“How Could the Decarbonisation of the Residential Building Stock Support a Just Transition in the Coal and Carbon Intensive Region of Megalopolis?”

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Introduction & Problem statement (1/2)

- Rural area until **1970** ➡ PPC **lignite mining*** and **power generation** started
- Since then, Megalopolis became a **major energy center** providing thousands of jobs to the Greek province:
- **Currently:**
  - 1 large lignite mine
  - 2 lignite power plants:
    - **"Megalopolis III"** (255MW)

      (in major malfunction since 2021)
    - **"Megalopolis IV"** (256MW)
  - 1 natural gas power plant
    - **"Megalopolis V"** (811MW)

Following the 1970s oil crisis, lignite offered security of reserves and stable prices.

INTRODUCTION & PROBLEM STATEMENT (2/2)

- The Greek NECP (2019) planned for a **lignite phase out** in Megalopolis by 2023, placing natural gas as an intermediate fuel.
- The **"Megalopolis III"** unit which also powered the District Heating system of Megalopolis (21.8 MW_{th}) has been in major malfunction since the end of 2021 and its decommissioning is planned.
- With the phase-out of **"Megalopolis III"** about 30% of the Megalopolis building stock (i.e., 516 buildings) needs to transition away from district heating.
- A **natural gas distribution network** is in development in Megalopolis to substitute District Heating.
- For the transition period, District Heating operates autonomously (LPG was proposed).

National Energy Climate Plan (NECP) 2019-2020

RESEARCH QUESTION

Following also the recent experience of the **energy crisis** and the consequent **uncertainty** in regard to the **natural gas supply** and **prices**, the plan for the **gasification of the heating sector** of the region is **put in question**.

We address the following **Research Question**:

"When it comes to the transition in the residential sector in the Megalopolis municipality, should we stick to the existing plan and invest in new natural gas infrastructure or should we invest in electrification right from the start?"

Model Application

DREEM
Dynamic High-Resolution Demand-Side Management Model

Building sector

Energy demand *simulation model*

Benefits *&* ***limitations*** *of demand-flexibility primarily for* ***consumers*** *& other* ***power actors*** *involved*

ELSEVIER

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A modular high-resolution demand-side management model to quantify benefits of demand-flexibility in the residential sector

Vassilis Stavrakas, Alexandros Flamos

SENTINEL
SUSTAINABLE ENERGY TRANSITIONS

TIPPING+

ENCLUDE
Energy Citizens for Inclusive Decarbonization

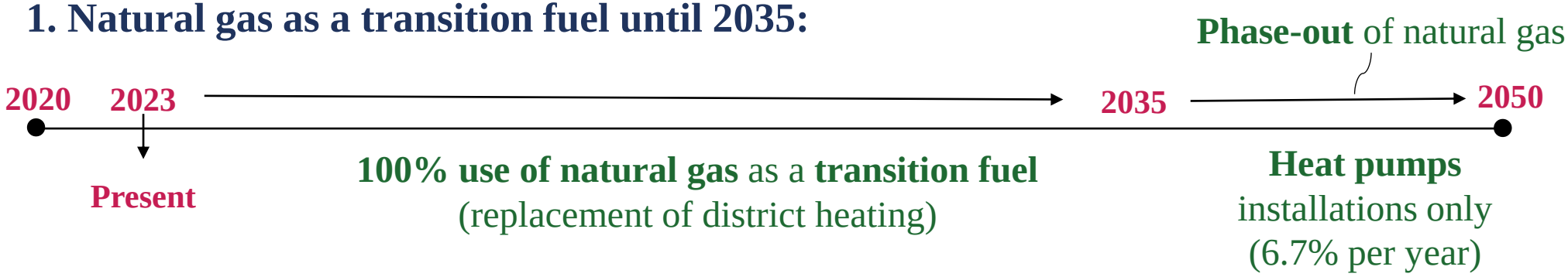
IAM COMPACT

ENPOR

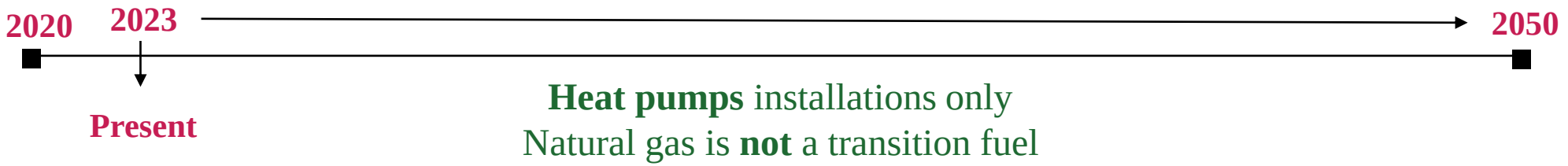
RENOVERTY

SCENARIO ANALYSIS

1. Natural gas as a transition fuel until 2035:



2. Investment only in electrification:



In dwellings built **before 1981**: exterior wall insulation & windows upgrades.
In dwellings built in the period **1981-2010**: exterior wall insulation.
(*Based on the renovation rate of 60,000 renovation/year, foreseen in the current NECP*)

How does each scenario affect final energy consumption in the region?

