

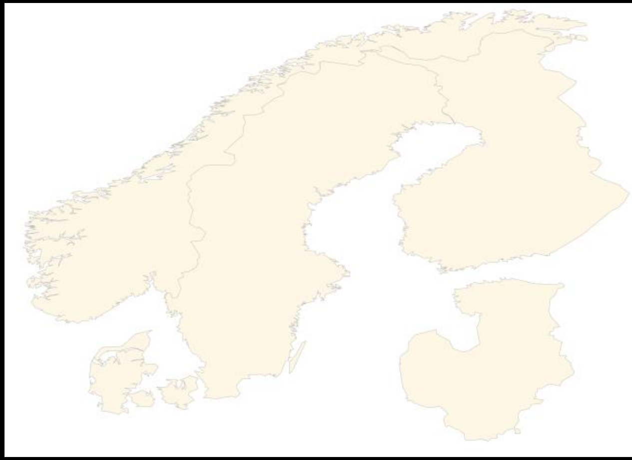

Sector coupling for high renewables in the case of Finland and electricity cooperation in the Baltic Sea Region

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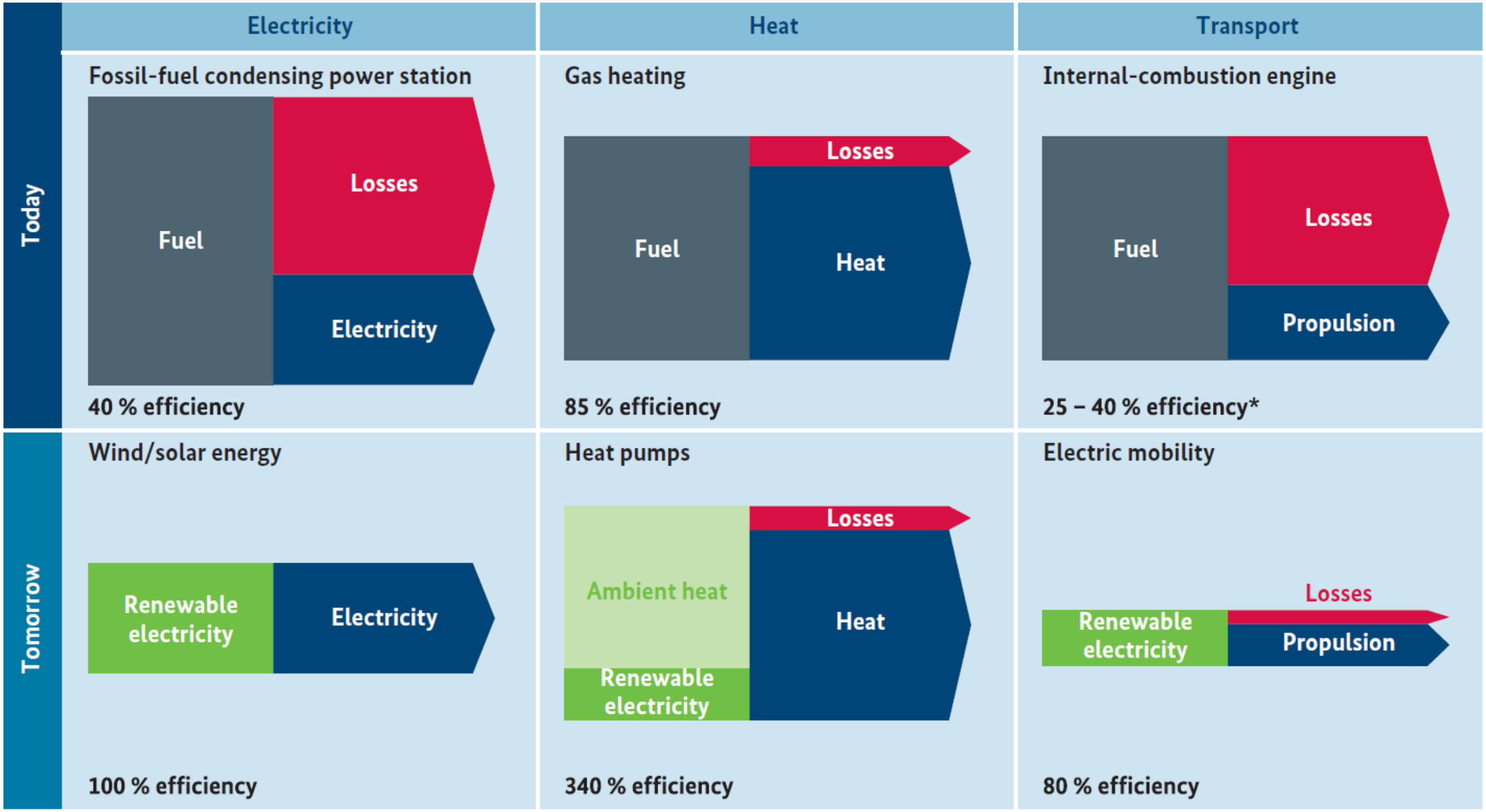
LUT University, Finland
19th Inter-Parliamentary Meeting on Renewable Energy and Energy Efficiency / EUFORES
Helsinki, November 22, 2019

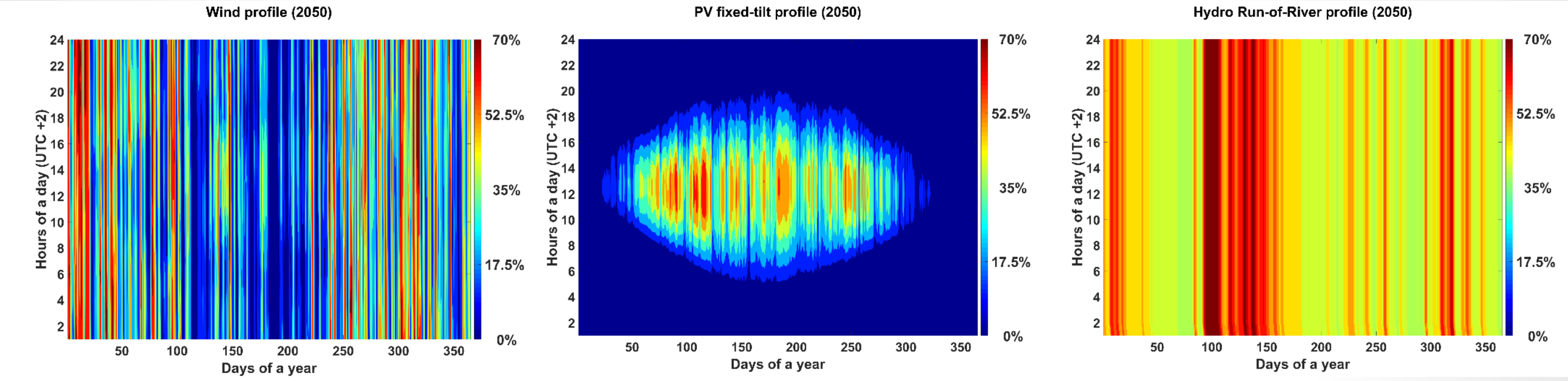
Key rationale for electrification: Efficiency



* The efficiency of internal-combustion engines in other applications (e.g. maritime transport, engine-driven power plants) can exceed 50 %.

Sector coupling for high renewables in the case of Finland

Methods – Energy resources



- Weather forecasting aids in predictability of variable renewable energy generation
- Hydropower is somewhat flexible on an hourly and multi-day basis
- Some natural seasonal complements exist between resources

