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ODYSSEE-MURE

"Monitoring EU Energy Efficiency First Principle and Policy Implementation"

National Report – Cyprus

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1. Introduction

This report provides information about the current trends and challenges of the energy system of Cyprus, with emphasis on the potential of energy efficiency policies and measures to contribute to the decarbonisation challenge of the Cypriot economy, as stipulated by the European Green Deal, the European Climate Law that was adopted in summer 2021, and the accompanying proposals of the European Commission that were published in July 2021 (‘Fit for 55’ policy package).

The emphasis of the report is on the policy challenges rather than on a mere description of the current situation. Therefore, descriptive Sections 2 and 3 are brief: Section 2 provides an overview of the energy landscape in the country, and Section 3 is a summary of the most recent country profile prepared in the frame of the Odyssee-Mure project. The main part of the report is Section 4: firstly, it shows the implementation of the ‘energy efficiency first’ principle as outlined in the country’s National Energy and Climate Plan; and secondly, it outlines the challenges of the increasingly ambitious energy and climate targets that appeared after the submission of the NECP, with the aid of modelling analysis that incorporates several energy efficiency measures across the national economy.

2. Overview of Energy Trends and Challenges in Cyprus

2.1. Current landscape of the energy system and greenhouse gas emissions in Cyprus[1]

Cyprus is among the EU Member States with the highest greenhouse gas emissions per person – 11.2 t CO_{2eq}/capita in 2019 compared to the EU average of 7.8 t CO_{2eq}/capita. Its GHG emission intensity (emissions per unit of GDP) is also 73% higher than the EU average. Total GHG emissions have grown by 57% between 1990 and 2019, whereas they declined by 24% in the EU during the same period. This was due to a strong increase in national GDP during the last 30 years (over 140%), but also because of the lack of strong energy efficiency and decarbonisation policies.

Economic activities subject to the EU Emissions Trading system are three oil-fired power plants, a cement plant and a small number of brick and tile factories. Oil-fired generation contributed to 90% of the total generation mix in 2019 and the remainder was supplied by renewable energy sources (mainly wind and solar photovoltaics). Once the required gas infrastructure is made available, a large part of the island's thermal power generation capacity is expected to run on natural gas from mid-2023 onwards.

In the sectors that are not subject to the EU ETS and are covered by a national greenhouse gas reduction obligation through the EU Effort Sharing Regulation, emissions were almost stable over the period 2005 - 2019. The initial 2030 target for these sectors was to reduce their emissions by 24% compared to 2005, whereas the proposed new target of the draft new Effort Sharing Regulation in the frame of the 'Fit for 55' package is for a 32% reduction.

Renewable energy sources accounted for 13.8% of gross final energy consumption in 2019, which means that Cyprus met its 13% commitment for 2020 already a few years earlier. However, a much higher share of renewables is necessary to keep the country on track with its 2030 decarbonisation targets, both in ETS and non-ETS sectors; a higher penetration of renewable energy, primarily solar photovoltaics, would also reduce the island's electricity costs. In terms of gross inland consumption, fossil fuels accounted for 90% in 2019; as all fossil fuels are currently imported, this high energy dependency demonstrates clearly that a fast penetration of renewables will yield large benefits in the country's fuel import costs and trade balance.

As far as end-using sectors are concerned, both buildings and transport are highly inefficient energy consumers in Cyprus. More than 90% of buildings were built before the introduction of mandatory energy performance requirements, which started after the country's accession to the EU in 2004. Building renovation rates are currently around 0.5% of the total building stock annually, below the EU average of about 1%, and must be accelerated strongly in order to keep the country on track with its energy efficiency obligations for 2030. As a result, coupled with a growing demand for space cooling, residential energy consumption per capita increased by about 15% between 2005 and 2019, as opposed to an EU-average decrease by 7.8%. The widespread adoption of solar water heating systems is currently the main technology option contributing to the relatively high renewable energy share in the heating and cooling sector.

[1] Based on official data from Eurostat, the national government, and factsheets of the European Commission.

Mobility is largely dependent on motor vehicles for the transport of both passengers and goods; there are no railways, and public transport modes account for about 2% of total passenger mobility. The share of electric vehicles is very low and there are very few public charging stations. As a result, land transport is responsible for more than half the GHG emissions of non-ETS sectors – which makes it very difficult for the country to meet its emission abatement obligations stemming from the Effort Sharing Regulation.

Transport fuels are taxed above the minimum levels foreseen by the current Energy Taxation Directive, and automotive diesel fuel is taxed slightly less than petrol. Fossil fuel subsidies exist but are not very pronounced: fuels used for power generation and agricultural gas oil are exempted from excise taxation.

Under current land management practices, Cyprus is projected to see slightly increasing net carbon removals by 2030. According to the European Commission, Cyprus is on track to reach its target but can implement additional measures and changes in land management to achieve higher net removals.

Energy cost for Cypriot households (as a percentage of their total expenditures) is close to the EU average for residential energy use, while it is higher than the EU average in transport fuel use due to the low share of public transport in passenger mobility. The share of the country's rural population at risk of poverty or social exclusion is slightly higher than in the EU, and so are energy poverty levels – based on the share of population unable to keep their homes adequately warm and the share of population with arrears on their utility bills.

2.2. The National Energy and Climate Plan of 2019

The Republic of Cyprus submitted its National Energy and Climate Plan (NECP) to the European Commission in January 2020. According to the NECP:

- The Planned Policies and Measures (PPM) scenario was considered to be able to make Cyprus meet its energy and climate goals as regards renewable energy shares (23% energy-wide and 14% for transport) and energy efficiency targets. In the event that the project of electricity interconnection of Cyprus with Greece and Israel is realised, penetration of renewable energy will be considerably higher – but the main PPM scenario of the NECP made the conservative assumption that electricity interconnection would not materialise.
- The NECP's impact assessment found that these measures could 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 0.3% increase in national GDP and a 0.3% rise in economy-wide employment in 2030. The changes in energy costs to end consumers would be very small and overall would have no adverse impact on the welfare of households and social equity.
- Road transport holds the key to emissions abatement both for 2030 and for the longer term. Investments in sustainable mobility, in line with the PPM scenario, would exceed 1.3 billion Euros throughout the period 2020-2030 but were expected to fully pay off because fuel import costs throughout the lifetime of these measures may decline considerably due to these investments, and also because of health benefits thanks to

reduced urban air pollution. In total, no higher investments would be required to realise the PPM scenario, but a re-allocation towards public investments for sustainable transport.

- 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.

- Even if implemented fast and effectively, Planned Policies and Measures were 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 estimated reduction could only reach 21% in the PPM scenario. However, with the aid of the flexibility mechanisms available in the ESR, the government found that Cyprus would not have any financial cost for purchasing additional GHG emission allowances because it would overachieve its non-ETS emission allocation during some of the years of the 2021-2030 period.

2.3. The Commission's assessment of the NECP and current trends

The European Commission's assessment of the NECP, published in October 2020, observed that the Commission's recommendation in the draft NECP had been partially addressed especially as regards measures to promote renewable energy and energy efficiency and reporting energy subsidies, whereas they were largely or fully addressed in other dimensions of the Energy Governance Regulation. **Especially the Cypriot energy efficiency targets (both for primary and final energy consumption) were considered to be of low ambition**. At the same time, the assessment mentioned two examples of good practices in the Cypriot NECP: (i) the very good analytical basis on the impact of the transition, including on employment; and (ii) the well-researched parts on energy poverty.

In line with this assessment, the European Commission included relevant Country-Specific Recommendations (CSRs) in the frame of the regular economic policy surveillance process (European Semester), e.g. to "focus investment-related economic policy on sustainable transport, environment, in particular waste and water management, energy efficiency and renewable energy" (CSR4.1 of 2019 and CSR3.3 of 2020).

2.4. The 'Next Generation EU' programme for Cyprus

Cyprus submitted its National Recovery and Resilience Plan (NRRP) to the European Commission in May 2021, and it was approved by the Council in August 2021. It amounts to about 1.2 billion Euros, out of which 41% is devoted to climate action. Major climate-related investments and reforms are about energy renovations of public and private buildings, installation of smart electricity meters, simplification of procedures for renewable energy investments, and electrification of transport through investments in public charging infrastructure and grants for the purchase of electric vehicles. These are in line with at least three of the major flagship initiatives of the EU Recovery and Resilience Facility – 'power up', 'renovate', and 'recharge and refuel' – and address the corresponding European Commission's CSRs that were mentioned above.

The Just Transition Fund for Cyprus amounts to about 100 million Euros at today's prices, is covered partly by Next Generation EU and partly by the MFF and will be largely devoted to modernising the electricity grid in order to accommodate more decentralised renewable energy sources, and partly to facilitating emission reductions in ETS installations (cement factory and brick and tile producing plants).

Overall, the EU budget, including the Cohesion Funds from the MFF, the Just Transition Fund and the entire 'Next Generation EU' programme, are scheduled to provide up to 2.5 billion Euros to allow for significant investments in greening the Cypriot economy. A preliminary assessment of the measures foreseen in the NRRP and the EU Cohesion Funds, conducted by the Directorate General for European Programmes, Coordination and Development (a Directorate of the Finance Ministry that is responsible for the economic aspects of the European Green Deal in Cyprus) has found **that the investments and reforms included in these packages are aligned with the NECP as regards energy efficiency, renewable energy penetration, and waste management** measures. However, **investments in sustainable mobility are lagging behind** and can hinder progress towards the necessary decarbonisation of the Cypriot economy.

