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Hydrogen in the German heating sector – An opportunity?

Lessons from a bottom-up study on possible pathways for an efficient and socially responsible approach to decarbonisation of the heating sector.

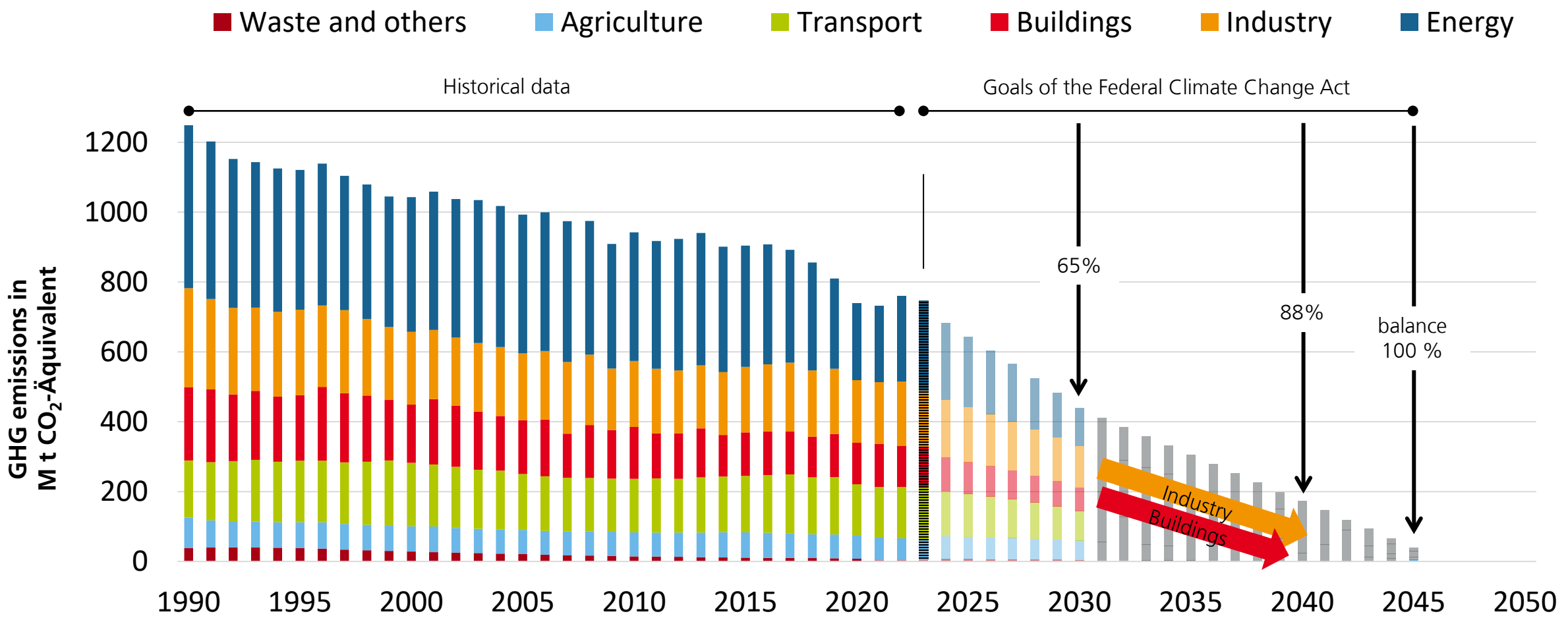
Image by Lounes DH from Pixabay

Study commissioned by the German National Hydrogen Council:

NATIONALER WASSERSTOFFRAT

Motivation: CO_2-reduction path for Germany

GHG-emissions in Germany – historical development and goals by Federal Climate Change Act



Historical data und estimation of the German Green-House-Gas (GHG)-emissions until 2022. Umweltbundesamt, 15.3.2023

Goal and methodology

Approach

- Analysis of 4 representitive supply areas
- Consideration of electricity, (incl. electromobility), heating as well as industrial processes and the grids where possible

Goals

- Analysis & evaluation of bottom-up transformation pathways for the heating sector
- Evaluation of the role of hydrogen in a climate-neutral heating supply

Collection of input data and creation of demand profiles

- ➢ Collection of all available data per building
- ➢ Generation of hourly load profiles per building and energy demand

- Space heating and domestic water heating, process heat
- Electricity demand (households, industry, e-mobility, commerce and services)
- Buidling, settlement types
- Mobility data
- Capacity of existing heat supply

