
Seminar on research in energy economics, Paris
Co-authored by Karsten Neuhoff

Dr. Nils May
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Moving beyond today's electricity demand: Flexibility and efficiency for reliable, affordable, and climate friendly energy services

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Basierend auf: AG Energiebilanzen (2016)
Overall fossil fuel bill in the EU

Annual expenditure
- CO\(_2\) at 30 Euro/t
- Domestic fossil fuel
- Imported fossil fuel

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DIW Berlin Calculations based on BP Statistical Review of World Energy; Energy Statistics for the EU-28; Bundesverband Solarwirtschaft e. V.; IEA; European Wind Energy Association; Bundesamt für Wirtschaft und Ausfuhrkontrolle, first published in Energy Journal (2016)
Use renewables to stabilize energy costs

**Similar cost level for serving demand with new wind and solar as with fossil fuel:**
Low capital costs key to unlock renewable potential

Annuitized Investment for wind and solar generation at scale to replace fossil fuels at:
- 10% capital costs
- 5% capital costs

Annual expenditure
- CO₂ at 30 Euro/t
- Domestic fossil fuel
- Imported fossil fuel

Illustration excludes system costs

DIW Berlin Calculations based on BP Statistical Review of World Energy; Energy Statistics for the EU-28; Bundesverband Solarwirtschaft e. V.; IEA; European Wind Energy Association; Bundesamt für Wirtschaft und Ausfuhrkontrolle, first published in Energy Journal (2016)
Outline

1. Financing costs of project developers
2. Financing costs of off-takers of long-term renewable energy contracts
3. Changes in effects with falling technology costs
Financing costs of project developers
Policy effects on financing

- **Overall research question:** How do different support policies affect the costs of renewables?
- **Research question 1:** What is the impact of support policies on project developers’ financing costs?
- **Case studies:** Butler and Neuhoff (2008), Klobasa et al. (2013), Tisdale et al. (2014)
- **Further differences between policies and investors:** Bürer and Wüstehagen (2009), Haas et al. (2011), Helms et al. (2015), Lüthi and Wüstehagen (2012), Schmalensee (2012)

→ Using interview data on the financing costs of onshore wind power in 23 EU countries in 2014, based on Diacore (2015)
Policies and revenue sources for renewable energy projects

- Feed-in tariff
- Sliding premium
- Fixed premium
- Green certificates
- No remuneration
Capital costs for wind power in the EU in 2014

Based on DIACORE (2016): The impact of risks in renewable energy investments and the role of smart policies

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Renewable energy policies in 2014

- Feed-in tariff
- Sliding market premium
- Fixed premium with annual production cap
- Quota with price floor
- Quota without price floor

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Main estimation

- **Dependent variable**: Financing costs are driven by national factors → Estimating the risk premium, i.e. the financing costs minus country-specific risk-free rates

- **Baseline estimator**: OLS estimator with interpretations of relative answers

\[ \text{risk premium}_i = \alpha + \beta_1 \text{FIP} + \beta_2 \text{TGC} + X \delta + u_i \]

- \( \alpha \): constant
- \( \beta_1 \): FIP-dummy
- \( \beta_2 \): TGC-dummy
- \( X \delta \): vector and coeff. of control variables
- \( u_i \): error term
- \( i \): interview observation

- **Robustness checks**: Alternative interpretations, interval estimator
Green certificate schemes are associated with an increase in financing costs by 1.2-1.3 percentage points.
Robustness checks

Try different interpretations of what is meant:

- **Different absolute codings** than before
- **Relative codings**, i.e. "slightly higher" meaning 5 percent higher, "higher" 10 percent higher, and "much higher" as 20 percent higher
- **Assume a normal distribution** of values and assume that the unspecified values adhere to same distribution as specified values: Interval estimator
Interval regression: Normality assumption

Shapiro-Wilk test does not reject normality of known values in the level specification.


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Interval regression results are very similar to OLS regression results.

