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In-Depth Assessment of the Energy Efficiency Potential in Cyprus

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Abstract

This paper presents results from the first in-depth study on the energy efficiency potential in Cyprus. Different energy models were combined in order to conduct simulations and provide recommendations to national authorities so that Cyprus can meet its targets in the frame of the EU energy and climate policies. The study assessed both the maximum theoretically available potential for energy efficiency improvements and the economically viable potential, and then translated these assessments to aggregate energy demand forecasts. The analysis shows that Cyprus cannot continue along a 'business-as-usual' path in improving the efficiency of its energy system if it is to achieve the EU decarbonisation goals for year 2030 and beyond. In theory, there is a large potential to increase the energy productivity of the Cypriot economy, its exploitation requires a very substantial mobilisation of financial resources, at a rate that has not been observed in the past. An intensification of smart financial tools to enable energy efficiency investments, coupled with a green tax reform that will gradually implement a carbon tax while reducing the tax burden of labour, can facilitate a smooth transition to a low-carbon economy.

Keywords: Building renovation; Decarbonisation; Energy forecast; Energy saving potential.

1. Introduction

Increasing the energy productivity of the global economy is considered as a key step to combat climate change. A major part of such an improvement is to raise the energy efficiency of an economy. The International Energy Agency calls energy efficiency as 'the first fuel', meaning that fuel

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consumption avoided due to efficiency measures is greater than the actual consumption of any other fuel, and outlines the several benefits brought about by energy efficiency improvements (IEA, 2014). This paper presents results from the first in-depth study on the energy efficiency potential in the Republic of Cyprus, with a somewhat stronger focus on the buildings sector, which is responsible for about 40% of energy consumption and 60% of electricity consumption in Europe (Eurostat, 2017a) and about one third of total energy demand in Cyprus (Kitsios et al., 2015). As the large majority of buildings is concentrated in urban areas, where about 70% of the global population lives, making the most out of this potential is crucial for ensuring climate resilience and resource efficiency in cities.

Energy consumption in Cyprus has grown in line with national income. Despite the recent economic crisis, fuel shares in final energy demand have remained essentially unchanged. Until natural gas is made available for domestic consumption, the country remains highly dependent on imported petroleum products, both for end uses and for power generation. This has obvious adverse effects on the island's energy security but also on the cost of energy: retail prices – particularly those of electricity – are highly dependent on international oil price fluctuations and are among the highest in Europe (Eurostat, 2017b). Energy intensity of the country (i.e. energy consumption per unit of economic output) also ranks highly in Europe, due to the lack of adequate public transport modes, the absence of energy performance requirements for buildings until recently, and the exclusive dependence on aviation for international travel.

The country is located in a hot spot in terms of climate change impacts: it already has a semi-arid climate and the Mediterranean region is expected to experience the most adverse climate change effects in Europe, with significant temperature increases and some drop in already low rainfall levels (Lelieveld et al., 2012). As a result, energy supply and demand are expected to be considerably affected in the medium and long term (Zachariadis and Hadjinicolaou, 2014); this reinforces the need for long-term energy planning as it constitutes an important part of a coherent climate change adaptation policy for the island.

As an EU member, Cyprus has implemented policies promoting renewable energy and energy efficiency measures in compliance with the relevant EU legislation. Although the country is expected to fulfil its 2020 targets, the 2030 EU energy and climate objectives are much more challenging. Reducing greenhouse gas emissions from the economic sectors not subject to the EU Emissions Trading System will require substantial effort in implementing new policies and mobilizing financial resources. Improving the energy efficiency of buildings, transport and industry is a high priority for decarbonising the Cypriot economy.

For this study, different energy models were combined in order to conduct policy-relevant simulations and provide recommendations to national energy and economic authorities so that Cyprus can meet its energy efficiency decarbonisation targets in the frame of the EU energy and climate policies. The study assessed both the maximum theoretically available potential for energy efficiency improvements and the economically viable potential, and then translated these assessment to aggregate energy demand forecasts. Section 2 of the paper describes the approach followed to assess these potentials, while Section 3 presents the results of the aggregate energy forecasts. Section 4 offers major conclusions and an outlook for policy-related interventions.

2. Exploring the Energy Efficiency Potential

Given the missing comprehensive overview on existing energy efficiency potentials in the Cypriot economy and the lack of a previous studies in that field, we carried out an assessment of firstly the overall existing theoretical and secondly the economically viable energy efficiency potential for the (a) household, (b) services and (c) industry sector. In the following paragraphs the methodology applied in order to estimate these potential are described. Transport is not covered in this paper since a separate study was commissioned to look into this sector.

Each sector exhibits different characteristics regarding energy related behaviour, available technologies for energy production and use, energy demand profile, and fuel substitution possibilities. Based on these specific characteristics and in order to obtain technically robust and plausible results, different methodologies were followed by sector. This potential was used as a benchmark in order to formulate the assumptions of the Maximum Technical Potential Scenario of our study.

2.1. Households

The maximum theoretical energy saving potential for the residential building sector is defined as the amount of the current energy consumption that will be saved if the existing residential building stock is upgraded to nearly zero energy buildings (nZEB), in line with the provisions of EU and national legislation.

On the other hand, the economically viable potential, which is a fraction of the maximum potential, is broadly defined as the amount of energy savings that can be attained if the more cost-effective measures are implemented given some real-world financial constraints that limit the funds available for supporting renovations of residential buildings.

The energy saving potential has been derived in both cases with the aid of 2EMRS (Energy Estimation Model for Residential Sector), a model that was further developed for this study and uses a simplified dynamic bottom-up algorithm using EnergyPlus, a simulation software that is widely used for modelling the energy efficiency of buildings (US DOE, 2017). Using technical and physical input parameters, the model estimates the final heating and cooling energy consumption of the existing residential building stock of Cyprus. The model uses characteristic building typologies, which were developed after a detailed analysis of the statistics of building construction permits per district and area provided by the Statistical Service of Cyprus (Cystat). This analysis distinguishes into 84 characteristic building typologies based on building type, construction period and climatic area. Climatic data used in the model refer to typical meteorological years, which are needed for the simulations. These files were extracted from Meteonorm Software for the three reference climate regions (hot, moderate and cold) of Cyprus. The hot climate region represents the southern coastal areas of the island, the moderate climate is characteristic for the mainland areas, while the cold region represents the mountainous areas of the island.

Other input data are:

- The usage factor of heating and cooling systems per construction period, which accounts for the percentage of total building space in which a heating/cooling system is not installed; this was derived from surveys conducted by Cystat.
- Technology and fuel usage efficiency per heating/cooling system and construction period. The efficiency figures of the fuel-based heating and cooling system for all construction periods were derived from studies carried out by the government of Cyprus under the provisions of article 5 of EU Directive 2010/31/EC, as well as from the EN 15316-4-X Standards.
- The time-dependent usage factor of heating/cooling systems, which is a correction factor considering the actual use of heating and cooling systems on a daily basis. This factor was estimated based on the results of a final energy consumption survey of households performed by

Cystat in 2009. This factor is assumed to be the same for all building typologies and heating/cooling system types.

More information about the actual figures of the above mentioned input data are provided in the detailed report of our study (Vougiouklakis et al., 2017).

Based on 2EMRS model runs, it was possible to assess (i) the maximum theoretical potential and (ii) the economically viable potential for energy efficiency improvements in the residential sector. In both cases this potential was estimated in terms of percentage reduction in: (a) heating energy consumption, (b) cooling energy consumption, (c) energy consumption for domestic hot water production and (d) electricity consumption for lighting and appliances (white goods).

