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Financing and innovation in energy transitions

Lecture at Energy Innovation Bootcamp – 2nd Edition, EUI Florence, 26–28 Nov 2019

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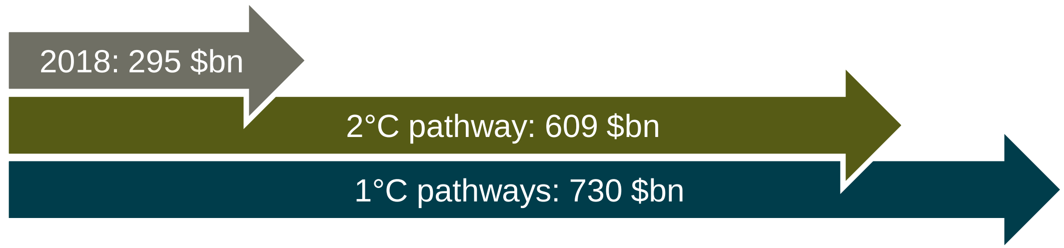
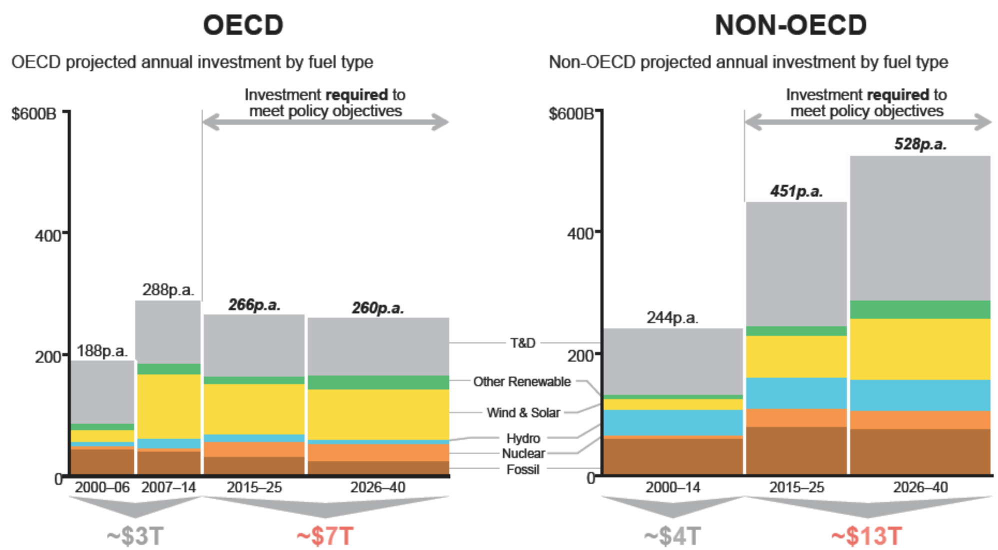
Agenda

Projected renewable energy investment needs

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



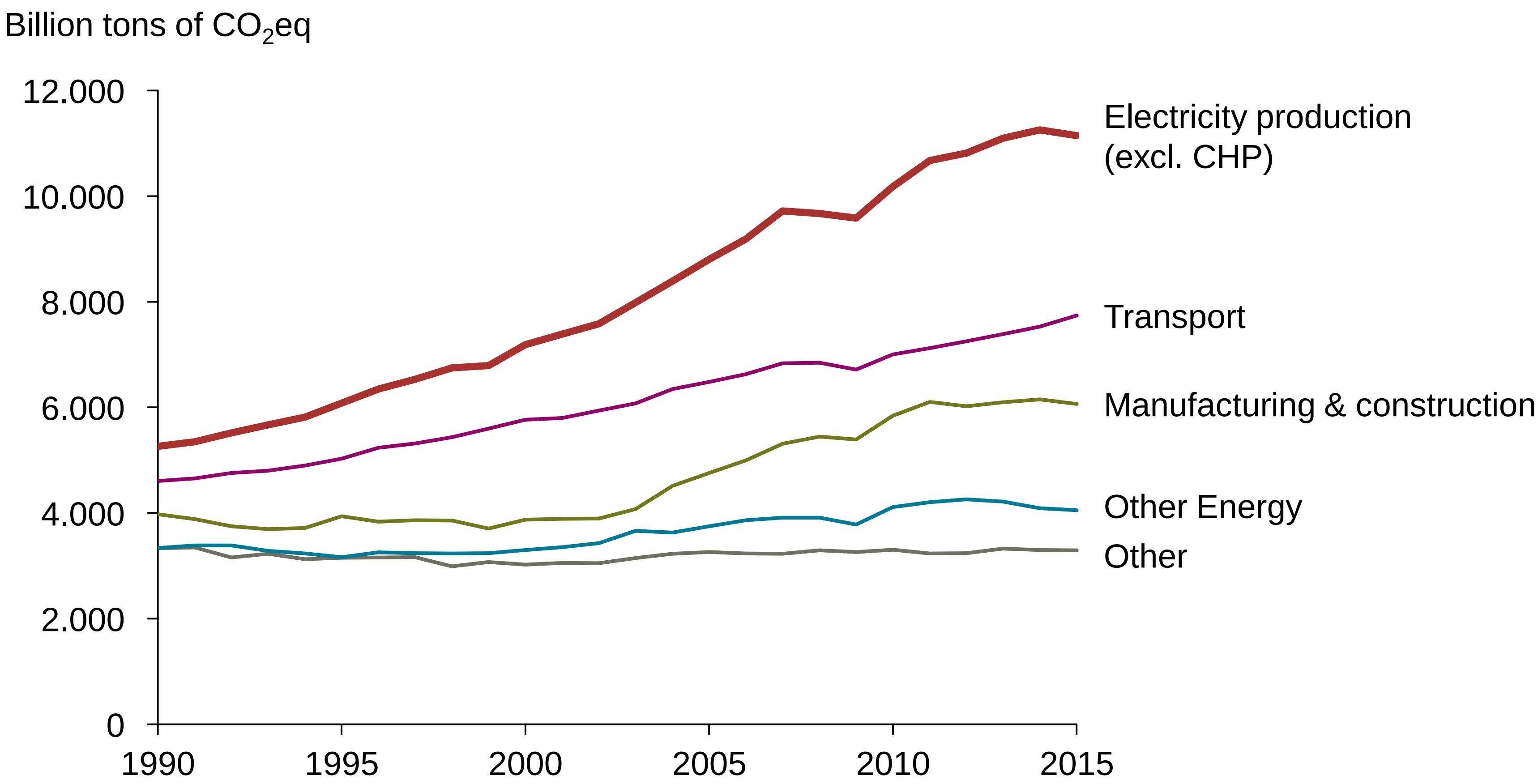
Investment need particularly high in non-OECD countries