### Table 3: Interval regression estimation results

<table>
<thead>
<tr>
<th></th>
<th>(1) Level</th>
<th>(2) Level</th>
<th>(3) Log</th>
<th>(4) Log</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dep. var:</strong> risk premium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sliding feed-in premium</td>
<td>-0.030</td>
<td>-0.130</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.535)</td>
<td>(0.228)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tradable green certificates</td>
<td>1.213**</td>
<td>1.222**</td>
<td>0.292**</td>
<td>0.333**</td>
</tr>
<tr>
<td></td>
<td>(0.417)</td>
<td>(0.414)</td>
<td>(0.094)</td>
<td>(0.108)</td>
</tr>
<tr>
<td>No policy</td>
<td>2.477***</td>
<td>2.484***</td>
<td>0.528***</td>
<td>0.557***</td>
</tr>
<tr>
<td></td>
<td>(0.458)</td>
<td>(0.451)</td>
<td>(0.105)</td>
<td>(0.110)</td>
</tr>
<tr>
<td>Retrosp. changes</td>
<td>-0.212</td>
<td>-0.207</td>
<td>-0.047</td>
<td>-0.023</td>
</tr>
<tr>
<td></td>
<td>(0.354)</td>
<td>(0.354)</td>
<td>(0.092)</td>
<td>(0.092)</td>
</tr>
<tr>
<td>Tenders</td>
<td>0.867</td>
<td>0.851</td>
<td>0.270</td>
<td>0.203</td>
</tr>
<tr>
<td></td>
<td>(0.604)</td>
<td>(0.534)</td>
<td>(0.177)</td>
<td>(0.125)</td>
</tr>
<tr>
<td>Equity investor</td>
<td>-0.320</td>
<td>-0.323</td>
<td>-0.057</td>
<td>-0.069</td>
</tr>
<tr>
<td></td>
<td>(0.304)</td>
<td>(0.311)</td>
<td>(0.080)</td>
<td>(0.078)</td>
</tr>
<tr>
<td>Utility employee</td>
<td>-0.369</td>
<td>-0.366</td>
<td>-0.122</td>
<td>-0.107</td>
</tr>
<tr>
<td></td>
<td>(0.522)</td>
<td>(0.516)</td>
<td>(0.129)</td>
<td>(0.119)</td>
</tr>
<tr>
<td>Banker</td>
<td>-0.592</td>
<td>-0.592</td>
<td>-0.229</td>
<td>-0.230</td>
</tr>
<tr>
<td></td>
<td>(0.496)</td>
<td>(0.500)</td>
<td>(0.198)</td>
<td>(0.208)</td>
</tr>
</tbody>
</table>

N: 53

Robust standard errors in parentheses
* p < 0.05, ** p < 0.01, *** p < 0.001

Fixed feed-in tariff and the Belgian and Romanian TGC systems with significant price floors are the baseline policy. In columns 2 and 4, also the feed-in premium is in the baseline. Academic/Consultants are the baseline respondent group.
Financing costs of off-takers of long-term RES contracts
Without implicit long-term contracts between project developers and energy consumers, project developers sign long-term contracts with private off-takers (Finon, 2011, Baringa, 2013, Newbery, 2016).

Research question II: Which effects does signing long-term contracts have on the off-takers?
Without implicit long-term contracts between developers and consumers, energy suppliers and consumers carry the price risks.

Rating agencies view energy suppliers‘ exposure to long-term contracts as liabilities (Standard & Poor‘s, 2017, Baringa, 2013)
→ Lead to worse financial parameters
→ Lead to worse credit rating
→ Lead to higher re-financing costs

→ Signing long-term contracts can lead to additional costs for energy retailers / industry
Impacts of long-term contracts

Off-takers re-financing costs

\[ c(d, e) = r_{\text{debt}}(g(d, e))d + r_{\text{equity}}(g(d, e))e \]

- \( c \): overall re-financing costs
- \( d \): debt
- \( r \): capital costs
- \( e \): equity
- \( g \): rating grade

- Long-term contracts evaluated as 'imputed debt' (Standard & Poor’s, 2017, Baringa, 2013)
- The increase in debt-equity ratio worsens the credit rating
- The worse credit rating increases the interest rate on all debt

Long-term contracts increase off-takers’ re-financing costs
Debt-equity ratios of the twelve largest EU utilities over time


EU utilities‘ debt-equity ratios have grown across the board.
Default spread as function of credit rating

Worsening ratings have stronger impacts for worse initial ratings.

Credit ratings of the twelve largest EU utilities over time


EU utilities' ratings have deteriorated across the board.
Extra costs of private power purchase agreements for new investments

The additional costs stand at around 20% of contract value for current average debt-equity ratios of 1.85.


Green certificate schemes increase the costs of renewable energies from e.g. 50€ per MWh to 65 €/MWh, or from 90€/MWh to 117€/MWh
Potential of power purchase agreements

Assumptions: debt-equity ratio may worsen by 0.5; only 50% of value of electricity counted as liability (lower end of Standard & Poor’s range)

PPAs for new installations are a far way from decarbonizing industry and utilities.

Source: May and Neuhoff (2019): Private langfristige Stromabnahmeverträge (PPAs) für erneuerbare Energien - kein Ersatz für öffentliche Ausschreibungen. DIW Aktuell
Changing policy effects with falling technology costs
Cost decline of large scale photovoltaics

Costs and funding of solar energy over time
In euro per megawatt-hour


Market risks have gained importance relative to regulatory risks
Sliding premium with falling costs

Assumption: Equity for uncertain revenues, 7% equity costs, 2% debt costs

Market value
Premium payment

Strike price = LCOE w/o additional risks

Additional revenues: Bank does not consider them for debt

Diagram:
- Strike price and LCOE (Euro/MWh)
- Investment costs into solar PV (Euro/kW)
- Scenario low power prices
- Scenario high power prices
- Benchmark without power price risks

Graphical representation shows the relationship between strike prices, LCOE, and investment costs in the context of solar PV projects.
Assumption: Equity for uncertain revenues, 7% equity costs
Financing model of the financing structure and costs of renewable energy investments:

- **How much debt and equity can be raised** to finance investments under a certain policy?

