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Energy and Reserve Markets:

Interdependent in a High-RES World

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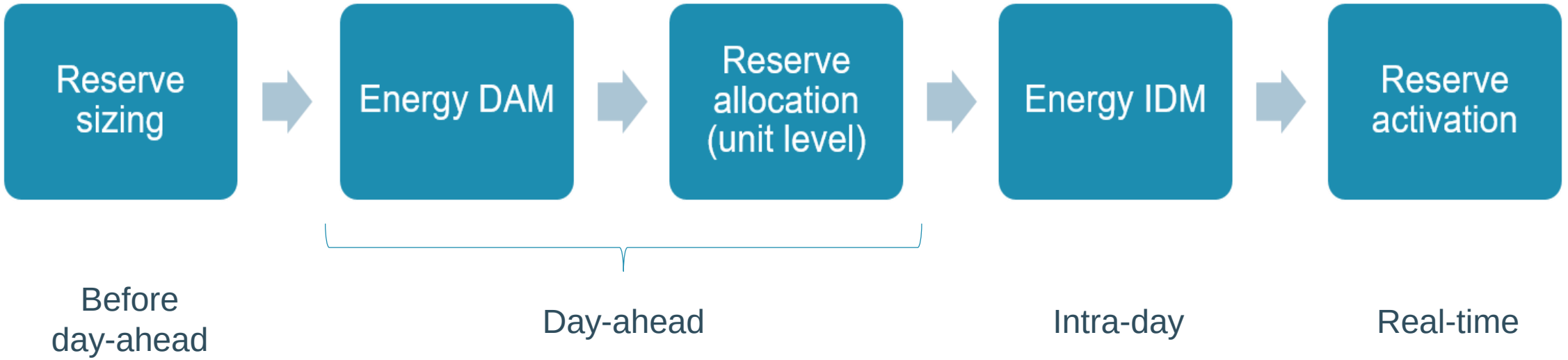
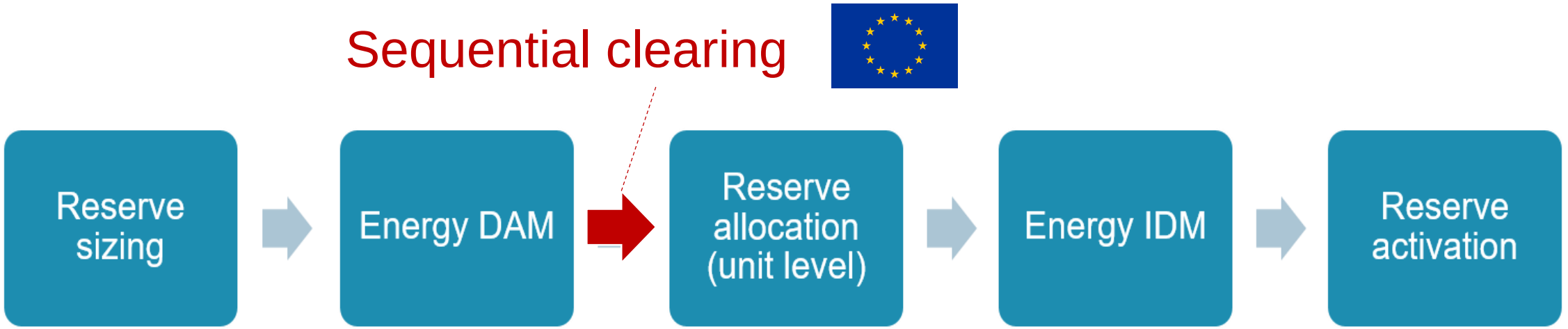
Agenda