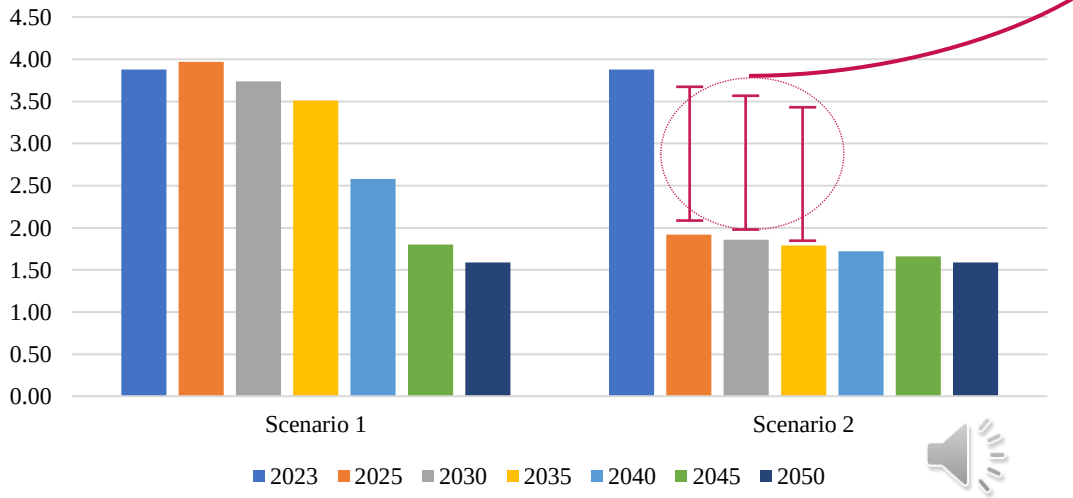
RESULTS (1/9)

Final energy consumption towards 2050 in the residential sector in Megalopolis:

	2023	2025	2030	2035	2040	2045	2050
Scenario 1	3.88	3.97	3.74	3.51	2.58	1.80	1.59
Scenario 2	3.88	1.92	1.86	1.79	1.72	1.66	1.59

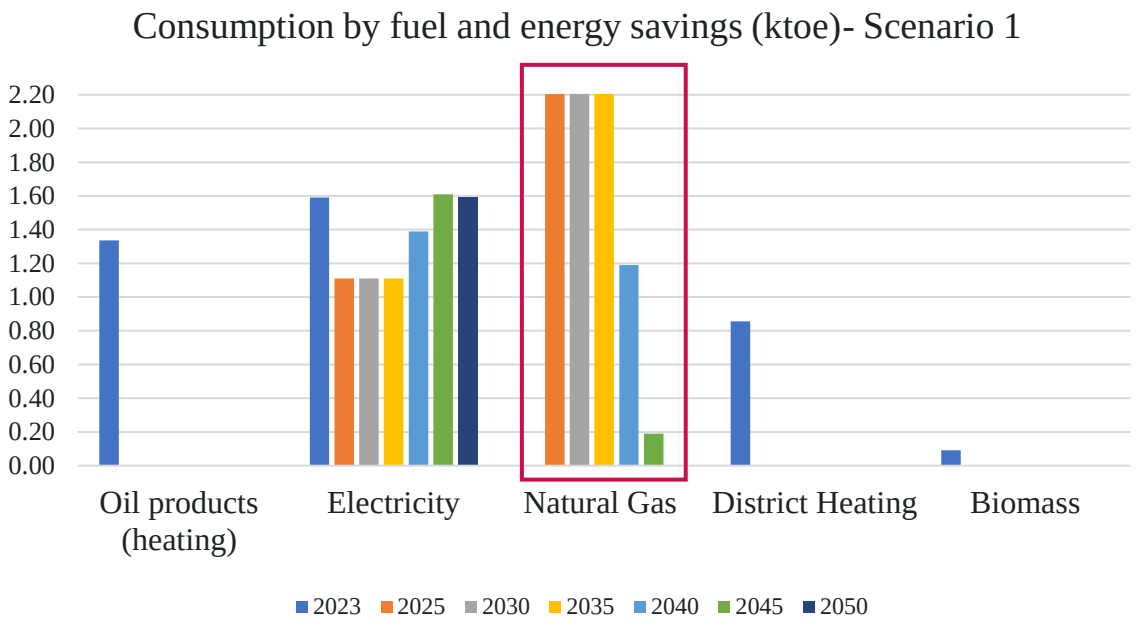
Electrification leads to **lower** annual final energy consumption from the beginning.

Until 2035 (mid-transition period) electrification leads to almost half annual final energy consumption!