- How does this translate into **financing costs**?

- How does this translate into **levelized cost of electricity**?

- How does this translate into **support costs and power price revenues**?

1. Calculation of debt that can be raised based on secure revenues

\[ D = \frac{Y(R_o - V)}{a_d} \]

2. Calculation of equity

\[
E = \frac{Y}{a_e} \int_{R_o}^{2P+2V} \frac{(P - V) - R_o}{2(P + V)} dp = \frac{Y}{a_e} \int_{0}^{2P+2V-R_o} \frac{p}{2P} dp = \frac{Y}{a_e} \frac{(2P + 2V - R_o)^2}{4(P + V)}
\]

\[
= \frac{Y}{a_e} \left( P - R_o + \frac{R_o^2}{4P} \right)
\]

<table>
<thead>
<tr>
<th>P</th>
<th>Realized net-market value, uniformly distributed between [0;2P]</th>
<th>P</th>
<th>Average net-market value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R_{s,o,f}</td>
<td>Reference price for symmetric, one-sided, fixed premium</td>
<td>( C_{s,o,f} )</td>
<td>Average cost to consumer per MWh</td>
</tr>
<tr>
<td>I</td>
<td>Investment cost (per MW)</td>
<td>Y</td>
<td>Yield – in full load hours per year</td>
</tr>
<tr>
<td>D</td>
<td>Debt in financing structure (per MW)</td>
<td>E</td>
<td>Equity in financing structure (per MW)</td>
</tr>
<tr>
<td>r_d</td>
<td>Interest rate on debt</td>
<td>r_e</td>
<td>Return expectation on equity</td>
</tr>
<tr>
<td>a_d</td>
<td>Annual debt serving factor (for 20 years)</td>
<td>a_e</td>
<td>Annual equity serving factor (for 20 years)</td>
</tr>
</tbody>
</table>
Approach

3. Calculation of bid price in competitive auctions

\[ R_o = 2P \left( 1 - \frac{a_e}{a_d} + \sqrt{\left(1 - \frac{a_e}{a_d}\right)^2 + \frac{a_e I}{Y P}} - 1 \right) \]

4. Calculation of overall price (electricity plus support) to electricity consumers

\[ \overline{C}_r = \frac{a_e}{Y} I + P \left( 1 - \frac{a_e}{a_d} \right) \left( 2 \left( 1 - \frac{a_e}{a_d} \right) + \sqrt{\left(1 - \frac{a_e}{a_d}\right)^2 + \frac{a_e C}{Y P}} - 1 \right) \]

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<td>Debt in financing structure (per MW)</td>
<td>E</td>
<td>Equity in financing structure (per MW)</td>
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<tr>
<td>r_d</td>
<td>Interest rate on debt</td>
<td>r_e</td>
<td>Return expectation on equity</td>
</tr>
<tr>
<td>a_d</td>
<td>Annual debt serving factor (for 20 years)</td>
<td>a_e</td>
<td>Annual equity serving factor (for 20 years)</td>
</tr>
</tbody>
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Total costs increase with increasing power price exposure

Higher (expected) market value increasingly affects the financing costs under sliding premia

- Further consequences:
  - Acceptance issues: Electricity consumers are not symmetrically hedged against high power prices
  - Larger investors benefit from their larger equity
  - Realization rates drop, Winners‘ curse

Results: If nothing changes, everything will change

Sliding premium: As technology costs decline optionality kicks in, the sliding premium offers less hedging, financing costs increase, total cost increase.

Without long-term hedging
30% cost increase from
• Project revenue risk (1)
• Liability in LT Contracts (2)

Matches overall assessments (3)

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LCOE and strike prices by 2025

Solar PV

Wind onshore

Wind offshore

Strike price and total costs of renewables provide differing assessments!


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Renewable energy costs in 2025 under various policies

Own calculations, based on cost parameters by Fraunhofer ISE (2018)


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Conclusion
Low financing costs are crucial for low-cost renewable energy deployment.

Role of support policies has changed: rather than covering extra costs, risk-hedging is taking center-stage.

Fixed premia, green certificate schemes and abolishing remuneration schemes imply significant extra costs due to imperfect risk-hedging.

Sliding premia used to be associated with low financing costs, but with decreasing technology costs, they lose their ability to hedge risks.

Contracts for difference function as sliding premia used to: have renewables participate in wholesale electricity markets while hedging power price risks.

Power Purchase Agreements can play a role in niches and for old installations – but not as drivers of energy transitions.

Please DO get into contact: nmay@diw.de