On the Socially Optimal Cost of Capital for Low Carbon Generation Investments

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Objective and Principal Elements

Objective

The development of a framework for discussing the socially optimal cost of capital for low carbon electricity generation technologies, in particular, nuclear energy; work partly undertaken at OECD NEA

- Approach is normative; work on empirical verification under way.

Principal Considerations and Elements

- Combining economics and finance (capital pricing asset model, CAPM);
- Cost of capital is the cost of risk; optimising risk allocation can (1) reduce overall economic cost of risk and (2) radically reduce the cost of risk for investors ;
- Long-term risk-free rate is at historic lows and likely to stay so;
- Low carbon projects may be able to off-set systemic investment risk;
- Measures exist to de-risk project-specific risks such as (1) political risk, (2) electricity market price risk and (3) construction risk;
- Not only efficiency: de-risking investors poses questions of moral hazard and distribution.

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Some References

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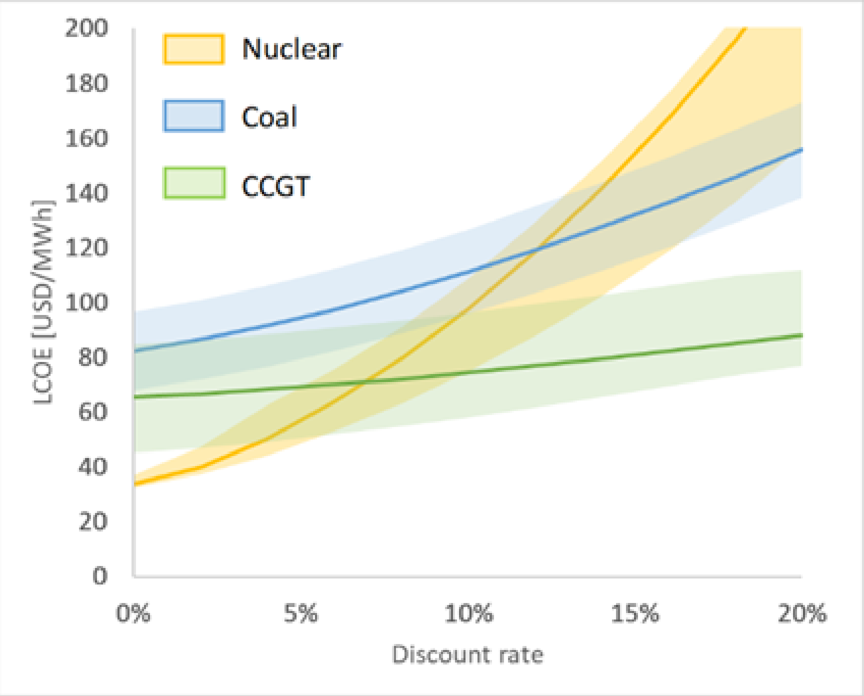
The importance of financing costs



1. Due to their high capital-intensity, the cost of all low carbon power generation technologies (nuclear, wind, solar PV, hydro…) depends heavily on the cost of capital;

2. Among the major dispatchable generation technologies, the LCOE cost of nuclear is the most sensitive to the cost of capital.

Source: IEA/NEA (2020), *Projected Costs of Generating Electricity*: 2020 Edition

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Risks are real!

- De-risking investments through the re-allocation of risks and lowering the cost of capital does not *per se* lower the underlying risks, *e.g.*,
  - Wind blowing at the "wrong" hour; solar PV not contributing to peak demand;
  - Limited short-term flexibility of nuclear; consumers resisting demand reduction;
  - Social costs of scarcity pricing during VOLL-hours (or avoiding them);

  Such risks imply costs at the level of the electricity no matter who bears them.

- However, optimizing risk allocation *lowers the economic cost of risk*.

- De-risking often shifts risks from investors to ratepayers or taxpayers. This can
  1. Improve risk management, e.g., by internalizing political risk
  2. Reduce the economic cost of risk through *risk spreading* (e.g., long-term contracts whose costs are integrated in consumer tariffs)
  3. Allow for politically more sustainable configurations.

