Phase II – Pathways to 2050

TenneT Webinar, Berlin

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Study Phase II - Introduction

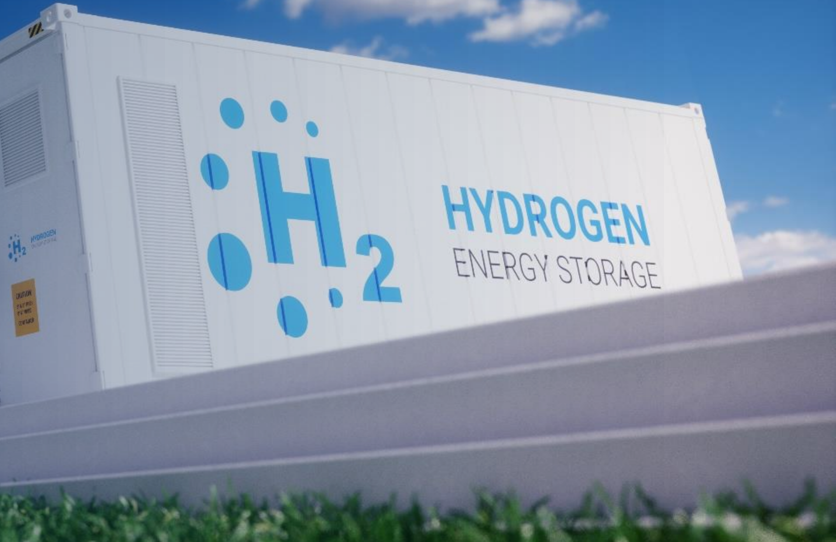
Achieving Paris Climate Agreement targets

- Defossilization of CO_2 emitting sectors necessary to meet 2°C or even 1.5°C goal
- Profound changes in energy demand and supply structure required
- Challenges for future energy systems and infrastructures

Coupling of electricity, hydrogen and methane infrastructures as key concept for integration of RES in the energy system

- Generation, conversion and utilization of renewable electricity, green hydrogen and green methane to cover energy demands
- Flexible use of advantageous energy carrier for transmission and storage
- Future energy system designs and transition path unclear

  ▶ Need for model based investigation of sector coupled systems



Study Phase II – Pathway to a Sector Coupled System in 2050

Previous Step: Infrastructure Outlook 2050 (IO2050): Sector Coupling in 2050 is necessary

Results:

- An energy system based on domestic RES depends on coupled gas and electricity grids
- Coupling of systems reduces need for additional electricity lines
- Need for adequately located PtG units as well as hydrogen and methane storages

2030 | 2035 | 2040 | 2045 | 2050

Present Study: Phase II – Pathways to 2050: Insights into possible paths to a sector coupled system from 2030 to 2050

Open Questions:

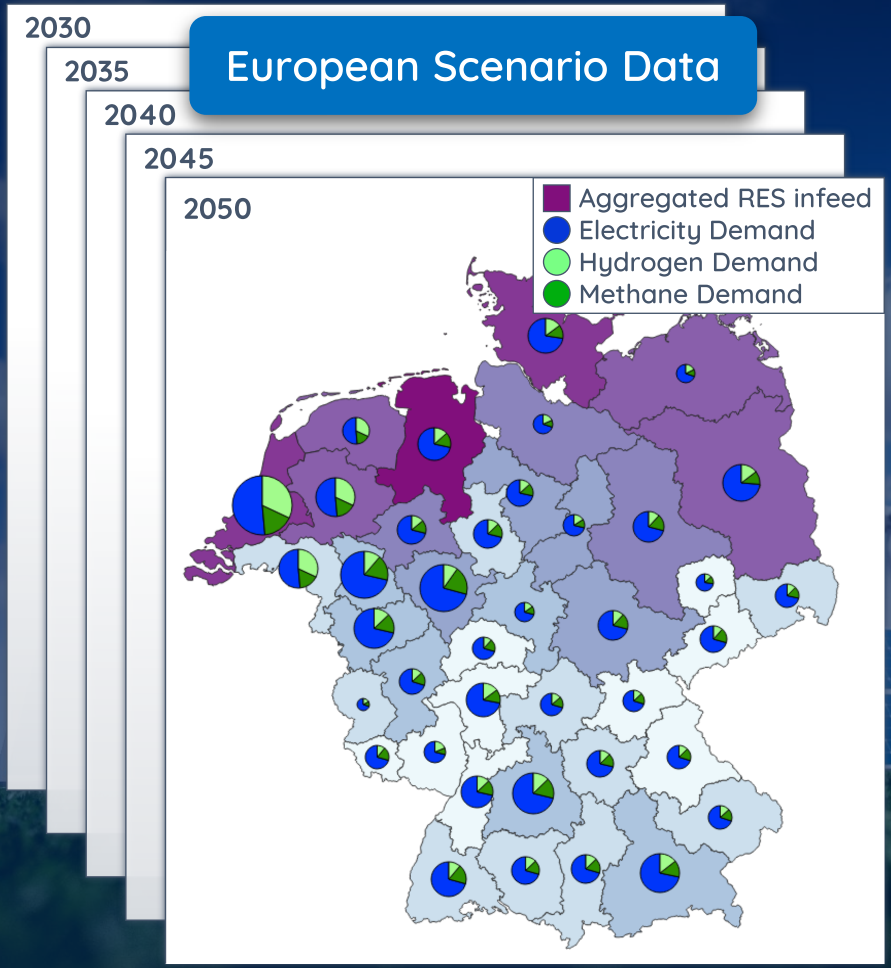
- When and where should sector coupling assets be installed to minimize overall costs?
- What infrastructure developments are necessary to meet the energy system's requirements?