2.5. Implications of the European Climate Law and the 'Fit for 55' package for Cyprus

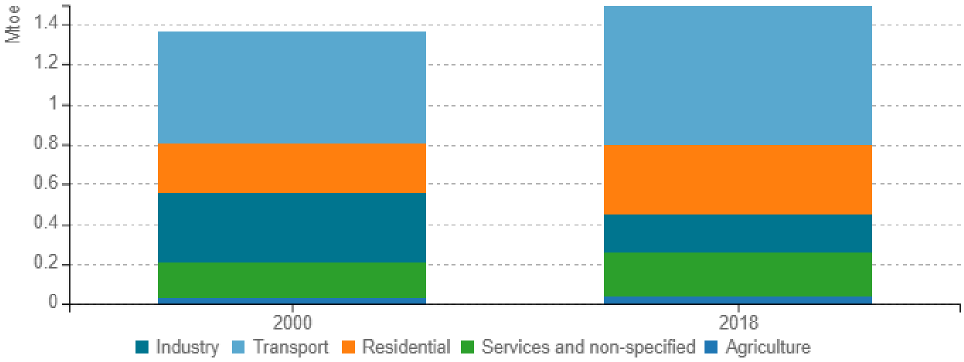
As in all EU Member States, the adoption of the European Climate Law in June 2021 and the 'Fit for 55' package with thirteen proposals for amendment of EU energy and climate legislation in July 2021 is presenting considerable challenges and opportunities for the socio-economic development of Cyprus. The proposed increased ambition of ETS sectors, the revised 2030 Effort Sharing Regulation target that is likely to reach 32% for Cyprus (versus 24% in the current ESR), and the stronger commitment for energy efficiency improvements and renewable energy penetration call for a careful design of the green transition in line with the goals of the European Green Deal. At the same time, significant budgetary means are provided by the EU to alleviate adverse social impacts: Apart from the Just Transition Fund, the new Social Climate Fund under 'Fit for 55', to be financed by the inclusion of heating and transport fuels in a new Emissions Trading System, includes 146 million Euros for Cyprus.

3. Energy Efficiency Trends and Policies[2]

3.1. Overview

Despite the temporary effects of the economic recession of years 2012-2015, energy consumption in Cyprus was higher in 2018 than in 2000. Increases in energy demand of both transport and buildings (residential and services) have been responsible for this development, while the share of industry in energy consumption has dropped both because of the smaller share of industry in total economic activity in 2018, and thanks to energy efficiency improvements in major industrial plants.

Figure 1: Final energy consumption by sector (normal climate)

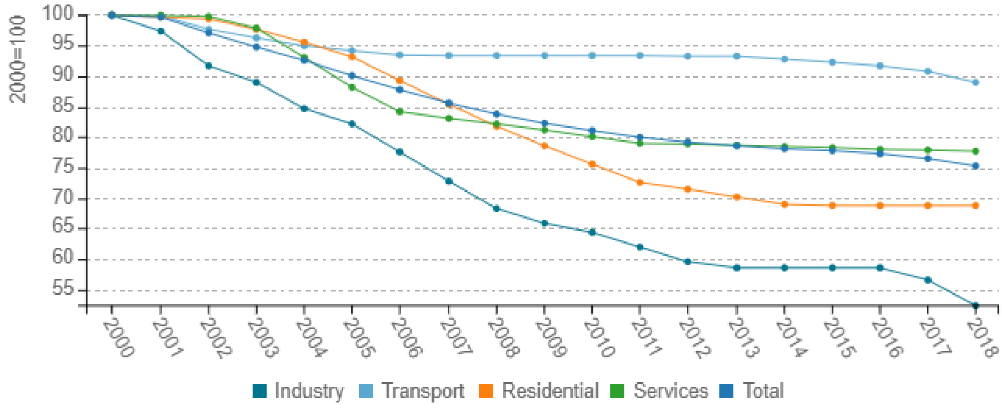


Source: ODYSSEE

Overall technical energy efficiency has improved by around 25% in Cyprus between 2000 and 2018. This has been driven by energy efficiency improvements in all sectors - buildings, industry and transport. Industry has shown the fastest increase in energy efficiency, mainly because the largest industrial energy consumer is by far the cement industry, which has undergone a major reconstruction and refurbishment of its plants. Transport has demonstrated the slowest energy efficiency improvement, especially in 2000-2015; both road transport and air transport have been responsible for the lack of progress in energy efficiency. Over the last years (2015-2018) progress in the residential and service sectors has remained stagnant too.

[2] See the full country profile, in both English and Greek language, at the Odyssee-Mure project website on https://www.odyssee-mure.eu/publications/efficiency-trends-policies-profiles/.

Figure 2: Technical Energy Efficiency Index

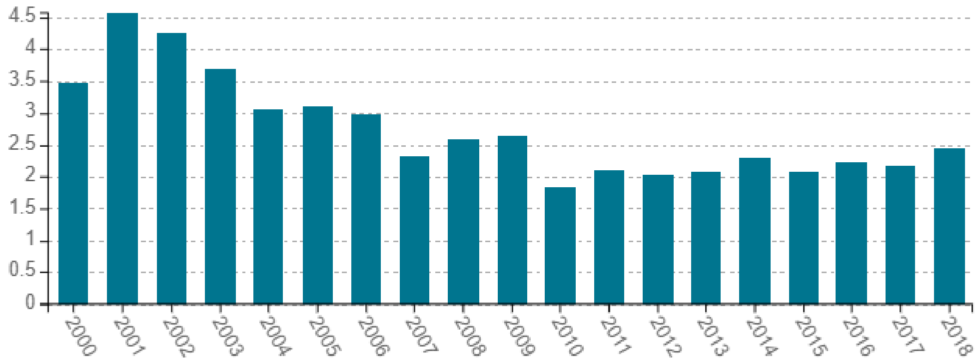


Source: ODYSSEE

3.2. Buildings

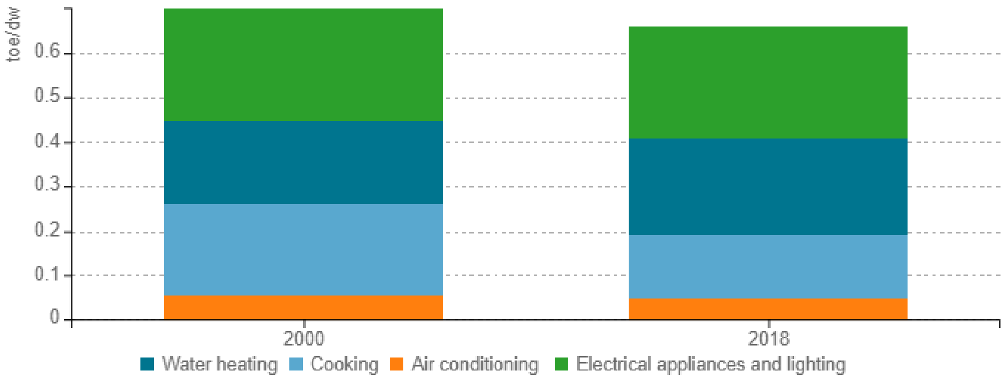
Energy efficiency in the buildings sector of Cyprus has improved steadily since the adoption of energy performance standards in the mid-2000s, and as a result of the implementation of all relevant EU legislation. Still, energy consumption of buildings is stagnant or even slightly grows as a result of the increasing number and size of dwellings, which outweighs energy efficiency improvements, and the increased utilisation of space heating appliances in modern buildings. Because of the relatively mild winters in Cyprus, space heating was used less in earlier years, but modern residential and office buildings always include space heating installations.

Figure 3: Energy consumption of space heating per m2 (normal climate)



Source: ODYSSEE

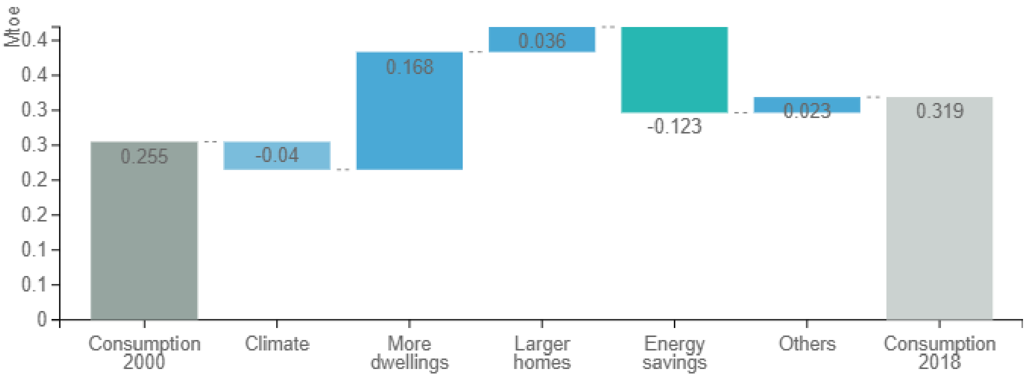
Figure 4: Energy consumption per dwelling by end-use (except space heating)



Source: ODYSSEE

Residential energy consumption per dwelling has fallen somewhat between 2000 and 2018, reflecting the improved energy performance of new buildings as well as the effect of a limited number of energy renovations in existing buildings. The share of main end uses in energy consumption does not seem to have changed significantly. Electrical appliances are responsible for the highest part of final energy consumption, followed by water heating - which however is predominantly satisfied through solar water heaters.

