Assessment of energy security coefficient for Baltic countries and Finland considering energy system resilience to disruptions

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Presentation outline

- Energy security definition
- Methodology framework for the energy security analysis
- Results of energy security coefficient for Baltic countries and Finland

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Energy security definition

Energy Security		
Energy supply reliability	Energy price acceptability	Energy system resistance to disruptions

Energy security – the ability of the energy system:

- to uninterruptedly supply energy to consumers under acceptable prices,
- to resist potential disruptions arising due to technical, natural, economic, socio-political and geopolitical threats.

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Methodology framework for the energy security analysis

Threats

- Identification and analysis of threats to energy security

Disruptions

- Formation of internal and external disruptions to energy system

Energy system modelling

- Model for energy system development implemented in OSeMOSYS tool
- Energy system modelling with stochastic disruption scenarios or pathways

Consequence analysis

- Disruption consequences: energy cost increase and unsupplied energy

Energy security metric

- Energy security coefficient – quantitative level of energy security

Methodological approach

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Threats to energy security

- A threat to energy security is defined as any potential danger that exists within or outside the energy system and that has a potential to result in some kind of disruption of that system.
- Common (regional) and country specific threats are identified.

Category	Threats
Technical	• technical problems or accidents in the energy production, resource extractions and transportation, energy transmission infrastructure and processing enterprises, • attacks on supply infrastructure.
Natural	• extreme temperature, wind, rainfall and other extreme meteorological phenomena or natural disasters.
Socio-political	• corruption, poor or inadequate management and investments in energy sector, • low government effectiveness and regulations, • high energy market concentration or formation of monopolies, • political instability of the consumer, supplier and transit countries, • the coercive manipulation of energy supplies, • increasing possibility of terrorist attacks and cyber-attacks, • increasing probability of armed conflict in the region, • international political and economic crises, • security concerns affecting the future of renewable energy, • shift in stability of European Union affecting the investments on strategic large-scale energy projects.

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Disruptions of energy system

Disruption	Parameter	Probability distribution	Value	
			qualitative	quantitative
Internal: • **Restriction of technology availability due to technology reliability and outage rate** • **Change of technology or energy project initial investment (capital cost) due to risk of investment for the candidate technology** **External:** • **Interruption or complete cut-off of energy supply** • **Price increase of energy sources**	Start	Uniform	–	From modelling first year to end year
	Duration	Exponential	Short-term	≤ 1 year
			Medium-term	> 1, ≤ 3 year
			Long-term	> 3 year
	Extent	Normal, lognormal	Small	≤ 33%
			Medium	> 33, ≤ 66%
			Large	> 66%
	Frequency of occurrence	–	Low	≤ 0.01
			Medium	> 0.01, ≤ 0.1
			High	> 0.1
	Technology or energy source	–	Any energy supply, production or transportation technology or any energy source in the energy system	–

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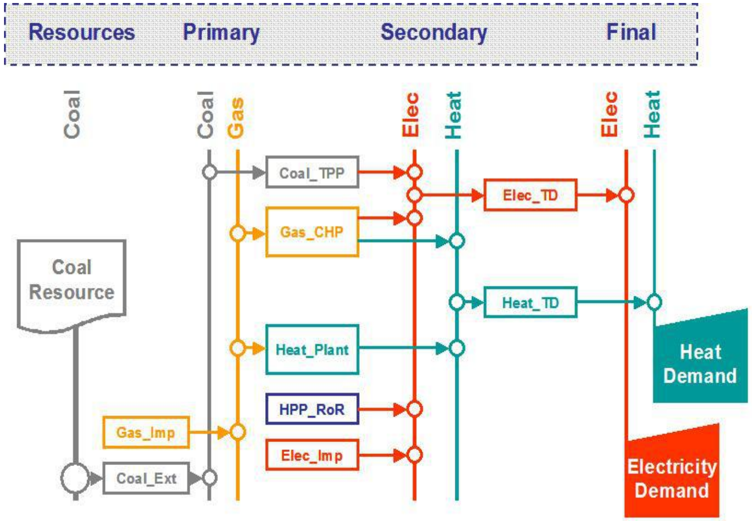
Modelling of disrupted energy system

- OSeMOSYS* (*Open Source Energy Modelling System*) tool is used and applied for the modelling of energy system development with stochastic disruptions.
- Method – linear programming (optimization). Open source – code available in 3 languages (Gnu MathProg, GAMS, Python). Solver – glpk (open-source).
- The objective function of the OSeMOSYS is to minimize the total discounted cost of energy systems to meet the given demand(s) for the energy system.
- **Model is applied for modelling of energy system in multiple (*n*) runs with various stochastic disruption scenarios using Monte-Carlo method.**



