWh}$

D_{Malta} *Maltese hourly electricity demand in MWh*

P_{MT} *Maltese average electricity generation price in* $\frac{€}{MWh}$

Malta‘s average electricity generation price – Alternative 2: Malta‘s EPS as of 2014/2015

Accordingly the **average electricity generation price** for **alternative 2: Malta‘s EPS as of 2014/2015** was computed. While the **Maltese average electricity production price** with the **future generation setup** for the **BOPS equals 151.5 euro per megawatt hour**, the equivalent setup **incorporating natural gas** as potential fossil fuel renders an **average electricity generation price of 98.4 euro per megawatt hour**.

So far, our main finding in addition to the implementation of the marginal cost curves for Malta‘s EPS is that for the examined dataset the average electricity generation price for Malta‘s power system in alternative 2 is significantly higher (some 6 percent) compared to the „traditional“ power plant production setup in alternative 1. When NG is incorporated in alternative 2, the price is yet the lowest. More precisely the BOPS NG alternative undercuts alternative 1 by more than 30 percent and alternative 2 by approximately 35 percent when solely HFO and GO are considered.

Moreover, the approach of simulating the average electricity generation price for distinct generation setups enabled to clearly identify the principal drivers that prompt cost increases. In sum, generators' different technical characteristics, in particular the fuel rate which depends on the calorific value of the utilized fossil fuel and the plant's thermal efficiency, and the fuel price reliance majorly influence Malta's average electricity generation price for the two revealed alternatives. This first part of the simulation primarily concentrated on the analysis of two cases, firstly Malta's isolated electricity generation setup and, secondly the „updated" plant mix with the additional interconnection capacity.

However, so far the calculations were performed without operating the cable, i.e. the results do not incorporate electricity imports or exports through the interconnector. Although the simulations have not included electricity transmission capacities yet, it was relevant to assess the average electricity production prices under Malta's future generation portfolio since, for instance, due to a cable failure or significant delays in its construction works could end up in Malta's EPS remaining isolated (for an indefinite time). In the following this thesis goes one step further and simulates explicitly the interconnection case.

4.3.3 Interconnection case: Price scenarios with interconnector

Malta's average electricity generation price – Alternative 3: 100 percent electricity import from Sicily

The available Sicilian hourly electricity spot prices and the Maltese hourly electricity demand data enabled to determine a first value of interest for the interconnection case, namely Malta's average electricity purchase price assuming that the total demand would have been satisfied by solely importing electricity from Sicily regardless of the cable's capacity. This purchase price is equivalent to the Sicilian average electricity generation price. For **alternative 3: 100 percent electricity import from Sicily** – considering exemplarily the available 2007 to 2010 price and demand data – the **Maltese electricity purchase price averages 101.6 euro per megawatt hour**. Computation was performed as follows in equation (7).

(7)

$$P_{MT} = \frac{\Sigma\,(P_{Sicily} \times D_{Malta})}{\Sigma\,D_{Malta}}$$

Where

P_{Sicily} *Sicilian hourly electricity spot price in* $\frac{€}{MWh}$

D_{Malta} *Maltese hourly electricity demand in MWh*

P_{Malta} *Maltese average electricity purchase price in* $\frac{€}{MWh}$

Tab. 17. recapitulates the average electricity generation price for the three alternatives.

Malta's average electricity generation price [€/MWh]		
Alternative 1: EPS in 2010	Alternative 2: EPS as of 2014/2015	Alternative 3: 100 percent import
142.7	151.5	101.6
	98.8 (including NG)	

Tab. 17. Summary table for different alternatives of Malta's average electricity generation price in the BOPS

The indicators in Tab. 17. provide a preliminary benchmark for Malta's average electricity generation price assessment. While alternatives 1 and 2 do not take into account the subsea cable's operation, alternative 3 acts on the assumption that Malta satisfies its total demand with electricity imports from Sicily. Although at present alternative 3 is merely hypothetical, since the cable has a net capacity lower than 200 megawatt and Malta's monthly load in average exceeds this value (cf. Fig. 31.), the option gives a first vision of the electricity purchase price level (and can become even more relevant when authorities pursue the idea of installing a second cable).

It is noteworthy that alternative 3 simulates an extreme scenario, namely that Malta's entire electricity supply is safeguarded by the interconnector. In practice this over-dependency on the cable's electric power imports would foster the island's state vulnerability to potential cable breakdowns. However, despite its theoretical nature, alternative 3 demonstrates that the average electricity generation price is significantly lower compared to Malta's generation setup in 2010 (alternative 1) and the future setup as of 2014/2015 (alternative 2). But the 100 percent electricity import alternative also shows that its average electricity production price is slightly higher than in alternative 2 when NG is included.

For now the calculated figures vitiate our hypothesis that electricity imports through the submarine cable do not inherently favor electricity prices for Maltese consumers. However, especially alternative 2 involving NG renders a future scenario in which prices are even lower and confirm the Sicilian high purchase price level. In the following this thesis further details the interconnector simulation. Even if Maltese electricity prices in the isolated case per se seem high and the interconnector possibly represents a viable remedy (cf. alternative 3), there is no evidence about the distribution of rents between utility (Enemalta) and consumers (e.g. retail prices).

Interconnector simulation – Example case in summer 2007

Fig. 37., Fig. 38. and Fig. 39. have implemented the interconnector and display the electricity supply and demand curves for two hours of a single day in summer 2007. These snapshots reveal exemplarily whether, and if so, to what extent the interconnector is utilized to import electricity to Malta's EPS (at this stage electricity exports are not considered). Demand values for the two reviewed hours represent the day's minimum and peak load. During the minimum demand hour Sicily's spot price is significantly lower than Malta's cheapest generator (in all three setups), that is why the interconnector supplies the lion's share of electricity, namely its full net capacity of 192 megawatt. The remaining quantity is provided by the plant with the lowest electricity production price/marginal costs in the respective generation setup. The other generators do not produce. For peak demand a distinct pattern of electricity import is observed. Since the Sicilian spot price at peak hour in this example summer week day is considerably higher than the marginal generation costs of the units that are required to satisfy the total demand, solely the future plant mix in Fig. 38 makes use of the interconnector to import a small capacity. As Fig. 37. and 39. demonstrate, for the selected peak demand hour Malta's power plants are more affordable than electricity imports through the cable.

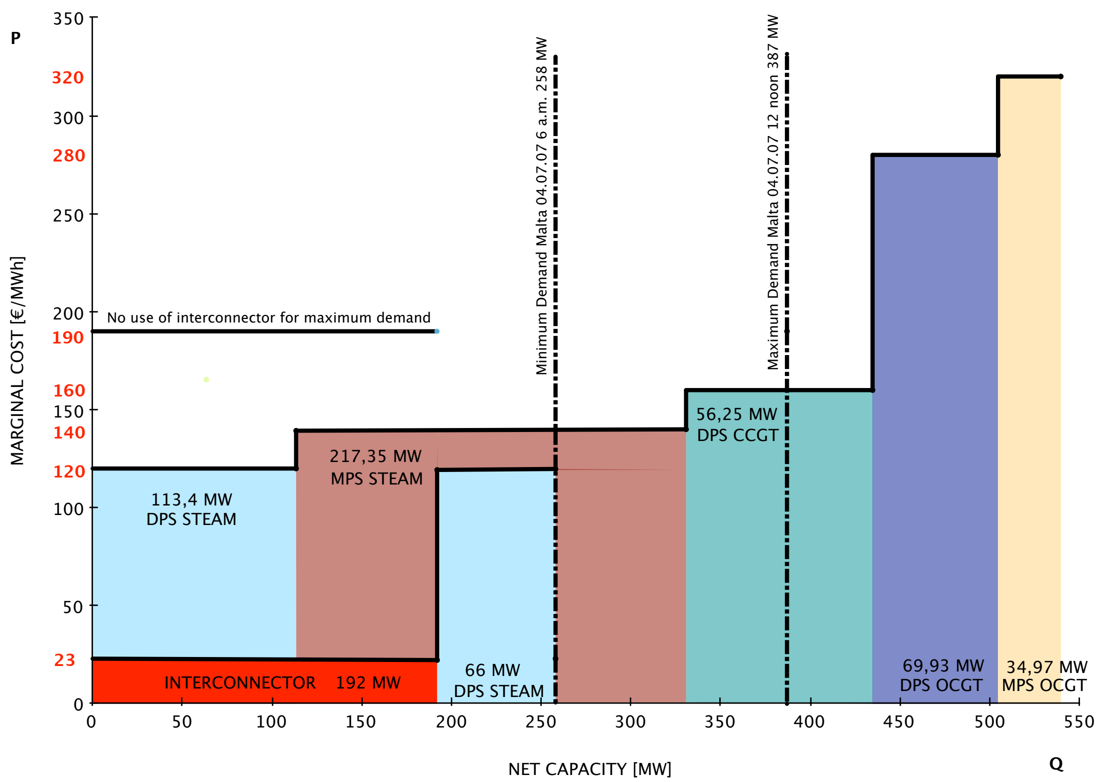

Fig. 37. Interconnector example for Malta's EPS in 2010 (BOPS)