Input data base year 2021

Energy system optimisation with DISTRICT & generation of grid data

- ➢ Energy system optimisation for 5 scenarios
- ➢ Sensitivities for electricity, gas and hydrogen costs

- Hourly values for seven representivite weeks each year
- Output:
  Installed capacities, Energy quantities by energy carrier and subarea, Building-specific demands for electricity and gas, Emission reduction development

Input data years 2025-2045

Grid calculations

- ➢ Simulation of selected grid areas of low and medium voltage, as well as gas grid at different pressure levels

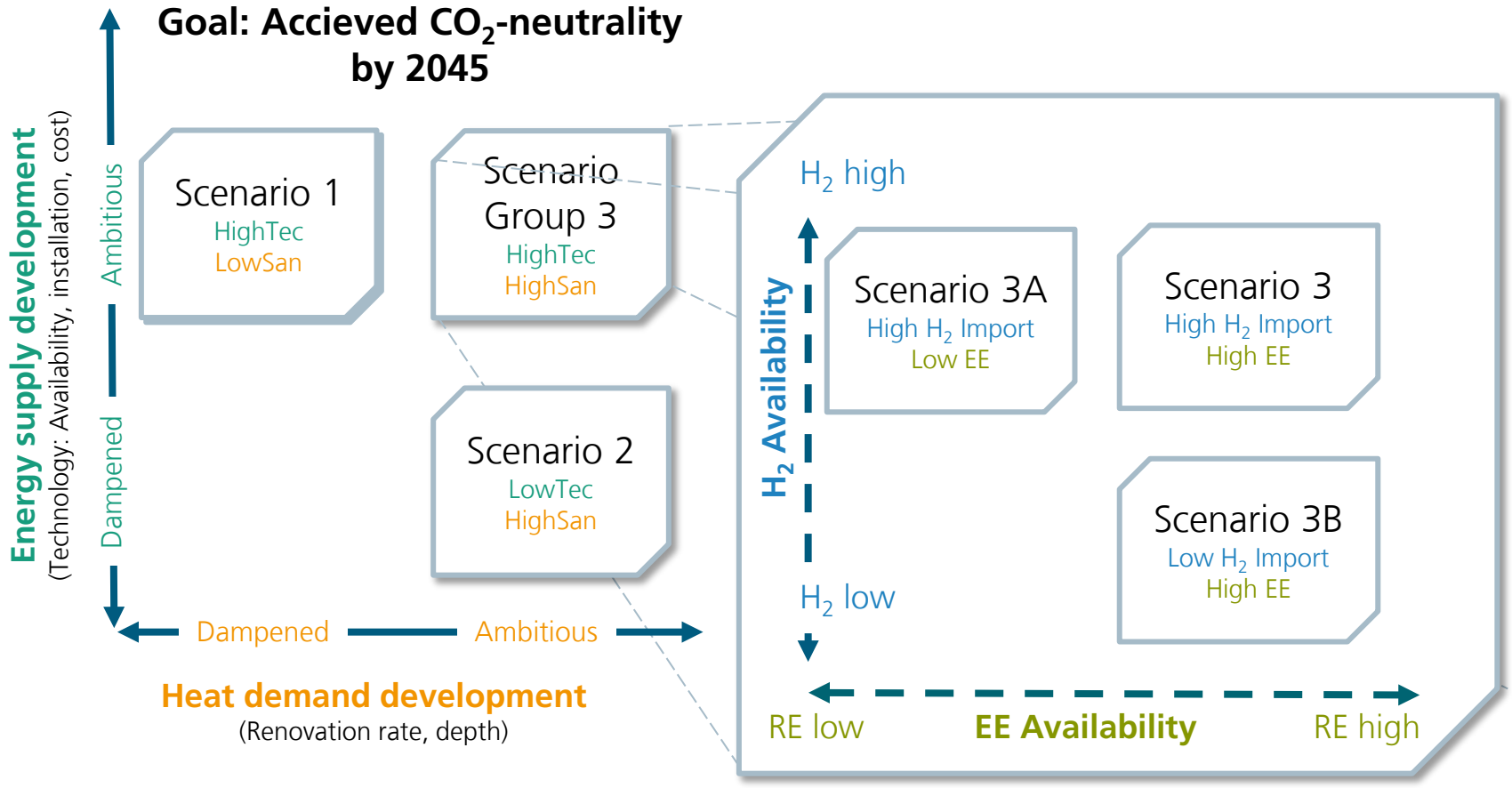
- Determination of grid load for coldest days (highest private heat demand)
  - Pressure and voltage band violations
  - Line and transformer overloads
- Cost estimation for grid reinforcements

