Consideration of Material Criticality for Battery Sub-Technologies in an Energy System Optimization Model for Belgium and the Netherlands

Thesis Research Project

Lilli Martens

13.12.2023

DLR

Overview

Research Institute

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

Institute of Networked Energy Systems, Department of Energy System Analysis

- System analysis and technology assessment in the field of energy supply
- Focus on scenario development, agent-based modelling

Introduction

Development of renewable energy technologies needs to increase

- Demand for raw materials will grow substaintially

Raises concerns about the availability of raw materials for the energy transition

- Valero et al. (2018)
- Moreau et al. (2019)
- Junne et al. (2020)
- Schlichenmaier & Naegler (2022)
- List of Critical Raw Materials from European Comission (2023)

Research Objective

- Integrate the criticality of a technology class into an energy system modelling framework to perform a multi-objective optimisation
- Analyse how the energy system design differs in Belgium and the Netherlands

How do designs of a fully renewable energy system in Belgium and the Netherlands differ if they are optimized to minimize the system cost and criticality of different battery sub-technologies in utility-scale energy storage systems?

Methodology

Battery Sub-Technologies

Criticality Factor

Energy system modelling framework (REMix)

Methodology – Sub-Technologies

Chosen sub-technologies:

- Lithium nickel cobalt manganese oxide (NMC-111)
- Lithium iron phosphate (LFP)
- Lead Acid
- Redox Flow

Techno-economic data for storage technologies:

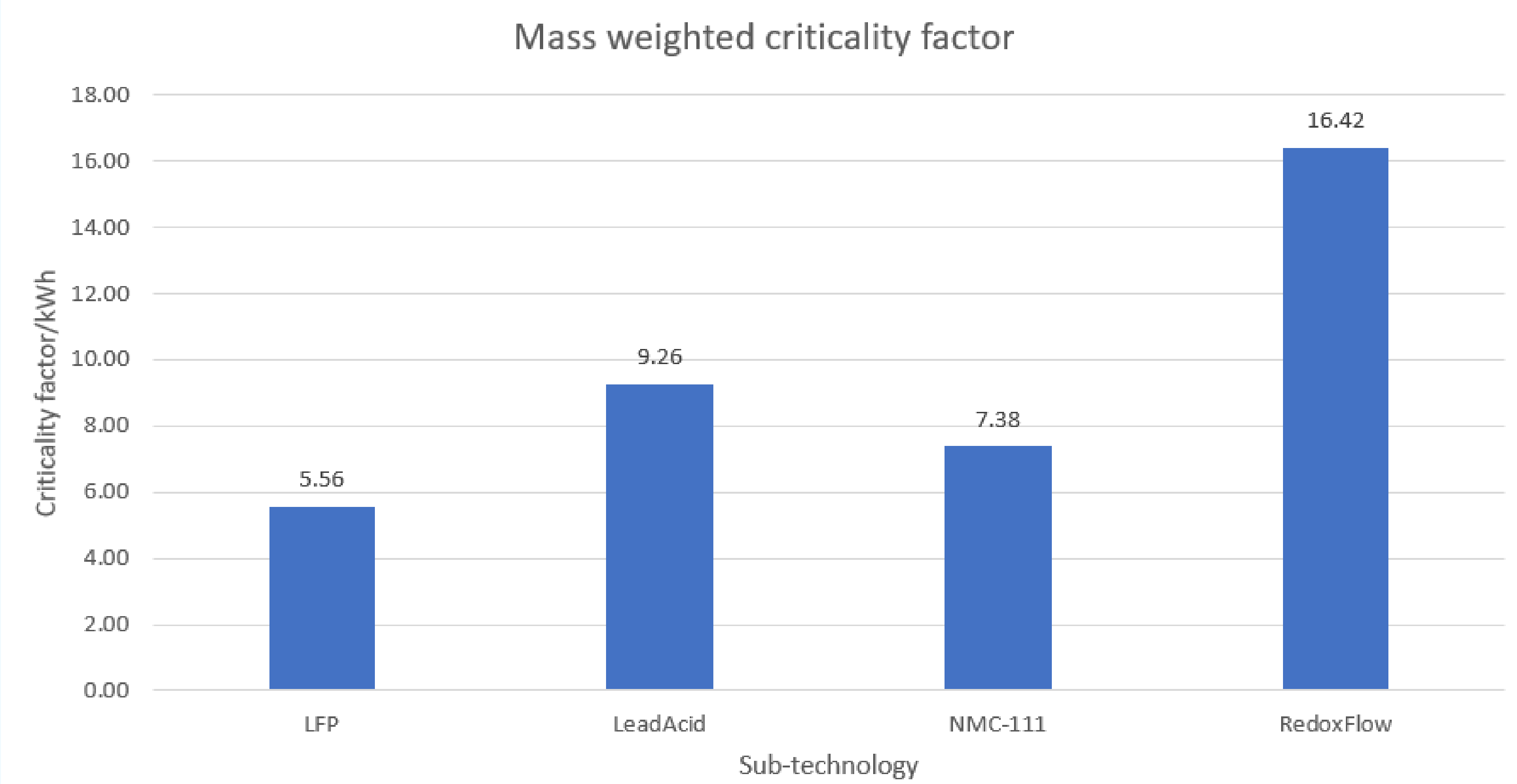
- Investment & Operation and Maintenance Cost
- Life time & Efficiency