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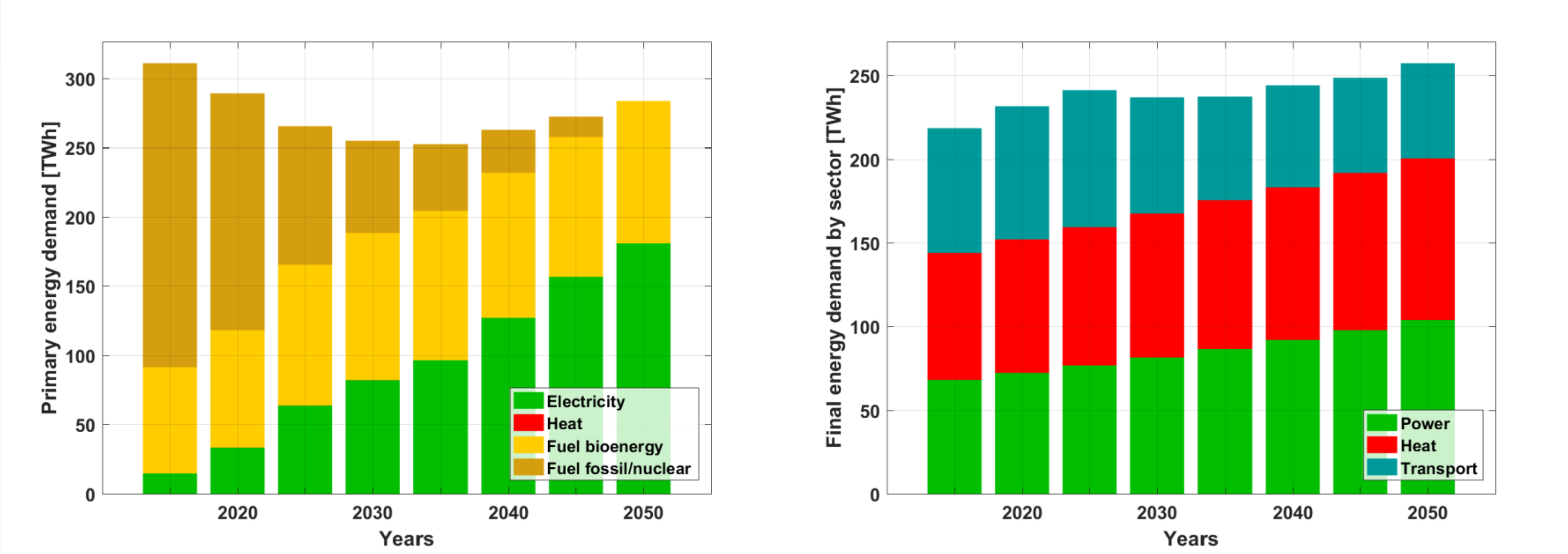
Results – Primary and Final Energy Demand



Key insights:

- Demands for final energy increase due to growing population
- Ratio of primary energy to final energy decreases throughout the transition

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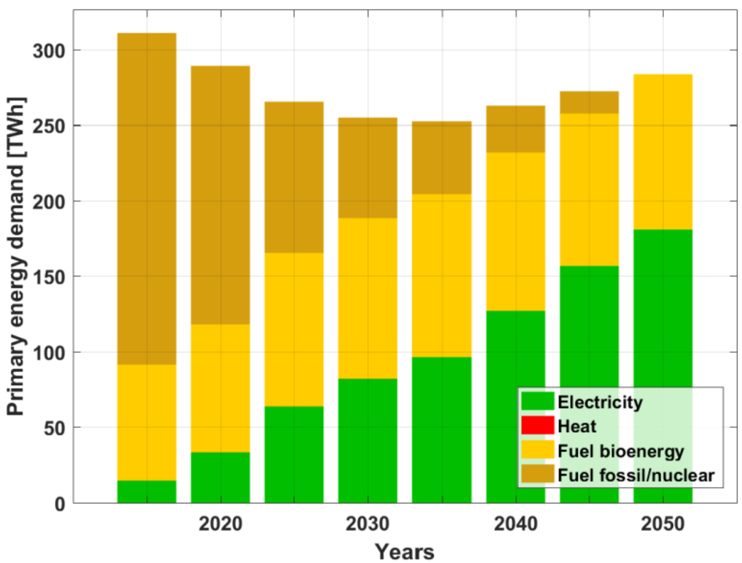
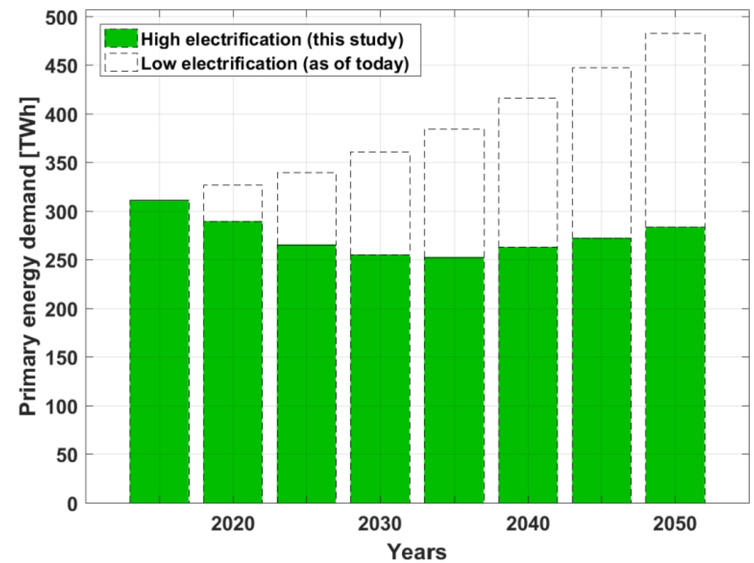
Results – Primary Energy Demand





Key insights:

- Primary energy decreases as fossil fuels are phased out, but increases at the end of the transition due to demands from storage and synthetic fuel production
- Higher levels of electrification lead to higher overall energy efficiency
- The role of biomass increases throughout the transition

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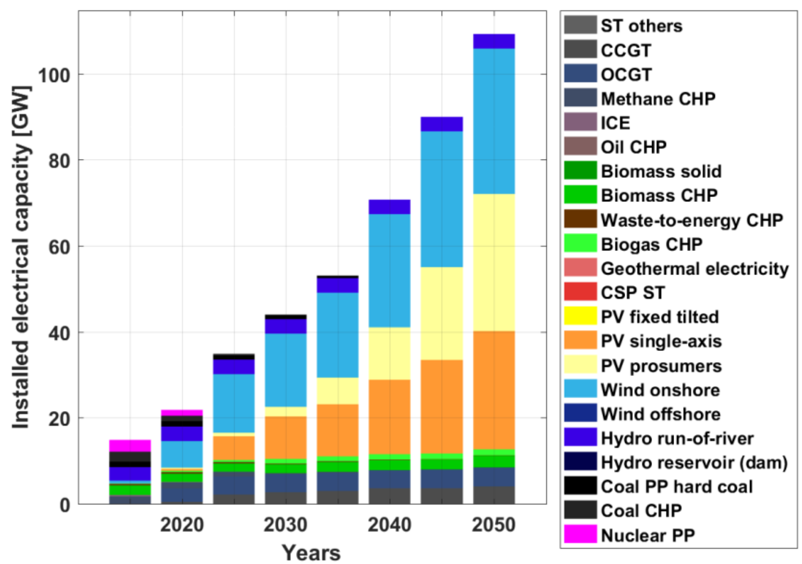
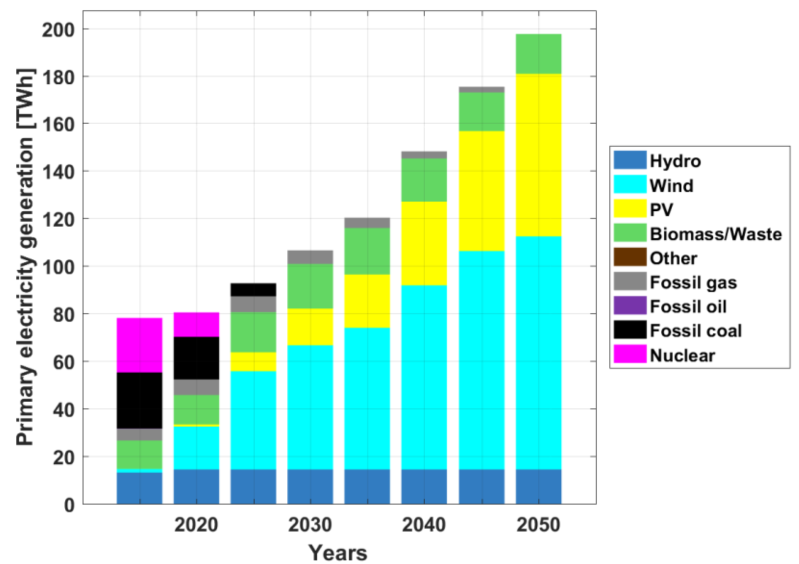
Results – Electricity supply





Key insights:

- Wind and solar PV provide the backbone of the transition
- Solar PV prosumers contribute 54% of PV capacity and 26% of final electricity
- Solar PV prosumers do not affect peak load in winter
- Dispatchable biomass and synthetic gas have important balancing roles
- The nature of CHP begins to change but hydropower maintains its key role

