Integration of Supply Chain within Energy System Modelling

Session 2: Embedding Supply Chain and Circularity in Modelling and System Planning

ALEXANDRE OUDALOV, SEBASTIAN PORRAS APPARICIO, HONGTAO KAN | GLOBAL MARKET INNOVATION, HITACHI ENERGY

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Outline

1. The growing importance of supply chain in energy transition
2. Integration of supply chain parameters in capacity expansion modeling tools
3. Effect of changes in different supply chain parameters on investment decisions
4. Concluding remarks

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Complex multi-tier supply chains

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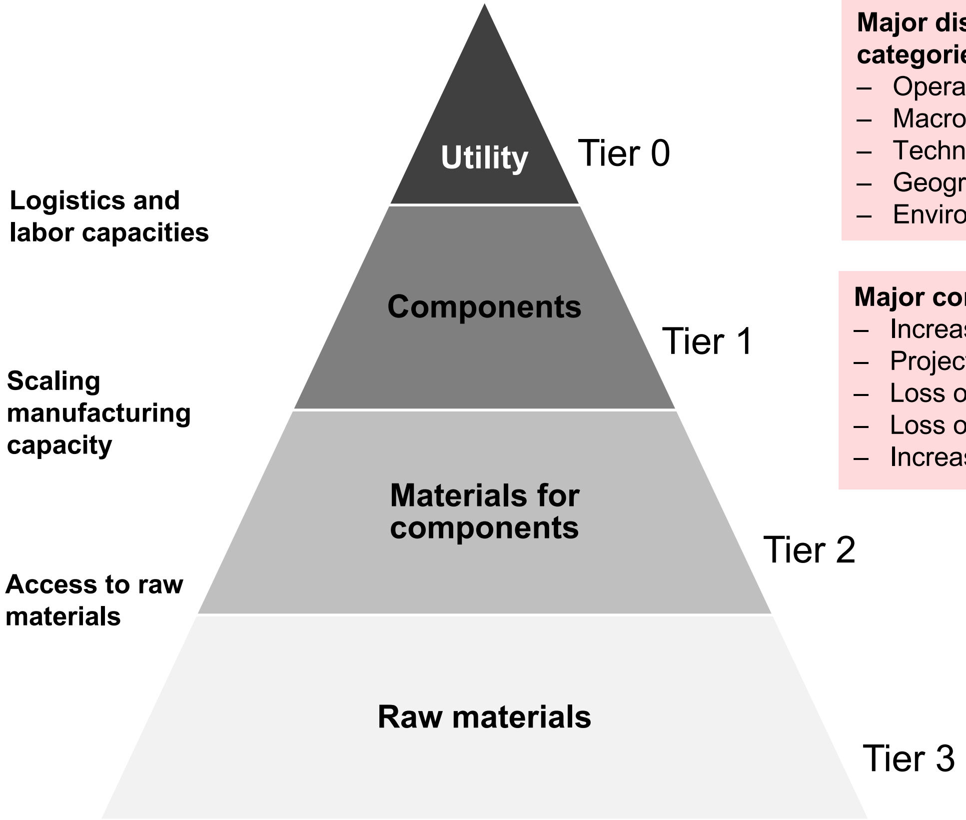
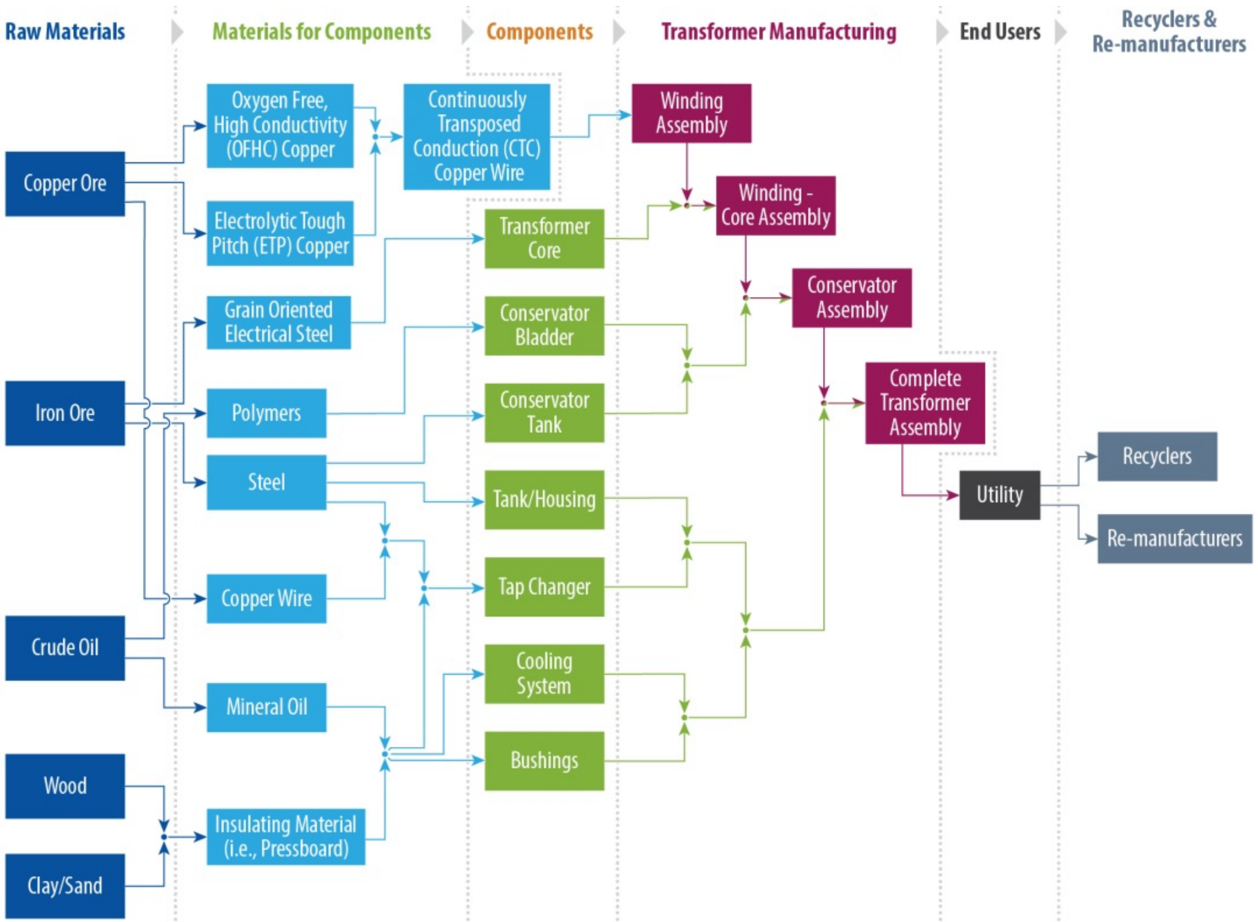
Supplier tier example



