IMPACT OF DR IN THE DEMAND REDUCTION PLAN

DSF potential contribution to 2023 and 2025 gas reduction – Technical appendix

Smart Energy Europe ASBL

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Table of contents

SUMMARY

DNV was commissioned by smartEn to calculate the theoretical potential contribution that demand-side flexibility (DSF) can have on the gas demand reduction, used for electricity production, for years 2023 and 2025 in EU27, Switzerland, Norway and United Kingdom. The particular focus is the winter months of each year. The methodology for this task was based on DNV's European Electricity Market Model.

The results indicate that a widespread activation of DSF could save up to 1.6% of total gas imports in 2023. This translates in a monetary saving of €16 bn. In 2025, the potential savings are nearly double, amounting to 3.1% reduction compared to gas imports and equivalent to €31.4 bn saving.

In both years, DSF enables load shedding, peak shaving and avoidance of RES curtailment to contribute to gas savings. **The main contributor is load shedding** amounting 92.2% and 75.3% in gas savings in 2023 and 2025 respectively. This is achieved by a maximum curtailed power of 9.6 GW and 15.1 GW in 2023 and 2025 respectively. Load shifting also contributes to gas savings, by 5.5% and 12.4%, with 18.0 GW and 27.8 GW average activated power in 2023 and 2025 respectively. Load shifting shaves peak demand, so it shifts demand from gas to other less expensive fuels, and reduces the curtailment of renewable generators. **The contribution of load shifting on gas reduction is significantly higher in 2025** due to a higher degree of electrification of transportation and heat demand, and a higher share of renewable generators in the energy mix.

Due to its potentially significant impact on demand reduction, DNV recommends to explore the energy efficiency effect of DSF in electric heating at European level. This effect was not included in this exercise due to lack of relevant studies that were applicable to the geographical scope.

1 METHODOLOGY

The scope of this study is to quantify the potential avoided gas consumption by enabling demand-side flexibility (DSF) in the years 2023 and 2025. The geographical scope is EU27 + Switzerland, Norway and UK.

The methodology to conduct this exercise was divided in three steps:

1. Simulating the electricity market for years 2023 and 2025 including all potential DSF options (i.e. *flex scenario*).

   This step involved input data adjustment and tailoring of DNV's European Power Market Model for years 2023 and 2025 to include all DSF technologies. The focus is on winter for both years, to be able to accurately compare the potential evolution over the next two years. The model includes shiftable loads (Electric Vehicle charging (EVs), Vehicle-to-Grid (V2G), heat pumps and batteries) and curtailable loads (industrial DSR and industrial electric heating).

   The simulations were performed on DNV's European Power Market Model that is run in PLEXOS Integrated Energy Modelling software.

2. The model's output is the electricity produced with gas for years 2023 and 2025 on hourly granularity, for all gas-fired technologies: open cycle gas turbines (i.e. gas peakers), gas power plants (combined cycle gas turbines - CCGTs), combined heat-power units (CHPs) and steam turbines. Simulating the electricity market for years 2023 and 2025 without DSF options (i.e. *no-flex scenario*)

   In this step, DNV adjusted the input data to remove the DSF flexibility from the system, i.e. all DSF technologies demand follow a fixed profile and are price inelastic. This applies to industrial and residential electric heating, industrial DSR, EV charging and V2G. In this scenario, batteries do not feed-in or off-take electricity from the grid.

   Note that electrolysers were modelled as flexible in both scenarios because they are typically in front-of-the-meter and there is not enough data on operational electrolysers to derive a fixed consumption profile.

   The model output is the electricity produced with gas for years 2023 and 2025 on hourly granularity, for all gas-fired technologies: gas turbines (i.e. gas peakers), gas power plants (CCGTs), CHPs and steam turbines.

3. Quantifying the gas savings

   Using the output from steps 1 and 2, DNV calculated the gas savings at European level.