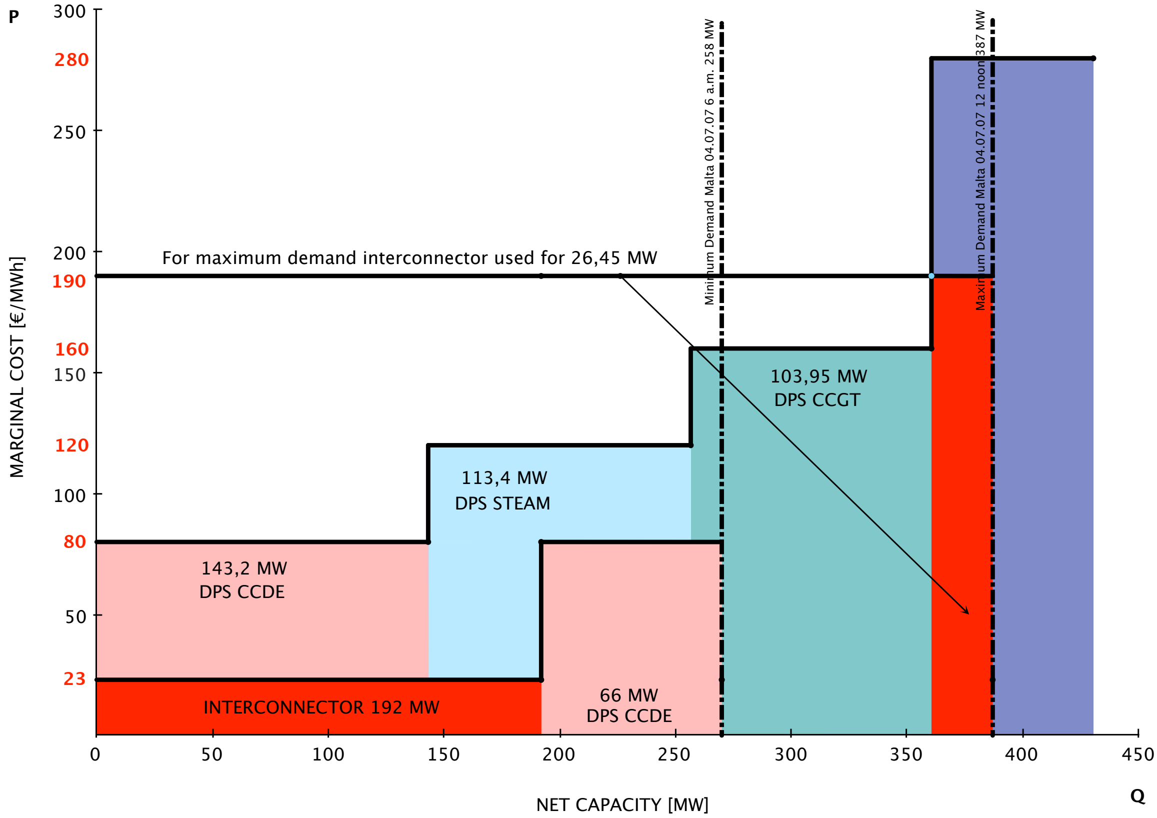

Fig. 38. Interconnector example for Malta's EPS as of 2014/2015 (BOPS)

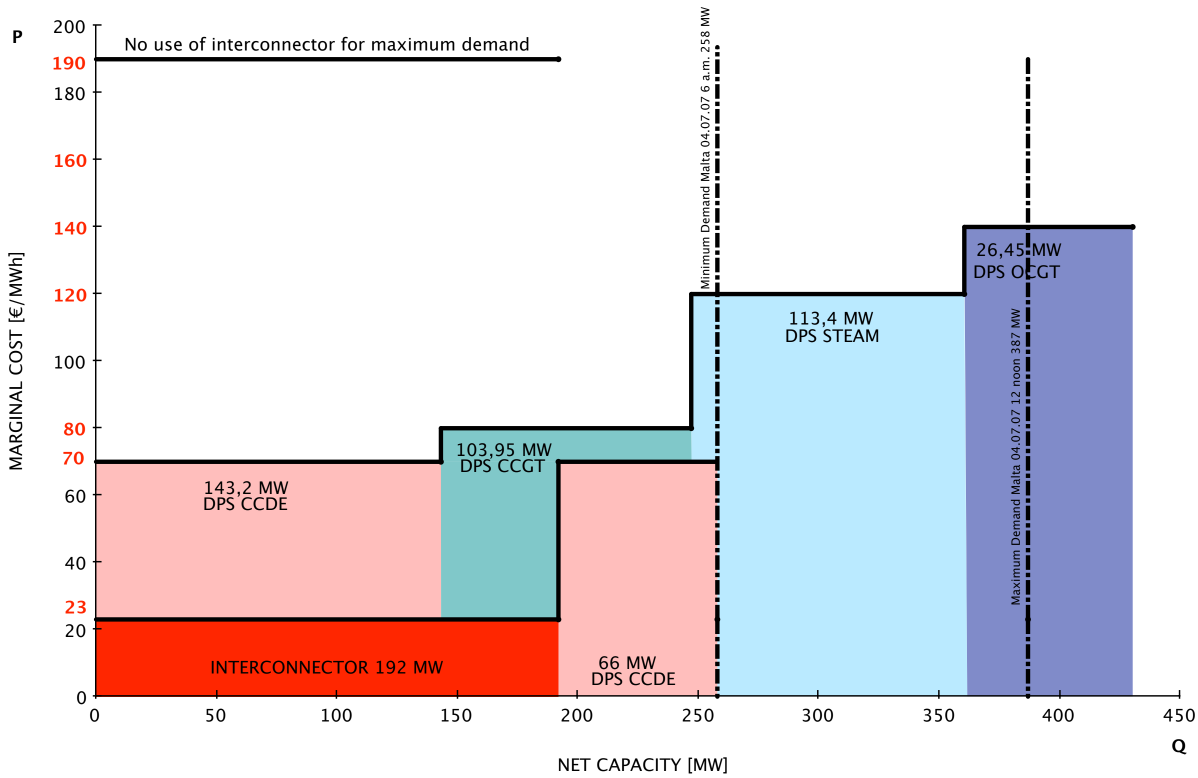

Fig. 39. Interconnector example for Malta's EPS as of 2014/2015 (BOPS including NG)

This manual simulation is not sufficient to draw final conclusions from the interconnection case. So far, it only reviewed two hourly snapshots of one particular day of our dataset and provides a general idea on how price scenarios look like when the link becomes operational. But to generally assess the cable's impacts a more sophisticated logic is needed that comprises the amount of hours during which electricity is imported respectively exported and determines the transferred quantities between Malta and Sicily. An automated algorithm was thus developed as follows.

Interconnector simulation in MATLAB

This thesis used MATLAB to simulate the interconnector's utilization. The algorithm's code is shown in appendix 1 for the generation setup 2010 and the BOPS (to compute the results for other generation setups and oil price scenarios the figures were changed accordingly). In the following we will have at look at its gradual development and highlight the essential components such as data processing, Malta's price determination and the implementation of electricity quantity import and export.

- Data import (Cf. line 3 ff. in appendix 1)

The MATLAB simulation refers to the equivalent data utilized to construct the marginal cost curves. Hourly spot price data for Sicily and hourly demand data for Malta therefore was imported for the period 2007 to 2010.

To simplify the simulation entirely inelastic demand was assumed, i.e. that the quantity demanded is unresponsive to changes in the price.

- Determination of Malta's price without interconnector (Cf. line 11 ff. in appendix 1)

The first major requirement to determine the Maltese electricity generation price was to establish the power plant characteristics, namely their electrical production net capacities and corresponding marginal costs that were retrieved from the calculations carried out in sub chapter 4.3.1. The next step was to determine the cumulative generation capacity which is required to simulate the stepwise supply curve. Malta's electricity spot price for every hour in the considered period is computed by means of a for-while-logic. For every hour first the marginal cost value of turbine one is assigned. However, this is solely true when the generation net capacity of the first power plant is sufficient to satisfy the demand. The while loop thus checks whether the cumulative generation capacity is lower or equal than the hourly demand value and if so, it runs until the demand value is met by the cumulative generation capacity and assigns the corresponding price/marginal cost value of the last power plant in the merit order. It is noteworthy that this report assumes all plants (in all generation setups and scenarios) being available 100 percent which further eases the simulation. To utilize the study‘s results in practice/industry, plants‘ availability factors must be checked since deviating availability can change the merit order and thus results in distinct electricity prices. As stated this paper neglects this effect.

- Determination of quantity imported and exported (Cf. line 43 ff. in appendix 1)

So far, the algorithm did not consider the interconnection case. The implementation of the interconnector inside MATLAB first necessitated to establish its characteristics such as the technical losses of four percent. To determine the quantity imported through the cable, the interconnector‘s net capacity of 192 MW and its purchase price (that is the Sicilian spot price depending on every hour between 2007 and 2010 multiplied by a compensation factor to account for the costs that result from the cable losses) were added to the matrix of power plant characteristics (cf. paragraph above). The matrix was extended by a third column that writes „1“ for Malta‘s power plants and „2“ for the interconnector to determine the cable‘s position in the merit order. A price, firstly, to align each plant‘s electricity generation price/marginal cost (including the cable) in ascending order, and secondly, to establish the merit order with regard to the net generation capacity (in particular the cumulative generation capacity) was introduced.

For electricity import two separate scenarios must be taken into account, i.e. in i.) we assume that the cable renders the lowest marginal cost in the merit order and its net capacity alone can satisfy the demand, then the total electricity quantity demanded can be imported from Sicily (with a limit of 192 MW) whereas in ii.) the cumulative generation capacity/net capacity of the submarine cable is lower than the demand to be satisfied and the algorithm therefore has to determine the cable‘s position within the merit order to evaluate whether electricity should be imported (no import will take place if the Sicilian spot price is too high), and if so, the logic also finds out the quantity to be imported to Malta. In short, in scenario ii.) three distinct options exist that are the import of a certain quantity, namely Malta‘s demand value minus the cumulative generation capacity (cf. Fig. 38. to satisfy maximum demand), the import of the cable‘s full capacity of 192 MW (cf. Fig. 37., Fig. 38. and Fig. 39. for minimum demand) and no electricity import in case the Sicilian price is higher than the marginal cost of Malta‘s plant(s) needed to meet the demand (cf. Fig. 37. and Fig. 39. for peak demand).

For electricity export the logic was set up accordingly. As stated above for the case of electricity import the algorithm already determined the situation in which no electricity is imported, i.e. in other words the no import case defines the scenario of electricity export. However, a small adjustment is needed to account for the particular situation where Malta‘s marginal cost equals the Sicilian price. Electricity is exported to Sicily if and only if the Maltese price is lower than the Sicilian spot price multiplied by 0.96 (due to the cable losses; this avoids electricity exports in situations where the Sicilian spot price is marginally higher than the Maltese price). The quantity to export is obtained from the differential between cumulative generation capacity and the demand value for every hour. Given that in certain hours the Sicilian price is much higher than the generation prices of Maltese power plants, Enemalta can achieve profits through electricity exports (cf. discussion on consumer impacts and rents).

