Modelling measures for fast, flexible and secure decarbonization of the Baltic states

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FINAL RESULTS FROM FASTEN PROJECT

Additional climate policies needed

- Objectives of the Paris Agreement require major and rapid actions on reducing greenhouse gas (GHG) emissions all over the world
  - Baltic countries have committed to be carbon-neutral as a part of EU by 2050
  - EU increased 2030 GHG reduction target to -55%
- Enhanced policy actions are necessary to
  - achieve these ambitious goals, and
  - realize the opportunities and avoid risks that economic sectors and societies will face.
- FasTen project (4/2020-12/2021) modelled and studied possible additional measures for Baltic countries
  - Funded by Nordic Energy Research, https://www.nordicenergy.org/article/baltic-nordic-research-in-decarbonization/

Baltic targets for 2030

Decarbonization

- Reducing total GHGs while maintaining LULUCF sinks
- National non-ETS target, noting that EU Commission suggested higher non-ETS target
- Increasing the share of renewable electricity, heat, and transport energy

Energy security

- Reduced imports by increasing domestic generation and production
- Increased interconnectivity and flexibility
- Long-term and short-term adequacy. Short-term particularly important with electricity.

Energy efficiency

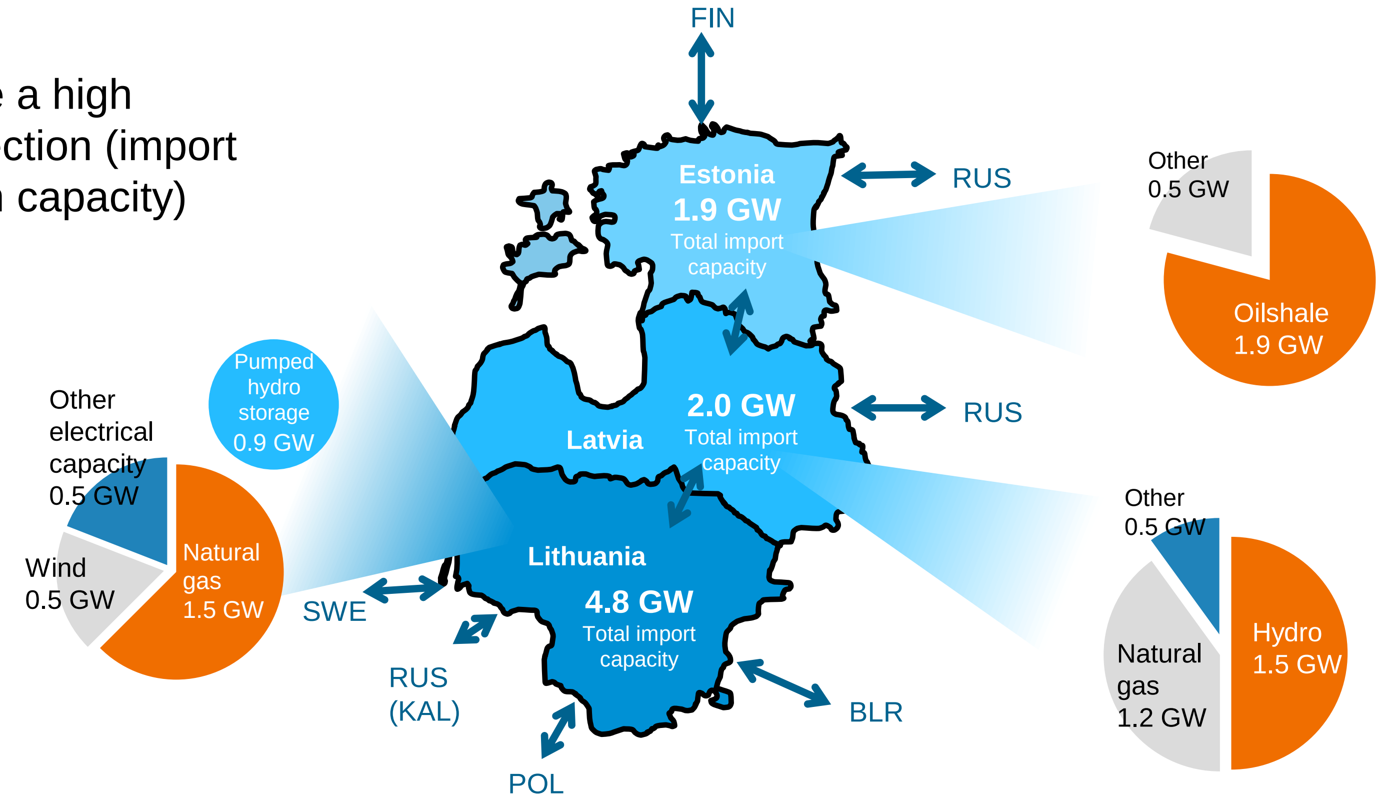
- Reduced primary and final energy use with special emphasis on energy renovations

Markets, research, innovation, competitiveness

- Large range of measures and targets

Baltic power system today

- Baltic countries have a high degree of interconnection (import capacity / generation capacity)
  - Estonia has been a net exporter of electricity on annual level, Lithuania a net importer
  - All Baltic countries have very high share of combined heat and power (CHP) generation.

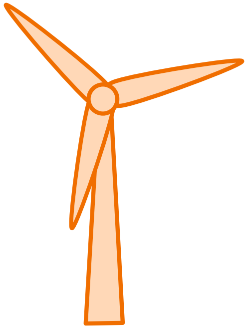


Key aspects towards 2030:

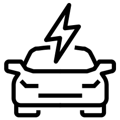
- Expansion of electricity generation from variable renewable sources
- Disconnection from BRELL and synchronization with Continental European grid
- A step towards electrifying end-uses

Challenges:

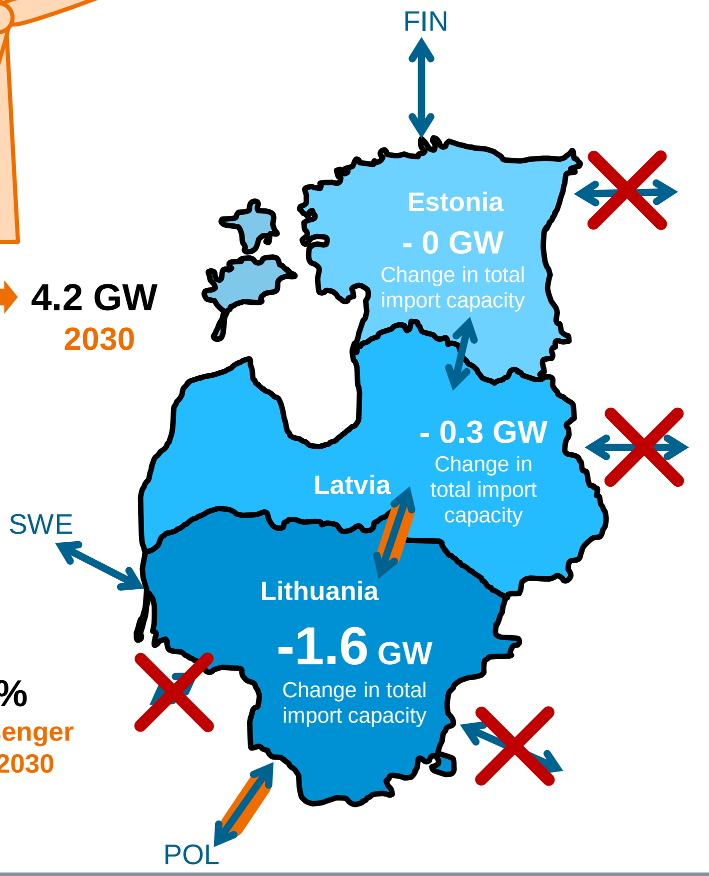
- Flexibility: balancing RES electricity generation with reduced cross-border capacity
- Energy security: Local backup and reserve power



