Draft Report:

Comprehensive Impact Assessment of the Planned Policies and Measures of the National Energy and Climate Plan of Cyprus

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Contents

List of tables

List of figures

Abbreviations

CH_4	Methane
CO_2	Carbon Dioxide
CO_{2eq}	Carbon Dioxide equivalent
CUT	Cyprus University of Technology
CyI	The Cyprus Institute
DLI	Department of Labour Inspection
ESR	EU Effort Sharing Regulation (EU) 2018/842
ETS	EU Emissions Trading System
GHG	Greenhouse gases
JRC	European Commission's Joint Research Centre
ktoe	Thousand tonnes of oil equivalent
LULUCF	Land Use, Land Use Change and Forestry
MARDE	Ministry of Agriculture, Rural Development and Environment of Cyprus
MECI	Ministry of Energy, Commerce and Industry of Cyprus
MOF	Ministry of Finance of Cyprus
MTCW	Ministry of Transport, Communications and Works of Cyprus
N_2O	Nitrous Oxide
NECP	National Energy and Climate Plan
NOx	Nitrogen Oxides
OSeMOSYS	Open Source Energy Modelling System
PaMs	Policies and Measures
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter with an effective diameter up to 2.5 microns (μm)
PM_{10}	Particulate Matter with an effective diameter up to 10 microns (μm)
PPM	Scenario with Planned Policies and Measures
SO_2	Sulphur Dioxide
SRSS	European Commission's Structural Reform Support Service
UCy	University of Cyprus
WEM	Scenario with Existing Measures

EXECUTIVE SUMMARY

This draft report is developed within a technical support project funded by the European Union via the Structural Reform Support Programme and implemented by a consortium led by the Cyprus University of Technology, in cooperation with the European Commission's Structural Reform Support Service (SRSS). According to the related Service Contract with SRSS, this report provides a comprehensive assessment of the energy, macroeconomic, environmental and social impacts of the planned policies and measures foreseen in the National Energy and Climate Plan (NECP) of Cyprus.

The analysis has been based on detailed modelling (from a previous joint JRC-CyI study) of the energy system of the country, which was mainly conducted with the OSeMOSYS optimisation model, for the two scenarios explored in the NECP – the scenario With Existing Measures and the scenario with Planned Policies and Measures that were provided from various stakeholders. Results of OSeMOSYS were then fed into other models in order to assess macroeconomic, employment and welfare impacts of the two scenarios. Information about emissions abatement and costs for non-energy-related GHG emissions were obtained from the relevant calculations of national authorities that are included in the NECP of Cyprus. The main findings of the Impact Assessment can be summarised as follows:

1. **Existing policies and measures are insufficient** to lead Cyprus to compliance with its obligations stemming from the Energy Union Governance Regulation. They cannot lead to compliance with the national renewable energy and energy efficiency targets, and they can only lead to 3% reduction in non-ETS emissions in 2030 compared to 2005 instead of the 24% target which is required from Cyprus up to 2030; this will require purchasing a significant amount of emission allowances to fill the 2030 emissions gap, which, under optimistic assumptions, will cost the Republic of Cyprus at least 133 million Euros cumulatively for the period up to 2030.
2. The Planned Policies and Measures (PPM) scenario, which has been recommended by staff of governmental authorities and is included in the proposed final NECP, **is able to make Cyprus meet its goals regarding energy efficiency and penetration of renewable energy sources. These measures can lead to a 0.4% increase in national GDP and a rise of 0.4% in total employment**. The changes in energy costs to end consumers will be small and overall will have essentially no adverse impact on the welfare of households and social equity.
3. **Additional investments to realise this scenario** (which can come from private, national and EU Funds) **amount to 244 million Euros'2016, are entirely feasible for the standards of the Cypriot economy and will pay off** because fuel import costs throughout the lifetime of these measures can decline considerably.
4. However, **successful implementation of the package of Planned Policies and Measures is not guaranteed** because it requires significant investments for energy renovations in buildings and industry and – most importantly – a substantial commitment to promote public transport and non-motorised transport modes (walking and cycling) as well as a shift to electric cars.
5. Even if implemented fast and effectively, **Planned Policies and Measures are not sufficient for reaching the non-ETS GHG emission reduction target of 24% by 2030**, as required from Cyprus in the Effort Sharing Regulation; the reduction can only reach 14% in the PPM scenario. In order to achieve full compliance, the government of Cyprus has to choose between different options, which are explained in more detail in Deliverable 6 of this study.
6. **Road transport holds the key to emissions abatement both for 2030 and for the longer term.** Investments in sustainable transport modes, although deemed costly, pay off because of multiple benefits from the reduction of the use of passenger cars. Coupled with a fast electrification of transport, they seem to be the only way to achieve the 2030 non-ETS emission reduction target.

Further comparisons of policies as well as a cost-benefit and cost-effectiveness assessment, are provided in Deliverable 6 of this study.

1 Introduction

This report is developed within a technical support project funded by the European Union via the Structural Reform Support Programme and implemented by a consortium led by the Cyprus University of Technology, in cooperation with the European Commission's Structural Reform Support Service (SRSS) under Service Contract SRSS/C2018/070.

According to Task 3 of the Tender Specifications of the Service Contract on the "Impact assessment of the Cyprus Integrated National Energy and Climate Plan", the project team has to carry out a comprehensive assessment of the energy, greenhouse gas emissions, macroeconomic, environmental and social impacts of the planned policies and measures foreseen in the National Energy and Climate Plan of Cyprus. This Deliverable 5 reports on the outcome of work under this Task.

According to the requirements of annex I of Regulation 2018/1999 of 11 December 2018 on the Governance of the Energy Union and Climate Action, Section B of each National Energy and Climate Plan should contain a chapter explicitly devoted to the impact assessment of this Plan. This chapter (Chapter 5 of Part I / Section B of the NECP) should contain the following information:

5. Impact Assessment of Planned Policies and Measures

5.1. Impacts of planned policies and measures described in section 3 on energy system and GHG emissions and removals, including comparison to projections with existing policies and measures (as described in section 4).

Projections of the development of the energy system and GHG emissions and removals as well as, where relevant of emissions of air pollutants in accordance with Directive (EU) 2016/2284 under the planned policies and measures at least until ten years after the period covered by the plan (including for the last year of the period covered by the plan), including relevant Union policies and measures.

Assessment of policy interactions (between existing policies and measures and planned policies and measures within a policy dimension and between existing policies and measures and planned policies and measures of different dimensions) at least until the last year of the period covered by the plan, in particular to establish a robust understanding of the impact of energy efficiency / energy savings policies on the sizing of the energy system and to reduce the risk of stranded investment in energy supply

Assessment of interactions between existing policies and measures and planned policies and measures, and between those policies and measures and Union climate and energy policy measures

5.2. Macroeconomic and, to the extent feasible, the health, environmental, employment and education, skills and social impacts, including just transition aspects (in terms of costs and benefits as well as cost-effectiveness) of the planned policies and measures described in section 3 at least until the last year of the period covered by the plan, including comparison to projections with existing policies and measures

5.3. Overview of investment needs

Existing investment flows and forward investment assumptions with regard to the planned policies and measures

Sector or market risk factors or barriers in the national or regional context

Analysis of additional public finance support or resources to fill identified gaps identified under point ii

5.4. Impacts of planned policies and measures described in section 3 on other Member States and regional cooperation at least until the last year of the period covered by the plan, including comparison to projections with existing policies and measures

Impacts on the energy system in neighbouring and other Member States in the region to the extent possible

Impacts on energy prices, utilities and energy market integration

Where relevant, impacts on regional cooperation

The following Sections describe the draft results of our analysis in line with the above mentioned chapters 5.1 – 5.4 of the Regulation. These results will be the basis for consultations with stakeholders in Cyprus, with a view to finalising the Impact assessment study for submission to the European Commission.

For easy reference, the list of agreed policies and measures of the two scenarios agreed by the government of Cyprus is provided in Appendix I.

It has to be noted that this is a draft version of Deliverable 5. At this stage, the contents of this report do not necessarily reflect the official views of the government of Cyprus.

2 Impacts on the Energy System and Emissions

The projected impacts of WEM and PPM scenarios on the energy mix and emissions are presented in the next sections until 2030. The outputs of the cost-optimisation model employed for the two scenarios until 2030 are subject to technical constraints, development plans and policy options conveyed to the project team by the authorities. For instance, in the WEM scenario solar PV capacity is constrained to a maximum of 750 MW, while this limit is removed for the period 2031-2050. Similarly, development of the EuroAsia Interconnector in the PPM scenario is enforced as a fixed investment and its cost-competitiveness is not assessed by the model. Scenario results for the entire period 2020-2050 are provided in APPENDIX II: OSeMOSYS Results for the Entire Period 2020-2050.

2.1 Existing Policies and Measures Scenario

The results for this section have been broken down by sector (i.e. electricity, transport, heating and cooling). Additionally, results regarding the primary energy supply and final energy demand are provided along with a forecast on the carbon dioxide emissions from both ETS and non-ETS sectors.

2.1.1 Electricity Supply Sector

2.1.1.1 Capacity

The projection offered by the model for the electricity supply sector is quite interesting and can be considered optimistic. Following the expected deployment of renewable energy technologies until 2020, as promoted by the existing support schemes and the development of the planned 50 MW CSP plant by 2021, an additional 390 MW of solar PV and 33 MW of biomass-fired facilities are deployed between 2021 and 2030. The increase in solar PV in this period coincides with the development of two new combined cycle gas turbines with a total capacity of 432 MW, which can operate as baseload and also offer flexibility to the system; flexibility is necessary when levels of variable renewable electricity generation increase. The new CCGT units allow a higher volume of low-cost gas-fired electricity generation, as these are the most efficient thermal units available. Despite the low fossil fuel price projections and the higher renewable energy technology prices adopted in the analysis as compared to EC recommendations, a substantial deployment of solar PV occurs in the period 2020-2030 (Table 1). This deployment is enabled by the deployment of Li-ion batteries during the same period, as these reach 41 MW in 2030.

Table 1 - Capacity projections in the electricity supply sector (MW) – WEM scenario.

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Vasilikos	836	836	836	836	836	836	836	836	836	836
Dhekelia	450	450	450	102	102	102	102	102	102	102
Moni	128	128	128	128	128	128	128	128	128	128
New CCGT	216	216	216	432	432	432	432	432	432	432
New ICE	0	0	0	0	0	0	0	0	0	0
New ST	0	0	0	0	0	0	0	0	0	0
New GT	0	0	0	0	0	0	0	0	0	0
Light fuel oil CHP	0	0	0	0	0	0	0	0	0	0
Solar PV	380	400	420	440	565	670	690	710	730	750
Solar Thermal	0	50	50	50	50	50	50	50	50	50
Wind	175	175	175	175	175	175	175	175	175	175
Biomass	50	50	50	50	50	50	50	50	50	50
Pumped Hydro	0	0	0	0	0	0	130	130	130	130
Li-Ion Batteries	0	0	0	0	0	21	21	21	21	41

It should be noted that based on a relevant IRENA publication[1], optimistic techno-economic characteristics were assumed for Li-ion batteries. This publication foresees that by 2030 battery life will exceed 15 years and round-trip efficiency will reach 95% at an installation cost of approximately 160 EUR2016/kWh. These projections are further corroborated by other recent publications examining the subject (e.g. by NREL[2]). All Li-ion batteries deployed are in-front-of-the-meter facilities and have 4 hours of storage; this results in 164 MWh of battery storage in 2030. No behind-the-meter battery storage is deployed as from a system's perspective it is deemed cost-optimum to deploy storage at the centralised level, where it can serve a larger array of generation technologies. It should be mentioned though that behind-the-meter storage could be profitable for end-consumers under a net-billing plan and in case Time-of-Use electricity tariffs are adopted in the future. Furthermore, in 2027 a 130 MW (1,040 MWh) pumped-hydro facility is also developed.

The deployment of batteries and solar PV can be attributed to the reduction of their respective capital cost over time. At the same time, increasing fuel and ETS prices make fossil-fired plants less competitive. However, the feasibility of these results has to be scrutinized thoroughly, as during low electricity demand and high PV output periods, a significant amount of curtailment may be observed. The results presented here estimate a curtailment level of 0.1% for solar PV and 0.5% for wind in 2030. Nonetheless, curtailment is not accurately captured by a long-term energy systems model as the one employed here. Hence, a separate detailed grid analysis study, like the one performed by JRC in a previous project[3], focusing on a single year in a much finer temporal resolution may be needed to properly assess this proposed outlook.

2.1.1.2 Generation

The technology deployment presented in Section 2.1.1.1 provides the generation mix shown in Figure 1. The substitution in the latter part of 2021 (i.e. in the period October-December) of oil-fired generation with gas-fired generation results in a transitional period as indicated below. In the post-2020 period, gas-fired generation dominates the electricity mix. The RES-E share in 2030 reaches 26%, as more solar PV and solar thermal is introduced in the system. It should be noted that the absolute contribution of fossil-fired generation remains relatively stable until 2030, and the increased demand in electricity drives solar PV deployment.

[1] IRENA, 2017. Electricity Storage and Renewables: Costs and Markets to 2030, International Renewable Energy Agency, Abu Dhabi.

[2] Cole, W.J., Frazier, A., 2019. Cost Projections for Utility-Scale Battery Storage (No. NREL/TP-6A20-73222, 1529218). NREL. https://doi.org/10.2172/1529218

[3] http://www.mcit.gov.cy/mcit/energyse.nsf/C1028A7B5996CA7DC22580E2002621E3/$file/Cyprus_RESGRID_summary_v16.pdf

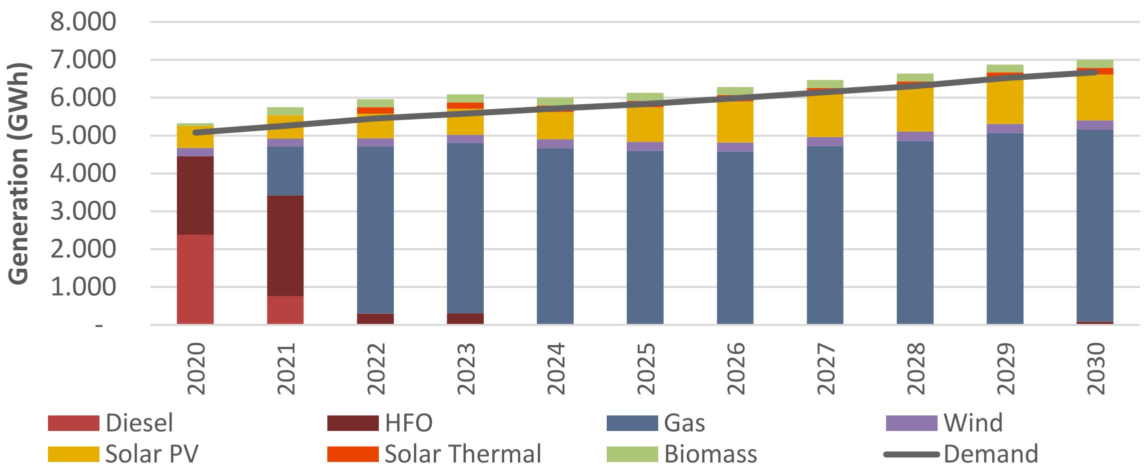

Figure 1 - Projected generation mix till 2030 – WEM scenario.

The deployment of solar PV discussed above increases the share of PV in the generation mix, which occurs gradually until 2030. Another factor which leads to the expansion of solar PV is the electrification of the transport sector, as this raises the demand for electricity throughout the year. Specifically, in 2030 approximately 91 GWh are consumed in the transport sector. This aspect is further elaborated in the relevant section later on in the report.

2.1.2 Transport Sector

The forecast for the transport sector foresees penetration of alternative fuels and technologies (Table 2). Regarding the passenger car fleet, the number of diesel vehicles are reduced over time; these are replaced by gasoline, gasoline hybrid and battery electric vehicles. Additionally, a moderate number of LPG conversions occurs. It is worth highlighting that a significant penetration of new electric vehicles appears in the fleet in the latter part of the modelling horizon. Significant investments occur in the period 2028-2030 which bring the number of BEVs to 28,000 by 2030. The number of gasoline hybrid vehicles is also substantial, as these increase to 60,000 by 2030.

The projected shift in the road transport fleet results in an equivalent change in the fuel consumption in the transport sector. As indicated in Table 3, gasoline remains as the main fuel consumed in road transportation for the entire model horizon. Gasoline consumption stays relatively constant until 2030. However, the use of diesel decreases slightly, dropping from 330 million litres in 2020 to 314 million litres by 2030. Similarly, biodiesel used for blending follows a similar trend, as the current blending mix is kept constant throughout the whole period. Even though bioethanol is not mixed with gasoline at the moment, it is assumed that it will occur after 2020. Forced blending was implemented for 2nd generation biodiesel, as the government of Cyprus has issued decrees which force blending of 2nd generation biofuels.

Electrification of the transport sector is regarded as a key step in the decarbonisation and diversification of fuel supply of this sector. A degree of electrification occurs in the projected scenarios by fully-electric vehicles. Therefore, electricity demand in the transport sector increases proportionally, reaching 91 GWh in 2030; this corresponds to **1.4%** of the total final electricity demand.

If the electricity demand in the transport sector increases further, it could pose challenges to the grid, but could also offer opportunities. On the one hand, electricity demand rises; this will not happen uniformly as charging will primarily occur at specific hours of the day. It can be expected that the overall load profile will be affected as a consequence. This is something that perhaps is not captured adequately by the current version of the model and may need to be amended in future iterations. The assumed charging profile can have a significant impact on the results and with increasing penetration of BEVs in the system, more information could become available to assist such an analysis.

Smart charging of vehicles and potential use of vehicle-to-grid systems, in which vehicle batteries can be used as additional supporting infrastructure by the grid operator, can offer demand response services that in turn can add flexibility and have an enabling effect for intermittent renewable energy technologies, subject to wider regulatory and market developments such as the introduction of Time-of-Use or dynamic pricing retail contracts. It has to be noted that changes in the transport sector are subject to the social behaviour of individuals, which is not a trivial matter to address in optimization models. The willingness of consumers to change their behaviour is a factor that may limit the transition of the transport sector to alternative fuels and technologies.

Table 2 – Projected vehicle fleet (total number of vehicles) – WEM scenario.

		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Passenger cars	**Diesel**	63,430	57,686	51,942	46,117	40,372	45,955	49,757	52,184	53,398	53,560
	Diesel hybrid	-	-	-	-	-	-	-	-	-	-
	Diesel PHEV	-	-	-	-	-	-	-	-	-	-
	Gasoline	485,322	498,502	512,515	525,566	539,054	542,056	531,595	524,305	502,231	483,574
	Gasoline Hybrid	5,170	5,170	5,170	5,170	5,170	5,170	18,738	32,387	46,117	59,927
	Gasoline PHEV	-	-	-	-	-	-	-	-	-	-
	BEV	100	100	100	100	100	100	100	100	13,830	27,641
	LPG	320	424	529	633	739	843	948	1,061	1,174	1,174
	Natural gas	-	-	-	-	-	-	-	-	-	-
	Hydrogen	-	-	-	-	-	-	-	-	-	-
		2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Buses	**Diesel**	3,058	3,097	3,141	3,186	3,230	3,274	3,318	3,362	3,406	3,450
	Diesel hybrid	-	-	-	-	-	-	-	-	-	-
	BEV	-	-	-	-	-	-	-	-	-	-
	CNG	-	-	-	-	-	-	-	-	-	-
		2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
MCs	**Gasoline**	51,685	52,442	53,175	53,910	54,667	55,424	56,133	56,893	57,626	58,383
	BEV	-	-	-	-	-	-	-	-	-	-
		2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Trucks	**Diesel**	13,166	13,355	13,545	13,734	13,923	14,112	14,301	14,489	14,678	14,542
	BEV	-	-	-	-	-	-	-	-	-	326
	Natural gas	-	-	-	-	-	-	-	-	-	-
		2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Light Trucks	**Diesel**	121,355	123,095	124,842	126,583	128,323	130,064	131,810	133,551	135,291	137,032
	BEV	-	-	-	-	-	-	-	-	-	-
	PHEV Diesel	-	-	-	-	-	-	-	-	-	-
	Hybrid diesel	-	-	-	-	-	-	-	-	-	-
Grand Total		**743,606**	**753,873**	**764,960**	**774,999**	**785,578**	**796,997**	**806,701**	**818,334**	**827,751**	**839,609**

Table 3 – Evolution of fuel consumption in the transport sector till 2030 – WEM scenario.

		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Biofuels	**L**	46,082,367	46,281,098	46,458,404	46,686,009	46,873,119	47,070,353	47,092,494	47,094,050	46,385,529	45,584,331
Diesel	**L**	324,017,296	318,223,507	312,523,322	307,964,981	302,930,656	308,488,340	312,438,592	314,793,727	315,990,158	314,370,316
Gasoline	**L**	514,647,402	524,877,092	534,595,444	543,997,567	553,160,485	550,717,190	546,737,657	544,143,812	529,349,052	515,930,500
LPG	**L**	425,155	561,664	699,015	835,012	971,297	1,105,403	1,239,239	1,382,260	1,622,554	1,616,118
Natural gas (STP)	**m^3**	-	-	-	-	-	-	-	-	-	-
Electricity (road)	**MWh**	313	308	307	307	306	306	306	306	42,250	91,350
Electricity (rail)	**MWh**	-	-	-	-	-	-	-	-	-	-

2.1.3 Heating and Cooling Sector

Continued investments in renewable energy technologies in buildings, as well as investments in heat pumps lead to an increase in the renewable energy share in the heating and cooling sector. The significant RE share increase projected until 2030 will be mainly driven by solar thermal technologies and heat pumps in buildings. The projected final energy demand of the Heating and Cooling sector is provided in Table 4. The RES share foreseen in the Heating and Cooling sector increases and reaches 39% in 2030.

Table 4 - Final energy demand in the Heating and Cooling sector (PJ) – WEM scenario.

	2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Electricity	7.83	8.12	8.30	8.51	8.69	8.91	9.14	9.38	9.64	9.79
Heating oil/light fuel oil/Gas Oil	6.88	6.83	6.70	6.67	6.69	6.70	6.69	6.68	6.65	6.62
Pet Coke	3.16	2.95	2.74	2.58	2.49	2.41	2.33	2.26	2.18	2.13
LPG	2.61	2.60	2.56	2.57	2.61	2.65	2.70	2.74	2.78	2.82
Biomass	1.04	1.02	0.99	1.04	1.10	1.16	1.21	1.25	1.29	1.33
Geothermal	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05
Solar thermal	3.01	3.03	3.03	3.11	3.20	3.29	3.40	3.51	3.63	3.75
RES share	**32.6%**	**33.2%**	**33.9%**	**34.8%**	**35.5%**	**36.2%**	**36.9%**	**37.6%**	**38.3%**	**39%**

2.1.4 Primary Energy Supply and Final Energy Demand

A moderate decrease in the primary energy supply can be observed in the middle of the period 2020-2030, but then increases back by 2030 (Table 5). The main driver of this is the incorporation of greater shares of renewable energy, which displaces fossil-fired generation in the electricity sector. Additionally, in 2020 heavy fuel oil is still used to a considerable extent until the introduction of less carbon-intensive natural gas in the power sector in the last quarter of the following year.

Table 5 – Primary Energy Supply evolution till 2030 (ktoe) – WEM scenario.

	2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Diesel	414	274	269	265	260	265	269	271	272	270
Gasoline	393	401	409	416	423	421	418	416	405	394
HFO	567	61	62	2	3	2	0	0	2	19
LPG	63	62	61	62	63	64	65	66	67	68
Heating Oil/light fuel oil	164	163	160	159	160	160	160	160	159	158
Pet coke	75	70	65	62	59	58	56	54	52	51
Natural gas	230	809	826	840	827	827	849	875	912	912
Hydrogen	-	-	-	-	-	-	-	-	-	-
Electricity	-	-	-	-	-	-	-	-	-	-
Biomass (includes biofuels)	110	110	109	110	112	113	114	115	116	117
Geothermal	1	1	1	1	1	1	1	1	1	1
Solar thermal	72	87	87	89	91	94	96	99	101	104
Solar PV	53	56	58	61	79	93	96	99	102	104
Wind	18	19	19	21	21	20	21	21	21	21
Total	***2,162***	***2,113***	***2,128***	***2,088***	***2,099***	***2,119***	***2,145***	***2,177***	***2,211***	***2,221***

Despite the modest reduction in primary energy supply, final energy demand is projected to increase (Table 6). The main driver in this case is the increased final electricity demand due to the broad trend for electrification in the economy (which in turn is generated by more efficient gas-fired plants and renewable energy technologies and therefore reduces primary energy needs). Continued electrification of the heating and cooling sector, as well as the considerable volume of electricity consumed in the transport sector have a significant role in the growth of electricity demand. The contribution of fossil fuels decreases with time. Furthermore, the total contribution of solar thermal in the electricity supply sector and the heating and cooling sector is projected to increase by 44% from 2020 to 2030.

Useful insights can be provided through a comparison of the final energy demand with the primary energy supply. Even though final energy demand undergoes a moderate increase between 2020 and 2030, primary energy supply stays at comparable levels. This is an indication of improved energy efficiency. Specifically, when final energy demand is measured as a share of primary energy supply, total energy efficiency amounts to 70% in 2020; this value increases to 75% in 2030. As shown in, the RES share in final energy demand is projected to increase gradually. The key sector driving this transition is the electricity supply sector. The 13% target for 2020 is expected to be achieved, while the share increases further to 20.7% by 2030. It should be noted that the above does not take into account fuel consumption of aviation and the special treatment of this sector in the case of Cyprus, in line with Directive (EU) 2018/2001. Taking aviation into account, these shares will slightly change.

Table 6 – Final Energy Demand evolution till 2030 (ktoe) – WEM scenario.

	2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Diesel	279	274	269	265	260	265	269	271	272	270
Gasoline	393	401	409	416	423	421	418	416	405	394
LPG	63	62	61	62	63	64	65	66	67	68
Heating Oil/light fuel oil/Gas oil	164	163	160	159	160	160	160	160	159	158
Natural gas	-	-	-	-	-	-	-	-	-	-
Pet Coke	75	70	65	62	59	58	56	54	52	51
Hydrogen	-	-	-	-	-	-	-	-	-	-
Electricity	452	469	479	492	502	515	529	542	561	574
Biomass (includes biofuels)	53	53	52	53	55	56	58	59	59	60
Geothermal	1	1	1	1	1	1	1	1	1	1
Solar thermal	72	72	72	74	76	79	81	84	87	90
Total	***1,553***	***1,566***	***1,570***	***1,584***	***1,600***	***1,619***	***1,636***	***1,652***	***1,663***	***1,666***

Table 7 – RE share in final energy demand across the energy system – WEM scenario (without considering consumption of aviation)

	All sectors	**Electricity**	**Heating and cooling**	**Transport (RED Recast methodology)**
2021	16.0%	18.1%	32.6%	6.2%
2022	17.0%	21.0%	33.2%	6.2%
2023	17.1%	21.1%	33.9%	6.1%
2024	17.7%	22.2%	34.8%	6.0%
2025	18.7%	25.1%	35.5%	6.0%
2026	19.6%	27.2%	36.2%	6.0%
2027	19.8%	27.0%	36.9%	6.1%
2028	20.1%	26.8%	37.6%	6.1%
2029	20.3%	26.3%	38.3%	6.6%
2030	20.7%	26.3%	39.0%	7.3%

2.1.5 Greenhouse Gas Emissions

Drawing directly from the model outputs, a greenhouse gas emission trajectory is extracted (Figure 2 and Table 8). A degree of decarbonisation is achieved initially by gas-fired generation and later by solar PV and solar thermal generation in the ETS sector in this scenario; total CO_2 eq emissions in the ETS sector drop from 3,150 ktons in 2021 to 2,410 ktons in 2030. The reduction in CO_2 eq emissions in the non-ETS sector is relatively moderate. Emissions in the non-ETS sector decrease from 2,790 ktons in 2021 to 2,800 ktons in 2030. The main driver for this is the continued dependence of the transport sector on oil products.

Table 8 – GHG emission trajectory in the ETS and Non-ETS energy-related sectors.

	Unit	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
ETS CO_2	**Mt**	3.11	2.38	2.41	2.23	2.19	2.19	2.22	2.28	2.36	2.41
Non-ETS CO_2	**Mt**	2.74	2.74	2.74	2.75	2.76	2.77	2.77	2.78	2.75	2.72
ETS CH_4	**kt**	0.11	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.05
Non-ETS CH_4	**kt**	1.77	1.81	1.84	1.87	1.90	1.99	2.20	2.39	2.56	2.72
ETS N_2O	**kt**	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01
Non-ETS N_2O	**kt**	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

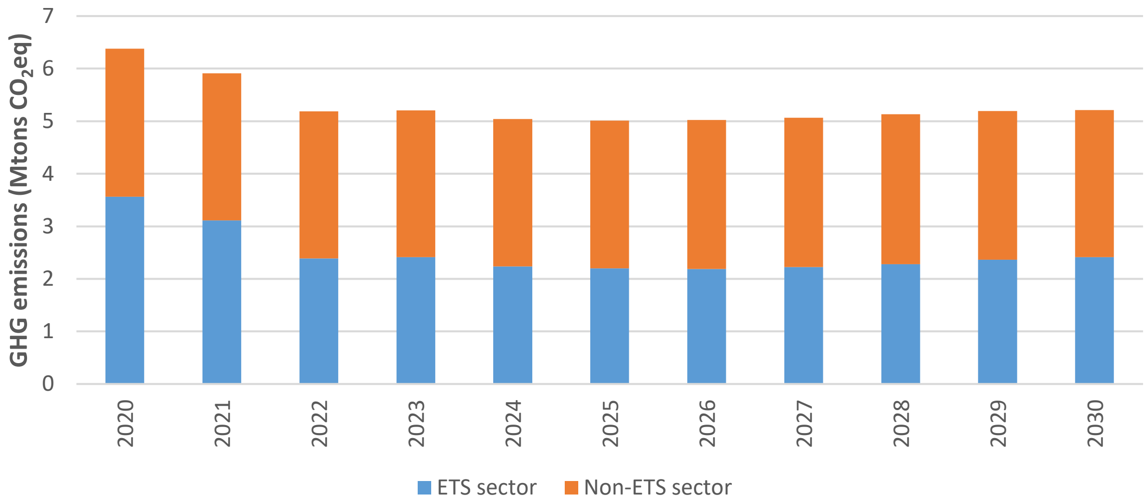

Figure 2 – Trajectory of greenhouse gas emissions in the ETS and non-ETS energy-related sectors – WEM scenario.