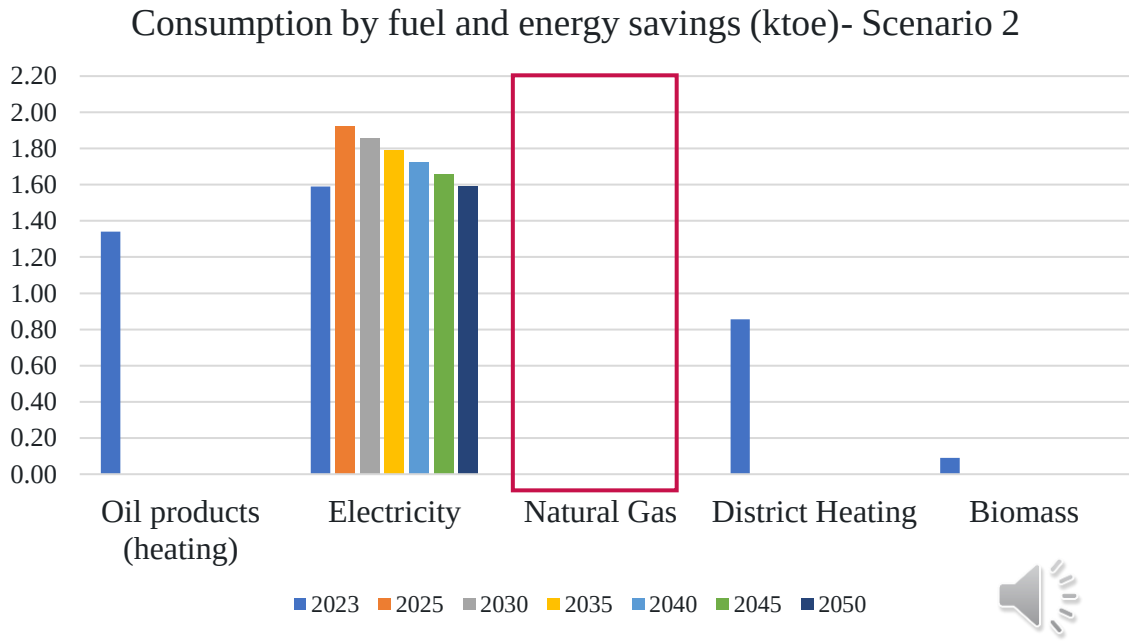


RESULTS (2/9)

Energy mix towards 2050 in the residential sector in Megalopolis – Cross-scenario comparison:



Electrification leads to full avoidance of the use of fossil fuels!



What about the environmental footprint?

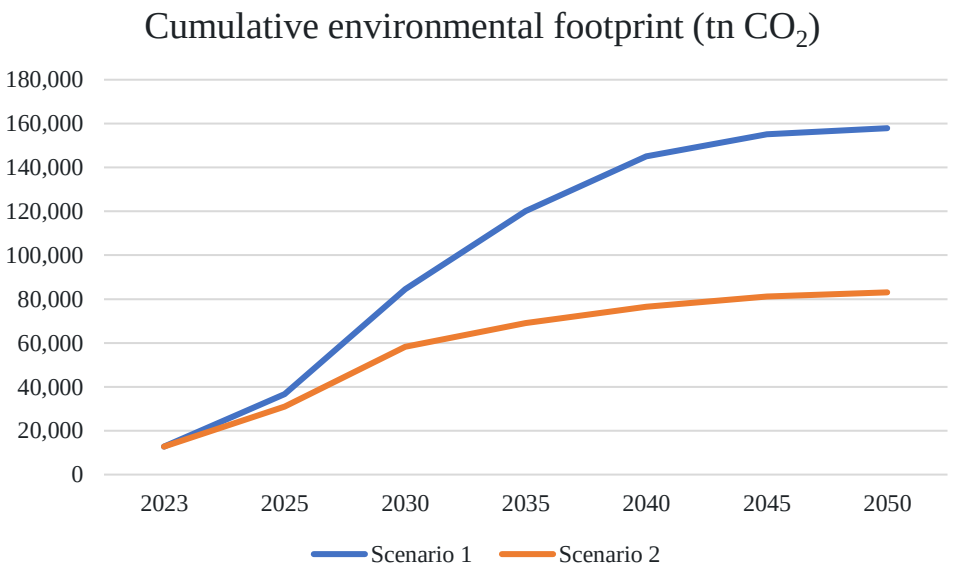
RESULTS (3/9)

Environmental Footprint

Total $tnCO_2$	2023	2025	2030	2035	2040	2045	2050
Scenario 1	12,792	11,633	8,159	6,760	3,792	1,122	174
Scenario 2	12,792	8,601	3,396	1,881	1,271	702	174

less ↓ 26% 58% 72% 66% 37%

Cumulative environmental footprint ($tnCO_2$)	2023	2025	2030	2035	2040	2045	2050
Scenario 1	12,792	36,752	84,495	120,059	145,025	155,072	**157,835**
Scenario 2	12,792	31,076	58,326	69,018	76,576	81,130	**83,039**



Investing in **electrification** rather than in **natural gas** leads to almost half $tnCO_2$ emitted towards 2050.

