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Sustainable energy policymaking for Cyprus

Nicosia 2015

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**SUSTAINABLE ENERGY
POLICYMAKING FOR CYPRUS**

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***“You will never do anything in this world without courage.
It is the greatest quality of the mind next to honor”***

Aristotle (384 BC – 322 BC)

I dedicate this to my daughter Agnes
for her 19th birthday anniversary and the beginning of her undergraduate
studies in *Philosophy, Politics and Economics; Ubi concordia, ibi victoria*
(where there is unity, there is the victory)

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Preface

“The true sign of intelligence is not knowledge but imagination”

Albert Einstein (1879 AD– 1955 AD)

Sustainable energy policymaking for Cyprus provides an insight to the current and future steps required for the Cyprus’s policymaking in sustainable energy. This is expected to play an important role in the future economic development of the island.

The current article collection resulted from publications during the past five years in local newspapers and journals. The popularize articles contained in this book are based on recent scientific publications, in reputable international peer reviewed journals and books.

The articles are written in simple non-scientific language suitable for a wide range of readers without any technical or economic background. Some of the articles suggest the establishment of the Cyprus Energy Strategy Council. Since then, this has been established by the President of Cyprus, His Excellency, Mr. Nicos Anastasiades, as an advisory body to the Government of Cyprus.

The current article collection book collection is divided into three sections namely:

- Alternative Energy Sources,
- Energy Markets, and
- Energy Strategies.

Sustainable energy policymaking for Cyprus is not by any means exhaustive, nor is it intended to be, but to provide current developments and ideas for the Cyprus future energy needs.

Dr. Andreas Poullikkas
Nicosia, 2015

Alternative Energy Sources

Renewable energy sources tap naturally occurring flows of energy to produce electricity, fuel, heat, or a combination of these energy types

Sustainable energy sources

To generate electricity in developed countries, 70-90% of their energy comes from burning fossil fuels, such as coal, oil and gas, or nuclear power. Fossil fuels release the powerful greenhouse gas carbon dioxide. Climate change, acid rain, mining, oil spills, and radioactive contamination are all unwanted impacts from the unsustainable way in which energy is generate and utilized.

As a result of the global warming effect illustrated in Figure 1, recent concerns on environmental protection and sustainable development resulted to the critical need for a cleaner energy technology. Some potential solutions have evolved including energy conservation through improved energy efficiency, a reduction in the fossil fuels and an increase in the supply of environmentally friendly alternative energy sources which is leading to the use of Renewable Energy Sources (RES) and an alternative to large scale source of energy production known as the Distributed Generation (DG) technologies.

RES and DG technologies are also often called alternative energy sources that use domestic resources that have the potential to provide energy services with zero or almost zero emissions of both air pollutants and greenhouse gases.

Figure 1: The effect of global warming (Source: U.S. National Climatic Data Center, 2001.)

Renewable energy sources tap naturally occurring flows of energy to produce electricity, fuel, heat, or a combination of these energy types. These inexhaustible sources of energy are domestically abundant and have less impact on the environment than conventional sources. They can provide a reliable source of energy at a stable price.

RES technologies are defined as the non-fossil energy sources, such as:

- ~ wind,
- ~ solar,
- ~ geothermal,
- ~ wave,
- ~ tidal,
- ~ hydropower,
- ~ biomass,

- ~ landfill gas,
- ~ sewage treatment plant gas and
- ~ biogas.

Table 1: Commercially available and emerging RES technologies

RES technology	Commercially available	Emerging technology
Wind turbines	✓	
Photovoltaic systems	✓	
Hydropower	✓	
Biomass	✓	
Geothermal	✓	
Fuel cells	✓	✓
Solar thermal	✓	✓
Wave energy		✓
Tidal energy		✓

Figure 2: World electricity production in 2013 (Source: EC, 2011)

The status of the various RES technologies is indicated in Table 1. An investment in renewable energy (and in energy efficiency)

is important to reduce negative economic, social, and environmental impacts of energy production and consumption. As illustrated in Figure 2, RES technologies are already important factors in the world's energy mix, contributing about 18% of the total world electricity requirements. The technical potential of RES technologies is given in Figure 3.

Figure 3: World RES technical potential (Source: World Energy Assessment - UNDP, 2010)

The environmental advantages of the production and use of RES electricity seem to be clear. Using RES technologies, like hydropower, biomass, geothermal, and wind energy, in electricity production reduces primary and greenhouse gas emissions.

Emissions such as SO_2 , CO_2 , and NO_x are reduced considerably, and the production and use of RES electricity contributes to diminishing acid rain and greenhouse effect. Solar- and wind-generated electricity can be used to electrolyze water for producing hydrogen gas.

Hydrogen can be used in fuel cells, which are a promising non-polluting technology for use as a source of heat and electricity for buildings and as an electrical power source for electric vehicles.

Future sustainable energy sources

The power industry is one of the few industrial sectors, which affect prosperity of every sphere of economic and social life and exert a direct influence on general technological progress. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be focused on efficiency and sustainability in energy production.

A sound national energy policy should encourage a clean and diverse portfolio of domestic energy supplies. Such diversity helps to ensure that future generations of Cypriots will have access to the energy they need. Renewable energy can help provide for our future needs by harnessing abundant, naturally occurring sources of energy, such as the sun, the wind, and biomass, which are the only available renewable energy sources in Cyprus.

Effectively harnessing these renewable resources requires careful planning and advanced technology. Through improved

technology, we can ensure that Cyprus will make use of clean, natural, renewable and alternative energy sources.

Renewable and alternative energy sources will not only help diversify Cyprus energy portfolio but they will do so with few adverse environmental impacts. Renewable energy sources tap naturally occurring flows of energy to produce electricity, fuel, heat, or a combination of these energy types. Cyprus has significant potential for renewable resource development especially from the sun and in less extent from wind and from biomass.

These non-depletable sources of energy are domestically abundant and have less impact on the environment than conventional sources. They can provide a reliable source of energy at a stable price. Alternative energy includes alternative fuels other than gasoline and diesel, the use of traditional energy sources, such as natural gas, in untraditional ways, such as for distributed energy at the point of use through micro-turbines or fuel cells and future energy sources, such as hydrogen and fusion.

Both renewable and alternative energy resources can be produced centrally or on a distributed basis near their point of use. Providing electricity, light, heat, or mechanical energy at the point of use diminishes the need for some transmission lines and pipelines, reducing associated energy delivery losses and increasing energy efficiency. Distributed energy resources may be renewable resources, such as biomass cogeneration or rooftop solar photovoltaic systems on homes, or they may be alternative uses of traditional energy, such as natural gas micro-turbines.

As we look to the long-term future of alternative energy technologies, there is significant promise in these technologies to

meet an ever-growing portion of future generations energy needs.

Hydrogen

In the long run, alternative energy technologies such as hydrogen show great promise. Hydrogen is the most common element in the universe and can be made from water. Converting hydrogen into energy is compatible with existing energy technologies, such as fuel cells, engines, and combustion turbines.

The energy for extracting hydrogen could come from existing, traditional fuels, or it could be derived from renewable energy sources, such as solar and wind, from nuclear, and from fossil, to achieve the cleanest possible energy cycle. Hydrogen can be converted into useful energy forms efficiently and without detrimental environmental effects. Unlike other energy sources, its production by-product is water.

In the future, hydrogen may be able to be used in furnaces and as a transportation fuel for automobiles, buses, trains, ships and airplanes. Hydrogen could also be converted directly into electricity by fuel cells. Combustion of hydrogen with oxygen results in pure steam, which has many applications in industrial processes and space heating. Moreover, hydrogen is an important industrial gas and raw material in numerous industries, such as computer, metallurgical, chemical, pharmaceutical, fertilizer and food industries.

An energy infrastructure that relies on hydrogen could enable much greater use of distributed energy systems. These systems are small, modular electricity generators that can be placed right where they are needed for heating, cooling, and powering offices, factories, and residences. Hydrogen fuel cells are a

promising type of distributed energy system that can provide the exacting reliability needed for the high-tech industry.

Fuel cells can produce electricity and heat from hydrogen, natural gas, and petroleum fuels, and fuel gases derived from coal and biomass. What makes fuel cells unique is that they can use fuels without combustion, simply by chemical reactions, making them extremely clean and efficient. Fuel cells were primarily developed to generate electricity, heat, and water in space vehicles.

The first-generation fuel cells for stationary power applications entered the commercial market in 1995. This type of fuel cell is used to generate very high-quality electricity and heat with negligible emissions in commercial and industrial settings. It is most likely to be used in cases where users are willing to pay a premium for cleaner, more reliable power than is available from the commercial grid.

The second generation of stationary fuel cells is currently in the demonstration phase, including a combined fuel cell–turbine hybrid. These fuel cells are expected to be more efficient and cost less when used in similar distributed energy systems. Smaller fuel cells for residential units are also being developed, and some are in the demonstration phase.

Despite technical progress, high costs remain the main deterrent to widespread fuel cell use. Significant cost reductions must be achieved before fuel cells will be competitive with internal combustion engines, and the size and weight of fuel cell systems must be reduced even more to accommodate vehicle packaging requirements.

The primary challenge to using more hydrogen in our energy systems is the cost of producing, storing, and transporting it. A serious challenge confronting a move toward distributed energy is the transition away from centralized energy systems of supply and production.

These challenges are not expected to be resolved overnight, but progress made in the last few years has already far surpassed the expectations of just a decade ago. A significant amount of promising research and development has already been completed. The automobile industry is aggressively exploring the fuel cell as the future of the industry. Moreover, a new first generation class of distributed energy technologies is already hitting the market.

Fusion

Fusion (the energy source of the sun) has the long-range potential to serve as an abundant and clean source of energy. The basic fuels, deuterium (a heavy form of hydrogen) and lithium, are abundantly available to all nations for thousands of years.

There are no emissions from fusion, and the radioactive wastes from fusion are short lived, only requiring burial and oversight for about 100 years. In addition, there is no risk of a melt-down accident because only a small amount of fuel is present in the system at any time. Finally, there is little risk of nuclear proliferation because special nuclear materials, such as uranium and plutonium, are not required for fusion energy.

Fusion systems could power an energy supply chain based on hydrogen and fuel cells, as well as provide electricity directly. Although still in its early stages of development, fusion research has made some advances. Internationally, an effort is underway in Europe, Japan, and Russia to develop plans for constructing a

large-scale fusion science and engineering test facility. This test facility may someday be capable of steady operation with fusion power in the range of hundreds of megawatts.

Both hydrogen and fusion must make significant progress before they can become viable sources of energy. However, the technological advances experienced over the last decade and the advances yet to come will hopefully transform the energy sources of the distant future.

The role of Cyprus in the Mediterranean solar plan

It is generally accepted that climate change is the result of the rapid growth of new economies around the world, since conventional fuels are used in order to meet their energy demand. Thus, the future environmental, economic and social challenges for the Mediterranean countries are very important and directly related to sustainability. The economic and social development in combination with the environmental protection of the Mediterranean region, constitute the basic ingredients for the viability of the area.

The Mediterranean region

The Mediterranean region is already highly polluted region with serious problems, such as, desertation, potable water shortage, and excessive pollution, from industrial activities as well as from marine activities. Based on recent studies, during the end of this century, the average temperature of the earth is expected to rise between 2.2 and 5.1 degrees Celsius.

It is, therefore, expected that the rise of sea water level will flood large land areas, imposing, thus, movement of population in higher altitudes. Demographic increase and the continuous increased economic activities of South Mediterranean countries

are expected to change considerably the current energy demand profile of the Mediterranean region. In particular, it has been estimated that by 2020 South Mediterranean countries energy needs will be doubled and that by 2050 their power needs will reach that of the European level.

On the other hand the European Union (EU) has already tuned its energy policy into achieving maximum reduction of carbon dioxide emissions from power generation plants. In this context, it has already set out a strategic objective of achieving at least a 20% reduction of greenhouse gases by 2020 compared to 1990.

