Phase II — Pathways to 2050

A joint follow-up study by Gasunie and TenneT
of the Infrastructure Outlook 2050

Executive Summary

To achieve Paris Climate Agreement targets for CO_2 emission reduction, energy supply, energy demand and the connecting energy infrastructure must undergo a profound transition. The coupling of the complementary energy infrastructures for electricity and gas (hydrogen[1] and methane) is considered to be a key concept to integrate renewable energy sources (RES) on a large scale in the energy system and to ensure security of supply. TenneT and Gasunie have conducted the study Infrastructure Outlook 2050 (IO2050) in 2019 to understand future designs of the integrated energy system for Germany and the Netherlands in the year 2050.

Based on findings and open questions of IO2050, the follow-up study Phase II: Pathways to 2050 (Phase II) focuses on transition pathways of the energy infrastructures [2] towards an integrated European energy system. Accordingly, the study aims at increasing the general understanding of influences and interdependencies in the development of integrated energy systems. Therefore, the impact of distinct future developments regarding RES supply and energy demands on the transforming energy infrastructure is analyzed. For this purpose, an integrated energy system model is developed. The model determines transition pathways of the European energy infrastructure by minimizing the total investment and operational costs of various technological options (i.e. energy transmission infrastructures, power-to-gas (PtG) units, power plants and storages). Based on this, the study puts a special focus on the Netherlands and Germany (focus area) and covers the timeframe from 2030 to 2050 in 5 year steps.

[1] Hydrogen transmission infrastructure is developed in all scenarios, based on partial re-purposing of existing methane infrastructure.

[2] Transmission capacities are considered as simplification of the target energy transmission infrastructures as defined in national network development plans