2.1.6 Air Pollutant Emissions

The aforementioned choices in energy technologies and fuel mix results in the air pollutant emissions projections shown in Table 9. Even though the increased renewable energy share across the economy leads to a reduction in NO_x and SO_2 emissions, $PM_{2.5}$ and PM_{10} emissions initially decline up to 2025, as a result of more stringent regulations in road vehicle transport and a decrease in diesel passenger cars, emissions remain relatively constant during the period 2025-2030 and even increase slightly. This is attributed to an elevated use of biomass in the Heating and Cooling sector. It should be mentioned that the National Emission Ceiling set for SO_2 constrains the use of HFO with high sulphur content in 2020.

Table 9 – Air pollutant emission projections until 2030 in the WEM Scenario.

Pollutant	Unit	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NO_x	**kt**	6.37	6.02	5.78	5.23	5.04	4.94	4.86	4.82	4.81	4.87
PM_{10}	**kt**	1.56	1.38	1.35	1.30	1.33	1.37	1.38	1.41	1.43	1.46
$PM_{2.5}$	**kt**	1.36	1.21	1.17	1.13	1.17	1.20	1.21	1.23	1.25	1.28
SO_2	**kt**	3.52	1.68	1.69	0.55	0.56	0.55	0.51	0.51	0.55	0.86

When the projections of DLI are taken into account for the remaining sectors of the economy that are not captured by the adopted methodology, a more comprehensive outlook is provided. It should be noted that DLI projects emissions for the major air pollutants only until 2030, and as such the horizon is limited in this case (Table 10).

Table 10 – Economy-wide air pollutant emissions projections in the WEM scenario until 2030.

Pollutant	Unit	2020	2025	2030
NO_x	kt	10.82	8.27	8.09
$PM_{2.5}$	kt	1.56	1.36	1.46
SO_2	kt	3.64	0.66	0.96

2.2 Planned Policies and Measures Scenario

2.2.1 Electricity Supply Sector

2.2.1.1 Capacity

The incorporation of the EuroAsia interconnector in the system at a Net Transfer Capacity of 1,000 MW, and to a lesser degree the lower electricity demand, in the PPM scenario leads to major changes in the investment outlook of the electricity supply sector (Table 11). Specifically, investments in new CCGT units are expected to be reduced by one unit as compared to the WEM scenario. Similarly, no investments occur in new steam turbines, gas turbines and CHP facilities. In addition, investments in batteries are also reduced drastically and are delayed to the end of the modelling horizon.

Table 11 - Capacity projections in the electricity supply sector (MW) – PPM scenario.

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Vasilikos	836	836	836	836	836	836	836	836	836	836
Dhekelia	450	450	450	102	102	102	102	102	102	102
Moni	128	128	128	128	128	128	128	128	128	128
New CCGT	216	216	216	216	216	216	216	216	216	216
New ICE	0	0	0	0	0	0	0	0	0	0
New ST	0	0	0	0	0	0	0	0	0	0
New GT	0	0	0	0	0	0	0	0	0	0
Light fuel oil CHP	0	0	0	0	0	0	0	0	0	0
Solar PV	380	400	420	440	460	480	780	1,080	1,380	1,680
Solar Thermal	0	50	50	50	50	50	50	50	50	50
Wind	175	175	175	175	175	175	175	175	175	175
Biomass	50	50	50	50	50	50	50	50	58	58
Pumped Hydro	0	0	0	0	0	0	130	130	130	130
Li-Ion Batteries	0	0	0	0	0	0	0	0	0	0

However, investments in solar PV capacity are increased substantially; these are higher by 930 MW in 2030 as compared to the WEM scenario. Such a high deployment is enabled by the trading opportunities offered by the interconnector. An exception is noticed in 2025, where PV capacity is reduced by 95 MW, as it is deemed cost-effective to rely on electricity imports via the interconnector for that particular point in time.

It is interesting to highlight that the investment in pumped hydro remains unaffected in this scenario. Other than energy arbitrage, this technology is assumed to be able to contribute towards meeting the demand for operational reserves. It should be mentioned that the interconnector was not allowed to contribute towards meeting operational reserves demand. It is possible that if the interconnector was allowed to do so, then pumped-hydro would likely not be deployed.

2.2.1.2 Generation

The above technology deployment provides the generation mix shown in Figure 3. For the majority of the model horizon, with the exception of the period 2024-2026 at annual net imports in the range of 380-445 GWh, the Cypriot grid becomes a net exporter of electricity. In the period 2027-2030 net exports of electricity range between 90 and 1,050 GWh annually. Electricity trade related results are very sensitive to the assumed electricity prices in Greece and Israel. Since these systems are not modelled explicitly, there are significant limitations in the adopted approach, as intra-year electricity cost and demand variations in the external systems are not captured.

Exported electricity is largely dependent on the increased solar PV generation. As compared to the WEM scenario, this increases from 1,215 GWh to 2,720 GWh in 2030 in the PPM scenario. Taking into account the net imports (see Figure 3), this leads to a RES-E share of 54% in 2030. When electricity exchange is not accounted for, RES share in generation amounts to 44% in 2030.

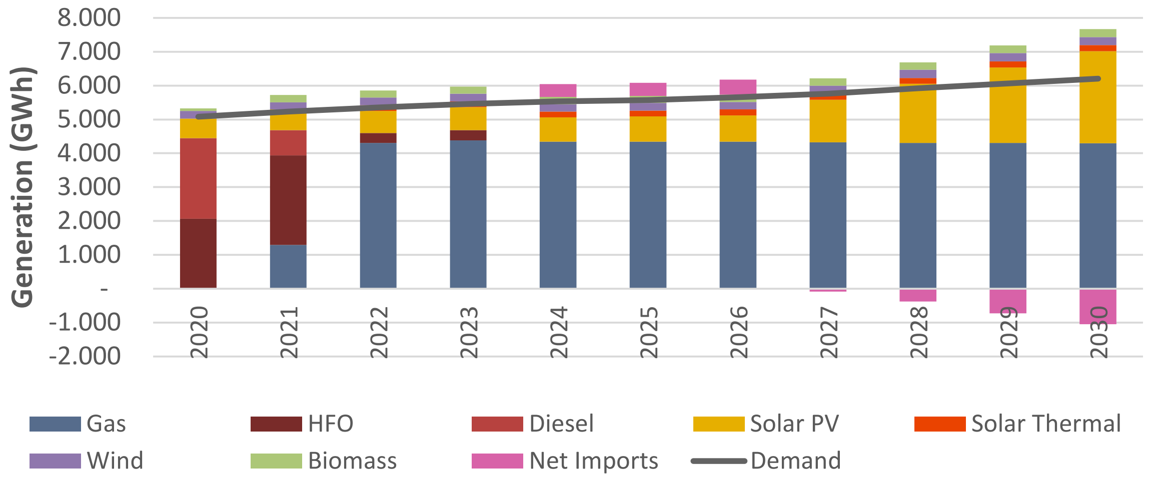

Figure 3 - Projected generation mix till 2030 – PPM scenario.

2.2.2 Transport Sector

Due to the assumed modal shift from passenger cars to sustainable transport modes, significant changes occur in the vehicle fleet of the PPM scenario. The most notable change is the lower projection in passenger cars compared to the WEM scenario. Specifically, the present scenario's passenger car fleet is lower by nearly 130 thousand vehicles in 2030.

Most of this reduction is experienced by gasoline-fired passenger cars; these are lower by about 150 thousand in 2030. Similarly, gasoline hybrid passenger cars are slightly reduced, while BEVs are increased by more than 25 thousand vehicles in 2030. On the other hand, a small number of diesel PHEV purchases can be noticed which were not present in the WEM scenario. In addition, a reduction in light truck and motorcycle fleets can be noticed, driven by the relevant mileage demand assumptions. On the contrary, the shift towards public transport creates a necessity for additional buses, which are higher by 2,560 units in 2030. As a result of the Clean Vehicles Directive for the public procurement of clean vehicles, a large number of these additional buses are fully-powered by electricity.

The outlook of fuel consumption in the transport sector changes as a result of the aforementioned transport fleet outlook (

Table 13). The biggest variation can be noticed in the consumption projection of gasoline. This decreases by 31% in 2030 as compared to the WEM scenario. This is attributed to the reduced use of passenger cars and higher use of sustainable transport modes. Increased use of buses does not affect diesel fuel sales, as they remain at similar levels as in the WEM scenario. As regards biofuels, the same assumption is made as in the WEM scenario, i.e. forced blending for 2nd generation biodiesel; as the government of Cyprus has issued decrees which force blending of 2nd generation biodiesel. Despite the penetration of natural gas in power generation and the assumed investments in at least one CNG refuelling station in each district of Cyprus, use of natural gas in motor vehicles is not deemed cost-effective in either of the two scenarios; this is of course directly affected by the relevant techno-economic assumptions adopted in the analysis.

In terms of electricity consumption in the transport sector, total consumption increases by 130 GWh in 2030 as compared to the WEM scenario. Annual electricity consumption in rail transport is assumed to remain at the same levels throughout the model horizon as the number of trips by the tram line in Nicosia was kept constant. It is important to highlight the drastic reduction in overall energy demand of the transport sector through the promotion of sustainable transport modes. It is estimated that additional cumulative investments in public transport for this scenario amount to 800-900 million EUR2016 to develop a tram line in Nicosia and increase the bus fleet, and an additional 500 million EUR2016 for creating the necessary infrastructure for sustainable transport until 2030. These levels of investment are very large compared to what's foreseen in other sectors, but they also lead to lower private investments in passenger vehicles of approximately 2 billion EUR2016 during the same period. It is noted that the materialisation of these projections will necessitate infrastructure investments that will need to be partly financed by EU funds, and an equivalent level of public acceptance and adoption of these modes of transport to make such investments successful. Using the SHARES methodology, RES-T share in this case has been estimated to rise to 14.8% in 2030. In the case of the WEM scenario, the equivalent value was limited to 7.3% in 2030.

Table 12 – Projected vehicle fleet (total number of vehicles) – PPM scenario.

		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Passenger cars	**Diesel**	63,430	57,686	51,942	46,117	53,722	59,304	63,107	65,534	61,529	57,281
	Diesel hybrid	-	-	-	-	-	-	-	-	-	-
	Diesel PHEV	-	56	127	189	252	367	465	587	692	799
	Gasoline	471,701	471,889	472,075	472,985	459,188	448,892	419,984	391,068	362,153	333,432
	Gasoline Hybrid	5,170	5,170	5,170	5,170	5,170	5,170	11,254	18,641	32,370	46,181
	Gasoline PHEV	-	-	-	-	-	-	-	-	-	-
	BEV	100	100	100	100	100	100	13,668	27,317	41,047	54,858
	LPG	320	424	529	633	739	843	948	1,061	1,174	1,174
	Natural gas	-	-	-	-	-	-	-	-	-	-
	Hydrogen	-	-	-	-	-	-	-	-	-	-
		2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Buses	**Diesel**	3,314	3,579	3,840	4,106	4,372	4,609	4,856	5,089	5,332	5,574
	Diesel hybrid	-	-	-	-	-	-	-	-	-	-
	BEV	-	30	69	103	138	200	254	320	377	436
	CNG	-	-	-	-	-	-	-	-	-	-
		2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
MCs	**Gasoline**	50,442	49,981	49,471	48,961	48,476	47,990	47,505	46,971	46,485	46,000
	BEV	-	-	-	-	-	-	-	-	-	-
		2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Trucks	**Diesel**	13,209	13,442	13,675	13,912	14,146	14,077	14,001	13,920	13,832	13,740
	BEV	-	-	-	-	-	302	611	925	1,245	1,571
	Natural gas	-	-	-	-	-	-	-	-	-	-
		2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Light Trucks	**Diesel**	121,024	122,434	123,850	125,260	126,670	128,080	129,490	130,906	132,316	133,726
	BEV	-	-	-	-	-	-	-	-	-	-
	PHEV Diesel	-	-	-	-	-	-	-	-	-	-
	Hybrid diesel	-	-	-	-	-	-	-	-	-	-
Grand Total		**728,711**	**724,791**	**720,849**	**717,537**	**712,972**	**709,934**	**706,142**	**702,340**	**698,554**	**694,771**

Table 13 – Evolution of fuel consumption in the transport sector till 2030 – PPM scenario.

		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Biofuels	**L**	45,442,427	44,999,743	44,543,200	44,154,549	43,762,259	43,246,255	41,959,069	40,647,451	39,267,997	47,662,323
Diesel	**L**	325,646,522	321,270,242	316,901,410	313,754,714	322,582,344	327,368,441	330,575,674	332,089,351	327,825,570	317,927,250
Gasoline	**L**	500,673,599	497,137,297	493,329,396	489,450,094	472,163,302	457,027,852	428,998,485	402,391,392	380,930,973	357,692,722
LPG	**L**	425,155	561,664	699,015	835,012	971,297	1,105,403	1,239,239	1,382,260	1,522,850	1,516,809
Natural gas (STP)	**m^3**	-	-	-	-	-	-	-	-	-	-
Electricity (road)	**MWh**	313	1,115	2,116	2,963	3,829	12,034	61,492	111,529	161,578	211,788
Electricity (rail)	**MWh**	-	-	-	-	-	-	-	9,126	9,126	9,126

2.2.3 Heating and Cooling Sector

The additional energy efficiency measures adopted in the PPM scenario lead to a decrease in the total final energy demand of the Heating and Cooling sector. A reduction of 4% is estimated by 2030 as compared to the WEM scenario. As shown in Table 14 all of the fuels indicate lower figures, while the RES share in the Heating and Cooling sector is comparable to that in the WEM scenario.

Table 14 - Final energy demand in the Heating and Cooling sector (PJ) – PPM scenario.

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Electricity	7.79	7.97	8.12	8.24	8.29	8.41	8.49	8.63	8.77	8.90
Heating oil/ light fuel oil/ Gas Oil	6.84	6.78	6.65	6.61	6.60	6.59	6.56	6.53	6.48	6.45
Pet Coke	3.15	2.93	2.72	2.56	2.47	2.40	2.33	2.26	2.20	2.15
LPG	2.59	2.57	2.53	2.53	2.56	2.58	2.61	2.64	2.66	2.70
Biomass	1.03	1.00	0.98	1.01	1.07	1.12	1.16	1.20	1.23	1.27
Geothermal	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05
District Heating and Cooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.26
Solar thermal	2.98	2.98	2.99	3.00	3.06	3.13	3.21	3.30	3.39	3.51
RES share	***32.6%***	***33.1%***	***33.9%***	***34.5%***	***35.2%***	***35.8%***	***36.5%***	***37.2%***	***38.7%***	***39.4%***

2.2.4 Primary Energy Supply and Final Energy Demand

Due to the changes in the energy mix and demand indicated in all the sectors (i.e. electricity, transport, heating and cooling), primary energy supply decreases considerably in this scenario. Specifically, by 2030 an 11% is achieved compared to the WEM scenario; this corresponds to a difference of 240 ktoe (Table 15). A considerable decrease is achieved in the use of gasoline, due to measures in the transport section, which is reduced by 120 ktoe in 2030. Similarly, a higher deployment of renewable energy technologies in the electricity supply sector reduces the supply of natural gas by 145 ktoe in 2030. On the other hand, primary energy supply from solar photovoltaics increases by 280 ktoe for the same year.

Table 15 – Primary Energy Supply evolution till 2030 (ktoe) – PPM scenario.

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Diesel	412	276	272	270	277	281	284	286	282	273
Gasoline	383	380	377	374	361	349	328	308	291	273
Heavy Fuel Oil	565	60	61	-	-	-	-	-	-	-
LPG	62	62	61	61	62	62	63	64	64	65
Heating Oil/light fuel oil/Gas oil	163	162	159	158	158	157	157	156	155	154
Pet coke	75	70	65	61	59	57	56	54	53	51
Natural gas	230	788	804	775	775	775	771	768	768	767
Hydrogen	-	-	-	-	-	-	-	-	-	-
Electricity	-	-	-	33	33	38	-8	-33	-62	-90
Biomass (includes biofuels)	109	109	108	108	110	111	111	111	122	129
Geothermal	1	1	1	1	1	1	1	1	1	1
Solar thermal	71	86	86	86	88	90	91	94	96	99
Solar PV	53	56	58	61	64	67	109	150	192	234
Wind	18	19	19	19	19	19	21	21	21	21
Total	***2,144***	***2,070***	***2,071***	***2,009***	***2,008***	***2,009***	***1,984***	***1,980***	***1,983***	***1,978***

Even though final energy demand in the WEM scenario shows a moderate increase over the period 2020-2030, a moderate decrease is illustrated in the PPM scenario (Table 16). This results in a total difference of 160 ktoe in 2030. Other than the aforementioned difference in gasoline consumption in the transport sector, a difference of 40 ktoe by 2030 is also observed in the final electricity demand.

In terms of overall system efficiency, through a comparison between primary energy supply and final energy demand, slightly improved figures can be noticed. This is estimated at 76% in 2030 in the present scenario versus 75% in the WEM scenario.

Table 16 – Final Energy Demand evolution till 2030 (ktoe) – PPM scenario.

	2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Diesel	280	276	272	270	277	281	284	286	282	273
Gasoline	383	380	377	374	361	349	328	308	291	273
LPG	62	62	61	61	62	62	63	64	64	65
Heating Oil/light fuel oil/Gas oil	163	162	159	158	158	157	157	156	155	154
Natural gas	-	-	-	-	-	-	-	-	-	-
Pet Coke	75	70	65	61	59	57	56	54	53	51
Hydrogen	-	-	-	-	-	-	-	-	-	-
Electricity	450	461	470	476	479	487	496	509	522	533
Biomass (includes biofuels)	53	52	51	52	53	54	54	55	55	61
Geothermal	1	1	1	1	1	1	1	1	1	1
District Heating and Cooling	-	-	-	-	-	-	-	-	6	6
Solar thermal	71	71	71	72	73	75	77	79	81	84
Total	***1,539***	***1,535***	***1,528***	***1,525***	***1,523***	***1,524***	***1,515***	***1,511***	***1,509***	***1,503***

As shown in Table 17, reduced primary energy supply and final energy demand in combination with a drastically increased renewable energy share in electricity supply, lead to a considerable increase in the overall renewable energy share. In the present scenario, this is estimated at 30.7% (Table 17) versus 20.7% in the WEM scenario by 2030.

Table 17 – RE share in final energy demand across the energy system – PPM scenario.

	All sectors	**Electricity**	**Heating and cooling**	**Transport (RED Recast methodology)**
2021	16.1%	18.2%	32.6%	6.3%
2022	17.2%	21.4%	33.1%	6.3%
2023	17.4%	21.6%	33.9%	6.3%
2024	17.7%	21.8%	34.5%	6.3%
2025	18.1%	22.2%	35.2%	6.4%
2026	18.4%	22.4%	35.8%	6.6%
2027	21.5%	30.9%	36.5%	7.3%
2028	24.3%	37.7%	37.2%	8.1%
2029	27.5%	44.6%	38.7%	9.4%
2030	30.7%	50.9%	39.4%	14.8%

2.2.5 Greenhouse Gas Emissions

As opposed to the WEM scenario, a greater level of decarbonisation is achieved in both ETS and non-ETS sectors (Figure 4). In the PPM, the deployment of the EuroAsia Interconnector enables further penetration of solar PV, and reduces CO_2 eq emissions by 400 ktons in 2030 (with a total of 2,014 ktons) as compared to the WEM scenario. A lower electricity demand also plays a role in this reduction. Similarly, in comparison to the WEM scenario, non-ETS sector CO_2 eq emissions reduce further by 370 ktons in 2030 (with a total of 2,430 ktons). In this case, the reduction is largely driven by a modal shift in the transport sector away from passenger cars towards sustainable transport modes. It is worth noting here that the model does not account for emissions occurring in other countries due to the exchange of electricity via the interconnector. In an EU context, emissions in Greece would be accounted for in the country's respective plan and targets, but the ones in Israel would not. Generation in Israel after the interconnector becomes operational may be done via carbon-intensive means (e.g. coal or gas), but this is not captured in the present analysis without explicitly modelling Israel's energy system.

Table 18 – GHG emission trajectory in the ETS and Non-ETS energy-related sectors.

	Unit	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
ETS CO_2	**Mt**	3.09	2.33	2.35	2.07	2.06	2.05	2.04	2.03	2.02	2.01
Non-ETS CO_2	**Mt**	2.71	2.68	2.65	2.63	2.62	2.60	2.55	2.49	2.43	2.35
ETS CH_4	**kt**	0.11	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Non-ETS CH_4	**kt**	1.76	1.80	1.82	1.85	1.95	2.04	2.16	2.29	2.42	2.55
ETS N_2O	**kt**	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-ETS N_2O	**kt**	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

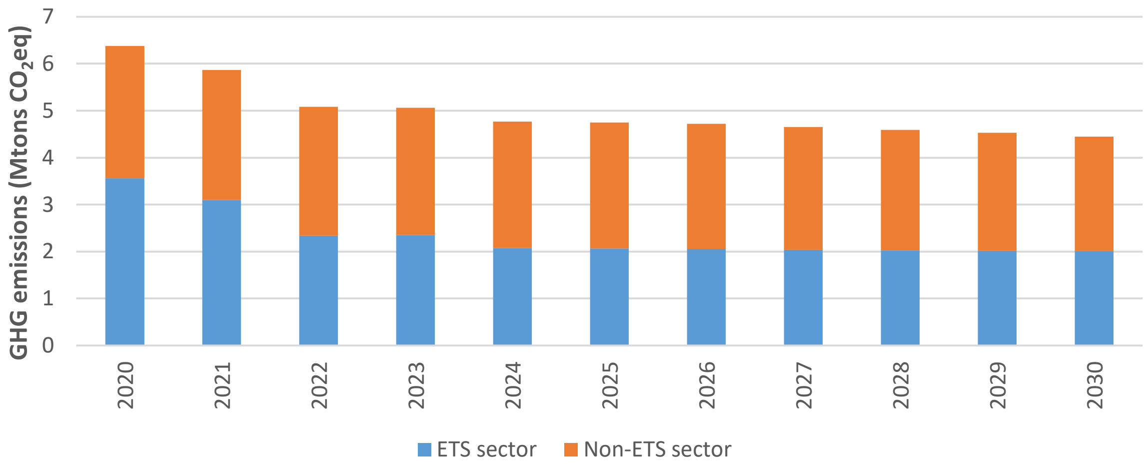

Figure 4 – Trajectory of greenhouse gas emissions in the ETS and non-ETS sectors – PPM scenario.

2.2.6 Air Pollutant Emissions

As compared to the WEM scenario, a reduced projection in air pollutant emissions is observed, as illustrated by Table 19. A reduction is noticed for all air pollutants, but $PM_{2.5}$ and PM_{10} indicate the highest reduction in the long-term. This is due to a lower use of biomass in the Heating and Cooling sector, as well as to lower fossil fuel consumption in road transport. Additionally, by 2030 a considerable difference is noticed in SO_2 emissions; this is attributed to a significantly higher RES-E share in the PPM scenario, which also completely displaces the small amounts of oil-fired generation observed in the WEM scenario. Finally, NO_x emissions are lower in the PPM scenario due to a lower gas-fired generation, as well as a lower dependence on fossil-fired passenger vehicles in the road transport sector.

Table 19 – Air pollutant emission projections until 2030 in the PPM Scenario.

Pollutant	Unit	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NO_x	**kt**	6.35	5.97	5.71	5.10	4.99	4.87	4.77	4.68	4.60	4.52
Difference from WEM		*0%*	*-1%*	*-1%*	*-2%*	*-1%*	*-1%*	*-2%*	*-3%*	*-4%*	*-7%*
PM10	**kt**	1.54	1.36	1.31	1.24	1.27	1.29	1.29	1.30	1.32	1.33
Difference from WEM		*-1%*	*-2%*	*-3%*	*-4%*	*-5%*	*-6%*	*-6%*	*-7%*	*-8%*	*-9%*
PM2.5	**kt**	1.35	1.19	1.14	1.09	1.11	1.13	1.14	1.15	1.16	1.18
Difference from WEM		*-1%*	*-2%*	*-2%*	*-3%*	*-5%*	*-6%*	*-6%*	*-6%*	*-7%*	*-8%*
SO_2	**kt**	3.52	1.67	1.67	0.50	0.50	0.50	0.50	0.49	0.49	0.49
Difference from WEM		*0%*	*-1%*	*-1%*	*-9%*	*-11%*	*-10%*	*-3%*	*-3%*	*-11%*	*-43%*

When the projections of DLI are taken into account for the remaining sectors of the economy that are not captured by the adopted methodology, a more comprehensive outlook is provided. As aforementioned, DLI projects emissions for the major air pollutants only until 2030, and as such the horizon is limited in this case (Table 20).

Table 20 – Economy-wide air pollutant emissions projections in the PPM scenario until 2030.

Pollutant	Unit	2020	2025	2030
NO_x	**kt**	10.81	8.22	7.74
PM2.5	**kt**	1.56	1.31	1.36
SO_2	**kt**	3.64	0.59	0.59

2.3 Energy Savings and their Effect on Energy Supply

As explained in the previous sections, the scenario with PPM (or PPM scenario) assumes the implementation of diverse energy efficiency policies for buildings and equipment in the Heating and Cooling sector, as well as important measures to enable a shift from passenger cars towards public and non-motorised transport modes. As a result of these measures, and in combination with the changes foreseen on power generation as explained in the previous parts of Chapter 2, the energy system of Cyprus is expected to become considerably more efficient by 2030 in comparison to that foreseen in the scenario with Existing Policies and Measures (or WEM scenario). This is illustrated in Table 21, which displays key energy consumption data and the calculated energy savings between the two scenarios. It is evident that the main portion of energy savings comes from the road transport sector. Electricity supply also requires less primary energy input in the PPM scenario, both because of the reduction in electricity demand and because of the faster penetration of renewables in the power generation system.

Despite the reduced needs for energy supply due to energy efficiency improvements, it seems that there is no risk of stranded investments in the PPM scenario. As explained in Section 2.2.1.1, the implementation of this scenario leads to a drop in new investments only: one CCGT unit less will be built, no new investments occur in steam turbines, gas turbines and CHP facilities, and new investments in batteries are reduced drastically. Existing power plants will continue to operate until the end of their technical lifetime. Therefore, there is no issue of stranded assets in the Cypriot economy due to the implementation of PPM.

2.4 Comparison with EU Climate and Energy Targets

Table 22 presents the projected total GHG emissions for the 2020-2030 period, split into the emissions of ETS and non-ETS sectors. These aggregate forecasts come from the calculations of MARDE to be included in the final report of the NECP of Cyprus. Similarly, Figure 5 illustrates the projected evolution of non-ETS GHG emissions for the two scenarios of the NECP.

In line with these emission forecasts, Table 23 provides an overview of the projected progress up to 2030 for meeting the EU energy and climate targets according to the WEM and PPM scenarios presented up to now. Although not all of these targets are entirely linked with the energy system (GHG emissions also depend on non-energy activities such as waste management and the use of fluorinated gases), the energy modelling results of this study play a crucial role for assessing the achievement of Energy Union related policy objectives. The package of PPM included in the corresponding scenario seems to be sufficient for meeting[4]:

- The renewable energy targets related both to total energy consumption and to road transport;
- The energy efficiency target declared by the Republic of Cyprus.

Conversely, fulfilling the emissions abatement target for non-ETS sectors turns out to be very challenging for the Cypriot economy: even under the PPM scenario, emissions fall by only 14%, leaving a 10% gap (or 398 kt CO_{2eq}) for complying with the country's Effort Sharing Regulation target of 24% reduction in emissions of 2030 compared to those of 2005.

Moreover, keeping in mind the declared objective by the European Commission and several national governments to achieve net zero carbon emissions by 2050, Table 23 demonstrates how much more is needed for aligning the emissions of Cyprus with the deep decarbonisation target. Even the PPM scenario falls short of putting Cyprus on track for strong decarbonisation; therefore Deliverable 6 of this study offers some recommendations on this aspect.

[4] We do not provide an assessment of the ability to meet the GHG emission reduction target in sectors subject to the EU ETS, because ETS installations have their own obligations which are separate from the national obligation that is relevant for non-ETS sectors. Moreover, each ETS sector that is relevant for Cyprus (power generation, cement production and ceramics/tiles production) has different allocations of emissions depending on provisions of the relevant EU legislation.

Table 21 – Projected evolution of savings in final and primary energy consumption in Cyprus up to 2030. All values are expressed in ktoe.

Scenario with Existing Measures	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Final energy consumption	1931	1955	1966	1991	2017	2046	2073	2099	2117	2128
Final electricity consumption	452	469	479	492	502	515	529	542	561	574
Final non-electricity consumption, of which:	1479	1486	1487	1499	1515	1531	1544	1556	1556	1554
Industry	226	222	216	215	216	218	220	222	224	225
Households	348	356	358	364	369	376	383	391	398	403
Services	236	243	248	255	261	267	274	281	288	293
Agriculture	43	42	42	42	42	42	42	43	43	43
Road Transport	701	704	706	710	712	716	716	716	709	702
Air Transport	377	388	396	406	417	427	437	446	454	461
Primary energy input for power generation	1060	1016	1037	995	1001	1015	1037	1067	1109	1128
Primary energy consumption	**2539**	**2501**	**2524**	**2494**	**2516**	**2546**	**2582**	**2623**	**2665**	**2682**
Scenario with Planned Policies and Measures	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Final energy consumption	1916	1922	1922	1931	1940	1952	1952	1957	1959	1960
Final electricity consumption	450	461	470	476	479	487	496	509	522	533
Final non-electricity consumption, of which:	1466	1462	1453	1455	1461	1465	1456	1447	1437	1426
Industry	225	220	214	211	212	213	214	215	217	219
Households	346	350	351	354	356	359	361	365	369	373
Services	234	238	242	246	248	252	254	258	263	266
Agriculture	42	42	41	41	41	41	41	42	42	42
Road Transport	691	685	678	672	666	660	645	630	614	598
Air Transport	377	388	396	406	417	427	437	446	454	461
Primary energy input for power generation	1056	995	1014	927	930	933	972	1011	1064	1105
Primary energy consumption	**2521**	**2457**	**2466**	**2382**	**2391**	**2398**	**2429**	**2459**	**2501**	**2531**
Energy Savings	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Savings in final energy consumption	15	32	44	59	77	95	120	142	158	168
Savings in final electricity consumption	2	8	10	15	22	28	33	33	39	40
Savings in final non-electricity consumption, of which:	13	24	34	44	54	66	88	109	119	128
Industry	1	2	2	3	4	5	7	7	7	7
Households	2	6	7	9	13	17	22	26	29	30
Services	2	5	6	9	12	15	19	23	26	27
Agriculture	0	0	0	0	1	1	1	1	1	1
Road Transport	10	19	29	38	46	56	71	86	96	104
Savings in primary energy input for power generation	5	21	24	68	71	82	65	56	45	23
Savings in primary energy consumption	**18**	**45**	**58**	**112**	**125**	**148**	**153**	**164**	**164**	**151**

Table 22 – Projected evolution of GHG emissions according to the WEM and PPM scenarios.