48% less!

And what about costs though?

Uncertainty about their evolution…

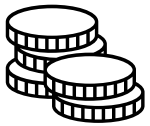
RESULTS (4/9)

Two different initial value cases for the energy costs!

Energy costs for Households (€/MWh)

"high-prices" case

	2022	2030	2050
Oil (Diesel heating oil)	123.2	166.5	199.0
Electricity	276.8	325.2	389.9
Natural gas	295.2	281.8	248.4



Energy costs for Households (€/MWh)

"low-prices" case

	2022	2030	2050
Oil (Diesel heating oil)	76.3	103.1	123.2
Electricity	48.2	56.6	67.9
Natural gas	175.2	167.3	147.4

Sources:

- Hellenic Ministry of Environment and Energy. Long Term Strategy for 2050. 2019.
- Hellenic Ministry of Development C and S. Εβδομαδιαίο δελτίο επισκόπησης τιμών καυσίμων (21/10/2022) 2022.
- Hellenic Ministry of Development C and S. Εβδομαδιαίο δελτίο επισκόπησης τιμών καυσίμων (28/10/2022) 2022.
- Hellenic Ministry of Development C and S. Εβδομαδιαίο δελτίο επισκόπησης τιμών καυσίμων (14/10/2022) 2022.
- Grigoriou R, Mayer J, Pallicska J. Household Energy Price Index (HEPI) for Europe Significant electricity price 2022.
- Hellenic Ministry of Development C and S. Εβδομαδιαιο δελτιο επισκοπησης τιμων καυσιμων. 2021.

Technological costs (€)

	2022	2030	2040	2050
Natural Gas boiler	5,000	4,904	4,713.4	4,713.4
Heat Pump	12,000	7,680	4,086.7	4,086.7
Envelope and windows upgrade (€)	5,000	5,000	5,000	5,000

Sources:

- https://ec.europa.eu/energy/sites/ener/files/documents/2018_06_27_technology_pathways_-_finalreportmain2.pdf
- https://renewableheatinghub.co.uk/european-heat-pump-association-interview-thomas-nowak

Building sector's ETS cost evolution (€/tn)

(2023-2025)	0
2026	30
2027-2030	50
2031-2050	100

Estimation of cost evolution based on the evolution of EU's established ETS system: https://tradingeconomics.com/commodity/carbon

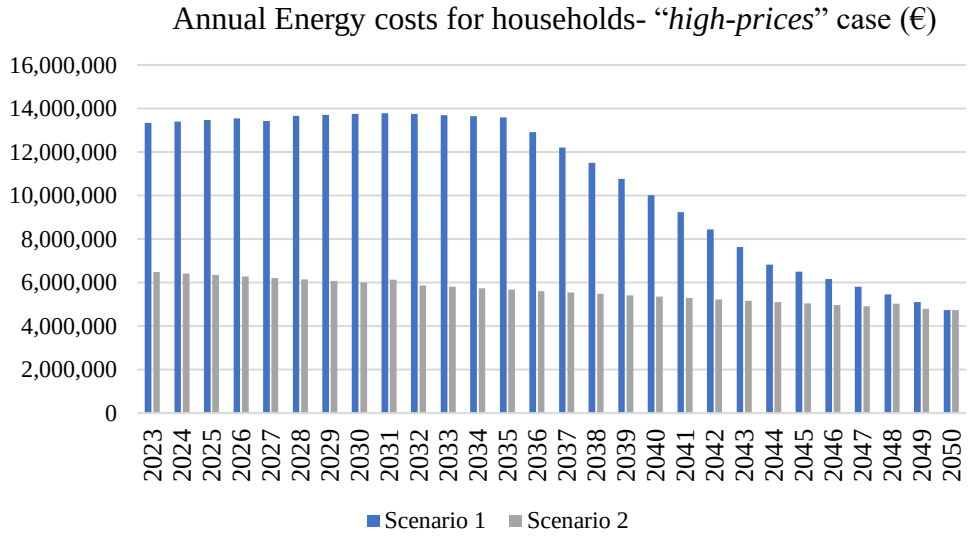
New Results (5/9)

Fuel & Electricity costs

"*high-prices*" case

Fuel & Electricity costs (€)

	2023	2025	2030	2035	2040	2045	2050
Scenario 1	13.33M.	13.47M.	13.75M.	13.58M.	10.01M.	6,94M.	4.73M.
Scenario 2	6.48M.	6.35M.	6.00M.	5.67M.	5.35M.	5.04M.	4,73M.

