Financing and innovation in energy transitions


Bjarne Steffen, Energy Politics Group, ETH Zürich
1 Intro: Financing along the energy innovation chain
2 Financing structures and the role of project finance
3 Cost of capital for new technologies
4 Policy instruments (common and uncommon)
5 Conclusion
Projected renewable energy investment needs

Annual renewable energy investments and investment needs (excl. biomass)

- 2018: 295 $bn
- 2°C pathway: 609 $bn
- 1°C pathways: 730 $bn

Investment need particularly high in non-OECD countries

From climate perspective, deployment of new technologies most crucial for electricity plants

Note: Other Energy includes CHP plants, heating plants and other energy industry own use.
Source: EPG calculations based on IEA data
Innovation chain from technology and business perspective

Barriers to (private) finance along the innovation chain

Innovation necessitates up- and downstream finance

“Upstream” finance: high risk equity

Basic/applied R&D → Demonstration

“Learning by doing and using”

“Downstream” finance: “conservative” equity, debt

Demonstration → Diffusion (niche, commercial)

- Learning by doing/using particularly important for technologies/products with high complexity regarding:
  - Product architecture
  - Production process
  - Both

- Most of the technologies leading to a 2/1.5° trajectory are rather complex in either or both ways

Classification of energy technologies according to their complexity

Excursus: Global diffusion patterns as empirical test for differences in complexity of product architecture (1/2)

Product architecture will impact how technology diffuses
- Complexity = number and linkages btw. sub-systems
- Empirical research placing RE technologies on continuum:

Complexity of product architecture

<table>
<thead>
<tr>
<th>Simple products</th>
<th>Design intensive prdcts</th>
<th>Complex prdct systems</th>
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<tbody>
<tr>
<td>low</td>
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<td>high</td>
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</table>

Technological progress reflected in cost learning curves – global or local
- Simple products often assembled from globally traded commodities → global learning, rapid deployment once globally cost competitive
- Complex products needed local design adaptation/local components/services → global and local learning, less rapid development

Excursus: Global diffusion patterns as empirical test for differences in complexity of product architecture (1/2)

No. of countries with first project

XX = Country in which first project has been realized in that year

Besides, financing conditions particularly important for capex-intense technologies (like many renewables)

Renewables w/ high upfront investment…

<table>
<thead>
<tr>
<th>Percentage of LCOE</th>
<th>Avr fossil fuel-based power</th>
<th>Solar Photovoltaic</th>
<th>Wind turbines (onshore)</th>
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<tr>
<td></td>
<td>3%</td>
<td>17%</td>
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<td>8%</td>
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<td>58%</td>
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<td>4%</td>
<td>12%</td>
<td>9%</td>
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</table>

…hence LCOE are sensitive to WACC

LCOE $/MWh (example solar PV)

- WACC 0%: 59, 100%
- WACC 4%: 27%, 73%
- WACC 8%: 44%, 56%
- WACC 12%: 56%, 44%

Note: Assumes 5% cost of debt, 10% cost of equity, European fuel costs. Fossil fuel based is the average of hard coal, natural gas and diesel.
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Project finance (PF) is a special way for capital investments

**Corporate Finance (CF)**

Financing of new project on the balance sheet of the sponsor

- Using assets and cash flows from existing firm to guarantee additional credit provided by lenders
- Cost of capital determined by sponsor solidity

**Project Finance (PF)**

Creating a special purpose vehicle (SPV) to incorporate new project

- No guarantee from sponsor’s assets, lenders depend on cash flows of new project alone
- Cost of capital cost determined by project cash flows and risks

Project finance (PF) has distinct characteristics

**Project Finance (PF)**

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**Key advantage for project sponsor: Non-recourse**
- Protects core business from being “contaminated” by potentially risky new project
- Pollio (1998) on use of PF for power generation projects: *Used to prevent lenders to recourse on core firm in case of project failure*

**Key drawback: Transaction cost**
- Cost for setting up SPV and structuring its financing
- Evaluation of future cash flows reliable for investors (by using external advisors)
- Up to 5–10% of total project cost

Renewables – comparably small & low-risk – are surging in PF
Global asset financing of new investment in renewable energy

Potential reasons to use PF from economic theory

1. Contamination risk
2. Debt overhang
3. Securitization

4. Information asymmetry btw. sponsor & lender
6. Agency conflicts btw. project owners & managers
   (Agency conflicts btw. project owners & contractual parties)

6. Allowing for horizontal joint ventures
7. Independence of civic projects

Quantitative analysis of extreme low-risk case DE

Case selection: Germany

Polar type sampling: DE as extreme example of low-risk environment for renewables
- «Best-in-class» as per UNDP
- Well-developed capital markets

Data: Utility-scale projects 2010–2015

Analysis of new dataset, combining asset list from grid regulator with financial info from trade register
- Showing finance structure in population
- Regression analysis to identify drivers

Results: High share of PF for RE, driven by new players

Renewables with much lower risk than fossil fuels – still, use more project finance