   Savings = Gas consumption for electricity production year *X* (no-flex scenario) – Gas consumption for electricity production year *X* (flex scenario)

   The savings are reported in three ways:

   - Absolute value in billion cubic meters of gas (bcm). The conversion bcm/TWh will be 1bcm = 10.54 TWh[1]
   - Relative percentage to total 2021 gas imports[2] and total gas consumption[3].
   - Cost saved on gas in (€)

   DNV quantified the savings for the full year 2023 and 2025 as well as the 2023 winter months (January – March).

   Note that these savings were based on electricity demand, not heat demand such as gas boilers.

1 https://atee.fr/energies-renouvelables/club-biogaz/conversion-des-energies
2 https://ec.europa.eu/info/news/focus-reducing-eus-dependence-imported-fossil-fuels-2022-apr-20_en
3 https://ec.europa.eu/eurostat/databrowser/view/NRG_CB_GASM__custom_3283139/default/table?lang=en and https://www.statista.com/statistics for UK & CH

2 MODEL SET-UP AND INPUTS & SCENARIO

To quantify the potential gas consumption savings achieved by the activation of DSF, DNV modelled the European power market considering the different DSF options available in 2023 and 2025.

DNV has used its European Market Model, a fundamental market model that simulates the day-ahead spot price by optimising the unit commitment and economic dispatch of electricity generation. The simulations are performed on an hourly time-resolution containing a detailed representation of generation, commodity prices and demand for all bidding zones, including the envisioned developments:

- Generation capacities are modelled on an individual basis with detailed techno-economic characteristics such as, but not limited to, efficiency, ramping ability, minimum stable level, fuel cost, other variable operating costs, maintenance and forced outage rates.
- Renewable generation takes volatility into account through the use of historical or re-analysed time series of, for example, data on wind speed and solar irradiation for different locations. These profiles take geographical correlation into account.
- Market exchanges between countries (i.e. bidding zones) are defined based on Net Transfer Capacities. The increase in available transmission capacity is based on available projections announced by individual TSOs and/or ENTSO-E.
- The demand consists of an hourly fixed demand profile, flexible demand-side management components and other flexible load originated by front-of-the-meter applications such as utility-scale batteries. Flexible demand is optimised against certain constraints within the model e.g. electric vehicles (EVs) need to be charged by a certain volume within a specified period (e.g. during the night or within one week).

The model set-up assumes that all flexible demand and generation, both front-of-the-meter and behind-the-meter, is exposed to the market.

2.1 Inputs

The inputs to the model are:

- Generation mix: DNV has used the generation mix based on current installed capacities and the predicted generation derived from DNV Energy Transition Outlook (ETO)[4] and country specific policy targets.
- Traditional demand[5]: DNV has used the predicted electricity demand for non-flexible loads.
- Non-traditional demand[6] and other flexible sources power:
  - Power-to-hydrogen: Electrolyser capacity is based on realized and planned capacity[7]
  - Utility scale batteries: DNV has used the installed (and predicted) battery capacity based on government targets and DNV's ETO.
  - Residential and commercial electric heating: The installed capacity is calculated by applying a ratio between today's installed base and 2030 ambitions.

[4] DNV's Energy Transition Outlook and sources are available on Energy Transition Outlook 2021 | DNV. The input data in our ETO and our European Market Model are based on the detailed expectations and forecasts of European countries and key actors (policy makers, network companies, market actors and -operators and technology providers). DNV uses her independent views on these expectations, outlooks and forecasts, to develop a single 'best estimate' pathway for the (system) developments in individual countries and Europe as a whole.

[5] 'Traditional demand' is the non-flexible electricity demand, such as the demand from continuous (base load) processes in industry, and a certain base load from household and commercial consumers.

[6] 'Non-traditional' are new and more flexible sources of demand, which are foreseen to develop in significant quantities over the coming decade and beyond. Examples are provided in the subs.

[7] Hydrogen Europe, Clean hydrogen monitor 2021

- EV charging and vehicle to grid batteries: DNV has used the installed (and predicted) EV adoption and battery capacity based on government targets and DNV's ETO.
- Industrial DSR and industrial electric heating: The installed capacity has been calculated based on government targets and DNV's ETO.

- Gas prices: Monthly gas prices are based on expected futures gas price for 2023[8], Figure 1. The gas prices for 2025 are assumed to be the same. Regarding efficiency, the model accounts for a high heating value efficiency of gas peaker plants of 30%.