This strategic objective represents the core of the new European energy policy. Recognizing the positive effects of renewable energy sources (RES) technologies towards achieving this goal, the EU has taken a range of specific actions in the direction of enhancing the integration of RES in the existing European power generation system as a major step towards the reduction of global warming and climate change phenomena.

Specifically, an action plan in the form of an EU Directive (2009/28/EC) on the promotion of the use of energy from RES has been introduced by the EU whereby a target of RES share of 20% out of the gross final energy consumption of the EU has been set to be reached by the year 2020.

The RES Directive sets out specific national targets to be achieved by each individual member state, regarding the share of RES generated in each member state by the year 2020. For Cyprus, the national target states that the share of energy produced from RES must be at least 13% out of the gross national final consumption of energy in 2020.

The Mediterranean solar plan

On the 13th of July 2008, forty three leaders from EU and Mediterranean countries, in a common statement, adopted a new framework of collaboration for the Mediterranean region. The Union for the Mediterranean. This has been, already, integrated within the EU policy, in which, among the 6 thematic priorities that were indicated for collaboration in the framework of Union for the Mediterranean, solar energy has a leading role.

Mediterranean region offers an ideal natural resource for the production of energy from RES and mainly from the sun. For example in desert conditions within a period of six hours the energy absorbed from the sun is by far greater than the world annual energy consumption. Furthermore, EU high technological achievements and know-how in solar energy production can provide the appropriate transmission system upgrades and connections in order to satisfy the energy needs for both the Mediterranean countries as well as the EU member states.

The main objective of the Mediterranean solar plan is the installation of solar power generation plants with a capacity of 20GW between the years of 2011 – 2020.

In order to achieve this, a detailed roadmap has, already, been agreed providing all relevant activities as well as time schedules, such as,

- (a) the choice of installation areas,
- (b) the potential of local industry for the development of the Mediterranean energy market,
- (c) initiatives for the production and efficiency of energy (solar energy or other RES technologies),
- (d) the progress that has taken place in the legislative and regulating reforms,

- (e) the available financing mechanisms,
- (f) the development of appropriate infrastructure for the transmission of the produced power in EU member states, etc.

Future challenges

The Mediterranean solar plan constitutes an ambitious attempt for the exploitation of the Mediterranean region natural resource in order to offer green energy and security of supply to the Mediterranean countries, as well as, to the EU member states.

The plan will contribute catalytically in the economic and social growth of countries involved and will create advance know-how and new places of work. However, the success of this undertaking will depend mainly upon two factors, the financing as well as the political will for collaboration on national and on country to country level.

Concerning financing it is estimated that the Mediterranean solar plan will cost approximately 80 billion Euros. EU financing mechanisms are not big enough to finance such ambitious project. Currently, discussions with various private initiatives, outside the framework of the Union for the Mediterranean, exist, that could undertake the cost for the realization of this investment.

Also, it is generally accepted that the private character of the initiative will be more flexible in order to overcome the political issues that may emerge. Regarding political will, already in national level, some participating countries, such as, Spain, Italy, Morocco and Algeria have made enough steps, faster than the other countries, and have shaped national plans for the exploitation of solar energy.

The case of Cyprus

Our country possesses the most important prerequisite for success towards the sustainable economic development which is the existence of capable, multi-discipline and university educated human resources. Nevertheless, the common characteristic of the scientific activities relating to detail analysis and long-term planning is the absence of the State as well as the absence of political parties.

Cyprus society is highly dependent on the political parties, and as such, the only “experts” allowed for speaking and for analyzing any subject, even scientific issues, are considered to be the representatives of the political parties. Cypriot technocrats with the relevant expertise and serious scientific background on the issue under discussion are only allowed to speak and provide their knowledge and expert views when they are politicized or become as candidate members of the Parliament.

The above situation cannot continue any longer. The existing energy situation and the existing economic development model need to be revised in order for Cyprus to shift to a more sustainable development model by using green technologies and implementing energy efficiency policies. With the creation by the State, for example, of a National Energy Policy Council it will be possible to implement a long-term energy strategy for the island.

Also, with the creation of a Centre of Renewable Energy Sources it will be possible to study and to implement the most appropriate RES technologies for Cyprus. By this way the passage of Cyprus to the sustainable development will be achieved with the least economic cost.

Finally, the benefit and the know-how that Cyprus will gain from collaborating in projects aiming to the design and application of high technologies that are to be implemented in Mediterranean region, show the way for a more active participation of Cyprus in the Mediterranean solar plan. Suitable planning and organization will help our country, to fully test and integrate RES technologies and in particular solar energy technologies into the island energy system. These can be later used in a larger scale in other EU member states.

The net metering supporting scheme for the promotion of photovoltaic installations

A feed-in tariff (FiT) scheme provides a guaranteed premium price to the green electricity producer and puts an obligation on the grid operators to purchase the generated electricity output. The price is typically guaranteed for a long period in order to encourage investment in new renewable energy sources for power generation (RES-E) plants.

FiT schemes are supply-side measures that push green electricity onto the market and are mostly used for the promotion of RES-E technologies in Europe. These schemes are well known for their success in deploying large amounts of wind, biomass and solar energy - both photovoltaics (PV) and concentrated solar power systems (CSP) - mainly in Germany, Denmark and Spain (as well as in Cyprus). The biggest advantage of FiT schemes is the long-term certainty of financial support, which lowers investment risks considerably.

Net metering is an electricity policy which allows utility customers to offset some or all of their electricity use with self produced electricity from RES-E systems. Net metering works by

utilizing a meter that is able to spin and record energy flow in both directions.

The meter spins forward when a customer is drawing power from the utility grid (i.e., using more energy than they are producing) and spins backward when energy is being sent back to the grid (i.e., using less energy than they are producing). At the end of a given month, the customer is billed only for the net electricity used.

Net metering works only for grid connected systems and what makes it so beneficial, besides offsetting a home's energy consumption with a RES-E system, is that excess energy sent to the utility can be sold back at retail price.

If more energy is produced than consumed, producers receive benefit for this positive balance, such as renewable energy credits (REC), which is credited on the customer's account toward the next billing cycle. If at the end of the year a surplus remains, then the customer depending on the utility policy may:

- (a) be paid for the total REC collected at avoidance cost rate
or
- (b) be paid for the total REC collected at retail price rate
or
- (c) transfer and use the total REC collected as a compensation for a possible negative balance in the following years
or
- (d) the total REC collected are granted back to the utility.

Net metering is gaining recognition as a simple and effective RES-E promotion incentive and it is currently used in the USA

and Australia. In Europe only Denmark and Italy are using net metering

A typical example how net metering works, is the following. A residential customer, Mr. Helios, added a rooftop PV system to his home, on his side of the meter. Mr. Helios wakes up early for his job and usually on most days, he is out of the house before sunrise. In these dark morning hours, Mr. Helios makes his coffee and breakfast while watching the morning news on TV.

The electric meter spins forward as Mr. Helios is consuming electricity from the grid. Determined not to waste a bit of electricity Mr. Helios shuts off all of his appliances as he heads off to work. Mr. Helios's solar panels now start churning out electricity as the sun rises and the produced electricity is sending back to the overstressed grid. His meter now spins in reverse.

When Mr. Helios returns at night to cook dinner and relax in front of the TV, the meter spins forward again as he consumes more electricity than his system generates. Mr. Helios's bill will show only his net consumption of electricity from the grid. Should it be a hot sunny month (when the grid needs the most help), or a month in which Mr. Helios's electricity use is low, any excess electricity his system generates is rolled over to his next bill, just as he might rollover excess cell phone minutes.

Net metering allows for the production of electricity that reduces demand on a strained grid. For the utility, this is exactly the same result as if Mr. Helios had installed a more efficient refrigerator.

The only way his utility would know the difference between using more efficient technologies (such as a refrigerator) and the use of customer sited distributed generation (DG), such as a PV

system, is if the utility installed a costly additional meter at Mr. Helios's home and undertook the burden and expense of reading both meters and billing Mr. Helios for the result of this process.

Some variations of the net metering mechanism are the time of use (TOU) metering and the market rate metering. TOU net metering employs a specialized reversible smart meter that is programmed to determine electricity usage any time during the day. TOU allows utility rates and charges to be assessed based on when the electricity was used, i.e., day or night and seasonal rates.

Typically the production cost of electricity is highest during the daytime peak usage period and low during the night, when usage is low. TOU metering is a significant issue for RES-E, since, for example, solar power systems tend to produce energy during the daytime peak-price period, and produce little or no power during the night period, when price is low.

In market rate net metering systems, the user's energy use is priced dynamically according to some function of wholesale electric prices. The users' meters are programmed remotely to calculate the value and are read remotely. Net metering applies such variable pricing to excess power produced by qualifying systems.

Market rate net metering systems have been implemented in California since 2006 and under the terms of California's net metering rules are applicable to qualifying PV and wind systems. Under California law the payback for surplus electricity sent to the grid must be equal to the (variable, in this case) price charged at that time. It can never be negative, meaning you cannot make money from selling the electricity back.

If you generate more electricity than you use then over a period of a month you will be billed zero and not make any money, in effect you give away your extra energy if you do not use it.

Net metering enables small systems to result in zero annual net cost to the consumer provided that the consumer is able to shift demand loads to a lower price time, such as by chilling water at a low cost time for later use in air conditioning, or by charging a battery electric vehicle during off-peak times, while the electricity generated at peak demand time can be sent to the grid rather than used locally. No credit is given for annual surplus production.

There are benefits that accrue to the utility, the customer, and the community from net metering. For the utility, a well-designed net metering policy provides a simple, low cost, and easily administered way to deal with PV residential systems. Utilities obtain electricity and capacity from small, distributed PV installations. This is electricity they don't have to generate themselves or purchase on the market.

For PV systems, this generation takes place every day of the year with a very high correlation with utility peak loads. Utilities call this a high load carrying capability since sunshine is relatively easy to predict. Thus, utilities obtain the benefit of additional capacity in their service territory paid for by their customers.

PV residential systems can, also, strengthen the distribution grid, especially in rural areas. This is because voltage tends to drop at the end of long distribution lines when loads are high. Grid connected PV systems tied to the distribution grid strengthen voltage and improve overall service. And this grid

support can defer maintenance and upgrades in the power distribution system, which is a tangible benefit to utilities.

Customers benefit from net metering of PV residential systems because they obtain a long-term guarantee of low utility bills. Communities benefit from the investment in local generation. This investment not only increases local property values but increases local business opportunities as well. It is the difference between paying rent and paying a mortgage.

There are also some misconceptions about net metering, such as that net metering hurts the utility bottom line by reducing revenues. This argument is similar to the one against energy efficiency, namely that customers reducing their purchases of electricity hurt utility revenues. This would be true if all households bought a PV system and put it on their roofs. However, PV net metering large-scale deployment is not expected happening in the near future.

The current market is small and does not affect even a fraction of a percentage point on a bottom line of any utility that reports these figures publicly. Nevertheless, any net metering policy should receive regular review to monitor progress of the technology and development of the market.

If PVs, and especially energy efficiency, which has a much larger potential for impacting rates than PVs, gets to the point where it actually reduces utility revenues, then rates should be restructured to guarantee that service.

Another misconception is that net metering represents a subsidy from one group of customers to another. This argument has to do with the methodology that utilities use to charge customers. The argument is that utilities charge all customers in the

same class a single rate, which represents an average cost of doing business plus profit. Thus a household who uses a lot of electricity during the day when the cost of obtaining electricity is higher pays the same as the household who uses electricity at night during off-peak hours.

One could argue that one type of consumer subsidizes another based on patterns of consumption, etc. Utilities and their customers have supported this averaging formula for years. For example, building a new home represents a cost for a utility because it must invest in new generating capacity in order to supply this electricity.