OSeMOSYS blocks of functionality:

- Objective
- Costs
- Capacity adequacy
- Energy balance
- Constraints
- Emissions

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*http://www.osemosys.org/

Energy security coefficient

- Disruption consequences:
  - unsupplied energy *UE* (from 0% to 100%):

    $$UE = (1 - (Served / Demand)) \times 100\%;$$

  - energy cost increase *ECI* (from 0% to 100% and more):

    $$ECI = ((FC - BC) / BC) \times 100\%.$$

- Energy security coefficient (ESC) – quantitative measure of energy security.
- ESC aims to evaluate the consequences of disruption scenarios in the energy system in terms of energy system resilience to disruptions:

$$ESC = \exp(-a_1 \times UE \times \exp(YS) - a_2 \times ECI \times \exp(YS))$$

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Model for Energy Security Coefficient Assessment (MESCA)

- Study: Regional Energy Security Case Study of the Baltic region and Finland.
- Countries: Finland, Estonia, Latvia, Lithuania.
- Sectors: electricity, district heating.
- Fuels (local, imported): coal, oil, oil shale (only for Estonia), natural gas, waste, biomass and nuclear fuel.
- Technologies (over 40 per country): PP, CHP, HOB, CC, hydro, wind, solar, electricity and fuel import, T&D network, unserved energy (dummy).
- Analysis period: 2015–2050.
- Time step: 1 year.
- Time slices per one year: 15 (5 seasons x 3 time slices per day).

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Data and scenarios

- Data from TIMES PanEU model: costs (capital, variable, fixed), lifetime, efficiency.
- Other sources: OSeMBE, MESSAGE, Technology data catalogues, transmission system operators, other.
- Scenarios analysed:

Scenarios	RES share in primary energy consumption	CO_2 prices
Base	According to TIMES PanEU Base scenario	According to TIMES PanEU Base scenario
BaseCO2Lin	According to TIMES PanEU Base scenario	Linear growth from 10 Eur/t in 2020 up to value estimated in TIMES PanEU Base scenario for 2050

- 500 runs for each scenario were performed.

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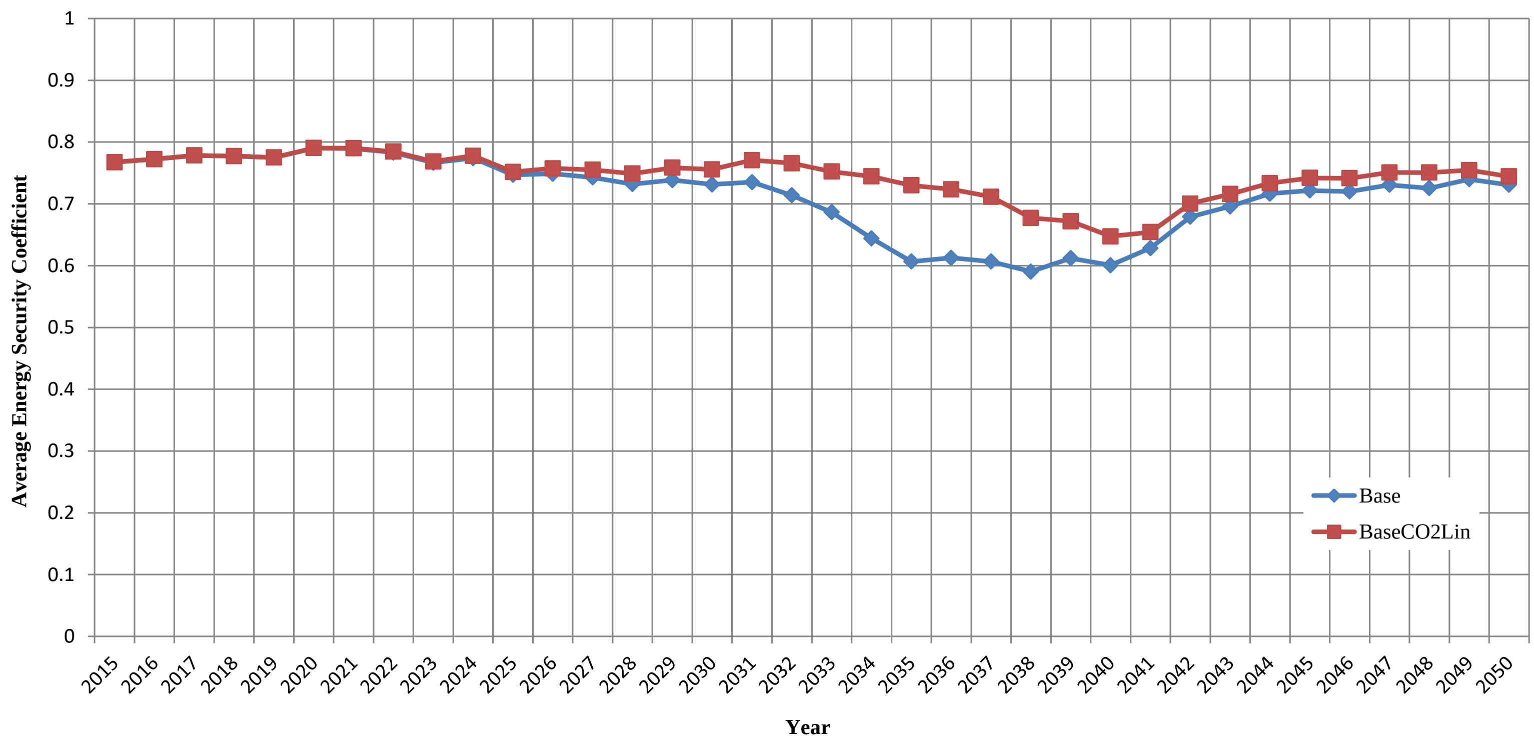
ESC results – Finland