Approach

- Development and application of an investment planning tool considering Europe from 2030 to 2050
- Development of consistent scenarios for the investigated scope
- Investigating different scenarios to evaluate impact of input parameter variation

Tailored Optimization Model developed for this Study

European Scenario Data



Input

Integrated Investment and Dispatch Model

- **Minimization of total system costs: Investment and dispatch**
- **Coverage of electricity, methane and hydrogen sectors**
- **Complying with given emission targets for the future**
- **Optimization of (de-)investment and dispatch of key assets**
- **High spatial resolution for focus area (e.g. DE with 35 regions)**
  - Transmission capacities for all sectors modelled with NTC approach
- **High temporal resolution**
  - Simulation of representative years (2030–2050) and representative situations (several characteristic weeks per year)

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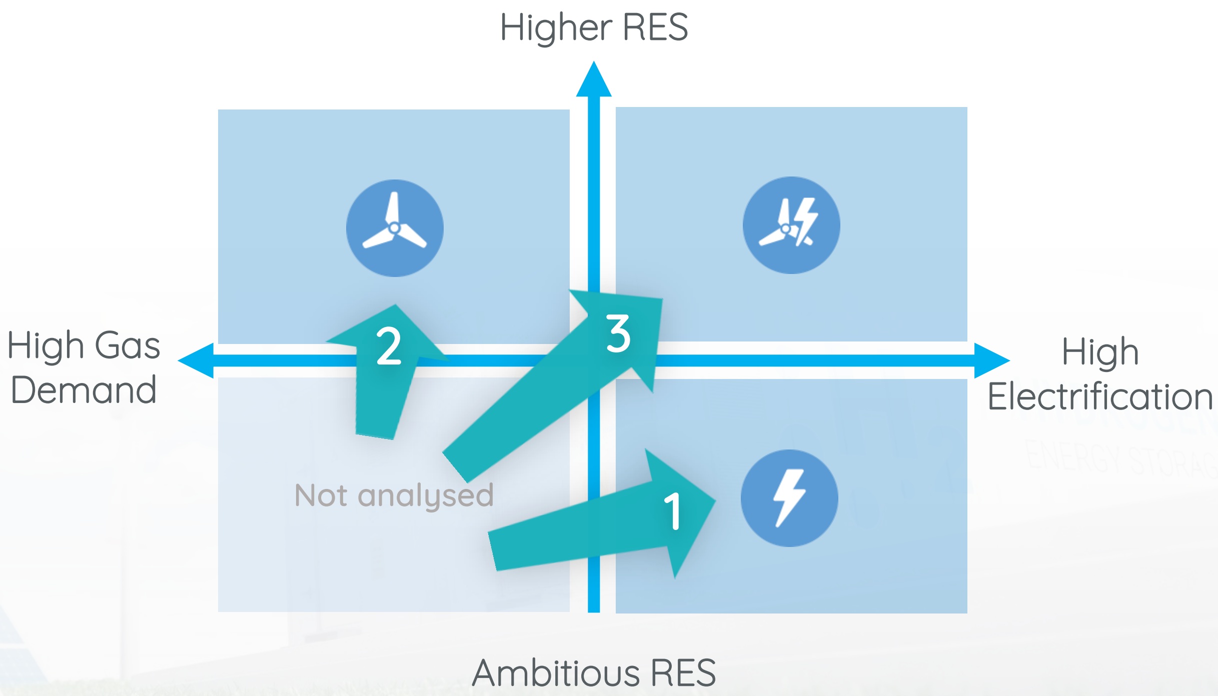
Scenarios

- Simulation of three scenarios with high expected impact on transport infrastructure
- Scenarios investigate
  1. higher electrification (EL & RES)
  2. higher RES (GAS & RES+)
  3. higher electrification & higher RES (EL & RES+)

All scenarios

- reach 95% CO_2 reduction target in 2050
- have the time horizon 2030 – 2050
- investigate 52 simulated regions in Europe, focus on DE and NL (focus area)



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Key Insights - Overview

Key Insights – What do the numbers tell us?