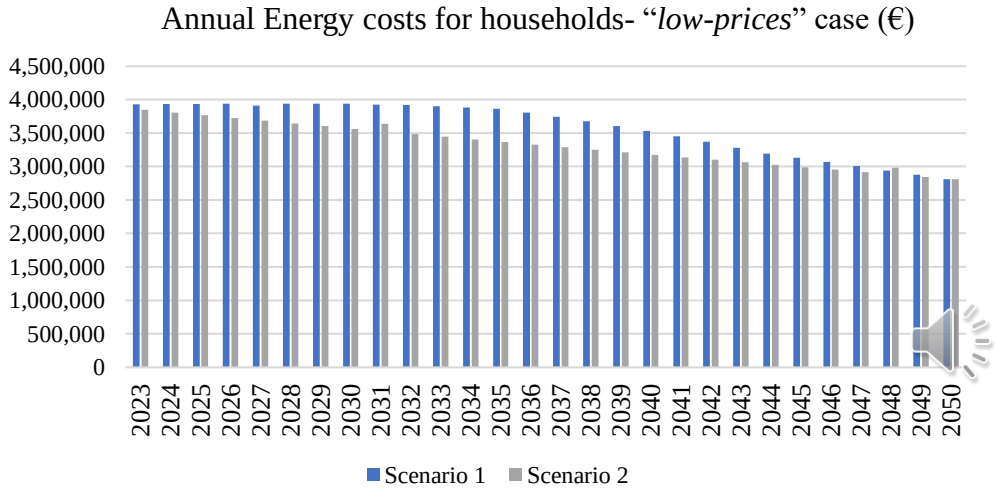


✓ Investing in **electrification** rather than in natural gas leads to **lower** annual energy costs in both price cases.

"*low-prices*" case

Fuel & Electricity costs (€)

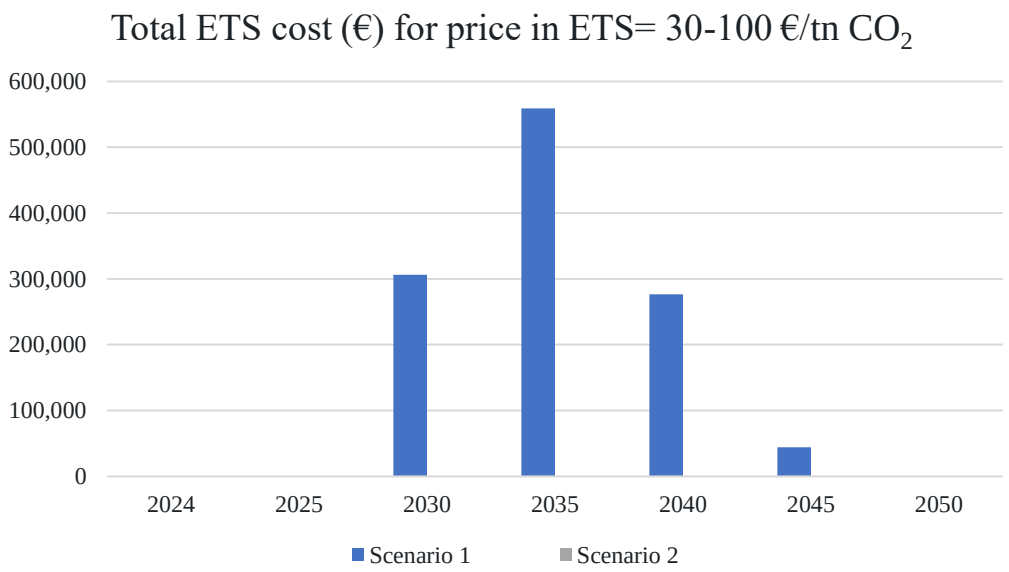
	2023	2025	2030	2035	2040	2045	2050
Scenario 1	3.93M.	3.94M.	3.94M.	3.88M.	3.53M.	3.13M.	2.81M.
Scenario 2	3.85M.	3.77M.	3.56M.	3.37M.	3.17M.	2.99M.	2.81M.



RESULTS (6/9)

If we also consider ETS-relevant costs for an ETS price of 30-100 €/tnCO_2 …

Extra ETS charges will most probably be undertaken by households…



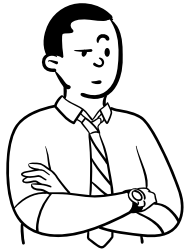
Scenario 1	2023	2026	2030	2035	2040	2045	2050	Total
Potential extra charges in bill/household with renovations (€)	0	56	89	167	92	21	0	**802**
Scenario 2								
Potential extra charges in bill/household with renovations (€)	0	0	0	0	0	0	0	**0**

The **electrification** scenario leads to **full avoidance** of the extension of the ETS costs to the residential sector.