Methodology – Criticality Factor

Criticality factor from MaTiC-M project

- Based on the Supply Disruption Probability (SDP) indicator from EU methodology

Mass weighted criticality factor on a technology level



Mass weighted criticality factor for chosen sub-technologies in 2023

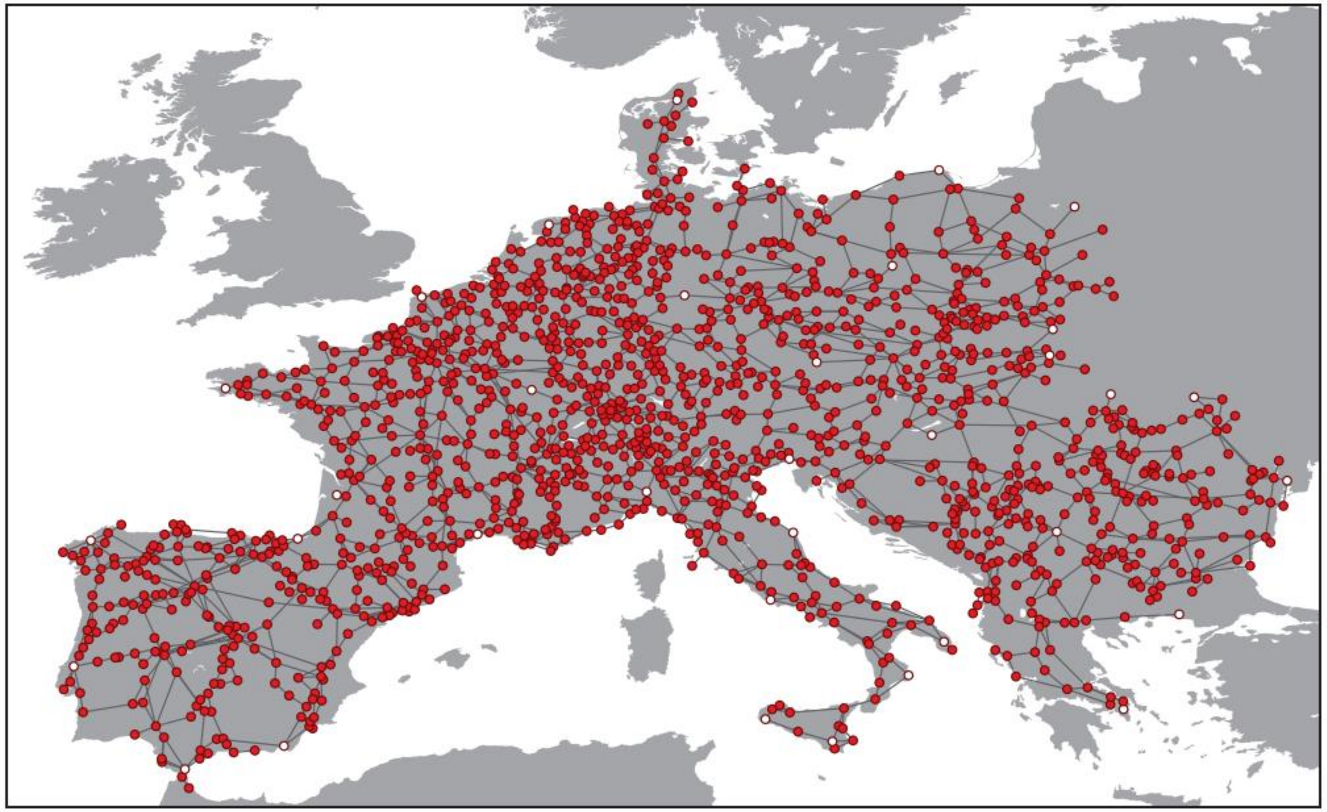
Methodology – REMix

- Large-scale, publicly available data set aimed at modelling renewable European electricity systems

- Simplified representation of Belgium and the Netherlands

- Electricity solely from solar photovoltaic and wind turbines

- Possibility of electricity import from outside the modelled system



Map of Network Nodes and Transmission Lines of Original Dataset

Methodology – REMix

Two indicators for the multi-objective optimisation:

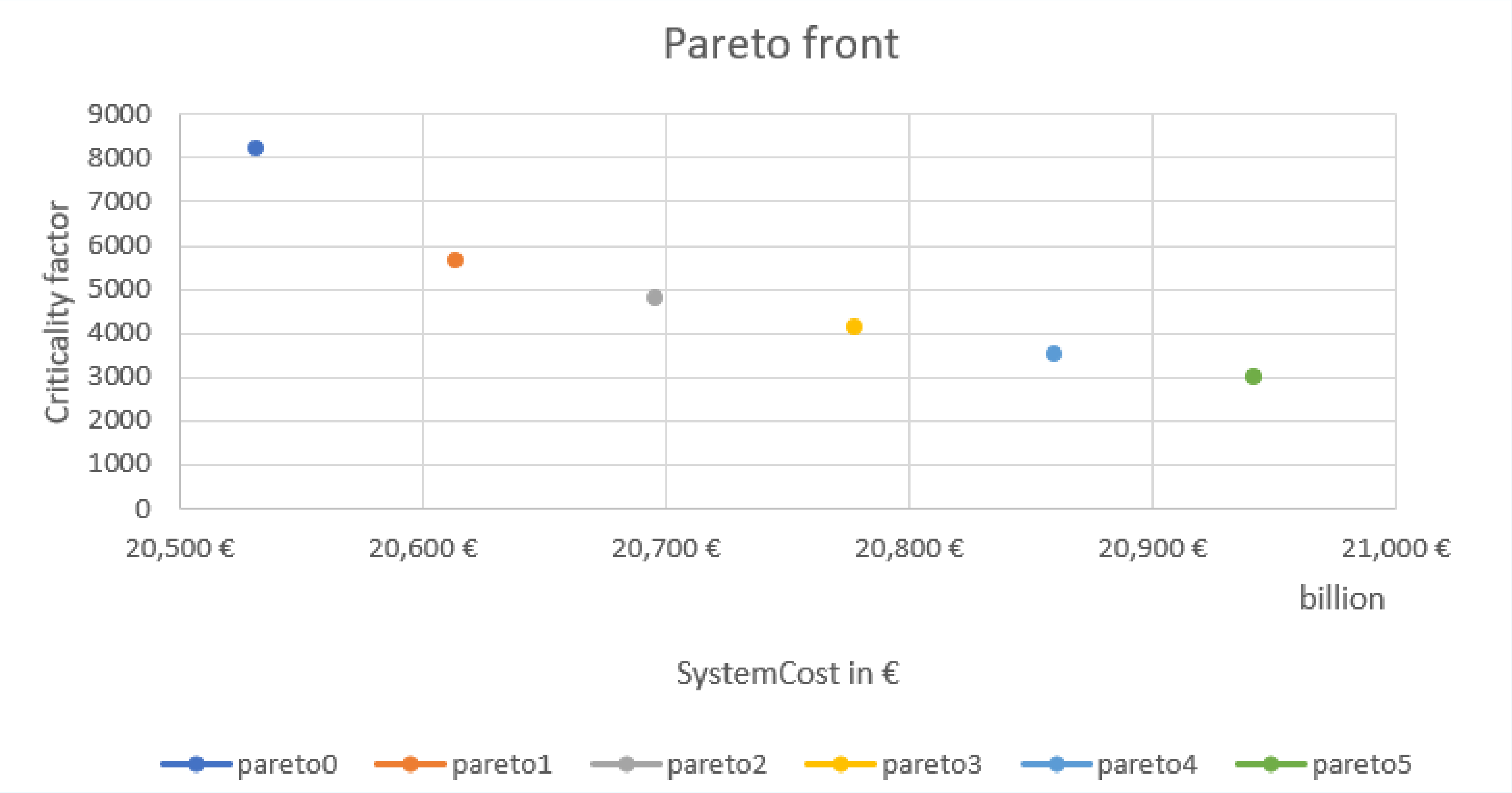
SystemCost	Criticality
1. Investment cost 2. Maintenance & Operation cost 3. Electricity import	1. Criticality factor

REMix built-in pareto method:

- 5 pareto points and a pareto factor of 1.02

1. Base scenario (cost optimisation)
2. Criticality scenario (multi-objective optimisation)

Results

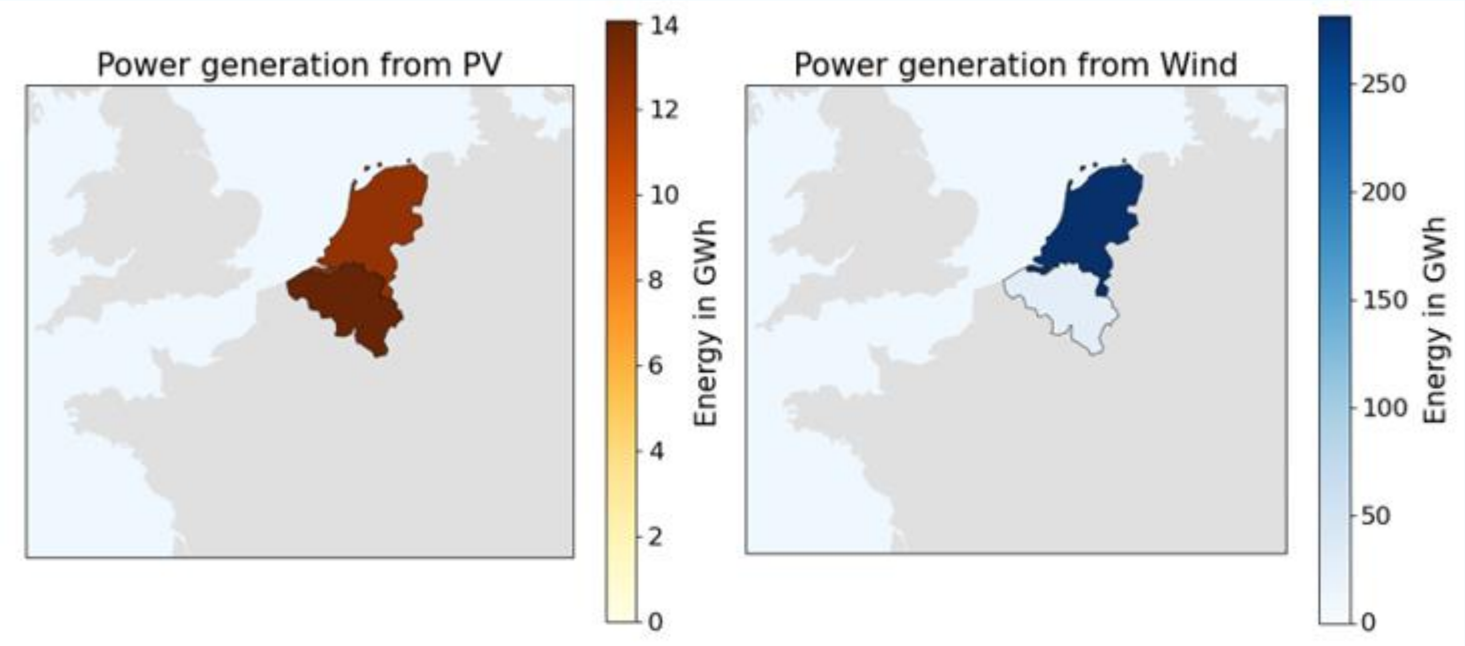


Pareto front of the results of the criticality scenario

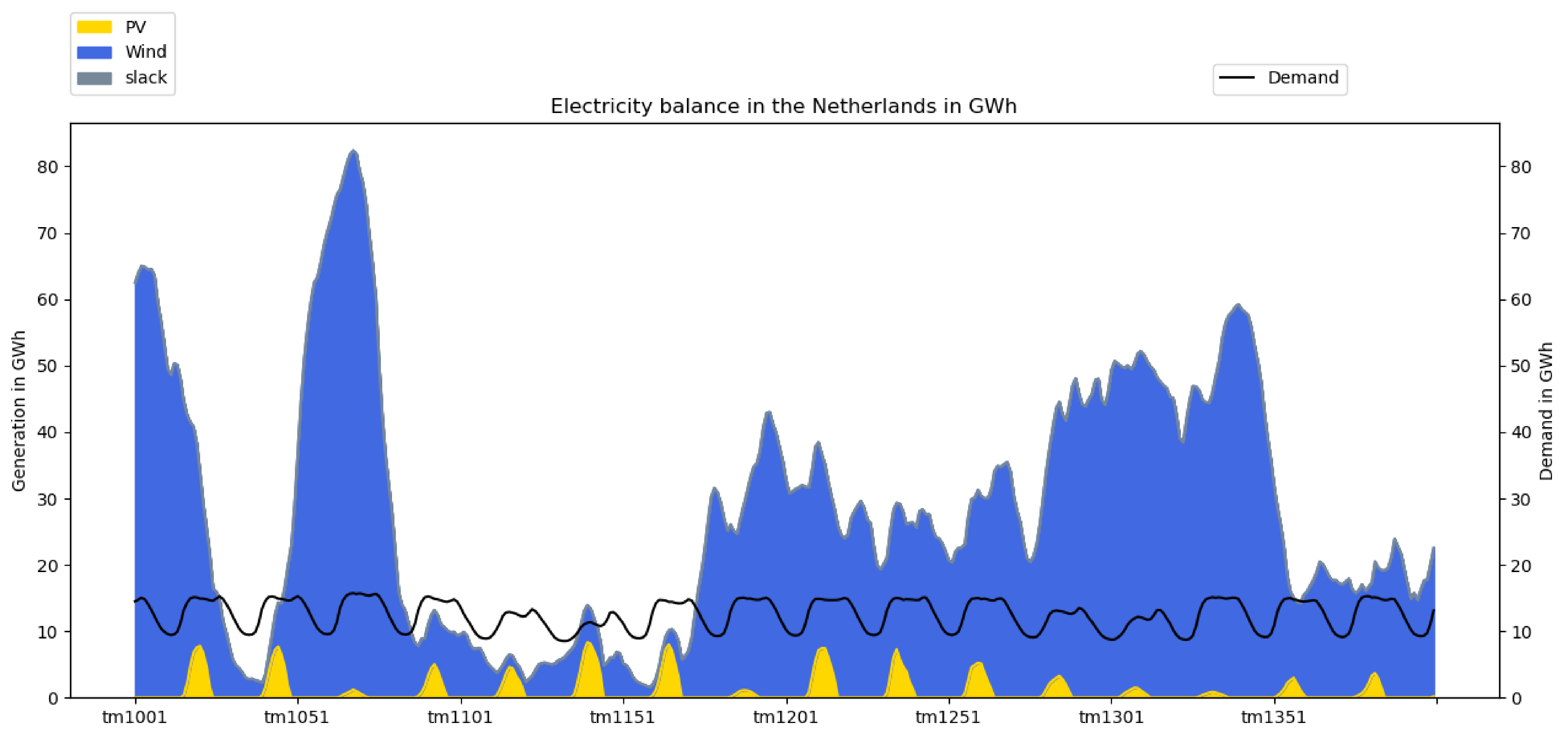
Results – Base Scenario

- Composition of SystemCost varies between Belgium and the Netherlands

Belgium	The Netherlands
- Electricity Import	- Investment in wind turbines and storage technologies