- Determination of Malta‘s price with interconnector (Cf. lines 46, 57, 64, 78 in appendix 1)

To define Malta‘s electricity generation price in the interconnection case necessitated small adjustments in the MATLAB code with regard to quantity import and export. Basically Malta‘s electricity price is computed accordingly to the scenarios i.) in which the cable‘s net capacity alone can satisfy the demand and exhibits the lowest marginal cost, therefore the total electricity quantity demanded can be imported from Sicily (with a limit of 192 MW) and ii.) where the cumulative generation capacity/the submarine cable‘s net capacity is lower than the demand to be satisfied and the algorithm therefore has to determine the cable‘s position within the merit order to evaluate whether and which amount of electricity should be imported. While for i.) Malta‘s electricity price is equal to the Sicilian spot price multiplied by the cost compensation factor to account for the cable losses in ii.) the Maltese price equals the clearing price that results from the dispatch in order to meet the demand. For the case of electricity export the price is obtained equivalent to alternative ii.).

- Determination of the rent with and without interconnector (Cf. line 30/31, 87 ff. in appendix 1); Example cases for the rent calculation are provided in chapter 4.3.4.

With regard to Malta‘s isolated power system the algorithm computes the rent as the product of the generation net capacity of the respective turbine and the differential between clearing price (last turbine in the merit order to satisfy the demand) and the turbine‘s marginal cost. The logic thus enables to calculate the total supplier rent without interconnector (it is the sum of the individual rents for each turbine). Regarding Malta‘s interconnected EPS, in addition to the rents for Malta‘s power plants, the rent for the interconnector (owner) must be determined. The interconnector rent is composed of two parts: i.) the rent for the quantity imported multiplied by the differential of Malta‘s (now interconnected) and Sicily‘s electricity price and ii.) the rent for the quantity exported multiplied by the reverse differential of Sicily‘s and Malta‘s electricity price. For both cases cable losses must be considered correspondingly. To calculate the rents for Maltese power plants in the interconnection case first the algorithm defines Malta‘s residual demand, that is the remaining demand that has to be produced by national generation capacity. Once again, the rent for each power plant is the product of price differential (clearing price with interconnection and turbine's marginal cost) and the remaining demand the respective turbine is able to contribute.

Results of interconnector simulation in MATLAB

The algorithm in MATLAB was enabled to calculate three crucial indicators for the interconnection case with regard to the three generation setups and oil price scenarios, namely the exact quantities imported and exported from Sicily to Malta and vice versa, the number of hours during which electricity imports and exports take place and the ratio of imported electricity to Malta's electric power system with respect to the total demand in the reviewed period 2007-2010. Tab. 18. thus lists the results of the interconnector simulation for the distinct generation setups.

	Results interconnector simulation for distinct generation setups								
	EPS in 2010			EPS as of 2014/2015			EPS as of 2014/2015 including NG		
	BOPS	LOPS	HOPS	BOPS	LOPS	HOPS	BOPS	LOPS	HOPS
Quantity [MW]									
Import	5011300,00	2774800,00	6166900,00	4234300,00	1648100,00	5509900,00	2994600,00	1313100,00	4250500,00
Export	579920,00	2618600,00	62879,00	233710,00	1505200,00	21162,00	1083800,00	2653700,00	330010,00
Hours [h]									
Import	27535,00	15963,00	33476,00	29172,00	16712,00	34085,00	22649,00	11547,00	29451,00
Export	5828,00	17624,00	843,00	4512,00	16602,00	485,00	10867,00	21593,00	4248,00
Ratio [%]									
Import/Total Demand	55,84	30,92	68,72	47,18	18,37	61,40	33,37	14,63	47,36
Import/Total Hours	78,53	45,53	95,47	83,20	47,66	97,21	64,59	32,93	83,99
Capacity utilization	83,05	80,11	92,54	66,37	46,84	82,16	60,58	58,92	68,04

Tab. 18. Result table of interconnector simulation for distinct generation setups

In all three generation setups as such Malta's EPS in 2010, EPS as of 2014/2015 and EPS as of 2014/2015 including NG the quantity of electricity imported is always the highest in the HOPS and lowest in the LOPS. For the BOPS in the three setups the imported quantity is in-between the imports for the LOPS and HOPS. In general, due to Malta's higher average price level to produce electricity compared to Sicily, the numbers for electricity exported indicate significantly lower values than for electricity import. It therefore approves the hypothesis found in many official reports that the interconnector is envisaged to be utilized in particular rather for importing electricity than exporting. However, for the LOPS in Malta's EPS as of 2014/2015 including NG the quantity of electricity exported to Sicily is higher than the quantity imported to the Maltese grid. The reason for this is two-fold provided that the LOPS has no influence on Sicily's prices assumed: the first is that Malta's power plants render significantly reduced marginal cost when NG is included as a fossil fuel to run the turbines, and the second results from the nature of the low oil price scenario.

The ratio of imported electricity to Malta‘s electric power system with respect to the total demand in the reviewed period 2007-2010 is a key finding for the thesis‘ interconnector simulation. This indicator renders that with the installation of the cable a significant share of electricity will be purchased and thus not generated on the EU island. While the interconnected system for the generation setup EPS in 2010 is purely hypothetical (the percentage of electricity import from Sicily would be the highest for the three oil price scenarios), Malta‘s future power system as of 2014/2015 yet imports close to 50 percent of its electricity needs considering the BOPS. Depending on occurring oil price volatility, the quantity imported would increase to over 60 percent in the HOPS and fall to some 18 percent in the LOPS. Electricity imports considerably decrease for the future generation setup that includes NG.

A second key indicator of the interconnector‘s simulation is the total number of hours during which electricity is imported and exported (to bear in mind that the number of hours during which electricity is imported has to be differentiated from the quantity imported, for instance, during one hour the imported quantity can be remarkably high, as opposed to some hours, in which solely very small quantities are imported). Similarly to the imported quantity, for the number of hours it is also primarily interesting to evaluate the ratio of the number of hours during which electricity is imported and the total number of hours (for this thesis the total number of hours is 35064 in the period 2007-2010). Interestingly, when we compare Malta‘s EPS in 2010 with the EPS as of 2014/2015, we find that although the import quantity ratio for the first setup in all three oil price scenarios is higher, the latter exhibits higher values with regard to the import hour ratio. Assuming Malta‘s EPS as of 2014/2015 together with the base oil price scenario to be very likely in the future, then during more than 80 percent of the hours in the reviewed period electricity is imported from Sicily. Once again, for the future setup that involves NG the percentage of imported hours will decrease.

By means of the computed values for quantity import and export another key indicator, namely the overall capacity utilization of the submarine cable was calculated. Equation (8) details how the numbers for the interconnector‘s capacity utilization (cf. Tab. 18.) were determined.

$$CU_c = \frac{\Sigma Q_{import} \times \Sigma Q_{export}}{I_{total} \times h_{total}} \quad (8)$$

Where

CU_c Capacity utilization of the cable c in the reviewed period in percent

Q_{import} *Quantity imported for generation setup g and oil price scenario j*

Q_{export} *Quantity exported for generation setup g and oil price scenario j*

I_{total} *Interconnector's net "generation" capacity*

h_{total} *Total number of hours in the reviewed period*

In general, the results of Tab. 18. demonstrate that the degree of the interconnector‘s capacity utilization is high. Capacity utilization ranges between 46 percent in Malta‘s future EPS as of 2014/2015 in the LOPS and more than 92 percent assuming that the cable would have been in place in Malta‘s EPS in 2010 (HOPS). In particular the high figures of Tab. 18. reveal that the lion‘s share of the total available interconnector net capacity for the reviewed period was utilized for both electricity imports and exports (even though the share for the imports is considerably higher).

Without drawing premature conclusions on the consumer impacts (this topic will be issued in the next part) according to the obtained capacity utilization indicator, it seems that this interconnection cable to link the Maltese and Sicilian power system is of crucial importance for the EU island state Malta. For the BOPS in Malta‘s EPS as of 2014/2015 more than 60 percent of the total cable‘s power capacity would be used to satisfy national demand needs and to export electricity to Sicily (cf. Fig. 41.). As the analysis showed, the significant price differential between the two countries makes Malta vulnerable to high fuel prices. The cable provides Malta with a mean to counteract its higher production prices for electricity and benefits most from electricity trades in the HOPS (capacity utilization is the highest in all three scenarios). The data for Malta‘s EPS in 2010 illustrates exemplarily that the interconnection line is strongly required (more than 80 percent of total interconnection capacity is used in the BOPS, cf. Fig. 40.).

In summary, Fig. 40., Fig. 41. and Fig. 42. display the monthly interconnector‘s capacity utilization according to the distinct generation setups regarding the base oil price scenario. It is differentiated between quantity imports (blue) and exports (red). The monthly breakdown of the interconnector‘s imports and exports with respect to Malta‘s power system confirms the trend of the cable‘s significantly high degree of capacity utilization, i.e. for the reviewed period (aggregated monthly data from 2007 to 2010) in Fig. 40. for each month the capacity used exceeds 70 percent of the total available capacity and in Fig. 41. and Fig. 42. the indicator also never falls below 50 percent. Referring to the future reference scenario Malta‘s EPS as of 2014/2015 (Fig. 41.) we observe higher imports during summer months (June, July, August) than in winter months (December, January, February). A potential reason for more capacity being imported during summer might be increased electricity needs due to the growing tourism sector in recent years. However, one exception is the month march where electricity import is highest. Contrarily, for electricity exports it is hard to identify a clear pattern. Largest quantities are exported in May and October. Once again, when NG is included in Malta‘s future generation setup electricity exports inherently rise due to the lower generation price level.

