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Session N° 74 – Decarbonization path: some considerations

GENeSYS-MOD case study
-
Berlins heat transition integrated in an European energy system

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Milan, 23-27 July

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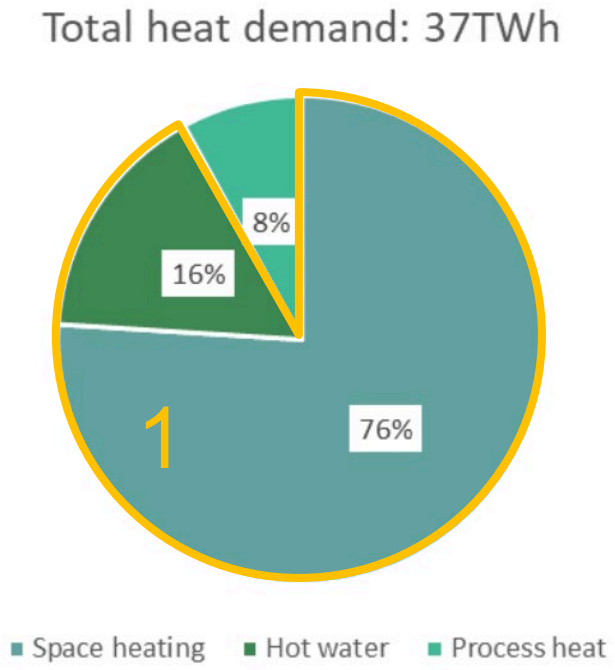
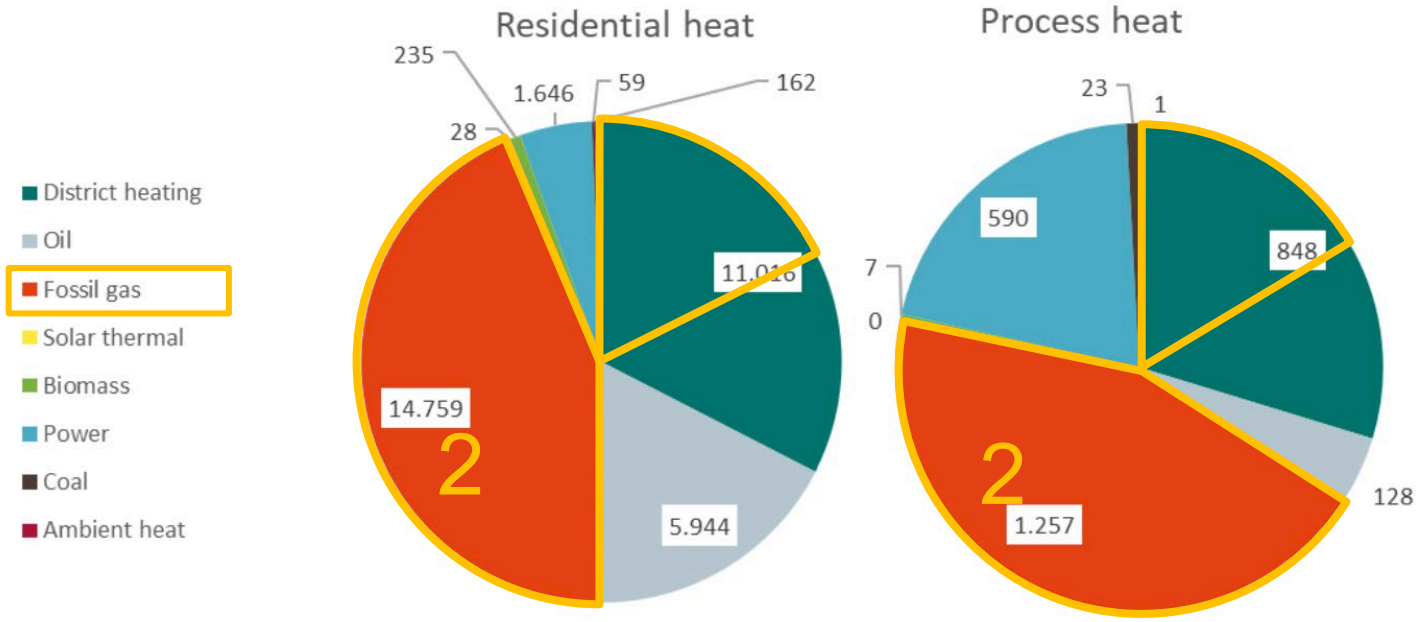
GENeSYS MOD

Heat is responsible for 56% of energy demand in Berlin



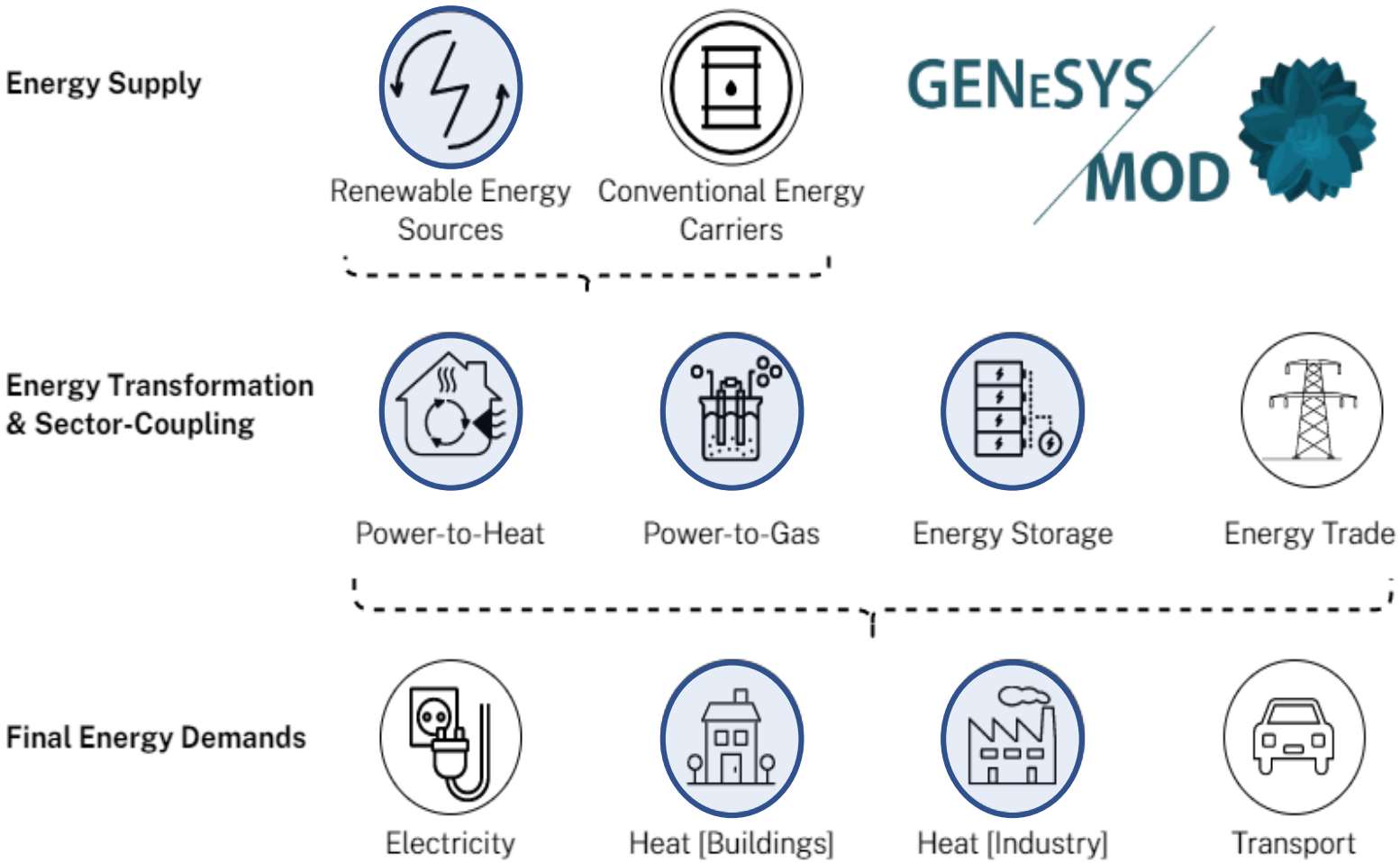
Heating demand in Berlin. Source: Own illustration.

