No-Regret Strategies for Decarbonising Space and Water Heating

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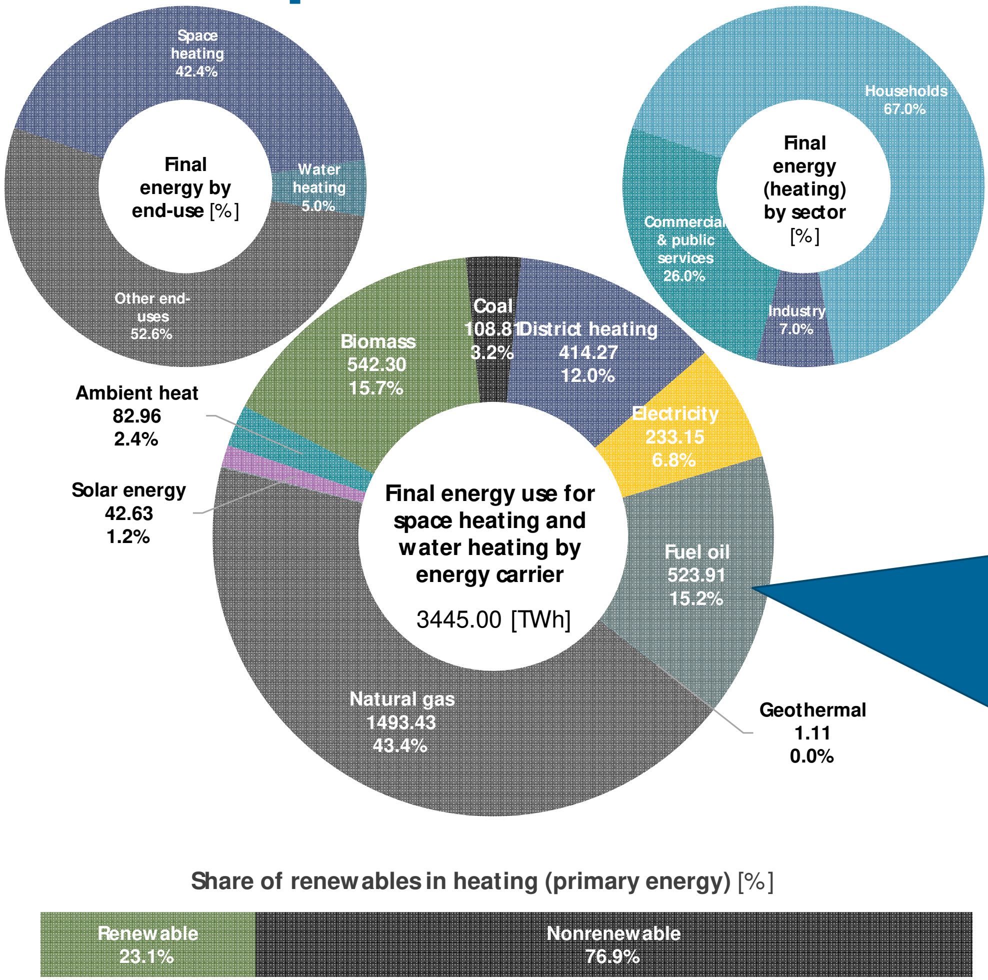
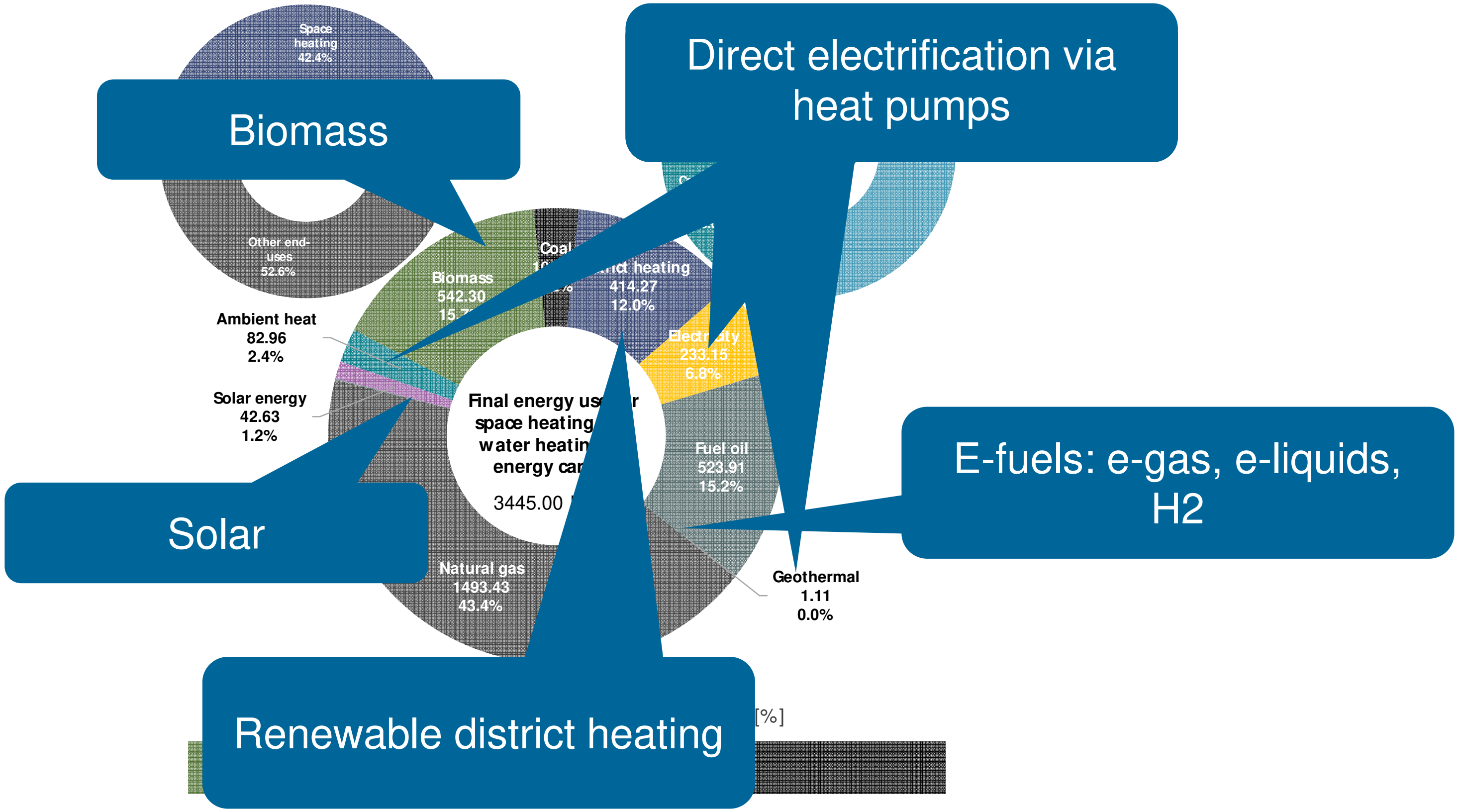
ISEC 2022, Graz