Scenario narratives

Focus on the role of hydrogen in the German heating sector

1. Moderate renovation speed & high innovation affinity
2. High renovation speed & low innovation progress
3. Best Case:
   High availability of renewables and hydrogen

   a. Low hydrogen costs development
   b. High renewable energy development



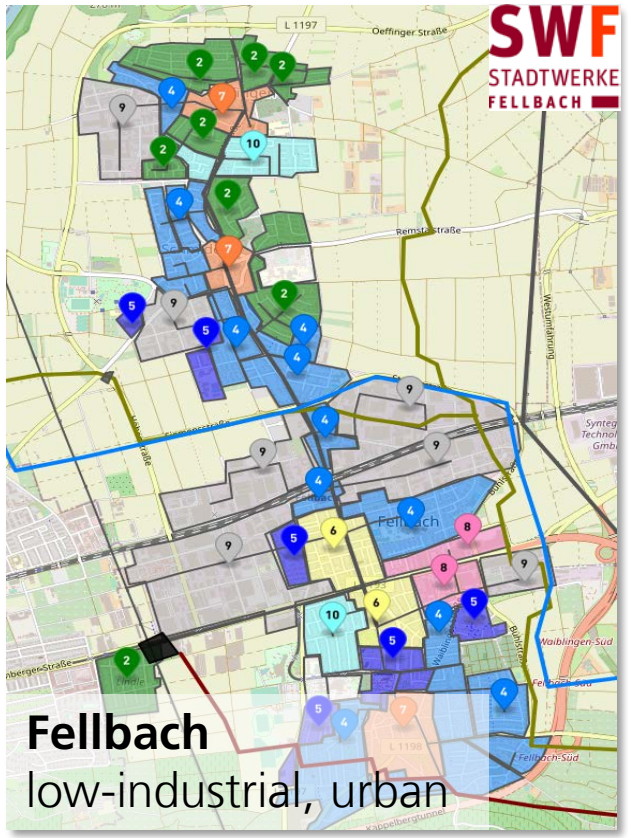
Scenario overview

Focus in the scenarios on the role of hydrogen

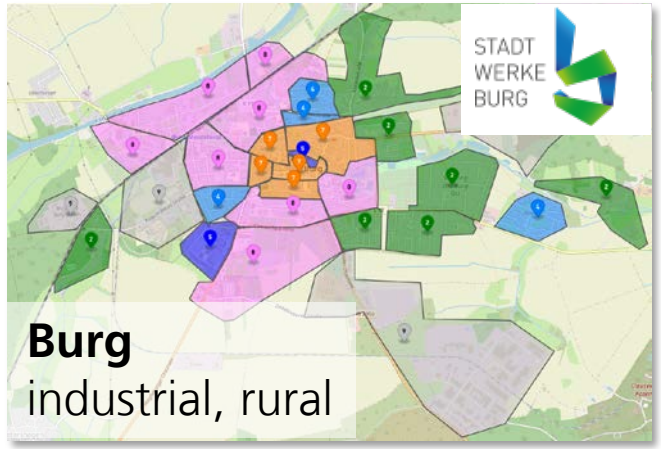
	Scenario 1 *Moderate renovation speed & high innovation affinity*	**Scenario 2** *High renovation speed & low innovation progress*	**Scenario 3** *High availability of renewables and hydrogen*	**Scenario 3A** *Low hydrogen costs development*	**Scenario 3B** *High renewable energy development*
Renovation rate / -depth	**1,2 %** / ≤ 45 kWh/(m²·a)	1,8 % / ≤ 45 kWh/(m²·a)	1,8 % / ≤ 45 kWh/(m²·a)	1,8 % / ≤ 45 kWh/(m²·a)	1,8 % / ≤ 45 kWh/(m²·a)
H_2-backbone avialable	**2030**	2035	**2030**	**2030**	2035
H_2-price & availability	**Low, High**	High, Low	**Low, High**	**Low, High**	High, Low
year	2025 2030 2035 2040 2045	2025 2030 2035 2040 2045	*Ref. Scenario 1*	*Ref. Scenario 1*	*Ref. Scenario 2*
households $\left[\frac{ct_€}{kWh}\right]$	- 12,5 10,8 9,0 8,3	- - 16,3 14,0 13,8			
industry $\left[\frac{ct_€}{kWh}\right]$	- 10 9 8 7,5	- - 14,5 13,0 12,5			
Electricity price	Moderate	Moderate	Moderate	High	Low
year	2025 2030 2035 2040 2045	*Ref. Scenario 1*	*Ref. Scenario 1*	2025 2030 2035 2040 2045	2025 2030 2035 2040 2045
households $\left[\frac{ct_€}{kWh}\right]$	23,7 21,7 21,8 21,9 22,1			26,7 27,6 28,1 28,6 29,4	23,2 20,6 20,3 20,0 19,6
industry $\left[\frac{ct_€}{kWh}\right]$	13,5 11,5 11,6 11,7 11,9			16,5 17,5 17,9 18,4 19,2	13,0 10,4 10,1 9,8 9,4
Technology cost	Moderate	High	Moderate	Moderate	Moderate
Heat pump exchange rate	Moderate	Moderate	High	High	High
RE-electricity availability	High	Moderate	High	Low	High
District heat	Hohe Austauschrate	Mittlere Austauschrate	Hohe Austauschrate	Hohe Austauschrate	Hohe Austauschrate