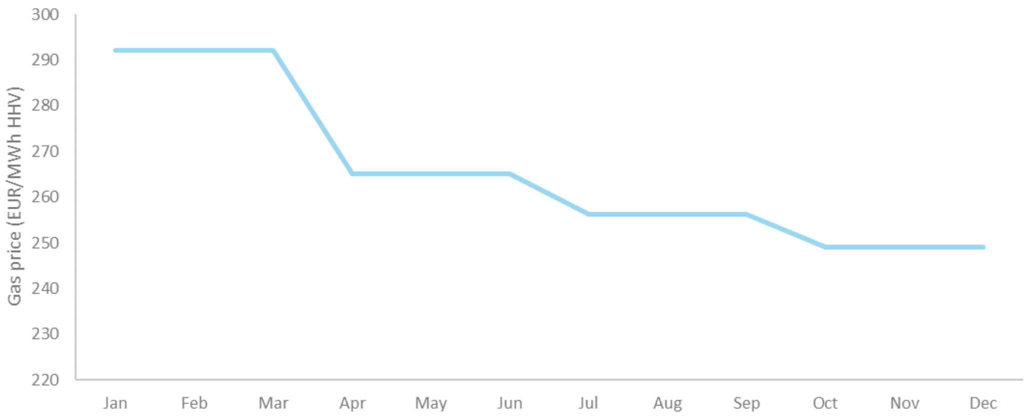

Figure 1 Gas price forwards 2023

- DSF Technologies. DNV has included the following DSF technologies as part of the European power system under the flex scenario:
  - Electric vehicle charging
  - Vehicle-to-grid
  - Behind-the-meter and front-of-the-meter batteries
  - Industrial demand-side response (DSR)
  - Residential and commercial electric heating
  - Industrial electric heating
  - District heating – combined heat and power (CHP)
  - Industrial heating – CHP

The scenario no-flex does not include the DSF technologies as vehicle-to-grid, batteries (front and behind the meter), and DSR. Moreover, technologies like EV charging, electric heating or CHPs are included with a fixed consumption or generation profile.

[8] Gas price (development) assumptions were researched and based on Montel data of TTF 24 August 2022 closing prices. Therefore, they do not include the pricing effects of the more permanent closure decision of the Nordstream-1 pipeline to Germany that was announced in early September 2022 and which appear to have a big impact upon (futures) prices, i.e. increasing them even further. Assessed economic impacts in this paper, may therefore be considered as conservative.

DNV

3 RESULTS

3.1 Year 2023

3.1.1 Winter months

The reduction of gas consumption during the winter months (i.e., January to March) is 2.4 bcm, corresponding to:

- -0.7% difference relative to total annual gas imports (i.e., 356 bcm); and
- -0.5% difference relative to total annual gas consumption (i.e., 497 bcm).

The savings on gas cost during the winter months are estimated at 7.3 billion euro. [9]

3.1.2 Full year

The results of the flex scenario show a reduction in gas consumption in 2023 of 5.7 bcm compared to the no-flex scenario, corresponding to:

- -1.6% difference relative to total annual gas imports (i.e., 356 bcm); and
- -1.1% difference relative to total annual gas consumption (i.e., 497 bcm).

The savings on gas cost in 2023 are estimated at 16.0 billion euro.[9]

The reduction in gas consumption corresponds to a reduction in power generation from gas-firing power plants of **30.7 TWh**. The total activated flexibility in the form of load shedding, due to activation of industrial DSR and curtailment of industrial electric heating demand, amounts to 28.3 TWh (92.2% of the saved gas consumption).

In terms of power, **the maximum curtailed load is 9.6 GW (out of 18.9 GW of installed capacity) on a specific day in January**; industrial DSR curtailment accounts for 6.9 GW, while industrial electric heating curtailment accounts for 2.8 GW. Regarding load shifting, DSF shaves peak demand and shifts generation from gas to other less expensive fuels (i.e. coal and lignite) contributing by 4.3% of gas savings. In addition, load shifting avoids renewable energy curtailment by 361.2 GWh (1.2% of saved gas consumption) compared to the no-flex scenario. The **average DSF activated power for shiftable technologies** (smart charging, V2G, residential electric heating and BESS) amounts to **18 GW**.

