INSTITUTE FOR EUROPEAN ENERGY AND CLIMATE POLICY

Study – economic viability of subsidizing fossil gas boilers to households in Corinth and Tripoli in Greece

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Executive Summary

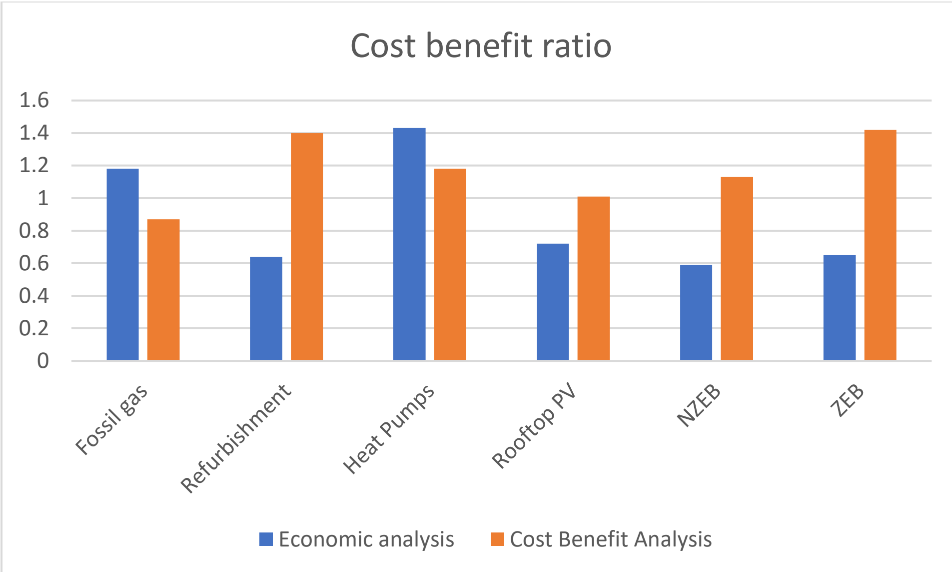
The purpose of this study is to examine through scenarios, the implementation of the Energy Efficiency First principle in practice, when comparing supply to demand side energy investments in the regions of Korinthia and Tripoli in Greece, which are being connected with new gas grid. This study assessed the investment costs for energy efficiency refurbishments with Renewable Energy Support (RES) in comparison to subsidizing the connections with gas boilers, which are financed under the public budget.

The scenarios evaluated are the energy upgrade of the building shell (Scenario 1), the installation of heat pumps (Scenario 2), the installation of photovoltaic systems with net metering (Scenario 3), the promotion of net zero energy consumption buildings (Scenario 4) and the promotion of buildings of zero energy consumption (Scenario 5) with photovoltaic systems. These scenarios were contrasted with the incumbent situation, where a further installation for gas boilers is expected (Scenario 0). The evaluation is carried out with the assumption that a large share of the available budget for the subsidization of gas boiler connections (12 m € estimated for these regions) could be allocated to finance energy efficiency upgrades and RES for net metering.

The Energy Efficiency First principle was applied through the assessment of the economic and social efficiency for each scenario separately, through economic and cost-benefit analysis, where the Multiple Benefits of energy efficiency were considered. The decision upon providing public support is when an investment might not seem economically efficient in the economic analysis, but is effective socially, then based on the social welfare maximization it should be financed through support mechanisms.

The results of the study show that heat pumps are characterized by the highest economic efficiency while scenarios with NZEB and ZEB are characterized by higher social efficiency. The energy efficiency upgrades, the introduction of photovoltaic systems for net metering and the ZEB and NZEB present negative economic efficiency, however, their social efficiency justifies the provision of public support. In contrast, fossil gas expansion is simultaneously characterized by low economic and social efficiency, which results in their implementation not being preferable compared to the other scenarios.

In brief, the most socially profitable solutions are the renovation of the building stock while promoting rooftop photovoltaics. Renovation is in all cases considered more economically viable than public spending on gas networks. Therefore, grants for the renovation of the building shell and zero-consumption buildings should be prioritized instead of subsidizing gas boiler connections, coupled with the evaluation of alternative means for financing the required investments. These measures should be put at the heart of municipalities through their contribution to energy subsidies upgrades of the most vulnerable (primarily) households, instead of the non-economical connection of homes to fossil gas.



The main conclusion of the study is that the Municipalities of Corinth and Tripoli could request a review of the €12 million for fossil gas connections in homes and instead use these amounts to

1. Energy upgrades of low-income households' homes (at least 700 households could structurally solve energy poverty)
2. Co-financing of photovoltaic roofs for 2,000 beneficiaries (low income) with offsetting in order to reduce their energy needs
3. Co-financing of existing programmes to replace oil boilers with heat pumps (with a minimum target of 1,600 households)
4. Co-financing for deep renovation of (low income) housing targeting 400-500 contractors.

The advantages of these policies will be many times greater compared to fossil gas, given the new European restrictions placed on the use of gas from 2026.

1. Introduction

The EU is going through a period where climate change and environmental degradation are increasing uncertainty about the future and threatening its very existence. The Green Deal is one of the ways to address these challenges, with Member States committing to making the European Union climate-neutral by 2050. The past decade is a milestone in the process of achieving this goal, with a commitment to reduce greenhouse gas (GHG) emissions by at least 55% by 2030 and efforts to achieve this target must be many times greater than the current ones.

Reducing GHG emissions requires both increasing the use of renewable energy sources (RES) and improving energy efficiency. Buildings account for more than 40% of final energy consumption and at least 36% of energy-related GHG emissions.[1] This creates a need for renewable and less polluting energy

[1] https://ec.europa.eu/info/news/focus-energy-efficiency-buildings-2020-lut-17_en

systems for domestic and public buildings. This will result not only in reducing GHG emissions but also in promoting energy savings, tackling energy poverty, improving health and well-being and creating new opportunities for growth and jobs.

Greece has a low energy performance of the building stock, due to the age and lack of renovation strategies in previous years. To reach the EU targets and the Long Term Renovation Strategy, it is therefore necessary to promote measures for the energy upgrade of buildings at a faster pace.

In the context of the National Energy and Climate Plan (NECP 2019) (but also in the draft new NECP in 2023), improving energy efficiency in all final consumption sectors is a major challenge and an optimal combination of both regulatory and legislative interventions and financial instruments is foreseen.

As part of the European Commission's Fit-for-55 legislative package[2], targeted policy measures have been included in the proposals for revision of the Energy Efficiency Directive, the Renewable Energy Directive, the [3]Emissions Trading Directive[4], the new Effort Sharing Regulation[5][6] and the Energy Performance Building Directive[7] for new policies to improve the energy performance of buildings more effectively.

More specifically, Minimum Energy Performance Standards (MEPS)[8] target existing buildings, with the aim of encouraging renovations that "meet a minimum performance standard by a given date or at a selected trigger point in the building's lifecycle." The Energy Performance of Buildings Directive provides for the renovation of the worst performing buildings, i.e. buildings belonging to categories G or F of Energy Performance Certificates. **It is noted that energy class G ranks among the 15% of the worst performing buildings in each country,** while the rest of the buildings in the country are distributed proportionally among the other categories between G and A corresponding to zero-emission buildings. **The impact assessment study of the Energy Performance of Buildings Directive concluded that these standards can support the achievement of final energy savings and reduction of energy costs, as well as enhance construction activity**[9].