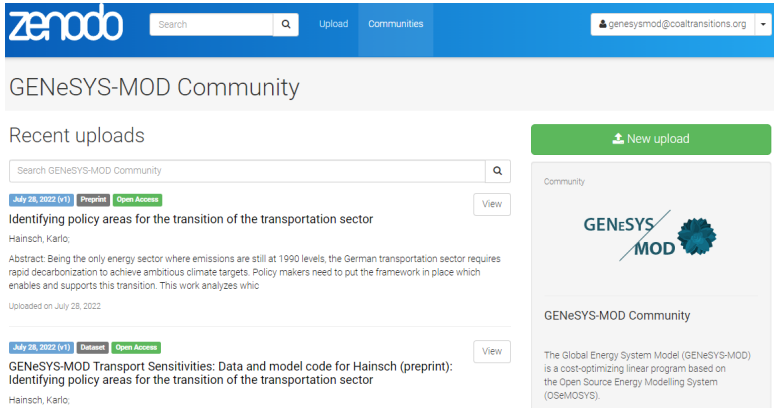


Final energy consumption by for residential and process heat. Source: Own illustration.

1. **Residential heat** is responsible for the **majority** of the **heat demand** (and total energy demand)
2. **Gas dominates** decentral residential heat, district heat and process heat

Expansion of the **G**lobal **EN**ergy **SYS**tem **M**odel (GENeSYS-MOD) for a detailed representation of the heating sector





Linear, cost optimizing, open-source energy system model with up to **hourly** resolution until **2050**

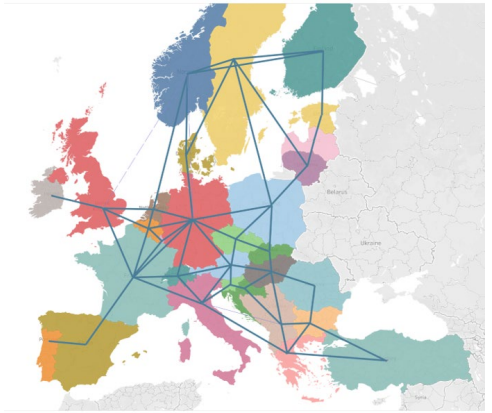
European energy market scenarios determine Berlin´s energy supply

Input parameter based on European and German model runs – e.g.:

- CO2-prices
- **Electricity** import quantities and costs
- **Hydrogen** import quantities and costs

Input parameter specific to the Berlin case study – e.g.:

- Renewable heat potential:
  - Currently still subject to **uncertainties** → currently several studies regarding renewable potentials are in progress for Berlin → Results should be available by end of the year.
- Heat demand
- CO2 reduction targets: **climate neutrality** by 2045



open ENTRANCE

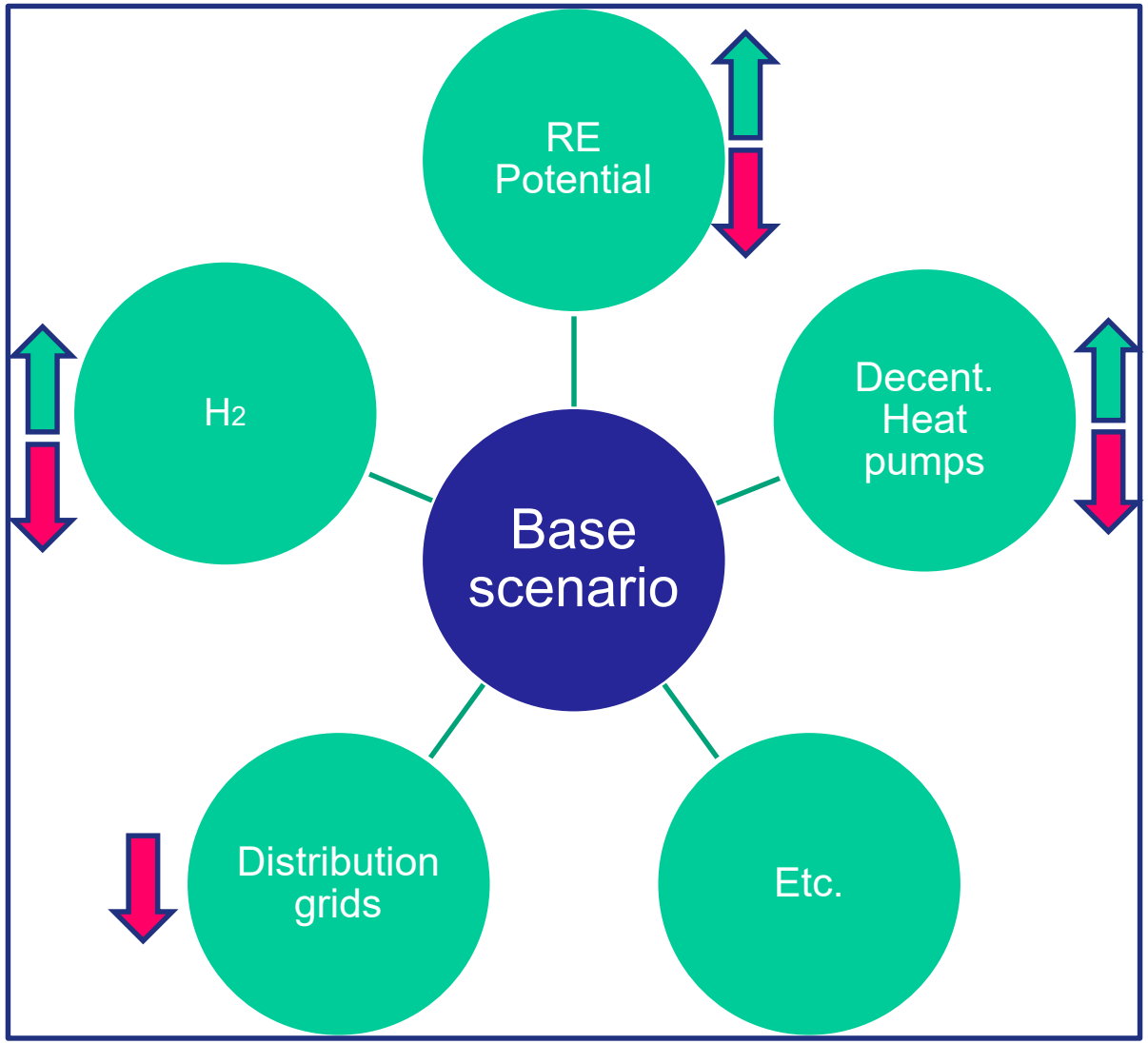
CO_2 | H_2 | Power

OPEN-HEAT-BE
DECARBONIZATION PATHWAYS FOR THE HEATING SECTOR IN BERLIN

Dealing with uncertainties – implementing sensitivities

Base scenario

- Medium **renewable heat** potential
  - Geothermal
  - Waste water
  - River water
  - Etc.
- No limitation in the **electricity distribution grid**
- Medium limitations for **decentral** aerial **heat pumps** – Ground-source heat pumps are limited to the amount of 1-2 family houses
- Medium **H_2-availability**
- **CO_2-Price** exceeds 100€ by 2035 and 355€ by 2050
- **Sensitivities** for the inputs will follow