Analysed supply areas of four representive cities/municipality

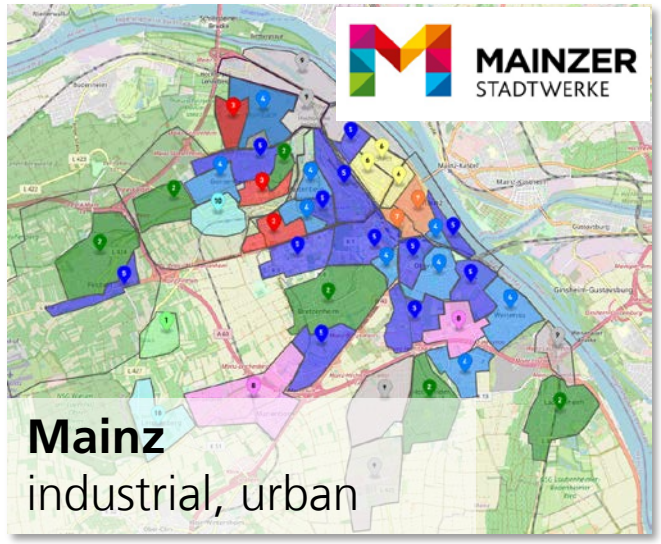
Diverse settlement structures, spread over Germany