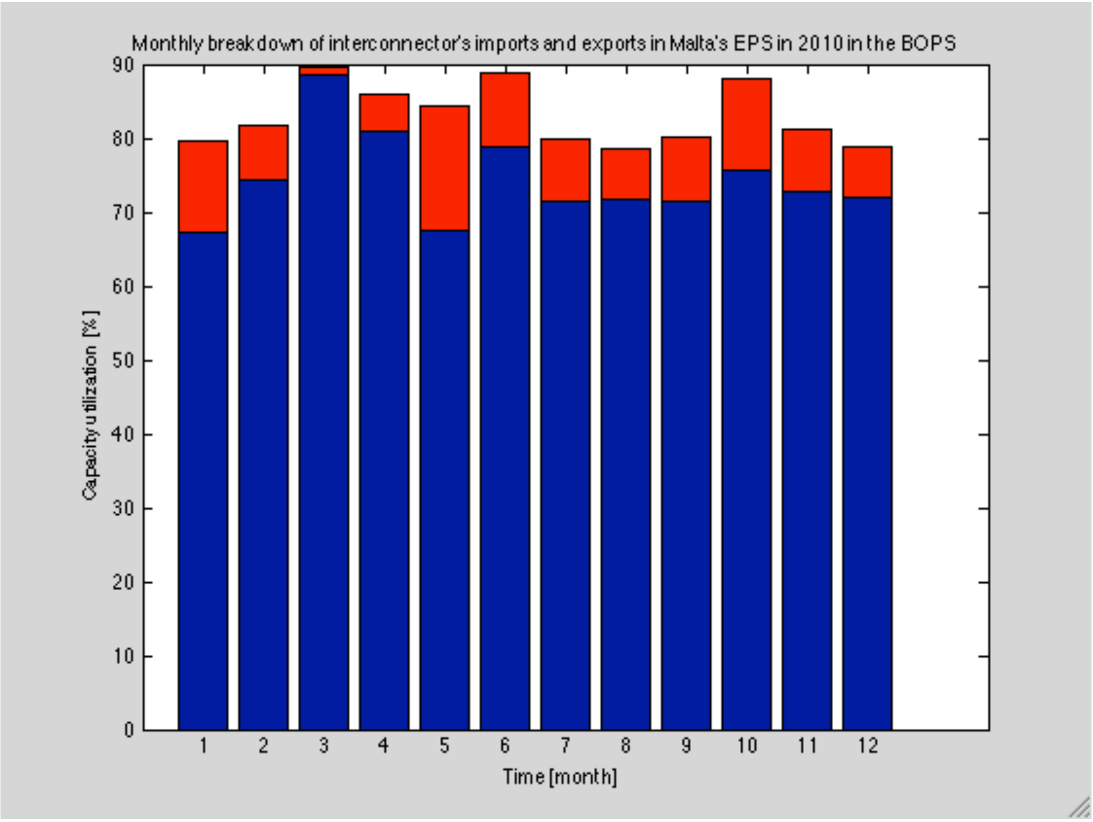

Fig. 40. Interconnector's capacity utilization for Malta's EPS in 2010 in the BOPS

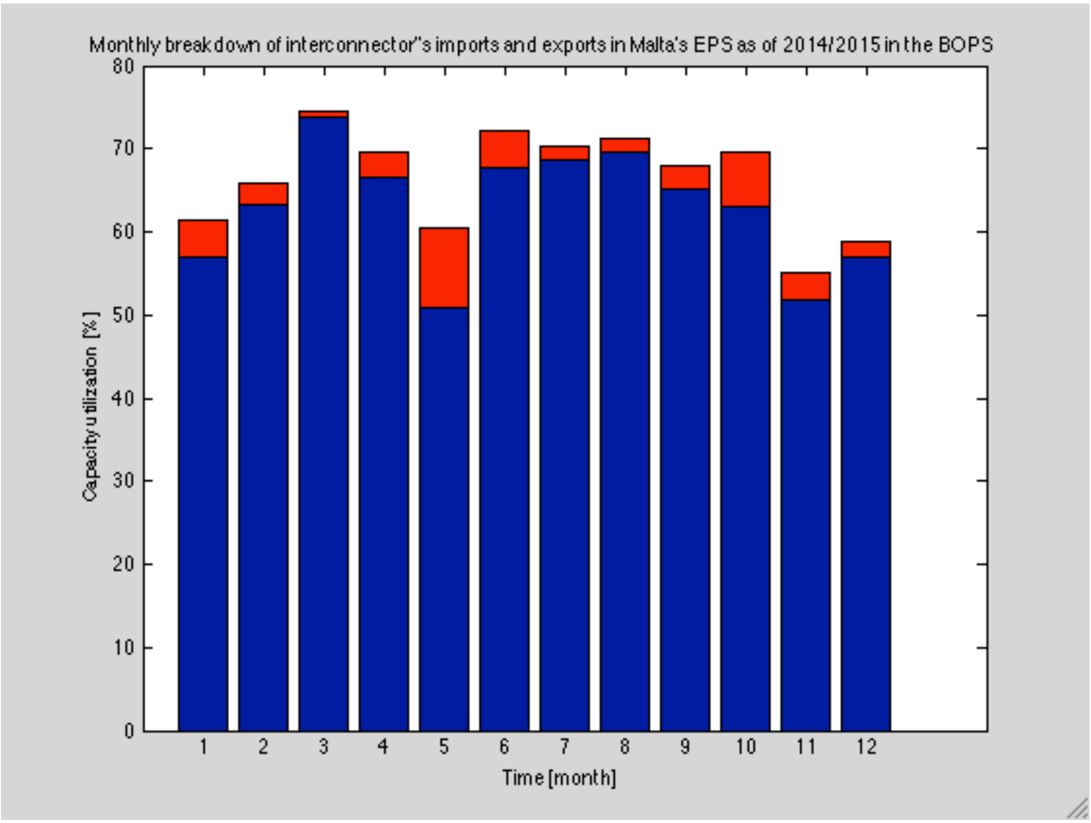

Fig. 41. Interconnector's capacity utilization for Malta's EPS as of 2014/2015 in the BOPS

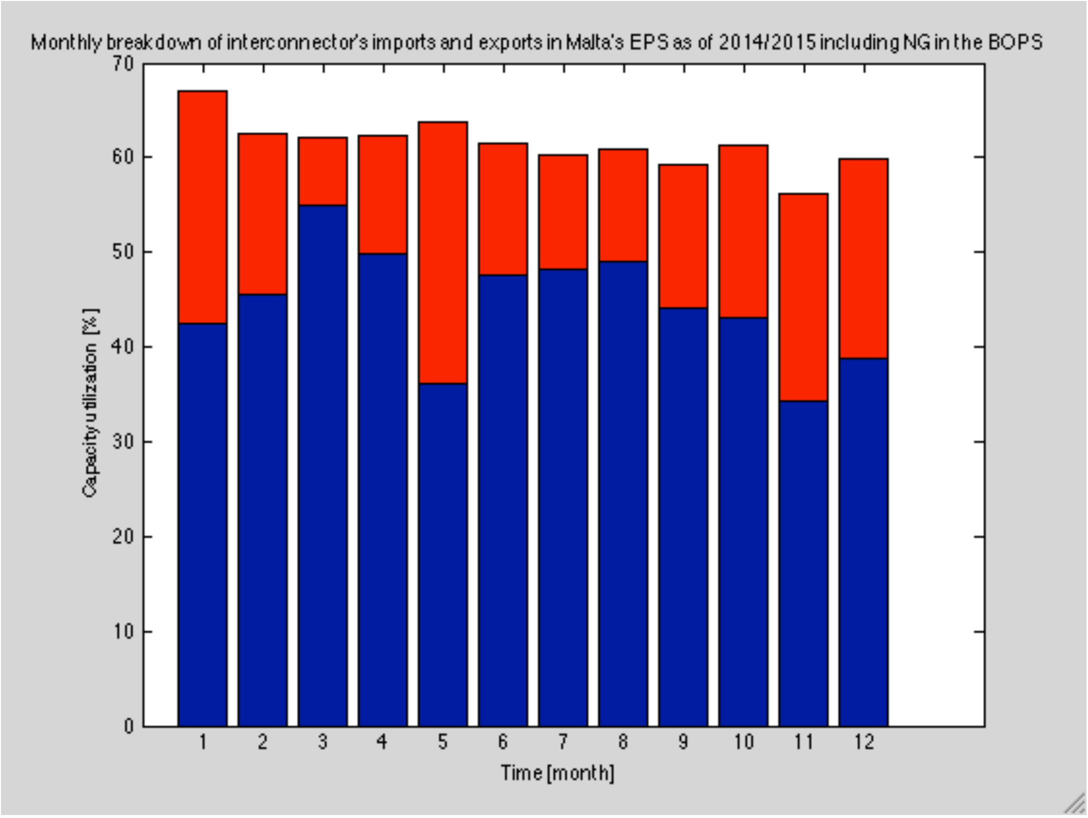

Fig. 42. Interconnector‘s capacity utilization for Malta‘s EPS as of 2014/2015 including NG in the BOPS

4.3.4 Implications for Malta‘s consumers

Malta‘s average electricity generation price with and without interconnector and the determined rents with respect to its isolated and the interconnected system are the key indicators that are required to assess the cable‘s impacts for Maltese consumers. Regarding the rent computation this thesis refers to Banfi and Filippini „*Resource rent taxation and benchmarking – A new perspective for the Swiss hydropower sector*“ (2010) who define a resource rent as a „surplus value, i.e. the difference between the price and the average production costs of a good“.[155] Since in a „competitive electricity market, the concept of resource rent can be illustrated graphically using the demand and supply curves“[156] their idea matches very well with this paper.

Fig. 43. displays the hourly electricity generation price for the reviewed period 2007-2010 with interconnection cable in the reference setup Malta‘s EPS as of 2014/2015 in the BOPS. When we determined the marginal cost curve for this generation setup we found that the cheapest unit is DPS CCDE with 80 €/MWh and a generation net capacity of 143.2 MW. Taking for granted that for most hours the demand would be higher this simultaneously implies a higher electricity price, Fig. 43. preliminarily demonstrates that

[155] Banfi/Filippini (2010), p. 2304; Cf. also Rothman (2000) which refers to David Ricardo‘s definition of rent from 1817.