(kt CO_{2eq})	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
WEM Scenario	**8828**	**8082**	**8108**	**7934**	**7903**	**7899**	**7931**	**7983**	**8032**	**8037**
ETS	4831	4095	4133	3964	3938	3937	3981	4045	4140	4195
non-ETS	3997	3987	3975	3970	3966	3962	3950	3937	3893	3843
PPM Scenario	**8735**	**7924**	**7912**	**7606**	**7575**	**7536**	**7452**	**7373**	**7294**	**7195**
ETS	4816	4046	4076	3805	3806	3807	3797	3793	3793	3792
non-ETS	3919	3878	3836	3802	3769	3729	3655	3580	3500	3403

Source: MARDE calculations.

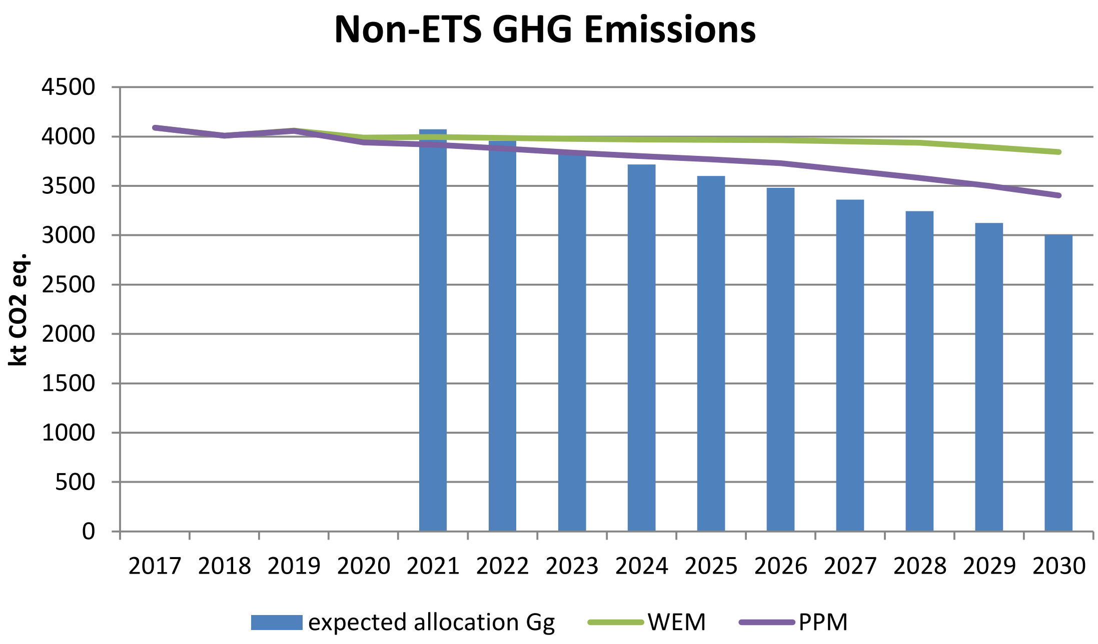

Figure 5 – Projected evolution of GHG emissions of non-ETS sectors according to the WEM and PPM scenarios. Source: MARDE calculations.

Table 23 – Progress towards meeting 2030 Energy Union objectives according to the two scenarios of the NECP of Cyprus.

		Progress Towards Target in Scenario:	
Energy Union Objective	**Target for 2030 Relevant for Cyprus**	***With Existing Measures***	***With Planned Policies and Measures***
Reduction of GHG emissions	Non-ETS Sectors: -24% compared to 2005	-3%	-14%
Promotion of Renewable Energy	Energy-Wide Share of Renewables: 23%	20.7%	30.7%
	Renewable Energy in Transport: 14%	7.3%	14.8%
Improvement of Energy Efficiency	National energy consumption target in the frame of 32.5% EU-wide improvement target	Not to be met	To be met - see NECP for more details

2.5 Application of the Energy Efficiency First Principle in Planned Policies and Measures

According to guidance provided by the European Commission, when designing their energy and climate policies, Member States should apply the Energy Efficiency First Principle, meaning that priority should be given to policies and measures that improve the efficiency of the energy system, and other decarbonisation measures should be considered only after energy efficiency actions are deemed unfeasible or very costly.

The package of Planned Policies and Measures foreseen in the PPM scenario of the Cypriot National Energy and Climate Plan seems to be in line with the Energy Efficiency First Principle, for the following reasons:

- As explained in the relevant section of the NECP of Cyprus, the measures of the PPM scenario are sufficient to comply with the energy efficiency obligations of the country as required in Article 7 of the Energy Efficiency Directive; this means that the appropriate measures have been taken into account.
- As a result of energy efficiency measures, energy supply of Cyprus will be lower in comparison to that of the WEM scenario, as explained in Section 2.3 above. This means that energy efficiency has indeed been given priority in comparison e.g. to stronger deployment of renewable energy.
- All cost-effective policies and measures that are related to energy efficiency have been included in the PPM scenario; these involve renovations of residential and tertiary buildings and industrial equipment, strong promotion of public and non-motorised transport and switch to electric cars. As will be shown in Deliverable 6, all these measures have a negative or near-zero total lifetime cost and are therefore cost-effective. Further energy efficiency measures are not recommended to be deployed because they have a very high cost per tonne of carbon abated (e.g. the renovation of very old buildings to become nearly-zero energy buildings) or are considered to be unrealistic (e.g. an increase in the number of energy renovations of buildings up to 2030, which would reach unprecedented levels of refurbishments that would

require very high financial and human resources to realise). This finding is based on two studies that were funded by the European Commission's Structural Reform Support Service in the recent past, and whose results were utilised in the NECP of Cyprus and in the current Impact Assessment study[5,6].

- It is particularly important to note that the PPM scenario foresees energy efficiency measures in transport (modal shift towards public and non-motorised transport and electrification of cars) which involve very significant investments that reach unprecedented levels for the standards of the Cypriot transport system. This underlines how strongly the Energy Efficiency First principle has been taken into account.

- Apart from the cost-effectiveness argument mentioned above, further prioritising demand-side measures such as energy efficiency improvements would put Cyprus at risk of not meeting the two main objectives of Table 23 which are related to energy supply: the renewable energy target and the reduction in emissions of ETS sectors – which in the case of Cyprus is predominantly power generation. Therefore, measures in the electricity supply that have been foreseen in the PPM scenario are indeed those which are absolutely necessary for Cyprus to meet the above mentioned commitments.

- As a result of the above considerations, energy efficiency measures in all end uses of the Cypriot economy, as foreseen in the PPM scenario and to the extent that they will be fully deployed, can greatly improve the security of energy supply of the country.

- The only further policy that is worth examining is the implementation of a green tax reform that would involve carbon pricing in non-ETS sectors of the Cypriot economy. Such a reform can indeed stimulate further improvements in energy efficiency and substitution of liquid fossil fuels by low- or zero-carbon energy forms. In September 2019 the Finance Minister of Cyprus announced that a green tax reform will be put in consultation in 2020 with the aim to adopt the relevant legal framework and implement such a reform in 2021. However, considerations for the adoption of such a reform were still at an early stage by the time of this writing, so that it could not be considered as part of the government's Planned Policies and Measures.

[5] Vougiouklakis Y., Struss B., Zachariadis T. and Michopoulos A. (2017), An energy efficiency strategy for Cyprus up to 2020, 2030 and 2050. Study funded by the European Commission Structural Reform Support Service under grant agreement SRSS/S2016/002 and from the German Federal Ministry of Economy and Energy.

[6] Zachariadis T., Michopoulos A. and Sotiriou C. (2018), Evaluation of the Effectiveness of Possible Climate Change Mitigation Policies and Measures. Final Report submitted to the European Commission's Structural Reform Support Service under Service Contract No. SRSS/C2017/024.

3 Macroeconomic and Social Impacts

3.1 Macroeconomic impacts

3.1.1 Methodology

To assess the macroeconomic impacts of the PPM scenario in comparison to the WEM scenario, we applied an input-output (IO) analysis. IO is a quantitative technique for studying the interdependence of production sectors in an economy over a stated time period, which has been extensively applied for policy impact evaluation, technical change analysis and forecasting[7].

In the frame of this project, we transformed the national Cyprus IO table available by the European Statistical Service (Eurostat) for 2015 to a system of linear equations accounting for the way in which the output of each economic sector is distributed through sales to other sectors (intermediate demand) and final demand (consumers). The IO framework has been incrementally extended to employ physical units to trace energy use and related environmental activities[8].

We thus developed and applied a dynamic input-output model to estimate the economy-wide effects of the two different scenarios examined for the economy of Cyprus over time (to 2030). The rationale of this approach is that the PPM scenario will involve additional and/or different types of investments during the period 2020-2030 in comparison to the WEM scenario. These changes in investment needs were used as input in the IO model of Cyprus in order to simulate their effects on the economic output and employment of each main sector of the Cypriot economy. More information about the methodological approach and the input data used is provided in Appendix III.

3.1.2 Input data

As a result of the simulations of the energy system with the OSeMOSYS model, for each one of the two scenarios (With Existing Measures and With Planned Policies and Measures) there is a projection of annual investments in each production sector of the economy as well as a projection of the annual expenditures of households for energy goods. For this analysis, investments are classified in seven categories, namely: (a) industry, (b) power generation technologies, (c) electricity storage technologies, (d) gas infrastructure, (e) electricity interconnector, (f) public transport, (g) private transport, and (h) buildings (energy efficiency measures).

These results of OSeMOSYS were introduced in the IO model through changes in its exogenous variables, that is, expenditure for investments per sector of economic activity. A critical parameter of the impact assessment is to what extent the production of the necessary equipment for implementing the investments of the two scenarios, and thus the relative expenditures, occurs inside the economy of Cyprus or abroad. The estimation of the associated macro-economic impacts is based on those investment expenditures that are spent inside the national economy and not directly imported from abroad. This analysis takes also into account the induced effects from energy savings, i.e., the reduced household expenditures for energy consumption.

Table 24 presents the total estimated vector of spending within the national economy associated with the development and operation of all the interventions under the WEM scenario, and Table 25 presents the corresponding figures for the PPM scenario. The allocation of spending to the various

[7] Miller, R.E., Blair, P.D. (2009). *Input-output analysis: Foundations and extensions* (2nd edn). Cambridge University Press, New York.

[8] Giannakis, E., Kushta, J., Giannadaki, D., Georgiou, G.K., Bruggeman, A., Lelieveld, J. (2019). Exploring the economy-wide effects of agriculture on air quality and health: Evidence from Europe. *Science of the Total Environment*, 663, 889-900.

economic sectors has been carried out on the basis of information obtained from a literature review[9,10] as well as based on experience from our earlier application of such studies for Cyprus. It is noted that the investment costs consist of the capital and operation and maintenance cost. As mentioned above, to measure more accurately the impact of investments in the economy investments for each sector are divided into local investments and imports.

3.1.3 Results

Table 26 presents the economy-wide effects in terms of generated economic output and employment created by the investments under the two scenarios. The investments in the PPM scenario results in an annual increase of the economic output of the country ranging between 0.15% and 0.40% higher compared to the annual increase due to the investments under the WEM scenario for the period 2020-2030. Similarly, investments in the PPM scenario results in an annual increase of national employment ranging between 0.14% and 0.43% higher compared to the annual increase due to the investments under the WEM scenario for the same period. Specifically, in 2030, the economic output and employment of the country under the PPM scenario will be higher by 0.39% and 0.40%, respectively, compared to the respective figures of year 2030 under the WEM Scenario.

The estimated macro-economic effects associated with the Planned Policies and Measures are relatively higher during the last years of the study period, i.e., from 2027 to 2030. The notable change in 2027 is attributed to the increased capital and operational investments for the Transportation and Construction sectors, i.e., the sectors with the highest output multipliers in the economy of Cyprus. This change is mainly due to the large investments foreseen in the PPM scenario in the road transport sector, with substantial investments in new buses, the Nicosia tramline and other interventions for sustainable urban mobility. Thus, the increase in the final demand for products and services of those sectors through demand for investments, generate indirect growth effects to the other sectors of the economy (e.g., Machinery and Equipment, Banking-Financing, Real Estate, Accommodation and Food Services and others).

[9] Tourkolias, C., Mirasgedis, S., Damigos, D. and Diakoulaki, D. (2009), Employment benefits of electricity generation: A comparative assessment of lignite and natural gas power plants in Greece. *Energy Policy* 37(10), 4155-4166.

[10] Markaki, M., Belegri-Roboli, A., Michaelides, P., Mirasgedis, S. and Lalas, D.P. (2013), The impact of clean energy investments on the Greek economy: An input–output analysis (2010–2020). *Energy Policy* 57, 263-275.

Table 24 - Annual spending associated with investments and private consumption under the WEM Scenario by sector of economic activity for the period 2020-2030 (in million Euros'2016).

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	1.1	1.5	1.9	2.3	2.7	3.1	3.6	3.6	3.7	3.8
Forestry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mining	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Food Manufacturing	3.6	4.9	6.2	7.6	9.0	10.4	11.9	12.0	12.2	12.6
Textile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood and Paper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chemical and Plastic Products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Metal Products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Machinery and Equipment	14.9	14.1	13.7	12.8	12.4	12.1	12.5	12.6	12.8	12.8
Energy	475.5	498.3	516.8	532.0	545.4	566.2	586.4	603.3	625.0	637.4
Construction	88.8	106.1	119.3	135.9	150.6	165.7	188.0	190.0	194.9	195.3
Trade	62.4	75.7	89.3	102.6	116.0	129.9	143.8	145.5	148.5	151.7
Accommodation and Food Services	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.5	1.6	1.5
Transportation	10.0	11.2	12.4	14.3	15.5	16.8	18.0	18.2	19.3	18.0
Banking-Financing	21.2	25.0	28.5	32.1	35.7	39.4	43.5	44.0	44.9	45.8
Real Estate	9.9	11.6	12.1	13.7	14.5	15.4	17.2	17.4	17.8	17.6
Public Administration	4.9	5.8	6.7	7.8	8.7	9.7	10.7	10.8	11.0	11.2
Education	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Health	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 25 - Annual spending associated with investments and private consumption under the PPM Scenario by sector of economic activity for the period 2020-2030 (in million Euros'2016).

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	1.1	1.4	1.7	2.0	2.3	2.7	3.1	3.1	3.1	3.1
Forestry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mining	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Food Manufacturing	3.5	4.5	5.6	6.7	7.8	8.9	10.4	10.4	10.4	10.4
Textile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood and Paper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chemical and Plastic products	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.2
Metal Products	4.0	4.0	4.0	4.0	4.1	4.1	4.1	4.1	4.1	4.1
Machinery and Equipment	17.3	16.6	16.4	17.5	17.4	17.3	17.0	17.2	17.0	16.8
Energy	473.3	493.7	510.9	523.2	533.4	551.0	568.9	584.3	604.2	616.1
Construction	131.0	151.4	167.7	180.9	196.6	213.4	246.3	271.4	289.1	292.8
Trade	62.0	73.1	84.3	95.5	106.6	118.4	132.6	136.3	137.6	137.3
Accommodation and Food services	1.2	1.3	1.5	1.7	1.8	2.0	2.2	2.5	2.7	2.6
Transportation	13.0	16.3	19.8	23.0	26.3	29.8	33.4	40.9	44.8	43.9
Banking-Financing	20.3	23.7	26.8	29.8	32.9	36.1	40.8	43.4	44.5	44.7
Real Estate	10.7	13.1	14.3	15.5	16.6	17.7	21.2	24.6	27.1	27.8
Public Administration	4.8	5.7	6.4	7.1	7.9	8.7	9.9	10.4	10.7	10.9
Education	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Health	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 26 - Annual total economic output (in million Euros'2016) and annual total employment (in thousand persons) associated with the investments under both scenarios for the period 2020-2030.

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total Economic Output										
With Existing Measures	59,038	60,610	62,119	63,553	64,916	66,380	67,944	69,464	71,037	72,514
With Planned Policies and Measures	59,199	60,766	62,264	63,671	65,018	66,479	68,079	69,699	71,324	72,798
Difference between Scenarios	0.27%	0.26%	0.23%	0.19%	0.16%	0.15%	0.20%	0.34%	0.40%	0.39%
Total Employment										
With Existing Measures	477,810	490,408	502,484	513,952	524,825	536,458	548,936	560,590	572,776	584,814
With Planned Policies and Measures	479,291	491,775	503,712	514,880	525,606	537,198	550,065	562,659	575,243	587,167
Difference between Scenarios	0.31%	0.28%	0.24%	0.18%	0.15%	0.14%	0.21%	0.37%	0.43%	0.40%

Note: Total economic output includes both intermediate and final demand and is hence higher than GDP which includes final demand only.

Table 27 presents the sectoral distribution of the generated economic output in the Cypriot economy in 2030 associated with the investments under the two scenarios. Evidently, the economic sectors that mainly benefit in the PPM scenario are: (a) Construction, (b) Metal products, (c) Wood and paper, (d) Transportation, and (e) Chemical and plastic products. The highest negative effects are observed in the economic output of the energy sector due to the reduced energy demand attributed to the implementation of energy efficiency measures in the PPM scenario. In the rest of the economy, there is a notable increase in the metal products output of the PPM scenario due to their use in the energy efficiency measures adopted in the PPM scenario, and an even larger increase in investments in construction. The construction sector has a strong local character and is skewed by large-scale investments, as the ones found in the PPM scenario, notably in new transport, energy and electricity interconnection infrastructure.

The differences are overall quite small however, without a single sector showing disproportionately large changes compared to the others. A minor negative effect in the economic output of traditional activities of the economy such as agriculture is created, principally due to lower numbers of biofuels diverted towards additives for diesel, which is forecasted to be used in larger quantities in the WEM scenario.

It is important noting that the above analysis is bound by the use of I/O as a tool for investigating the distribution of investments cross-sectorally. The IO model does not allow for the simulation of fiscal effects, which may be important in this case since the measures in the PPM scenario assume large public investments in public transport infrastructure, and associated reductions in private investments in private vehicles. This alone could have a large effect on the government budget, but it is not captured in this model.

Table 27 - Change in economic output by main sector of the national economy of Cyprus in 2030 due to investments in the PPM scenario, in comparison to the WEM scenario.

Sectors of economic activity	2030
Agriculture	-0.08%
Forestry	0.00%
Mining	0.30%
Food Manufacturing	-0.06%
Textile	0.04%
Wood and Paper	0.73%
Chemical and Plastic Products	0.43%
Metal Products	1.50%
Machinery and Equipment	0.12%
Energy	-1.17%
Construction	2.65%
Trade	-0.20%
Accommodation and Food Services	0.07%
Transportation	0.65%
Banking-Financing	0.35%
Real Estate	0.35%
Public Administration	0.06%
Education	0.01%
Health	0.00%
Other Services	0.21%

3.2 Socio-economic impacts

The implementation of strong energy and climate policies typically leads to changes in the relative prices of energy commodities in comparison to a ‘business as usual’ price trajectory. These price changes in turn affect the cost of living of households in different ways. This section focuses on analysing the distributional effects induced by policies of the Planned Policies and Measures Scenario in comparison to the Existing Policies and Measures Scenario; this involves an assessment of how much Cypriot households of different income, location (urban and non-urban areas) and demographic characteristics are affected by the changes in prices of electricity and fuels due to the implementation of the PPM scenario.

3.2.1 Expenditures of Cypriot households on energy goods

A main concern with energy and environmental policies is that they may have a disproportionate effect on the most vulnerable parts of society by raising energy prices. Expenditures for energy goods are generally found to be regressive, i.e. low-income households spend a higher fraction of their income on these goods than high-income households. Despite this widespread belief, regressivity of energy expenditures is not always the case. Table 28 shows the annual expenditures of Cypriot households on main energy items (electricity, heating fuels and transport fuels), both in absolute terms and as a fraction of their annual income. This information comes from the Household Expenditure Survey conducted by the Statistical Service of Cyprus on a representative sample of 2,700 households in year 2009.

According to the information of Table 28, Cypriot households used to spend on average about 3,000 Euros per year on fuels and electricity or 7.3% of their income; poorest households spent less than 1,000 Euros (9.2% of their income) while richest ones close to 5,000 Euros per year (4.9% of their income). This means that overall the expenditures on energy goods are indeed regressive. Half of these expenditures are for transport fuels on average, but the distribution among income groups is quite different: the poorest spend more on electricity and the rich spend more on automotive fuels. Overall, regressivity is strongest in the case of electricity, where poor households spend (as a fraction of their income) more than double than rich households do. This means that a change in the prices of electricity has a greater distributional effect than a change in the prices of other energy commodities.

It has to be noted that these observations are based on the survey of the statistical Service of Cyprus of the year 2009. Data from a more recent survey have not been fully analysed yet; if available before the end of the project they will be incorporated in the final version of the Impact Assessment.

Table 28 - Annual expenditure of Cypriot households on energy goods in year 2009.

	Expenditures in Euros'2015 for:			
Income Group	**Electricity**	**Heating Fuels (oil, LPG, biomass)**	**Transport Fuels (gasoline, diesel)**	**All Energy Goods**
Poorest 10%	416	155	386	957
10%-20%	628	223	689	1540
20%-30%	717	224	1075	2016
30%-40%	839	244	1242	2324
40%-50%	1043	335	1464	2843
50%-60%	1177	350	1667	3194
60%-70%	1349	471	1830	3650
70%-80%	1458	538	2199	4195
80%-90%	1537	513	2140	4190
Richest 10%	1661	840	2377	4878
All households	**1088**	**390**	**1516**	**2994**

	Expenditures as % of annual income for:			
Income Group	**Electricity**	**Heating Fuels (oil. LPG. biomass)**	**Transport Fuels (gasoline. diesel)**	**All Energy Goods**
Poorest 10%	4.0%	1.5%	3.7%	9.2%
10%-20%	3.9%	1.4%	4.3%	9.6%
20%-30%	3.4%	1.1%	5.2%	9.7%
30%-40%	3.2%	0.9%	4.7%	8.8%
40%-50%	3.2%	1.0%	4.6%	8.8%
50%-60%	3.0%	0.9%	4.3%	8.2%
60%-70%	3.0%	1.0%	4.1%	8.1%
70%-80%	2.8%	1.0%	4.2%	7.9%
80%-90%	2.4%	0.8%	3.3%	6.4%
Richest 10%	1.7%	0.8%	2.4%	4.9%
All households	**2.7%**	**1.0%**	**3.7%**	**7.3%**

Source: Household Expenditure Survey 2009 of the Statistical Service of Cyprus; data analysed by Economics Research Centre, University of Cyprus.

3.2.2 Changes in energy prices between WEM and PPM scenarios

Table 29 and Table 30 present the projected evolution of prices of fuels and electricity respectively, according to the WEM and PPM scenarios of the NECP. In the absence of other policies (e.g. change in energy taxation) that could affect energy prices, changes between the two scenarios can be foreseen only in the retail prices of electricity and automotive fuels, while prices of other fuels used for heating or in industry are not affected.

In the case of electricity, changes in power generation costs will be the composite result of various differences between the WEM and PPM scenarios as explained in Chapter 2 – mainly due to the higher penetration of renewables and the existence of electricity interconnection towards the end of the decade. As a result, electricity costs are expected to be 5.2% lower in the PPM scenario in 2030. Taking into account other fixed costs of power generation, this decrease in generation costs is estimated to lead to a drop in consumer prices of electricity of about 4% by 2030.

In the case of automotive fuels, the change in prices is due to the assumption that the 2030 renewable energy target obligation in the transport sector is achieved in the PPM scenario. This leads to additional blending of automotive gasoline and diesel with (more costly) second generation bioethanol and biodiesel respectively in this scenario, thereby increasing the retail prices of gasoline and diesel by 1.3% and 1.9% respectively in 2030, or by 1.5% as a weighted average of the increases in total automotive fuel expenditure of Cypriot households.

If households were not able to react to these price changes, it would be possible to compute the change in the cost of living of each income group by multiplying the percentage change in prices of Table 29 and Table 30 by the corresponding expenditures of Table 28. However, in reality households adjust their consumption and their expenditures after a price change according to their preferences. The way each household reacts depends on different socio-demographic characteristics and on each household's consumption pattern. Therefore, detailed modelling of consumer behaviour is necessary, and the modelling approach that was adopted in our study is briefly explained in the next section.

Table 29 - Projected evolution of electricity generation costs in the WEM and PPM scenarios.

Existing Policies and Measures Scenario

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Average electricity cost (EUR2016/MWh)	97.8	86.3	88.7	91.2	93.9	95.3	98.3	99.1	99.8	100.9
Annual growth rate	-8.7%	-11.8%	2.8%	2.9%	3.0%	1.5%	3.2%	0.8%	0.8%	1.0%
Rate of change as compared to 2018	6.1%	-6.4%	-3.8%	-1.1%	1.9%	3.3%	6.6%	7.5%	8.3%	9.4%

Planned Policies and Measures Scenario

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Average electricity cost (EUR2016/MWh)	97.8	86.7	89.1	81.2	89.4	89.8	96.3	95.8	96.4	95.6
Annual growth rate	-8.7%	-11.4%	2.8%	-8.9%	10.1%	0.5%	7.2%	-0.6%	0.6%	-0.8%
Rate of change as compared to 2018	6.1%	-6.0%	-3.3%	-11.9%	-3.1%	-2.6%	4.5%	3.9%	4.5%	3.7%

Difference (Planned - Existing Policies and Measures)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Average electricity cost	0.0%	0.5%	0.5%	-11.0%	-4.8%	-5.7%	-2.0%	-3.3%	-3.4%	**-5.2%**
Retail electricity price (estimated)										**-4.0%**

Table 30 - Projected evolution of automotive fuel prices in the WEM and PPM scenarios. Excise taxes are included; 19% Value Added Tax not included.

Existing Policies and Measures Scenario

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Blended Gasoline Price (EUR2016/GJ)	41.9	43.1	44.3	45.6	47.0	47.3	47.6	47.9	48.2	48.5
Annual growth rate	6.4%	2.8%	2.9%	2.9%	3.0%	0.6%	0.6%	0.6%	0.6%	0.6%
Rate of change as compared to 2018	10.8%	14.0%	17.2%	20.6%	24.2%	25.0%	25.8%	26.6%	27.4%	28.2%
Blended Diesel Price (EUR2016/GJ)	37.3	38.4	39.5	40.7	42.0	42.2	42.5	42.8	43.1	43.4
Annual growth rate	2.8%	2.9%	2.9%	2.9%	3.1%	0.7%	0.7%	0.6%	0.6%	0.6%
Rate of change as compared to 2018	6.9%	10.0%	13.2%	16.6%	20.2%	21.0%	21.8%	22.6%	23.4%	24.1%

Planned Policies and Measures Scenario

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Blended Gasoline Price (EUR2016/GJ)	41.9	43.1	44.3	45.6	47.0	47.3	47.6	47.9	48.2	49.1
Annual growth rate	6.4%	2.8%	2.9%	2.9%	3.0%	0.6%	0.6%	0.6%	0.6%	1.9%
Rate of change as compared to 2018	10.8%	14.0%	17.2%	20.6%	24.2%	25.0%	25.8%	26.6%	27.4%	29.9%
Blended Diesel Price (EUR2016/GJ)	37.3	38.4	39.5	40.7	42.0	42.2	42.5	42.8	43.1	43.4
Annual growth rate	2.8%	2.9%	2.9%	2.9%	3.1%	0.7%	0.7%	0.6%	0.6%	2.5%
Rate of change as compared to 2018	6.9%	10.0%	13.2%	16.6%	20.2%	21.0%	21.8%	22.6%	23.4%	26.5%

Difference (Planned - Existing Policies and Measures)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Blended Gasoline Price	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**1.3%**
Blended Diesel Price	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**1.9%**

3.2.3 Modelling approach

Household demand for energy and the subsequent distributional effect of energy efficiency or renewable energy policies has been analysed in several countries. These studies rely, inter alia, on data from household expenditure surveys conducted annually by national statistical agencies; this enables the empirical estimation of detailed income and substitution patterns. However, in some countries (Cyprus being one of them) household expenditure surveys are conducted less frequently. This poses problems to performing empirical demand analysis, as price variation over time is limited. To overcome this problem, an alternative approach was developed and applied with data from Cypriot households by Pashardes et al.[11]. This approach is based on the fact that price changes differ across goods, hence their effect can vary between households due to preference heterogeneity. For example, vegetarians are not affected by changes in the price of meat; therefore, when the only item in the food basket that increases in price is meat, only meat eaters face an increase in the unit cost of food.

In the case of energy, the unit cost is made from the prices of items such as electricity, gasoline, gas, heating oil, solid fuels and renewable sources. To the extent that these items do not increase proportionately in price and their shares in consumption vary across households due to preference heterogeneity, then the unit cost of energy also varies across households. Similar to the vegetarian example mentioned above, households without a car are not affected by a change in automotive fuel prices, whereas multi-car households may see a considerable increase in their cost of living if fuel prices rise.