1 Imports

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 scenarios.

2 Coordinated Investments

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.

3 Infrastructure Investments

Further development of the energy transmission infrastructure (electricity, H_2 and CH_4) 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 an affordable energy transition.

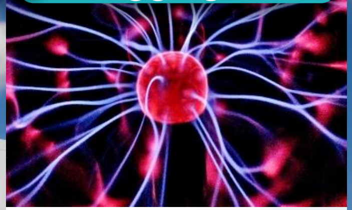
4 Power-to-Gas Investments

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

5 Flexibility

Storages and dispatchable power plants as sources for flexibility are required to ensure a reliable, CO_2-neutral demand coverage for each energy carrier.

6 Integrated Energy System



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.

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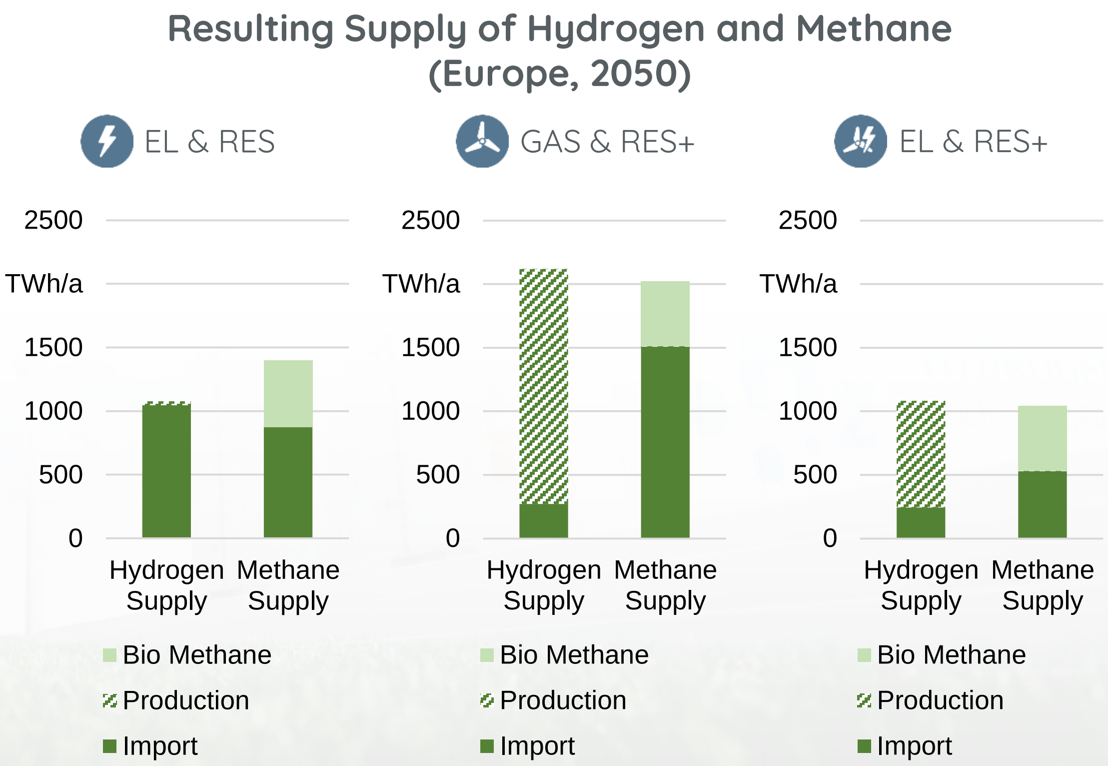
Key Insights - Imports

Key Insights – Global imports of CO_2 neutral gases to Europe & high RES

1 Imports

- Regardless of the total installed RES capacities within Europe, a complete European energy autarky is not achievable in any of the scenarios.
- Imports of CO_2 neutral energy carriers are an essential part of the European energy supply in all scenarios.
- Extensive 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 simultaneously.