[156] Ibid.

electricity imports might favor Malta‘s electricity prices in this generation setup and oil price scenario, i.e. the price often falls below the stated 80 €/MWh. The characteristic rectangular shape of the price curve in the graph implicates that the price level due to increased demand during summer months is higher. Unless the electricity needs are not supplied by Malta‘s domestic power plants, imports take place but at a significantly higher price level. As such Fig. 43. does not provide evidence for a change in the electricity generation price. Hence, Tab. 19. lists the obtained simulation results for electricity prices and rents in all three generation setups and the respective oil price scenarios with and without cable.[157]

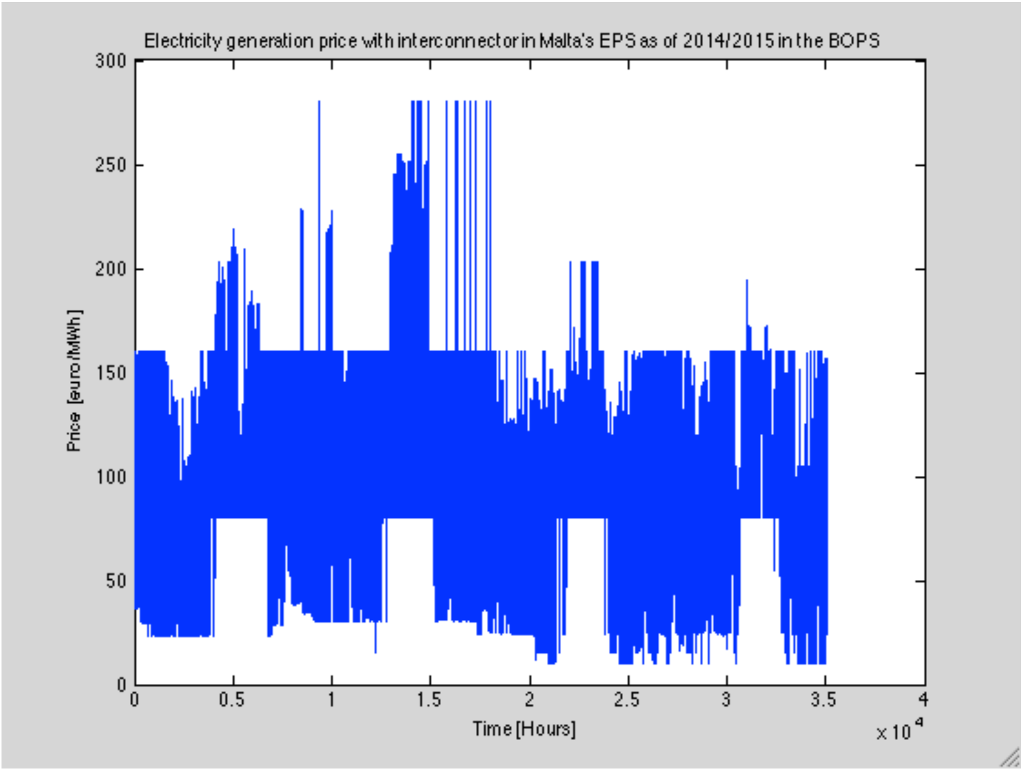

Fig. 43. Electricity generation price with interconnector in Malta‘s EPS as of 2014/2015 in the BOPS

	EPS 2010			EPS as of 2014/2015			EPS as of 2014/2015 (NG)		
	BOPS	LOPS	HOPS	BOPS	LOPS	HOPS	BOPS	LOPS	HOPS
Electricity generation price [€/MWh]									
Price without interconnector	142	81	204	151	85	216	98	67	147
Price with interconnector	122	90	165	107	85	125	95	72	109
Rent [Mio. €]									
Supplier without interonnector	101	50	151	448	274	662	250	160	388
Supplier with interonnector	57	228	33	175	273	111	211	242	156
Interconnector owner	184	95	397	5	48	139	62	111	80
Total with interconnector	241	323	430	180	321	250	273	353	236

Tab. 19. Result table for generation prices and rents with and without interconnector

[157] Only the different oil price scenarios in one generation setup should be compared; Comparing EPS 2010 and EPS as of 2014/2015 distorts the interpretation because they render different generation capacities and thus influence the price. See discussion in the following.

At first glance it seems questionable that the average electricity generation price without subsea cable in Malta's EPS as of 2014/2015 is higher than in the generation setup 2010. It can be explained by the marginal cost curves that were previously constructed. While in the „traditional" setup the cumulative generation net capacity of the first two units is usually sufficient to meet the demand, in the „updated" setup the cumulative production capacity is reduced and often requires the third turbine whose marginal cost is higher than of the second generator in the aforementioned „traditional" setup. When the average demand value of about 256 MW is exceeded (that is almost equal to the cumulative generation capacity of the first two units in the „updated" setup), the price tends to be higher than in the „traditional" case since the third, more costly turbine is needed and thus in total leads to a higher average electricity generation price in the 2014/2015 generation setup without interconnection cable.

The tendency of the electricity generation price within each generation setup regarding the oil price scenario is clear. Regardless of the interconnection cable the price is highest in the HOPS, lowest in the LOPS and in-between in the BOPS. However, to compare Malta's average electricity generation price without and with interconnector necessitates further analysis. The numbers found in the simulation reveal that the electricity price with interconnection to Sicily is lower in the BOPS and HOPS (for all three generation setups) than it was the case in Malta's isolated system. For the LOPS Malta's spot price is equal or higher with subsea interconnection. The interpretation of these results for Maltese consumers will be done once the figures for the rents are introduced. The second part of the table consists of the rents differentiating between the total rent for the supplier without interconnector (sum of cumulative rent for each plant) and the total rent with interconnector (separating the supplier's cumulative rent for each plant and the rent resulting from the interconnector for the cable owner).

Illustration of rent calculations (Cf. paragraph on rent determination)

While Fig. 44. by means of the marginal cost curve for Malta's EPS as of 2014/2015 (BOPS) exemplarily shows how the supplier rent in the isolated system for a typical hourly demand value in summer is determined, Fig. 45. renders the supply curve that defines both the rent for the interconnector owner and the rent for the supplier given that due to Sicily's lower price level electricity is purchased through the interconnection cable. Fig. 44. and Fig. 45. highlight that the opportunity of electricity import changes the distribution of rents and thus explains the different numbers obtained for the rents in Tab. 19. In Fig. 44. the total rent belongs to the electricity supplier (to cover the plants' fixed costs) whereas in Fig. 45. the rent for the supplier significantly decreases.

In this particular situation the lion's share of the rent appertains to the interconnector owner which consequently diminishes the supplier's share of rent. Fig. 45. displays a common scenario, in which the Sicilian price is lower than the lowest marginal cost value in Malta's power plant portfolio. As a consequence the interconnector runs as a „base load plant" at full capacity and shifts the supply curve to the right in the x-dimension. As opposed to the isolated scheme in Fig. 45. the rent for DPS CCDE is lower and no rent is obtained for DPS STEAM.

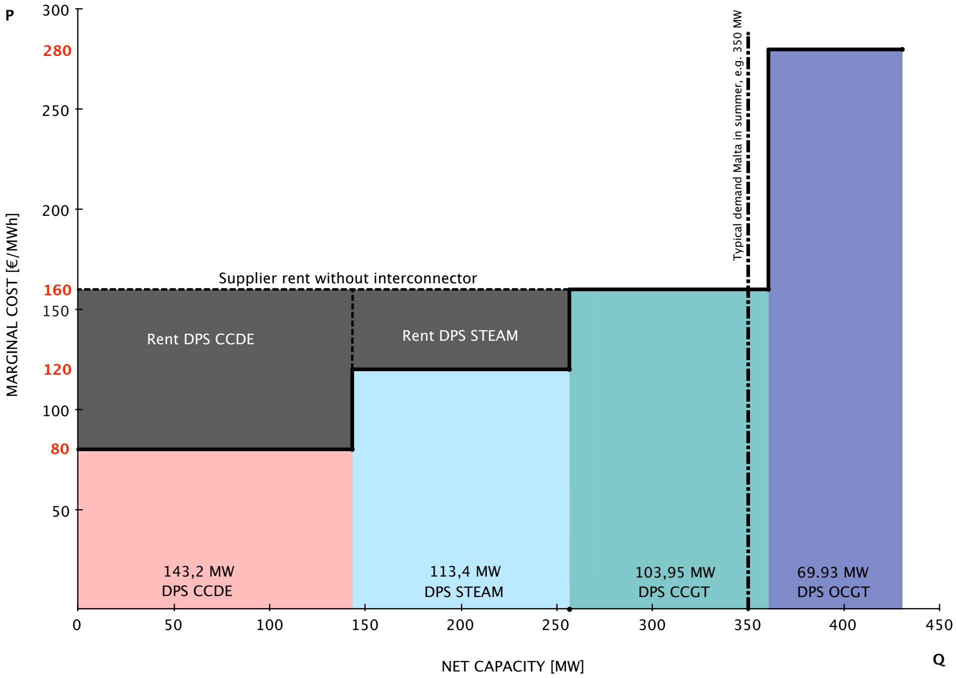

Fig. 44. Example supplier rent without interconnector for Malta's EPS as of 2014/2015 (BOPS)

