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# Discount and hurdle rates: the dark horses of capacity expansion planning

Smaranda Sgarciu, Iegor Riepin, Felix Müsgens

BTU Cottbus-Senftenberg

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# Research focus

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## Hurdle rates

The *Hurdle Rate* (HR) is the minimum required rate of return on a project required by an investor (Mellichamp, 2017).

Annuity calculation

$$\text{Annuity} = \text{HR} \cdot \frac{\text{Costs}_{\text{overnight}}}{(1 + \text{HR})^{t}}$$

## Discount rates

The *Discount Rate* (DR) is the time dependent decrease in the future cash flows of a social planner reported to the present time (Karp and Traeger, 2013).

$$\text{DF} = \frac{1}{(1 + \text{DR}_{y})^{(y-1) * n}}$$

Objective function: Investment costs, Operational costs

*How **sensitive** are the outputs of state-of-the-art capacity expansion models and **related policy take-aways** to changes in the discount and hurdle rate assumptions?*

# Our contribution

- Analyzing the impact of hurdle rates and social discount rates on key outputs of the generation capacity investment model: the **investment mix** and **carbon emission intensity**.

- Illustrating the **energy system development pathways** resulting from various assumptions on hurdle rates, social discount rates and three energy futures from TYNDP (ENTSOE, 2018).

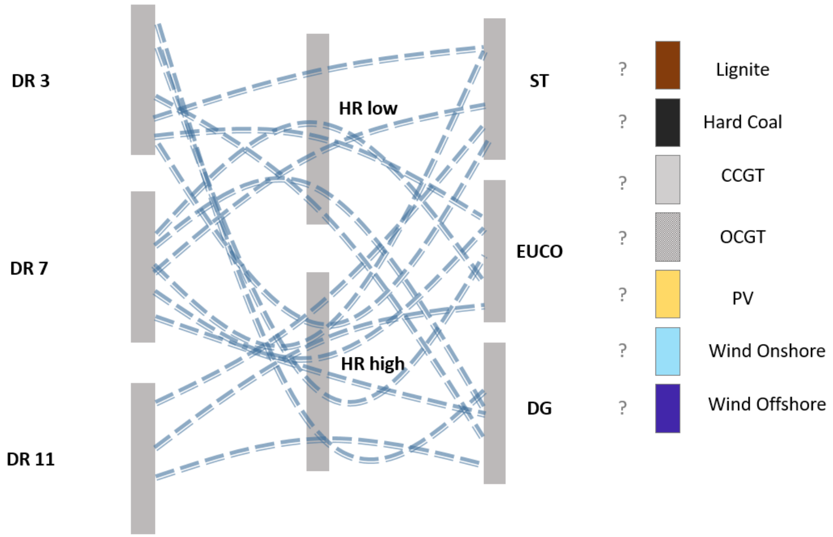


*Fig. 1: Using Sankey diagram to accentuate which parameter combination will lead to certain investments*

# Methodology

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- Bottom-up investment **optimization** model.
- **Greenfield** cost minimization problem which determines **investments** in both conventional and RES technologies; capacity of storage systems is implemented exogenously.
- **Pan-EU** geographical scope | country-based nodal structure.
- **Hourly** dispatch of electricity | three years (2020, 2025, 2030).

# Scenario set-up

| Discount rates | | | | | | |
|---|---|---|---|---|---|---|
| 3% | 5% | 7% | 9% | 11% | 13% | 15% |

**Technology specific hurdle rates (NERA, 2015)** | Risk types: allocation, carbon price volatility, policy

| Technology | Low risk | Medium risk | High risk |
|---|---|---|---|
| Nuclear | 10.5% | 12.4% | 17.4% |
| Lignite | 8.9% | 10.2% | 19.4% |
| Hard Coal | 8.9% | 10.2% | 19.4% |
| CCGT | 8.0% | 12.2% | 15.3% |
| OCGT | 8.0% | 12.2% | 15.3% |
| Photovoltaic | 6.9% | 8.5% | 13.4% |
| Wind Onshore | 7.5% | 8.7% | 13.3% |
| Wind Offshore | 9.3% | 10.9% | 14.2% |