Thus, Pashardes et al. constructed a consumer theory based measure of the unit cost of composite goods commonly used for empirical demand analysis, and used the variation in this cost across households to estimate a demand system from a limited household expenditure surveys. They applied the method to estimate the price elasticity of household demand for energy in the context of an integrable complete demand system using data drawn from three household expenditure surveys conducted in Cyprus in 1996, 2003 and 2009 by the Statistical Service of Cyprus. Then they simulated the welfare effects of price increases assumed to result from the adoption of EU's 2020 energy and climate package on households grouped by income, location and demographic characteristics.

We use the same model in this study, simulating the effect of the price changes in electricity and automotive fuel mentioned in section 3.2.2 for the year 2030, in order to explore the welfare impact of the PPM scenario as compared to the 'business as usual' evolution foreseen in the WEM scenario.

3.2.4 Simulation of welfare impacts

Based on the relative weight of expenditures on different energy goods (last row of Table 28), and on the outcome of Table 29 and Table 30 that the PPM scenario foresees changes in consumer prices of -4%, 1.5% and 0% for electricity, transport fuels and heating fuels respectively compared to the WEM scenario, the weighted average of the change in all energy goods is about -0.7%. This means that the PPM scenario will have a slightly positive effect (i.e. a decrease) on the cost of living of Cypriot households up to 2030. It may lead to some reallocation of expenditures from electricity (which becomes cheaper) to transport fuels (which become somewhat more expensive), but the net impact will be small. It may also have a positive distributional effect albeit very small: households in the low-income deciles may experience an increase in their purchasing power of the order of 10-20 Euros'2015 per year, or about 0.05% of their income, accompanied by a corresponding reduction in the purchasing power of high-income groups. Obviously these changes are too low to be considered substantial.

There is one caveat to this assessment: electricity becomes cheaper in the PPM scenario (and leads to the zero-cost-of-living-change mentioned above) thanks to the electricity interconnection of Cyprus

[11] Pashardes P., Pashourtidou N. and Zachariadis T., Estimating welfare aspects of changes in energy prices from preference heterogeneity. *Energy Economics* 42 (2014), 58–66.

with neighbouring countries. However, by the time of this writing (October 2019) it is not entirely clear how the interconnection project will be financed on behalf of the Republic of Cyprus. Based on some preliminary information provided to the project team, the PPM scenario already assumes an extra charge on electricity tariffs that would help finance a part of the interconnection project. In order to be more conservative, we can further assume (without further modelling) that the additional charge to electricity consumers will be even higher, and would be comparable to the price reduction foreseen in the PPM scenario. In such a case, one could assume that the electricity price does not change between the WEM and PPM scenarios, and the only additional change is the 1.5% increase in automotive fuel prices.

Even under this assumption, the changes in household welfare are expected to be very small. This becomes evident if one observes the results of the welfare simulations shown in Tables 4, 5 and 6 of Pashardes et al., keeping in mind that the effects of that study were simulated assuming a 7.6% increase in the composite cost of all energy goods by 2020[12], whereas we assume here an increase of less than 1% in total energy costs in 2030. In our case, by 2030, total welfare costs are expected to be around 0.05% of the income of poorer households or about 10-20 Euros'2015 per year, and correspondingly the welfare costs of richer households may amount to 15-30 Euros'2015 per year or 0.03-0.04% of their annual income. Rural households, which spend about 10% on average more on transport fuels, may experience a slightly higher cost than urban households (at the upper end of the range mentioned above), but all costs and welfare losses are projected to lie at very low levels.

To summarise, the implementation of the PPM scenario is not expected to cause any substantial costs or benefits to households nor affect the distribution of income or poverty levels in the Cypriot society. Despite the considerable investments required and emission reductions achieved in the PPM scenario, as described in other sections of this Impact Assessment, there will be essentially no impact on energy affordability and social equity is projected to be negligible.

3.3 Employment impacts

3.3.1 Additional human resources in renewable power generation

Investments in renewable energy technologies could have substantial local economy benefits in terms of job creation. Based on the results described in Chapter 3 of this report and on average figures provided through a relevant IRENA report[13], a quantification of the employment potential is conducted for utility-scale PV installations in each scenario (Table 31).

Table 31 – Human resource requirements (person days) for different stages of utility-scale solar PV investments in each scenario (2020-2030).

	WEM scenario (358 MW)	**PPM scenario (1,288 MW)**
Planning (e.g environmental, health and safety legal, real estate and taxation experts)	15,179	54,611
Manufacture (e.g. factory workers, industrial engineers, logistics experts)	360,000	1,293,796
Installation and Connection (e.g civil, electrical and mechanical engineers, construction workers, technical personnel)	281,961	1,014,429
Operation and Maintenance (e.g. operators, energy regulation, electrical and telecommunication experts, accountants)	97,090/year 1,941,800 over 20 years	349,306/year 6,986,120 over 20 years

[12] See Pashardes et al. (*Energy Economics* 42 (2014)), end of page 63.

[13] IRENA, "Renewable Energy Benefits: Leveraging Local Capacity for Solar PV" (Abu Dhabi: International Renewable Energy Agency, 2017), https://www.irena.org/publications/2017/Jun/Renewable-Energy-Benefits-Leveraging-Local-Capacity-for-Solar-PV.

Decommissioning (e.g. construction workers, truck drivers, environmental, safety and logistic experts)	36,874	132,664
Total	**2,635,814**	**9,481,620**

Assuming 220 working days in a year, and a total project lifetime of 20 years, the above totals are equivalent to 599 permanent employment positions for the WEM scenario, and 2,155 positions for the PPM scenario. These figures are broadly in line with the findings of increased employment found though the IO macroeconomic analysis in paragraph 3.1.3.

In the case of wind installations, these are limited to 17.5 MW in both scenarios. As such when IRENA's average estimates in regards to human resource requirements for onshore wind[14] are employed, the employment potential is significantly lower than for solar PV (Table 32). Again, the total new positions for wind is equivalent to 10.4, using the assumption of the previous paragraph.

Table 32 – Human resource requirements (person days) for different stages of wind investments (2020-2030).

	Existing and PPM scenarios (17.5 MW installed capacity)
Planning (e.g environmental, health and safety legal, real estate and taxation experts)	903
Manufacture (e.g. factory workers, industrial engineers, logistics experts)	6,638
Installation and Connection (e.g civil, electrical and mechanical engineers, construction workers, technical personnel)	12,068
Operation and Maintenance (e.g. operators, energy regulation, electrical and telecommunication experts, accountants)	933/year 23,325 over 25 years
Decommissioning (e.g. construction workers, truck drivers, environmental, safety and logistic experts)	2,947
Total	**45,881**

It should be noted that the above estimates refer to gross additions in human resources; in other words, they assess the additional employment in renewable power generation but do not take into account the fact that reduced investments in other sectors (e.g. fossil fuelled power plants or petrol stations) may lead to elimination of jobs in those sectors. The following sections provide more information on this topic. Furthermore, since wind and solar PV equipment is primarily imported, aspects such as the manufacture of the components may not have an impact in the local economy.

3.3.2 Net employment impacts: The international evidence

As outlined in Chapter 2 and will be further elaborated in Chapter 4 of this report, the scenario with PPM involves substantial additional investments in renewable power generation, energy efficiency in buildings and public transport, accompanied by reductions in the investments in fossil fuel power plants and conventional motor vehicles in comparison to the scenario with WEM.

As 'green sectors' account for a significant fraction of jobs in Europe and worldwide, there has been a growing interest in assessing the employment impact of the energy transition. According to a review of available studies conducted by the UK Energy Research Centre[15], the renewable energy and energy

[14] IRENA, "Renewable Energy Benefits: Leveraging Local Capacity for Onshore Wind" (Abu Dhabi: International Renewable Energy Agency, 2017), https://www.irena.org/publications/2017/Jun/Renewable-Energy-Benefits-Leveraging-Local-Capacity-for-Onshore-Wind.

[15] UK Energy Research Centre (2014), Low Carbon Jobs: the Evidence for Net Job Creation from Policy Support for Energy Efficiency and Renewable Energy, UKERC Technology & Policy Assessment Function, London, UK.

efficiency sectors are clearly more labour-intensive than the sectors related to fossil fuel power generation, both in terms of short-term construction phase jobs and in terms of average plant lifetime jobs. On average, 0.35 jobs are created per annual GWh of renewable energy generated or per energy saved thanks to an energy efficiency measure, compared to 0.2 jobs per annual GWh for fossil fuelled power plants.

When using such data, however, one should be cautious because it is not always clear i) whether such figures always express a net growth in jobs (i.e. jobs created minus jobs eliminated in other economic sectors); ii) whether this is a long-lasting effect or is meaningful only for the short to medium term; and iii) to what extent this effect is different if an economy is close to reaching full employment levels.

Other studies in European countries have found that the adoption of renewable energy and energy efficiency policies yield net employment effects ranging from neutral (i.e. close to zero) to slightly positive (i.e. increase in employment)[16,17]. The European Commission's impact assessment related to its declaration of the intention to reach net carbon neutrality by 2050 contains, apart from modelling results, an extensive review of the available literature on employment impacts of green policies in Europe[18]. There seems to be a consensus that the transition towards more renewable energy and energy efficiency is unlikely to lead to negative aggregate effects on employment at both national and EU-wide level. What is particularly important in the assessment of the employment impact is how the additional green investments are financed, e.g. through public or private investments, taxes, subsidies etc.

According to the UK Energy Research Centre, investment in renewables and energy efficiency can contribute to short-term job creation so long as the economy is experiencing an output gap, such as is the case during and shortly after recession. In the long term, if the economy is expected to return to full employment, 'job creation' is not as important as overall economic efficiency, taking into account environmental externalities, the desired structure of the economy, and the dynamics of technology development pathways. "In other words, the proper domain for the debate about the long-term role of renewable energy and energy efficiency is the wider framework of energy and environmental policy, not a narrow analysis of green job impacts".

3.3.3 Overall assessment of the net employment impacts in Cyprus

In the case of Cyprus, one can express with reasonable confidence the conclusion that the risk of reducing country-wide employment from the implementation of the PPM scenario is very low. This is based on:

- Results from the economic modelling reported in Section 3.1, which indicate a slight increase in net employment (2,353 new positions in 2030 between the two scenarios, see Table 26);
- The international evidence mentioned above about positive employment effects of green policies;
- The fact that the number of employees in the fossil fuel sector (power plants, oil companies etc.) is relatively limited. On the contrary, it should be expected that a significant number of additional jobs may be created to enable deployment of energy efficiency and renewable

[16] Pestel N. (2014), Employment effects of green energy policies. IZA World of Labor 2014: 76; doi: 10.15185/izawol.76.

[17] Meyer I. and Sommer M.W. (2014), Employment Effects of Renewable Energy Supply – A Meta Analysis. WWWforEurope Policy Paper No. 12.

[18] See especially Section 4.10.6 in European Commission's "In-Depth Analysis in Support of the Commission Communication COM(2018) 773 - A Clean Planet for all", Brussels, 28 November 2018.

energy measures because of the substantial shift of investment towards these sectors up to 2030.

At any rate, the implementation of the PPM scenario in Cyprus is very likely to yield positive employment impacts, at least in the short to medium term. **These are expected to be stronger if the measures assumed in the scenario are implemented without reducing the purchasing power of Cypriot households and without absorbing a large amount of national public funds**. Public investments that can be supported from the EU budget and private investments that may be facilitated through financing instruments of the European Investment Bank or Cypriot banks may be particularly beneficial in this regard.

3.4 Environmental and health impacts

As shown in Sections 2.1.6 and 2.2.6 of this report, implementation of the PPM scenario leads to considerable reductions in the emissions of air pollutants which cause health effects. Table 33 uses information from Table 10 and Table 19 and shows the relative change in emissions of the three main air pollutants in the year 2030, compared to those of the WEM scenario. The decrease in PM emissions by 6.8% is due to a lower use of biomass in the Heating and Cooling sector, as well as to lower fossil fuel consumption in road transport. NOx emissions are lower in the PPM scenario by 4.3% due to a lower gas-fired generation, as well as a lower dependence on gasoline and diesel passenger cars. The strongest drop is expected in SO_2 emissions (38.5%), thanks to the significantly higher share of renewable power generation in the PPM scenario, which also completely displaces the small amounts of oil-fired generation observed in the WEM scenario. Electrification of road vehicles also contributes to the fall of SO_2 emissions.

The health effects of the main air pollutants are well documented in the literature, and there is a growing number of assessments about the actual impacts to human health due to exposure of people to high levels of ambient concentrations of certain air pollutants. The impacts are usually expressed in premature deaths and in years of life lost. Premature deaths are deaths that occur before a person reaches an expected age. This expected age is typically the life expectancy for a country stratified by sex. Years of life lost (YLL) are defined as the years of potential life lost due to premature death. It is an estimate of the average number of years that a person would have lived if he or she had not died prematurely[19].

According to the European Environment Agency, exposure of Cypriot population to high levels of ambient concentrations of PM, NO_2 and ozone gave rise to about 580, 240 and 30 premature deaths per year respectively in year 2016[20]. Emission reductions shown in Table 33 for the PPM scenario will lead to an improvement in air quality, especially in cities, and thus to a decrease in premature deaths and years of life lost. It has to be noted that there is no direct relationship between emissions and ambient air concentrations, and a part of air pollution is due to transport of air pollutants from other countries. These two facts underline that it is not straightforward to assess the change in health impacts from the reduction of national air emissions alone. Still, one can reasonably estimate that under the PPM scenario, the number of premature deaths caused by emissions of PM and NOx may decrease by about 30 per year.

Exposure to SO_2 concentrations has decreased over the past few decades in Europe. Since 2007, the exposure of the urban population to concentrations above the EU daily limit value has remained under

[19] European Environment Agency (2018), Assessing the risks to health from air pollution. https://www.eea.europa.eu/themes/air/health-impacts-of-air-pollution/assessing-the-risks-to-health

[20] European Environment Agency (2019), Air quality in Europe – 2019 report. EEA Report No. 10/2019, Copenhagen. doi: 10.2800/822355.

0.5%. Therefore, seriously adverse impacts on human health are expected to be very few. However, SO_2 emissions are still regulated at EU level because of the role of this substance to corrosion in buildings and acidification of soils causing loss of biodiversity. Under the Directive (EU) 2016/2284 on the Reduction of National Emissions of Certain Atmospheric Pollutants, Cyprus is committed to reducing its national SO2 emissions (compared to those of year 2005) by 83% by 2029 and by 93% from 2030 onwards. Implementation of the PPM scenario will not lead to full compliance with these targets but will contribute towards compliance. Similarly, it will help Cyprus achieve the corresponding obligations about the emissions of NOX and $PM_{2.5}$. All these are side-benefits of the decarbonisation policy.

The health benefits mentioned above can also be expressed in monetary terms by using assessments of the external cost of each pollutant; this is the sum of the economic damage caused per tonne of pollutant emitted to the atmosphere on human health, crops, materials and biodiversity – although damages related to human health dominate. For assessing the cost of NOx, PM and SO_2 emissions, calculations of European studies were used: results from the CASES project[21] for emissions from power plants, and from Ricardo-AEA[22] for road transport emissions. All values were transformed to constant Euros per tonne of pollutant. As explained elsewhere[23], these damage costs increase over the years, so that a variable external cost is used per year. The last column of Table 33 contains an estimate of the reduction in damage costs thanks to the reductions in pollutant emissions in the PPM scenario; overall the economic benefit due to reduced air pollution of the PPM scenario exceed 23 million Euros'2016 in 2030; as a total over the whole decade 2020-2030 the benefit exceeds 60 million Euros'2016. Benefits are strongest from the reduction in PM emissions because these have the most adverse health impacts and hence the highest damage costs per tonne[24].

Table 33 – Reduction in emissions of air pollutants in the PPM scenario compared with the WEM scenario, and avoided damage costs in year 2030 thanks to these reductions.

Pollutant	**Change in emissions in 2030**	**Avoided damage costs in 2030 (mio Euros'2016)**
NO_x	-4.3%	3.2
PM	-6.8%	14.0
SO_2	-38.5%	6.3
Total benefit		23.5

[21] FEEM (2008), CASES (Cost Assessment for Sustainable Energy systems) – Final Conference Proceedings and External Costs Database. 2008.

[22] Ricardo-AEA (2014), Update of the Handbook on External Costs of Transport. Report for the European Commission's Directorate General for Mobility and Transport.

[23] Sotiriou C. and Zachariadis T., Optimal Timing of Greenhouse Gas Emissions Abatement in Europe. *Energies* 12 (2019), 1872; doi:10.3390/en12101872.

[24] As explained, the damage cost varies over the years; for the year 2030, based on the literature cited in the text, the assumed marginal damage costs per tonne of NOx, PM and SO2 were 9,006, 140,000 and 17,122 Euros'2016 respectively.

4 Investment Needs

4.1 Financial Implications of WEM scenario in the Electricity Supply Sector

Investments foreseen in power generation will significantly affect electricity costs in total. Thus, due to the considerable investments in the electricity supply sector, the average cost of gross electricity generation increases gradually during the modelling period. Undeniably, this is a function of the assumed fuel price and technology costs adopted in the model. Figure 6 provides a breakdown of the different system cost components; these are all undiscounted[25]. As illustrated, a reduction in cost is achieved when the system shifts fully towards gas-fired generation in 2021. It can be noticed that variable costs (i.e. fuel costs) are the main driver of the electricity cost till 2030. Regarding the actual investment costs, these are illustrated for each technology in Figure 7.

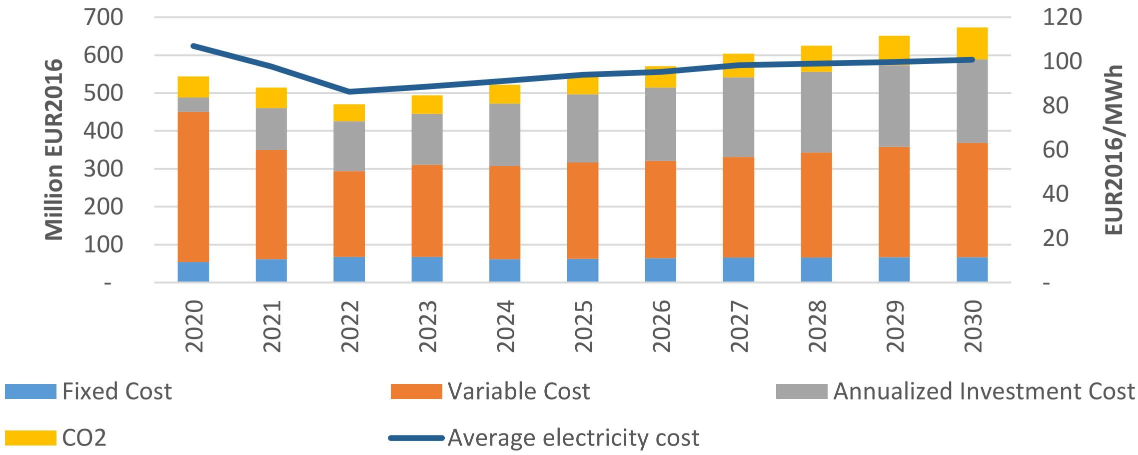

Figure 6 – Average cost of electricity and breakdown of system cost components – WEM scenario.

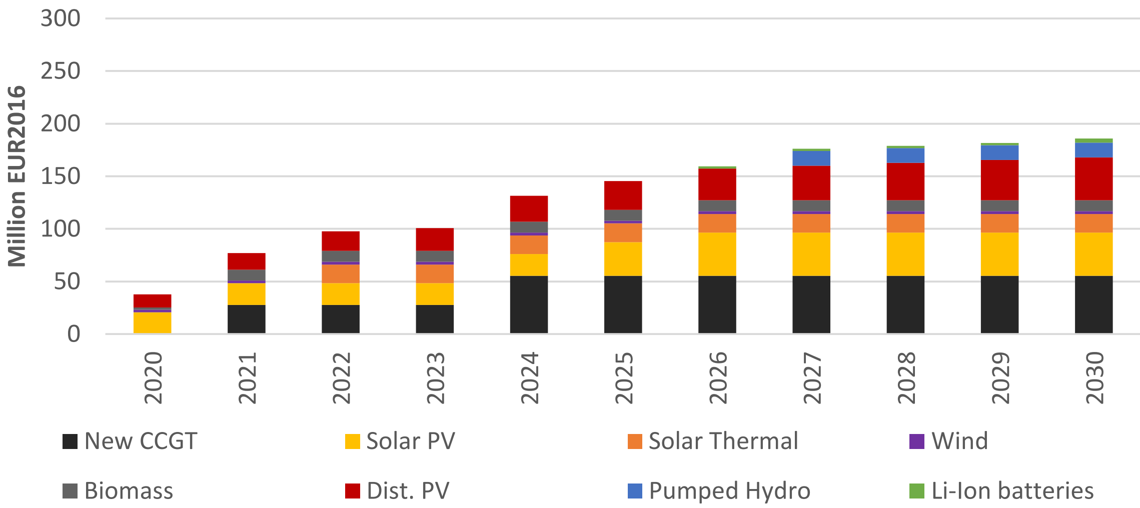

Figure 7 – Annualized investment costs in generation and storage technologies in the period 2020-2030 – WEM scenario.

4.2 Financial Implications of PPM scenario in the Electricity Supply Sector

Due to the higher RES penetration, and reduced dependence on fossil-fired generation, both enabled by the interconnector, the cost of electricity remains relatively stable throughout the model horizon

[25] Undiscounted costs are reported to avoid giving the wrongful impression that costs are expected to decrease dramatically with time. Taking into account that the discount rate adopted is 8.5% for most technologies in the electricity sector, if the cost were to be discounted to the first year, then the values after the first few years would be distorted (i.e. reduced) substantially.

in the PPM scenario (Figure 8). In comparison to the WEM scenario, electricity cost reduces by 5% in 2030. The reduction in cost is also driven by the lower investments in conventional thermal facilities and battery storage.

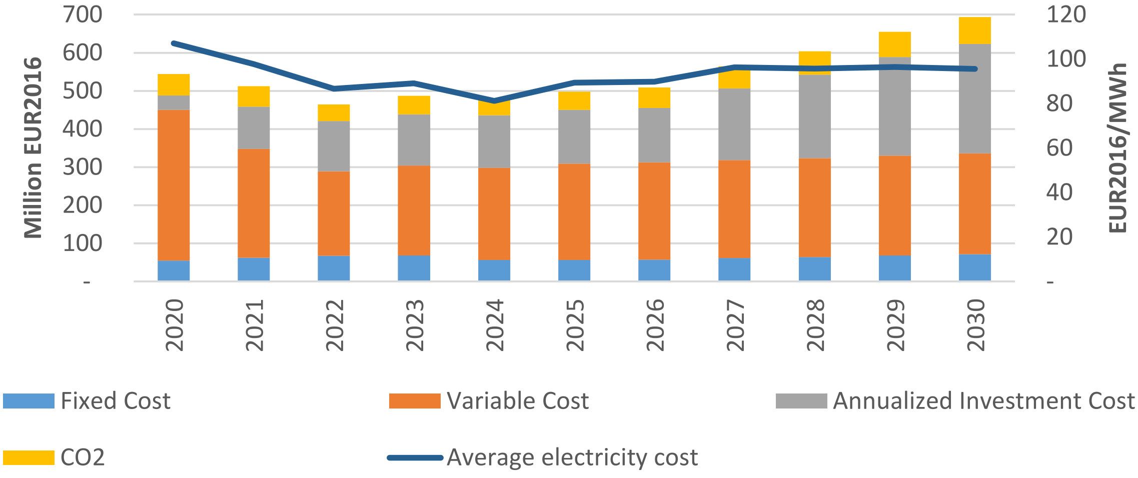

Figure 8 – Average cost of electricity and breakdown of system cost components – PPM scenario.

As compared to the WEM scenario, investment requirements in the electricity supply sector (which are presented in Figure 9) are considerably higher in the PPM scenario. These are mainly driven by higher utility-scale solar PV deployment; annualised investments in this technology amount to 130 million EUR in the latter case, as opposed to 40 million EUR in the former case in 2030.

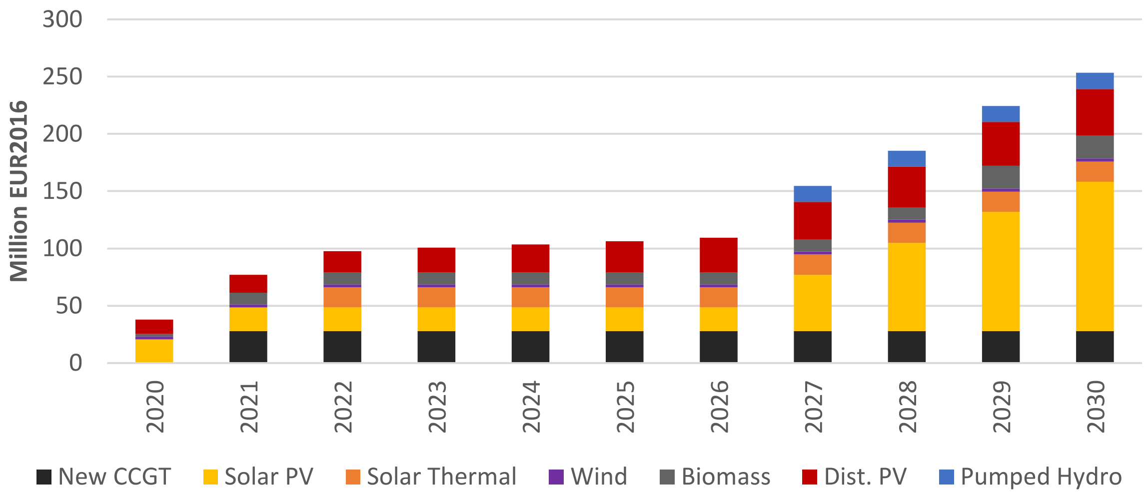

Figure 9 - Annualized investment costs in solar PV, solar thermal and storage technologies in the period 2020-2050 – PPM scenario.

4.3 Additional Economy-Wide Investment Needs in the PPM Scenario

In contrast to what is projected for electricity supply alone, the PPM Scenario foresees that the level of economy-wide investments needed up to 2030 to implement all these measures is lower than that of the WEM Scenario. Table 34 presents these estimated investment needs.

More specifically, the power generation and electricity storage sector needs fewer investments in the PPM Scenario because, as explained in Chapter 2, energy efficiency measures reduce the demand for electricity compared to WEM. The electricity interconnection, however, requires a substantial amount of investments; based on some preliminary information, we assume that the national contribution of Cyprus up to 2030 may amount to 118 million Euros. This is a low amount, but one has to keep in mind that a) three countries will be involved in financing the interconnector and b) the total investment cost for the interconnector will be much higher, but will extend to a much longer period in the future.

Enabling a significant modal shift towards sustainable modes of transport is an important ingredient of a serious decarbonisation policy, and this is reflected in the PPM Scenario. The purchase of new, clean buses and the construction of a tram line are costly measures, with investments expected to exceed 1.3 billion Euros'2016. However, these additional investment needs – which are expected to be covered by the national budget and perhaps partly through EU funds – are counterbalanced by the decline in purchases of new vehicles, which saves (mainly private) expenditures of about 2 billion Euros'2016 throughout the 2020-2030 period. These very substantial savings account for 15-20% of the annual purchase costs of new cars foreseen in the WEM Scenario.

Energy renovations in buildings of the residential and tertiary sector, if implemented actively up to an extent that is considered realistic in Cyprus, will require by the year 2030 additional investments of about 770 million Euros. This amount is expected to come from a combination of public and private investments and is the result of extensive data collection and discussions with MECI in the frame of previous Technical Assistance studies[26]; this amount is consistent with the level of achievable energy savings in households and services which have been calculated in the PPM scenario. Similarly, investments in industry to reach realistic energy savings foreseen in this scenario amount to 67 million Euros'2016 for the period 2020-2030.

In total, as shown in Table 34, implementation of the PPM is projected to lead to additional economy-wide investments for the period up to 2030 of 244 million Euros'2016 (or 1.3% of the GDP of year 2016) higher than those foreseen in the WEM Scenario. The main reason for the relatively low increase in investment needs, as explained above, is the substantial decline in the expenditures for new cars because of the significant shift towards public and non-motorised transport foreseen in this scenario. This counterbalances the amount of investments required for promoting public transport, cycling and walking through the implementation of Sustainable Urban Mobility Plans that the government of Cyprus is currently preparing. Even if the above mentioned decline in private car investments is considered ambitious and optimistic and one assumes lower reductions in the purchase of new cars, the additional investment needs are not expected to amount to more than 1.4 billion Euros'2016 for the entire period 2020-2030; these may account for about 5-6% of one year's GDP, but are still modest and entirely feasible for the Cypriot economy.

Out of the investments shown in Table 34, those for the electricity interconnector and private transport are expected to come from private sources, whereas those for sustainable transport modes are expected to come from public funds. As regards buildings and industry, it should be expected that about half of the amount of 837 million Euros will come from public funds in order to mobilise an equal amount of private funds for energy renovations and replacement of equipment, appliances and machinery. This is in line with the experience obtained by national authorities from the implementation of energy efficiency subsidy schemes during the last years. As a result, it should be expected that about 1.4 billion Euros for sustainable transport investments and about 400 million Euros for renovations in buildings and industrial plants will have to be funded from the government budget, or from EU funds. **In view of the substantial amount of funding needed, it is advisable that a considerable portion of this comes from EU funds such as the EU Structural Funds or loans from the European Investment Bank.**

[26] For a summary, see Zachariadis T., Michopoulos A., Vougiouklakis Y., Piripitsi K., Ellinopoulos C. and Struss B., Determination of Cost-Effective Energy Efficiency Measures in Buildings with the Aid of Multiple Indices. *Energies* 11 (2018), 191; doi:10.3390/en11010191. The full Technical Assistance study is available on the webpage of MECI.

Indications about the cost-effectiveness of these investments is provided in Deliverable 6 of this study.

Table 34 – Cumulative additional investment needs in the period 2020-2030 to implement the PPM scenario in comparison to the WEM scenario.