The European Commission has also decided on a new greenhouse gas emissions trading scheme[10] (ETS2), which will set a floating price cap on CO2 emissions from the buildings and road transport sectors and will come into force from 2026 based on ongoing negotiations. This system is also cap-and-trade, like the existing emissions trading scheme, and does not directly concern buildings or cars but suppliers of directly

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[2] https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/
[3] https://data.consilium.europa.eu/doc/document/ST-10745-2021-REV-2/en/pdf
[4] https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/
[5] https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/revision-phase-4-2021-2030_en
[6] https://data.consilium.europa.eu/doc/document/ST-10867-2021-INIT/en/pdf
[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0802&qid=1641802763889
[8] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0802&qid=1641802763889
[9] https://eur-lex.europa.eu/resource.html?uri=cellar:daf643a4-5da2-11ec-9c6c-01aa75ed71a1.0001.02/DOC_1&format=PDF
[10] European Commission, Directorate-General for Climate Action, *Possible extension of the EU Emissions Trading System (ETS) to cover emissions from the use of fossil fuels in particular in the road transport and the buildings sector : final report*, 2021, **https://data.europa.eu/doi/10.2834/779201**

distributed fuels. These areas will continue to be covered by the Effort Sharing Regulation[11], which means that national policies will continue to contribute to reducing emissions in the buildings and transport sectors. Carbon pricing may develop a new market for innovative solutions, but depends on energy price flexibility (and flexibility in demand) in each country as well as consumers' response to price increases. However, the impact of the new emissions trading system on these sectors could create higher costs for households, which would increase the risk of energy poverty.

An additional measure to decarbonise heating and cooling in residential buildings foresees phasing out the installation or sale of new fossil fuel burners by 2030. There is, however, the potential to trap poor households in the use of outdated technologies, as heat pumps are more expensive to invest upfront, although their operating costs are likely to be lower than those of fossil fuel burners due to higher efficiency. The only way to ensure that this phenomenon is mitigated is to put in place a stable and clear policy framework, which can allow energy-poor households to switch to renewable heating systems.

Finally, all the above legislative developments are also affected by the past energy crisis, which has highlighted the need to implement long-term measures both to protect consumers from future energy price increases and to achieve ambitious energy and climate targets.

The 2019 National Energy and Climate Plan (NECP),[12] provided for the direct use of fossil gas in final energy consumption sectors as a transitional fuel for the energy transition. To this end, it envisaged the implementation of investments of € 1.5 billion for network expansion and gas storage projects by 2030. Similarly, in the pipelines under construction in various areas (such as Tripoli and Corinth) it was decided to grant a subsidy for the replacement of oil heating systems with fossil gas in the new networks. Public funding is implemented through two calls through the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (EPAnEK) concerning the subsidy of both households and public/municipal bodies that want to replace the existing heating system with a fossil gas system.

The first call is addressed to Municipalities and Public Bodies for the municipal/public buildings they own and has a budget of € 1,000,000, while the second with a budget of € 12 million. It is addressed to the NSRF Staff Structure of the Ministry of Environment and Energy in order to benefit households under energy poverty in Tripoli and Corinth.

This public aid must be justified in terms of economic and social viability, all the more so now that it has been universally understood that the source of the energy crisis was the gas itself and the prices that followed. The energy crisis proved that this policy carries risks, so it is imperative to evaluate alternatives that will lead to a long-term response to the phenomenon. This study attempts to assess the economic and social efficiency of interventions promoting RES and energy efficiency in order to replace the future use of fossil gas in the domestic sector. These results originate from economic and cost-benefit analysis that assess the economic performance of the examined scenarios with the maximization of social welfare. The following scenarios are considered:

1. Scenario 1: Energy upgrade of the building envelope
2. Scenario 2: Installation of heat pumps

[11] https://data.consilium.europa.eu/doc/document/ST-10867-2021-INIT/en/pdf
[12] https://energy.ec.europa.eu/system/files/2020-01/el_final_necp_main_el_0.pdf

3. Scenario 3: Installation of rooftop photovoltaic systems (PV)
4. Scenario 4: Promoting nearly zero-energy buildings (NZEB)
5. Scenario 5: Promotion of zero-energy buildings (ZEB)

In addition, the economic and social profitability of the baseline scenario is assessed that subsidizes the replacement of oil heating systems with fossil gas in the cities of Tripoli and Corinth in Peloponnese where a new gas grid is being built (Scenario 0).

All scenarios are assessed under the assumption that the largest part of the available budget for subsidizing the connection of fossil gas to homes (€ 12 million) will be used to finance the RES and energy efficiency interventions. In order to present the potential effects of the energy price crisis, the study concludes with a sensitivity analysis taking into account high fuel prices. It is worthy to note that for this study the energy prices of 2021 were used as weighted prices for the 15-year period, (as the current increased prices could have stable increases (following the proposals of the European Commission). However, it is understandable that the results with current prices would highlight much more strongly the uneconomic viability of fossil gas as a more expensive fuel, while also accelerating the payback time of investments in energy upgrading of buildings.

2. Methodology

The scenarios are valued follows the logic of benchmarking them through financial indicators, such as Net Present Value (NPV) and Internal Rate of Return (IRR). Each scenario considers the necessary investment in the specific technology concerned.

Economic Analysis: The financial analysis determines the direct economic impact of the investment, concerns exclusively the private investor and the analysis is based on market prices.

Cost-benefit analysis: The cost-benefit analysis identifies the indirect economic, as well as the environmental and social impacts of the investment, while it concerns the whole society and the analysis takes into account market prices and external economies caused by the investment.

As regards the indicators of the analysis on the basis of which the comparison is made

Net Present Value (NPV): Expresses the net value (benefit or cost) resulting from discounting at present the annual net cash flows (i.e. the cash situation) over the life of an investment. If the NPV is positive (>0) the investment is approved, otherwise it is rejected.

Internal Rate of Return (IRR): It expresses the discount rate at which the NPV is zeroed and thus the profitability of the investment is assessed by comparing the EBD with the discount rate. If the IRR is higher than the discount rate, the investment is approved, otherwise it is rejected.

The basis of the scenario comparison in the study is whether an investment in a technology is economically (Economic Analysis) and/or socially (Cost/Benefit Analysis) efficient. Thus, if an investment in economic terms, based on indicators, is not efficient, but socially beneficial and efficient, then the state should help to implement the investment with the appropriate policies and funding. Conversely, if an investment is not socially efficient, then the state should not finance it regardless of whether it is cost-effective or not.

3. Scenario analysis

The assumptions and outcomes of the scenarios considered are presented separately in the following sections.

Scenario 1: Energy upgrade of the building envelope

Scenario 1 examined the shifting of the available budget from the expansion of the fossil gas network to insulate the external walls and replace existing frames with new, more energy-efficient ones in residential buildings. The benefit for the households is the reduction of energy costs due to reduced energy demand for space heating and cooling.

In addition, it was considered that the benefited households will not need to install a new fossil gas boiler given the reduced energy demand for space heating by maintaining the existing heating system, thus reducing the required investment costs.

For the calculation of the economic benefit, the weighted average cost of purchasing energy products for space heating was calculated based on the data submitted to EUROSTAT for 2021 regarding the final energy consumption for residential heating.

Economic analysis

The assumptions of the economic analysis are presented in Table 1, as reflected in the NECP (2019) and in the recent official announcements for the subsidy to connect fossil gas boilers.

Table 1: Assumptions for the economic analysis in Scenario 1.

