Integration Costs of Variable Renewable Energy Technologies in European Energy Systems

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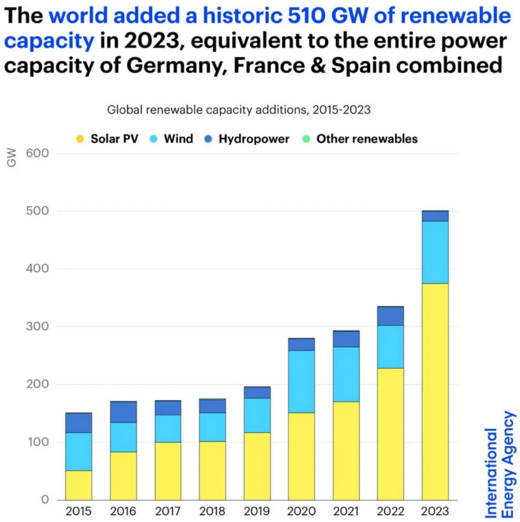
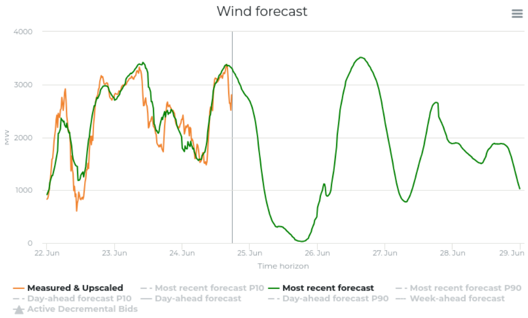
Introduction