Major disruption categories:
- Operational
- Macroeconomic
- Technology
- Geographic
- Environmental

Major consequences:
- Increased costs
- Project delays
- Loss of productivity
- Loss of sales
- Increased lead times



Modern supply chains in the power system sector encompass multiple tiers spanning from raw materials to the final grid infrastructure

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Source: US Department of Energy

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Manufacturing capacity a crucial step for accelerating energy transition

Solar PV

- The world installed 417 GW of solar generation in 2023, almost twice as much as in 2022.
- China's PV module manufacturing capacity nearly tripled during 2022, from about 198 gigawatts a year to about 562 GW/year, and then rose by a further 84% to over 1 TW/year at the end of 2023.

Wind

- Total of 30 wind turbine manufacturers installed ~120 GW of new capacity in 2023.
- Global manufacturing capacity of wind turbines stood at 166 GW in 2022, up from 154 GW in 2021. It is forecast that the global wind turbine production capacity will reach 175 GW by 2024.

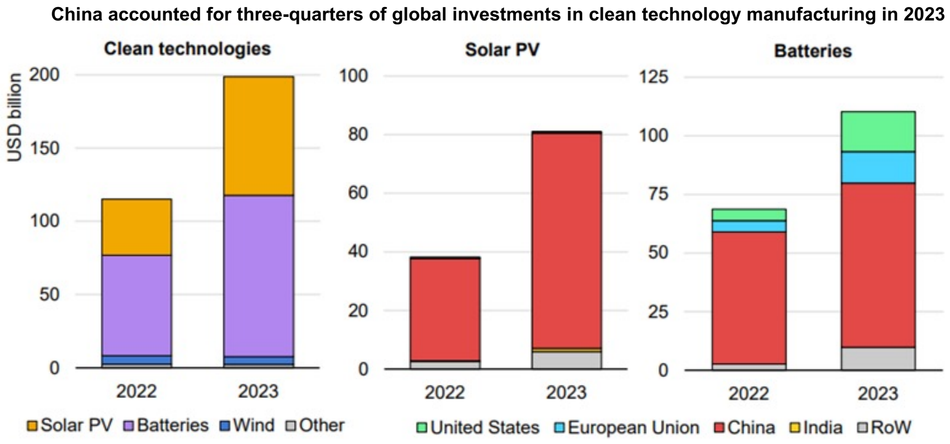
Batteries

- Global manufacturing capacity will reach 6.5 TWh in 2030 from 2.8 TWh as of March 2024. Demand from the EV sector is expected to reach 3.7 TWh in 2030.
- Mined resources might become a bottleneck of battery capacity development by end of the decade.

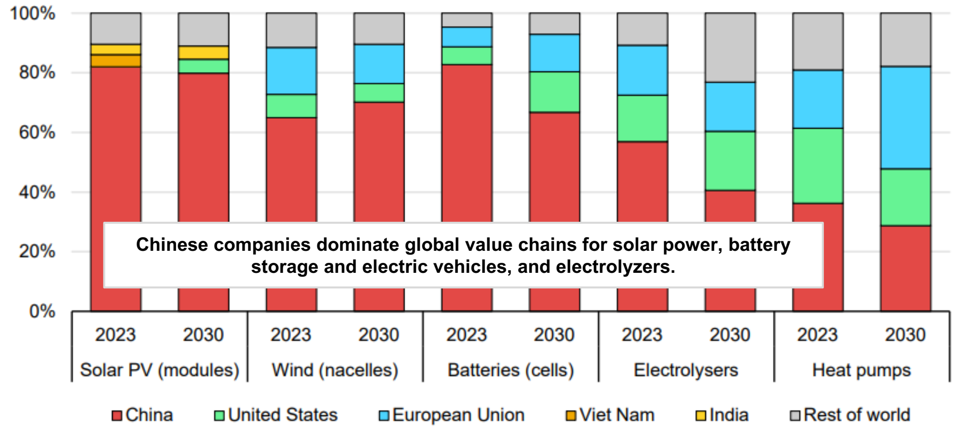
Girds

- Transformer lead times have been increasing for the last 2 years - from 50 weeks in 2021, to 120 weeks in 2024. Large transformers have lead times up to 210 weeks

Clean technology manufacturing investment by technology and region, 2022-2023



Geographical concentration of current and announced manufacturing capacity, 2022-2023



T&D grids become increasingly important for a success of clean energy transitions, but they currently receive less attention compared to solar PV and batteries

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Source: IEA, Wood Mackenzie, S&P Global

Hitachi Energy expands capacity to meet growing demand

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Hitachi Energy's ongoing and future capacity investments

2021-2023

Invested $3 billion in manufacturing and engineering footprint, and R&D. Increased its workforce by more than 8,000.

2024-2027

Invest over $1.5 billion to ramp up global transformer manufacturing capacity and create over 4000 jobs:

– $330 million to expand and modernize its flagship factory in Sweden and hire 2000 additional employees
– $180 million in a new state-of-the-art transformer factory in Finland
– $30 million expansion and modernization of the power transformer manufacturing facility in Germany will generate up to 100 new jobs
– $100 million upgrade and modernization of power transformer factory in Canada

In June 2024, announced additional $4.5 billion investments in manufacturing, engineering, digital, R&D and partnerships by 2027, doubling the investments done in 2020-2023.