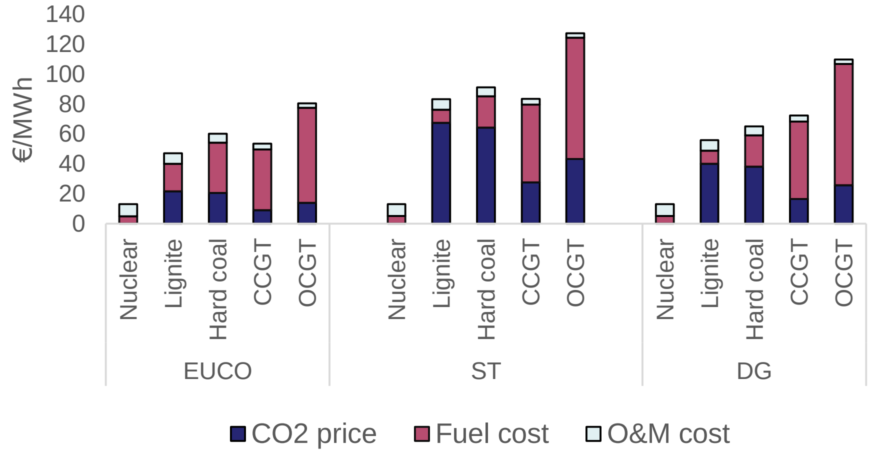


*Fig. 2: Cost data for each scenario from the TYNDP 2018 Report*

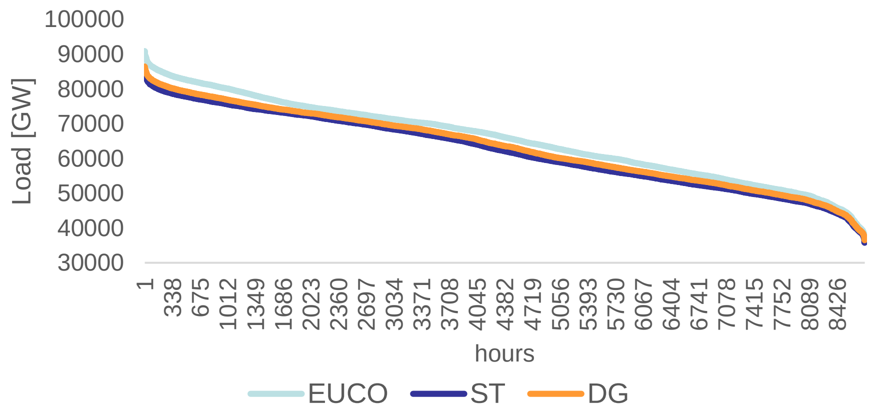


*Fig. 3: Load duration curve for Germany in each TYNDP scenario*

# Mathematical formulation

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## Objective function

$$\min \mathrm{tc} = \sum_{s} \mathrm{OC_s} + \sum_{i,n,y,s} \mathrm{DF_y} \cdot \mathrm{cap_{i,n,y,s}} \cdot \mathrm{IC_i}$$

$$oc_s = \sum_{s,y} \cdot DF_y \cdot \left( \sum_{i,n,t} (g_{i,n,t,y,s} \cdot VC_{i,n,t,y}) + \sum_{n,t} (shed_{n,t,y,s} \cdot VOLA_n) \right)$$

## Market clearing condition

$$DEMAND_{n,t,y,s} = \sum_{conv} g_{conv,n,t,y,s} + \sum_{res} g_{res,n,t,y,s} + shed_{n,t,y,s} + \sum_{nn} (flow_{nn,n,t,y,s} - flow_{n,nn,t,y,s})$$