Note: 2014 investments assumed to be equal to average annual investments in 2007-2013 for OECD and 2000-2013 for non-OECD

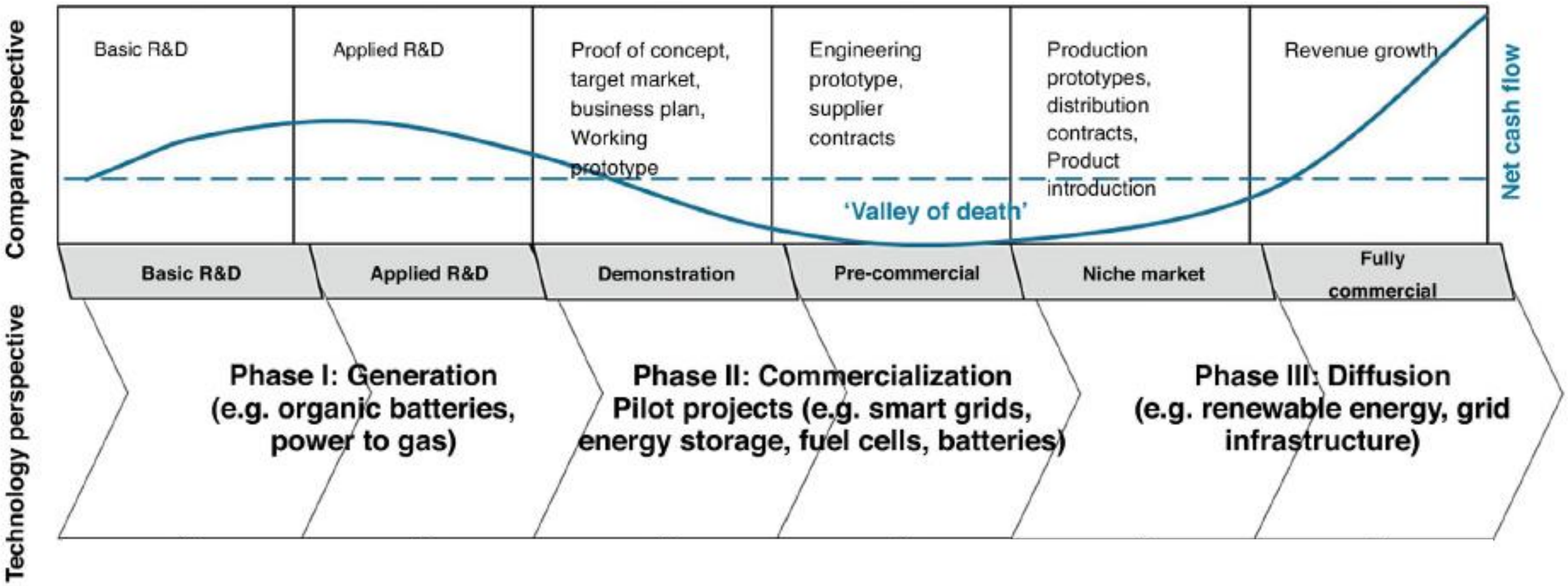
Source: Top: 2018 from BNEF, pathways from McCollum et al. 2018, Nature Energy 3, 589-599. Bottom: World Economic Forum (2016): The future of electricity in fast-growing economies (based on IEA World Energy Outlook 2015),