0.9 GW → **4.2 GW**
2017 **2030**



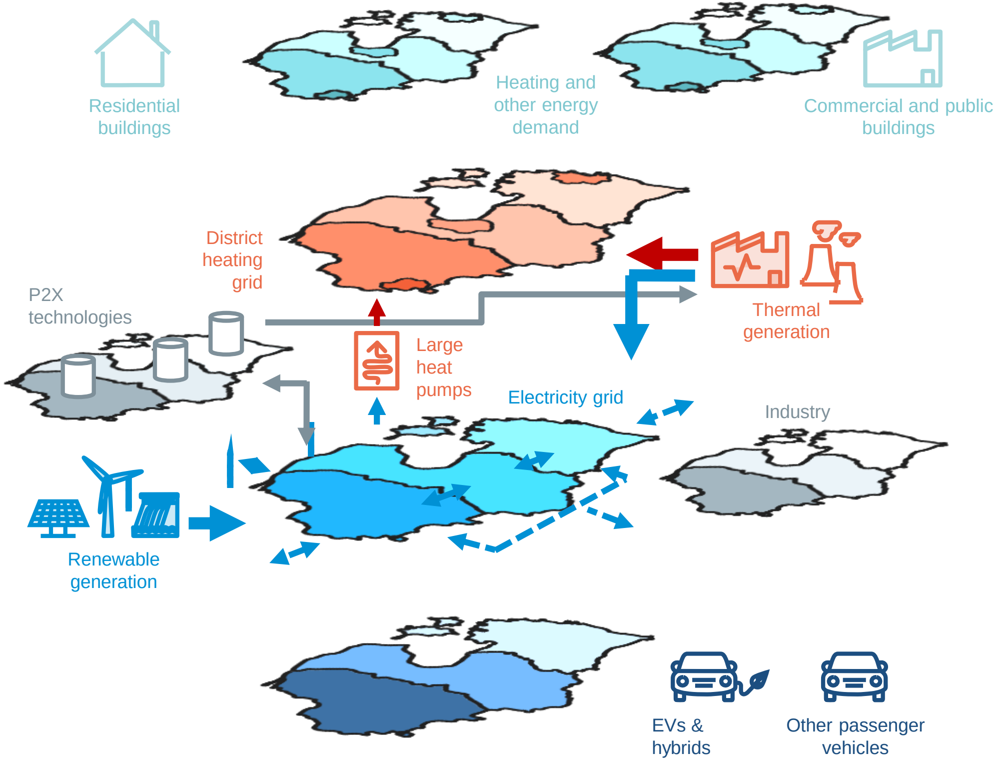
~0 % → **3 %**
of passenger km's 2017 **of passenger km's 2030**



Modelling development towards 2030

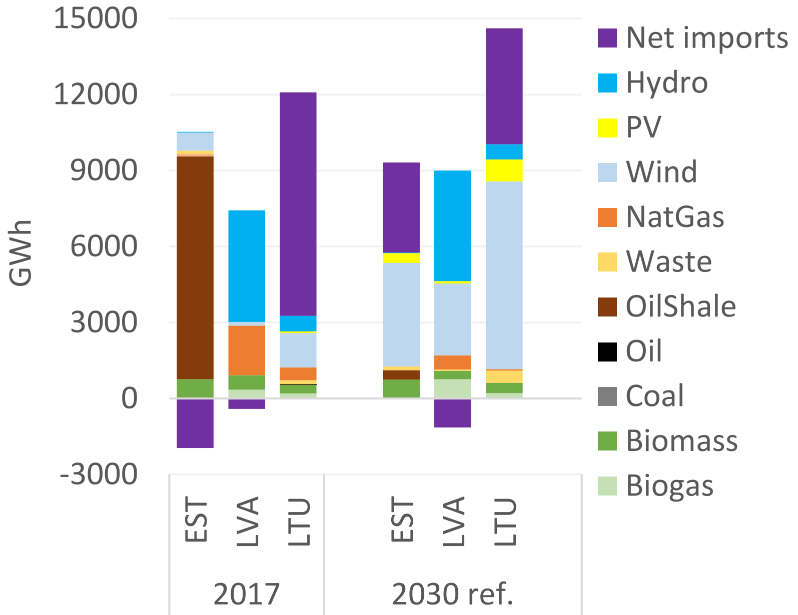
Baltic Backbone model: Improving the modelling capabilities

- FasTen project models energy systems with improved sectoral integration at hourly level
- Range of technologies and policies compared with target indicators
- Deep dives to most promising options
- Open source model, download from https://gitlab.vtt.fi/backbone/projects/fasten-model



Baltic annual electricity supply towards 2030

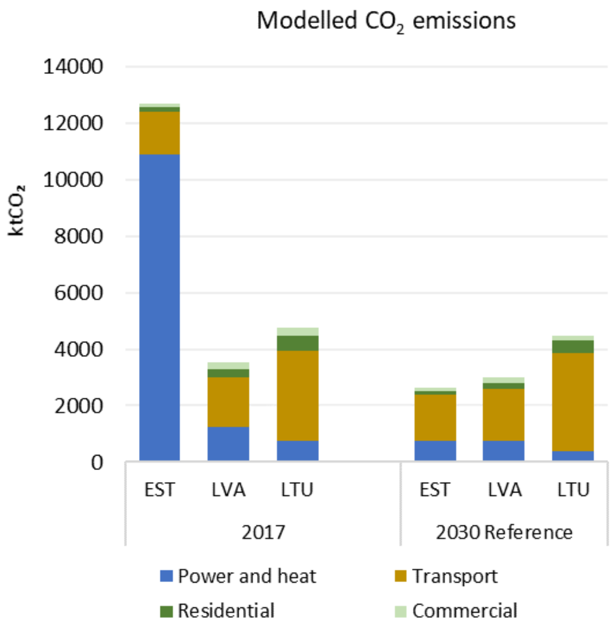
- In FasTen 2030 reference scenario
  - Domestic generation increases in Latvia and Lithuania, but reduces in Estonia
  - Wind and solar replace fossil fuels
  - As a region, Baltic countries remain dependent of imports.
- 2030 reference system is based on national plans



Increasing transport demand makes non-ETS* target difficult to achieve

- Modelled 2030 reference scenario sees a slight increase in non-ETS CO_2 emissions and final energy use due to increasing transport demands.
  - This makes the overall target very difficult to achieve
  - Reductions in the non-ETS emissions typically more difficult than in the ETS sector

Non-ETS = sectors outside EU emission trading scheme (EU ETS). Includes for example, transport, buildings, agriculture, and small industries and power producers. Countries have individual non-ETS emission reduction targets whereas ETS target is common to all EU.

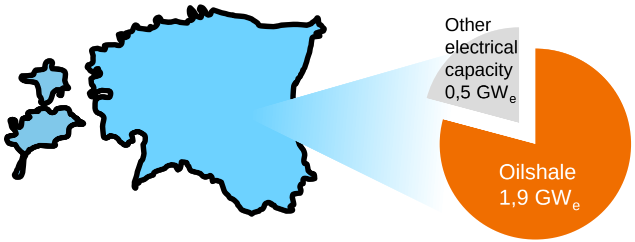


** Transport includes only passenger vehicles

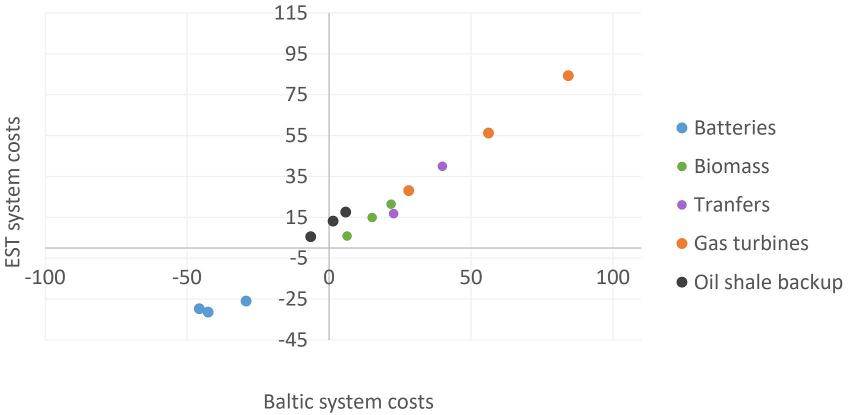
Estonia: Additional capacity needed in 2030