## Selected system constraints

| | |
|---|---|
| $cap_{i,n,y-1} \leq cap_{i,n,y}$ | $\forall\ i, n, y$ |
| $g_{conv,n,t,y,s} \leq cap_{conv,n,y,s} \cdot AF_{i,n}$ | $\forall\ n, t, y, s$ |
| $g_{reservoir,n,t,y,s} \leq CAP^{existing}_{reservoir,n,y,s} \cdot AF_{reservoir,n}$ | $\forall\ reservoir \in i, n, t, y, s$ |
| $g_{res,n,t,y,s} \leq cap_{res,n,y,s} \cdot PF_{res,t,n}$ | $\forall\ res \in i, n, t, y, s$ |
| $cap_{i,n,y,s} \leq CAP^{max}_{i,n}$ | $\forall i, n, y$ |

# Results (i). The impact of Hurdle Rate on investments in generation technologies

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**Driver:** Increasing the Hurdle Rate penalizes the capital intensive technologies.

**Wind Offshore:**
-26% in EUCO
-64% in DG
-68% in ST

**Solar PV:**
-35% in EUCO

**Wind Onshore:**
approx. -10%

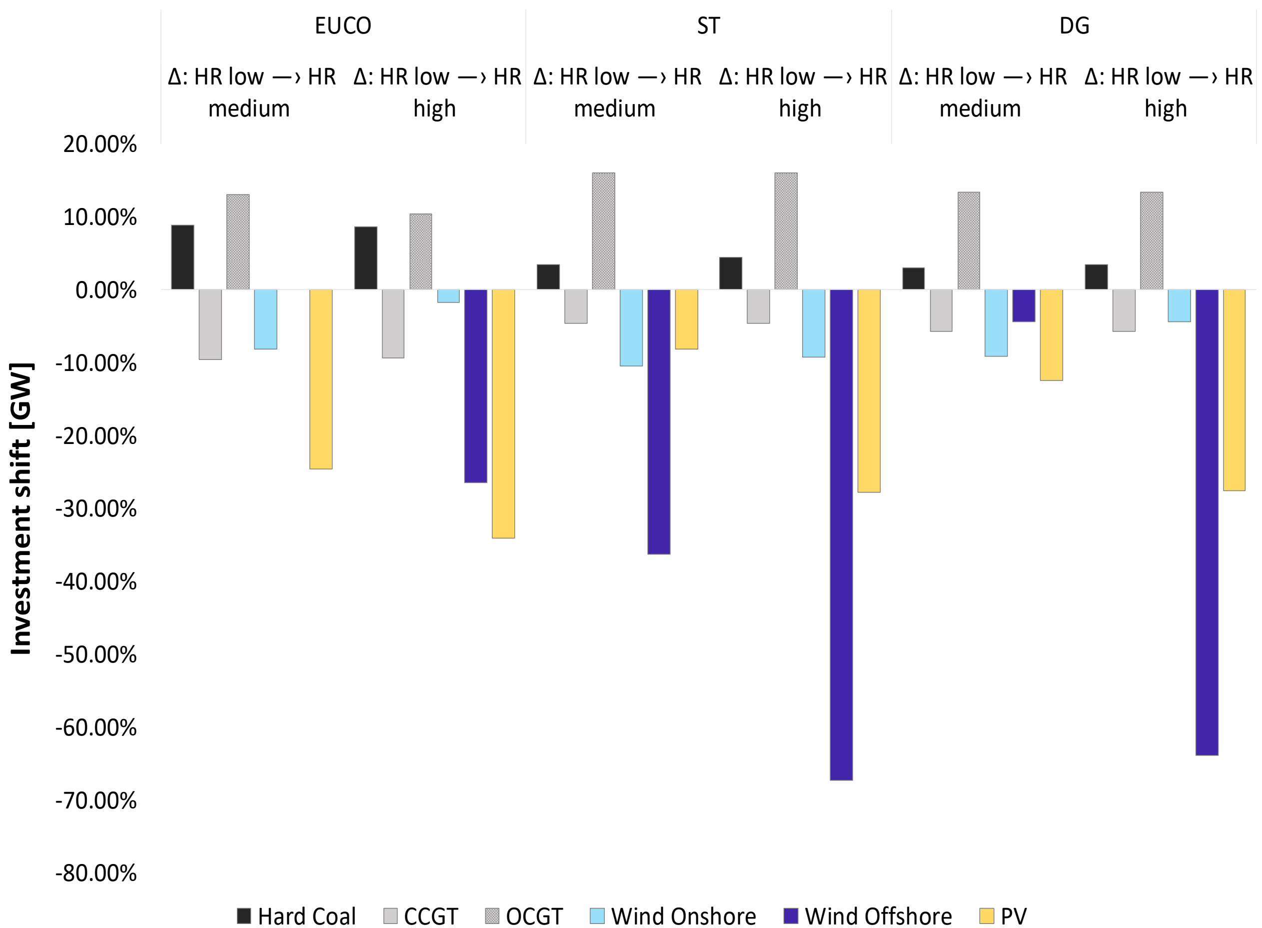


*Figure 4: Shifts of investment mix relative to low risk HR scenario, keeping DR constant at 5%.*

# Results (i). The impact of Hurdle Rate on Carbon emission intensity

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**Take-away:** A lower hurdle rate results in a system with lower carbon emissions intensity.

The ST and DG setting exhibit a similar pattern in the emission intensity reduction, approx. **10% (if HR high is taken as a reference)**.

In the EUCO setting, a low risk hurdle rate causes a remarkable fall of **27%** in the carbon emission intensity.