1. **Research question**
2. **Methodology**
3. **Results**

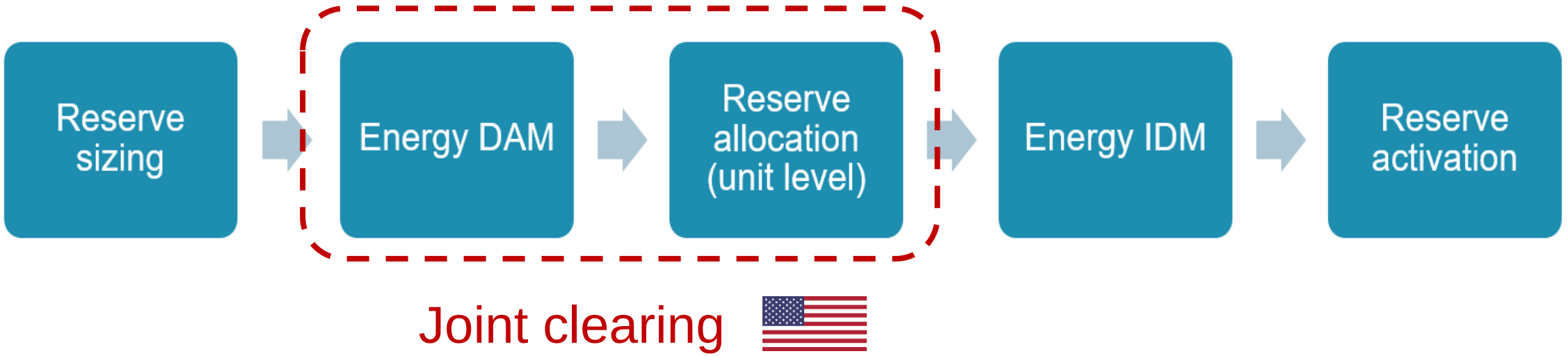
Energy and reserve markets run from before day-ahead until real-time



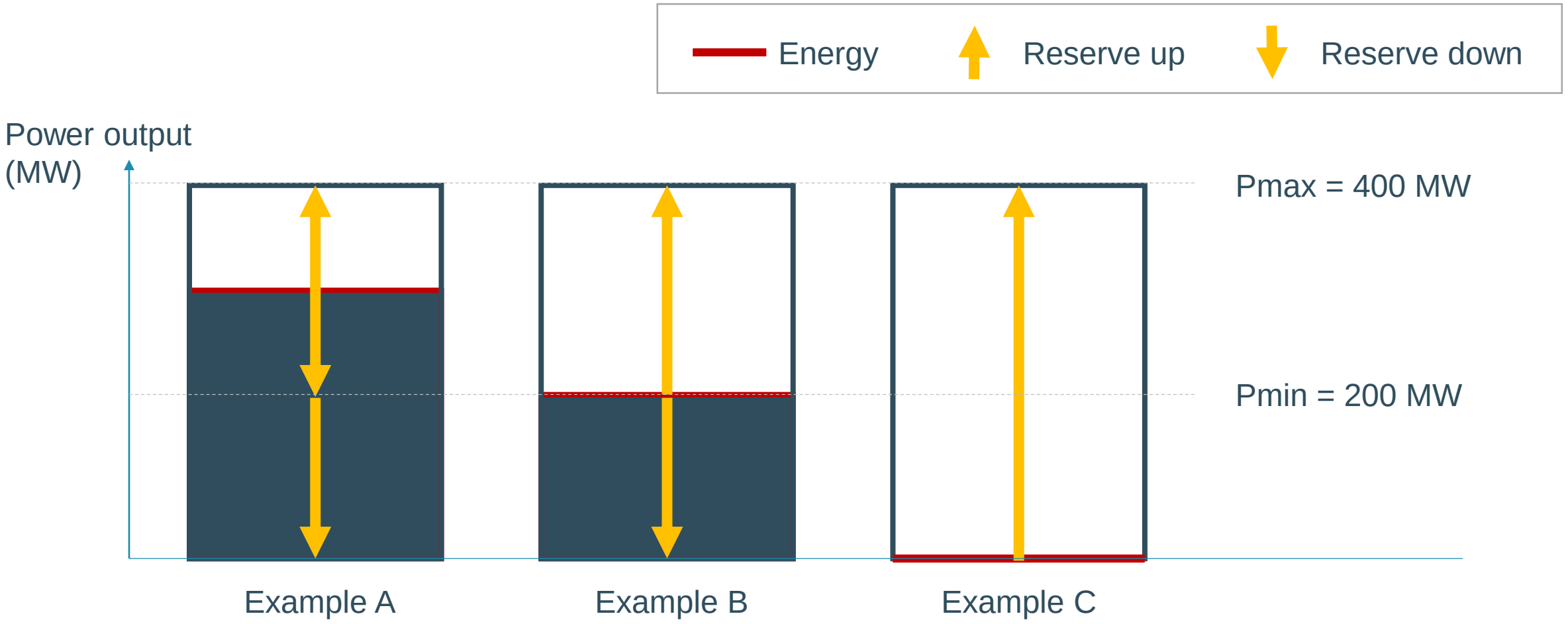
Energy and reserve scheduling can happen sequentially…



… or energy and reserve scheduling can happen jointly



Scheduling of energy and reserves are interdependent: example of a CCGT



Research question

How does the **interdependency of energy and reserve markets** change with

increasing shares of intermittent renewable (wind and solar PV)?

