RUB

RUHR-UNIVERSITÄT BOCHUM

Are renewables profitable across Europe in 2030?

An analysis of market-based profitability in a central-planning least-cost system

Jonas Finke, Valentin Bertsch, Valeria Di Cosmo __ 27.09.2022 __ INREC 2022__ jonas.finke@rub.de

Chair of
Energy Systems &
Energy Economics

Introduction

Motivation

- **Energy transition** with political targets and various measures across EU
- **National Energy and Climate Plans** (NECPs) aim at 2030

- **Energy system models** support decisions, often central planning of least-cost systems
- However: **private-sector investments** and **profitability** needed
  - Internal rates of return (IRRs) or net present values (NPVs)
  - Driven by costs, revenues → natural resources, market values → system design
- System design **unknown** and **uncertain**

➢ Cannot assess profitability against some **static system “background”**,
but do endogenous investment planning and profitability assessment together

Existing literature & research questions

Existing literature:

- **Technology mix** in least cost systems, e.g. [1,2]
- **Economic viability**, but not profitability (IRR, NPV), e.g.
  - levelised cost of electricity [3]
  - market values [4,5]
  - uncovered costs [6]
- **Profitabilty** with static prices and tariffs, e.g. [7,8]

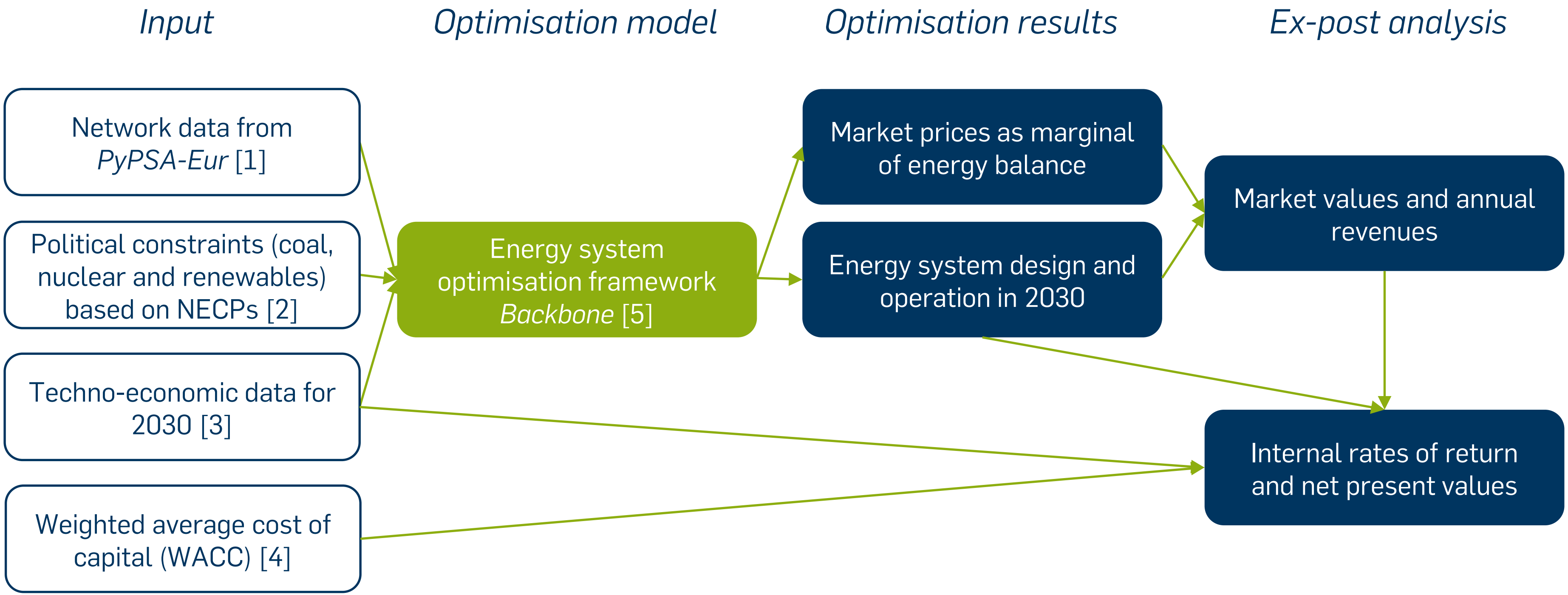
Research questions:

- Are renewables **profitable in 2030 across Europe** based on current **expansion plans**?
- What **drives their profitability**, especially through indirect effects via the system design?

