IRENA
International Renewable Energy Agency

RENEWABLE ENERGY ROADMAP FOR THE REPUBLIC OF CYPRUS

SUMMARY FOR POLICY MAKERS

January 2015

Cover photo: An old wind pump next to Faneromeni Church, Nicosia, Cyprus. (Emanuele Taibi / IRENA)

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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This report has been made possible by a Voluntary Contribution from the Government of the Federal Republic of Germany. This roadmap was developed by IRENA, in cooperation with the Ministry of Energy, Commerce, Industry and Tourism (MECIT) of the Republic of Cyprus.

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FOREWORD: REPUBLIC OF CYPRUS

Cyprus has one of the highest electricity prices in Europe, due to high reliance on liquid fuel for power generation. However, a major transition is imminent for electricity supply. On one hand, indigenous natural gas discoveries are to be developed in the coming years. On the other hand, the costs of renewable power supply options have fallen dramatically. Meanwhile, concerns about greenhouse gases and local pollutants have increased, reflecting stringent European Union regulations.

Renewable energy offers a way for Cyprus to reduce both the cost and the environmental impact of generating electricity. In the wake of the recent economic recession, turning to renewables can help to reduce fuel imports, strengthen the trade balance and create local jobs. The success of solar water heaters, for example, can be replicated for solar photovoltaics (PV).

Cyprus has set out to attain a higher share of renewables, and this roadmap helps to assess optimal investment strategies in the power sector. Solar PV and wind power will play a major role in the roadmap to 2030. Roadmap findings will play an important role to revise existing energy policies and develop new ones.

As part of the same engagement, the energy planning model used to quantify the possible pace and benefits of renewable energy deployment given different conditions has been handed over to the Government of Cyprus. The model will remain an important tool for assessing future energy policies and examining different energy pathways, and will assist in determining the optimal penetration of RES for electricity supply, identifying the technical and economic potential for further increasing electricity production by RES.

We would like to thank IRENA for this support and look forward to a continued close cooperation in the future.

H.E. Yiorgos Lakkotrypis
Minister of Energy, Commerce, Industry and Tourism
Republic of Cyprus

FOREWORD: IRENA

The versatility, the diversity and, increasingly, the cost-competitiveness of renewable energy makes such sources essential for energy security and access around the world. For islands, in particular, clean, indigenous renewable energy is inherently more attractive than costly fossil-fuel imports. Countries such as Cyprus, which depend heavily on imported petroleum products, are investing in clean energy sources to provide affordable energy, green jobs and modern supply chains, while contributing to reducing greenhouse-gas emissions in the post-2015 world.

As an active participant in global efforts to ensure a sustainable energy future, the Republic of Cyprus has engaged with IRENA to develop a renewable energy roadmap for the country. The Ministry of Energy, Commerce, Industry and Tourism, along with a range of stakeholders, has worked closely with IRENA to examine least-cost pathways for the evolution of the power generation mix, the increasing role that renewable energy will play within it, and the impact of key decisions on energy policy that Cyprus is confronted with making today.

I trust this roadmap will prove useful in the country's pursuit of accelerated renewable energy deployment. As our world strives for a future based on clean, secure and affordable energy for all, Cyprus can be the lighthouse that helps illuminate the course for others.

Adnan Z. Amin
Director-General
International Renewable Energy Agency

EXECUTIVE SUMMARY

Roadmap structure

The Renewable Energy Roadmap for the Republic of Cyprus is based on three complementary sections. The details of what is covered by each section and how each of them relates to the others are described below.

1) Cyprus energy balance and demand forecasts

As a first step to analysing the potential for renewable energy deployment in Cyprus and answering key questions related to the impacts of key policy decisions for the energy sector, it was necessary to develop an extensive understanding of the current energy use in Cyprus, as well as demand forecasts, based on more detailed examination of current energy use and its possible future evolution in each demand sector. This analysis was developed together with the Cyprus University of Technology (CUT) and is detailed in "Cyprus Energy Balance and Demand Forecasts", one section of the full roadmap report, which provides:

- A detailed national energy balance based on official 2012 data and provisional 2013 data, with detailed analysis of residential energy demand by end-use and a breakdown of final and useful energy demand in hotels; and
- forecasts of final energy demand up to the year 2040 for a number of scenarios reflecting different sets of assumptions on Cyprus' economic and energy system development.

