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REKK POLICY BRIEF

01 2025

JANUARY 2025

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DAILY GAS DEMAND IN EUROPE: HOW MUCH DOES TEMPERATURE MATTER?

Building-heating related use of natural gas is highly temperature-dependent. The majority of buildings in Europe are heated with natural gas, which has been a stable and cheap fuel for the early 2000's. Russia's war in Ukraine and the curtailment of Russian pipeline gas to Europe, in tandem with Nord Stream 2 explosion and other geopolitical events created the energy crisis of 2021-2023, which caused an unprecedented price increase in the previously relatively cheap and abundant fuel, natural gas. Consequently, household end-user price of natural gas has increased 40% from 2021 to 2022 in Europe: this caused a swift reaction in gas demand.[1]

Although the crisis is well-documented and followed in media and academic articles, no thorough and detailed analysis of the relationship between natural gas demand and temperature is documented for the 2021-2024 period. In this short analysis, we provide an EU27-wide assessment of the relationship between gas demand and temperature, and describe how the gas consumption could develop in the first quarter of 2025.

Moreover, as a practical use case for the temperature-consumption relation, we provide an outlook for storage use in Q1 2025.

TEMPERATURE DATA

Historical temperature data is constantly monitored by weather stations scattered throughout Europe. Up-to-date weather information is crucial for demand management and forecasting. Daily metering of mean average temperatures allows us to map the connection between heating-related gas use.

The main source of data was the NOAA data collection[2] of individual stations located in Europe. Data cleaning and imputation was done by linearly interpolating missing temperature data with the temperature of days before and after the missing period. In case longer periods (several months) were missing, nearby measurement point data was imputed with nearby NOAA stations, or nearby stations of the ECA&D[3] database. Annex 2. lists the name and location of each station, along with the level of missing data and in case imputation was performed, the source of the alternative station. Figure 1 maps the weather stations used for the analyis.

The dataset obtained has daily average temperature data for each of the EU27 countries for the period 01.01.2002. to 31.12.2024. Daily temperature data were then transformed into heating degree days (HDD) applying the methodology of Eurostat:[4]

$$\begin{aligned} T_d \leq 15°C \quad & Then \quad HDD_d = 18 - T_d \\ & Else \quad HDD_d = 0 \end{aligned}$$

where T_d is the mean air temperature.

To ensure data quality, daily heating degree days were aggregated to an annual level and compared with the Eurostat's data publication 'Heating and Cooling degree days in Europe'.[5] The annual heating degree days were compared with the daily aggregated data - the two time series showed strong correlation and were at the same level.

1 ACER MMR 2023: Energy Retail and Consumer Protection 2023 Market Monitoring Report 3.2.2. 64

2 Global Surface Summary of the Day – GSOD.

3 Klein Tank, A.M.G. and Coauthors, 2002. Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment. Int. J. of Climatol., 22, 1441-1453.

4 https://ec.europa.eu/eurostat/cache/metadata/fr/nrg_chdd_esms.htm

5 https://ec.europa.eu/eurostat/databrowser/view/nrg_chdd_a/default/table

FIGURE 1. LOCATION OF WEATHER STATIONS USED FOR THE ANALYSIS

Temperatures vary greatly across Europe, but this disaggregated approach allows us to control for geographical and climatic differences to a point. However, there is strong correlation between the measurement points, so for instance whenever it is a cold winter in Germany, it is a cold winter for Europe all over. Temperatures indicate a trend of warmer winters and consequently lower heating demand.

GAS CONSUMPTION DATA

Daily gas consumption was retrieved mainly from ENTSOG transparency platform, which lists distribution and final consumption exits for each market zone. Distribution exit covers the building-heating and weather dependent consumption, while final consumption exits relate to power plant or large industrial users' consumption, which is not weather-related. Daily data were added for distribution and transmission and these totals were considered for most countries. All values were reported in energy units (kWh).

Two EU27 countries (Malta and Cyprus) have no considerable weather-dependent gas consumption, and for this reason these are omitted. Daily data was obtained from ENTSOG for 17 countries (BE, BG, CZ, EE, FR, GR, HR, HU, IE, IT, LU, LV, NL, PL, PT, RO, SI), while for the remaining 8 (AT, DE, DK, ES, FI, LT, SE, SK) national TSO data was used. The reason for this is the lack of data availability on the ENTSOG data portal.