Energy use for space and water heating, EU-27



Decarbonisation pathways?

Energy demand for space and water heating in the EU-27 in 2017



Source: Fraunhofer ISI in ENER/C1/2018-494 – Renewable Space Heating under the Revised Renewable Energy Directive, 2021

Project background

- Renewable Space Heating under the Revised Renewable Energy Directive. ENER/C1/2018-494, December 2019 – August 2021

- Potentials and levels for the electrification of space heating in buildings. ENER/C1/2019-481, November 2020 – June 2022. Lead: Consentec

- Renewable Heating and Cooling Pathways, Measures and Milestones for the implementation of the recast Renewable Energy Directive and full decarbonisation by 2050. ENER/C1/2019-482, November 2020 – June 2022. Lead: Öko-Institut

Research question

- What are favourable and less favourable decarbonisation pathways of space and water heating for the EU-27 by 2050 in terms of overall primary energy consumption, costs, barriers and policy implications, taking into account the impact of the heating sector on the overall energy system?

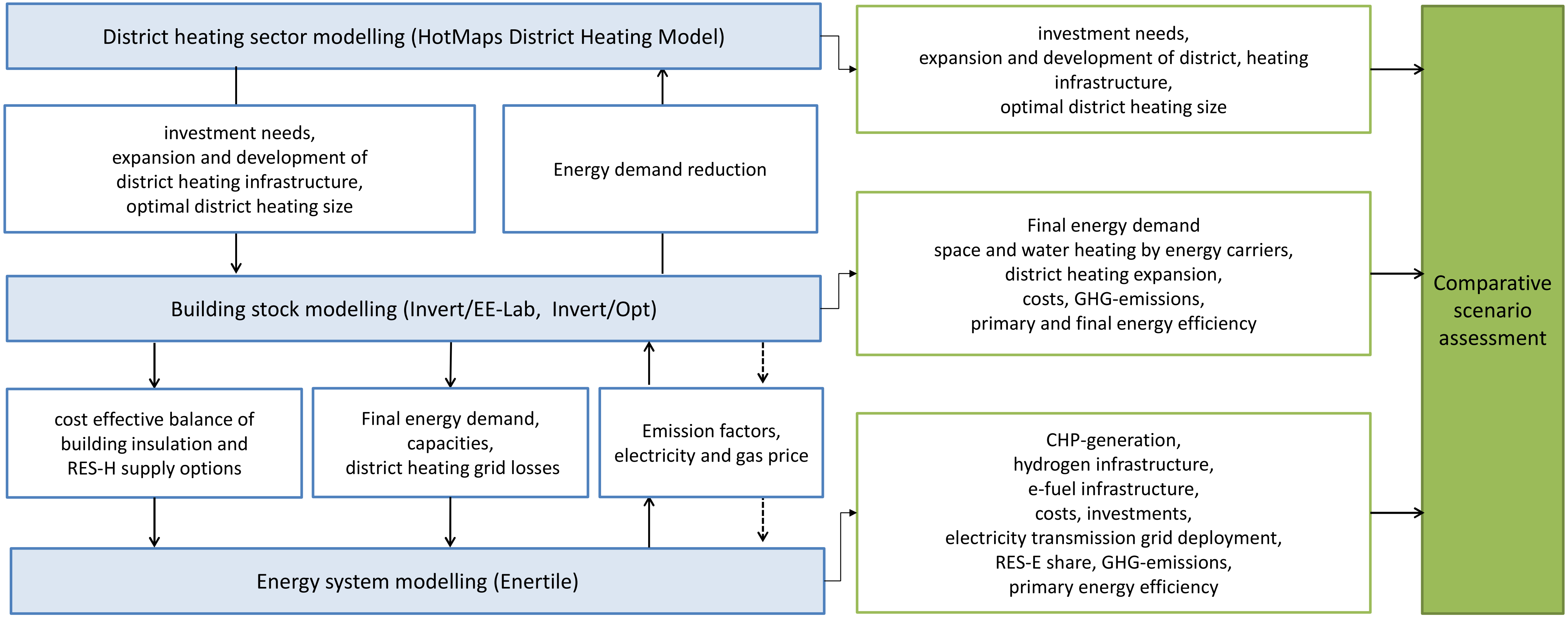
- What are robust strategies and no-regret measures for decarbonising the space and water heating sector?