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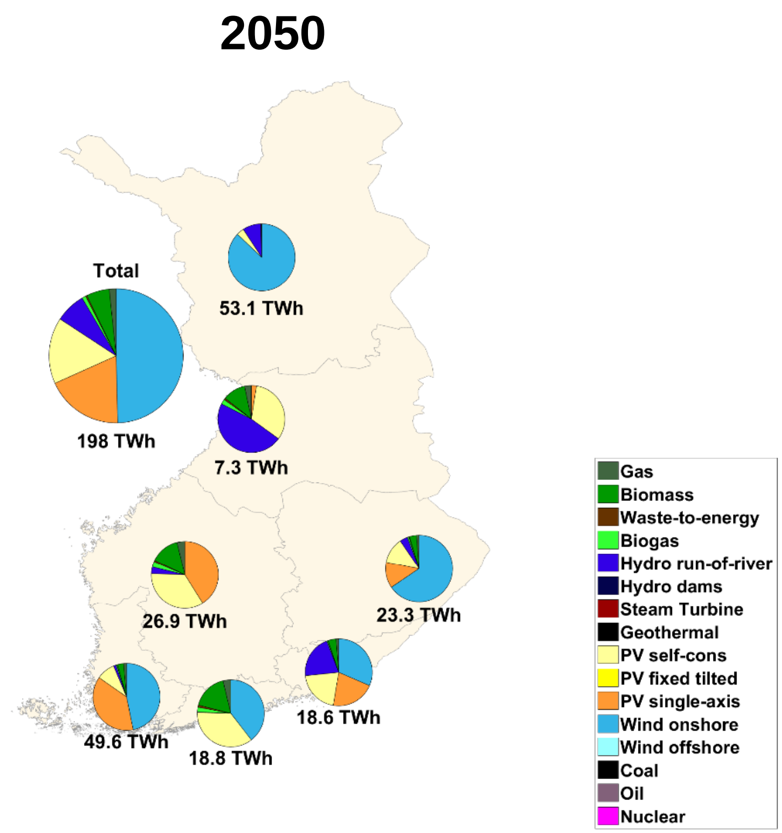
Results – Electricity supply



Key insights:

- Wind and solar PV become the backbone of the system
- Bioenergy becomes increasingly relevant, hydro maintains important role

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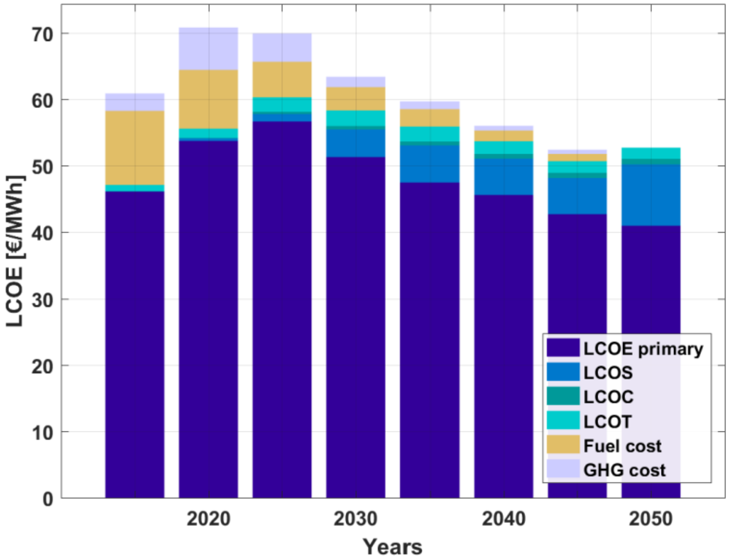
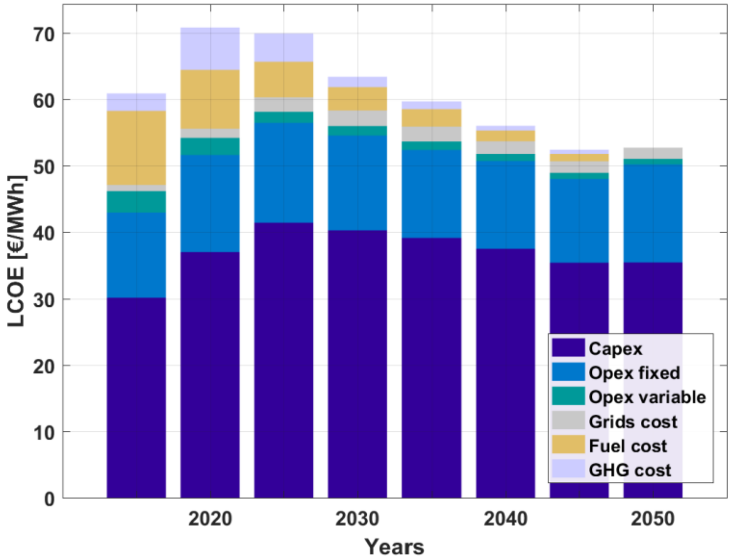
Results – Electricity supply





Key insights:

- Fuel and GHG costs decrease throughout the transition
- Primary generation costs drop through adoption of low-cost wind and solar PV
- These lead to greatly reduced levelized cost of electricity
- Costs of storage, curtailment and transmission become noticeable
- Capital costs increase marginally at first and then stabilise

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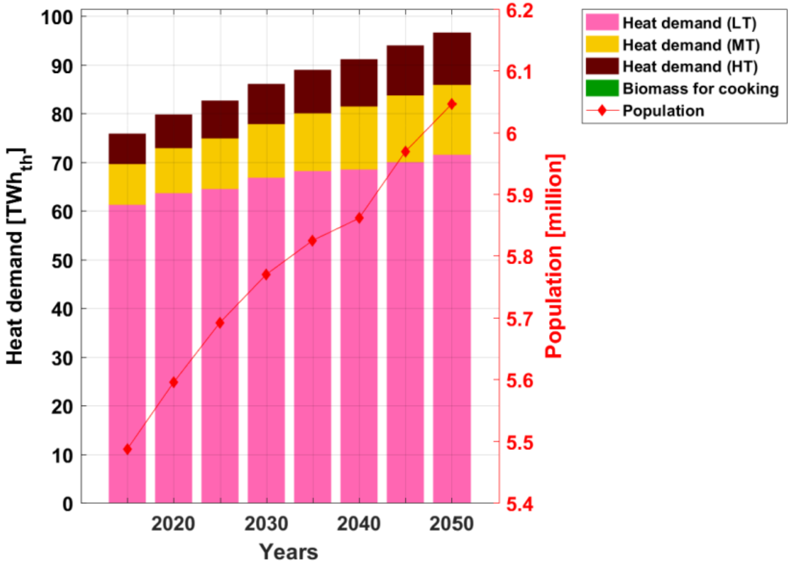
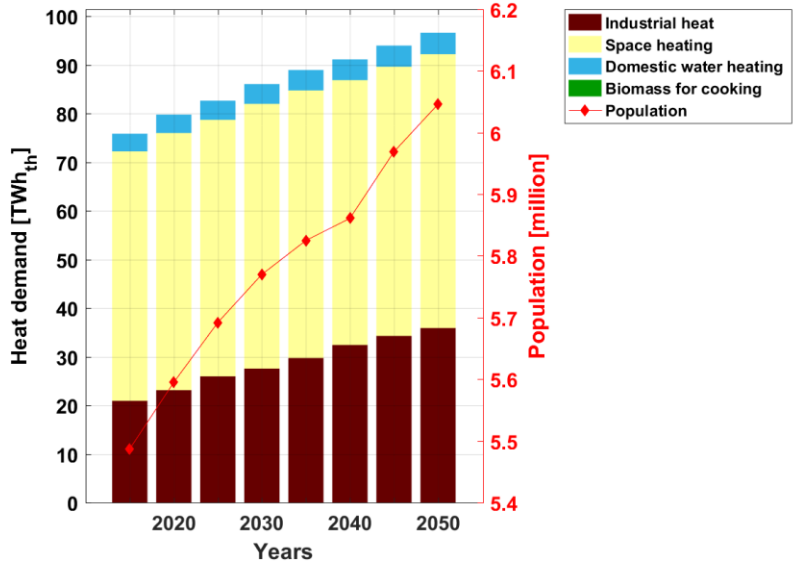
Results – Heat sector





Key insights:

- Heat demands increase with projected population and GDP growth
- Different heat demands for different sectors of life are part of the modelling
- Industrial heat and steam demands are accounted and satisfied appropriately