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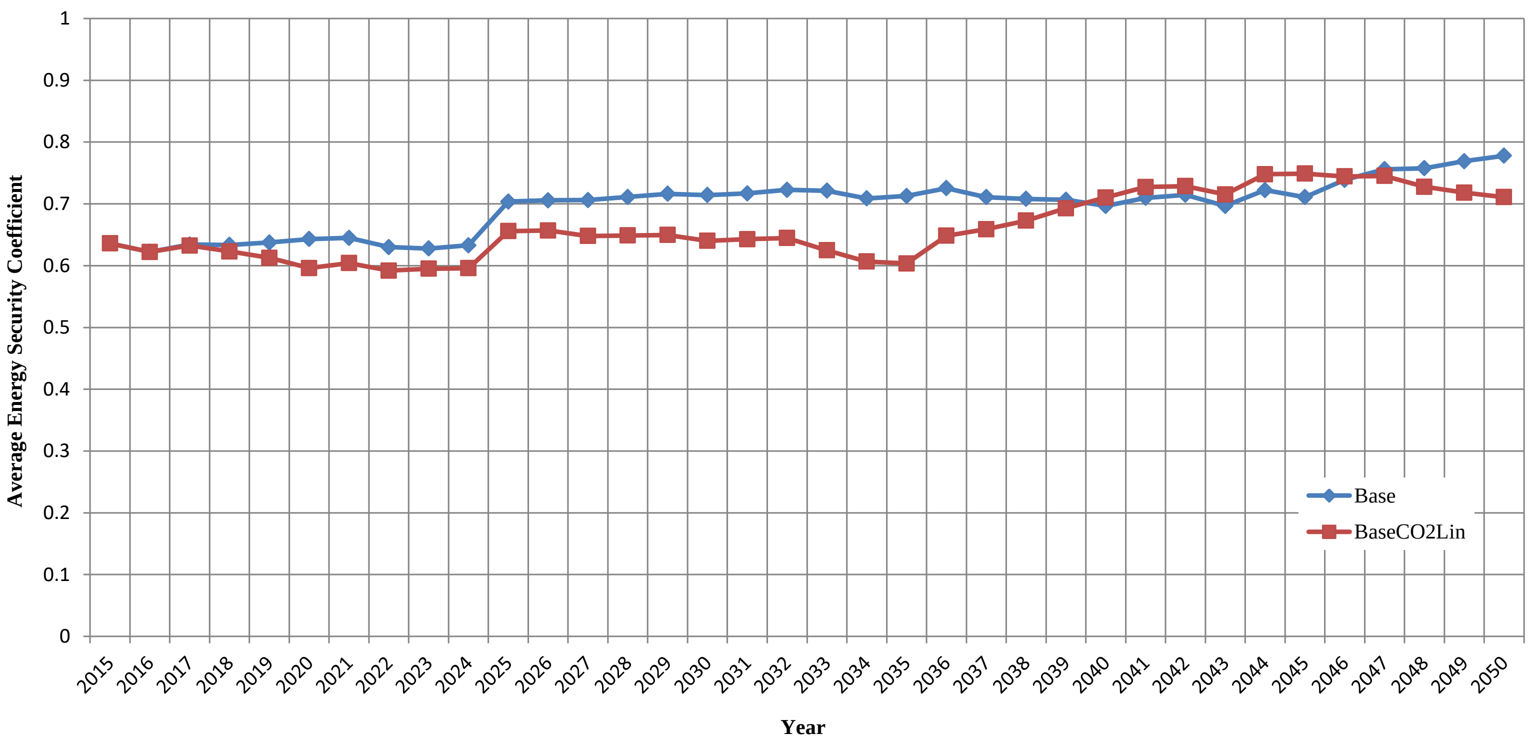
ESC results – Estonia