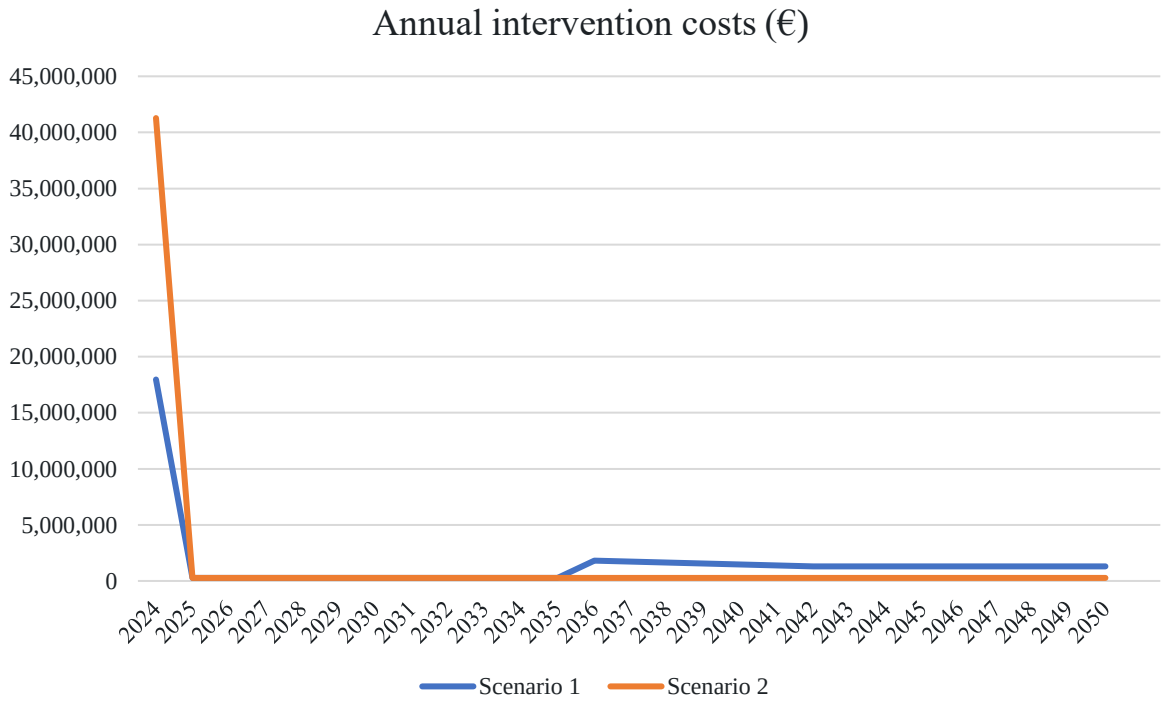
More than half of the building sector's emissions are **already covered by the existing ETS**, notably **the provision of electricity** for use in buildings and most emissions of district heating. However, many homes are still heated with outdated systems that use polluting fossil fuels such as coal and oil.

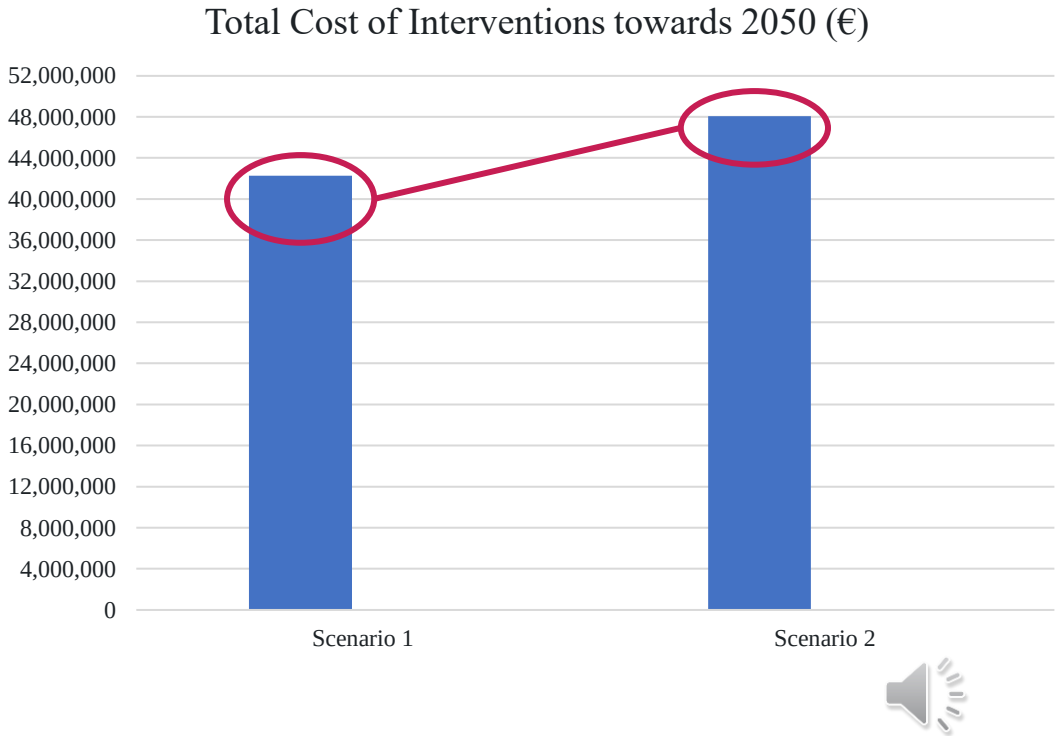
RESULTS (7/9)

Intervention costs…



Investing in **electrification from the beginning** leads to **higher renovation costs**.