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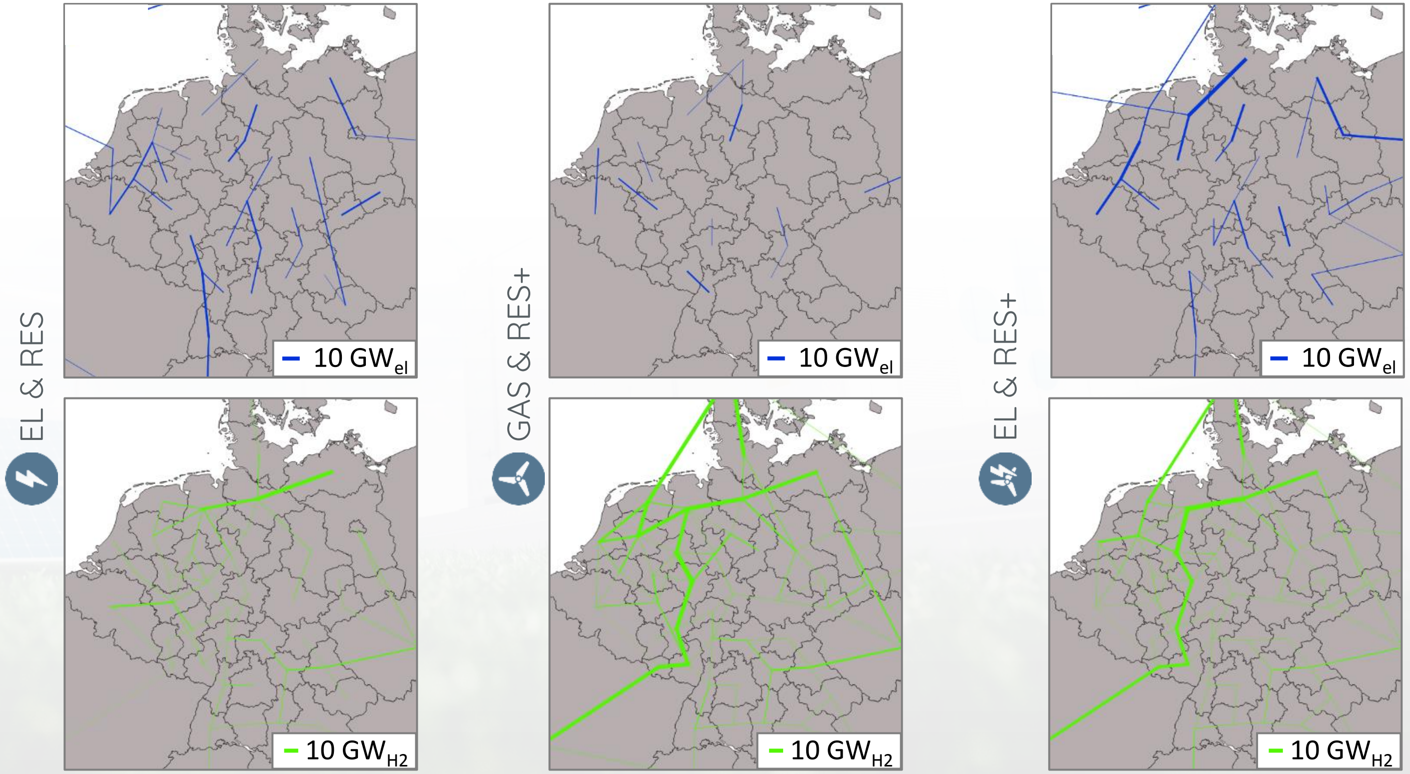
Key Insights – Infrastructure Investments

Key Insights - Energy transmission infrastructure (electricity, H_2 and CH_4) beyond 2030

3 Infrastructure Investments

- Electricity transmission infrastructure needs to be expanded beyond 2030 in all scenarios.
- EU-wide hydrogen grid needs to be developed by refitting of existing methane transmission infrastructure.
- Existing methane transmission infrastructure sufficient for future needs. No expansion required.

Development of Electricity and Hydrogen Infrastructures (Focus Area, 2050)