- Additional domestic capacity is needed to replace phased out of oil shale capacity
  - Battery electricity storages seem cost-efficient option to provide reserves and balance variable generation up to a certain capacity
  - Biomass CHP has low additional costs and would provide both fossil-free electricity and district heating
  - Keeping 1 shale oil unit as a back-up capacity could be a cheap option to preserve domestic generation capacity as energy security measure
- 200 MW battery unit included to the reference scenario and two shale oil CHP units kept as backup (400 MW)

Current capacity:

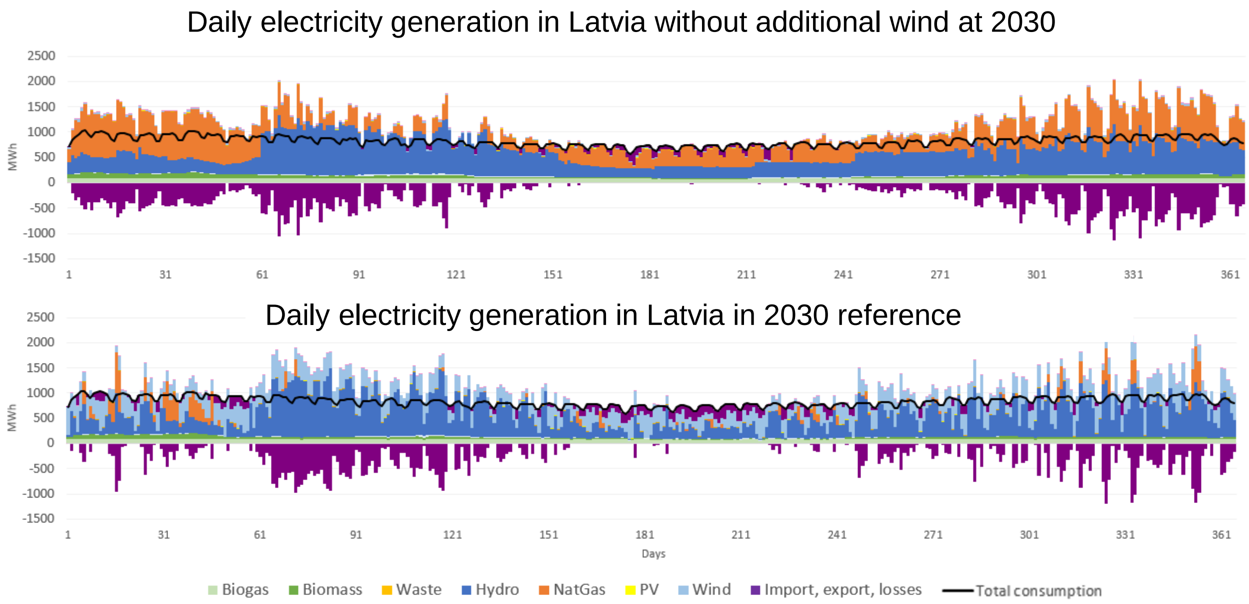


Modelled options for new capacity:



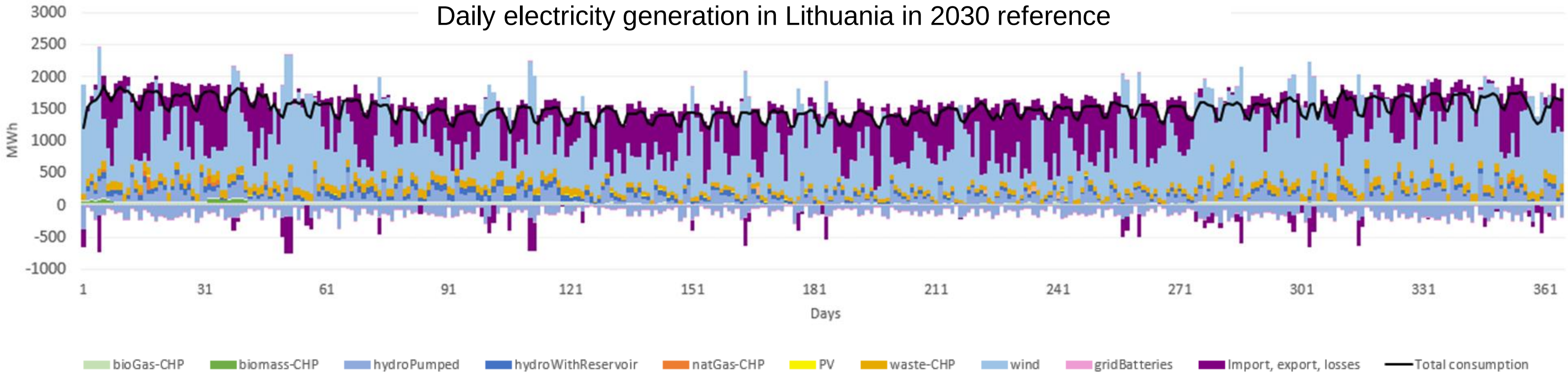
Latvia: Wind power can reduce operation hours of large CHP units

- Additional wind capacity reduces imports (especially in Estonia and Lithuania), but also the operation hours of CHPs (especially in Latvia).
- For an example, Riga's large natural gas CHP units reduce operating hours below 1000 h/year in the 2030 reference scenario, that is not enough for commercial operation, especially in warm years.



Lithuania: Up to 80% VRE generation share in 2030

- In 2030 reference, Lithuania produces up to 80% of power generation and 55% of total power demand by variable wind and solar
- Simultaneous with the decrease of import capacity by -1,6 GW
  with desynchronization from BRELL
- While our modelling does not detect significant operational issues, some could appear with more detailed grid modelling. Real-life experience on such high-VRE systems are still limited.



Modelled additional policies

- Additional wind power
- Additional solar PV
- Solar district heat collectors
- Large heat pumps for district heating
- Building level heat pumps
- Building energy renovations
- Transport biofuels
- Electric vehicles
- Lower passenger volumes in private cars

Overview of the impact of additional policies

- Impacts of additional policies beyond reference vary from country to country depending on local resources and the base level in 2030 reference system
  - Table summarizes the results for Baltic countries
- Measure can help with one target, but counteract with another
- Measures can lower costs up to a point, but eventually costs start to increase
- Deep dive to modelled additional policies and their costs are presented after the summary
- Some measures much easier to implement than others.

	Decarbonization					Energy efficiency		Energy security	Costs
	ETS CO_2	non-ETS CO_2	RES-E	RES-H	RES-T	Primary energy	Final energy	Domestic elec. Generation	system costs
Additional wind power									
Additional solar PV									
Grid batteries									?
Solar district heating									
Heat pumps, district heating									
Heat storages, district heating									?
Heat pumps, buildings									
Energy renovations									?
Transport biofuels									
Electric vehicles									?
Lower passenger volumes									?

* We were not able to include costs of all policies in this analysis

** Green color signifies positive development, e.g. reducing emissions, and red color signifies negative development, e.g. increasing costs. The darker the color, the bigger the impact. See deep dive to modelled policies for further info.

Summary of Baltic opportunities, benefits, and risks 1/2

Opportunities

- Wind power seems relatively cheap option to increase domestic generation and reduce emissions. Wind lowers total system costs up to a point (slightly below reference scenario) but additional deployment increases the total costs.
- Electrification of transport and heating can reduce non-ETS emissions and increase energy efficiency with relatively small costs.
- Utilization of biomass, municipal waste, process heat and heat pumps for district heating can help decarbonize centralized heat generation.

