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Supplementary Information for:

Replacing gas boilers with heat pumps is the fastest way to cut German gas consumption

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In this supplement, we show our used data that is not easily accessible.

Supplementary Note 1: Gas use in German industry

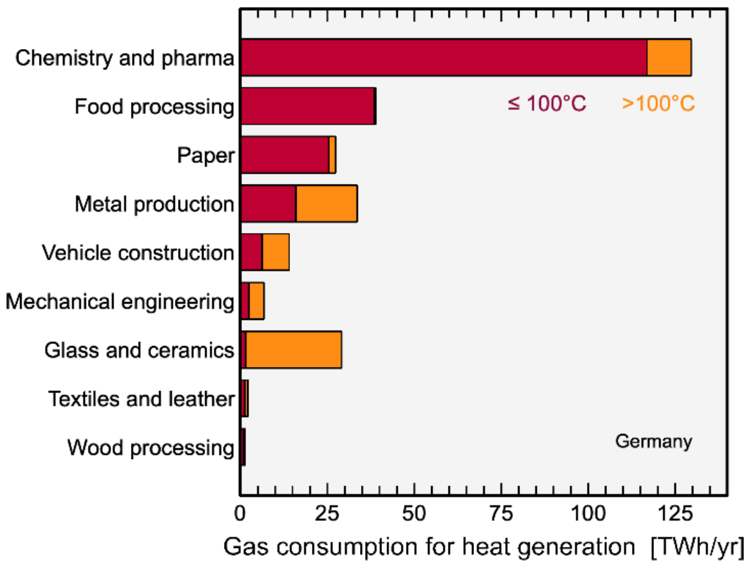

Figure S1 | Annual gas use of German industry[1]. The heat below 100 °C is estimated from a Europe-wide study[2] scaled down to Germany.

To ensure that no serious errors occur when scaling down from a Europe-wide study[2] to Germany, the three values used in our study (chemistry and pharma, food processing, and paper industries) were compared with two doctoral theses on heat consumption in German industry[3,4]. Only the values for the chemical industry differ significantly, as some sources evaluate waste heat use separately.

Supplementary Note 2: Hourly load profiles for gas consumption

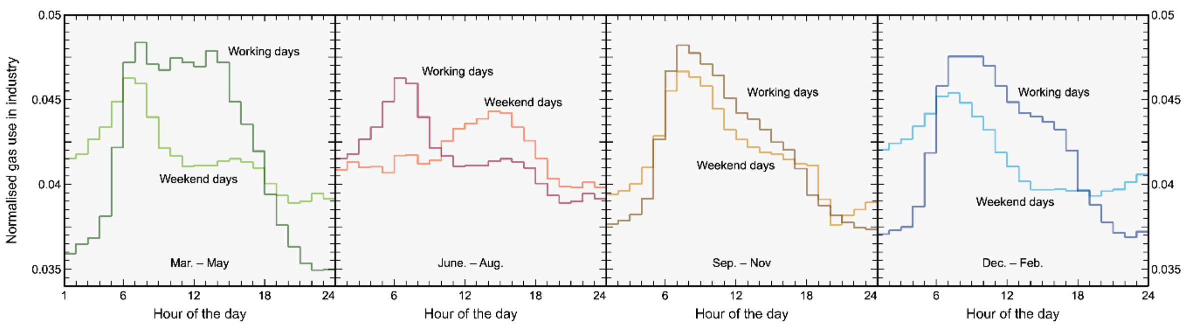

Figure S2 | Hourly load profiles of industry in Germany, taken from the database of the energy load curve adjustment tool[5] (eLOAD) of the Fraunhofer Institute for Systems and Innovation Research (ISI). These load profiles comprise all kinds of industries, not only the chemical, paper and food processing industry, and are normalised to unity.

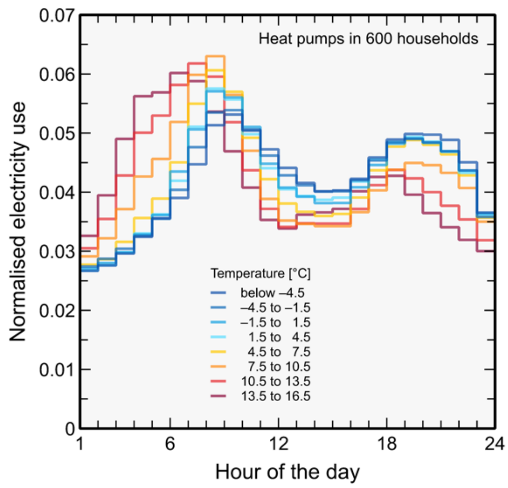

Figure S3 | **Hourly data of electricity use of heat pumps** in 600 private households, averaged from the half-hourly data from Ref. [6] to hourly data, distinguished between eight ranges of average daily outdoor temperature, and normalised to unity.

For the hourly load curves of residential heating, we do not use the curves for gas demand, as gas can be stored in the gas grid and therefore easily delivered when there is an immediate demand for heat, while heat pumps draw electricity where it is beneficial to smooth demand throughout the day, e.g. encouraged by flexible electricity tariffs and enabled by some local heat storage. We have therefore averaged the half-hourly data from Ref. [6] to hourly data, based on approximately 600 households with heat pumps. A distinction is made between eight ranges of average daily outdoor temperature. With using this load profile, we also account for frost formation and defrosting at the heat pump. In these hourly load curves, the characteristic peak in the morning and evening of gas heating is smoothed out significantly. Our model calculations show that this smoothing significantly reduces the number of load hours of gas-fired power plants, as more renewable electricity can be used. This also reduces the required expansion of electricity grid capacities.