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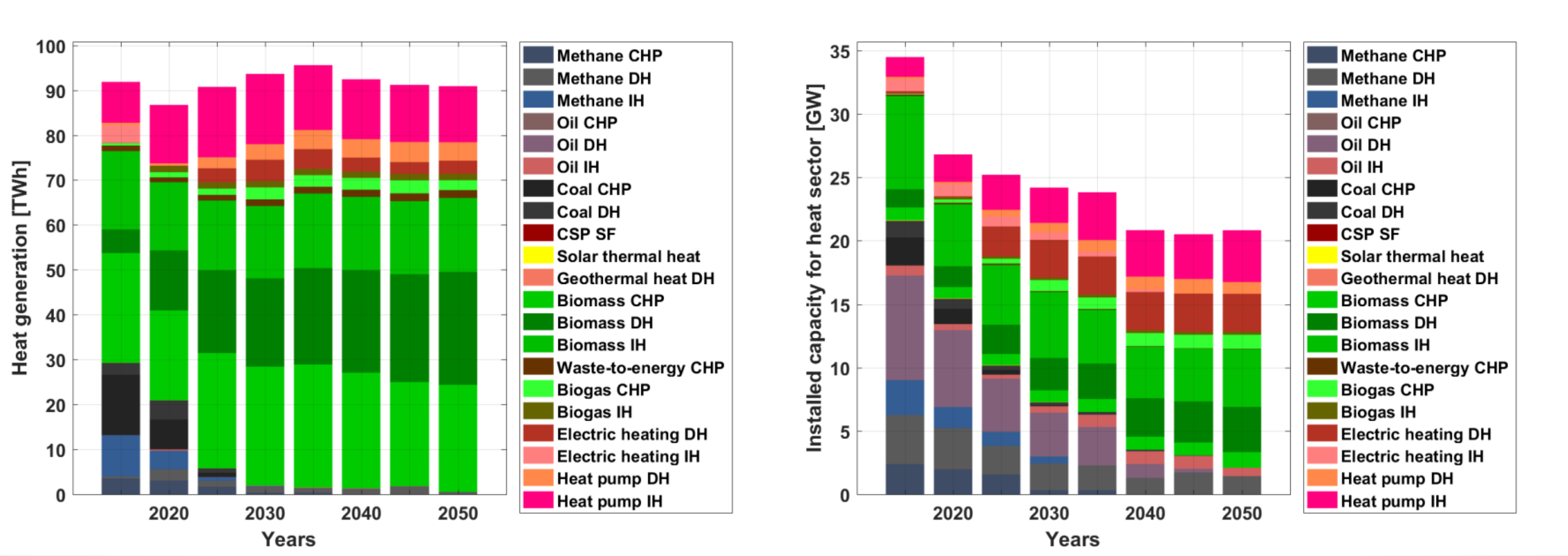
Results – Heat sector



Key insights:

- Biomass and electricity become the main heat resources as fossil fuels are phased out of the energy system
- Less heat is produced in traditional CHP plants, especially low temperature DH
- Electric heating and heat pumps increase in significance

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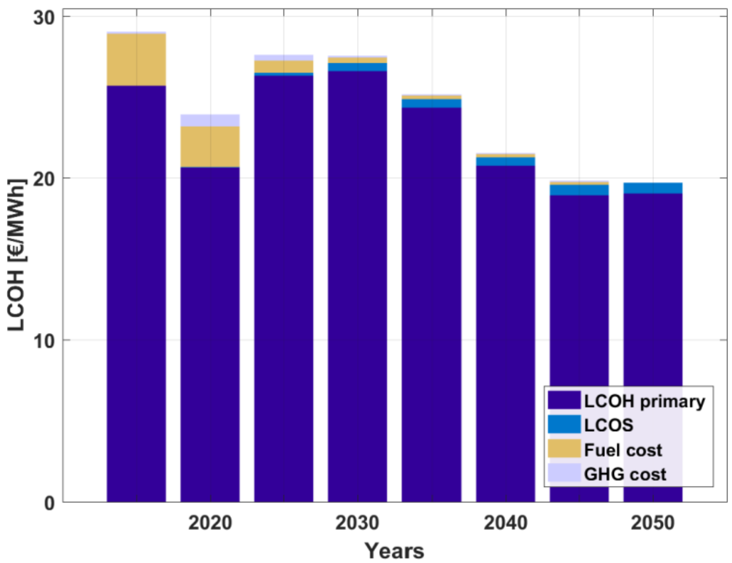
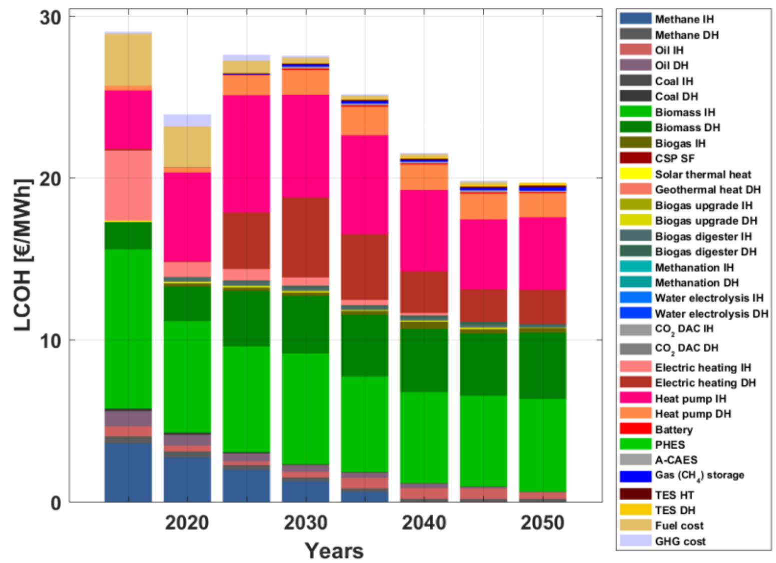
Results – Heat sector





Key insights:

- The cost of heat remains relatively stable throughout the transition
- The cost structure changes as production modes change
- Storage of heat is a new cost, but offset by lack of fossil fuel and GHG costs
- A shift to lower cost centralized heat production based on electrification and greater use of biomass

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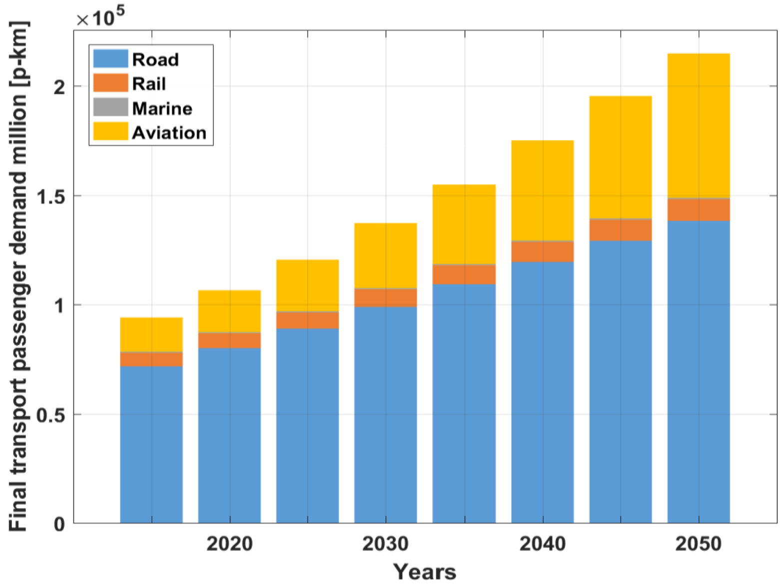
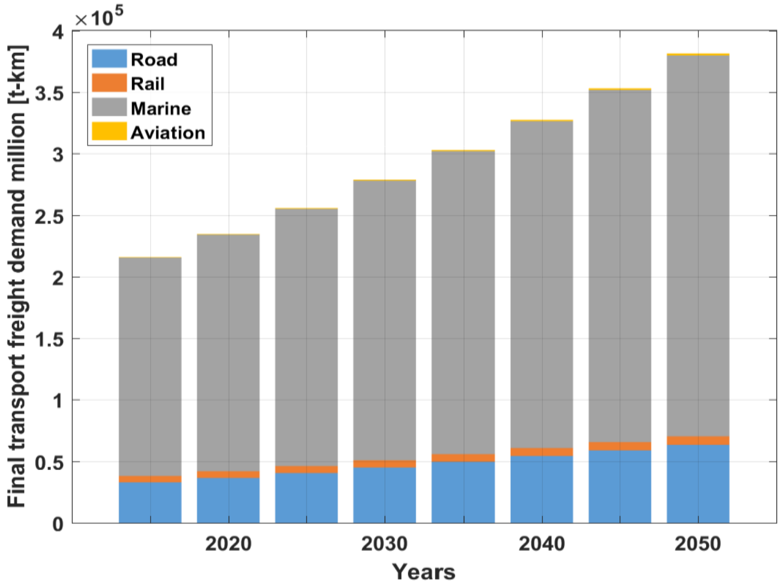
Results – Transport sector





Key insights:

- Demands represent a rather optimistic development of transport sector

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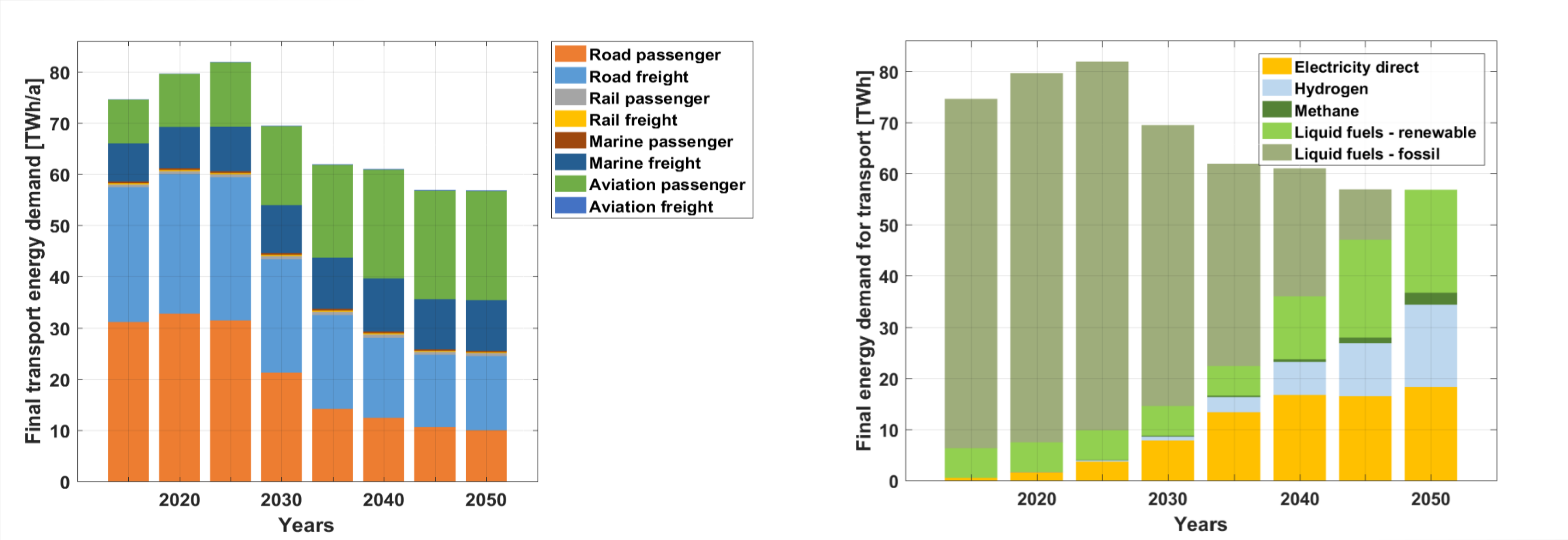
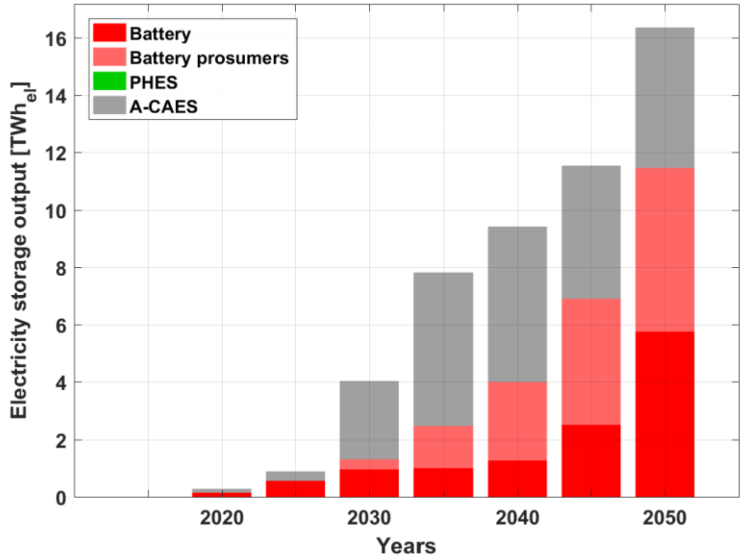
Results – Transport sector

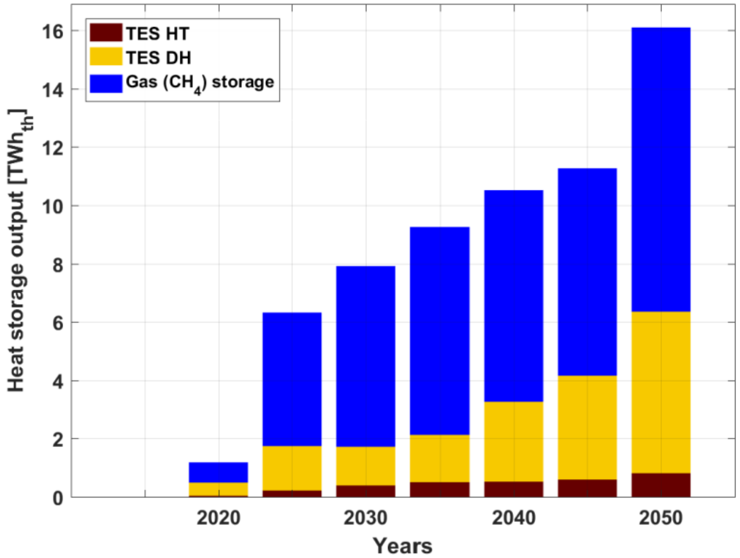


Key insights:

- Despite increasing transport demands, there is lower final energy demand
- Primarily due to electrification of many modes of transport
- Fossil-based liquid fuels replaced by biofuels (minor) and synthetic fuels (major)
- Hydrogen becomes an important energy carrier

Results – Storage





Key insights:

- The relevance of storage increases over the transition
- Electric storage becomes prominent, possibly in the form of EV batteries
- Prosumer batteries contribute 6 TWh
- Gas storage has a prominent role as seasonal storage
- Hydrogen and CO_2 storage will also be needed

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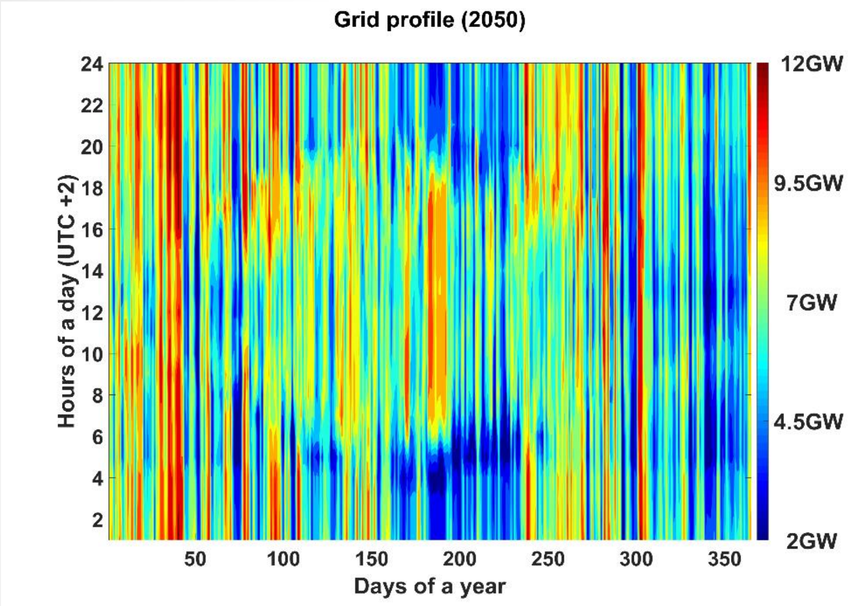
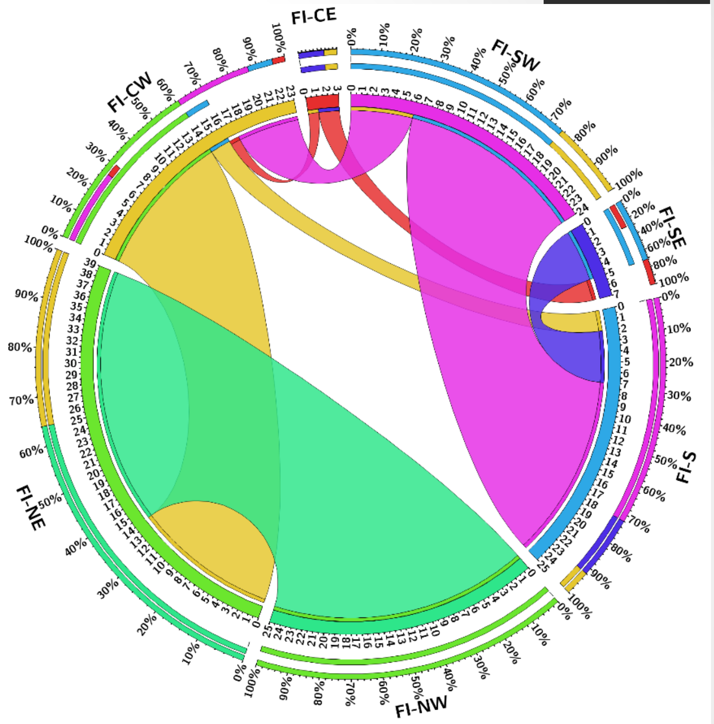
Results – Inter-regional transmission