In the maximum theoretical potential, we assumed the energy upgrade and retrofitting of the entire building envelope stock and the gradual penetration of the following interventions for existing buildings:

• High efficiency heat pumps for cooling in all buildings

• 90% High efficiency heat pumps + 10% high efficiency boilers for heating in multi-family buildings, located in urban and rural areas

• 80% High efficiency heat pumps + 20% high efficiency boilers for heating in single family buildings located in urban areas

• 50% High efficiency heat pumps + 50% high efficiency boilers for heating in single family buildings located in rural areas.

For high efficiency heat pumps, a seasonal coefficient of performance (SCOP) for heating of 600% and a seasonal energy efficiency ratio (SEER) for cooling of 650% were considered. For the high efficiency boilers, which burn LPG, an annual fuel utilization efficiency (AFUE) of 96.5% was assumed.

Apart from 2EMRS model runs, this analysis was also based on the findings of earlier studies conducted by the government of Cyprus (JRC, 2016).

As far as the economically viable potential is concerned, we adopted the following approach: Based on the modelling analysis that led to identification of the maximum energy saving potential, it turned out that the following non-prioritised energy interventions should be mainly considered in order to improve the energy efficiency of the current residential building stock:

(a) Insulation of the horizontal elements (roof, ceiling, etc.)

(b) Insulation of the vertical elements (reinforced elements, masonry)

(c) Installation of shading devices

(d) Installation high efficiency windows (frame and glasses)

(e) Installation of LED lighting bulbs

(f) Use of high efficiency heat pumps

(g) Use of solar thermal collectors

(h) Use high efficiency boilers (in rural areas)

The study of Zangheri (2016) has shown that under a scenario which assumes policies recognised as particularly appropriate for Cyprus, the total expenditure in renovations is foreseen to account for about 450-500 million EUR until 2030. This level of expenditures, compromising both private and co-financed interventions, is considered by national energy authorities as a challenging but realistic prospect for the period up to 2030 and was therefore adopted in this analysis in the form of a 'budget constraint'.

The average intervention cost of a deep renovation (i.e. leading to a nZEB class) per average dwelling (i.e. weighted average after considering single family, two-families and multi-family buildings) is estimated at about 65,000 EUR, meaning that an equivalent number of just 7,700 buildings in the household sector could be fully upgraded with this amount until 2030. However, the consideration that only deep renovations could be implemented in the household sector – apart from being unrealistic in pure technical and market-related terms – is also non-optimal in cost efficiency terms, since the combination with other Energy Efficient (EE) interventions will increase both the total achieved savings and the affected households, keeping simultaneously stable the overall budget expenditure.

More specifically, considering that the ratio of energy saving/intervention cost of specific individual measures is higher than the ratio of integrated renovation and taking in consideration a mix of the (a)-(h) previously illustrated energy efficiency interventions, a mean ratio of around 1:5 is estimated in terms of affected buildings for the same available total amount of expenditures. Therefore, it turns out that on average 33,400 dwellings can be assumed to be renovated in the realistic scenario (i.e. under the hypothesis that 1/6 is kept for deep renovation so that some demonstration projects of nZEB refurbishments are possible). This would include all different building typologies: single-family house up to multi-family blocks of flats.

This building stock, after considering some market-related characteristics and the opinion of local stakeholders, could be allocated per construction period as follows:

- 4% renovation of the building stock constructed before 1970 (1,635 dwellings);
- 9% renovation of the building stock constructed during 1971-1990 (10,250 dwellings);
- 20% renovation of the building stock constructed during 1991-2007 (21,200 dwellings); and
- 1% renovation of the building stock constructed from 2008 up to now (315 dwellings).

As a result, Table 1 illustrates the overall energy saving potential for the household sector for both cases – the maximum theoretical case and the economically viable case. More detailed results for each end use is provided in the full report of our study (Vougiouklakis et al., 2017).

TABLE 1

Theoretical and economically viable energy saving potential for the Cypriot residential sector

	Final energy consumption [toe]							
Fuel	Electricity	Gas oil	Kerosene	LPG	Biomass	Solar	Geothermal	Total
Current situation	127,557	51,545	9,807	42,440	8,559	57,678	1,551	299,146
Max potential	50,922	-	-	27,343	-	65,883	1,628	145,776
Savings	*60.1%*	*100.0%*	*100.0%*	*35.6%*	*100.0%*	*-14.2%*	*-5.0%*	*51.3%*
Realistic potential	121,689	43,727	8,420	41,092	7,394	59,742	1,582	283,646
Saving	*4.8%*	*15.2%*	*14.1%*	*3.2%*	*13.6%*	*-3.6%*	*-2.0%*	*5.2%*

2.2. Services

As in the residential sector, the maximum theoretical energy saving potential for the tertiary sector is defined as the amount of the current energy consumption that will be saved if the existing building stock is upgraded to nZEB, in line with the provisions of EU and national legislation. On the other hand, the economically viable potential, which is a fraction of the maximum potential, is broadly defined as the amount of energy savings that can be attained if the more cost-effective measures are implemented given some real-world financial constraints that limit the funds available for supporting renovations of service buildings.

The maximum theoretical potential was estimated in terms of percentage reduction in: (a) heating energy consumption, (b) cooling energy consumption, (c) energy consumption for hot water production and (d) electricity consumption for lighting and appliances, assuming the gradual penetration of high efficiency heat pumps and boilers. Moreover, demand side management/demand response measures were considered.

Due to the significant diversity of building types, pattern uses, equipment etc. in the tertiary sector, as well as the lack of an adequate existing model, this analysis was performed with the aid of in-situ visits of the study team and interviews with the energy managers of large facility owners, such as banks, hotels and office blocks; interviews with directors of energy management companies; data provided by local companies that are highly involved with the design, construction and maintenance of facilities; and available data from national energy authorities. Furthermore, replacement of all existing street lights at municipal and community level as wee as in motorways was assumed.

Table 2 summarises the results on the maximum theoretical energy saving potential for the service sector per fuel, including street lighting. More detailed information is provided in the main report of this study (Vougiouklakis et al., 2017).

With regard to the economically viable potential, based on the analysis that led to identification of the maximum energy saving potential as well as the review of the existing literature, the following energy interventions were considered in order to improve the energy efficiency of the current service building stock:

(a) Insulation of the horizontal elements (roof, ceiling, etc.)

(b) Installation of shading devices

(c) Insulation of the vertical elements (reinforced elements, masonry)

(d) Use high efficiency windows (frame and glasses)

(e) Installation of LED lighting bulbs

(f) Use of high efficiency heat pumps

(g) Installation of Building Energy Management Systems (BEMS)

TABLE 2

Maximum theoretical energy saving potential in the Cypriot service sector

Fuel	*Final energy consumption [toe]*		*Savings*
	Current situation	*Maximum efficiency*	
Electricity	149,214	39,724	*73.4%*
Gas oil	24,612	-	*100.0%*
LPG	12,024	25,881	*-115.2%*
Kerosene	2,050	-	*100.0%*
Light fuel oil	100	-	*100.0%*
Biomass	4,905	1,962	*60.0%*
Sum	*192,905*	*68,095*	*64.7%*
Solar & Heat Recovery	10,380	14,020	-35.1%

Moreover, specific interventions were considered for individual sub-sectors that relate to different energy demand profiles and type of energy end-uses. In particular the following interventions were considered for Hotels and Lodges, health facilities and shopping malls:

(a) Heat recovery from cooling systems

(b) Installation of solar thermal collectors

(c) Use of solar cooling

(d) Use of CHP

Zangheri (2016) has shown that under a scenario which assumes policies recognised as particularly appropriate for Cyprus, the total expenditure in renovations is estimated to about 7.5-8.0 million EUR until 2030. Such an extremely low amount of expenditures for energy efficiency measures in the service sector would lead to very low savings and to largely untapped energy efficiency potential. Considering the current and foreseen expenditures during the period until 2020, in our study an average annual total expenditure for energy efficiency interventions for both public and private buildings in the service sector of around 20-30 million EUR should be seen as realistic for the period until 2030 if an appropriate mix of instruments and policies are in place.

