Breaking free from fossil gas

A new path to a climate-neutral Europe

Deep dive buildings and district heating – Agora Online Event

Andreas Graf (Agora Energiewende)

Martin Jakob, Michael Steck (TEP Energy)

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«Breaking free from fossil gas»

Climate neutrality means an end to the burning of fossil fuels. A new Agora Energiewende project has modelled a robust fossil gas phase-out pathway for the EU.

Project scope and basic settings:

- → Decarbonisation pathways until 2050, with Russian gas phase out as quickly as possible (by 2027).
- → Focus on long-lasting demand reductions, as opposed to short-term behavioural changes.
- → Cost-optimized balance between direct electrification and "no-regret" applications of hydrogen.
- → Modelled sectors in 5-year steps: power, buildings, industry + infrastructure including interconnectors and storage (transport and agriculture sectors covered by existing studies).
- → EU energy system is modelled country per country. Energy demand modelled bottom-up by TEP Energy (buildings) and Wuppertal Institute (industry); power sector and energy supply modelled for the whole EU with an optimisation model by Artelys.

«Breaking free from fossil gas»

The EU-27 modelling work was accompanied by “deep dives” in 9 focus countries with 1 partner per country

National partners:

- **Bulgaria:** Center for the Study of Democracy (CSD)
- **Czechia:** Nano Energies
- **Greece:** FACETS S.A.
- **Croatia:** University of Zagreb – Faculty of Mechanical Engineering and Navel Architecture)
- **Hungary:** Regional Centre for Energy Policy Research (REKK)
- **Italy:** ECCO Climate
- **Poland:** Forum Energii
- **Romania:** Energy Policy Group (EPG)
- **Slovenia:** University of Ljubjana – Laboratory of Energy Policy (LEST)

«Breaking free from fossil gas»

Key messages

1	Fossil gas use in Europe can be halved by 2030 and completely phased out by 2050. This is possible while maintaining today's level of industrial production and fully ensuring security of supply, without disruptive behavioural changes.
2	By 2040, EU greenhouse gas emissions could decline by 89% relative to 1990 levels, with a projected remaining Union greenhouse gas budget for the 2030-2050 period of 14.3 Gt.
3	Europe will need a significant amount of renewable hydrogen to become climate neutral, but the demand by 2030 could be only a fifth of that foreseen in REPowerEU.
4	EU rules on gas, hydrogen, and infrastructure planning must reflect the projected rapid decline in fossil gas demand.

«Breaking free from fossil gas»
The webinar series

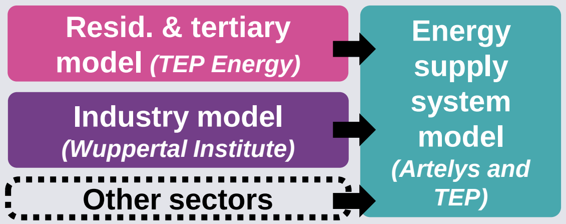
- → ***4 May*** *– <u>Study launch webinar</u>*
- → ***24 May*** *– <u>Deep dive power sector and energy supply (with Artelys)</u>*
- → ***20 June*** *– <u>Deep dive industry and refineries (with Wuppertal Institute)</u>*
- → ***22 June*** *– <u>Deep dive buildings and district heating (with TEP Energy)</u>*

Background and methodology

Assumptions on final energy demand and CO_2 emissions

Approach

Evolution of final energy demand:
- Buildings: TEP Energy (1)
- Industry : Wuppertal Institut (1)
- Transport: Transport & Environment, Road2Zero scenario (2)



Carbon budget approach:
- Overall carbon budget over the pathway split into yearly carbon budgets
- Greenhouse gas emissions of non-modelled sectors based on exogenous sources
    - Transport: Transport & Environment (2)
    - Agriculture and Waste: European Environment Agency (3)
    - LULUCF: European Commission (4)
- CO_2 price not an exogenous assumption for the modelling work

(1) Agora - Breaking free from fossil gas (this study)
(2) Road2Zero scenario of the T&E study "Advanced renewable fuels in EU Transport"
(3) Scenario "With Additional Measures" of the European Environment Agency
(4) European Commission Climate Target Plan impact assessment (assumes a five-year delay)

→ The two most dimensioning constraints in the optimisation of the energy supply system are the evolution of the final energy demand and constraints on GHG emissions.

→ The evolution of final energy demand, computed by TEP Energy for the residential, tertiary and by Wuppertal Institute for the industry were used as inputs for the optimisation of the upstream energy supply system.

→ Yearly carbon budgets available for the upstream energy sector have been determined at the European level, based on the European climate ambition and the emissions foreseen in all other sectors.

Buildings and District heating

Buildings	District heating
Fossil energy to phase out ↘ → Energy-efficiency → Substitution: ↗ • Heat pumps • District heating • Renewable gases (biogene and synthetic)	→ Decarbonize existing systems ↘ → Expand provision ↗

Buildings

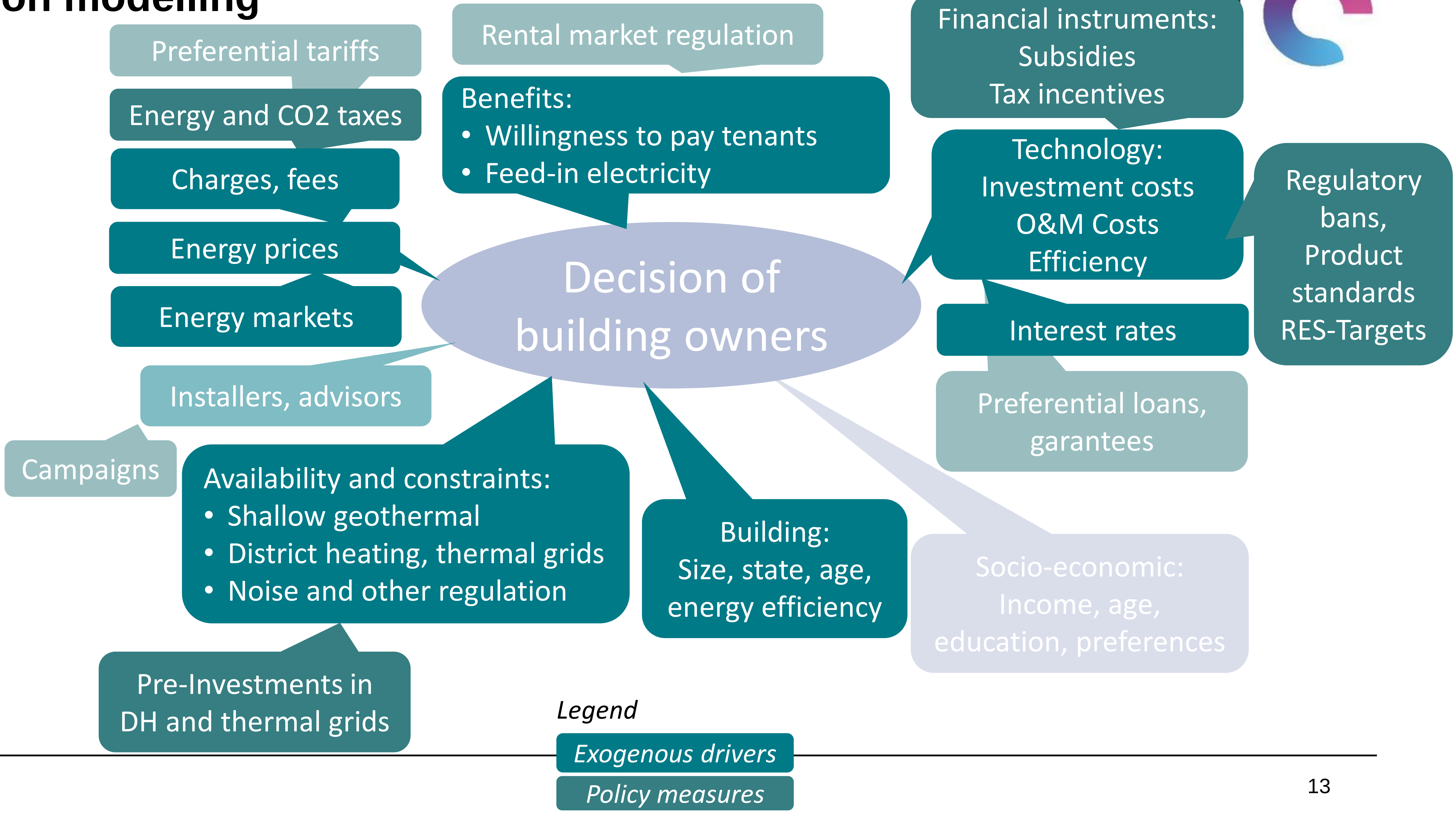
Buildings: Scope

- Includes energy used inside the building, e.g. for heating, hot water, cooking, lighting, appliances
- Final energy:
  - delivered by the gas, electricity or district heating grid, by delivery of fuels.
  - Ambient Heat: tapped by heat pumps from air (air/air or air/water HP), ground/geothermal (brine/water HP) and water (water/water HP). Thus, shallow geothermal heat pumps are included.
- Electricity consumption for heat pumps is accounted separately from ambient heat.
- Electricity:
  - Heat applications (e.g. heat pumps) and other appliances (e.g. lighting)
  - Electric consumption of lighting decreasing due to further diffusion of LED and installation of day-light and occupancy controls in the residential and tertiary sectors.
  - Moderate reduction of electric consumption for other appliances.

FORECAST – Focus Building Sector
Main input parameters

	Residential sector
Main drivers	- No of households - Building area [m²] by type of building and by age class
Prices	- Energy prices - Taxes
Technology data	**Building related data:** - Insulation levels - Heating system efficiency - Heating system and envelop retrofit costs - Lifetime **Appliance data by efficiency class** - Market share - Specific energy consumption - Lifetime - Standby power, Standby hours

Decision modelling



Agora Energiewende

TEP

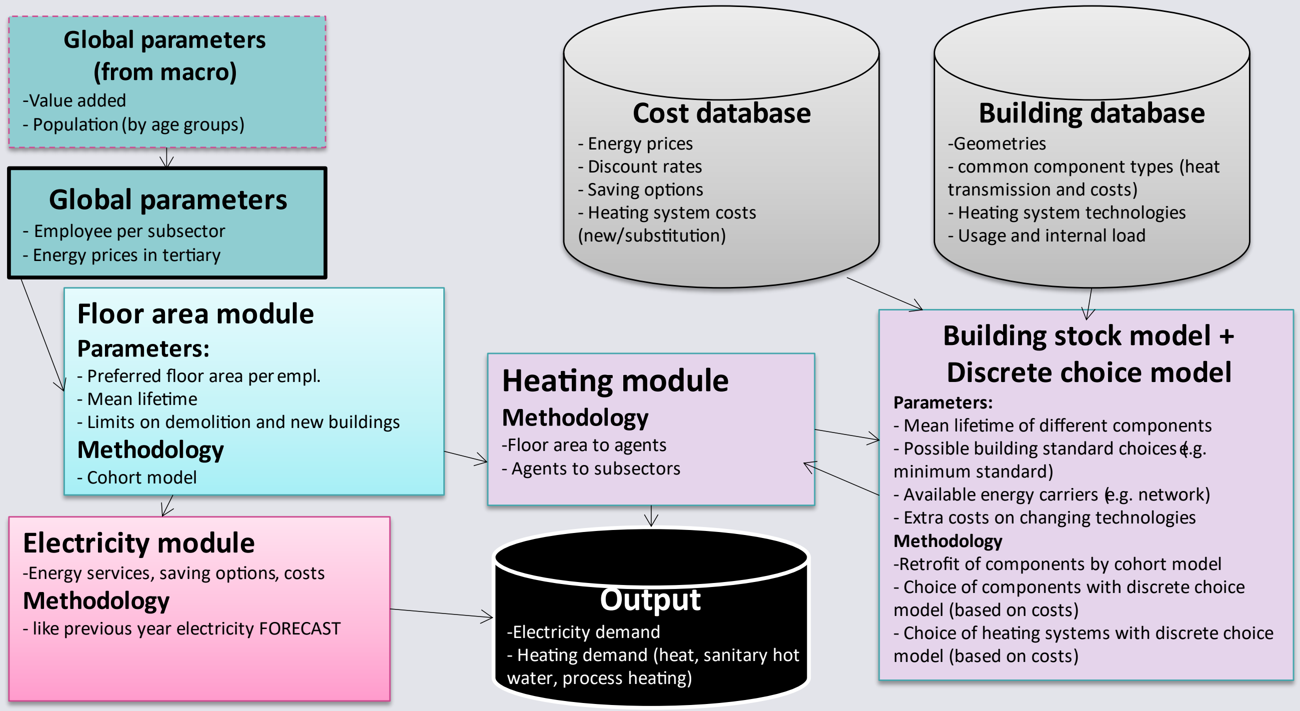
Buildings modelling: input and output

Input	Output

• Population, number of employees
• Specific floor area per employee or person
• Detailed building stock data:
  ○ 2+8 building typologies, 5 age classes
  ○ 4 building elements: walls, windows, roof, basement
  ○ Building codes per building element
  ○ Investment & life-cycle costs of refurbishment measures
  ○ 12+ different heating technologies, incl. costs per technology and replacement type
• Energy carrier prices, Carbon prices, energy taxes and other policy instruments (codes and standards, subsidies, tax incentives, bans/mandatory requirements)
• Potentials and limitations: decentral (thermal) Renewable Energy Sources (RES) and central district heating, infrastructure (cost curve) based on fundamentals gained in other projects (including spatial and topological analysis)
• Calibrated to Eurostat final energy demand for residential and tertiary sector
	• Final energy demand per energy carrier (including DH) and country, per year
	• Specific heat demand per m2 energy reference area
	• Energy related CO2 and GHG emissions
	• Investment costs for refurbishment measures, heating technologies and district heating (DH) infrastructure and heat generation
	• Installation rates for heating systems and envelope retrofit measures

Buildings modelling: FORECAST model

Model and data base



TEP Energy and Fraunhofer ISI

→ Scope

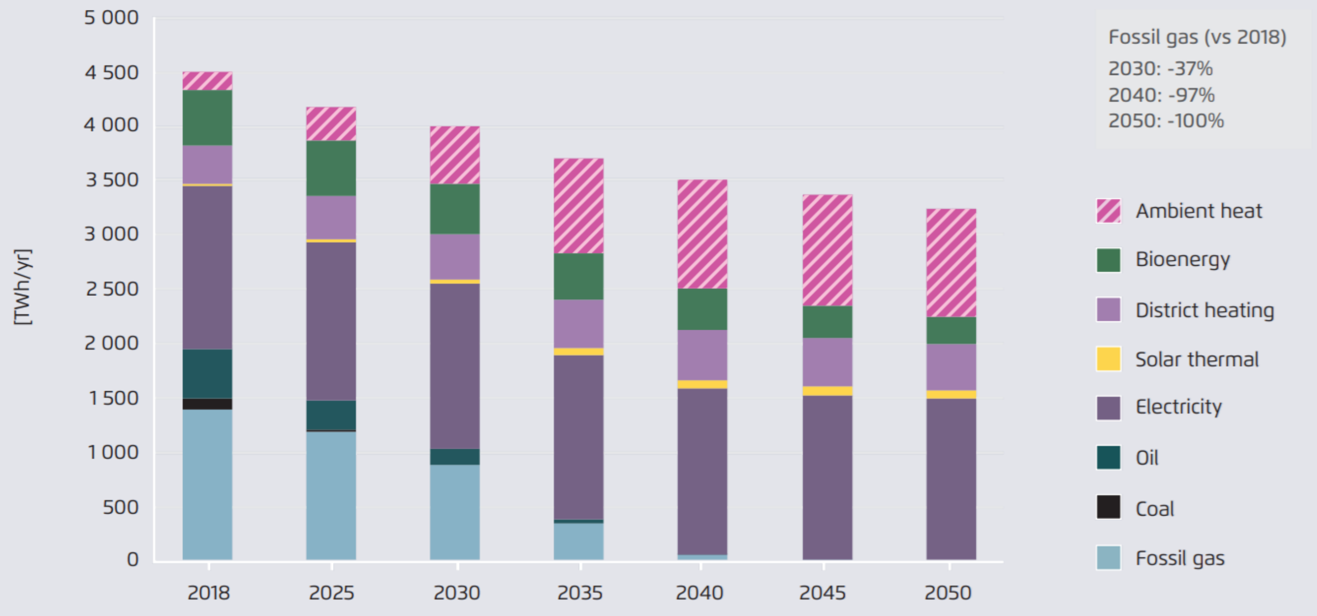
- Residential, services (and industry) sector buildings final heating demand per fuel type, incl. district heating, electricity, fossil gas, hydrogen and biogas, fuel oil and renewable sources
- Development of the building stock in terms of specific heat energy demand differentiated for new and refurbished buildings
- Integration of remaining carbon budgets and emission reduction targets for all countries
- Focus on nine core countries with respect to assumptions (national policies, national targets)