Under the Capital Asset Pricing model (CAPM) the capital costs of a nuclear new build project is the sum of the following components

- The **risk-free rate** (high-quality government bonds) plus the country risk premium
- The **correlation** of the risk of a **nuclear** power project with **systemic** risk
- The **systemic risk** itself, which is the **market** risk of a perfectly diversified portfolio
- **Project-specific** or **idiosyncratic** risks of a new nuclear power project, typically
  - **political risk,**
  - **electricity price risk** and
  - **construction risk.**

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Formally this looks like this

$$r_{LC} = r_f + \beta_{LC} * r_s + \sum_i^n r_{I-LCi}$$

r_{LC} the cost of capital of a **low carbon power generation project**

r_f the risk-**free** rate (high-quality government bonds)

β_{LC} the **correlation** of the risk of a **nuclear** power project with **systemic** risk with $\beta_{LC} = \frac{cov\,(r_n, r_s)}{var\,(r_s)}$

r_s the **systemic** risk, *i.e.*, the **market** risk (r_m or a perfectly diversified portfolio) minus the risk-free rate, that is $r_s = r_m - r_f$.

$\sum_i^n r_{I-LCi}$ the sum of the **project-specific** or "idiosyncratic" risks of a new low carbon generation projects, typically **(1) political risk, (2) electricity price risk and (3) construction risk.**

Key hypothesis:
Each one of the components can be radically de-risked

The real long-term **risk-free** rate is zero but needs to be adjusted by relevant country risk or firm premium;

If nuclear energy is part of a defensive low-carbon infrastructure against CC impacts, its **correlation with system risk** becomes zero or, in some interpretations, even negative;

(1) Political risk: can and should be internalised by governments as they preside the societal processes that evaluate the strategic choice in the energy mix;

(2) Electricity price risk: long-term arrangements that provide predictable prices corresponding to average costs minimise capital costs and eliminate price risk; the capital-intensity of low carbon generation requires to shift away from marginal cost pricing in deregulated markets;

(3) Construction risk: its economic cost can be minimised through risk spreading over either rate payers (regulated asset base (RAB), construction work in progress (CWP)) or taxpayers (loan guarantees or direct public financing.

If in context of reaching net zero all options for de-risking are implemented, the socially optimal cost of capital low carbon power generation is equal to the risk-free rate plus the appropriate country (firm) risk premium.

The risk-free rate

$$r_{LC} = r_f + \beta_{LC} * r_s + \sum_i^n r_{INi}$$

Some Examples of Current Borrowing Rates for Governments with High Credit Ratings

- On 14 January 2022, the real yield (nominal yield minus inflation) on 30-year United States inflation-protected government bonds was **-0.10%**;
- On 13 January 2022, the **nominal** yield (before inflation) on 30-year *obligations assimilables du trésor* (OAT) of France was **0.94%**;
- On 23 November 2021, an auction for 50-year index-linked UK gilts resulted even in a real yield of **-2.39% (!)**.
  - For public borrowing, the risk-free rates needs to be adjusted further by country risk;
  - For private borrowing, the risk-free rate will need to be adjusted adjusted by firm-specific bankruptcy risk;
  - Working assumption: the underlying real long-term risk-free rate is currently zero.

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The correlation with systemic risk

$$r_{LC} = r_f + \beta_{LC} * r_s + \sum_i^n r_{INi}$$

- Long-term systemic risk r_s is estimated by Gollier and Baumstark (2014) at **3%**.
- Key however is the correlation β_{LC} of the benefits of a nuclear power generation project with overall market developments and economic growth:
  - If the benefits of low carbon projects are expected to rise in line with economic growth β_{LC} **= 1**
  - If the benefits are expected to remain stable or to increase as climate change and emission reduction efforts negatively impact economic growth β_{LC} **= 0** or even β_{LC} **< 0;**
  - Question: are low-carbon electricity generators long-run ***protective low-carbon infrastructures*** that can to some extent off-set systemic risk?
    - Working assumption: yes, to some extent, with β_{LC} **= 0**.
    - Answers may differ between public and private sector due to myopia or herd behaviour.

Correlation of risks of low carbon projects with systemic risk I

$$r_{LC} = r_f + \beta_{LC} * r_s + \sum_i^n r_{INi}$$

1. As climate change and efforts to combat it intensify, implicit and explicit carbon prices will rise.

2. This will *decrease* profitability throughout the economy…

3. …but will *increase* the value of existing low carbon investments.

4. If this holds true (1), including a low carbon investment will reduce an investment portfolio's Sharpe ratio already with $\beta_{LC} = 0$ and reduce its standard deviation the $\beta_{LC} < 0$.

5. If this holds true (2), investors will accept very low returns on low carbon investments since they will reduce overall portfolio risk and provide portfolio insurance.