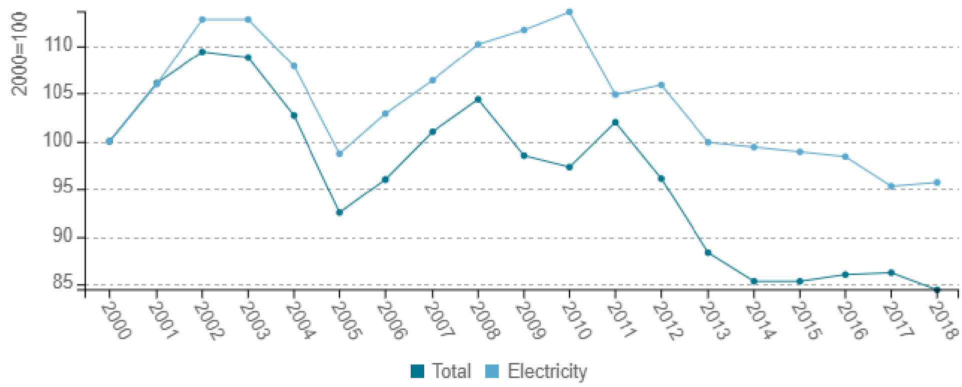
Figure 5: Main drivers of the energy consumption variation of households



Source: ODYSSEE

The increase in the number and size of dwellings has been primarily responsible for the rise in total residential energy consumption between 2000 and 2018. It has been only partly counterbalanced by energy efficiency improvements.

Figure 6: Energy and electricity consumption per employee (normal climate)



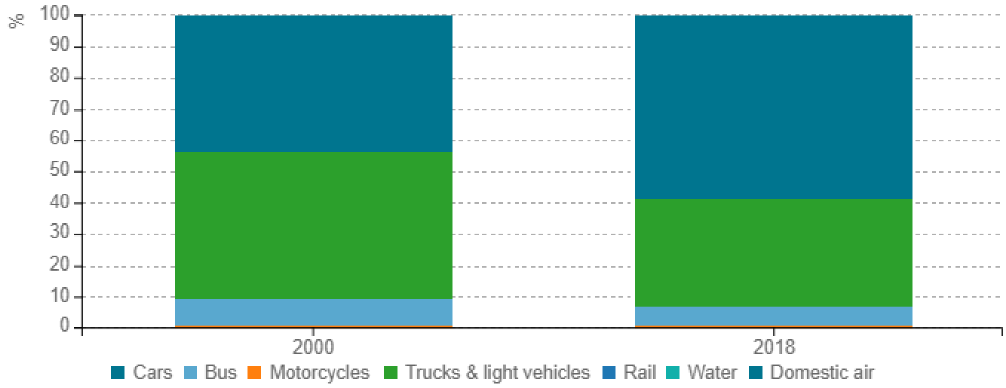
Source: ODYSSEE

Energy consumption per employee in the service sector of Cyprus has declined, essentially after 2010, as the combined effect of the economic downturn of 2012-2015 and energy efficiency improvements. The sector depends on electricity by more than 80% to cover its energy needs.

3.3. Transport

Transport accounts for half of final energy consumption in Cyprus. This is due to the very low use of public transport, despite recent investments in public buses which have not been adequate to induce a significant modal shift in passenger transport - which is still dominated by cars.

Figure 7: Transport energy consumption by mode

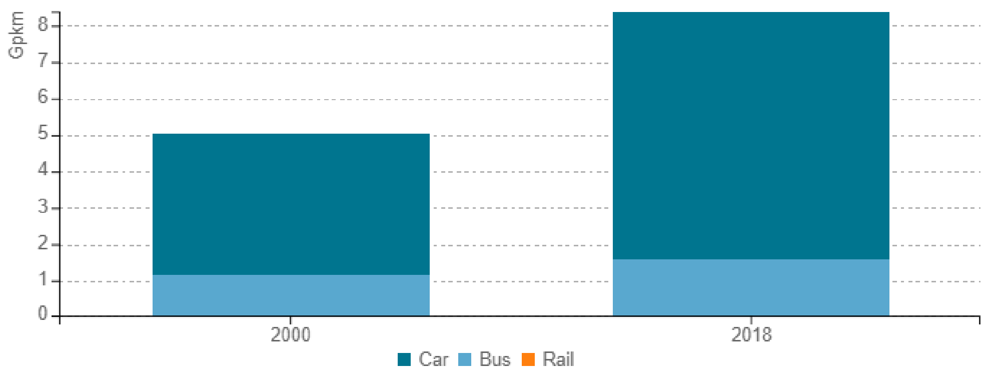


Source: ODYSSEE

Attempts to strengthen the public transport system, which consists of urban and interurban buses, have not been effective up to now. Therefore, the share of cars in total passenger traffic has remained very high in Cyprus; in fact it has slightly risen further between 2000 and 2018.

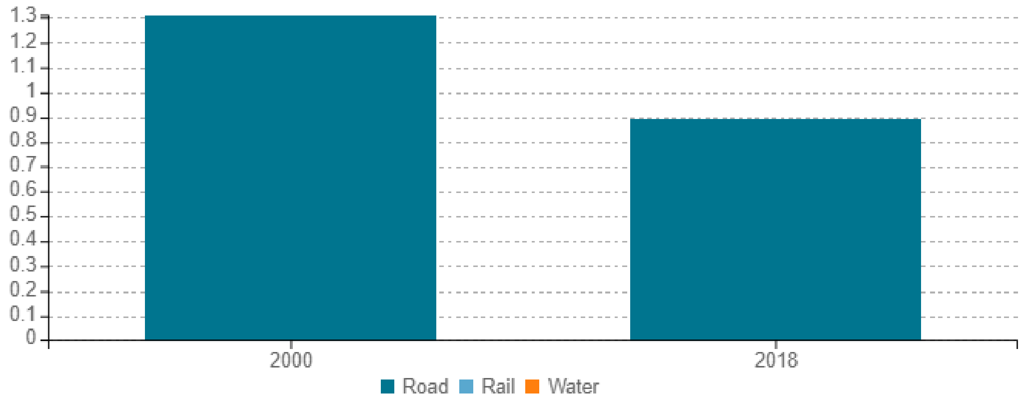
Inland freight transport is conducted only with trucks.

Figure 8: Modal split of inland passenger traffic



Source: ODYSSEE

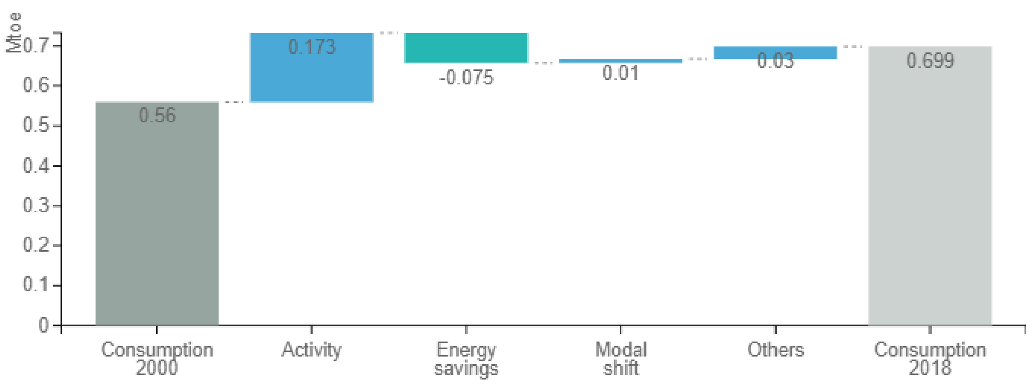
Figure 9: Modal split of inland freight traffic



Source: ODYSSEE

Despite some energy efficiency improvements because of the gradual renewal of the stock of motor vehicles, increases in total passenger kilometres and tonne kilometres travelled have been stronger; therefore, total energy consumption of transport has risen by more than 25% between 2000 and 2018.

Figure 10: Main drivers of the energy consumption variation in transport

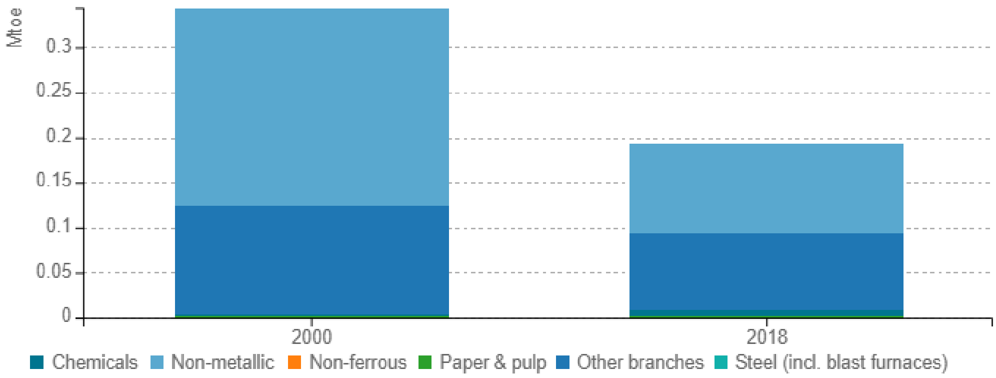


Source: ODYSSEE

3.4. Industry

Industrial activity in Cyprus has been steadily declining. This has led to a drop in final energy consumption of the industrial sector. The fall in energy use has been accelerated by substantial energy efficiency improvements across the sector and mainly in the cement industry.

