FROM LAGGARD TO LEADER? MALTA'S TRANSITION TOWARDS LOWER CO_2 EMISSIONS AND A LARGER RENEWABLES SHARE WITH ASPECTS OF ENERGY STORAGE

Manfred WEISSENBACHER[1], Janis MUENCHRATH[2]

[1, 2]: Institute for Sustainable Energy, University of Malta, Msida, MSD 2080, Malta,
E-mail: manfred.weissenbacher@um.edu.mt; janis.muenchrath.13@um.edu.mt
[2]: Institute of Power Transmission and High Voltage Technology (IEH), University of Stuttgart, Keplerstraße 7, 70174 Stuttgart, Germany

Abstract:

The EU island member state of Malta is heavily dependent on energy imports. Renewable energy shares have traditionally been minimal and electricity generation is based on heavy fuel oil and gas oil. However, profound changes are underway as the power sector is being shifted to natural gas, delivered to the main island in form of LNG, while the hitherto isolated Maltese electricity grid will be connected to Europe through an HVAC interconnector to Sicily. The considerable decrease in carbon dioxide emissions associated with this transition might influence policy makers' attitude with regard to the current 2030 target discussions, where those EU member states favoring binding and high renewable energy share goals are confronted with a group of other member countries that prefer greenhouse gas reduction targets. While the Maltese power sector transition will reduce overall national carbon dioxide emissions below 1990 levels, achieving high renewable shares will be challenging. Though Malta has managed to reach the two percent intermediate renewables share target for 2012, the national renewable energy action plan needs to be revised, not at last due to the impact of the new fossil fuel setup. In turn, energy storage options might facility the way towards implementation of offshore wind power and the further rise in photovoltaic contribution.

Keywords: Malta, natural gas, carbon dioxide, energy storage, renewable energy

1 Introduction

In 2005 the island state of Malta was the only European Union member country with a renewable energy consumption share of zero percent, and it was not before 2011 that a one percent share had been achieved. Meanwhile electricity production from non-renewables is mainly based on imported heavy fuel oil that is associated with high levels of both local air pollution and CO_2 emissions per kWh generated. However, substantial changes during the next few years will alter the Maltese energy landscape in terms of fossil fuels, renewables, as well as electricity grid infrastructure.

2 The Current Power Sector Situation

2.1 Status of Fossil Electricity Generation

Malta produces some 2.3 TWh of electricity per year for a population of about 410 thousand. More precisely, electricity production was 2.28 TWh in 2012, up from 2.17 TWh in 2011 and 2.11 TWh in 2010. Until recently practically all electricity was produced at two power stations burning heavy fuel oil (ca. 86 percent) and gas oil (ca. 14 percent) and releasing some 1.9 million tonnes of CO_2 per year (2011). However, only 130 MW of nominal capacity at Marsa, the older one of these two stations, remained in operation after Enemalta, the single, state-owned utility, in December 2012 took a new extension at the Delimara station into operation. This new extension, a Diesel engine/combined cycle that currently runs on heavy fuel oil, significantly increased Maltese power generation efficiency through its individual efficiency of 46% at a nominal capacity of 149 MW[1]. The other units at Delimara are steam turbines (120 MW, 32% efficiency[2]), a combined cycle gas turbine plant (110MW, 39%[3]), and two open cycle gas turbines of 37 MW each (commissioned 1994) that, like an additional 37 MW open cycle gas turbine at Marsa (1990), operate at 20% efficiency. Meanwhile, the Marsa 130 MW worth of steam turbines exhibit an average efficiency of 25%. In total, the current nominal capacity amounts to 620 MW, de-rated to 570 MW during the summer due to high ambient temperatures. This compares to a peak load of above 410 MW on hot summer days, while the base load is ca. 160 MW.

2.2 The Electricity Grid

The Maltese electricity grid is currently isolated. With Delimara power station at the southern coast, and Marsa power station in a south-central position, electricity is fed quite peripherally into the grid to be distributed across the country via two double 132kV cables and various 33kV (and smaller) power lines. Losses are high, given that the entire Maltese archipelago covers just 316 km^2. In 2011, Malta's two power stations consumed 5.7 percent of the total electricity produced, while ca. 4.6 percent of the electricity actually sent out was lost during transmission and distribution before reaching consumers. Thus, for each unit of electricity used by consumers (1/0.954 x 1/0.943 =) 1.112 units of electricity need to be produced at the power stations, which increases the emissions caused by a unit of electricity used at the consumer end from the (2011) average of 0.8907 kg of carbon dioxide emitted per kWh of electricity produced at the power station to (0.8907 x 1.112 =) 0.990 kg of carbon dioxide per kWh (Weissenbacher, 2012a). What is more, nearly ten percent of the sent out electricity is "unaccounted for," with much of it attributed to theft.

[1] The extension consists of eight Wartsila 18V46, 4 stroke medium speed diesel engines, operating in combined cycle mode, with eight heat recovery boilers and one 12 MW steam turbine (Dresser Rand).
[2] Two 60MW Conventional Steam Boiler/Turbine Units- commissioned 1992.
[3] Two 37MW gas turbines, One 36MW steam turbine- commissioned 1999.

2.3 Renewables

Malta started out with the lowest renewables share of all EU member countries and was committed to reach a 10 percent renewable energy share of gross final energy consumption by 2020 with a trajectory as shown in Table 1.