Key policy assumptions for buildings

- **Fossil fuel subsidies:** No explicit fossil fuel subsidies enabled in the modelling.
- **Carbon pricing:** CO_2 price of 39 €/tCO2 in 2027 rising to 49 €/tCO_2 in 2030 and 200 €/tCO_2 in 2040 to reflect an EU emissions trading system for building and transport fuels.
- **Efficiency in buildings:** High energy efficiency standards for the thermal envelope of new construction and existing buildings in line with reinvestment cycles for components. However, no explicit modelling of minimum energy performance standards.
- **Fossil fuels in new buildings:** No fossil fuels allowed in new buildings from 1 January 2027.
- **Fossil heating in existing buildings:** Modelling assumptions simulating ecodesign & energy labelling rules that restrict the installation of fossil heating appliances from 1 January 2027.
- **Coal heating phase-out:** Country specific coal phase-out dates in district heating and individual boilers before 2035.
- **Fossil cooking phase-out:** Phase out of fossil fuels in cooking appliances by 31 December 2030.

Buildings are nearly fossil gas-free by 2040. Efficiency, heat pumps & decarbonized district heating are the key levers for achieving a fossil free building stock.

Total final energy consumption in the buildings sector, EU-27

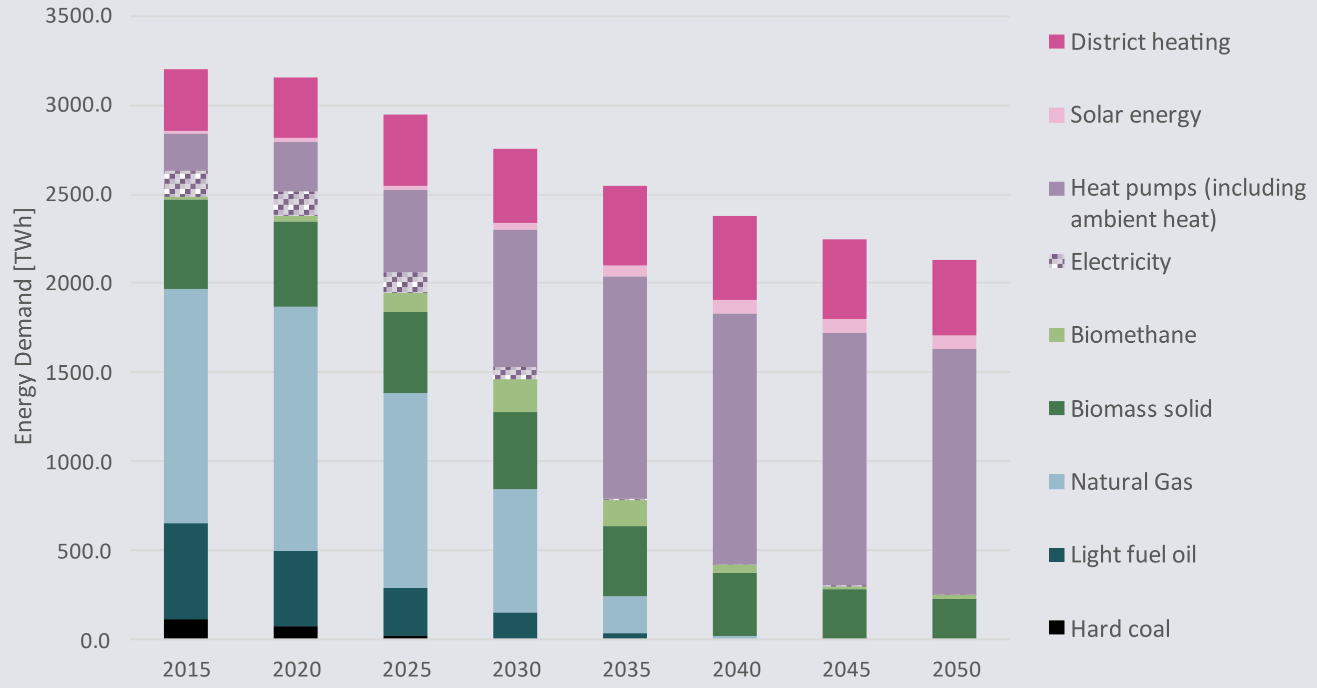


Artelys, TEP Energy, Wuppertal Institute modelling (2023)

- Total final energy demand: reduced by 25% to 30% despite an increase heated floor area (+9.5%)
- Fossil fuel consumption: reduced by 80% by 2035 and almost phased-out by 2040
- Ambient heat tapped by heat pumps drastically increased to cover 30% of buildings' total final energy demand
- HP (ambient heat and electricity) cover about 40% of heating demand in 2050
- District heat is becoming more efficient and expands its market share by 2050
- Other direct renewable heat sources, notably solar thermal and the continued use of bioenergy (though slightly lower) allow for additional gas displacement.

Buildings are nearly fossil gas-free by 2040. Efficiency, heat pumps & decarbonized district heating are the key levers for achieving a fossil free building stock.

Energy consumption of Hot Water and Space Heating in buildings sector, EU-27

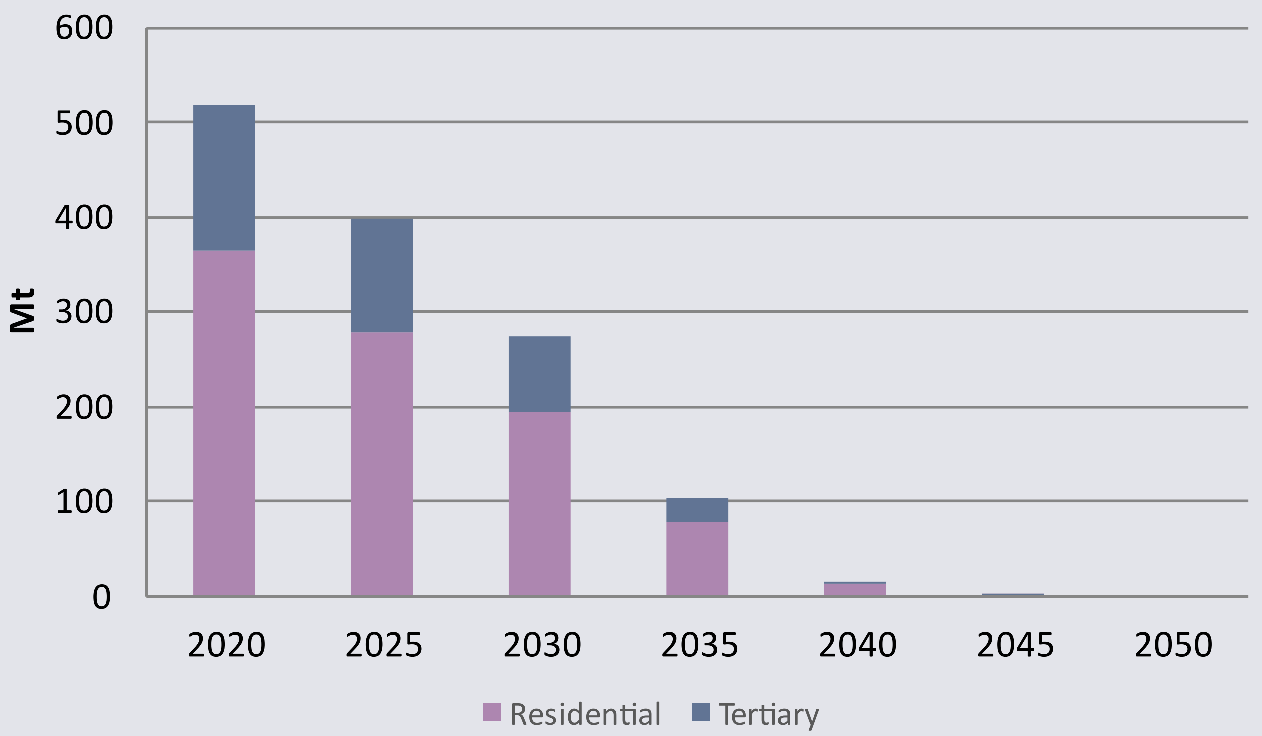


Artelys, TEP Energy, Wuppertal Institute modelling (2023)

- → Fossil energy in 2020 still dominating
- → Accelerated decrease from now
- → Phase-out of fossil energy (coal, heating oil, gas) up to 2035-2040
- → Heat pumps to become the dominating technology after 2030
- → DH increases slightly in absolute terms, a bit more in relative terms
- → This structural change also is enabled by efficiency improvements (retrofit, new buildings)

Greenhouse gas emissions in the building sector – EU-27

Direct GHG emissions in the building sector [in Mt CO2eq] - EU27

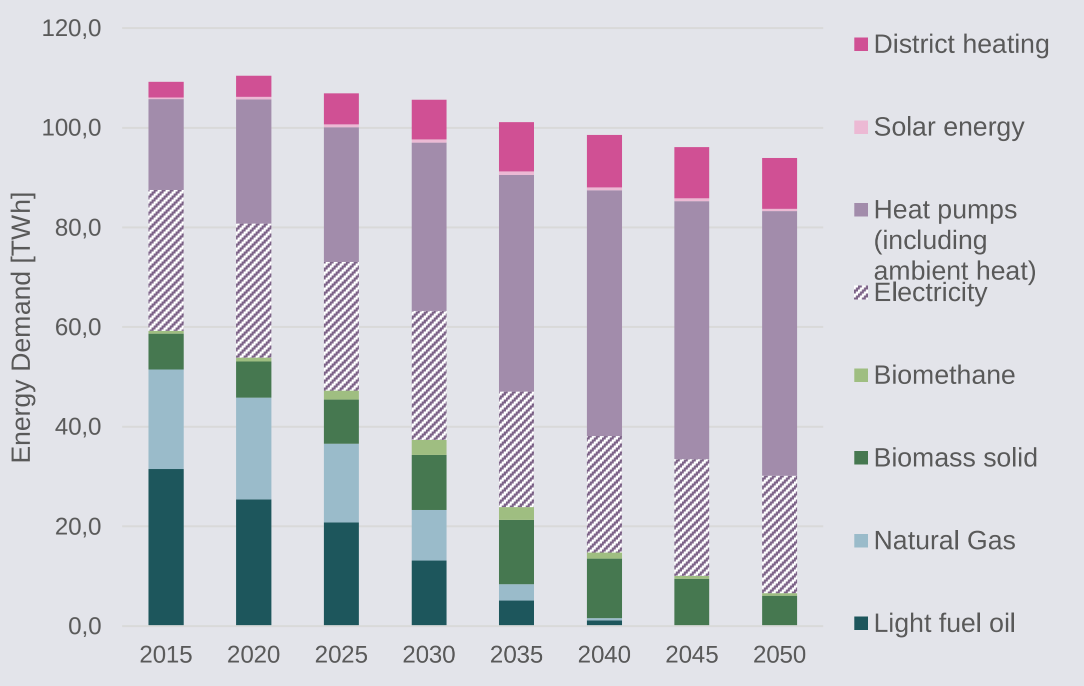


TEP Energy modelling (2023)

- GHG emissions decline by 47% from 2020 to 2030
- The residential sector is responsible for 70% of emissions in 2020 and 2030, rising to 80% in 2040

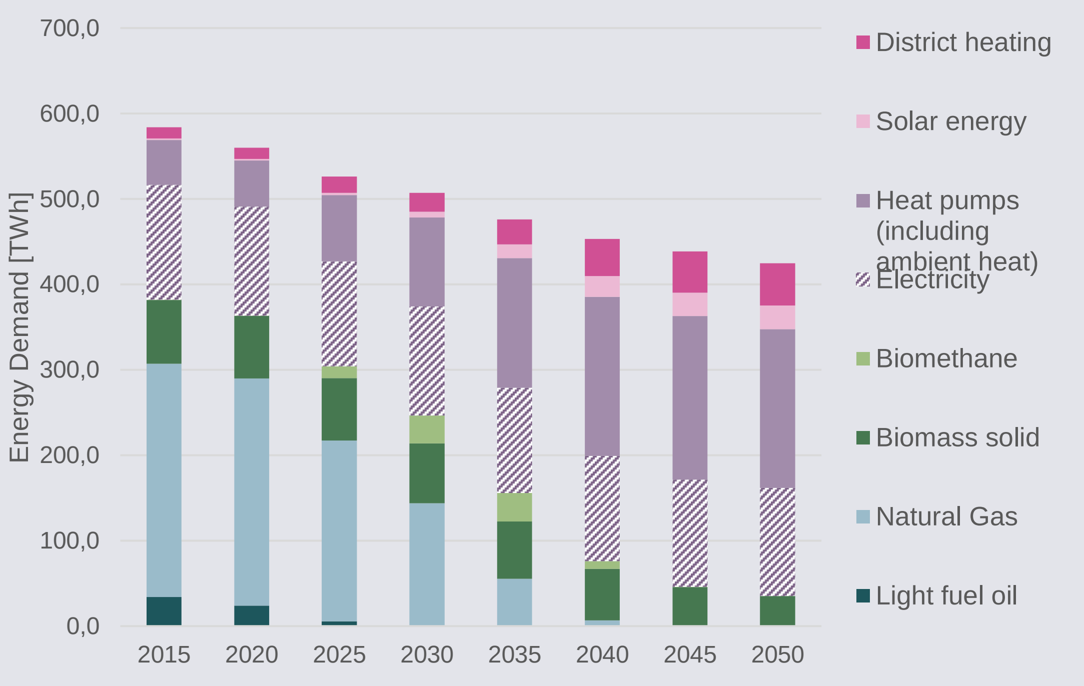
Role of Heat pumps (HP) for achieving a fossil free building stock: historical HP countries and newcomers

Final energy consumption in the buildings sector, Switzerland



Artelys, TEP Energy, Wuppertal Institute modelling (2023)