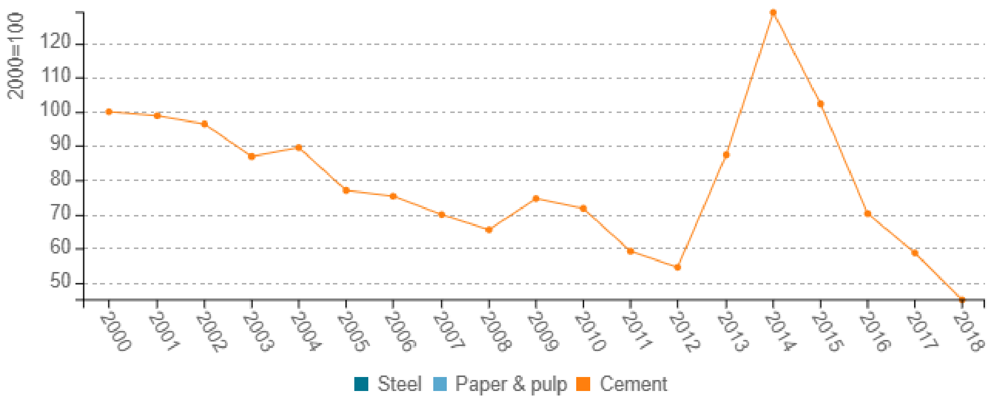
Figure 11: Final energy consumption of industry by branch



Source: ODYSSEE

Final energy consumption of the industrial sector in Cyprus has dropped substantially over the last two decades because of a strong decline in industrial economic activity. The non-metallic minerals sector, dominated by the cement industry, is currently the only energy-intensive industrial activity in Cyprus and is responsible for more than half of industrial energy use.

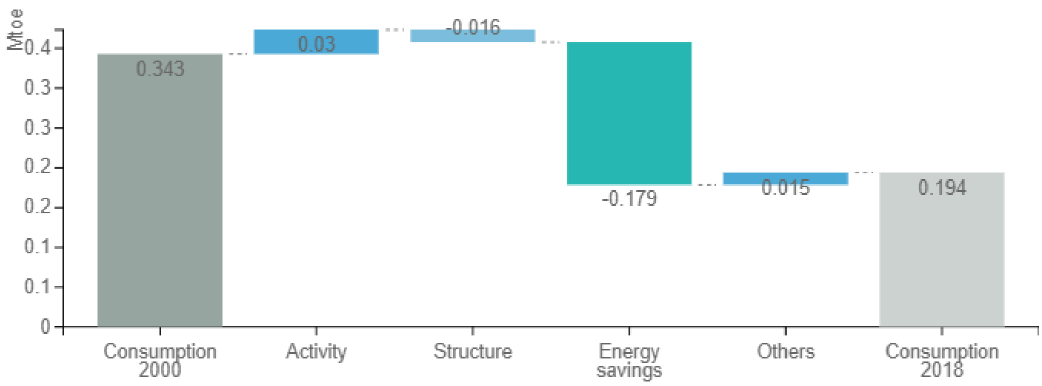
Figure 12: Unit consumption of energy-intensive products (toe/t)



Source: ODYSSEE

Unit consumption of the cement industry - the only energy-intensive industry of Cyprus - has declined since 2000. The increase after 2012 is an artefact of the decreasing denominator of this index (tonnes of cement production) because production of cement has dropped substantially in 2013-2015 because of the decline of the Cypriot construction industry due to the economic downturn. However, production of clinker (which was exported for cement production abroad) continued and hence energy consumption of the cement plant continued as well.

Figure 13: Main drivers of the energy consumption variation in industry



Source: ODYSSEE

Energy savings, mainly effected in the cement industry, as well as structural changes (i.e. a shift towards less energy intensive industrial activities) have been the major contributors of the decline in industrial energy consumption.

3.6. Summary of main energy efficiency policies adopted in 2018-19

Table 1: Main energy efficiency policies in Cyprus as available in the MURE database.

Sector	Measure	Description
Cross-cutting measures	Energy efficient street lighting	Replacement of existing lighting systems in public roads (motorways and local roads) with new, more efficient ones, in the period 2018-23.
	Net billing scheme for high-efficiency cogeneration (HECHP)	Applies to commercial, industrial and public administration consumers for the installation of HECHP systems of up to 5 MW mainly for covering their own consumption
	Fund of Funds providing soft loans for energy efficiency	Low-interest loans by private banks to cover the capital cost for implementing energy efficiency investments. Target groups are households, SMEs and public sector
Buildings	Smart electricity meters	The measure concerns the gradual installation of 400,000 electricity smart meters on the building stock of the country between the period 2021-2027
	Reduced VAT for energy renovations in the residential sector	Since December 2015, renovations of private residences are subject to a VAT rate of 5% instead of the standard VAT rate of 19%. The renovations subject to reduced VAT include thermal insulation of external walls and replacement of doors and windows of the building.
	Access to finance for energy renovations	Low-Interest Loans Provided by the Cyprus Cooperative Bank
	Support schemes for promoting energy efficiency investments in buildings	Renovations of existing dwellings are co-funded by this scheme. They address Individual energy efficiency measures in public buildings and dwellings.
Transport	CO_2-based vehicle taxation	Annual circulation taxes are mainly calculated on the basis of a vehicle's certified CO_2 emission levels. The CO_2 component was strengthened in 2019.
Industry	Energy audits	Apart from organisations that are legally obliged to conduct energy audits, grants have been available to other businesses for voluntary energy audits and the implementation of recommendations included the energy audit report.

Source: MURE database - https://www.measures.odyssee-mure.eu/

4. The ‘Energy Efficiency First’ Principle in the Recent Formulation of Energy and Climate Policy of Cyprus

4.1. Background

To meet the EU’s energy and climate targets, EU Member States had to establish and submit by the end of 2019 a ten-year national energy and climate plan (NECP) for the period from 2021 to 2030. Rules about this obligation are determined by the Regulation on the Governance of the Energy Union and Climate Action (EU/2018/1999). NECPs describe how each country intends to address issues related to energy efficiency, renewable energy, greenhouse gas emissions reductions, cross-country connections of electricity grids and research related to climate stabilisation. The NECP is accompanied by an impact assessment that focuses on the impact of national policies on energy use, greenhouse gas emissions, health, macroeconomic development, employment, social equity, investment needs and regional cooperation.

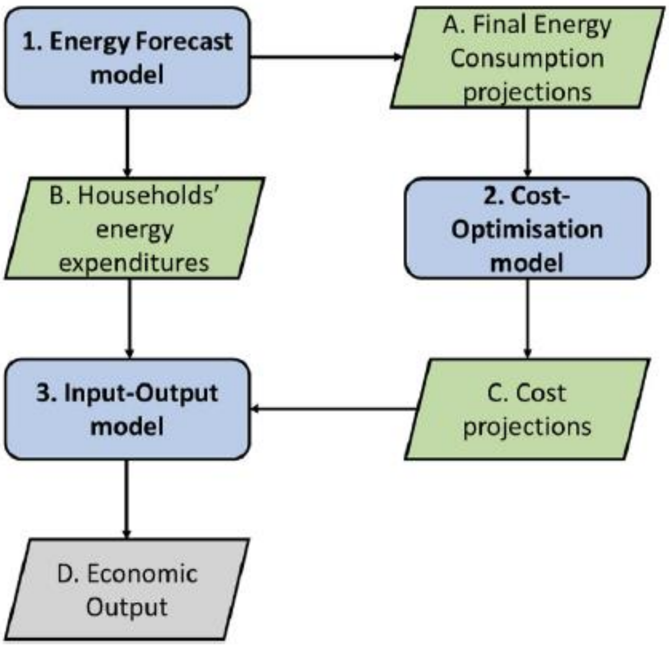
The European Commission’s guidance to Member states was that, when designing their energy and climate policies and preparing the NECPs and the associated impact assessment, they should apply the Energy Efficiency First Principle, meaning that priority should be given to policies and measures that reduce primary or final energy consumption and improve energy security, and other measures should be considered only after energy efficiency actions are deemed unfeasible or very costly.

This section summarises key findings from the impact assessment of the NECP of Cyprus that illustrate how national authorities addressed the Energy Efficiency First Principle in its final NECP which was submitted to the European Commission in January 2020.

4.2. Methodology

To analyse energy, environmental and diverse economic impacts, four computational models were used and soft-linked, i.e. output of some of the models was used as input to others. As it is not possible to explore all possible environmental and economic impacts with one model that would represent the energy system, the national economy and the income structure of households with reasonable accuracy, using a combination of computational models is a frequent practice in the related literature. Figure 14 provides a scheme of this approach.

Figure 14: Simplified flowchart with the soft-linking process for the models used in the National Energy and Climate Plan. The models are indicated in light blue colour, while the steps where information is generated from one model and passed on to the next are indicated in light green.



Source: Taliotis et al., *Energy Strategy Reviews* 29 (2020) 100495.
https://doi.org/10.1016/j.esr.2020.100495

In the case of Cyprus, the NECP modelling work was implemented as follows:

- An energy forecast model was used to project final energy demand in the residential, commercial, industrial and agricultural sectors of the Cypriot economy. This model has been used to support national energy strategies in the past. It uses projections of national GDP and international oil prices, along with assumptions on the short-term and long-term income and price elasticities of energy demand.

- A dynamic cost-optimisation model was employed to project the technology and energy mix in the electricity supply and transport sectors. It was developed within the Open-Source Energy Modelling System (OSeMOSYS), which is a long-term cost-optimisation energy system model that has been used in numerous international studies. It is a bottom-up demand-drive model that determines the optimal energy mix and technology choice per year, with the objective to minimise total discounted system cost over the entire modelling horizon subject to technical and environmental constraints.