Sector	mio Euros'2016	% of GDP of year 2016
Power generation (new CCGT plants, PVs etc.)	-10	-0.1%
Electricity storage technologies (pumped hydro & batteries)	-13	-0.1%
Electricity Interconnector	118	0.6%
Sustainable Mobility (buses & tram, bus lanes, cycle lanes etc.)	1,378	7.5%
Private transport (shift to sustainable transport modes, more efficient cars, electric cars, biofuels etc.)	-2,067	-11.2%
Residential & commercial buildings (energy efficiency renovations)	770	4.2%
Industry	67	0.4%
Total Additional Investments	**244**	**1.3%**

5 Impacts on Other Member States and Regional Cooperation

5.1 Regional Infrastructure Projects

A key theme that arises implicitly in the analysis is that of regional cooperation. The Cypriot NECP has regional impact directly associated to two major pieces of infrastructure, which will enable trade of electricity, via the EuroAsia Interconnector on the one hand, and natural gas, via the EastMed pipeline on the other hand. The modelling effort has made an attempt to illustrate the benefits offered by the EuroAsia Interconnector on the electricity supply system of Cyprus. Nonetheless, as the systems of Greece and Israel are represented as simple nodes of electricity demand and supply, the insights offered by the present outputs have significant limitations.

In order to estimate the electricity exchange between the three countries, separate electricity prices in each node are adopted. The volume of imported and exported electricity is then driven by the price difference between each node, constrained only by the assumed Net Transfer Capacity of the Interconnector segments. The marginal price for the Cypriot system is calculated endogenously by the model based on the cost of the available technologies and fuels at each point in time. The equivalent values for Israel and Greece are based on results from ENTSO-E's latest Ten-Year Network Development Plan[27], as shown in Table 35. The estimated value in the PPM scenario by the present analysis is also included for comparison.

One significant limitation with the adopted approach is that it assumes that electricity cost does not change throughout the year in Israel and Greece. In reality, there should be seasonal and daily variations in marginal electricity prices depending on the load profile and technology availability in each respective system at each point in time. As such, even though the average annual electricity price in Cyprus is higher, there are instances where this falls below the assumed annual prices of Greece and Israel. For instance, generation from solar PV at a considerably low cost can occur during midday, which can then be exported for a profit. Additionally, the approach assumes that infinite demand for electricity exists in the external systems whenever excess electricity generation is available in the Cypriot system. For instance, when excess solar photovoltaic or wind generation exists that cannot be taken up by the system, it can be exported instead of curtailed. However, this assumes that Greece and Israel have an equivalent demand that can take up this excess, which could not necessarily be the case.

Table 35 – Assumed electricity prices in Greece and Israel and calculated prices in Cyprus in the PPM scenario (EUR2016/MWh).

	2025	**2030**
Greece	73.5	74.2
Israel	63.0	75.9
Cyprus	*89.4*	*95.6*

The assumptions made in the PPM scenario regarding the EuroAsia Interconnector lead to the electricity exchange outlook shown in Table 36. It is observed that in 2025, when electricity prices in Israel are quite low, there is a net import of electricity to Cyprus, while a substantial volume of electricity is also exported to Greece from Israel. However, as electricity prices in Israel increase from 2030 onwards, both Greece and Cyprus export significant volumes of electricity to Israel. Overall, with the exception of the first few years of interconnector operation, Cyprus becomes a net exporter of electricity to Israel, fuelled primarily by solar PV and solar thermal technologies.

Even though domestic gas production and the potential development of the East Med pipeline are not explicitly modelled in the present analysis, it is expected that the project will not have direct impacts on the energy mix of the island. Since natural gas, whether imported or domestic, will be provided to

[27] ENTSO-E, "TYNDP 2018 - Europe's Network Development Plan to 2025, 2030 and 2040," 2018, https://tyndp.entsoe.eu/tyndp2018/.

the internal market at international market prices, the cost-competitiveness of gas-fired technologies will remain unaffected.

Table 36 – Electricity trade of the Cypriot electricity supply system with Greece and Israel in the PPM scenario (GWh).

	2025	2030	2035	2040	2045	2050
Exports to Israel	-	1,758	6,977	7,677	7,199	7,454
Exports to Greece	7,186	-	-	-	-	-
Imports from Israel	7,575	-	-	-	-	-
Imports from Greece	-	706	6,042	5,260	5,147	4,941
Net Imports*	**389**	**-1,052**	**-936**	**-2,417**	**-2,052**	**-2,513**

**Note: Negative Net Imports denote net positive exports of electricity.*

Nonetheless, revenues attained through the exports of domestic natural gas may be recirculated in the Cypriot economy, thus affecting the purchasing power of economic actors. Similarly, the revenue secured by the state could to a degree be utilised for the support of clean energy technologies. For instance, the existence of financial incentives could promote further investments in technology options that facilitate the decarbonisation of the system; such technologies include but are not limited to solar photovoltaics, electric vehicles, heat pumps or energy efficiency measures.

Efforts of the local authorities in the near future should be directed to reaching an agreement with neighbouring countries as to the assumptions to be employed in regards to major infrastructure projects. This is of critical importance in the case of the EuroAsia Interconnector[28], especially since it has a drastic effect on the Cypriot energy outlook, as shown in section 2.2.1. However, assumptions regarding size and development schedule of other projects such as the EastMed pipeline that will connect Israel, Cyprus and Greece's gas markets (and potentially Italy's) also have to be agreed upon, as these affect the projected energy balance and trade potential of the countries in question. Similar observations apply for the case of other potential gas pipeline development between Cyprus and Egypt.

5.2 Market integration

A long-term cost-optimisation model has been used for the scenario analysis. These types of models assume that a perfectly functioning and predictable market exists in the system in question. This in turn implies that perfect competition occurs between the market participants, who act as price-takers and provide energy at a marginal production cost, while perfect foresight allows market participants to be fully aware of all present and future conditions affecting the cost at which they provide or purchase energy. In essence, since optimisation models assume perfect market conditions, model outputs are presented in terms of potential for improvement so as to recognize the extent at which cost-competitive investments of certain technology choices are financially viable. The EU has placed significant importance in the full liberalisation of the internal electricity market.[29] It should be noted that the plans for the full implementation of a competitive electricity market in Cyprus are gradually moving forward. Once fully implemented, the electricity market would create a favourable environment for investors, under which the technology investments foreseen in generation and storage infrastructure can occur.

[28] Recent developments regarding the EuroAsia Interconnector occurred after finalisation of the bulk of the present analysis. Specifically, it has been decided that development of the portion of the cable connecting Crete with Attica will not be undertaken within the PCI-status EuroAsia Interconnector project, but will rather be developed as a national project. As such, this could have a significant impact on the electricity exchange potential between Cyprus, Israel and Greece. The degree of this impact will depend on the capacity of the two separate projects (i.e. Crete-Attica and Crete-Cyprus-Israel), the timeline for their full operation, as well as the interoperability between the two projects.

[29] European Union, "Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 Concerning Common Rules for the Internal Market in Electricity and Repealing Directive 2003/54/EC (Text with EEA Relevance)," Pub. L. No. 32009L0072, OJ L 211 (2009), http://data.europa.eu/eli/dir/2009/72/oj.

For instance, in the conducted scenario runs, a pumped-hydro project of 130 MW is deemed as cost-competitive, not only for energy arbitrage, but also for provision of operational reserve. This centralized storage option can store electricity from variable RET in periods of high output, as a preferred alternative to curtailment. Additionally, if flexibility of existing thermal units in Cyprus is not improved and output from thermal plants cannot be ramped down or even shut off easily to accommodate variable generation, storage can be useful for the operation of these units as well. For instance, the most efficient units in Cyprus are the combined-cycle gas turbines, but these cannot be turned on and off constantly as the cost of operation would increase dramatically. Instead, they could potentially be run constantly for long periods of time, even at low loads, making use of the storage infrastructure.

Therefore, it can be argued that centralized storage – while primarily an enabler for RET – can act for the benefit of the whole system. Control of the centralized storage to an extent can be handled by the Transmission System Operator (TSO), but the most complex issue is agreeing on which stakeholder would act as the investor of such a project and hence bear the financial risk. The market environment in which the project operator will function and generate profit has to be clear. Since a functioning liberalized electricity market structure is still in its early development stages in Cyprus, conditions are not yet ideal for investors. Generally, in Europe the legal framework of handling storage assets in unbundled markets is not perfectly clear as requirements such as grid support become more prominent[30]. Depending on the status of the network operator, a complete or partial ownership and operation by either the transmission and distribution system operator or a third-party is a plausible business model that allows provision of both network and market services.

Despite the fact that deployment of lithium-ion batteries is capital-intensive, it is calculated as economically optimal to also develop this storage option, as it allows for additional cost-competitive generation from variable renewable energy options. In this case, a lower system cost is achieved through time of use arbitrage, where cheap electricity from solar PV can be used to charge the storage during the day and then be used during peak demand periods in the evening. Provision of ancillary services, in terms of operational reserves, can further increase the attractiveness of this technology as an option.

Further, lithium ion batteries can be deployed at both the centralized and the distributed level; for instance, at residential or commercial buildings. In order for the technology option to provide grid support, installation of ICT infrastructure is a prerequisite, as it assumes operation of a smart grid[30], which will have a cost associated to it. At the same time, even though decentralized batteries can potentially offer both energy arbitrage and ancillary services for the grid, the cost of capital lies with the consumer. As such, incentives will have to be given to provide the market conditions for consumers to invest in such a technology and be willing to offer use of their infrastructure for facilitating in a smooth operation of the grid.

Furthermore, the establishment of a competitive electricity market internally is important for the operation of a regional electricity market. As illustrated in section 2.2.1, the establishment of an interconnection in Cyprus, allows for an increase in the renewable energy share in the electricity supply sector. This increased RET deployment corresponds mainly to solar PV and assumes that at times when generation will exceed domestic demand, the excess can be transmitted to Israel or Greece. Similarly, it is assumed that during periods of low PV output, electricity can be readily

[30] Abhishek Shivakumar et al., "Business Models for Flexible Production and Storage," Policy Report (INSIGHT_E, December 2015), http://www.insightenergy.org/system/publication_files/files/000/000/041/original/PR_4_Business_models_final.pdf?1465204190.

procured from these neighbouring systems. This assumes the existence of a framework through which the involved systems can trade at cost-efficient prices and volumes, similar to the way Nord Pool is structured. This Nordic power exchange currently operates in 9 countries (Nordics, Baltics, Germany and UK)[31] and trades electricity between market participants at the intraday or day-ahead stages, as well as allowing for long-term contracts of up to five years[32]. A similar approach could be adopted for the development of an Eastern Mediterranean market in the future to facilitate integration of greater shares of RET in the region.

[31] Nord Pool, "Power Without Borders - Annual Report 2015," 2016, http://www.nordpoolspot.com/globalassets/download-center/annual-report/annual-report_nord-pool_2015.pdf.

[32] N. Flatabo et al., "Experience with the Nord Pool Design and Implementation," *IEEE Transactions on Power Systems* 18, no. 2 (May 2003): 541–47, https://doi.org/10.1109/TPWRS.2003.810694; Audun Botterud, Tarjei Kristiansen, and Marija D. Ilic, "The Relationship between Spot and Futures Prices in the Nord Pool Electricity Market," *Energy Economics* 32, no. 5 (September 2010): 967–78, https://doi.org/10.1016/j.eneco.2009.11.009.

APPENDIX I: List of Policies and Measures

RES: Renewable Energy Sources; EE: Energy Efficiency; WST: Waste management; AGR: Agriculture; IEM: Internal energy market; SEC: Energy Security; TRA: Transport΄; R&I: research, innovation and competitiveness

WITH EXISTING MEASURES				WITH PLANNED POLICIES AND MEASURES			
ADOPTED		IMPLEMENTED		PLANNED		PROVISIONAL	
RES	Support scheme for the production of electricity from renewable energy sources for own use Category A:Net-metering	RES	Support scheme for the production of electricity from RES-Feed-in Tariffs for RES installations	RES	Support scheme for the installation of net-metering photovoltaic systems with capacity up to 20KW, in public schools buildings.	RES	Framework for Repowering of existing RES systems
RES	Support scheme for the production of electricity from renewable energy sources for own use Category A:Net-billing	RES	Support scheme for the promotion of renewable energy sources and energy saving	RES	Support scheme for storage units	RES	Support Scheme for RES in order to promoto innovation and reduce CO2
RES	Self-consumption of electricity from renewable energy sources	RES	Thermal Conductivity MAP and Ground Temperatures up to 100m depths using neural networks	RES	District heating and cooling based on RDF fired cogeneration technologies in tourist areas and rural areas	RES	Statistical Transfer Study and taking advantage of Union Development Platform (Article 8.2)
RES	Stand alone RES systems	RES	Map for Water Depth around the island for offshore wind parks. Preliminaty study contacted for wind speeds around the island	RES	Subject to Electricity Interconnection open support schemes for other MS	RES	Energy Storage, Further analysis for both behind the meter and cental storage for further Penetration of RES (Vehicle to Grid option and smart charging)
RES	Installation of net-metering PV systems in houses of vulnerable consumers	EE	Support Scheme for promoting energy audits in SMEs	RES	Develop a political and technical framework for one stop shop procedure for RES projects	RES	Contact Survays to measure the existing heat pumps Performance and provide incentives for reporting the replacement of old heat-pumps
RES	Support scheme for the installation or replacement of solar water heaters in households	EE	Grant Scheme for promoting roof thermal insulation and encouraging the use of RES (end use) in the residential sector	RES	Create a financing mechanism in the sense of soft green loans to support further the RES developments in household section	RES	70% RES on all new buildings from on net annual consumption
RES	Rural development programme 2014-2020 of the Ministry of Agriculture, Rural Development and Environment.	EE	Minimum energy performance requirements for new and existing buildings, requirements for technical building systems installed in existing buildings, inspections for heating systems and a/c systems	RES	Renewable Energy Communities, develop framework and incentive mechanisms	RES	Incentive Scheme for process heat RES Systems (CSP) to heavy industrial process
RES	Support scheme for the installation of RES systems that will operate in the competitive electricity market	EE	Support scheme encouraging the use of RES (end use) in the residential, tertiary, industry and agriculture sector (primary consumption energy savings)	RES	Improve forecasting modelling tool for Weather to Energy production using Real Time Sattelite measurements and Real time output measuresments from the RES plants. Correlation between PV and Wind on forecasting errors	RES	Conduct studies by Wind Association for offshore floating Wind Parks in Cyprus Exlusive ecnomic zone
RES	Incentives for encouraging the use of RES in different types of developments.	EE	Enegy efficiency obligations in public purchases and national green public procurement action plan.	RES	Virtual netmeting for multiapparment buildings and for Buildings that they do not have enough sapce for installing on premises the required PV System	RES	Hybrid GAS turbine with CSP and natural GAS or diesel with storage option

RES	Certification of small-scale RES system installers	EE	Implementation of measures aimed at attaining energy savings in existing pubic buildings (annual obligation)	RES	**Renewable Cooling Measures** - Vapour compression cooling systems , Single Split Devices, Multi Split Devices, Reversible heat Pumps, Photovoltaic Cooling, etc based on minimum requirements on efficiency of the cooling system (By 31 December 2021, the Commission shall adopt delegated acts in accordance with Article 35 to supplement this Directive by establishing a methodology for calculating the quantity of renewable energy used for cooling and district cooling and to amend Annex VII.)	EE	Efficient district heating and cooling based upon RDF fired cogeneration technologies in tourist areas (primary energy savings)
RES	Research and innovation programs in the sector of RES	EE	RES& EE fee applied on electricity consumption.	RES	Create a framework for water to air and ground to air open loop geothermal systems based on technical potential available	EE	Introduction of enviromental fees for the use of the road network
RES	Renewable Energy Communities	EE	Motor vehicle taxes based on CO2 emmisions.	EE	Uptake of energy performance procurement in public sector by removing procurement hurdles	R&I	European Structural and Investment Funds in the new Programming Period 2021 – 2027
RES	25% RES in new Buildings	EE	Integrated Fleet Management System (Central Government vehicles)	EE	Removing barriers that impede the uptake of energy performance contracting and the implementation of energy efficiency investments in general	R&I	Increase of the annual spending in research and innovation related to energy and climate in order to reach an average of 15m Euros per year
RES	Create localised tools for selecting the appropriate PV size and scheme	EE	Technical guidance promotion of NZEB and electronic tool kit for consumers	EE	Energy efficiency in defence and water sector	R&I	Contact surveys and methodology (or simple onlinde software tools) for tracking down the various white applicances that are directly related with the RES technologies
EE	Energy efficiency Obligation scheme	EE	Energy taxes in road trasport fuels	EE	Fiscally neutral green tax reform by increasing environmental taxes while reducing labor taxation	TRA	Increase the use of cars that have low or no GHG emissions
EE	Financing tool providing soft loans for energy efficiency investments	EE	Financing measures for energy efficiency in existing hotels and agricultural sector	EE	Scheme to subsidize realised CO2 emission reductions for companies that participate to the Energy efficiency network	IEM	Development of natural gas network pipeline infrastructure in Cyprus
EE	Solar water heater replacement scheme	EE	Energy efficiency network with voluntary agreements of businesses to reduce their energy consumption	EE	Preparation of the corridor and future development of a tram infrastructure		
EE	Increase of energy efficiency in electricity generation due to the increase of efficiency and the switching of the fuel to natural gas (primary consumtion energy savings)	EE	Applying a lower VAT rate for the renovation and repair of private dwellings.	EE	Additional floor space “allowance” for new and rennovated buildings with higher energy efficiency than minimun energy performance requirements -Revision		
EE	Financing tools for energy efficiency investment using European Structural and Investment Funds in the new Programming Period 2021 – 2027	EE	Net billing Scheme for high efficiency cogeneration (HECHP)	IND	Preparation of the proper recovery system for F-gases in equipment		
EE	Individual energy efficiency interventions and energy efficiency retrofits in selected governmental and municipal buildings	EE	Pilot projects for installing high efficiency cogeneration in public buildings	WST	Reduction of waste to solid waste disposal sites from sorting at production level		

EE	Energy efficient street lighting	EE	Energy efficiency in electricity infrastracture by upgrading the medium nominal voltage of 11kV to 22kV in selected areas.	WST	Reduction of organics to landfills		
EE	Sustainable Urban Mobility Plans (Increasing the share of cycle, pedestrian and PT trips, increase use of busses)	EE	"Park and drive stations" for the use of public busses instead of private cars	WST	Promotion of anaerobic digestion for the treatment of the organic fraction of the municipal solid waste		
EE	Targeted awareness raising actions for energy efficiency	EE	Grant schemes for promoting deep renovation in residential and commercial buildings	WST	Biogas recovery from old sold waste disposal sites (deep unmanaged)		
EE	Smart meters roll out	EE	Obligatory energy audits in non-SMEs	IEM	Regulatory Decision on Storage Systems that are installed before the metering point.		
EE	Use of buses that have low or no GHG emissions	EE	Effective market survaillance for energy labeling of energy related products, tyres and eco design.	IEM	Amend the national law to enable operation of the electricity market and make the Market Operator/TSO independent from the vertically integrated electricity company		
EE	Installation of pubic electric car charging stations	EE	Capacity building, targeted trainings, information workshops and events, promotion of energy managers in public buildings and enterprises	IEM	Amend Trade and Settlement Rules and Transmission and Distribution Rules to allow for Demand Response in the market according to Art. 15(8) Directive 2012/27/EU		
EE	Minimum energy performance requirements for new and existing buildings, requirements for technical building systems installed in existing buildings, inspections for heating systems and a/c systems-revised	EE	Use of telemelatic system for public busses	TRA	Increase the use of buses that have low or no GHG emissions		
SEC	Ministerial Decision 77.286 on 16/11/2014 for the establishment of the New Energy and Industrial Area of Vasilikos	EE	Additional floor space “allowance” for new and rennovated buildings with higher energy efficiency than minimun energy performance requirements	TRA	Increasing the share of cycle, pedestrian and PT trips		
SEC	Ministerial Decision 77.286 on 16/11/2014 for concession to the KODAP suitable land in the Vasilikos area for the construction of privately owned oil terminal storage	EE		TRA	Enchance planting of trees		
IEM	Electricity Interconnectivity of Cyprus	EE		R&I	Financing tool for energy efficiency investment		
IEM	Cyprus TSO Ten Year Network Development Plan 2019-2028 according to Article 63 of the Laws for the Regulation of the Electricity Market from 2003 to 2017.	SEC	Tender announcement for the LNG Import Terminal.	R&I	Support schemes to promote energy efficiency investments in agricultural sector		
IEM	Regulatory Decision 05/2017 on the Implementation of a Binding Schedule for the Full Implementation and Operation by the DSO of the Meter Data Management System (MDMS).	SEC	Ministerial Decision ΚΔΠ 212/2014 for holding of emergency oil stocks equivalent to 90 days of net imports of petroleum products.	R&I	Fiscally neutral green tax reform by increasing environmental taxes while reducing labor taxation		

IEM	Regulatory Decision 02/2018 on the Implementation of a Binding Schedule for the Mass Installation and Operation by the DSO of Advanced Metering Infrastructure (AMI).	SEC	Ministerial Decision 84.952 on 14/5/2018 for the Signing of a Memorandum of Understanding and Agreement between the Government of the Republic of Cyprus and the Companies Marketing Petroleum Products, namely BP Eastern Mediterranean Ltd, ExxonMobil Cyprus Ltd, Hellenic Petroleum Cyprus Ltd, Intergaz Ltd, Petrolina (Holdings) Public Ltd and Synergaz Ltd for the relocation of petroleum and liquefied petroleum gas installations from the Larnaca coastline to the Vasilikos area	AGR	Further promotion of anaerobic digestion for the treatment of animal waste		
IEM	Ministerial decision that dedicates MECI as National Competent Authority (NCA). One of NCAs' obligations according to EU Regulation 347/2013/EC is to achieve real priority status for PCIs in public sector.	SEC	1. Single Action Plan for the restoration of the electrical system after power blackout, 2. Setting certain Quality of Electricity Supply Indicators	RES/ IEM	Citizen Energy Communities		
IEM	Ministerial decision that dedicates MECI as NCA. Transparency and public participation is an obligation for NCA according to EU Regulation 347/2013/EC.	IEM	MoU between the countries of Cyprus, Greece, Israel and Italy (05/12/2017, Nicosia).	RES	one-stop Shop for the permitting procedure of RES systems Digital Application		
IEM	Ministerial decision that dedicates MECI as NCA. The development of the One-Stop Shop 4Energy PCIs is an obligation for NCA according to EU Regulation 347/2013/EC.	IEM	Ministerial Order (no. K.D.P. 289/2015) regarding the energy poverty, the categories of vulnerable customers of electricity and the measures to be taken to protect such customers.	IEM/ RES	Introduction of Smart Systems/Meters in the Electricity network for grid management and empowering Consumers		
IEM	Ministerial decision that dedicates MECI as NCA. According to EU Regulation 347/2013/EC the NCA shall publish a manual of procedures for the permit granting processapplicable to projects of Common Interest	TRA	Increasing the share of cycle, pedestrian and PT trips	IEM/ RES/ EE	Dynamic Electricity Tariffs (hourly/half hourly		
IEM	Ministerial decision that dedicates MECI as NCA. Cross Border collaboration with other EU Member States and Third Countries is an obligation for NCA according to EU Regulation 347/2013/EC.	TRA	Motor vehicle taxes based on CO2 emmisions.	IEM/ RES	Investigation/Study on Capacity Mechanisms/Regulation		
IEM	Financial assistance of PCIs according to chapter V, article 14 of the EC Regulation 347/2013	TRA	Revised motor vehicle taxes based on CO2 emmisions.				
IEM	Regulatory Decision 01/2017 on the Implementation of a Binding Schedule for the Full Commercial Operation of the New Electricity Market Model.	TRA	Integrated Fleet Management System (Central Government vehicles)				

TRA	Installation of pubic charging stations	TRA	Replacement of the conventional transport fuels with biofuels				
R&I	Energy efficiency network with voluntary agreements of businesses to reduce their energy consumption	R&I	RESTART 2016 - 2020				
		R&I	Grant Scheme to Enhance Buisiness Innovation				
		R&I	European Territorial Cooperation Programs - INTERREG				
		R&I	Climate-KIC				
		R&I	Horizon 2020				
		R&I	LIFE				
		AGR	Promotion of anaerobic digestion for the treatment of animal waste				

APPENDIX II: OSeMOSYS Results for the Entire Period 2020-2050

A.II.I. Existing Policies and Measures Scenario

The results for this section have been broken down by sector. Additionally, results regarding the primary energy supply and final energy demand are provided along with a forecast on the carbon dioxide emissions from both ETS and non-ETS sectors. A short comparison with the results of the EU Reference Scenario 2016 and POTEnCIA is included in each section.

A.II.I.I. Electricity Supply Sector

A.II.I.I.I. Capacity

The projection offered by the model for the electricity supply sector is quite interesting and can be considered optimistic. Following the expected deployment of renewable energy technologies until 2020, as promoted by the existing support schemes and the development of the planned 50 MW CSP plant by 2021, an additional 390 MW of solar PV and 33 MW of biomass-fired facilities are deployed between 2021 and 2030. The increase in solar PV in this period coincides with the development of two new combined cycle gas turbines with a total capacity of 432 MW, which can operate as baseload and also offer flexibility to the system. Despite the low fossil fuel price projections and the higher renewable energy technology prices adopted in the analysis as compared to EC recommendations, an aggressive deployment of solar PV continues in the period 2031-2040 (Table 37). This deployment is enabled by an equally aggressive deployment of Li-ion batteries during the same period, as these reach 229 MW (916 MWh) in 2040. It should be noted that based on a relevant IRENA publication[33], optimistic techno-economic characteristics were assumed for Li-ion batteries. This publication foresees that by 2030 battery life will exceed 15 years and round-trip efficiency will reach 95% at an installation cost of approximately 160 EUR2016/kWh. These projections are further corroborated by other recent publications examining the subject (e.g. by NREL[34]).

The heavy investments on solar thermal are also worth noting, especially from 2035 onwards. These reach 450 MW in 2035, 850 MW in 2040 and 1,200 MW at the end of the modelling horizon. Increasing fuel and ETS costs call for the use of RE technologies, and the existence of thermal storage makes solar thermal an attractive alternative for baseload generation, and some of the associated grid services that thermal generation normally provide.

Table 37 - Capacity projections in the electricity supply sector (MW) – WEM scenario.

	2025	2030	2035	2040	2045	2050
Vasilikos	868	868	608	0	0	0
Dhekelia	102	102	0	0	0	0
Moni	150	150	0	0	0	0
New CCGT	432	432	432	432	432	432
New ICE	0	0	0	0	0	0
New ST	0	0	0	228	228	228
New GT	0	0	0	124	124	124
Light fuel oil CHP	0	0	9	31	41	39
Solar PV	565	750	1,269	1,523	1,527	1,758
Solar Thermal	50	50	450	850	1,100	1,200
Wind	175	175	175	175	158	158
Biomass	50	50	50	68	68	63
Pumped Hydro	0	130	130	130	130	130
Li-Ion Batteries	0	41	42	229	369	833

[33] IRENA, 2017. Electricity Storage and Renewables: Costs and Markets to 2030, International Renewable Energy Agency, Abu Dhabi.

[34] Cole, W.J., Frazier, A., 2019. Cost Projections for Utility-Scale Battery Storage (No. NREL/TP-6A20-73222, 1529218). NREL. https://doi.org/10.2172/1529218

All Li-ion batteries deployed are in-front-of-the-meter facilities and have 4 hours of storage; this results in 164 MWh of battery storage in 2030 and 916 MWh in 2040. No behind-the-meter battery storage is deployed as this is not deemed cost-optimum under the current assumptions followed. Furthermore, in 2027 a 130 MW (1040 MWh) pumped-hydro facility is also developed.

The aggressive deployment of batteries and solar PV can be attributed to the reduction of their respective capital cost over time. At the same time, increasing fuel and ETS prices make fossil-fired plants less competitive. However, the feasibility of these results has to be scrutinized thoroughly, as during low electricity demand and high PV output periods, a significant amount of curtailment may be observed. The results presented here estimate a curtailment level of 0.1% for solar PV and 0.5% for wind in 2030 and 18.6% for solar PV and 20.2% for wind in 2040. Despite this level of curtailment, renewable energy technologies are deemed cost-effective due to their decreasing investment cost. Nonetheless, curtailment is not accurately captured by a long-term energy systems model as the one employed here. Hence, a separate detailed analysis focusing on a single year in a much finer temporal resolution may be needed to properly assess this proposed outlook.

Comparison with EU Reference Scenario 2016

EU Reference Scenario 2016 projections are comparable to the present results for the year 2020. It projects that solar capacity will reach 338 MW and wind capacity will reach 216 MW. In contrast, the present model estimates a 360 MW and a 175 MW capacity, for solar and wind technologies, respectively.

In respect to 2030 there are some differences regarding the electricity capacity results between the two models. Specifically, the EU's Reference Scenario 2016 projects a thermal capacity of 1,455 MW, whereas the present scenario projects 1,552 MW. Also, there are differences regarding the total renewable energy capacity. Solar capacity reaches 529 MW in the EU Reference Scenario, and 800 MW (PV and CSP) in the present model, while wind capacity is 229 MW in the former and 175 MW in the latter case. Finally, biomass-fired facilities are limited to 11 MW in the EU Reference Scenario, but their capacity is increased to 50 MW in the present model.

There is a big difference between the two models for the installed capacity of solar PV in 2040. Specifically, the EU Reference scenario projects that only a further 50 MW solar PV will be added to the system between 2030 and 2040, whereas this model projects approximately 770 MW.

It is worth noting that no information is given regarding the penetration of any storage technologies in the EU Reference Scenario 2016. Therefore, no comparison regarding this aspect can be made.

Comparison with POTEnCIA results 2018

A comparison between this model and the results from the POTEnCIA model for Cyprus reveals significant differences. At first, in the POTEnCIA results gas-fired facilities are limited to the existing 11 MW internal combustion engine(s) until 2028, and gradually from 64 MW in 2029 to 119 MW by 2040. In contrast, due to the assumed fuel shift to gas in 2021 in the present scenario, gas-fired facilities are projected to exceed 1,000 MW by the end of 2021. These increase to 1,240 MW by 2030, but then decrease to 785 MW by 2040, due to the decommissioning of existing plants.