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



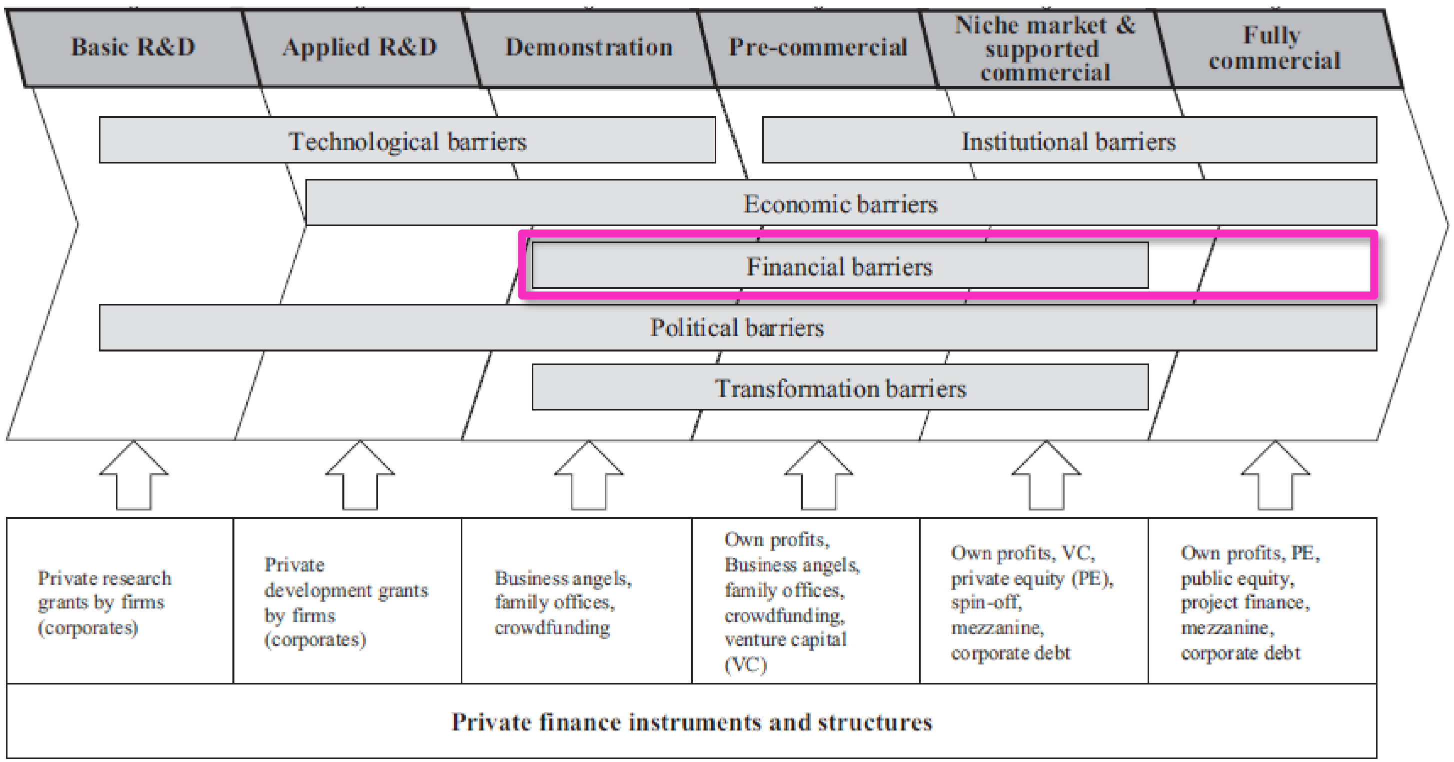
Note: Other Energy includes CHP plants, heating plants and other energy industry own use.
Source: EPG calculations based on IEA data

Innovation chain from technology and business perspective



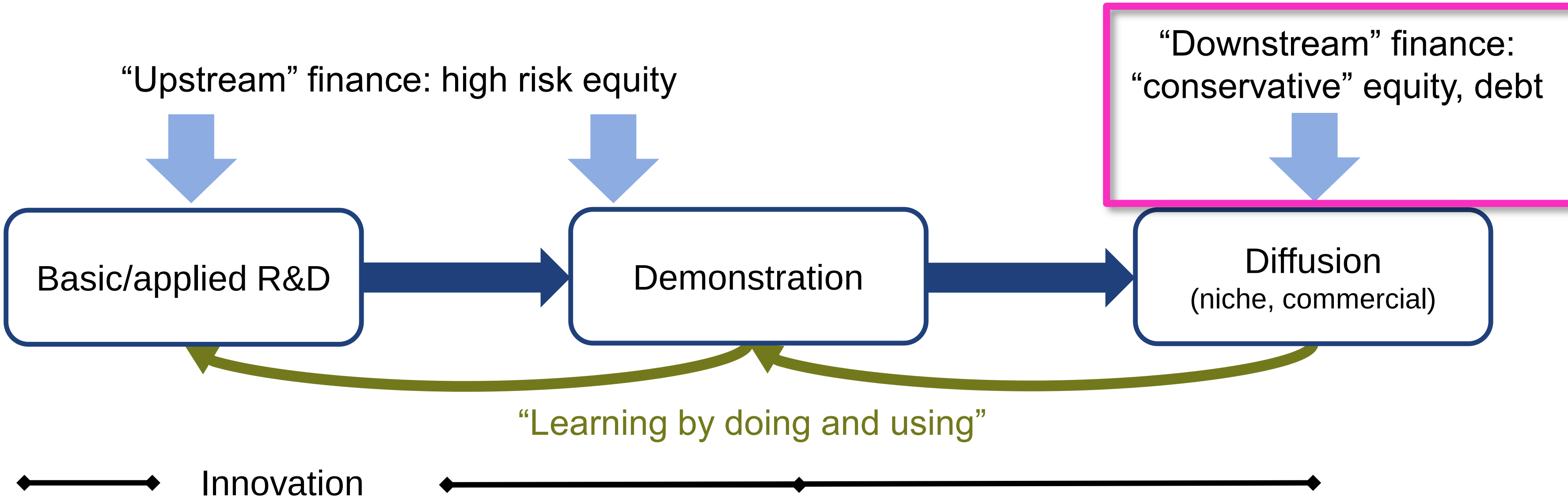
Source: F Polzin, M Sanders, F Täube (2017), A diverse and resilient financial system for investments in the energy transition, Current opinion in environmental sustainability 28, 24-32.