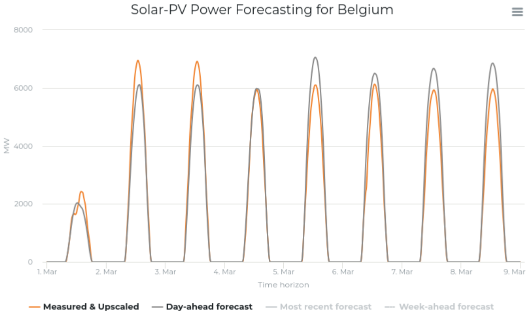
Introduction



Introduction

Characteristics of VRE technologies! Uncertainty and Variability



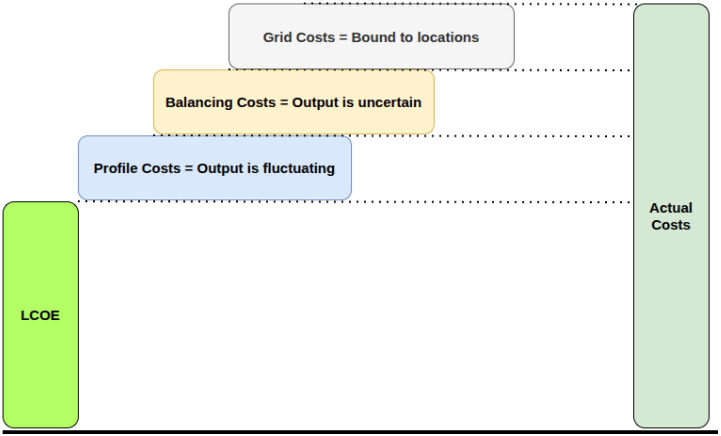


A perfect forecast eliminates uncertainty, but variability remains

Courtesy: Elia Dashboard

Introduction

Integration costs: the additional system cost when integrating VRE



Addapted from Ueckerdt et al. 2013

Introduction
challenges of managing the variability and uncertainty of VRE

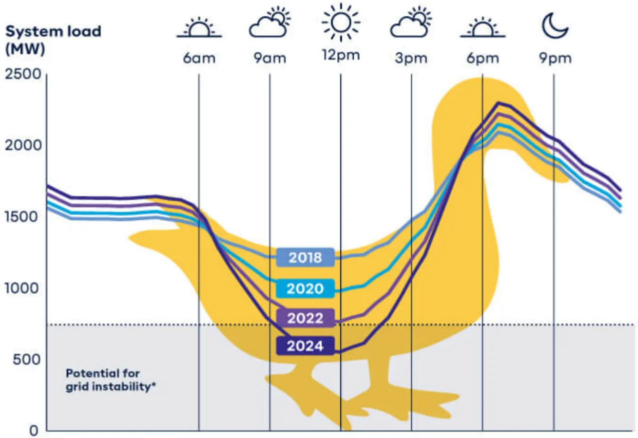
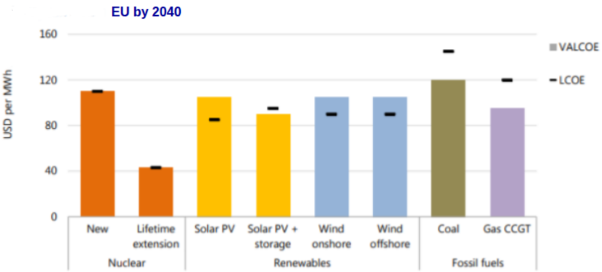


Image credentials: Jens C Thomsen

Introduction

IEA- VALCOE: Assessing the true economic competitiveness of technologies

$$VALCOE_x = LCOE_x + \overbrace{\overbrace{[\bar{E} - E_x]}^{Energy\ value} + \overbrace{[\bar{C} - C_x]}^{Capacity\ value} + \overbrace{[\bar{F} - F_x]}^{Flexibility\ value}}^{Value\ adjustments}$$



A simplified economic model, not a full system analysis tool.

Image credentials: IEA

Methodology

Objective

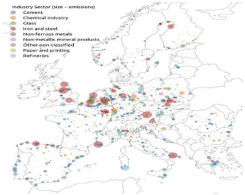
Compute the integration costs in a simple and straightforward way!

Utilize an energy system model

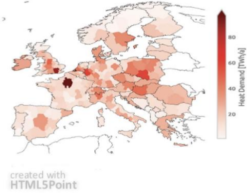
Image credentials: IEA

PyPSA-Eur

Industrial sector model

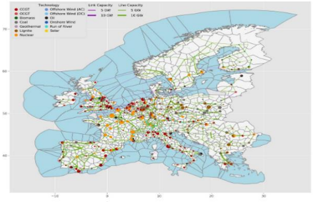


Heat demands

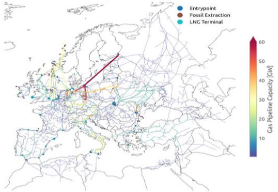


Workflows and scripts to extract all demands, generation, potentials, costs, ...

Existing grid and power plants



Detailed gas grid model



Hourly time series

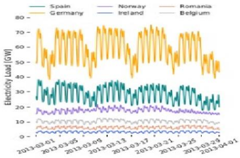
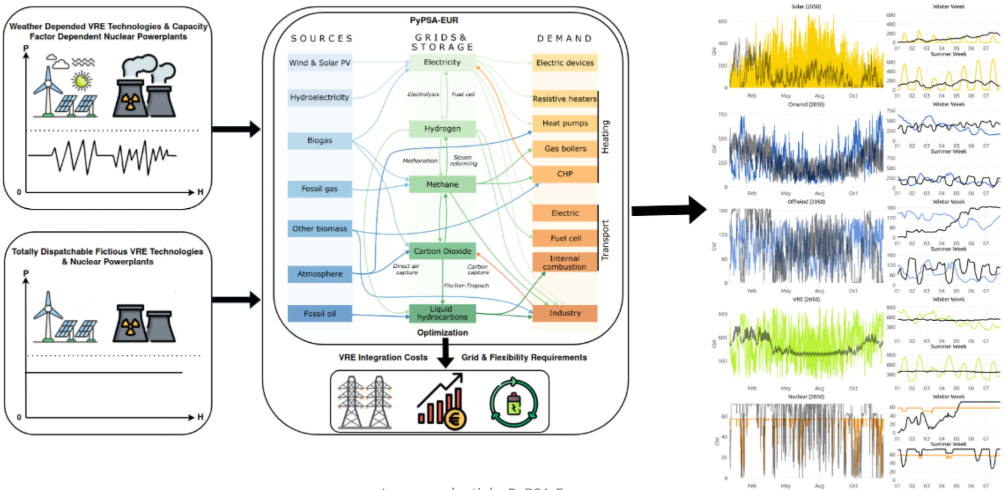