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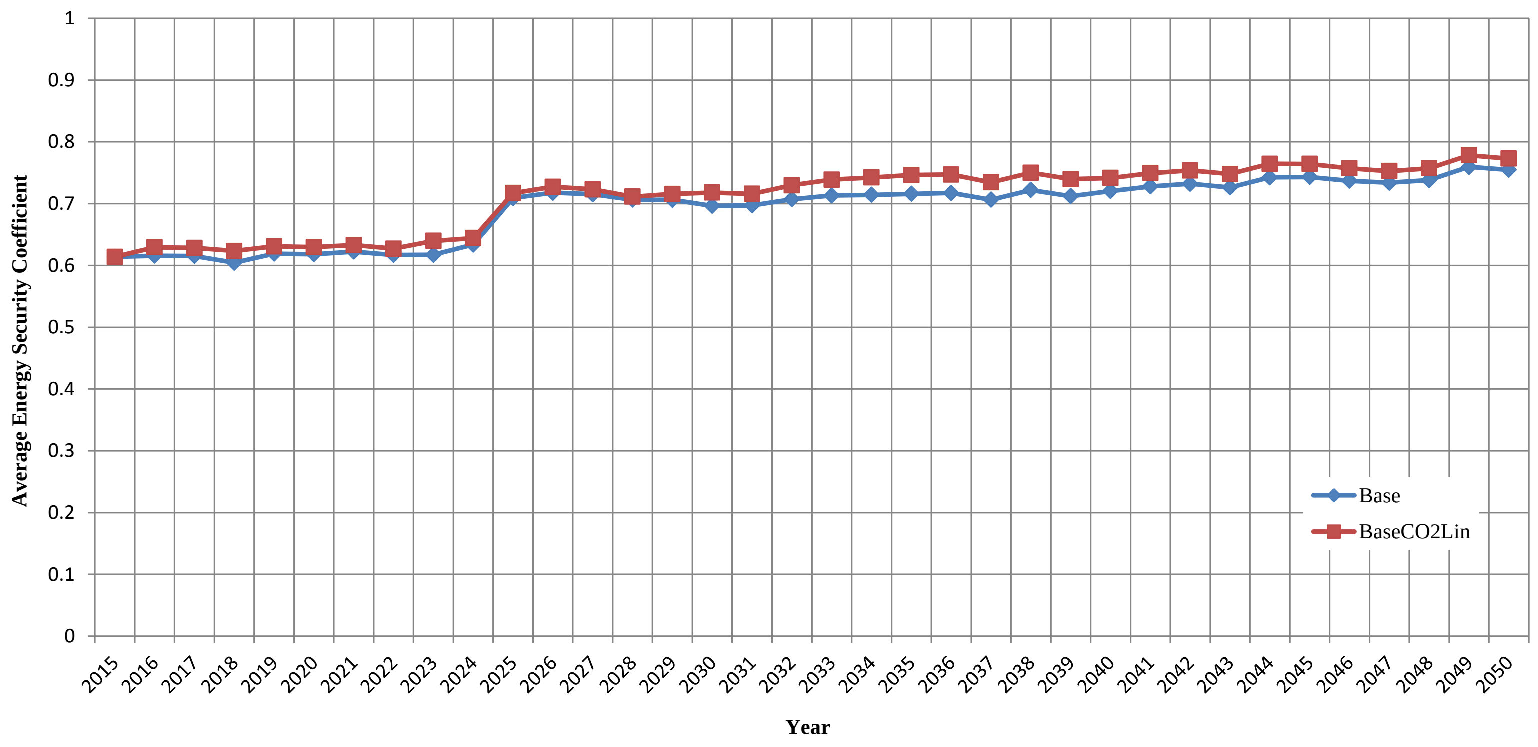
ESC results – Latvia