Supplementary Note 3: New additions of renewable power capacities in Germany

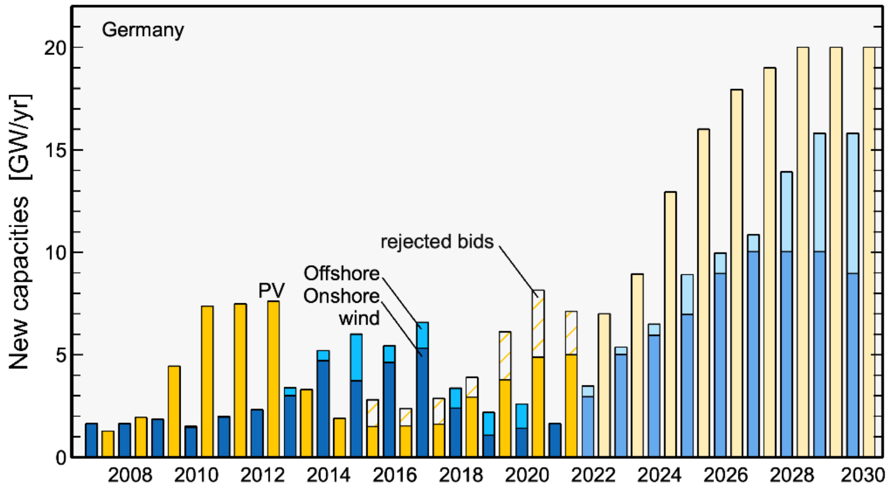

Figure S4 | (Planned) addition of onshore and offshore wind and PV capacities. The years between 2022 and 2030 are according to the plans of the German Federal Ministry of Economics and Climate Protection[1] (BMWK 2022).

The German government has tendered new PV capacities since 2015. The maximum bid entry price was rather low (usually near 8 €ct/kWh) but new capacity was tightly limited, leading to a total of 12 GW of rejected bids, shown as hashed columns. The ministerial plan for 2022 to 2030 shows similar growth to the rejected PV bids and to onshore wind between 2011 and 2015 and is therefore likely to be translated into action.

Table S1 | Factors for the addition of new renewable power capacities relative to 2020, according to the plans of the Federal Ministry of Economics and Climate Protection[7] , shown in Figure S4.

	Wind onshore	Wind offshore	PV
2021	1.03	1	1.092593
2022	1.083634	1.084282	1.222222
2023	1.174811	1.140469	1.3878
2024	1.283151	1.224751	1.627451
2025	1.409726	1.533783	1.923747
2026	1.572773	1.692981	2.255991
2027	1.755127	1.824086	2.607843
2028	1.937482	2.44215	2.978214
2029	2.119836	3.359882	3.348584
2030	2.282883	4.446177	3.718954

Supplemental Note 4: building stock in Germany

Gas consumption in German residential buildings (Figure 1) is calculated from Tables S1 and S2. The tables show that only 4% of apartment buildings are unrefurbished, and two thirds of the buildings constructed before 1979 have already been refurbished to some extent for energy efficiency. One third of all apartment buildings have even been extensively refurbished by the commercial housing industry[8]. The detached houses are mostly privately owned; hence the focus so far has not been on full modernisation, but only on partial modernisation, which does not improve energy efficiency as much[8].

There was 3.9 billion m² of housing space in Germany in 2020[9]. Of these, 2.3 billion m² can be found in detached and semi-detached houses, 1.5 billion m² in apartment buildings. Thus, it is not surprising that in Figure 1, considerably less heating is used for apartment buildings than for detached houses, although about half of housing (almost 21.4 million flats) is in apartment buildings.

Not all houses will be equipped with heat pumps, therefore space requirements won't be limiting the deployment of heat pumps.

Table S2 | Data on the building stock in Germany from Ref. [8].