Investments in expansion of manufacturing capacity are pivotal to provide the necessary grid technologies and infrastructure to support a cleaner, more efficient energy future worldwide

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Supply chain features in the capacity expansion model

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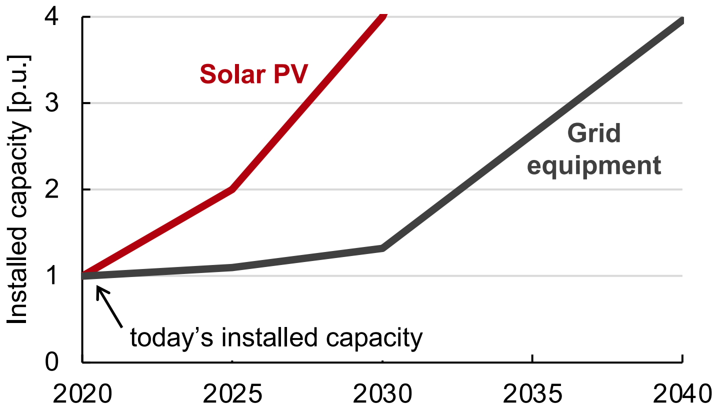
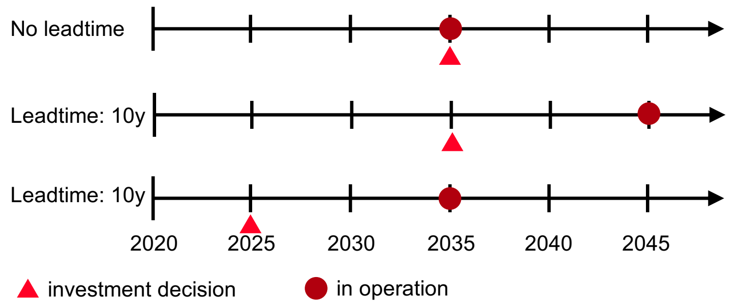
Maximum capacity expansion per step



- The maximum investment capacity per step is constrained as a ratio of the installed capacity of the previous investment step e.g., it can be doubled, tripled, etc.
- It represents the investment capacity of each one of the available technologies for each step, which is linked to the manufacturing capacity, product delivery, workforce availability and other factors in the supply chain as well as the available space.

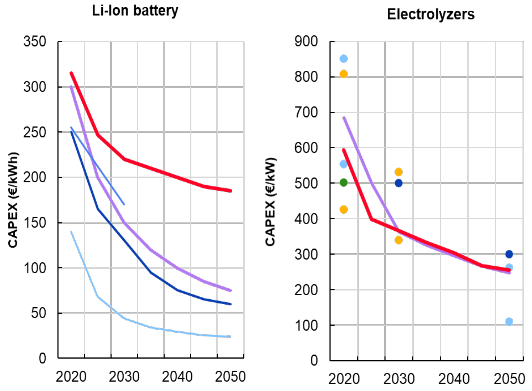
Infrastrucutre deployment delays

Overnight investment cost is divided equally over time range between investment decision and actual operation



- The construction of transmission lines is subject to a long process (permissions, social acceptance, environmental assessments, etc.) from the moment that the investment decision is made to their commissioning, which can take up several years.
- If a lead time is considered and the investment decision is done same as in the overnight case, then the infrastructure would be in operation only in the future, leading to extra costs and the incapability to meet certain targets. The investment decision needs to be done in advance.

Technology learning curves



We assign different technology costs assuming cost reduction due to volumes.

- The accuracy of the investment costs forecast of the different technologies are subject to several macro trends (technical, political, economic, etc.) that can directly affect the supply chain of the required infrastructure.
- Raw material scarcity, political tensions, manufacturing bottlenecks, policies, etc. can affect the price trajectory either increasing or decreasing.

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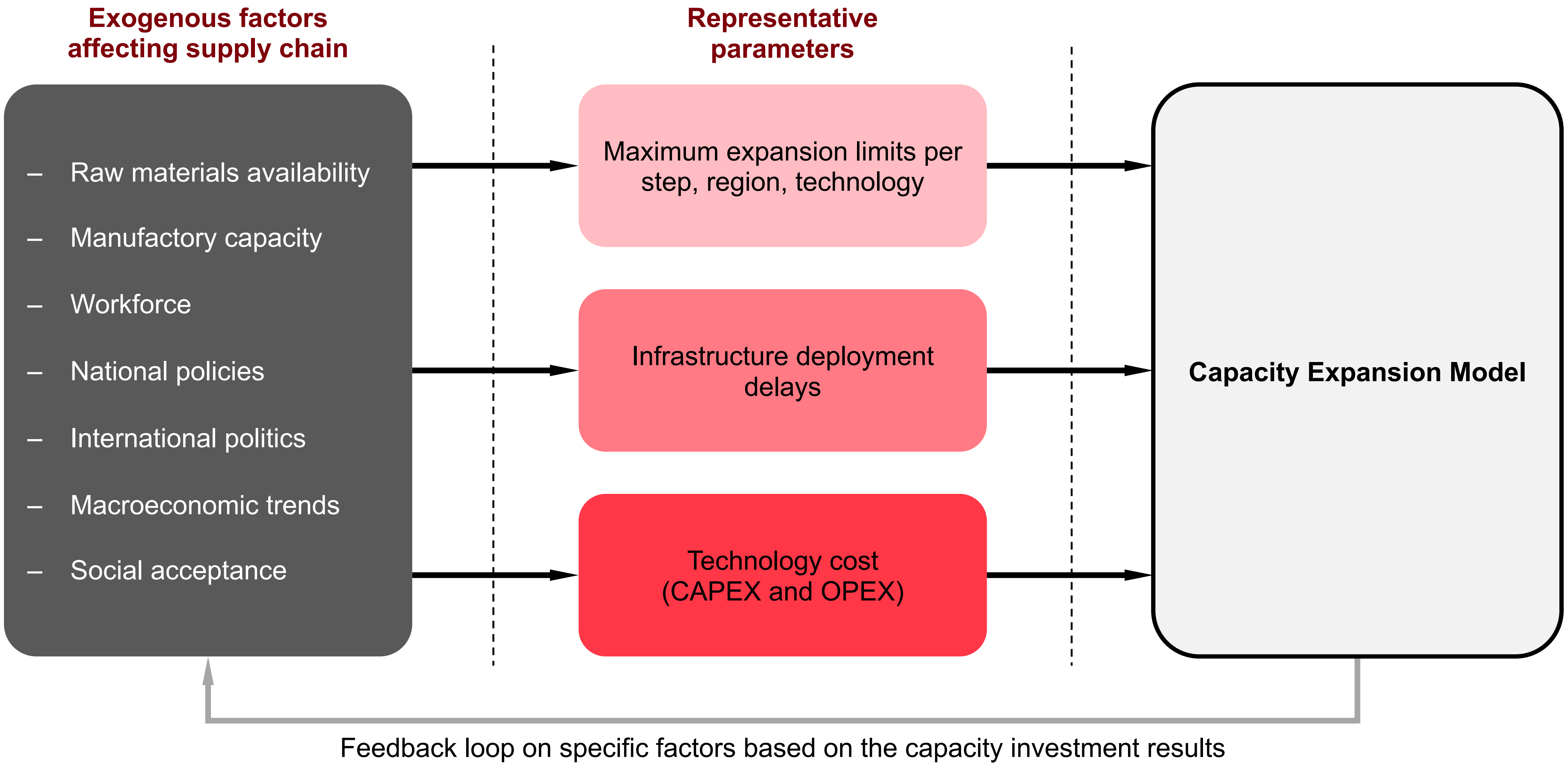
Supply chain features in the capacity expansion model: workflow