Size	Value	Unit
Available budget for gas network expansion	12,000,000	€
Unitary Investment Cost	18,000[13]	€
Avoided cost from installing fossil gas boiler	4,000	€
Number of affected households	667	Nr of households
Unitary energy consumption for space cooling	580[14]	kWh
Unitary energy consumption for space heating	6,500	kWh
Fossil gas boiler efficiency	95%	%
Oil boiler efficiency	80%	%

[13] Average cost of technologies from Energy Saving programs

[14] All unit household consumption is derived from Eurostat - disaggregated final energy consumption in households

Size	Value	Unit
Energy saving rate for space cooling	60%[15]	%
Energy saving rate for space heating	60%	%
Energy saving for space cooling	348	kWh
Energy saving for space heating	3,900	kWh
Electricity price	0.18	€/kWh
Weighted fuel price for space heating	0.09	€/kWh
Fossil gas price	0.07	€/kWh
Operational and maintenance cost – Baseline scenario	0	€
Operational and maintenance cost – Alternative scenario	0	€
Remaining value[16]	10%	% investment cost
Interest rate	3%	%

The results of the economic analysis highlight the particularly low cost-effectiveness of Scenario 1 – energy efficiency upgrades (Table 2), making it imperative to provide a subsidy to the households concerned. The logic is that since, according to the economic analysis the investment is not profitable, but it is socially beneficial, it can be justified to finance the cost of the investment to achieve the maximization of social welfare.

Table 2: Economic analysis results in Scenario 1.

NPV	-3,925,098 €
IRR	-1%
Cost Benefit Ratio	0.64

Cost-benefit analysis

For the elaboration of the cost-benefit analysis, the methodological approach developed in the framework of the European project PRODESA was applied[17].

[15] Balaras et al., 2007. European residential buildings and empirical assessment of the Hellenic building stock, energy consumption, emissions and potential energy savings. Building and Environment 42, 1298–131
[16] Because energy upgrades are longer lasting than other measures, we leave some residual value
[17] **Source:** PRODESA, 2021. Economic evaluation of the energy efficiency projects, Deliverable D2.6.

The following external costs and benefits were included in the assessment of this scenario in addition to the costs and benefits, which are quantified in the context of the economic analysis:

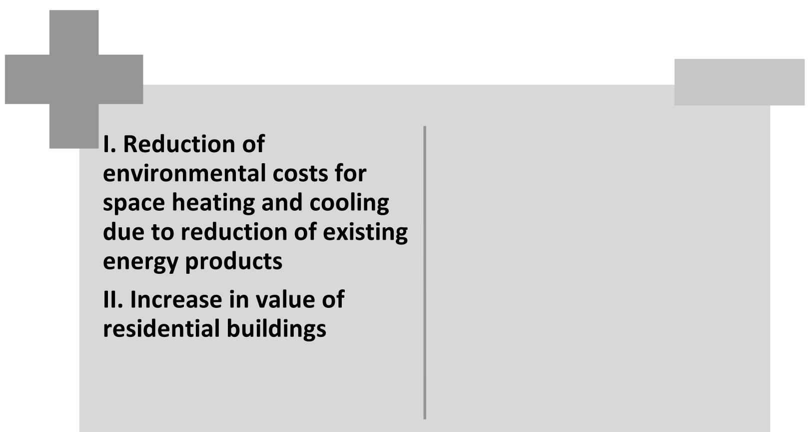
Environmental costs from the operation of the examinees/technologies

The external cost unit values used concern both the impacts on human health, agricultural production and monuments from all primary and secondary pollutants, as well as the effects of climate change and the depletion of natural resources. More specifically, the unit cost for heat pump for space cooling was considered equal to €23.5/MWh, while the weighted average external cost of energy products for space heating was estimated at €23.4/MWh based on data submitted to EUROSTAT for 2021.

Increase in the value of residential buildings due to energy upgrade.

The increase in the value of residential buildings was determined by calculating the quotient of cost savings from energy saving and RES interventions with a capital recovery factor, which was considered equal to 3%. This component shall be taken into account in the year of implementation of the investment concerned.

The following figure summarises the external costs and benefits components considered in this scenario.



The assumptions of the economic analysis were considered the same in the case of the cost-benefit analysis with the only difference that taxes and levies are deducted from the energy prices, because they are a cost for the individual but not for the national economy and society, as well as VAT from the cost of the investment. The results of the cost-benefit analysis (Table 3) confirm the high social efficiency of the intervention in question, justifying the provision of a grant to the households concerned.

Table 3: Results of cost-benefit analysis in Scenario 1.

NPV	2,407,822
IRR	10%
Cost Benefit Ratio	1.4

Indicatively, it is mentioned that the provision of a subsidy of 50% significantly improves the economic efficiency of the examined scenario, therefore the subsidy for the energy upgrade of households maximizes the social benefit at a low cost, and it is thus preferred over the equal expenditure for the extension of fossil gas pipelines.

Scenario 2: Installation of heat pumps

Scenario 2 examines the shifting of the available budget from the expansion of the fossil gas network to the installation of heat pumps in residential buildings. The benefit for households is the reduction of total energy costs due to the reduction of space heating costs.

In addition, it is considered that the benefited households will not need to install a new fossil gas boiler given the reduced energy demand for space heating by maintaining the existing heating system, thus reducing the required investment costs.

For the calculation of the economic benefit, the weighted average cost of purchasing energy products for space heating was calculated based on the data submitted to EUROSTAT for 2021 regarding the final energy consumption for residential heating.

Economic analysis

The assumptions for the economic analysis are presented in Table 4.

Table 4: Assumptions for the economic analysis in Scenario 2.

Size	Value	Unit
Available budget for gas network expansion	12,000,000	€
Unitary Investment Cost	6,000	€
Avoided cost from installing fossil gas boiler	4,000	€
Number of affected households	2,000	Nr. households
Unitary energy consumption for space cooling	580	kWh
Unitary energy consumption for space heating	6,500	kWh
Fossil gas boiler efficiency	95%	%
Oil boiler efficiency	80%	%
Heat pump efficiency	4.5	
Energy saving rate for space cooling	0%	%
Energy saving rate for space heating	0%	%
Energy saving for space cooling	0	kWh

Size	Value	Unit
Energy saving for space heating	0	kWh
Electricity price	0.18	€/kWh
Weighted fuel price for space heating	0.09	€/kWh
Fossil gas price	0.07	€/kWh
Operational and maintenance cost – Baseline scenario	0	€
Operational and maintenance cost – Alternative scenario	0	€
Remaining value	0%	% investment cost
Interest rate	3%	%

The operating and maintenance costs of heat pumps are considered to be offset by the incumbent costs of operating and maintaining the systems used to meet space heating needs.

The results of the economic analysis highlight the cost-effectiveness of the scenario with heat pumps (Table 5). Heat pumps in this case are considered a cost-effective measure that can operate on the market to some extent also in the absence of financing support.

Table 5: Economic analysis results in Scenario 2.

NPV	3,507,092 €
IRR	16%
Cost Benefit Ratio	1.43

Cost-benefit analysis

For the elaboration of the cost-benefit analysis, the methodological approach developed in the framework of the European project PRODESA was applied[18].