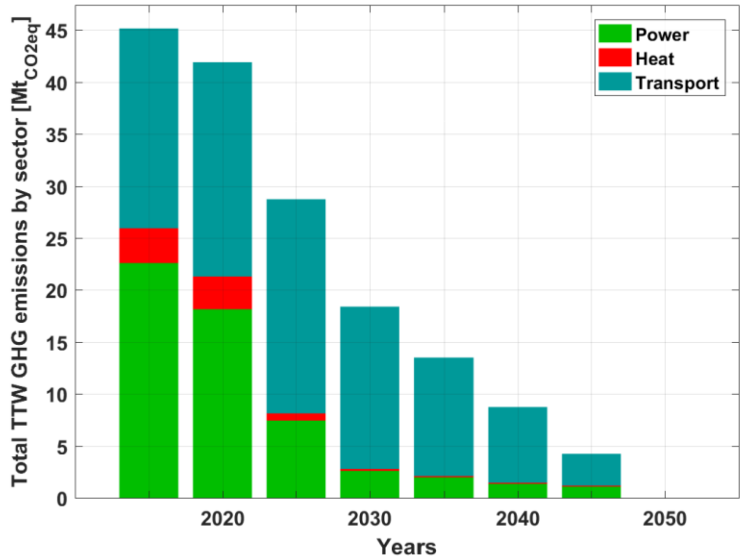




Key insights:

- Fourfold increase in interregional transmission capacity; greater in north
- Grid peaks will be related more to supply (especially wind) than consumption
- **Electricity tends to move north-to-south and west-to-east**
- This may result in disruption to traditional energy companies and energy markets in the absence of appropriate regulation

Results – GHG emissions



Key insights:

- The majority of heat and power emissions are eliminated by 2030
- Transport emission reduction will take longer unless more aggressive action is taken to speed up the transition
- EU aim for 100% emission-free vehicles by the early 2030s can help
- Finnish government aim of net zero emissions by 2035 could also be met
- **International aviation and marine** modes would need special measures to achieve defossilisation in a faster time frame

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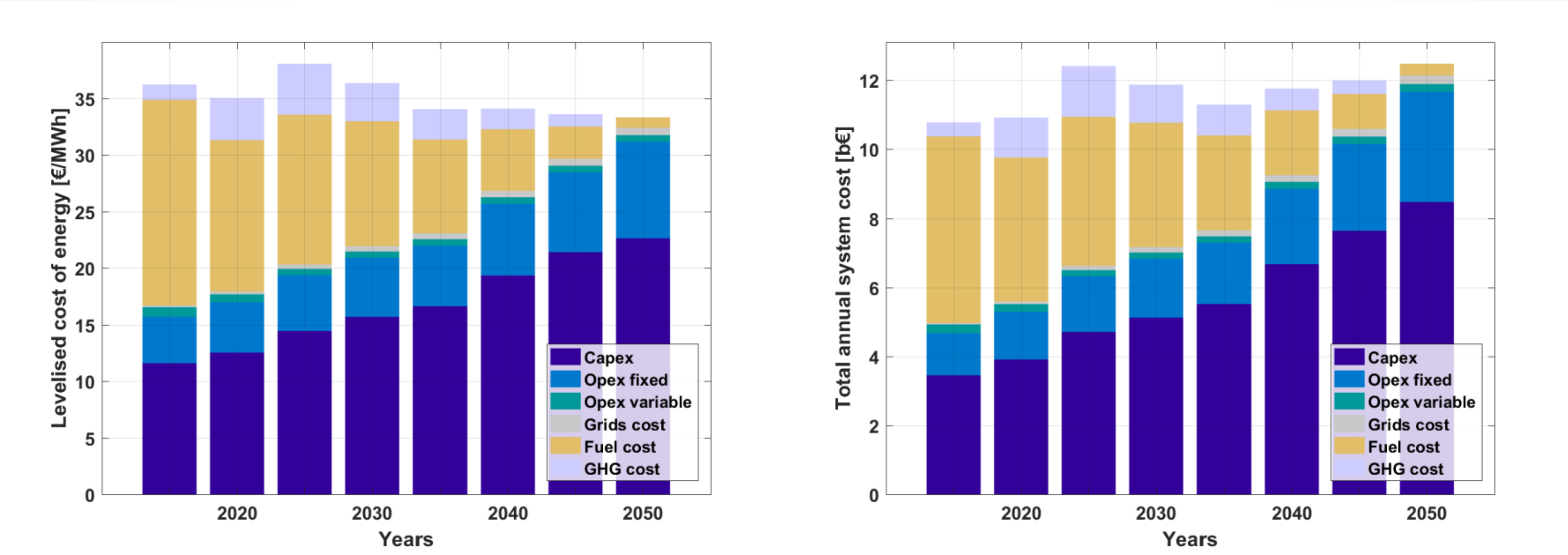
Results – Total Energy System Costs



Key insights:

- Overall levelized cost of energy **decreases** over the transition
- Capital investments will be needed, but fuel and emission costs will be lower
- Many of these capital costs will represent domestic investment and jobs
- Total annual system costs remain rather stable and appear affordable

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Role of Sector Coupling

Key insights:

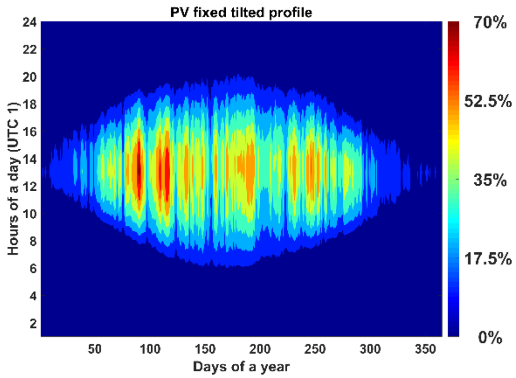
- **Power-to-X is the central element of a future energy system, since electricity is the universal platform**
- Electricity-based hydrogen emerges to the 2nd relevant energy carrier (for fuels, chemicals)
- Flexibility in the energy system is key:
  - Supply response (hydro reservoirs, bioenergy) for indirect balancing of solar and wind
  - Grid interconnections, in particular for balancing wind energy
  - Smart demand response: BEV (smart charging, V2G), heat pumps, electrolysers
  - Storage (hours, days, weeks, seasons; electricity, heat, fuels)
- **Cross-border integration may be less important than cross-sectoral cost reduction**
- **Efficient sector coupling substantially reduces curtailment**
- Low-capex batteries and low-capex electrolysers are key for the energy transition
- No flexibility from CO_2 direct air capture units, H_2-to-X synthesis and desalination

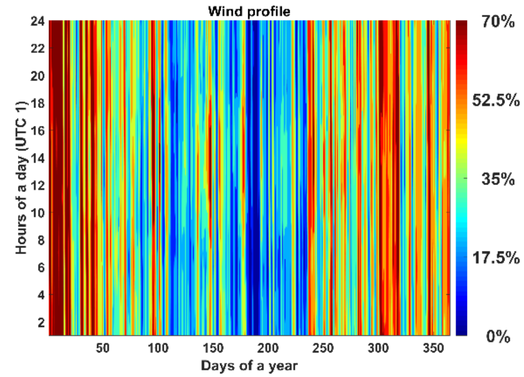
Electricity cooperation in the Baltic Sea Region

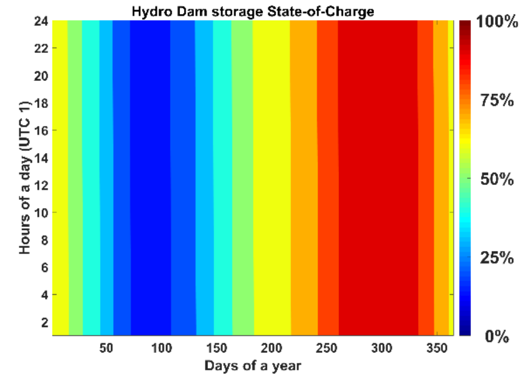
Highlights

- A 100% renewable power system with energy storage solutions can provide reliable, sustainable energy services before 2050
- A 100% renewable energy system is lower in cost than the current system based on nuclear and fossil fuels
- Interconnections between Baltic countries can result in further cost savings
- A well-designed 100% renewable energy system with energy storage solutions can provide power system stability in all 8760 hours of the year