Potential benefits

- Reduced emissions
- Diversified energy mix, increased domestic shares, and reduced dependency on Russian power and natural gas

Risks and threats

- Decreased possibilities for electricity trade
- Switching imported fossil fuels to imported biofuels in transport will increase costs
- Reduced full load hours of CHP units
- Reduced use of Latvia’s natural gas storage
- Increased system costs

Summary of Baltic opportunities, benefits, and risks 2/2

National viewpoints / differences

- Estonia
  - + Significant reductions in emissions and increase in renewable generation.
  - – Decreased domestic electricity and fuel production, lack of existing balancing capacity.
- Latvia
  - + Reservoir hydro helps balancing. No electricity import dependency. Decreased reliance on imported gas. Heat pumps and solar collectors may offer benefits in capital.
  - – Reduced electricity generation in gas-fired power plants risk to commercial operation.
- Lithuania
  - + Increased domestic electricity generation and decreased reliance on imported natural gas and power. Increased utilization of Kruonis pumped hydro storage and new grid batteries.
  - – Reliance on imports/exports to balance electricity generation. Negligible electricity generation in gas-fired power plants risking commercial operations.

Regional collaboration

- Stronger synchronization with Nordic countries and Continental Europe
- Joined investments in e.g. offshore wind
- Balancing generation from variable RES
- Sharing electricity reserves and backup capacity over borders

Bigger than Baltic

- Impacts of other countries' energy policies impact electricity trade prices and availability
- Impacts of CO_2 prices
- European energy and climate targets create additional demands and limitations on decisions

Deep dive to modelling results

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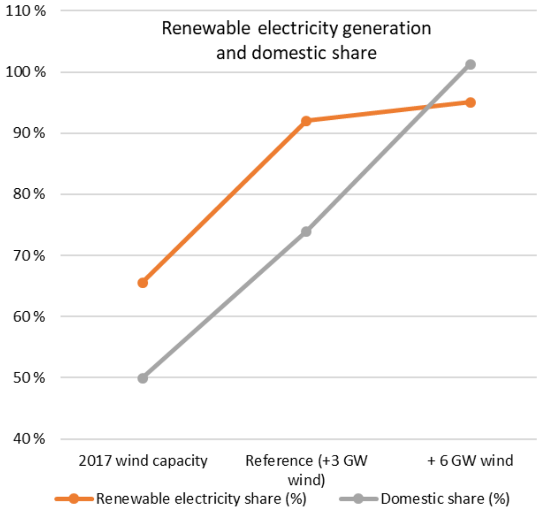
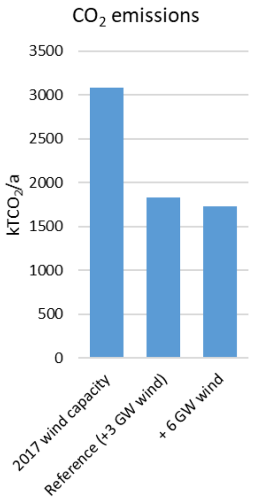
Additional wind and solar power

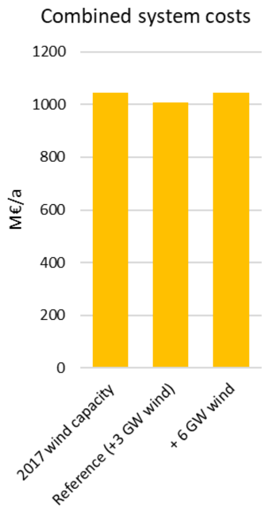
- Additional wind power
- Additional solar PV
- Large heat pumps for district heating
- Building level heat pumps
- Building energy renovations
- Transport biofuels
- Electric vehicles
- Lower passenger volumes in private cars

Additional onshore and offshore wind: Clear benefits in emissions and renewable share

- Compared a range of scenarios:
  - Min: ”2017 wind capacity” 0.9 GW
  - Reference: 3.8 GW
  - Max: 6.8 GW (”+6 GW”)
- Significant benefits in Baltic totals:
  - Reducing ETS CO_2 emissions (3.1 → 1.7 kt CO_2),
  - increasing renewable (66 → 95%) and domestic (50 → 101%) electricity generation share,
  - without expansion of system costs.
- Largest benefits between minimum and reference

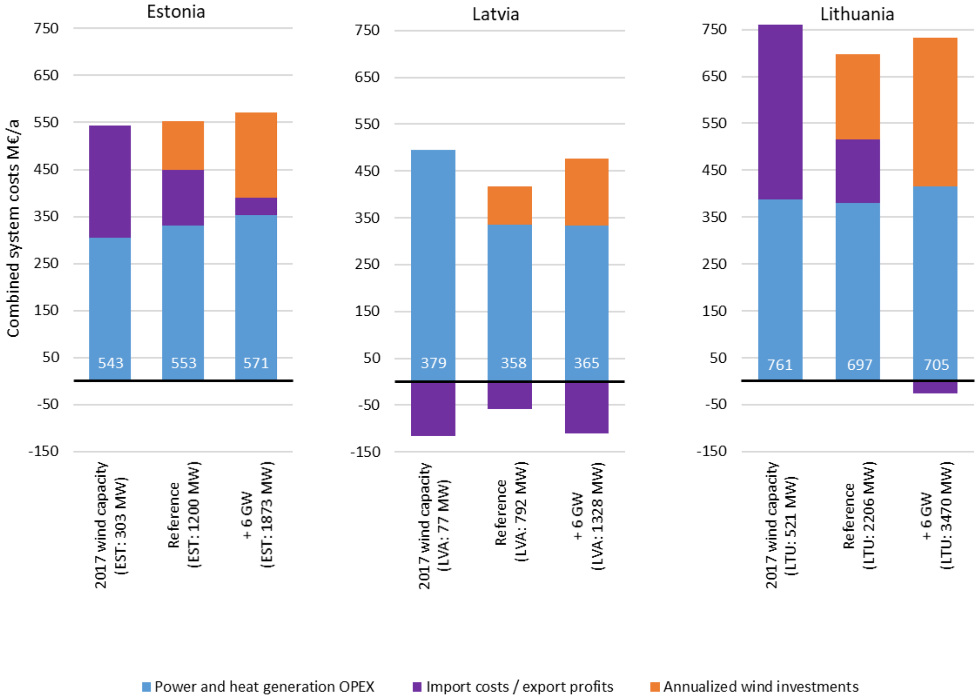






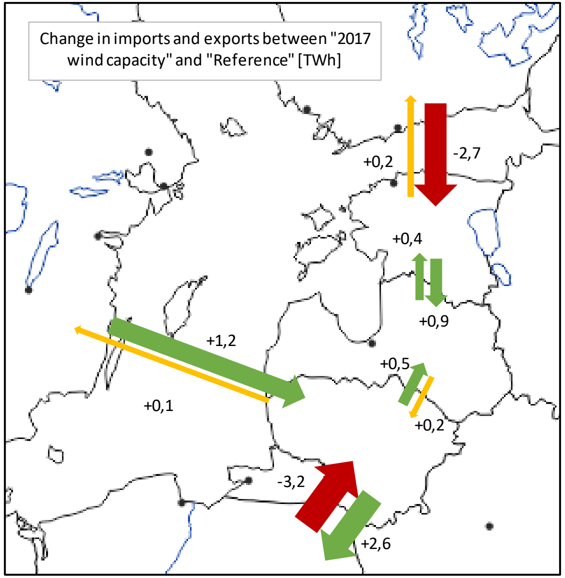
Additional onshore and offshore wind: Cost impact small, but differs by country