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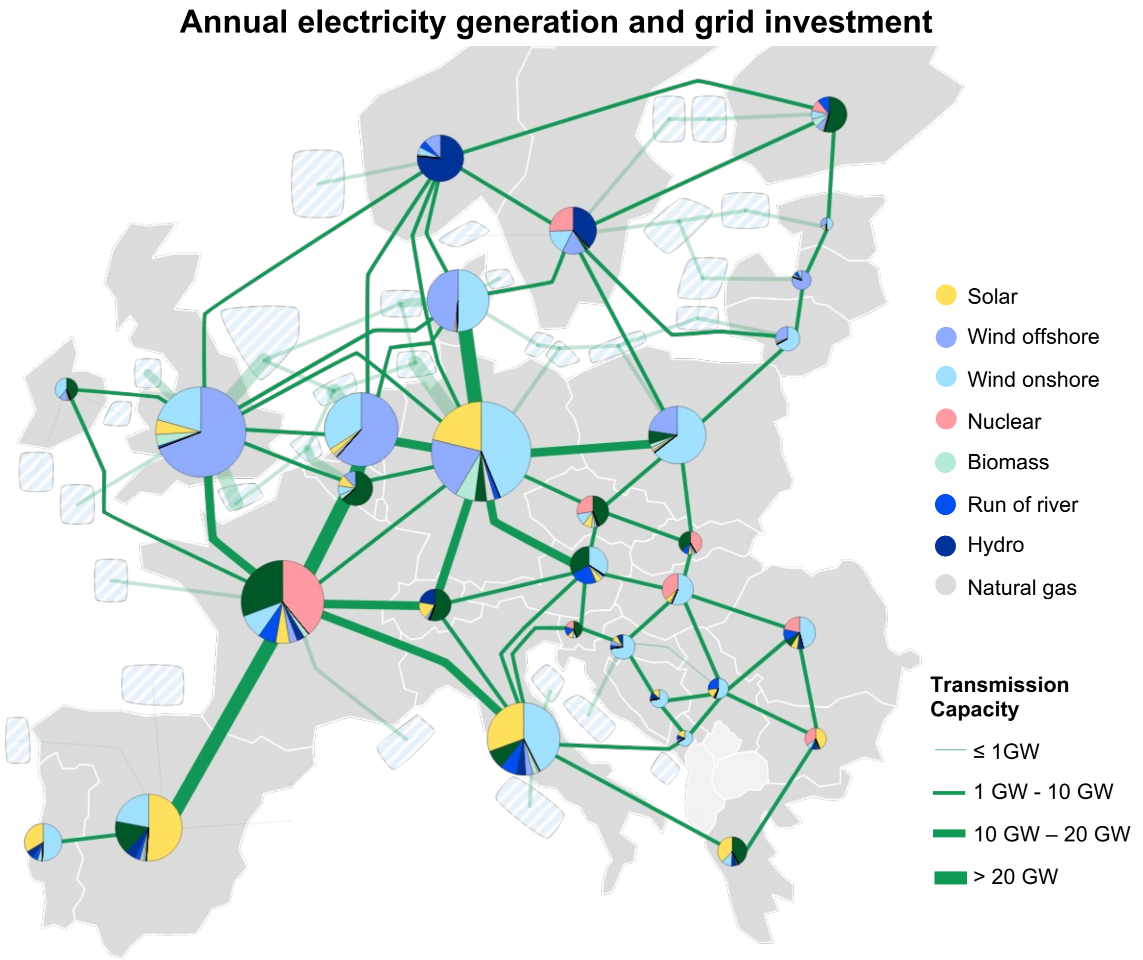
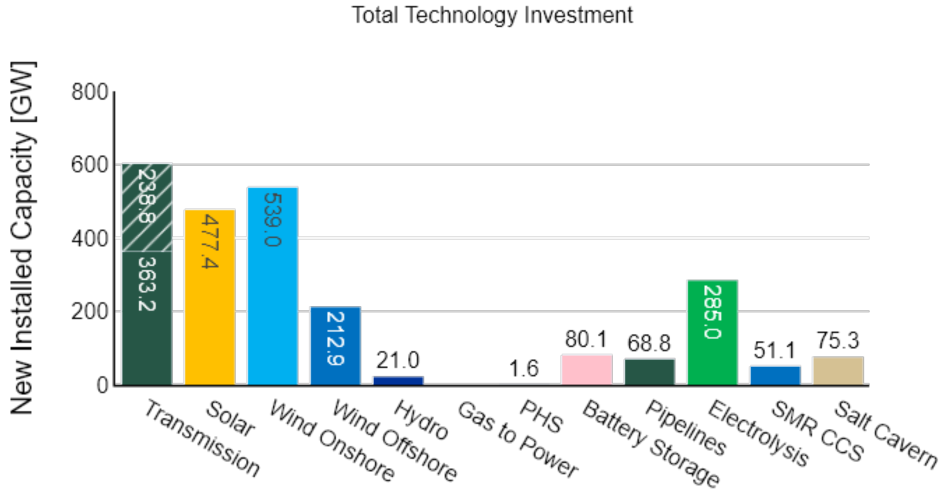
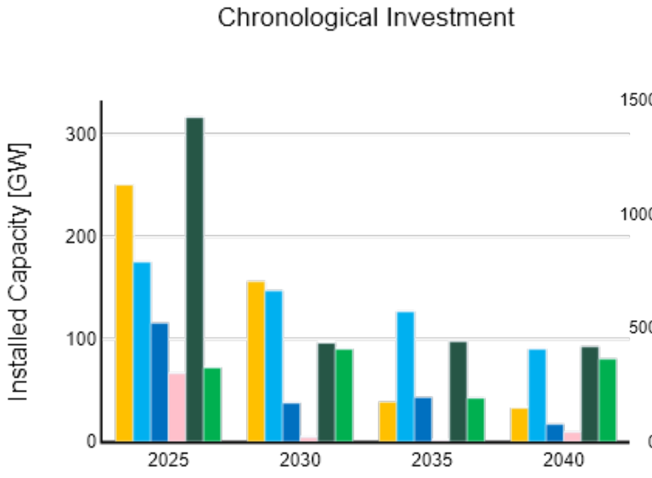
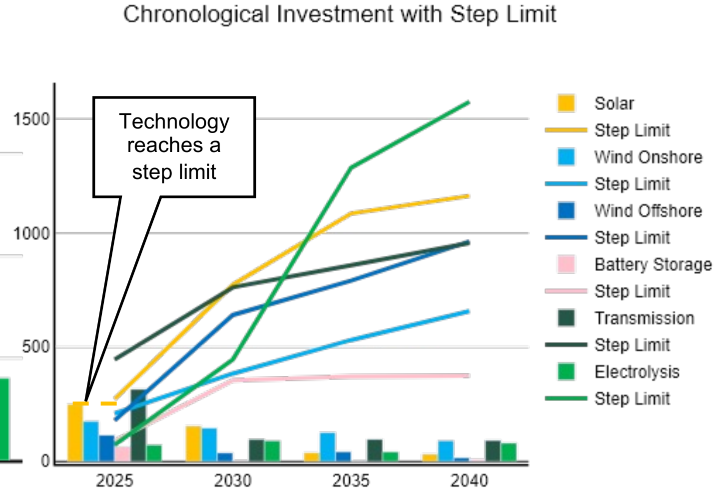
Supply chain features in the capacity expansion model: case study

