The Relevance of European Cooperation for a Cost-Effective Energy Transition

Deep insights from cross-sectoral energy system modelling

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analytical. quantitative. tech.

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Cooperation from Planning to Realization

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Agenda

Introduction, Methodology & Scenarios

Scenario Framework

Base: Collective Efforts

Limited Transport Corridors: Independent Pursuit

Slow-Wind: Reduced Expansion of Wind Energy

Anti-Flex: Low System Flexibility

Summary

Outlook

Derivation of Counter-Scenarios from Statements

Research Theses & Scenarios

Coordinating the energy transition across European countries enhances the cost-efficiency of the energy system.

The integrated and coordinated transition to a cost-efficient renewable energy system reduces Europe's dependence on imports and avoids compensation costs in individual sectors.

An energy system built upon renewable sources requires cross-regional and local flexibilities.

BS

Base
Collective Efforts

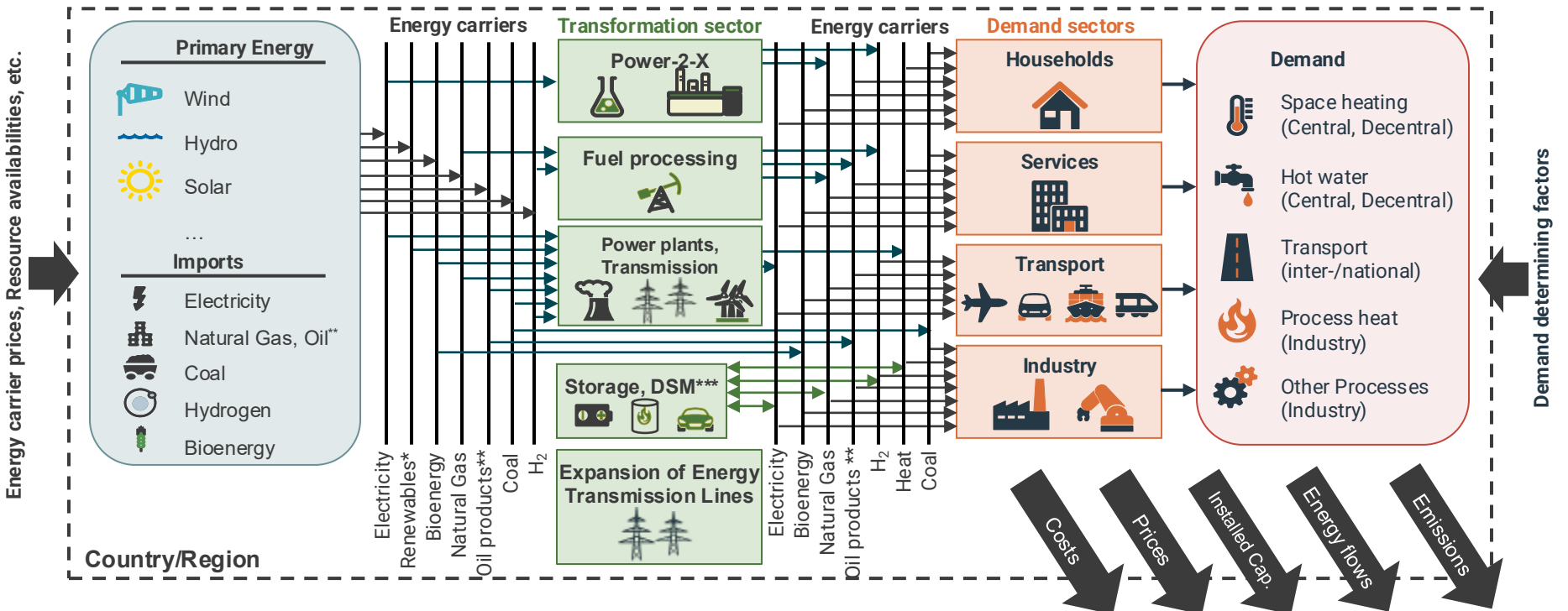
Limited Transport Corridors
Independent Pursuit