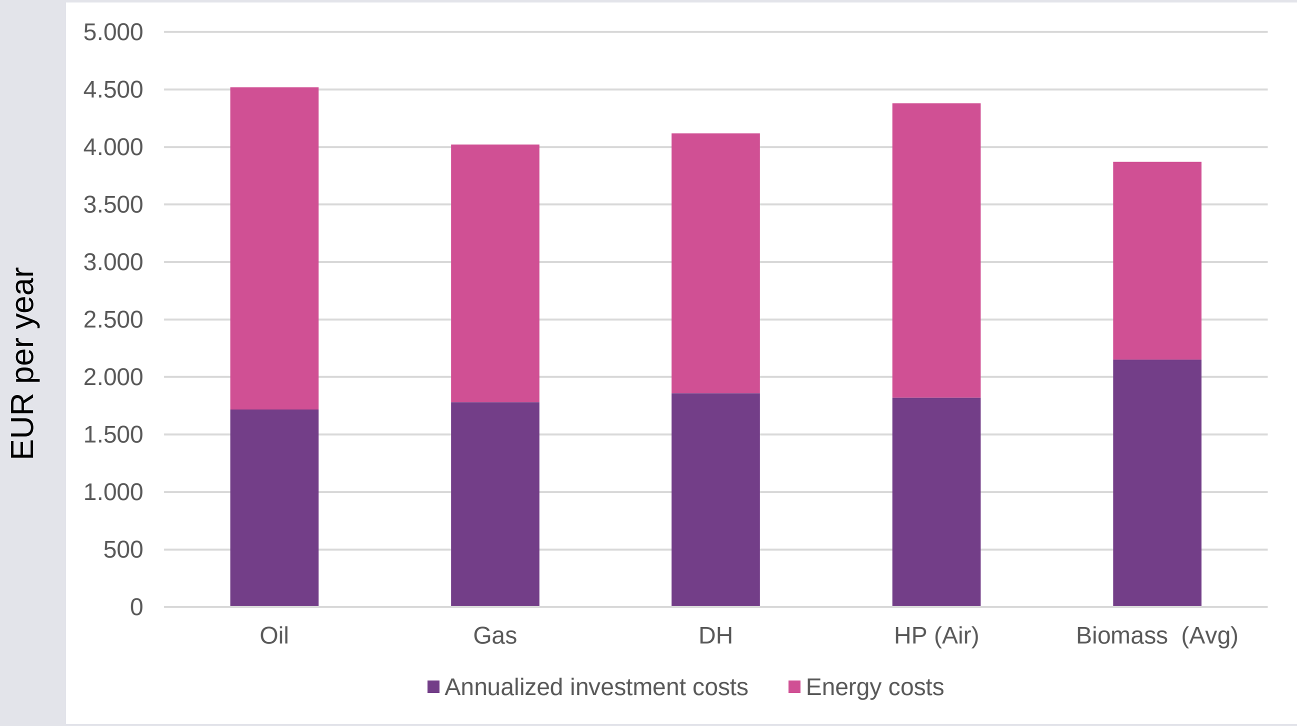
Final energy consumption in the buildings sector, Italy



Artelys, TEP Energy, Wuppertal Institute modelling (2023)

Economics and policy of heating system changes

Annualized heat generation costs SFH: heating system change 2025 - Germany



TEP Energy modelling (2023)

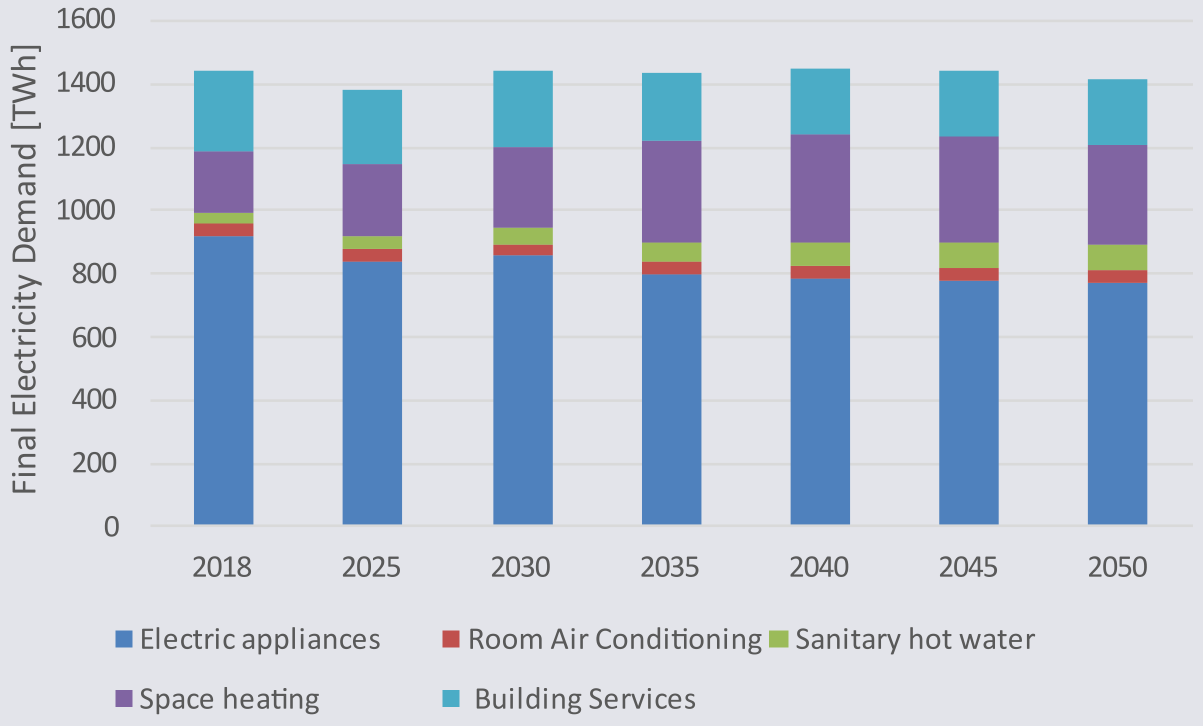
Ranking of heat generation costs of individual heating systems depend on

- → Investment costs of heating systems (by country)
- → Interest rate
- → Technical efficiency
- → Willingness to pay
- → Relative energy prices, including taxes, by country
  - Ratio of electricity price and fuel prices
  - Favourable for HP: ratio <3

Policy measures to foster HP market take-up: Quality assurance (efficiency, noise, quality of installation), preferential tariffs, incorporate HP in building standards and labels

Deep dive: Electricity demand

Final electricity demand in the buildings sectors (EU-27)



Source: TEP Energy (2023)

→ Total development of electricity demand about 1400 TWh, almost constant up to 2050

→ Explained by counteracting effects

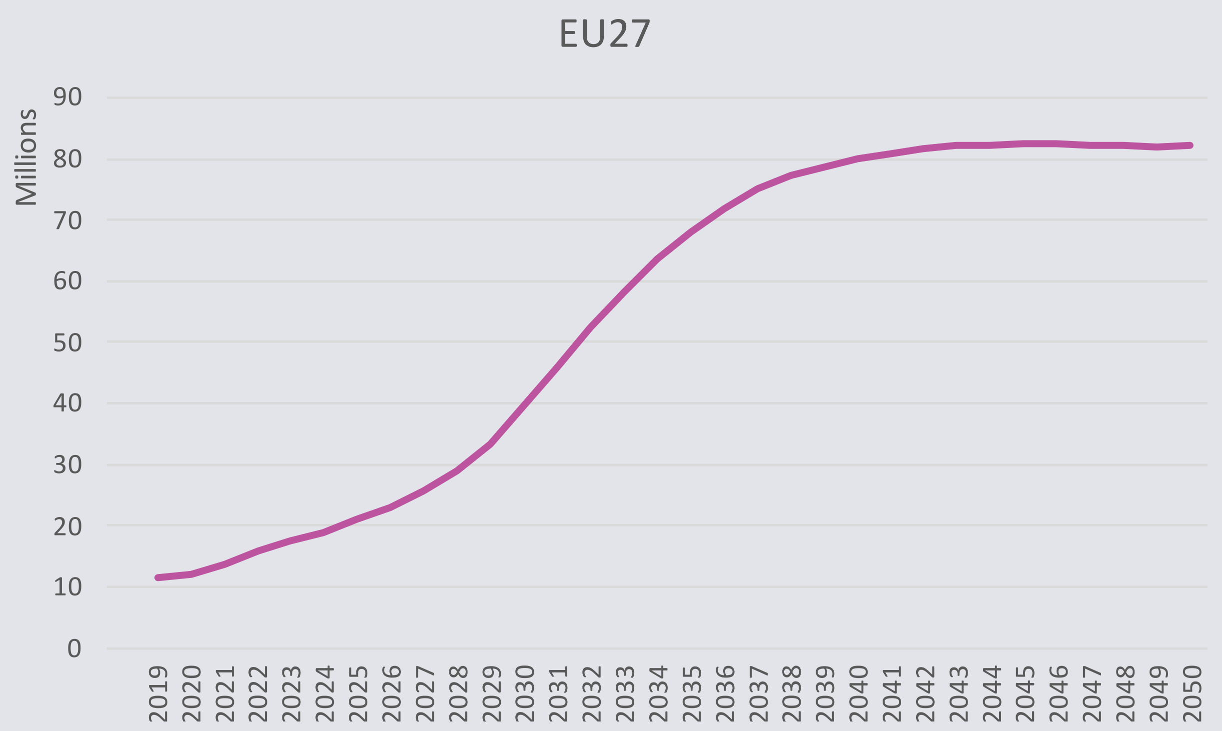
- Electricity demand from space heating: increases from 200 TWh (2020) to 320 TWh (2050)
- Electricity demand from water heating also increases (by 46.5 TWh)
- Electricity demand from appliances and building services including cooling: decrease from ~1000 TWh to 800 TWh

→ Energy efficiency improvements (appliances & buildings) & replacement of older appliances through more efficient technology (e.g. heat pumps) help to keep electricity consumption in check.

→ Note: These results don‘t include EV charging.

Deep dive: heat pumps

Number of Heat Pumps – EU27

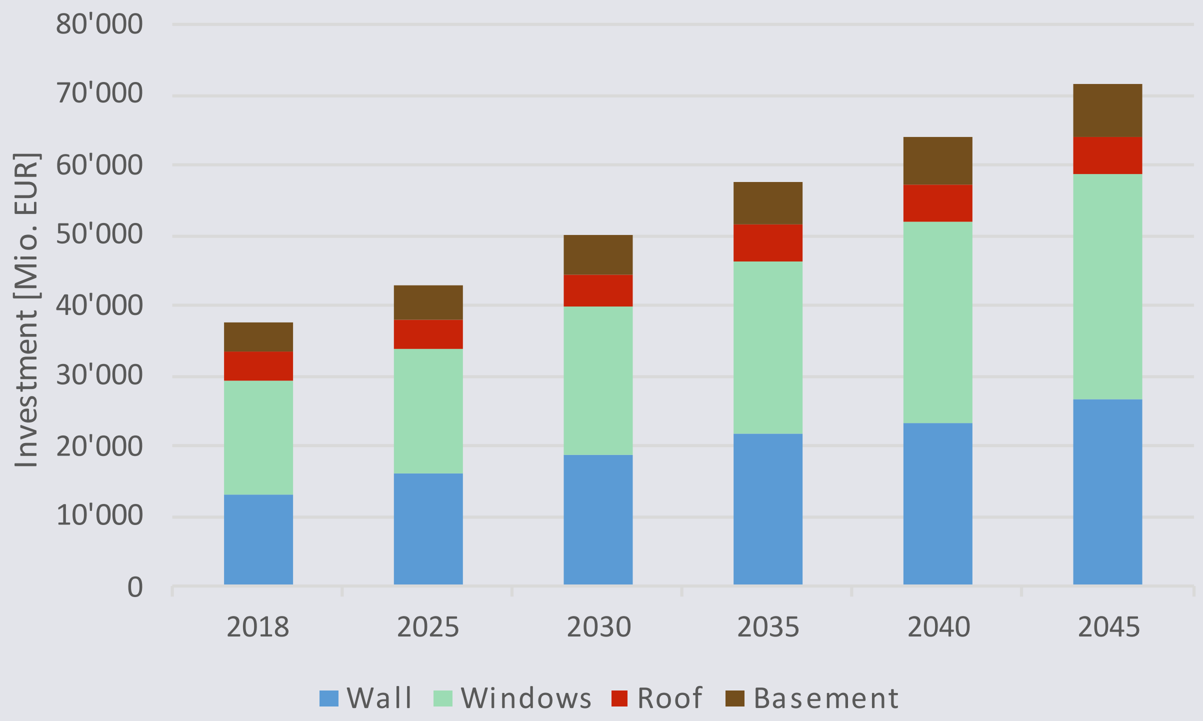


TEP Energy modelling (2023)

- Number of heat pumps increases to 39.6 Mio in 2030, 80 Mio. in 2040 and 82 Mio. in 2050.
- This represents an average increase of 2.75 million heat pumps per year from 2020-2030 and 4 million heat pumps per year from 2030-2040.
- Note: The number of heat pumps are calculated based on the modelled energy demand and aligned with the stock numbers of EHPA. Future higher buildings standards and lower heat demand per building/dwelling is considered by assuming in average smaller HP devices.

Deep dive: building renovations & construction

Investment in Building Components

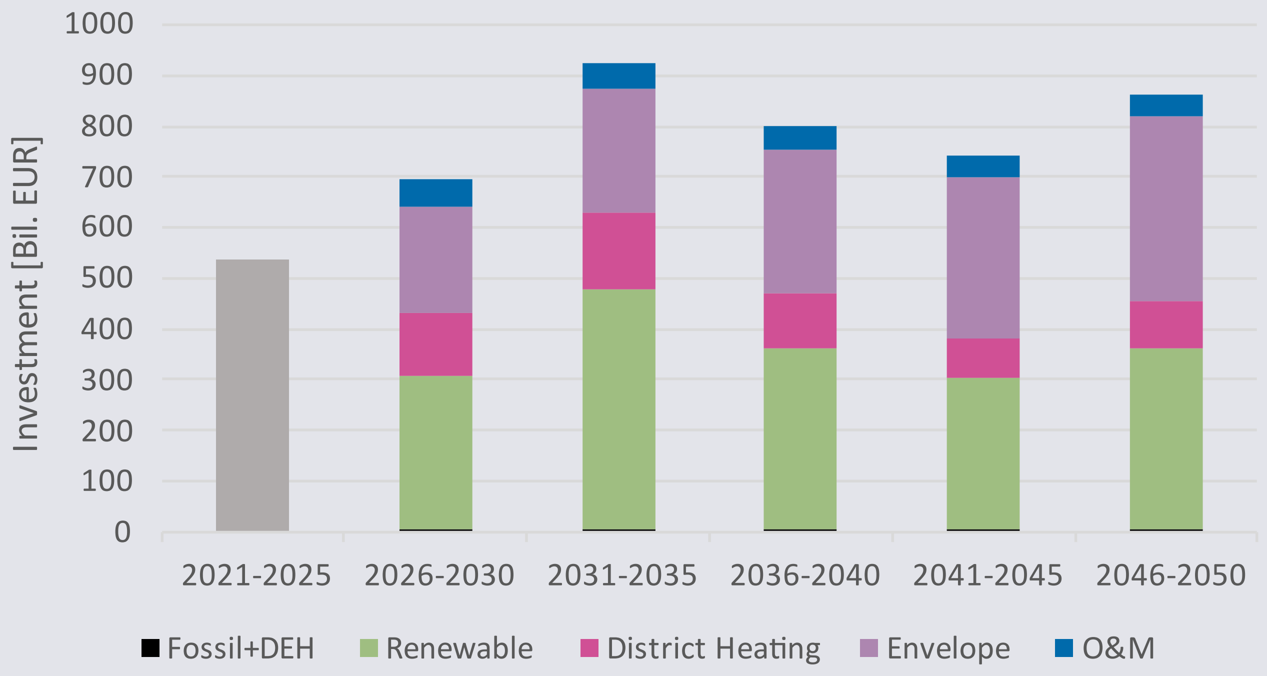


TEP Energy modelling (2023)

- → Improving energy-efficiency of building needs investment into building components: Wall, window, roof and basement.
- → Due to high retrofit rates and high specific costs (per m2), windows are of high relevance
- → Building investments to increase from less than 40 bn EUR to more than 70 bn EUR
- → As a result of these investments, specific energy demand in existing buildings is substantially reduced by about
  - 10% between 2020 and 2030
  - 20% between 2020 and 2040

Total investment needs for the buildings sector

Sum of overnight investments into buildings during 5-year periods, EU27



Source: TEP Energy

- Decarbonisation needs investment into Renewable Energy Systems (RES) and energy-efficiency (building envelope).
- Total investment in buildings to be increased, especially up to 2035
- No investments into fossil energy systems and Direct electric heating from 2027
- Building envelope investments remain relevant, also for value preservation
- District heating (inside & grid estimate)

District Heating

District heat: is it useful, is it needed and if yes, why?