Taking into consideration the potential for specific measures that was mentioned by local energy consultants, energy managers and owners of specific commercial facilities during meetings that were held in the frame of this study and by applying an energy efficient mix of interventions on the basis of an annual budget of around 25 million Euros, energy savings of the order of 6% until 2030 have been considered as realistic – both in economic and market terms. On top of this, an additional amount of electricity savings at the range of 2.4% was assumed for the same period, in order to take into account the foreseen replacement of all street lighting before 2030. The cost for this intervention in street lighting is adding to the previous estimation of budget expenditure and is contributing to an estimated mean annual increase of the foreseen budget at around 1-2 million Euros (i.e. overall budget of around 20 million Euros).

2.3. Industry

This maximum theoretical energy saving potential in industry was estimated in terms of percentage reduction per fuel (electricity, heavy fuel oil, gas oil) on the following individual subsectors, which account for over 70% of total industrial energy consumption in Cyprus: (a) cement industry, (b) food and beverages, (c) mining, (d) water supply, (e) plastics (f) building material industry, (g) pharmaceutical and cosmetic industry. Moreover, demand side management/demand response measures were considered. Due to the significant diversity of industries, pattern uses, process and equipment use, as well as the lack of existing data, the analysis was based on in-situ visits of the study team and interviews with the energy managers of the plants, as well as on data provided by local companies that are highly involved with the design, construction and maintenance of industrial equipment.

It was assumed that the substitution of industrial equipment with more efficient one will be implemented until 2030. After this year, further technological improvements were assumed, mainly regarding the introduction of advanced automation systems that enable further energy savings. For the longer run, further very energy efficient technologies were assumed to penetrate gradually.

Under this assumption for the theoretical potential the overall coefficient of performance of heating, cooling and electricity use in the industry sector is considered to be highly improved and that also improvements in the energy related processes could result in reduced energy demand. Based on the above information sources, the maximum theoretical energy saving potential was assessed to be 34% for electricity and 5% for fuel oil and gas oil.

As far as the economically viable potential is concerned, the following interventions were considered in order to improve the energy efficiency of the industrial sector:

(a) Use of high efficiency electric motors

(b) Use of inverters

(c) Installation of automations

(d) Use of heat recovery systems

(e) Installation of LED lighting bulbs

(f) Installation of energy efficient compressed-air systems

(g) Use of CHP

As agreed with national authorities, the economically viable potential for the industrial sector was defined as "the amount of the current energy consumption that will be saved if industrial plants upgrade and/or replace their equipment and install high efficiency one which is available in the market based on their economic capability/plans". Based on this assumption, and taking into account the results of consultation meetings with energy managers of specific industrial units, the realistic energy saving potential for the industrial sector until 2030, was estimated to be 6.2% for the consumption of electricity and 0.5% for the consumption of fuel oil and gas oil.

3. Long-Term Forecasts of Final Energy Demand

The implementation of measures to exploit the energy saving potential explained in the previous Section was taken into account in order to produce projections of final energy demand up to 2050 with the aid of a national energy forecast model. This model has been used since some years in order to prepare national action plans submitted by the government of Cyprus to the European Commission and to UNFCCC, and as a basis for the renewable energy roadmap of Cyprus that was prepared by the International Renewable Energy Agency in 2015 (IRENA, 2015).

The model, whose mathematical specification is described in the detailed report of this study, calculates future final energy consumption per year in each major economic sector of Cyprus (agriculture, cement industry, other industry, households, services, road passenger transport, road freight transport and air transport) as a function of future macroeconomic variables and future energy prices. Simultaneously it calculates fuel shares in each sector, depending on technology costs (investment, operation, maintenance and fuel costs), the penetration potential of various technologies and technical constraints for the uptake of new technologies, and allows computing future final energy consumption by sector and fuel.

3.1. Macroeconomic and oil price assumptions

As regards the macroeconomic development, an official forecast was provided to the study team by the Ministry of Finance of Cyprus in October 2016. According to this, the economy of Cyprus is assumed to follow a path of sustained growth, starting with growth rates of real GDP of 2.7-2.8% per year and gradually slowing down to annual growth of around 2.3% from 2030 onwards. Private consumption is assumed to grow at a slower pace than GDP in the short and medium term because it has been hit less by the economic downturn of recent years and has remained at relatively higher than expected levels.

The contribution of each major economic sector to GDP (which is based on assumptions of the study team) is assumed to remain essentially constant. The GDP share of industry, which was around 13% in the mid-1990s, fell to 10% in 2005 and to 7% in 2014-15, is assumed to rebound slightly, reaching a share of 8% in the longer term. A stronger rebound is expected in the construction sector, whose share plunged from 11% to just over 4% during the years of the financial crisis, and is assumed to gradually revert to 8.5% in 2030 and 9% by 2050. The contribution of agriculture, around 2% today, is assumed to slightly decline to 1.7% in the long term. Finally, the service sector is assumed to keep its dominant role in the economy and continue contributing by more than 80% to national economic output. Table 3 and Figure 1 summarise these macroeconomic assumptions.

TABLE 3

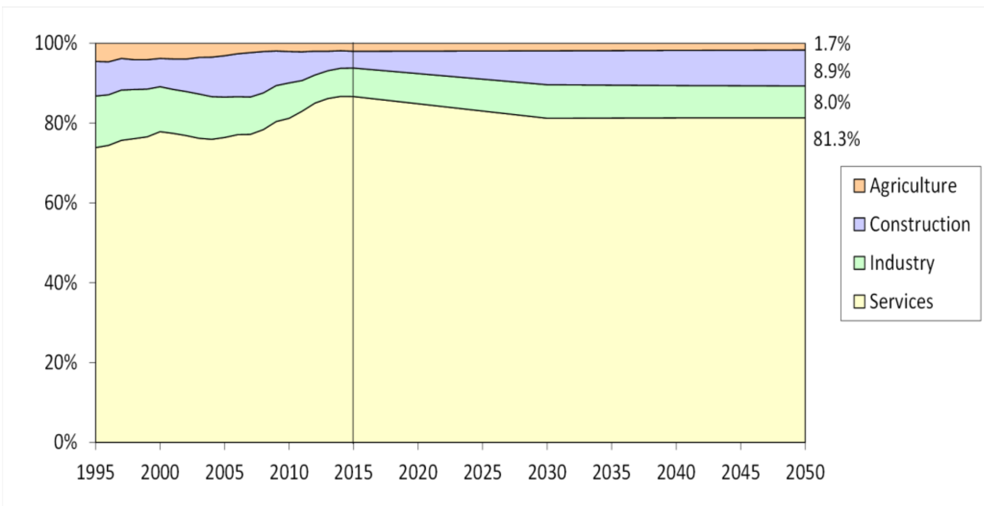
Assumptions on the evolution of GDP, private consumption and sectoral GDP shares in Cyprus

	Actual values in 2015 (million EUR)	*Forecast of real growth rates (average over each period)*			
		2016-2020	*2020-2030*	*2030-2040*	*2040-2050*
GDP	15 355	2.8%	2.5%	2.3%	2.3%
Private consumption	10 376	2.1%	2.2%	2.3%	2.3%
Sectoral GDP shares	*Actual in 2015*	*2020*	*2030*	*2040*	*2050*
Agriculture	2.0%	2.0%	1.9%	1.8%	1.7%
Industry	7.1%	7.6%	8.4%	8.1%	8.0%
Construction	4.2%	5.6%	8.5%	8.8%	8.9%
Services	86.6%	84.8%	81.2%	81.3%	81.3%

Source: Values of 2015 based on national accounts from Cyprus Statistical Service (last updated on 14 October 2016). GDP forecast based on projections of the Ministry of Finance of Cyprus in October 2016. Future sectoral GDP shares are assumptions of the study team.