Base scenario results - district heat supply

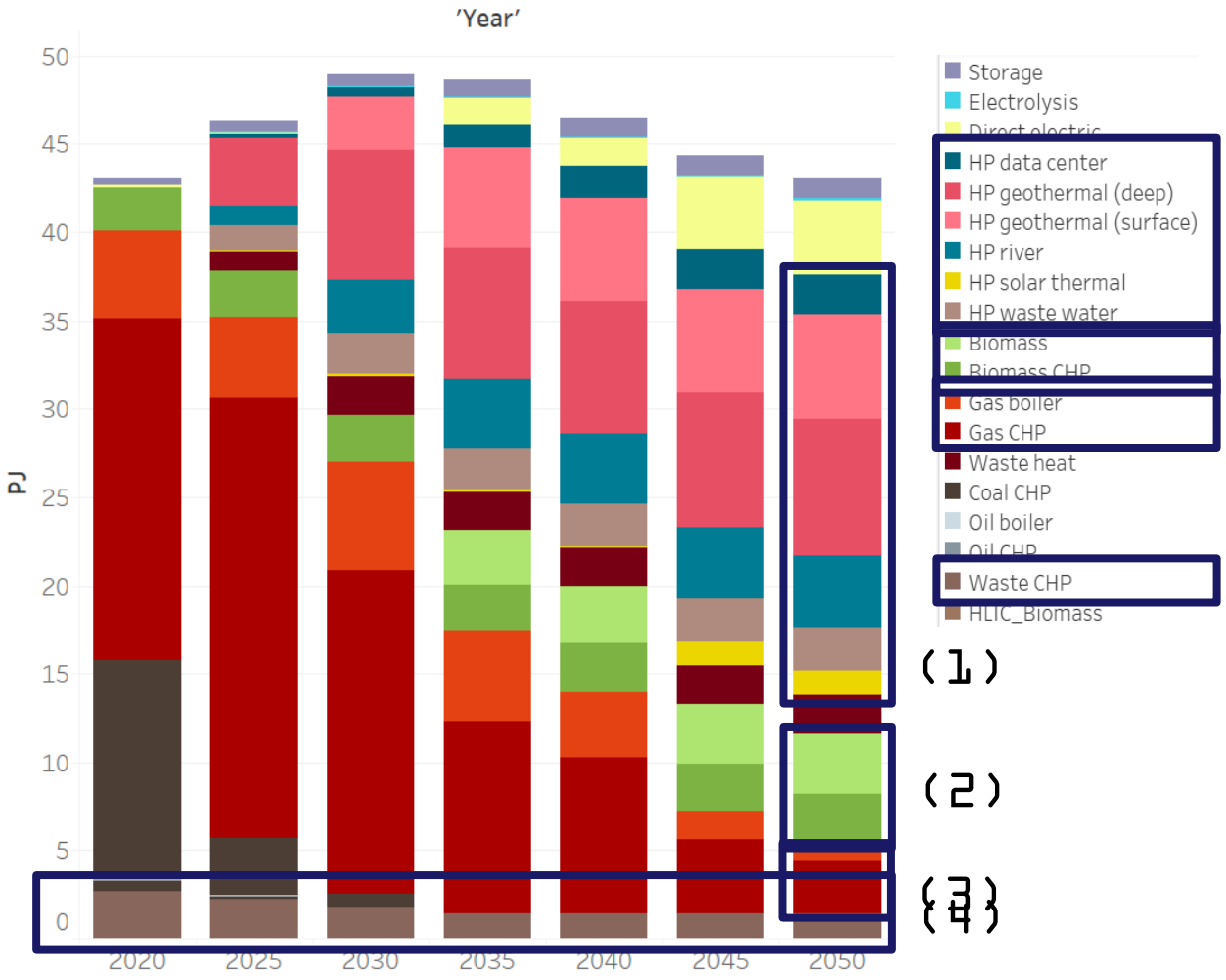
Developments of district heat supply

(1) **Heat pumps** will supply the **majority** of **district heat**

(2) Usage of **biomass will increase**

(3) Heat from **gas and coal** will **decrease.** Remaining gas-fired CHPs and boiler will be operated with **mainly imported hydrogen** or **synthetic gas**

(4) **Waste** quantitites will **decrease** in the future due to measures towards a **circular economy.** Hence, contribution of waste incineration to the district heat supply will shrink



Base scenario results - district heating capacities

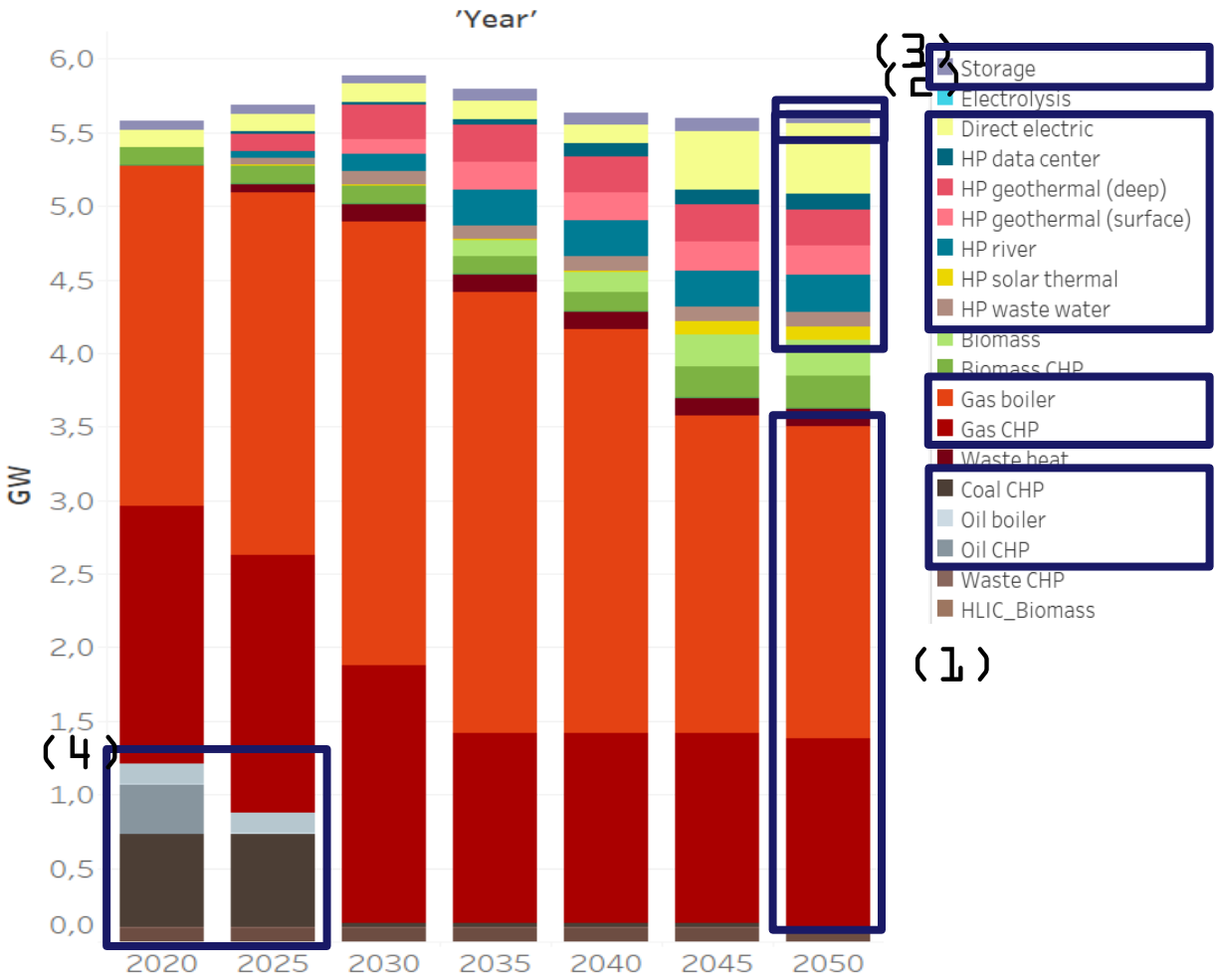
Developments of district heat capacities