Year	2011-2012	2013-2014	2015-2016	2017-2018	2020
Target	2%	3%	4.5%	6.5%	10%

Table 1: Malta's 2020 renewable energy share target with trajectory (MRRA, 2011).

Malta faces various challenges with regard to renewables for several reasons. Most importantly, Malta has a population density of about 1,300 people per km^2, making it one of the world's most densely populated nations, while renewable energy sources tend to have low energy intensities per unit of area. Wind turbines close to urban settings are opposed, and Malta largely relies on imports for its food security. Land will thus hardly be set aside for the production of biofuels (which need to be imported) or ground-based solar PV parks. Furthermore, the waters around Malta quickly deepen beyond depths suitable for conventional offshore wind technology, though a reef has been identified that could potentially carry a 95 MW wind park. The previous government in turn made offshore wind the cornerstone of its renewable energy plan (Table 2).

Renewable Energy Option	%	GWh/year
Offshore wind	3.48	216
Biofuels	2.40	149
Energy from waste –Electricity	2.18	135
Solar PV	0.69	43
Onshore wind	0.61	38
Solar water heating	0.52	32
Energy from waste – Heat	0.32	20
TOTAL:	**10.20**	**634**

Table 2: The contribution of different renewable energy options to 2020 gross final energy consumption according to Malta's National Renewable Energy Action Plan submitted in June 2010 and resubmitted in May 2011 (MRRA, 2010, 2011).

As will be described below, the offshore wind park, which remained in the planning stage, is problematic for various reasons. On the other hand photovoltaic (PV) systems, which are represented conservatively in Malta's National Renewable Energy Action Plan (NREAP), began to spread substantially, with 17 MWp of total PV capacity having been installed by the end of 2012, and ca. 30 MWp by the end of 2013. Notably, Malta enjoys a mean global horizontal solar radiation of ca. 5 kWh/m²/day, and new PV systems yield around 1650 kWh/kWp/year. Thirty MWp would thus initially deliver 49.5 GWh/year and already overshoot the PV target of Malta's National Renewable Energy Action Plan. The drivers behind the increase in installed PV systems in Malta in recent years include falling PV system prices; grant schemes providing 50 percent of the eligible expenditure up to a maximum of €3,000; additional grant schemes for commercial establishments; and modest feed-in tariffs of 25 cents/kWh (Gozo: 28 cents/kWh) up to 4,800 kWh/year for households, guaranteed for 8 years, and 20 cents/kWh up to 160,000 kWh/year for commercial premises, guaranteed for 7 years. (After the feed-in tariff years, the marginal cost per kWh of electricity incurred by Enemalta for the particular year will be provided. This marginal cost is presently €0.11/kWh.) To be sure, the feed-in tariff schemes have now been revised to reflect changing market PV prices, and differentiated tariffs exists for systems that did (up to 50%) or did not benefit from a grant scheme, that are ground- or roof-based, and that are placed at residential or non-residential premises. Installations below 1MWp of capacity in 2013 were assigned a feed-in tariff of about €0.16 to €0.17 per kWh for 20 years.[4]

Based to a good part on the accelerated spread of PV systems, but also due to the substitution obligation with regard to biodiesel (now pre-mixed into fossil diesel); a substantial increase in solar thermal systems, increased use of wood pellets ("imported biomass"); a contribution from a mechanical-biological waste treatment plant that includes an annual electricity production of some 4.7 GWh from anaerobic digestion (AD) gas; and an additional AD setup that produces electricity at a sewage treatment plant, Malta managed to achieve a two percent renewable energy share in 2012 as required by the trajectory (Table 3).

Renewable Energy Category	2011	2012
	GWh	
RES-electricity		
PV	8.43	13.17
Micro-Wind	0.00	0.1
Waste-to-Energy (CHP)	1.55	8.85
RES-heat		
SWH	31.44	45.14
Waste-to-Energy (biogas to RTO)	3.08	2.50
Biomass imports	6.61	9.60
Bio-diesel in industry	0.88	2.53
Waste-to-Energy (CHP)	1.39	7.30
RES-transport		
bio-diesel	15.30	34.28
TOTAL:	**68.68**	**123.47**

Table 3: Maltese renewable energy consumption data for 2011 and 2012 (Ministry for Energy and the Conservation of Water, 2013).

2.4 Electricity prices, Consumption Trends, GDP

Electricity tariffs vary according to consumption levels, with residential rates ranging from 16.1 cents/kWh to 70.0 cents/kWh (inclusive 5 percent VAT), and nonresidential daytime rates ranging from 14.6 cents/kWh (very high consumption) to 21.7 cents/kWh (exclusive VAT). An increase in tariffs around 2009 seemed to be a driver behind the reduced electricity

[4] Find the detailed feed-in tariffs regulations at this link: http://justiceservices.gov.mt/DownloadDocument.aspx?app=lom&itemid=11430&l=1

consumption in 2009/10 that disrupted the long-term trend, however, the decrease in consumption turned out a short-term effect and coincided with an economic downturn (Figure 1). Notably, the uptake of PV grants also peaked in 2010, but clarification of the extent to which electricity prices or other factors (such as saturation) influenced uptake trends is pending further analysis. Final electricity consumption in 2011 was spilt into 33% residential and 67% non-residential, with the latter including 29% industry and the remaining 38% including the commercial sector.