Method

- Modelling framework: (1) Buildings, (2) District Heating Grids, (3) Electricity, e-fuels, H2 and district heating generation
- Baseline scenario: without achieving decarbonisation, no economic optimisation
- Scenarios with full decarbonisation by 2050, cost minimisation, technology focused:
  - Direct RES
  - Electrification
  - E-fuels
  - Hydrogen
  - District Heating
  - Best case scenario
- Comparative asssessment

- Target year 2050
- Focus space and water heating in residential and non-residential buildings, EU-27

Modelling framework: sectoral cost-minimization with feedback loops



Specification of technology scenarios, (1) Buildings

For the cost-minimal choice of the technology diffusion we applied an upper and lower restriction of the floor area supplied by the corresponding technology.

		Baseline Task 4	Direct RES-H Task 5	Electrification Task 6	e-fuels Task 7.1	H2 Task 7.2	District heating Task 8
Buildings (*	Efficiency of building envelope	Baseline policies	Optimised				
	Biomass	Baseline assumptions	upper boundary: high; lower boundary: none; full resource potentials	upper boundary: moderate; lower boundary: none; moderate resource potentials			upper boundary: low; lower boundary: none; low resource potentials (**)
	Solar thermal	Baseline policies	upper boundary: high; lower boundary: none	upper boundary: moderate; lower boundary: none; moderate resource potentials			upper boundary: high; lower boundary: none
	Direct electric heating		upper boundary: moderate; lower boundary: none	upper boundary: high; lower boundary: high	upper boundary: moderate; lower boundary: none		
	Heat pumps						
	Gas based heating systems	Baseline policies	upper boundary: moderate; lower boundary: none		upper boundary: high; lower boundary: high	upper boundary: high; lower boundary: high	upper boundary: moderate; lower boundary: none
	Liquid fuel heating systems	Baseline policies	upper boundary: low; lower boundary: none		upper boundary: high; lower boundary: moderate	upper boundary: low; lower boundary: none	

(*) In the building sector, the mix of all measures (building envelope and heating systems) is optimised under minimisation of life cycle costs. The table indicates the constraints (upper and lower boundary) for this optimisation, as share of the heated floor area in the total building stock which can (or needs to) be covered by a certain technology. In addition, for biomass systems, an overall resource constraint is applied.

(**) In the district heating scenario, we assume a higher biomass allocation for district heating and a lower allocation of individual biomass heating, compared to the other scenarios. The settings are defined in a way to result in total in a similar biomass constraint as in the direct RES-H scenario.

Specification of technology scenarios, (2) Upstream supply

		Baseline Task 4	Direct RES-H Task 5	Electrification Task 6	e-fuels Task 7.1	H2 Task 7.2	District heating Task 8
District heating	Expansion potential of grid	Baseline policies	upper boundary: moderate; lower boundary: none				upper boundary: high; lower boundary: high
District heating	Biomass	Baseline assumptions	optimised under moderate reduction of ressource potentials	optimised under strong reduction of ressource potentials	optimised under moderate reduction of ressource potentials		optimised under reduction of ressource potentials (**)
District heating	Solar thermal		strong increase	small increase	moderate increase		strong increase
District heating	Deep geothermal		strong increase	small increase	moderate increase		strong increase
District heating	Heat pumps	Optimised					
District heating	Direct electric heating						
District heating	Hydrogen	No deployment	Optimised				
District heating	E-fuels		Optimised				
Power sector	Electricity demand in other sectors	exogenously determined (in line with 1.5 tech scenario)					
Power sector	Biomass	Limited deployment					
Power sector	Other direct RES	Optimised					
Electricity Transmission	Cross-border interconnectors	2030 TYNDP + optimal expansion					
H2 generation	Hydrogen demand in other sectors	exogenously determined (in line with 1.5 tech scenario)					
H2 generation	Import	At high prices					
E-fuels generation	E-fuels demand in other sectors	exogenously determined (in line with 1.5 tech scenario)					
E-fuels generation	Import	At very high prices					

(**) In the district heating scenario, we assume a higher biomass allocation for district heating and a lower allocation of individual biomass heating, compared to the other scenarios. The settings are defined in a way to result in total in a similar biomass constraint as in the direct RES-H scenario.