(1) Significant **capacities of gas-fired CHPs** and **boiler remain** for meeting the **peak demands** during the heating periods. However, **not the full capacity is needed** any more by 2050.

(2) In total **1 GW** of large-scale **heat pumps** and **500MW** direct **electric heaters**

(3) **Seasonal heat storage** is **limited** to **90MW** in the base scenario. If more storage is enable, the model opts for the **higher storage** → leads to lower capacities and usage of direct electric heaters

(4) **Coal and oil-fired boiler** and



*Note: CHPs are displayed with electric and thermal capacity here. The thermal capacity is hence lower than the depicted values.

Base scenario results- disctric heating in 2045

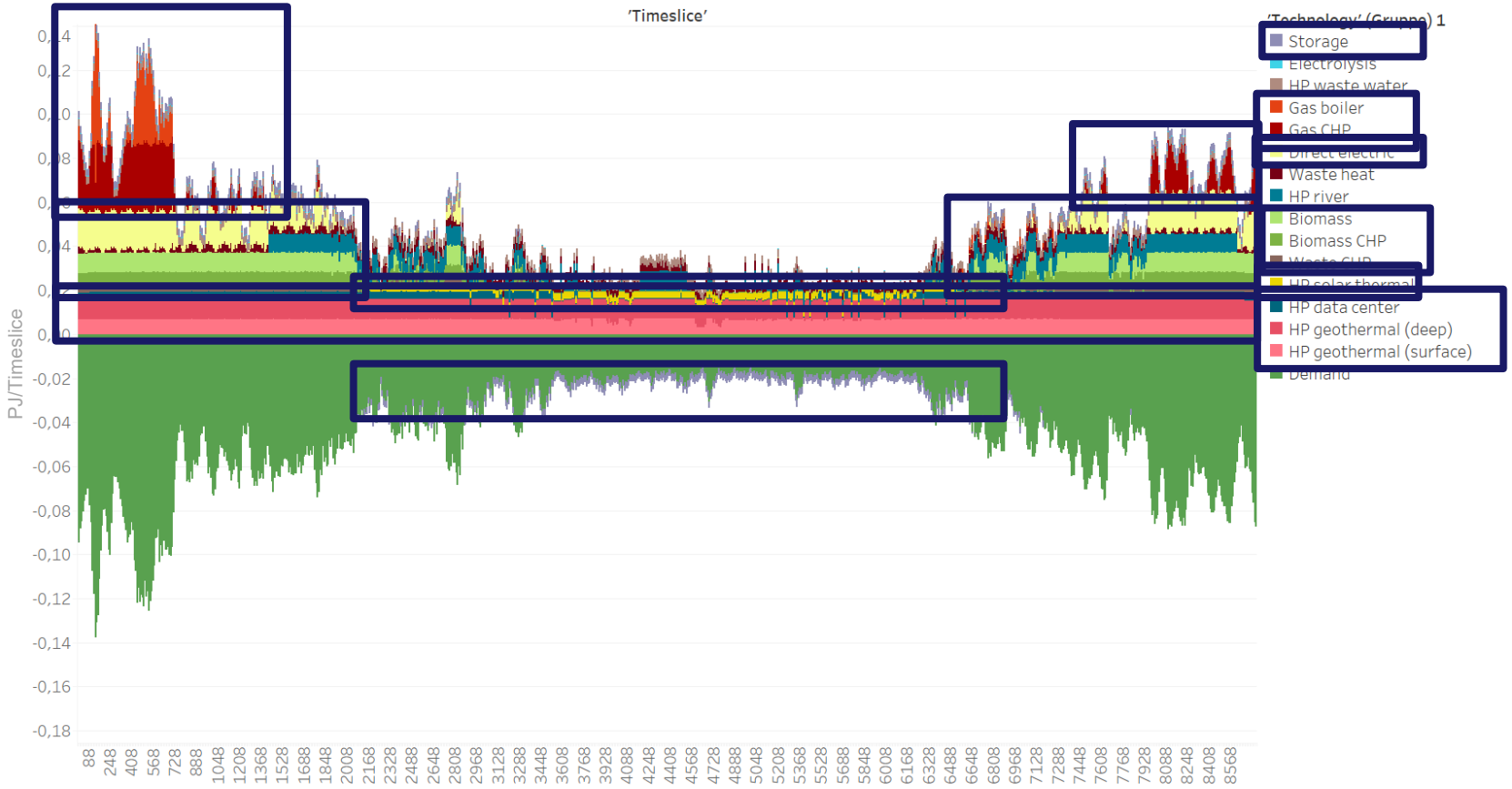
District heating in 2045

(1) **Peak loads**: gas boiler and gas CHPs. Fossil gas replaced with synth. Gas

(2) **Base load** year around by geothermal, data center, waste water **HPs**

(3) **Additional base load** during heating periods with direct electric, biomass, and waste CHP