"High-emitting assets are significantly more sensitive to economy-wide fluctuations than low-emitting ones… Our results suggest that carbon emission reduction might serve as valuable risk mitigation strategies (Trinks *et al.*, 2022)."

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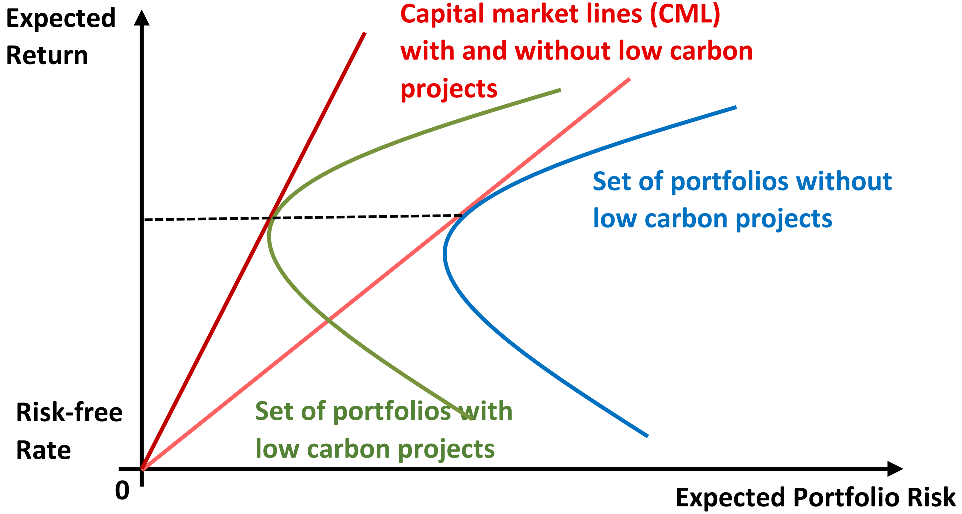
Correlation of risks of low carbon projects with systemic risk II

$$r_{LC} = r_f + \beta_{LC} * r_s + \sum_i^n r_{I-LCi}$$



The slope of the capital market line (CML) for a portfolio *P* with an expected return r_P is the latter's *Sharpe ratio* (SR_P):

$$SR_P = \frac{r_P - r_f}{\sigma_P}$$

De-risking project-specific (idiosyncratic) risks

$$r_{LC} = r_f + \beta_{LC} * r_s + \sum_i^n r_{I-LCi}$$

Investing in a new low carbon power plant typically requires manage **political risk**, **electricity market price risk** and **construction risk**. Governments possess effective means and are the party best placed to manage each one of the three risks. Social optimality thus implies to allocate them here:

- **Political risk:** government presides the societal processes that evaluate the strategic choice of nuclear power; efficient internalisation thus implies allocating political risk here;
- **Electricity market price risk:** given the high capital-intensity of all low carbon generation options (nuclear, hydro, VRE, storage, efficiency…), *net zero* will require to move away from marginal cost pricing in deregulated markets towards long-term price stability and average cost pricing;
- **Construction risk:** risk spreading, *i.e.*, sharing project-specific risks between a large number of individuals such as electricity consumers or taxpayers, can reduce the economic costs of such risks; mechanisms such as regulated asset base (RAB), construction work in progress (CWP), loan guarantees or direct public financing advance such risk-spreading to different degrees.

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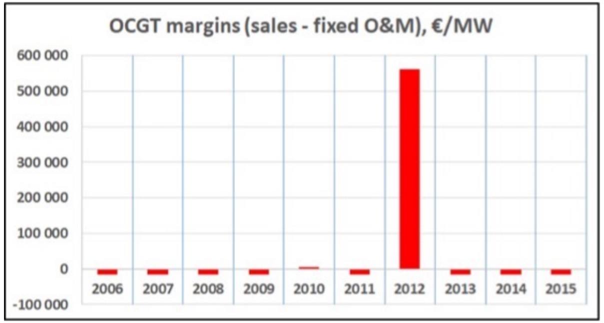
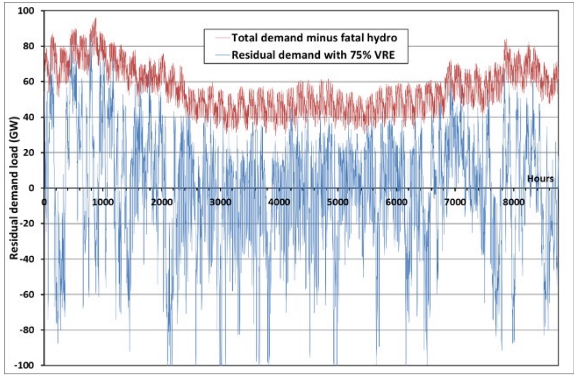
De-risking electricity market price risk I

$$r_{LC} = r_f + \beta_n * r_s + \sum_i^n r_{I-LCi}$$



Source: Weale et al. (2021)