FIGURE 1

Historical evolution (1995-2015) and assumed future development of sectoral GDP shares in Cyprus



The energy system of Cyprus is almost entirely dependent on oil products, hence retail fuel prices – in the absence of changes on energy taxes – will change in the future in line with the evolution of international crude oil prices. The latter are assumed to develop in line with the central scenario ("New Policies Scenario") of the International Energy Agency's World Energy Outlook 2016, which was published in November 2016 (IEA, 2016). According to the IEA's forecast, crude oil price is expected to rebound from its current quite low levels of $40-50 per barrel, and reach $79 per barrel in 2020 (at constant prices of year 2015), with a further increasing trend in later years, to $111 in 2030 and $124 in 2040. For the purpose of this study we extrapolated IEA's trend up to 2050, which leads to a crude oil price of $137 per barrel (at 2015 prices). We assumed for the entire forecast period that the exchange rate between the euro and the US dollar will remain constant at 1.11 USD/EUR, which is the average exchange rate of year 2015 according to Eurostat.

3.2. Scenarios considered

Three alternative scenarios were developed in the frame of this study, with their main differences lying in the magnitude and intensity of energy efficiency related policies and measures. Macroeconomic and energy price developments described in the previous Section were kept constant in all scenarios.

- The Reference Scenario includes all relevant policies and measures that have already been implemented or are officially planned to be adopted by the government of Cyprus in the near future. The timeline of implementation of these measures (and the energy savings they will bring about) is consistent with plans of national energy authorities. Policies considered in the Reference Scenario comprise:
    - The implementation of the Energy Labelling Directive (2010/30/EC).
    - The implementation of the Energy Efficiency Directive (2012/27/EU) and more specifically:
    - Implementation of measures for the achievement of the obligatory target for energy savings at end use level by 2020, as set by article 7 of the Directive (including, amongst others, the

continuation up to 2020 of financial incentives for renovating households). No additional post-2020 measures are assumed.

- Renovations and other measures of upgrading energy efficiency in buildings owned and used by the central government. Such measures are planned to be implemented until 2020 but essentially discontinue after 2020 in this Scenario.
- Energy efficiency requirements on purchasing by public bodies
- Energy efficiency measures in street lighting
- Obligation for energy audits for non-SMEs
- Energy efficiency information and education measures.

- The implementation of the Energy Buildings Directive (2010/31/EC) and more specifically:

  - Regular inspections of central heating systems with boiler and air-conditioning systems in large buildings.

  - The implementation of new, more stringent minimum energy performance requirements by 2017 as an intermediate step towards NZEB.

  - Requirements in energy performance, operation, adjustment and control of technical building systems installed in existing buildings.

  - The requirement to issue energy performance certificates for sale and rent of buildings and apartments.

- Training of industry engineers and energy managers, and some modest industrial investments in automations or replacement of electric motors or compressed-air systems with more energy efficient ones.

➢ The Maximum Technical Potential Scenario, which was based on the findings of the bottom-up analysis with regard to the maximum theoretical energy saving potential in Cyprus, as described in Section 2 of this paper, after adapting them to the official energy statistics of year 2015. It should be emphasised that this scenario should not be approached as a policy scenario, since it goes far beyond the possibly available budget and the market capability to implement all these measures. On the contrary this scenario should serve merely as an indicator of the existing maximum potential.

- The Realistic Scenario, which was based on the findings of the bottom-up analysis with regard to the economically viable potential as described in Section 2 of this paper, after adapting them to the official energy statistics of year 2015.

3.3. Results

Figures 2 to 8 present a comparison of the projected evolution of final energy demand and final energy intensity in the main economic sectors of Cyprus. What follows is an outline of the main findings of this comparison.

In aggregate terms, a strong decoupling between energy consumption and economic output is foreseen throughout the forecast period. Overall, compared to the evolution of the Reference Scenario, the Maximum Technical Potential Scenario foresees energy savings in the household sector that may reach 36% by 2030 and almost 55% by 2050. In the services sector, the corresponding savings are 32% in 2030 and 57% in 2050, whereas in industry they reach 20% by 2030 and 21.5% by 2050. Potential savings are markedly lower in agriculture as well as in road transport, where no significant behavioural or infrastructure changes have been assumed which might allow a better organisation of freight logistics, or an increased use of public transport modes.

Following a different trajectory, the Realistic Scenario foresees a small or modest improvement in the intensity of energy use. Compared to the Reference Scenario, and in accordance with the assumptions explained in the previous Sections, modest energy savings are projected in households (5.3% in 2030 and almost 17% in 2050), whereas the corresponding savings are somewhat higher in the service sector up to 2030 (around 6%) and increase gradually afterwards to reach 24% by 2050. Industrial energy savings are even lower – 3.3% by 2030 and 7% by 2050, focusing mainly on reduction in the consumption of electricity due to investments in automations and more efficient motors, compressed air systems and lighting.

Finally, agricultural energy use is projected to evolve smoothly, without substantial improvements in energy intensity in the Reference Scenario. The Maximum Technical Potential Scenario foresees energy savings of 11% and 23% in 2030 and 2050 respectively due to the use of more efficient equipment and machinery, whereas the Realistic Scenario projections are for energy savings of just over 2% in 2030 and 11% in 2050.

As regards the evolution of fuel shares the main findings are the following:

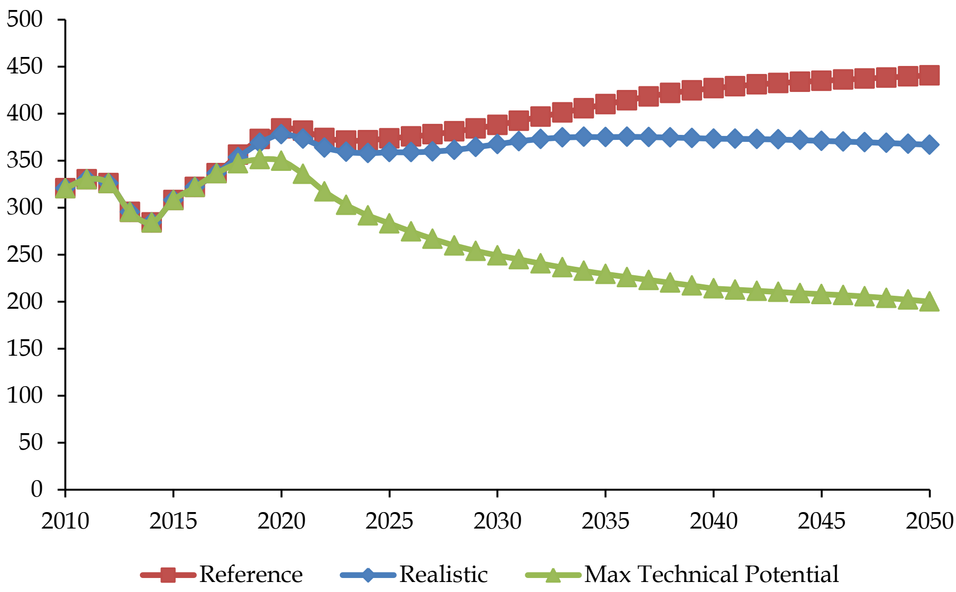
The Maximum Technical Potential Scenario, in line with what was outlined in the definition of its assumptions, projects that the shares of gas oil and biomass gradually diminish in the household and service sector, whereas electricity and LPG gain shares, although the use of these energy forms declines in absolute terms because of the strong implementation of energy efficient buildings, equipment and appliances. As a result, the only fossil fuel to be used in these two sectors by 2050 is projected to be LPG; all other energy needs of buildings and processes are projected to be covered by electricity and solar-generated heat – plus a very small fraction of biomass in the service sector. The share of electricity in total energy consumption declines between today and 2050, especially in the service sector; this is a result of the improvement in the energy efficiency of electric heating (heat pumps), lighting and appliances, which is expected to be considerably stronger than the improvements in LPG-fired boilers used for heating and hot water production. CNG-powered and electric vehicles are forecast to penetrate road transport, accounting for up to 20% of the sector's final energy demand in 2050.

On the other hand, in the Realistic Scenario the evolution of fuel shares is similar to that of the Reference Scenario, with a somewhat faster decline in the importance of gas oil and biomass (in the household sector) and gas oil and light fuel oil (in the service sector). Only in transport can one observe a significant difference between Reference and Realistic scenarios, due to the considerable penetration of CNG-powered vehicles in the latter scenario – which dominates among alternative fuels, thus leaving fewer shares in electric vehicles.

FIGURE 2

Final energy demand and energy intensity in households according to the three scenarios of this study

Final Energy Demand in Cyprus (ktoe) - Households



Final Energy Demand in Households per Unit of GDP (toe/MEuro'2005)

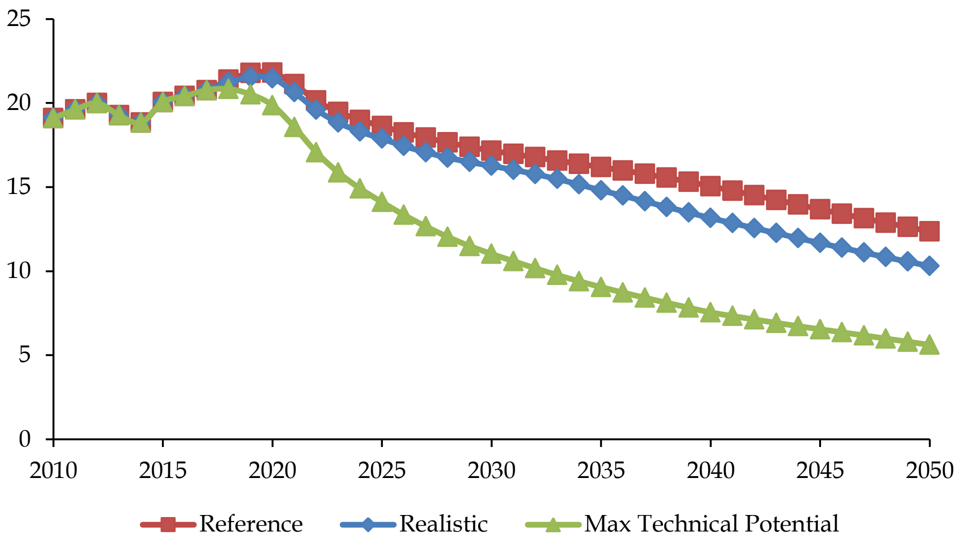
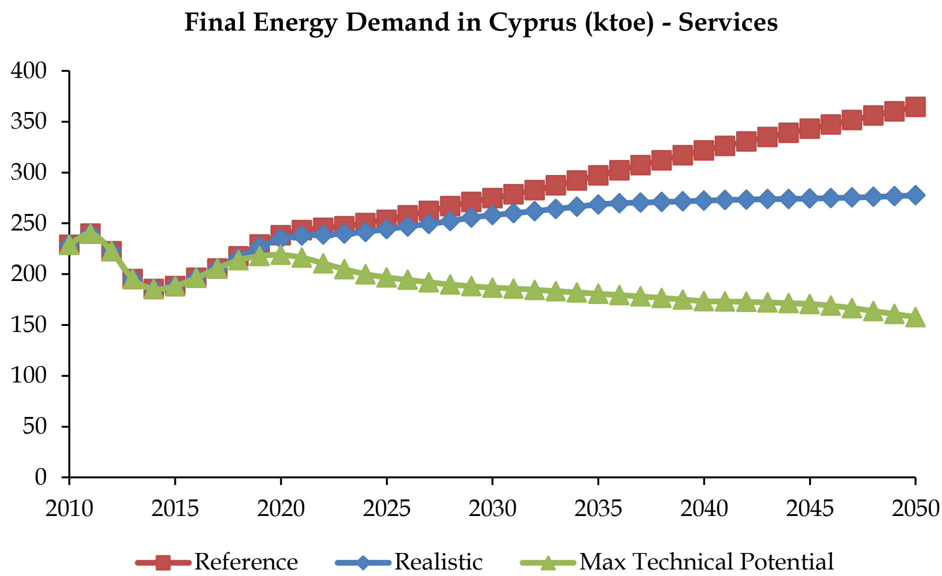


FIGURE 3

Final energy demand and energy intensity in services according to the three scenarios of this study



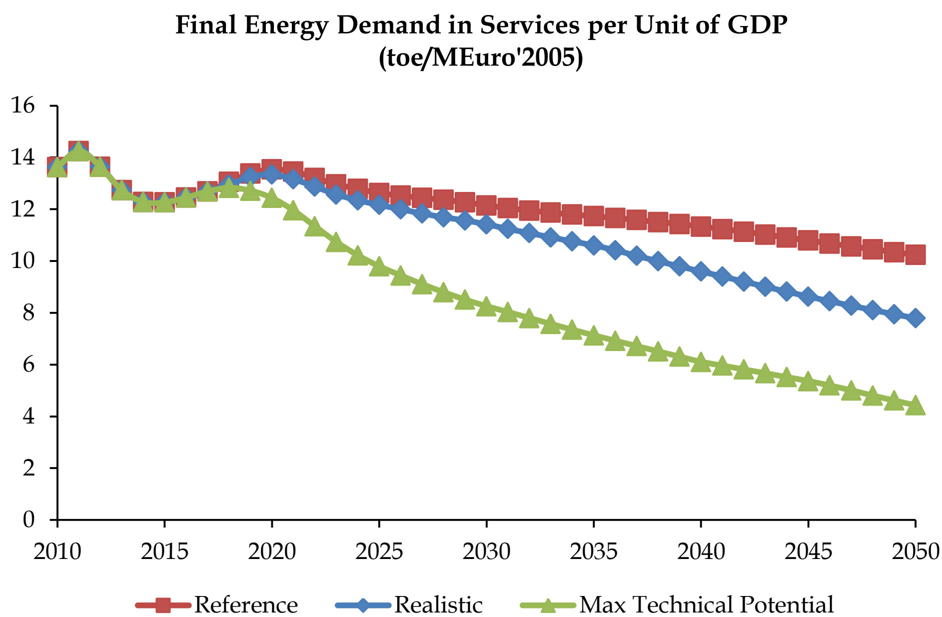


FIGURE 4

Final energy demand and energy intensity in industry according to the three scenarios of this study