German power generation projects 2010–2015

<table>
<thead>
<tr>
<th>Feed-in tariff</th>
<th>Project finance</th>
<th>Corporate finance</th>
<th>No. of projects</th>
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<td>Wind onshore</td>
<td>88%</td>
<td>12%</td>
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<td>50%</td>
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<tr>
<td>Gas</td>
<td>6%</td>
<td>94%</td>
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<tr>
<td>Merchant</td>
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<tr>
<td>Hard coal</td>
<td>22%</td>
<td>78%</td>
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<tr>
<td>Lignite</td>
<td>100%</td>
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Key reason: small balance sheets of new players in industry

Results from regression analysis on rationales to use project finance

1. Contamination risk
2. Debt overhang
3. Securitization
4. Information asymmetry btw. sponsor & lender
5. Agency owners & mgrs
6. Horizontal joint ventures
7. Independence civic prjcts

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Towards a dynamic perspective on financing conditions

Previous literature

Renewable energy (RE) cost dynamics
- Detailed understanding on renewable energy technology cost reductions, large ‘experience curve’ literature (e.g., Nemet 2006; Ferioli et al. 2009)

Role of financing dynamics of RE cost
- Conceptual studies on drivers impacting RE investment decisions (e.g., Wüstenhagen & Menichetti 2012)
- Hypothetical studies on impact of financing conditions on technology costs (e.g., Schmidt 2014; Hirth & Steckel, 2016)

Our research questions

1. How and why did solar PV and wind onshore financing conditions in DE change over time?
2. What is the effect of these changes on technology costs?

Challenges:
- Scarce data, as financial details of project finance deals not disclosed
- For “why” part: Interest rate levels affected by multitude of drivers

We followed a mixed-method approach in four steps

1. **Descriptive:** Elicitation and mapping of project finance data
   - Cost of equity, cost of debt/debt margin
   - Leverage, loan tenor, debt service coverage ratio

2. **Qualitative:** Investor interviews to identify drivers for changes
   - Semi-structured interviews, grounded theory-type coding of arguments

3. **Quantitative:** Regression analysis for experience curves
   - Various specifications of dependent and independent variables

4. **Model-based:** Split-up of LCOE into technology cost effects
   - Calibration of levelized cost of electricity (LCOE) in different settings

Step 1: Historic development of the cost of capital

Step 1: The data (other financial indicators)

a) Loan tenor duration

b) Leverage

c) Resource estimation

d) Debt service coverage ratio

### Step 2: The drivers

#### Drivers of changes in financing conditions

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<th>Level</th>
<th>Drivers of changes in financing conditions</th>
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<tr>
<td>Economy</td>
<td>• <strong>Capital markets</strong>: Low-cost liquidity, few investment alternatives, low return expectations</td>
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<td>• <strong>Banks</strong>: Low-cost refinancing, low bank fees, preference for project finance</td>
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<td>Renewable energy sector</td>
<td>• <strong>Availability of performance data</strong>: Accumulated operation experience of RET assets</td>
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<td></td>
<td>• <strong>Technology reliability</strong>: Proven track record of technology, low default rates of projects</td>
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<td></td>
<td>• <strong>Support policies</strong>: Regulatory environment, e.g. introduction of exposure to market risks</td>
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<tr>
<td>Renewable energy financing industry</td>
<td>• <strong>Learning by doing</strong>: In-house RET knowledge, better risk assessment and due diligence processes</td>
</tr>
<tr>
<td></td>
<td>• <strong>Investment ecosystem</strong>: Standardised investment structures, frame contracts, partner networks</td>
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<td></td>
<td>• <strong>Market entry of investors</strong>: New investor types (e.g., large banks, insurers, pension funds), increasing investor competition</td>
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Step 3: Experience and general interest rate effects

Identification of experience effect:

\[
\text{DebtMARGIN}(I_t) = \text{DebtMARGIN}(I_0) \left( \frac{I_t}{I_0} \right)^{-h_t}
\]

Comparison of experience effect and general interest rate level

Solar PV

ER = 11 \pm 7\%
Step 4: Channels of improved financing costs

Solar PV

- Change in financing cost: 41%

Wind onshore

- Change in financing cost: 40%

LCOE components
- Financing expenditures
- Capital and operating expenditures

Change in financing cost from
- Experience effect
- General interest rate effect
- Lower capital expenditures
Side note: Cost of capital differs strongly between countries

Side note: Cost of capital differs strongly between countries

In models, CoC assumption is crucial for cost comparison

**Global cost comparisons\(^1\)**

- Ongoing academic debate on realistic assumptions for global “100% RE” models
- One example: Bogdanov et al. 2019 showing lowest LCOE in Sudan & DR Kongo

**Critique: Uniform CoC can lead to misleading results\(^2\)**

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Conducive policies for (low-cost) project finance

Generally efficient capital markets
- Diverse and competitive banking industry (incl. banks providing PF for small projects)
- Appropriate regulatory requirements (cf. Basel III, Solvency II,…)

Favorable conditions specifically for renewable energy project finance
- High certainty on revenue streams, as they are provided by feed-in tariffs (but necessarily RPS etc.) – to be considered in designing “re-risking” policies
- Conducive PF ecosystem – legal entities, insurance market, standardized deal structures
  (On the flipside, weak balance sheets of incumbent utilities less an issue)

Low-cost public loans, guarantees, etc.
A more fundamental question: Does the type of investor (esp. public vs. private) affect the direction of innovation?