Therefore, customers subsidize solar systems through net metering no more than they subsidize construction of new homes. Both represent expanding business opportunities, and electric utilities have figured out a way to accommodate this economic growth through existing rate structures for more than a century.

A final misconception is that net metering represents a burden for small utilities. The opposite is actually true because large organizations are better equipped to handle more complicated arrangements. Net metering is as simple as it gets to administer because it requires no special equipment, no new rates to establish and no new procedures. All that is required is that the utility adds a line in the ledger for each net metering customer to carry forward credits until the end of the year.

Compare this with the alternative of FiT supporting scheme, which requires installation of another meter. Then the utility must make special trips to read this meter and readjust its accounting procedures to keep track of another meter for a single account. A recent survey in the USA found that the cost of read-

ing the extra meters for residential PV systems alone outweighed the cost of net metering.

Desalinated water production cost using photovoltaics

The world demand of desalination equipment is expected to grow by more than 10% annually in the next two decades. This demand is derived by the reduced per capita share of fresh water in the world and by the increasing concern for water quality, which is based on the increasing water pollution. Reverse Osmosis (RO) is the only process that can be competitive for most kinds of water at any capacity. RO desalination is well developed and has been in commercial use for three decades for desalting low salinity brackish water. RO use for seawater desalting is becoming increasingly more reliable and cost competitive.

The cost of RO desalination has been going down and will continue to do in the future because of technology improvements and market forces. The cost of RO desalination depends on many variables including feed water salinity and quality, plant size, finance cost, energy cost, process type, infrastructure requirements, intake type, plant reliability and operation and maintenance (O&M) requirements. In order to obtain the desired plant life and reliability with minimum cost, proper cost analysis should be performed.

In recent years the photovoltaic (PV) industry has been experiencing a dramatic growth at a global level. Continuous increase of conventional fuel costs as well as growing pressure to turn towards renewable energy sources are the main drivers behind this rapidly expanding industry which since the start of the decade has achieved continuous annual growth of around 30%. An important PV application, which is currently emerging in the Mediterranean region, is the operation of RO desalination plants integrated with PV systems in order to satisfy the RO requirements in electrical energy either partly or fully.

Desalination technology selection

During the past ten years several countries facing water shortage problems have investigated and selected the least cost desalination technology in order to cover their needs. For example in the case of Morocco, it was concluded that seawater desalination with RO plants, compared to other desalting methods, is the most economical option. For the case of Spain, it was estimated that independent RO units for sea water desalination is the least cost option, compared to cogeneration and hybrid desalination systems. Also, a comparative study carried out by the International Atomic Energy Agency, concerning the use of various desalination technologies have demonstrated that in most cases the RO desalination units are the most economic option.

Based on previous work available in the literature, it can be concluded that RO desalination technology compared to other alternative desalting options is more economic in terms of capital cost, energy consumption and O&M cost. In the case of energy consumption RO technology requires less primary energy for the production of 1m^3 of desalinated water. This is illustrated in Table 2 where a comparison is presented for the most commonly used desalting processes.

Table 2: Energy consumption comparison for different desalination technologies

Technology	Equivalent electricity consumption (kWh/m ³)
Independent MSF plant	13.7
Independent MED plant	10.8
Cogeneration (Rankine power cycle and MSF plant)	7.4
Cogeneration (Rankine power cycle and MED plant)	6.2
Independent RO plant	4.0

The comparison is based on the equivalent electricity energy consumption required for the production of 1m³ of desalinated water in kWh/m³. We observe that when using a multi stage flash (MSF) desalination process the equivalent electricity energy consumption required is 13.7kWh/m³ and in the case of multi effect distillation (MED) desalination process the equivalent electricity energy consumption is 10.8kWh/m³.

When a cogeneration (power-water production) scheme is used in conjunction with MSF desalination process the equivalent electricity energy consumption is 7.4kWh/m³ and in the case when a cogeneration (power-water production) scheme is used in conjunction with MED desalination process the equivalent electricity energy consumption is 6.2kWh/m³. When using a RO desalination process the equivalent electricity energy consumption required is 4kWh/m³.

Finally, current technological developments on RO systems, concerning the integration of pressure recovery units, already achieved a reduction of the RO energy consumption below 4kWh/m³. Additionally, in recent years the RO market has been experiencing a dramatic growth at a global level. This increase is a result of technological achievements enabling for the reduc-

tion of the membranes cost, which is a dominant cost component for the operation of RO plants.

Cost of desalinated water using PVs

As mentioned earlier an important application of PV technologies, which is currently emerging in the Mediterranean region, is the operation of RO desalination plants integrated with PV systems in order to satisfy the RO requirements in electrical energy either partly or fully.

Figure 4: Desalinated water production cost as a function of RO plant capacity

To investigate the economics of this application, the operation of a RO desalination plant and the electricity requirements, which are partly and/or fully covered by PVs were simulated. Details concerning this investigation can be found in Poullikkas A., 2010, “An optimization model for the production of desalinated water using photovoltaic systems”, *Desalination*, 258, 100-

105. Taking into account various RO plant capacities the desalinated water cost have been determined for various cases from which the requirements in electrical energy are covered partly (25%, 50%, 75%) and/or fully (100%) from PVs. The results indicated that the production cost of desalinated water is increased with the degree of integration of PVs for partial and/or total electricity requirements of the RO plant as illustrated in Figure 4.

More specifically, for a RO desalination plant of $40000\text{m}^3/\text{day}$ the desalinated water production cost increases by approximately 9% with the use of PVs for the 25% coverage of the total electricity requirements of the RO plant. For the satisfaction of the total electricity requirements of the RO plant with PVs the desalinated water production cost increases by approximately 39%, e.g., from $0.87\text{€}/\text{m}^3$ to $1.21\text{€}/\text{m}^3$.

The use of pumped hydroelectric energy storage systems for the large scale integration of renewable energy sources

Electricity consumption and power demand have significantly increased worldwide during the last years. Also, in order to reduce the greenhouse gases emissions, the developed countries and especially the European Union (EU) are investing in the large penetration of renewable energy sources for power generation (RES-E). These developments will increase the energy costs and will introduce problems in the security of supply.

Small isolated island power generation systems, such as the case of Cyprus, will be affected most by the above problems and especially with the introduction of wind energy in the power system, which will cause high variability and uncertainty in power generation and demand for system reserve, thus making the use of a pumped hydroelectric energy storage (PHES) system essential.

Therefore, the use of a PHES will provide a number of key factors for new developments and solutions to the security of the electricity supply, reduction of the degree of vulnerability of the

supplies by diversifying the sources, promotion of the rational use of energy, reduction of the energy dependence on external sources by increasing as much as possible the use of RES-E technologies, guarantee of a stable and safe energy supply contribution in the protection and conservation of the environment.

The fundamental principle of PHES technology is the storage of electric energy in the form of hydraulic potential energy by pumping water to high elevation, where it can be stored indefinitely and then released to pass through hydraulic turbines and generate electrical energy.

A typical PHES plant is composed of two reservoirs of equal volume situated to maximize their height difference, known as the head. As a rule of thumb the head must be in excess of 300m in order for the PHES plant to become economically viable, however, this will depend on various factors. As illustrated in Figure 5, these reservoirs are connected by a system of waterways along which a pumping-generating station is located.

Under favorable geological conditions, the station will be located underground otherwise it will be situated on the lower reservoir. The principal equipment of the station is the pumping-generating unit, which is generally reversible and used for both pumping and power generation, functioning as a motor and pump in one direction of rotation and as a turbine and generator in opposite direction.

The electrical storage volume, therefore, depends on the volume of the reservoirs and the altitude difference between these two reservoirs. To store electricity, water from the bottom reservoir is pumped into the upper one.

Figure 5: Principle of operation of a PHES plant

To generate electricity, the upper reservoir opens the gate and water pours down the pipe, spinning the turbine and generating electricity. Pumping typically takes place mainly during off-peak periods, when electricity demand is low and electricity prices are low. Generation takes place during peak periods, when electricity demand is high, as illustrated in Figure 6.

The PHES is economical as it flattens out the variations in the load on the power grid, permitting thermal power stations, such as coal fired plants and nuclear power plants that provide base load electricity to continue operating at their most efficient capacity, while reducing the need to build special power plants which run only at peak demand times using more costly generation methods. A major advantage of combining PHES systems with other sources such as RES-E systems is the positive environmental impact. Instead of having another plant provide en-

ergy during the peak demand hours, the stored energy can be utilized to provide the power. No fossil fuels are burned for this system, nor are there any pollutants released into the atmosphere.

Figure 6: Load demand and generation of PHES

For isolated island power systems, such as the case of Cyprus, PHES technology seems to be the most promising way to exploit the available RES-E potential, such as, wind potential, at a high penetration degree. In larger islands such a power plant could substitute one or more base thermal units, making thus the investment even more profitable. Based on a recent study carried out for Cyprus three locations were identified where PHES systems can be utilised with total capacity of 530MWe. Such installations can allow Cyprus to reach up to 50% RES-E penetration by the year 2040.

The strategic role of renewable energy sources in the EU

European Union (EU) Member States adopted their national renewable energy sources (RES) action plans setting out their national targets for the share of RES consumed in electricity, heating and cooling and transport, and measures for achieving the national overall RES targets and measures supporting the growth of RES in each of the energy consuming sectors.

All Member States submitted their plans to the European Commission in 2010 and the Commission evaluated the plans, including the adequacy of measures envisaged by the Member States for reaching their national RES targets. The evaluation of the plans shows that the share of RES in the EU final energy consumption would reach 20.6% in 2020.

Based on Member State projections for RES use and their sectoral targets, the combined EU RES share:

- ~ in electricity will grow from 19.4% in 2010 to 34% in 2020,
- ~ in heating and cooling respectively, from 12.5% to 21.5%, and
- ~ in transport from 5% to 11%.

In the next decade the strongest growth will occur:

- ~ in wind power (from 2% to 14.1% of the total electricity consumption), and
- ~ in solar electricity (from 0% to 3% of the total electricity consumption).

In the electricity sector, by 2020 wind would become the most important RES technology providing 40% of all RES electricity compared to 25% in 2010, the contribution of photovoltaic and solar thermal electricity would also grow from current 3% to 9%.

The contribution of biomass is expected remain almost unchanged (18% in 2010 compared to 19% in 2020), while the role of hydro would decrease from 50% in 2010 to 30% in 2020. The role of geothermal and wave and tidal are still expected to remain marginal in 2020 with respectively 1% and 0.5%.

In the heating sector the analysis of Member State projections indicate that biomass would maintain its dominance (80% of all renewable heating in 2020, down from 90% in 2010), solar energy based heating would increase to 6% compared to 2% in 2010 and geothermal is expected to contribute 2% in 2020 compared to the current 1%. The use of heat pumps would also increase from 6% in 2010 to 11% in 2020.

Concerning the transport sector, in 2020 the first generation biofuels (biodiesel and bioethanol) are still expected to maintain their predominance with 66% and 22% share of the total RES use in transport compared to the current 71% and 19%.

The contribution of lignocellulosic biofuels and biofuels made from wastes and residues and the renewable electricity is expected to make up the rest of contribution, around 12%, towards the RES share in transport in 2020.

RES technologies of the future

To move to a secure clean and efficient energy system by 2050 and continue to be a major industrial player in the field of RES technologies, EU must lead the race to new generations of technologies, spearhead renewable integration in the energy system and develop and invest in high-tech manufacturing systems. The RES sector has already demonstrated its vitality and innovation potential by rolling-out to the market new generations of technologies in a fast time.

For instance, in less than 30 years the size of wind turbines has increased by a factor of 10 while photovoltaic panels have decreased their cost by more than 80%. These trends are bound to continue.

The RES sector by its variety of resources and concepts from sunlight, wind, tides, waves, household waste, hydrogen from algae, aviation fuel from genetically modified microbes, synthetic photosynthesis is a fertile ground for new concepts. The following sections provide a brief overview of the main trends expected in this field for the post-2020 horizon.