More specifically, the following external costs and benefits are used to assess this scenario in addition to the costs and benefits, which were quantified in the context of the economic analysis:

Environmental costs from the operation of the examinees/technologies

The external cost unit values used concern both the impacts on human health, agricultural production and monuments from all primary and secondary pollutants, as well as the effects of climate change and the depletion of natural resources. More specifically, the unit cost for the energy-efficient heat pump was

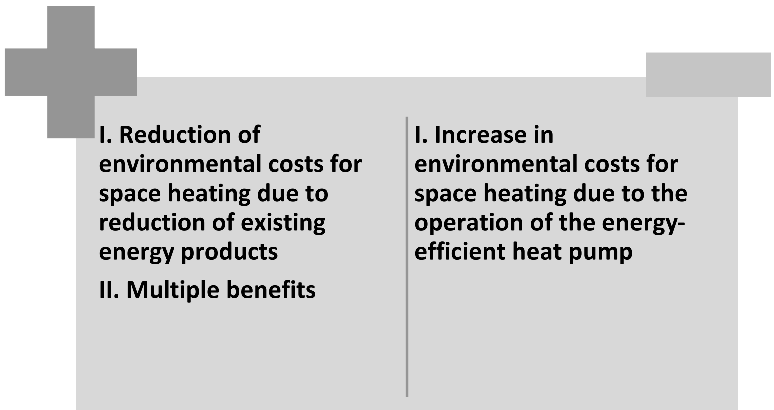
[18] **Source:** PRODESA, 2021. Economic evaluation of the energy efficiency projects, Deliverable D2.6.

considered equal to €14.2/MWh, while the weighted average external costs of energy products for space heating were estimated at €23.4/MWh based on data reported to EUROSTAT for 2019 (Table 1).

II. Multiple benefits from the implementation of energy saving interventions, such as improving comfort conditions in buildings and combating energy poverty, reducing morbidity and mortality cases, etc.

The calculation was carried out assuming that the multiple benefits are equal to 2%[19] of the cost savings resulting from the installation of the heat pump. This component is obtained on an annual basis after the implementation of the considered investment.

The following figure summarises the external costs and benefits components taken into account in the scenario considered.



The assumptions of the economic analysis were considered the same in the case of the cost-benefit analysis with the only difference being that taxes and charges were deducted from the prices of energy products, because they are a cost for the individual but not for the national economy and society, as well as VAT from the cost of investment.

The results of the cost-benefit analysis (Table 6) confirm the social efficiency of the intervention under consideration, justifying the use of policy measures for the installation of heat pumps in the households concerned. Given that heat pumps are highly cost-effective, policy measures could focus on facilitating loans and perhaps less on providing a grant.

Table 6: Results of cost-benefit analysis in Scenario 2.

NPV	1,444,218
IRR	10%
Cost Benefit Ratio	1.18

[19] European project PRODESA calculation

Scenario 3: Installation of photovoltaic systems

Scenario 3 examines the shifting of the available budget from the expansion of the fossil gas network to the installation of photovoltaic systems in residential buildings through a net metering scheme.

The benefit of households is the reduction of energy costs due to the electricity produced that is offset.

Economic analysis

The assumptions for the preparation of the economic analysis are presented in Table 7.

Table 7: Assumptions for the economic analysis in Scenario 3.

Size	Value	Unit
Available budget for gas network expansion	12,.000,000	€
Unitary investment cost – PV	7,200	€
Installed capacity – PV	3	kW
Installation cost – PV	2,400	€/kW
Use rate – PV	15%	%
Number of affected households	1,667	Nr of households
Electricity consumption	4,000	kWh
Electricity price	0.18	€/kWh
Electricity price – net metering	0.09	€/kWh
Operational and maintenance cost – Baseline scenario	0	€
Operational and maintenance cost – Alternative scenario	100	€
Remaining value	0%	% investment costs
Interest rate	3%	%

The results of the economic analysis highlight the reduced cost-effectiveness of the scenario under consideration (Table 8).

Table 8: Economic analysis results in Scenario 3.

NPV	-4,140,866
IRR	0%

Cost Benefit Ratio	0.72

Cost-benefit analysis

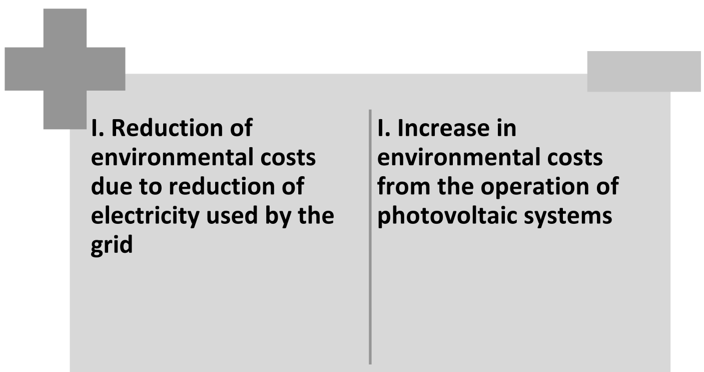
For the elaboration of the cost-benefit analysis, the methodological approach developed in the framework of the European project PRODESA was applied[20].

More specifically, the following external costs and benefits were used to assess this scenario in addition to the costs and benefits, which were quantified in the context of the economic analysis:

<u>Environmental costs from the operation of the examinees/technologies</u>

The external cost unit values used concern both the impacts on human health, agricultural production and cultural heritage monuments from all primary and secondary pollutants, as well as the impacts of climate change and the depletion of natural resources. More specifically, the unit cost for photovoltaic systems was considered equal to 14.1 €/MWh, while the corresponding price for the electricity used by the grid was obtained equal to 48.5 €/MWh.

The following figure summarises the external costs and benefits components taken into account in the scenario considered.



The assumptions of the economic analysis were considered the same in the case of the cost-benefit analysis with the only difference being that taxes and charges were deducted from the prices of energy products, because they are a cost for the individual but not for the national economy and society, as well as VAT from investment costs and operating and maintenance costs.

The results of the cost-benefit analysis (Table 9) confirm the social efficiency of the intervention under consideration, justifying the provision of targeted programmes to the households concerned. In contrast to Scenario 2 (heat pumps), the planned policies could focus on providing a grant specifically for low-income households) due to the low cost-effectiveness of photovoltaic systems on the roof.

Table 9: Results of cost-benefit analysis in Scenario 3.

NPV	256,827

[20] **Source:** PRODESA, 2021. Economic evaluation of the energy efficiency projects, Deliverable D2.6.

IRR	3%
Cost Benefit Ratio	1.02

Scenario 4: Promoting nearly zero-energy buildings

Scenario 4 examined the shift of the available budget for the expansion of the fossil gas network to promote nearly zero energy buildings. These buildings can be achieved through the combination of thermal insulation of external walls, the replacement of existing frames with new more energy efficient ones in residential buildings and the installation of a heat pump.

The benefit of households concerns the reduction of energy costs due to both the reduced energy demand for space heating and cooling, as well as the operation of the heat pump.

In addition, it was considered that the beneficiary households will not be required to install a new fossil gas boiler given the reduced energy demand for space heating by maintaining the existing heating system, thus reducing the required investment costs.

Economic analysis

The assumptions for the economic analysis are presented in Table 10.

Table 10: Assumptions for the economic analysis in Scenario 4.