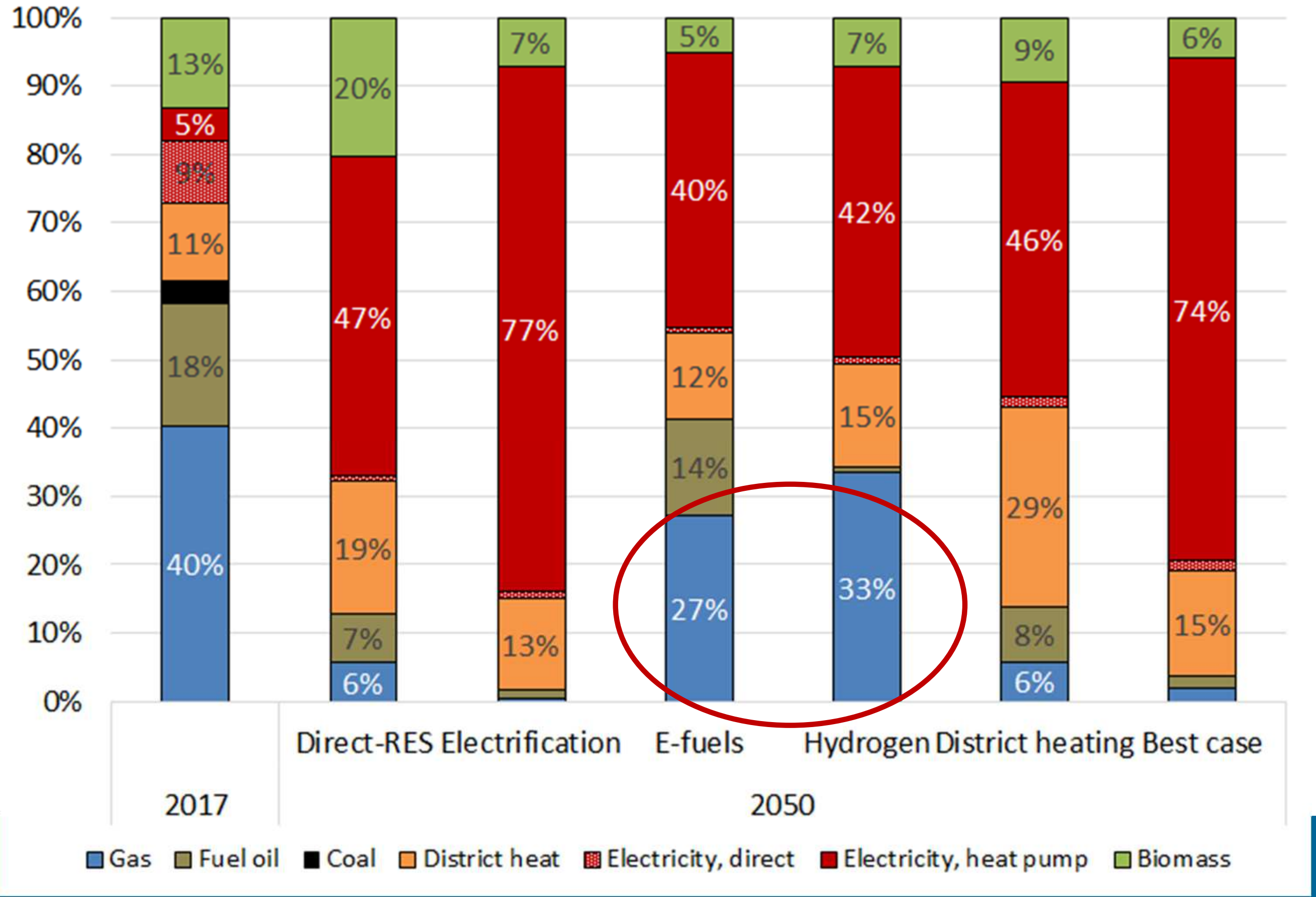
Szenario-Spezifikation: Annahmen zum Gas-Mix

Scenario (down) / Fuel (right)	Hydrogen			e-gas			e-liquid		
	Share on gaseous heating fuels						Share on liquid heating fuels		
	2030	2040	2050	2030	2040	2050	2030	2040	2050
Baseline	0%	0%	0%	0%	0%	0%	0%	0%	0%
Hydrogen	5%	34%	90%	0%	2%	5%	0%	2%	5%
E-fuels	0%	2%	5%	5%	34%	90%	5%	34%	90%
Direct RES-H / Electrification / District Heating	1%	4%	10%	1%	4%	10%	1%	4%	10%

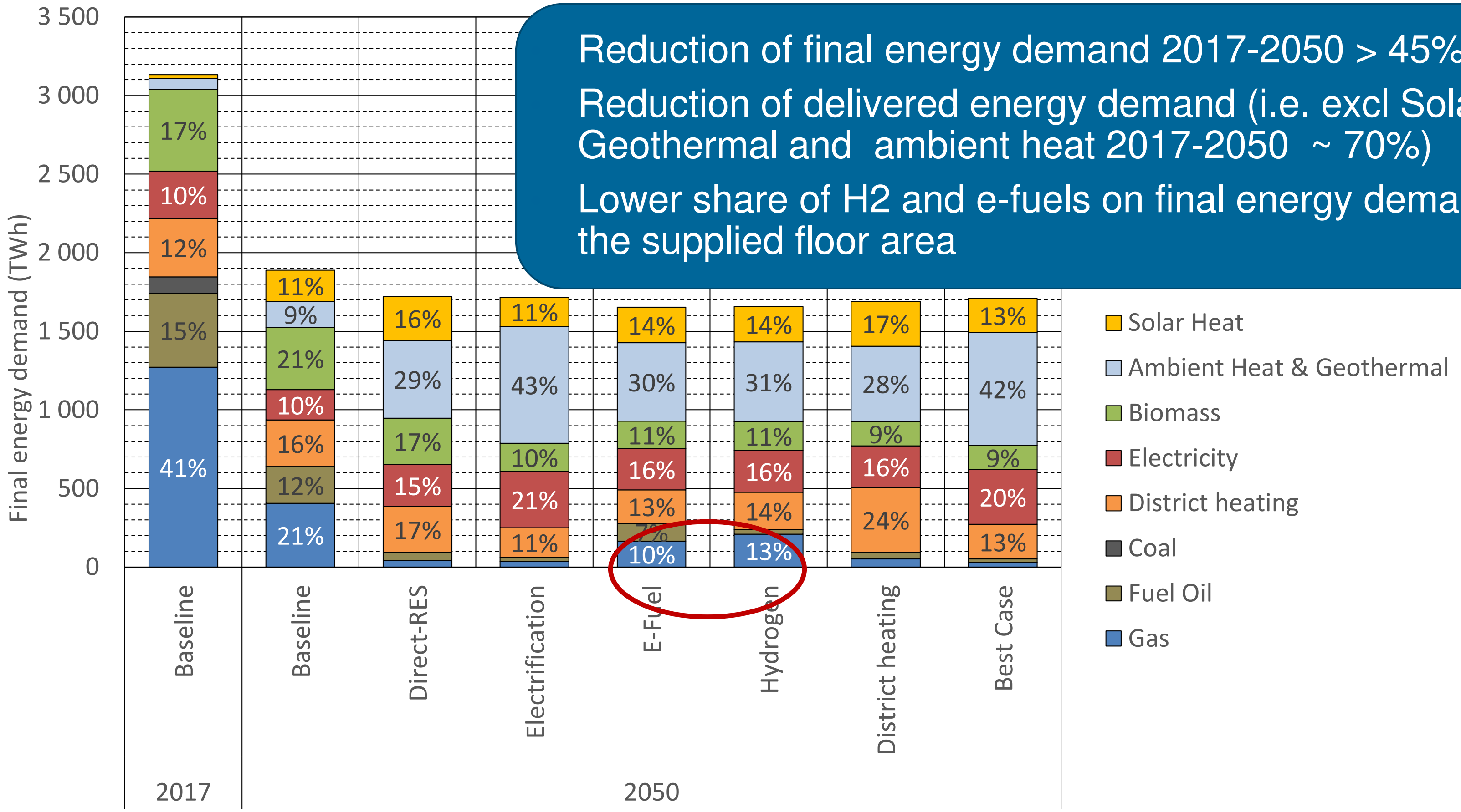
Szenario-Spezifikation: Annahmen zu Import-Preisen