Wind

Wind energy is among the most advanced renewable energy technologies. The industry targets to supply 20% of Europe's electricity in 2020, 33% in 2030, and 50% in 2050 wind power. Major investments in technologies, mass production and deployment will be needed to reach these targets.

On-shore wind systems require focus on innovative designs to reduce visual impact and noise and on solutions for not so favourable conditions such as complex terrains and extreme weather.

Innovative solutions to ease transport of all components, speed-up on site assembly and installation and minimize external impact in the construction phase are also needed. Improved confidence of wind power generation is necessary to maximize its value on the electricity market. Additional cost reductions have to be achieved by using new control systems and methods for optimization of operation and reduced maintenance.

Very large wind turbines, from 10 to 20MW, are required for the offshore to compensate for the high cost of support structures, in particular for deep waters. New concepts for multi-service/multi-use floating platforms, as well as new wind turbine designs, such as vertical axis turbines, should be developed, demonstrated and readied for commercial deployment.

The intelligent use of advanced materials will become more and more important to enable larger area rotors but also in respect to the shortage of raw materials for the generators. Furthermore, reliable and affordable solutions for assuring grid stability as well as for balancing demand and production in the presence of high shares of wind electricity will have to be developed and demonstrated.

Focused technological development and demonstration action for increased availability and reliability for both onshore and especially offshore wind turbines is indispensable to make wind energy fully cost competitive and maintain important investments in wind energy in the absence of preferential tariff schemes.

Solar photovoltaics

A broad variety of photovoltaic technological routes will continue to characterise the sector after 2020 depending on the specific requirements and economics of the various applications.

Typical commercial flat-plate module efficiencies are expected to increase to 25% in 2030 with the potential of increasing up to 40% in 2050 due notably to wafer equivalent technologies and new device structures with novel concepts.

The operational lifetime of photovoltaic modules is expected to increase from 25 years to 40 years. The use of energy and materials in the manufacturing process will become significantly more efficient, leading to considerably shortened photovoltaics system energy payback times.

At the same time, affordable materials will replace the expensive ones currently used (e.g. copper instead of silver). Increased R&D is needed to bring thin film technologies to maturity and long-term reliability and to create the necessary experience in industrial manufacturing.

Beyond 2020, the efficiency of commercial modules could reach more than 20% for CIGS (14% max module efficiency today), 16% for a-Si, and 15% for CdTe, with new and improved device structures and substrates, large area, non-vacuum deposition techniques, interconnection, roll-to-roll manufacturing and packaging.

The concentrated PV technology is presently moving to commercial-scale applications. Further R&D efforts are required in optical systems, module assembly, tracking systems, high-efficiency devices with the potential of reaching module efficiencies higher than 45%.

Emerging PV technologies such as advanced inorganic thin film technologies, organic solar cells (OPV and DSC), also based on novel concepts like quantum and excitonic structures with their

potential for cost reduction and performance improvement will represent an increasing share of the PV deployment post 2020.

Concentrated Solar Power (CSP)

The mainstream approach to CSP (oil circulating in trough receivers) appears to have a limited potential for cost reduction. When that approach is used, dispatchability analyzed as CSP future promise, does not seem sufficient, together with mass production, to assure competitiveness. More research on advanced concepts, able to bring technology innovations is necessary.

Beyond 2020 substantial increases (above 600 °C) in the operating temperature of the heat transfer fluids are to be expected compared to the current mainstream technology. This will be achieved by studying materials and components which are reliable at very high temperature, developing new heat transfer fluids, more efficient cycles and new system architectures, and optimising the plant control system. Gains in efficiency will be considerable, more than 20% compared to the current state of the art.

In terms of dispatchability, the storage capacity will be improved (above 250 kWh/m³) thanks in particular to the study and implementation of ad-hoc thermochemical processes. This will make storage systems much more cost effective.

With regard to the environmental profile, beyond 2020 a significant reduction of water consumption (below 0,25 l/kWh) can be obtained (in particular through the use of dry cooling systems) while at the same time maintaining the overall efficiency of the plant.

As regards multi-purpose plants and hybridisation, beyond 2020 it should be possible to optimise the hybridisation of CSP plants with other renewable energy sources and to efficiently couple the production of electricity with other uses (e.g., desalination). CSP solar power plant exploiting possible efficiencies, cost reduction, performances improvements coming from innovative combined production of electricity and fresh water are strategically and symbolically relevant for exploitation in the Middle East and North Africa region.

Ocean energy

The ocean possesses a vast potential of energy, however, ocean energy device deployment and survivability in a very harsh environment is challenging and capital costs associated with pre-production prototypes are very high. In the last few years an increasing number of devices are reaching full-scale live testing and proving reliability over sustained periods. By 2020, full scale ocean energy systems are expected to have demonstrated their operational performance and survivability in real conditions.

Further technological advances would still be needed in the key areas of energy converter and power take-off components, deployment and installation methods, development of design, operation and maintenance of single and multiple device arrays with an objective of technological advancement from R&D to demonstration, pre-commercial and finally to large scale commercialisation.

The deployment, in the sea environment, of large ocean energy farms for the electricity generation of tomorrow presents also relevant logistic challenges related to the installation of the devices, the connection to the grid, the continuous monitoring and the maintenance. Strong synergies between off-shore wind,

ocean and the grid are also expected to be implemented for connection, transmission and distribution.

Power storage

Electricity storage is a clear key technology priority for the development of the European power system 2020 and post-2020, in the light of the increasing market share of renewable and distributed generation and the growing limitations of the electricity grid.

A cost efficient storage solution would consider different electricity storage technologies at different levels of the grid, and take also additional measures into account, such as an improved demand response, an optimised mix of renewable generation reducing variability, smart grid solutions increasing the resilience of the grid. The technological challenge requires to significantly increasing storage capacity over the coming decades. Because the further expansion of pumped hydro storage is limited, it is necessary to develop demonstrate and deploy new storage technologies.

A wide array of principles, such as, mechanical, (electro)-chemical and physical is available to store electricity. However, today hydropower plants with storage remains the most common and competitive storage technology at the energy system level. All other technologies are to some extent locked in the development stage facing multiple barriers from technological issues, market uncertainty, regulation and economics.

An overriding priority should be given to research and development in particular on materials and control system to generate new concepts, mature and improve the operational characteristics and economics of emerging technologies and to ensure optimum interoperability with the electric grid.

This should be complemented by industrial-scale demonstration projects across the EU for near-to-market technologies such as Compressed Air Energy Storage and Lithium-ion batteries to build industrial capacity and to provide data that can validate their performance and demonstrate their business cases and value to regulators, utilities, and investors.

Besides, there are relevant regulatory and market issues at stake. Traditionally, the storage service was carried out by the vertically integrated grid operators. In the today liberalised and unbundled electricity market, there is no particular economic incentive to provide storage services.

It is necessary the proper regulatory framework, so the market signals to incentivise the building of storage capacity and provision of storage services and allow storage to capitalise on its ability to intervene and generate revenues from all the electricity market segments.

Power grids

Electricity grids will need to integrate and connect to the loads, 34% of RES electricity by 2020. This percentage is expected to reach 64 to 97% in 2050. Much of the RES electricity generation will be concentrated in locations far from consumption centres or widely dispersed. Meshed networks for bulk transport of renewable electricity to distant load centres require research and innovation in materials, technologies, controls, and network codes.

The variability of RES generation will require technical and management tools to offset this variability with all flexibility options such as active demand, cost effective storage and interaction among various energy networks. Millions of small produc-

ers, active loads and flexible grid structures will require equipment, policies and algorithms for sensing, communication and automation of their interaction to ensure security of supply.

Energy Markets

Restructuring means that one or more segments of the current electrical system will be open to competition, typically generation and marketing

The meanings of natural monopoly and of the electricity sector restructuring

The theory of natural monopoly

A natural monopoly is said to occur when production technology causes long-run average total costs to decline as output expands. In such industries, the theory goes, a single producer will eventually be able to produce at a lower cost than any two other producers, thereby creating a natural monopoly, as higher prices will result if more than one producer supplies the market.

From the beginning, electric companies were primarily local businesses serving local needs. At the same time that the movement for regulation was growing so was the idea that geographic concentration and other economic factors made electric power service a natural monopoly, characterized by economies of scale and scope and the need for large capital investments. It was assumed that large investments in equipment and duplication of facilities would be a waste of financial and material resources, and would lead to overall higher costs for companies and therefore higher prices to customers.

Monopoly was thought to be the “natural” outcome of such a situation, with one company minimizing the waste of resources to serve customers. As electric utilities began to touch the lives of more and more people, there was nearly universal recognition that their development must be subject to some public influence. The investor-owned power companies won the official designation as natural monopolies that they sought, thus gaining the right to sell electricity in a non-competitive market. In return for this privilege, they agreed to pass along the benefits of monopoly to consumers in the form of reasonably priced electricity and good service.

The reasons above have been put forward as justification for natural monopoly, and one of the most popular is the idea that electricity is a necessary. The condition of necessity is an attribute of natural monopoly, however, this condition alone is not sufficient to create a natural monopoly because many other products and services are vital. Not only are there other goods and services that would require monopoly power because they also are necessary to the public, technological changes have provided adequate substitutes for electric utility services, increasing significantly the cross-elasticity of demand. This is important as a true monopoly would typically tend to produce a product that has a very low cross-elasticity with other industries.

Always looking to cut costs, many large industrial corporations, which use tremendous amounts of electricity, began complaining about the differences in rates, as well as having to buy electricity from their local monopoly utility. Instead, these large customers wanted to shop for the cheapest power available. They also argued that new companies should be allowed to generate and sell electricity, which would put competitive pressure on the utilities to reduce their rates.

The immediate impact of this trend toward negotiating prices with industrials was slight, however, the longer-term implications were greater. As industrial consumers mounted de facto deregulation, fewer retail customers remained to pay for historical costs incurred by the utilities and to bear the risks related to future capital spending and operating decisions of the utilities. As a result, non-industrial customers also had a greater incentive to search for marketplace alternatives to utility regulation. As a result commercial consumers and residential groups, began to apply tactics similar to the industrials, including increased political involvement.

What is restructuring of the electricity sector?

It is convenient to think of the electricity industry as made up of four functions, such as:

- (a) electricity generation (the simple production of electricity,
- (b) transmission (the movement of electricity over high-voltage lines from the generators to power substations in cities, towns and rural areas),
- (c) distribution (the movement of electricity over lower-voltage lines from power substations to customers), and
- (d) marketing (the sale of electricity to customers).

For example the generation of electricity is not a natural monopoly. Generation is inherently competitive, and should be recognized as such by market rules governing the industry. Any sizeable electricity market can support many individual power plants of efficient scale. Entry can also be facilitated with rules that encourage new investments while protecting consumer and environmental interests. The operation of these power plants is coordinated over the electricity grid by an independent system operator without requiring the control of a single owner.

Most regions in the world are served by integrated electric utilities, each of which performs all four functions, from generating electric power to selling it. These utilities established monopolies in transmission and distribution, which were extended into generation and marketing. Restructuring means that one or more segments of the current system will be open to competition, typically generation and marketing. Restructuring typically encompasses five fundamental elements (with some regulation retained from an independent regulator, at least in the initial stages), such as:

- ~ Electricity generation is opened to competition with free entry of new power plants and private contracts
- ~ Transmission and distribution remain in the hands of the utilities and under regulatory control because they are viewed as natural monopolies
- ~ Marketing to consumers is opened to competition
- ~ Electricity prices are free to move
- ~ A range of market instruments, including long-term contracts, spot sales and market-making activities, is allowed and encouraged. Other key elements may include ensuring sufficient generation capacity (and fuel supplies) and also the encouragement of private market-making activity to hedge the risks from price volatility. A mixture of market instruments for conducting electricity sales is important in creating well-functioning markets. Long-term contracts distribute the risks between buyers and sellers and enable planning. Spot sales allow a response to changing market conditions.