Slow-Wind
Reduced Expansion of Wind Energy

Anti-Flex
Low System Flexibility

Conceptual View of the Model

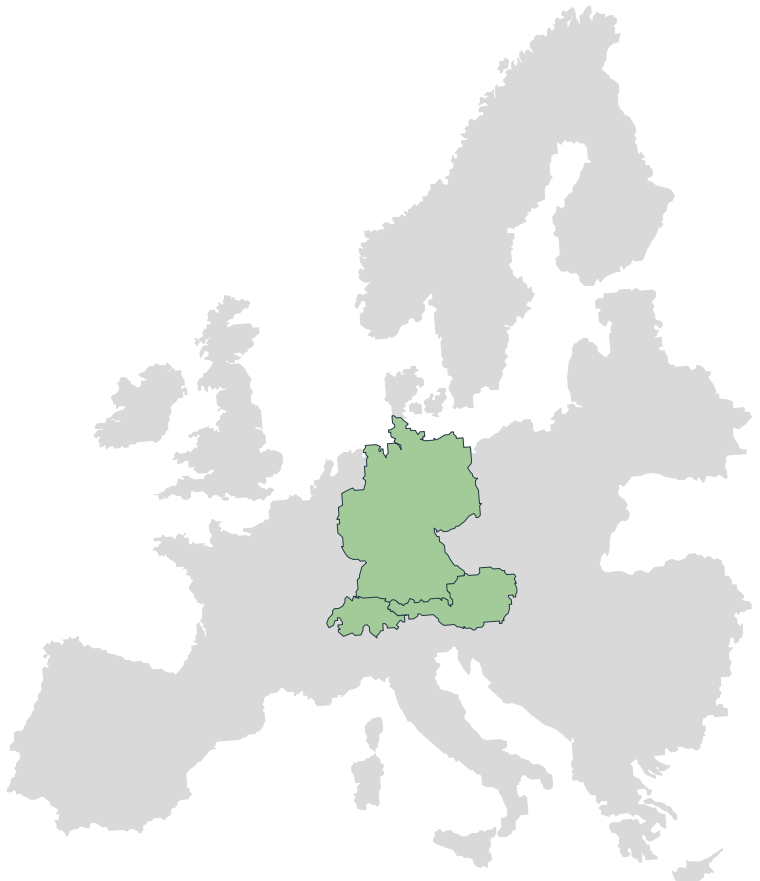
A Sector-Coupled Approach for Europe's Energy System



* Renewables include energy sources such as wind, photovoltaic (PV), and others.
** Oil products encompass petroleum (crude oil) as well as naphtha (used in the chemical industry) and kerosene (used in aviation) derived from the Fischer-Tropsch synthesis.
*** Demand-Side Management (DSM) covers the residential, industrial, and transportation sectors, including Vehicle-to-Grid (V2G) applications in the transportation sector.

Modelling Europe with Focus on DACH

A Sector-Coupled Approach for Europe's Energy System



Modelling of 50 Regions in Europe!

Evaluation focus is on the DACH-region.

Defining Core Specifications & Assumptions

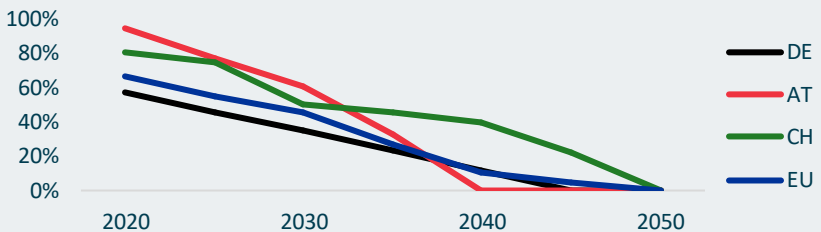
Scenario Framework

Fundamental Data

TYNDP-2022
… with national adjustments

- NEP (DE)
- ÖNIP (AT)
- EP2050+ (CH)
- …

Pathway to CO_2-Neutrality compared to 1990



European Green Deal and Effort Sharing Regulation must be respected.

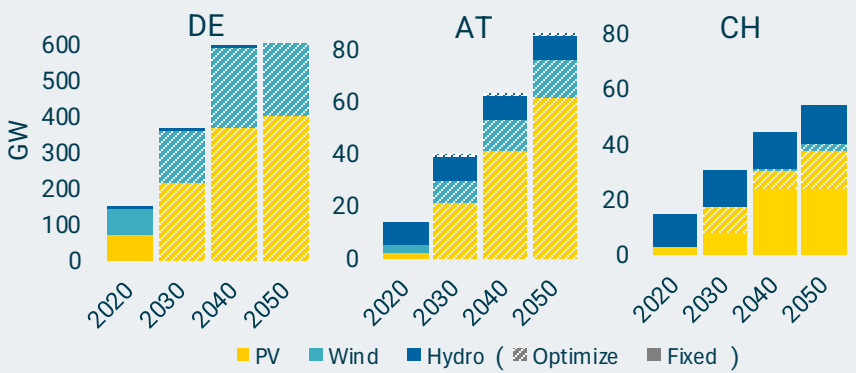
The driving force behind the energy transition.