The national energy balance, along with two of the demand forecast scenarios developed, were used as key inputs to the second section of the roadmap and the electricity supply model on which that section is based.

2) Electricity supply model

In order to examine options for economically optimal deployment of renewable energy in Cyprus under different scenarios, and to understand the potential impact of key policy decisions on the power generation mix, a long-term energy planning model of the current power system in Cyprus was developed. The Electricity Supply Model for Cyprus (ESMC) has been developed using the long-term energy modelling platform called the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) (IIASA 2012). This is a dynamic, bottom-up, multi-year energy system model allowing the use of linear and mixed-integer optimisation techniques.

This model was used to analyse the optimal evolution of the Cyprus electricity generation mix to meet electricity demand under different sets of assumptions, which led to the definition of six main scenarios (see Figure 1), which are explained below.

- **Energy Efficiency Demand Scenario without Interim Gas Solution Scenario (SC1):** Demand factors for this scenario are taken from an energy efficiency scenario developed in a separate study examining energy demand projections (Zachariadis *et al.* 2014). None of the

major projects under consideration are implemented, except the production of domestic natural gas for the internal market in 2022; a transition period is assumed where indigenous gas for power generation becomes available in 2023. Specifically, the Interim Gas Solution, the EuroAsia Interconnector and the LNG export terminal are excluded from this scenario.

- **Extra Efficiency Demand Scenario with Interim Gas Solution Scenario (SC2):** This scenario follows the same logic as SC1, with the exception of different final electricity demand assumptions and the success of the Interim Gas Solution negotiations. Demands are taken from the Extra Efficiency Scenario (Zachariadis *et al*. 2014), which also assumes a decoupling between economic growth and electricity demand. Thus, demand in this scenario is lower than in SC1. Also, the interim gas solution is allowed to make gas available for the power sector, which means that a limit is imposed on the maximum contribution of renewables in the generation mix, so as to ensure consumption of a minimum volume of gas based on the likely minimum quantity requirements to be purchased for the Interim Gas Solution to happen.

- **Energy Efficiency Scenario Demand with Interim Gas Solution Scenario (SC3):** This scenario follows the same assumptions and final electricity demand as SC1. However, the Interim Gas Solution negotiations are assumed to be successful, as in the case of SC2. By comparing SC1 with SC3, outputs from this scenario can provide insights regarding the effects of the interim solution.

- **LNG Export Terminal Scenario (SC4):** In this scenario, assumptions are the same as in the previous scenario (SC3), but investment in a liquefaction facility for export purposes is allowed. Since the interconnector is not deployed in this scenario, storage is again deemed necessary beyond certain predefined limits (discussed later in section 3.4.6.1).

- **EuroAsia Interconnector Scenario (SC5):** This scenario assumes that the EuroAsia Interconnector will be implemented as planned, but no liquefaction facility will be developed. Unless a separate grid analysis indicates otherwise, the assumption here is that storage is not a prerequisite in the case of high renewable energy penetration. The Interim Gas Solution is assumed to be successful as in SC3. Final electricity demands are the same as in SC1 and SC3. The aim of this scenario is to identify the price at which imported electricity becomes cost-competitive enough to be part of the Cyprus power generation mix. Since investment cost for development of the cable connection has not been considered in the analysis, the economic and other benefits from the deployment of the interconnector should outweigh the cost of the associated infrastructure for the interconnector to add value to the electrical system. In the presence of an interconnector, the impact on renewable energy deployment would be twofold: no storage would be required and more variable renewable energy can enter the power generation mix without the need for storage, which would reduce its competitiveness.