Size	Value	Unit
Available budget for gas network expansion	12,000,000	€
Unitary Investment Cost -Wall Insulation	18,000	€
Unitary Investment Cost -Heat Pump	8,000	€
Avoided cost from installing fossil gas boiler	4,000	€
Number of affected households	462	Nr of households
Unitary energy consumption for space cooling	580	kWh
Unitary energy consumption for space heating	6,500	kWh
Fossil gas boiler efficiency	95%	%
Oil boiler efficiency	80%	%
Heat pump efficiency	4.5	
Energy saving rate for space cooling	60%	%
Energy saving rate for space heating	60%	%

Size	Value	Unit
Energy saving for space cooling	348	kWh
Energy saving for space heating	3,900	kWh
Electricity price	0.18	€/kWh
Weighted fuel price for space heating	0.09	€/kWh
Fossil gas price	0.07	€/kWh
Operational and maintenance cost – Baseline scenario	0	€
Operational and maintenance cost – Alternative scenario	0	€
Remaining value	10%	% investment cost
Interest rate	3%	%

The operating and maintenance costs of heat pumps are considered to be offset by the existing costs of operating and maintaining the systems used to meet space heating needs.

The results of the economic analysis highlight the particularly low economic profitability of the scenario under consideration (Table 11), making it imperative to provide a subsidy to the households concerned.

Table 11: Economic Analysis results in Scenario 4

NPV	-5,021,095
IRR	-2%
Cost Benefit Ratio	0.59

Cost-benefit analysis

For the elaboration of the cost-benefit analysis, the methodological approach developed in the framework of the European project PRODESA was applied[21].

More specifically, the following external costs and benefits components were used to assess this scenario in addition to the costs and benefits, which were quantified in the context of the economic analysis:

Environmental costs from the operation of the examinees/technologies

The external cost unit values used concern both the impacts on human health, agricultural production and cultural heritage monuments from all primary and secondary pollutants, as well as the impacts of climate change and the depletion of natural resources.

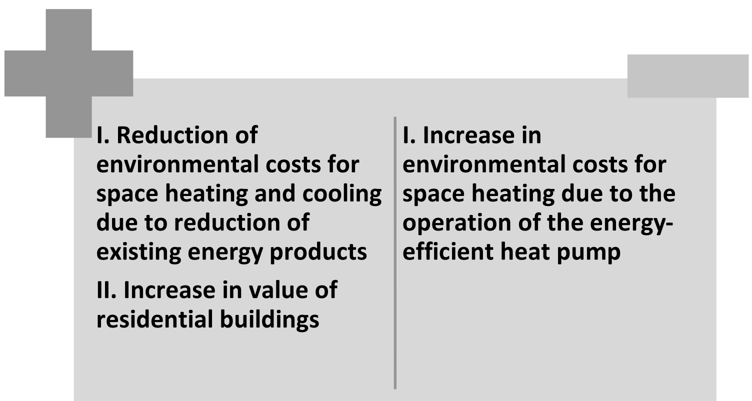
[21] **Source:** PRODESA, 2021. Economic evaluation of the energy efficiency projects, Deliverable D2.6.

More specifically, the unit cost for the existing heat pump for space cooling was considered equal to 23.5 €/MWh, while the weighted average external cost of energy products for space heating was estimated at 23.4 €/MWh based on data submitted to EUROSTAT for 2019 (Table 1). Finally, the unit cost for the energy-efficient heat pump was considered equal to €14.2/MWh.

Increase in the value of residential buildings due to energy upgrade.

The increase in the value of residential buildings was determined by calculating the cost savings from energy saving and RES interventions with a capital recovery factor, which was considered equal to 3% (equivalent to the discount rate we assess and the total investment). This component shall be taken into account in the year of implementation of the investment concerned.

The following figure summarises the external costs and benefits components taken into account in the scenario considered. In order to more realistically reflect the environmental costs of the heat pump, we take into account that the construction and life cycle of a heat pump require material and electricity consumption costs.



The assumptions of the economic analysis were considered the same in the case of the cost-benefit analysis with the only difference being that taxes and charges were deducted from the prices of energy products, because they are a cost for the individual but not for the national economy and society, as well as VAT from the cost of investment.

The results of the cost-benefit analysis (Table 12) highlight the social efficiency of the intervention under consideration, thus documenting the provision of a grant to the households concerned. It should be noted that social efficiency is significantly affected by the double lining required in the case of the heat pump. The double investment concerns the replacement of the heat pump (after the end of the 12-year life) with a new heat pump for the next 12 years, until the repayment of the investment in the building envelope that has a lifespan of 25 years.

Table 12: Results of cost-benefit analysis in Scenario 4.

NPV	553.203
IRR	4%

Cost Benefit Ratio	1,13

Scenario 5: Promotion of zero-energy buildings

Scenario 5 examined the shift of part of the available budget for the expansion of the fossil gas network to promote zero energy buildings.

These buildings can be led to zero energy consumption through the combination of thermal insulation of external walls, the replacement of existing frames with new more energy efficient ones in residential buildings, the installation of a heat pump and the installation of photovoltaic systems through energy netting.

The benefit of households concerns the reduction of energy costs due to both the reduced energy demand for space heating and cooling, as well as the operation of the heat pump and photovoltaic systems.

In addition, it was considered that the beneficiary households will not be required to install a new fossil gas boiler given the reduced energy demand for space heating by maintaining the existing heating system, thus reducing the required investment costs.

For the calculation of the economic benefit, the weighted average cost of purchasing energy products for space heating was calculated based on the data submitted to EUROSTAT for 2021.

Economic analysis

The assumptions for the preparation of the economic analysis are presented in Table 13.

Table 13: Assumptions for economic analysis in Scenario 5.

Size	Value	Unit
Available budget for gas network expansion	12,000,000	€
Unitary Investment Cost – Wall Insulation	18,000	€
Unitary Investment Cost – Heat Pump	8,00.	€
Unitary Investment Cost – PV	8,400	€
Avoided cost from installing fossil gas boiler	4,000	€
Installed capacity – PV	4	kW
Installation cost – PV	2,100	€/kW
Nr of affected households	349	Nr of households
Unitary energy consumption for space cooling	580	kWh
Unitary energy consumption for space heating	6,500	kWh

Size	Value	Unit
Fossil gas boiler efficiency	95%	%
Oil boiler efficiency	80%	%
Heat pump efficiency	4.5	
Energy saving rate for space cooling	60%	%
Energy saving rate for space heating	60%	%
Energy saving for space cooling	348	kWh
Energy saving for space heating	3,900	kWh
Energy consumption after the interventions	4,810	kWh
Electricity price	0.18	€/kWh
Electricity price – net metering	0,.10	€/kWh
Weighted fuel price for space heating	0.09	€/kWh
Fossil gas price	0.07	€/kWh
Operational and maintenance cost – Baseline scenario	0	€
Operational and maintenance cost – Alternative scenario	100	€
Remaining value[22]	10%	% interest rate
Interest rate	3%	%

The operating and maintenance costs of heat pumps were considered to be offset by the existing costs of operating and maintaining the systems used to meet space heating needs.

The results of the economic analysis highlight the particularly low cost-effectiveness of the scenario under consideration (Table 14), making it imperative to provide a subsidy to the households concerned.

Table 14: Economic analysis results in Scenario 5.

NPV	-4,630,463
IRR	-1%
Cost Benefit Ratio	0.66

[22] Because energy upgrades are longer lasting than other measures, we leave some residual value

Cost-benefit analysis

For the elaboration of the cost-benefit analysis, the methodological approach developed in the framework of the European project PRODESA was applied[23].

More specifically, the following external costs and benefits components were used to assess this scenario in addition to the costs and benefits, which were quantified in the context of the economic analysis:

Environmental costs from the operation of the examinees/technologies

The external cost unit values used concern both the impacts on human health, agricultural production and monuments from all primary and secondary pollutants, as well as the effects of climate change and the depletion of natural resources.