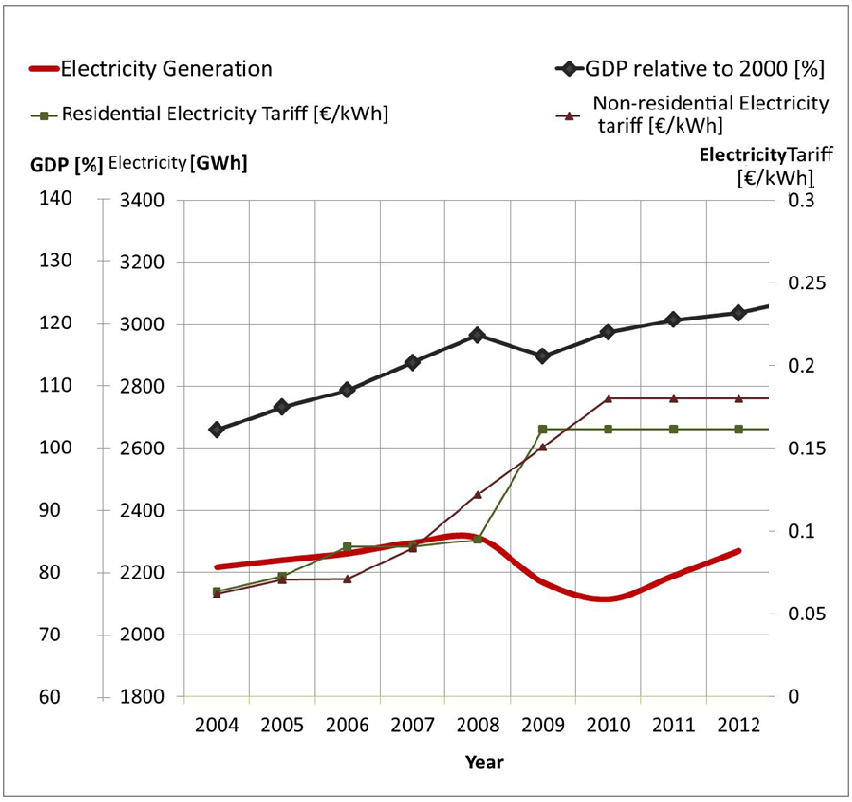

Figure 1: Historic trends in electricity tariffs, electricity generation/consumption, and GDP.

3 The Upcoming Setup

3.1 Interconnector to Sicily

A 200 MW (at 220 kV) HVAC submarine cable to Sicily, the longest HVAC (rather than HVDC) interconnection in the world, is currently being implemented, with completion now expected by late 2014 or early 2015. At a stated cost of €182 million, part-financed through the European Energy Programme for Recovery, the project includes the construction of a distribution hub that was to connect the planned offshore wind park to the Maltese grid. Grid stability in the context of the offshore wind park integration was in fact cited as a principal reason why the interconnector was required, and it was proposed that the interconnector capacity may be doubled with a second 200 MW cable later on (Lahmeyer, 2009). However, with the expected changes in Malta's NREAP, the most significant immediate effect might be that the completion of the interconnector will allow for the total decommissioning of the old Marsa power station to take the remaining 130 MW worth of steam turbines out of service. (The interconnector's impact on Malta's carbon footprint from electricity production will be discussed further below.)

3.2 New Gas-fueled Power Station

According to the general election campaign pledge by the party in government since March 2013, Malta is currently shifting its electricity generation infrastructure from oil to gas. (The electorate has been promised a 25% reduction in utility bills.) At the core of the restructuring plan is an LNG *Floating Storage Unit* with a land-based regasification installation supplying a new 200 MW gas-fired power station (combined cycle gas turbines) that should be operational by the end of 2015. (There are no gas pipelines to Malta and natural gas is currently not being used.) In addition, Delimara power station's 144 MW extension that started to operate in December 2012 will be converted to use natural gas as well (while it was originally designed to run on diesel). To be sure, there is still considerable dispute about the precise setup of the LNG *Floating Storage Unit,* principally because the current proposal maintains that a gas storage barge should be permanently berthed in Marsaxlokk Port close to the Delimara power station, while opponents claim this to be unsafe and lobby for a vessel out at sea that should store LNG and have an onboard re-gasificator. However, the latter technology is more rare and expensive, and would jeopardize the time-frame to which the government has committed itself. (The converted FSRU Toscana, moored some 12 nautical miles offshore from Livorno, is one reference project.) Notably, the investment for the new gas power plant will be placed by an Independent Power Producer to ensure heavily indebted Enemalta is not being burdened. As soon as the new gas plant is coming online, the 120 MW steam plant at Delimara will be decommissioned.

3.3 Future Generation Capacity Compared to Future Demand

The implementation of the interconnector and the new gas power station will combined allow for most of the older generation capacity to be switched off within just two years. Figure 2 shows projections for required electricity generation (and import) capacity, with the promised tariff reduction that might bring 2020 demand back up to previous projections.

Meanwhile Figure 3 illustrates how electricity generation and import capacity will change during the next few years, with an indication of peak load that needs to be met. Note that in the depicted scenario peak loads increase proportionally with overall demand, while increased overall wealth and lower electricity tariffs may lead to higher cooling loads and more pronounced summer peak demand. Also note that renewables are excluded in this scenario. As described further below, contribution from photovoltaic installations right at the time when summer peak loads are experienced, may well allow for the Delimara gasoil part to remain offline. Increased grid efficiency would reduce the generation requirement.