Prices in €/MWh	2020	2030	2040	2050
Hydrogen	120	100	90	80
E-fuels (synthetic methane)	180	160	150	130

Scenario results: share of heated area by energy carrier, residential and tertiary buildings, EU-27



Scenario results: final energy demand space heating and hot water, residential and tertiary buildings, EU-27

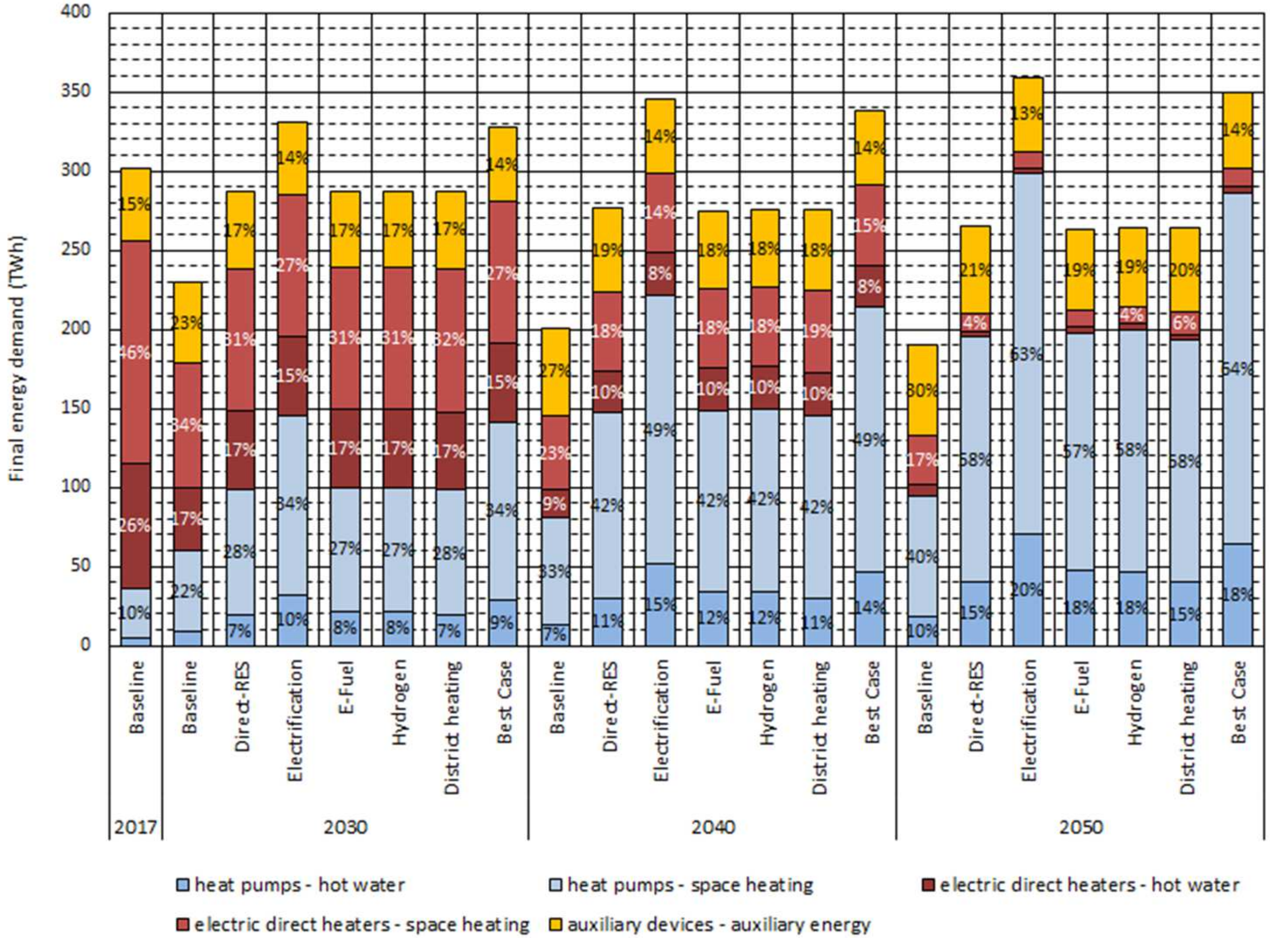


Reduction of final energy demand 2017-2050 > 45%

Reduction of delivered energy demand (i.e. excl Solar, Geothermal and ambient heat 2017-2050 ~ 70%)

Lower share of H2 and e-fuels on final energy demand than on the supplied floor area