Data was retrieved for the entire period of 01.01.2021 – 31.12.2024. in all countries. Data cleaning was done only when outliers were present, e.g. more than 10 times natural gas consumption. In this case, simple average of the previous and following day was substituted.

Daily data is fitting well with annual Eurostat data for the EU27: when summing up the daily data for 2023, daily data is 5% below the Eurostat annual totals. On national level, major markets have a strong fitting: for 12 countries (AT, DE, EE, ES, FR, GR, IT, LU, LV, NL, PT, SI), the daily data is 5% below the annual aggregates, for another 5 countries it is below 10% (BG, CZ, HR, HU, RO), while for 8 countries it is above 10% (BE, DK, FI, IE, LT, PL, SE, SK). The above 10% differential can not be pinpointed for Belgium, Denmark, Finland, Poland and Sweden. For Ireland, power plant consumption was omitted from the totals on purpose due to low correlation with weather. Similarly, directly connected consumers in Lithuania were also disregarded. For Slovakia, only distribution exits were considered. (for details see Annex 1)

METHOD AND RESULTS

Weather-related heating demand is simply estimated for each country by fitting daily HDD data with gas consumption data in TWh for the 01.01.2021-31.12.2024 period.

$$C_{i,t} = \beta_{i,0} + \beta_{i,1} \times HDD_{i,d} + \varepsilon$$

Where i denotes the country indices while d denotes the day indices. Results of the equations are listed in Table 1. The coefficient of the HDD can be interpreted as the effect of 1 degree Celsius, i.e. in case of Germany if a winter day is 1 degree Celsius colder, then gas consumption in Germany is 0.15 TWh higher. The estimation provides a strong fit (R^2>0.7) for 20 countries (AT, BE, BG, CZ, DE, DK, EE, FR, HR, HU, IE, IT, LT, LU, LV, NL, PL, RO, SI, SK), while for the remaining 5 countries (ES, FI, GR, PT, SE) it is weaker (R^2<0.6) due to the fact that mainly the power sector utilises natural gas and no heating-related consumption exists. The 20 countries with strong fitting cover 87% of EU27 annual natural gas demand.

2025 Q1 GAS DEMAND FORECAST

By drawing up this simple relationship between temperature and gas consumption, we can easily draft future scenarios of cold, average and mild winter months and quantify the effect of temperature on the EU27 gas demand. Our approach is fitting as it differentiated between the countries' uni-

TABLE 1. RESULTS OF THE DAILY GAS CONSUMPTION ESTIMATE

		OBS	R2	Bo	B1
AT	**Austria**	1188	0.82	0.13	0.02
BE	**Belgium**	1188	0.79	0.23	0.02
BG	**Bulgaria**	1188	0.75	0.05	0.00
CZ	**Czechia**	1188	0.89	0.10	0.02
DE	**Germany**	1188	0.83	1.35	0.15
DK	**Denmark**	1188	0.76	0.03	0.00
EE	**Estonia**	1188	0.81	0.00	0.00
ES	**Spain**	1188	0.31	0.81	0.03
FI	**Finland**	1188	0.48	0.02	0.00
FR	**France**	1188	0.86	0.56	0.11
GR	**Greece**	1188	0.22	0.03	0.00
HR	**Croatia**	1188	0.78	0.05	0.00
HU	**Hungary**	1188	0.75	0.12	0.02
IE	**Ireland**	1188	0.79	0.03	0.00
IT	**Italy**	1188	0.73	1.29	0.11
LT	**Lithuania**	1188	0.86	0.01	0.00
LU	**Luxembourg**	1188	0.83	0.01	0.00
LV	**Latvia**	1188	0.70	0.01	0.00
NL	**Netherlands**	1188	0.78	0.50	0.05
PL	**Poland**	1188	0.86	0.32	0.02
PT	**Portugal**	1188	0.01	0.13	0.00
RO	**Romania**	1188	0.91	0.13	0.02
SE	**Sweden**	1188	0.53	0.01	0.00
SI	**Slovenia**	1188	0.81	0.02	0.00
SK	**Slovakia**	1188	0.71	0.07	0.00

que gas demand. The strong relationship of temperature and heating ensures the robustness of our results.