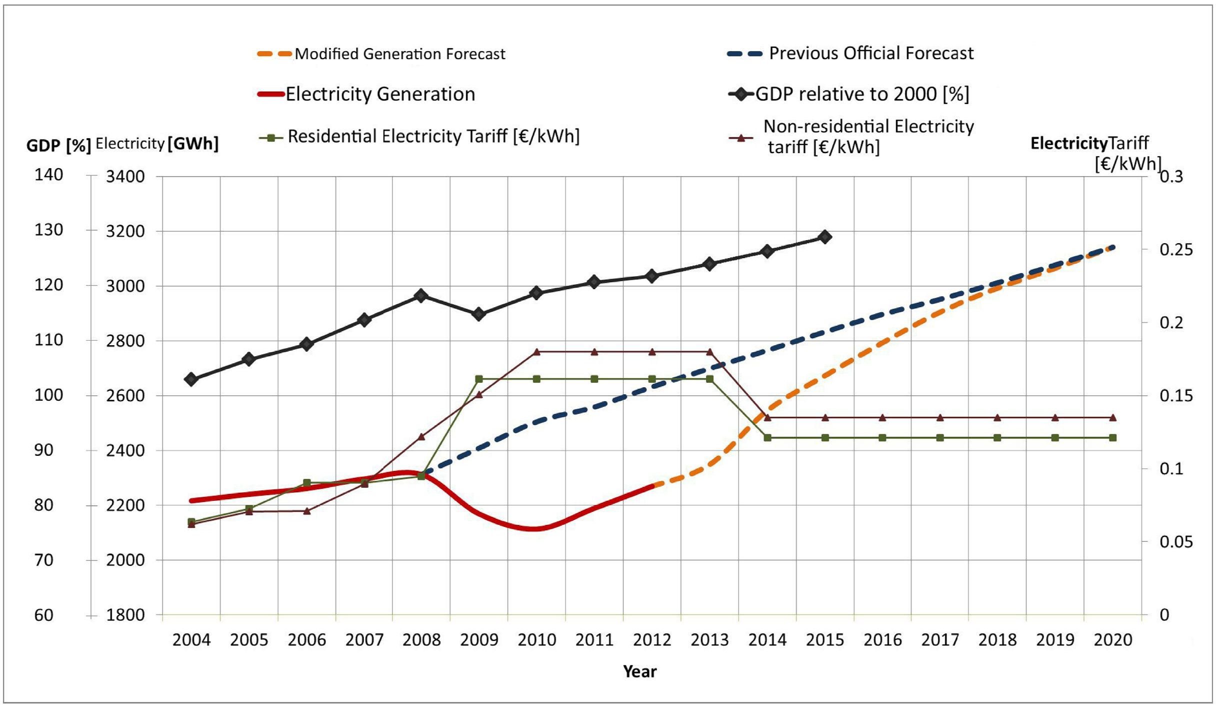

Figure 2: Projections for required electricity generation (and import) capacity, with reduced electricity tariffs as suggested by government pledges.

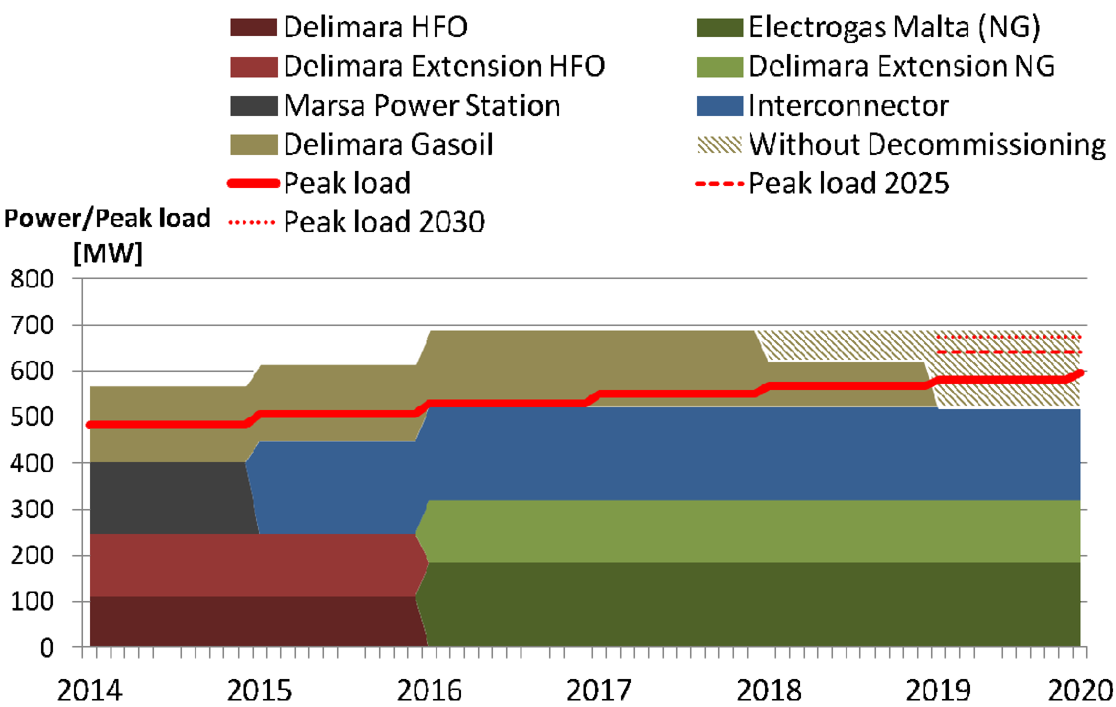

Figure 3: Scenario showing peak demand projections with changes in electricity generation and import capacity in future years (excluding renewables).