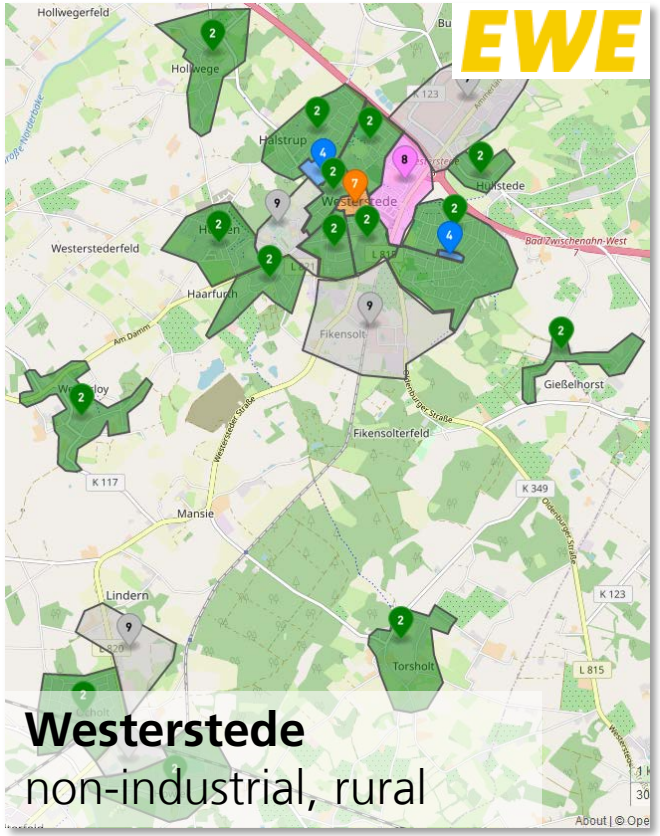
Fellbach
low-industrial, urban



Burg
industrial, rural

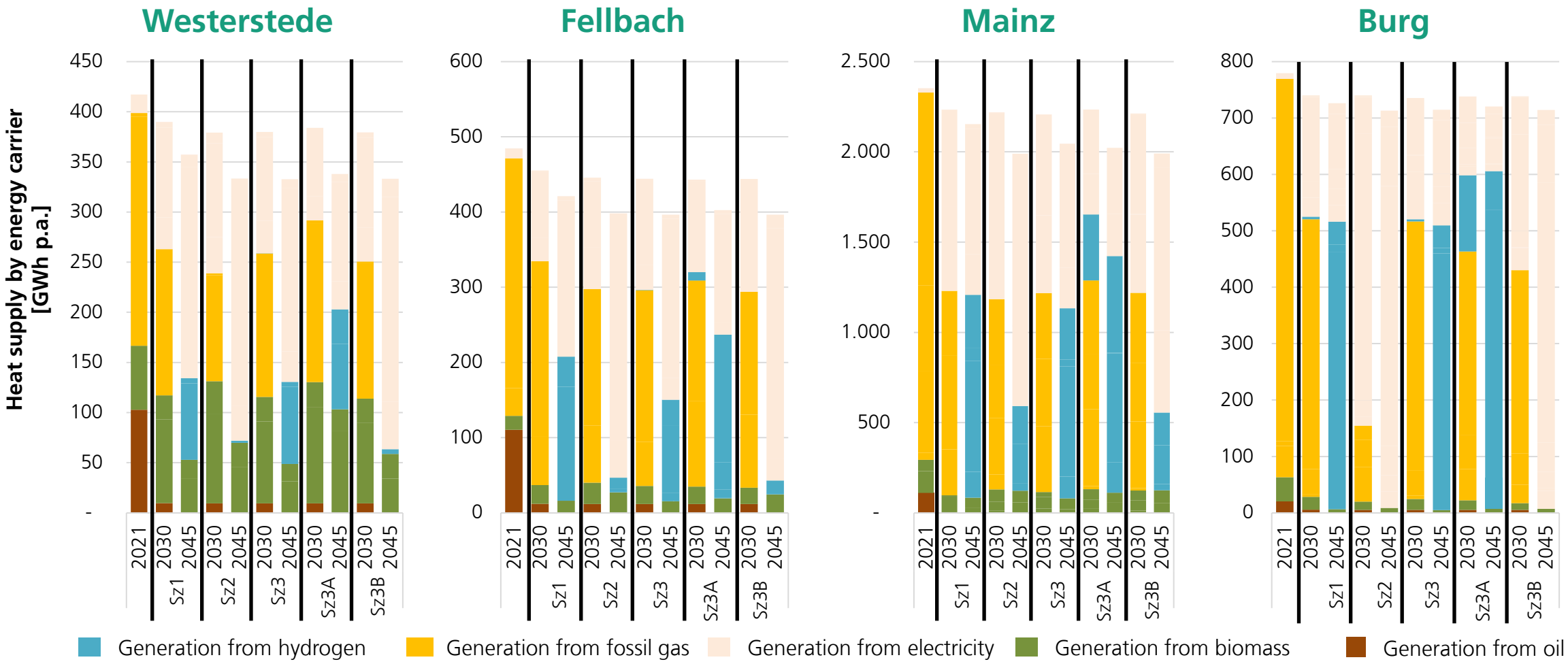


Mainz
industrial, urban



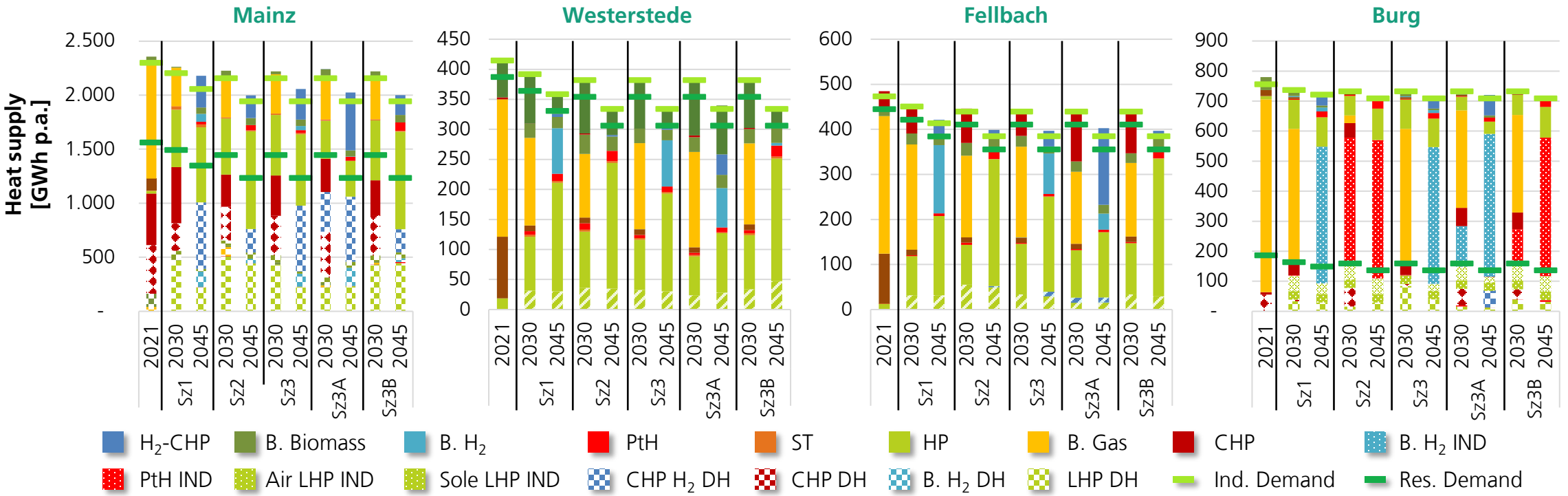
Westerstede
non-industrial, rural

All zero-emission energy carriers will be needed to decarbonise the heating supply