Infrastructure costs (e.g., natural gas pipelines) are not included!

So, does this mean that investing in electrification from the beginning costs more?

Let’s assess financial aspects in a more comprehensive way!

RESULTS (8/9)

Cross-scenario comparison - Household level

Despite the higher intervention costs electrification scenario leads to **lower total charges** per household

"high-prices" case

	2023	2025	2030	2035	2040	2045	2050	Total
Scenario 1								
Annual extra charge on bill/household and fuel costs per household with interventions (ETS 30-100) (€)	8,844	3,873	4,042	4,072	3,333	2,228	1,705	**94,873**
Cumulative extra charge on bill/household and fuel costs per household with interventions (ETS 30-100) (€)	8,844	12,717	32,703	53,143	72,268	85,283	94,873	
Scenario 2								
Annual extra charge on bill/household and fuel costs per household with interventions (ETS 30-100) (€)	13,451	1,864	1,767	1,674	1,583	1,495	1,409	**55,959**
Cumulative extra charge on bill/household and fuel costs per household with interventions (ETS 30-100) (€)	13,451	15,315	24,344	32,953	41,048	48,696	55,959	

41% less!

"low-prices" case

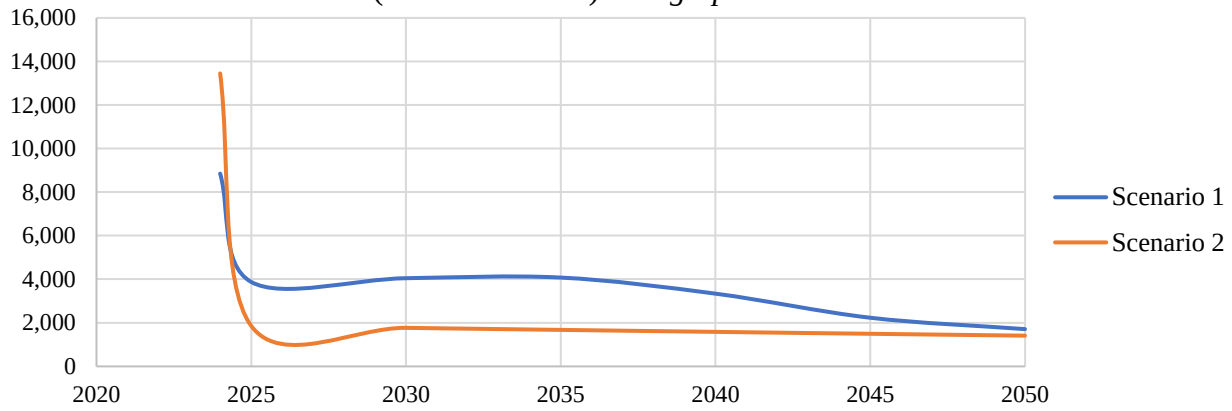
	2023	2025	2030	2035	2040	2045	2050	Total
Scenario 1								
Annual extra charge on bill/household and fuel costs per household with interventions (ETS 30-100) (€)	6,174	1,184	1,274	1,331	1,506	1,279	1,162	**41,250**
Cumulative extra charge on bill/household and fuel costs per household with interventions (ETS 30-100) (€)	6,174	7,358	13,693	20,331	28,451	35,200	41,250	
Scenario 2								
Annual extra charge on bill/household and fuel costs per household with interventions (ETS 30-100) (€)	12,716	1,136	1,079	1,023	969	917	866	**38,721**
Cumulative extra charge on bill/household and fuel costs per household with interventions (ETS 30-100) (€)	12,716	13,852	19,360	24,619	29,573	34,261	38,721	

6% less!

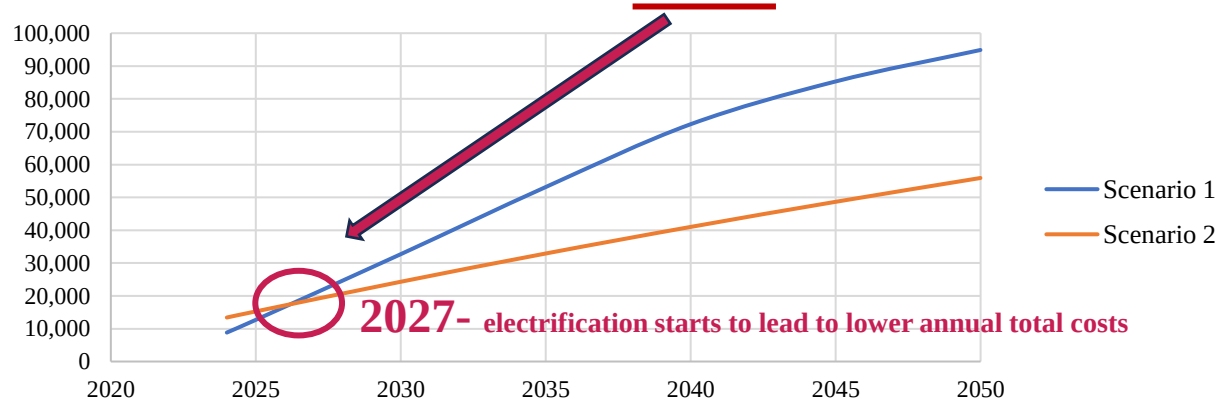
RESULTS (9/9)