- **LNG Export Terminal and EuroAsia Interconnector Scenario (SC6):** A combi-

nation of Scenarios SC4 and SC5 has been conducted, with both the liquefaction facility and the interconnector considered. Assumptions regarding the Interim Gas Solution are the same as in SC4, while the assumptions regarding the necessity of storage are the same as in SC5.

Additionally, several sensitivity analyses were undertaken. The demand scenarios considered in the MESSAGE model were based on the demand forecast developed by CUT. In particular, one demand scenario was used for five out of six supply scenarios, with the scenario with the lowest electricity demand used only for evaluating the possible benefits in one of the six scenarios (SC2).

The modelling work using MESSAGE was developed together with the Swedish Royal Institute of Technology (KTH) and is detailed in the full roadmap report, in the section "*Electricity Supply Scenarios for the Republic of Cyprus*". This section considers six specific scenarios examining the optimal deployment of renewable energy and thermal generation for the period 2013-2030. The scenarios were designed by IRENA and KTH in consultation with the Ministry of Energy, Commerce, Industry and Tourism (MECIT), to provide insights into key energy related decisions that Cyprus is facing. This part of the report forms the core of the roadmap and provides key insights into how different policy decisions affect the optimal evolution of the electricity system in Cyprus.

3) Technical studies investigating VRE integration

In order to provide insights and state-of-the-art information on how to accelerate the deployment of variable renewable energy (VRE) generation, while maintaining stable operation of the electricity grid, the roadmap includes the results of two studies examining how VRE integration could be supported through:

1. VRE production forecasting
2. State-of-the-art of technologies for the provision of grid support services from variable renewable energy systems

These studies were developed by IRENA, as defined in the scope of work of the Cyprus roadmap, and are included at the end of this report. They provide key insights into the state of the art of some key tools and measures that can be used to facilitate the integration of large shares of VRE into Cyprus' electricity system.

Key roadmap findings

The following conclusions have emerged from the roadmap analysis:

- To better position Cyprus for the revision of its energy policy and associated plans, this report provides quantitative insights on the impacts of major upcoming policy decisions;
- Several renewable energy technologies (RETs), including photovoltaics (PV) and wind, can already produce electricity at a lower cost than Cyprus' current oil-fired power plants;
    - Based on this analysis, renewable energy could provide 25% to 40% of Cyprus' total electricity supply in 2030. In these scenarios solar PV will be the

dominant source with about 500 – 1,000 megawatts (MW) of capacity providing 15% to 27% of the electricity supply while wind will be the second most important renewable energy source with about 175 – 375 MW of capacity providing 5% to 9% of the electricity supply.

- The deployment of renewable energy in Cyprus has the potential to create between 11,000 and 22,000 jobs in Cyprus by 2030, based on IRENA's estimates of the job-creation potential of different RETs;

- The accelerated deployment of renewable energy along with the shift of thermal generation to natural gas is estimated to lower generation cost to EUR 83-92 per megawatt-hour (MWh) by 2030. Costs in 2013 were around EUR 130/MWh, based primarily on heavy fuel oil and diesel generation.

- The following recommendations would help to minimise electricity generation costs in Cyprus:

  - Create market incentives for investment in increasing the flexibility of thermal generation, to reduce must-run requirements and increase the space for integration of renewable energy into the market;
  - Minimise the requirements for provision of ancillary services from distributed renewable energy in the grid codes and allow renewable energy to participate in the market for ancillary services;
  - Move from a net-metering scheme to net-billing, where renewable electricity that is fed into the grid is sold either at market price or at a feed-in tariff below marginal generation cost; and
  - Maintain the feed-in tariff regime until a well-functioning market, which allows full participation of renewable energy (including provision of ancillary services), is in place.