Agenda

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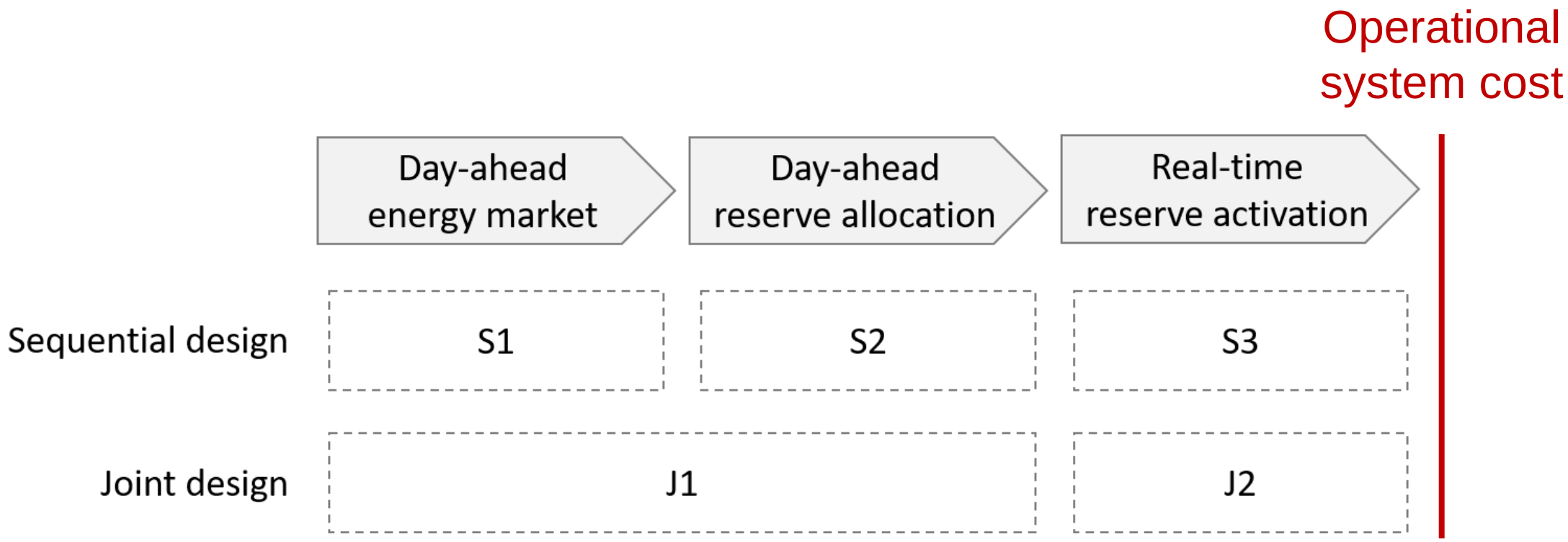
We optimize the operational system cost of sequential and joint market clearing with a unit commitment model



Overview of the framework, consisting of 3 market phases (energy market, reserve allocation and reserve activation) and 2 market designs (sequential and joint design), with 5 different model runs

We consider a future scenario of Central Western Europe as case study (Energy Transition)

	Current System	Energy Transition
Load		
Annual (TWh)	1 177	1 241
Peak (GW)	200	238
Installed capacity (GW)		
Nuclear	79	60
Lignite	21	12
Coal	34	33
CCGT	62	53
OCGT	7	6
ICE	11	3
Hydro & Bio	44	44
Wind	68	115
Solar PV	52	99
Fuel prices (€/MWh)		
Coal	9	16
Gas	17	25
Oil	55	74
CO2	18	27

Overview of the considered scenario for the Central Western European power system.