(4) **Heat for storages**: solar thermal HPs



Base scenario results - (decentral) residential heat supply

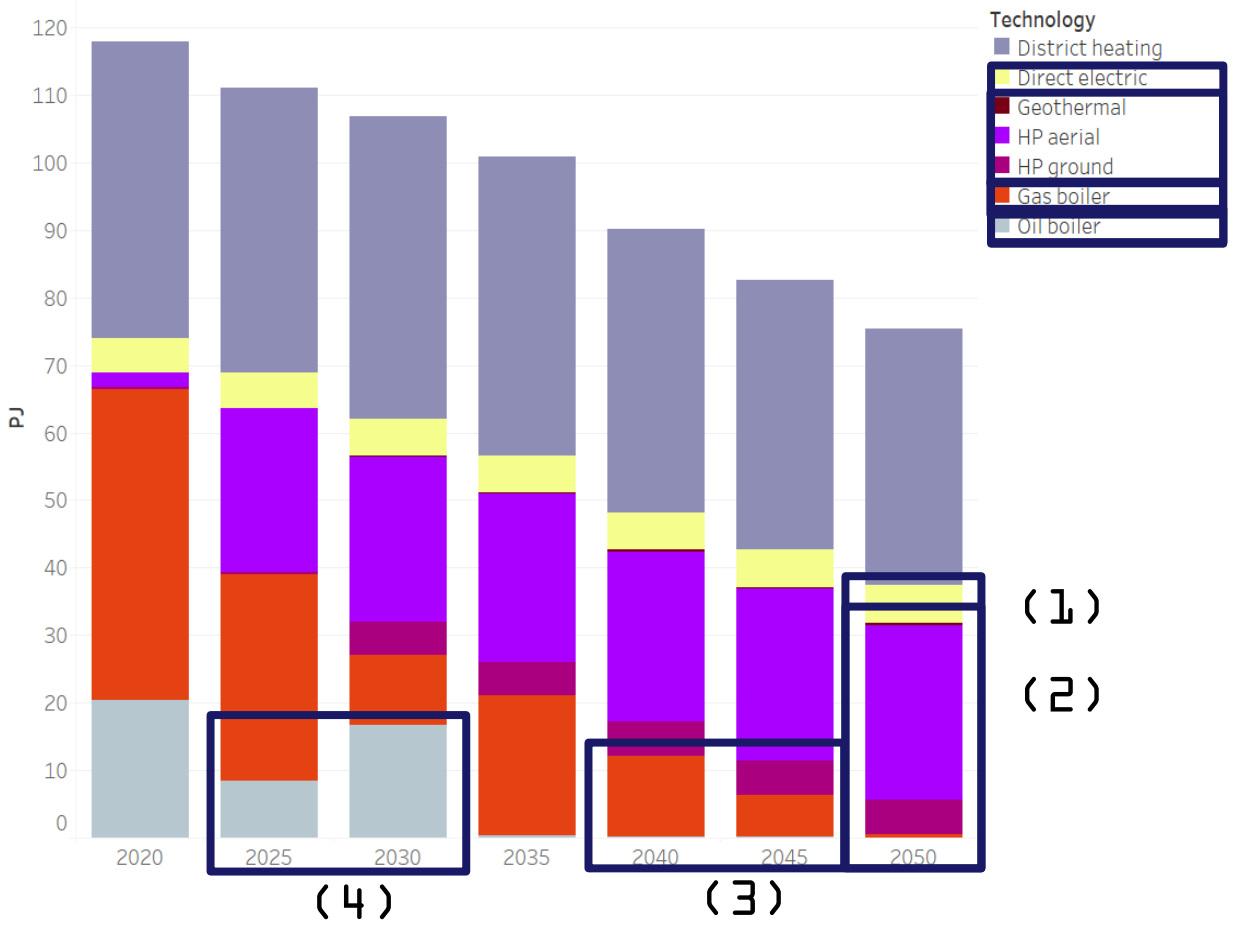
Developments of residential heat supply

(1) Only around **50% of residential heat** will be produced by **decentral** applications.

(2) In 2050, the decentral heat supply will be **almost entirely electric** - mainly (air-source) heat pumps.

(3) (Synthetic) **gas will not be used by 2045** in the decentral heat supply.

(4) **Oil boiler** will **cease to operate by 2030**.

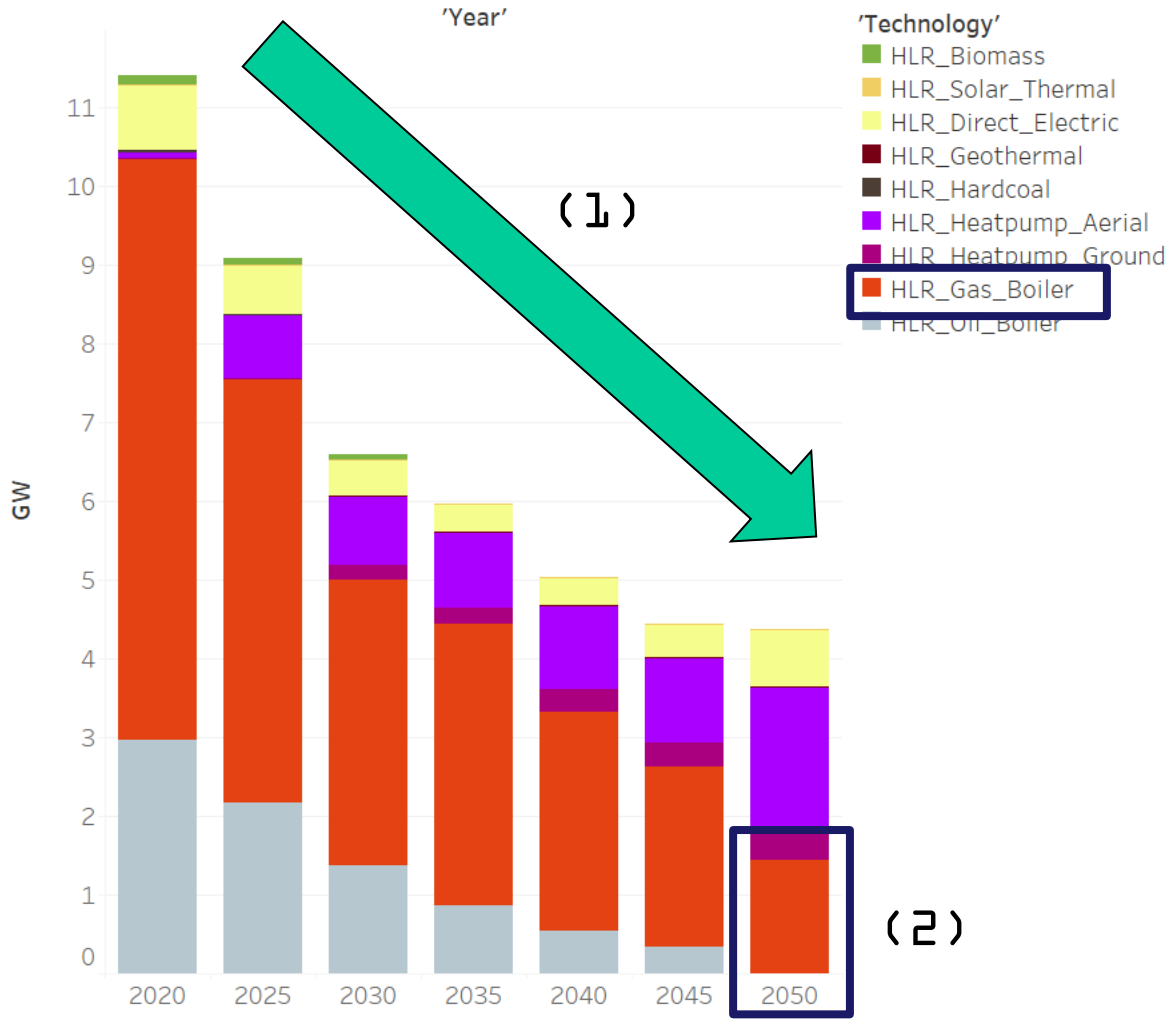


Base scenario results - (decentral) residential heat capacities

Developments of residential heat supply

(1) Installed **capacity halves** between 2020 and 2050 due to:
- **Efficiency measures**
- Connection to **district heating** grid

(2) Until 2030, **new gas boilers will be installed.** They can be interpreted as **bivalent heating** systems consisting of a heat pump and gas boiler for peak supply. In the current model, bivalent heating systems are not explicitly considered. The **gas boilers will remain as capacity in 2050 but will not operate anymore.**



Conclusion & Lookout

- **Feasibility**
  - **100% Renewable** heat supply is **possible for Berlin** in the base case
- **Uncertainty**
  - Uncertrainty regarding **renewable potential** and deployment of **decentral heat pumps**
  - **Seasonal storages** are a preferred option for the model and enable more efficient operation of large-scale heat pumps → **Uncertainties** on the **scale** they can have in Berlin
- **Sensitivity**
  - Base case still relies on **hydrogen** which is not efficient to use in a the heating sector from a thermodynamic perspective
    - Pathways relying on **hydrogen** in the heating and transportation sector have **high risks of fossil-fuel lock-ins** if hydrogen cannot be produced in sufficient quantities from renewables
  - We will hence examing different options for Berlin via **sensitivities** to design options which can **decrease the risk** of lock-in due to reliance on hydrogen in the future in the heating sector.