Barriers to (private) finance along the innovation chain



Source: F Polzin (2017), Mobilizing private finance for low-carbon innovation – A systematic review of barriers and solutions, Renewable and Sustainable Energy Reviews 77, 525-535.

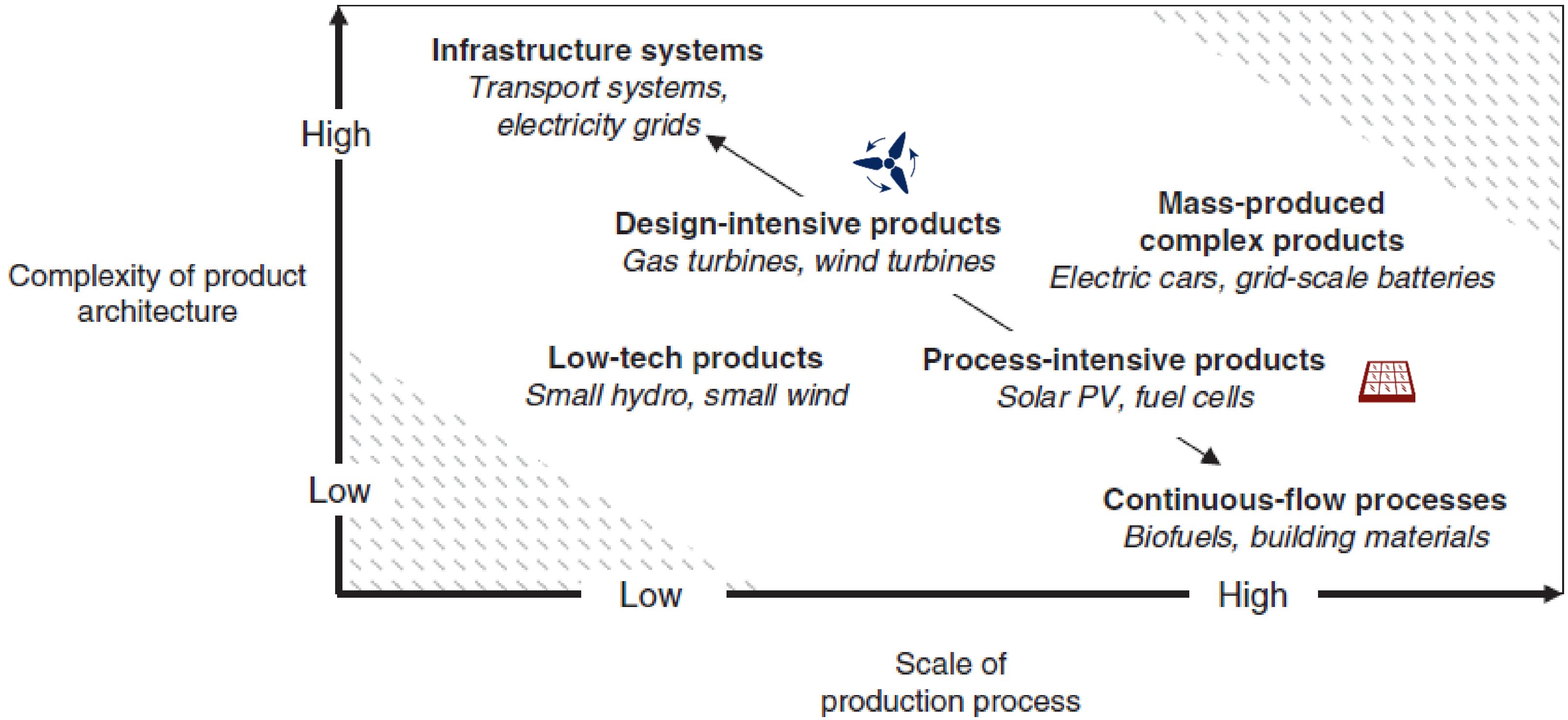
Innovation necessitates up- <u>and</u> downstream finance



- 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

Source: Schmidt, T. S., Huenteler, J. (2016), *Global Environmental Change* doi:10.1016/j.gloenvcha.2016.02.005

Classification of energy technologies according to their complexity



Source: Huenteler, J., Schmidt, T. S., Ossenbrink, J., & Hoffmann, V. H. (2016). Technology life-cycles in the energy sector—Technological characteristics and the role of deployment for innovation. Technological Forecasting and Social Change, 104, 102-121.