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Three main insights

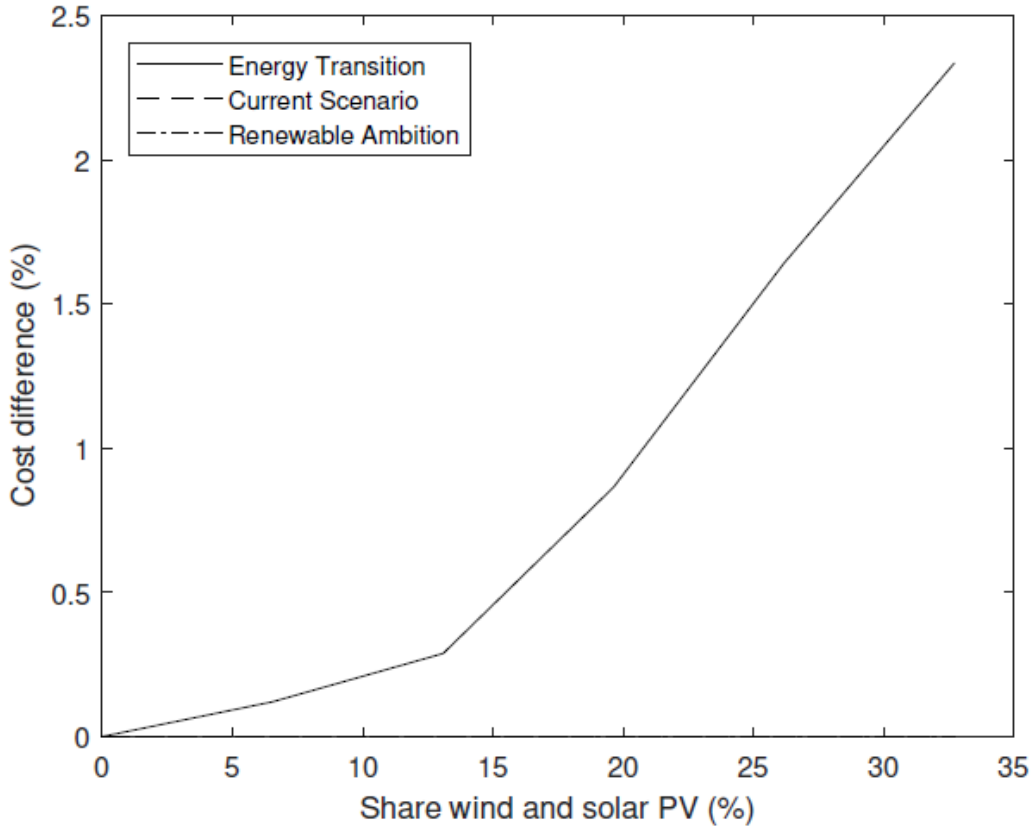
1. The **additional cost of sequential energy-reserve markets increases** (more than linearly) with increasing wind and solar PV.

2. This increase in cost for reserves can be largely offset by further **opening up reserve markets for renewables and load.**

3. There is a **cost related to not acting or acting too late**.

1

Additional cost of sequential energy-reserve markets increases (more than linearly) with increasing wind and solar PV…



Difference in operational system costs between sequential and joint energy-reserve clearing, for different shares of wind and solar PV (cost evaluated for a full year after real-time phase, Energy Transition)