- The projected levels of energy-related investments across the economy and the associated costs for operation and maintenance of all technology options, are fed by the cost-optimisation model to the IO model to estimate the economy-wide impacts on economic growth across the different sectors of the local economy. Input-Output (IO) analysis studies the interdependence of production sectors in an economy over a stated time period and is extensively applied for policy impact evaluation.

- Changes in retail energy prices, which are the output of the demand forecast model and the optimisation model, were used as input in a household demand model that has been econometrically estimated on the basis of Family Expenditure Surveys of Cyprus. The model was used to simulate the welfare effects of price increases on households grouped by income, location and demographic characteristics.

Further details about this procedure are provided by Taliotis et al.[3]

Following the guidelines of Regulation EU/2018/1999, the NECP considered two main scenarios: a Scenario 'With Existing Measures' (WEM) and a Scenario 'With Planned Policies and Measures' (PPM).

The WEM scenario assumes a continuation of the policies that have already been adopted by the government of Cyprus, either in implementation of EU policies or as national initiatives. Power generation is considered to shift to natural gas by the end of 2021, in line with national plans, renewable energy penetration and energy efficiency improvements in buildings and industry are assumed to continue at the current pace, and small interventions in the road transport and agriculture are taken into account.

The PPM scenario assumes stronger energy efficiency measures in buildings and industry, induced by diverse financial incentives that facilitate energy renovations, a faster penetration of renewable energy in electricity production. Most importantly, in line with political decisions taken by the Transport Ministry, it assumes a substantial shift from private cars to public transport modes (buses and a tram system for Nicosia), as foreseen in Sustainable Urban Mobility Plans. PPM includes two variants – one assuming that the electricity interconnection of Cyprus with Greece and Israel (EuroAsia Interconnector) will proceed as planned and become operational by the year 2024, and one assuming that the interconnection project will not be implemented at least until 2030. The variant without interconnection was the one that was officially used by national authorities as the PPM scenario of the NECP that was submitted to the European Commission. A more detailed description of the policies and measures included in each scenario is provided in the NECP[4].

4.3. Findings

According to the analysis of national authorities, 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:

- 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. 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

[3] Taliotis C., Giannakis E., Karmellos M., Fylaktos N., Zachariadis T., 2020. Estimating the economy-wide impacts of energy policies in Cyprus. *Energy Strategy Reviews* 29, 100495 (2020).

[4] Republic of Cyprus, 2020. *Cyprus' Integrated National Energy and Climate Plan*. Nicosia, January.

transport and switch to electric cars. As was shown in the impact assessment that formed Chapter 5 of the NECP, 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 its Impact Assessment[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 binding objectives of EU legislation that 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.

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[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] Sotiriou, C., Michopoulos, A. and Zachariadis, T. (2019), On the cost-effectiveness of national economy-wide greenhouse gas emissions abatement measures. *Energy Policy* 128, 519–529. https://doi.org/10.1016/j.enpol.2019.01.028.

4.4. Challenges on implementing ‘Energy Efficiency First’ in the frame of the European Green Deal

4.4.1. Background

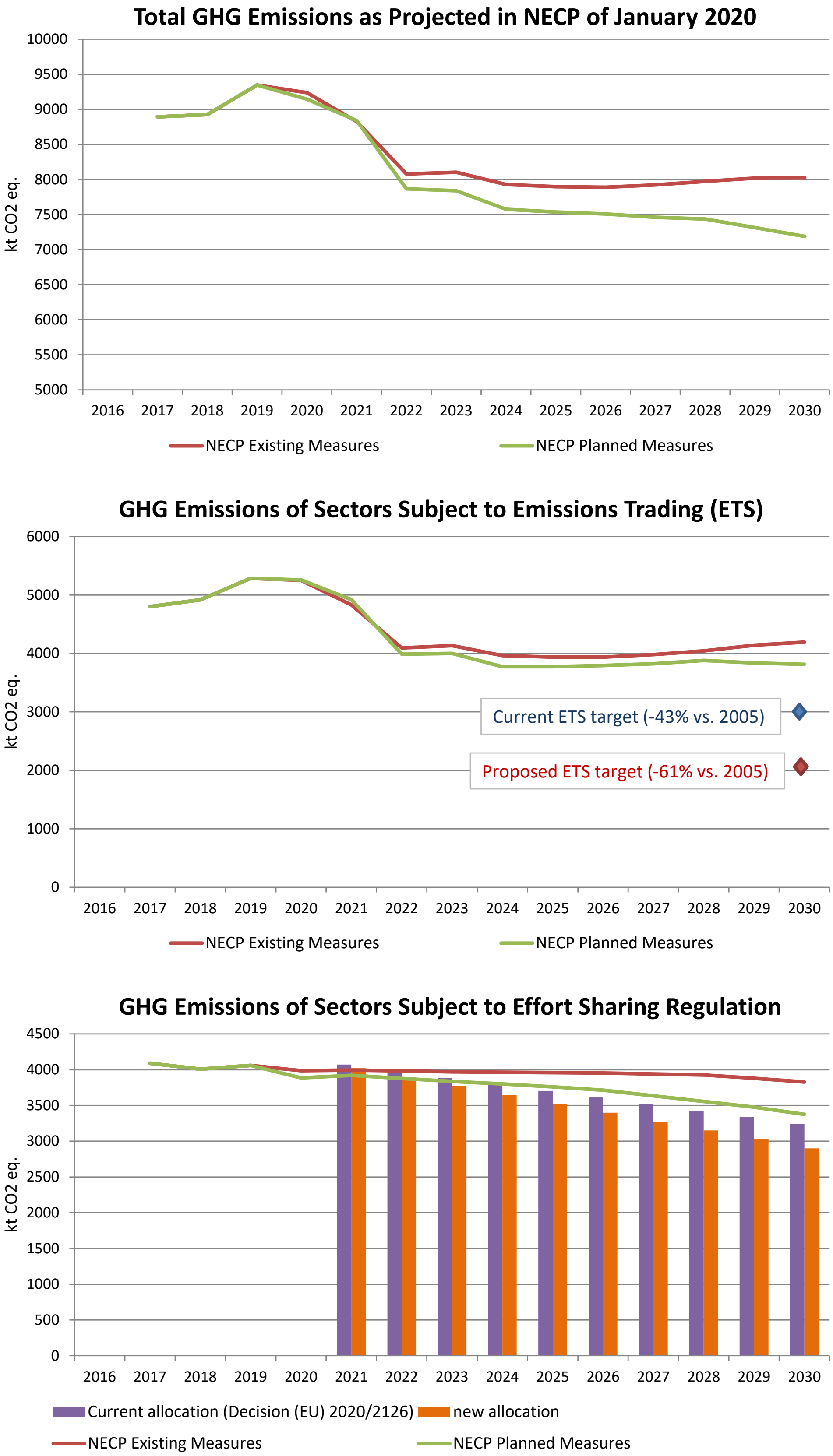
In October 2020, the European Commission published the assessment of the NECP of Cyprus, in which it stated that “The ‘energy efficiency first’ principle has been applied in planned policies and measures” and “The application of the ‘energy-efficiency first’ principle is an important element that has been taken into consideration in the NECP”, which indicates that the European Commission essentially accepted the argumentation summarised above as adequate for addressing the principle. At the same time, the Commission underlined the “need to ensure that the ‘energy-efficiency first’ principle is properly implemented across all areas of the energy system”[7].

In the meantime, however, the EU has adopted more ambitious climate targets through the European Green Deal and the European Climate Law. In this context, the policy proposals that were released in July 2021 with the ‘Fit for 55’ package call for higher economy-wide energy savings and increasingly stringent requirements for energy renovations in houses, businesses, and the wider public sector. The ‘Energy Efficiency First’ principle has also become a binding principle in the formulation of national policies.

Figure 15 below describes the size of the decarbonisation challenge for Cyprus, showing the projected evolution of GHG emissions according to the two scenarios of the NECP mentioned above. Both for sectors subject to the current EU Emissions Trading System and for those subject to the Effort Sharing Regulation, the current scenarios are far from sufficient for Cyprus to reach its 2030 targets.

[7] European Commission (2020), Assessment of the final national energy and climate plan of Cyprus. Document SWD(2020) 912 final.

Figure 15: GHG emission projections for Cyprus up to 2030.



Therefore, national governments are faced with additional challenges. It is therefore essential that the entire cost-effective potential for energy savings is studied carefully within the constraints of financial, technical and human resources.

To explore this potential in Cyprus, we first conducted a study of the cost-effectiveness of greenhouse gas (GHG) emission abatement options, comprising mainly energy efficiency measures as the 'low-hanging fruit'. We then expanded the analysis to explore additional measures that could help achieve the more ambitious 'Fit for 55' targets.

Residential Sector

To explore GHG abatement options for residential buildings, we used data from a recent detailed national study (Vougiouklakis et al., 2017 – see footnote 5), which applied an engineering methodology to assess the maximum technical potential for energy savings in buildings, and then adapted these estimates to take into account realistic financial and technical constraints of the national market. Vougiouklakis et al. (2017) estimated the final heating and cooling energy consumption of the existing residential building stock using characteristic typologies of buildings in Cyprus, which were developed after a detailed analysis of official statistics. They distinguished into 84 building typologies based on building type, construction period and climatic area. We have extensively relied on data from that detailed modelling work, but have aggregated them in order to arrive at a meaningful number of building variants which would be appropriate for the purpose of our study. We distinguished in two building types that turned out to be the most significant: single-family houses and multi-family buildings. We also classified buildings according to construction period based on the most important distinction: buildings completed before 2008 and from 2008 onwards. In this way, eight building typologies (i.e. four building types with and without refurbishment) were used instead of the initial 84. This classification of buildings (two building types and two construction periods with and without refurbishment) is the most significant because energy performance regulations essentially started to be implemented in post-2008 buildings and have continued to evolve thereafter in line with the relevant EU legislation (Vougiouklakis et al., 2017; pp. 7-21).