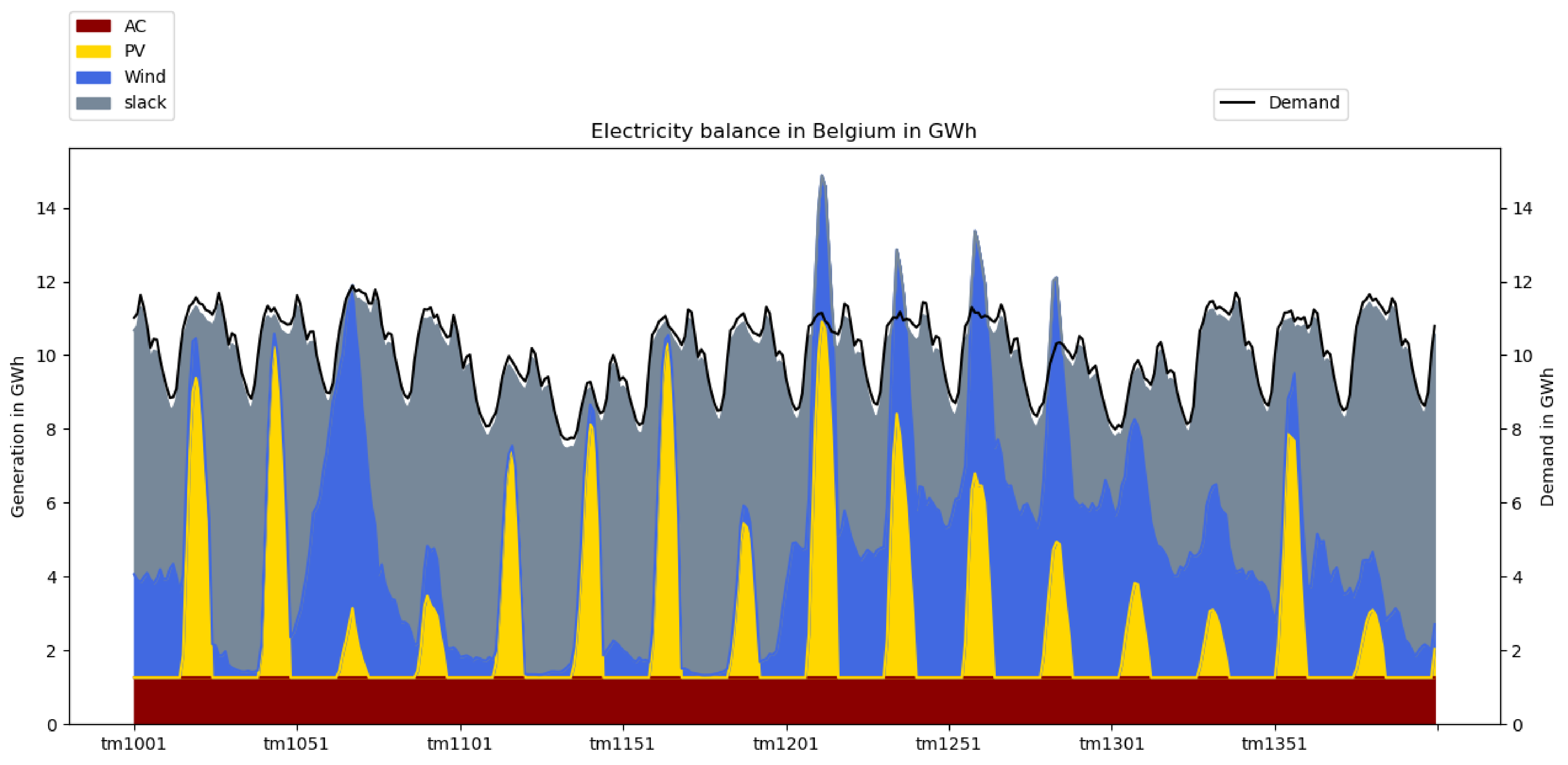


Results – Base Scenario



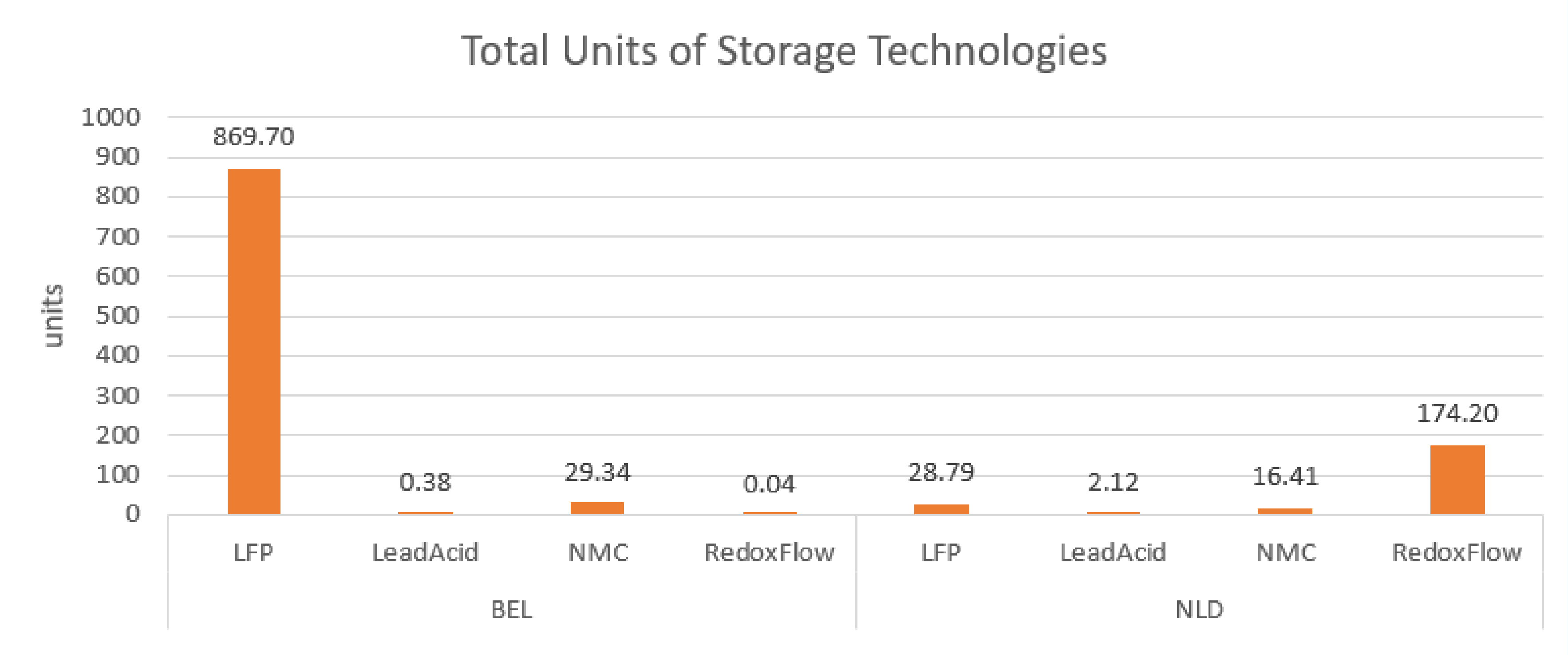
Electricity Balance in the Netherlands between 11.02.2013 15:00:00 until 28.02.2013 07:00:00

