Deliverable 3.4: Scheme for market organization of autonomous electricity systems

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1. Introduction

The study summarized in this report was conducted in the frame of the STORIES project and constitutes the deliverable of Task 3.4. “Market development and organization”. The report has been prepared by the Regulatory Authority for Energy of the Hellenic Republic (RAE) with contribution from the Instituto de Engenharia Mecanica Polo I.S.T. (IDMEC-IST) and National Technical University of Athens (NTUA). The purpose of the work was to (a) review the organization of the electricity market in a number of non-interconnected islands that are either a separate country themselves, such as Malta and Cyprus, or part of an larger EU country such as the Spanish, Greek and Portuguese islands and (b) propose a scheme for the market organization of two selected autonomous systems; Crete (Greece) and Corvo (Portugal).

In this context, the legislative framework and any additional experiences on island electricity market organization were investigated and critically appraised. In the study several parameters affecting the market structure such as the size of the generation system, network constraints, topology, existing regulations and the respective legislative framework related to RES implementation have been taken into account. The study revealed that as a result of the liberalization process the electricity sector has undergone a considerable reform in all countries reviewed, however the implementation market reforms within comparatively small autonomous systems has been proven a difficult and slower process due to a number of technical and economical barriers.

This report is structured as follows. In the remaining part of this section, the possible players taking part in an electricity market are described and generic models of reform to introduce competition in the electricity market are presented. Section 2 highlights the particularities of isolated electricity systems and the difficulties related to market reform and liberalization. An overview of the current market organization in Cyprus, Malta and the Spanish islands is provided. Section 3 presents the current status of market organization in the Greek islands with emphasis on the island of Crete. Main factors impeding market liberalization are listed and a market organization scheme foreseeing a single system operator and more than one producer/supplier is proposed. Section 4 presents the market organization in the Portuguese islands with emphasis on the island of Corvo. A market organization scheme is proposed for this island taking into account the island’s specialties. General remarks on the market organisation schemes of autonomous electricity systems are summarised in the Conclusions Section.
1.1. Electricity markets and players

The liberalized electricity market accommodates a number of players, namely

- The producers,
- The network owner(s),
- The system operator(s) – transmission and distribution
- The consumers
- The traders in the role of electricity suppliers and/or balance providers
- The market operators

Market-places also appear in a number of different forms such as pools, exchanges, bilateral and central management models.

The number of players taking part in electricity market, their inter-relationships, their role, as well as the way power is transmitted differentiates between countries and depends on the level of market liberalization, the size of the system etc. The next paragraphs highlight the role and responsibilities of each player category.

An Electricity Producer generates power and feeds into the network. This energy can be produced from conventional and renewable power plants.

The Network Owners own the national grid, regional and/or local networks that transport electricity from production to consumption. In some cases, Network Owners may also be Transmission System Operators (TSO).

Following Directive 96/92/EC, Member States were obliged to designate a TSO to be responsible for the operation, maintenance, and, if necessary, the development of the transmission system in a given area and its interconnections with other systems. In other words it is the Transmission System Operator (TSO) who runs the national grid ensuring that power plants work together in a reliable way and that production and import corresponds to consumption and export (if any). Regional networks transmit electricity from the grid to the local networks, and in some cases to large-scale consumers, for instance industries. The local networks distribute electricity to the consumers within a certain geographical area and by analogy a Distribution system operation may also be established.

The Consumers, from industries to households, take electricity from the electricity network and consume it. In general the consumer must have an agreement with an electricity trader.
(or supplier) to be able to buy electricity. The consumer also has an agreement with the network owner in order to be connected to his network. For connection and transmission, the consumer pays a network fee (network account). Agreements between consumers and energy traders vary from country to country and in some markets do not exist.

The **Power Trading Company** sells electricity to the final customers. The power trader can have the role of **Electricity Supplier** and/or **Balance Provider**. Both roles can exist within the same or different companies. The electricity supplier has a supply agreement with the consumer. The balance provider is financially responsible for the electricity that the trader sells always being in balance with the electricity purchased to cover consumption.

Organized **market-places**, for example the power exchange Nord Pool, as well as brokers, provide standard agreements which make it easier for the players in the market to do business with each other. For example Nord Pool has a spot market for physical trading and also a financial market-place. A smaller part of the physical electricity trading in the electricity market is carried on through bilateral agreements between electricity producers and electricity traders. The main part of the trade today is done on the spot market.

The bottom part of Figure 1 illustrates the physical transfer of power and the upper part the financial transfer, where power is purchased and sold. Financial transaction route can differentiate depending on the the market model adopted by each country.

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**Figure 1. Physical and financial transfer of power [5,6]**
1.2. Different models of reform to introduce competition

The purpose of this session is to provide a brief outline of the generic approach towards reforming of the electricity sector and introduction of competition.

Prior to liberalisation, the electricity sector almost everywhere in the EU (and also in the world) evolved with vertically integrated geographic monopolies that were either state-owned or privately-owned and subject to price and entry regulation as natural monopolies. The primary components of electricity supply: generation, transmission, distribution, and retail supply were integrated within individual electric utilities. These firms in turn had de facto exclusive franchises to supply electricity to residential, commercial and industrial retail consumers within a defined geographic area. Despite their individual differences, paths to market reform and competition span in three distinct directions e.g. Stoft (2002), Wilson (2002), Hunt (2002), Strapoli (2001), Petrov, K., Joskow (2003).

1. **The Single buyer model.** In the single buyer model, independent power producers (IPPs) generate electricity and sell it to the “single buyer”, often the national power company or the TSO. In turn the single buyer sells the purchased energy to distributors. Two types of agreements are signed “Power Purchase” between the IPP and the single buyer and “Power Selling” between the Single Buyer and the Distributors (suppliers). There are no access arrangements and no direct trading between IPPs and the distributors.

2. **Bilateral Contracts.** In this model, producers, suppliers, distributors and in general all eligible customers establish bilateral short, medium or long term contracts. Access to the network (Third Party Access) is provided by the TSO under regulated or negotiated tariffs.