[1] Zappa et al., *Is a 100% renewable European power system feasible by 2050?*, Applied Energy 2019.
[2] Zappa et al., *Can liberalised electricity markets support decarbonised portfolios in line with the Paris Agreement? A case study of Central Western Europe*, Energy Policy 2021.
[3] Kost et al., *Levelised Cost of Electricity – Renewable Energy Technologies*, 2021.
[4] Ruhnau et al., *Heating with wind: Economics of heat pumps and variable renewables*, Energy Economics 2022.
[5] Böttger and Härtel, *On wholesale electricity prices and market values in a carbon-neutral energy system*, Energy Economics 2022.
[6] Gillich and Hufendiek, *Asset profitability in the electricity sector: An iterative approach in a linear optimization model*, Energies 2022.
[7] Tu et al., *The profitability of onshore wind and solar PV power projects in China – A comparative study*, Energy Policy 2019.
[8] Lopez Prol and Steininger, *Photovoltaic self-consumption is now profitable in Spain: Effects of the new regulation on prosumers' internal rate of return*, Energy Policy 2020.

Method & data

Method overview

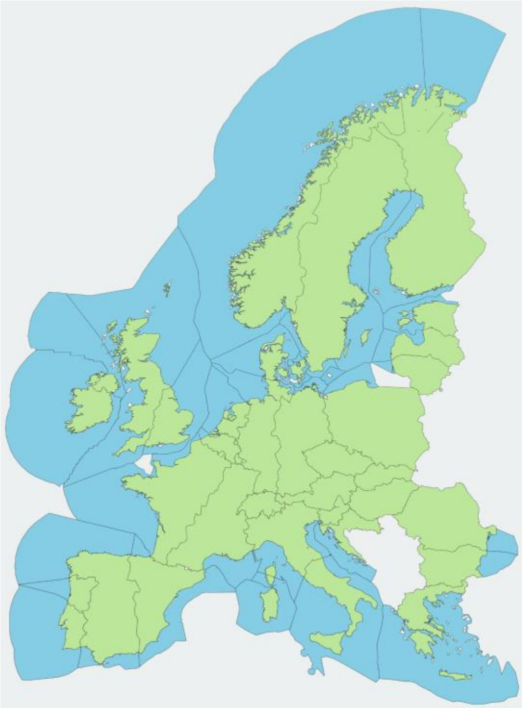


Scenarios are analysed across the whole chain, not with static system design

[1] Hörsch et al., *PyPSA-Eur: An Open Optimisation Model of the European Transmission System*, Energy Strategy Reviews 2018.
[2] National Energy and Climate Plans (NECPs) submitted to EU by member states, see https://ec.europa.eu/energy/topics/energy-strategy/national-energy-climate-plans_en
[3] Pietzcker et al., *Tightening EU ETS targets in line with the European Green Deal: Impacts on the decarbonisation of the EU power sector*, Applied Energy 2021.
[4] Steffen, *Estimating the cost of capital for renewable energy projects*, Energy Economics 2020.
[5] Helistö et al., *Backbone – An Adaptable Energy Systems Modelling Framework*, Energies 2019.

Step 1: Optimisation model

- EU + CH + NO + UK – CY – MT, 1-2 nodes per country
- One year, hourly resolution
- Demand profiles from 2018 scaled to 2030
- Coal and nuclear exits
- National renewable share targets (capacity-based formulation)
- Existing renewable capacities from 2019 [1]
- Minimum of 1 MW to allow computation of IRRs
- CO_2 price of 129 €/t



- Investment planning for solar PV, onshore & offshore wind, gas
- Minimise total system costs (invest, O&M, fuel, CO_2)

[1] IRENA, *Renewable capacity statistics 2020*, 2019.