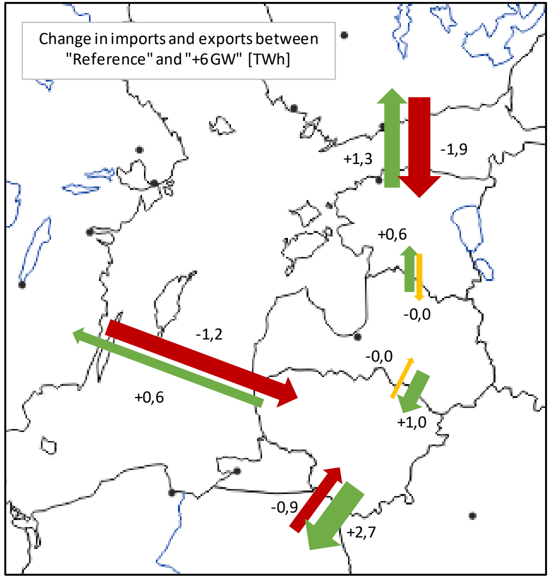
- Additional wind capacity:
  - is substituting imports in Estonia and Lithuania, and
  - lowering generation costs in Latvia.
- Final cost impact will depend on import price levels and wind investment level in neighboring countries.
- According to national plans, wind investments are largest in Lithuania, followed by Estonia and finally Latvia. Scenarios are proportional to plans.



Additional onshore and offshore wind: Impacts in imports and exports not linear

- <u>Low wind ("2017 wind capacity"):</u>
  - Very large imports from Finland and Poland
  - Large imports from Sweden.
- <u>Towards "Reference":</u>
  - Imports from Finland and Poland reduced.
  - Relative import share of Sweden increases.
  - Export to Poland increases.
- <u>Towards very high wind ("+ 6 GW"):</u>
  - Imports reduce further evenly.
  - High exports especially to Poland.

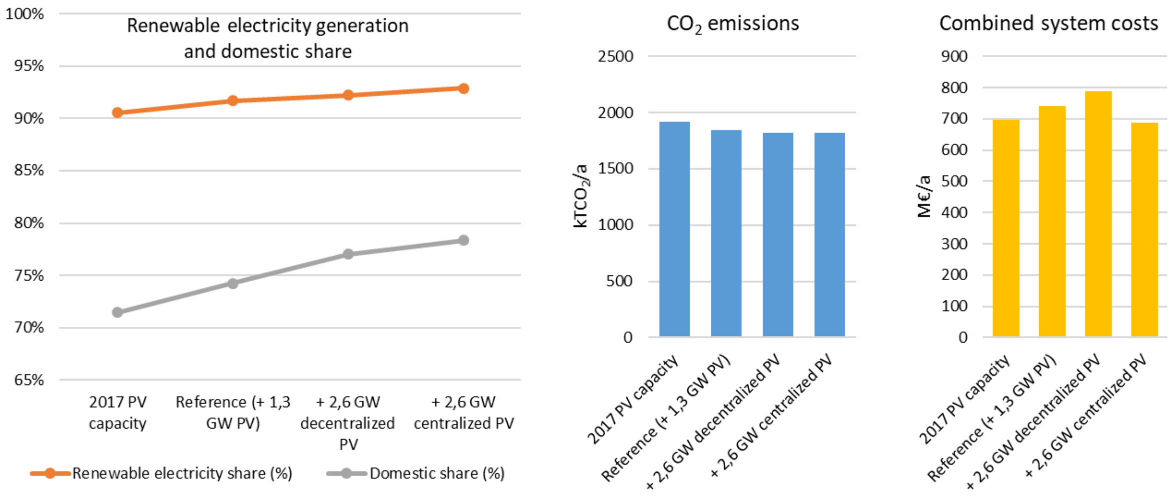




Additional decentralized and centralized PV: Small benefits in emissions, better in domestic share

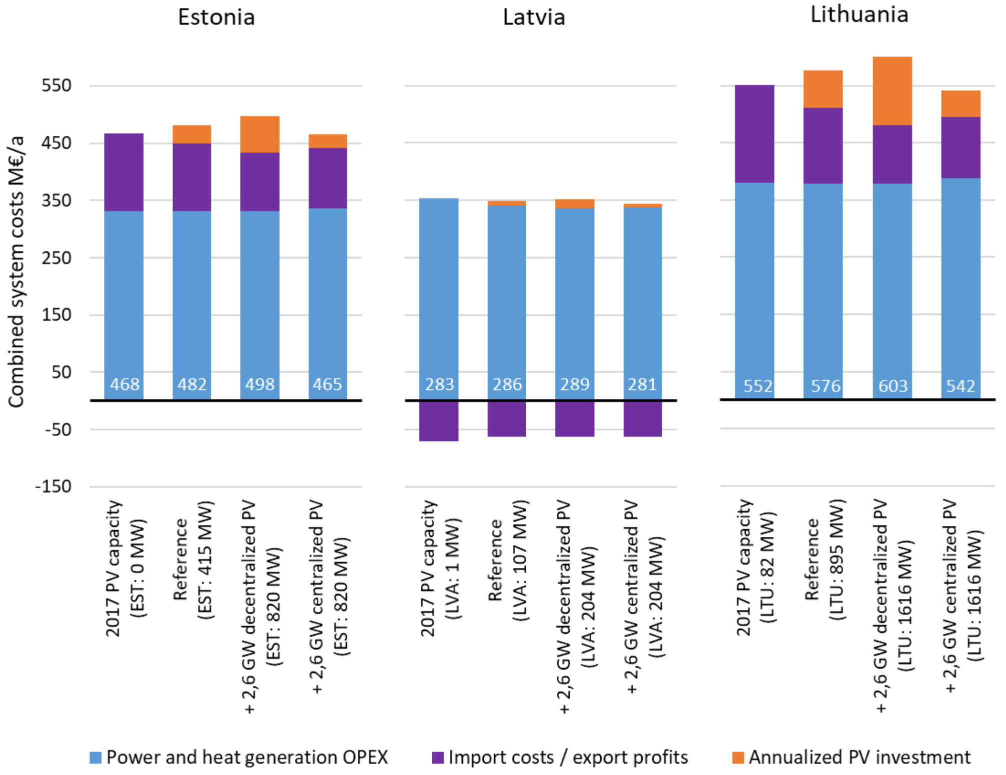
- Compared a range of scenarios:
  - Min: ”2017 PV capacity” 0,09 GW
  - Reference: 1,3 GW
  - Max: 2,6 GW centralized (”utility-scale”)
  - Max: 2,6 GW decentralized (”building-scale”)

  (Note: All PV scenarios have the rather high wind deployment of ”Reference”)
- Small benefits in Baltic totals:
  - Reducing ETS CO_2 emissions (1,9 → 1,8 kt CO_2),
  - increasing renewable (91 → 93%) and domestic (71 → 78%) electricity generation share,
  - with slightly lower to slightly higher system costs depending on deployment of decentralized or centralized PV



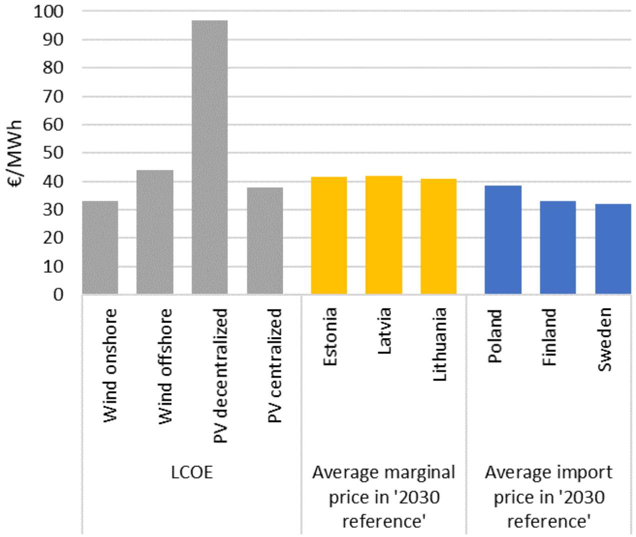
Additional decentralized and centralized PV: Potential cost benefits with centralized PV