3. **Wholesale markets (pools).** Pool markets represent a centralized concept where all energy is sold by the generators and purchased by the suppliers through the pool. This is achieved by the centralized scheduling of all generation units through the pool, whereas all suppliers must purchase their entire demand from the pool. A pool is thus characterized by the uni-directional exchange of energy from producers to the pool, and from the pool to suppliers. Running in parallel to the spot markets, financial instrument markets can also be created to ensure price volatility or the possibility of negotiating direct bilateral contracts between producers and consumers for different time lines. These markets may co-exist with old industrial structures or the organized wholesale markets.

Table 1 summarizes the differences in reforming and market design in various countries in 2007.
1.3. Characteristics of isolated electricity systems

The same market reforms, that have characterized the European electricity sector over the last 10-15 years, were proven extremely challenging to implement in the case of small isolated systems due to a number of technical as well as economical reasons.

Isolated electricity systems, are characterized by several peculiarities that complicate and raise the costs of electricity generation. More specifically, generation units installed in isolated systems cannot be of too high nominal capacity as the loss of one generator would affect the overall system. As a result, the technical management of the network with regard to the frequency and voltage control is far more complicated and economies of scale cannot be adequately exploited, certainly not at the same level as in large electricity systems.
Isolation also makes it necessary to maintain more reserve capacity (spinning reserve) to ensure adequate supply than would have been the case of large interconnected systems, which by default provide greater stability. Further, it is well acknowledged (e.g. Weisser, 2004) that electricity supply in remote and autonomous systems is more expensive due to the high fuel transportation costs. Limited space and strong public opposition also hinders the development of new conventional plants.

Clearly, these constraints call for different approaches than those applied in mainland territories since high costs suppress the development of competition at the generation site. Note that until market opening these high generation costs were usually borne by the national vertically integrated incumbent and were in turn socialized over the consumers at national level (as remains the case of Spain and Greece). Clearly, regulation thus plays a highly important inter-territorial redistribution role. In recognition to the difficulties outlined above for market reform and the development of competition, Directives 2003/54/EC and 2009/72/EC distinguish between “small” and “micro” isolated systems and provided special clauses and the possibility of derogation from several of the rules in reference to market opening.

In these circumstances, the introduction and development of renewable energy sources provide a valuable alternative to conventional production based on fossil fuels, both from a social and economic point of view. Arguably, RES in autonomous systems can provide a solid instrument for meeting most objectives of the European energy policy: economic efficiency, environmental friendliness and security and diversification of supply. However, the interruptible and irregular nature of wind and solar power, together with the electricity systems’ isolation can severely limit the RES penetration. As analyzed above there are several ways of introducing competition. The most obvious way is by connecting the autonomous system to other, larger ones. However, this is not always possible due to financial as well as technical reasons. In this case, the single buyer model and the bilateral contracts approach may provide a comparatively good alternative (Kozloff, 1998).

Although the characteristics of isolated systems are intrinsically the similar, each European country hosting such systems has adopted different approaches towards market organization. In the next section an overview of the current market organization in Cyprus, Malta and the Spanish islands is provided.
2. Market organization of isolated electricity systems in three European countries

2.1. Malta

Malta has no indigenous primary energy sources and therefore relies on imported fuels, mainly heavy fuel oil and light distillate, for generation purposes. The generation system consists of two power stations, which supply all the electrical power needs of the islands of Malta and Gozo. They are interconnected by means of a distribution grid as no transmission system exists. The Maltese national electricity grid is not connected to any other electrical network.

Because of its’ small electricity consumption (below 3000 Gwh in 1996), Malta’s electricity system is considered to be a ‘small isolated system’ as defined in Directive 2003/54/EC. As a consequence, Malta has requested derogation from a number of articles of the directive 2003/54/EC, the most important of which are Articles 20(1) and 21(1) related to the promotion of competition in the European electricity markets. Furthermore, Malta has requested for derogation from Chapter IV of the Electricity Directive 2003/54/EC, as regards the nomination of a system transmission operator since there is no transmission system in the island. The derogation has been granted by Decision 2006/859/EC of 28 November 2006. As a result Malta, although not obliged to promote free electricity market structures, must strive to ensure that there is no abuse of dominant position of the national incumbent *Enemalta Corporation*.

Enemalta Corporation acts as a generator, distributor and retailer/supplier to 246 000 electricity customers. Legislative framework which foresees for independent producers (IPPs) that may generate electricity to meet their own needs or sell electricity to Enemalta (single buyer model) is in place but to date no grid-connected generators have been installed to the island.

The same situation (i.e. no market opening) holds for the supply side. Enemalta Corporation is the only supplier of electricity to final consumers and subsequently there is no possibility for consumers to choose among different suppliers. Figure 2 shows schematically the market structure in Malta.
2.2. Cyprus

Cyprus is an isolated island country with no physical energy links to other EU Member States, a relatively small electricity market and no gas market. Cyprus, like Malta has no indigenous primary energy sources and therefore relies on imported fuels, mainly heavy fuel oil and light distillate, for generation purposes.

The electricity market has been 67% open since 2009 for all non-household customers, who are now free to select their electricity supplier. Cyprus has derogation from the Directive 2003/55/EC permitting a delay for full market opening until 2012 (households). The Electricity Authority of Cyprus (EAC), which is the national vertically integrated utility is involved in all functions of the electricity market (generation, supply and distribution) and exclusively responsible for the supply of the 33% captive customers. There is a single Transmission System Operator (TSO) which is unbundled in legal and management terms from the system owner (EAC), and is responsible for the balancing of the electricity market. Furthermore, there is a bundled distribution network, owner and DSO as part of the EAC.

The legal framework foresees for competition in the generation market (between EAC, Independent Power Producers, RES and autoproducers) and the market model selected is that of bilateral contracts. However, EAC remains the only power producer in the island. The same applies in terms of electricity supply. Although 67% of electricity consumers in Cyprus are free to select their electricity supplier, the EAC has been their only choice so far. It is obvious thus, that, although the framework for competition in Cyprus exists the
market in practice is not yet operational. Figure 3 shows schematically the market structure in Cyprus.