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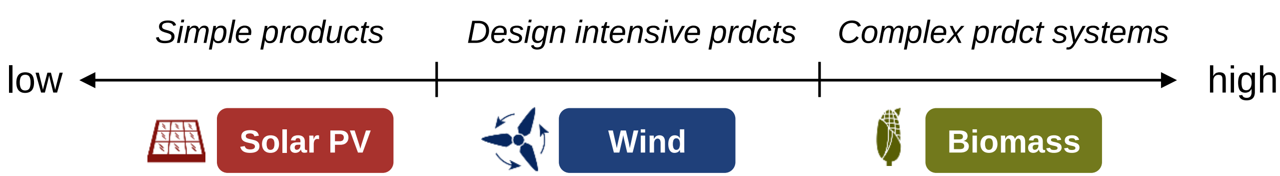
Excursus: Global diffusion patterns as empirical test for differences in complexity of product architecture (1/2)

Technology complexity

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



Global cost reduction

Technological progress reflected in cost learning curves – global or local

- Simple products often assembled from globally traded commodities
  → <u>global learning, rapid deployment once globally cost competitive</u>
- Complex products needed local design adaptation/local components/services
  → <u>global and local learning, less rapid development</u>

Source: Steffen, B., Matsuo, T., Steinemann, D., & Schmidt, T. S. (2018). Opening new markets for clean energy: The role of project developers in the global diffusion of renewable energy technologies. *Business and Politics*, 1-35.

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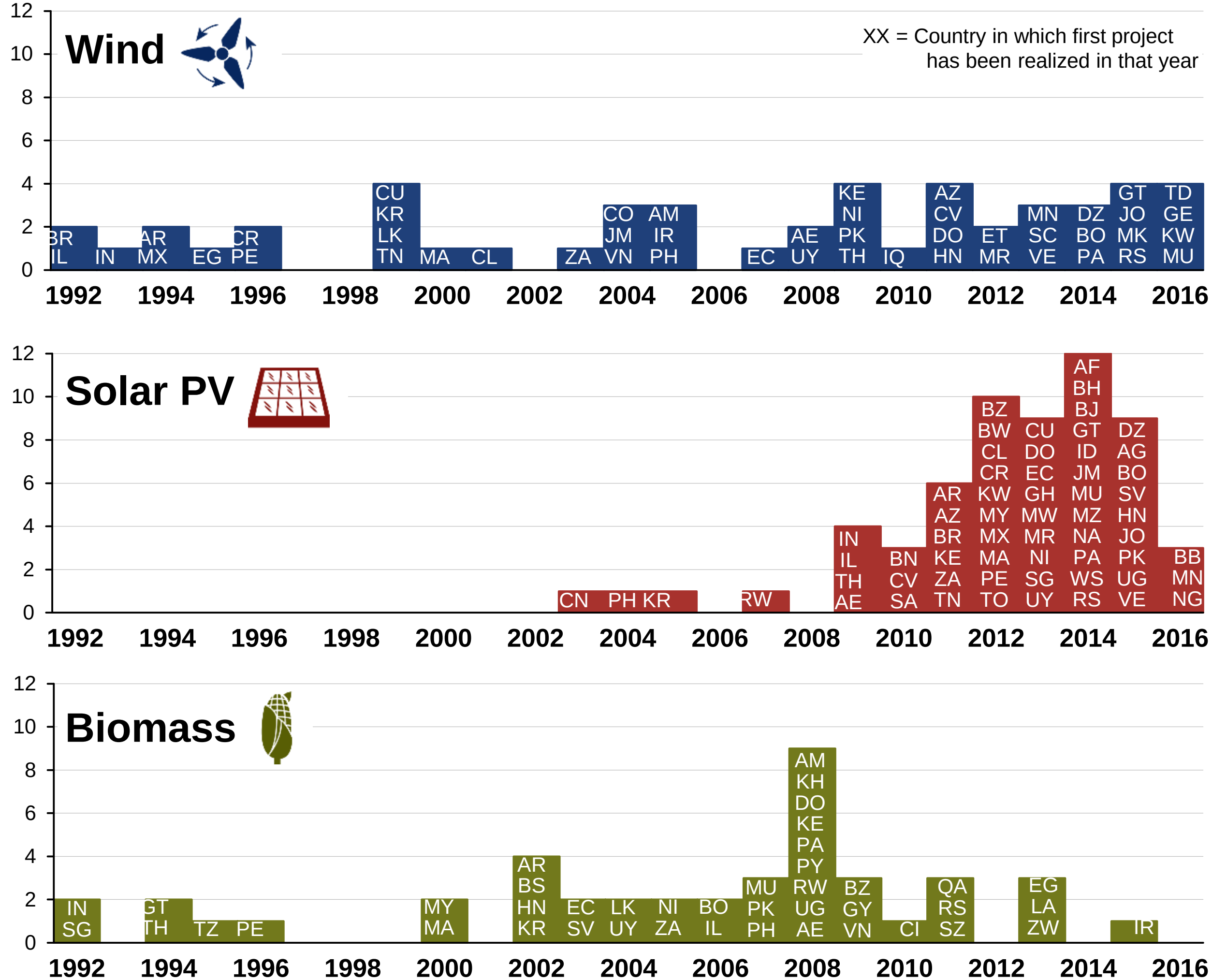
Excursus: Global diffusion patterns as empirical test for differences in complexity of product architecture (1/2)