Carbon emission reductions in residential buildings are primarily due to the implementation of energy efficiency measures. Substitution towards lower-carbon fuels does not present a large abatement potential because most heating, cooling and hot water needs are satisfied through electric appliances, and the substitution of oil-fired boilers with biomass-fired ones is a realistic option for mountainous areas only, which account for less than 5% of the residential building stock of the country. We therefore considered the following measures:

- Deep renovation, i.e. renovation of the building envelope so that it becomes a near-Zero Energy Building (nZEB);
- Roof insulation;
- Wall insulation;
- Insulation of pilotis[8] (for apartment blocks only);
- Replacement of heating and cooling systems with modern highly efficient heat pumps;
- Replacement of windows;

[8] Pilotis are columns or similar structural elements that support a building above ground.

- Replacement of lightbulbs and electric appliances with modern highly efficient ones;
- Installation of solar thermal water heaters.

The implementation of these measures can incur different costs and cause different emission abatement levels according to building type and construction period. As a rule, the measures involve upfront investment costs, which however may be counterbalanced by fuel cost savings throughout the lifetime of the investment because of the energy savings that this investment yields. Fuel cost savings may be the composite result of a reduction in energy demand, if the same fuel continues to be used, and/or a change in the fuel price, if fuel substitution occurs.

Table 2 presents the cost data and energy savings for each individual measure for the four different classes of buildings considered in our study. Note that the savings shown in Table 2 refer to the demand for *useful* energy, i.e. space heating, space cooling, light and domestic hot water. To convert useful energy to the corresponding amount of *final* energy, which is required to calculate emissions abatement, the corresponding efficiency figures have to be used. Therefore, Table 3 shows the main technologies, and their corresponding average thermal efficiency, used for space heating and cooling in residential buildings in Cyprus by construction period. To calculate final energy savings by abatement option, we compare with the predominant technology in each case, i.e. oil-fired boiler for older buildings and ait-to-air split type heat pumps for more recent ones. Heat pumps are essentially the only technology used for space cooling, but with different seasonal energy efficiency ratios (SEER) depending on the age of the buildings. Note that the energy savings shown in Table 2 refer to operation of equipment that satisfies optimal thermal comfort requirements.

Table 4 shows the cumulative number of interventions foreseen for residential buildings up to 2030, as determined by Vougiouklakis et al. (2017). They have been based on an empirical assessment of the realistic potential in the household sector of Cyprus, taking into account financial, technical and behavioural aspects.

By combining the information of Tables 2 to 4 it is possible to calculate the total discounted costs and energy savings from all measures to be implemented until 2030. To translate energy savings to GHG emission savings, standards GHG emission factors were used from the United Nations Intergovernmental Panel on Climate Change.

Tertiary Sector

In the service sector, which is very diverse as it includes offices, shops, schools, hospitals, hotels etc., carbon emission abatement options are also primarily associated with energy efficiency measures. For this purpose, results from the study of Vougiouklakis et al. (2017) were used like in the residential sector. Additional energy simulations for a typical office building were performed for two different construction periods. Besides energy efficiency measures on the building envelope and in lighting equipment, installation of modern high-efficiency heat pumps and solar thermal heaters in buildings such as hotels, sports centres etc. were considered.

In addition to the above measures, the use of cogeneration (CHP – combined heat and power generation) was also considered for a number of installations of the tertiary sector. This mainly involves hotels and hospitals, which have considerable thermal energy needs, for end uses that require hot water. It was assumed that up to 80 CHP units can be realistically installed, with a nominal electricity capacity of 100 kW each. To achieve the maximum possible emission savings, it was assumed that the CHP units will be fuelled by LPG and replace gas oil fired boilers. In line with relevant industrial information, a total thermal efficiency of 89.7% was assumed for these units (34.2% for electricity and 55.5% for thermal energy), as opposed to 75% thermal efficiency of currently installed boilers.

Cost and energy savings data for this sector are presented in Table 5. As already mentioned for the residential sector, energy savings refer to the demand for *useful* energy, and efficiency figures of Table 3 are used to convert useful energy to *final* energy, which is required for emissions calculations. Final energy savings by abatement option are calculated through comparison with the predominant technology in each case, i.e. variant refrigerant flow heat pump systems for both space heating and space cooling, for buildings of all ages – but with different average seasonal energy efficiency ratios (SEERs) depending on their age.

Table 6 shows the cumulative number of interventions foreseen for service sector buildings up to 2030, which has been determined empirically by Vougiouklakis et al. (2017) taking into account financial, technical and behavioural aspects.

Industry

In the industrial sector, GHG emission abatement measures were explored with emphasis on the following subsectors that are relevant for Cyprus: (a) cement industry, (b) food and beverages, (c) mining, (d) water supply, (e) plastics (f) building material industry, (g) pharmaceutical and cosmetic industry. Due to the significant diversity of industries and the variety of processes and equipment applied, as well as the lack of existing data, the analysis was based on in-situ visits and interviews with the energy managers of the plants, and on data provided by local firms that are highly involved with the design, construction and maintenance of industrial equipment.

The following measures were considered in the industrial sector:

- Replacement of electricity transformers with modern highly efficient ones (i.e. achieving an efficiency of at least 95% under each loading percentage);
- Replacement of electric motors with modern highly efficient ones (efficiency class IE3 according to standard IEC 60034-30-1);
- Replacement of electric inverters with modern highly efficient ones (i.e. achieving an efficiency of at least 98% under each loading percentage);
- Installation of LED light bulbs;
- Installation of photovoltaics;
- Replacement of fuel oil fired burners with modern efficient ones, so that, in combination with the existing installed boilers, they achieve an efficiency of over 90%;
- Cogeneration.

Out of the possible measures, priority was given to those deemed as realistic by the industry, i.e. those which correspond to their economic capability and which involve technologies that are already available in the Cypriot market.

Cogeneration was considered for a number of industrial installations, for end uses (e.g. process hot water) that require thermal energy. It was assumed that up to 30 CHP units can be realistically installed in industrial plants across Cyprus, with a nominal electricity capacity of 100 kW each. To achieve the maximum possible emission savings, it was assumed that the CHP units will be fuelled by LPG and replace boilers burning fuel oil. In line with relevant industrial information, a total thermal efficiency of 89.7% was assumed for these units (34.2% for electricity and 55.5% for thermal energy), as opposed to 75% thermal efficiency of currently installed boilers.

Table 7 illustrates the costs and assumed energy savings for the above mentioned measures, taking into account the diversity of uses and operation modes of equipment in industrial plants of Cyprus.

Road Transport

The transport sector is responsible for a considerable amount of non-ETS emissions of Cyprus. According to the official National Greenhouse Gases Inventory Report, transport contributed by 31.3% to energy related GHG emissions in 2015 and to 22.8% of total national GHG emissions for the same year, exhibiting an increase of 57% during the period 1990-2015.

Two measures were primarily considered, in line with priorities set by national authorities, for reducing carbon emissions of transport: promotion of public transport and promotion of low-CO_2 vehicles. In order to stay in line with national policies that have been submitted up to now, mitigation measures that we considered for this sector are:

- Infrastructure investments for public transport
- Use of alternative fuels (e.g. CNG, electricity) for cars and/or trucks without changes in vehicle taxation.

Infrastructure investments for public transport

Cyprus has a very low share of public transport in passenger mobility (around 2%), hence increasing the modal share of buses seems to be a meaningful and necessary policy option. This mitigation measure is accompanied by the related investment cost, operation and maintenance cost and fuel cost of new buses, to be accompanied by large energy and emission savings due to the lower use of private cars.

With appropriate incentives for public transport, it is assumed that there will be a shift of a certain amount of passenger kilometres from private cars to buses. Based on the occupancy rates of each mode, there will be a reduction in the distance travelled with private cars and a rise in the distance travelled with buses. This will induce a change in fuel costs: extra fuel costs because of the additional operation of buses, minus the avoided fuel costs of cars due to the reduction in their use. The associated emission reduction will be due to the decreased use of fuel (and hence lower emissions) in passenger cars, minus the additional emissions to be generated by the more intensive use of buses.

Use of alternative fuels for cars and/or trucks

For this measure it is assumed that, as a result of subsidies or a regulatory obligation, a fraction of new cars sold each year use a low-carbon or zero-carbon powertrain. This entails a change in all costs; alternative fuelled vehicles are generally more costly to purchase but have lower fuel costs. Emission reduction is achieved due to the use of a lower-carbon fuel.

Using alternative fuels is assumed not to affect total passenger mobility (i.e. passenger kilometres of private cars), but only the average emission factor of new cars, and hence also the average emission factor of all cars in use. In the case of passenger cars, fuel switch is assumed to take place from conventional (petrol and diesel powered) cars to fully electric cars. In the case of freight transport, fuel switch is assumed to occur from diesel powered to CNG-powered trucks.

The data and assumptions used for the cost-effectiveness calculations in the road transport sector are quite detailed and are not provided here for brevity; they are available in the publication of Sotiriou et al. (2019) – see footnote 6.

Apart from the above measures, one more was considered from the agricultural sector - reduction of emissions from manure management from the promotion of anaerobic digestion for animal waste.

Table 2: Costs and energy savings for each individual measure considered in residential buildings.