The Weather Year is 2012

it dictates renewable potentials

and determines heat demands

Renewable Expansion Paths



Ambitious Renewable expansion.

Generous optimization interval.

Green Energy Carriers & Carbon Capture

The combination of biomass and CC allow for negative CO_2 emissions.

Unavoidable emissions in the industry, heating and transport sector make this technology crucial.

Defining Core Specifications & Assumptions

Scenario Framework

Flexible Power Plants are built as Needed

Each scenario requires different amounts of flexible production.

Storage Options are Free to be Expanded

Renewable energy sources require high temporal flexibility.

- Batteries
- PHS
- Water Tanks
- Hydrogen Storage

The Development of Energy Transport Corridors is Optimized

Electricity transport corridors are open for optimization after 2030.

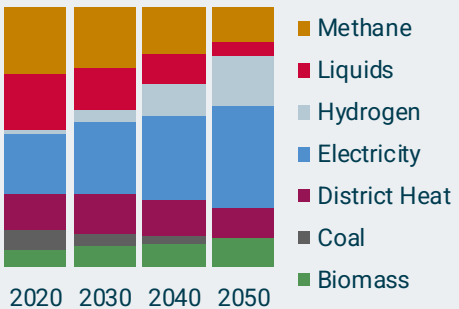
Hydrogen pipelines can be retrofitted from gas infrastructure or newly built.

Decarbonization of the Transport Sector

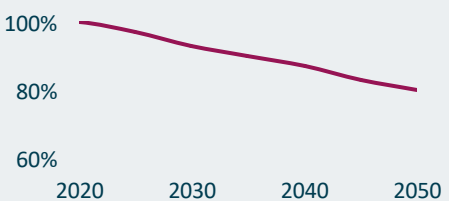
is achieved through a shift to mostly electricity and hydrogen.

Industry Demands Shift

towards more electricity and away from fossil fuels.

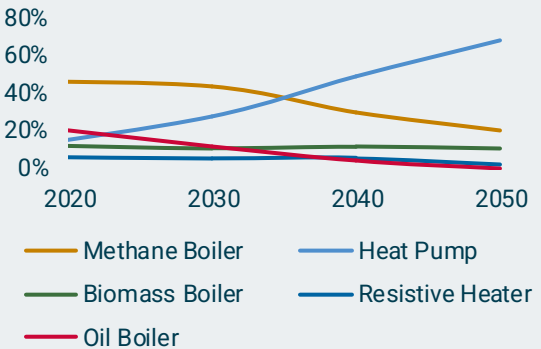


Heat Demands Decrease due to Renovations



Each country achieves individual renovation goals.

The Decentral Heat Technologies are Set



Fixed extension paths for all countries are given.

The District Heating Sector is Free for Optimization

For example, CHPs allow for sector coupling with the electricity sector.

The Ideal Scenario as the Reference

Base: Collective Efforts

BS

Base
Collective Efforts

The European countries support trade with each other.
Ambitious Renewable Energy Expansion is allowed.