Results – Base Scenario



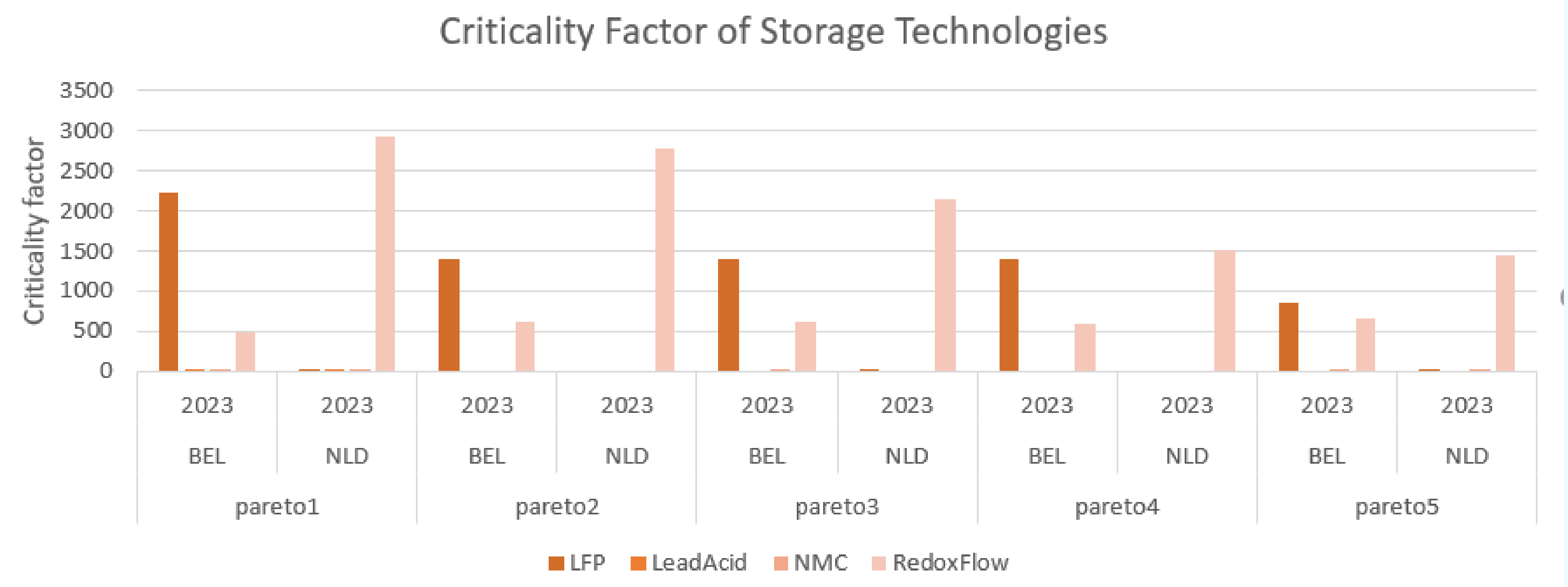
Results – Base Scenario

- High share of Redox Flow in NL relates to high share of wind power
- Less expensive LFP in BEL due to less intermittency by renewable energy sources