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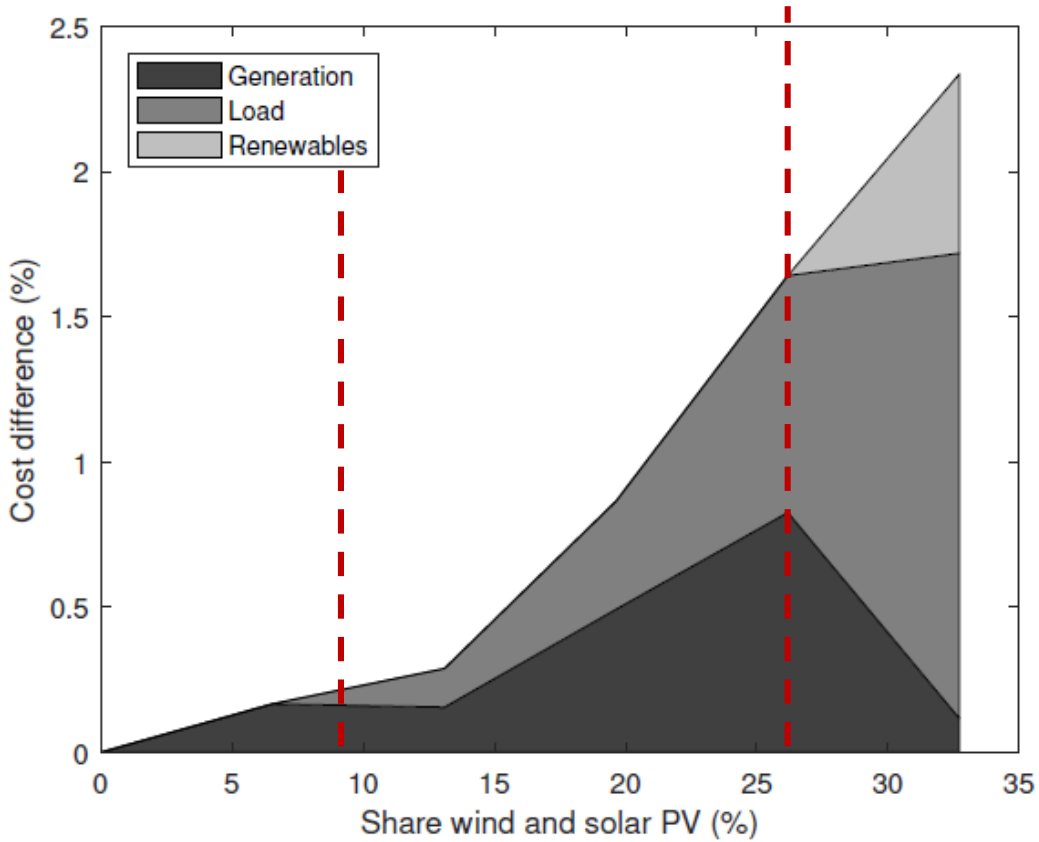
1

… caused by the use of more expensive reserves from generation, load and renewables



Drivers of difference in operational systems costs between sequential and joint energy-reserve clearing in the Energy Transition scenario, for different shares of wind and solar PV (cost for a full year after real-time phase).

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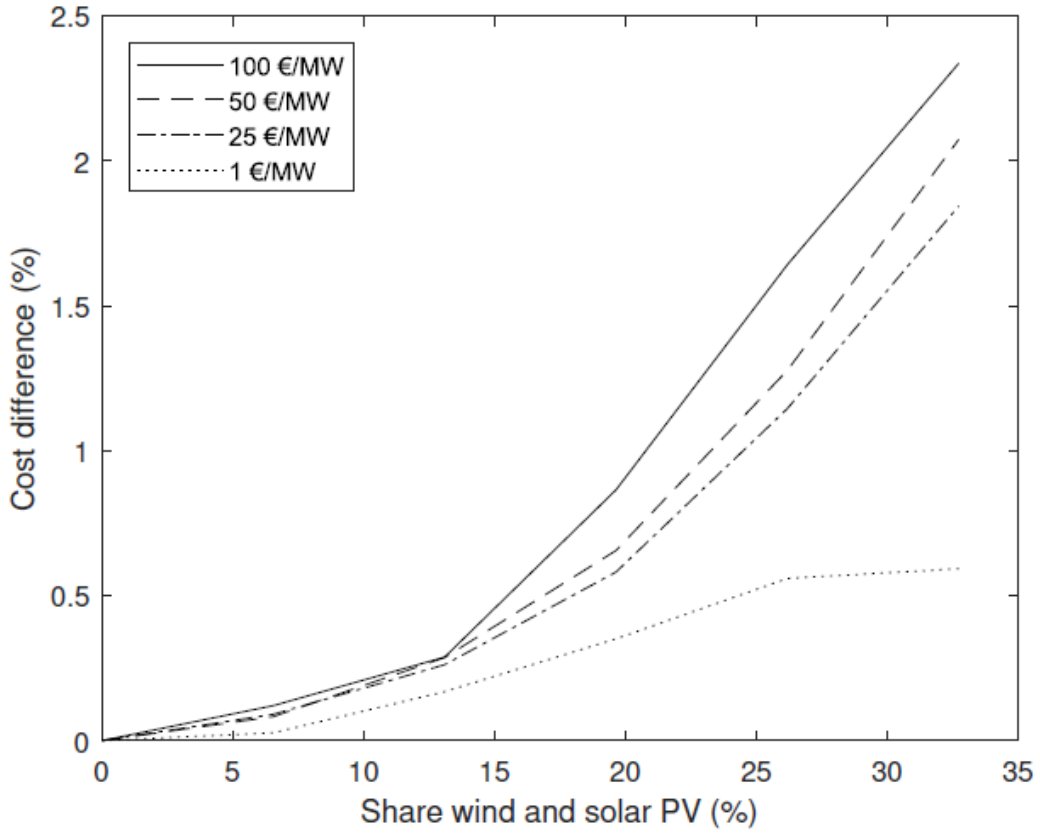
2