The reason for the above discrepancy is most probably an assumption for a continued reliance on fuel oil- and diesel-fired generation in the POTEnCIA scenario. These two options dominate the projections in terms of conventional thermal facilities until 2040. Diesel-fired plants have a projected capacity of 663 MW in 2025 and 440 for the period 2030-2040. Fuel oil-fired facilities have a projected capacity of 653 MW in 2025, 533 MW in 2030, 413 MW in 2035 and 125 MW by 2040. These capacities likely refer to the existing plants.

Lastly in terms of conventional thermal generation options, a coal-fired steam turbine of 9 MW is deployed in 2029. This option is not considered at all in the present model.

Moreover, there are also differences regarding the capacity of RES. For instance, the capacity of wind turbines is projected to be slightly higher by 2020; specifically, 206 MW instead of 175 MW for most of the horizon in the present model. Taking into account the decommissioning of some of the installations, wind in POTEnCIA increases to 209 MW in 2040 with the installation of 11 MW offshore wind turbines.

In regards to the solar capacity, the POTEnCIA scenario is less optimistic than the EU Reference Scenario 2016 and the present scenario. Solar thermal is not considered at all, while solar PV capacity is limited to 124 MW in 2020 and 171 MW in 2030, as opposed to 360 MW and 750 MW respectively in the present scenario. The capacity of solar PV is projected to increase to 568 MW by 2040 in the POTEnCIA scenario results. This is comparable to the EU Reference Scenario 2016, but still short of the total 1,523 MW projected by this scenario. Similar to the EU Reference Scenario 2016, no clarification regarding the deployment of storage technologies is provided.

Regarding the biomass facilities, no existing plants are indicated, despite an existing capacity of 11 MW. It is possible that the 11 MW of gas-fired facilities quoted as existing may refer to biogas facilities, as those do not appear in any other category of the results. Nonetheless, POTEnCIA results project solid biomass and waste facilities to reach 39 MW by 2030 and 83 MW by 2040. These are comparable to the 68 MW projected in this scenario by 2040 (inclusive of biogas-fired facilities).

Finally, POTEnCIA results indicate that 11 MW geothermal facilities are already integrated in the system. Such facilities do not exist in the electricity supply system, while no indications for such a potential deployment have been provided by the authorities. Hence, this option is not considered in the present scenario.

A.II.I.I.II. Generation

The technology deployment presented above provides the generation mix shown in Figure 10. The substitution in the latter part of 2021 (i.e. in the period October-December) of oil-fired generation with gas-fired generation results in a transitional period as indicated below. The share of renewables in the final electricity consumption reaches nearly 16% in 2020, therefore the respective target is achieved. In the post-2020 period, gas-fired generation dominates the electricity mix. The RE share in 2030 reaches 28%, as more solar PV is introduced in the system. It should be noted that the absolute contribution of fossil-fired generation remains relatively stable until 2032, and the increased demand in electricity drives the PV deployment.

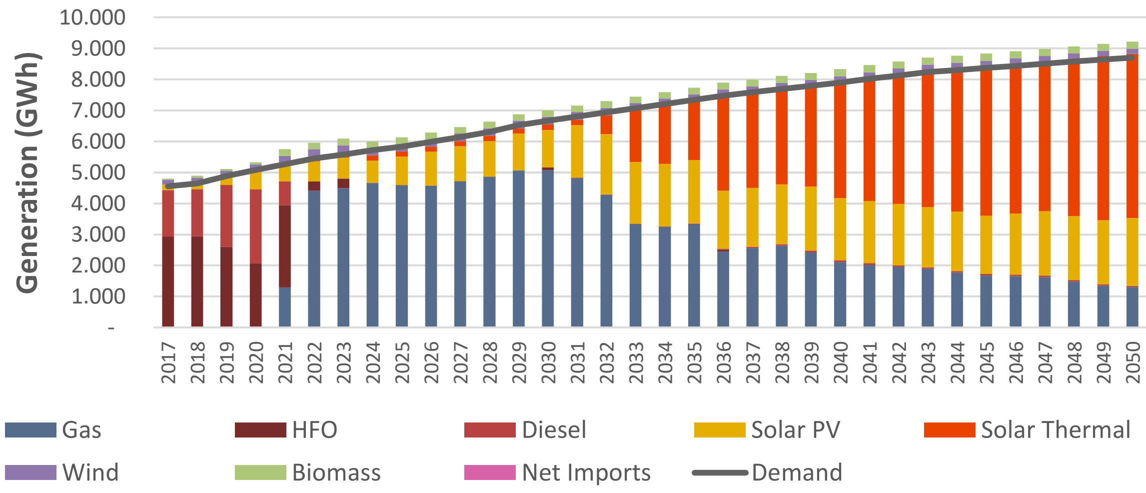

Figure 10 - Projected generation mix till 2050 – WEM scenario.

The deployment of solar PV discussed above increases the share of PV in the generation mix, which occurs gradually until 2040. Another factor which leads to the expansion of solar PV is the electrification of the transport sector, as this raises the demand for electricity throughout the year. Specifically, in 2030 approximately 91 GWh are consumed in the transport sector, and by 2040 the annual consumption rises to approximately 585 GWh. This aspect is further elaborated in the relevant section later on in the report. With the introduction of solar thermal, the RE share in generation reaches as high as 74% in 2040.

A.II.I.II. Transport Sector

The forecast for the transport sector foresees penetration of alternative fuels and technologies (Table 38). Regarding the passenger car fleet, the number of diesel vehicles are reduced over time; these are replaced by gasoline, gasoline hybrid and battery electric vehicles. Additionally, a moderate number of LPG conversions occurs. It is worth highlighting that a significant penetration of new electric vehicles appears in the fleet in the latter part of the modelling horizon. Significant investments occur in the period 2028-2030 which bring the number of BEVs to 28,000 by 2030, while this increases further to 177,000 by 2040. The number of gasoline hybrid vehicles is also substantial, as these increase to 60,000 by 2030 and 200,000 by 2040.

Table 38 – Projected vehicle fleet (total number of vehicles) – WEM scenario.

		2025	2030	2035	2040	2045	2050
Passenger cars	Diesel	40,372	53,560	67,476	72,492	30,502	5,016
	Diesel hybrid	-	-	-	-	-	-
	Diesel PHEV	-	-	-	-	-	-
	Gasoline	539,054	483,574	381,415	279,334	306,367	382,254
	Gasoline Hybrid	5,170	59,927	125,850	200,639	222,298	227,621
	Gasoline PHEV	-	-	-	-	-	-
	BEV	100	27,641	98,633	173,422	222,298	227,621
	LPG	739	1,174	963	437	562	562
	Natural gas	-	-	-	-	-	-
	Hydrogen	-	-	-	-	-	-
		2025	2030	2035	2040	2045	2050
Buses	Diesel	3,230	3,450	3,715	4,006	4,315	4,646
	Diesel hybrid	-	-	-	-	-	-
	BEV	-	-	-	-	-	-
	CNG	-	-	-	-	-	-
		2025	2030	2035	2040	2045	2050
MCs	Gasoline	54,667	58,383	62,806	68,087	74,642	77,267
	BEV	-	-	-	-	-	-
		2025	2030	2035	2040	2045	2050
Trucks	Diesel	13,923	14,542	14,015	13,512	13,406	14,752
	BEV	-	326	2,002	3,742	5,182	5,272
	Natural gas	-	-	-	-	-	-
		2025	2030	2035	2040	2045	2050
Light Trucks	Diesel	128,323	137,032	147,643	159,035	166,457	164,373
	BEV	-	-	-	-	4,867	20,539
	PHEV Diesel	-	-	-	-	-	-
	Hybrid diesel	-	-	-	-	-	-
Grand Total		785,578	839,609	904,516	974,707	1,050,896	1,129,924

The projected shift in the road transport fleet results in an equivalent change in the fuel consumption in the transport sector. As indicated in Table 39, gasoline remains as the main fuel consumed in road transportation for the entire model horizon. However, gasoline consumption is reduced from 521 million litres in 2020 to 391 million litres in 2040. The use of diesel also decreases steadily during the period dropping from 330 million litres in 2020 to 318 million litres by 2040. Similarly, biodiesel used for blending follows a similar trend, as the current blending mix is kept constant throughout the whole period. Even though, bioethanol is not mixed with gasoline at the moment, it is assumed that it will occur after 2020. Forced blending was implemented for 2nd generation biofuels, as the government of Cyprus has issued decrees which force blending of 2nd generation biodiesel.

Electrification of the transport sector is regarded as a key step in the decarbonisation and diversification of fuel supply of this sector. A degree of electrification occurs in the projected scenarios by fully-electric vehicles. Therefore, electricity demand in the transport sector increases proportionally, reaching 91 GWh in 2030 and 587 GWh in 2040; which corresponds to 1.4% and 7% of the total final electricity demand, respectively.

This poses challenges to the grid, but also offers opportunities. On the one hand, electricity demand rises; this will not happen uniformly as charging will primarily occur at specific hours of the day. It can be expected that the overall load profile will be affected as a consequence. This is something that perhaps is not captured adequately by the current version of the model and may need to be amended in future iterations. The assumed charging profile can have a significant impact on the results and with increasing penetration of BEVs in the system, more information could become available to assist such an analysis.

Smart charging of vehicles and potential use of vehicle-to-grid systems, in which vehicle batteries can be used as additional supporting infrastructure by the grid operator, can offer demand response services that in turn can add flexibility and have an enabling effect for intermittent renewable energy technologies, subject to wider regulatory and market developments such as the introduction of Time-of-Use or dynamic pricing retail contracts. It has to be noted that changes in the transport sector are subject to the social behaviour of individuals, which is not a trivial matter to address in optimization models. The willingness of consumers to change their behaviour is a factor that may limit the transition of the transport sector to alternative fuels and technologies.

Table 39 – Evolution of fuel consumption in the transport sector till 2050 – WEM scenario.

		2025	2030	2035	2040	2045	2050
Biofuels	**Litres**	46,873,119	45,584,331	42,333,324	39,274,006	38,585,099	39,873,328
Diesel	**Litres**	302,930,656	314,370,316	320,628,324	318,694,853	283,874,142	260,367,733
Gasoline	**Litres**	553,160,485	515,930,500	447,189,859	391,215,943	416,913,771	467,574,402
LPG	**Litres**	971,297	1,616,118	-	153,750	689,349	-
Natural gas (STP)	**m3**	-	-	-	-	-	-
Electricity (road)	**MWh**	306	91,350	337,677	587,257	767,492	838,105
Electricity (rail)	**MWh**	-	-	-	-	-	-

Comparison with EU Reference Scenario 2016

Detailed results regarding the transport sector are not provided by the EU Reference Scenario 2016, thus a detailed direct comparison cannot be made. Furthermore, demand in this scenario is expressed in vehicle-kilometres, whereas the EU Reference Scenario 2016 breaks this down into passenger-kilometres and tonne-kilometres. Since the assumptions on occupancy and load rate of vehicles are not shared, a comparison regarding demand cannot be reached either. Nonetheless, the rate of electrification between the two scenarios can be compared. The share of electricity in the transport sector increases slowly to 0.6% and 1.3% by 2030 and 2040 respectively in the EU Reference Scenario 2016. However, the corresponding figures in the present scenario are 1.1% by 2030 and 7.8% by 2040. Similarly, the EU Reference Scenario 2016 projects the RES share in the transport sector to fluctuate around 10% throughout the period from 2020 to 2040, whereas this effort indicates that it will gradually increase to 7.3% in 2030 and 29.2% in 2040[35], as a result of increased use of electricity and an equivalent increase of the RES-E share. The inconsistency observed in the two models for the period until 2030 may be attributed to different assumptions regarding biofuel blending between the two scenarios.

Comparison with POTEnCIA results 2018

Unlike the present effort, POTEnCIA results foresee a continued reliance on conventional ICE for passenger cars. Contrary to the present effort, very little deployment occurs on BEVs; these amount to 3,155 by 2030 and 8,255 by 2040. It is interesting to note that a small deployment in fuel-cell vehicles is also foreseen (240 by 2030 and 965 vehicles by 2040). Additionally, deployment of LPG is higher in the POTEnCIA scenario (6,735 vehicles by 2040) as opposed to the current scenario (1,174 by 2030 and 437 by 2040).

Penetration of electric battery-powered 2-wheelers is notable, as 10% in 2030 and 21% of the fleet in 2040 in this mode of transport is projected to be electric. In the case of buses, some investments in PHEVs occur; 203 vehicles of the total 3,303 buses in 2040. Contrary, in this scenario only diesel-fired ICE buses are projected throughout the model horizon. A high deployment of PHEVs is foreseen for light duty trucks, with a deployment 3,876 by 2030 and 21,760 by 2040, whereas this scenario foresees continued reliance on diesel-fired light trucks. A small number of BEV and fuel-cell vehicles is also deployed in the POTEnCIA case – 407 and 223 vehicles respectively by 2040. In addition, heavy trucks are projected to be entirely diesel-fired ICE in the POTENcIA scenario, while the present scenario foresees up to 326 fully-electric trucks by 2030 and 3,742 units by 2040.

Electricity demand in the transport sector is significantly lower in the POTEnCIA scenario; 26 GWh in 2030 and 96 GWh in 2040. In contrast, due to the high deployment of BEVs, electricity consumption in the transport sector in the present scenario amounts to 91 GWh in 2030 and 587 GWh in 2040.

In terms of CO_2 emissions, road transport emissions decrease from 1.73 Mt in 2020 to 1.55 Mt in 2030 and 1.47 Mt in 2040. These are lower than the present scenario, which projects equivalent emissions at 2.69 Mt in 2020, 2.63 Mt in 2030 and 2.27 Mt in 2040. The greater emissions estimated here can to an extent be attributed to a higher demand. The POTEnCIA scenario assumes a demand of 7.43 billion veh-km in 2020, 8.19 billion in 2030 and 8.68 billion in 2040, whereas the present effort assumes 9.26 billion veh-km in 2020, 10.61 billion in 2030 and 12.32 billion in 2040. Potential differences in assumed vehicle fuel efficiency may affect projected CO_2 emissions as well.

A.II.I.III. Heating and Cooling Sector

Continued investments in renewable energy technologies in buildings, as well as investments in heat pumps lead to an increase in the renewable energy share in the heating and cooling sector. The significant RE share increase projected until 2030 and 2040 will be mainly driven by solar thermal technologies in buildings. The projected final energy demand of the Heating and Cooling sector is provided in

Table 40. The RES share foreseen in the Heating and Cooling sector is higher compared to that of the EU Reference Scenario up to 2030, as it reaches 24.1% in 2020 and 29.7% in 2030. Further, it is limited to 37.6% in 2040, whereas this scenario projects it will reach 50.1%.

[35] RES shares are calculated using the SHARES methodology.

Table 40 - Final energy demand in the Heating and Cooling sector (PJ) – WEM scenario.

PJ	2025	2030	2035	2040	2045	2050
Electricity	8.69	9.79	10.42	10.87	11.31	11.71
Heating oil/light fuel oil/Gas Oil	6.69	6.62	6.13	5.80	4.99	4.24
Pet Coke	2.49	2.13	1.92	1.72	1.58	1.47
LPG	2.61	2.82	2.81	2.69	2.48	2.19
Biomass	1.10	1.33	1.44	1.63	1.65	1.62
Geothermal	0.06	0.05	0.07	0.09	0.14	0.21
Solar thermal	3.20	3.75	4.77	5.99	7.09	8.20
RES share	***35.5%***	***39.0%***	***44.4%***	***50.1%***	***56.1%***	***62.0%***

Comparison with POTEnCIA results 2018

EU Reference Scenario 2016 results do not provide the required detail in terms of final energy demand by sector to allow a comparison of Heating and Cooling results. As such a comparison is made with POTEnCIA results only. A key point of difference between the present scenario and the POTEnCIA results is the contribution of solar thermal in the Heating and Cooling sector. POTEnCIA scenario projects 65 ktoe in 2020, 61 ktoe in 2030 and 70 ktoe in 2040, while the present scenario foresees a contribution by solar technologies of 72 ktoe in 2020, 90 ktoe in 2030 and 143 ktoe in 2040.

A.II.I.IV. Primary Energy Supply and Final Energy Demand

A moderate decrease in the primary energy supply can be observed across the time horizon (Table 41). The main driver of this is the incorporation of greater shares of renewable energy, which displaces fossil-fired generation in the electricity sector. Additionally, in 2020 heavy fuel oil is still used to a considerable extent until the introduction of less carbon-intensive natural gas in the power sector in the last quarter of the following year.

Table 41 – Primary Energy Supply evolution till 2050 (ktoe) – WEM scenario.

	2025	2030	2035	2040	2045	2050
Diesel	260	270	276	274	244	224
Gasoline	423	394	342	299	319	357
Heavy Fuel Oil	3	19	4	-	-	-
LPG	63	68	67	64	60	52
Heating Oil/light fuel oil/Gas oil	160	158	147	138	119	101
Pet coke	59	51	46	41	38	35
Natural gas	827	912	594	397	315	245
Hydrogen	-	-	-	-	-	-
Electricity	-	-	-	-	-	-
Biomass (includes biofuels)	112	117	118	121	120	120
Geothermal	1	1	2	2	3	5
Solar thermal	91	104	276	464	586	651
Solar PV	79	104	176	173	161	189
Wind	21	21	19	17	14	14
Total	***2,099***	***2,221***	***2,066***	***1,991***	***1,978***	***1,993***

Despite the reduction in primary energy supply, final energy demand is projected to increase (Table 42). The main driver in this case is the increased electricity demand, which in turn is generated by more efficient gas-fired plants and renewable energy technologies. Continued electrification of the heating and cooling sector, as well as the considerable volume of electricity consumed in the transport sector have a significant role in the growth of electricity demand. The contribution of fossil fuels decreases with time. Furthermore, the total contribution of solar thermal in the electricity supply sector and the heating and cooling sector is projected to increase by 44% from 2020 to 2030 and 644% from 2020 to 2040.

Useful insights can be provided through a comparison of the final energy demand with the primary energy supply. Even though final energy demand undergoes a moderate increase between 2020 and 2040, primary energy supply illustrates a moderate decrease. This is an indication of improved energy efficiency. Specifically, when final energy demand is measured as a share of primary energy supply, total energy efficiency amounts to 70% in 2020; this value increases to 75% in 2030 and 86% in 2040.

As shown in Table 43, the RES share in final energy demand is projected to increase gradually. The key sector driving this transition is the electricity supply sector. The 13% target for 2020 is achieved, while this increases further to 20.7% by 2030 and 43.8% by 2040.

Table 42 – Final Energy Demand evolution till 2050 (ktoe) – WEM scenario.

	2025	2030	2035	2040	2045	2050
Diesel	260	270	276	274	244	224
Gasoline	423	394	342	299	319	357
LPG	63	68	67	64	60	52
Heating Oil/light fuel oil/Gas oil	160	158	147	138	119	101
Natural gas	-	-	-	-	-	-
Pet Coke	59	51	46	41	38	35
Hydrogen	-	-	-	-	-	-
Electricity	502	574	631	679	720	749
Biomass (includes biofuels)	55	60	61	64	64	63
Geothermal	1	1	2	2	3	5
Solar thermal	76	90	114	143	169	196
Total	***1,600***	***1,666***	***1,685***	***1,705***	***1,735***	***1,783***

Table 43 – RE share in final energy demand across the energy system – WEM scenario.

	2025	2030	2035	2040	2045	2050
All sectors	18.7%	20.7%	33.9%	43.8%	48.9%	52.5%
Electricity	25.1%	26.3%	56.6%	74.0%	80.5%	85.5%
Heating and cooling	35.5%	39.0%	44.4%	50.1%	56.1%	62.0%
Transport (RED Recast methodology)	6.0%	7.3%	15.9%	29.2%	38.2%	41.7%

Comparison with EU Reference Scenario 2016

In comparison to the EU Reference Scenario 2016, the final energy demand in the present model is higher. When aviation is excluded, since it is not reported here either, the EU Reference Scenario 2016 projects final energy demand at 1452 ktoe, 1396 ktoe and 1454 ktoe for the years 2020, 2030 and 2040, respectively. the energy demand reported here is higher by about 80 ktoe in 2020, 270 ktoe in 2030 and 250 ktoe in 2040. As mentioned above, a major reason for this discrepancy is related to the final electricity demand; a difference of 47 ktoe exists for 2020, 130 ktoe for 2030 and nearly 175 ktoe for 2040.

In regards to the overall RES share in final energy demand, the EU Reference Scenario 2016 projects 18.4% in 2030 and 20.3% in 2040. The equivalent figures in the present effort are 20.7% in 2030 and 43.8% in 2040.

Comparison with POTEnCIA results 2018

Final energy demand is for the majority of the horizon lower in the POTEnCIA outlook than the present model (1,647 ktoe vs 1,534 ktoe in the present scenario in 2020, 1,570 vs 1,666 ktoe in 2030 and 1,552 vs 1,705 ktoe in 2040). The difference is mainly attributed to the higher electricity demand assumed in the present effort; this is higher by 230 ktoe in 2030 and 315 ktoe in 2040 in the present effort.

Similarly, gross inland consumption is lower in the POTEnCIA scenario. Specifically, this is projected at 2,300 ktoe in 2020, 2,205 in 2030 and 1,991 ktoe in 2040, versus 2,209 ktoe in 2020, 2,221 ktoe in 2030 and 1,993 ktoe in 2040 in the present scenario. This inconsistency is likely attributed to different assumptions regarding economic growth and thus energy demand.

An interesting observation relates to the projected outlook for the domestic production of natural gas in the POTEnCIA scenario. Although not explicitly mentioned in the results, it can be deduced from some of the indicators that no production of natural gas is foreseen. Carbon dioxide emissions in the primary energy production sectors remain zero throughout the modelling horizon till 2050. Similarly, consumption in pipeline transport remains at zero levels; hence no imports or exports via pipeline are considered either.

A.II.I.V. Greenhouse Gas Emissions

Drawing directly from the model outputs, a greenhouse gas emission trajectory is extracted (Figure 11 and Table 44). A degree of decarbonisation is achieved initially by gas-fired generation and later by solar PV and solar thermal generation in the ETS sector in this scenario; total CO_2 eq emissions in the ETS sector drop from 3,560 ktons in 2020 to 2,410 ktons in 2030 and 1,140 ktons in 2040. The reduction in CO_2 eq emissions in the non-ETS sector is relatively moderate. Emissions in the non-ETS sector decrease from 2,820 ktons in 2020 to 2,800 ktons in 2030 and 2,470 ktons in 2040. The main driver for this is the continued dependence of the transport sector on oil products.

Table 44 – GHG emission trajectory in the ETS and Non-ETS energy-related sectors.

	Unit	2025	2030	2035	2040	2045	2050
ETS CO_2	**Mt**	2.19	2.41	1.61	1.14	0.93	0.75
Non-ETS CO_2	**Mt**	2.76	2.72	2.54	2.35	2.25	2.23
ETS CH_4	**kt**	0.04	0.05	0.03	0.02	0.02	0.01
Non-ETS CH_4	**kt**	1.90	2.72	3.56	4.43	4.44	4.30
ETS N_2O	**kt**	0.005	0.006	0.004	0.003	0.002	0.002
Non-ETS N_2O	**kt**	0.04	0.04	0.05	0.05	0.05	0.05

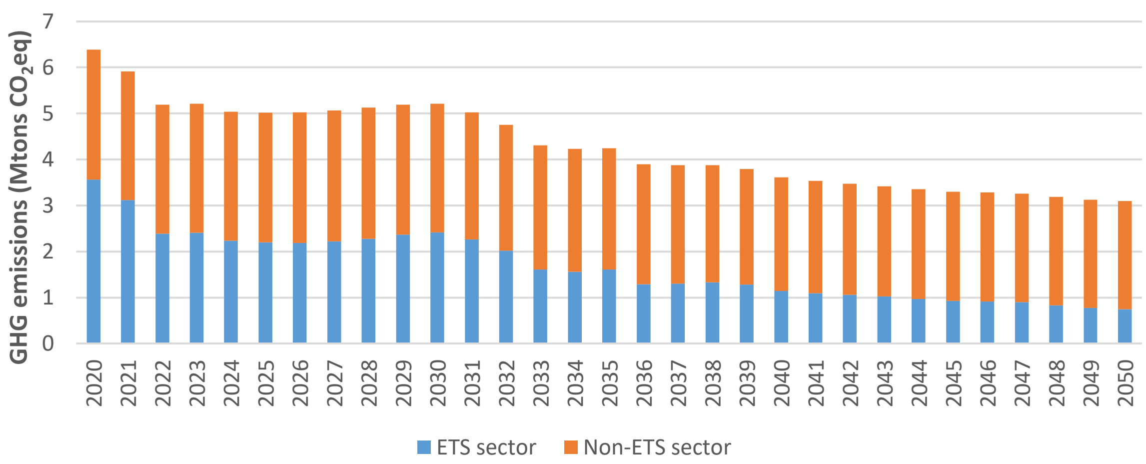

Figure 11 – Trajectory of greenhouse gas emissions in the ETS and non-ETS energy-related sectors – WEM scenario.

Comparison with EU Reference Scenario 2016

The above results are not consistent with those of EU Reference scenario 2016. Specifically, the total energy related CO_2 emissions in that report are projected to reach 5.4 Mt in 2020, whereas here 6.4 Mt are estimated. Similarly, the EU Reference scenario's projection indicates 4.9 Mt in 2030 and 5.2 Mt in 2040, whereas the scenario provided here indicates 5.2 Mt by 2030 and 3.6 Mt by 2040. The reason for the difference observed in 2040 is twofold; on one hand, a greater share of RES-E is projected in the present scenario, while on the other hand the carbon intensity of the transport sector is much higher in the EU Reference Scenario 2016. Whereas the present scenario foresees transport CO_2 emissions at 2.3 Mt in 2040, transport-related CO_2 emissions in the EU Reference scenario reach 3 Mt in the same year.

Comparison with POTEnCIA results 2018

Due to the assumed prolonged dependence on heavy fuel oil and diesel for electricity generation, emissions in the ETS sector remain at high levels for the majority of the projected horizon in the POTEnCIA scenario results. As aforementioned, road transport CO_2 emissions are lower in the POTEnCIA model results than this scenario, due to significantly lower transport demand projections in the former case.

In terms of total CO_2 emissions in the sectors considered in the present effort (i.e. heating and cooling, road transport and electricity generation), the projection is lower in the POTEnCIA outlook for the majority of the model horizon. Specifically, the total projected is 5.5 Mt in 2020, 4.8 Mt in 2030 and 4.2 Mt in 2040 in the POTEnCIA scenario versus 6.4 Mt in 2020, 5.2 Mt in 2030 and 3.6 Mt in 2040 in the present scenario. The inconsistency in 2020 could be attributed to the higher final energy demand and primary energy supply in the present effort. For instance, as mentioned in section 3.1.2, final electricity demand here is nearly 20% higher in 2020. Since this is powered mainly by HFO, the resulting difference in emissions is substantial.

A.II.I.VI. Air Pollutant Emissions

The aforementioned choices in energy technologies and fuel mix results in the air pollutant emissions projections shown in Table 45. Even though the increased renewable energy share across the economy leads to a reduction in NO_x and SO_2 emissions, PM2.5 and PM10 emissions initially decline up to 2025, as a result of more stringent regulations in road vehicle transport and a decrease in diesel passenger cars, but then an increase is observed until 2040 and 2050. This is attributed to an elevated use of biomass in the Heating and Cooling sector. It should be mentioned that the National Emission Ceiling set for SO_2 constrains the use of HFO with high sulphur content in 2020.

Table 45 – Air pollutant emission projections until 2050 in the WEM Scenario.

Pollutant	Unit	2025	2030	2035	2040	2045	2050
NO_x	**kt**	5.04	4.87	4.67	4.83	4.58	4.33
PM10	**kt**	1.33	1.46	1.49	1.66	1.66	1.65
PM2.5	**kt**	1.17	1.28	1.32	1.48	1.48	1.46
SO_2	**kt**	0.56	0.86	0.54	0.44	0.38	0.33

When the projections of DLI are taken into account for the remaining sectors of the economy that are not captured by the adopted methodology, a more comprehensive outlook is provided. It should be noted that DLI projects emissions for the major air pollutants only until 2030, and as such the horizon is limited in this case (Table 46).

Table 46 – Economy-wide air pollutant emissions projections in the WEM scenario until 2030.

Pollutant	Unit	2020	2025	2030
NO_x	**kt**	10.82	8.27	8.09
PM2.5	**kt**	1.56	1.36	1.46
SO_2	**kt**	3.64	0.66	0.96

A.II.I.VII. Financial Implications of WEM scenario in the Electricity Supply Sector

Investments foreseen in power generation will significantly affect electricity costs in total. Thus, due to the considerable investments in the electricity supply sector, the average cost of gross electricity generation increases gradually during the modelling period. Undeniably, this is a function of the assumed fuel price and technology costs adopted in the model. Figure 12 provides a breakdown of the different system cost components; these are all undiscounted[36]. As illustrated, a reduction in cost is achieved when the system shifts fully towards gas-fired generation in 2021. It can be noticed that variable costs (i.e. fuel costs) are the main driver of the electricity cost till 2031. Regarding the actual investment costs, these are illustrated for each technology in Figure 13. From 2032 onwards, the considerable investments in solar PV, solar thermal and storage technologies substitute the variable costs as the main driver for the cost of electricity. The rate at which these investments occur is considerably high in the period 2030-2050 and raises the question of adequate funding to finance all this infrastructure.

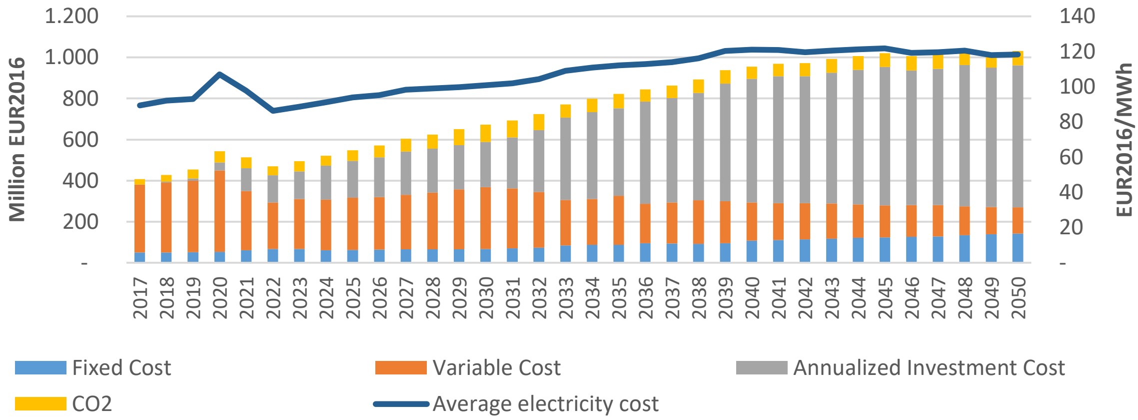

Figure 12 – Average cost of electricity and breakdown of system cost components – WEM scenario.