Cross-scenario comparison - Household level

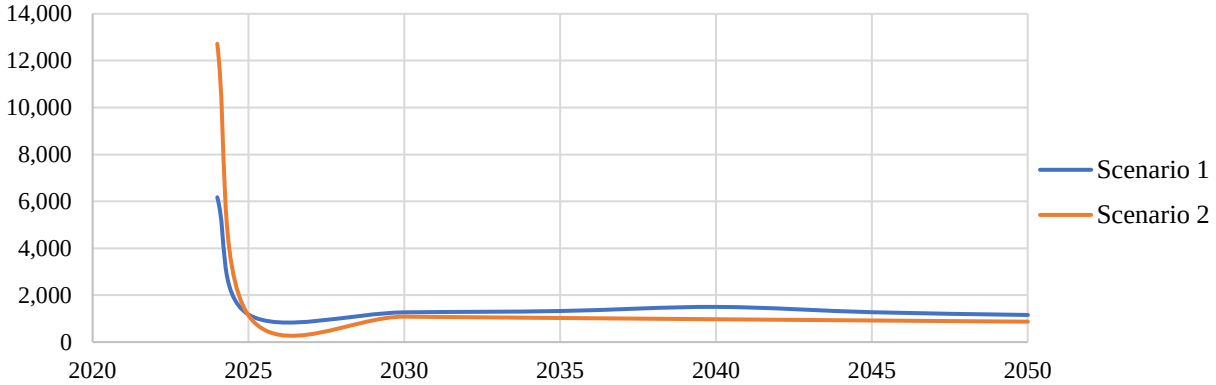
Annual extra charge on bill/household and fuel costs per household (ETS 30-100€/tn) – "*high-prices*" case



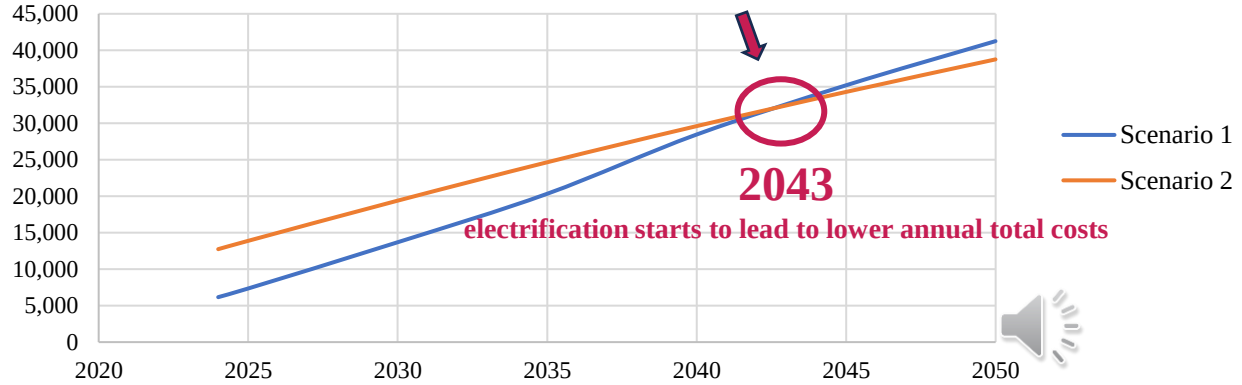
Cumulative extra charge on bill/household and fuel costs per household (ETS 30-100€/tn)- "*high-prices*" case



Annual extra charge on bill/household and fuel costs per household (ETS 30-100€/tn)- "*low-prices*" case



Cumulative extra charge on bill/household and fuel costs per household (ETS 30-100€/tn)- "*low-prices*' case



CONCLUSIONS & POLICY IMPLICATIONS

- Investing in **electrification** from the beginning leads to **lower annual energy consumption** and a **better environmental footprint** towards 2050.

- Investing in **electrification** from the beginning leads to **lower** ETS, and energy, and thus, **lower total costs** at the household level, in comparison to **investing in natural gas as a transition fuel**.

- Investing in natural gas, except for increasing the region's energy dependence, significantly **burdens households** over the energy transition period and **widens energy poverty**.

- Megalopolis should reconsider its policies related to the energy transition of the residential sector, so as to contribute to Greece's energy independence, be **consistent with the objectives set by the EU,** and **protect** the most **vulnerable citizens**.

- Need for policy measures and decisions with **long-term impact** instead of horizontal short-term impact measures that do not address **deeply** the **energy transition challenges** (e.g., energy poverty, etc.)

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