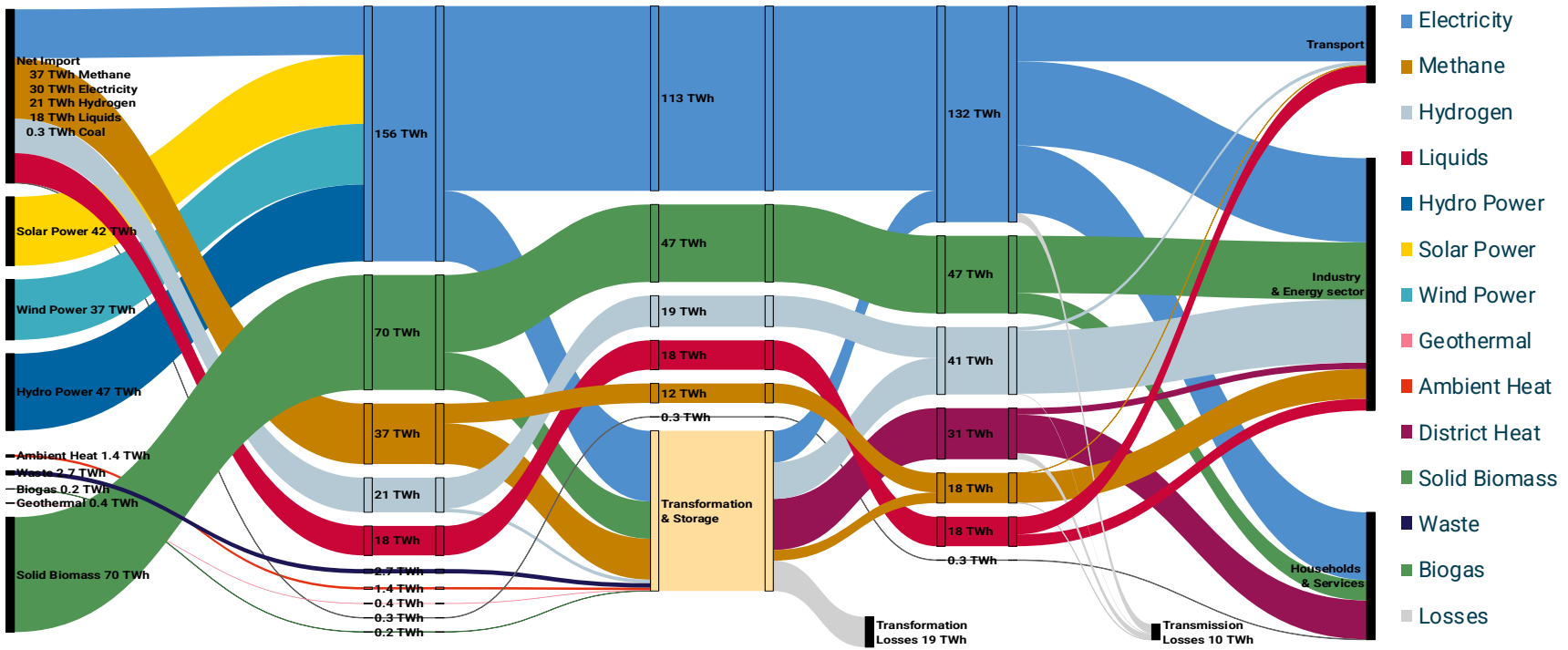
The energy transition is faced with collective efforts.

The baseline for this study.
Effects in the scenario are analyzed as differences to Base.

Deepening the Sense of Sector-Coupled Modelling

Base: Collective Efforts

Example for Energy Transformations in 2050



An example for the energy transitions in 2050. The shown country is Austria. On the left side the primary energy is displayed. On the right side the final energy demands.

Imports represent fully decarbonized energy carriers (green fuels or decarbonized through carbon management). Transport includes demand for international aviation and navigation. The ambient heat shown here only includes high-capacity central heat pumps from district heating generation and not those from decentralized systems in households and industry.

Limited European Interconnection – Scenario Definition

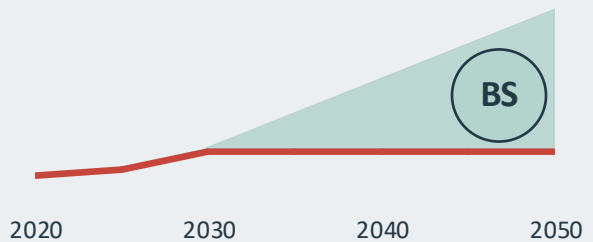
Limited Transport Corridors: Independent Pursuit

Limited Transport Corridors
Independent Pursuit

Electricity Transport Corridors

The electricity transport corridors are fixed to values from 2030.

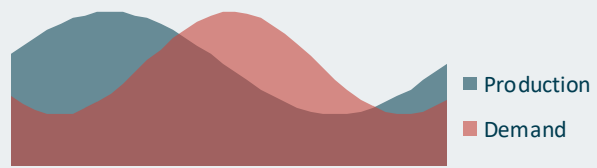
This is contrary to the base scenario (BS).



Self-sufficiency Levels

Increasing levels of primary energy self-sufficiency until 2050.