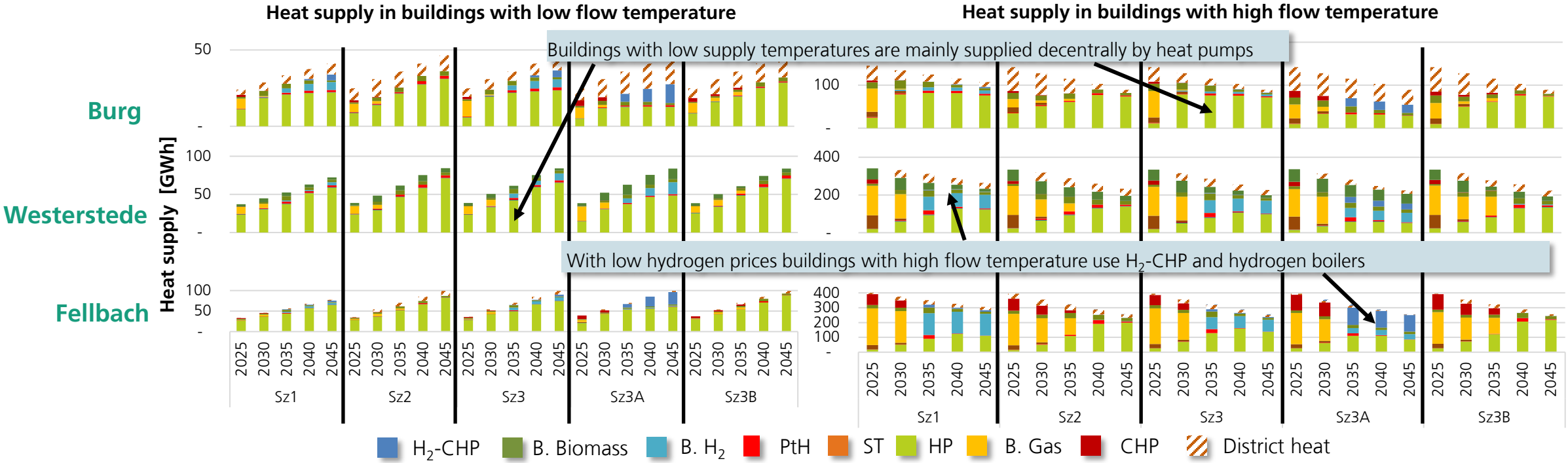
No »one-size fits all« solution exists. The heating supply path differes for every analysed region

- The solution of every supply area varies in dependence of the share of process heat demand, population density and local energy potential from environmental heat and renewable energies for electicity generation