Extend of refurbishment	Built from [year] to [year]	before 1919	1919 1948	1949 1978	1979 1986	1987 1990	1991 1995	1996 2000	2001 2004	2005 2008	after 2009
Apartment buildings											
Not or slightly modernised	Share of all buildings [%]	1.1	0.8	2.1	0.9	0.4	0.9	0.9	0.3	0.2	0.7
	Share of apartment buildings [%]	6.59	4.79	12.57	5.39	2.40	5.39	5.39	1.80	1.20	4.19
	Share of usable floor space [%]	2.4	1.5	4.8	2.1	0.9	2.3	2.2	0.8	0.8	2.1
	Share of final energy consumption [%]	2.8	1.8	5.4	2.3	0.8	1.9	1.7	0.6	0.5	0.8
	Share of CO_2(eq) emissions [%]	2.9	1.8	6	2.3	0.9	2	1.9	0.6	0.5	0.8
	Final energy consumption [TWh]	17.53	11.45	34.31	14.28	5.23	11.79	10.5	3.65	3.03	4.88
	CO_2(eq) emissions [million t]	3.85	2.42	7.88	3.04	1.16	2.64	2.45	0.83	0.6	1
Medium to largely modernised	Share of all buildings [%]	1	0.7	2.5	0.2	0.1	0.2	0	0		
	Share of apartment buildings [%]	5.99	4.19	14.97	1.20	0.60	1.20	0	0		
	Share of usable floor space [%]	2.2	1.5	5.9	0.8	0.3	0.5	0.1	0		
	Share of final energy consumption [%]	2.4	1.7	6	0.7	0.2	0.4	0.1	0		
	Share of CO_2(eq) emissions [%]	2.4	1.8	6.6	0.7	0.2	0.4	0.1	0		
	Final energy consumption [TWh]	15.22	10.81	38.12	4.42	1.48	2.44	0.46	0.07		
	CO_2(eq) emissions [million t]	3.2	2.3	8.72	0.97	0.33	0.53	0.11	0.01		
Extensively modernised	Share of all buildings [%]	0.5	0.5	2.6	0.1	0					
	Share of apartment buildings [%]	2.99	2.99	15.57	0.60	0					
	Share of usable floor space [%]	0.9	0.8	6.1	0.3	0					
	Share of final energy consumption [%]	0.9	0.7	5.4	0.3	0					
	Share of CO_2(eq) emissions [%]	0.8	0.7	6.3	0.3	0					
	Final energy consumption [TWh]	5.46	4.56	34.38	1.79	0.13					
	CO_2(eq) emissions [million t]	1.04	0.92	8.29	0.4	0.02					
Standalone houses											
Not or slightly modernised	Share of all buildings [%]	3.4	3	10.2	5.2	2.6	4.1	6.1	3.8	2.8	5.7
	Share of standalone houses [%]	4.10	3.61	12.29	6.27	3.13	4.94	7.35	4.58	3.37	6.87
	Share of usable floor space [%]	2.6	2.1	6.7	3.8	1.7	3	4.5	2.8	2.1	4.6
	Share of final energy consumption [%]	3.5	2.7	8.6	4.1	1.5	2.7	4	2.1	1.2	1.7
	Share of CO_2(eq) emissions [%]	3.3	2.5	8.6	3.8	1.4	2.5	3.6	2.2	1.2	1.8
	Final energy consumption [TWh]	22.3	17.38	54.19	26.07	9.9	17.42	25.07	13.45	7.84	10.48
	CO_2(eq) emissions [million t]	4.4	3.32	11.32	5.05	1.85	3.28	4.71	2.95	1.64	2.36
Medium to largely modernised	Share of all buildings [%]	4.5	4.6	13.2	2.3	0.6	0.6	0.3	0	0	
	Share of standalone houses [%]	5.42	5.54	15.90	2.77	0.72	0.72	0.36	0.00	0.00	
	Share of usable floor space [%]	4.1	3	9.2	1.7	0.4	0.3	0.4	0	0	
	Share of final energy consumption [%]	5.2	3.8	11.4	1.7	0.4	0.3	0.3	0	0	
	Share of CO_2(eq) emissions [%]	4.8	3.5	11.1	1.7	0.3	0.3	0.2	0	0	
	Final energy consumption [TWh]	33.02	23.84	71.96	11.09	2.26	1.85	1.98	0.11	0.12	
	CO_2(eq) emissions [million t]	6.37	4.58	14.61	2.2	0.42	0.35	0.3	0.02	0.02	
Extensively modernised	Share of all buildings [%]	1.8	1.9	5.7	0.5	0	0.1	0			
	Share of standalone houses [%]	2.17	2.29	6.87	0.60	0.00	0.12	0.00			
	Share of usable floor space [%]	1.8	1.4	3.8	0.4	0	0	0			
	Share of final energy consumption [%]	1.8	1.4	3.7	0.3	0	0	0			
	Share of CO_2(eq) emissions [%]	1.7	1.3	3.5	0.3	0	0	0			
	Final energy consumption [TWh]	11.32	9.17	23.68	2.13	0.08	0.19	0.02			
	CO_2(eq) emissions [million t]	2.21	1.73	4.65	0.42	0.01	0.03	0			

Table S3 | Data on the building stock in Germany from Ref. [8]. The specific room heat (SRH) is given in [kWh/m²/yr]. The gas usage (in TWh) is calculated by the authors from the total gas usage in 2020, which was 273.3 TWh.

Apartment buildings

Class	Share [%]	Cumulative share [%]	TWh (gas)	SRH from	to
H	1.9	1.9	2.18	250	and more
G	4.0	5.9	4.60	200	250
F	9.7	15.6	10.71	160	200
E	15.5	31.1	18.26	130	160
D	24.4	55.5	21.19	100	130
C	21.0	76.5	23.04	75	100
B	14.3	90.8	12.89	50	75
A	5.3	96.1	5.05	30	50
A+	4.0	100.1	3.92	less than	30

Standalone houses

Class	Share [%]	Cumulative share [%]	TWh (gas)	SRH from	to
H	14.3	14.3	29.68	250	and more
G	10.9	25.2	22.11	200	250
F	13.4	38.6	22.62	160	200
E	12.8	51.4	9.19	130	160
D	14.0	65.4	29.08	100	130
C	10.0	75.4	15.49	75	100
B	8.8	84.2	15.58	50	75
A+	7.2	91.4	12.41	30	50
A+	8.6	100.0	15.22	less than	30

Supplemental Note 5: Water heating temperature of heat pumps

The heat pump must feed a minimum water temperature into the heating circuit to ensure a pleasantly high room temperature. This water temperature depends strongly on the insulation of the building and on the design of the heating circuit, for example on the size of the radiators. In the past, radiators were often generously dimensioned to ensure sufficiently high room temperatures in all rooms even on the coldest winter days. The quick installation of heat pumps requires that the heating circuit is left as it is, except that perhaps one or two of the smallest radiators are enlarged. This keeps the installation time short and the budget small. However, this implies that on the coldest winter days, not all rooms may be heated to the desired temperature, for example the bedrooms during the day. Additionally, some installers may still calculate according to outdated norm which require to take account of even lower temperatures than the current norm. The supplementary note 10 indicates that this situation only occurs on a few winter days a year. However, installers in Germany are currently bound by strict requirements that must be met on the coldest winter days and therefore refrain from installing heat pumps. The government needs to alleviate this responsibility of installers, for example by sharing it with customers, to trigger a boom in heat pump installation.