2030	2040	2050
35%	60%	80%



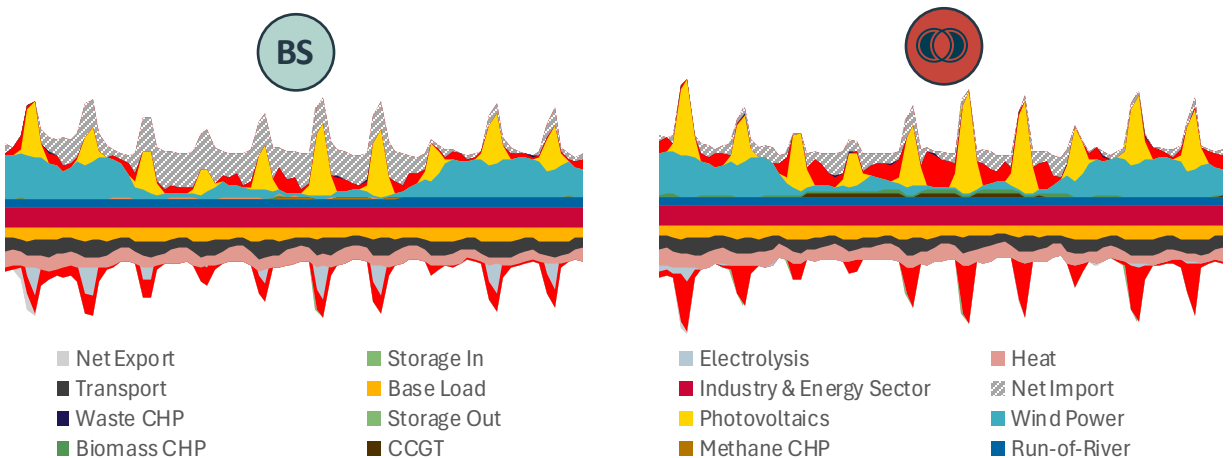
The self-sufficiency is defined to be on a yearly basis. Temporary higher imports are allowed.

Analyzing Effects on the Electricity Balance

Limited Transport Corridors: Independent Pursuit

Limited Transport Corridors
Independent Pursuit

Electricity Timeseries – Austria in 2050 from 16.02. to 26.02.



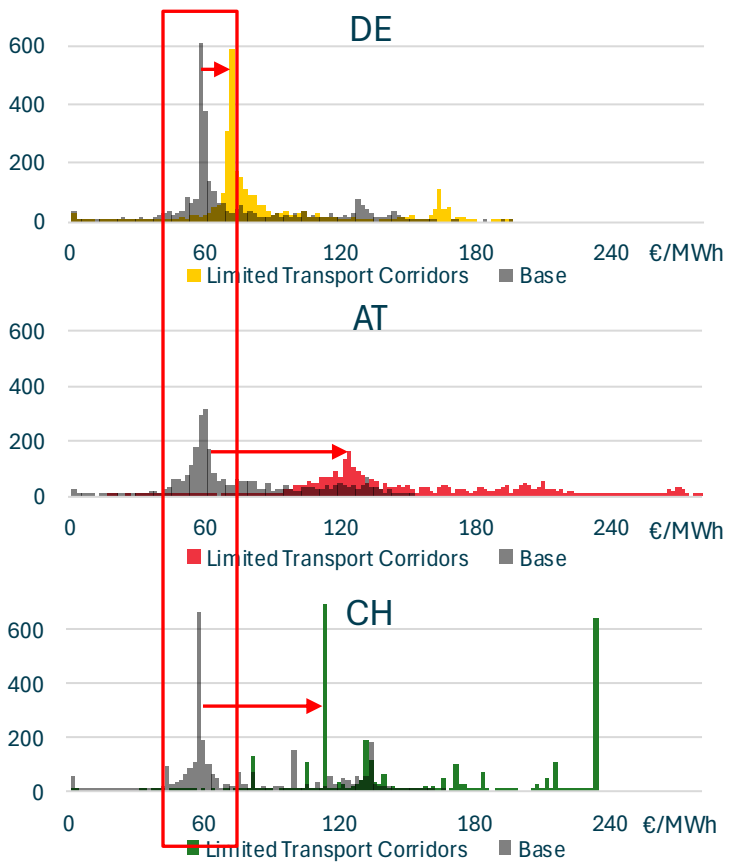
1.	**Residual load peaks can only partially be supplied through imports.** Also, excess production cannot be exported properly.
2.	**Consequently, energy needs to be supplied locally.** Flexible power plants are utilized more.
3.	**Storage technologies for temporal flexibilities are expanded much more.** The temporal flexibility is necessary to use renewable energy effectively.

Impacts on the Marginal Costs in 2050

Limited Transport Corridors: Independent Pursuit

Limited Transport Corridors
Independent Pursuit

Electricity Marginal Costs – Histograms



1. **An overall shift to higher costs compared to "Base" occurs.**
This is an indicator for an overall more expensive energy system.

2. **The highest peaks in the base scenario overlap.**
This underlines the smoothing effects of trade on the marginal costs.