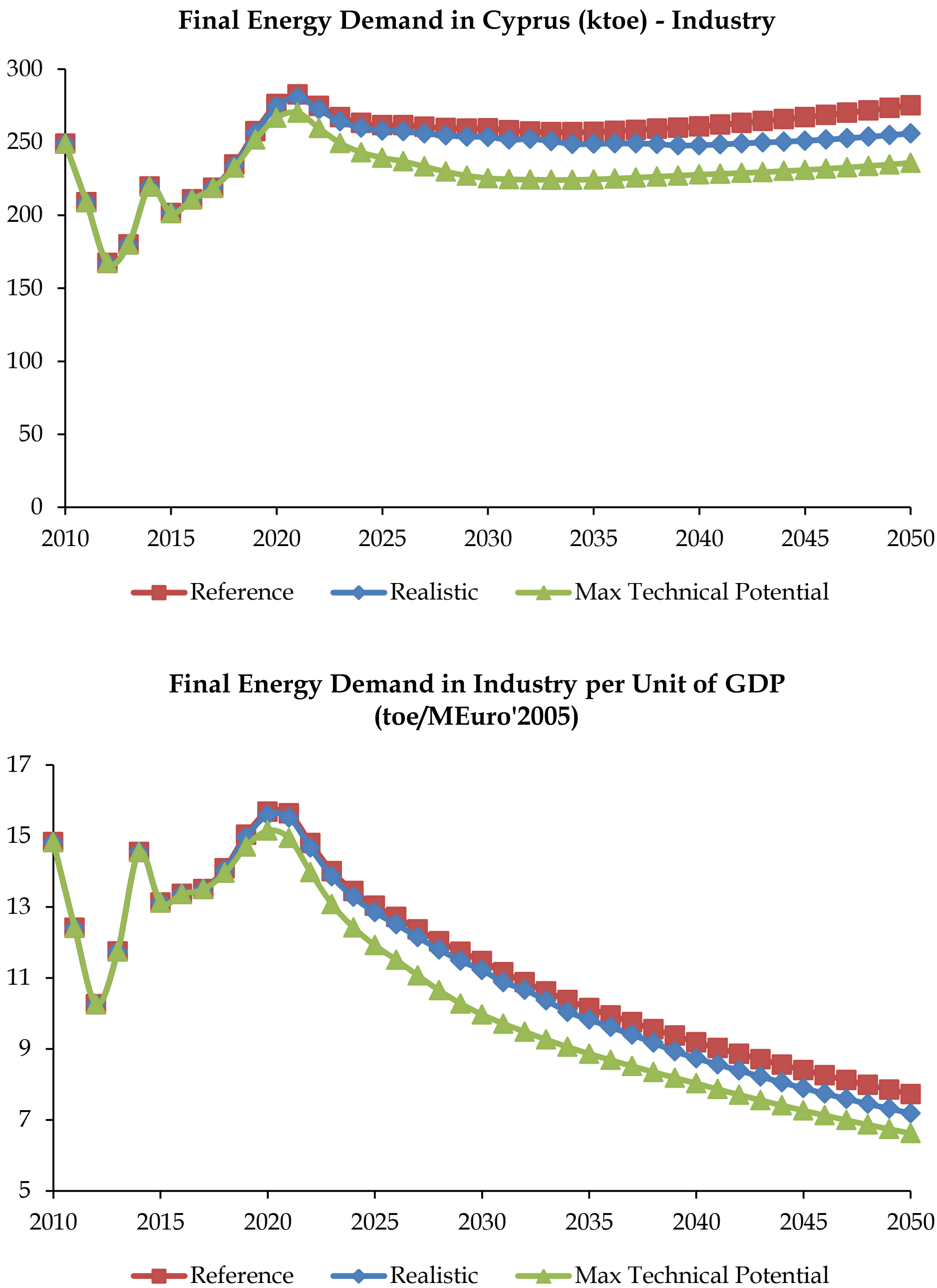
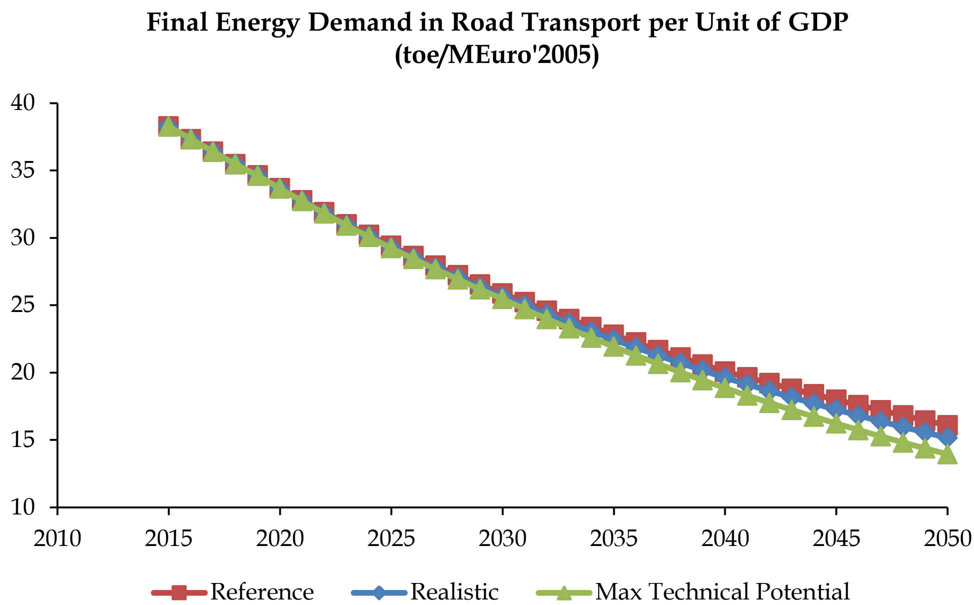


FIGURE 5

Final energy demand and energy intensity in road transport according to the three scenarios of this study