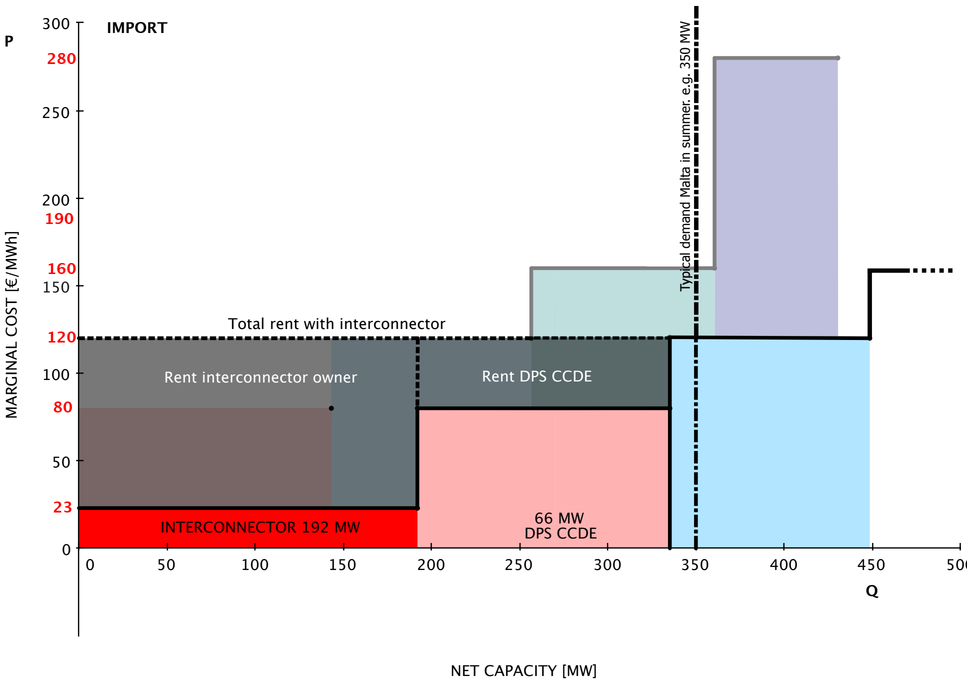

Fig. 45. Example total rent with interconnector through import for Malta's EPS as of 2014/2015 (BOPS)

Fig. 46. and Fig. 47. demonstrate how rents are computed when electricity is exported. In Fig. 46. Sicily's price is lower than the marginal cost of Malta's most expensive generator. The rent is defined as described on page 100. Fig. 47. shows an extreme scenario where the Sicilian price is higher than the unit with the highest marginal cost in Malta.[158]

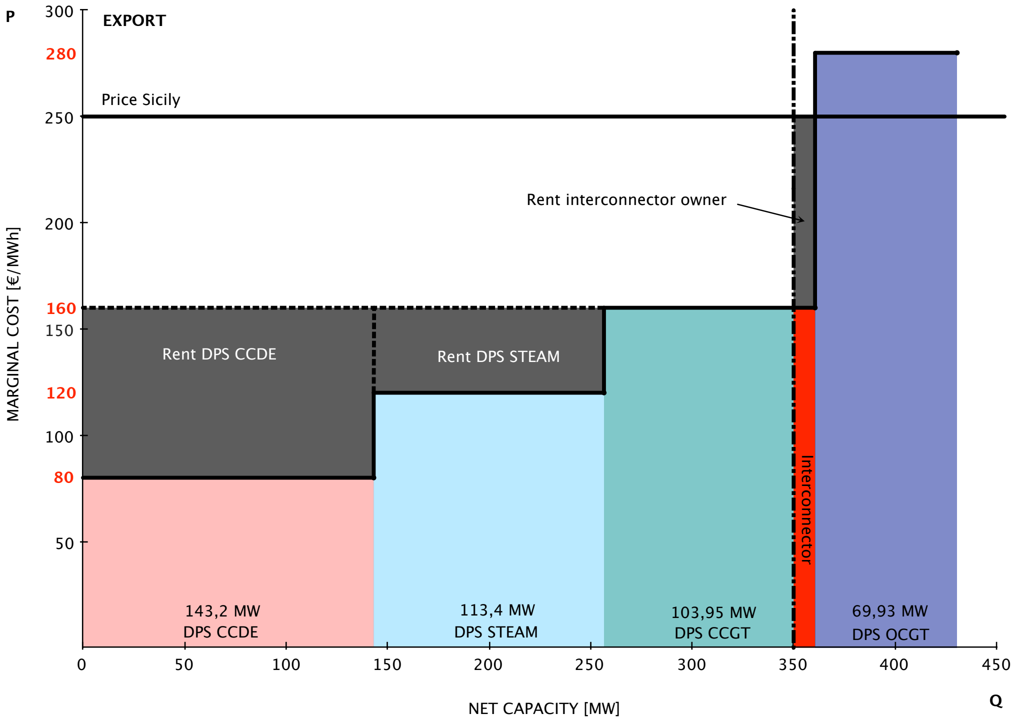

Fig. 46. Example (a) total rent with interconnector through export for Malta's EPS as of 2014/2015 (BOPS)

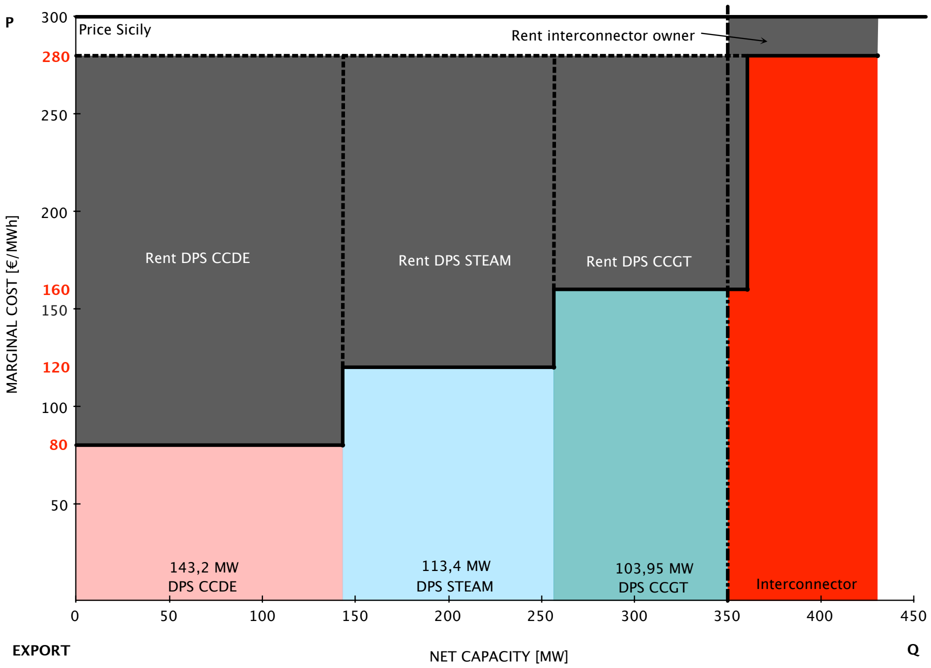

Fig. 47. Example (b) total rent with interconnector through export for Malta's EPS as of 2014/2015 (BOPS)

[158] We assume that in the interconnection case Malta's electricity market price will not exceed the marginal cost of the most expensive unit. The supplier can sell its export quantity to the interconnector owner at most at the price of the most expensive turbine (cf. Fig. 47.).

For the interpretation of Tab. 19. we must bear in mind the fundamental difference for the rent distribution between Fig. 46. and Fig. 47., i.e. with a price that exceeds the value of Malta's most expensive unit, the electricity supplier can benefit from significantly higher rents to cover the costs for his power plants compared to the situation where Sicily's price is lower than the marginal cost of the most expensive generator.

Discussion of consumer impacts

In the following this thesis sheds light on the concrete consumer impacts of the interconnection cable. We therefore refer to the future generation setup Malta's EPS as of 2014/2015. Fig. 48. illustrates the numbers found in the simulation retrieved from Tab. 19. In principle, according to economic theory we expect that the **rents for the electricity supplier** together with **the price to be higher in Malta's isolated power system** that entails a **monopoly position of the vertically integrated utility Enemalta**. However, this is only partially coherent with Fig. 48.

While in the **BOPS the rent for the supplier decreases from 448 million euro to 175 million euro** (the rent for the interconnector owner equals 5 million euro) when **Malta's grid is connected to Sicily**, also the **average electricity generation price falls from 151 euro per megawatt hour to 107 euro per megawatt hour** and **thus demonstrates that the cable may essentially benefit Maltese consumers**. The potential electricity price reduction for the consumer suggests that the **introduction of competition** to Malta's power system by linking its EPS to the European market in this specific generation setup and oil price scenario **increases the welfare for Malta's citizens**. In the **HOPS** a similar effect can be observed, the **decline in the supplier's rent** and **average electricity generation price** (**more than 70 percent**) compared to the BOPS is even **considerably higher** and **confirms the hitherto finding** that the **interconnector has a positive impact for the electricity price of Maltese consumers**.

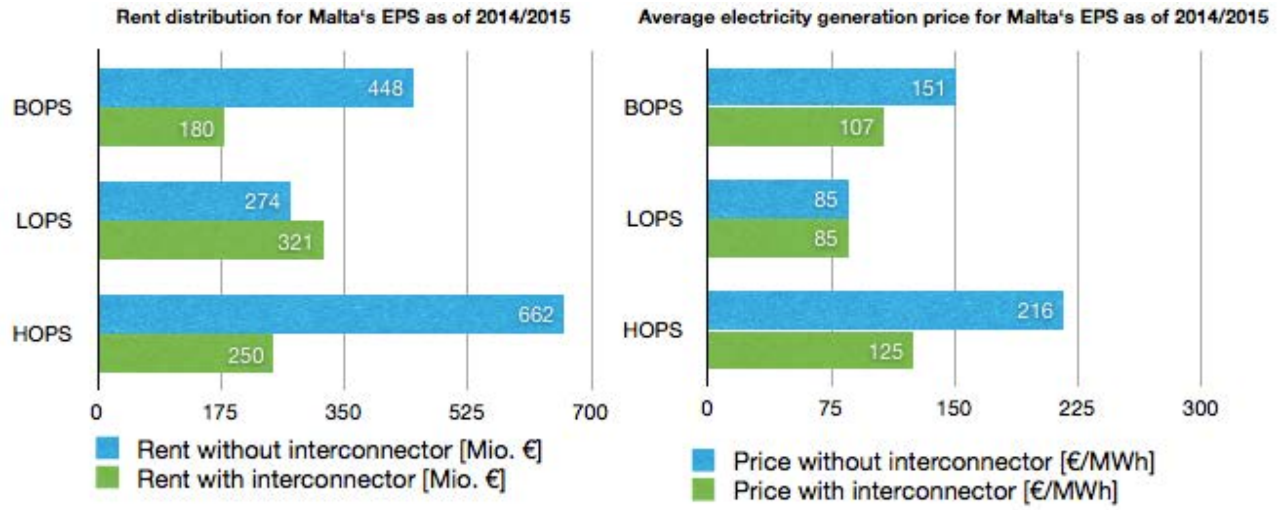

Fig. 48. Rents and electricity prices for Malta's EPS as of 2014/2015

Yet, the **LOPS renders a different picture**. As opposed to the BOPS and HOPS in which both the part of the supplier‘s rent and the total rent including the rent for the interconnector owner diminish, and moreover the average electricity generation price is significantly lower, in the **LOPS the total rent** altogether for the supplier and interconnector owner **increases from 274 million euro to 321 million euro while the average electricity production price remains unchanged at 85 euro per megawatt hour**. Despite the results obtained for the BOPS and HOPS, the **two indicators** in Fig. 48. for Malta‘s future generation mix considering a low oil price scenario finally **validate our hypothesis that the interconnector does not inherently favor electricity prices for Maltese consumers** even if Malta is integrated to the European competitive electricity market.