A market creating policy: (Green) state investment banks

**KfW investments 2012-2016**

- **On-shore**: 20.9
- **Off-shore**: 1.9
- **PV**: 8.2
- **W2E & E. Efficiency**: 1.4

**GIB investments 2012-2016**

- **On-shore**: 0.2
- **Off-shore**: 2.2
- **PV**: 9.4
- **W2E & E. Efficiency**: 5.2

**CEFC investments 2012-2016**

- **On-shore**: 0.2
- **Off-shore**: 0.3
- **PV**: 1.5
- **W2E & E. Efficiency**: 0.6

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Qualitative case study allows to identify effective mechanisms

Case selection and method

Comparative study of 3 cases
- Industrialized countries w/ SIB heavily involved in RE finance
- GIB in UK, and CEFC in AU: Green SIB on national level, with 5 years track record
- KfW in DE: Not exclusively green SIB, but largest RE investor

Data iteratively analyzed
- Semi-structured interviews with 56 interviews from investors (SIB and others) and developers
- Qualitative content analysis to identify key themes by mapping developer demands to bank offerings

Results: SIBs take four key roles, well beyond capital provision

A. Capital Provision and De-risking Roles
- Direct funding for crucial gaps, concessional or commercial terms
- De-risking instruments (e.g., guarantees)

B. Educational Role
- Specialist internal expertise (e.g. accurately assessing risks)
- Financial innovation and standardization

C. Signaling Role
- SIB reputation crowding-in private equity and debt
- “SIB participation signal” with effect on financing cost

D. First or Early Mover
- Early movers with respect to new technologies (in the country), new deal structures, new manufacturers and developers

In developing countries, multilateral development banks are key.

Power generation pathway of developing countries crucial for climate change

Could multilateral development banks (MDB) take the role of SIB in dev. countries?
- Long track record in power generation financing, and toolbox with de-risking and invest instruments
- Ambitious goals for climate finance – yet also competing policy areas and interest
- The role of MDB in financing high- and low-carbon assets is poorly understood

Bottom-up analysis of 800+ projects and programs 2005–15

New RE investment rose from ~10% to ~50% of all MDB power generation invest

Total financial commitments (excluding guarantees)
(USD\textsubscript{2015} billion)

<table>
<thead>
<tr>
<th>Year</th>
<th>Geothermal</th>
<th>Solar (PV + CSP)</th>
<th>Wind</th>
<th>Multiple/other renewables</th>
<th>Hydro</th>
<th>Unspecified</th>
<th>Gas</th>
<th>Heavy fuel oil</th>
<th>Coal (hard coal &amp; lignite)</th>
<th>Multiple/other non-renewable</th>
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Impact: Estimated 118 GW new capacity 2007–2015

Share of power-generation capacity added during 2007–2015 through projects with MDB participation
(Estimate based on assumptions)

**All technologies**

- **By regions**
  - Low: 0% 0.0 GW
  - Lower middle: 20% 21.0 GW
  - Upper middle: 10% 17.0 GW
  - High: 6% 16.8 GW

- **By income group**
  - Low: 96% 3.2 GW
  - Lower middle: 22% 57.3 GW
  - Upper middle: 4% 50.3 GW
  - High: 1% 6.7 GW

**Fossil fuel technologies**

- **By regions**
  - Low: 0% 0.0 GW
  - Lower middle: 14% 9.5 GW
  - Upper middle: 6% 8.7 GW
  - High: 2% 1.9 GW

- **By income group**
  - Low: 53% 0.9 GW
  - Lower middle: 17% 32.8 GW
  - Upper middle: 2% 19.1 GW
  - High: 3% 3.7 GW

**Hydropower**

- **By regions**
  - Low: 0% 0.0 GW
  - Lower middle: 51% 13.3 GW
  - Upper middle: 22% 30.4 GW
  - High: 6% 16.8 GW

- **By income group**
  - Low: 48% 1.4 GW
  - Lower middle: 41% 2.2 GW
  - Upper middle: 60% 8.0 GW
  - High: 2% 4.2 GW

**Non-hydro renewables**

- **By regions**
  - Low: 0% 0.0 GW
  - Lower middle: 61% 5.4 GW
  - Upper middle: 1% 0.2 GW
  - High: 1% 0.2 GW

- **By income group**
  - Low: 100% 0.7 GW
  - Lower middle: 21% 8.1 GW
  - Upper middle: 5% 12.2 GW
  - High: 1% 2.0 GW

Different patterns – often RE invest “on top” of conventionals

Total commitment for power generation projects by MDB
USD$_{2015}$ billion, based on bottom-up analysis of project data

Stark differences between public and private sector branches

Financial commitments to power-generation technologies by branches of regional MDBs
10 years 2006–15

Commitment per bank
(USD\textsubscript{2015} billion)

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Related papers (and underlying datasets) from our group


See also:

Thank you for your attention!

@BjarneSteffen