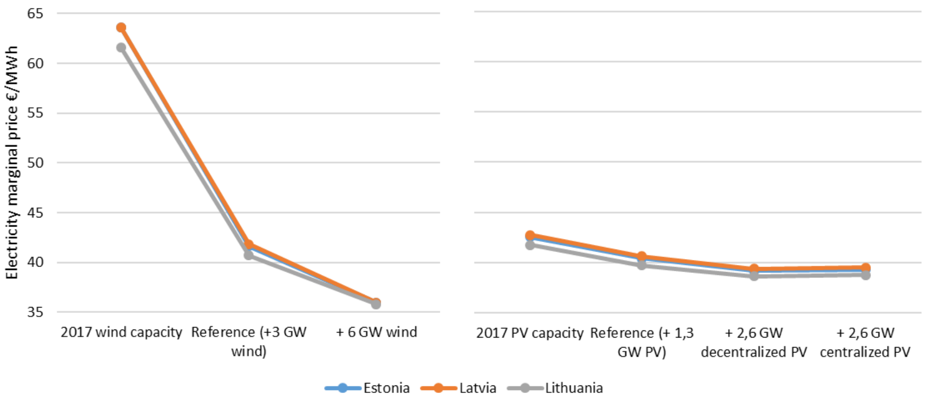
- Addition of PV:
  - substitutes imports in Estonia and Lithuania PV,
  - lowers operational costs and reduces exports in Latvia, and
  - can support wind by reducing low-VRE hours, especially in Lithuania.
- Centralized PV could be slightly more cost-efficient than rooftop installations, depending on land prices
- According to national plans and projections to 2030, PV investments would be largest in Lithuania, followed by Estonia and finally Latvia. Modelled additional scenarios are proportional to reference 2030.



Comparison of wind and PV deployment: Onshore wind best, centralized PV may become increasingly feasible

- Based on simplified LCOE analysis (on the right), cost order of VRE technologies in the Baltic setting from best to worst is: 1) onshore wind, 2) centralized PV, 3) offshore wind, 4) decentralized PV
- Impact on electricity marginal prices per MW (below) is larger with wind than PV: Wind capacity has full load hours 3000-4000 h/year, PV only 1000 h



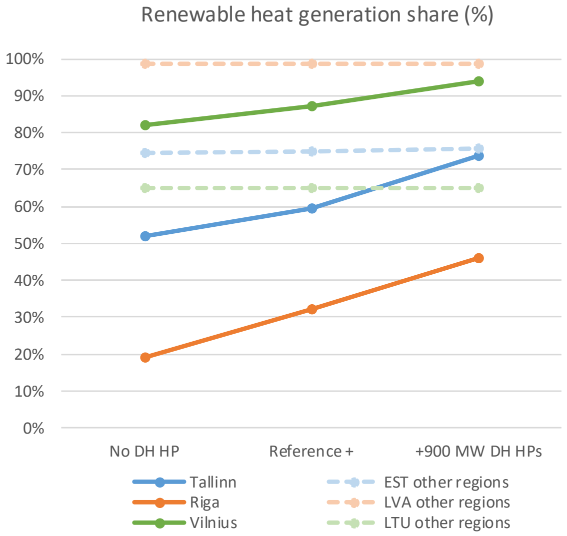


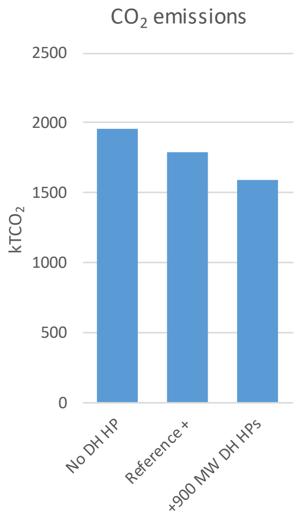
Large heat pumps for DH

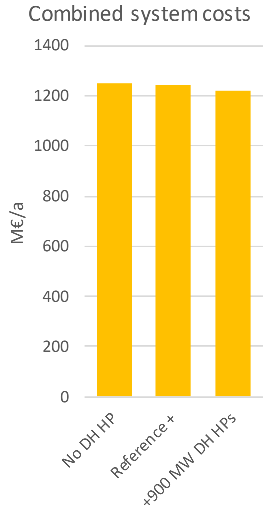
- Additional wind power
- Additional solar PV
- Large heat pumps for district heating
- Building level heat pumps
- Building energy renovations
- Transport biofuels
- Electric vehicles
- Lower passenger volumes in private cars

District heating heat pumps (DH HP): Emission reductions in capital regions

- Compared a range of scenarios:
  - Min: ”No DH HP” 0 MW
  - ”Reference +”: 300 MW
  - Max: 900 MW
- Benefits in Baltic totals:
  - Reducing ETS CO_2 emissions (2,0 → 1,6 kt CO_2),
  - with slight reduction in system costs.
- Benefits in renewable heating share are focused in capitals, where substitutes fossil generation (natural gas boilers)

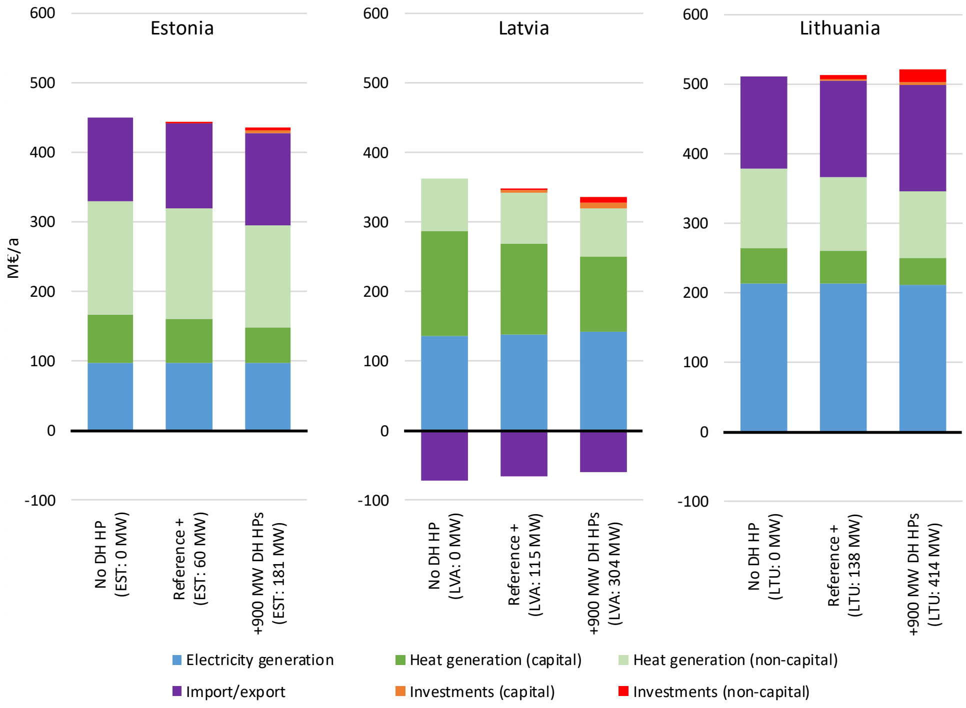






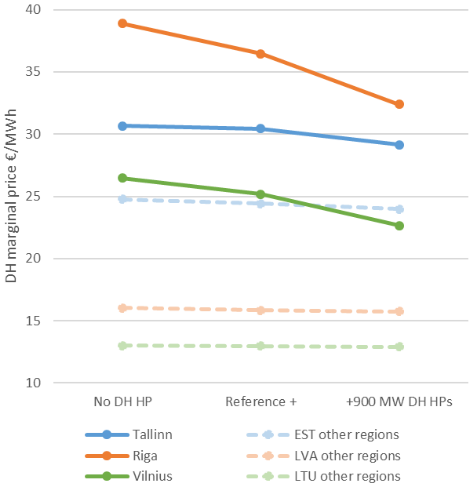
District heating heat pumps (DH HP): Cost effective in Riga and potentially Tallinn