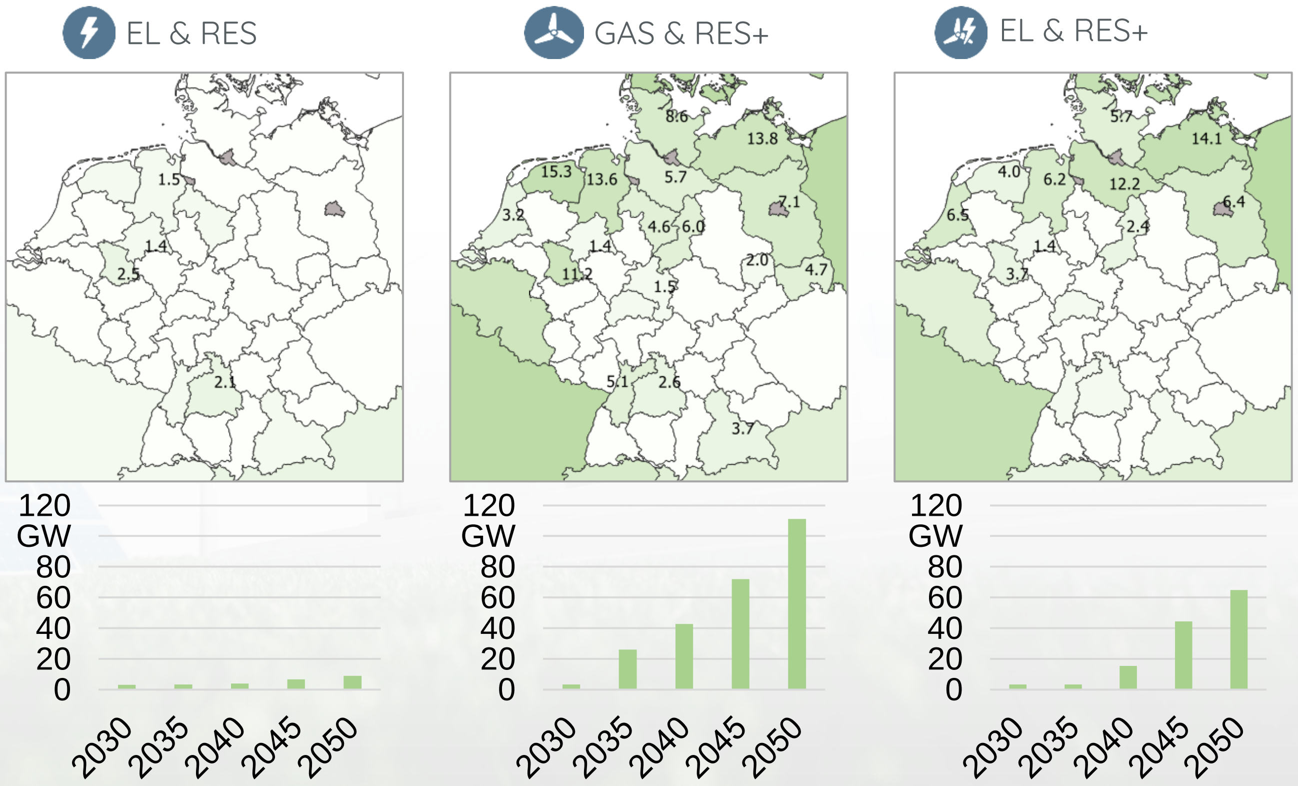
Key Insights – Power-to-Gas Investments

Key Insights – Power-to-Gas is a key technology for the energy transition

4 Power-to-Gas Investments

- Investment in and dispatch of PtG units depend on the overall and regional surplus of RES supply to the energy system.
- PtG units are largely located close to electricity production centers from wind energy.
- In the Electrification scenario, PtG may play an important role outside of Europe to facilitate increased imports of CO_2 neutral energy carriers.

Resulting Electrolyzer Capacities (Focus Area, 2050)



Key Stakeholder Impacts

Key Stakeholder Impacts – What do we need to do?

1

Prepare already today for investments in energy transmission infrastructure beyond 2030.

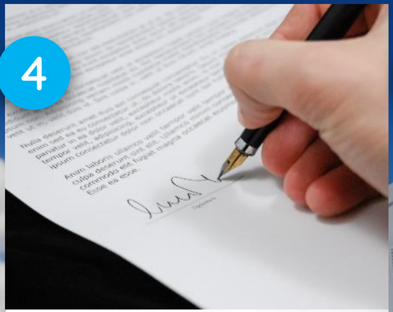
2

Developments on the demand side (electric, gas or hybrid) need to be considered in combination with energy transmission grids.

3

Determine desired RES development for after 2030.

4



Legal and regulatory frameworks need to facilitate and steer transition paths.

5

Policy measures, enabling cost reduction and upscaling of PtG, shall be defined and implemented at an early stage.

6

International cooperation is key for an affordable, sustainable and reliable energy system.