So far the simulation disclosed two distinct situations, i.e. while the interconnector achieved a large price reduction for the base and high oil price scenario – initially Malta‘s isolated power system revealed significant higher average electricity production prices in these scenarios compared to the LOPS – for the low oil price scenario the subsea cable could not lower the price. The large price differential that results from the modification of Malta‘s small isolated system in the BOPS and HOPS implies a tremendous loss of rent for the electricity supplier Enemalta that can not be compensated through the rents gained by the interconnector (although it is a quasi new power plant).[159] When the difference in price is small as shown in the LOPS (in fact in the LOPS 2010 and LOPS including NG the price level in the interconnected scheme is higher due to increased electricity exports) we observe the reverse situation in which the supplier rent little decreases but the rent for the interconnector owner that operates a „power plant“ at low marginal cost increases, i.e. Maltese consumers do not benefit from the cable installation.

Fig. 49. depicts the two key indicators for **Malta‘s future EPS including NG** as fossil fuel in the **base oil price scenario**. Contrarily to the two previous cases in this scheme **a win-win situation is achieved**.

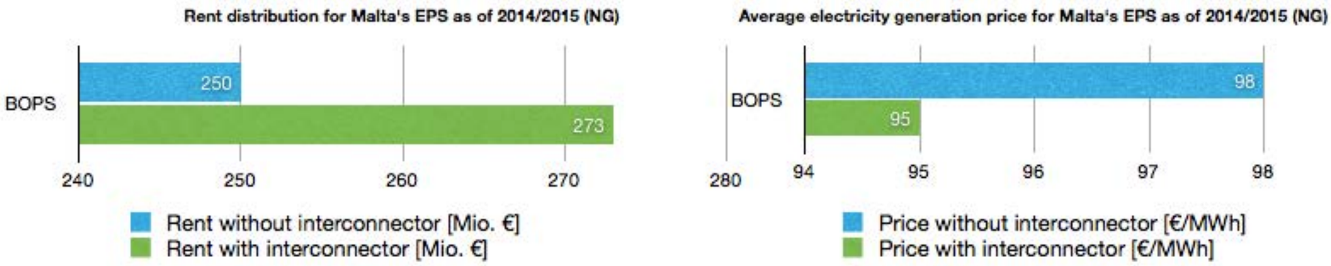

Fig. 49. Rents and electricity prices for Malta‘s EPS as of 2014/2015 including NG (BOPS)

[159] In case Enemalta owns the subsea cable, the interconnector rent belongs to Enemalta. We will further investigate this aspect in the following discussion.

Incorporation of natural gas in the future generation setup with interconnector **boosts both an increase in total rent from 250 to 273 million euro** and **a decrease in the average electricity generation price from 98 euro per megawatt hour to 95 euro per megawatt hour**. Other win-win situations – demonstrating even a more significant effect of total rent increase and electricity price fall – are identified for Malta‘s EPS of 2010 in the BOPS and HOPS (cf. numbers of Tab. 19.). The reason for these beneficial scenarios is simple and linked to the generators‘ marginal costs. More precisely, in the two latter scenarios the **variation between the first turbine‘s marginal cost value** (they are the highest among all others) and **the interconnector‘s marginal cost value** results in **larger rents for the interconnector owner** than in other options. Although the supplier‘s share of rent in all three win-win scenarios is smaller compared to the isolated case, the surplus achieved through the interconnector is the reason why the total rent with interconnector is higher. The most expensive power plants leave the market (cf. Fig. 45.), which lets the spot price drop, thus consumers potentially benefit from a lower price level when Malta‘s system is connected to Sicily. While this drop of spot price is likely to result in consumer value, the fact that two power plants „drop out“ of the market momentarily produces risks for Enemalta, namely whether the increase in rent can cover fixed costs for these power plants.

In short, the **simulation of the cable interconnection between Malta and Sicily**, in particular the calculation of the key indicators rent, electricity price and generator marginal cost **evidenced** that it **cannot be simply approved** that the **subsea link automatically decreases the electricity price level for Maltese consumers**. The **simulation‘s results reveal whether** and **in which of the presented generation setups and distinct oil price scenarios Malta‘s interconnected power system benefits the final consumer**. Although this thesis **cannot generalize** the effect of the submarine cable for Maltese electricity consumers, the **study concludes that its impact significantly depends** on i) **the considered generation setup and oil price scenario**, ii) **the market design** (monopoly vs. competition) and iii.) **the variation between the generator‘s and interconnector‘s marginal cost**.

Without significant price shocks the base oil price scenario for Malta‘s future EPS as of 2014/2015 appears to be likely. Doubtlessly, **the implications for Maltese consumers largely rely on the role of the national utility Enemalta**, especially the degree of market opening and cable ownership can influence future outcomes. Assuming that the incumbent owns the cable and the electricity market place is opened to Sicily – with a limited cable capacity of 192 MW – the simulation showed that consumers will possibly benefit from the utility‘s lower average production price. However, as **Enemalta remains in the position of single national electricity supplier**, **the imports at low cost through the**

interconnector do not inherently imply that retail prices for consumers will be passed through.

Possibly in short term Enemalta retains its monopoly position and **keeps the current price level of its isolated system, so consumer bills do not change** (cf. discussion for long term situation in chapter 5). Beyond that at present entire market liberalization in Malta seems unrealistic, this would require increased interconnection capacity and could potentially weaken Enemalta's hegemony. This is particularly true when a third party would own the cable and thus gain its rents. Enemalta would lose any mean to cover the fixed costs for its power plants, since the entire demand would be satisfied by more affordable electricity imports.

Abstract Chapter 5

Chapter 5 concludes that the five objectives of this master's thesis are achieved. It recapitulates the key findings of our qualitative and quantitative analysis. It finally also addresses how the European electricity market liberalization practically applies to the EU island's micro grid. Moreover, special attention is paid to Enemalta's future positioning. One major conclusion is that a decline in production prices only implicates a positive short term effect for consumers when it is passed through to the retail tariffs by Enemalta. Future research should concentrate on the cable's long term consequences for consumers. For EU regulation of isolated power systems decision makers must better consider potential negative outcomes those giant infrastructure projects entail. Finally, the interconnector will enhance the creation of a single European electricity market. However, the Malta case study suggests to thoroughly rethink infrastructure projects such as the submarine cable installation between Malta and Sicily.

5. CONCLUSIONS

Fundamentals, institutional challenges and consumer impacts of the Malta-Sicily interconnector

According to the defined targets this master‘s thesis achieved to establish an objective point of view for the interconnection‘s project framework. It presents the drivers that have forced the small European island state Malta to radically revise its hitherto energy policy and unsustainable electricity generation mix. In depth this paper qualitatively contrasts electricity key indicators for the two EU member states and points out the heterogeneity of their present architectures with respect to country characteristics, electricity generation mix, power demand, electric grid, domestic stakeholders and institutions, regulatory framework and market design. Moreover, the qualitative part of the work reveals why a common electric power system is potentially vulnerable. Institutional disturbances are found on both sides: While in Malta the vertically integrated incumbent Enemalta with its significantly leveraged financial structure failed to adequately prompt investments, in Italy the patchwork of state level and regional authorities entailing uncertainty in decision power and legislative authority – especially in Sicily – demonstrates a major institutional obstacle.

In sum, it is the political interference in electricity relevant questions in both countries that results in an institutional puzzle and impedes the power system development. No doubt exists about the interconnector‘s advantages – for instance to ease the compliance with EU imposed energy requirements by purchasing „green“ electricity from other countries – however, over-reliance on imported electricity can threaten Malta‘s security of electricity supply, in particular when peak loads of both EPSs coincide. Since Italian (particularly Sicilian) electricity prices are also among the highest in Europe, the interconnection cable does not inherently imply lower electricity prices for Maltese consumers.

Furthermore, this thesis succeeds to deliver a quantitative impact simulation of the submarine cable for Maltese electricity consumers focussing on the electricity generation price as a textbook example indicator. Official hourly electricity spot price data from 2007 to 2010 provided by Italy‘s market operator GME and the corresponding demand data received through Enemalta enabled to construct the marginal cost curves for the Maltese past and future generation setup. To incorporate fuel price volatility in the marginal electricity generation cost determination, the simulation considers three oil price scenarios: the base oil price scenario (BOPS), low oil price scenario (LOPS) and high oil price scenario (HOPS). As such the supply curves – different depending on generation setup and oil price scenario – present the first key result of the quantitative analysis.

By means of these curves Malta's average electricity generation price first in the base case, i.e. isolated system, and then in the interconnection case for 100 percent electricity import from Sicily was defined. The interconnector simulation goes further and allows to find quantity imports/exports and the cable's degree of capacity utilization. In general, the simulation proves that the lion's share of the total available interconnector net capacity in the reviewed period was utilized (with higher degree of electricity import).