More specifically, the unit cost for the existing heat pump for space cooling was considered equal to €23.5/MWh, while the weighted average external cost of energy products for space heating was estimated at €23.4/MWh based on data submitted to EUROSTAT for 2021.

In addition, the unit cost for the energy-efficient heat pump was considered equal to 14.2 €/MWh. Finally, the unit cost for photovoltaic systems was considered equal to 14.1 €/MWh, while the corresponding value for the electricity used by the grid was obtained equal to 48.5 €/MWh.

Increase in the value of residential buildings due to energy upgrade.

The increase in the value of residential buildings was determined by calculating the quotient of cost savings from energy saving and RES interventions with a capital recovery factor, which was considered equal to 3%. This component shall be taken into account in the year of implementation of the investment concerned.

The assumptions of the economic analysis were also considered in the case of the cost-benefit analysis with the only difference being that taxes and charges were deducted from the prices of energy products, because they are costs for the individual but not for the national economy and society.

I. Reduction of environmental costs for space heating and cooling due to reduction of existing energy products and electricity used by the grid **II. Increase in value of residential buildings**	**I. Increase in environmental costs for space heating due to the operation of energy-efficient heat pump and photovoltaic systems**

[23] **Source:** PRODESA, 2021. Economic evaluation of the energy efficiency projects, Deliverable D2.6.

The assumptions of the economic analysis were also considered in the case of the cost-benefit analysis with the only difference being that taxes and charges were deducted from the prices of energy products, because they are a cost for the individual but not for the national economy and society, as well as VAT from investment costs and operation and maintenance costs.

The results of the cost-benefit analysis (Table 15) highlight the social efficiency of the intervention examined by substantiating the provision of a grant to the households concerned. The double investment required in the case of the heat pump due to its lifetime (12 years and therefore its replacement) is offset by the economic benefit resulting from the installation and operation of photovoltaic systems (with a longer lifetime) leading to higher social efficiency compared to Scenario 4.

Table 15: Results of cost-benefit analysis in scenario 5

NPV	3,637,585
IRR	14%
Cost Benefit Ratio	1.42

Scenario 0: Installation of gas boilers

Scenario 0 examines the current situation where a scheme is financing gas burner connections replacing oil burners with €12 million € in both cities. The benefit of households concerns the reduction of energy costs due to the promotion of fossil gas for space heating (but again taking the lowest prices of 2021).

It is important to note that the cost of installing a new gas boiler in households is not taken into account. We believe that the €12 million will lead to a number of households connecting directly (around 8,000). We have not taken into account the cost of installing the boiler (with an average cost of 4.000 €) as the cost could be absorbed by the provider possibly, and also even without it, both financial and cost-benefit analysis do not consider the investment profitable.

For the calculation of the economic benefit, the weighted average cost of purchasing energy products for space heating was calculated based on the data submitted to EUROSTAT for 2021 regarding the final energy consumption for this use in residential buildings.

Economic analysis

The assumptions for the economic analysis are presented in Table 16.

Table 16: Assumptions for the economic analysis in Scenario 0.

Size	Value	Unit
Available budget for gas network expansion	12,000,000	€
Avoided cost from installing fossil gas boiler	0	€
Number of affected households	8,000[24]	Nr of households
Unitary energy consumption for space cooling	580	kWh
Unitary energy consumption for space heating	6,500	kWh
Fossil gas boiler efficiency	95%	%
Oil boiler efficiency	80%	%
Unitary energy consumption for space heating – Fossil gas	5,474	kWh
Electricity price	0.18	€/kWh
Weighted fuel price for space heating	0.09	€/kWh
Fossil gas price	0.07	€/kWh
Operational and maintenance cost – Baseline scenario	0	€

[24] The estimate is that the 100,000 inhabitants of the two municipalities correspond to 43,000 households, out of which 15-18% will benefit.

Size	Value	Unit
Operational and maintenance cost – Alternative scenario	0	€
Remaining value	10%	% κόστους επένδυσης
Interest rate	3%	%

The operating and maintenance costs of gas boilers were considered to be offset by the existing costs of operation and maintenance of the systems used to cover space heating needs.

The cost-effectiveness of the scenario considered is low (Table 17).

Table 17: Economic Analysis results in Scenario 0

NPV	8,628,610 €
IRR	12%
Cost Benefit Ratio	1.18

Cost-benefit analysis

For the elaboration of the cost-benefit analysis, the methodological approach developed in the framework of the European project PRODESA was applied[25].

More specifically, the following external costs and benefits were used to assess this scenario in addition to the costs and benefits, which were quantified in the context of the economic analysis:

Environmental costs from the operation of the examinees/technologies

The external cost unit values used concern both the impacts on human health, agricultural production and monuments from all primary and secondary pollutants, as well as the effects of climate change and the depletion of natural resources. More specifically, the unit cost for the energy-efficient gas boiler was considered equal to €17.9/MWh, while the weighted average external cost of energy products for space heating was estimated at €23.4/MWh based on data submitted to EUROSTAT for 2021.

II. Multiple benefits from the implementation of energy saving interventions, such as improving comfort conditions in buildings and combating energy poverty, reducing morbidity and mortality, etc.

The calculation was carried out assuming that multiple benefits equal to 2% of the cost savings resulting from the installation of gas boilers. This component is obtained on an annual basis after the implementation of the investment under consideration.

The following figure summarises the external costs and benefits components taken into account in the scenario considered.

[25] **Source:** PRODESA, 2021. Economic evaluation of the energy efficiency projects, Deliverable D2.6.

+	−
I. Reduction of environmental costs for space heating due to reduction of existing energy products **II. Multiple benefits**	**I. Increase in environmental costs for space heating due to the operation of the fossil gas boiler**

The assumptions of the economic analysis were also considered in the case of the cost-benefit analysis, with the only difference being that taxes and charges were deducted from the prices of energy products, because they are a cost for the individual but not for the national economy and society, as well as VAT from the cost of the investment. More specifically, the fossil gas price was considered equal to €0.06/kWh, while the weighted fuel price for space heating was equal to €0.05/kWh.

The results of the cost-benefit analysis (Table 18) do not highlight the social efficiency of the intervention under consideration, so the provision of a grant to the households concerned is not substantiated. The reason is that both economic and cost-benefit analysis consider the investment inefficient.

Table 18: Results of cost-benefit analysis in Scenario 0

NPV	-6.617.597
IRR	-10%
Cost Benefit Ratio	0,87

Summary of scenarios

Table 19 summarises the results of the scenarios examined.