Our parameters for quantifying the water heating temperature are listed in Table S4.

Table S4 | Parameters for quantifying the water heating temperature $T_{heat} = m*T_h + a$ for the different building energy classes from A to G, shown in Figure 2. T_h is the hourly outdoor temperature in °C. Classes F and G are capped at 60 °C.

Parameter	A	B	C	D	E	F	G
m	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5	−0.5
a	32.5	36.25	39.5	43	47.5	55	57.5

Supplemental Note 6: Sensitivity of the results to COP variations

The COP of heat pumps, shown in Fig. 3, is given by the polynomial *. It varies not only with the temperature difference at which the heat pump operates (i.e. water supply temperature, T, minus outdoor air temperature) and with the water supply temperature T, but also with whether the heat pump operates at full or partial load. Between about 20% and 100% load, the COP usually varies by 0.4 or sometimes even up to 0.6. To account for this variation, a lower COP is indicated by the dashed line in Figure S5. It is based on the heat pumps used for the standard DIN V 18599 Part 5 Section Heat Pumps[10]. The W55 is a collection of heat pumps designed for a T of 55°C and used for heating circuits with radiators instead of underfloor or panel heating. The W35 with a T of 35°C for underfloor heating is rarely operated above 40°C and therefore we ignored its values above 40°C when determining the lower COP.

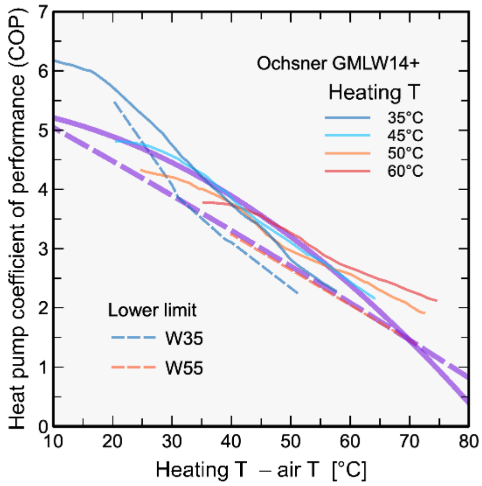

Figure S5 | **Addition of a lower COP** (dashed line) to Fig. 3 of the main text, based on a collection of heat pumps used for the DIN V 18599 standard[10]. These heat pumps are designed for either a water flow temperature of 55°C, optimised for heating circuits with radiators, or of 35°C, optimised for floor or panel heating (dashed thin lines).

This lower bound of the COP serves as a sensitivity analysis. In Figure S6, the modelled results are added to Fig. 5 of the main text, using this lower bound (dashed lines). The variations caused are of similar magnitude as the variations between different meteorological years and between different agglomerations in Germany.

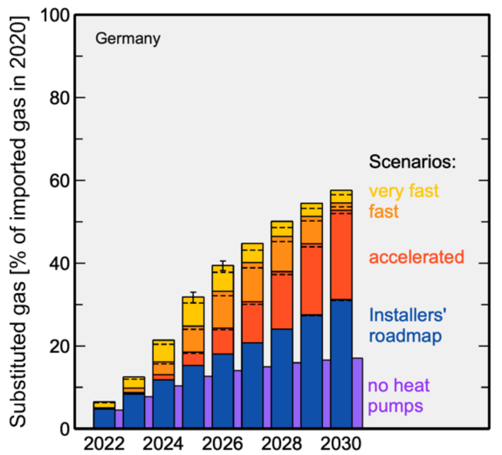

Figure S6 | **Model uncertainties**. Dashed lines: addition of the lower bound of the COP, shown in Fig. S5, to the modelling results of Fig. 5 of the main text.

Supplemental Note 7: Scenarios for the number of installed heat pumps

Starting from 110 000 installed heat pumps in Germany in 2020 (see Figure 4), the scenarios of future installations is described by the factors in Table S5.

Table S5 | Factors for the installed heat pumps in Germany between 2022 and 2030 according to the different scenarios.