Source: NEA (2019)

- High shares of low carbon-generators with low variable costs increase price volatility, number of scarcity hours and capital costs;
- In a fully decarbonised system, prices will (after allowing for demand response and storage) oscillate between zero and VOLL;
- Hourly volatility will be compounded by annual volatility as even slight changes in VRE production, total capacity or demand will substantially affect year-on year profitability;
- Capital costs will become unsustainable for highly capital-intensive LC-generators in deregulated markets with price equal to marginal costs,
- This will require a shift toward hybrid markets with long-term contracts prices at average costs, eliminating price risk for LC-investors (Keppler, Quemin, Saguan, 2021).

Hypothesis: share of VRE is optimised otherwise added system costs would need to be imputed to VRE costs.

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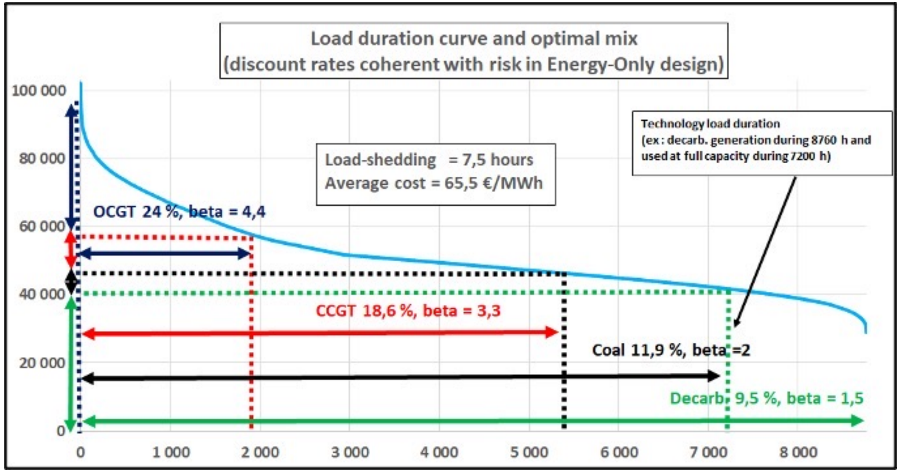
De-risking electricity market price risk II

$$r_{LC} = r_f + \beta_n * r_s + \sum_i^n r_{I-LCi}$$



Source: Peluchon (2021)

A detailed CAPM analysis of the electricity market gives average system costs, capital costs for low carbon-generators and load-shedding hours in different market designs:

- **Deregulated market with residual carbon emission:** Avg. cost 65.5 €/MWh; capital cost 9.5%; VOLL-hours 7.5;
- **NET ZERO - Deregulated market :** Avg. cost 118.3 €/MWh; capital cost 22% (16% with DR and storage); VOLL-hours 52;
- **Regulated market under *net zero*:** Avg. cost 82.5 €/MWh; capital cost 3.2%; VOLL-hours 3.

De-risking construction risk

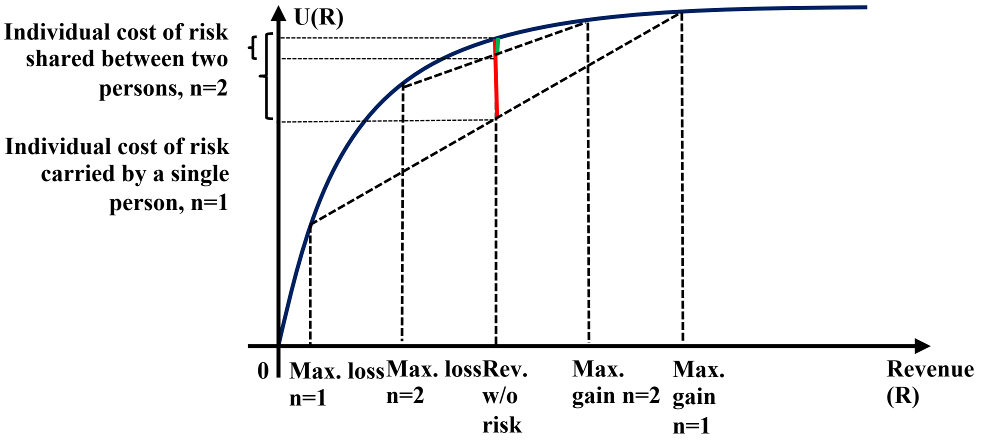
$$r_{LC} = r_f + \beta_{LC} * r_s + \sum_i^n r_{I-LCi}$$