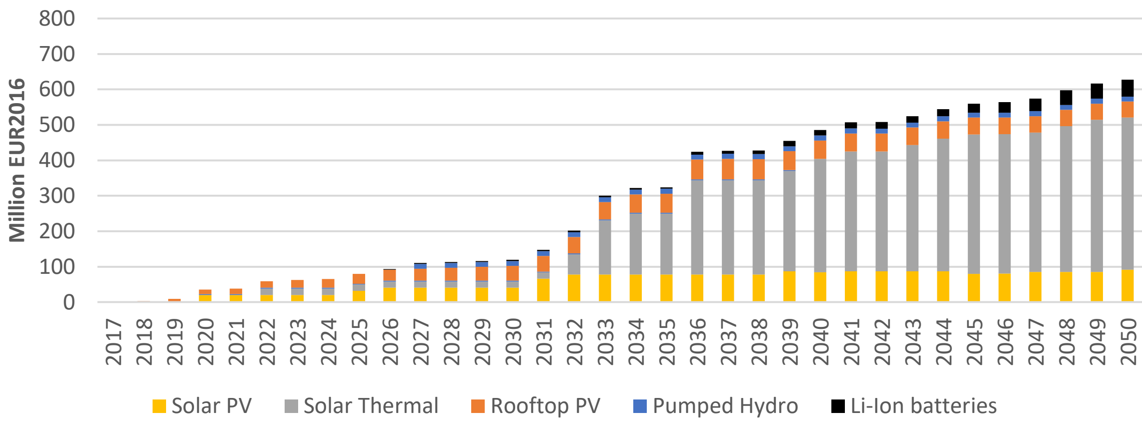

Figure 13 – Annualized investment costs in solar PV, solar thermal and storage technologies in the period 2020-2050 – WEM scenario.

Comparison with EU Reference Scenario 2016

In comparison to the EU Reference Scenario 2016, the average cost of electricity generation is slightly lower in the present scenario. The former projects a cost of around 110-120 EUR2016/MWh for the entire period between 2020 and 2040, whereas the present scenario projects a cost between 90-120

[36] Undiscounted costs are reported to avoid giving the wrongful impression that costs are expected to decrease dramatically with time. Taking into account that the discount rate adopted is 8.5% for most technologies in the electricity sector, if the cost were to be discounted to the first year, then the values after the first few years would be distorted (i.e. reduced) substantially.

EUR2016/MWh. A potential reason for this difference is that technology and fuel cost assumptions were not aligned between the two models; the present model assumes considerably lower fuel price projections. Similarly, the assumptions regarding photovoltaics and battery storage have significant discrepancies. For instance, utility-scale PV assumed here has an investment cost of 1160 EUR2016/kW in 2020 and 890 EUR2016/kW in 2030, whereas the EU Reference Scenario 2016 assumes 840 EUR/kW in 2020 and 700 EUR/kW in 2030. On the other hand, the present model assumes that the battery storage cost will drop to 150 EUR2016/kWh by 2030, while the EU Reference Scenario 2016 assumes a constant cost of 8,250 EUR2016/kWh until 2050.

Comparison with POTEnCIA results 2018

Variable operation and maintenance and fuel costs are projected to remain the dominant cost component for electricity throughout the modelling horizon in the POTEnCIA scenario. Furthermore, the cost of electricity is projected to be significantly higher in this case. POTEnCIA results indicate a cost of 190 EUR2016/MWh in 2020, which then increases to 232 EUR2016/MWh in 2030 and then drops to 181 EUR2016/MWh by 2040. The difference from the 90-120 EUR2016/MWh projected by the present effort is substantial.

The difference is driven mainly by the variable cost component. In POTEnCIA scenario results, annual variable costs range between 530-790 million EUR2016; the vast majority of these are fuel costs. In contrast the present model projects annual variable costs at 255-460 million EUR2016. This can potentially be attributed to the differences in assumed fuel prices. Also, the use of more expensive diesel and HFO as opposed to natural gas as the main generation fuel, drives the cost upwards in the POTEnCIA scenario results.

A.II.II. Planned Policies and Measures Scenario

The below sections present the results for the PPM scenario for each of the sectors.

A.II.II.I. Electricity Supply Sector

A.II.II.I.I. Capacity

The incorporation of the EuroAsia interconnector in the system at a Net Transfer Capacity of 1,000 MW, and to a lesser degree the lower electricity demand, in the PPM scenario leads to major changes in the investment outlook of the electricity supply sector (Table 47). Specifically, investments in new CCGT units are reduced by one unit as compared to the WEM scenario. Similarly, no investments occur in new steam turbines, gas turbines and CHP facilities. In addition, investments in batteries are also reduced drastically and are delayed to the end of the modelling horizon.

Table 47 - Capacity projections in the electricity supply sector (MW) – PPM scenario.

	2025	2030	2035	2040	2045	2050
Vasilikos	868	868	608	0	0	0
Dhekelia	102	102	0	0	0	0
Moni	150	150	0	0	0	0
New CCGT	216	216	216	432	432	432
New ICE	0	0	0	0	0	0
New ST	0	0	0	0	0	0
New GT	0	0	0	0	0	0
Light fuel oil CHP	0	0	0	0	0	0
Solar PV	460	1,680	2,845	3,021	3,021	2,984
Solar Thermal	50	50	50	850	1,050	1,250
Wind	175	175	175	175	158	158
Biomass	50	58	58	58	58	58
Pumped Hydro	0	130	130	130	130	130
Li-Ion Batteries	0	0	0	145	209	452

However, investments in solar PV capacity are increased substantially; these are higher by 930 MW in 2030 and 1,320 MW in 2040 as compared to the WEM scenario. Such a high deployment is enabled by the trading opportunities offered by the interconnector. An exception is noticed in 2025, where PV capacity is reduced by 95 MW, as it is deemed cost-effective to rely on the interconnector for that particular point in time.

It is interesting to highlight that the investment in pumped hydro remains unaffected in this scenario. Other than energy arbitrage, this technology is assumed to be able to contribute towards meeting the demand for operational reserves. It should be mentioned that the interconnector was not allowed to contribute towards meeting operational reserves demand. It is possible that if the interconnector was allowed to do so, then pumped-hydro would likely not be deployed.

A.II.II.I.II. Generation

The above technology deployment provides the generation mix shown in Figure 14. For the majority of the model horizon, with the exception of the period 2024-2026 at annual net imports in the range of 380-445 GWh, the Cypriot grid becomes a net exporter of electricity. In the period 2027-2040 net exports of electricity range between 90 and 2,420 GWh annually. Electricity trade related results are very sensitive to the assumed electricity prices in Greece and Israel. Since these systems are not modelled explicitly, there are significant limitations in the adopted approach, as intra-year electricity cost and demand variations in the external systems are not captured.

Exported electricity is largely dependent on the increased solar PV generation. As compared to the WEM scenario, this increases from 1,215 GWh to 2,720 GWh in 2030 and from 2,010 GWh to 4,460

GWh in 2040 in the PPM scenario. Taking into account the net imports (see Figure 14), this leads to a RES-E share of 54% in 2030 and 119% in 2040. When electricity exchange is not accounted for, RES share in generation amounts to 44% in 2030 and 85% in 2040.

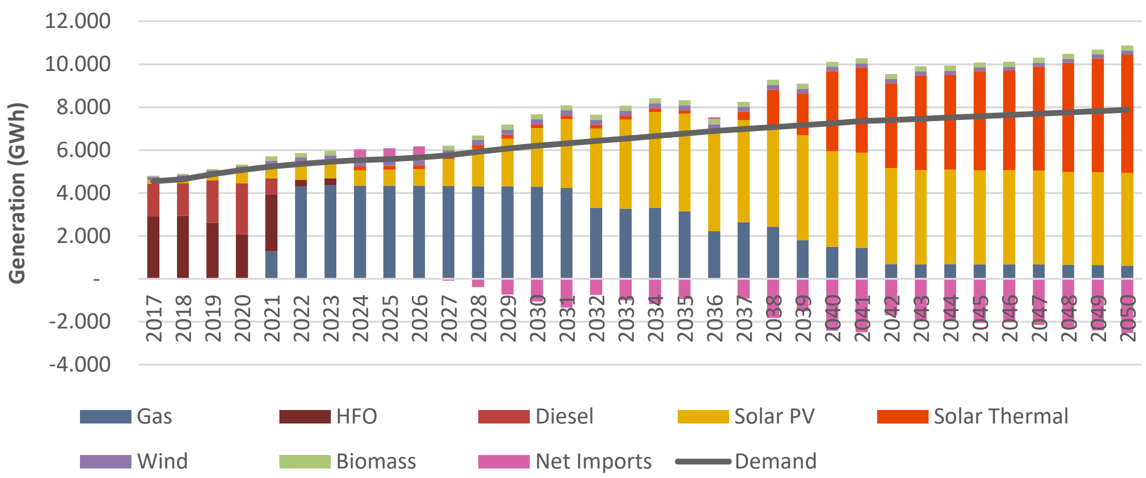

Figure 14 - Projected generation mix till 2050 – PPM scenario.

A.II.II.II. Transport Sector

Due to the assumed modal shift from passenger cars to public transport, significant changes occur in the vehicle fleet of the PPM scenario (Table 48). The most notable change is the lower projection in passenger cars compared to the WEM scenario. Specifically, by 2030 the present scenario's passenger car fleet is lower by nearly 130 thousand vehicles in 2030 and 150 thousand vehicles in 2040.

Most of this reduction is experienced by gasoline-fired passenger cars; these are lower by about 150 thousand and 160 thousand in 2030 and 2040. Similarly, gasoline hybrid passenger cars are slightly reduced, while BEVs are increased by more than 25 thousand vehicles in 2030 and 2040. On the other hand, a small number of diesel PHEV purchases can be noticed which were not present in the WEM scenario.

In addition, a reduction in light truck and motorcycle fleets can be noticed, driven by the relevant mileage demand assumptions. On the contrary, the shift towards public transport creates a necessity for additional buses, which are higher by 2,560 units in 2030 and 2,970 units in 2040. As a result of the Clean Vehicles Directive for the public procurement of clean vehicles, a large number of these additional buses are fully-powered by electricity.

The outlook of fuel consumption in the transport sector changes as a result of the aforementioned transport fleet outlook (Table 49). The biggest variation can be noticed in the consumption projection of gasoline. This decreases by 31% in 2030 and 38% in 2040 as compared to the WEM scenario. This is attributed to the reduced use of passenger cars and higher use of public transport. Increased use of buses does not affect diesel fuel sales, as they remain at similar levels as in the WEM scenario.

In terms of electricity consumption in the transport sector, total consumption increases by 130 GWh in 2030 and 140 GWh by 2040 as compared to the WEM scenario. Annual electricity consumption in rail transport is assumed to remain at the same levels throughout the model horizon as the number of trips by the tram line in Nicosia was kept constant. It is important to highlight the drastic reduction in overall energy demand of the transport sector through the promotion of public transport (i.e. buses and rail). It is estimated that additional cumulative investments in public transport for this scenario amount to approximately 1 billion EUR2016 until 2030. These levels of investment are very large compared to what's foreseen in other sectors, but they also lead to lower private investments of approximately 2 billion EUR2016 during the same period. It is noted that he materialisation of these projections will necessitate an equivalent level of public acceptance and adoption of these modes of transport to make such investments successful.

Table 48 – Projected vehicle fleet (total number of vehicles) – PPM scenario.

		2025	2030	2035	2040	2045	2050
Passenger cars	**Diesel**	53,722	57,281	71,197	62,864	30,502	5,016
	Diesel hybrid	-	-	-	-	-	-
	Diesel PHEV	252	799	1,474	1,923	2,110	2,273
	Gasoline	459,188	333,432	220,912	121,228	141,074	203,481
	Gasoline Hybrid	5,170	46,181	112,103	186,893	222,298	227,621
	Gasoline PHEV	-	-	-	-	-	-
	BEV	100	54,858	125,850	200,639	222,298	227,621
	LPG	739	1,174	963	437	53	159
	Natural gas	-	-	-	-	-	-
	Hydrogen	-	-	-	-	-	-
		2025	**2030**	**2035**	**2040**	**2045**	**2050**
Buses	**Diesel**	4,372	5,574	5,669	5,923	6,359	6,733
	Diesel hybrid	-	-	-	-	-	-
	BEV	138	436	804	1,049	1,151	1,239
	CNG	-	-	-	-	-	-
		2025	**2030**	**2035**	**2040**	**2045**	**2050**
MCs	**Gasoline**	48,476	46,000	49,557	53,408	57,687	61,176
	BEV	-	-	-	-	-	-
		2025	**2030**	**2035**	**2040**	**2045**	**2050**
Trucks	**Diesel**	14,146	13,740	13,246	12,781	13,957	15,044
	BEV	-	1,571	3,247	4,988	5,182	5,272
	Natural gas	-	-	-	-	-	-
		2025	**2030**	**2035**	**2040**	**2045**	**2050**
Light Trucks	**Diesel**	126,670	133,726	144,063	155,192	157,785	152,580
	BEV	-	-	-	-	9,403	25,075
	PHEV Diesel	-	-	-	-	-	-
	Hybrid diesel	-	-	-	-	-	-
	Grand Total	**712,972**	**694,771**	**749,084**	**807,324**	**869,857**	**933,291**

Using the SHARES methodology, RES-T share in this case has been estimated to rise to 14.8% in 2030 and 40.4% in 2040. In the case of the WEM scenario, the equivalent figures were limited to 7.3% in 2030 and 29.2% in 2040.

Table 49 – Evolution of fuel consumption in the transport sector till 2050 – PPM scenario.

		2025	2030	2035	2040	2045	2050
Biofuels	**Litres**	43,762,259	47,662,323	34,471,184	31,274,131	31,565,909	32,310,605
Diesel	**Litres**	322,582,344	317,927,250	328,061,714	314,776,375	289,651,186	261,767,087
Gasoline	**Litres**	472,163,302	357,692,722	289,527,562	243,581,622	277,112,681	322,322,470
LPG	**Litres**	971,297	1,516,809	-	-	64,849	-
Natural gas (STP)	**m3**	-	-	-	-	-	-
Electricity (road)	**MWh**	3,829	211,788	464,532	717,179	814,642	886,001
Electricity (rail)	**MWh**	-	9,126	9,126	9,126	9,126	9,126

A.II.II.III. Heating and Cooling Sector

The additional energy efficiency measures adopted in the PPM scenario lead to a considerable decrease in the total final energy demand of the Heating and Cooling sector. A reduction of 4% and 13% is indicated by 2030 and 2040, respectively, as compared to the WEM scenario. As shown in Table 50 all of the fuels indicate lower figures, while lower investments in renewable energy technologies in the present scenario result to a moderately lower RES share in the Heating and Cooling sector.

Table 50 - Final energy demand in the Heating and Cooling sector (PJ) – PPM scenario.

PJ	2025	2030	2035	2040	2045	2050
Electricity	8.29	8.90	9.38	9.71	10.04	10.38
Heating oil/light fuel oil/Gas Oil	6.60	6.45	5.73	4.92	4.16	3.48
Pet Coke	2.47	2.15	1.93	1.68	1.49	1.34
LPG	2.56	2.70	2.56	2.33	2.06	1.77
Biomass	1.07	1.27	1.29	1.26	1.21	1.17
Geothermal	0.05	0.05	0.05	0.06	0.06	0.07
District Heating and Cooling	0	0.26	0.26	0.26	0.26	0.26
Solar thermal	3.06	3.51	4.10	4.65	5.02	5.38
RES share	***35.2%***	***39.4%***	***44.2%***	***49.5%***	***54.5%***	***59.6%***

A.II.II.IV. Primary Energy Supply and Final Energy Demand

Due to the changes in the energy mix and demand indicated in all the sectors (i.e. electricity, transport, heating and cooling), primary energy supply decreases considerably in this scenario. Specifically, by 2030 and 2040 an 11% and 15% reduction is achieved, respectively, compared to the WEM scenario; these correspond to a difference of 240 and 310 ktoe in the two years respectively (Table 51). A considerable decrease is achieved in the use of gasoline, due to measures in the transport section, which is reduced by 120 ktoe in 2030 and 110 ktoe in 2040. Similarly, a higher deployment of renewable energy technologies in the electricity supply sector reduces the supply of natural gas by 145 ktoe in 2030 and 130 ktoe in 2040. On the other hand, primary energy supply from solar photovoltaics increases by 280 ktoe in 2030 and 210 ktoe in 2040.

Even though final energy demand in the WEM scenario shows a moderate increase over the model horizon, a moderate decrease is illustrated in the PPM scenario (Table 52). This results in a total difference of 160 ktoe in 2030 and 240 ktoe in 2040. Other than the aforementioned difference in gasoline consumption in the transport sector, a difference of 40 ktoe in 2030 and 55 ktoe in 2040 is also observed in the final electricity demand.

Table 51 – Primary Energy Supply evolution till 2050 (ktoe) – PPM scenario.

	2025	2030	2035	2040	2045	2050
Diesel	277	273	282	271	249	225
Gasoline	361	273	221	186	212	246
Heavy Fuel Oil	-	-	-	-	-	-
LPG	62	65	61	56	49	42
Heating Oil/light fuel oil/Gas oil	158	154	137	118	99	83
Pet coke	59	51	46	40	36	32
Natural gas	775	767	561	266	120	108
Hydrogen	-	-	-	-	-	-
Electricity	33	-90	-80	-208	-176	-216
Biomass (includes biofuels)	110	129	121	119	117	116
Geothermal	1	1	1	1	1	2
Solar thermal	88	99	113	432	518	603
Solar PV	64	234	391	383	377	372
Wind	19	21	19	17	15	16
Total	***2,008***	***1,978***	***1,873***	***1,681***	***1,617***	***1,630***

In terms of overall system efficiency, through a comparison between primary energy supply and final energy demand, slightly improved figures can be noticed at the end of the modelling horizon. This is estimated at 76% in 2030 and 87% in 2040 in the present scenario versus 75% in 2030 and 86% in 2040 in the WEM scenario.

Table 52 – Final Energy Demand evolution till 2050 (ktoe) – PPM scenario.

	2025	2030	2035	2040	2045	2050
Diesel	277	273	282	271	249	225
Gasoline	361	273	221	186	212	246
LPG	62	65	61	56	49	42
Heating Oil/light fuel oil/Gas oil	158	154	137	118	99	83
Natural gas	-	-	-	-	-	-
Pet Coke	59	51	46	40	36	32
Hydrogen	-	-	-	-	-	-
Electricity	479	533	583	623	651	677
Biomass (includes biofuels)	53	61	54	51	50	49
Geothermal	1	1	1	1	1	2
District Heating and Cooling	-	6	6	6	6	6
Solar thermal	73	84	98	111	120	129
Total	***1,523***	***1,503***	***1,489***	***1,463***	***1,473***	***1,491***

As shown in Table 53, reduced primary energy supply and final energy demand in combination with a drastically increased renewable energy share in electricity supply, lead to a considerable increase in the overall renewable energy share. In the present scenario, this is estimated at 30.7% versus 20.7% in the WEM scenario by 2030.

Table 53 – RE share in final energy demand across the energy system – PPM scenario.

	2025	2030	2035	2040	2045	2050
All sectors	18.1%	30.7%	40.4%	61.0%	65.3%	69.5%
Electricity	22.2%	50.9%	70.1%	112.1%	117.2%	122.8%
Heating and cooling	35.2%	39.4%	44.2%	49.5%	54.5%	59.6%
Transport (RED Recast methodology)	6.4%	14.8%	20.8%	37.7%	51.1%	53.9%

A.II.II.V. Greenhouse Gas Emissions

As opposed to the WEM scenario, a greater level of decarbonisation is achieved in both ETS and non-ETS sectors (Figure 15 and Table 54). In the PPM, the deployment of the EuroAsia Interconnector enables a further penetration of solar PV, and reduces CO_2 eq emissions by 400 ktons in 2030 (with a total of 2,014 ktons) and 350 ktons in 2040 (with a total of 790 ktons) as compared to the WEM scenario. The lower domestic electricity demand also plays a role in this reduction. Similarly, in comparison to the WEM scenario, non-ETS sector CO_2 eq emissions reduce further by 370 ktons in 2030 (with a total of 2,430 ktons) and 390 ktons in 2040 (with a total of 2,080 ktons). In this case, the reduction is largely driven by a modal shift in the transport sector away from passenger cars towards public transport. It is worth noting here that the model does not account for emissions occurring in other countries due to the exchange of electricity via the interconnector. In an EU context, emissions in Greece would be accounted by the generation data for the country towards EU targets, but the ones in Israel would not. Generation in Israel after the interconnector becomes operational may be done via carbon-intensive means (e.g. coal), but this is not possible to be captured here without explicitly modelling Israel's energy system.

Table 54 – GHG emission trajectory in the ETS and Non-ETS energy-related sectors.

	Unit	2025	2030	2035	2040	2045	2050
ETS CO_2	**Mt**	2.06	2.01	1.50	0.79	0.43	0.39
Non-ETS CO_2	**Mt**	2.62	2.35	2.17	1.96	1.90	1.86
ETS CH_4	**kt**	0.04	0.04	0.03	0.02	0.01	0.01
Non-ETS CH_4	**kt**	1.95	2.55	3.38	4.15	4.29	4.11
ETS N_2O	**kt**	0.005	0.005	0.004	0.002	0.001	0.001
Non-ETS N_2O	**kt**	0.04	0.04	0.05	0.05	0.04	0.04

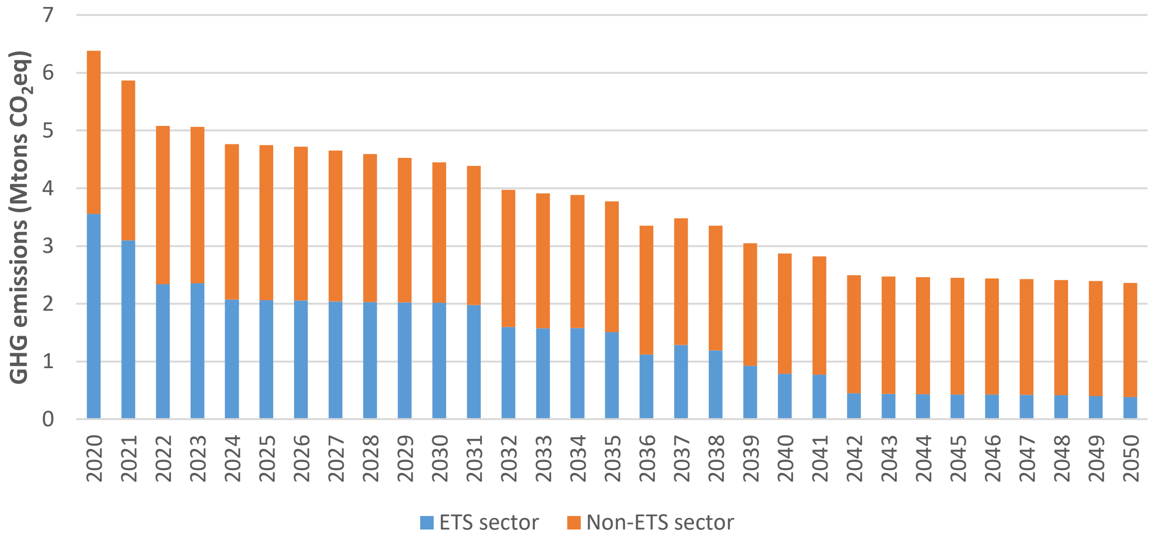

Figure 15 – Trajectory of greenhouse gas emissions in the ETS and non-ETS sectors – PPM scenario.

A.II.II.VI. Air Pollutant Emissions

As compared to the WEM scenario, a reduced projection in air pollutant emissions is observed, as illustrated by Table 55. A reduction is noticed for all air pollutants, but $PM_{2.5}$ and PM_{10} indicate the highest reduction in the long-term. This is due to a lower use of biomass in the Heating and Cooling sector, as well as to lower fossil fuel consumption in road transport. Additionally, by 2030 a considerable difference is noticed in SO_2 emissions; this is attributed to a significantly higher RES-E share in the PPM scenario, which also completely displaces the small amounts of oil-fired generation observed in the WEM scenario. Finally, NO_x emissions are lower in the PPM scenario due to a lower gas-fired generation, as well as a lower dependence on fossil-fired passenger vehicles in the road transport sector.

Table 55 – Air pollutant emission projections until 2050 in the PPM Scenario.

Pollutant	Unit	2025	2030	2035	2040	2045	2050
NO_x	**kt**	4.99	4.52	4.47	4.25	3.94	3.67
Difference from WEM		*-1%*	*-7%*	*-4%*	*-12%*	*-14%*	*-15%*
PM_{10}	**kt**	1.27	1.33	1.32	1.27	1.23	1.21
Difference from WEM		*-5%*	*-9%*	*-11%*	*-23%*	*-26%*	*-27%*
$PM_{2.5}$	**kt**	1.11	1.18	1.18	1.13	1.09	1.06
Difference from WEM		*-5%*	*-8%*	*-11%*	*-24%*	*-26%*	*-27%*
SO_2	**kt**	0.5	0.49	0.43	0.37	0.32	0.27
Difference from WEM		*-11%*	*-43%*	*-20%*	*-16%*	*-16%*	*-18%*

When the projections of DLI are taken into account for the remaining sectors of the economy that are not captured by the adopted methodology, a more comprehensive outlook is provided. As aforementioned, DLI projects emissions for the major air pollutants only until 2030, and as such the horizon is limited in this case (Table 56).

Table 56 – Economy-wide air pollutant emissions projections in the PPM scenario until 2030.

Pollutant	Unit	2020	2025	2030
NO_x	kt	10.81	8.22	7.74
PM2.5	kt	1.56	1.31	1.36
SO_2	kt	3.64	0.59	0.59

A.II.II.VII. Financial Implications of PPM scenario in the Electricity Supply Sector

Due to the higher RES penetration, and reduced dependence on fossil-fired generation, both enabled by the interconnector, the cost of electricity remains relatively stable throughout the model horizon in the PPM scenario (Figure 16). In comparison to the WEM scenario, electricity cost reduces by 5% in 2030 and 16% by 2040. The reduction in cost is also driven by the lower investments in conventional thermal facilities and battery storage.

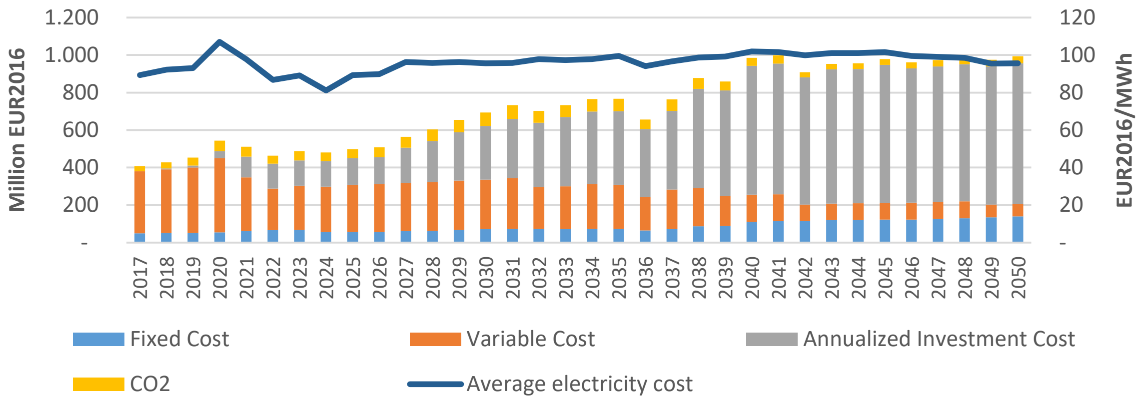

Figure 16 – Average cost of electricity and breakdown of system cost components – PPM scenario.

As compared to the WEM scenario, investment requirements in the electricity supply sector (which are presented in Figure 17) are considerably higher over the duration of the model horizon in the PPM scenario. These are mainly driven by higher utility-scale solar PV deployment; annualised investments in this technology amount to 130 million EUR in the latter case, as opposed to 40 million EUR in the former case in 2030.

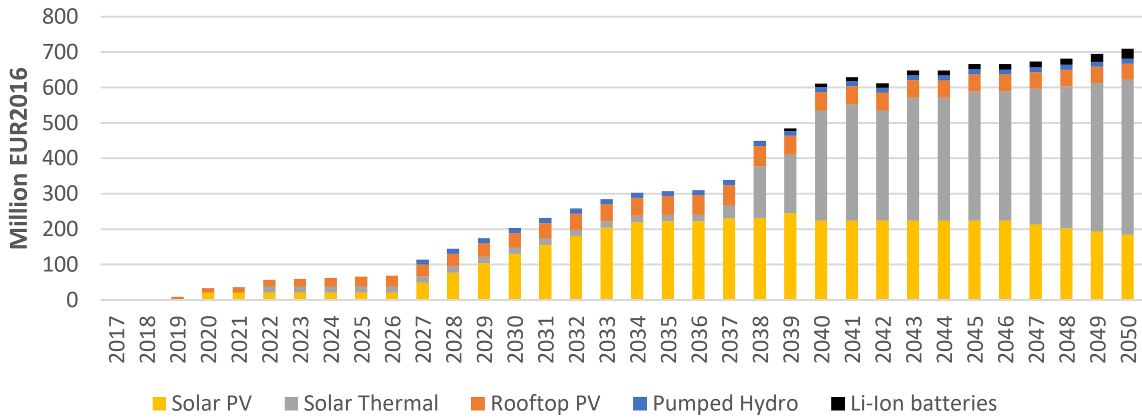

Figure 17 - Annualized investment costs in solar PV, solar thermal and storage technologies in the period 2020-2050 – PPM scenario.