Based on past temperature data, a cold, an average and a mild Q1 (January-March) were simulated. As temperatures have constantly been rising, we opted to select these winters from the past 5 years. For this reason, 2021 was selected as a cold, 2024 as a mild, and 2019 as an average winter.

Applying the temperature for each country and estimating a cold, average and mild winter shows us the Q1 2025 estimated demand for Europe. In a cold winter, Q1 EU27 gas demand is estimated at 1387 TWh. For an average winter, it would be 1250 TWh, while for a mild winter, 1127 TWh. As a simple comparison, historical gas consumption Q1 in 2024 was 1130 TWh, Q1 in 2023 was 1145, and Q1 in 2022 was 1330 TWh.

IMPLICATIONS FOR STORAGE USE

Depending on the demand scenario, the utilisation of storages could vary significantly. Besides storage there are alternatives to supply the daily gas needs: pipeline, LNG and local production. For this simple exercise, we opted to use a simple rule of thumb for the sources of supply: we have used a daily average of 2022-2024 flows. This means approximately 3.5 TWh of LNG, 4.6 TWh of pipeline and 1 TWh of daily natural gas production. Fixing these daily sources of supply, storage use is determined as the difference of the daily demand and the sum of other sources.

This approach is quite simplistic, as it does not consider the prices and the infrastructure at all. However, it provides a robust and easy-to-understand outlook for the future.

With low demand assumed, storages would close at 46%. This demand is a Q1 winter identical with Q1 2024.

An average demand like Q1 2019 would mean that storages closed at 36%.

With high demand, storages could be depleted at 23%.

Comparing these values to historical storage use, it can be seen that a harsh winter would leave storages below the 2019-2023 lowest fill-up and this would make it really hard to meet the 90% storage target by the end of injection season - it may be worthwhile to consider an adjustment in stoage targets, if this is the case.