Figure 3. Electricity market organization of Cyprus

2.3. Spain, Spanish islands and extra-peninsular Electricity Systems (SEIEs)

The Spanish Electric Power Act 54/1997 (LSE) has brought major liberalization in the electricity activities in Spain, through the creation of a competitive electricity generation market and a system for third party access to transmission grids and distribution networks and the progressive empowerment of consumers to decide freely on their electricity supplier.

The above mentioned principles must be incorporated in the island and non mainland electricity regulatory framework, albeit under the condition that these principles will also reflect the specific characteristics arising out of their location, according to article 12 of the 1997 electricity act. Decree 1747/2003 establishes a new model regarding the main operation rules of Spanish islands and extra-peninsular Electricity Systems (SEIEs).

The LSE prescribes a wholesale electricity market for energy suppliers and demanders to jointly determine the price of acquiring energy in the pool. The management of the economic relations between the stakeholders and the technical management of the system are conducted by two independent operators, such as OMEL (Electricity Market Operator).
and REE (Spanish Electricity Grid) respectively. To calculate the regulated electricity tariff, the regulated transmission tariff is charged on top of the wholesale market price, and for small customers, the distribution tariff (access tariff) is also added. Supplier companies will gain a margin from their customers. A series of surcharges and taxes are also added, which have to be paid by all consumers.

In the case of the SEIEs, the intention was to consider their peculiarities on the premise that regulation will stay as close as possible to the general principles of the LSE. In this sense, the activities of transmission, distribution and supply follow the general criteria applied on the mainland with regard to the rules of operation and retribution of regulated activities. In the same way, market operators and the grid have practically the same faculties as in the mainland system, although they are subject to special technical operating particularities established in the legislation for SEIEs. Having mentioned the common elements, we will now describe the main particularities established in the legislation for SEIEs for regulating the operation of the electricity industry. These are as follows:

1. Planning of regulated activities encompasses not only transmission, but also generation, and must be done in a coordinated manner with the Regional Government. It includes at least estimates of additional power that has to be installed in order to meet forecasted demand and taking under consideration specific security of supply criteria.

2. Calls for tenders for new capacity can only be convened by the Regional Government if the minimum level of reserve power cannot otherwise be reached.

3. A generation dispatch is established by declared variable costs, which works on an order of merit. In the dispatch, managed by the network operator, the installations participate on the basis of an ordinary regimen, and they can also do so under a special regimen to cover the demand of distributors and suppliers.

4. The activity of generation is external to the mainland supply market and its retribution contemplates an additional element to compensate the specific costs that are included as a surcharge on the general, nationwide tariff. The cost of each generator in ordinary regimen (Cg) represented by the retribution for generators, for each group (i) by the hour (h), is established from the average mainland price, using the following expression:

   \[
   C_g(i,h) = e(i,h) \times (PMP + PrF(i,h)) + Gpot(i,h) \times Pdisp(i,h) \quad (1)
   \]

   The first sum of the formula is intended to cover the variable costs, where e(i,h) is the energy generated in kWh. PMP is the average annual price approved for determining the electricity tariff in the mainland system in euros/kWh, which
includes the charges for providing complementary services. \(PrF\ (i,h)\) is the operating premium in euros/kWh that complements the PMP as retribution for fuel costs. The second sum of the formula represents what is known as the power guarantee that is established to remunerate the costs of investment, operation and maintenance. It is calculated by multiplying the unit value \(Gpot\ (i,h)\) by the available power of each generator \(Pdisp\). It must give consideration to the reserve level necessary to maintain the electricity system and it is calculated by the availability really provided to the system. The premium \(PrF\) and the retribution for power guarantee \(Gpot\) are established by the Ministry of the Economy based on a report by the National Energy Commission and classified by technologies. This bears in mind the cost of the fuel used, interest rates that represent the cost of the resources and the costs of operation and maintenance.

5. The energy generated by the facilities in ordinary and special regimen can be bought by distributors to supply consumers subject to tariff, by suppliers to supply their customers and by consumers who decide to go directly to the market. The purchased price will be the final average hourly price for stakeholders of this kind in the mainland system as a whole. However, each SEIE can adapt this hourly price to the local seasonal structure of the demand in order to put out the right economic signals to consumers.

In short, points 4 and 5 describe a system where consumers pay a tariff, in some cases equal to the price for the mainland Spanish system, while generators receive a compensation for their higher generation costs. This compensation is financed from a surcharge on the entire national system tariff. Figure 4 shows schematically the market organization in Spain.
Regarding the regulatory regime on the Canary Islands, prior to market opening Unelco-Endesa was the local vertically integrated company responsible for managing the system, generating most of the electricity and having exclusive control over the transmission, distribution and supply of the electricity. Two significant changes have taken place. The first is the appointment, in April 2006 of Red Eléctrica (REE) as the Canary Islands electricity system operation. REE is not the owner of the transmission network but, as the system operator, is responsible for ensuring access to the grid to all stakeholders in conditions of transparency and equality. In this sense, REE acts as a single buyer that buys energy using a generation allotment method (based on minimising the variable costs of the generator units) and delivering it to the distribution network for its later sale, or directly to qualified customers. Furthermore, as the network manager, REE is responsible for long term transmission network planning, proposing the resources and the means to achieve the supply guarantee level for each island electricity system. As the partly responsible for security, REE studies and authorizes or rejects the works proposed by the installation owners that need to be carried out on the transmission network and they issue the necessary orders for exploiting the network.

The second modification concerns the appearance of the figure of supplier who buys energy from the network operator at the same price as for the mainland system. Although they could, in fact, operate as such since 2003, the presence of REE in the Canary Islands may facilitate the entry of new suppliers and increase the specific weight of this activity in the market, because it allows for greater transparency in the operations of the system. This
element could promote free competition and improve the economic efficiency of the electricity system. However Unelco-Endesa is the sole transporter and it is practically the sole generator for the different island systems.