APPENDIX III: Methodology to Assess Macroeconomic Impacts

Input-output (IO) analysis is a quantitative technique for studying the interdependence of production sectors in an economy over a stated time period (Miller and Blair, 2009), and it has been extensively applied for policy impact evaluation, technical change analysis and forecasting[37].

The static version of the IO model can be formulated by the equation (1):

$$X = AX + Y \qquad (1)$$

where, X is an $n \times 1$ vector of production in each sector of economic activity; Y is the final demand for each sector's product; A is a (nxn) matrix of technical coefficients a_{ij} that denotes the total output from sector i that is required to produce one unit of output in sector j as follows:

$$a_{ij} = x_{ij}/x_j \qquad (2)$$

In the dynamic IO model, supply and demand move towards equilibrium at a rate which is a function of the unplanned change in inventories because of changes in demand. The basic equation of IO analysis in equilibrium conditions is the following[38]:

$$X(t)^E = A \times X(t)^E + Y_{EXP}(t) + Y_{CONS}(t) + Y_{INV}(t) + INV\dot{E}NT^E \qquad (3)$$

where, the superscript E indicates variables at their equilibrium levels and the dot over the variables indicates a first derivative with respect to time. Total demand is the sum of intermediate demand $(A \times X(t)^E)$ and final demand that consists of exports $\left(Y_{EXP}(t)\right)$, private and government consumption $\left(Y_{CONS}(t)\right)$, investment demand $(Y_{INV}(t))$ and the planned change in inventory in each sector $\left(INV\dot{E}NT^E\right)$.

The economy, in general, is not in equilibrium. Divergence between the equilibrium levels change inventories[39]. Defining changes in inventories as the equilibrium changes plus any changes due to disequilibrium adjustments, equation (3) becomes:

$$X(t) = A \times X(t)^E + Y_{EXP}(t) + Y_{CONS}(t) + Y_{INV}(t) + INVENT(t)^E - INVENT(t) + U(t) \qquad (4)$$

where, $INVENT^E(t)$ is the equilibrium level of inventories; $INVENT^E(t) - INVENT(t)$ is the equilibrium change in inventories, and $U(t)$ is the difference between actual rate of production and the equilibrium levels.

[37] Elias Giannakis and Adriana Bruggeman, "Economic Crisis and Regional Resilience: Evidence from Greece: Economic Crisis and Regional Resilience," *Papers in Regional Science* 96, no. 3 (August 2017): 451–76, https://doi.org/10.1111/pirs.12206.

[38] Thomas G. Johnson, "The Dynamics of Input-Output Introduction," in *Microcomputer Based Input-Output Modeling: Applicatons To Economic Development* (Westview Press, 1993); John M. Bryden et al., *Towards Sustainable Rural Regions in Europe Exploring Inter-Relationships Between Rural Policies, Farming, Environment, Demographics, Regional Economies and Quality of Life Using System Dynamics*, 1st ed. (Routledge, 2011); Sara Alva-Lizarraga, Karen Refsgaard, and Thomas G. Johnson, "Comparative Analysis of Agriculture and Rural Policies in Västerbotten and Hordaland Using the POMMARD-Model," *Food Economics - Acta Agriculturae Scandinavica, Section C* 8, no. 3 (September 2011): 142–60, https://doi.org/10.1080/16507541.2011.607589.

[39] Johnson, "The Dynamics of Input-Output Introduction"; Alva-Lizarraga, Refsgaard, and Johnson, "Comparative Analysis of Agriculture and Rural Policies in Västerbotten and Hordaland Using the POMMARD-Model."

In such system dynamic models, the production changes in response to the short-term imbalance in supply and demand, i.e., $U(t)$ [39]. By differentiating equation (4) we create the primary dynamism in the model:

$$\dot{X}(t) = \Delta[X(t) - (A \times X(t)^E + Y_{EXP}(t) + Y_{CONS}(t) + Y_{INV}(t) + INVENT(t)^E - INVENT(t))] \quad (5)$$

where, Δ is the inter-sectoral adjustment rate. Consequently, changes in exogenous expenditures, i.e., expenditures for investments, exports and private and government consumption, represent changes in the final demand of the economic sectors.

Typically, dynamic IO models impose a capacity constraint on production. Here, this feature is ignored due to a lack of information on sectoral capacity, capital purchase coefficients and fixed investment coefficients[40]. Instead, production is constrained when labour supply is lower than the labour demand[41].

The initial static equilibrium conditions of the dynamic IO model were based on the latest available IO table of Cyprus for the year 2015[42], which includes 65 sectors of economic activity. The national table was aggregated into 20 sectors of economic activity.

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40 Alva-Lizarraga, Refsgaard, and Johnson, "Comparative Analysis of Agriculture and Rural Policies in Västerbotten and Hordaland Using the POMMARD-Model"; Elias Giannakis, Sophia Efstratoglou, and Demetris Psaltopoulos, "Modelling the Impacts of Alternative CAP Scenarios through a System Dynamics Approach" 15 (2014): 21.

41 Bryden et al., *Towards Sustainable Rural Regions in Europe Exploring Inter-Relationships Between Rural Policies, Farming, Environment, Demographics, Regional Economies and Quality of Life Using System Dynamics*; Alva-Lizarraga, Refsgaard, and Johnson, "Comparative Analysis of Agriculture and Rural Policies in Västerbotten and Hordaland Using the POMMARD-Model."

42 Eurostat, "Symmetric Input-Output Table at Basic Prices," accessed September 25, 2019, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=naio_10_cp1700&lang=en.

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Draft Report:

Overall Comparison of Policies and Measures and Recommendations Regarding the National Energy and Climate Plan of Cyprus

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Nicosia, October 2019

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Overall Comparison of Policies and Measures and Recommendations Regarding the National Energy and Climate Plan of Cyprus

Contents

Abbreviations

CH_4	Methane
CO_2	Carbon Dioxide
CO_{2eq}	Carbon Dioxide equivalent
CUT	Cyprus University of Technology
CyI	The Cyprus Institute
DLI	Department of Labour Inspection
ESR	EU Effort Sharing Regulation (EU) 2018/842
ETS	EU Emissions Trading System
GHG	Greenhouse gases
ktoe	Thousand tonnes of oil equivalent
LULUCF	Land Use, Land Use Change and Forestry
MARDE	Ministry of Agriculture, Rural Development and Environment of Cyprus
MECI	Ministry of Energy, Commerce and Industry of Cyprus
MOF	Ministry of Finance of Cyprus
MTCW	Ministry of Transport, Communications and Works of Cyprus
N_2O	Nitrous Oxide
NECP	National Energy and Climate Plan
NOx	Nitrogen Oxides
OSeMOSYS	Open Source Energy Modelling System
PaMs	Policies and Measures
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter with an effective diameter up to 2.5 microns (μm)
PM_{10}	Particulate Matter with an effective diameter up to 10 microns (μm)
PPM	Scenario with Planned Policies and Measures
SO_2	Sulphur Dioxide
SRSS	European Commission's Structural Reform Support Service
UCy	University of Cyprus
WEM	Scenario with Existing Measures

1 Introduction

This report is developed within a technical support project funded by the European Union via the Structural Reform Support Programme and implemented by consortium led by the Cyprus University of Technology, in cooperation with the European Commission's Structural Reform Support Service (SRSS) under Service Contract SRSS/C2018/070.

According to Task 4 of the Tender Specifications of the Service Contract on the "Impact assessment of the Cyprus Integrated National Energy and Climate Plan", the project team has to carry out a comparison of the policy options included in the two scenarios of the National Energy and Climate Plan of Cyprus, and a summary analysis covering the key elements of the impact assessment presented in Deliverable 5 of this project. This draft Deliverable 6 reports on the outcome of work under this Task. More specifically, Section 2 of this report compares the policy options in terms of costs and benefits to the Cypriot society and cost-effectiveness. Section 3 provides the conclusions of the impact assessment study and main policy recommendations regarding the compliance of the Republic of Cyprus with its commitments within the framework of the Energy Union. An outlook towards deep decarbonisation by the mid-21st century is also provided.

It has to be noted that this is a draft version of Deliverable 6. At this stage, the contents of this report do not necessarily reflect the official views of the government of Cyprus.

2 Discussion of Policy Options

The Impact Assessment of the National Energy and Climate Plan of Cyprus, as presented in Deliverable 5 of this study, leads to some clear indications about the outlook of energy and climate policy of the country with a view to meeting the objectives foreseen in the EU Energy Governance Regulation. The following sections focus on a cost-benefit and a cost-effectiveness assessment of the policy options that seem to be available to Cyprus at this stage.

2.1 The Overall Costs and Benefits of Planned Policies and Measures

Table 1 displays a summary of the projected change in total energy system costs of the PPM scenario in comparison to the corresponding costs of the WEM scenario. Cost differences are presented for each main group of measures that are included in the PPM scenario: power generation, electricity storage, construction of the electricity interconnector, measures for promoting public and non-motorised transport, measures related to motor vehicles, and policies related to energy efficiency improvements in buildings and industry.

Cost differences are presented separately for investment costs and operation & maintenance costs; the latter also include fuel costs, and in many cases these are negative, reflecting the savings in fuel expenditures that can be achieved in the case of energy efficiency measures in transport, buildings and industry. Note that fuel costs that were included in these calculations are net of taxes and duties in order to reflect the societal effect from the reduction of fuel import costs. At the end of the table we have added the economic benefits foreseen due to reduced damages from air pollution, in line with the assessment shown in Section 3.4 of Deliverable 5.

It is evident that the policies and measures foreseen in the PPM scenario are expected to be beneficial to society. Total benefits, including the environmental ones, are close to 600 million Euros'2016 by 2030, representing 1.9% of the country's projected GDP[1] in that year. The additional investments,

[1] According to the macroeconomic assumptions used in the NECP, national GDP is projected to be 30.893 billion Euros'2016.

especially in energy efficiency measures and sustainable transport modes, although designed to be effective over a longer time horizon, pay off already by the end of the decade: fuel cost savings in buildings and industry as well as reduction in the purchase and use of private cars lead to a substantial decrease in operation costs and therefore to the total energy system costs. The benefits become also somewhat larger thanks to the improvements in air quality and the associated benefits from lower health impacts.

One might argue that these results are optimistic because of the projected strong reduction in the fleet of passenger cars, which leads to much lower investments for private transport in the PPM scenario. However, if one observes the figures of Table 1, it is evident that the PPM scenario leads to lower energy system costs even without the reductions in investments of private transport. This points to a clear conclusion that **the implementation of Planned Policies and Measures will be beneficial to society, leading to a reduced fuel import bill and improved air quality.** This finding is in line with international evidence, such as the European Commission's in-depth analysis of the carbon neutrality objective,[2] the World Bank[3] or other organisations.[4]

The above conclusion is valid as long as the policies and measures foreseen in the PPM scenario are actually realised. There are financial and behavioural barriers that may delay or cancel the deployment of some of these measures. However, our analysis shows that the government of Cyprus should proceed with these measures as they seem to be the only way for the country to approach its long-term energy and climate policy commitments.

[2] European Commission, "In-Depth Analysis in Support of the Commission Communication COM(2018) 773 - A Clean Planet for all", Brussels, 28 November 2018.

[3] World Bank (2014), *Climate Smart Development*. International Bank for Reconstruction and Development/The World Bank and ClimateWorks Foundation, Washington, DC.

[4] Coalition for Urban Transitions (2019), Climate Emergency, Urban Opportunity. Washington, DC.

Table 1 – Projected change in energy system costs in Cyprus according to the PPM scenario in comparison to the WEM scenario.

Sector	Costs (mio Euros'2016)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Power Generation (new thermal and renewable power plants)	Investment	0	0	0	0	-28	-39	-48	-19	8	45	71
	Operation & Maintenance	0	-2	-6	-7	-28	-26	-26	-33	-42	-55	-62
	Total	**0**	**-2**	**-6**	**-7**	**-55**	**-65**	**-74**	**-53**	**-34**	**-9**	**9**
Electricity storage technologies (pumped hydro & batteries)	Investment	0	0	0	0	0	0	-2	-2	-2	-2	-4
	Operation & Maintenance	0	0	0	0	0	0	0	0	0	0	0
	Total	**0**	**0**	**0**	**0**	**0**	**0**	**-3**	**-2**	**-2**	**-2**	**-4**
Electricity interconnector	Investment	0	0	0	0	16	16	16	17	17	18	18
	Operation & Maintenance	0	0	0	0	0	0	0	0	0	0	0
	Total	**0**	**0**	**0**	**0**	**16**	**16**	**16**	**17**	**17**	**18**	**18**
Sustainable mobility (buses & tram, cycle lanes, bus lanes etc)	Investment	8	29	50	71	92	113	135	156	226	248	250
	Operation & Maintenance	-1	1	3	5	7	9	11	13	26	28	31
	Total	**7**	**30**	**53**	**76**	**99**	**122**	**146**	**169**	**252**	**276**	**280**
Private transport (shift to sustainable transport modes, more efficient cars, electric cars, biofuels etc.)	Investment	-2	-43	-84	-127	-165	-207	-244	-255	-277	-311	-353
	Operation & Maintenance	-54	-87	-121	-156	-191	-221	-261	-321	-383	-423	-491
	Total	**-55**	**-131**	**-205**	**-283**	**-356**	**-428**	**-504**	**-576**	**-659**	**-733**	**-844**
Heating and Cooling (buildings & industry)	Investment	76	76	76	76	75	74	73	72	72	84	83
	Operation & Maintenance	1	-4	-16	-19	-32	-48	-63	-83	-97	-110	-113
	Total	**77**	**73**	**60**	**57**	**43**	**26**	**10**	**-11**	**-25**	**-26**	**-30**
Difference in Total System Costs	Investment	83	62	42	20	-10	-43	-70	-31	45	81	66
	Operation & Maintenance	-54	-93	-141	-178	-243	-286	-340	-425	-496	-559	-636
	Total	**28**	**-31**	**-99**	**-158**	**-253**	**-329**	**-409**	**-456**	**-451**	**-478**	**-571**
Difference in Environmental Costs		**0**	**-2**	**-4**	**-5**	**-7**	**-9**	**-12**	**-15**	**-18**	**-21**	**-23**
Difference in Total System Costs Including Environmental Costs		**28**	**-33**	**-103**	**-164**	**-260**	**-337**	**-421**	**-470**	**-469**	**-499**	**-594**

2.2 Ranking of Policies and Measures According to their Cost-Effectiveness

Which measures should be prioritised among those included in the list of Planned Policies and Measures? A first answer could be that all measures have to be implemented because, as shown in Table 23 of Deliverable 5, even their full deployment is not sufficient to make Cyprus comply with the legally binding target of the Effort Sharing Regulation, i.e. to reduce its non-ETS emissions by 24% in 2030. However, as public policy always has to take into account practical or political constraints, it is still useful to provide recommendations about the costs and emissions abatement potential of each measure.

Such an analysis can only partly be made with models like OSeMOSYS, because it requires detailed 'bottom-up' information on each technology or measure, which is not always available in energy system models. We therefore report in this section some results of a previous Technical Assistance study that was conducted for the government of Cyprus, which was also funded by the European Commission's Structural Reform Support Service and has undergone peer review in an academic journal[5]. Data used in that study are consistent with those used in the OSeMOSYS model and in the present report.

The study led to the construction of a baseline and several alternative marginal emission abatement cost curves for policies and measures in the Cypriot non-ETS sectors. Nationally appropriate data were collected from earlier studies and from the local market. The results of this detailed analysis showed that the most cost-effective measures are the following:

- Roof insulation in pre-2008 residential multi-family buildings;
- The installation of heat pumps in pre-2008 residential buildings;
- Cogeneration in the industrial and tertiary sector;
- Increased use of anaerobic digestion for animal waste;
- Replacement of oil-fired burners in industry.

Measures that are not recommended to deploy because they have a very high cost per tonne of carbon abated are the renovation of very old buildings to become nearly-zero energy buildings, and wall insulation of pre-2008 buildings. All other measures are worth investing in, and most of them lead to negative social costs, which means that they yield benefits to society because the fuel cost savings during the lifetime of these investments outweigh the initial investment costs. The benefits are even stronger if the reduction in health damages because of lower pollutant emissions are also taken into account.

However, at a realistic rate of building and equipment renovations, many of the above cost-effective measures have a relatively limited potential to reduce GHG emissions up to 2030. Therefore, it is absolutely necessary to proceed with policies for decarbonising road transport, i.e. with the promotion of public and non-motorised transport and the electrification of the car fleet. Only these measures can yield significant emission reductions, and although they seem to be more costly than others, they are beneficial to society if all their benefits are taken into account.

Obviously, the findings of that project are in line with the results reported in the previous section of this report. Therefore, the recommendations mentioned above are fully relevant for this study as well.

That study dealt with non-ETS sectors only. As regards the justification of ETS-related measures that are included in the PPM scenario of this Impact Assessment study, i.e. those related to power generation, electricity storage and interconnection, it should be noted that their cost-effectiveness is

[5] Sotiriou C., Michopoulos A. and Zachariadis T., On the cost-effectiveness of national economy-wide greenhouse gas emissions abatement measures. *Energy Policy* 128 (2019) 519–529.

clear if one calculates from Table 1 the cumulative costs of these three measures for the entire period 2020-2030. They amount to -195 million Euros'2016, which means they are beneficial to society; and at the same time they are necessary for reaching the ETS emission reduction target and the renewables penetration target as shown in Table 23 of Deliverable 5.

2.3 Cost-effectiveness of other measures

The measures that are described in the previous section relate to energy use, agriculture and waste. Apart from these measures, additional options are included in the PPM Scenario, namely a) the proper recovery of fluorinated gases in industrial equipment and b) afforestation. This section comments on the cost-effectiveness of these two measures, based on information available to the project team which was provided by governmental authorities in August and September 2019.[6]

- As regards fluorinated gases, a legislative obligation is under preparation, which will apply to new installations and new amounts of gases to be used in existing installations. For gases that are currently in use, which have not been regulated up to now, a financial support scheme has been prepared by MARDE in order to facilitate their proper recovery. The scheme has been designed in such a way that it leads to emission reductions which correspond to avoided costs (for purchasing additional emission allowances due to non-compliance with the ESR target) that are higher than the cost of the scheme. In other words, benefits of emission reductions outweigh the costs. This has been estimated assuming gradually increasing emission allowance prices, which overall lie around 30-35 Euros per tonne of CO_{2eq}. Therefore, one can safely state that fluorinated gas recovery passes the cost-effectiveness and cost-benefit test and is worth pursuing.

- As far as afforestation is concerned (the main LULUCF-related measure that seems to be relevant for Cyprus), MARDE announced in September 2019 plans to proceed with planting of trees around Cyprus. Starting from around 70,000 trees in 2020, it is planned to reach 300,000 trees planted per year in 2030. Moreover, MTCW prepared a proposal for planting of trees around urban and inter-urban roads of Cyprus. According to MCTW, up to one million trees can be planted next to roads by 2030. MARDE's proposal does not include a cost assessment. MCTW's proposal estimates a cost of 72 million Euros for creation of the infrastructure for the one million trees (not including watering and maintenance costs). As regards the emission reductions due to absorption of CO_2, MCTW estimates a capture of about 2.5 kt CO_2 per year by 2030, starting from very low levels and increasing gradually as trees grow. If one assumes a total absorption of 10 kt throughout the period 2020-2030, to account for the gradually increasing number of trees planted, at a cost of 72 M€ (plus watering and maintenance), this action leads to a very high cost per tonne of CO_2 abated. This clearly does not pass the cost-effectiveness test. However, if one keeps in mind that trees have a very long lifetime and will absorb higher amounts of CO_2 when they grow further, this measure can be considered as important (and maybe cost-effective) in the longer term. Still, for achieving the 2030 non-ETS emission target, it seems to be an option with low potential and large uncertainty about its feasibility.

[6] By the time of writing this draft deliverable (early October 2019) this information was not available in the form of published reports; it is expected that the relevant data will be included in the final NECP of Cyprus.

2.4 Multi-criteria assessment of the two scenarios

Based on the main results of the impact assessment that were presented in Deliverable 5, and on the cost-benefit and cost-effectiveness appraisals reported in the previous sections of this Deliverable, it is possible to compare the WEM and PPM scenarios of the Cypriot NECP on the basis of a set of criteria. This section provides a brief multi-criteria evaluation of the two scenarios.

1. **Energy and environmental criteria**: The Planned Policies and Measures Scenario is clearly the preferred scenario with regard to all energy and environmental criteria included in the energy Union strategy. It can lead to:

    - Lower GHG emissions (14% lower in 2030 compared to 2005, as opposed to only 3% emission reductions in the WEM scenario);
    - Improved energy efficiency, which can lead to compliance with the requirements of Article 7 of the Energy Efficiency Directive, as opposed to non-compliance in the WEM scenario;
    - Improved penetration of renewable energy sources, reaching 30% of total energy consumption in 2030 and leading to compliance with the corresponding EU-wide objective, as opposed to 20.7% in the WEM scenario which is not sufficient to meet the EU-wide commitment;
    - Achievement of the EU objective for reaching 14% share of renewable energy in transport by 2030, as opposed to just 7% in the WEM scenario;
    - Improvement in air quality thanks to a reduction in emissions of air pollutants NOx, PM and SO_2 of 4.3%, 6.8% and 38.5% respectively in 2030 compared to the WEM scenario, leading to fewer public health problems in the population of Cyprus, to a decrease in premature pollution-related deaths and to a reduction in health-related economic damages of 23.5 million Euros'2016.

Thus the PPM scenario is the one that can enable Cyprus to contribute to the EU's objective to comply with its international climate obligations deriving from the Paris Agreement.

2. **Economic criteria**: The Planned Policies and Measures Scenario is also the preferred scenario with regard to the economic criteria considered in this study. More specifically, it can result in:

    - A small increase in national GDP by the year 2030, of the order of 0.4% compared to the WEM scenario; this will be a result of the re-allocation of investments in the PPM scenario and the re-adjustment of economic output towards activities with higher local value added, coupled with a decline in costs for importing fossil fuels thanks to the substantial decrease in fossil fuel consumption compared to the WEM scenario;
    - An overall benefit to society that can reach 594 million Euros'2016 in 2030 (or 2% of that year's GDP) compared to the WEM scenario; this benefit will be a combination of reduced energy system costs (thanks to energy savings in buildings, industry and primarily in road transport) and reduced health-related economic damages.

3. **Social criteria**: The Planned Policies and Measures Scenario is also estimated to yield slightly better results in employment and social welfare because:

    - It is projected to lead to somewhat higher employment, about 0.4% higher in 2030 compared to the WEM scenario, which means about 2350 more full-time work positions; this will be a result of the re-structuring of the economy towards jobs in economic sectors that benefit from the increased promotion of energy efficiency and renewable energy.

- It is expected to have an essentially zero effect on social equity, i.e. negligible effects on the distribution of income between households of different income groups; this will be the composite result of changes in electricity and fuel prices between the WEM and PM scenarios as explained in Section 3.2 of Deliverable 5 of this study.

4. **Governance criteria**: In terms of administrative costs, simplification of planning, reporting and monitoring obligations, and ensuring a coordinated and coherent implementation of the Energy Union strategy across its five dimensions, the PPM scenario is not expected to add considerable administrative burden compared to the WEM scenario; conversely, because the PPM scenario is clearly superior to the WEM scenario in all other criteria mentioned above, it will certainly contribute to a better implementation of the Energy Union strategy across its five dimensions.

3 Conclusions and Policy Recommendations

Deliverable 5 presented the results of the Impact Assessment study of the National Energy and Climate Plan of Cyprus. The analysis has been based on detailed modelling of the energy system of the country, which was mainly conducted with the OSeMOSYS optimisation model. Final energy demand projections for sectors other than road transport have been derived from a separate demand forecast model that has been used for the assessment of national energy efficiency action plans of Cyprus in the recent past, which were then input to OSeMOSYS. The optimisation results, as shown in Chapter 2 of Deliverable 5, along with the associated costs and calculated emissions of GHGs and air pollutants, have been fed into other models in order to assess the macroeconomic and employment impacts of the two scenarios that were explored. Apart from the above energy-related data and results, information about emissions abatement and costs for non-energy-related GHG emissions were obtained from the relevant calculations of national authorities that are included in the NECP of Cyprus.

The main findings presented in the Impact Assessment report, some of which are illustrated in Figure 1, can be summarised as follows:

1. **Existing policies and measures are clearly insufficient to lead Cyprus to compliance with its obligations** stemming from the Energy Union Governance Regulation. They cannot lead to compliance with the national renewable energy and energy efficiency targets, and they can only lead to 3% reduction in non-ETS emissions in 2030 compared to 2005; this will require purchasing a significant amount of emission allowances to fill the 2030 emissions gap, which, under optimistic assumptions, will cost the Republic of Cyprus at least 133 million Euros[7] in the period up to 2030. Moreover, non-compliance with the 2030 target of 14% renewable energy in transport will lead to additional costs in the WEM scenario, because the gap in renewable share will have to be covered through the Statistical Transfer procedure.
2. **The Planned Policies and Measures scenario**, which has been agreed by governmental authorities and is included in the NECP, **is able to make Cyprus meet its goals regarding energy efficiency and penetration of renewable energy sources**. If fully implemented, these measures will lead to **net economic benefits to the society of more than 500 million Euros'2016** by 2030, accompanied by **small positive effects on economic indicators** – a 0.4% increase in national GDP and a 0.4% rise in total employment in 2030. The changes in energy costs to end consumers will be very small and overall will have essentially no adverse impact on the welfare of households and social equity.
3. **Road transport holds the key to emissions abatement both for 2030 and for the longer term.** Investments in sustainable mobility may exceed 1.3 billion Euros throughout the 2020-2030 period and can therefore be considered as costly. However, these investments are expected to fully pay off because of multiple benefits from the reduction of the use of passenger cars, which can yield aggregate economic benefits to society of the order of 2 billion Euros'2016. Coupled with a fast electrification of the passenger car sector, they seem to be the only way to achieve the

[7] This calculation is based on assumptions provided by MARDE about the evolution of ETS allowance prices up to 2030. They are considered to be optimistic because Cyprus will not have the right to 'borrow' emission allowances from ETS installations, and since most EU Member states expect to be in deficit of allowances for meeting their 2030 ESR targets, it is likely that the cost for purchasing allowances to cover the non-ETS emissions gap will be considerably higher.

2030 non-ETS emission reduction target and shift the whole Cypriot economy to a low-carbon path towards 2050.

4. **The required additional investments to realise the PPM scenario (244 million Euros) are entirely feasible** for the standards of the Cypriot economy and will pay off because fuel import costs throughout the lifetime of these measures may decline considerably due to these investments.
5. However, **successful implementation of the package of Planned Policies and Measures is not guaranteed** because it requires significant investments for energy renovations in buildings and industry and – most importantly – a substantial commitment to promote public transport and non-motorised transport modes (walking and cycling) as well as a shift to electric cars.
6. Among the list of Planned Policies and Measures, some measures are more cost-effective than others (e.g. roof insulation or installation of heat pumps in buildings). However, **with very few exceptions, all other measures pass the cost-effectiveness test and can be deployed without delay.**
7. Non-energy-related measures can also contribute to emission reductions. Recovery of fluorinated gases seems to be cost-effective, while extensive planting of trees may be a measure with relatively limited potential and high cost up to 2030, but is an important ingredient of decarbonisation policy in the longer term.
8. **On the way to decarbonisation of the energy system, research and innovation can play an important role**. Although great technological breakthroughs are unlikely to come from research in Cyprus alone, the existence of a critical mass of researchers in topics such as energy efficiency, renewable energy sources and fuels, and emission abatement measures can accelerate a) the demonstration and deployment of novel technologies in Cyprus, b) the implementation of innovative measures under the particular conditions of the Cypriot market, and c) the development of expertise for innovative services related to low-carbon technologies.
9. **Even if implemented fast and effectively, Planned Policies and Measures are not sufficient for reaching the non-ETS GHG emission reduction target of 24% by 2030**, as required from Cyprus in the Effort Sharing Regulation; the reduction can only reach 14% in the PPM scenario. In order to achieve full compliance, the government of Cyprus has to choose between three options:
    a. Not proceed with further GHG emission abatement measures and use instead flexibility mechanisms to purchase emission allowances, with the associated costs; these are estimated to reach at least 56 million Euros up to 2030 but as indicated in point 1 above, may reach much higher levels if several EU Member States are in need to purchase emission allowances to fill their own emission abatement gap.
    b. Implement stronger emission abatement policies and measures (e.g. double the number of energy renovations of buildings, increase cogeneration plants or biogas production plants from waste, encourage accelerated replacement of conventional cars with electric ones); however, all these measures are costly and extremely difficult to implement at such a scale within the short time frame available; therefore they cannot be considered as a realistic alternative.
    c. Induce energy conservation measures through the adoption of a fiscally neutral green tax reform, by imposing a gradually increasing carbon tax on all non-ETS sectors. The revenues of

such a tax can be recycled in the economy by reducing labour taxes and providing financial support to energy conservation and green transport policies. Such a reform can have substantial economic benefits without harming low-income households or the competitiveness of firms[8].

10. In view of the declared political commitment of the European Union to carbon neutrality by 2050, the measures foreseen in the NECP of Cyprus and the options mentioned above for filling the non-ETS emissions abatement gap, have to be assessed in light of the need for deep decarbonisation. It has been shown that it is impossible to attain the 2050 target if there is low ambition about decarbonisation in 2030.[9,10,11] Therefore, **purchasing allowances to fill the 2030 emissions gap is both costly and does not lead to a strong decarbonisation path towards 2050**; instead it locks the Cypriot economy to an unsustainable path.

11. In September 2019 the Finance Minister of Cyprus announced that a green tax reform will be put in consultation in 2020 with the aim to adopt the relevant legal framework and implement such a reform in 2021. As this measure is still provisional and no specific details have been agreed, it has not been included by authorities in the Planned Policies and Measures scenario of the NECP. Based on the previous considerations outlined in this section, **the gradual implementation of a green tax reform from 2021 onwards seems to be a necessary additional policy, both for leading Cyprus to achievement of the non-ETS emission reduction target of 2030 and for enabling the transition to a net-zero-carbon economy by 2050**.

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Figure 1 – Overview of the findings of the Impact Assessment study as regards compliance with the national non-ETS emissions target of Cyprus.