No. of countries with first project

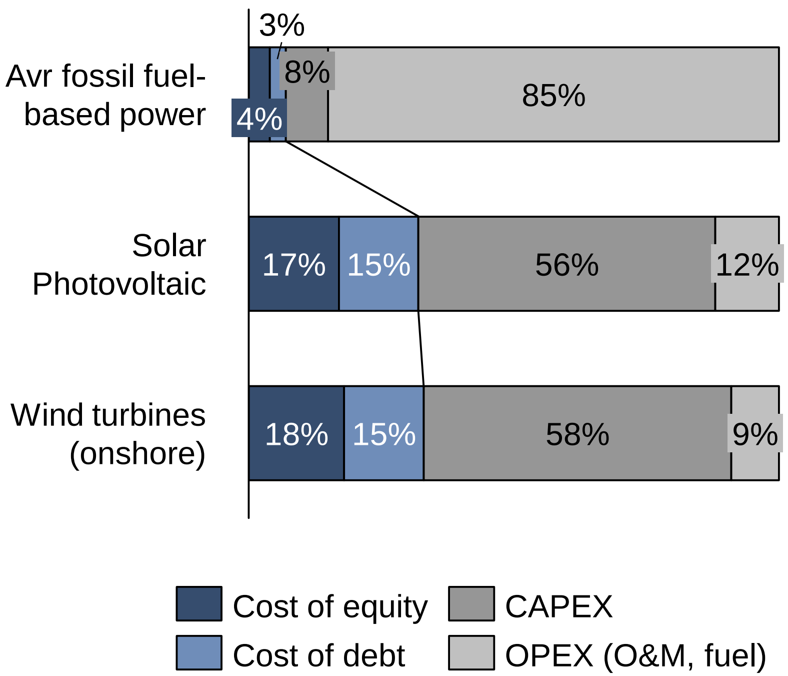


Source: Steffen, B., Matsuo, T., Steinemann, D., & Schmidt, T. S. (2018). Opening new markets for clean energy: The role of project developers in the global diffusion of renewable energy technologies. *Business and Politics*, 1-35.

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

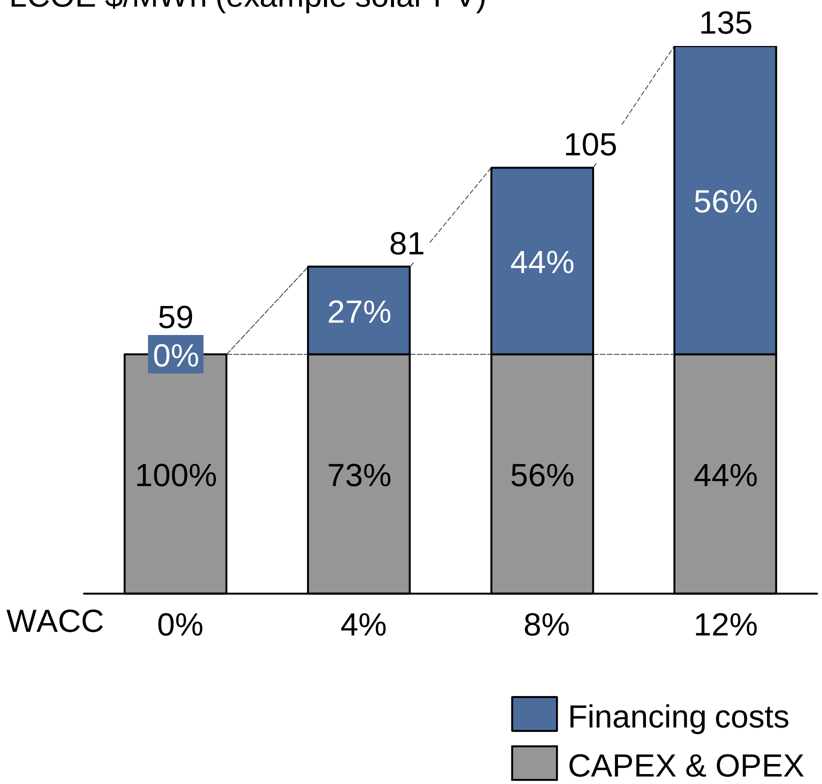
Renewables w/ high upfront investment…

Percentage of LCOE



…hence LCOE are sensitive to WACC

LCOE $/MWh (example solar PV)



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.

Agenda

Project finance (PF) is a special way for capital investments

Corporate Finance (CF)

Financing of new project <u>on the balance sheet</u> of the sponsor

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

Project Finance (PF)

Creating a <u>special purpose vehicle</u> (SPV) to incorporate new project

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

Typical use cases according to Basel II framework

- "Large and complex installations"
- Power plants, chemical processing plants, mines

Source: BCBS, 2006: International Convergence of Capital Measurement and Capital Standards, Bank for International Settlements.