Liberalisation and privatization of the electricity sector in EU

Since mid-1990s, the EU Commission has advanced a programme for the creation of a liberalised market in energy (electricity and gas) across the EU, which facilitates commercial and household customers to buy power from the cheapest provider. Regulation would be replaced with competitive forces to deliver consumer choice while driving prices lower. According to the revised EU directives, in fully liberalised markets, energy producers would be able to sell electricity and gas across national borders, increasing competition and lowering energy prices in the process.

This was to force incumbent energy utilities to become more efficient, encourage new entrants and investment and boost economic growth across the entire region. More recently, the debate on energy objectives of the European Commission has grown to include:

- (a) security of supply,
- (b) greenhouse gas reduction, and
- (c) sustainable production and consumption.

To facilitate these objectives the EU recognised the need to improve the quality of networks and the connectivity between such networks. Given the historic association between national grids and networks and national suppliers, improving connectivity between national grids and networks was viewed as a facilitator to building a wider market, as the more end-consumers are reached, the greater the extent of competition between potential suppliers. In addition, economies of scale and efficiencies of modern networks with enhanced connectivity between national grids could help deliver objectives around energy security and climate change.

Setting the stage

How did the plans made in Brussels progress over time? Against those upbeat aspirations, although the UK and Scandinavian countries opened their electricity markets and allowed competition and foreign investment in all the segments of the energy business, other European markets have remained dominated by single enterprises, often former state-owned utilities.

For example, the Electricité de France (EDF) dominates 87% of France's electricity market, whilst in Germany, RWE and E.ON control between them 80% of the domestic energy market. Promoting competition in such concentrated markets has been difficult, especially given the reluctance of their national governments to accept that the expected benefits of private investment and competition could materialise in the energy sector. Because of declining long run average cost curves in generation, increasing returns to scale meant bigger was better but lack of competition required regulation.

Historically, electricity industry operated as natural monopoly owning electricity grids whilst pricing, investment, return on capital and many other aspects of their business were regulated

by governments. It was argued in some quarters that national champions had an important role in securing European energy supply as long as the anti-competitive aspects of dominant players could be tempered through fair and equal third-party access (TPA) and cross-boarder connectivity. Thus, in order to open up the vertically integrated structures found within national boundaries, the EU Commission initiated various measures to promote equal and fair TPA to these grids so that owners or operators of networks would not abuse their natural monopoly and inhibit fair and equal access by other energy suppliers and thus foster competition.

As progress in achieving fair and equal TPA was slow, the EU Commission promoted new energy directives and regulations for both electricity and gas in 2003, requiring vertically integrated incumbents to unbundle/separate the operation of the transmission from other parts of their energy business and thus facilitate TPA.

In 2007, the Commission took these measures further by promoting ownership unbundling (OU), according to which incumbent utilities had to separate not only the operation but also the ownership of their various energy businesses. Integrated utilities were to be split into legally independent:

- (a) Generation,
- (b) Transmission and
- (c) Distribution

companies, so that access to networks could not be used to protect the competitive position of incumbents. It was argued, for the full benefits of competition to manifest, the business of selling energy needed to be separated from the business of producing and transmitting it.

Initial forays

Meanwhile, as an unintended consequence, to prepare for unbundling and gain a competitive advantage across national boundaries, horizontal acquisitions became commonplace as illustrated in Table 3. While some utilities made cosmetic steps towards unbundling, the most visible reaction across the European energy markets involved national and cross-border mergers and acquisitions, which allowed incumbent energy utilities to consolidate their position across the EU market, while in the UK (the most open energy market in the EU) almost all the unbundled domestic incumbents were ultimately acquired by their European still vertically integrated counterparts.

Table 3: Examples of mega mergers and acquisitions in the EU since 2000

Acquirer	Acquired	Date of M&A
E.ON (Germany)	Powergen (UK)	2002
RWE (Germany)	Innogy (UK)	2002
E.ON (Germany)	Aquila (UK)	2003
Suez (France)	Electrabel (Belgium)	2005
RWE (Germany)	National Power (UK)	2005
E.ON (Germany)	Ruhr Gas (Germany)	2005
Iberdrola (Spain)	Scottish Power (UK)	2007
Enel (Italy) and Accion (Spain)	Endesa (Spain)	2007
GDF (France)	Suez (France/Belgium)	2007
EDF (France)	British Energy (UK)	2008
RWE (Germany)	Essent Energie (Netherlands)	2009
Vattenfall (Sweden)	Nuon (Netherlands)	2009

Horizontal integration across newly connected national markets appeared to be replacing vertical integration as a means of enhancing returns. In contrast to the intentions of the EU Commission to foster a competitive market structure and behaviour,

we see that a small number of large European integrated companies continue to dominate the regional electricity market.

Further, vertical integration from power generation, transmission and supply to consumers via company-owned networks remains prevalent. The EU aspirations such as fair and equal third-party access to grids, the level playing field of network market liberalisation, along with European-wide contracting for power remain largely unattained.

While in certain markets like the UK the power grid is owned by a third-party without upstream supplies or downstream customers, in much of Europe network unbundling has yet to take place. Nonetheless the threat of vertical unbundling has led many companies to seek horizontal dominance across several markets in lieu of vertical dominance of single markets, leveraging upon home country advantages.

Looking across the economic landscape, we see an industry dominated by some long-established companies such as,

- ~ RWE and E.ON Ruhr (of Germany),
- ~ EDF and GDF Suez (of France/Belgium),
- ~ Enel (of Italy),
- ~ Vattenfall (of Sweden),
- ~ Iberdrola (of Spain),

and a number of newer, but still integrated, utilities such as,

- ~ CEZ (of Czech Republic),
- ~ OMV (of Austria),
- ~ PPC (of Greece),
- ~ Polish Energy (of Poland) and
- ~ MOL (of Hungary).

Meanwhile, the process of acquisitions and consolidations continued apace. As a result, despite a new set of legislative measures proposed to promote competition, the electricity markets in many European countries remain barely competitive, without fair third-party access.

Later developments

Reviewing the latest developments, we find that the cross-boarder acquisition trend continues and is leading to the consolidation of energy utilities that are becoming regional in scope and are now expanding into Central and South-East Europe through a second wave of acquisitions. In the international business literature, the popular paradigm explaining foreign direct investment maintains that to succeed, investing companies need to have some type of ownership, internalization and location advantages over their competitors, they being domestic or foreign.

From this perspective, one can argue that the European incumbents are well positioned to invest in the lesser known energy markets of Southern and Eastern Europe. While the attractiveness of the Eastern European countries to European incumbent majors conforms to the foreign direct investments (FDI) paradigm, the acquisitions by the major European incumbents remain challenging from several perspectives. Despite perceived ownership, internalization and location advantages, the interest of European incumbents in the lesser known energy markets of Southern and Eastern Europe requires further scrutiny.

For the host countries keen for investment in infrastructure, it was important to create attractive conditions for direct investment with commitment to reform, minimise sovereign risk for investors and mediate the concerns of domestic consumers, un-

accustomed with competitive a market for power. However, this necessary condition may not be sufficient to yield the kind of returns to which the utility 'majors' were accustomed. This raise the question of why these utilities are eager to operate in markets where the competitive segment is to be limited at first and where competitive market forces are presumably supposed to preclude excessive returns. In addition, the process of internationalisation for energy companies can be a lengthy and difficult one.

If, following EU directives, competitive market conditions were created in these emerging markets, what hope would there be for earning supra-normal returns the 'majors' could no longer expect in Western European markets? It is, perhaps, likely that investors might have envisioned other means of creating market power, such as replacing vertical integration with horizontal integration across the region?

Electricity generation cost in isolated power systems

In 2008, the European Union (EU) settled on a policy agenda whose purpose was to comply with certain key energy objectives, such as, sustainability, competitiveness and security of supply. To that end, goals were established to reduce greenhouse gas emissions by 20%, to increase the share of renewable energies in primary energy consumption by 20% and to improve energy efficiency by 20% (the well known 20–20–20 initiative). Along the same lines, Cyprus Government set measures to reduce emission levels and its dependence on oil, thanks to the introduction of natural gas and to the promotion of renewable energy sources, especially solar and wind power, to generate electricity.

Cyprus represents a clear example of an isolated energy system of relative important size within the EU. Isolated grids feature a set of characteristics that usually imply a greater energy dependency and vulnerability, requiring the need for specific planning. Generally, these systems do not have access to every technology available, nor can they be connected to continental grids, such as the European grid, if necessary. That is why the role of renewable energies and their complementarity with fossil fuels presents a solid path for Cyprus to achieve its main en-

ergy commitments to the EU. A study of the electrical system in Cyprus can serve as an example for other similarly sized isolated systems in which the only endogenous energy source is provided by renewable energy sources.

Characteristics of isolated electrical systems

Isolated electrical systems exhibit a series of characteristics that contribute to increase the cost and the uncertainty of the electricity generation. The main problem facing these types of electrical systems, is the increased cost of the electricity supply caused by, among other things, high fuel transportation costs resulting from the distance of supply sources and by the absence of endogenous energy sources.

The smaller the electrical system size, however, the more the expenses will be. The power generation units cannot exceed a certain size since the loss of a unit or a group of units would mean the loss of a high percentage of the entire system. As a result, economies of scale cannot be adequately exploited like in large electrical systems, which serve to complicate the technical control of the grid in terms of frequency and voltage.

The isolation also requires maintaining a greater reserve capacity to ensure an adequate supply. Also, the greater flexibility offered by interconnected grids is not available in isolated power systems. Thus, such isolated systems require be planning and treating differently from continental grids.

Territories belonging to a country normally charge the same rate, meaning that isolated systems, due to the higher supply costs, must be subsidized by the citizenry as a whole, as in Greece or Spain. Obviously, in such a situation, regulations play an important interterritorial redistributive role. Under these conditions, the introduction and development of renewable en-

ogenous energy sources is an important complement to conventional models based on fossil fuels.

This complementarity offers a solid tool for achieving the main energy policy goals, such as, economic efficiency, respect for the environment and security and diversification of the supply. And yet, the interruptible and irregular nature of renewable energy sources, along with the isolation of the economy, can significantly condition the penetration rate of renewables into these electrical systems. So, given the current state of technology in renewable sources, these economies continue to rely on conventional plants as the basis for their electrical systems. Hence, ideally, these plants should be as efficient as possible and be able to provide the greatest guarantee of the security of supply.

The electrical system in Cyprus

Cyprus depends on external sources of energy and features almost no diversification. The electric industry in Cyprus has the features of an isolated system because it is disconnected from the large European grid or other neighbouring grids. The installed capacity on the island of Cyprus, as well as the peak demand, are similar to those on the islands of Crete, Malta and Canary Islands, all within the EU territory. Also, Cyprus power system is comparable to that of the islands of Puerto Rico, Jamaica and Trinidad and Tobago.

For such small isolated power systems means that oil derivatives are used almost exclusively as the primary energy source, which also limits the technologies utilized and the size of the generating units. Thus, in 2010, 98% of the power generation units in Cyprus used fuel oil. In comparison to other isolated systems, this extreme reliance on oil is not unusual. In Malta, for example, the reliance on oil is 100% and in the Canary is-

lands is 74%. Trinidad and Tobago rely 100% on natural gas, while Jamaica is 98% dependent on oil.

Electricity regulation in Cyprus

The regulation of the electrical system Cyprus features some notable differences with respect to the European main grid, such as, (a) greater level of intervention in planning the sector at the generation stage and (b) high electricity cost due to the dependence in oil products. As a consequence of this energy planning a set of appropriate measures will allow the power generation system to diminish its dependence on oil from the current 98% to 54% by 2020.