The Arrow and Lind theorem (1970) states that investments can be evaluated at the risk-free rate if their risks are spread over a sufficiently large number of individuals. This is typically the case in public investment projects. Their reasoning depends on three key assumptions:

1. Risk aversion (see graph);
2. Project returns being a small share of each individual's income;
3. No correlation of project outcome with income or economic growth (question of β_{LC}).

Key question: should rate payers (RAB, CWP) or tax payers (public investment) bear the risk?

- If rate payers, ensure symmetry between costs and benefits;
- If tax payers, the size of the investment should not affect public borrowing costs.



Putting it all together

$$r_{LC} = r_f + \beta_n * r_s + \sum_i^n r_{I-LCi}$$

r_f The long-term **risk-free** rate is zero but needs to be adjusted by relevant country risk premium;

$\beta_n * r_s$ If low carbon generation is part of a defensive low-carbon infrastructure against CC impacts, its correlation with system risk becomes zero or, in some interpretations, even negative;

$\sum_i^n r_{I-LCi}$ **(1) Political risk:** can and should be internalised through indemnification clauses;

(2) Electricity price risk: appropriate long-term arrangements that provide predictable prices corresponding to average costs minimise capital costs and eliminate price risk;

(3) Construction risk: its economic cost can be minimised through risk spreading over either rate payers or tax payers.

r_{LC} The socially optimal **cost of capital of a low carbon power generation project** is equal to the risk-free rate plus the appropriate country risk premium.

Public and private investments

- **Do the preceding results also pertain to privately funded projects? Yes.** If low carbon generation projects do reduce portfolio risk with $\boldsymbol{\beta_{LC}}$ **= 0** then also private investors will accept very low rates for such projects as they improve the performance of their portfolios.
  - Of course, myopia or herd behaviour may delay full realisation of this effect;
  - Private investors would be highly interested in fully de-risked low carbon projects although it would raise questions of moral hazard and distribution;
- What does the term "***risk free rate plus country risk premium***" mean in the case of a private entities? It means "***risk free rate plus firm-specific bankruptcy risk premium***".
  - This is akin to equity premium (Newbery, 2021) minus the systemic risk;
  - In the case of a project company with a fully de-risked low carbon project investment, the firm-specific bankruptcy premium should be equal to zero.
- Arguments make no use of **social discount rate (SDR)** or **social time preference rate (STPR)**. Concepts have been introduced to ensure that the **well-being of future generations is adequately taken into account**. With privately optimal long-term rates (50 years) for the cost of capital at close to or below zero (-2.39%), they no longer provide guidance for decision-making.

Moral hazard in project management and incentive compatibility

- Complete de-risking can lead to **moral hazard** issues, *i.e.*, project managers, contractors and sub-contractors may not strive to complete projects at lowest possible cost in the shortest possible time;
- This establishes the **normative** nature of the result that the socially optimal rate for low carbon new build projects is the risk-free rate plus any appropriate country (or firm) risk premium;
- The preceding results assume complete contracts, fully aligned incentives for all parties as well as absence of transaction costs and opportunism;
- In the real world these issues exist and may, in the absence of appropriate incentive and oversight structures, provide arguments for less than complete de-risking (*e.g.*, hybrid RAB, Newbery *et al.* 2019), strong public oversight or even public investment.

Concluding Remarks

- The approach presented is less radical than it looks; historically, low carbon generation including nuclear power projects have benefitted from different forms of de-risking of low carbon new build projects along the lines discussed above;
- The primary purpose of this research is to provide a systematic framework and a common language to discuss de-risking and cost of capital in low carbon power generation project;
- The final allocation of risks is not only an economic efficiency issue but also an issue of fairness and distribution; different countries will chose different allocations;
- **Key observation 1 (conceptual):** the proposed approach depends on recognising that climate change is likely to fundamentally impact the magnitude and structure of systemic financial risk;
- **Key observation 2 (empirical):** the full de-carbonisation of electricity generation (*net zero*) will not happen without systematic de-risking of low carbon new build projects.