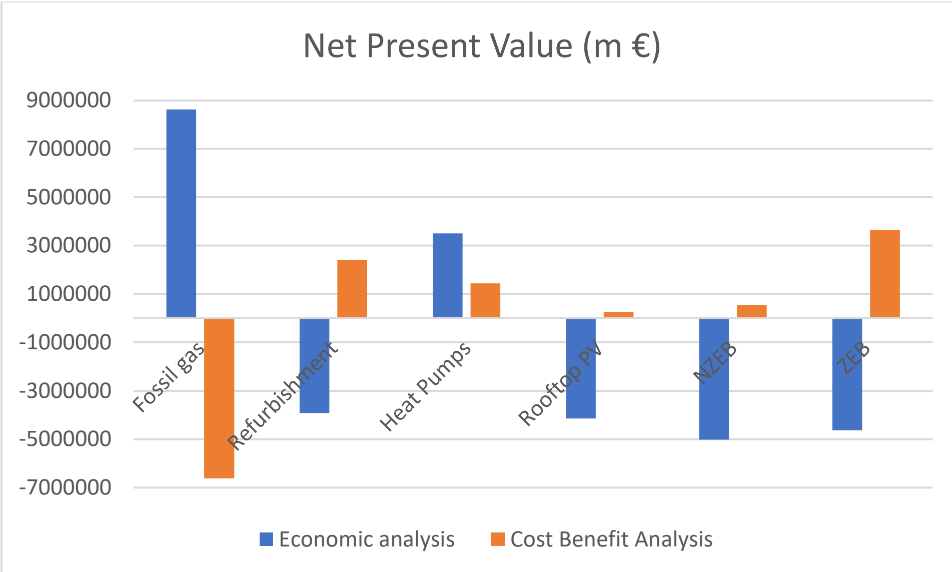
Table 19: Results of scenarios considered.

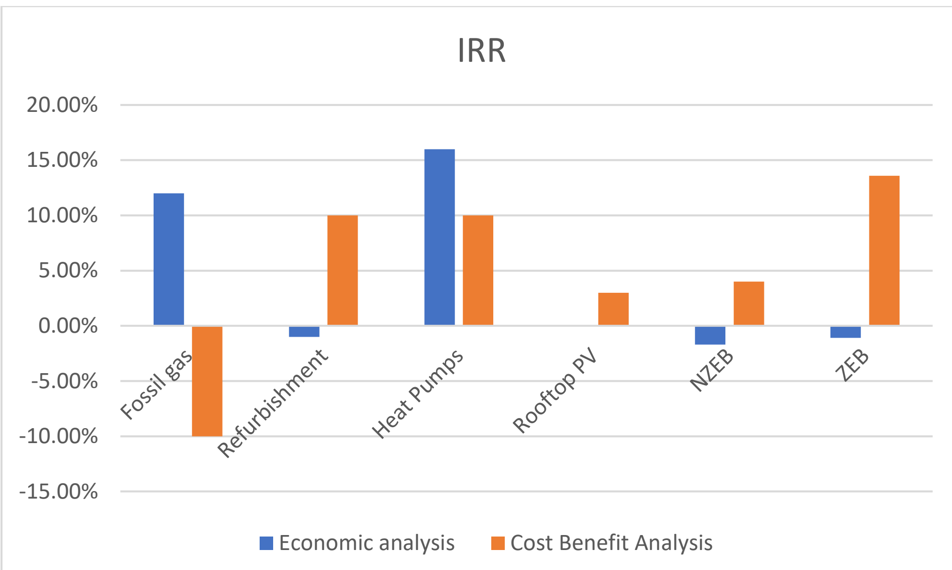
Scenario	Analysis	NPV	IRR	Cost Benefit ratio
Fossil gas	**Economic**	**8,628,610 €**	1%	0.94
	Cost-Benefit	**-6,617,597 €**	-16%	0.73
Energy upgrade	**Economic**	**-3,925,098 €**	-1%	0.64
	Cost-Benefit	**2,407,822 €**	10%	1.40
Heat pumps	**Economic**	**3,507,092 €**	16%	1.43
	Cost-Benefit	**1,444,218 €**	10%	1.18
Rooftop PV	**Economic**	**-4,140,866 €**	0%	0.72
	Cost-Benefit	**256,827**	3%	1.02
NZEB	**Economic**	**-5,021,095 €**	-2%	0.59
	Cost-Benefit	**553,203 €**	4%	1.13
ZEB	**Economic**	**-4630,463 €**	-1%	0.66
	Cost-Benefit	**3.,627,585 €**	14%	1.42

Scenario 2 is characterised by the highest economic efficiency, while Scenarios 1 and 5 are characterised by the highest social efficiency. However, Scenarios 2 and 4 also lead to positive social efficiency.

Scenario 1, which is characterised by negative economic efficiency, leads to positive social efficiency justifying the provision of a grant to maximise social welfare. Similarly, a grant is required in the case of Scenarios 4 and 5 given their low cost-effectiveness. The same conclusion can be drawn for Scenario 3 given its marginal social efficiency.

Scenario 0 is characterized by positive economic but negative social performance, so its implementation is not preferred compared to the other scenarios examined.


Net Present Value (m €)
9000000
7000000
5000000
3000000
1000000
-1000000
-3000000
-5000000
-7000000
Fossil gas
Refurbishment
Heat Pumps
Rooftop PV
NZEB
ZEB
Economic analysis
Cost Benefit Analysis


IRR
20.00%
15.00%
10.00%
5.00%
0.00%
-5.00%
-10.00%
-15.00%
Fossil gas
Refurbishment
Heat Pumps
Rooftop PV
NZEB
ZEB
Economic analysis
Cost Benefit Analysis

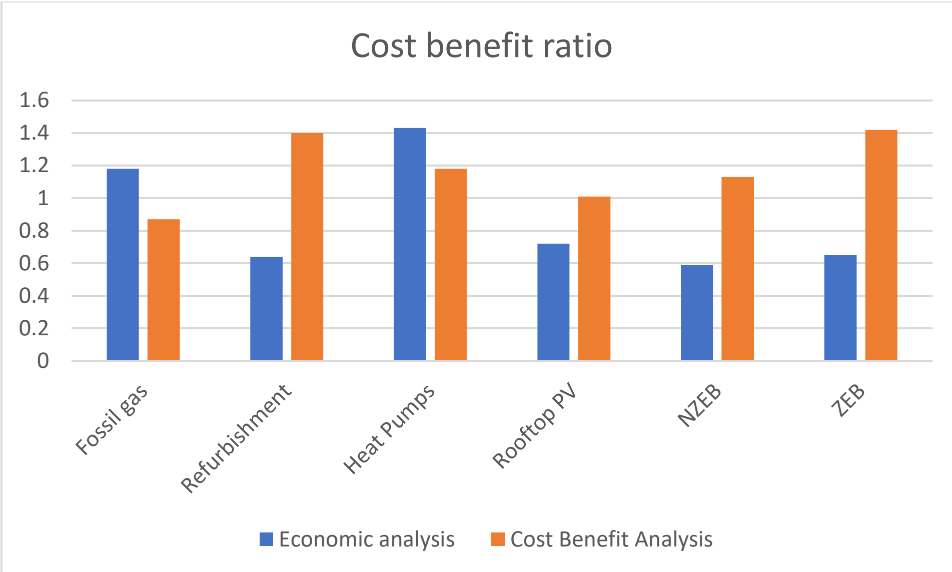


Figure 1: Comparison of NPV, IRR and Benefit-Cost Ratios of scenarios considered.

4. Policy measures and conclusions

Role of municipalities

Based on the scenario calculations, it is important that the two regions focus on the renovation of the building stock while promoting PV on roofs as they qualify as the most socially efficient solutions (Scenarios 2, 3, 5), as presented in Chart 1. As far as this renovation is concerned, it is in all cases more economically viable than public expenditure on fossil gas networks, both at the level of simple building interventions (as defined in the "Exoikonomo" type programs – incumbent subsidy programs for energy efficiency refurbishments) and in the promotion of nearly zero consumption buildings. Municipal programmes could be drawn up for the above actions, instead of spending them on gas connections, which would be more efficient.