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Thank you very much!

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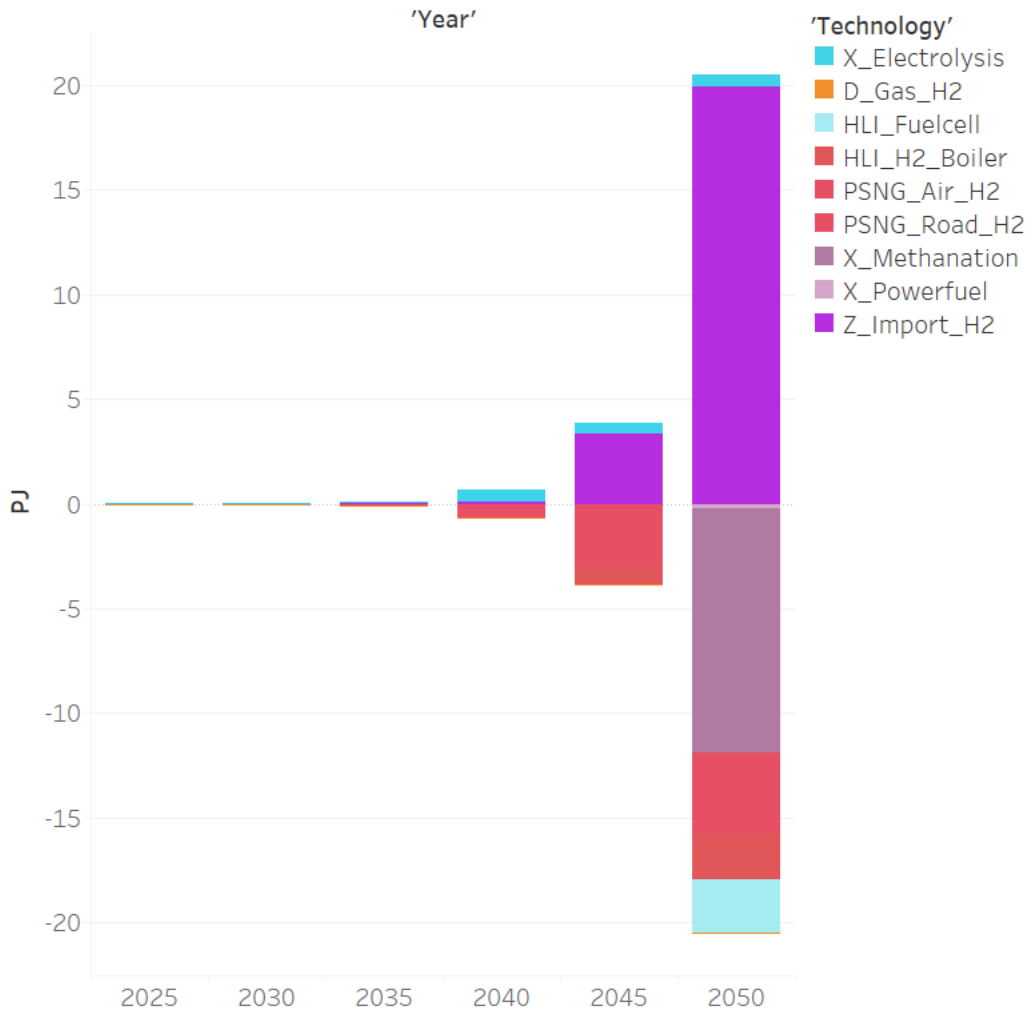
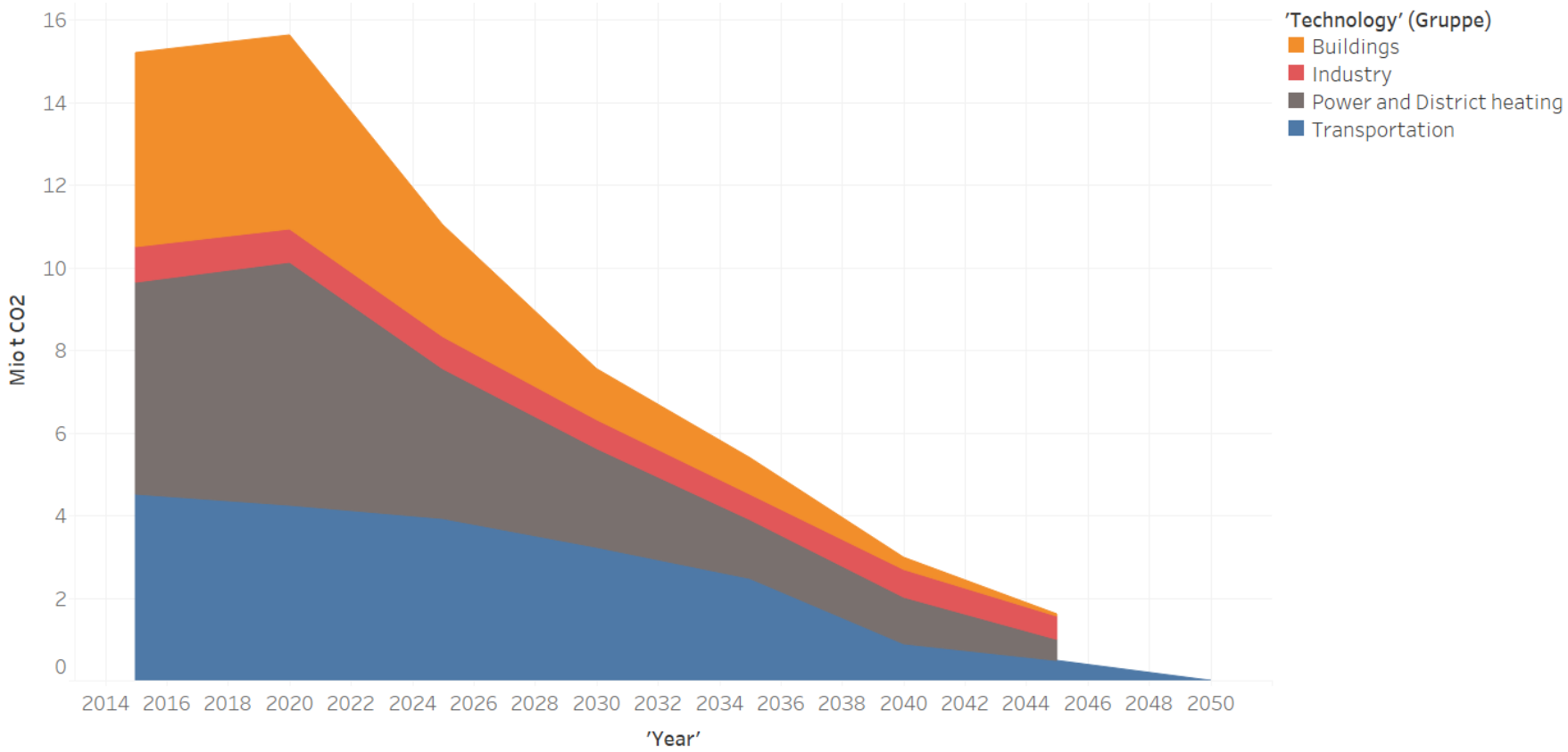
Ergebnisse aus dem Basisszenario - H2