- Certain features of the electricity market currently being designed would affect the competitiveness of renewables and should be reconsidered:

  - Production forecast closes at 3:00 p.m. of the day before, with no re-denomination allowed on the same day;
  - Limited size of the day-ahead market due to thermal generation must-run and operating reserves constraints, with no incentives to invest in flexibility or dispatchability;
  - RETs are not allowed to provide ancillary services through the market, with compulsory requirements applied to all RETs through grid codes; and
  - Uncapped and non-compensated RET curtailment justified by system security concerns creates a substantial risk for renewable energy investors.

- To improve the quality and reliability of national energy balance it is recommended to:

  - Publish the annual energy balance of Cyprus and extend its coverage to accommodate all available statistical information, *e.g.*, for industrial subsectors; and
  - Conduct energy surveys at regular intervals (every few years), particularly

for sectors with diverse energy use such as households and tourism.

- There is substantial potential for energy efficiency improvements and further penetration of renewables in the tourism sector, provided that appropriate policies are implemented.

- The Ministry of Energy, Commerce, Industry and Tourism should consider making a long-term commitment to energy modelling work for both final energy demand and electricity supply as this would greatly expand in-house capacity to assess the potential impacts of energy policy decisions and changes in the energy market conditions.

- Accurate forecasts support high levels of VRE generation by reducing integration costs for the transmission system operators (TSO) and distribution system operator (DSO) while also reducing financial risk and increasing revenues of IPPs and utilities operating VRE assets.

- There is a strong correlation between the value of forecasting and electricity market design. In particular short-term markets and full market access (*i.e.*, including participation in the ancillary services market) for VRE producers increases the effectiveness of forecasting in reducing VRE integration costs and increasing the share of VRE generation.

- Current and near term advances in power electronics allow VRE assets to provide grid support services (GSS). In combination with limited amounts of energy storage, VRE can provide the full range of GSS already today. These capabilities should be factored into Cyprus' proposed market design and future energy planning efforts.

(Peter Journeay-Kaler / IRENA)

INSIGHTS FOR POLICY MAKERS

This section provides a review of the main findings and specific policy recommendations that have emerged from the roadmap analysis. It is intended to assist policy makers in identifying the main insights that will affect important upcoming policy decisions.

Cyprus is at a major crossroad for the development of its energy system. The key driving elements for the evolution of Cyprus' energy system are:

- the potential availability of natural gas, either imported or indigenous, within this decade;
- the plan to open up the monopolistic electricity market to competition, with a view to reduce cost and give choice to consumers;
- the imminent end of derogations given to the electricity sector of Cyprus with respect to the application of EU emission limits, particularly according to the Large Combustion Plants Directive (Directive 2001/80/EC setting emission limits for SO2, NOx and dust) and the free allocation of CO_2 certificates;
- new techno-economic developments, particularly with respect to RETs, power electronics, smart and energy efficient technologies; and
- the current economic situation of Cyprus, which is seeing increasing need for reduced energy costs in businesses and households.

This is reflected in the analysis through the six key scenarios developed. These scenarios