Single-family house built before 2008

Intervention	Change in useful energy demand [kWh_{th}]		Investment cost* [€]	Maintenance cost* [€]	Lifetime [y]
	Heating	Cooling			
Deep renovation (to nZEB)	817	-12493	26600	1447	30
Roof insulation	359	-9751	4250	85	30
Wall insulation	-360	-978	13100	262	30
Windows replacement	280	-742	9250	1100	30
Lighting [kWh_{el}]	-1240		650	20	15
Solar thermal	-2000		1200	100	20
Energy Demand for: [kWh]	12460	21095			

Single-family house built after 2008

Intervention	Change in useful energy demand [kWh_{th}]		Investment cost* [€]	Maintenance cost* [€]	Lifetime [y]
	Heating	Cooling			
Deep renovation (to nZEB)	-978	-1422	34600	2787	30
Roof insulation	-1126	-510	2750	55	30
Wall insulation	-440	-842	11600	232	30
Windows replacement	-387	-28	20250	2500	30
Lighting [kWh_{el}]	-1595		800	36	15
Solar thermal	-2000		1200	100	20
Energy Demand for: [kWh]	13300	12680			

Multi-family building built before 2008

Intervention	Change in useful energy demand [kWh_{th}]		Investment cost* [€]	Maintenance cost* [€]	Lifetime [y]
	Heating	Cooling			
Deep renovation (to nZEB)	-8278	-19581	46750	3447	20
Roof insulation	-2936	-12943	3350	67	20
Wall insulation	-1481	-1731	15650	313	20
Pilotis insulation	-3090	3426	3350	67	20
Windows replacement	704	-3460	24400	3000	20
Lighting [kWh_{el}]	-3460		1750	53	15
Solar thermal	-6000		3600	300	20
Energy Demand for: [kWh]	15640	45560			

Multi-family building built after 2008

Intervention	Change in useful energy demand [kWh_{th}]		Investment cost* [€]	Maintenance cost* [€]	Lifetime [y]
	Heating	Cooling			
Deep renovation (to nZEB)	-5578	-3341	80800	6150	20
Roof insulation	-573	-1289	5000	100	20
Wall insulation	-2526	-2809	26800	536	20
Pilotis insulation	-1317	358	5700	114	20
Windows replacement	-949	424	43300	5400	20
Lighting [kWh_{el}]	-6385		3250	98	15
Solar thermal	-12000		7200	600	20
Energy Demand for: [kWh]	14777	43285			

* Without VAT

Source: Vougiouklakis et al. (2017)

Table 3: Technologies and fuels used in residential buildings of Cyprus by construction period and their corresponding efficiency figures. "Usage" denotes the shares of each technology in the stock of appliances of the corresponding building types.

Heating systems for pre-2008 residential buildings

Technology	*Fuel*	*Efficiency*	*Usage*
Central heating	Gas oil	80%	23.6%
Heat pump	Electricity	320%	15.2%
Stove	Electricity	100%	17.1%
Stove	LPG	70%	23.0%
Fireplace	Biomass	30%	7.3%
Storage	Electricity	100%	4.5%

Heating systems for post-2008 residential buildings

Technology	*Fuel*	*Efficiency*	*Usage*
Central heating	Gas oil	80%	9.1%
Heat pump	Electricity	320%	38.6%
Stove	Electricity	100%	18.2%
Stove	LPG	70%	4.5%
Fireplace	Biomass	30%	8.0%
Storage	Electricity	100%	9.1%

Cooling systems for pre-2008 residential buildings

Technology	*Fuel*	*Efficiency*	*Usage*
Heat pump	Electricity	250%	100.0%

Cooling systems for post-2008 residential buildings

Technology	*Fuel*	*Efficiency*	*Usage*
Heat pump	Electricity	320%	100.0%

Current (New) heat pump specifications

Type	*Seasonal Energy Efficiency Ratio*	*Seasonal Coefficient of Performance*	*Comment*	*Investment cost* [€]*	*Maintenance cost* [€]*	*Lifespan [y]*
Split, Air-to-Air (AA)	515%	475%	Actual data; applicable to residential single family buildings before 2008	3,200	128	15
Package, VRV	500%	460%	Actual data; Applicable to commercial buildings	92,500	3,700	15
Split, Air-to-Air (AA)	515%	475%	Actual data; applicable to residential single family buildings after 2008	4,000	160	15
Split, Air-to-Air (AA)	515%	475%	Actual data; applicable to residential multi family buildings before 2008	9,600	384	15
Split, Air-to-Air (AA)	515%	475%	Actual data; applicable to residential multi family buildings after 2008	14,400	576	15

Source: Vougiouklakis et al. (2017) and estimates based on national statistical surveys of energy use in households.

Table 4: Number of energy efficiency interventions in existing residential buildings of Cyprus up to 2030.

Intervention	Total number of interventions up to 2030	Fraction of current building stock
1. Single- and two-family houses		
Deep renovation (nZEB)	1,000	0.3%
Roof insulation	12,000	3.9%
Wall insulation	2,500	0.8%
Window frame system upgrade	3,500	1.1%
Lighting and electronic appliances	21,000	6.8%
Heat pumps	2,500	0.8%
Solar thermal system for hot water production	3,500	1.1%
2. Multi-family buildings		
Deep renovation (nZEB)	500	0.4%
Roof insulation	3,500	2.8%
Wall insulation	600	0.5%
Ground floor/level insulation	300	0.2%
Window frame system upgrade	2,000	1.6%
Lighting and electronic appliances	5,500	4.4%
Heat pumps	1,500	1.2%
Solar thermal system for hot water production	500	0.4%

Source: Vougiouklakis et al. (2017).

Table 5: Costs and energy savings for each measure considered in commercial buildings and for LPG-fired cogeneration in the tertiary sector.

Office building before 2008 (1990)

Intervention	Change in useful energy demand [kWh_{th}] Heating	Change in useful energy demand [kWh_{th}] Cooling	Investment cost* [€]	Maintenance cost* [€]	Lifespan [y]
Deep renovation (to nZEB)	-9,720	-21,300	141,000	6,520	20
Roof insulation	-2,515	-7,270	12,000	240	20
Wall insulation	-4,010	-490	55,000	1,100	20
Pilotis insulation	-3,115	4,480	9,000	180	20
Windows replacement	1,470	-12,890	65,000	5,000	20
Lighting [kWh_{el}]	-12,200		7,600	228	18
Solar thermal [kWh_{th}]	-6,000		3,600	300	20
Energy Demand for: [kWh]	16,890	84,185			

Office building after 2008

Intervention	Change in useful energy demand [kWh_{th}] Heating	Change in useful energy demand [kWh_{th}] Cooling	Investment cost* [€]	Maintenance cost* [€]	Lifespan [y]
Deep renovation (to nZEB)	-3,460	570	128,000	6,260	20
Roof insulation	-415	-665	9,500	190	20
Wall insulation	-1,890	-960	47,000	940	20
Pilotis insulation	-720	755	6,500	130	20
Windows replacement	-490	1,270	65,000	5,000	20
Lighting [kWh_{el}]	-12,200		7,600	228	18
Solar thermal [kWh_{th}]	-12,000		7,200	600	20
Energy Demand for: [kWh]	10,875	60,800			

	Electricity Production [kWh/y]	Heat Production [kWh/y]	Gas Oil Substitution [kWh/y]	Investment cost* [€]	Maintenance cost* [€/y]	Lifespan [y]	Capacity [units]
CHP 100 kWel - LPG	815,760	1,322,640	1,765,000	165,000	4,950	15	30

* Without VAT

Table 6: Number of energy efficiency interventions in existing commercial buildings of Cyprus up to 2030.

Intervention	Total number of interventions up to 2030	Fraction of current building stock
Deep renovation (nZEB)	800	0.9%
Roof insulation	3,000	3.5%
Wall insulation	600	0.7%
Pilotis insulation	150	0.2%
Window frame system upgrade	800	0.9%
Lighting and electronic appliances	7,000	8.2%
Heat pumps	3,500	4.1%
Solar thermal system for hot water production	2,500	2.9%

Table 7: Data and assumptions used in the cost-effectiveness calculations for the industrial sector.

Intervention	*Savings [kWh/kW/a]*	*Investment cost* [€/kW]*	*Maintenance cost* [€/kW]*	*Lifespan [y]*	*Overall Savings [kWh/a]*	*Overall Investment cost* [€]*	*Overall Maintenance cost* [€]*	*Capacity [kW]*
Electricity Transformer	234	15	0.15	20	14,865,000	1,740,000	17,400	
Electric Motor (up to 250 kW)	6	50	0.50	20	34,685,000	493,500,000	4,935,000	
Electric Motor (> 250 kW)	6	80	0.80	20				
Electric Inverter (up to 300 kW)	240	75	0.75	10	272,525,000	183,600,000	1,836,000	
Electric Inverter (> 300 kW)	240	100	1.00	10				
Lighting	1,898	780	31.20	13	173,425,000	72,860,000	2,914,400	
Photovoltaics	1,700	1,000	40.00	20	4,250,000	2,500,000	100,000	2,500
Burner replacement (LFO)	224	4.60 - 8.50	0.34	10	1,325,940	56,500	2,933	

	Electricity Production [kWh/y]	*Heat Production [kWh/y]*	*Fuel Oil Substitution [kWh/y]*	*Investment cost* [€]*	*Maintenance cost* [€/y]*	*Lifespan [y]*	*Capacity [units]*
CHP 100 kWel - LPG	815,760	1,322,640	1,765,000	165,000	4,950	15	30