3.4 Cost Reductions

The new power infrastructure will allow for electricity to be available at much lower cost due to fuel cost differences, higher efficiencies of the new generation capacity, and lower cost of imported electricity. Figure 4 shows a cost comparison scenario for projected 2016 demand for four supply setups (including 90MWp of PV installations in all setups). The cost scenario for heavy fuel and gas oil (“oil”) is based on Enemalta’s full-cost recovery rate for electricity production of 2009 (0.146€/kWh), adjusted for higher oil prices, while imported electricity cost (interconnector) is based on projected Sicilian market prices (IPEX). The cost of electricity produced from gas is taken as €95.99 per MWh, according to the power purchase agreement that Enemalta signed with the Independent Power Producer, i.e. ElectroGas Malta, a consortium comprising Siemens GMBH, Socar, Gasol Plc and GEM Holdings. The unit price charged to Enemalta has been locked in for five years, and the same figure has been assumed for electricity produced at the Delimara extension that will be converted to gas.

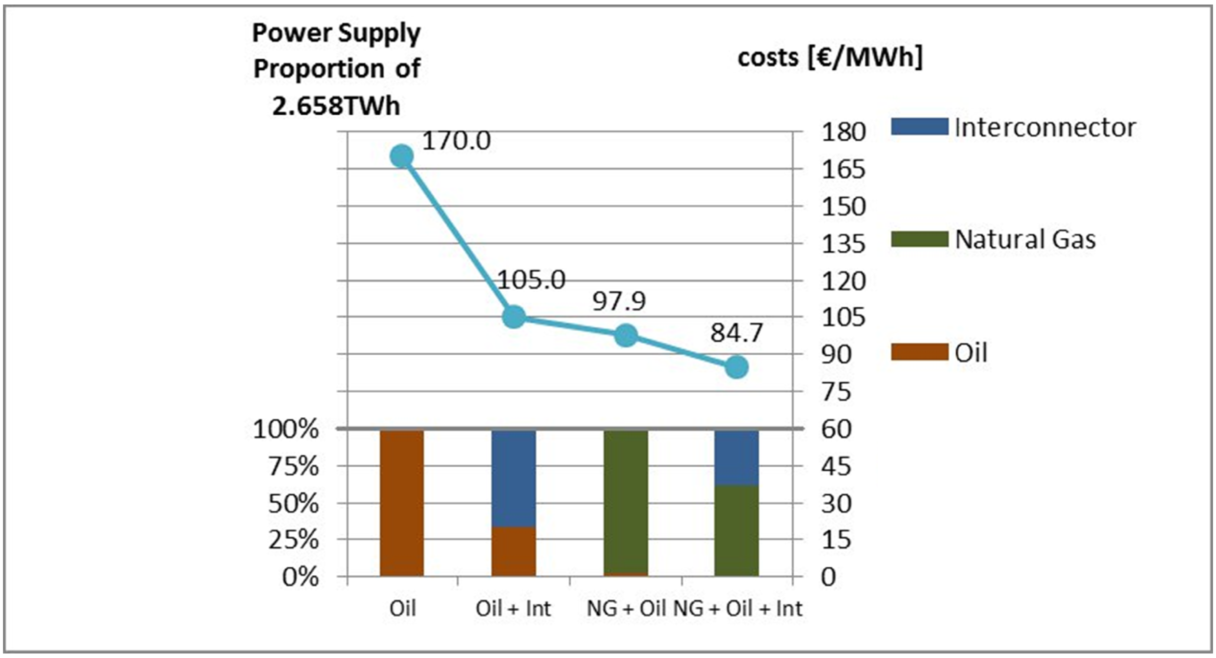

Figure 4: Cost scenarios for projected 2016 demand. See main text for assumptions.

3.5 CO_2 Emissions Reduction

Carbon dioxide emissions will be substantially reduced due to the upcoming electricity situation. Figure 5 shows the dominant contribution of Maltese power generation to overall greenhouse gas emissions.