The main initiatives affecting the electrical industry are (a) the rational use of energy with the increase of the overall efficiency in the industry, (b) renewable energy sources by increasing their contribution to reach a 13% of the primary energy sources, which would imply a 16% of electricity generation by 2020 (an installed wind capacity for the Cyprus of 300MW is proposed for 2020, along with 192MW in photovoltaic energy, 17MW in biomass and 75MW in solar thermal technologies, also for 2020) and (c) natural gas would be used in combined cycle technologies bringing a total of the power generation share of 30% by 2020.

Final remarks

In isolated electrical systems the complementarity between fossil and renewable energies offers a solid path to achieving sustainable development. For Cyprus, the cost of generating electricity from natural gas is the most inexpensive. Regarding renewable energy sources biomass is the least cost option followed by the wind technology. Achieving sustainable development requires the maximum exploitation of endogenous energy sources and the introduction of natural gas. This situation

would allow for significant reductions in not only cost, but also in CO₂ emissions. Additional investment in the grid as well as the construction of liquefied natural gas regasification plants would be essential components in any plan to introduce natural gas to the island.

The complementarity between fossil energies (and natural gas in particular) and renewable energies is a relevant factor for the energy policy of Cyprus isolated system where few supply options exist, since it is the only way to reduce dependence, increase diversification and lower greenhouse gas emissions.

The cost of integration of renewable energy sources

The European Union (EU) has already tuned its energy policy into achieving maximum carbon dioxide (CO₂) emissions reduction from power generation plants. In this context, it has already set out a strategic objective of achieving at least a 20% reduction of greenhouse gases by 2020 compared to 1990 levels.

This strategic objective represents the core of the new European energy policy. Recognizing the positive effects of renewable energy sources (RES) technologies towards achieving this goal, the EU has taken a range of specific actions in the direction of enhancing the integration of RES in the existing European power generation system as a major step towards the reduction of global warming and climate change phenomena.

Specifically, an action plan in the form of an EU Directive (2009/28/EC) on the promotion of the use of energy from renewable sources has been introduced by the EU whereby a target of renewable energy share of 20% out of the gross final energy consumption of the EU has been set to be reached by the year 2020.

The RES Directive sets out specific national targets to be achieved by each individual member state, regarding the share of RES generated in each member state by the year 2020. For Cyprus, the national target states that the share of energy produced from RES must be at least 13% out of the gross national final consumption of energy in 2020.

In line with the above EU energy policy, Cyprus needs to focus into building a comprehensive RES penetration and CO₂ emissions reduction energy strategy. This would serve two goals:

- (a) it would underscore Cyprus' determination to achieve the national RES energy target and thus align Cyprus with the pan-European efforts to reduce greenhouse gases and
- (b) it would minimize any future costs that would be necessary under the EU emissions trading scheme mechanism due to excessive CO₂ emissions.

Currently, minimal specific action has been directed towards the building of such an energy strategy in Cyprus apart from the promotion of RES technologies for power generation (RES-E) through a range of government subsidy schemes. Evidently however, these financial incentive schemes have managed to trigger noticeable activity in terms of electricity generation from RES-E.

Specifically, wind energy projects have largely benefited from these schemes and are therefore currently spearheading the penetration of RES-E generation in the island, since the majority of licenses granted concern the implementation of large wind parks. Currently one wind park with a capacity of 82MWe is in operation, while the total wind power capacity is expected to increase to 165MWe by 2013.

In the last few years, photovoltaic and biomass systems have, also, been consistently introduced in Cyprus, in a smaller scale than wind parks, with total capacities reaching today 3MWe and 4.5MWe respectively.

However, other forms of renewable electricity generation that utilize solar energy, such as the concentrated solar thermal power technologies, have not yet been fully investigated and therefore their capabilities as a significant means for reduction of CO₂ emissions have so far remained downgraded in Cyprus.

In view of the expanding RES-E generation in Cyprus and having in mind the national RES energy target for 2020, it is crucial for Cyprus to consider the cost of integrating the necessary mixture of RES-E technologies (wind, photovoltaic, CSP, biomass) in its existing and future power system up to the year 2020.

For such investigation, it is fundamental to perform an analysis of the new technical, economic and environmental status that the integration of such technologies will affect the current and long term strategic planning of the Cyprus power system expansion. As with all other European countries the additional cost for RES-E integration will be covered from the electricity consumers.

The period remaining to 2020 is limited and possible non-compliance with the target of 13% RES penetration will result, for Cyprus, significant financial penalties. As shown in Figure 7, recent studies have shown that if we act today the additional cost resulting for the promotion of RES-E and other sustainable technologies and/or measures, by the year 2020, will be high, but this is expected to decrease considerably by the year 2050.

If we act after 2020, apart from the cost for the promotion of RES technologies the cost of carbon dioxide emissions trading should, also, be taken into account. The latter is expected that after 2020 will be increased significantly. Finally, if we delay further using a wait and see scenario by only following the developments, then the additional cost that the electricity consumer will be required to pay after 2030 will be extremely high.

Figure 7: Energy additional cost

It is an obligation of the Cyprus Government to immediately implement a new energy strategy with new approaches, incentives and penalties. As a first step, the current economic model supporting our economy needs to be updated by introducing aspects of sustainable development and of green economy.

It is, also, necessary to create appropriate mechanisms, structures and committees, such as, the establishment of a National Energy Strategy Committee, for the preparation of a long term (up to 2050) unified energy, environment and water strategy. Failure to achieve this the cost of renewable energy sources in-

tegration will be extremely high for the island economy. Thus, we must act now, to shape tomorrow's energy era for Cyprus.

The use of batteries for large electricity storage

Balancing power supply and demand is always a complex process. When large amounts of renewable energy sources (RES), such as photovoltaic (PV), wind and tidal energy, which can change abruptly with weather conditions, are integrated into the grid, this balancing process becomes even more difficult. Effective energy storage can match total generation to total load precisely on a second by second basis. It can load-follow, adjusting to changes in wind and PV input over short or long time spans, as well as compensating for long-term changes.

While conventional power generation plants may take several minutes or even hours to come online and will consume fuel even on spinning reserve standby, storing renewable energy for later use effectively produces no emissions. Some well established technologies offer significant energy storage capacity but require specific geographical features and considerable infrastructure. Others can be deployed rapidly to whenever they are required, but currently offer restricted capacity, often at high cost.

Although, due to their cost, batteries traditionally have not widely been used for large-scale electricity storage, they are

now used for energy and power applications. Energy applications involve storage system discharge over periods of hours (typically one discharge cycle per day) with correspondingly long charging periods.

Power applications involve comparatively short periods of discharge (seconds to minutes), short recharging periods and often require many cycles per day. Secondary batteries, such as lead-acid and lithium-ion batteries can be deployed for energy storage, but require some re-engineering for grid applications.

Grid stabilization, or grid support, energy storage systems currently consist of large installations of lead-acid batteries as the standard technology. The primary function of grid support is to provide spinning reserve in the event of power plant or transmission line equipment failure, that is, excess capacity to provide power as other power plants are brought online, especially in the case of isolated power systems.

These systems can take energy from the grid when either the frequency or voltage is too high and return that energy to the grid when the frequency or voltage begins to sag. The current implementation can provide a few minutes of energy, but overall grid management, including shifting peak loads, and supporting RES, will require longer durations of storage and therefore re-engineering of storage systems to handle greater energy to power ratios.

Considering the current operational and planned large scale battery energy systems around the world it can be observed that the largest battery energy storage systems use sodium-sulfur batteries, whereas the flow batteries and especially the vanadium redox flow batteries are used for smaller battery energy storage systems. The battery energy storage systems are mainly

used as ancillary services or for supporting the large scale solar and wind integration in the existing power system, by providing grid stabilization, frequency regulation and wind and solar energy smoothing

Specifically, the Amplex Group has employed a battery energy storage system with sodium-sulfur batteries in the United Arab Emirates, with a capacity of 350MWe, which is used as ancillary service for grid stabilization, frequency regulation, voltage support, power quality, load shifting and energy arbitrage. Furthermore, in Laurel Mountain of West Virginia of USA, a battery energy storage system with lithium-ion batteries and a capacity of 32MWe and 8MWh has been employed, which is used for helping large scale wind integration in the existing power system by providing frequency regulation and wind energy smoothing.

The Golden Valley Electric Association has employed a battery energy storage system with nickel-cadmium batteries in Alaska of USA, with a capacity of 27MWe and 14.6MWh, which is used as ancillary service for spinning reserve and power system stabilization. Moreover, the Puerto Rico Electric Power Authority has employed a battery energy storage system with lead-acid batteries in Puerto Rico, with a capacity of 20MWe and 14MWh, which is used as ancillary service for frequency control and spinning reserve. Finally, The Sumitomo Densetsu Office has employed a battery energy storage system with vanadium redox flow batteries in Japan, with a capacity of 3MWe and 0.8MWh, which is used as ancillary service for peak shaving.

Regarding the planned large scale battery systems, the most important is the Rubenius battery energy system in California, USA, which will have a capacity of 1000MWe and will require an area of 1,416,400m². The battery system that will be used is

sodium-sulfur type and the system will be used for helping for large scale solar and wind integration in the existing power system, by providing grid stabilization, frequency regulation, voltage support, power quality, load shifting and energy arbitrage.

By comparing the different types of batteries, as well as other types of large scale energy storage systems, it can be concluded that lithium-ion batteries and sodium-sulfur batteries have high power and energy densities and high efficiency, but they have high production costs. Also, pumped hydro energy storage systems and compressed air energy storage systems have high capacity, but they have special site requirements.

Furthermore, with the exception of pumped hydro energy storage systems and compressed air energy storage systems, all the other energy storage systems are fully capable and suitable for providing power very quickly in the power system. Regarding the energy applications, sodium-sulfur batteries, flow batteries, pumped hydro energy storage systems and compressed air energy storage systems are fully capable and suitable for providing energy very quickly in the power system, whereas the rest of the energy storage systems are feasible but not quite practical or economical.

Sustainable electric vehicles for transportation

Growing concerns over security of energy supply, climate change and health are driving a shift in the European Union (EU) transport sector from fossil to alternative fuels and new electric vehicle propulsion systems capable of delivering long-term sustainability. In the EU, three quarters of transport greenhouse emissions come from road transport. Transport is especially vulnerable to oil supply disruption and price volatility and despite huge reductions in emissions of harmful pollutants, there remain concerns over air quality and noise, especially in urban areas.

Transport is an important building block in the EU energy-climate policy. Without a significant contribution from transport, EU climate and energy package, which includes targets for 2020 for energy efficiency, a target minimum share for renewable energy and targets for reducing greenhouse gas emissions, cannot be reached. This is why significant effort has recently been placed in the further reduction of harmful tail-pipe emissions from road vehicles and towards the promotion of electric vehicles.

Indeed, electric vehicles are a promising technology for drastically reducing the environmental burden of road transport. More than a decade ago and also more recently, they were advocated by various actors as an important element in reducing carbon dioxide (CO₂) emissions, air pollutants and noise of particularly passenger cars and light commercial vehicles.

At the same time, the electric passenger cars that are being developed are not yet competitive with conventional vehicle technology. Costs are still high and battery technology is still being developed, and there exist many uncertainties with respect to crucial issues, such as (a) battery technology, (b) impacts on emissions, (c) interaction with electricity generation and (d) costs and business case of large scale introduction.

Currently there are three main types of electric vehicles that have passed from the demonstration to the production stage of the manufacturing process. These are the hybrid electric vehicles (HEVs), the plug-in electric vehicles (PHEVs) and the full electric vehicles (FEVs). The major difference between these types of vehicles is that for the last two types, the battery can be externally recharged. In addition, FEVs operate only on battery charge and therefore always employ the charge depleting mode of operation requiring high power, high energy battery packs primarily.

On the other hand, PHEVs offer the possibility of on-board battery charging and the option of charge depleting or charge sustaining modes of operation. Therefore, their demands on battery performance are less strict compared to FEVs. Finally HEVs, which were the first type of electric vehicles to be manufactured, offer higher travelling range compared to PHEVs and FEVs due to the existence of the ICE.