Load shedding therefore is the main responsible mechanism for the assessed savings in gas consumption, indicating that greater flexibility in (industrial) demand can help to efficiently offset a significant part of European gas consumption. However, the impact that this daily shifting has on the total gas reduction is lower simply because the energy mix is dominated by gas technologies, especially during the winter months. An increase of intermittent renewable capacity would therefore increase the DSF potential gas savings.

3.2 Year 2025

3.2.1 Winter months

The reduction of gas consumption during the winter months (i.e., January to March) is 4.7 bcm, corresponding to:

- -1.3% difference relative to total annual gas imports (i.e., 356 bcm); and
- -0.9% difference relative to total annual gas consumption (i.e., 497 bcm).

The savings on gas cost during the winter months are estimated at 14.5 billion euro.[9]

9 There are costs to replace gas by other means of generation/demand reduction that are not quantified in this study

3.2.2 Full year

The results of the flex scenario show a reduction in gas consumption in 2025 of 11.0 bcm compared to the no-flex scenario, corresponding to:

- -3.1% difference relative to total annual gas imports (i.e., 356 bcm); and
- -2.2% difference relative to total annual gas consumption (i.e., 497 bcm).

The savings on gas cost in 2025 are estimated at 31.4 billion euro.[9]

The reduction in gas consumption corresponds to a reduction in power generation from gas-firing power plants of **59.1 TWh**.

The total activated flexibility in the form of load shedding, due to activation of industrial DSR and curtailment of industrial electric heating demand, amounts to 44.5 TWh (75.3% of the saved gas consumption). In terms of power, the maximum curtailed load is **15.1 GW (out of 25.6 GW of installed capacity)** on a day of January; industrial DSR curtailment accounts for 10.3 GW, while industrial electric heating curtailment accounts for 4.8 GW. Regarding load shifting, DSF shaves peak demand and shifts generation from gas to other less expensive fuels (i.e. coal and lignite) contributing by 7.4% of gas savings. In addition, load shifting avoids renewable energy curtailment by 2977 GWh (5.0% of saved gas consumption) compared to the no-flex scenario. The **average DSF activated power** for shiftable technologies (EV charging, V2G, residential electric heating and BESS) amounts to **27.8 GW**.

Load shedding therefore is the main responsible for the assessed savings in gas consumption in 2025 as well. Although in both years 2023 and 2025 the gas reduction can be attributed, to a large extent, to industrial load curtailment, **in 2025 other factors, like renewable energy curtailment avoidance and peak shifting (due to load shifting), make a more significant impact, doubling the gas savings in 2025**. This behaviour is observed because in 2025 renewable generation represents a larger share in the generation mix, and because the electrification of transportation and heat demand has progressed. It is therefore observed that DSR makes a greater impact on a further electrified system with higher renewable installed capacity.

4 LIMITATIONS AND RECOMMENDATIONS

Regarding the modelling of DSF, DNV has modelled industrial DSR and industrial electric heating demand as curtailable loads. However, they may in practice turn out to (partially) behave as shiftable load, for instance, industrial processes demand may be curtailed, but it can be increased at a later moment (e.g. next day or next week). DNV acknowledges this as a model limitation, and whether there is sufficient electricity not generated by gas fired power plants available at those times to serve the additional demand is not investigated. Typically, however, such loads would be shifted to times of less expensive generation.

As for residential electric heating, DNV has taken a conservative approach and considered it as shiftable load rather than curtailable. Potential energy efficiency effects on residential electric heating[10] are not considered in the modelling due to data unavailability and uncertainties about the widespread (European) applications of findings. DNV acknowledges that residential heating flexibility could provide additional savings, next to the savings that are provided by load shifting according to the results. Therefore, DNV recommends exploring DSF electric heating efficiency considerations at European level.

[10] Such as presented in RTE's 2016 report on *'Evaluation des Economies d'Energie et des affets de bord associés aux effacements de consommation'*

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