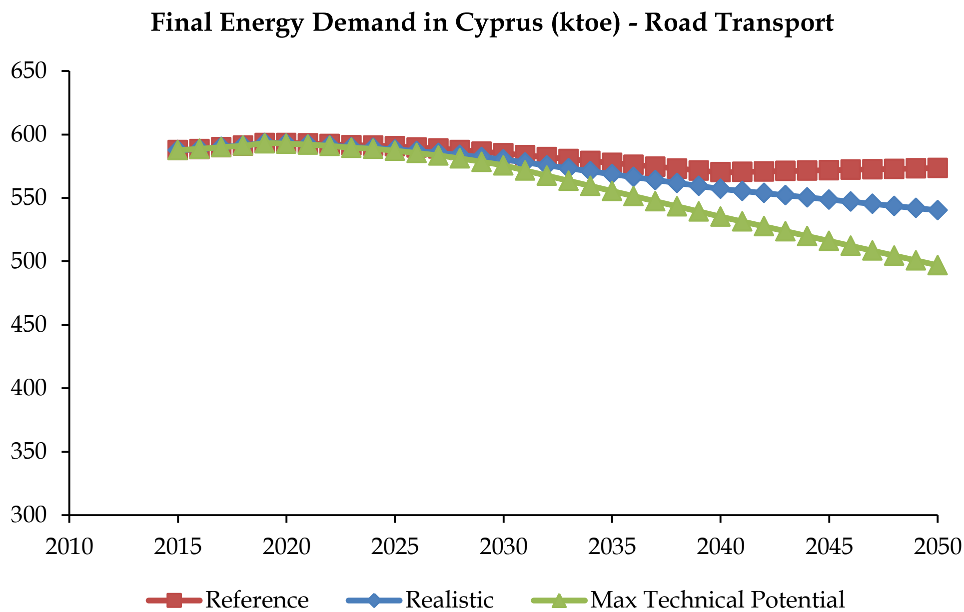
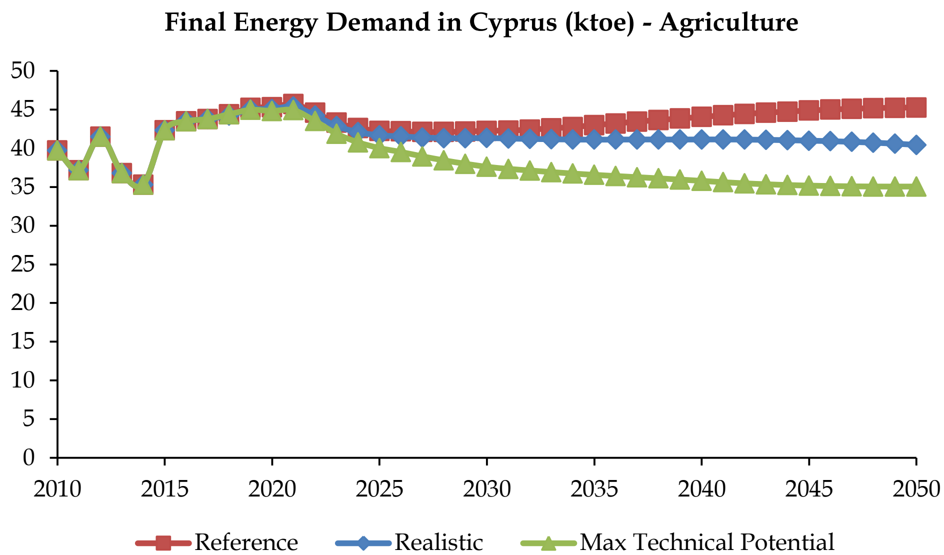


FIGURE 6

Final energy demand and energy intensity in agriculture according to the three scenarios of this study



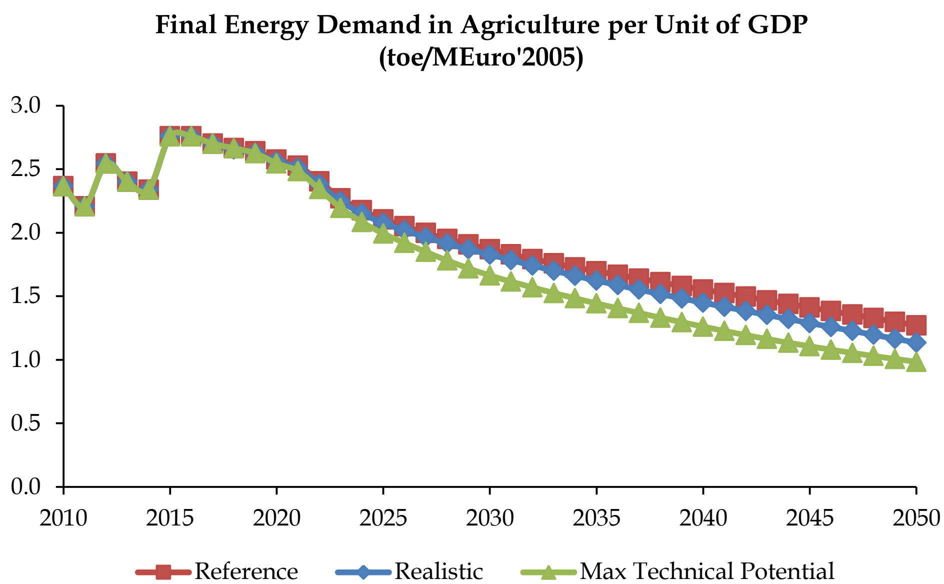
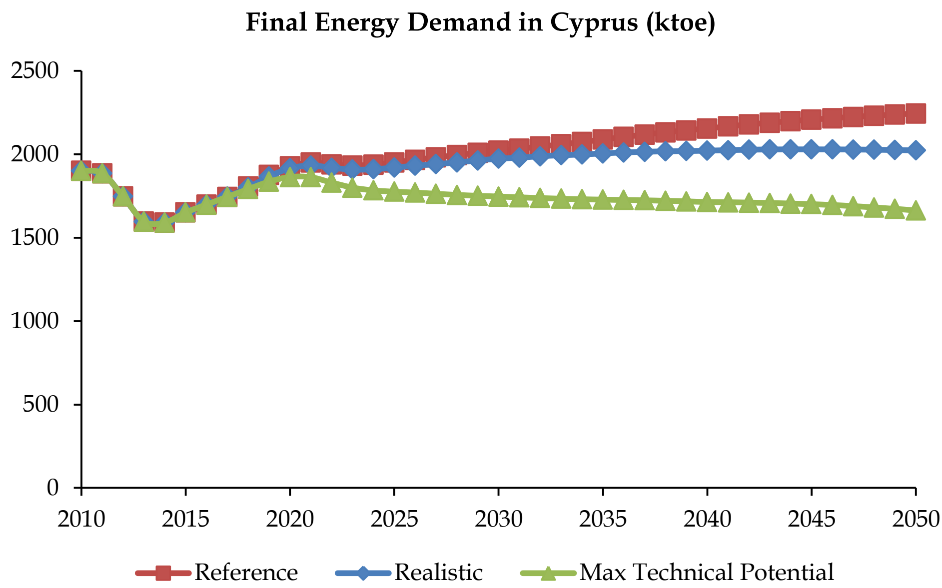


FIGURE 7

Aggregate final energy demand and energy intensity in Cyprus up to 2050, according to the three scenarios of this study