Base scenario









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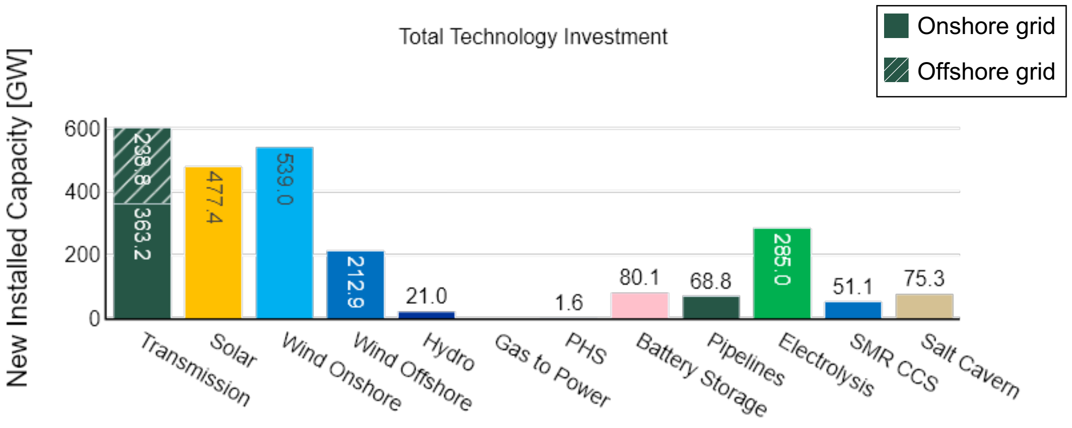
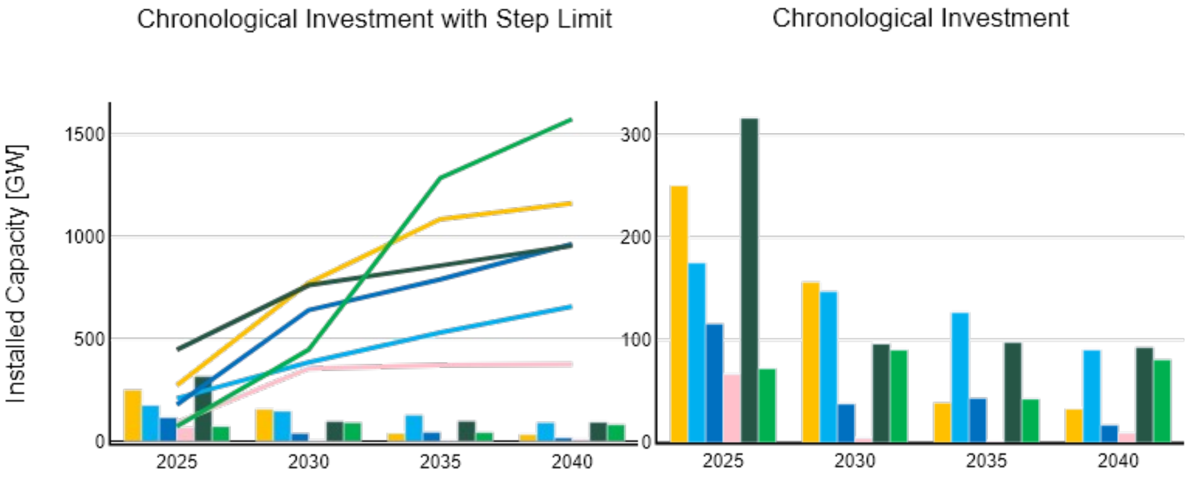
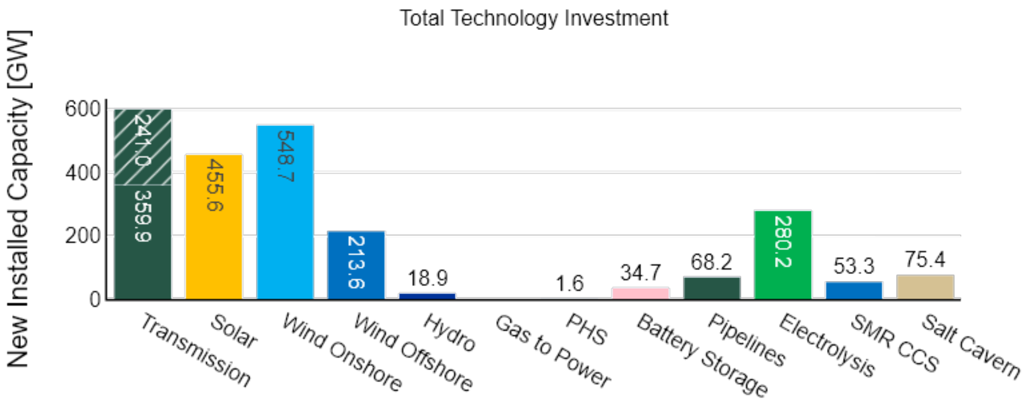
Supply chain features in the capacity expansion model: case study