This finding therefore preliminarily approves that the subsea cable can play a crucial role to prospectively safeguard large parts of Maltese electricity needs. But with regard to the cable's implications for Maltese consumers the simulation allows to compare the average electricity production price with and without interconnector as well as the rents achieved in both cases. The quantitative results of sub chapter 4.3.4 thus lead to an essential conclusion of this thesis, namely that the newly installed interconnector between the EU island state and Sicily does not per se reduce the electricity price level for Malta's citizens. In particular our critical investigation has numerically shown that the effect of the link for consumers largely depends on distinct factors such as the addressed generation setup, the oil price scenario and the electricity market design. For Malta's prospective interconnected generation setup as of 2014/2015 the simulation proves that consumers in the BOPS and HOPS potentially benefit from lower prices, i.e. their welfare increases, but the main indicators also evidenced the reverse situation for the LOPS in which the average electricity generation price remains unchanged and consumers consequently do not benefit from the interconnection to the Sicilian market. Once again whether and to what extent Malta's consumers really profit from the cable installation also depends on the role Enemalta, the incumbent, continues to play with regard to the European electricity market liberalization framework (cf. discussion in the following).

European policy and regulatory framework

The starting point of this thesis was to highlight the current developments in European electricity policy. Our Malta case study simulates how the theoretical concept of market liberalization practically applies to the EU island's micro power system. The subsea cable to link Malta's grid with the Sicilian will certainly for the first time open the island's hitherto isolated system to another electricity marketplace. However, for now uncertainty prevails about the real degree of market opening and the effect for Maltese final consumers. It seems most probable that in the short term the „national champion" Enemalta stays the sole supplier, i.e. monopolist, on the island. For a perfect competitive market that would significantly weaken Enemalta's position (assuming that the cable is owned by a third party) and imply larger benefits for the consumer, the interconnection capacity is at present not sufficient.

The aforementioned simulation's key finding that for Malta's prospective generation setup with cable interconnection in the BOPS and HOPS the average electricity production price decreases only implicates a positive short term effect for consumers when this price decline is passed through to the retail tariffs by Enemalta. If Enemalta undermines to lower tariffs for end consumers and if Enemalta remains the sole provider of electricity, then possibly consumer bills will not change or will even tend to be higher than without interconnection cable. This is coherent with our qualitative analysis which revealed the importance of the government's subsidies for the incumbent utility, i.e. as financial state aid disagrees with the EU's vision of a competitive electricity market and Enemalta heavily relies on those measures, the most likely scenario seems that the customer surplus achieved through electricity imports – exemplarily in the BOPS and HOPS in Malta's EPS as of 2014/2015 – will be utilized to repay Enemalta's debts (that additionally increase due to the cable installation).

Finally, assuming that in the short term Enemalta will not lower the electricity price level for end consumers, only an investment analysis can disclose whether the cable to Sicily is beneficial for the long term retail price level. The evolution of Malta's isolated power system potentially implies an abrupt shortfall of financial state aid. Together with the addressed distinct market developments it thus offers large room for future research. In a next step our work should also include the most recent data set from both state authorities. Furthermore, although a long term analysis is out of scope of this master paper, it prospectively enables to envisage an investigation that examines the interconnector's profitability with and without European funding.

The particular case of Malta's interconnection to Sicily allows to generally discuss its implications for the EU regulation of isolated power systems. Our analysis gave a holistic overview regarding the distinct key challenges such small electric systems face. From Malta's case study we conclude that decision makers – in particular the EU – should not disregard potential negative outcomes those giant infrastructure projects entail. In collaboration with the member states that will be interconnected primarily the future price impact for end consumers should be scrutinized in a thorough way. Special attention must also be paid to islands' market architectures that are often equivalent to Malta's with one vertically integrated utility. As our study evidenced, the incumbents can significantly influence to what degree consumers benefit from the new interconnection line in the short term.

Another lesson from Malta's example concerns the islands' security of electricity supply. Although the Sicilian electricity price level in EU comparison is high, our simulation proved that Malta would tend to meet electricity needs by imports. When the future price level in

Sicily remains about the same as in the past, the interconnector will be quasi operated as a base load plant for Malta‘s EPS with low variable production cost.

As our results revealed the newly installed interconnection cable will then challenge the utilization of Malta‘s most expensive generation technologies and thus hamper their cost recovery. The insight for the European perspective is as follows: When such interconnection cables are planned, decision makers must at the same time design capacity mechanisms that safeguard the operational readiness of the generators with the highest marginal costs. Since the submarine cable will reduce the rents for the residual technologies other measures are needed. If such additional payments are not provided to the most costly units and these are, for example, technically not ready for use, security of supply can be endangered when the demand is high (and these power plants are needed) or cable failure occurs.

To merge Malta‘s and Italy‘s electric power system certainly brings forward the creation of a single European electricity market. However, other infrastructure projects such as the failed bridge installation between Sicily and Italy‘s mainland have demonstrated the difficulty of aligning politicians and industry and put into question the necessity of this kind of public project for European citizens. Malta‘s and Italy‘s systems‘ heterogeneity and the public controversy accompany the construction process. Coherently, this master‘s thesis has in some example scenarios shown that the connection cable does not inherently benefit Maltese consumers.

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APPENDIX

The algorithm displayed in the following was gradually developed in MATLAB. The author was instructed by Ludovic Gaudard of Geneva University.

```
clear all, clc, close all

% data import from textfile
path='/Users/janries/Dropbox/Malta_Jan/Data/';
eval(['a=importdata(''',path,'PriceConso.txt'');']);

p_sicily=a.data(:,3); % price Sicily in euro per MWh
p_italy=a.data(:,4);  % price Italy in euro per MWh
d_malta=a.data(:,5);  % demand Malta in MWh

gen_setup_2010=[113.4   120.00;
217.35  140.00;
103.95  160.00;
79.93   280.00;
34.97   440.00
]; % [Net capacity    Marginal Cost]

% determine cumulative generation capacity
cumulative_gen_capacity=cumsum(gen_setup_2010(:,1)); % sum capacity values in
column 1

p_malta=zeros(size(d_malta,1),1); % define matrix with zeros
rent_malta=zeros(size(gen_setup_2010,1),1); % define matrix with zeros
for ihour=1:size(d_malta,1) % available hours
    j=1; % means generator 1
    while cumulative_gen_capacity(j)<=d_malta(ihour)% loop to check cumulative
capacity wiht demand value
    j=j+1;
    end
    p_malta(ihour,1)=gen_setup_2010(j,2); % price assignment
    if j>1  % rent only if not first turbine
     for irent=1:j-1 % and not the last turbine

rent_malta(irent)=rent_malta(irent)+gen_setup_2010(irent,1)*(p_malta(ihour,1)-ge
n_setup_2010(irent,2));
     end % rent calculation in vector form, determine surface, i.e. capacity ti-
mes differential of price malta and VC of turbine
    end
end



%interconnector simulation

cable_losses=0.04; % definition of cable characteristic


% Import -> Quantity
```

```
q_import=zeros(size(d_malta,1),1); % define matrix with zeros
q_export=zeros(size(d_malta,1),1); % define matrix with zeros
p_malta_inter=p_malta; % malta's price with interconnector
for ihour=1:size(d_malta,1)% available hours
    gen_portfolio=gen_setup_2010;
    gen_portfolio(:,3)=1; % 1=malta, i.e. write 1 in third column
    gen_portfolio(end+1,:)=[192 p_sicily(ihour)*(1+cable_losses) 2]; % 2=sicily;
i.e. write 2 in third column
    Pali=sortrows(gen_portfolio,2);
    cumulative_gen_capacity=cumsum(Pali(:,1));
    j=1;
    if cumulative_gen_capacity(j)>d_malta(ihour) % checks if generation capacity
of first PP is higher than Maltese demand
        if Pali(1,3)==2
            q_import(ihour)=d_malta(ihour);
            p_malta_inter(ihour)=p_sicily(ihour)*(1+cable_losses); % malta's
price with interconnector
        else
            q_import(ihour)=0; % no import from Sicily
        end
    else                      % other
    while cumulative_gen_capacity(j)<=d_malta(ihour) % number of PP needed to
satisfy demand
    j=j+1;
    p_malta_inter(ihour)=Pali(j,2); % malta's price with interconnector
    end
    pos=find(Pali(:,3)==2); % position of the cable in the merit order
    if pos==j % cable is the marginal unit
        q_import(ihour)=d_malta(ihour)-cumulative_gen_capacity(j-1);
    elseif pos<j % cable used at full capacity
        q_import(ihour)=192;
    else % price in sicily is too high, i.e. no cable use
        q_import(ihour)=0; %  price in sicily is higher than in Malta

% Export quantity

    while Pali(j,2)<p_sicily(ihour)*(1-cable_losses)
    q_export(ihour)=min(192,cumulative_gen_capacity(j)-d_malta(ihour));
    p_malta_inter(ihour)=Pali(j,2); % malta's price with interconnector
    j=j+1;
    end

    end
    end

end

%RENT
% determination of interconnector rent
rent_inter=q_import'*(p_malta_inter-p_sicily*1.04)+q_export'*(p_sicily*0.96-p_ma
lta_inter);


% determination of rent for Maltese PP
rent_malta_inter=zeros(size(gen_setup_2010,1),1);
cumulative_gen_capacity=cumsum(gen_setup_2010(:,1));
for ihour=1:size(d_malta,1)
```

```
    residual_d=d_malta(ihour)-q_import(ihour)+q_export(ihour); % determine the
remaining demand
    if residual_d>0 % PP needed to satisfy residual demand
        j=1;
        while cumulative_gen_capacity(j)<residual_d
            j=j+1;
        end
        for irent=1:j

rent_malta_inter(irent)=rent_malta_inter(irent)+(p_malta_inter(ihour)-gen_setup_
2010(irent,2))*min(gen_setup_2010(irent,1),residual_d);
    residual_d=residual_d-gen_setup_2010(irent,1);
        end
    end
end
```