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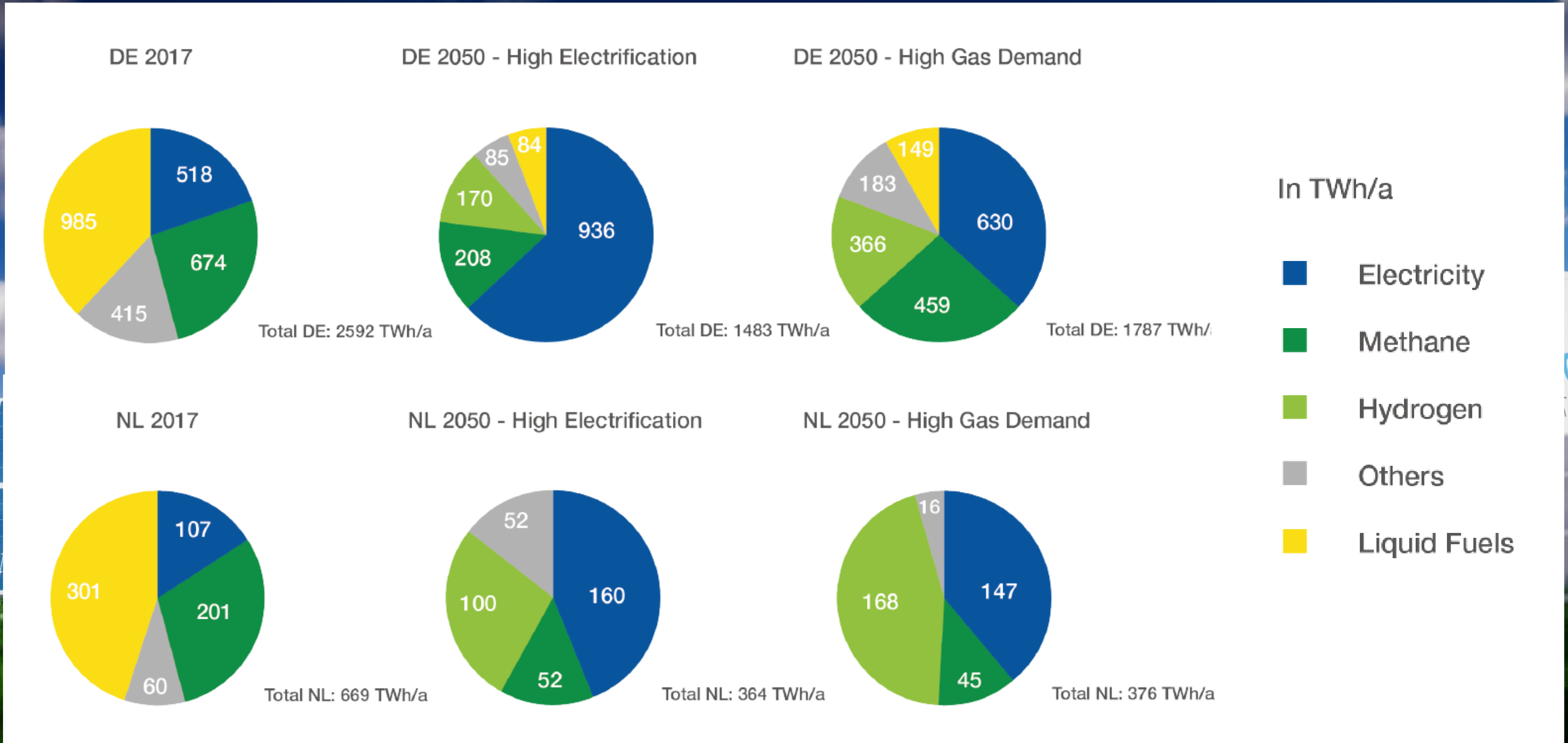
Scenario Data

Scenario Data - Demand

Energy Demands [TWh/a] 2050		EL & RES Germany	EL & RES Netherlands	Gas & RES+ Germany	Gas & RES+ Netherlands	EL & RES+ Germany	EL & RES+ Netherlands
Buildings Heating	Electricity	164	23	113	15	164	23
	Hydrogen	0	6	0	61	0	6
	Methane	24	22	170	19	24	22
	Others	19	41	118	5	29	41
Buildings Appliances	Electricity	173	66	213	66	173	66
Industry	Electricity	490	47	217	47	490	47
	Hydrogen	37	68	163	68	37	68
	Methane	171	1	267	1	171	1
Transport	Electricity	110	24	86	18	110	24
	Hydrogen	133	25	203	39	133	25
	Methane	13	29	21	24	13	29
	Liquid Fuels	84	0	149	0	84	0