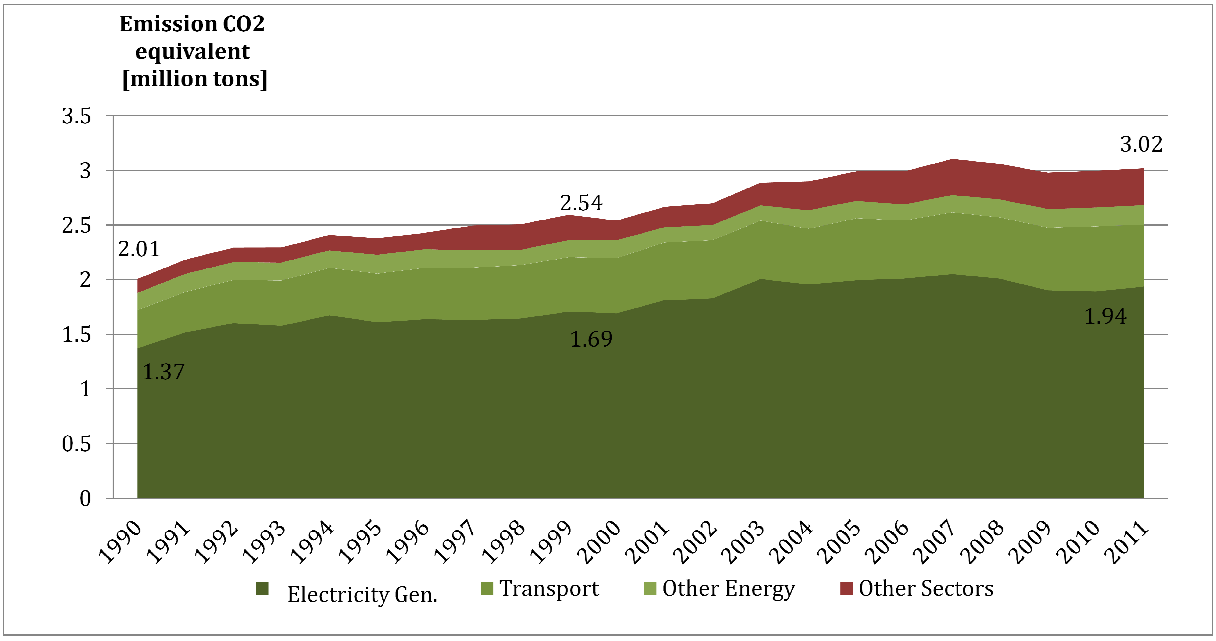

Figure 5: Contribution of different sectors to Maltese greenhouse gas emissions. The “Other Energy” category includes energy used in manufacturing industries, construction, etc., while “Other Sectors” includes emissions from agriculture, waste, solvents and other relevant processing and production (Eurostat).

Referring to the same scenarios as depicted in Figure 4, Figure 6 shows that the “NG+Oil+Int” scenario (that practically has no oil contribution) would reduce power sector emissions from two million tonnes of carbon dioxide to 883 thousand tonnes when compared to the old setup. (The same scenario for 2020 would achieve a reduction from 2.17 million tonnes to 957 thousand tonnes.) In this scenario we assumed that a minimum of 150 MW of electricity has to be purchased from ElectroGas, while the required remainder will either be provided by the Maltese gas installations or purchased through the interconnector at the respective lower price. (Sicilian prices tend to be lower during mid-day.) The carbon footprint associated with imported electricity is based on the current Sicilian power generation mix.

To be sure, the carbon footprint of imported electricity would not appear in the official emissions inventory of the importer. In 1990, total Maltese GHG emissions were 2.01 million tonnes of CO_2 equivalent. If 2020 electricity supply requirements are taken as 3.14 TWh, and an average of 180 MW worth of electricity (1.577 TWh) each are purchased from the new ElectroGas plant and through the interconnector (while ignoring the Delimara extension and photovoltaic contributions), power sector emissions within Malta would be reduced to 542 thousand tonnes of CO_2 equivalent. (Emissions factor of 0.344kg/kWh assumed for the modern ElectroGas plant as well as the Delimara extension.) If the ElectroGas plant and the 144MW Delimara extension would combined deliver 300MW on average, and the remainder be purchased through the interconnector, 2020 power sector emissions within Malta would account to 904 thousand tonnes of CO_2. If all non-electricity emissions would combined remain at the 2011 level of 1.08 million tonnes of CO_2 equivalent, Malta’s emissions in 2020 would thus be 1.62 million tonnes in the scenario without the Delimara extension, reducing nationwide 2020 emissions to 80.6% of total 1990 emissions despite more than doubling the electricity consumption and in the absence of any other emissions reduction measures.