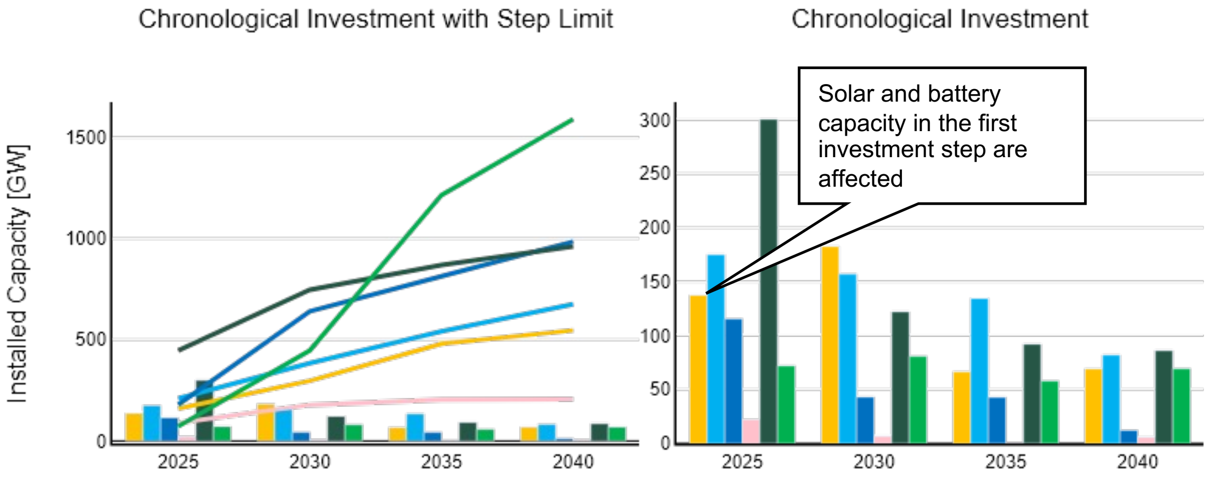
Base case – Solar PV step limit 200%





Lower scaling capacity solar PV – Solar PV step limit 100%





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Supply chain features in the capacity expansion model: case study

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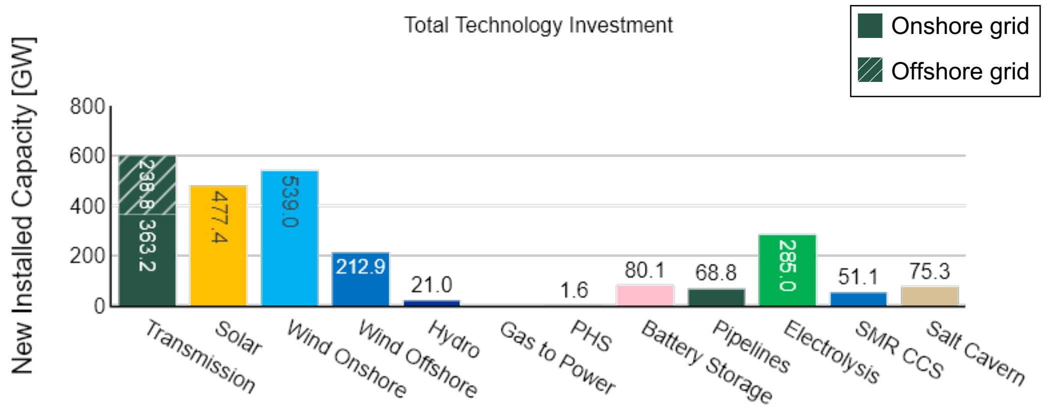
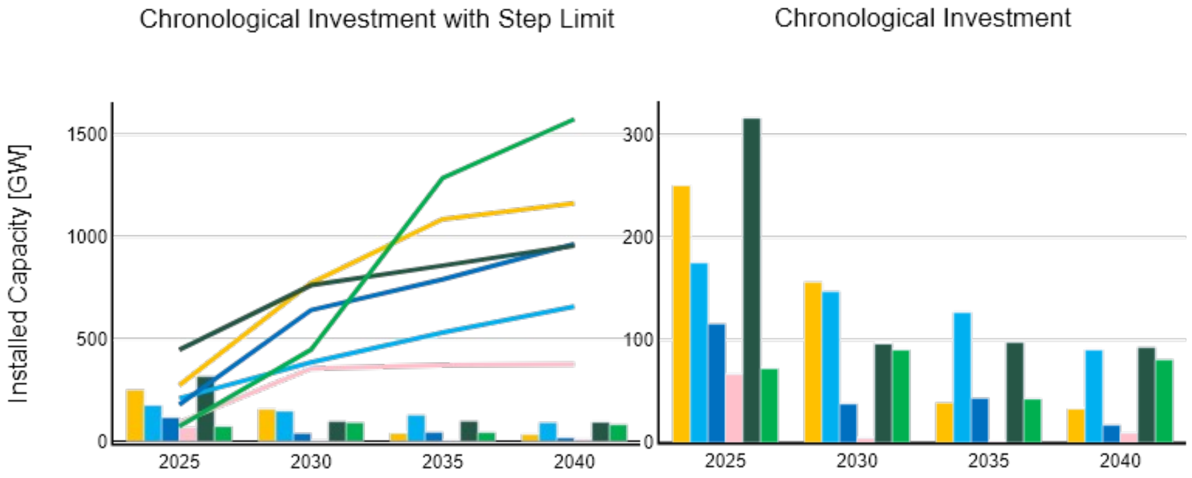
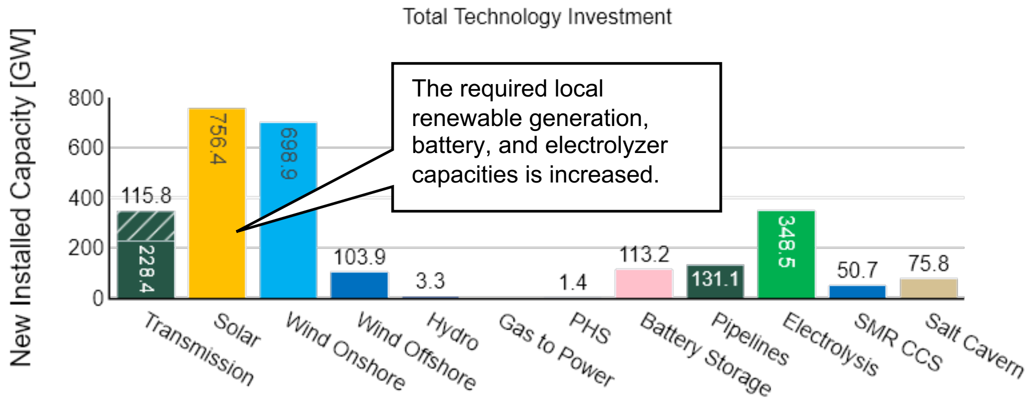
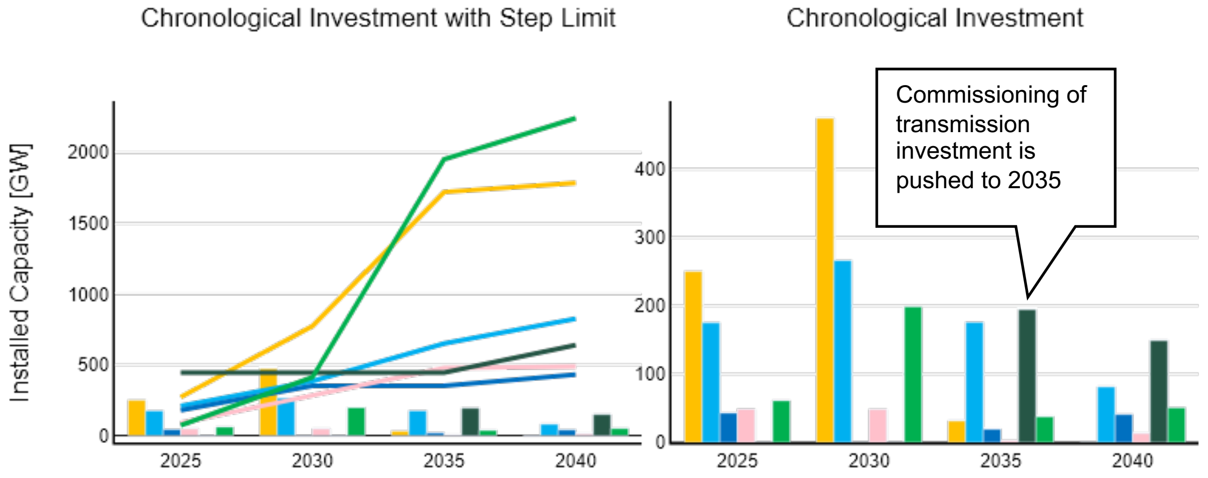
Base case – No lead time