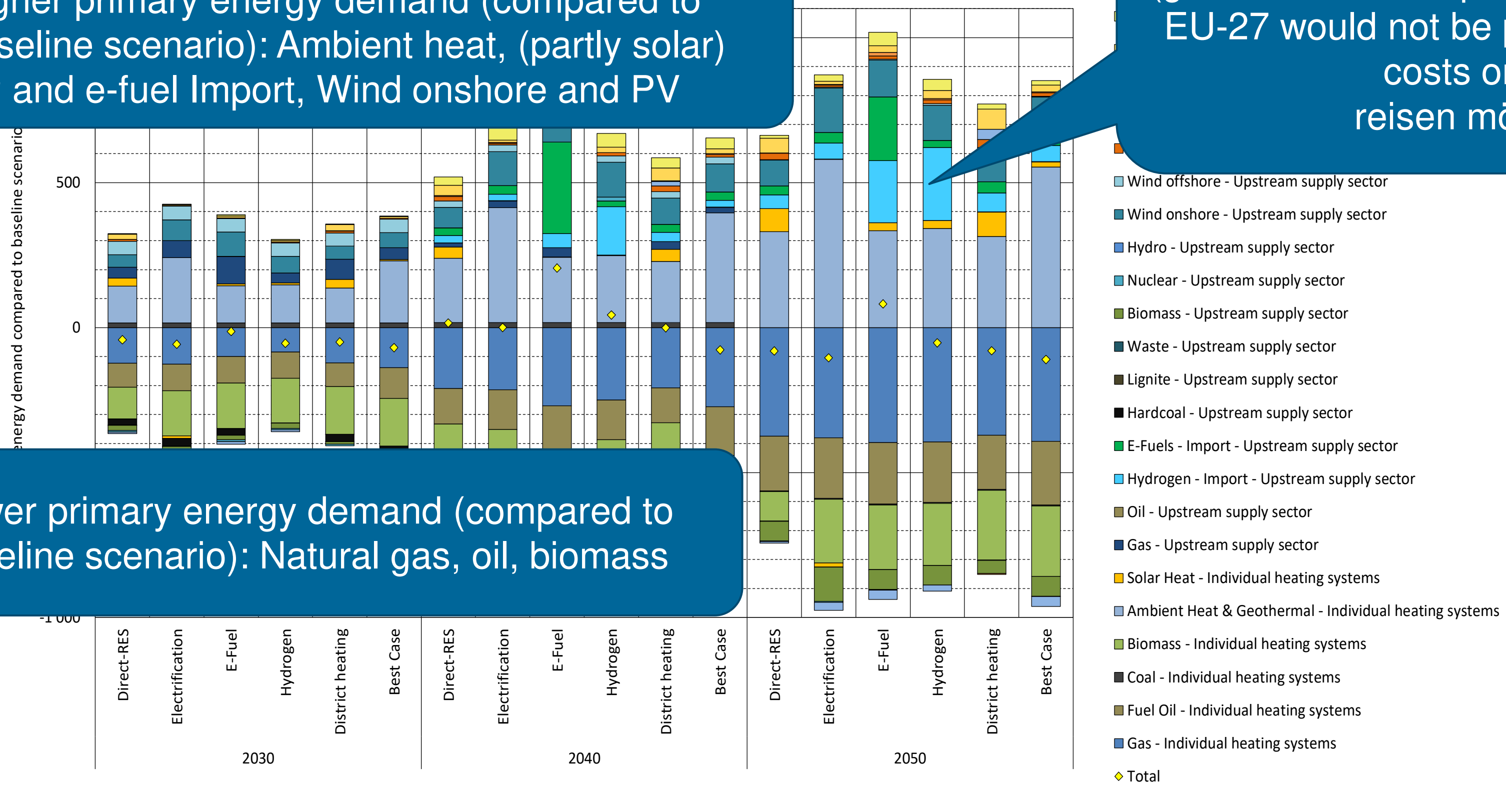
Scenario results: final electricity demand space heating and hot water, residential and tertiary buildings, EU-27



Scenario results: additional primary energy demand, compared to baseline scenario, EU-27

Higher primary energy demand (compared to baseline scenario): Ambient heat, (partly solar) H2 and e-fuel Import, Wind onshore and PV

Relevant share of H2 and e-fuel imports (generation of this part of H2 and e-fuels in EU-27 would not be possible at the same costs or lower)
reisen möglich ist)