Average Marginal Costs of Electricity in 2050

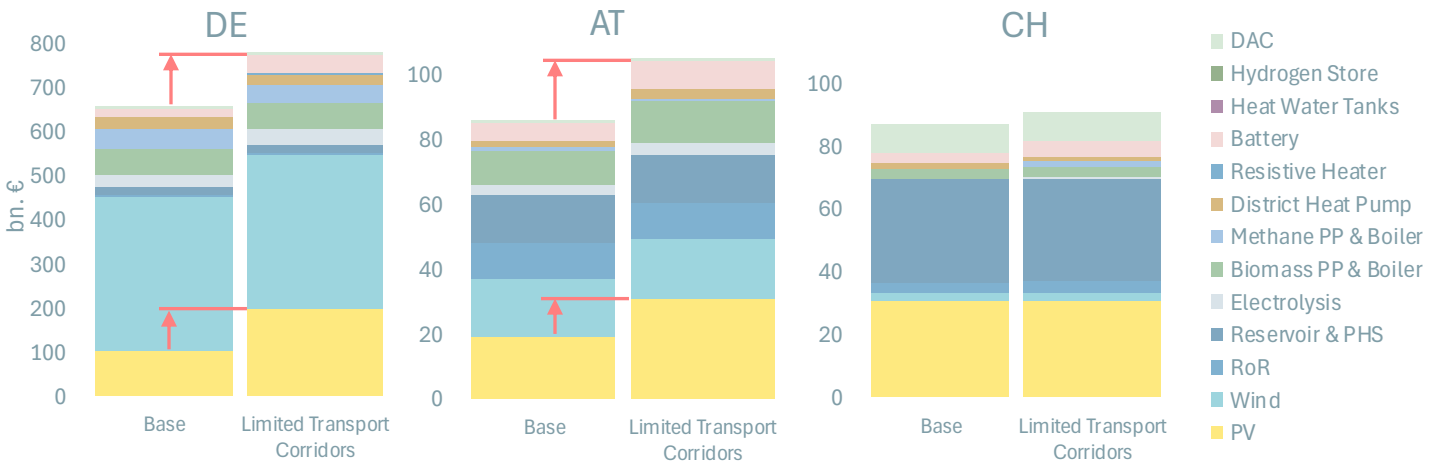
[€/MWh]	DE	AT	CH
Limited Transport Corridors	80	143	150
Base	69	71	75

Quantifying Increased Investment Needs

Limited Transport Corridors: Independent Pursuit

Limited Transport Corridors
Independent Pursuit

Accumulated Investment Costs until 2050



1. **Investment costs increase.**

DE: +19 %

AT: +22 %

CH: +4 %

2. **The highest increases can be observed for PV and batteries.**

PV are necessary to compensate for trade and batteries for temporal flexibility.

3. **+ 56 %**

in annual total European system costs of the energy system in 2050 excluding the final energy consumers.

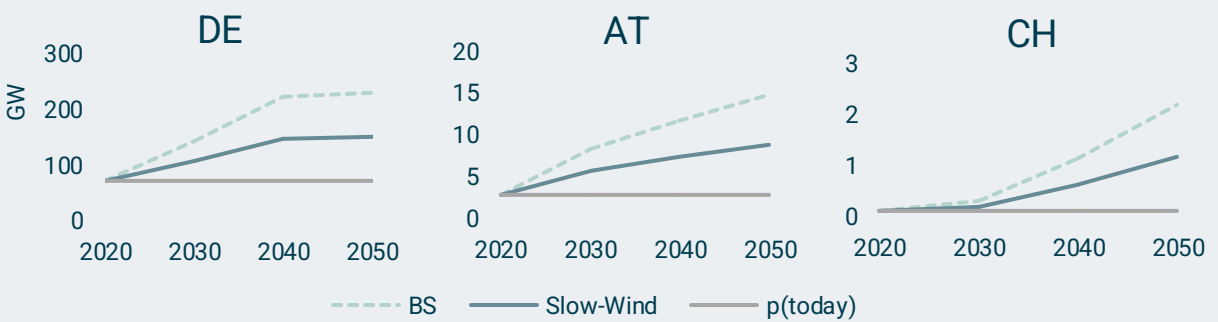
Reduced Wind Park Expansion – Scenario Definition

Slow-Wind: Reduced Expansion of Wind Energy

Slow-Wind
Reduced Expansion of Wind Energy

Delayed Wind Park Expansion

The maximum wind park expansion paths across Europe are reduced.
Half the planned potentials are realizable.