Lead time for transmission lines (10 years)





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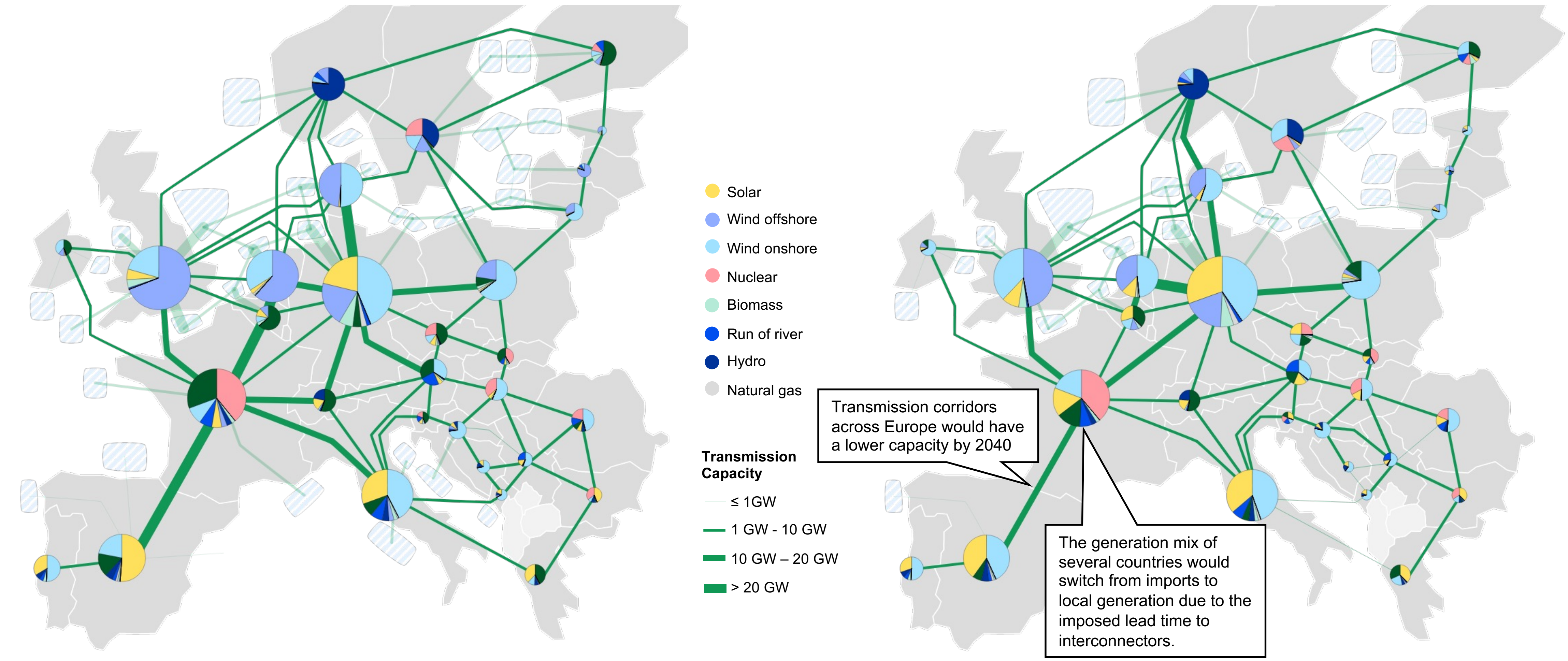
Supply chain features in the capacity expansion model: case study

Base case – No lead time

Lead time for transmission lines (10 years)