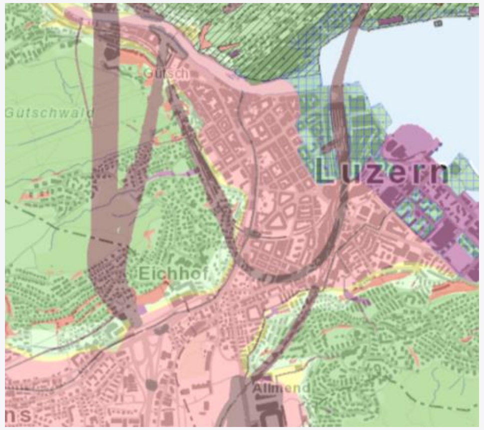
Two types of motivation	Two examples of constraints

Two types of motivation

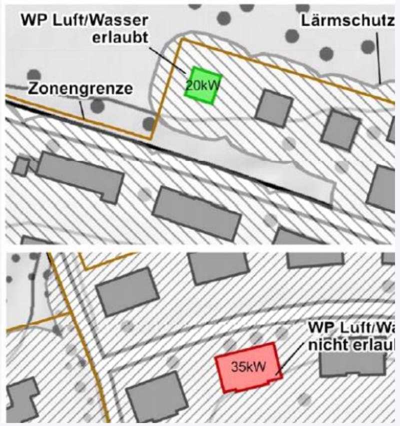
- → Positive motivation:
  - Favourable energy density
  - Low cost solution for building owners
  - Few actors to decarbonise building stock
- → Decentralized systems
  - Renewable energy potentials limited
  - Constraints: space, noise
  - Might be more costly
  - A lot of actors (building owners) to be convinced

Two examples of constraints

Borehole HP not allowed ground-water areas

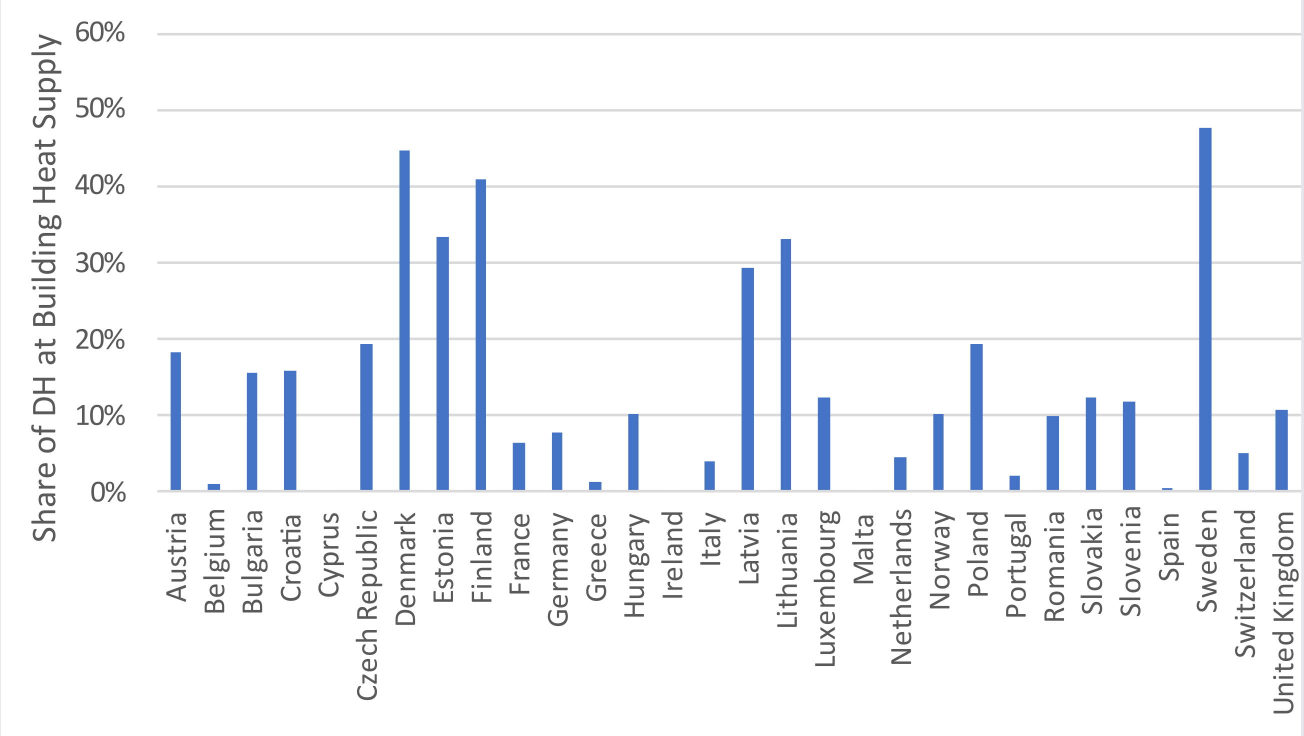


Air/water HP emit noise in and need space



District heating (DH): starting from very different sitations

Share of DH at Building Heat Supply in 2020



TEP Energy and Wuppertal Institute (2023)

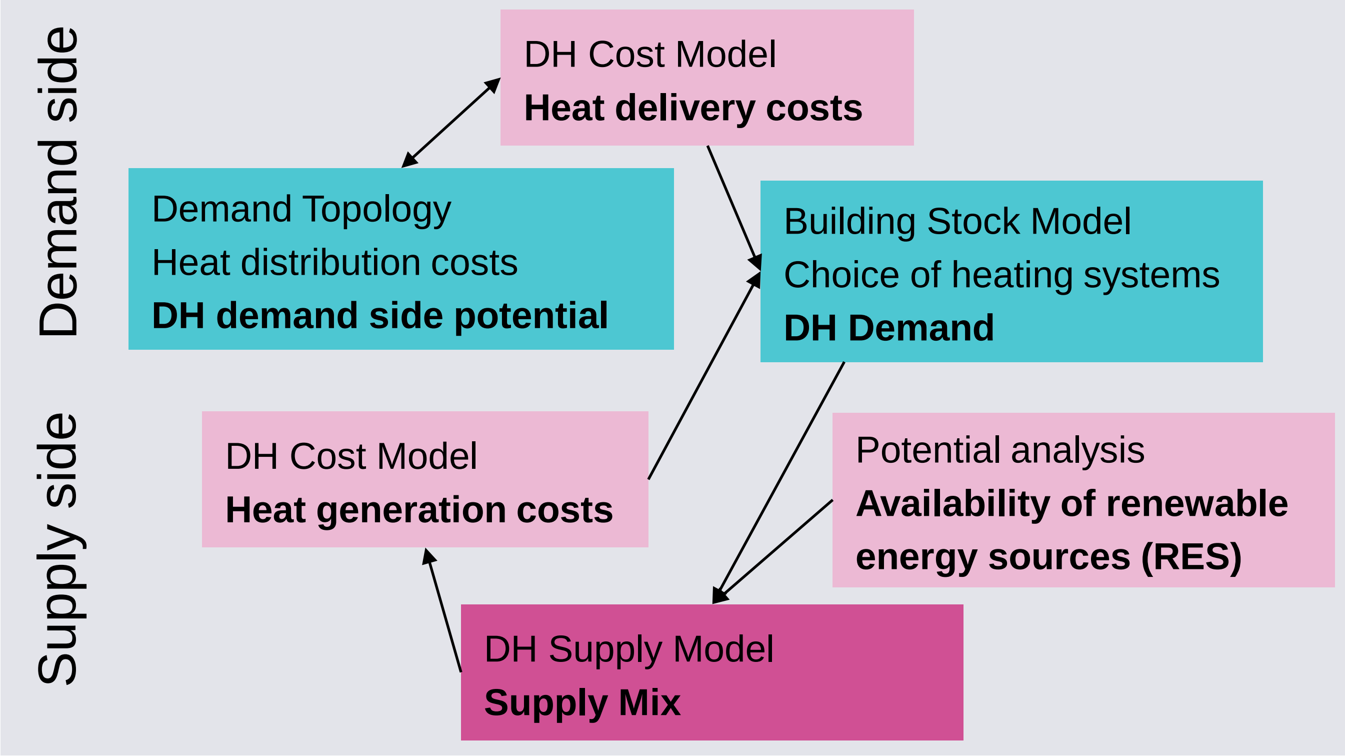
Two types of countries (focus on 9 national partners):

→ Historical experience countries (PL, CZ, BG) :
  - to lower DH temperature to accommodate RES
  - to get DH provision more efficient
  - to keep and slightly increase DH coverage

→ "Newcomer" counties (IT, GR, HR, HU, RO, SI):
  - to increase DH coverage
  - mainly in cities where decentral renewable energy systems are a challenge (limited potentials, noise restriction, env. protection)

DH modelling: demand and supply

Conceptual modeling approach DH generation and provision



TEP Energy and Wuppertal Institute (2023)

Demand side :

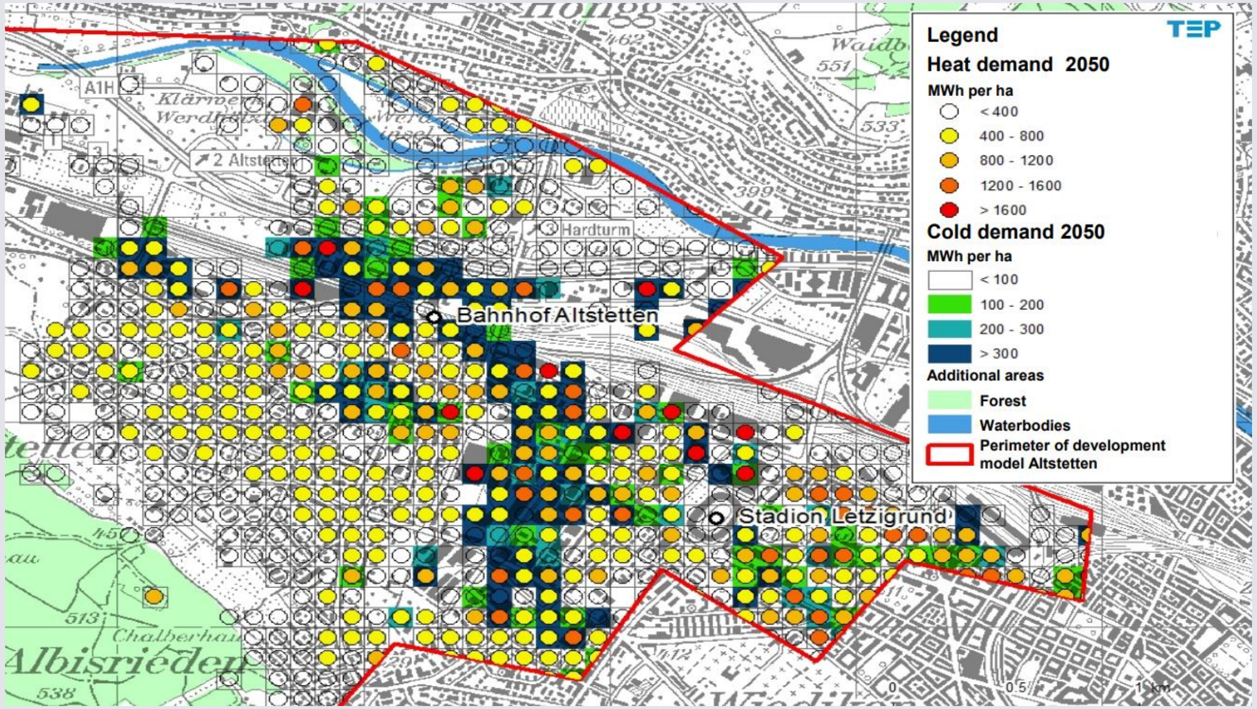
- → Heat distribution costs
- → Constraints (depending on topology of built environment)
- → Decision of owners to connect (also depending on competitiveness of decentral alternatives)

Supply side

- → Potentials
- → Heat distribution infrastructure
- → Heat generation costs
- → Actor to build up and operate DH infrastructure

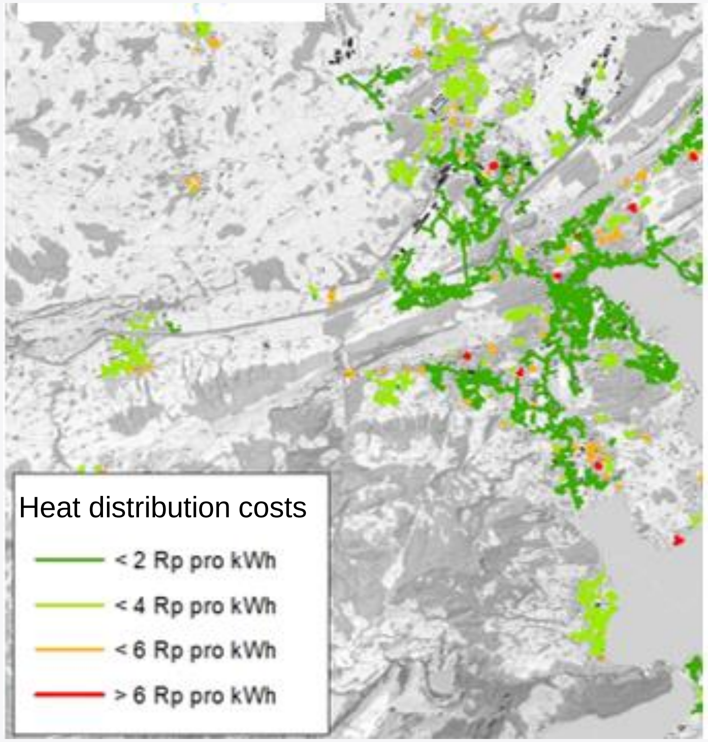
District heat: spatial energy analysis demand side

Example of thermal heat and cold demand



TEP Energy (2023)