Year	Installers	Accelerated	Fast	Very fast
2022	0.016099	0.019477	0.035024	0.128406
2023	0.035419	0.055223	0.113902	0.275248
2024	0.058602	0.113902	0.261101	0.552548
2025	0.086422	0.203526	0.472051	0.829848
2026	0.119805	0.326394	0.683000	0.976690
2027	0.159866	0.472051	0.830200	1.029570
2028	0.207938	0.617707	0.909077	1.045855
2029	0.265626	0.740576	0.945454	1.050621
2030	0.33485	0.910697	0.961064	1.051995

Supplemental Note 8: Saved CO_2 emissions

Combustion of pure methane gives a CO_2-to-methane mass ratio of 2.75. Since LNG is not pure methane, the ratio is[11] 2.56. However, the official inventory of some LNG companies in Australia[12] adds an average of 54.3% to local CO_2 emissions. This is due to the extraction, processing, cooling and subsequent transportation. It also depends on the CO_2 content of the raw gas before the cleaned gas is cooled (this amount of CO_2 is normally discharged into the atmosphere). This results in a CO_2-to-methane mass ratio of 3.95. However, methane leakage is not accounted for fully and, in the case of coal, is well above the official Australian government inventories[13]. As these considerations are beyond the scope of this paper, we use the ratio of 3.95 and note that this is a lower bound and neglects part of the methane emissions. We then use the official conversion of 1 TWh to 0.692 Mt of LNG. With this, the saved CO_2 emissions, calculated from Fig. 5, are listed in Table S6. We assume that fracking gas, imported from the US and Canada, cause similar emissions.

Table S6 | Saved CO_2 emissions in Mt in each year in Germany, considering the value chain of LNG from Australia, neglecting most methane emissions.

Year	Installers	Accelerated	Fast	Very fast
2022	12.5	12.7	13.2	16.6
2023	22.1	23.0	25.4	31.8
2024	31.0	34.2	41.6	54.1
2025	40.3	48.4	63.7	80.5
2026	47.	63.4	85.3	100.3
2027	54.7	79.8	103.2	114.5
2028	63.4	98.9	120.1	129.0
2029	72.5	116.7	133.3	141.0
2030	82.3	137.9	142.3	150.1

Supplementary Note 9: Modelling in different locations within Germany

To account for variations in air temperature across Germany, we modelled with hourly temperature data from the German Weather Service (DWD)[14] from the most populous metropolitan areas: Berlin, Ruhr-Cologne Region (Düsseldorf), Rhine-Main and Rhine-Neckar Region (Frankfurt), Hamburg, Hanover, Nuremberg-Erlangen-Munich Region (Munich) and Stuttgart. Figure S7 shows that Hanover is closest to the median of these sites. Therefore, all data were modelled with the temperature data from Hanover, and the standard deviation due to the choice of locality (multiplied by a factor of 2 to be on the safe side) is represented in Figure 5 of the main text by the error bar in 2026. This also includes the "heat island" effect of cities.

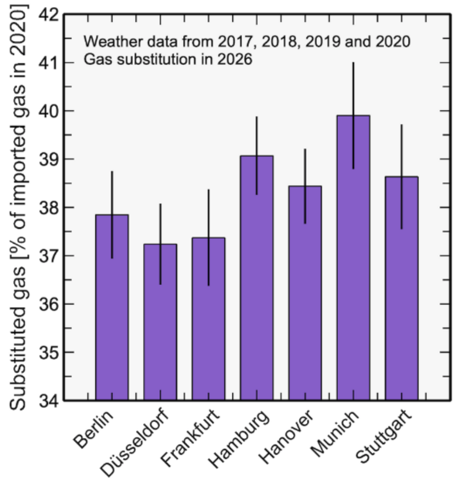

Figure S7 | **Influence of location within Germany** on the amount of modelled gas substitution: the median in 2026 in the biggest metropolitan areas, with the standard deviation from the weather years 2017 to 2020[14]. Hanover is the median and therefore used in our modelling.

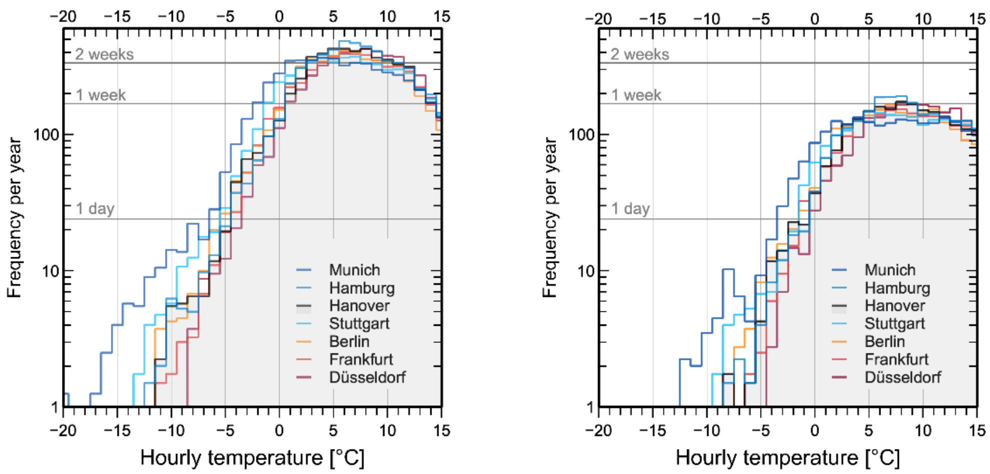

Figure S8 | **Average frequency of hourly outdoor temperature values over one year of heating season**, using data from 2017 to 2020[14], binned in intervals of 1 °C. Black line: Hanover, the median location of gas substitution in Fig. S7. **a)** Sum of all hours during the heating season, which includes all days with an average daily temperature below 13.98 °C[15]. On average over the indicated locations, outdoor temperature is below –5 °C (or below 0 °C) on about 3.5 days (or 24 days) per year. Since air-to-water heat pumps usually operate during the day when the air is warmest and store the heat for the next morning in a boiler, panel **b)** sums up all the hours from a) that are between 7 am and 6 pm. With that restriction, outdoor temperature is below –5 °C (or below 0 °C) on about 16 hours (or 140 hours) per year. This explains why the COP of heat pumps stays above 2 in most building insolation classes on most days, and with an efficiency of 50% of gas-fired power plants, a net amount of gas is substituted.