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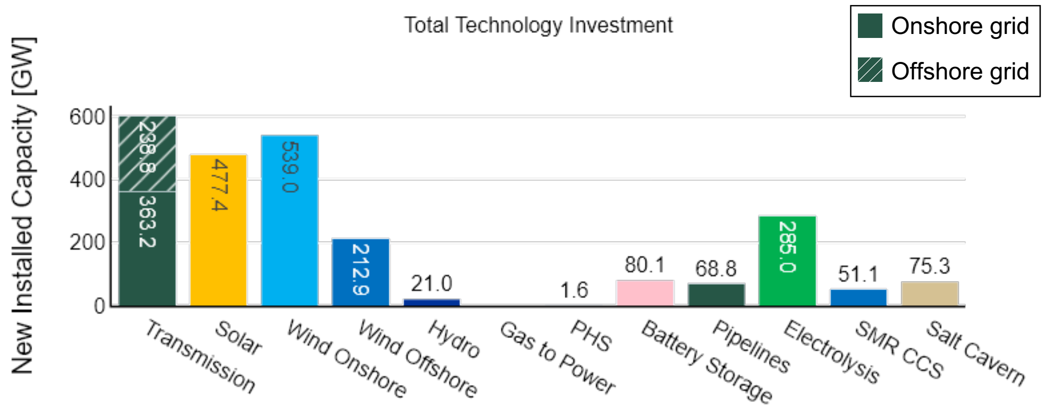
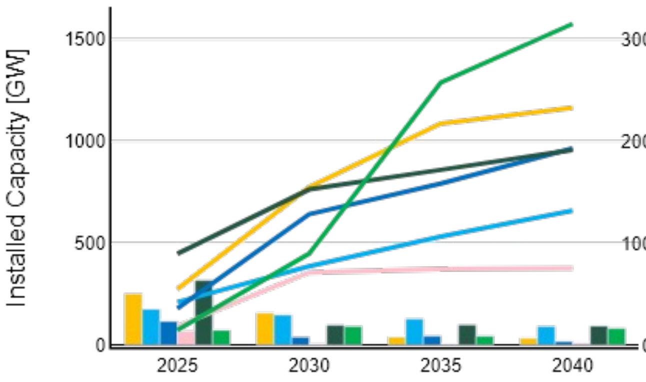
Supply chain features in the capacity expansion model: case study

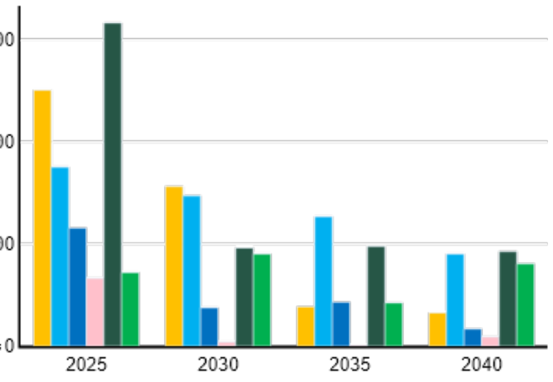
Base case – Normal learning curve



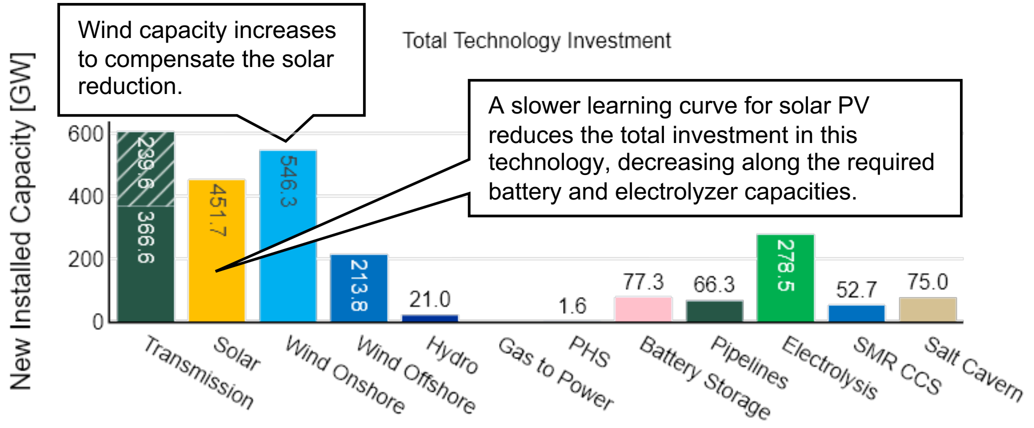
Chronological Investment with Step Limit



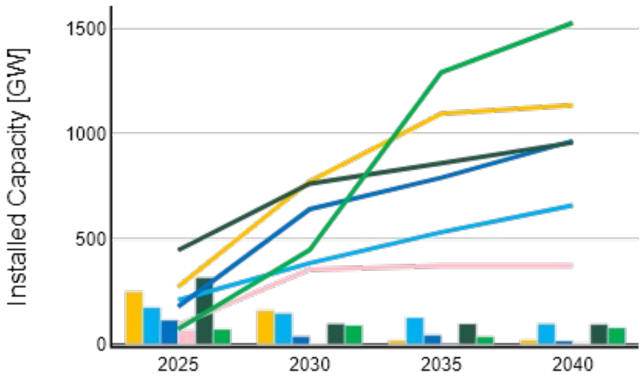
Chronological Investment



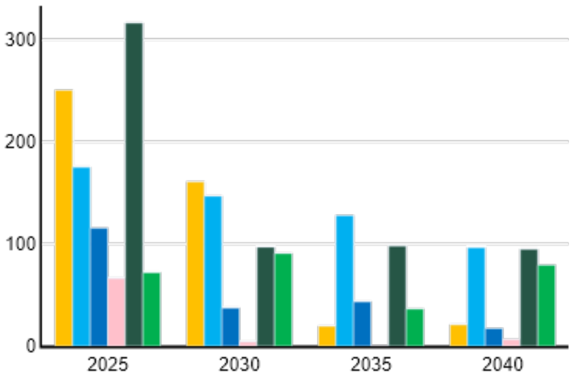
Slower solar PV learning curve



Chronological Investment with Step Limit



Chronological Investment



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Key take aways

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Role of supply chain in energy transition

Renewables are advancing rapidly, but outdated power grids may hinder the energy transition

Expanding renewables, storage, electric vehicles, and grids requires large amounts of raw materials

Additionally, manufacturing capacity, transport logistics, and a skilled workforce are crucial for a resilient and flexible supply chain

Supply chain in energy modeling

Supply chain in capacity expansion planning can be represented by parameters such as capacity upscaling limits, deployment delays and costs per technology, region, and investment step

Currently, these parameters are defined exogenously based on educated guess

Uncertainties in the parameters can be addressed through sensitivity analysis

Future work

Incorporate circularity into the capacity expansion model to optimize the use of both energy and material resources

Develop exogenous tools to compute supply chain limitation parameters by leveraging AI/ML to account for multiple risk factors

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