Although the electricity market in the Canary Islands undergoes considerable changes towards a fully liberalization there are some barriers in this process. The most serious is the fact that the regional authorities only promote calls for procurement tenders if they do not reach the minimum level of reserve power and that new generating companies are obligated to present tenders for more than one island, one of which cannot be Tenerife or Gran Canaria. Additionally the LSE excludes island production from the mainland supply market. They could have introduced other competitive mechanisms, like the possibility of establishing bilateral contracts between producers and Supplier companies or qualified customers.

With regard to supply activities, there are some fundamental problems that have to be solved. The first problem is the competition represented by a regulated tariff by default (if it is very low) that could act as a refuge for consumers and a constraint on an adequate development of the sales and Supplier activity. The elimination of this default tariff does not seem to pose major problems for large consumers, but this is not the case for domestic. In any event, while the default tariff remains, an attempt must be made to avoid opportunist behaviour that acts as a constraint on free competition in sales and Supplier. Another, more serious problem is the competitive edge that the existing distributor-Supplier companies has over all other Supplier companies which generate market power and makes it more difficult for new companies to enter the market. In an attempt to minimize this effect, there should be at least a correct separation between the activities of distribution and sales and marketing.
3. Electricity market organization in Greece and the Greek islands

3.1. General

The legal framework regarding the electricity market organization in Greece is included in a series of Laws and Codes, the most important of which are:

- The Electricity Grid Code introduced in 2005
- Law 3468/2006 on the promotion of RES as amended by Law 3734/2009

This legislation package sets the electricity market rules (organisation and operation), established the power exchange, sets the fundamentals and restrictions of the market organization in the non-interconnected islands and sets the ground for the establishment of a non-interconnected islands’ operation code.

In detail, the liberalisation of the electricity sector started in 1999, with the enactment of Law 2773/1999, which aimed at compliance with the provisions of Directive 96/92/EC. According to the provisions of the Law, the electricity sector was divided into two sub-sectors: the networks have remained monopolistic and regulated, whereas free market rules have been applied for electricity generation and supply to eligible customers. The Law imposed, as a condition for any activity in the electricity sector, the issuance of a relative license, issued upon decision by the Minister of Development after a simple opinion of RAE. Furthermore, the Law adopted the basic rules for the organisation of system and market operation, and empowered the Minister of Development broadly to decide, after (simple) opinion of RAE, about the issuance of the secondary legislation deemed necessary for the regulation of specific organisational issues, including the regulation of prices.

During the first years of market restructuring, the System Operation Code (2001), the Power Exchanges Code (2001), the Authorisations regulation (2000) and the Supply Code (2001) have been adopted. Law 2773/1999 was subsequently amended with the provisions of Laws 2837/2000, 2941/2001, 3175/2003, 3377/2005 and 3426/2005. Substantial amendments aiming at the enhancement of market opening and competition in the electricity sector has been included in Law 3175/2003. More specifically, according to the provisions of this Law:
• A Mandatory Pool System was introduced for power generation and wholesale supply, covering the entire market for the interconnected system. All suppliers got the obligations to purchase energy from the Pool and all generators can operate only if selected by the market operator according to their economic bids to the Pool. The Pool was designed to operate on an hourly and daily basis.

• In order to allow for recovery of fixed and capital cost and therefore promote the construction of new power plants, generators acquired the right to submit free economic bids to the Pool, which have been restricted to reflect at least their variable costs.

• All consumers became eligible from July 2004, with the only exception being households and consumers located on non-interconnected islands. Also by July 2007 all customers, except those located on the islands, will become eligible.

• In addition, a capacity assurance mechanism has been adopted, based on the obligation of suppliers to hold capacity certificates and the obligation of generators to issue and market these certificates. To promote new investment, the Law provided for the possibility of organising capacity tenders in Greece, which would guarantee part of future revenues of new investors, in relation to the capacity certificate system.

• A delegation for the issuance of a new System Operation and Power Exchanges Code was also introduced. That Code would aim at setting the details of organisation of the wholesale market and the establishment of a capacity assurance mechanism.

• Electricity traders were allowed to operate.

• Generators acquired the right to choose their natural gas supplier from July 2004.

The proposal for a new System Operation and Power Exchanges Code was prepared by RAE and was approved in May 2005. Further amendments of Law 2773/1999 were introduced with the provisions of Law 3426/2005 which was enacted for the purpose of implementing the provisions of Directive 2003/54/EC. The provisions of this Law may be summarised by the following:

• It granted the right to choose supplier to all customers, by 1 July 2007, when household customers become eligible, with the exception however of the customers situated on the non-interconnected islands.

• Reform of the licensing procedures regarding generation units of non-interconnected islands.

• Clarification of the HTSO duties and responsibilities, regarding the maintenance and expansion of the Transmission System; reinforcement of TSO’s independence vis-à-vis PPC’s management and competencies.

- Clarification of the public service obligations regime.
- Delegation for the issuance of a non-interconnected islands’ Operation Code, which shall include rules regarding the operation of the electricity generation units situated on such islands, as well as rules on dispatching and grid operation, aiming at promoting reliability and economic performance.
- Facilitation of the criteria for the granting of supply licenses.
- Enhancement of the Regulator’s role and duties.

Finally, in October 2006 Law 3468/2006 was enacted with the purpose to further promote the generation of electricity produced from Renewable Energy Sources (RES) and High-Efficiency Cogeneration of Electricity and Heat. The Law included new incentives principally as regards photovoltaic plants as well as several facilitations of the complex administrative procedure for getting the operation permits.

Also for the purpose of simplification of administrative procedures, the Law 3325/2005 was enacted, regulating the licensing procedures for industrial installations and operation, including also energy-related infrastructure.