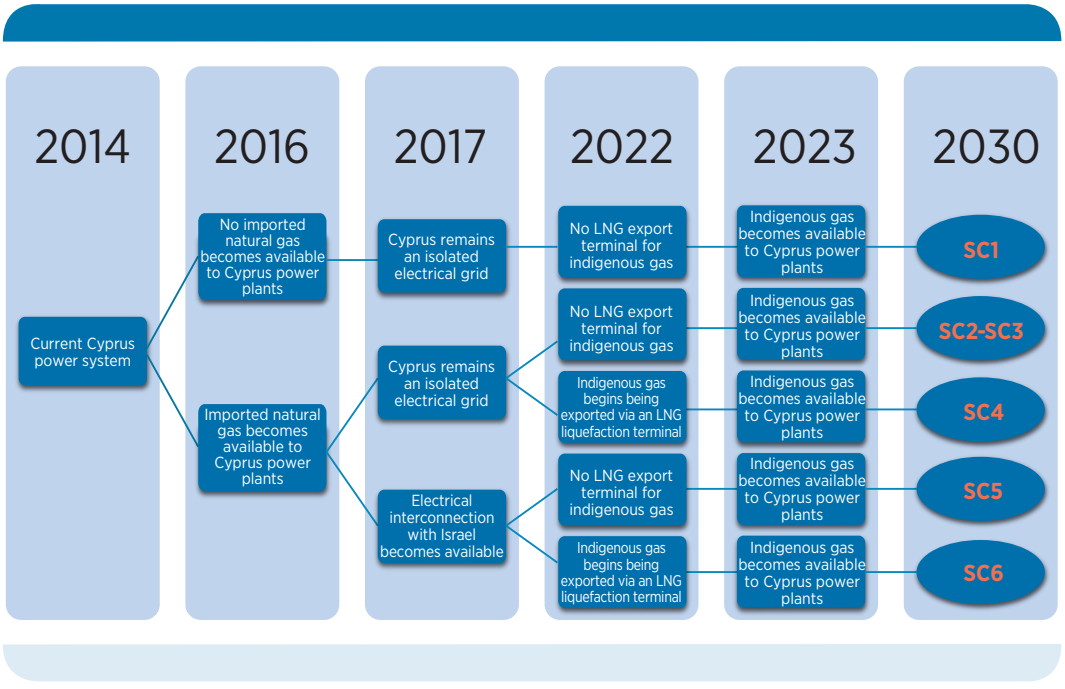

Figure 1: Policy Decision Tree and Resulting Scenarios

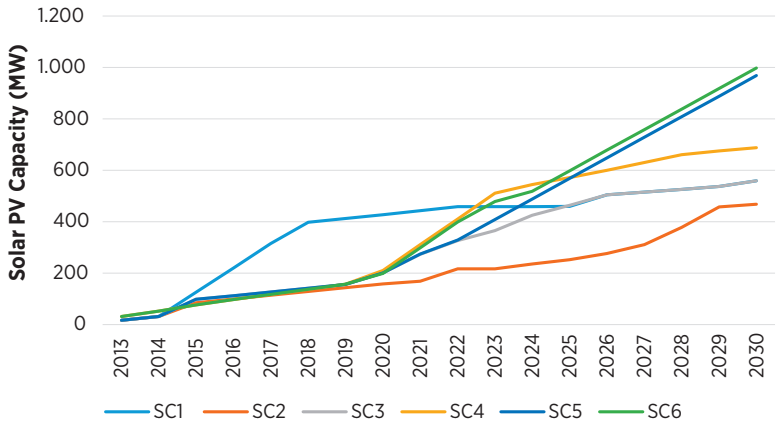

Figure 2: Development of solar PV capacity under different scenarios

are based on possible combinations of major developments for the energy system of Cyprus, particularly: availability of imported gas, availability of an international electrical interconnection, availability of indigenous gas and related infrastructure.

Figure 1 illustrates a decision tree defining the six key scenarios based on the combinations of the above energy sector developments.

The analysis of these scenarios shows that **several RETs can already produce electricity at a lower cost than power plants fueled by oil products.**

RETs have the potential to provide a substantial contribution to the electricity mix of Cyprus. Based on this analysis, **between 25% and 40% of Cyprus' electricity supply can come from renewables in 2030**, in the economically optimal mix. Solar PV is the predominant renewable energy technology in all scenarios, supplying between 15% and 27% of the electricity consumed in Cyprus in 2030.

Wind is the second most important RET, contributing between 5% and 9%. The scenarios on the low-end of the renewable energy share are limited in penetration of variable RET based on the constraints obtained by the Ministry of Energy, Commerce, Industry and Tourism. The ministry's constraints are based on provisional results from a study on grid stability commissioned by CERA, which will be revised by a subsequent study under development by the Joint Research Centre (JRC) of the European Commission. Nonetheless, mandatory renewable energy targets for 2020 are exceeded in all scenarios. In the absence of constraints related to must-run, operating reserve and stability-related concerns, solar PV will reach higher shares at a steady pace. In the absence of imported gas becoming available for power generation in 2016, solar PV deployment will be strongly accelerated (see SC1 and Figure 2). It is recommended to explore scenarios without the availability of natural gas and imposed technical constraints on variable renewables (currently based on a non-finalised study).