Supplementary Note 10: hourly resolved examples

Figures S9 and S10 show modelling examples in winter and summer 2025, both for electricity and for gas.

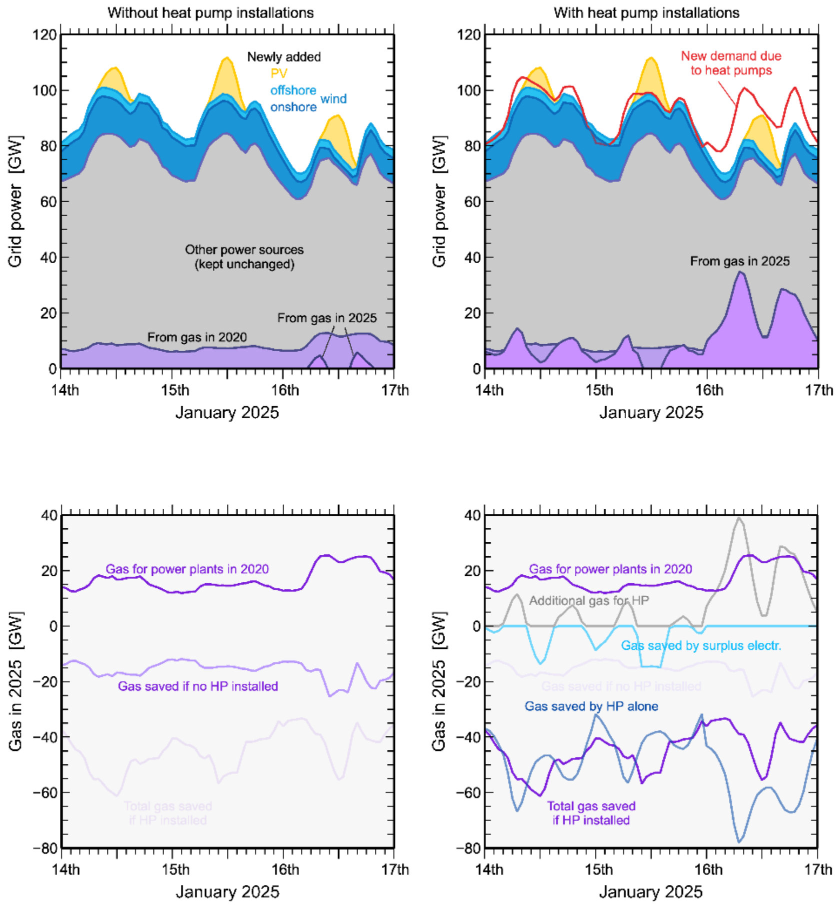

Figure S9 | Excerpt from modelled hourly time series in winter 2025, using weather data from 2020, for the cases of no heat pumps and with heat pumps installed according to the very fast scenario. Positive amounts of gas mean consumed gas, while negative amounts mean substituted gas. While more gas must be consumed by gas-fired power plants to provide electricity to heat pumps, more gas is still substituted than without heat pumps, even on such winter days.