Although tank-to-wheel efficiencies of electric vehicles show that these vehicles have higher fuel economies than conventional gasoline vehicles, the well-to-wheel efficiency is a more appropriate measure to use for comparing fuel economy and CO₂ emissions in order to account for the effect of electricity consumption from these vehicles.

Importantly, the amount of greenhouse gas emissions from electric vehicles depends on the fuel and technology used for electricity generation. From the perspective of a full cycle analysis, the electricity used to recharge the batteries must be generated from renewable or clean sources such as wind, solar, hydroelectric or nuclear power in order for such vehicles to have zero emissions.

On the other hand, when electric vehicles are recharged from electricity produced from conventional technology power plants such as oil or coal-fired plants, they may produce equal or sometimes more greenhouse gas emissions than conventional gasoline vehicles.

Finally, and although in the short term electric vehicle technologies will not reach maturity and financial support will still be needed to speed up innovation and promotion, an action plan for the adequate adoption of electric vehicles in the EU and Cyprus markets is required.

In this framework, Cyprus needs to perform the following next steps in order to safeguard a smooth and safe transition to the electric vehicle market:

- (a) estimation of adequate tariff levels for electric vehicle charging; these levels could vary depending on the time of day of the charging, e.g., peak or off-peak hours,
- (b) geographical location of possible charging stations,

- (c) reinforcement of local electricity distribution networks and
- (d) decision on the charging standards to be adopted for conventional or fast charging.

Electricity demand flexibility – “flexiwatts” could change how energy is consumed

The key to changing the balance of power between utilities and their customers is the customers' ability to control when and how they use electricity and for that demand flexibility is very important. “Flexiwatts” come from demand flexibility, which is using communication and control technology to shift electricity use across hours of the day. The premise is to use smart technology to move things like air conditioning, water heating, and electric vehicle charging to times when load is lower and electricity is cheaper.

Devices now have the capability to control those functions and can be programmed to know when the lower price periods are. Demand flexibility need not complicate or compromise customer experience. Technologies and business models exist today to shift load seamlessly while maintaining or even improving the quality, simplicity, choice, and value of energy services to customers.

A utility business model that accurately values for distributed energy resources (DERs) can potentially lower system wide

costs while contributing to the foundation of a reliable, resilient, affordable, low-carbon grid of the future. But if utilities' plan for the future is just to build more infrastructure on both sides of the meter, their costs could be significant. Customers are going to invest in DERs. If utilities don't send the right price signals, customers will invest in a way that serves their own best interests instead of a way that serves system-level best interests.

To make demand flexibility work, customers must have some form of time varying pricing. It could be time-of-use pricing, which increases the price of electricity during the highest priced daily periods. Or it could be real-time pricing, which sets hourly electricity prices, or critical peak pricing, in which the grid operator reserves the right to increase the price sharply at certain peak hours.

The best pricing is pricing that reflects utility costs. Real time pricing is an example of that. Demand charges sometimes are and sometimes aren't. Technology specific pricing is shortsighted. Pricing consumers can use to their advantage should be an option for all customers. Customers can have demand flexibility with minimal investment.

Solar and battery storage are commonly noted as the biggest threats - and opportunities - for the utility business model, but when consumers use their electricity may matter just as much to utilities as if they produce it themselves. What utilities must recognize is that while widespread solar-plus-storage is likely years off for many of them, demand flexibility is available to customers now and makes load defection an increased reality. Demand flexibility is a critical third technology along with solar and battery storage. For many of the things batteries can do for a customer, it can do them much cheaper.

The opportunity is available equally to vertically integrated investor owned utilities, deregulated transmission and distribution providers, and retail electricity providers in deregulated markets. The keys are offering rates that encourage changes in customer behaviors and to take advantage of the changes they make.

Utilities need to understand “flexiwatts” as a way to get to grid cost reductions, not just a threat to revenues. They can then construct rates reflecting utility marginal costs to ensure that customer bill reduction (and thus, utility revenue reduction) can also lead to meaningful grid cost decreases.

Having taken these steps, utilities should be able to see where demand flexibility will take them and harness enabling technology and third-party innovation to build customer-facing business models that target both lower bills for their customers and reduced sunk costs. State regulators can support utilities in making a transition by pushing them to see demand flexibility as an opportunity instead of a threat.

They can frame demand flexibility as a potentially lower-cost alternative to a subset of traditional grid infrastructure investment. They can also support the introduction of new rate structures that balance the potential complexity of highly granular rates against the large value proposition for customers and the grid and facilitate utility-private sector partnerships likely to lead to innovation. Given the benefits this should be a near term priority. It is a big opportunity and a cost-effective opportunity.

Energy Strategies

A sound energy policy should encourage a clean and diverse portfolio of domestic energy supplies

Energy and Geopolitics in the South East Mediterranean region

Currently there are three major geopolitical events, which are putting the stability of the Eastern Mediterranean at risk. Firstly, most of the region is in a deep monetary and economic crisis. In particular Cyprus is already in a deep monetary and economic crisis. Usually, European analysts approach the Cyprus sovereign debt crisis in a one-dimensional manner. They consider the continuation of Cyprus's European Union membership exclusively in the context of its ability to address its debt crisis.

They do not take into account the geostrategic importance of Cyprus being the connecting bridge between three continents: Europe, Asia and Africa. Secondly, the Arab Spring is causing turmoil in the surrounding area. In particular Egypt, Syria and Libya are in turmoil and their new end states are far from certain. Thirdly gas and oil discoveries, if not well managed, could further destabilize the region.

Furthermore, the Arab-Israeli conflict is showing no signs of abating while the Iranian nuclear crisis is destabilizing not only the whole region, but is also causing confrontation between leading out of area players. In addition, major powers are competing for a redistribution of power in the Eastern Mediterrane-

an region; and Cyprus is a part of this region. The United States and Israel have been the key players for 60 years. The European Union as such is not acting as a major player, but members such as the United Kingdom and France have been involved in the area for decades, if not centuries. Russia, on the other hand, is attempting a comeback, having abandoned the Mediterranean two decades ago after the implosion of the Soviet Union. Turkey is also staging a return as an independent player after nearly a century since the fall of the Ottoman Empire.

More worryingly, the European Union is in retreat in the Eastern Mediterranean. The economic crisis in the Eurozone has undermined its position and the appeal of the European model. The situation in Cyprus is particularly worrisome for the European Union. Cyprus is the most south-easterly outpost of the European Union in a region of considerable instability. The geopolitical consequences would be just as profound as the financial and economic ramifications. Cyprus lies on the geostrategic crossroad between three continents. Today Cyprus is poised to become a significant transit route for gas and oil from the Eastern Mediterranean basin.

The Eastern Mediterranean undoubtedly has to remain a key interest for the EU. It is a highly unstable region where its interests intersect with those of several major powers, namely the United States, Russia and Turkey. Furthermore, the recently discovered hydrocarbon resources in the Eastern Mediterranean could free Europe from overdependence on Russian gas. Currently, realignment of alliances is taking place. Cyprus already started discussions with Tel Aviv in order to cooperate closely in exploring and exporting gas, and in the safety of the gas rigs. Greece, Cyprus, Israel and the United States have enhanced military collaboration.

On the other hand Turkey aims at being the leading Muslim power in the region. It occupies a unique geopolitical position, controlling the land bridges linking both the Caucasus and Europe with the Middle East. The Turkish Straits command the passage between the Black Sea and the Mediterranean. Politically it is the most advanced Muslim country with a lay democracy and offers an alternative model for Arab countries emerging from the upheaval of the Arab Spring. But this is not enough!

Turkey is doing everything in its power to become a true energy hub for supplying gas and oil to Europe from diversified sources, using its geographic position between multiple energy suppliers and the European market. The European's Union Southern Corridor includes several projects on Turkish soil. Turkey already plays a vital role in various gas pipeline projects and in the future will play an essential part in supplying Caspian gas via the Trans-Anatolian Pipeline (TAP).

In addition, Turkey wants to get involved in transporting gas and oil from Iraq, Azerbaijan's Shah Deniz-II field, Turkmenistan and the newly discovered gas fields in the Eastern Mediterranean. Turkey signed a gas deal with Azerbaijan in October 2011, not only providing gas for its domestic market, but also sending gas to Europe through its pipelines, reducing Europe's dependence on South Stream.

These alternative pipelines bypassing Russia will not only cause Gazprom to lose substantial revenues, but also diminish Russia's economic and political leverage on Europe. Russian ambition to dominate the European gas market is taking it on a collision course with Turkey. This is already apparent in Cyprus where Ankara moves to block Cyprus' exploration of offshore gas fields. Relations with Greece and Cyprus reached a new low

when Turkey insisted on participating in the exploitation of gas off the coast of Cyprus.

Due to the economic crisis there is currently a political reluctance in the European Union to launch grand new strategies. The European Union continues to analyse the events in the Eastern Mediterranean almost exclusively from an economic and financial viewpoint. Outside of these issues, Europe seems only to be roused by challenges that threaten the immediate social and economic fabric of the Union, such as migration. The geopolitical importance of the region hardly plays any role, preventing the European Union to develop a comprehensive strategy.

On the same time the Eastern Mediterranean region remains of paramount interest to the European Union. On the positive side, it promises to reduce energy dependence on Russia. On the worrying side, the outcomes of the Arab Spring and the economic and financial crisis are far from certain, and could result in the European Union's southern flank mired in instability for a protracted period.

Therefore, it is paramount that European Union develops a comprehensive strategy, with positive and proactive action addressing economic issues, energy interests and the Arab Spring. An economically viable exploitation of recently discovered hydrocarbon deposits in the Eastern Mediterranean region requires progress in solving three protracted conflicts, namely the Middle East peace process, the Cyprus problem and the Greek-Turkish rivalry.

The European Union needs to find a delicate balance between preserving its relationship with Israel, supporting Greece and Cyprus and containing Russian influence in the Eastern Medi-

terranean. Failure to make substantial progress in these problem areas will not only jeopardise fully exploiting the energy deposits, but will also heighten the risk of international conflict.

Future sustainable energy systems

The power industry is one of the few industrial sectors, which affect prosperity of every sphere of economic and social life and exert a direct influence on general technological progress. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be focused on efficiency and sustainability in energy production.

A sound energy policy should encourage a clean and diverse portfolio of domestic energy supplies. Such diversity helps to ensure that future generations will have access to the energy they need. Renewable energy can help provide for our future needs by harnessing abundant, naturally occurring sources of energy, such as the sun, the wind, and biomass. Effectively harnessing these renewable resources requires careful planning and advanced technology.

Through improved technology, we can ensure that clean, natural, renewable and alternative energy sources will be used in the future. Renewable and alternative energy sources will not only

help diversify world's energy portfolio but they will do so with few adverse environmental impacts.

Alternative energy includes alternative fuels other than gasoline and diesel, the use of traditional energy sources, such as natural gas, in untraditional ways, such as for distributed energy at the point of use through micro-turbines or fuel cells and future energy sources, such as hydrogen and fusion.

Both renewable and alternative energy resources can be produced centrally or on a distributed basis near their point of use. Providing electricity, light, heat, or mechanical energy at the point of use diminishes the need for some transmission lines and pipelines, reducing associated energy delivery losses and increasing energy efficiency. Distributed energy resources may be renewable resources, such as biomass cogeneration or rooftop solar photovoltaic systems on homes, or they may be alternative uses of traditional energy, such as natural gas micro-turbines.

The European Union's (EU) main long-term goal in the field of energy is the conversion of the existing EU energy system, which is heavily dependent on fossil fuels, to a sustainable energy system based on differentiated energy sources of higher energy efficiency. This will enable the EU to face the challenges posed by the security of the energy supply and the climate change while, at the same time, increasing the competitiveness of the European energy industries.