*Cost values without VAT

4.4.2 Results

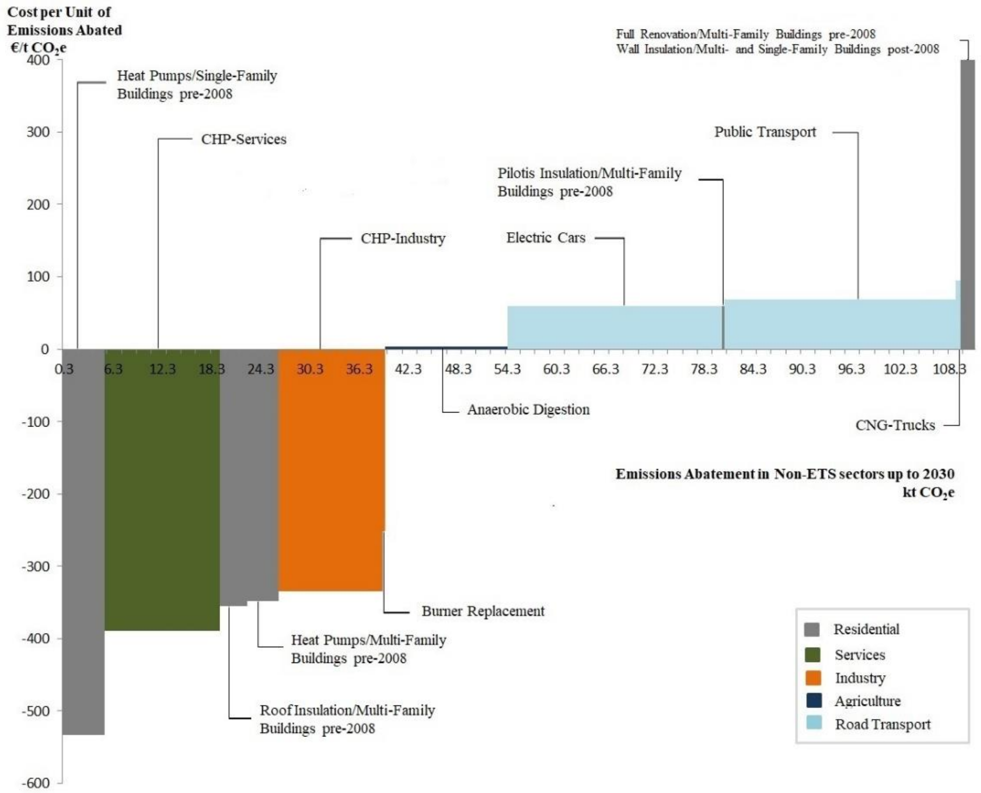
Based on the methodology, the data and the assumptions described in the previous sections, it is possible to assess the discounted costs and GHG emission savings for each one of the individual measures that have been considered.

Figure 16 highlights the results of the cost-effectiveness calculation, by showing the marginal GHG emissions abatement cost curve when only non-ETS emissions are considered. This means that a) measures reducing electricity-generated emissions are excluded; and b) abatement calculations include only the reduction of direct GHG emissions, thereby ignoring the indirect effect on emissions due to changes in electricity consumption, which would be subject to the ETS. In this framework, the most cost-effective measures turn out to be the following:

- the installation of heat pumps in pre-2008 residential buildings;
- cogeneration in the industrial and tertiary sector;
- roof insulation in pre-2008 residential multi-family buildings;
- the increased use of anaerobic digestion for animal waste;
- the replacement of burners in industry.

In terms of emission abatement potential, heat pumps, industrial and commercial cogeneration, animal waste exploitation, and promotion of electric cars and public transport seem to be the most promising measures.

Figure 16: Marginal GHG emissions abatement cost curve for Cyprus, taking into account the emissions abatement potential in non-ETS sectors. Each measure is coloured according to the economic sector to which it belongs, as shown in the legend of the graph.



It is also evident from Figure 15 that implementation of all these measures is expected to yield net social benefits because the measures with negative costs outweigh those with positive costs: the size of the shaded area beneath the horizontal axis is greater than the size of the area of measures above the axis. The issue of MACs with negative costs has been widely discussed in the literature. Obviously, MAC calculations may largely ignore adjustment costs, behavioural aspects, transaction costs or other market failures. Still, since our appraisal views the cost-effectiveness of measures from a societal (public policy) perspective, these results send two clear policy messages:

- First, a large number of the GHG emission mitigation measures considered here – all of them related to energy efficiency improvements – can yield net benefits to society and therefore have to be adopted; even if some costs of market failures are underestimated, the net benefits are so large that they almost certainly outweigh actual costs.
- Second, because of the large potential social benefits, authorities can accelerate progress towards decarbonization of the economy by removing financial and regulatory barriers that hinder the full implementation of these measures – and thus can help alleviate market failures and increase net societal gains.

These results are similar to those coming out from other national studies as outlined by Sotirou et al. (2019).

4.4.3. Additional measures for compliance with the European Green Deal

In light of an even more stringent decarbonisation targets adopted by the European Climate Law, we expanded the list of emission abatement measures from fourteen (as explained in Section 4.4.2 above) to twenty-three mitigation options; the additional measures, so-called advanced measures, capture an expansion of the basic ones and are presented in the lower part of Table 8. Especially with regard to residential building renovations, the combination of basic and advanced measures covers renovations in the total stock of single-family dwellings built between years 1991 and 2007. Regarding the multi-family buildings, the basic measures suggest interventions on 60% of the total multi-family stock. Keeping in mind the difficulties of renovating this type of buildings due to their size and multiple ownership, we expanded the measures to buildings of a different construction period. Therefore, some advanced measures were selected to address older multi-family buildings, constructed between the years 1971 and 1990, which represent 10% of the total stock.

Table 8: Description of the basic and advanced mitigation measures related to energy efficiency improvements.

Description	Sector
Basic measures	
Full Renovation in Multi-Family building constructed 1991-2007	Residential
Roof Insulation in Multi-Family buildings constructed 1991-2007	Residential
Wall Insulation in Multi-Family buildings constructed 1991-2007	Residential
Wall Insulation in Single-Family buildings constructed 1991-2007	Residential
Pilotis Insulation in Multi-Family buildings constructed 1991-2007	Residential
Heat Pumps in Multi-Family buildings constructed 1991-2007	Residential
Heat Pumps in Single-Family buildings constructed 1991-2007	Residential
Combined heat and power generation	Services
Combined heat and power generation	Industry
Burner Replacement in Industry	Industry
Promotion of Public Transport	Road Transport
Electric Private & Light Goods Conveyance Vehicles	Road Transport
Low-Carbon Trucks	Road Transport
Advanced measures	
Full Renovation in Multi-Family buildings constructed 1971-1990	Residential
Roof Insulation in Multi-Family buildings constructed 1971-1990	Residential
Wall Insulation in Multi-Family buildings constructed 1971-1990	Residential
Wall Insulation in Single-Family buildings constructed 1991-2007+	Residential
Pilotis Insulation in Multi-Family buildings constructed 1971-1990	Residential
Heat Pumps in Multi-Family buildings constructed 1971-1990	Residential
Heat Pumps in Single-Family buildings constructed 1991-2007+	Residential
Promotion of Public Transport/BEV Buses	Road Transport
Electrical Private & Light Goods Conveyance Vehicles+	Road Transport

The analysis was conducted with a multi-objective optimisation approach, in order to explore trade-offs between stronger emission abatement and higher abatement costs. The results are described and discussed elsewhere[9]; Section 5 provides the main conclusions.

5. Conclusions

In light of the European Green Deal and the decisions taken recently by EU leaders to raise the ambition for reducing greenhouse gas emissions in 2030, our analysis has explored how challenging it is for Cyprus, as is reportedly the case for most EU countries, to meet their non-ETS decarbonisation commitments. Figure 15 has highlighted this challenge.

Even to reach modest emission abatement, fast deployment of measures is required for electrification of transport, shift to public transportation, and energy renovations of buildings, much beyond the speed at which such interventions had been implemented up to now. Interestingly, the ambitious targets for 2030 that can help Europe (and Cyprus) stay on track for achieving net zero GHG emissions in 2050, although seemingly more costly than the less ambitious ones, seem to yield net benefits to society if optimisation is conducted taking into account external costs in addition to the financial ones; the avoided economic damages thanks to the more ambitious decarbonisation policies, coupled with fuel cost savings throughout the lifetime of the interventions, demonstrate that there is no dilemma between climate ambition and economic costs. Still, the optimal decarbonisation path is capital-intensive and fiscally challenging - it requires investments of the order of 5% of Cyprus's annual national GDP every year of the decade 2021-2030, out of which a substantial part will have to come from public funds. Although this level of spending is feasible, it requires a well-targeted orientation of public and private investments towards low-carbon interventions across the entire economy, with a special emphasis on energy efficiency investments.

EU leaders, along with international organisations, have outlined the importance of such a green transition in the aftermath of the COVID-19 pandemic; it has been well documented that a "return-to-normal" economic stimulus is not only environmentally unsustainable but also economically inferior to a green economic recovery plan comprising mostly energy efficiency measures. Political will and societal engagement can overcome economic, financial, and behavioural barriers to build infrastructure, mobilise capital, and change production and consumption patterns on the way to stabilise the global climate. In this context, sound analyses which demonstrate the cost-effectiveness and net benefits to society of energy efficiency improvements can support the effective implementation of the 'Energy Efficiency First' principle.

[9] Sotiriou C. and Zachariadis T., A multi-objective Optimisation Approach to Explore Decarbonisation Pathways in a Dynamic Policy Context. *Journal of Cleaner Production* 319 (2021) 128623. doi: 10.1016/j.jclepro.2021.128623