Scenario Data - Demand

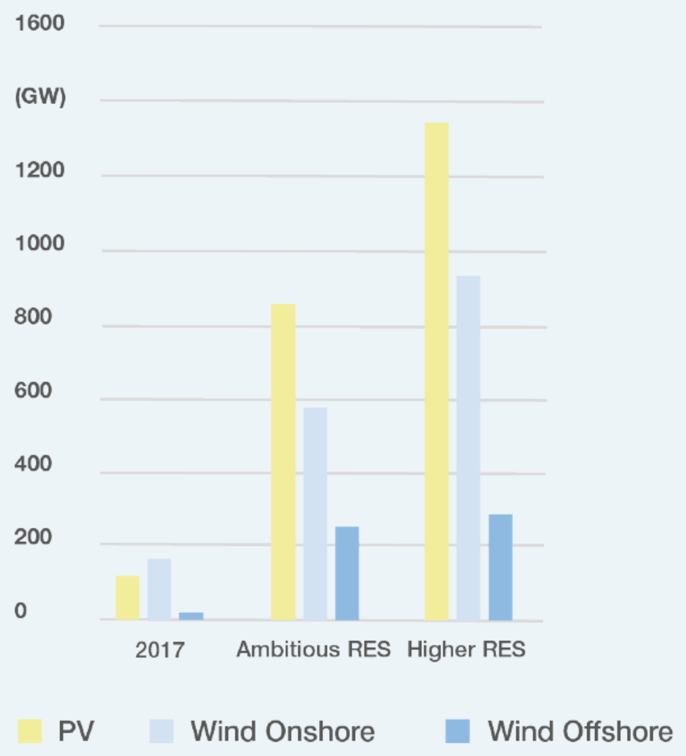


Scenario Data – Generation Capacities

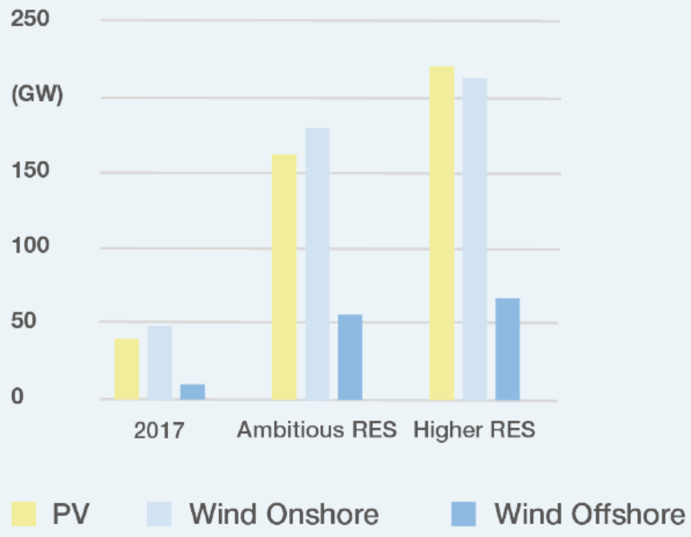
Generation Capacities [GW]		2050	EL & RES		Gas & RES+		EL & RES+	
			Germany	Netherlands	Germany	Netherlands	Germany	Netherlands
	RES	PV	165	34	218	85	218	85
		Wind Onshore	179	14	210	16	210	16
		Wind Offshore	53	53	64	53	64	53
		Biomass	10	0,5	10	0,5	10	0,5
		Run-of-River	4	0,1	4	0,1	4	0,1
	Power Plants	Nuclear	0	0	0	0	0	0
		Lignite	0	0	0	0	0	0
		Coal	0	0	0	0	0	0
		Oil	3	0	3	0	3	0
		Hydrogen	Based on Simulation Results					
		Methane						