Abundant Renewable Resource Potentials







Resource	Units	Norway	Denmark	Sweden	Finland	Estonia	Latvia	Lithuania	Total	2050 Utilisation
Solar PV	GW	1457	194	2026	1522	204	290	294	5987	<1%
Onshore wind	GW	109	14	151	114	15	22	22	447	11 %
Hydro dams	GW	30	0	17	0	0	0	0	47	79 %
Hydro RoR	GW	14	0	8	5	0	1	1	29	67 %
Waste	TWh	1	2	2	3	0.5	0.7	0.8	10	100 %
Biomass waste	TWh	2	1	70	58	6	4	11	152	100 %
Biomass residues	TWh	8	15	48	37	4	8	13	133	0 %
Biogas	TWh	1	28	7	13	0.5	0.5	4	54	100 %
Biomass total	TWh	12	46	127	111	11	13	29	349	62 %

Comment on biomass potential:
in a full energy system consideration the total biomass potential is also used for heating purposes and for biofuels in the transport sector

Important Steps to Reach 100% RES

1. **Eliminate subsidies for fossil fuel and nuclear power generation**
   - Account real costs of CO_2 emissions, heavy metal emissions, and socialization of risks associated with nuclear power (e.g. limited liability insurance)
2. **No new investments in coal and nuclear power**
3. **Substitute natural gas with sustainable biogas/biomethane/Power-to-Gas over time**
   - Gas infrastructure and conversion technologies remain important
4. **Avoid extra taxation for RES (good example from Sweden)**
5. **Promote solar PV prosumerism (e.g. missing 3-phase balancing in Finland)**
6. **Electrify transportation as much as possible**
   - Biofuels for shipping, aviation and sectors where electrification is difficult
7. **Improve energy efficiency in buildings**
   - Expand use of electric heat pumps and bio-based CHP
8. **Promote regional interconnections and sharing of grid solutions**
9. **Set clear targets to achieve a fully sustainable energy system (e.g. DK, NO, SE)**

Outcomes and Impacts of 100% RES

1. Achieving a more sustainable and resilient energy sytem
2. Reduction of CO_2 emissions and associated costs
3. Job creation associated with RES
4. Improved health of people and environment
5. Improved trade balances through no imports of fossil and nuclear fuels
6. Elimination of unfair sharing of risks and rewards related to nuclear power
7. Reduction of heavy metal emissions
8. Challenges associated with grid reinforcement (HV, MV and LV) are manageable
9. By achieving high shares of RES before other EU member states, the Baltic region can become a showcase and blueprint for the rest of Europe
   - Possibilities to export solutions

Key Findings 100RES – Capacities, Generation, CO_2

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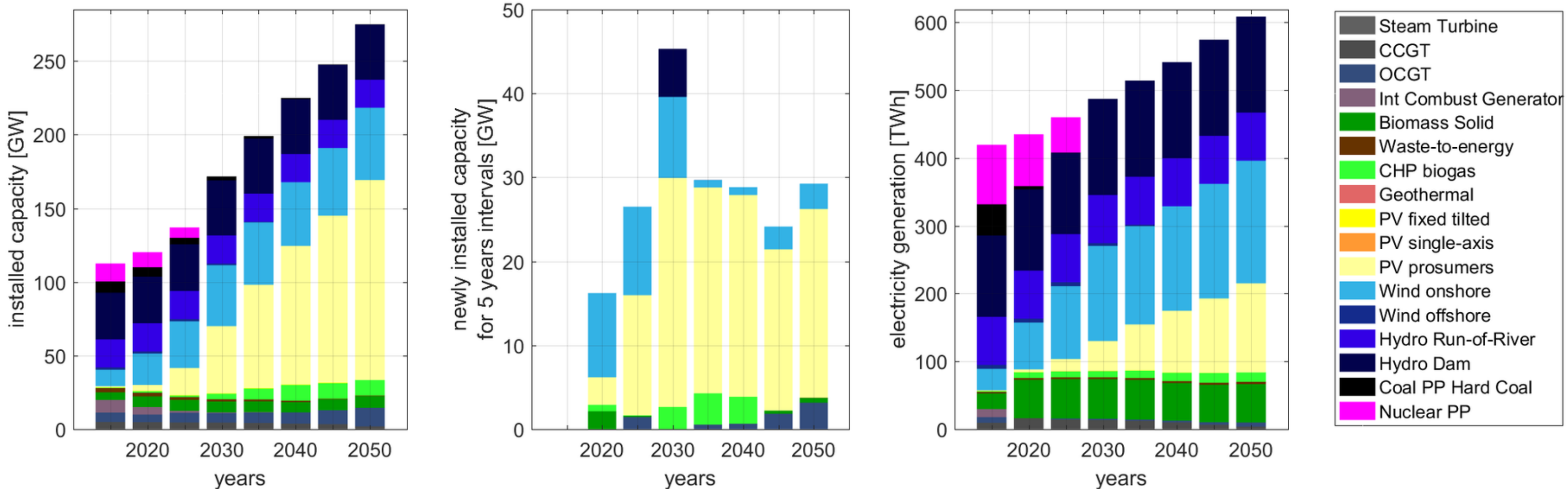
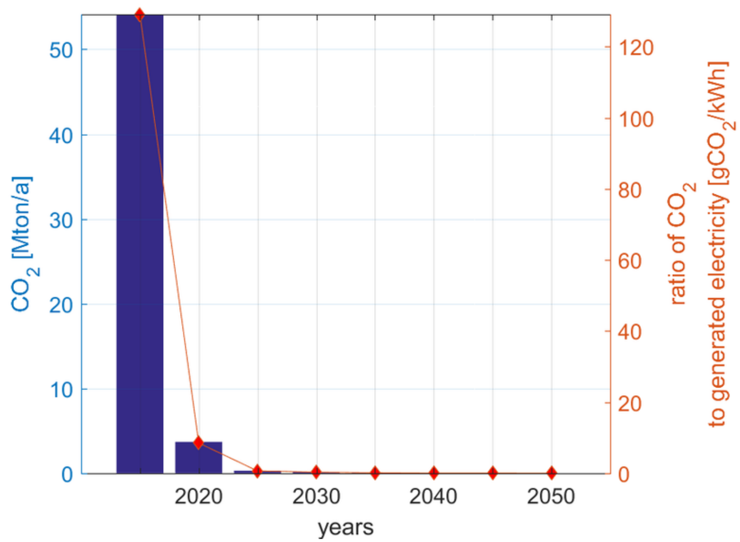
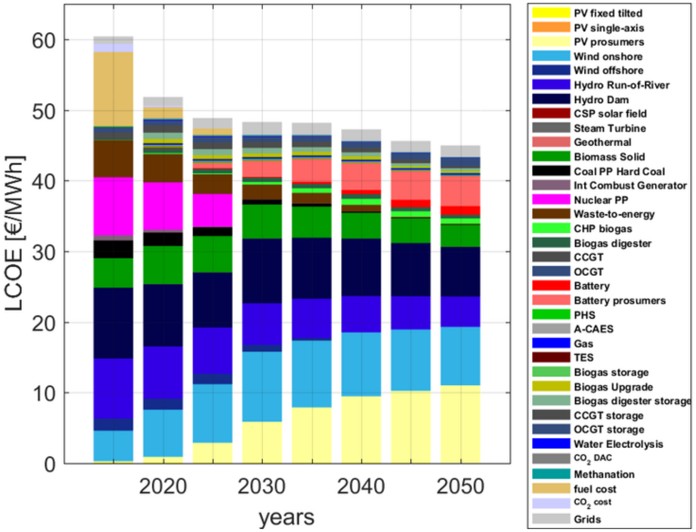