Step 2: Ex-post profitability assessment

$$\text{market value} = \frac{\sum_t \text{generation}_t \cdot \text{price}_t}{\sum_t \text{generation}_t}$$

$$\text{annual revenue} = \sum_t \text{generation}_t \cdot \text{price}_t - \text{costs for O\&M, fuel, } CO_2$$

$$\text{IRR} = i \qquad \text{s.t.} \qquad \text{NPV} = \sum_{t \in T} \frac{1}{(1+i)^t} \text{CF}_t = 0$$

- Cash flows CF:
  Annual revenue for each year of lifetime
  plus investment in year 0
- Discount all cash flows
- Weighted average cost of capital (WACC)
  reflects country- and technology-specific risk

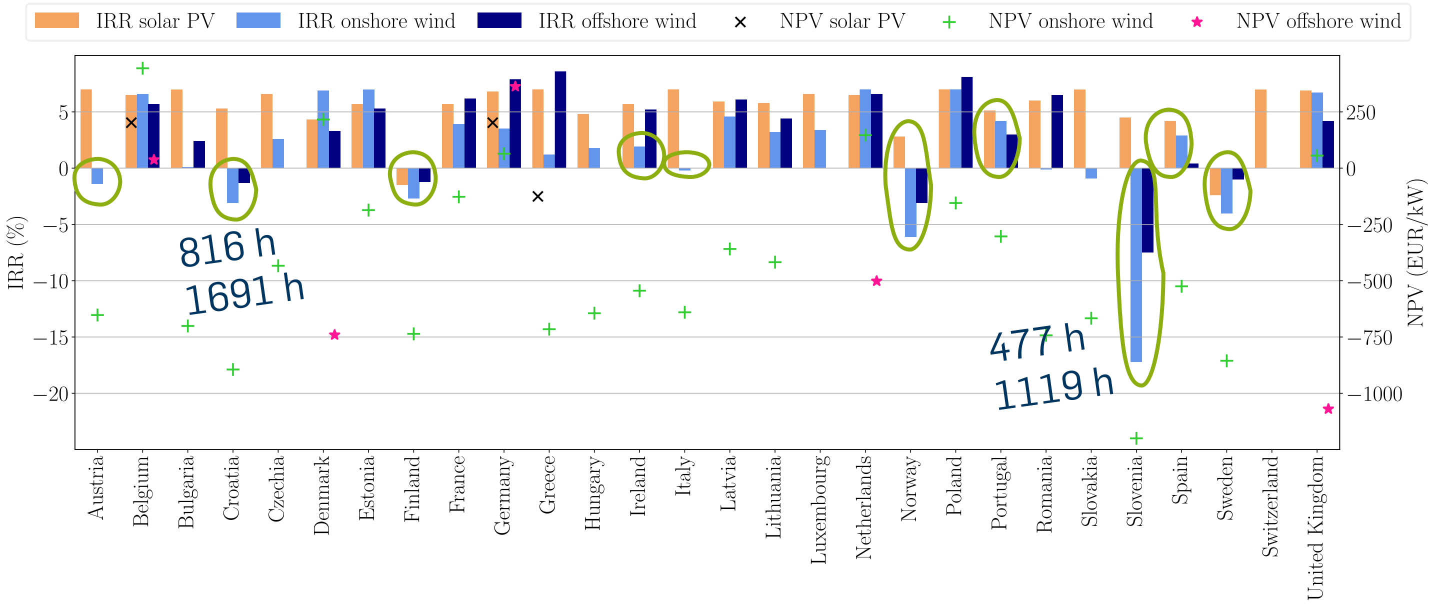
Results & discussion

Base scenario: IRRs and NPVs (1)