Project finance (PF) has distinct characteristics

Project Finance (PF)

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*

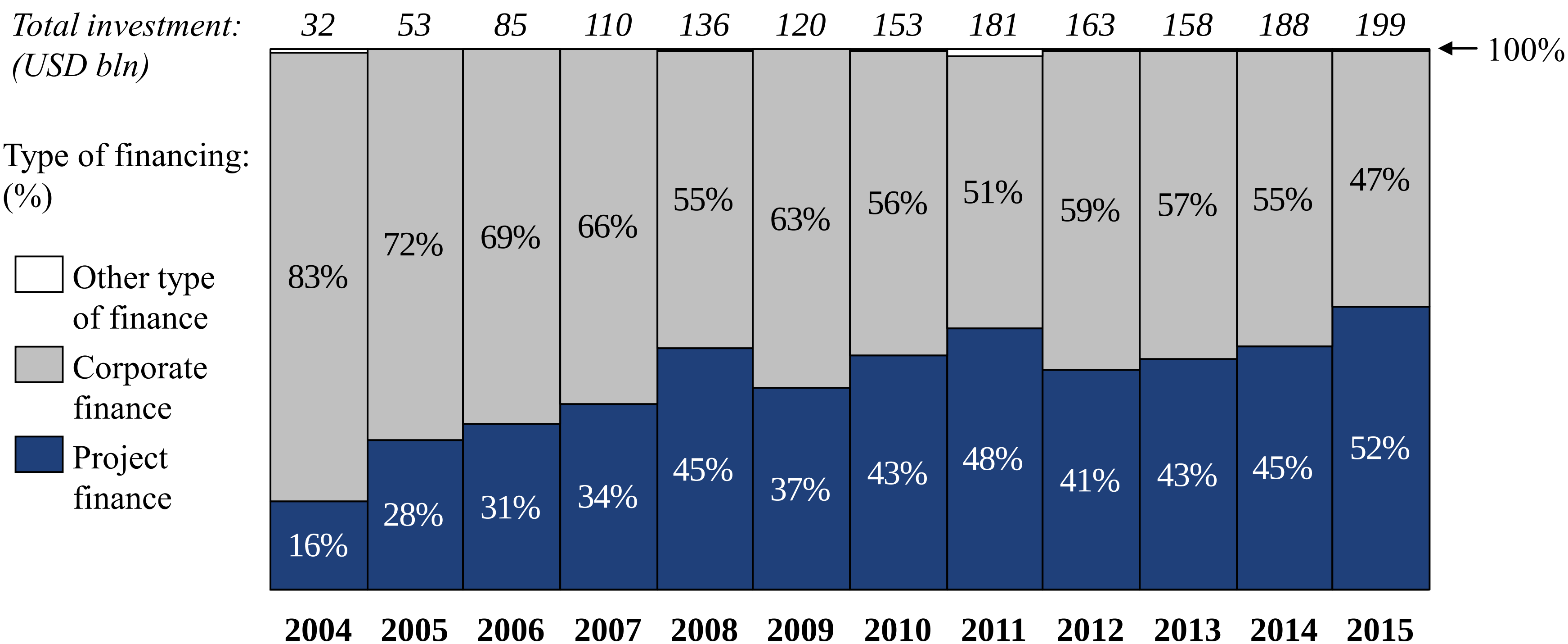
Key drawback: Transaction cost

- 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

Source: Esty, B.C., 2004: Why Study Large Projects? An Introduction to Research on Project Finance. Eur. Financ. Manag. 10, 213–224. Pollio, G., 1998: Project finance and international energy development. Energy Policy 26, 687–697.

Renewables – comparably small & low-risk – are surging in PF

Global asset financing of new investment in renewable energy



Source: BNEF data provided by OECD, 2016: Fragmentation in clean energy investment and financing, in: OECD Business and Finance Outlook 2016. OECD Publishing, Paris, pp. 141–175.

Potential reasons to use PF from economic theory

Negative financial synergies with existing business

1. Contamination risk
2. Debt overhang
3. Securitization

(Further) market imperfections

4. Information asymmetry btw. sponsor & lender
6. Agency conflicts btw. project owners & managers

 (Agency conflicts btw. project owners & contractual parties)

Considerations reg. organizational structure

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

Steffen, B. (2018), The importance of project finance for renewable energy projects, Energy Economics (69), 280–294.

Quantitative analysis of extreme low-risk case DE

Case selection: Germany

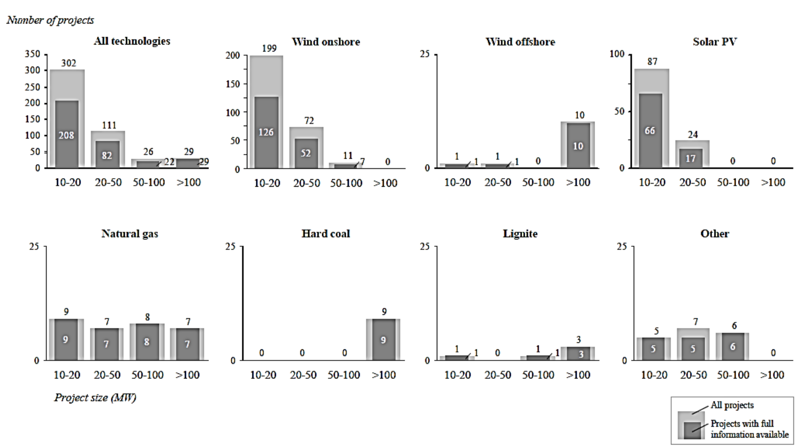
Polar type sampling: DE as extreme example of low-risk environment for renewables