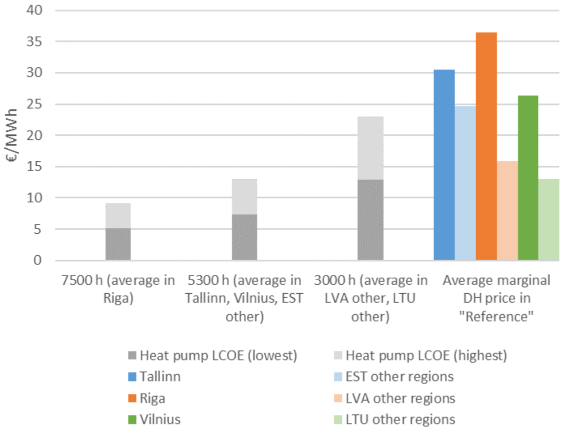
- Addition of district heating HPs:
  - Lowers heat generation costs (especially in capitals),
  - but increases electricity imports (especially in Estonia and Lithuania).
  - Supports domestic electricity generation by CHP units in Latvia.
- Regionally, cost impacts are
  - Positive: in Riga
  - Neutral: in Tallinn & Estonia other regions
  - Negative: in Vilnius, Latvia other regions and Lithuania other regions
- Heat pump investment prices and efficiencies vary according to heat source, the presented results are from excess heat pumps.



District heating heat pumps (DH HP): Operation supported by DH storages, benefits in Riga

- Heat pumps lower DH marginal prices in all capitals, but most effectively in Riga, where they are used up to 7500 h/a (compared to 3000-5300 h/a in other regions)
- DH storages in Riga (150 MW / 550 MWh in “Reference” scenario) support usage of heat pumps.
- Combined impacts of heat pumps and DH storages could improve cost efficiency also in Estonia and Lithuania. This seems a clear topic for further research.



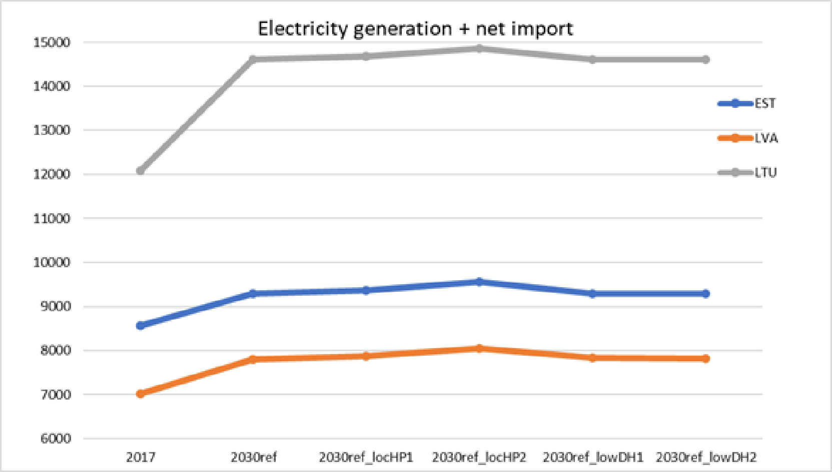


Building sector measures

- Additional wind power
- Additional solar PV
- Large heat pumps for district heating
- Building level heat pumps
- Building energy renovations
- Transport biofuels
- Electric vehicles
- Lower passenger volumes in private cars

Building level scenarios: introducing heat pumps and energy renovation

2030ref	**Reference scenario: heat pump energy production** **EST 1006 GWh** **LVA 272 GWh** **LTU 415 GWh** **Reference scenario: energy final consumption for heating and hot water** **EST DH 9949 GWh** **LVA DH 14407 GWh** **LTU DH 15377 GWh**
2030ref_locHP1	+200GW produced by local HPs for each country
2030ref_loCHP2	+500GW produced by local HPs for each country
2030ref_lowDH1	Scenario with **25%** lower district heating demand
2030ref_lowDH2	Scenario with **45%** lower district heating demand



- HP introduction leads to higher electricity consumption and net import increase in system
- Next step – combining scenarios to balance energy generation an import-export

Building level scenarios

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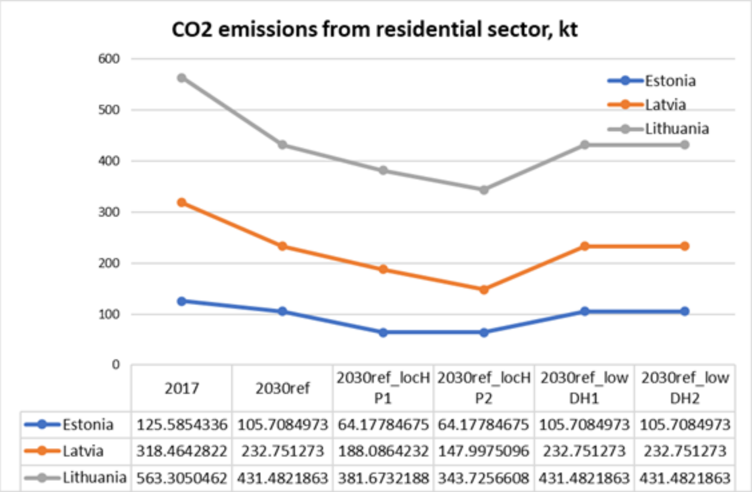
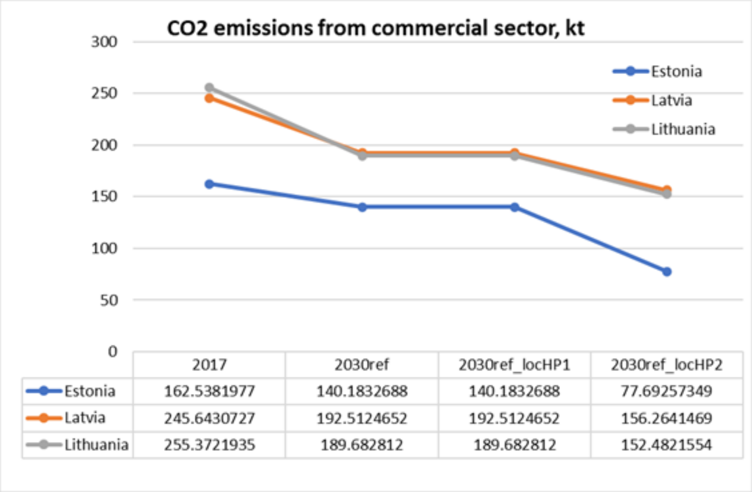