Group 1:
Low IRR and NPV for wind due to **natural resource conditions**

Group 2:
Low IRR and NPV due to **low relative market values**

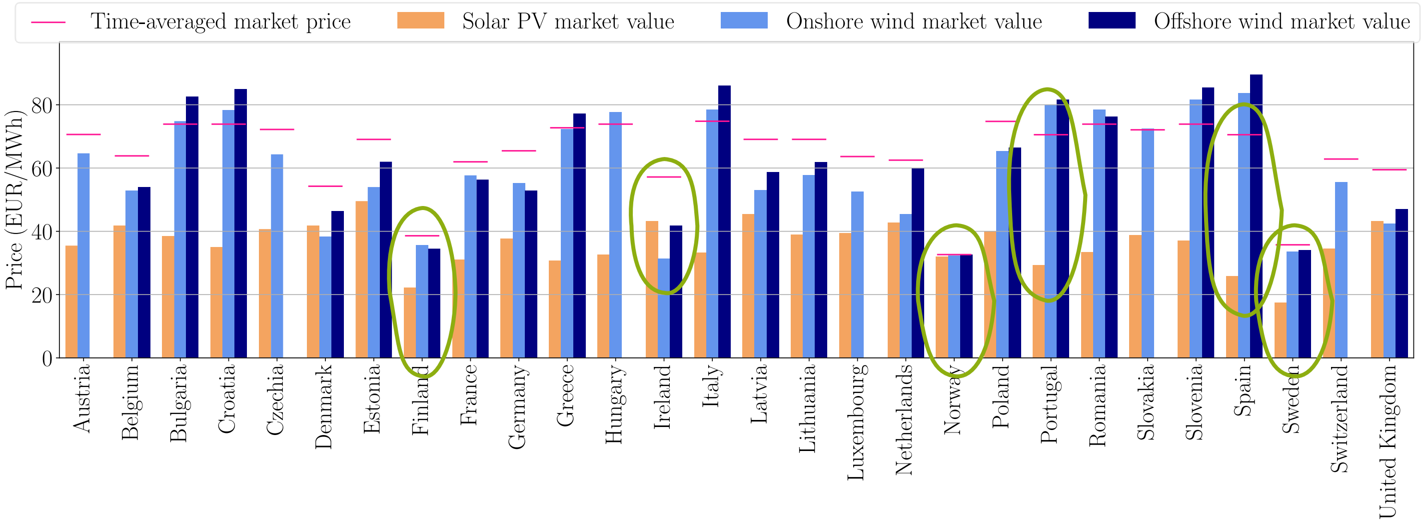
Group 3:
Low IRRs and NPVs due to **low market prices**



Base scenario: Market prices and values

Group 2:
Low IRR and NPV due to **low relative market values**

Group 3:
Low IRRs and NPVs due to **low market prices**



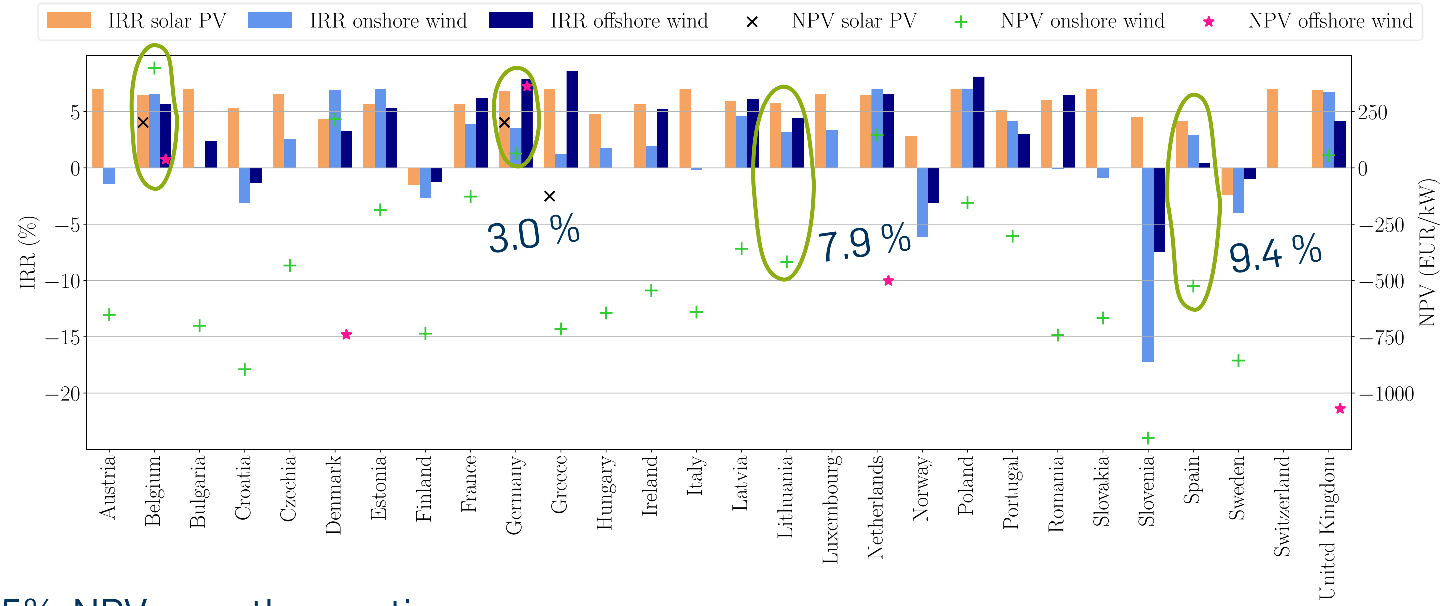
Base scenario: IRRs and NPVs (2)