Image credentials: PyPSA-Eur

Methodology



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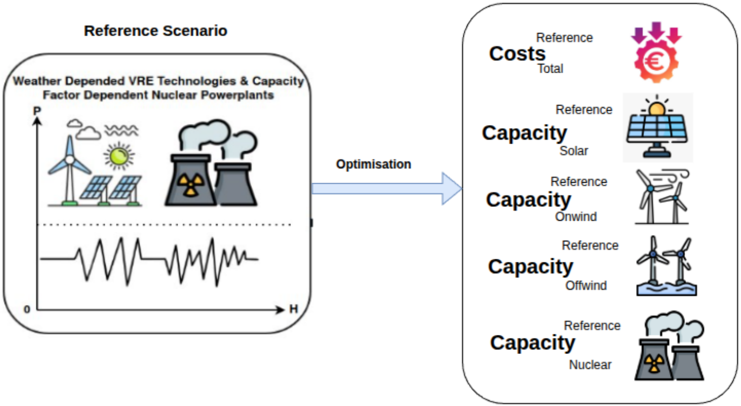
Methodology

Reference scenario computes the total annualised system costs and optimised capacities of renewable technologies



Methodology
Example: Solar integration costs

Equal Capacities

$$\text{Capacity}^{\text{Flexible solar}}_{\text{Solar}} = \text{Capacity}^{\text{Reference}}_{\text{Solar}}$$

$$\text{Capacity}^{\text{Flexible solar}}_{\text{Onwind}} = \text{Capacity}^{\text{Reference}}_{\text{Onwind}}$$

$$\text{Capacity}^{\text{Flexible solar}}_{\text{Offwind}} = \text{Capacity}^{\text{Reference}}_{\text{Offwind}}$$

Generation Constraints

$$\sum_{i,t} \text{Generation}^{\text{Flexible solar}}_{i,t} \leq \sum_{i,t} \text{Generation}^{\text{Reference}}_{i,t}$$

Modified Capacity Factor

$$0 \leq \text{Capacity Factor}_{\text{Solar}} \leq 1$$

Methodology
Example: Solar integration costs

$$\text{Costs}_{\text{Total}} = \text{Costs}^{\text{Reference}}_{\text{Total}} - \text{Costs}^{\text{Flexible solar}}_{\text{Total}}$$

$$\text{Integration Costs}_{\text{Solar}} = \frac{\text{Costs}_{\text{Total}}}{\sum_{i,t}^{\text{Flexible solar}} \text{Generation}_{i,t}}$$

$$\text{LCOE}^{\text{Adjusted}}_{\text{Solar}} = \text{LCOE}_{\text{Solar}} + \text{Integration Costs}_{\text{Solar}}$$