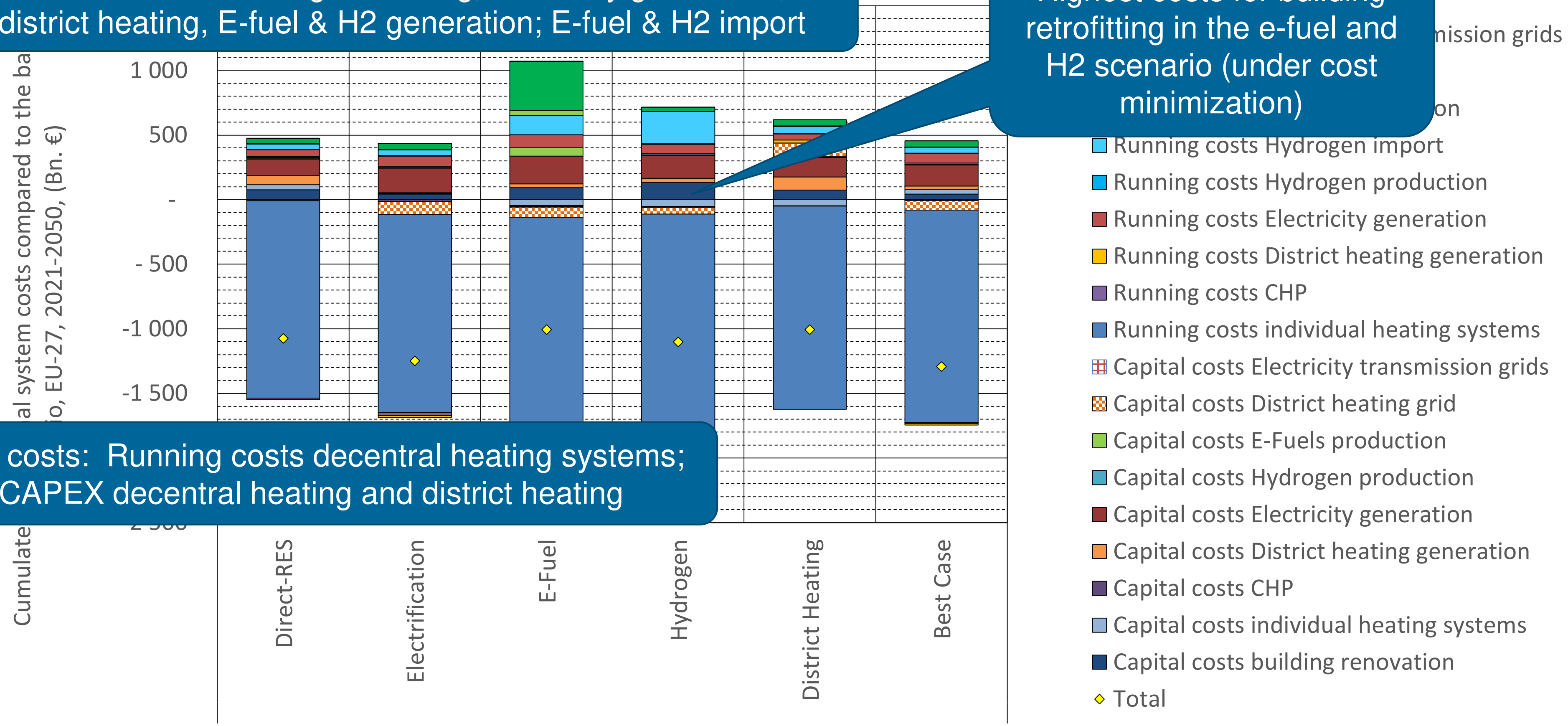


Lower primary energy demand (compared to baseline scenario): Natural gas, oil, biomass

Scenario results: Additional cumulated system costs compared to the baseline scenario, EU-27, 2021-2050

Higher costs: CAPEX building retrofitting, electricity generation, partly district heating, E-fuel & H2 generation; E-fuel & H2 import

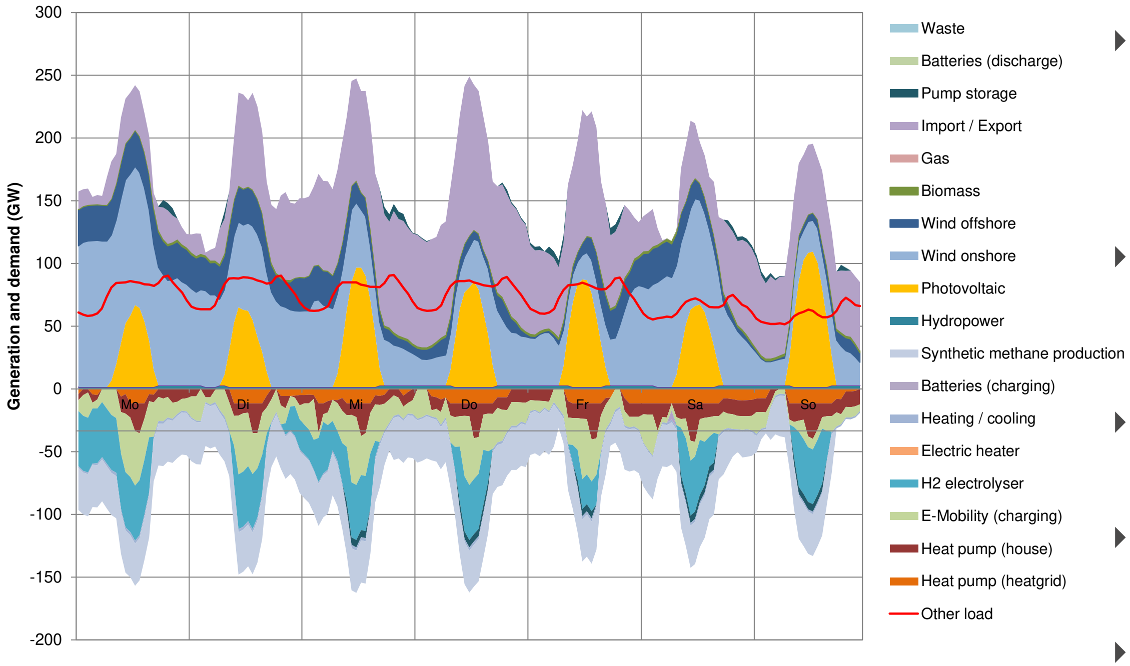
Highest costs for building retrofitting in the e-fuel and H2 scenario (under cost minimization)



Lower costs: Running costs decentral heating systems; partly CAPEX decentral heating and district heating

Dispatch overview for the best-case scenario

Typical week (CW 8) in Germany



- The large amount of imported electricity is a result of the energy balanced throughout the EU
- Wind onshore plays predominant role in generation
- Heat grids take up wind energy
- Heat pumps addtionally match PV peaks
- Hydrogen and synthetic methane generation and storage prevent RE curtailment

Conclusions

Conclusions (1)

- Heat pumps tend to be used towards the upper limit of the scenario constraints, depending also on the building type.
- E-fuels and H2 need to be pushed into the model. The model tries to minimise the use of these energy carriers.
- Biomass heating systems tend to be econmically viable. Biomass potentials restrict the use.
- Economic viability of district heating differs between regions. Since district heating was limited to areas with high heat densities and thus lower costs, in these areas district heating is mostly economical.
- Highest renovation activities occur in buildings with H2 and e-fuels, due to their high variable costs. This is in contrast to the current political discussion.