Group 4:
High NPVs due to **high IRRs together with low WACC**

Group 5:
Positive IRR and negative NPV due to **high WACC**

Generally:

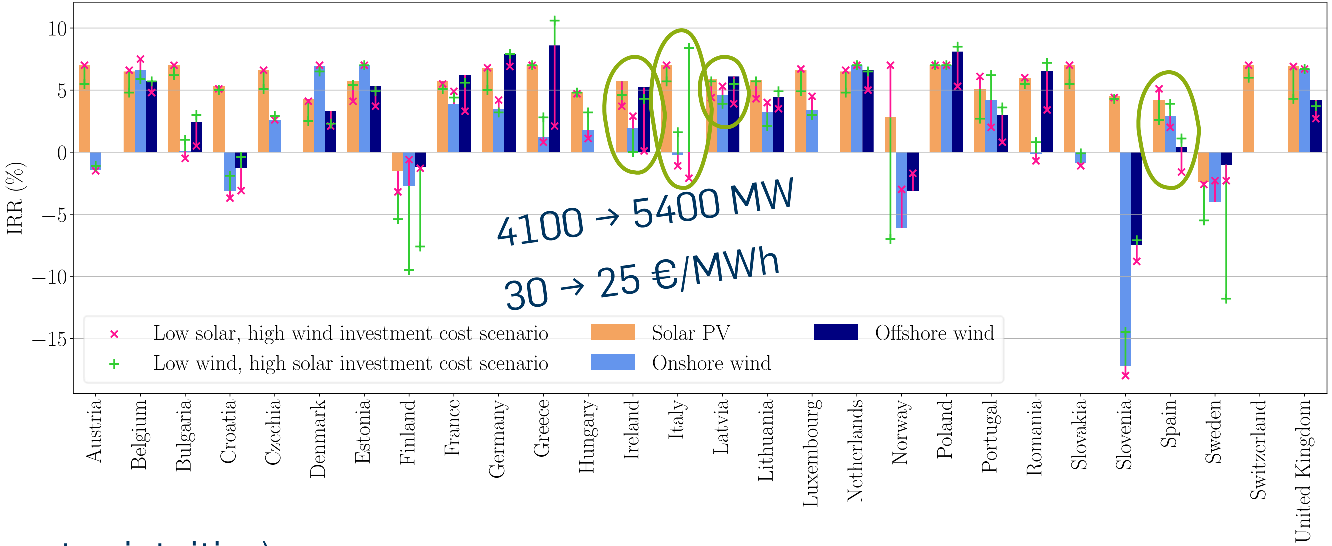
IRRs &NPVs well aligned



IRRs mostly around 5%, NPVs mostly negative

Scenario: renewable investment costs*

Intuitive effect: IRRs correlate **negatively** with investment cost (directly via IRR equation)



No or **opposite** effect (counter-intuitive):

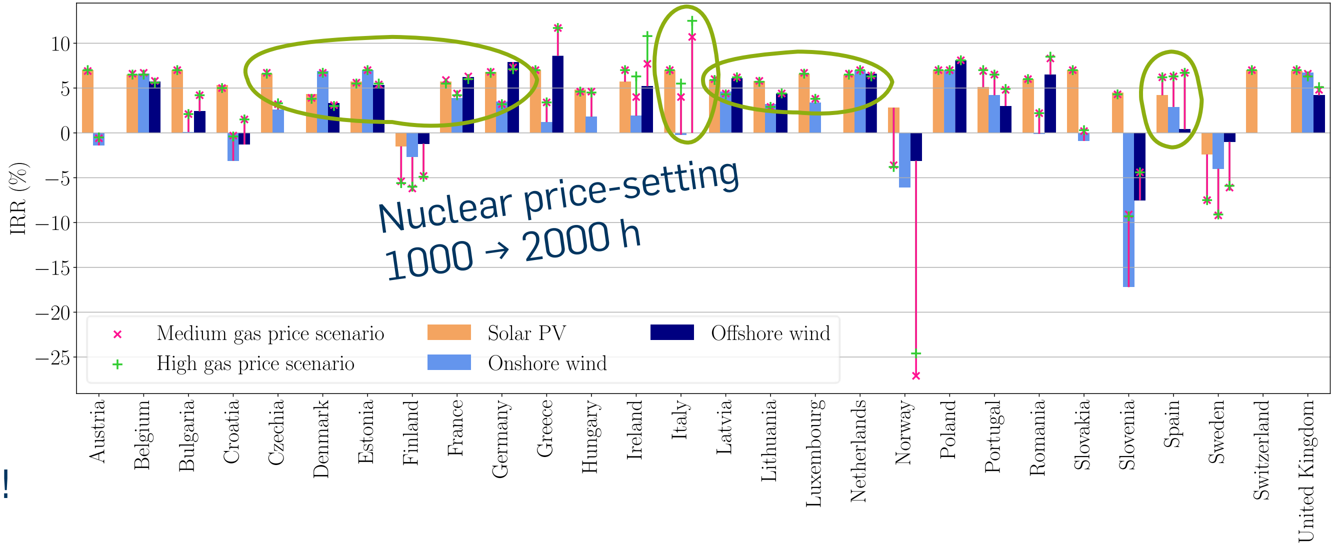
- Invest cost ↘, investment ↗, market value ↘ (*merit-order effect*), revenues ↘
- Market value can counterbalance or even overcompensate investment cost