Demand side potential as a function of heat distribution costs



Topology resulting from spatial energy analysis

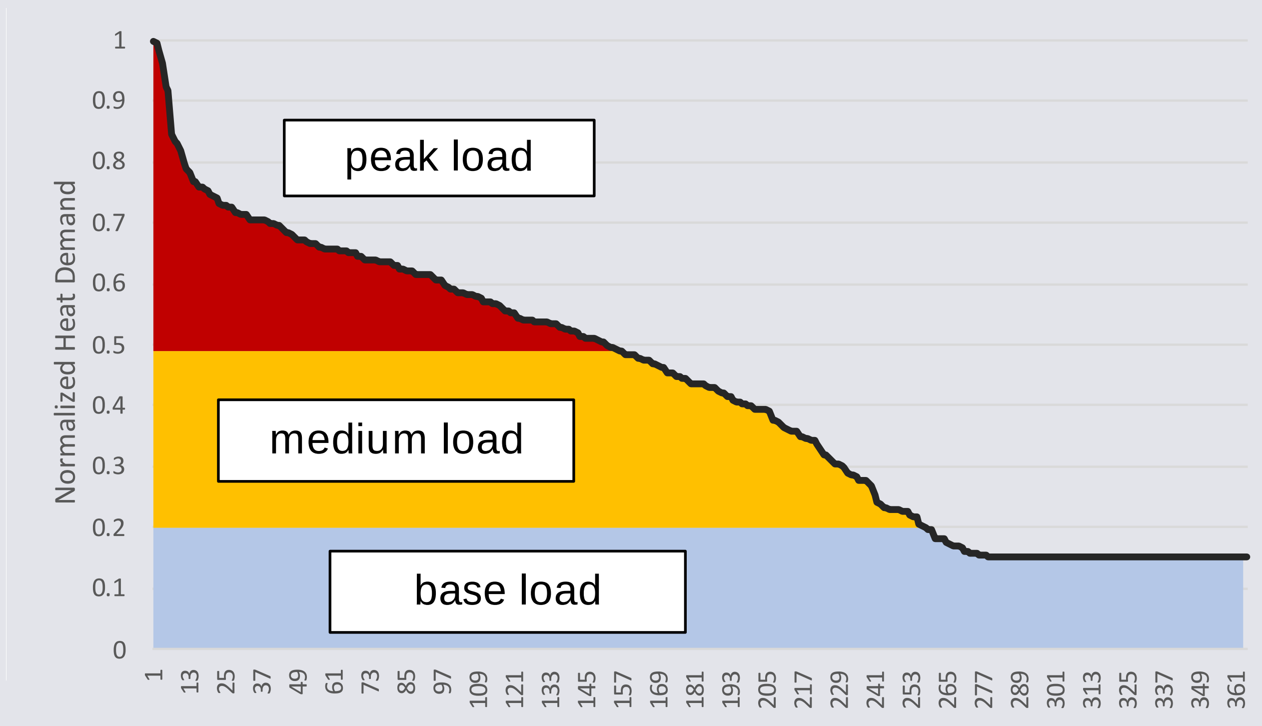
Municipalities in Switzerland with more than 10’000 inhabitants
Share of energy floor area

	Assumed marginal costs of heat distribution Low	Medium	High
Only thermal grids (decentral solutions constraint)	17 %	23 %	24 %
Thermal grids & decentral solutions (geothermal, air)	35 %	63 %	71 %
Decentral solutions: geothermal and air	16 %	6 %	3 %
Decentral solutions: only air	6 %	2 %	1 %
Decentral solutions: only geothermal	18 %	4 %	1 %
None of them	8 %	2 %	1 %
Total	**100 %**	**100 %**	**100 %**

Quelle: eigene Berechnungen TEP Energy

District heat generation: smart energy concept

Illustration of assumed heat supply logic



TEP Energy (2023)

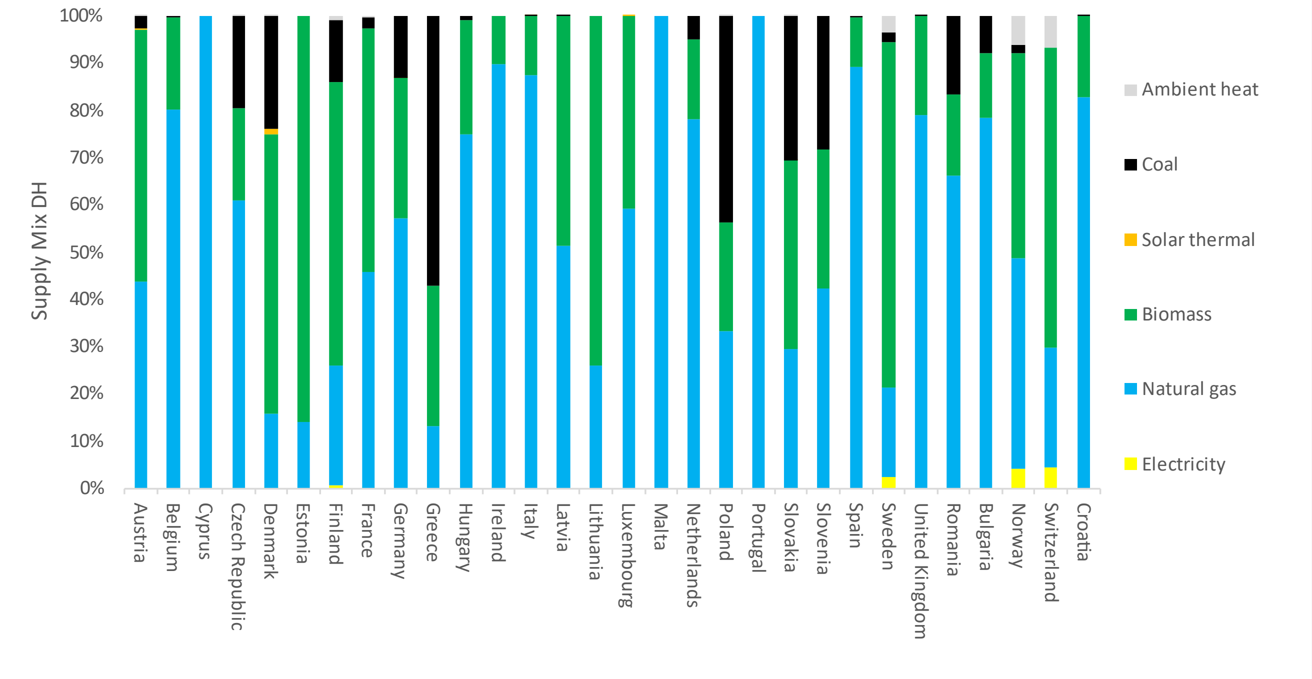
- The district heating supply modelling covers the full mix of technologies needed to cover the heat supply for base and peak load.
- Heat pumps, solar thermal, geothermal and waste are assumed to be covering the base load.
- Peak load is assumed to be provided by gaseous energy carriers and direct electric applications for a yearly energy share of 15-20%.
- Hydrogen and biogas/biomethane are assumed to be used in district heating as peak load technologies.
- Solid biomass is assumed to be covering a medium range of heat supply between base load and peak load.

District heat: Background note for interpreting the results

- → Includes energy that is used on site in heat generation for district heating. Grid losses are included.
- → Includes heat generation from CHP and heat processes
- → Ambient Heat in DH is the source for heat pumps and can be from the air (air/air or air/water HP) or from the ground or ground water (water/water HP)
- → Deep geothermal heat that can be used for district heating without the need of heat pumps is accounted separately.
- → Electricity for heat applications is shown, whereas primary energy for producing electricity is balanced in the energy sector.
- → In some cases, country specific restrictions (via limits to consumer *willingness to pay*) based on expert judgement were applied to avoid overshooting the deployment potentials for district heating. Without adjusting the model assumptions, DH would not be competitive to other heating systems in some countries.

District heating (DH): starting from very different sitations

Share of DH energy provision mix

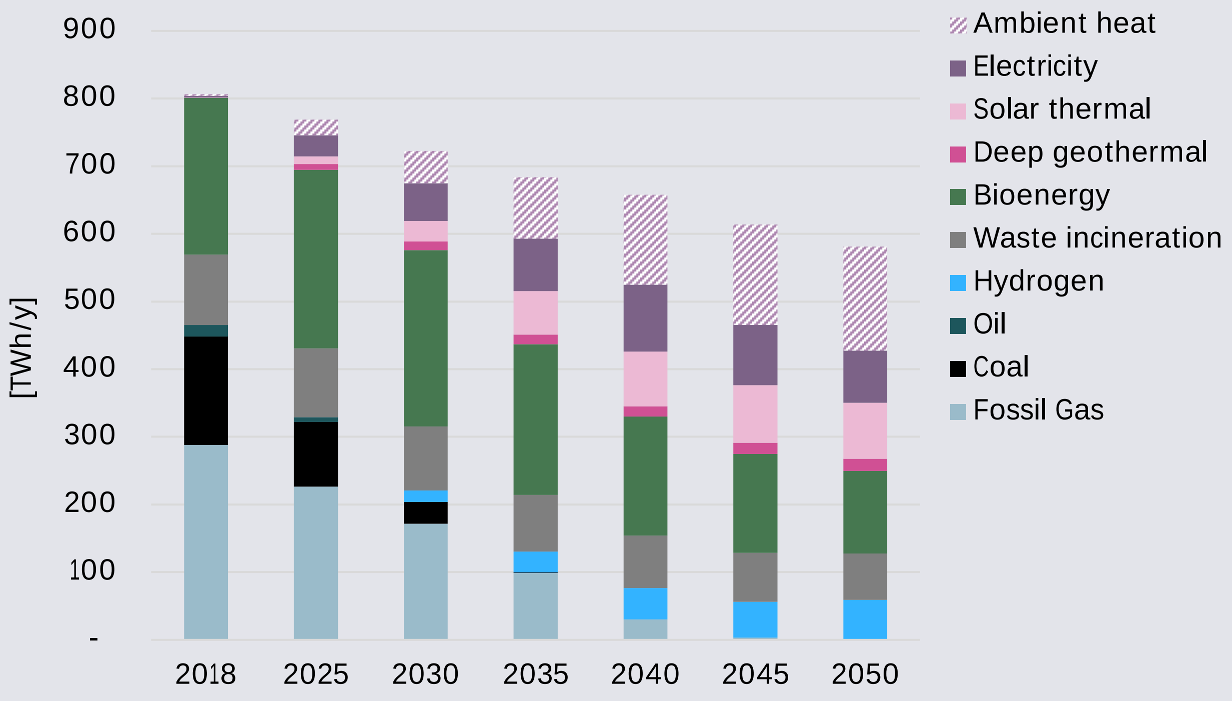


TEP Energy and Wuppertal Institute (2023)

- → Gas is dominating in many countries
- → Coal important in some countries (e.g. Poland, Slovakia, CZ, Greece)
- → Biomass: important role in selected countries (e.g. Nordics, Baltics, Switzerland)
- → Ambient heat / heat pumps still negligible

District heat supply can become more efficient despite an increase in heated surface by 2050.

Final energy delivered by district heating, EU-27

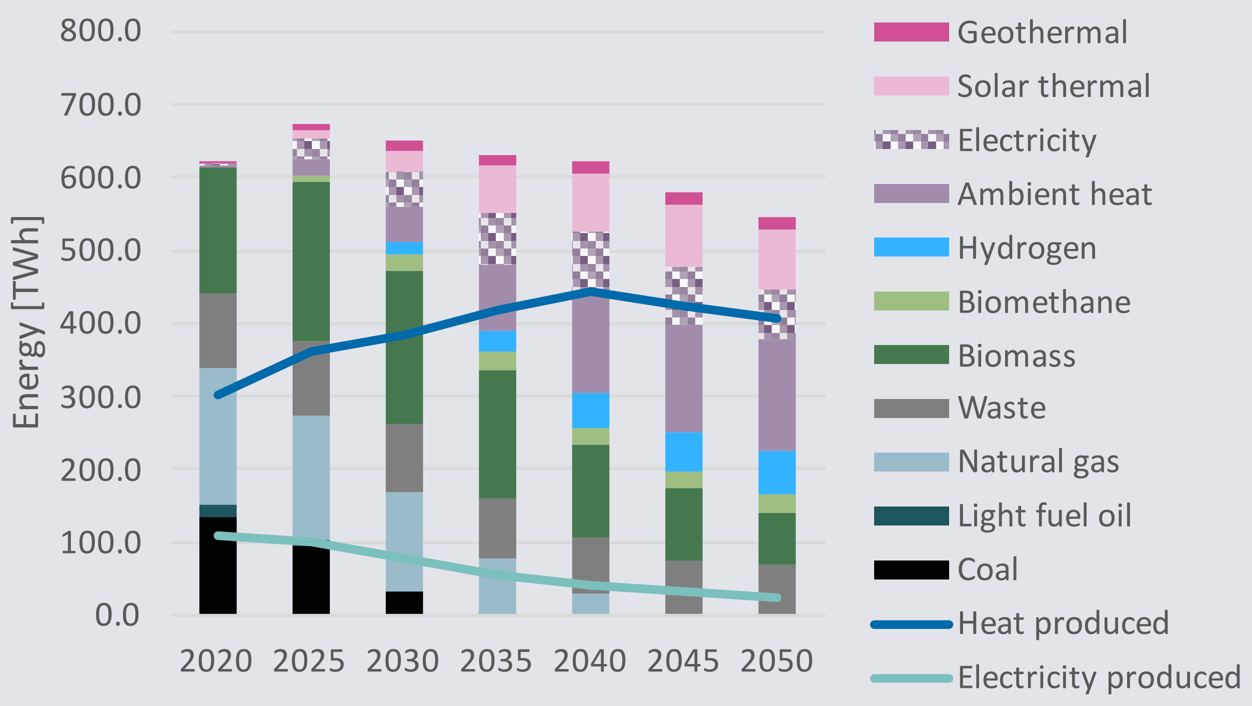


Artelys, TEP Energy, Wuppertal Institute modelling (2023)

- In 2018, the district heating supply mix is dominated by fossil gas (36% of the total), biomass (29%), coal (19%) and waste (13%)
- District heating sees a quite linear reduction in fossil-gas demand over time, declining by 40% from 2018 to 2030 to 170 TWh, and by 90% by 2040.
- Coal is phased out by 2035.
- Fossil fuels are gradually replaced by heat-pumps and solar thermal. These technologies account for roughly 50% of the energy consumption by 2050 if considering ambient heat.
- Hydrogen starts playing a role in 2030 to replace fossil gas, while biomass declines, from 265 TWh in 2025 to 120 TWh in 2050.