Rolle von Technologien

- Wärmepumpen werden tendenziell bis zur oberen Restriktion eingesetzt.
- Biomasse-Heizsysteme sind in der Regel wirtschaftlich rentabel. Biomassepotenziale schränken die Nutzung ein.
- Die wirtschaftliche Rentabilität von Fernwärme ist von Region zu Region unterschiedlich. Da die Fernwärme auf Gebiete mit hoher Wärmedichte und damit niedrigeren Kosten beschränkt wurde, ist Fernwärme in diesen Gebieten meist wirtschaftlich.
- E-Fuels und H2 müssen über Restriktionen in das Modell gedrückt werden. Aufgrund der hohen variablen Kosten minimiert das Modell den Einsatz dieser Energieträger (auch in den e-fuel und H2 Szenarien sinkt der Gasbedarf um 85% im Vergleich zu 2017 mit entsprechenden Konsequenzen für Gasverteilnetzkosten):
  - Kombination von Solarwärme mit H2 und e-fuels
  - Höchste Sanierungsaktivitäten in Gebäuden mit H2 und e-fuels
  - Einsatz von H2 und e-fuels in effizientesten Gebäuden

Conclusions (2)

- If measures and the overall system are optimised (according to our modelling approach), the costs do not deliver a clear criteria for a decision, in particular between H2, direct RES and district heating.

- Limitations and uncertainties need to be considered e.g. regarding:
  - Costs and impact of renovation: are assumed as additional costs to renovation measures required for safety and esthetical reasons.
  - Energy price levels
  - Behavioural aspects (some rebound effects are considered, but uncertainties remain)
  - Infrastructure costs, in particular for the H2 scenario

Arguing for Green Gas in space and water heating

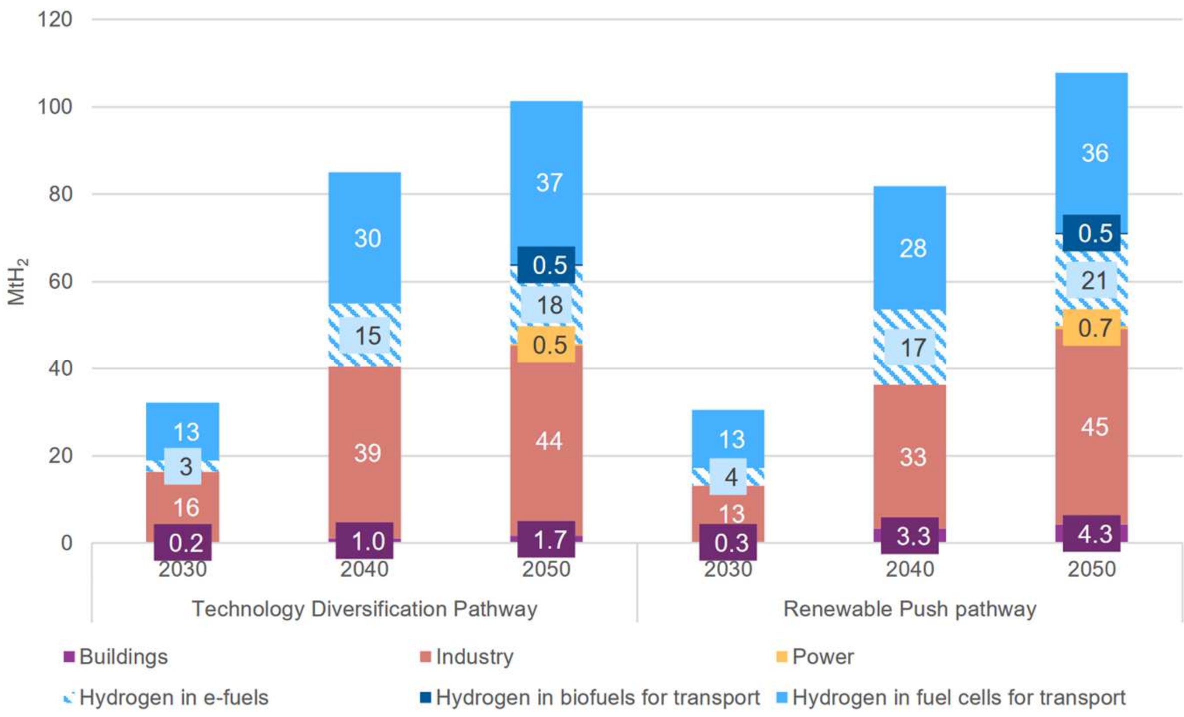
- Heat pumps are efficient and useful in new construction and in extensively retrofitted buildings (with low flow temperatu[illegible] in inefficient buildings [illegible]ow temperatu[illegible]
- It will not [illegible] retrofit all buildings in the foreseeable future.
- Therefore, (renewable) gas and/or H2 is needed in unrenovated buildings.

?

Arguing based on our analysis

- Due to high variable costs of H2 and green gas, they would have to be used in the most efficient buildings, if at all.
- But if buildings need to be retrofitted anyway, there is no reason for H2 and green gas.
- In any case, H2 and green gas is more expensive than alternatives when the system is fully decarbonized.

H2 spielt auch in Hydrogen-Roadmaps keine Rolle im Raumwärmesektor



Quelle: Hydrogen4EU, 2021

Robust strategies for decarbonising space and water heating

- Robust strategies across all scenarios:
  - Building renovation
  - Heat pumps
  - District heating in suitable areas
  - At least partial gas phase out (even in e-fuel and H2 scenarios, the amount of gas demand strongly reduces)
- Biomass resource allocation across sectors remains an important policy issue
- National, regional and local planning of infrastructure is crucial
- Strong regulatory policy framework

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