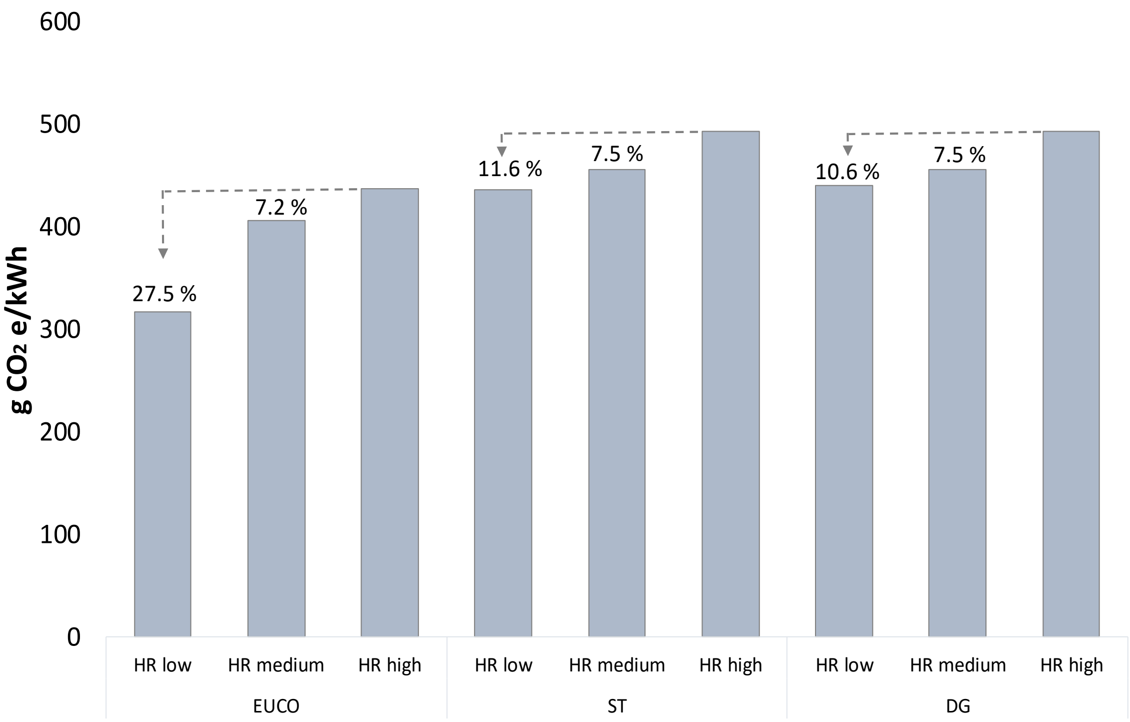


*Figure 5: Carbon emission intensity of the investment mix.*

# Results (ii)
# The impact of Discount Rate

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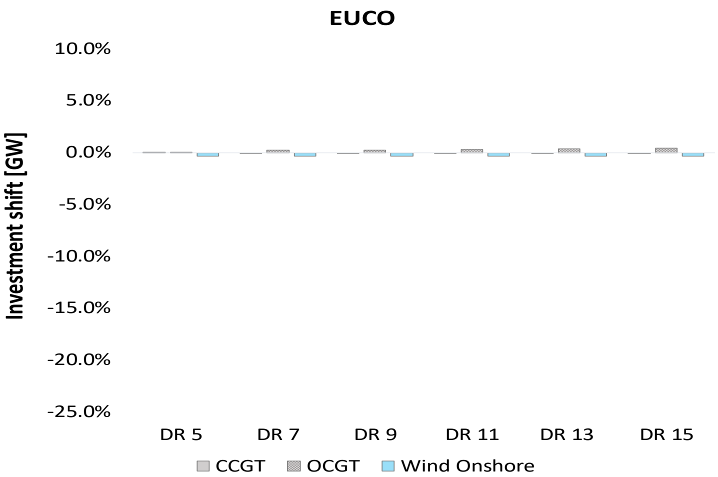