FIGURE 2. ESTIMATED STORAGE USE WITH MILD WINTER, LOW DEMAND

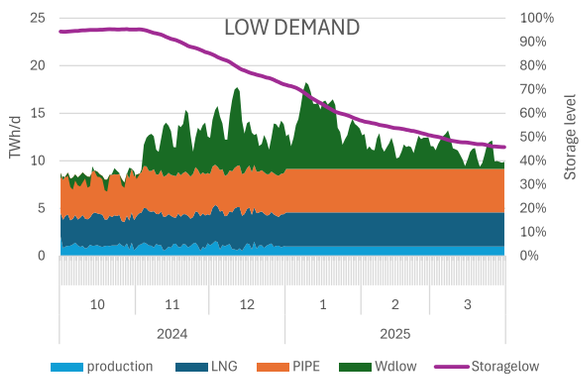


FIGURE 3. ESTIMATED STORAGE USE WITH AVERAGE WINTER, AVERAGE DEMAND

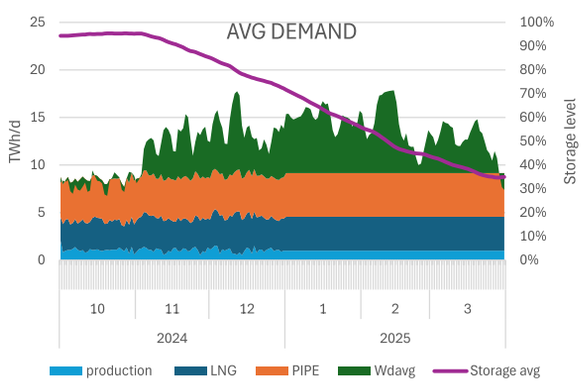


FIGURE 4. ESTIMATED STORAGE USE WITH COLD WINTER, HIGH DEMAND

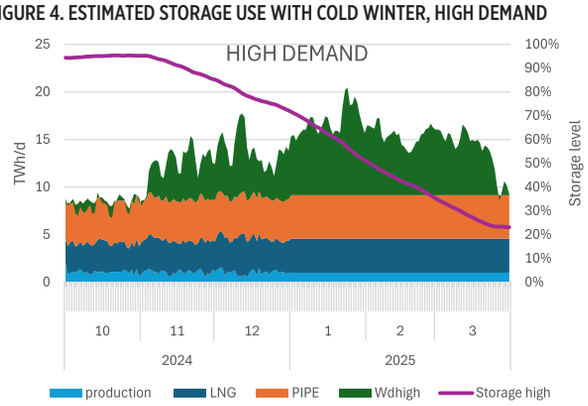
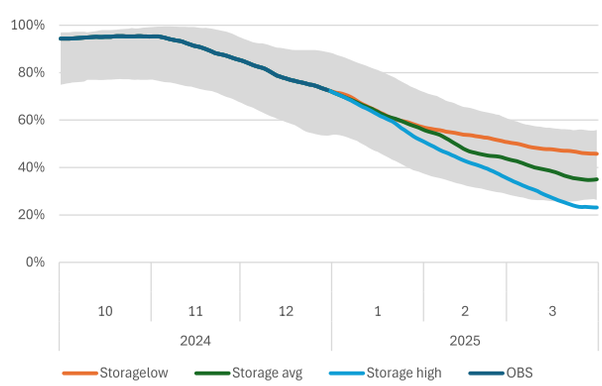


FIGURE 5. STORAGE USE FOR ALL THREE SCENARIOS AND 2019-2023 STORAGE USE RANGE



ANNEX 1.. DAILY NATURAL GAS CONSUMPTION DATA SOURCES AND RELATION TO EUROSTAT AGGREGATES

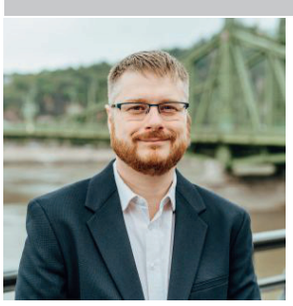
Country	Data source	Data granularity	Distribution exit	Final consumers	Total	Note	2023 CAL daily sum	2023 Eurostat sum	DIFF
AT	AGGM	Daily	no	no	yes		75.0	76.5	-2%
BE	ENTSOG	Daily	yes	yes	yes		131.6	158.4	-17%
BG	ENTSOG	Daily	no	yes	no		26.3	28.1	-6%
CY	-	-	-	-	-	-	-	-	-
CZ	ENTSOG	Daily	yes	no	no		69.1	74.4	-7%
DE	THE	Daily	yes	yes	yes	Aggregate SLP and RTM consumption for all DE market zones	820.2	821.3	0%
DK	ENERGI dataservice	Daily	no	no	yes	DK exit	20.9	25.3	-17%
EE	ENTSOG	Daily	no	no	yes	Elering exit	3.4	3.5	-2%
ES	Enagas	Daily	no	no	yes	Demand	323.7	326.0	-1%
FI	Gasgrid Finland	Daily	no	no	yes	Gas consumption	13.4	17.1	-22%
FR	ENTSOG	Daily	yes	yes	yes	Térega and GRTGaz area	386.0	380.0	2%
GR	ENTSOG	Daily	yes	yes	yes		50.5	51.7	-2%
HR	ENTSOG	Daily	no	yes	no	Final consumers only	26.1	28.1	-7%
HU	ENTSOG	Daily	yes	yes	yes		85.2	91.1	-6%
IE	ENTSOG	Daily	yes	yes	no	Non- daily metered, daily metered, large consumers.	18.6	53.5	-65%
IT	ENTSOG	Daily	yes	yes	yes		625.3	653.1	-4%
LT	Amber Grid	Daily	yes	yes	yes	Distribution related consumption only	6.6	17.3	-62%
LU	ENTSOG	Daily	yes	yes	yes		6.1	6.4	-5%
LV	ENTSOG	Daily	no	yes			8.2	8.4	-3%
MT	-	-	-	-	-	no weather-dependent gas consumption	-	4.4	-
NL	ENTSOG	Daily	yes	yes	yes		283.8	291.1	-2%
PL	ENTSOG	Daily	yes	yes	yes	H-Gas + L-Gas	179.9	203.5	-12%
PT	ENTSOG	Daily	yes	yes	yes		47.1	48.8	-4%
RO	ENTSOG	Daily	yes	yes	yes		93.1	102.2	-9%
SE	ENERGI dataservice	Daily	no	no	yes	SE exit	6.1	9.0	-33%
SI	ENTSOG	Daily	no	no	yes		8.8	8.9	-1%
SK	Eustream	Daily	yes	no	yes	Domestic SPP + Veolia	38.1	46.6	-18%
EU27 total	**-**	**-**	**-**	**-**	**-**	**-**	**3353.1**	**3534.6**	**-5%**