* In the “Low solar, high wind (LSHW) investment cost” scenario, investment costs for solar PV is decreased and for wind is increased and in the “Low wind, high solar (LWHS) investment cost” scenario vice versa. The respective values are from the same source, but are the values for the years 2020 and 2040 for higher and lower cost, respectively.

Scenario: gas price of **25**, 50, 100 €/MWh

Intuitive effect:
IRRs correlate **positively** with gas price (via marginal cost of price setting gas units)

Difference between medium and high gas price: gas **substituted** completely or partially?!



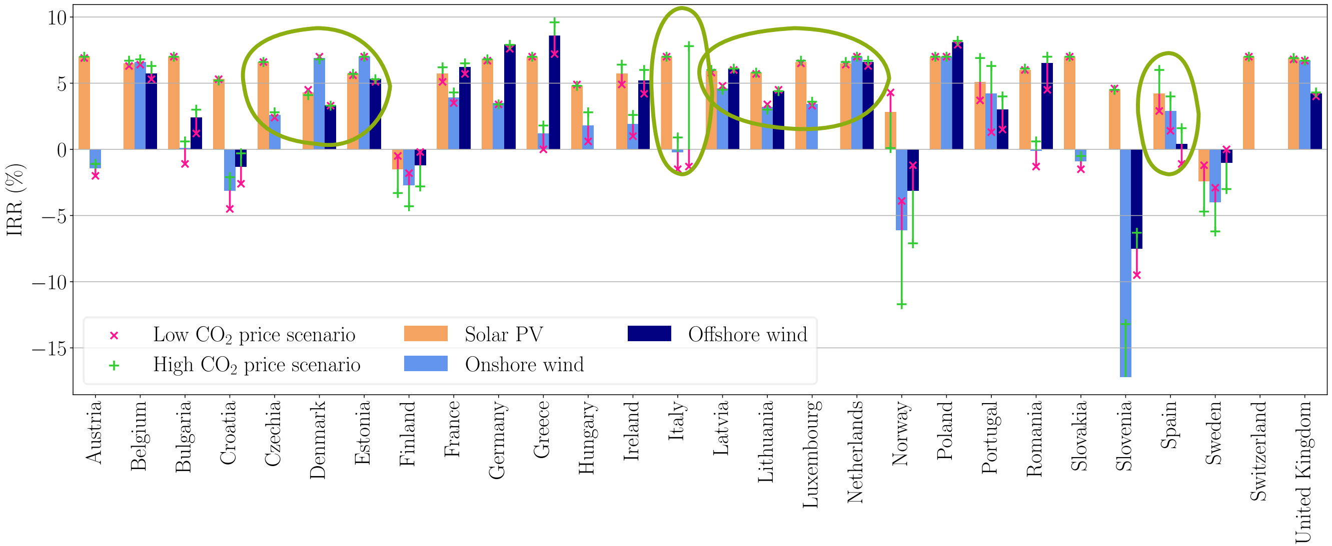
(Over)compensating effect (counter-intuitive):

Gas price ↗, renewable investments ↗, hours with zero or low nuclear prices ↗, revenues –

Scenario: CO_2 price of 100, **129**, 160 €/t

Results and effects **similar** to gas prices

Intuitive effect:
IRRs correlate **positively** with CO_2 price (via marginal cost of price setting fossil units)