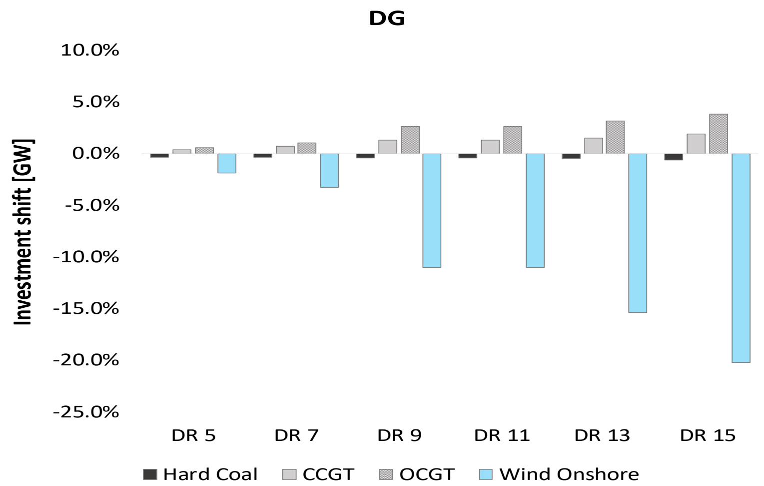


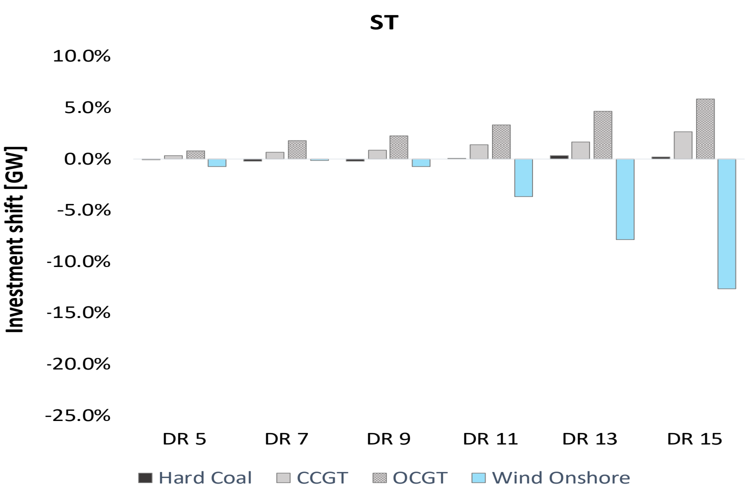


**Take-away:** Smaller discount rate benefits the transition to renewable energy sources.

Careful: results depict sensitivity to DR, while having HR fixed to a single value (High Risk).