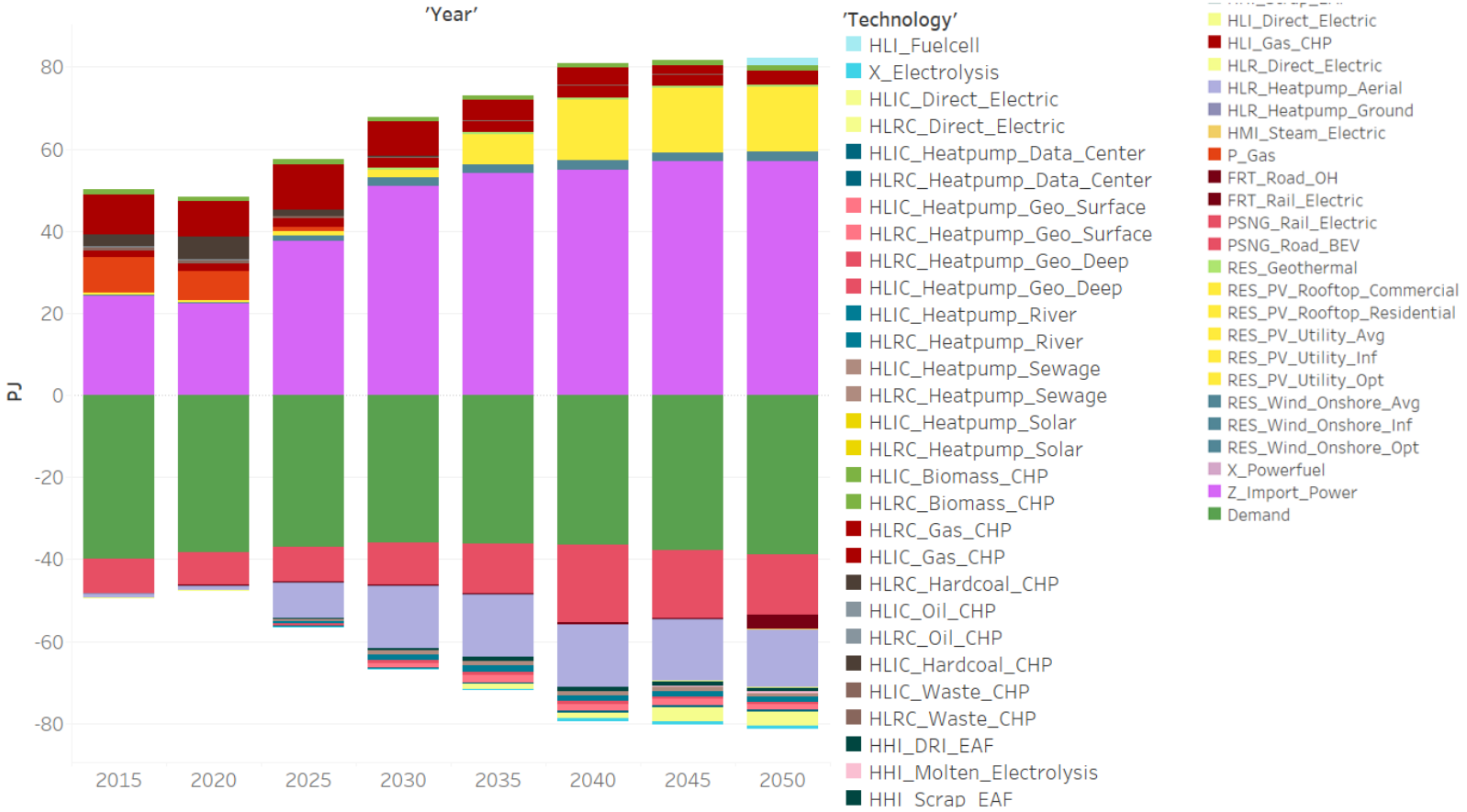


Ergebnisse aus dem Basisszenario - Emissionen

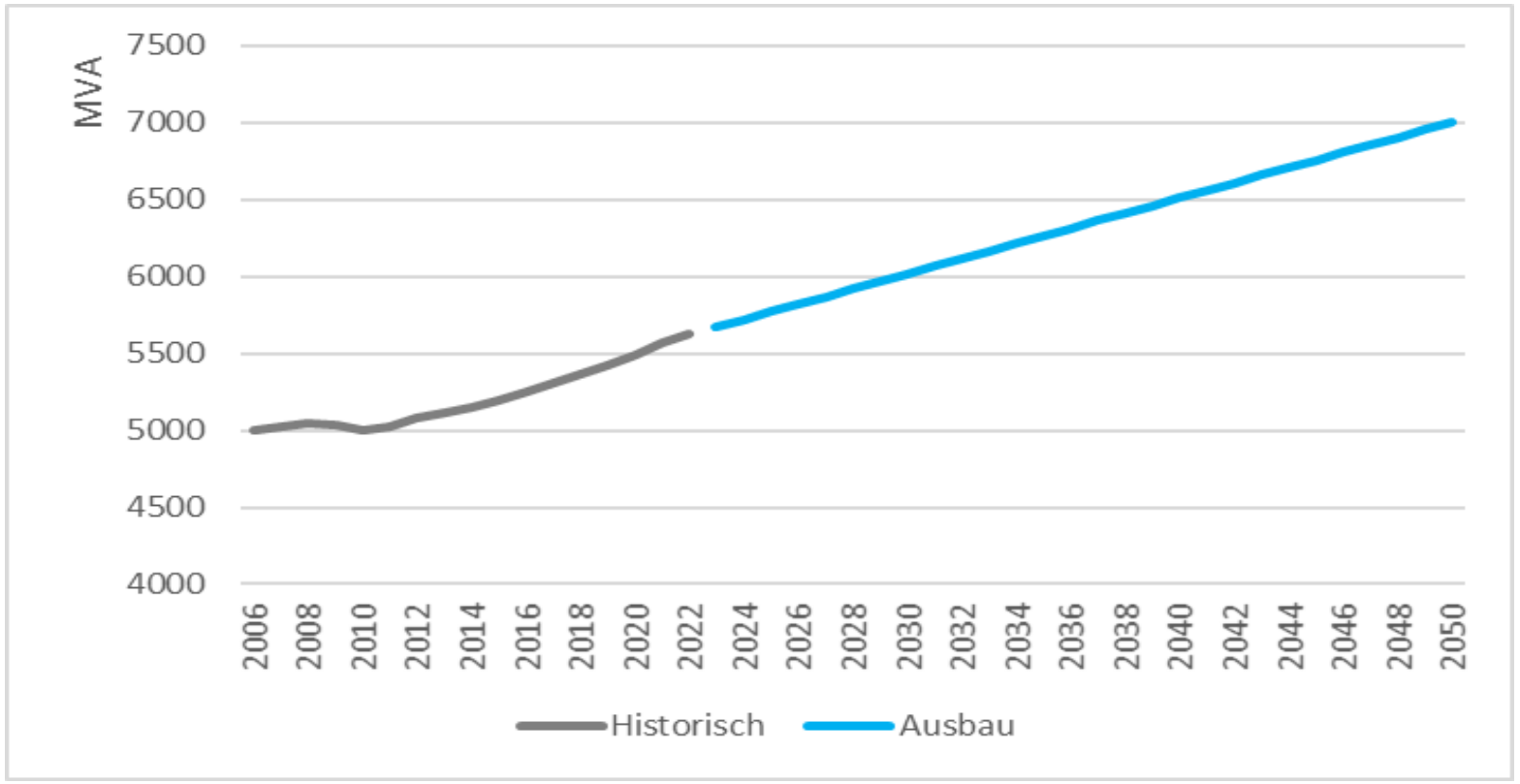


- Total emissions of ca. 195 Mio. t CO2 since 2020
- → Around 1.75° C at 67% likelihood (Hirschl et al. 2021)