Currently, Figure 8, oil holds an important position in the EU energy system since it is used widely in the industrial, residential and transport sectors. Natural gas is also used in all sectors including electricity generation (together with coal and nuclear energy).

Figure 8: EU energy system today

Figure 9: EU energy system between 2020-2030

Figure 10: EU energy system between 2040-2050

In the envisaged energy system of 2020, Figure 9, based on the long-term energy targets of the EU, the use of oil will be limited only to the transport sector. Natural gas will emerge as the dominant energy source.

In addition, the novel technologies of natural gas reforming and coal gasification with carbon capture and sequestration will, also, be used for hydrogen production which is an environmentally friendly fuel, free of harmful emissions. This will lead, further, to the creation of the first hydrogen communities in which green hydrogen will be produced from renewable energy sources of distributed generation.

The first hydrogen power generation units, called HYPOGEN (hydrogen power generation) plants, will be in commercial use and will cover part of the electricity demand without any harmful emissions of carbon dioxide. By 2040, Figure 10, it is hoped that oil will be fully substituted by hydrogen as an energy source. Hydrogen will be generated either by the reforming of

natural gas and gasification of coal or by renewable energy sources. This step will complete the transformation of the existing energy economy to a hydrogen economy.

EU energy policy towards 2030

EU leaders on the 23rd of October 2014 committed by 2030 to reduce greenhouse gas emissions by at least 40%, and increase energy efficiency and renewables by at least 27%. The deal is a clear message to big polluters such as China and the United States ahead of UN talks in Paris next year to agree global legally binding greenhouse gas emissions.

Efficiency and renewables targets

An EU target of at least 27% is set for the share of renewable energy consumed in the EU in 2030. This target will be binding at EU level. It will be fulfilled through Member States contributions guided by the need to deliver collectively the EU target without preventing Member States from setting their own more ambitious national targets and supporting them, in line with the state aid guidelines, as well as taking into account their degree of integration in the internal energy market.

The integration of rising levels of intermittent renewable energy requires a more interconnected internal energy market and appropriate back up, which should be coordinated as necessary at regional level.

An indicative target at the EU level of at least 27% is set for improving energy efficiency in 2030 compared to projections of future energy consumption based on the current criteria. It will be delivered in a cost-effective manner and it will fully respect the effectiveness of the European trading scheme system in contributing to the overall climate goals.

This will be reviewed by 2020, having in mind an EU level of 30%. The Commission will propose priority sectors in which significant energy-efficiency gains can be reaped, and ways to address them at EU level, with the EU and the Member States focusing their regulatory and financial efforts on these sectors.

These targets will be achieved while fully respecting the Member States' freedom to determine their energy mix. Targets will not be translated into nationally binding targets. Individual Member States are free to set their own higher national targets.

Interconnectivity

The European Council noted the fundamental importance of a fully functioning and connected internal energy market. Agreement was also reached on increasing the interconnectivity of Europe's energy markets. Interconnectivity is an important part of the EU's plans for Energy Union, which is partly intended to wean some member states off their dependence on Russian gas. EU leaders renewed their 2002 commitment to increase energy trading through electricity connectors to 10% by 2020.

Built into that is a commitment to subsequently up that percentage to 15%. The agreement specifically names so-called "energy islands", such as, Spain Portugal and the Baltic states. They should have the highest priority, according to the conclusions.

Malta, Cyprus and Greece also needed special attention, EU leaders agreed.

Energy security

Regarding energy security in the context of the Ukraine crisis, EU leaders endorsed further actions to reduce the EU's energy dependence and increase its energy security for both electricity and gas. Without going into detail, EU leaders agreed to implement critical projects of common interest in the gas sector, such as the North-South corridor, the Southern Gas Corridor, and the promotion of a new gas hub in Southern Europe.

Also mentioned were key infrastructure projects enhancing Finland's and the Baltic States' energy security. These countries were singled out as the most vulnerable in the case of a complete disruption of Russian gas supplies. The Commission was also tasked to set up task forces on specific interconnectors with member states for the purpose of their speedy implementation.

Monitoring process

The European Commission will monitor progress on the issue and will report on financing possibilities. The Council invited the executive to make legislative proposals on funding, if appropriate.

Integrated energy policy for Cyprus

In my book *The Energy Future of Cyprus* (*Το Ενεργειακό Μέλλον της Κύπρου*) published in 2009 I wrote, “...the energy model supported the economic and social development in Cyprus, is inefficient, uneconomic, catastrophic for the environment and unable to respond to recent and future challenges. The time for drawing a strategic plan concerning the energy future of Cyprus has arrived. Energy, environmental, economic and social reasons impose a revision of the current situation. The shift towards a sustainable development model is a matter of survival of our country...”.

Today, after the catastrophic explosion at Mari, which severely affected the operation of Vasilikos power station we need to move fast in order to draw a sustainable energy policy for the future of Cyprus! We need to act fast with a scientifically supported long-term integrated energy strategy, as it is the main subject of the above book, where it is described how Cyprus could transform its uneconomic energy system into a sustainable system by 2050.

It is a fact that in Cyprus all discussions relating to the energy concern only the electrical sector, which is wrong. The sectors

of heating and cooling, transport, energy saving and management of hydrocarbons are equally important.

For example:

- ~ How many electric cars are expected in Cyprus until 2020 or 2050?
- ~ Where the charging points of these cars will be located by 2020 and with what incentives?
- ~ How we can explore Cyprus hydrocarbons deposits within a sustainable driven development?
- ~ How we can promote the use of solar heating?
- ~ What is the Cyprus target for the integration of all types of renewable energy sources by 2030 or 2050?
- ~ What is the long-term target of Cyprus for independency from conventional fuels and for the shift towards the hydrogen economy?
- ~ How many green jobs are expected in the coming years?

All these questions concern long-term energy planning which is under study by many EU countries with some of them already published their targets up to year 2050.

It is clear that it is now the time for changes in Cyprus. We need to redefine the energy priorities of Cyprus, which should aim,

- (a) on the long-term energy planning with the aim of gradually shifting from the use of oil to the use of natural gas,
- (b) to reduce energy waste with the introduction of compulsory energy saving measures, especially in the building sector,
- (c) the use of decentralised generation and
- (d) in the efficient and effective promotion of renewable energy sources and in particular of the solar systems, since they

can provide under certain conditions, energy sufficiency and independence with simultaneous protection of the environment.

For the scientific investigation of the above issues we need to change the existing decision making structures, since, energy matters are scattered within various ministries, resulting in the creation of an inefficient, complex and static system, providing a very complex decision making system for Cyprus energy issues.

It is now the time as we suggested, and strongly support, for the last 6 years, for the creation of a national energy strategy council, which will be composed by energy experts in order to develop an integrated long-term energy strategy for Cyprus. Already, during the last 2 years a positive position for the need to create such a council expressed from various bodies and parties.

The national energy strategy council will submit proposals to the state where the suggested policies will be approved by the Council of Ministers and will be implemented by the various competent Governmental departments. A lack of long-term integrated energy planning will lead our country into adventures, which have just started. We can no longer depend on the wait and see scenario since day by day the additional cost for the Cypriot consumer is increasing.

Renewable energy strategies for sustainable development in Cyprus

Sustainable energy development strategies typically involve three major technological changes, such as:

- (a) energy savings on the demand side,
- (b) efficiency improvements in the energy production and
- (c) replacement of fossil fuels by various sources of renewable energy.

Consequently, large-scale renewable energy implementation plans must include strategies for integrating renewable sources in coherent energy systems influenced by energy savings and efficiency measures.

First, the major challenge is to expand the amount of renewable energy in the supply system. Renewable energy is considered an important resource in many countries around the world, but on a global scale less than 15% of primary energy supply is renewable energy, and the major part is hydropower and wood fuels in developing countries.

Renewable sources, such as wind and solar, only constitute a very small share of the total supply. However, the potential is

substantial. And in some regions and countries, the share of renewable energy has grown substantially during the last couple of decades.

Two major challenges of renewable energy strategies for sustainable development can be identified. One challenge is to integrate a high share of intermittent resources into the energy system, especially the electricity supply. The other is to include the transportation sector in the strategies.

Cyprus is now facing the above two problems of integrating the high share of intermittent electricity from renewable energy sources and including the transportation sector in the future strategies. Hence, reaching this stage of making sustainable energy strategies the issue is not only a matter of savings, efficiency improvements and renewables. It also becomes a matter of introducing and adding flexible energy technologies and designing integrated energy system solutions. Such technological changes are necessary in order to bring about further sustainable development.

It is estimated that solar photovoltaic and wind energy for power generation in Cyprus will reach around 500MW by 2020. Meanwhile, Cyprus has a great potential for other sorts of renewable energy, especially concentrated solar power. Therefore, Cyprus is in many ways a typical example of the situation in many countries: the transportation sector is totally fuelled by oil but the potential of intermittent renewable sources is substantial.

However, when reaching a high share of intermittent resources in combination with energy savings, the making of sustainable energy strategies becomes a matter of introducing and adding flexible power technologies and designing integrated power

system solutions. Such technological changes are required in order to generate further sustainable development aiming of converting present energy systems into a 100% renewable energy system.

The following improvements of system flexibility are essential to the conversion of Cyprus's energy system into a 100% renewable system:

- ~ First, oil for transportation must be replaced by other sources. Given the limitations in biomass resources, solutions based on electricity become key technologies. Moreover, such technologies increase the potential of including wind and solar power in the ancillary services of maintaining voltage and frequency in the electricity supply.
- ~ The second key point is to add electrolyzers to the system and at the same time provide for a further inclusion of intermittent renewable energy sources in the voltage and frequency regulation of the electricity supply.

By implementing the above key technological changes the Cyprus energy system can be converted into a 100% renewable energy system. The cost however of such conversion needs to be assessed!

EU energy policy towards 2030 for Cyprus

The European Council has already focused its energy strategy towards achieving maximum greenhouse gas reductions from the energy sector and sustainable development. In the framework of the European Union 2030 climate and energy policy the European Council recently endorsed 4 targets:

- (a) A binding EU target of 40% less greenhouse gas emissions by 2030, compared to 1990 levels
- (b) A target of at least 27% renewable energy consumption by 2030
- (c) A 27% energy efficiency increase by 2030
- (d) The completion of the internal energy market by achieving an electrical interconnection target of 15% by 2030. Special attention will be paid to the more remote and less well-connected parts of the single market such as Malta, Cyprus and Greece.

Also, on energy security, the European Council endorsed further measures to reduce the EU's energy dependence and increase the security of its electricity and gas supplies. This will be achieved by European funding for the implementation of criti-

cal projects of common interest in the gas sector, such as the North-South corridor, the Southern Gas Corridor and the promotion of a new gas hub in Southern Europe.

Both electrical interconnections of remote and isolated systems as well as the implementation of the Southern Gas Corridor are of significant importance to Cyprus. For example interconnecting Cyprus power system to the European main system, or with Israel, will increase the penetration of renewable energy sources to the island. In addition the energy security will be increased and the carbon dioxide emissions will be decreased considerably.

The Cyprus Government has already shown, both at national and also at regional and international level, its keen interest in contributing towards efforts to reduce global warming and climate change. Cyprus has already setup a short to medium term action plan regarding the efficient management of indigenous hydrocarbons as well as for the use of sustainable energy technologies.

Also, the President of the Republic has recently appointed the Cyprus Energy Strategy Council, which will be responsible for the integrated long-term energy strategy of Cyprus. The Council will provide the vision of our country for sustainable energy development and will set-up the optimum path towards energy efficiency, large-scale use of renewables in all sectors and effective management and utilization of Cyprus indigenous hydrocarbons.

The interest of the Cyprus Government in the efforts for reduction of the effects of climate change is therefore granted. We sincerely hope that the international community begins to take considerable action today in order to effectively control the

problem. Otherwise the problem may prove to be too difficult to control in the future, with devastating results to our environment.

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