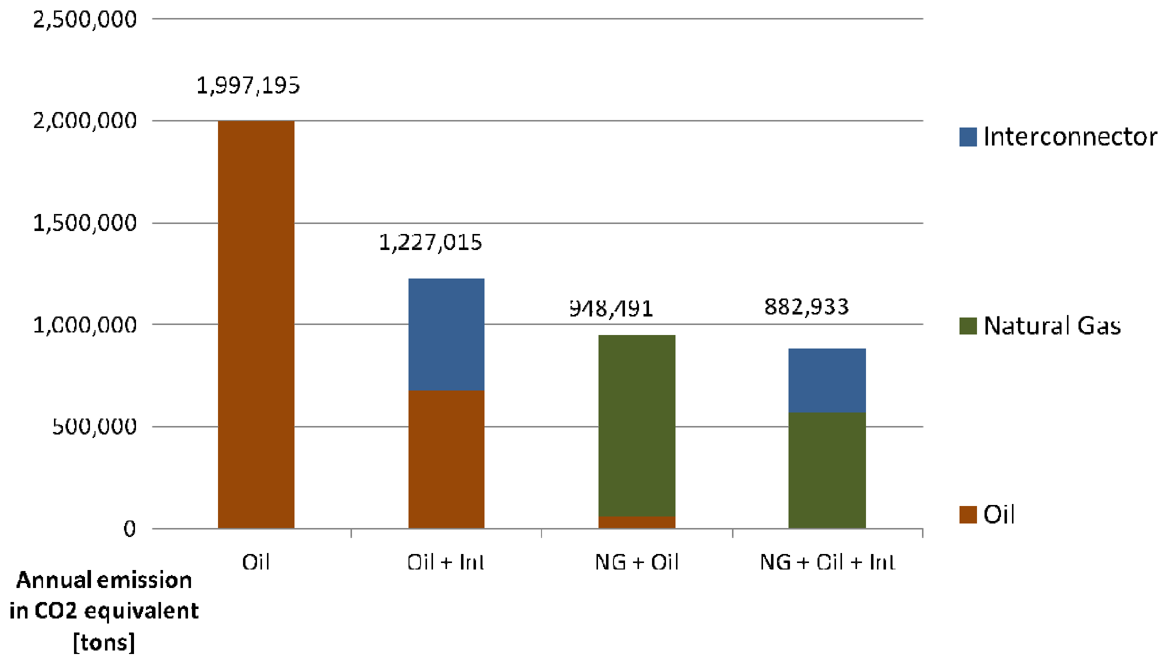

Figure 6: Emissions scenarios for 2016 demand with color codes according to electricity generation contributions as in Figure 4. Emissions associated with electricity imports are based on the Sicilian power mix. Emissions from oil in the “Oil+Int” scenario are 677,173 tonnes of CO_2 equivalent, while emissions from gas in the “NG+Oil+Int” scenario are 566,171 tonnes.

3.6 Gas Pipeline to Sicily

An additional energy infrastructure project that might come into existence in the somewhat more distant future is a natural gas pipeline between Malta and Sicily. An according plan has been selected by the European Commission as "project of common interest" (PCI) under the guidelines for the trans-European energy infrastructure (TEN-E) and will thus be eligible for European funding. Generally, such project benefits at least two Member States; contributes to market integration and further competition; enhances security of supply; and reduces CO_2 emissions. This particular PCI has been defined as a 150km pipeline with a capacity of 4.4 MCM/day from Sicily to an offshore storage unit in Malta, and a 12 km pipeline from this unit to Delimara (European Commission, 2013). Additional gas supply would allow for the remaining oil-based electricity generation capacity at Delimara to be converted to gas, while additional electricity generation capacity at the Delimara site would require substantial upgrades of the electricity distribution networks.

3.7 Future of Renewables

Malta’s NREAP needs to be revised for various reasons. If imported biofuels are excluded, offshore wind is supposed to cover nearly half the planned generated renewable energy, even though the proposed project involves several problems. Apart from the fact that it is generally risky to base such high share of the total target on a single project, it has been demonstrated that the offshore wind plant as proposed generates electricity at a cost that is about twice as high compared to local PV electricity, and about three times as high compared to local onshore wind (Weissenbacher, 2012b). What is more, this cost analysis is based on life-time electricity generation, but ignoring the market value of electricity at the time of (intermittent) generation. This flaw in the concept of levelized cost of energy (LCOE) points towards providing an additional incentive to shift the planned wind capacity towards photovoltaic installations delivering their entire yield during day-time (Weissenbacher, 2012b). This is in addition to generally greater difficulties of grid integration, less predictable power output, a longer construction period, and other greater (perceived) risks when compared to photovoltaics. Notably, the profound changes in the Maltese fossil power sector have put wind at even greater disadvantage: Since the new 200 MW gas power station will be financed by a private-sector investor, a power purchasing agreement close to full-load capacity needs to be expected. However, as Malta's base load is substantially lower, at ca. 160 MW, wind power generated during night time would be difficult to integrate, unless the excess energy is either exported through the new interconnector or stored as discussed below.

Meanwhile, photovoltaic capacity has increased tremendously. While less than 20 MWp worth of PV installations have been operating in Malta by the end of 2012, over 55 MWp had been authorized (including operating ones) by the end of 2013, suggesting that well over 60 MWp will be operational by the end of 2014. This confirmed a previous assessment that plenty of rooftop space would be available to host the planned PV capacity plus an additional 141 MWp or so that would be necessary to replace the entire proposed offshore wind electricity generation (Weissenbacher, 2012b). Notably, a lot more PV capacity can be placed on the existing rooftop space if PV panel tilt angles are lowered from what is commonly considered the "optimum" angle, because less spacing would in turn be required to avoid cross-shading. As the space reduction is substantial, while the output decrease due to the lowering of the tilt is minimal, a much larger PV electricity output per utilized space will result while the cost increase is small (Weissenbacher, 2012b, 2013a, 2013b). Compared to the traditional 30^{o} tilt angle, a 15^{o} angle, for instance, would provide for a 22% electricity increase per year, and a 33% increase in July, per unit of area utilized. Summer output is relevant in this context, because Malta experiences a summer daytime electricity peak demand that is substantially higher than the winter evening peak. It has thus been suggested to include tilt angle management into macro-planning efforts (Weissenbacher, 2013a), but panel orientation is just as relevant in scenarios of higher PV penetration. If the widening difference between Malta's winter and summer electricity peak is assumed to be 80 MW, for instance, and the actual maximum output from PV installations (tilt angle of 30^{o}) as a bit below 80 percent of the nominal peak output, then we would need a bit more than 100 MWp to cover the difference. With more than 60 MWp already expected by the end of 2014, and more output shifted towards the summer/mid-day through lower tilt angles, overall management of panel orientation away from true south would distribute and match total national PV output better with respect to demand profiles. It would also help avoiding the known disadvantages of PV electricity contributing very large shares during mid-day hours of sunny (weekend) days. Should policy makers ever perceive the PV share as unmanageably high, the further increase in PV system installations can be curbed through further adjustment of feed-in tariffs. (To be sure, Malta's new power infrastructure will impact even existing PV investments, because the payment received for each kWh after the initial FIT period will be based on the marginal cost of electricity incurred by Enemalta for the particular year. This is currently €0.11/kWh, but will be lower after the new gas infrastructure and the interconnector come online.)