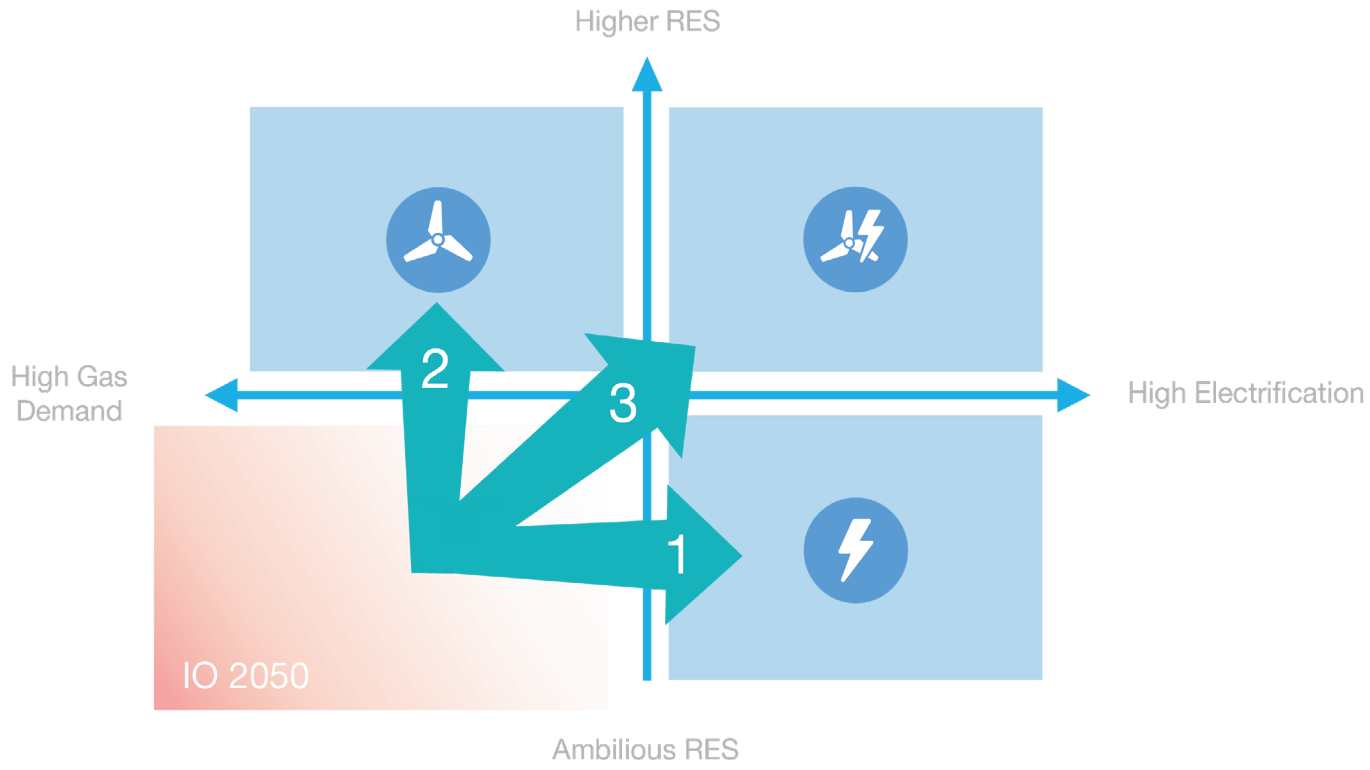

Figure 1: Developed combined scenarios

Building on the results of IO 2050 and other latest studies, three different scenarios have been developed. All scenarios assume a 95% decarbonization target within the energy system. The scenarios vary type and amount of installed RES as well as energy demand (focus on electrification vs. focus on gas). Those scenarios represent highly ambitious developments with regard to energy supply and demand to provide further insights on the impact of challenging frameworks to the energy infrastructure in general and to the energy transmission systems in particular:

	(EL & RES)	High electrification and ambitious RES
	(Gas & RES+)	High gas demand and very ambitious RES
	(EL & RES+)	High electrification and very ambitious RES expansion

KEY INSIGHTS

What do the numbers tell us

Global imports of CO_2 neutral gases to Europe, i.e. green hydrogen, synthetic methane and others, will become an essential part of the energy supply in all our scenarios

Regardless of the total installed RES capacities within Europe, a complete European energy independency is not achievable in any of the scenarios. Accordingly, imports will remain an essential part of the European energy supply. However, a shift towards CO_2 neutral energy carriers, like green hydrogen and synthetic methane, is necessary to reach CO_2 emission targets.

Highly ambitious RES development - surpassing current accelerating national plans in Europe - is necessary to work towards CO_2 reduction targets in line with the Paris Agreement and to decrease European energy imports simultaneuously. The developed scenarios for this study underline that ambitious expansion of RES capacities in Europe is required to cover the expected growing European electricity demand. If, in addition, gas demand is to be covered by domestic RES in combination with PtG units, the expansion need for RES capacities rises even further.

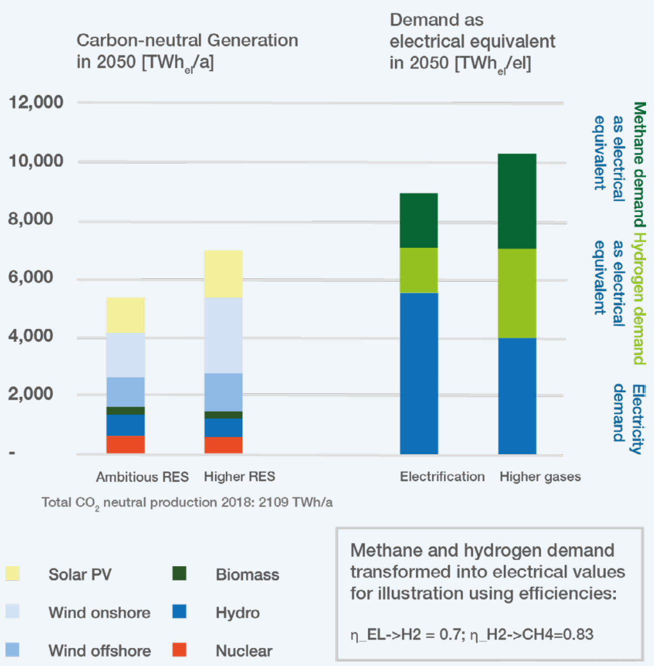

Figure 2: European supply compared with demand in 2050

Investment decisions on the demand side (electric, gas-based or hybrid) need to be coordinated with the development of the integrated energy infrastructure in order to avoid inefficiencies.