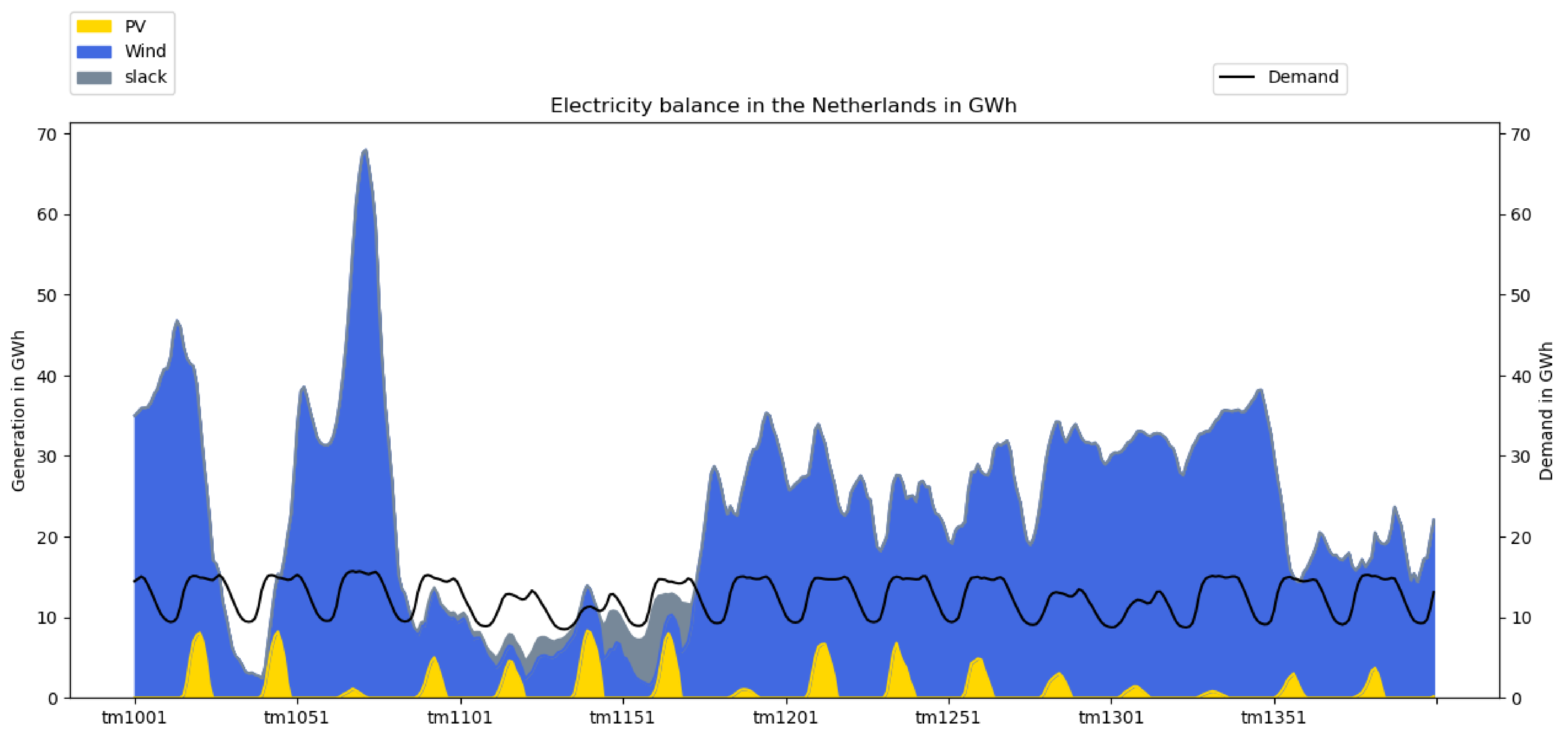


Results – Criticality Scenario

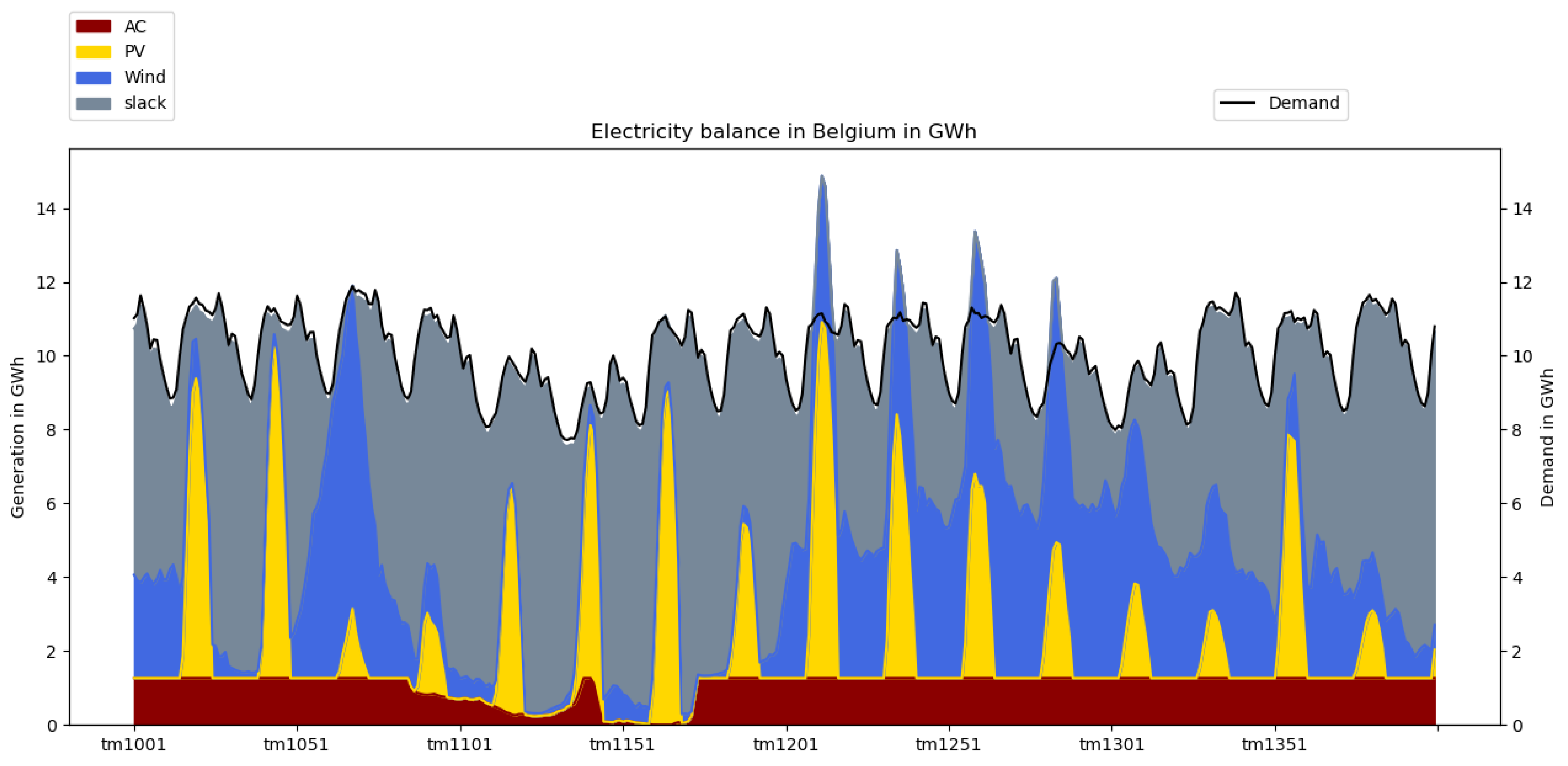
- The decrease in criticality results from the decrease in storage capacity
- The increase in cost results from the increase in electricity import needed to substitute the reduced storage capacity