3.8 Energy Storage

Very large shares of PV electricity and the integration of wind power would be possible through energy storage investments. Energy storage considerations within the current study have focused on identification of large-scale options that may store energy for several hours. As pumped hydro storage is usually the preferred choice where geography allows it, it was investigated if the established technology can be adapted to the use of sea water and modest volumes/hydraulic heads because Malta's arid islands show a maximum elevation of just 230 meters above sea level. A Seawater Pumped Storage installation at Okinawa, Japan, globally the only operating plant of this kind, has been found as reference (Japan Commission on Large Dams, 2001). It is being investigated if such installation could be extended to sea ground level, which would mean to include aspects of Ocean/Offshore Compressed Air Energy Storage (OCAES), another technology that seems to fit Malta's settings. OCAES works similar to traditional CAES, but utilizes the pressure prevalent at great depths in oceans (North Carolina State University, 2012). Two locations in Maltese waters (with depths above 600m) have been identified where OCAES might be feasible, but the technology is immature, only small prototypes exist, and the capital cost would be high. Selling electricity through the interconnector, especially during Sicilian year-around morning and evening price peak periods, is thus taken into consideration to justify the investment costs into the storage infrastructure that would facilitate high Maltese renewable energy penetration and integration.

4 Conclusion

This study has clearly shown and quantified that the upcoming power sector setup characterized by a shift from oil to gas and an interconnection to Sicily will substantially reduce carbon emissions associated with Malta's electricity consumption, and thus also significantly lower the total national carbon footprint. Local non-carbon air pollution will also substantially decrease. However, the involvement of an Independent Power Producer from whom fossil electricity will have to be purchased in large quantities will actually complicate the integration of renewable electricity. Integration of wind power may only be possible if energy storage infrastructure will be simultaneously established. In the context of the current discussion of 2030 goals at the European level, carbon dioxide emissions reduction through modernization of the fossil sector may prompt a member state to prefer carbon emissions reduction over binding renewable energy share targets. Also, the Maltese example suggests that the promise of reduced utility bills remains a powerful strategy to help winning elections, while lower electricity prices may in turn prompt increased energy consumption.

5 References

European Commission (2013), “Projects of Common Interest by Country,” http://ec.europa.eu/energy/infrastructure/pci/doc/2013_pci_projects_country.pdf

Eurostat, European Commission, http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

Japan Commission on Large Dams (2001), “Outline of the Okinawa Island Plant,” http://classic-web.archive.org/web/20030430003158/http://www.jcold.or.jp/Eng/Seawater/Outline.htm

Lahmeyer. (2009) Consultancy Service for the Authorisation of the Interconnection Malta–Sicily. Bad Vilbel/Marsa: Lahmeyer International GmbH/Malta Resources Authority, December.

Ministry for Energy and the Conservation of Water (2013), Buttigieg, Ch., The Renewable Energy Sector in Malta, April.

MRRA. (2010) Proposed National Renewable Energy Action Plan. Floriana: Ministry for Resources and Rural Affairs, June.

MRRA. (2011) National Renewable Energy Action Plan. Floriana: Ministry for Resources and Rural Affairs, May.

North Carolina State University (2012), Department of Mechanical and Aerospace Engineering, Engineering Mechanics and Space Systems Laboratory, “Primary Research Areas,” http://www.mae.ncsu.edu/mazzoleni/emssl

Weissenbacher, M. (2012a), "Introduction to Maltese Energy Settings" in *Renewable Energy Atlas, Ragusa - Agrigento - Malta, Project R.E.S.I., Renewable Energy Scenarios in Islands*, ed. M. Weissenbacher. Coord., Project R.E.S.I., Renewable Energy Scenarios in Islands, Malta. Available online at: http://www.resiproject.eu/site/wp-content/uploads/2013/05/atlante_gb_bassa.pdf

Weissenbacher, M. (2012b), "How the Changing Economics of Photovoltaic Systems Will Reshape the Renewable Energy Plans of Malta and Other Mediterranean Nations", Proccedings of the *12th IAEE European Energy Conference,* 12 September (Venice).

Weissenbacher, M. (2013a), "When Space Becomes More Valuable Relative To Photovoltaic Panels: The Case for Low Tilt Angles to Maximize the Renewable Electricity Yield per Available Area and to Facilitate Grid Management in Areas of Summer Peak Electricity Demand.", IEWT 2013: 8. Internationale Energiewirtschaftstagung, TU Wien, February 13-15 (Vienna).

Weissenbacher, M. (2013b), "Towards a Paradigm Shift in the Definition of “Optimal Inclination” of Photovoltaic Panels: How Lower Tilt Angles Can Substantially Increase the Electricity Output per Unit of Utilized Space." Proceedings: The 8th Conference on Sustainable Development of Energy, Water and Environment Systems. September 22-27 (Dubrovnik, Croatia)

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