Main insights

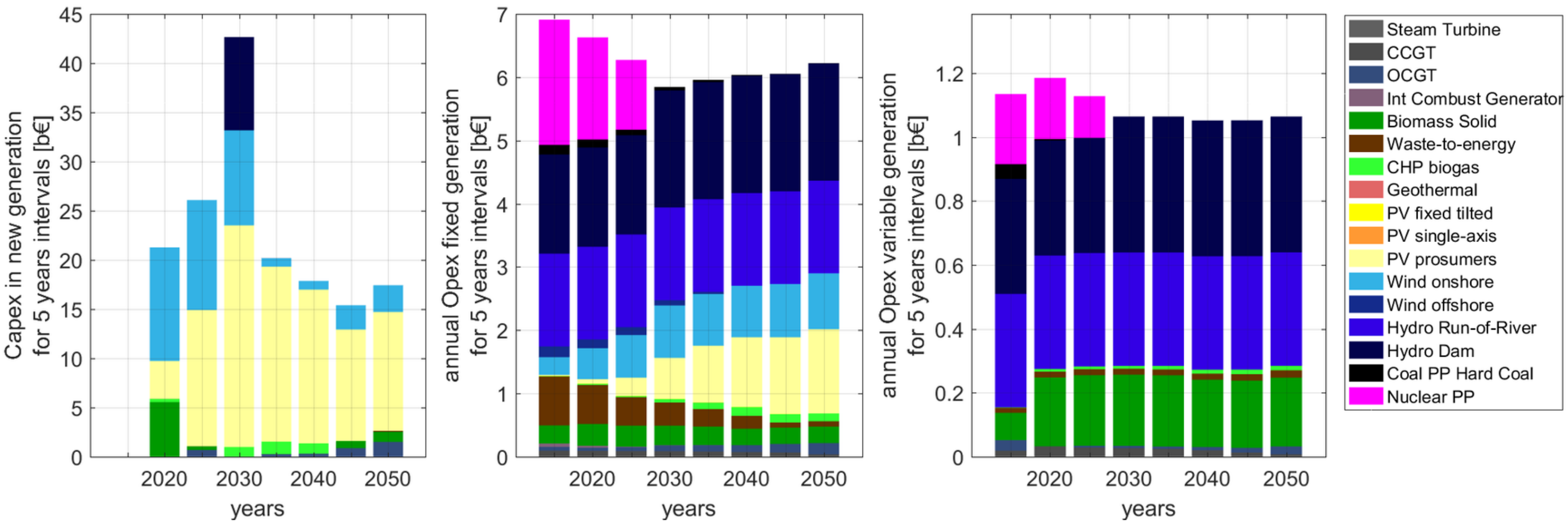
- RE generation already reached 61% in 2015
- Increasing relevance of electricity
- Phase out of coal by 2025 and nuclear plants by 2030
- Increasing levels of solar PV prosumers and onshore wind
- Fossil natural gas replaced over time by sustainable biogas/ biomethane and SNG
- Decarbonisation of power sector by 2035
- Bioenergy to be used in all energy sectors

Key Findings 100RES – Investments, Cost

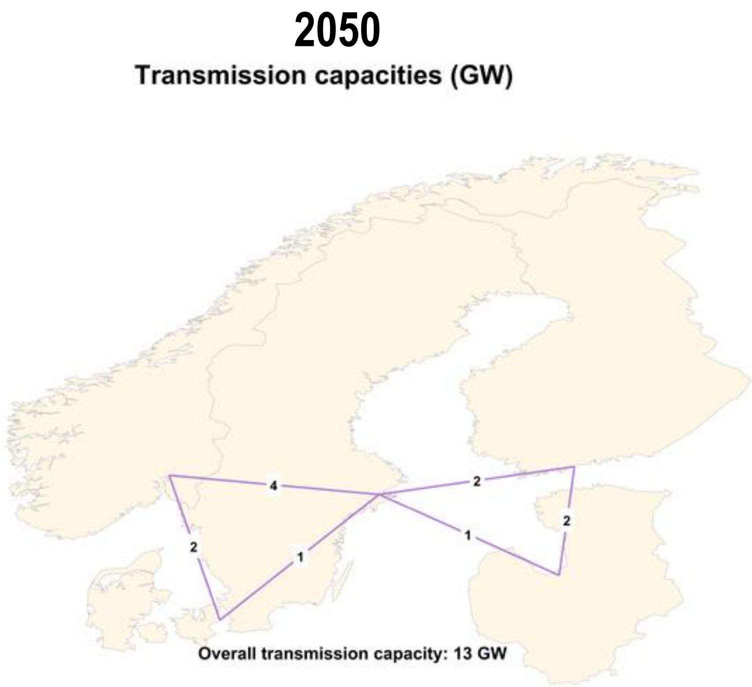


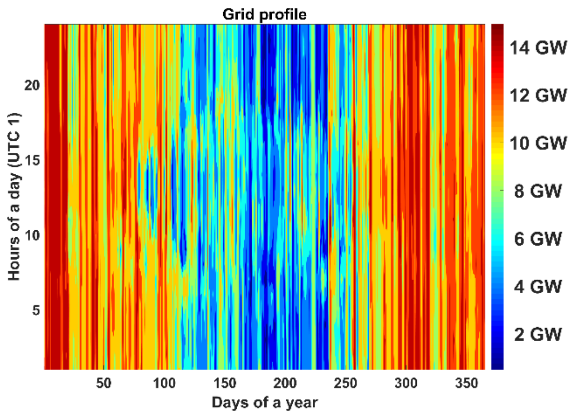
Main insights

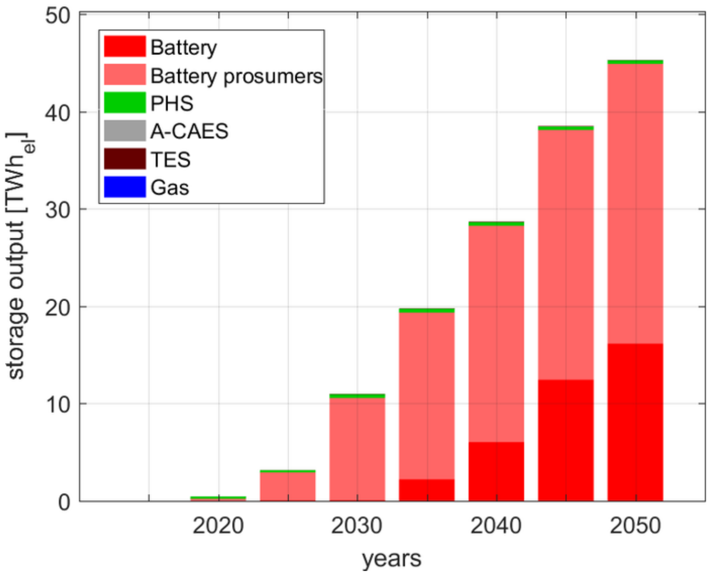
- Decreasing LCOE over time (from 60 to 45 €/MWh)
- Decreasing fossil fuel and CO_2 costs
- New investments in solar PV and onshore wind
- Relevance of storage increases over time
- Curtailment of excess electricity low due to interconnections
- Other low carbon technologies (nuclear and fossil CCS) are (substantially) more expensive and risky



Key Findings 100RES – Interconnections, Storage







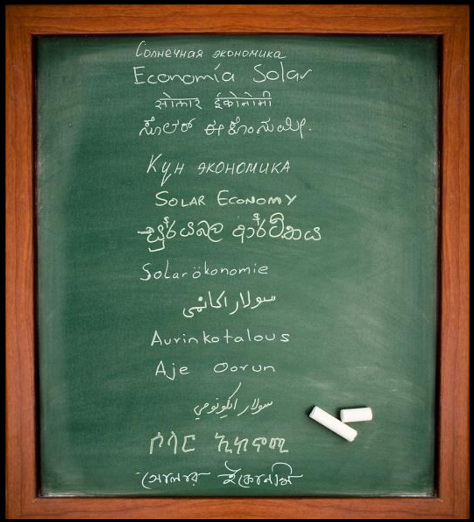
Main insights

- Storage becomes increasingly relevant as source of flexibility
- Current interconnections amount to approximately 12 GW
- Simulation results do not show significant need for expansion (+1 GW between Finland and Estonia)
- 15% of total generation of 587 TWh is traded to other Baltic regions and not consumed in the region of origin
- Strengthening of interconnections between Estonia, Latvia and Lithuania may also be needed

Summary – 100% RES is Possible and Feasible

- A 100% renewable energy system is a least cost option for the Baltic region (given the high cost of new nuclear and fossil-CCS alternatives)
- 100% RES can result in job creation and improved trade balances
- 100% RES also represents lower health and economic risks, and higher overall energy system resilience beyond CO_2 emission reductions
- Current barriers to high shares of RES can effectively be overcome through effective policy and planning
- The Baltics can become the first region in the EU to achieve 100% RES
  - almost complete decarbonisation of power sector by 2035
  - this can serve as a showcase for other member states

Thank you for your attention …
… and to the team!



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all publications at: www.researchgate.net/profile/Christian_Breyer
new publications also announced via Twitter: @ChristianOnRE

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Summary – Transition for Finland

- New forms of energy supply will be seen in the future
  - Wind energy, solar energy, and distributed energy prosumers
  - CHP has a reduced role
- Energy storage will become less expensive and more common
  - Batteries for short-term storage (possibly EV batteries)
  - Power-to-Gas, Power-to-Liquids and TES for longer-term storage
- There will be new patterns of supply and demand due to prosumers
  - This may be disruptive to traditional power and heat companies
  - Energy from the grid will be lower, but peak power will remain high
- Prosumers may still have more to offer in the form of heat, Vehicle-to-Grid connections, smart charging and demand response
- Achieving the ambitious goals of the Paris Agreement appears feasible and economically competitive with a transition towards 100% RE
- A vision of the future of energy can help a variety of actors develop expectations of what life could be like in the future, and then act accordingly in the present
- Further discourse is needed to consider the desirability of such a vision and how it can best be implemented

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