Results – Criticality Scenario

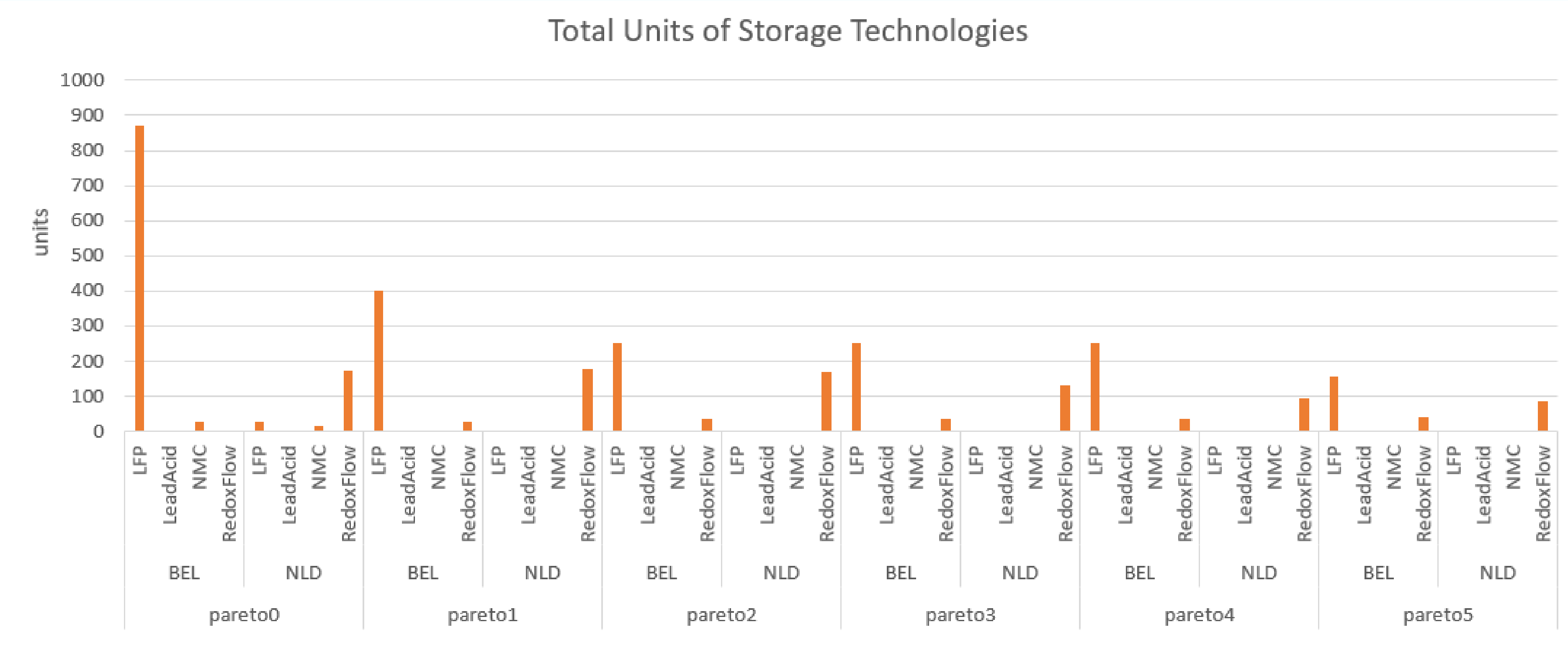


Results – Criticality Scenario



Results – Criticality Scenario

- Total number of storage units decreased in both countries
- Shift from LFP to Redox Flow batteries in BEL



Discussion

Criticality factor	Sub-Technologies	Proof of Concept

▪ Limitations to the calculation of criticality factor
▪ Other methodologies with different focus points
	▪ Current market distribution among battery types
	▪ Promising new technologies, e.g. sodium-ion batteries
		▪ Immense upscaling potential
		  ▪ European model
		  ▪ Technological scope
		  ▪ Pareto implementation

Conclusion

Implementation of a criticality factor for one technology has an effect on the design of the energy system

Reduction of storage capacity to reduce criticality

Changes in the choice of sub-technology due to characteristics of battery

Substitution with other technologies due to missing implementation of criticality

A first approach at considering criticality in energy system modelling with many potential expansions