Scenario Data – Generation Capacities

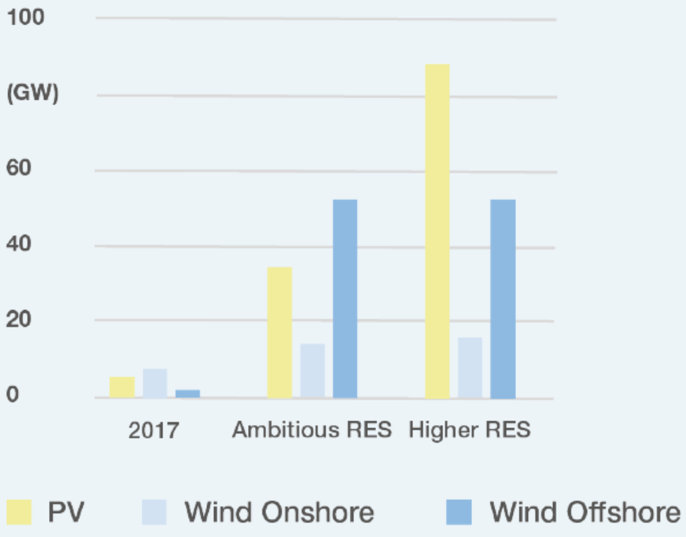
Europe



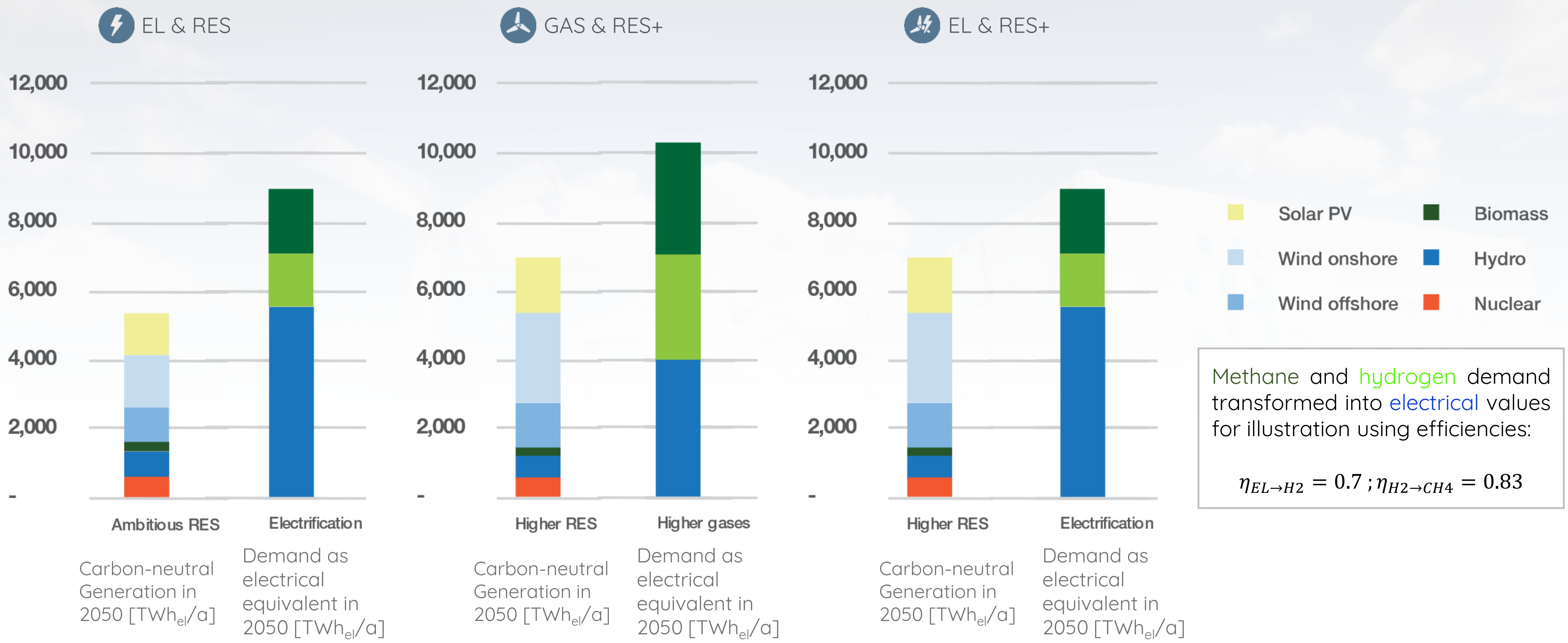
Germany



Netherlands



Scenario Data – Supply & Demand



Methane and hydrogen demand transformed into electrical values for illustration using efficiencies:

$$\eta_{EL\rightarrow H2} = 0.7\,;\eta_{H2\rightarrow CH4} = 0.83$$

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Scenario Data – Investments

Assumed Expansion and Reutilization Costs

Grid Expansion

- Data based on German Grid Development Plans, Input from Partners, Assumptions
- Assumed distance from node center to node center to consider necessary internal grid expansion

Power Line Connection	2.2	Mio. € /(GW*km)
Methane Pipeline Connection	0.2	Mio. € /(GW*km)
Hydrogen Pipeline Connection	0.2	Mio. € /(GW*km)
Methane to Hydrogen Conversion	0.01	Mio. € /(GW*km)

Power Plant Investments

- Due to strict RES targets, only investments in CH4- and H2-fired power plants modelled

CH_4-fired power plants:	750	Mio. € / GW
H_2-fired power plants:	750	Mio. € / GW

Power to Gas Units

AEL:	2030: 790 Mio. € / GW	2050: 363.4 Mio. € / GW
PEM:	2030: 1350 Mio. € / GW	2050: 243 Mio. € / GW
Methanation:	2030 until 2050: 400 Mio. € / GW	

Scenario Data – Imports

Assumptions on Gas Imports

Prices

- Decreasing prices assumed for import of H_2, due to assumption of increasing availability of green H_2
- Increasing CH_4 price due to increasing share of green CH_4
- Price assumptions based on Frontier Economics and World Energy Outlook

CO_2 neutrality of imports

- CO_2 neutrality assumed for imported H_2
- Imported CH_4 contains rising share of green methane: in 2050 95% CO_2 neutral

Assumed Development of CO_2 Neutrality and Prices[1] for Gas Imports