As mentioned above, after the enactment of Law 3175/2003, a new System Operation and Power Exchanges Code, providing for the organisation of a competitive day-ahead wholesale market, was adopted (2005). The applicable model is the one of the mandatory pool system, consisting mainly of the following:

![Figure 5. Market organization in Greece [11]](image)
The HTSO is granted the duties of the market operator. Within that framework, the HTSO:

- Collects (a) the demand declarations that are submitted by the load representatives and exporters, and (b) the generation offers that are submitted by the generators and the importers.
- Computes the system marginal price – SMP for each hour of next day by sorting in ascending order the economic bids.
- Determines the operation schedule for the next day applying least cost unit commitment based on economic offers and system constraints.
- Controls the operation of power plants and the use of interconnections.
- Settles financial transactions, and manages imbalances.
- Plans for and carries out the provision of ancillary services, such as voltage control, reactive power and power reserves.
- Generation offers include an economic bid (except RES other than large hydro), which has ten steps for each hour of the next day and must be equal or higher than the unit fuel cost of the plant. A price cap is applicable (150 €/MWh).
- Withholding capacity is not permitted except in case of planned or unplanned outage; otherwise the HTSO is responsible for imposing penalties to generators.
- All financial transaction between the HTSO and generators and suppliers are carried out on the basis of the SMP.
- Bilateral contracts with physical delivery are not permitted; but, bilateral contracts about financial settlements (e.g. contracts for differences) are permitted and are uncontrolled.
- Capacity Certificate Obligations for load representatives, i.e. suppliers and auto-supplied customers, apply. More specifically, according to the capacity assurance mechanism: Capacity Certificates are issued by all generators, refer to a future date and declare technical availability of certain power capacity (even future) from a specific power plant – Generators may price freely their Certificates.
- Each supplier bears the obligation to submit to the HTSO Capacity Certificates up to a level covering the peak load of his customers; otherwise a penalty is applied by the HTSO.
- Suppliers purchase their Certificates from Generators after bilateral financial agreements that are not regulated. Vertically integrated companies (e.g. PPC) are not obliged to enter into such financial agreements.
- During a transitory period, in order to purchase power from Day Ahead Wholesale market, suppliers other than PPC may just pay a fee which is currently set at 35,000 €/MW-year.
• Total cost borne by suppliers is equal to SMP, plus capacity payments corresponding to Capacity Certificates.
• In case of inadequacy of supply, the HTSO may organise tenders for new capacity by granting capital revenue guarantees. The first tender was launched in 2006. This tender was stopped in summer 2007, since upon complaint related to the tender rules and specifications the Commission decided that it did not comply with the general principles of EU legislation.

As far as it concerns Liberalisation of the retail supply market the opening started on 19 February 2001 when consumers connected to the HV System or the MV Network acquired the right to choose supplier. With the provisions of Law 3175/2003 from 1 July 2004 all non-household customers situated on the interconnected system (circa 70% of the annual electricity consumption) became eligible. However, in 2003 still only five eligible customers were served partially by a supplier other than PPC, covering a small part of their load through imports.

According to Law 3426/2005, on 1 July 2007 all customers, including households, became eligible. However, the practical consequences of market opening are rather negligible, since nobody has changed supplier so far. This is mainly due to the regulated tariffs that PPC is obliged to apply: these tariffs are often below cost, making new entrance into the supply business almost impossible.

3.2. Greek non-interconnected islands

Greek islands whose electricity distribution system is not connected to the mainland’s grid or distribution system (Law 2773/1999) are characterized as “non-interconnected islands”. Most of the Greek islands in the Aegean Sea are not interconnected with the electricity grid of the mainland and have local autonomous systems. Some of them are interconnected to each other in groups. The biggest isolated systems are those of the islands of Crete and Rhodes.

Except Crete, the energy demand of all remaining non-interconnected islands was below 500GWh in 1996 and thus may be considered to be isolated micro-systems. A request for derogation according to Art. 26, Directive 2003/54/EC regarding the small non-interconnected islands (not including Crete and Rhodes) was submitted by the Greek Government to the Commission. If such derogation is granted, consumers situated on such islands will remain non-eligible, and PPC will remain the sole generator, distributor and supplier operating on such islands. Under these circumstances only in Crete and Rhodes a liberalized electricity market could be established.
Oil is almost exclusively the energy form used for electricity production in the non-interconnected islands; oil-fired plants cover almost the total electricity produced in these islands. The percentage of RES is still small (10%). With the exception of RES, all generation licenses at the Greek islands are held by PPC. PPC also holds licenses for one new oil-fired plant to be built on Rhodes (120MW) and a second natural gas fired to be built on Crete (500 MW). Furthermore, projects for large-scale interconnection of the islands with the electricity grid of the mainland are currently under consideration.

The legal framework sets the fundamentals towards a fully liberalized energy market in which independent energy producers and suppliers may become active at least in Crete due to the existence of a Mechanism of Revenues for Public Service Obligations (PSO).

PPC is also the grid operator of all the non-interconnected islands (including Crete) and responsible for the technical and economic management of the system in the non-interconnected islands. According to the Law PPC is obliged to:

i) Manage the overall generation activity making sure that the electricity demand is satisfied and that priority to Renewable Energy Sources (RES) is assigned during dispatch.

ii) Ensure third party access to the local grids.

iii) Settle any payments to/from the independent generators and suppliers taking action in the market of the non interconnected islands.

As in other cases examined in Section 2 of this report, the legal framework required for market opening is in place however PPC remains the single generator from conventional sources, the single supplier and the system/market operator. The price and methodology for remunerating the (conventional) energy producers and purchasing energy (supplier) is under consideration. Because the same company acts as generator and supplier a “compensation” practice between the costs of produced and supplied energy is adopted. The consumers (in mainland and non-interconnected islands) pay for the electricity according to regulated tariffs as there is only one producer and supplier. The extra cost for the electricity production in the non-interconnected islands is recovered from the so called revenues for “public service obligation”.

Feed-in tariffs are foreseen for the energy produced from RES which vary according to the RES type and installed capacity of the plant. The current tariffs are shown in Table 2 but they are under revision.
### 3.3. The autonomous system of Crete

Crete is the largest Greek island and lies approximately 160 km south of the Greek mainland. Its main characteristics regarding population, surface and energy needs are given in Figure 6.