Base scenario results - electricity



Bisher nicht ausreichend betrachtete Restriktion - Verteilnetzausbau → Ausbaugrenzen



Installierte Leistung in MVA auf Mittel/Niederspannung in Berlin. Quelle: Stromnetz Berlin (2023)

Bisher nicht ausreichend betrachtete Restriktion - Verteilnetzausbau → Fernwärme und dezentrale Wärme

H2020 Gradual Development Scenario

- Beschränkungen führen zu Installation von H2-Boilern und dezentralen CHPs → Netzumbau notwendig
- Wärmepumpen nur noch etwa ein Drittel der Raumwärme
- Auch Einfluss auf Fernwärme, da dort dann weniger Gas eingesetzt werden kann → Mehr Elektrodenkessel die über Mittel-/Hochspannungsnetz versorgt werden.

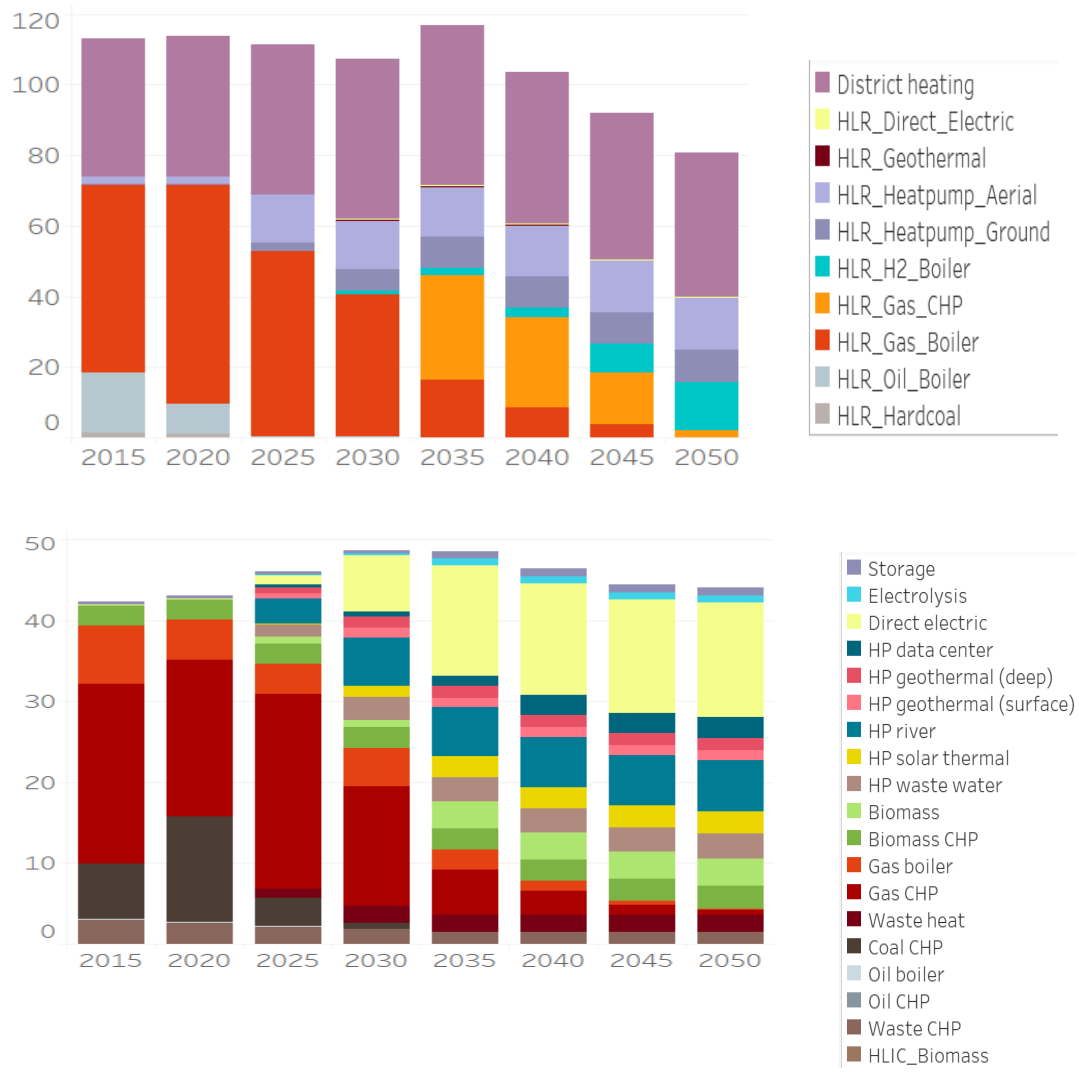


Table 23: Heat pump potential for different heat sources in the scenarios MedRes and LowRes.
Source: Own calculations based on Egelkamp et al. (2021), Ritzau et al. (2019), Dunkelberg et al. (2021,2020), Blöcher et al. (2019).

Heat source	2015	2020	2025	2030	2035	2040	2045	2050
in MW				*Scenario MedRes*				
River	250	250	250	250	250	250	250	250
Geo (deep)	250	250	250	250	250	250	250	250
Geo (surface)	200	200	200	200	200	200	200	200
Solar	175	175	175	175	175	175	175	175
Wastewater	100	100	100	100	100	100	100	100
Data center	0	0	0	20	40	100	100	100
				Scenario LowRes				
River	125	125	125	125	125	125	125	125
Geo (deep)	125	125	125	125	125	125	125	125
Geo (surface)	100	100	100	100	100	100	100	100
Solar	88	88	88	88	88	88	88	88
Wastewater	50	50	50	50	50	50	50	50
Data center	0	0	0	10	20	50	50	50

Table 24: Investment costs for large-scale heat pumps.

Source: Own calculations based on European Commission et al. (2017, 54) and Dunkelberg et al. (2020, 125 f.).

Heat source	2015	2020	2025	2030	2035	2040	2045	2050
				in M€/GW				
River	1077	987	942	898	868	838	823	808
Geo (deep)	2643	2613	2603	2593	2543	2493	2443	2393
Geo (surface)	2096	2066	2056	2046	1996	1946	1896	1846
Solar	3943	3943	3724	3509	3356	3205	3044	2954
Wastewater	1300	1200	1145	1091	1055	1018	1000	982
Data center	720	660	630	600	580	560	550	540

Annahmen – Entwicklung der Gebäudewärmenachfrage

In GWh	2020	2025	2030	2035	2040	2045	2050
Wärmenachfrage in OPEN-HEAT-BE	33,850	31,353	30,000	27,000	24,000	22,000	20,000
Wärmenachfrage in der Wärmestrategie BAU	33,850	33,297	32,744	31,017	29,290	27,769	26,248
Wärmenachfrage in der Wärmestrategie Klimaschutz	33,862	31,353	28,843	24,890	20,937	18,626	16,315