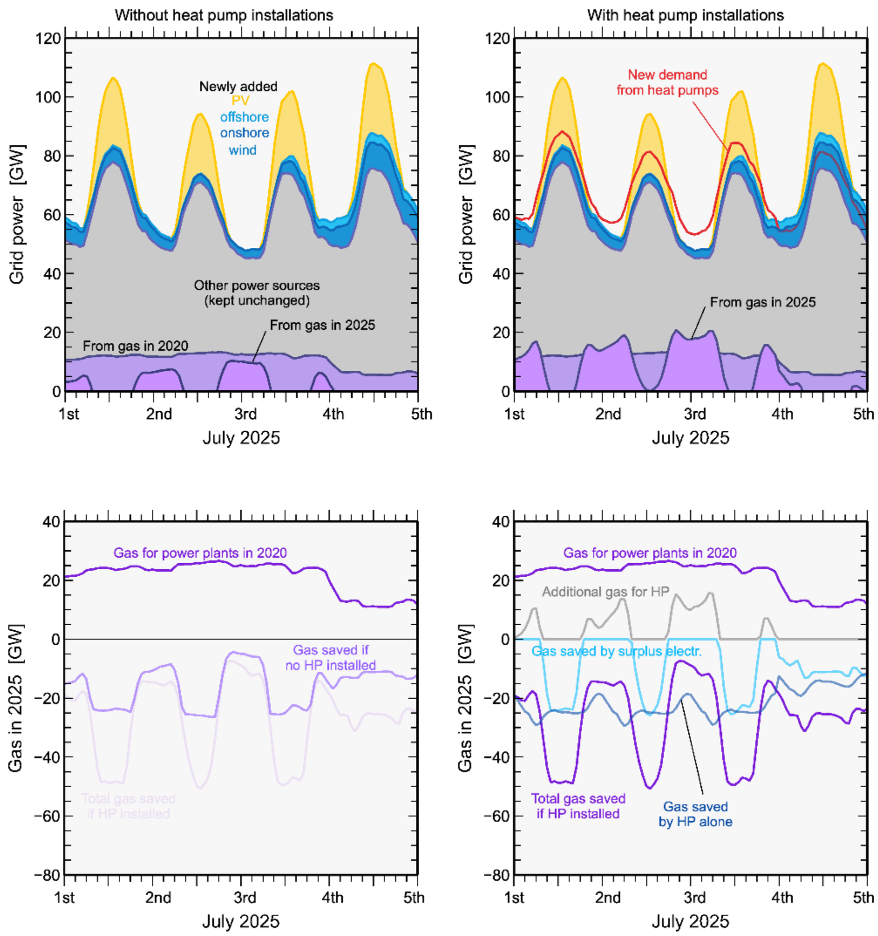

Figure S10 | Excerpt from modelled hourly time series in summer 2025, as in Figure S9. Also on such summer days, more gas is consumed by gas-fired power plants than without heat pumps, but overall a net amount of gas is substituted. As more batteries are installed or become available with vehicle-to-grid in the coming years, PV power generation will extend from daytime to night time, further reducing the load hours of gas-fired power plants and further reducing the amount of needed gas.

Supplementary Note 11: Gas-fired power plants for providing balancing power

We would like to emphasise that only multi-fuel ICE/OCGT should be added to the grid. They can burn not only fossil methane, but also (renewable) hydrogen and biomethane (up to 100% each) and can therefore be used as a renewable balancing option in the future. Such balancing power capacities will be necessary when the annual share of renewables exceeds 80%, which is planned to be the case by about 2030[7]. In this way, stranded assets in the gas system are avoided. In particular, biogas can be used to deliver power at peak hours instead of base power, reducing the load hours of fossil-gas in gas-fired power plants.

Supplementary Note 12: Immediate substitution of fossil gas

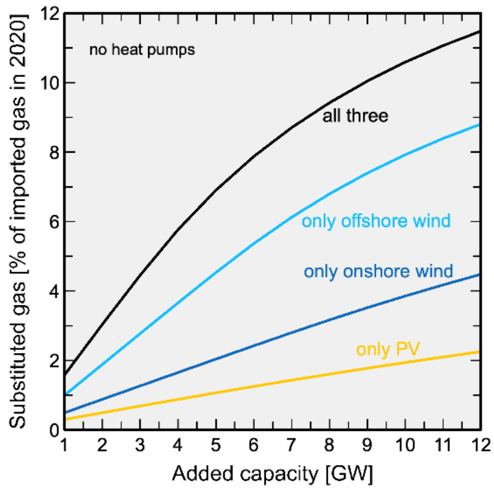

Figure S11 | Short-term additions of PV and wind capacities substitute gas by reducing load hours of gas-fired power plants. Modelling of the year 2022, in percentage of imported gas in 2020.

Figure S11 shows how much gas can be substituted by reducing the load hours of gas-fired power plants through the addition of PV, onshore or offshore wind capacities in 2022. The additional capacities of the different renewable energies do not add up exactly, which is why the curve is also shown where all three types of renewable energies are added.

The German government has tendered new PV capacity since 2015, with the highest bid entry being rather low (about 8 €ct/kWh). The government still rejected many bids by means of capacity limitations, 12 GW in total (see Fig. S4). Furthermore, the government has de facto stalled the addition of onshore and offshore wind after 2017 (Fig. S4). Had the addition continued as in 2017, 15 GW more onshore and 5 GW more offshore wind capacities would have been added by now.

An additional, even more immediate change in infrastructure than installing heat pumps may be activated by the German government if it immediately calls for the re-submission of rejected PV bids, and if it calls for immediate resumption of wind farm projects that were halted after 2017 due to strict government regulations. If all these missed-out opportunities could be installed, more than 10% of total gas imports would be substituted, which is nearly a quarter of gas imports from the Russian Federation, by reducing the load hours of gas-fired power plants

Modelling results

Table S7 | Simulation results, shown in Figs. 5 and 6.

Result from modelling	Label	Unit
Heat pumps:		
Gas replaced by heat pumps	(1)	TWh_g
Additional Gas required by heat pumps from gas-fired power plants	(2)	TWh_g
Net gas saved by heat pumps	(3)	TWh_g
Share of Russian gas imports in 2020	(4)	%
Share of total imported gas imports in 2020	(5)	%
Heat pumps plus load hours of gas-fired power plants:		
Remaining additional electricity	(6)	TWh_e
Additional electricity for reduction of load hours of gas-fired power plants	(7)	TWh_e
Addition of wind and solar	(8)	TWh_e
Additional gas reduction of load hours	(9)	TWh_g
Total gas saved	(10)	TWh_g
Share of Russian gas imports in 2020	(11)	%
Share of total imported gas imports in 2020	(12)	%
Exclusively load hours of gas-fired power plants:		
Saved gas if only load hours of gas-fired power plants are reduced	(13)	TWh_g
Share of Russian gas imports in 2020	(14)	%
Share of total imported gas imports in 2020	(15)	%