![Map of Crete](image)

**Table 2. Feed-in tariffs for RES energy (€/MWh)**

<table>
<thead>
<tr>
<th>Electricity production from</th>
<th>Mainland</th>
<th>Non-interconnected islands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>87.85</td>
<td>99.45</td>
</tr>
<tr>
<td>Off-shore wind</td>
<td>194.95</td>
<td></td>
</tr>
<tr>
<td>Small hydro &lt;15MW</td>
<td>87.85</td>
<td>99.45</td>
</tr>
<tr>
<td>Photovoltaics &lt; 100kWp</td>
<td>457.14</td>
<td>907.14</td>
</tr>
<tr>
<td>Photovoltaics &gt; 100kWp</td>
<td>467.14</td>
<td>467.14</td>
</tr>
<tr>
<td>Solar thermal &lt; 5MW</td>
<td>264.95</td>
<td>264.95</td>
</tr>
<tr>
<td>Solar Thermal &gt; 5MW</td>
<td>244.95</td>
<td>264.95</td>
</tr>
<tr>
<td>Other RES</td>
<td>87.85</td>
<td>99.45</td>
</tr>
<tr>
<td>Cogeneration</td>
<td>87.85</td>
<td>99.45</td>
</tr>
</tbody>
</table>

![Figure 6. The autonomous system of Crete](image)
Hourly energy demand of the island in 2008 is depicted in Figure 7. As shown its peak demand was 650MW and its energy consumption was about 3TWh. The energy demand on the island is covered mainly by three conventional power stations located in Iraklion, Chania and Atherinolakkos with a total installed capacity in 2008 of 800MW and comprising steam turbines, open cycle gas turbines, one CCGT and several Diesel units. Additionally there are about 161MW of wind parks installed on the island, corresponding to 14% of the total energy supply, 1,5MW of PVs and 300kW of hydro-power.

RES applications for hybrid power plants (HPS) -plants combining RES and storage units- of about 360 MW and 273MW of solar thermal power plants are under consideration by the Regulatory Authority for Energy of the Hellenic Republic, while 90 MW of PVs are already licensed. In the next years the installed capacity of conventional power units will be increased in order to meet the energy demand, while 220MW of wind power and 90MW of PVs are foreseen to be installed.

The question arising is how to operate such a system and organize the electricity market which consists of several players:
- one System Operator (TSO)
- producers, producing electricity from different types of units (conventional units, RES, HPS etc.)
- retailers/suppliers and
- eligible consumers
Although there are certain barriers to be overcome as described above which refer to all isolated systems, Crete because of its yearly energy demand is a system offering proper conditions to set rules in order to boost new players to enter the market.

A scheme of possible market organization in Crete is given in Figure 8. The exact relations and transactions between the players have to be identified. Special attention is given to HPS.

A single TSO is responsible for the technical and economic management of the system and among others:

i) manages the generation activity making sure that the electricity demand on the island is satisfied.

ii) secures that there is no discrimination between generators operating on the island.

iii) undertakes bilateral contracts with holders of generation and supply license and makes sure that the latter have access to the grid.

iv) is responsible for the settlement of payments regarding the independent generators and suppliers taking action in the market of the island.

Such an electricity market structure foresees a daily ahead market organization and the participation of all players (producers and suppliers). The following paragraphs describe in detail the envisaged operation of the Cretan electricity market.

The TSO is responsible for forecasting the next day demand on an hourly basis as well as the amount of any auxiliary services necessary to be included in the daily schedule so as to ensure uninterrupted energy supply. Additionally the TSO is responsible for forecasting the
energy to be produced from the Hybrid Power Stations (HPS). In this way TSO requires the HPS to provide a guaranteed but not compulsory level of energy in a daily basis.

Based on the TSO’s forecasts and their storage capacity, HPS submit

- A daily offer of energy to be produced,
- Capacity availability and
- Energy absorption needs

The latter (energy absorption) is only allowed in the case there is a requirement for guaranteed power and energy from the HPS.

All other producers (conventional power units) are not required to provide an offer for a certain amount of energy to be produced (just an energy offer not a price and energy pair as is done in the mainland). The price at which this energy will be remunerated is already declared and corresponds to the variable cost of the unit regarding its technical characteristics.

From their side suppliers declare the load of their customers.

The operation schedule is determined by the TSO in order to achieve minimum generation cost. In these terms the SMP of the island is calculated.

Priority in dispatch is always given to RES producers. Energy produced by the HPS’s firm output units is also prioritized in reference to the conventional power units, which supply the grid mainly at peak load hours in order to cover conventional capacity deficits. The TSO is not obliged to meet the total energy offer of the HPS producer.

On the contrary TSO allows energy absorption from the grid to the HPS in the load curve “valley” (low load hours). Additionally maximum exploitation of the RES system in order to fill up the storage system of HPS- RES energy stored, rather than directly fed to the load is required. In this way operation of other wind farms is not affected.

The storage part of the HPS should operate in the same mode as the conventional peak units: providing frequency and voltage regulation as well as spinning reserve. Storage systems (e.g. variable speed pumps) should follow RES production. In this way turbines should be dispatched for rated power but possibly operated at reduced power and energy output, to absorb wind power from other wind farms.

According to these basic market operation rules Figure 9a shows the energy demand and supply in the system of Crete in 2012 regarding HPS of 250MW. The energy demand is...
covered by all types of units (steam turbines- brown, gas turbines-yellow, CC-orange and Diesel units-red, wind farms- green and HPS-blue). As described HPS submits a daily energy offer and TSO dispatches it regarding the load curve. In this way energy required at peak load hours is provided by HPS leading to effective smoothing of the load curve (peak shaving and valley filling) and minimizing the conventional generation (e.g. start-stops, fast power ramps).

In order to make it clear Figure 9b shows a different operation way of the HPS leading to a lot of start-stops of conventional power units as well as fast power ramps.

As far as it regards financial transactions all energy producers should be remunerated for the
- Produced energy
- Capacity availability
- Ancillary services

Figure 9. Two different operation ways of HPS
Possible revenue to remunerate the energy produced from conventional power units could be the island’s SMP as calculated from the TSO or the declared variable cost of its unit taking part in the load coverage.