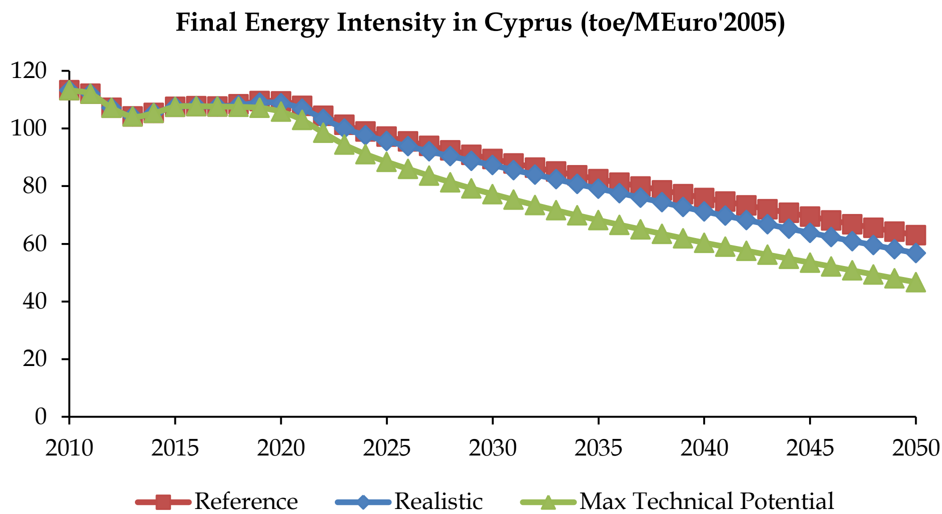
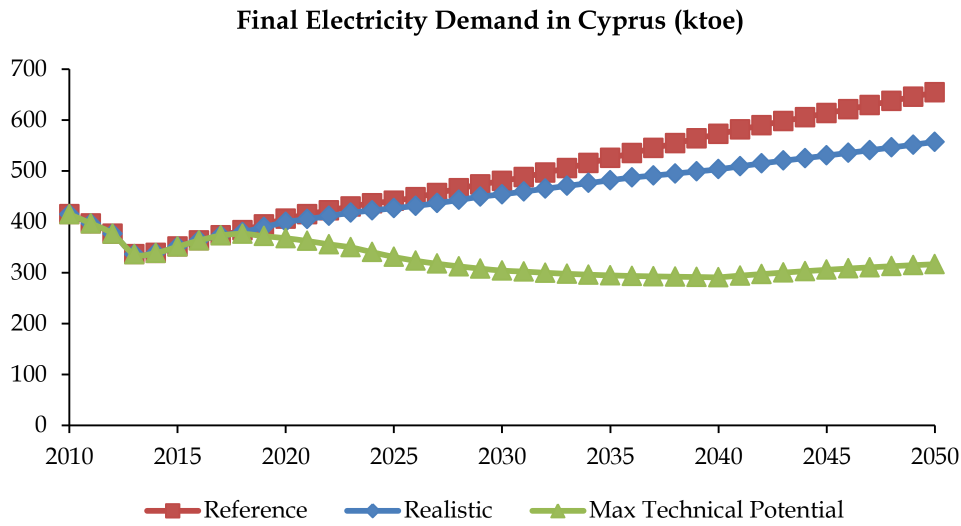
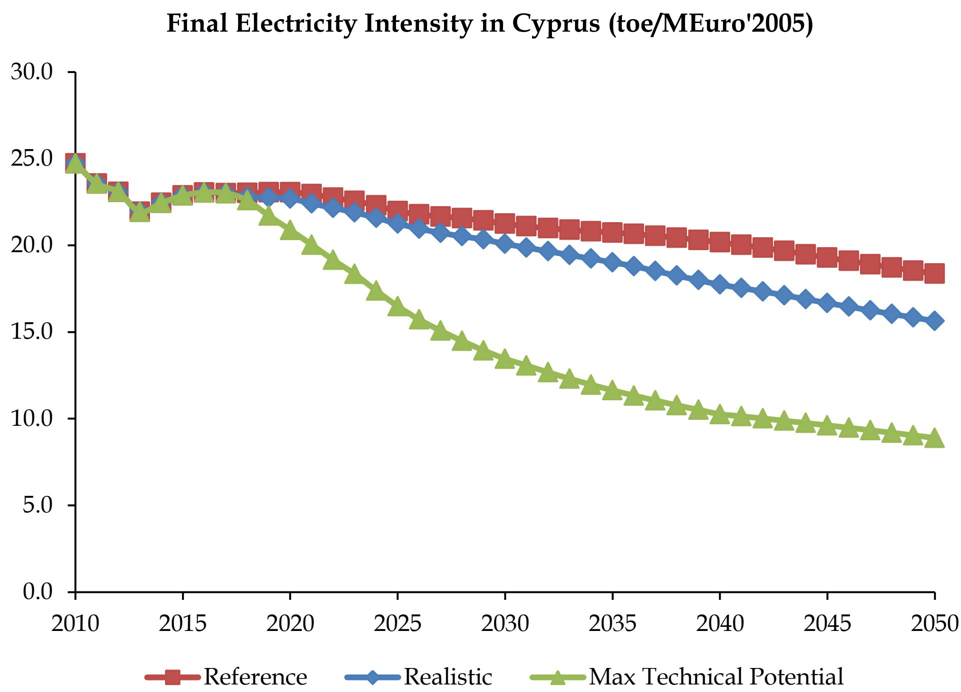


FIGURE 8

Aggregate final electricity demand and electricity intensity in Cyprus up to 2050, according to the three scenarios of this study





4. Discussion and Conclusions

The results shown in the previous Section highlight that Cyprus could substantially increase the energy productivity of its economy, especially in the household and service sectors which account for a large part (30%) of the country's final energy needs and for the major portion of electricity consumption (around 80% in 2015). However, this requires a very substantial mobilisation of financial resources, at a rate that has not been observed in the past. Based on cost data available to the authors from the market of Cyprus, the average intervention cost of a deep renovation per average dwelling (i.e. weighted average after considering single family, two-family and multi-family buildings) is estimated at about 65,000 Euros. Assuming, as in the 'maximum technical potential' scenario, that it is technically realistic to consider that 90-95% of all buildings can be renovated (since some buildings are very old and require very substantial re-construction to become nZEB), this leads to a cost of around 14 billion Euros. If all these renovations are to be implemented gradually up to the year 2040, with a residential building stock of about 430,000, this would require annual deep renovations of about 18,600 residential buildings for each year from 2018 to 2040, at a cost of 648 million Euros/year. Similarly, deep renovations in buildings of the service sector would require expenditures of the order of 9 billion Euros in total, leading to annual renovations of about 3,500 commercial buildings for each year from 2018 to 2040, at a cost of 409 million Euros/year. This means that an annual renovation rate of 4.3% of all buildings would be necessary, at a cost of more than one billion Euros per year – accounting for about 5% of the country's annual GDP. These figures are only theoretically feasible; real-world economic constraints render such a consideration implausible.

On the other hand, the 'realistic scenario' assumes energy refurbishments for around 1% of the existing number of buildings every year from 2018 to 2030, which is a feasible objective. As shown in detail by Vougiouklakis et al. (2017), the proposed level and allocation of energy efficiency investments in buildings according to the 'realistic scenario' will require expenditures amounting to 870 million EUR until 2030, with a rather balanced budget distribution – 60% for residential buildings and 40% for service sector buildings. These annual expenditures represent 0.33% of the annual GDP of Cyprus over the 2018-2030 period, which is considered realistic. Thus, the 'realistic scenario' shows that Cyprus can meet its 2020 energy efficiency commitments with only a slight further tightening of relevant policies. However, the 2030 objective of reducing non-ETS emissions by 23%, as foreseen in the current EU 'Effort Sharing' proposal, is not possible without significant energy refurbishments (including a substantial number of deep renovations) in all types of buildings.

Furthermore, the road transport sector (which has not been the focus of this paper) is an important impediment to the decarbonisation attempts of Cyprus. Without a drastic implementation of policies that can reduce the energy intensity of motor vehicles and enable the penetration of low- or zero-carbon fuels, it is not possible for Cyprus to meet the EU's long-term decarbonisation target of 80-95% reduction in greenhouse gas emissions by 2050. More analysis on road transport was provided by a separate study (Heidt et al., 2017)

To conclude, the analysis presented in this paper shows that Cyprus cannot continue along a 'business-as-usual' path in improving the patterns of its energy system if it is to achieve the broader EU decarbonisation goals for year 2030 and beyond. Apart from reducing the carbon footprint of power generation, it is imperative to improve the energy efficiency of both buildings and road transport. Substantial funds should be allocated for this purpose. An intensification of smart financial tools to enable energy efficiency investments, coupled with a green tax reform, that will gradually implement a carbon tax on non-ETS sectors while reducing at the same time the tax burden of labour as a compensation to consumers and firms, can ensure a smooth transition to a low-carbon economy.

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