Scenarios

Scenario: net-zero by 2050

4 technologies considered for the integration cost assessment

Considered Nodes: BE, FR, NL, GB, DE

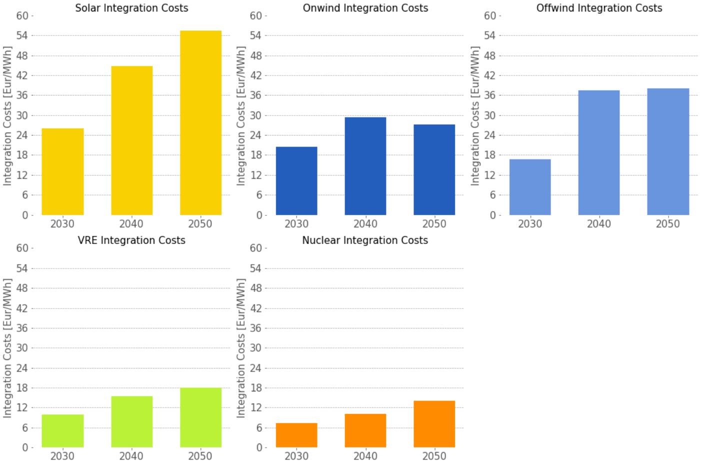
Optimisation: Greenfield

Configuration:

- Carbon budget: 2030 (–55%), 2040 (–85%), 2050 (net zero)
- Current demand projections + expected efficiency improvements
- Transmission lines espansion,max 50%
- Increased EV shares upto 85% by 2050
- CCS is allowed

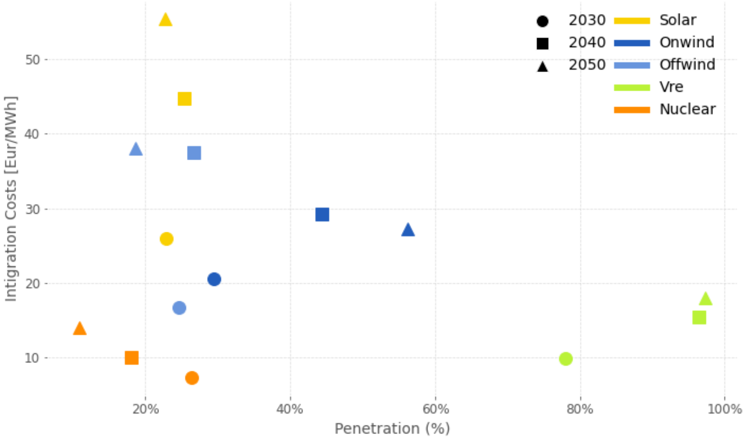
Results

Results
Integration costs

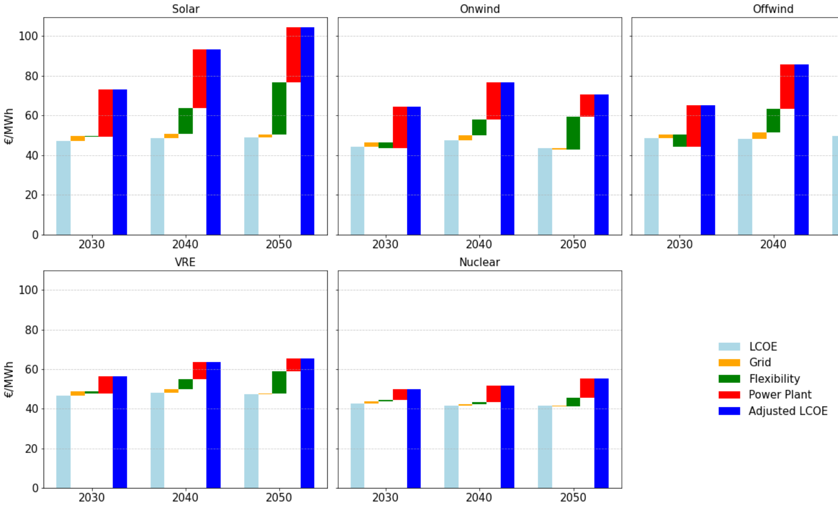


Results

Integration costs with penetration level in power system



Results
Distribution of integration costs



Conclusions

Conclusion

Conclusion:

- Integration costs computations can be made in a simple way using existing modeling tools.
- Solar integrations costs are 55 Euros/MWh compared to 13 Euros/MWh for nuclear by 2050.
- Complementarity and the diversity of different renewable energy sources; when combined, integration costs remain marginal even above 80% penetration.

Thank You!