HPS producers should be remunerated in a different way for the energy produced from the hybrid station’s firm output units, exploiting the energy stored in the storage system and for energy the RES units of the hybrid station supply directly to the Network of the island. The first revenue could be calculated according to the mean marginal cost of the conventional peak units operating on the island (Law 3468/2007). Calculations for the system of Crete could lead to **219 €/MWh for an HPS connected to the grid in 2008**. Such a way of remuneration depends on circumstances and market rules and could change depending on the day which HPS will be connected to the grid, case that arise bank financing issues and in this way feasibility issues.

Another option is to remunerate this energy by fixed feed-in tariffs calculated by taking into account time series data and forecasts for various parameters as fuel cost, emissions expenses, operation and conservation cost and which would be reviewed every 3-5 years.

As far as it concerns the energy the RES units of the HPS supply directly to the Network of the island it can be priced according to the existing feed-in tariff depending on RES technology as given in Table 1. Power produced in the RES units of the hybrid station and directly supplied to the Network of the island may be compensated to the power the hybrid station absorbs from that network for fulfilling its storage system.

Conventional and HPS producers should be remunerated for their capacity availability and ancillary services provided in the same way and in a way to be able to cover their fixed cost.

HPS have to pay for the energy absorbed from the Network for fulfilling their storage system. There are again two options for pricing such energy: according to Law 3468/2007 and thus conducted on the basis of the mean variable cost of the conventional base units operating on the island (annual mean variable cost – **75 €/MWh for an HPS connected to the grid in 2008 in Crete**) or according to a fixed tariff taking into account time series data of different crucial parameters.

Energy producers (conventional and HPS) may pay penalties (motivation for efficiency) because of systematic non compliance to the TSO’s requirements.

Energy suppliers on the other hand may purchase energy, in uniform SMP over Greece.
As it can be is well known electricity supply in Crete is also more expensive because there are high fuel transmission costs in comparison to the mainland. TSO does financial settlement and recovers the extra production cost (difference) from the revenues for Public Service Obligations.

4. Electricity market organization in Portugal and the Portuguese Islands

4.1. General

The electricity sector in Portugal has a mixed ownership structure: some companies are fully or partially privatized while others are public-owned. EDP Produção, fully owned by Energias de Portugal (EDP), is the dominant player, accounting for 61% of total demand in 2006. EDP is the former public monopolist, 25.49% owned by State. Other major players are Tejo Energia (100 %) privatised, 50% controlled by International Power), accounting for 9.8 % of total demand in 2006, and Turbogás (100 %) privatised, controlled 60% by International power and 40% by EDP), accounting for 9.1% of total demand in 2006. Several licences issued for auto-producers. Until 30 June 2007 the market model was based on Power Purchasing Agreements (PPA) in public sector and bilateral contracts in market. In the 1st of July began the Iberian Electricity Market (MIBEL), based on a Derivatives Market operated by OMIP, in Lisbon, and a Daily Market operated by OMIE (ex-OMEL), in Madrid. Virtual Power Auctions and bilateral contracts are also foreseen. Two PPA still remains in force (Tejo Energia e Turbogás). Red Eléctrica National SA (REN) holds exclusive licence as TSO for networks above 45 kV, under Regulated TPA regime. The transmission company is owned by State (20%), EDP (10%), Caixa Geral de Depósitos (CGD) (20%) and Parpública SGPS (30%). Legal unbundling is in place for transmission.

There is one Distribution Company, EDP Distribuição, and 10 small distributors, operating under Regulated TPA regime. EDP Distribuição, a legally unbundled subsidiary of EDP, is the dominant player accounting for almost 98% of total energy distributed in 2006. Suppliers may freely buy and sell electricity. To this effect, they have the right to access the transmission and distribution grids, against the payment of regulated tariffs. Consumers may freely choose their supplier. In addition, supplier switching will not be encumbered in any way whatsoever in contract terms. In order to simplify and materialize supplier switching, the figure of the supplier-switching logistic operator is created Last resort supplier has also been established by law, for consumer protection. The purpose is to supply electricity, in conditions of quality and continuity-of-supply, to consumers – namely

<table>
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<th>0202</th>
<th>29/06/20102</th>
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<td>WP</td>
<td>Doc. Type:</td>
<td>Order Nº:</td>
<td>Date:</td>
</tr>
</tbody>
</table>
the less-favoured ones. In this way, it was created EDP Serviço Universal, a legally unbundled subsidiary of EDP Distribuição.

### 4.2. The island of Corvo

The island of Corvo is one of the 9 islands in the Azores archipelago and together with S. Miguel and Flores form the Western Group. It is the smallest island on the archipelago with an area of 17 km² and is situated at 31° 5′ West longitude and 39° 40′ North latitude. The island is an inactive volcano named Monte Grosso and its crater, a lake, is the island highest point, circa 720 m. There is only one settlement, Vila Nova do Corvo, where some 400 people reside.

![Figure 10. The crater on the island of Corvo](image)

The supply of electricity to an isolated small island such as Corvo is very limited, while there is a great concern with environmental issues related to fossil fuel supply, such as water and land contamination and pollution by oil products and wastes through leakage during shipping handling and storage. The incidence of small-scale oil spills during loading that occurs adjacent to the storage facilities is very common in Corvo. The fuel cost in Corvo is the highest of the entire archipelago, nearly 5 times more than average in Azores. The island’s annual demand of approximately 1084 MWh and peak of 182 kW is covered by four diesel generators, two sets of 120kW and two of 160kW. However, the demand is met by two generators one of each group.

Although Kozloff (1998), in reference to small systems in which the improvements arising from competition are limited, proposes the single buyer model as an intermediate solution between competition and regulation such a model could not be operated in the case of Corvo. The low annual energy demand of the island makes impossible the development of
any electricity market structure. In order to be able to propose a scheme of market organization the interconnection of the island to other islands is necessary.

Regarding the electricity market organization on the island itself the only solution is the proposal of specific rules under which an energy system that combines RES and storage (HPS) could be operated on the island in order to provide security of supply. There are two possible solutions regarding the technology of the storage system – hydrogen and a pumped-hydro. The RES technology could be wind energy.