This analysis provides insights for the key policy decisions that will determine the evolution of the energy sector in Cyprus. Instead of suggesting one pathway as the optimal to follow, different scenarios provide **quantitative insights on the impacts of different policy decisions,** to better position Cyprus for the revision of its energy policy and associated plans (*e.g.,* the National Renewable Energy Action Plan). Given the game-changing nature of some of the policy decisions to be taken for the energy sector of Cyprus, **this analysis outlines an optimal roadmap for each of the possible scenarios**, without associating a probability to each of them. The difference among different scenarios in terms of cost of generation, investment needs, compliance with policy targets and optimal power generation mix can guide the government in taking policy decisions that will lead to the most desirable scenario and associated optimal roadmap.

- **In combination, renewables and natural gas are expected to lower the generation cost to EUR 83-92/MWh by 2030** (Table 1). This is compared to 2013 levels estimated at about EUR 130 /MWh, where power is generated mostly by burning heavy fuel oil and diesel.

Based on an IRENA analysis titled *Renewable Energy and Jobs* (IRENA, 2013c), solar PV can provide 18-20 new jobs per additional megawatt-peak (MWp) installed, while wind in a similar context like Cyprus (*e.g.*, Greece) can provide 8.8 jobs per MWp (see table 2.2, page 42 of IRENA 2013c). The deployment of 1 gigawatt-peak (GWp) of PV over the period 2013-2030 can lead to about 20,000 new jobs (see Table 2), with about additional jobs still exceeding 10,000 in the scenario with the lowest renewable energy deployment (SC2). In the case of Cyprus, synergies can be leveraged between the existing solar thermal industry, which is already well-established, and the rapidly growing solar PV market. Therefore a dedicated analysis on the job impact for Cyprus would be a valuable extension of this work.

Policy recommendations

In order to minimise the electricity generation cost for the Cyprus system, the following recommendations can be made.

- **Create market incentives for investment in flexibility for thermal power plants**, to reduce the must-run requirements and

Table 1: Renewable energy shares, generation cost and system investment per scenario

	SC1	SC2	SC3	SC4	SC5	SC6
Renewable energy share in 2020	27.9%	19.5%	17.8%	17.9%	17.8%	17.9%
Renewable energy share in 2030	25.6%	28.3%	25.6%	26.4%	40.1%	33.2%
of which:						
solar PV	*15.2%*	*17.4%*	*15.2%*	*15.2%*	*26.8%*	*22.0%*
wind	*5.7%*	*5.5%*	*5.7%*	*5.1%*	*8.7%*	*6.6%*
Cumulative generation system investments 2013-2030* (billion EUR)	1.10	0.70	1.06	1.46	1.45	1.55
Average generation cost in 2013-2030 (EUR/MWh)	101.0	91.6	90.4	91.5	88.9	89.1

** The cost of some investments such as grid investments, electrical interconnector cost, and energy efficiency measures are not included.*

Table 2: Estimated additional jobs generated by wind and solar PV deployment in Cyprus

	Installed capacity in 2030 (MW)		Estimated additional jobs	
	Wind	PV	Wind	PV
SC1	251	559	2,209	10,621
SC2	175	468	1,540	8,892
SC3	251	559	2,209	10,621
SC4	275	688	2,420	13,072
SC5	372	968	3,274	18,392
SC6	352	998	3,098	18,962

increase the space for integration of RET into the market (see the case of Denmark, *e.g.*, from Blum and Christensen 2013).