ANNEX 2. WEATHER STATION DATA USED

Co.	Station	LAT	LON	Imputed data %	Imputed data #	Imputed point	LAT	LON
AT	WIEN/INNERE STADT	48.20	16.37	1%	112	-	-	-
BE	BRUSSELS NATL	50.90	4.48	0%	12	-	-	-
BG	SOFIA	42.70	23.41	0%	13	-	-	-
CY	PAFOS INTL	34.72	32.49	0%	14	-	-	-
CZ	PRAHA-KARLOV / KLEMENTINUM	50.07	14.43	23%	1,915	PRAHA-KLEMENTINUM (ECA&D)	50.05	14.25
DE	SCHONEFELD	52.38	13.52	13%	1,061	BERLIN - MITTE (ECA&D)	52.32	13.23
DK	AARHUS	56.30	10.62	0%	14	-	-	-
EE	TALLINN	59.41	24.83	0%	15	-	-	-
ES	MADRI-COLMENAR	40.65	-3.73	2%	169	-	-	-
FI	HELSINKI VANTAA	60.32	24.96	0%	8	-	-	-
FR	PARIS-MONTSOURIS	48.82	2.33	1%	56	-	-	-
GR	ATHINAI, GR	37.88	23.74	11%	937	TANAGRA (NOAA)	38.34	23.57
HR	ZAGREB	45.74	16.07	5%	379	-	-	-
HU	FERIHEGY	47.44	19.26	0%	15	-	-	-
IE	DUBLIN	53.42	-6.27	0%	13	-	-	-
IT	BOLOGNA	44.54	11.29	0%	15	-	-	-
LT	VILNIUS INTL	54.63	25.29	0%	14	-	-	-
LU	LUXEMBOURG	49.63	6.21	0%	12	-	-	-
LV	RIGA	56.97	24.05	0%	14	-	-	-
MT	LUQA	35.86	14.48	0%	15	-	-	-
NL	ROTTERDAM	51.96	4.44	0%	13	-	-	-
PL	LECZYCA	52.00	19.15	11%	913	WARSZAWA-OBSERWATORIUM II (ECA&D)	52.13	21.02
PT	LISBOA	38.78	-9.14	0%	25	-	-	-
RO	BUCURESTI FILARET	44.42	26.10	51%	4,308	BUCURESTI-BANEASA (ECA&D)	44.31	26.05
SE	BROMMA	59.35	17.94	0%	14	-	-	-
SI	LJUBLJANA/BEZIGRAD	46.07	14.52	5%	385	LJUBLJANA BEZIGRAD (ECA&D)	46.04	14.30
SK	BRATISLAVA-LOLIBA	48.17	17.12	44%	3,667	KOSICE (ECA&D)	48.40	21.13

REKK FOUNDATION

The goal of the REKK Foundation is to contribute to the formation of sustainable energy systems in Central Europe, both from a business and environmental perspective. Its mission statement is to provide a platform for open-ended, European-wide dialogue between government and business actors, infrastructure operators, energy producers and traders, regulators and consumers, professional journalists and other interested private entities. The Foundation will develop policy briefs and issue papers with forward-looking proposals concerning challenges posed by energy and infrastructure systems and organize regional forums allowing stakeholders to become familiar with the latest technological and regulatory developments within the industry.



Péter Kotek graduated in 2009 at the Corvinus University of Budapest as an economist, majoring in market analysis. He joined REKK in the same year as a research associate. From 2015, he is working as a senior research associate. His areas of interest are ancillary services market in electricity, LNG and gas storage markets. He has participated actively in REKK's gas market modelling work since 2015.

Borbála Takácsné Tóth has worked with REKK since its creation in 2004. In 2001 she received an M.A. in International Relations and European Studies at the CEU in Budapest. Borbala is an economist and received her degree from the Budapest University of Economic Sciences in 1998. Between 2001 and 2003 she was Head of the President's Secretariat responsible for international relations of the Hungarian Energy Office. Her main fields of expertise include: regional co-operations; security of supply issues; energy geopolitics; major infrastructure initiatives in the gas sector and incentives for investments; competition cases in the gas market; and the effect of gas release programs on competition in the gas market in Europe.