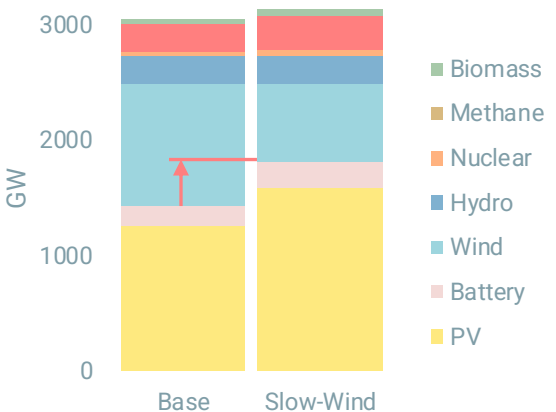


Analyzing Shifts in Energy Generation and Sector Coupling

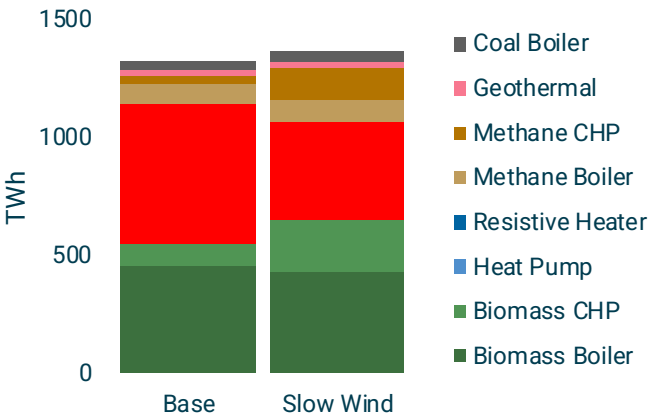
Slow-Wind: Reduced Expansion of Wind Energy

Slow-Wind
Reduced Expansion of Wind Energy

Installed Power Production Capacities in Europe in 2050



District Heat Production in Europe in 2050



1. **The missing wind capacities are compensated primarily with PV.**
   Batteries increase accordingly.

2. **The higher volatility introduced by PV requires more flexible power plants.**

3. **CHPs are more relevant**
   because they supply electricity and heat.

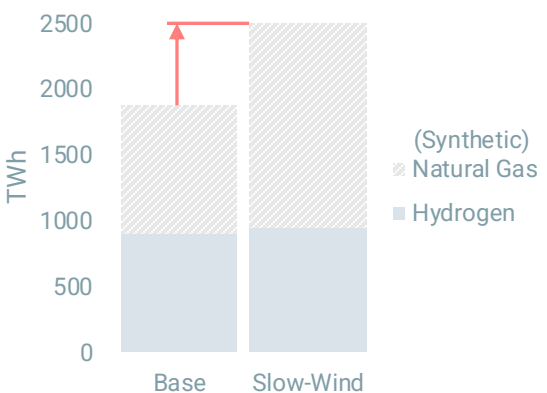
4. **Less electrification of the district heating sector.**
   Goes hand in hand with more CHPs.

Impacts on Global Dependence and System Costs

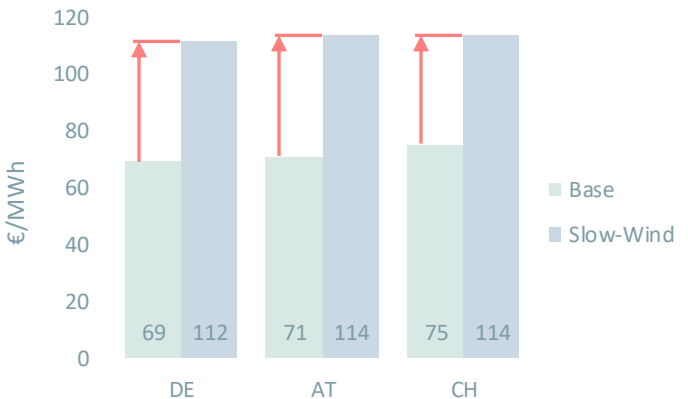
Slow-Wind: Reduced Expansion of Wind Energy

Slow-Wind
Reduced Expansion of Wind Energy

Global (Synthetic) Natural Gas & Hydrogen Import in Europe in 2050



Average Marginal Costs of Electricity in 2050



1. **Increased global natural gas imports are the result.**
   The European primary energy self-sufficiency falls by 7%.

2. **The average marginal cost of electricity increase across Europe.**

3. **+ 10 %**
   in annual total European system costs of the energy system in 2050 excluding the final energy consumers.