- Minimise the requirements for **provision of ancillary services from distributed RET** (*e.g.*, small-scale residential PV) in the grid codes, and allow RET to **participate in the market** for ancillary services. In this way, the participation of only a minimal part of the RET generators would be sufficient to compensate for the rest of the variable RET, minimising the cost of providing the needed ancillary services (see Van Hulle *et al*. 2014).
- Consider moving **from a net-metering scheme towards asymmetric net-billing**, where electricity fed into the grid is purchased either at market price or at a feed-in tariff below marginal generation cost. This would allow both a reduction of windfall profits for net metering customers – due to the large difference between generation cost from PV and the current tariff – as well as the reduction of grid integration costs, as a net-billing scheme would provide strong incentives for maximising self-consumption of electricity produced from PV. Currently all net metering customers pay a fixed fee for grid use, a measure that does not promote self-consumption and penalises all customers equally. Moving to a net-billing scheme can promote smarter consumption patterns, lead to the deployment of small-scale storage systems and intelligent appliances, and generally leverage all the potential benefits from distributed PV. The same policy can replace the existing self-generation support scheme, which has not been very successful up to now, especially in agricultural and other commercial consumers, who are unable to derive benefits from it.
- According to this analysis, acceleration of the deployment of RET can reduce generation cost substantially, especially under the current conditions where oil products are used to generate most of the electricity. However, the slow permitting process slows down the necessary deployment, and current policy and future market uncertainty increase the risk for investors. As PV, concentrated solar power (CSP) and wind are capital-intensive (but have no fuel cost), they are much more sensitive to cost of capital compared to thermal power plants. **Increasing the risk for investors in RET would reduce their competitiveness** much more than would be the case for investors in fossil fuel-powered plants, with a double impact on electricity generation cost for Cyprus.

This means that less RET deployment will take place, with a higher generation cost. For each 12 MWp of utility-scale PV that gets delayed compared to the suggested roadmap, this analysis estimates that total generation cost will increase by EUR 1 million per year. One suggestion could be to maintain the **feed-in tariff regime** until a well-functioning market that allows for full participation of RET, including provision of ancillary services, is in place. One possible way to achieve this is to provide a feed-in tariff set at **marginal generation cost minus grid integration cost** for as many years as the estimated break-even time. This should be revised yearly for new installations, to account for reductions in the cost of RET and changes in grid integration costs; however, **it should not be revised retroactively for existing installations**. Once their feed-in period expires, RET generators will be allowed to sell electricity (and services) on the market, which by then should be fully operational.

- Based on the decision tree in Figure 1, no fuel switch will happen before 2016, in any of the scenarios. Therefore, for 2015 the best policy option is to **create the enabling conditions** for accelerated deployment of **utility-scale solar PV,** which is the cheapest available generation option. PV generation cost for 2015 in Cyprus is estimated to be below EUR 80/MWh, displacing diesel and less efficient heavy fuel oil (HFO) units, for which the variable generation cost (short-run marginal cost, or SRMC) ranges between EUR 120-130/MWh. However, due to the current uncertainty on permitting, licensing and future market design, the environment in 2015 is not conducive to deployment of RET. In particular, certain features of the future market currently being designed would affect the competitiveness of renewables and likely slow down investments. Key concerns related to current design of the electricity market, related to deployment of renewables, are:
  - production forecast closes at 3:00 p.m. of the day before, with no re-denomination allowed on the same day;
  - limited size of the day-ahead market due to conservative constraints on must-run for thermal power plants and operating reserves, with no incentives to invest in flexibility for reducing the must-run requirements;
  - RET will not be allowed to provide ancillary services through the market, with requirements being enforced to all RET through grid codes;
  - RET can be curtailed without compensation if TSO requests to do so because of system security concerns, and no cap is set on max curtailment, which creates a substantial risk for RET investors.
- One of the major achievements in the development of this analysis has been the creation of a platform for productive discussions among key stakeholders in the energy sector of Cyprus. The added value of having a modelling platform to support discussions on quantitative results should justify support for creating in-house capacity on energy planning modelling. In this way future policy development will benefit from quantitative-based discussions supported by a commonly agreed modelling platform, which can provide insights on impacts from different policies being considered, and assess sensitivity of results to specific assumptions used.

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