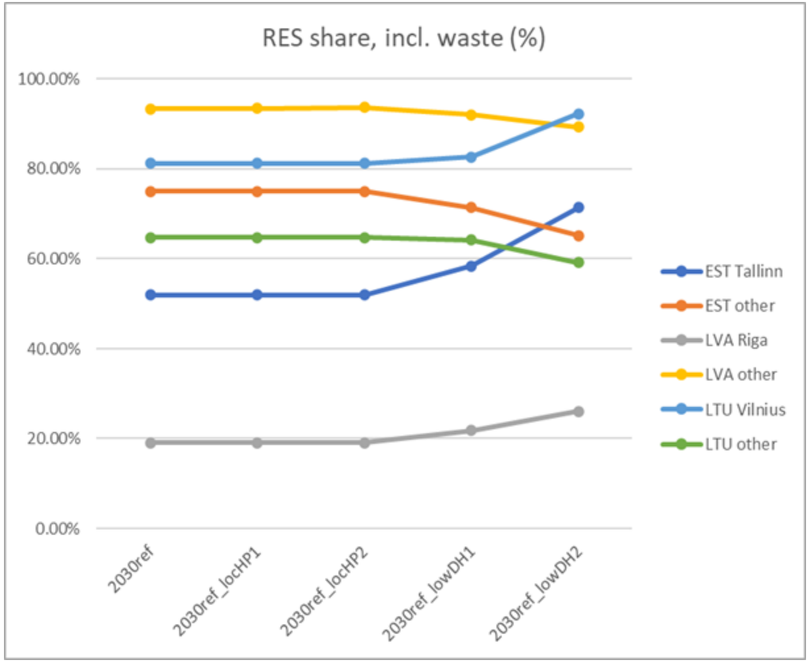
	2017	2030ref	2030ref_locHP1	2030ref_locHP2	2030ref_lowDH1	2030ref_lowDH2
Estonia	125.5854336	105.7084973	64.17784675	64.17784675	105.7084973	105.7084973
Latvia	318.4642822	232.751273	188.0864232	147.9975096	232.751273	232.751273
Lithuania	563.3050462	431.4821863	381.6732188	343.7256608	431.4821863	431.4821863



	2017	2030ref	2030ref_locHP1	2030ref_locHP2
Estonia	162.5381977	140.1832688	140.1832688	77.69257349
Latvia	245.6430727	192.5124652	192.5124652	156.2641469
Lithuania	255.3721935	189.682812	189.682812	152.4821554

- Both residential and commercial sectors reflect CO2 emissions reduce
- The introduction of HPs gives the most noticeable impact on emissions

Building level scenarios



- RES share increase in renovation scenarios for capitals: Tallinn, Riga, Vilnius
- Not successful for RES implementation increase in other regions of the countries
- Vilnius RES share very high, whereas Riga under 30% (use of large-scale gas-fired CHP)
- Negligible impact of local HPs introducing to RES share total

Transport sector measures

- Additional wind power
- Additional solar PV
- Large heat pumps for district heating
- Building level heat pumps
- Building energy renovations
- Transport biofuels
- Electric vehicles
- Lower passenger volumes in private cars

2030 base scenario

		2017	2030
Travel		58.42 Bpkm	+14.83 Bpkm
Number of cars		2.77 Million	3.76 Million
EV share		0.08%	2.5%
Charging pattern: direct/overnight		50%/50%	50%/50%
Biofuel share in fuel blend	EST	0.2%	10%
	LVA	1.35%	10%
	LTU	6%	10%*
CO_2 emissions in transport		6452 kt	6770 kt

* Biofuel share in petrol – 10%, in diesel 7%

Transport scenarios analyzed

Base scenarios:

- 2030ref ⬅ Reference scenario
- 2030EVhigh ⬅ Increased EV share to 13.5%
- 2030dmd-20 ⬅ Decreased travel demands by 20%

Biofuel share scenarios:

- 2030bio15 ⬅ 15% biofuel share in petrol and diesel
- 2030bio20 ⬅ 20% biofuel share in petrol and diesel

Charging scenarios:

- 2030chg25-75 ⬅ EV charging: 25% direct; 75% overnight
- 2030chg75-25 ⬅ EV charging: 75% direct; 25% overnight

Charging scenarios with high EV count:

- 2030EVhigh-25 ⬅ Increased EV share + 25% direct and 75% overnight charging
- 2030EVhigh-75 ⬅ Increased EV share + 75% direct and 25% overnight charging

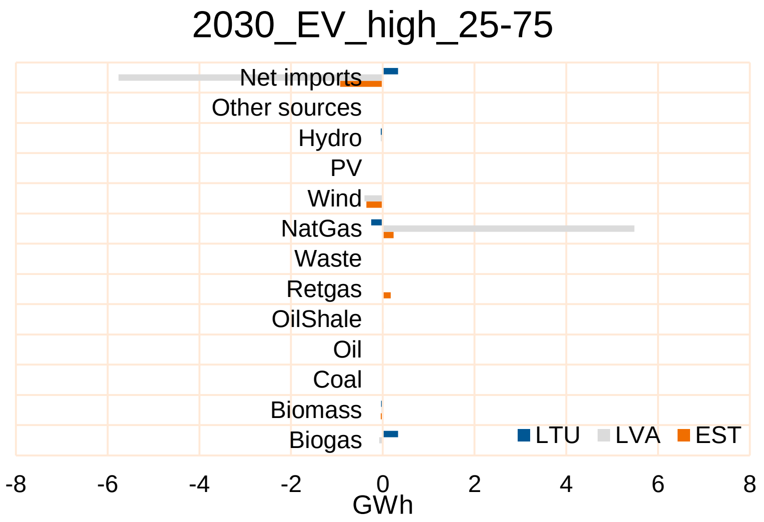
Effects of transport measures

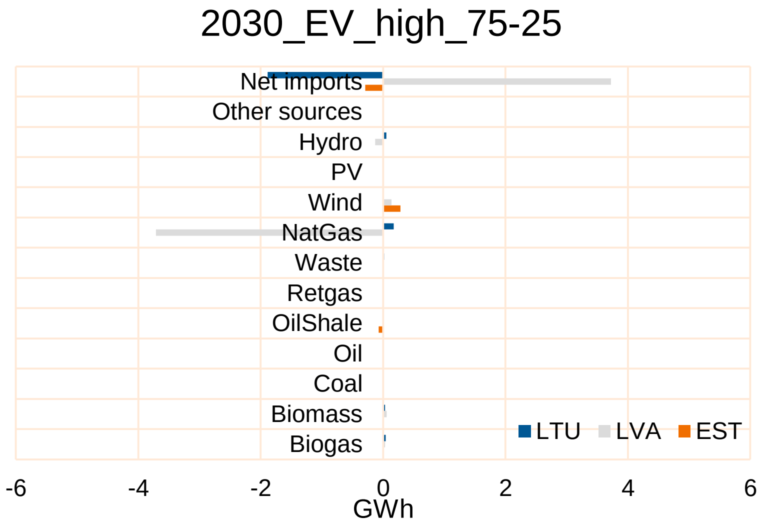
		Base			Biofuel share		Charging		Charging with high EV count	
		2030ref	2030EVhigh	2030dmd-20	2030bio15	2030bio20	2030chg25-75	2030chg75-25	2030EVhigh-25	2030EVhigh-75
Decarbonization	CO_2	9922	9203	8564	9463	9092	9922	9922	9205	9202
	non-ETS CO_2	8062	7293	6708	7604	7232	8062	8062	7294	7293
	RES-E	96%	95%	96%	96%	96%	96%	96%	95%	95%
	RES-H	62%	62%	62%	62%	62%	62%	62%	62%	62%
	RES-T	7%	11%	7%	12%	15%	7%	7%	11%	11%
Energy efficiency	Primary en.	73045	70083	67339	73045	73042	73044	73044	70093	70079
	Final en.	76458	75240	70605	76458	76458	76458	76458	75236	75240
Energy security	Domestic gen.	24797	24969	24786	24797	24796	24797	24796	24974	24966
Costs	system costs	4121	3957	3651	4209	4282	4121	4121	3958	3957

- The reduction of car use is the most impactful emission reduction measure till 2030. 20% reduction in travel would decrease emissions in Baltic states by 1 358 kt CO_2.
- Increasing biofuel content in fuel blends to 15% would yield emissions lower by 459 kt CO_2 and increasing to 20% by 830 kt CO_2.
- Boosting the number of electric cars in the fleet to 13.6% by 2030 from expected 2.5% would reduce emissions by 719 kt CO_2.

EV charging effects on the power system

- Modelling results show that electric vehicle charging patterns have practically negligible effects on the fuel mix in the power system even at relatively high share of electric vehicles (13.6%) in the car fleet.





Modelling measures for fast, flexible and secure decarbonization of the Baltic states

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FINAL RESULTS FROM FASTEN PROJECT