This increase in cost for reserves can be largely offset by further opening up reserve markets for renewables and load



Difference in operational system costs between sequential and joint energy-reserve clearing in the Energy Transition scenario, for different shares of wind and solar PV and different levels of allocation costs for load and renewables.

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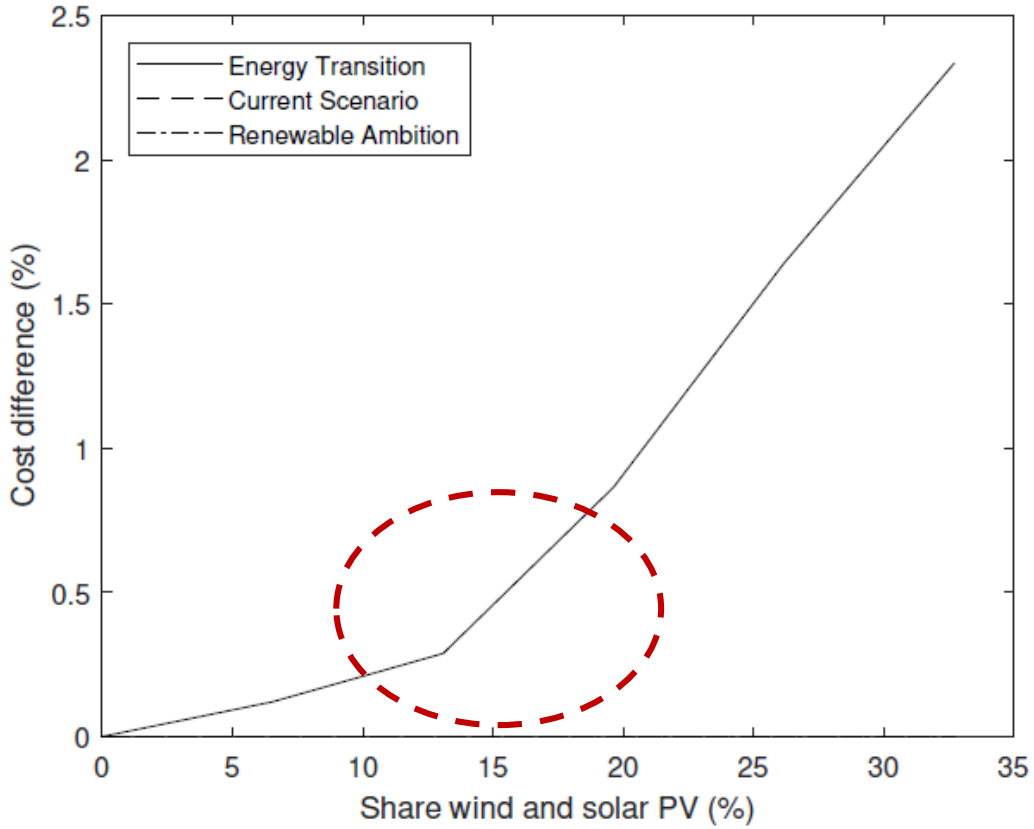
3

There is a cost related to not acting or acting too late.



Difference in operational system costs between sequential and joint energy-reserve clearing, for different shares of wind and solar PV (cost evaluated for a full year after real-time phase, Energy Transition)

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Recap – Three main insights from analysis

1. The **additional cost of sequential energy-reserve markets increases** (more than linearly) with increasing wind and solar PV.

2. This increase in cost for reserves can be largely offset by further **opening up reserve markets for renewables and load.**

3. There is a **cost related to not acting or acting too late**.

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