The main solution for space heating supply are heat pumps and district heating

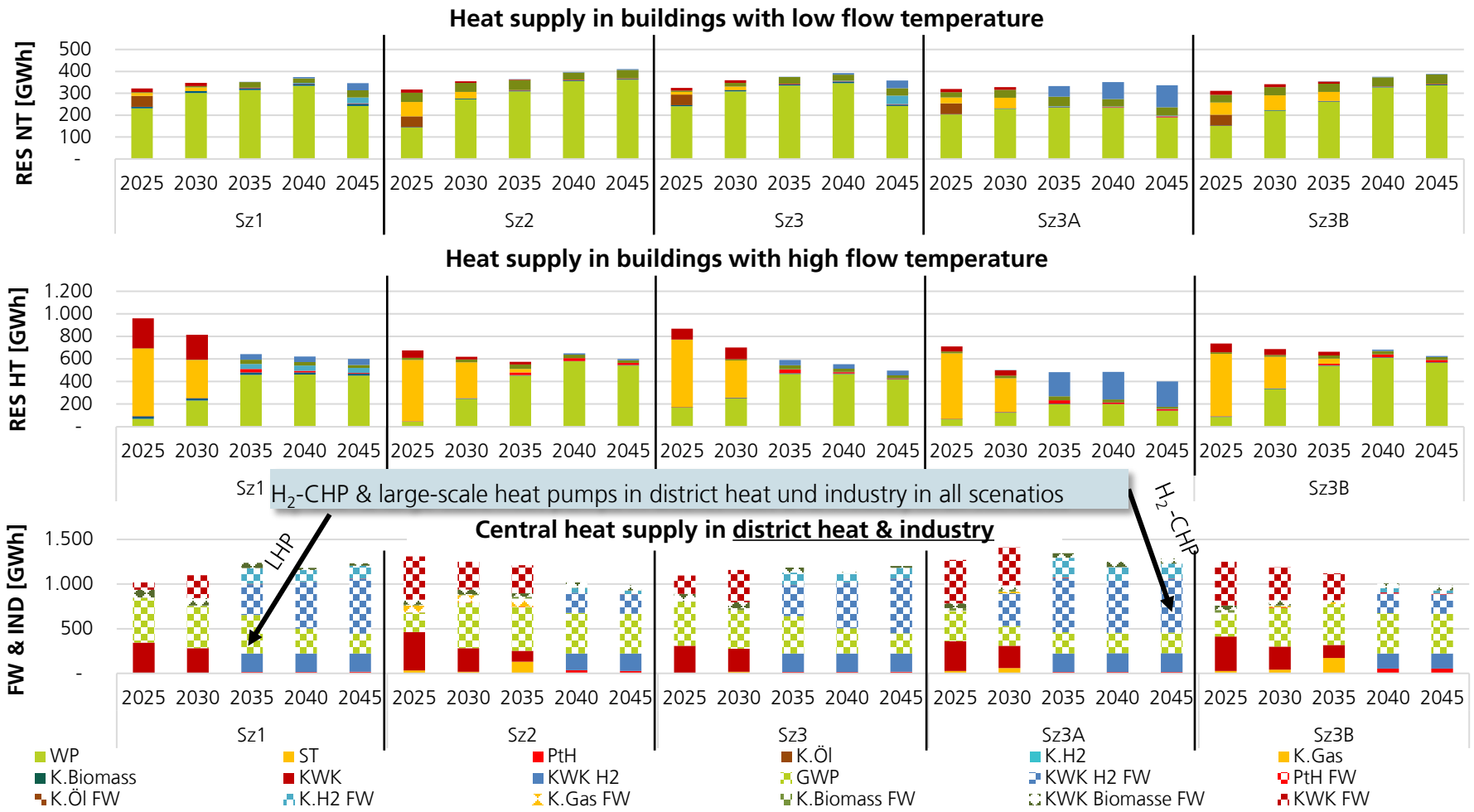
- Comparing the four analysed supply areas shows municipalites without siginificant process heat demand (Westerstede, Fellbach) are mainly supplied by heat pumps und district heating. Hydogen may partically be used in district heating supply.
- With lower H_2-consumer prices than 7 ct/kWh für industry costumers und 9 ct/kWh für household costumers after 2035, a significant share of space heating is supplied by hydrogen boilers decentrally installed.