Energy consumption in district heating plants

Energy consumption (input) in district heating systems, EU-27

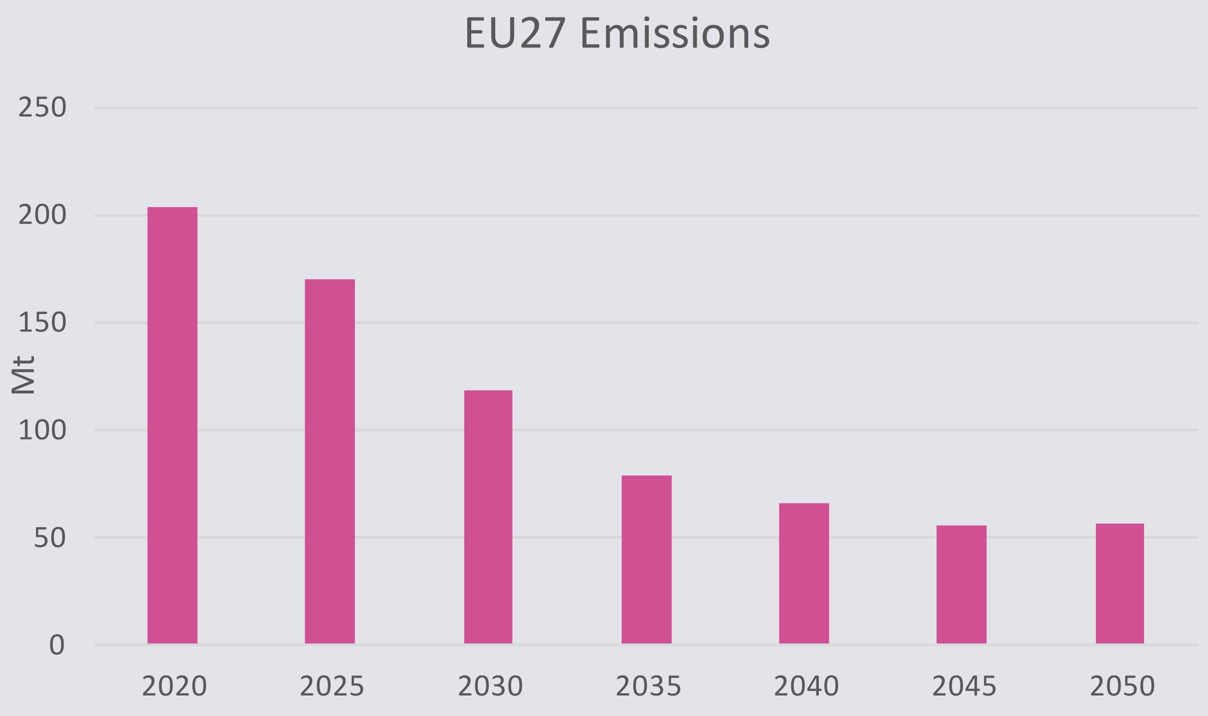


TEP Energy

- Floor area served by district heating rises by more than 2/3 between 2020 and 2030 (+68% vs 2020 levels) and more than doubles by 2040 (+107%).
- However, energy consumption only increases by 17% until 2030 and 33% by 2040 thanks to efficiency improvements.

Greenhouse gas emissions in district heating – EU-27

Direct GHG emissions in the DH sector [in Mt CO2eq] – EU27

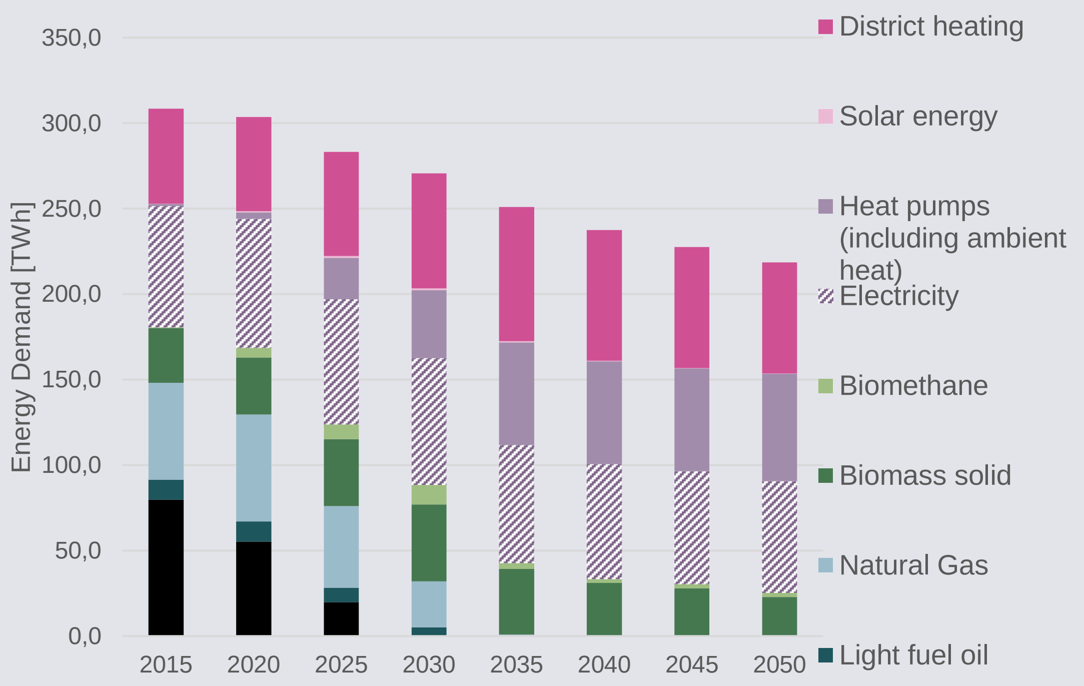


TEP Energy modelling (2023)

- GHG emissions decline by 72.4%
- District heating generation sees steady reduction in fossil gas demand over time, declining by 40% in the period from 2018 to 2030, reaching 90% reduction by 2040 and nearly phasing out by 2045.
- The slightly slower fossil gas reduction before 2030 can be explained by growing demand for district heating, as more homes are connected to new and existing district heating networks to displace fossil gas in decentralised heating.
- Remaining emissions from waste treatment plants (could by captured and stored)

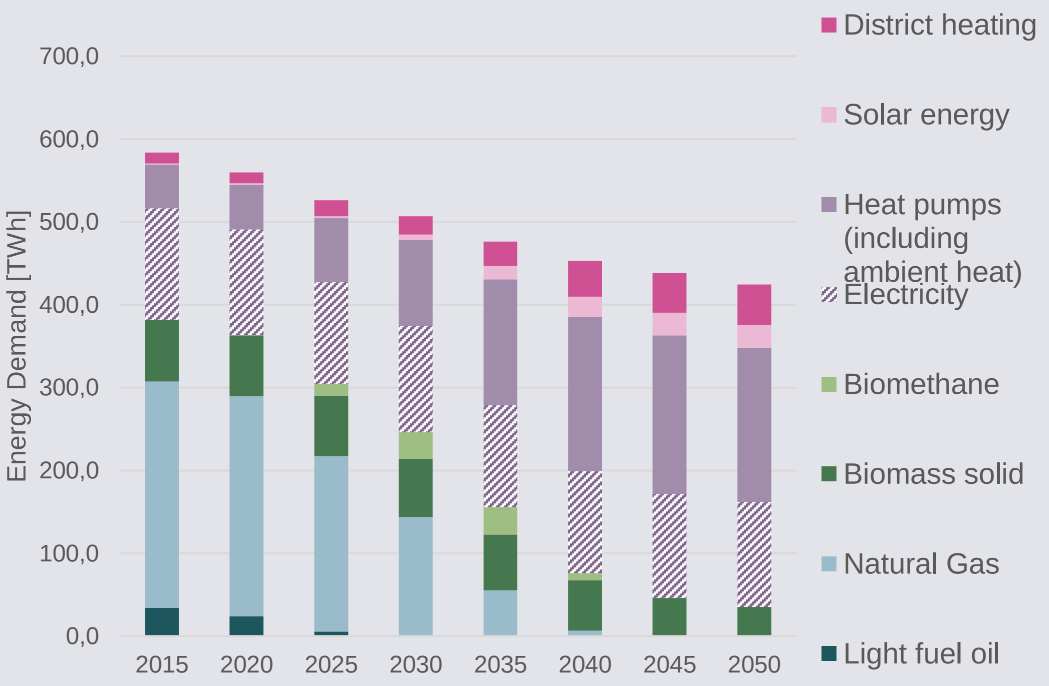
Role of district heating for achieving a fossil free building stock: historical DH countries and DH “newcomers”

Final energy consumption in the buildings sector, Poland



Artelys, TEP Energy, Wuppertal Institute modelling (2023)

Final energy consumption in the buildings sector, Italy



Artelys, TEP Energy, Wuppertal Institute modelling (2023)

District heating: conclusions

- → Part of the decarbonisation solution, especially in situations where decentral systems are constraint
- → Could be an opportunity for energy utilities (convert gas business to DH business
- → Challenges:
  - Needs time and investments
  - Structural situation and interests of players
    - Utilities to convert their business
    - Integrated vs. specialized single energy providers (e.g. gas)
    - Dual or triple role of (local) governments: authorities, tax recipients, owner
- → Policy measure and regulation

Agora Energiewende
Anna-Louisa-Karsch-Str.2
10178 Berlin

T +49 (0)30 700 1435 - 000
F +49 (0)30 700 1435 - 129

www.agora-energiewende.de

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Kontaktieren Sie mich gerne:

Andreas.graf@agora-energiewende.de
Martin.jakob@tep-energy.ch
Michael.steck@tep-energy.ch

Agora Energiewende ist eine gemeinsame Initiative der Stiftung Mercator und der European Climate Foundation.

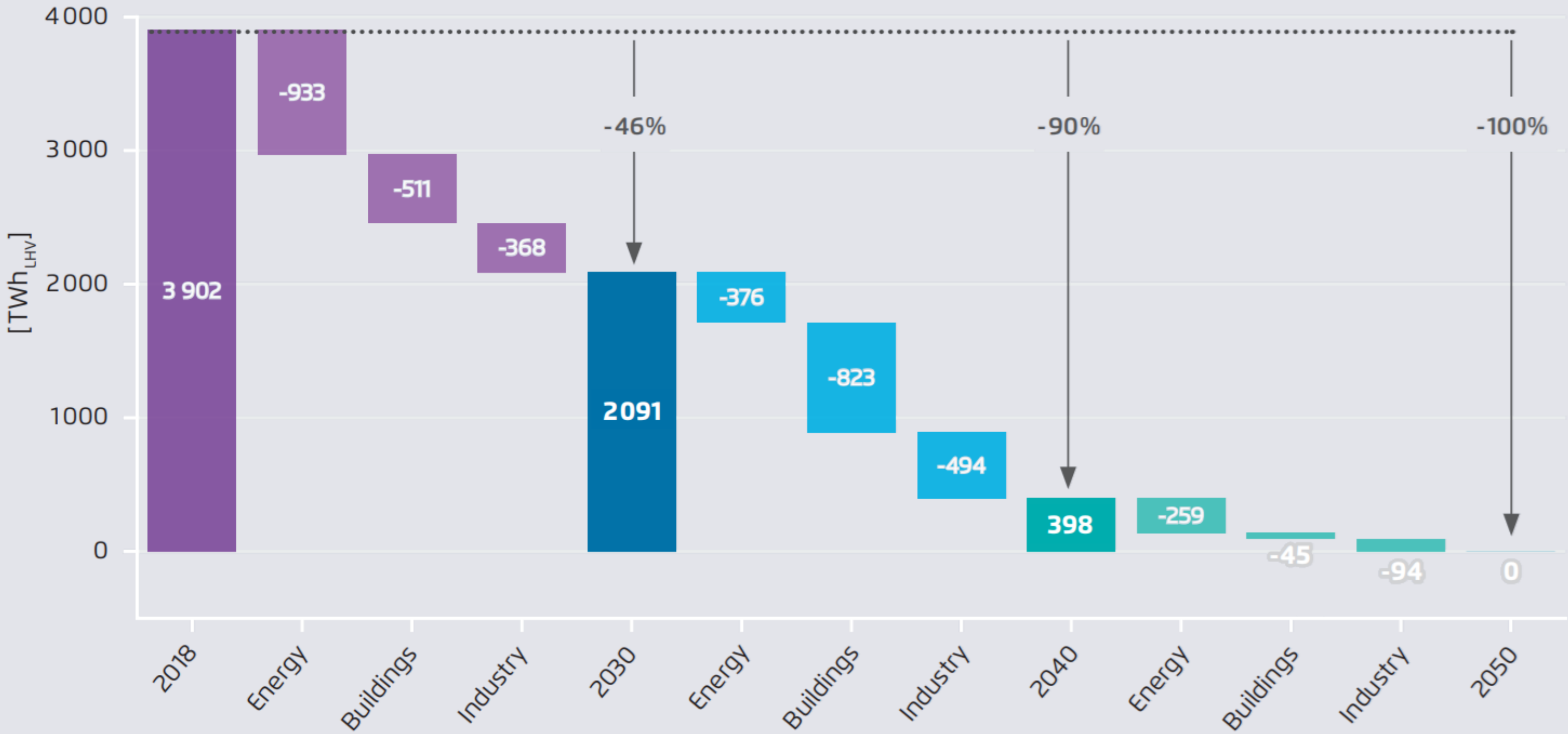
Annexes

«Breaking free from fossil gas»
Key messages

1	Fossil gas use in Europe can be halved by 2030 and completely phased out by 2050. This is possible while maintaining today's level of industrial production and fully ensuring security of supply, without disruptive behavioural changes. The phase-out requires a fast ramping up of energy efficiency and renewable energy, as well as the electrification of applications in the buildings and industry sectors.
2	By 2040, EU greenhouse gas emissions could decline by 89% relative to 1990 levels, with a projected remaining Union greenhouse gas budget for the 2030-2050 period of 14.3 Gt. The sectoral transition pathways developed in this report show that based on latest technological progress, an EU greenhouse gas reduction target of -90% by 2040 is realistic. It would avoid 3.3 Gt more greenhouse gas emissions than projected in the EU's 2020 Climate Target Plan.
3	Europe will need a significant amount of renewable hydrogen to become climate neutral, but the demand by 2030 could be only a fifth of that foreseen in REPowerEU. By prioritising direct electrification and reserving its use for no-regret applications, the EU would need only 116 TWh of renewable hydrogen by 2030, compared to 666 TWh in REPowerEU. This is more cost-effective, more realistic from a security of supply perspective and consistent with the hydrogen sub-targets in the new Renewable Energy Directive. The REPowerEU target should thus be revised.
4	EU rules on gas, hydrogen, and infrastructure planning must reflect the projected rapid decline in fossil gas demand. (1) A new impact assessment is needed for the EU gas and methane package. (2) Governments should evaluate the impact of the decline in gas demand on gas supply and distribution infrastructure, and when updating their National Energy and Climate Plans. (3) The sale of new fossil gas-burning equipment in buildings should end quickly.

Fossil gas use in Europe, a focus of this study, can be halved by 2030 and completely phased out of the EU energy system by 2050 with structural demand reduction measures only.