In short, the Municipalities of Corinth and Tripoli could request a review of the €12 million subsidy for residential gas connections, to rather finance:

1. Energy upgrades of low-income households' homes (at least 700 households could structurally solve energy poverty)
2. Co-financing of photovoltaic roofs for 2,000 beneficiaries (low income) with offsetting in order to reduce their energy needs
3. Co-financing of existing programmes to replace oil boilers with heat pumps (with a minimum target of 1,600 households)
4. Co-financing for deep renovation of (low income) housing targeting 400-500 contractors.

The advantages of these policies will be by far more significant compared to the subsidy of fossil gas heaters, given the new European restrictions placed on the use of gas from 2026.

What policies could be pursued in Greece?

Based on the conclusions of the initial study ( ), existing and new policies in the revised National Energy and Climate Plan (NECP) should focus on financing other individual policy measures (through existing or new programmes) for the renovation of the building envelope and zero-energy buildings. **Given the situation of low-income households (already more than 500,000) in energy poverty, it appears that full financing of these interventions is required in order to find a structural solution.** So far, the existing programs (as shown in the report of the Energy Saving program for 2021) have received only 14000 applications belonging to the first income category (thus covering less than 3% of households in total in this income category, about 500,000 in Greece), so greater targeting towards this group is required. This means that multiple annual programmes of at least 50% subsidy must be designed and implemented (and with increased rates up to 80-90%) in order to achieve the renovation potential of 83,000 households.

Alongside grants for home renovations, it is equally important to facilitate financing to electrify residential heating by replacing gas burners earlier, both with heat pumps and photovoltaic systems that can reduce energy needs. Financing is required at a high rate for low-income households as they are excluded from private financing and existing Programs have not been able to adequately target them - along of course with the fact that a large portion of these households are tenants, so the problem of sharing benefits (split incentive) between tenants and landlords is more acute. There are, however, good examples of the European project ENPOR tackling the phenomenon of split incentives. Regarding heat pumps, the respective programs for the [26]replacement of fossil fuel burners with heat pumps (under the Energy Saving program or new programs) should target 250,000 households with the amount of € 1.5 billion, while respectively 400,000 households with PV on the roof with the same amount.

It is therefore important that Greece reviews its policy priorities and designs and implements policies based on the social efficiency of interventions. The above analyses show that expenditure, with strict economic criteria, is more efficient in all scenarios (1-5) and expenditure should be reallocated in the next period. More specifically, in order to address energy poverty, the resources that Greece receives for energy upgrades from the Social Climate Fund (€4 billion), the Recovery Fund (€4.5 billion upgrade program with €1.5 billion participation of the Fund), the Just Transition Fund (€1 billion in the first pillar) should be immediately allocated to the electrification of heating, energy upgrades and PV on the roof frontloaded either in the form of subsidies or facilitation for lending. Regarding the duration of the interventions, it consists of:

1. In 2022/2023 to immediately launch a program for the installation of heat pumps, which has a high economic viability. Please note that this programme will not require a large level of state assistance, due to its cost-effectiveness, but financing (such as borrowing) should be facilitated.

[26] http://www.enpor.eu. Some examples are the 110% Super Bonus renovation package in Italy (https://www.theguardian.com/world/2022/apr/13/italys-superbonus-110-scheme-prompts-surge-of-green-home-renovations) or the corresponding scheme for sharing energy costs in rent depending on the condition of the house (https://www.euractiv.com/section/energy/news/germany-splits-carbon-tax-for-heating-between-landlords-and-tenants/)

Accordingly, it is recommended that the heat pump installation program be accompanied by a program for the installation of photovoltaics on the roof with the provision of a subsidy in order to improve its economic efficiency. These two programs, or in the form of a "package" (i.e. rooftop photovoltaics and replacement of burners with heat pumps) should run annually for the next 5 years.

2. In 2023 and for each year, part of the resources of €9.5 billion should be used to cover the corresponding percentage of households for energy upgrades of buildings and nearly zero consumption buildings.

More specifically, an indicative distribution of interventions over time could follow the planning, which is depicted in Table 35, for an available budget of € 3 billion. It is noted that in case half of the budget is given through low-interest or zero borrowing, then it will be available to refinance energy-vulnerable households after the repayment of the loans.

Table 20: Recommended policy measures

Year	Measures
2022	PV (10 thousand buildings)
	Heat pumps (20 thousand buildings)
	Energy upgrade ZEB (8 thousand buildings)
2023	PV (14 thousand buildings)
	Heat pumps (45 thousand buildings)
	Energy upgrade ZEB (14 thousand buildings)
2024	PV (14 thousand buildings)
	Heat pumps (45 thousand buildings)
	Energy upgrade ZEB (14 thousand buildings)
2025	PV (14 thousand buildings)
	Heat pumps (45 thousand buildings)
	Energy upgrade ZEB (14 thousand buildings)

In any case, it is recommended to evaluate alternative means of financing the required investments in accordance with the provisions of the NECP, such as, but not limited to, the introduction of tax incentives and the provision of low-interest loans in order to supplement the resources foreseen for the provision of direct subsidies. In order to facilitate consumers financially, it would also be important to establish a legislative framework to provide for programmes to save and reduce consumption energy to residential consumers[27] by energy providers or other market players (through various forms of Energy Performance Contracting (EPC)). The investment for energy saving can thus be paid by the energy providers and the amount saved can be received back by the provider from the next bill to repay his investment.

The prioritization of investments in energy upgrades is fully in line with[28] the European Energy Efficiency First Principle (as defined in the European Governance Regulation and the Revised Energy Efficiency Directive - Article 3 - in the Fit-for-55 package presented by the European Commission). This Principle requires that in order to approve public funding to increase energy supply, through new gas pipelines, networks and others, a social cost-benefit analysis should be carried out comparing this investment with the corresponding one in energy savings, as proposed in Scenarios 1-5. If the investment is more efficient on the demand side, as shown in the existing study, the return of public funding to supply will not be justified. Based on the calculations, since energy efficiency technology scenarios, such as energy upgrading of buildings, nearly zero-energy buildings and zero-energy buildings, are more socially efficient than supply scenarios (Scenario 0 with gas input), supply financing through gas networks will not be justified in line with the Energy Efficiency First Principle.

In connection with the implementation of the Energy Efficiency First Principle, Greece should include in the calculations the components of external costs (such as climate costs or additional costs of importing fossil fuels and others) and benefits from each technology, since current decisions in the vortex of the energy crisis are taken without such calculations. Correspondingly, if the multiple benefits of energy upgrading of buildings (such as improved health, increase in building value and others) are included in the calculations, then the proposed policies will converge towards energy upgrading and electrification of heating. Based on the existing NECP, the rate of renovation and replacement of residential buildings with new nearly zero energy consumption can reach a combined 12-15% of all dwellings by the year 2030. Over an annual time horizon, the target is to upgrade or replace by new, more energy-efficient buildings or building units, while the NECP stipulated that this is served by consolidating fossil gas infrastructure, thus without taking into account the Energy Efficiency Principle First. Without a proper social cost-benefit study, the financing aspect of demand management through energy savings is not taken into account in policy decisions, leading to decisions that are not socially optimal. First, by demonstrating the economic and social benefits of each technology and policy choice, it should therefore become central to decision-making in the revised NECP so that energy transition decisions are economically and socially efficient.

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[27] This possibility is also indirectly offered in the National Energy Saving Enforcement Scheme as established since 2017.

[28] http://www.enefirst.eu