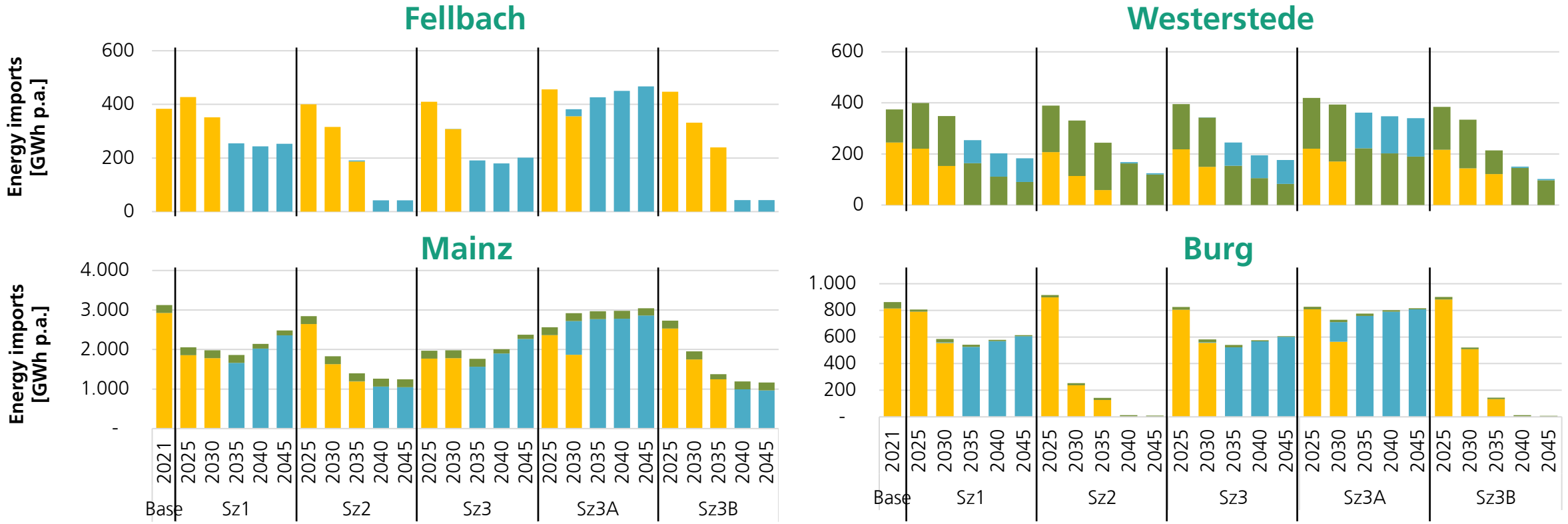
Hydrogen is used in district heating and for the supply of process heat in industrial applications

Detailled analysis Mainz

- The supply of space heating is almost exclusively by district heat und decentral heat pumps.
- Mainz has a high district heat grid expansion ausbau and redensification in all scenarios supplied by H_2-Boilers, H_2-CHP & Large-scale heat pumps (LHP).
- CHP embrace an important function in the steady supply of Heat capacity in district heating.



The energetic quantity of sales in the gas grid drops in the majority of scenarios – even if hydrogen is used for space heating



- In gas grid areas in which the methan gas sales are diminishing and hydrogen is not required in the long term decentrally, a customized conversion or demolition of the infrastructure is coercively required.

Lessons learned:
A sector coupled bottom-up approach is complex and requires on-site analysis.

- Evaluation of supply areas need to be performed on aregional level considering all existing infrastructures.
- Additonal infrastructure expansion, renewable heat and electricity potential, as well as the exisiting building stock must be considered.
- A high amount of reinstallations of heating units will be necessary until 2045.

Possible Spread of heating supply technologies in buildings in Westerstede in 2045

Results summary

The heat market is complex and requires on-site analysis.

1. The future heat sector is primarily determined by the required temperature levels of heat demand and the availability of local heat sources.

2. Accurate energy system knowledge is essential in municipal heat

3. The use of hydrogen ensures the achievement of long-term climate goals in industry and district heat.

4. If market development leads to lower hydrogen end-user prices, it expands the solution space for decarbonizing private households.

5. The scenarios show that for the economic attractiveness of hydrogen use in decentralized space heating, hydrogen end-user prices should be at most half as high as electricity end-user prices.

6. In addition to the expansion of the production market, a forward-looking construction or conversion of necessary infrastructure is imperative.

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Thank you for the attention