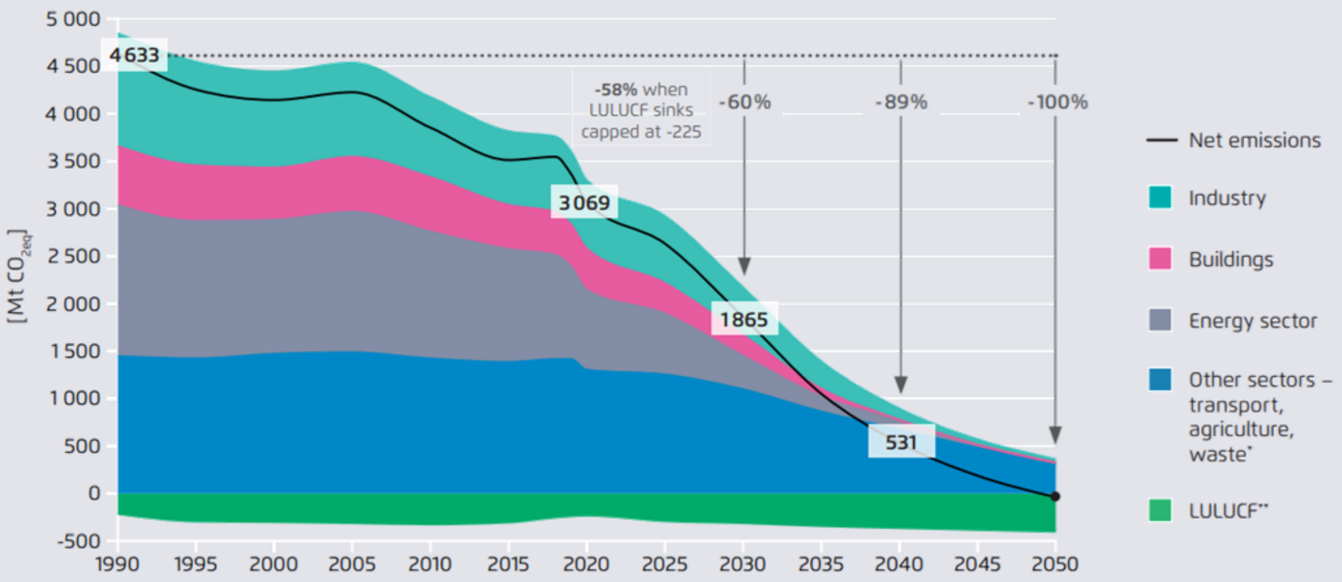
Evolution of total fossil gas consumption in the EU-27, 2018-2050 (in TWh_{LHV})



Artelys, TEP Energy, Wuppertal Institute modelling (2023)

Accelerated GHG reductions can be achieved with the right investments starting today: net-GHG emissions reductions of -60% by 2030, -89% by 2040 and -100% by 2050

GHG emissions by sector in the EU-27



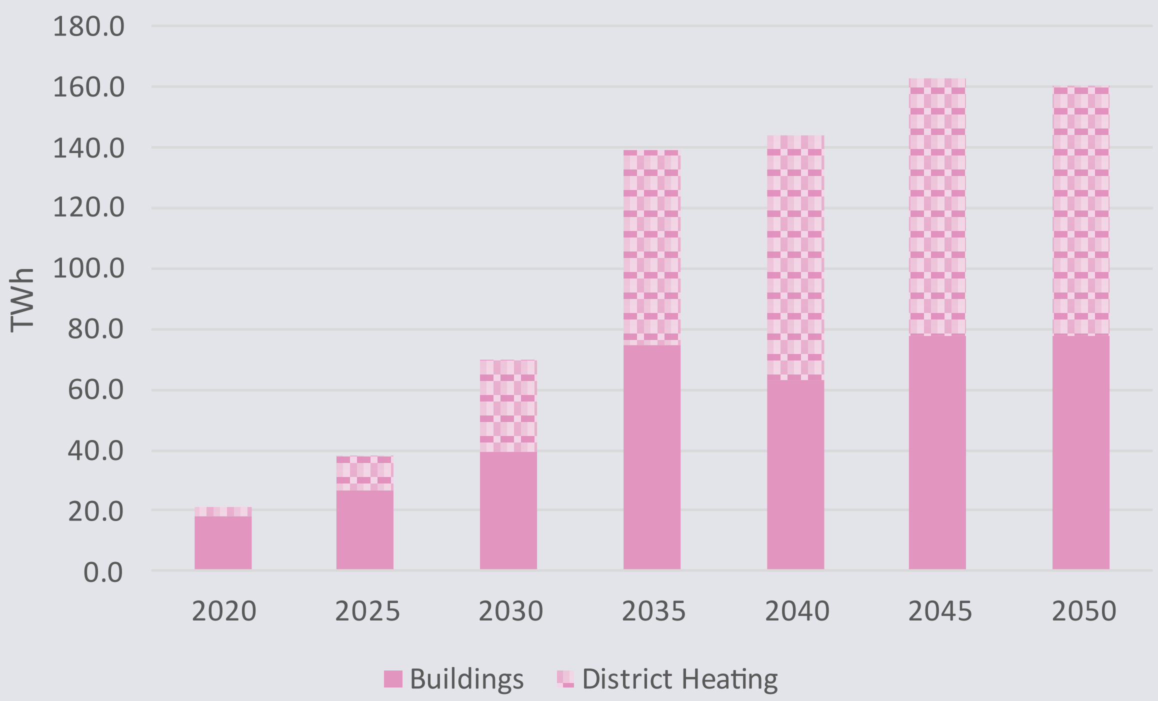
Eurostat; Artelys, TEP Energy, Wuppertal Institute modelling (2023)
* Based on scenarios by Transport & Environment (Transport) and the European Commission (Agriculture & Waste)
** Based on the LULUCF+ scenario from the EC Climate Target Plan impact assessment (assumes a 5-year delay)

- A target of -90% by 2040 would avoid 3.3 Gt more GHG emissions than projected in the EU's 2020 Climate Target Plan.
- Transport, agriculture, waste and LULUCF covered by existing studies by Transport & Environment and the European Commision: Additional efforts in these sectors could achieve further reductions by 2040.
- Broadly speaking, the last 10% of residual emissions will be the hardest to mitigate

Deep dives

Deep dive: Solar Thermal

Solar thermal production in buildings and district heating (in TWh) – EU27

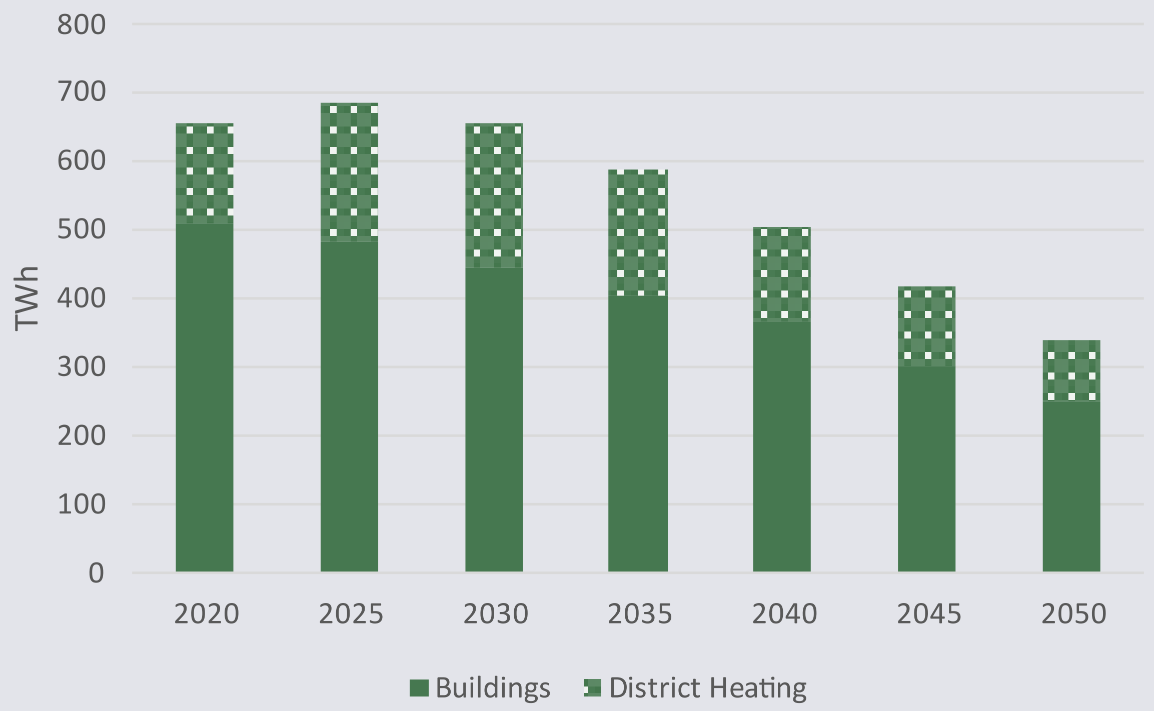


TEP Energy

- Solar thermal buildings produce 78 TWh by 2050
- Solar thermal district heating produces 83 TWh by 2050
- 78 bil. Euro invested in Solar thermal in 2050
- Note: Solar thermal is modelled as secondary system in combination with other heating system.

Deep dive: solid biomass

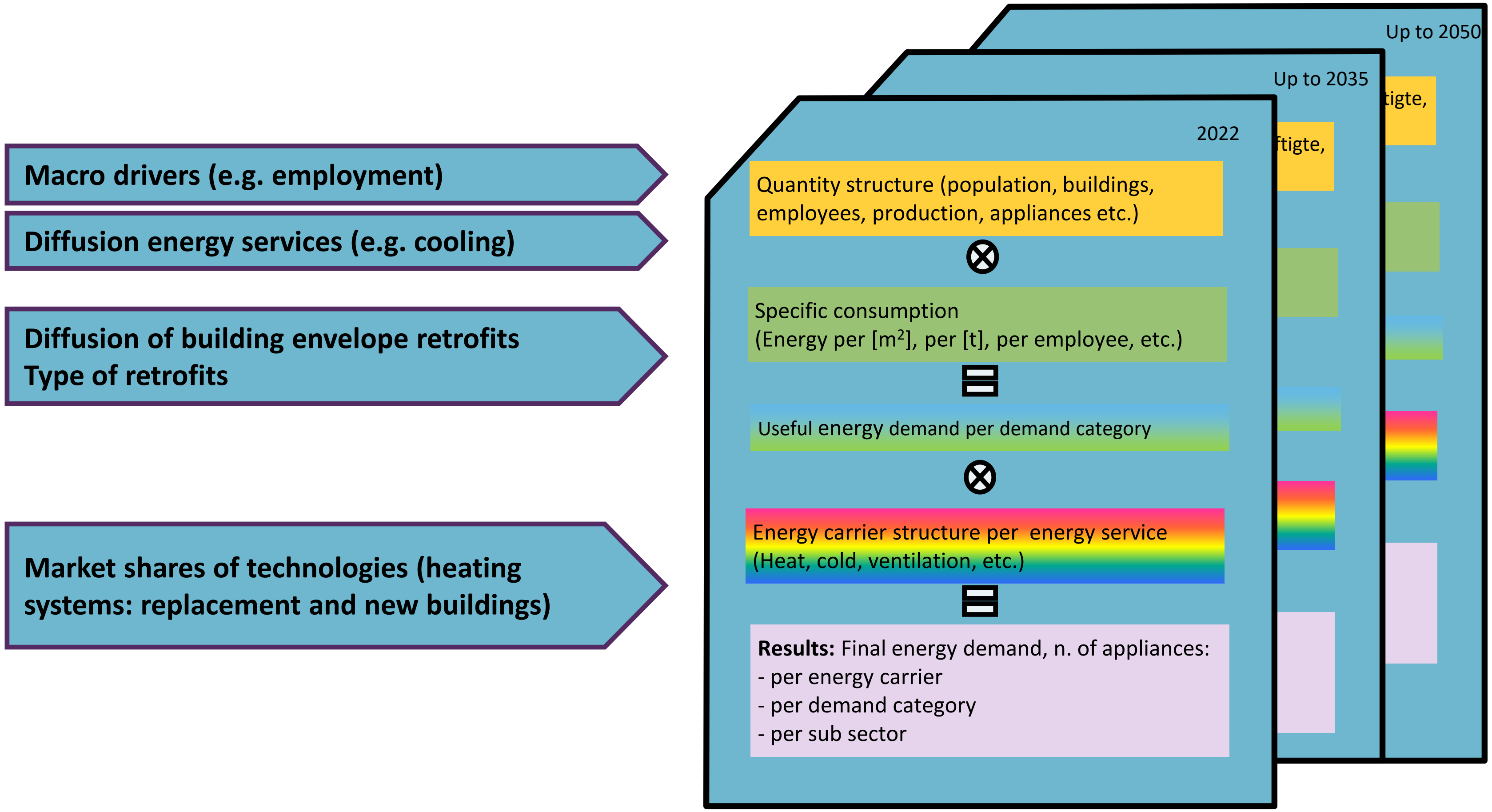
Final energy demand for solid biomass in buildings and district heating EU27



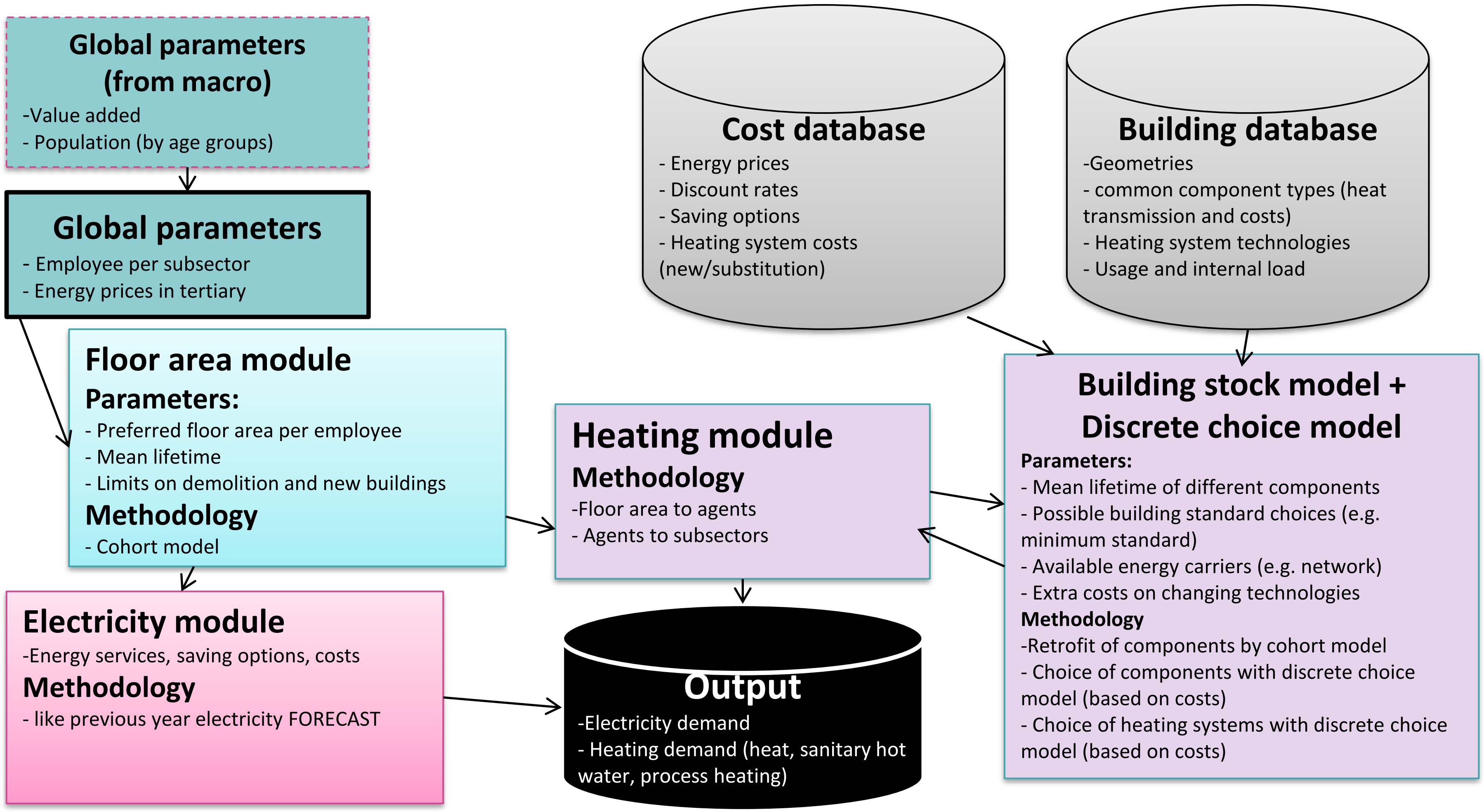
TEP Energy modelling (2023)