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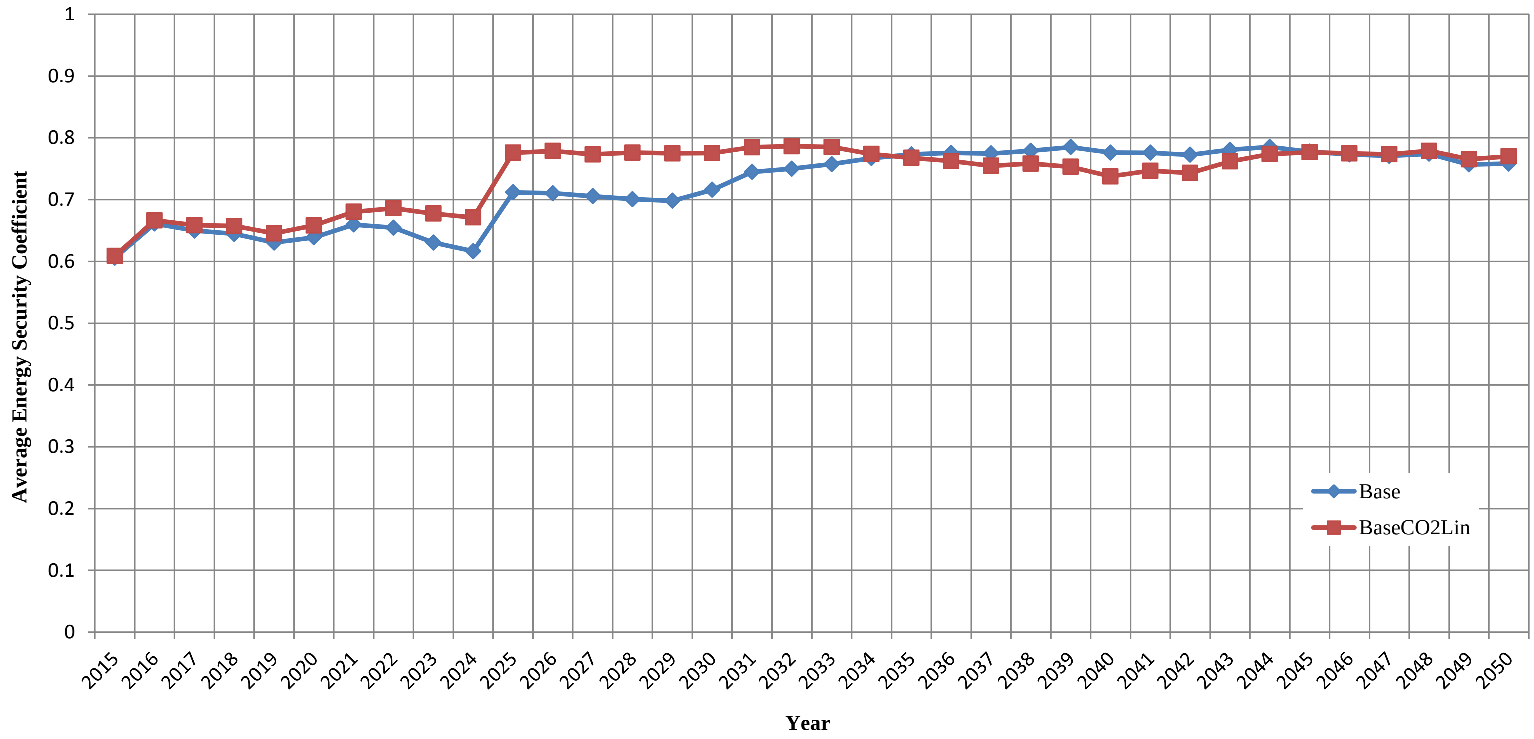
ESC results – Lithuania



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Conclusions

Energy system modelling with various disruptions using the probabilistic method allows to:

- evaluate the energy system's resilience to these disruptions;
- enables to compare different energy system scenarios in terms of the energy security quantitative measure.

The modelling exercise on evaluation of energy security coefficient (ESC) for Baltic countries and Finland revealed that:

- ESC performance is highly dependent on generation adequacy.
- Lack of capacity might lead energy system to face some failures and being not sufficient to cope with technical and other disruptions.

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Conclusions (cont.)

- Too large penetration of new capacities in short-term period might also lead to problems since there is a huge economic burden for energy system to cope with severe consequences of economic disruptions due to over-investment risk.
- Diversification of energy supply sources is a significant measure to increase energy security. This measure of energy security might also be implemented through power interconnectors with other countries by increasing capacities of power lines. It also enables higher power market integration and diversification of supply routes, which helps to enhance energy security.
- When comparing the ESC performance between countries within different scenarios, it was observed that the highest average ESC is recorded in the BaseCO2Lin scenario for Finland and Lithuania (0.74) while the lowest ESC is observed in the BaseCO2Lin scenario for Estonia (0.66). In addition, all the analysed scenarios in this case study demonstrate that the average ESC is higher than 0.65.

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Thank you for your attention

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