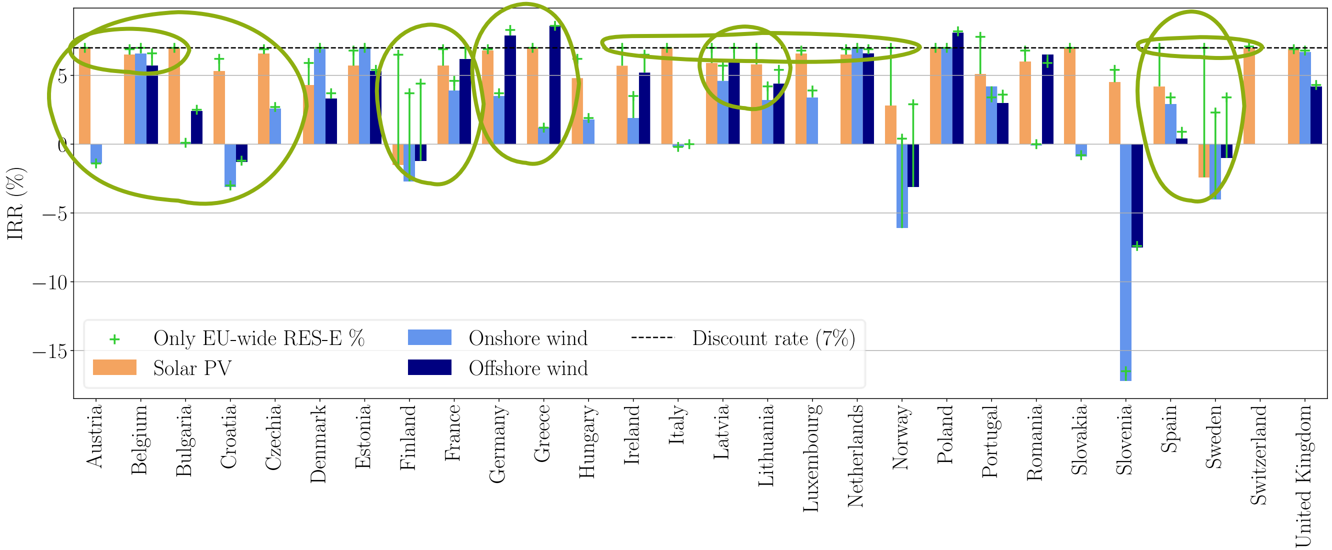
(Over)compensating effect (counter-intuitive):

CO_2 price ↗, renewable investments ↗, hours with zero or low nuclear prices ↗, revenues –

Scenario: only EU-wide RES-E share target (65%)

Often no or low effect

Strong **positive effect** on IRRs via increased market prices and values



Consistency check, compare e.g. [1]

- IRRs ≥ discount rate in linear model without constraints like renewable shares
- Where overall target and 2019 capacities exceeded: IRRs ≥ 7 %

[1] Brown and Reichenberg, *Decreasing market value of variable renewables can be avoided by policy action*, Energy Economics 2021.

Limitations

- Natural resource conditions can vary strongly within each country (spatial resolution)
  - Full load hours
  - Heterogeneous generation profiles
- Only wholesale electricity market and marginals as market prices
  - Flexible demand, capacity markets
  - Own use, e.g. residential systems
- Extrapolation from 2030 to lifetime
  - System design
  - Climatic conditions
- Homogeneous WACC in expansion planning, real WACC only for NPV calculation
  - No comprehensive data available

Conclusion & outlook

Conclusions & outlook

- Many IRRs > 0, however IRR < discount rate / WACC **not profitable**
- Therefore, renewable targets **not feasible in the market without additional support**
- Profitability is driven by
  - Natural resource conditions → distributed heterogeneously
  - Investment & capital cost → **policy-driven** (EU taxonomy, guaranteed feed-in tariffs)
  - Renewable share targets → **policy-driven** (EU vs national targets)
  - Market values → driven by system design (CO_2 and gas prices)
- Counter-intuitive effects through endogenous investment planning, e.g. via merit-order effect

Future work

- Influence of different market designs and EU taxonomy
- Heterogenous WACC for expansion planning
- Generate more profitable, thus feasible, model outcomes

Thank you for your attention!

Jonas Finke
Chair of Energy Systems and Energy Economics
Ruhr-Universität Bochum
jonas.finke@rub.de