Methodology & assumptions: Buildings

FORECAST Model – Focus Building Sector
Methodology: example tertiary

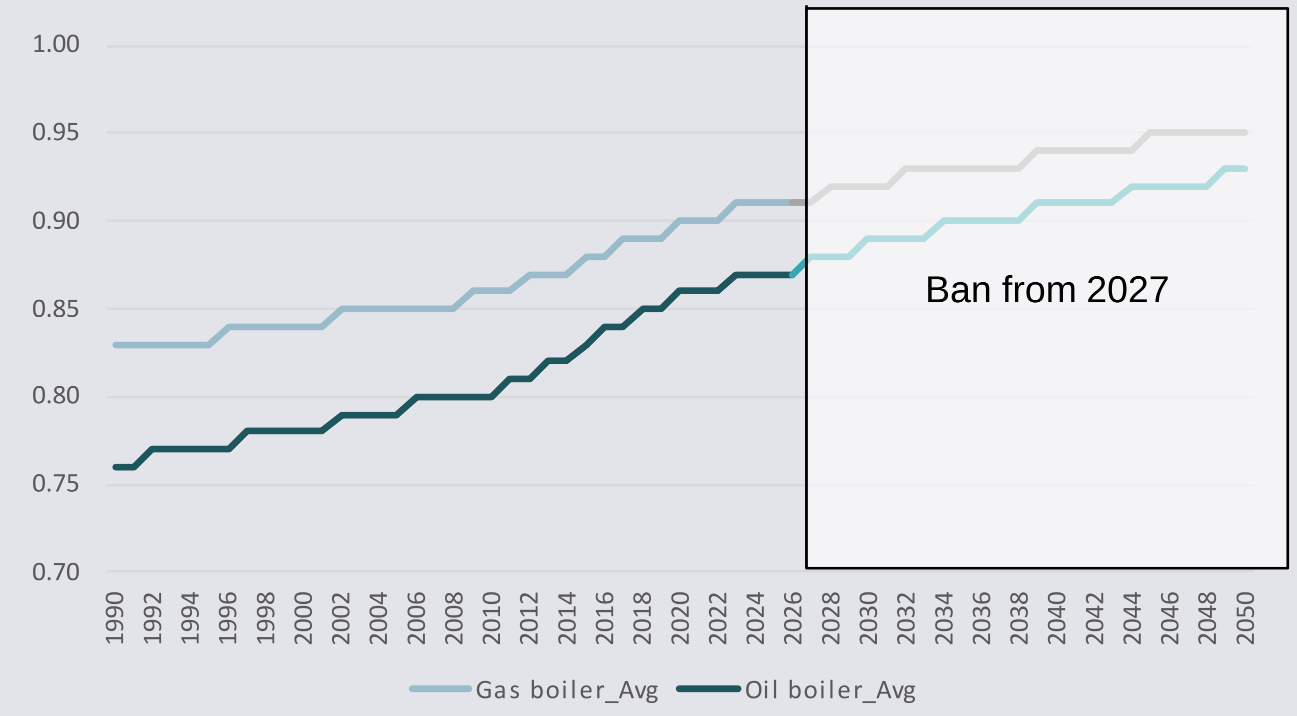


FORECAST Model – Focus on the Building Sector
Tertiary model structure



Key technology assumptions
Phase out of stand-alone fossil fuel boilers

Efficiency of heating system

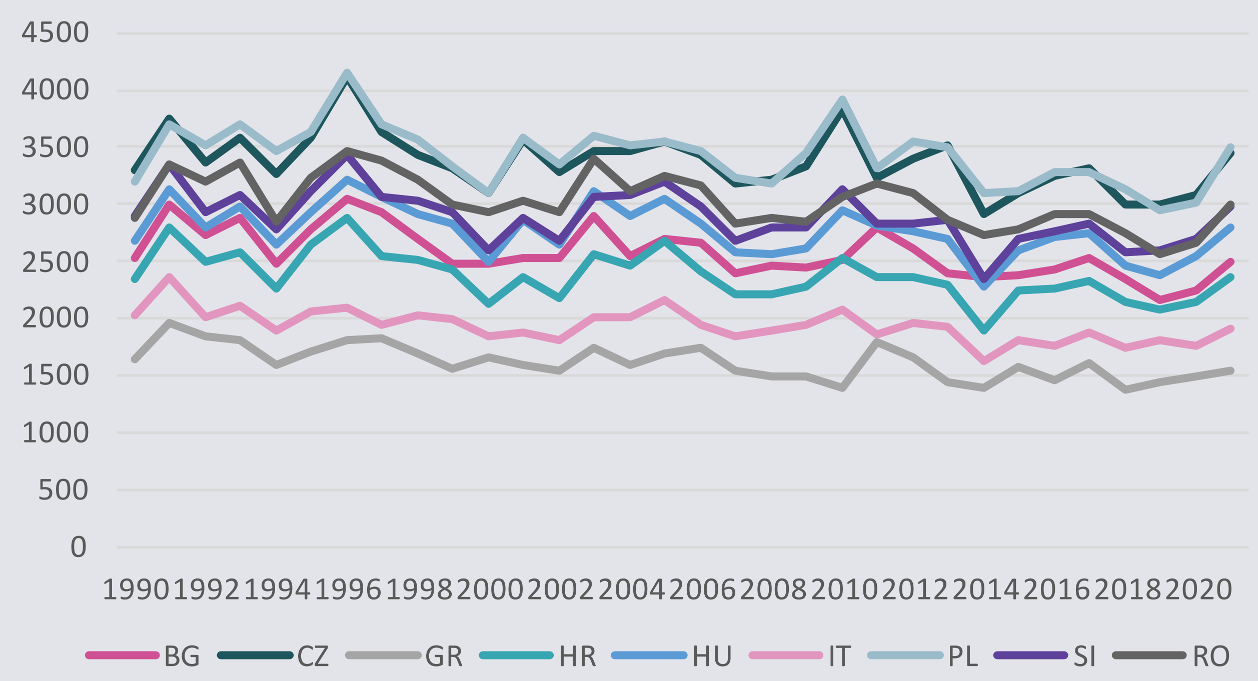


TEP Energy (2023)

- Ban of stand-alone fossil fuel boilers from 2027 based on boiler efficiency values, simulating a revision of Ecodesign rules currently under discussion.
- The rule is assumed to only apply to new installations, not existing ones.
- The efficiency values for heating appliances are based on lower calorific value and an average over all countries and includes distribution losses in the building.
- The modelling also assumes reduced *willingness to pay* for fossil fuel boilers before the ban to reflect the impact of the war in Ukraine.

Heating degree days

Heating degree days

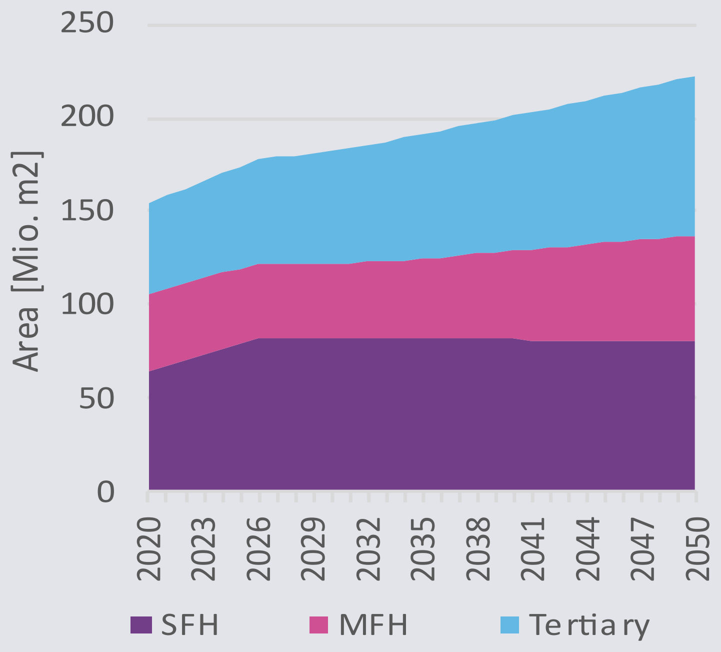


TEP Energy based on Eurostat (2023)

- From 2022: Average HDD 1980-2012
- Data from Eurostat (EU definition)
- Used for climate correction only for space heating (not for sanitary hot water)

Households and floor area

Floor area by building type in Bulgaria



TEP Energy (2023)

→ Floor area is based on values per occupant (residential sector) resp. per employee (tertiary sector). Development of population and employment is based on macro economic data that forms the basis of the simulation model.

Energy prices & technology data

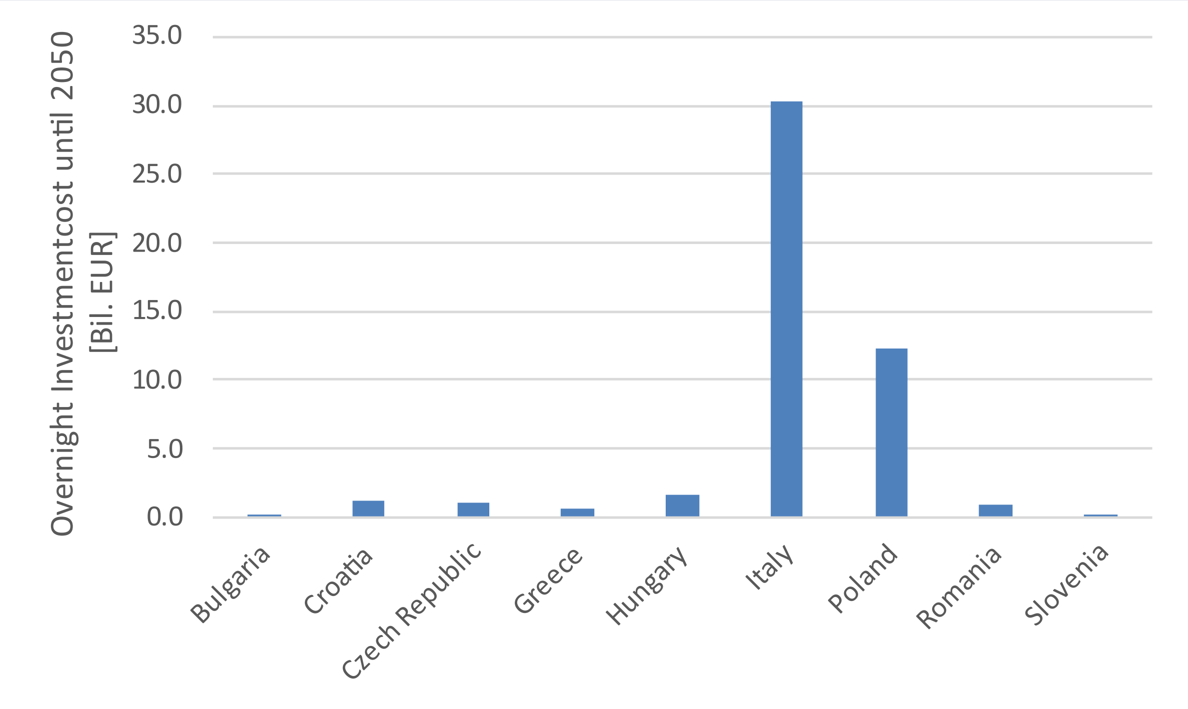
Exemplary energy prices in the residential sector - with taxes, distribution, etc.

TEP Energy (2023)

- → Consumer prices are derived from energy commodity prices that were determined by the simulation of the energy sector.
- → Technical and economic parameters of the different heating systems are defined in the simulation framework of FORECAST. These values are used and updated in numerous European projects.

Investments in district heating grid and generation infrastructure

Calculation Approach

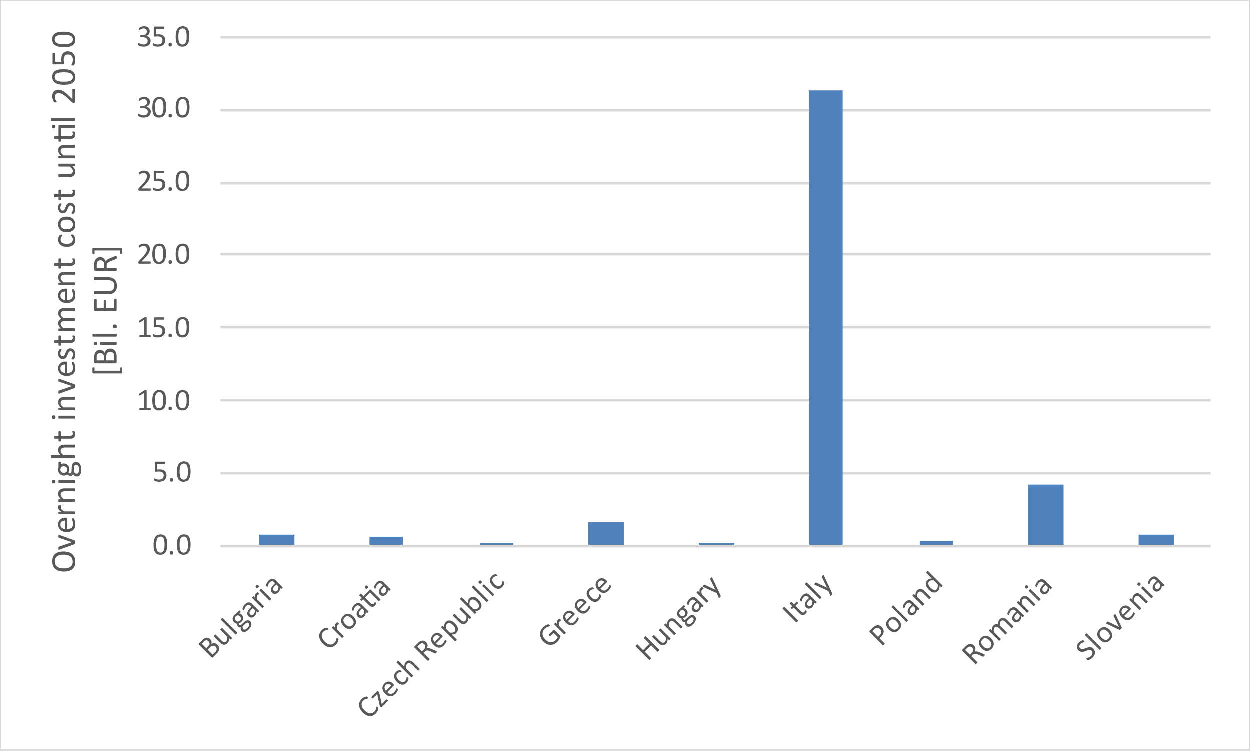


TEP Energy (2023)

- Based on DH heat provision
- Cost for heat generation: 4 ct/kWh heat in Germany, transferred to other countries via producer price index
- Economic period: 25 years (heat generation) resp. 35 years (grid)
- Discount rate: aligned with energy sector: 5.25%
- Approach: investment into distribution and generation is financed by their costs at given rate and over economic period
- Investment costs are based on the additional DH energy demand of the buildings sector (between 2022 and 2050), meaning they only cover grid expansion, not maintenance or replacement of the existing grid.

Investment in solar thermal

Example of the deep dive countries



TEP Energy (2023)

Calculation approach:

- → Model results: covered by solar thermal
- → Based on TEP data set: 1000 EUR/m2 for material incl. hot water tank and complete installation in Germany.
- → Labor: 33%, Material: 67%
- → Prices transferred to other countries by producer price and wage index.
- → Solar gain calculated based on country specific global horizontal irradiation and installation efficiency.
- → Needed area is defined by heat demand (simulation result) and solar gain.
- → Investment for new installations only, replacement, renovation of existing stock is not included.