The investment decisions (i.e. location and installed capacities) of energy intensive industries and other main energy consumers have a high impact on necessary investments as well as the development of the entire integrated energy infrastructure. This needs to be incorporated when defining supportive measures for the usage of different energy carriers.

Further development of the energy transmission infrastructure for electricity, hydrogen, and methane beyond 2030 is essential for the future energy system. This development needs to be planned timely in an integrated way to find optimal solutions for a faster and affordable energy transition.

Due to the increasing total electricity demand in combination with a growing RES supply, the electricity transmission infrastructure needs to be expanded further beyond 2030. The expansion need is strongest in the scenarios with High Electrification (EL & RES and EL & RES+).

In all scenarios, a high share of the final energy demand is assumed to be covered by hydrogen as energy carrier. To enable this, an EU-wide hydrogen grid needs to be developed. This can be done efficiently by refitting of existing methane transmission infrastructure.

Power-to-Gas is a key technology for the next step in the energy transition

To further investigate the assumption on PtG capacities from IO 2050, this study is focused for the first time on the co-optimized investment and dispatch across all energy infrastructure assets. Based on the optimally coordinated dispatch of flexibility options across all energy carriers (e.g. energy transmission and batteries) electrolyser capacities reach high full load hours in the investigated scenarios. However, investment and dispatch of these units depend on the overall surplus of RES supply to the energy system. Accordingly, higher RES capacities as well as lower end-user electrification promote the installation of PtG units, which reach 110 GW in Germany and the Netherlands in scenario (Gas & RES+) in 2050.

Even in the scenario (EL & RES), PtG units may play a significant role. In this scenario CO_2 neutral hydrogen needs to be imported from sources outside of Europe. This may include sourcing it from PtG units or other means to generate CO_2 neutral hydrogen.

Storages and dispatchable power plants as sources for flexibility are required to ensure a reliable, CO_2-neutral demand coverage for all hours of the year.

The energy infrastructure is especially stressed in situations, when there is either a very high or a very low supply by domestic renewables. The applied model invests in their installation and utilizes them to their full capacity in the respective hours. Storages on the electricity site (pumped-storage and batteries) are used for short-term shifting of smaller energy volumes. For hydrogen and methane, large storage capacities were assumed in salt caverns and pore storages respectively providing flexibility especially for seasonal storage. However, for some simulated situations with very high and/or long lasting residual electricity load, investments in and the dispatch of power plants based on CO_2 neutral gases are calculated by the model – although the resulting full load hours are far below today's level (less than 1000 hours in all scenarios in 2050). In order to ensure investments in these assets, adaptions in the policy fram work are required.

A smart, flexible investment in and usage of European energy infrastructure – both for electricity and gas – plays an important role for the aim of an affordable energy system.

The optimization used in the study has shown the close interaction of investment and dispatch decisions of energy transmission, conversion and storages in future energy systems. This underlines the strong interdependencies of investment and dispatch considerations in integrated energy system planning. Accordingly, an integrated framework for investment and operation strategy is essential for the successful energy transition.

KEY STAKEHOLDER IMPACTS

What do we need to do?

- Prepare today for investments in energy transmission infrastructure beyond 2030! Construction of new electricity transmission infrastructure and refitting existing methane infrastructure to hydrogen are both required.

- Developments on the demand side (electric, gas or hybrid) need to be considered in combination with energy transmission grids to avoid inefficiencies. Especially energy intensive industries and other main users need to be incorporated given their impact.

- Determine desired RES development for after 2030 enabeling the decorbonization targets and allowing for acceptable levels for energy imports! This will have a profound impact on infrastructure development after 2030.

- Legal and regulatory frameworks need to facilitate and steer transition paths. First step is the implementation of an integrated system development plan. Mid-term goal could be further harmonization of regulations and markets of electricity and gas.

- Policy measures, enabling cost reduction and upscaling of PtG, shall be defined and implemented at an early stage in order to have PtG technologies well developed to meet the challenges ahead.

- International cooperation is key for an affordable, sustainable and reliable energy system. Increasing interdependencies of energy transmission infrastructures in Europe, as a cost-minimal source for flexibility, require strong political cooperation as well as alignment within Europe and also globally.