*Figure 6: Shifts of investment mix in relative terms based on [DR = 3%] scenario in the EUCO, ST and DG settings.*

# Results (iii)
# Sankey Diagram

Tracking down the overlapping effects of the three degrees of freedom:

1. choice of the HR
2. choice of the DR
3. development of energy system parameters (cost levels, demand) form three TYNDP energy futures.

**Take-away:**

Low HR in combination with lower DRs (below 7%) drive most of the investment in RES. Gas-fired power plants are predominantly invested with high HR and DR.

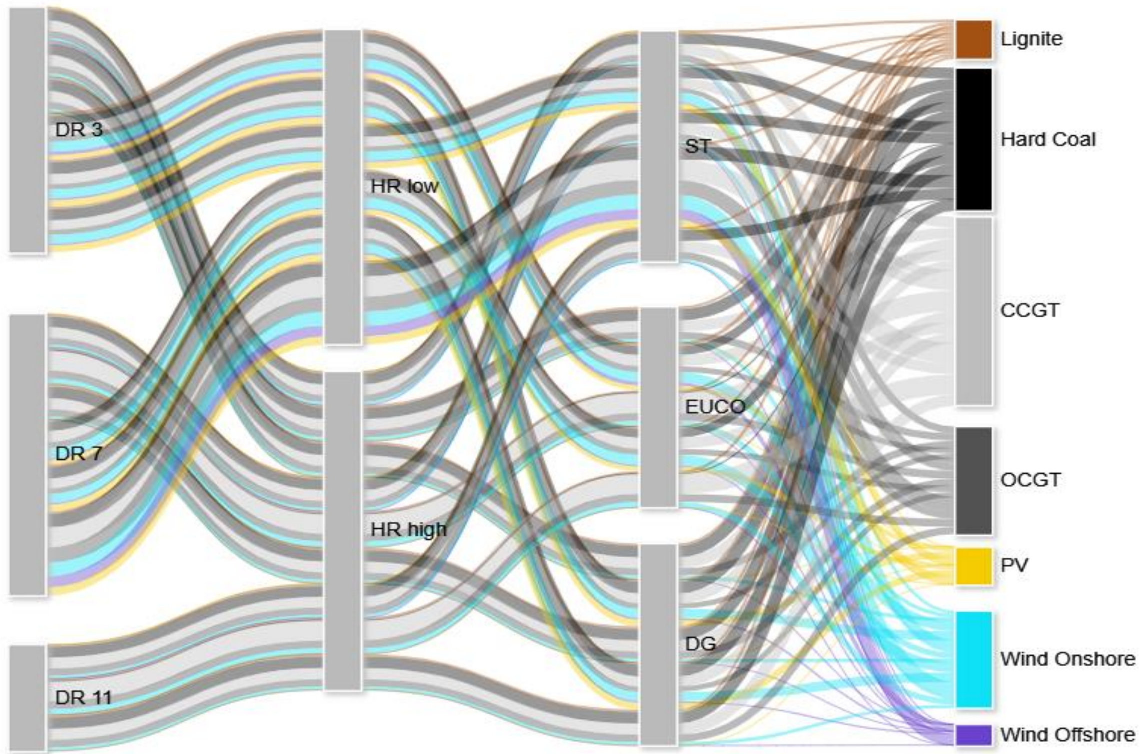


*Figure 6: Sankey diagram depicting the distribution of the investment flows for each technology*

# Conclusions

## Modelling take-aways

- ✓ The choice of risk-based hurdle rate exerts substantial influence on the key outputs of the investment optimization models (investment mix, carbon emission intensity).
- ✓ Lower hurdle rates facilitate larger shares of renewable technologies in the optimal investment mix, leading to a more decarbonized system.
- ✓ Certain combinations of discount and hurdle rate lead to a system configuration, which favors RES installations or to one mainly dominated by gas and coal-fired technologies.

## Policy take-aways

- ✓ Low discount rates fostered by the European Central Bank make climate and energy targets attainable.

# Contact information:

Smaranda Sgarciu

Chair of Energy Economics

BTU Cottbus-Senftenberg

Smaranda.Sgarciu@b-tu.de

+49 (0) 355 69-4513