Installers' roadmap

year	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
2022	7.50	0.11	7.39	1.38	0.76	19.56	19.25	22.22	38.51	45.90	8.60	4.73	43.70	8.18	4.50
2023	16.50	0.31	16.19	3.03	1.67	35.75	32.31	41.58	64.63	80.82	15.13	8.32	74.85	14.02	7.71
2024	27.30	0.54	26.76	5.01	2.76	57.61	43.41	67.24	86.82	113.58	21.27	11.70	100.47	18.81	10.35
2025	40.26	0.61	39.65	7.42	4.08	89.49	53.92	103.77	107.83	147.48	27.62	15.19	123.19	23.07	12.69
2026	55.81	0.88	54.93	10.29	5.66	122.04	59.71	141.82	119.43	174.36	32.65	17.96	136.52	25.57	14.06
2027	74.48	1.30	73.17	13.70	7.54	155.76	63.53	182.10	127.07	200.24	37.50	20.62	145.61	27.27	15.00
2028	96.87	1.48	95.39	17.86	9.83	202.20	68.23	236.56	136.45	231.85	43.42	23.88	154.70	28.97	15.93
2029	123.75	1.71	122.04	22.85	12.57	255.19	71.62	299.18	143.23	265.28	49.68	27.32	161.06	30.16	16.59
2030	156.00	2.17	153.83	28.81	15.84	308.94	73.61	364.38	147.22	301.05	56.38	31.01	165.29	30.95	17.02

Accelerated scenario

year	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
2022	9.07	0.20	8.87	1.66	0.91	19.03	18.74	22.22	37.48	46.36	8.68	4.77	43.70	8.18	4.50
2023	25.73	1.08	24.65	4.62	2.54	32.80	29.68	41.58	59.37	84.01	15.73	8.65	74.85	14.02	7.71
2024	53.06	3.21	49.85	9.34	5.13	49.61	37.59	67.24	75.18	125.03	23.41	12.88	100.47	18.81	10.35
2025	94.82	6.55	88.27	16.53	9.09	72.69	44.31	103.77	88.61	176.88	33.12	18.22	123.19	23.07	12.69
2026	152.06	13.09	138.97	26.02	14.31	93.26	46.39	141.82	92.79	231.76	43.40	23.87	136.52	25.57	14.06
2027	219.91	22.22	197.69	37.02	20.36	113.52	47.09	182.10	94.17	291.86	54.65	30.06	145.61	27.27	15.00
2028	287.77	27.75	260.02	48.69	26.78	146.16	50.85	236.56	101.70	361.71	67.73	37.25	154.70	28.97	15.93
2029	345.01	29.29	315.72	59.12	32.52	188.80	55.47	299.18	110.95	426.67	79.90	43.94	161.06	30.16	16.59
2030	424.27	35.11	389.15	72.87	40.08	228.20	57.68	364.38	115.36	504.51	94.48	51.96	165.29	30.95	17.02

Fast scenario

year	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
2022	16.32	0.95	15.37	2.88	1.58	16.78	16.55	22.22	33.09	48.46	9.07	4.99	43.70	8.18	4.50
2023	53.06	6.10	46.97	8.80	4.84	25.40	23.07	41.58	46.13	93.10	17.43	9.59	74.85	14.02	7.71
2024	121.64	20.99	100.65	18.85	10.37	33.65	25.73	67.24	51.46	152.12	28.49	15.67	100.47	18.81	10.35
2025	219.91	43.10	176.81	33.11	18.21	45.63	28.16	103.77	56.31	233.12	43.66	24.01	123.19	23.07	12.69
2026	318.19	66.05	252.14	47.22	25.97	59.55	29.83	141.82	59.67	311.81	58.39	32.11	136.52	25.57	14.06
2027	386.76	75.92	310.84	58.21	32.01	79.91	33.26	182.10	66.52	377.36	70.66	38.87	145.61	27.27	15.00
2028	423.51	66.20	357.31	66.91	36.80	116.20	40.94	236.56	81.88	439.19	82.24	45.23	154.70	28.97	15.93
2029	440.46	51.78	388.68	72.78	40.03	165.46	49.38	299.18	98.77	487.45	91.28	50.20	161.06	30.16	16.59
2030	447.73	39.89	407.84	76.37	42.00	222.08	56.36	364.38	112.72	520.56	97.48	53.61	165.29	30.95	17.02

Very fast scenario

year	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
2022	59.82	15.87	43.95	8.23	4.53	8.48	8.41	22.22	16.82	60.76	11.38	6.26	43.70	8.18	4.50
2023	128.23	36.87	91.36	17.11	9.41	13.55	12.50	41.58	24.99	116.35	21.79	11.98	74.85	14.02	7.71
2024	257.42	87.12	170.29	31.89	17.54	17.52	13.86	67.24	27.72	198.01	37.08	20.39	100.47	18.81	10.35
2025	386.60	126.03	260.57	48.80	26.84	26.69	16.97	103.77	33.94	294.52	55.15	30.33	123.19	23.07	12.69
2026	455.01	131.79	323.22	60.53	33.29	42.84	21.82	141.82	43.64	366.86	68.70	37.78	136.52	25.57	14.06
2027	479.65	116.55	363.09	67.99	37.40	66.57	27.79	182.10	55.59	418.68	78.40	43.12	145.61	27.27	15.00
2028	487.23	89.09	398.14	74.56	41.01	104.55	36.91	236.56	73.82	471.97	88.38	48.61	154.70	28.97	15.93
2029	489.45	65.69	423.76	79.35	43.64	154.66	46.50	299.18	93.01	516.77	96.77	53.22	161.06	30.16	16.59
2030	490.09	49.37	440.73	82.53	45.39	211.47	54.08	364.38	108.15	548.88	102.78	56.53	165.29	30.95	17.02

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