As far as it regards the wind-pumped-hydro system the natural crater located at around 720 m above sea level can be used as the upper reservoir, that has to be waterproofed. As lower reservoir a storage tank should be constructed. Regarding the reservoirs, their maximum storage capacity should be of appropriate size to provide security of supply for a longer dry period. Although Corvo has a high wind average speed, there are some seasonal variations. There are moments when wind does not blow for some days, and there will be not enough water storage capacity to guarantee energy supply during that time. Therefore the diesel engines currently installed in the island will remain to supply back-up power.

Regarding operation of the wind-pumped-hydro power station, excess electricity from the wind farms will be used to supply power to the pumps that will lift water from the lower to the upper reservoir. Water will be “turbined” at the hydro station to supply power when production from the wind farm is not enough to supply the island’s electrical demand. Fresh water will be used in the pumped-hydro system instead of sea water, given environmental concerns. Fresh water will be added to cover losses through evaporation and other possible water losses.

The above mentioned system will be operated in a way providing except from the requested energy, auxiliary services, as frequency and voltage regulation as well as spinning reserve. The storage system (e.g. variable speed pumps) should follow RES production. In this way turbines should be dispatched for rated power but possibly operated at reduced power and energy output, to absorb wind power from other wind farms.

Another possible solution – already studied in detail in Task 2.2. of the STORIES-Project – could be the introduction of hydrogen as a storage means and wind energy as an electricity production source into the power supply system of the island.

The concept of the proposed system is to produce more green electricity to serve the demand by using wind turbines and diesel generators. Due to the intermittent nature of wind energy, a hydrogen storage system is introduced. The storage system consists of the
electrolysis unit, which uses excess energy from the wind turbines to generate hydrogen, a storage section that stores the produced hydrogen and a fuel cell that uses hydrogen as a feedstock in order to produce electricity to serve the electrical load when it is needed.

The analysis demonstrated that the optimum wind energy & hydrogen power system for Corvo consists of the following equipments:

- 2 Fuhrländer, model FL100, wind turbines with a nominal capacity of 100 kW each;
- 1 Diesel Generator Set running on diesel with a nominal capacity of 120 kW;
- 1 Diesel Generator Set running on diesel with a nominal capacity of 160 kW;
- 1 PEM Fuel Cell with a nominal capacity of 50 kW;
- 1 Alkaline Water Electrolyser with a nominal capacity of 80 kW, capable of producing ca. 19 Nm$^3$/hr of hydrogen;
- A hydrogen storage tank with a total capacity of 200 kg of hydrogen.

The simulation results for the optimized RES & hydrogen power system showed that the power generation cost on the island decreases, and more than half the electricity is produced from wind energy, making a considerable increase of RE penetration from zero to 80%. Moreover, the introduction of RES and hydrogen as an energy storage medium in the power system results in a significant decrease in emission production on the island. The following table outlines the main differences between the existing and the proposed power system.

### Table 3. Summary results for Corvo

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing power system</th>
<th>Proposed power system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional capacity (kW)</td>
<td>560</td>
<td>280</td>
</tr>
<tr>
<td>Wind installed capacity (kW)</td>
<td>0</td>
<td>200</td>
</tr>
<tr>
<td>Fuel cell capacity (kW)</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>Yearly production (kWh/yr)</td>
<td>1,084,413</td>
<td>1,557,893</td>
</tr>
<tr>
<td>Electric demand (kWh/yr)</td>
<td>1,084,411</td>
<td>1,084,411</td>
</tr>
<tr>
<td>Excess electricity (kWh/yr)</td>
<td>0</td>
<td>153,472</td>
</tr>
<tr>
<td>Renewable energy penetration</td>
<td>0%</td>
<td>80%</td>
</tr>
<tr>
<td>Diesel fuel (L/yr)</td>
<td>288,051</td>
<td>89,024</td>
</tr>
<tr>
<td>Cost of energy (€/MWh)</td>
<td>259</td>
<td>145</td>
</tr>
<tr>
<td>CO$_2$ emissions (kg/yr)</td>
<td>758,532</td>
<td>234,323</td>
</tr>
<tr>
<td>CO emissions (kg/yr)</td>
<td>1,872</td>
<td>621</td>
</tr>
</tbody>
</table>


The proposed system results in a remarkable reduction (43%) in the power generation cost. Moreover, with the proposed system the 80% of the electricity needs of the island would be covered by renewable energy, which uses a free feedstock for the production of energy, decreasing the island’s heavy dependency on imported fuel and the production of harmful emissions and enhancing the security of supply, which is an important issue taking into account the long distance of this island from larger islands and Continental Portugal.

The financial viability of the proposed system was investigated based on the NPV and IRR indices and the results showed that the proposed system is a quite profitable investment. However, the proposed system was also examined in terms of its environmental and social implications. A cost-benefit analysis was performed aiming to identify and assess the benefits and costs of the RES-energy storage system from the perspective of the environment and the society. The results showed that an 80% penetration of wind energy into the power system of Corvo island coupled with the introduction of hydrogen energy storage is profitable both from the perspective of the investor and the society. Thus, the proposed wind energy & hydrogen storage power system for Corvo is an attractive proposal that shows private and social interest.

More details regarding the system can be found in the Deliverables 2.2. and 3.3. of the STORIES- Project.
5. Conclusions

The study revealed that the introduction of competition in small isolated systems has been characterized by a series of difficulties. Parameters such as the generation system size, network constraints, topology, existing regulations and the respective legislative framework have affected market structures. Based on study findings it may be concluded that the most crucial parameter affecting the market structure is the actual size of the generation system. Nevertheless, both in generation and supply, introduction of competition is possible provided that a suitable model of regulation is designed and properly applied. The most obvious way to circumvent all complexities related to the organization of isolated systems is obviously by connecting them with other, larger systems. However, when this is not possible, there are other feasible solutions and to this end Hybrid Power Systems can provide a most promising alternative since, given suitable incentives, they can lead to increased investor interest, enhanced RES penetration levels and secure uninterrupted energy supply.

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