Low System Flexibility– Scenario Definition

Anti-Flex: Low System Flexibility

Anti-Flex
Low System Flexibility

Significant Reduction in Energy Storage

The set upper limits are relative to optimization results in Base: batteries, hydrogen stores, water tanks

Pumped hydro storage expansions are reduced to pessimistic scenario values for 2030.

BS

2

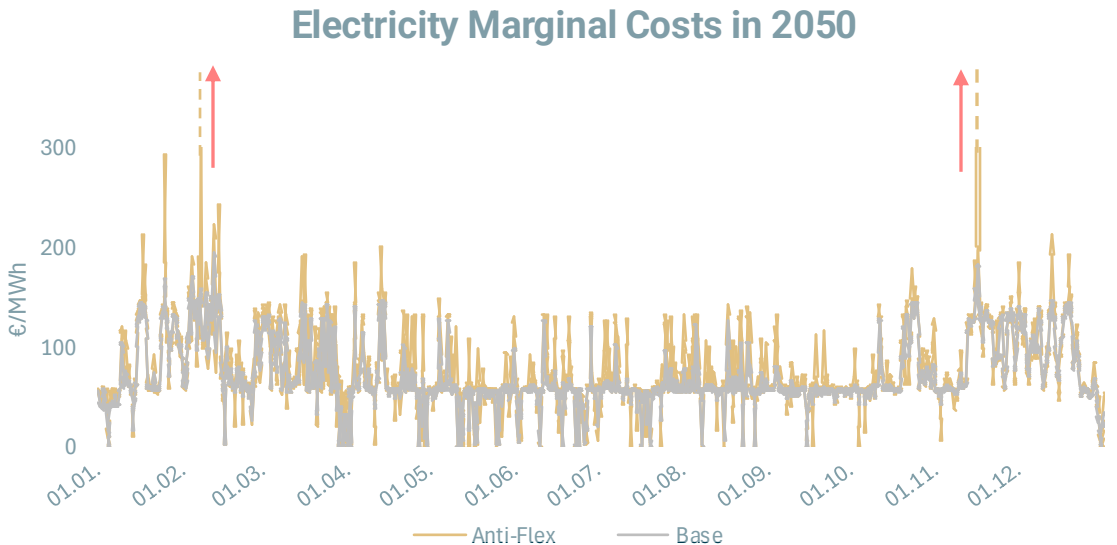
Demand Side Management is Not Possible.

This is true for industrial purposes and for battery electric vehicle charging.

Effects on European Energy

Anti-Flex: Low System Flexibility

Anti-Flex
Low System Flexibility



1. **Price spikes occur more often, and they are worse.**

In cases of continental renewable doldrums, the marginal prices reach extreme values.

2. **Energy transport corridors are expanded more.**

The temporal flexibility is replaced by spatial flexibility.

3. **Flexible power plants have a higher relevance.**

DE: +29 %

AT: +54 %

CCGT expansion in 2050 compared to Base.

Key Insights of the Scenario Based Analysis

Summary of Findings

Limited Transport Corridors
Independent Pursuit

Limited transport corridors and high self-sufficiency targets lead to …

- significant increases in annual European system costs.
- substantial disparities in electricity marginal costs between countries.
- additional investment costs for power generation and energy conversion.

Coordinating the energy transition across European countries enhances the cost-efficiency of the energy system.

Slow-Wind
Reduced Expansion of Wind Energy

Failing to achieve national renewable expansion goals leads to …

- higher system costs across Europe.
- an increased dependence on global imports.
- less electrification of the energy system.

The integrated and coordinated transition to a cost-efficient renewable energy system reduces Europe's dependence on imports and avoids compensation costs in individual sectors.

Anti-Flex
Low System Flexibility

Insufficient energy storage options in the European energy system leads to …

- more frequent and higher electricity marginal price spikes.
- a higher dependence on flexible power plants.
- an increased need for energy transport corridors.

An energy system built upon renewable sources requires cross-regional and local flexibilities.

Cooperation from Planning to Implementation

Outlook

The collaboration of European TSOs in the development of the applied energy system model …

… will diversify perspectives and can propel innovative solutions.

… allows for the sharing of best practices and leads to a more robust and validated data foundation.

… would allow for great agility through the readily available expertise about the individual market regions.

Enabling a free internal and European electricity market in the energy transition becomes more challenging.

A quick pace in modelling advancements is necessary.

Collaborative effort will be pivotal in addressing both current challenges and future opportunities.

This ensures that the continent remains at the forefront of the global energy transition.