- «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



		A (all sponsors)	B (all sponsors)	C (all sponsors)	D (all sponsors)	E (all sponsors)	F (only RegMun[a])
Project size	Installed capacity	2.271	2.758	1.944	4.051*	3.611	0.458
		(2.175)	(2.483)	(2.636)	(2.436)	(3.370)	(3.090)
	Installed capacity squared	-1.038	-1.804	-1.299	-1.618*	-1.633	0.296
		(0.854)	(1.157)	(0.916)	(0.969)	(1.322)	(1.047)
Project risk	Merchant risk (no feed-in tariff)	-2.559***	-2.190***	-2.702***	-4.824***	-0.935	-3.827
		(0.771)	(0.803)	(0.886)	(0.642)	(1.438)	(3.513)
	Renew. tech. risk[b] (wind offshore)	-2.391*	-2.596*	-2.012	-3.347**	-2.663	-1.607
		(1.268)	(1.394)	(1.898)	(1.422)	(1.907)	(1.811)
Technology controls	Hard coal		2.396				
			(2.786)				
	Solar PV		2.673***				
			(1.026)				
Free CF pot.[c]	CAPEX to OPEX ratio					4.049***	4.724*
						(1.478)	(2.473)
Sponsor type	Big four utility	-0.810	-0.458	-0.787		-0.662	
		(0.876)	(0.903)	(0.869)		(1.016)	
	Regional/municipal utility	-0.425	-0.555	-0.393		-0.474	
		(0.833)	(0.874)	(0.852)		(0.962)	
	Foreign utility/IPP	0.948	1.073	0.940		1.250	
		(1.038)	(1.039)	(1.025)		(1.208)	
	Project developer	2.371***	2.024**	2.409***		2.297**	
		(0.812)	(0.926)	(0.839)		(0.933)	
	Industry	-0.620	-0.913	-0.573		-1.057	
		(1.017)	(0.987)	(1.046)		(1.152)	
	Cooperative/individuals	3.604***	3.541***	3.623***		3.638***	
		(1.259)	(1.283)	(1.263)		(1.348)	
	Horizontal joint venture	1.381*	1.889**	1.368*	0.147	2.239**	1.749
		(0.722)	(0.803)	(0.715)	(0.835)	(0.974)	(1.264)
Interaction terms	Installed capacity × Merchant risk			0.194			
				(0.560)			
	Big four utility × No merchant risk				-2.313***		
					(0.761)		
	Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
	Pseudo-R^2	0.522	0.534	0.523	0.429	0.578	0.347
	Observations	292	287	292	341	276	64

Standard errors in parentheses

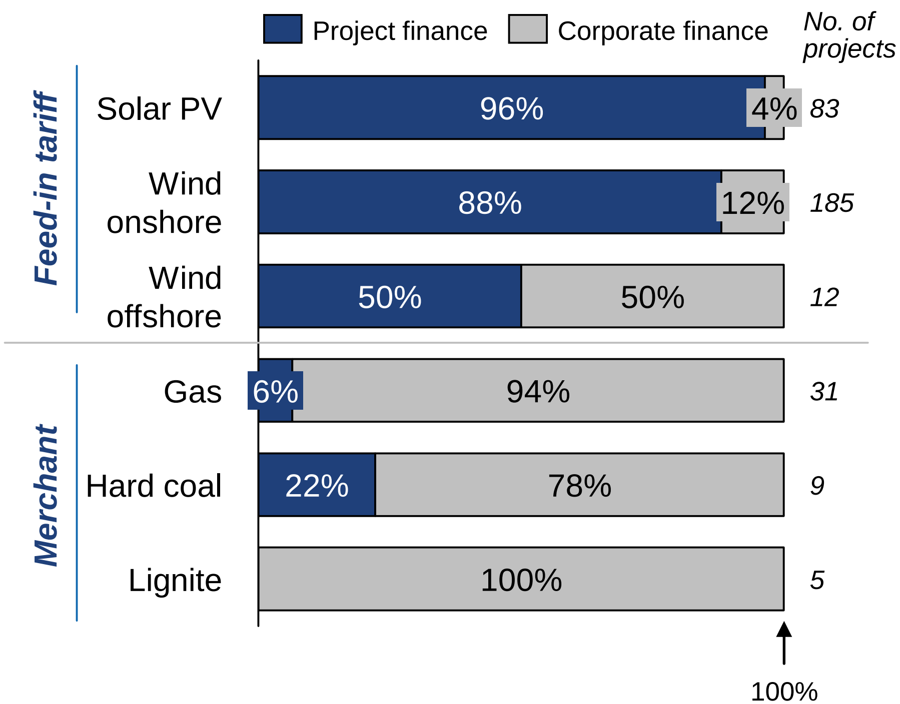
[a]RegMun = Regional/municipal utility [b]Renew. tech. risk = Renewables technology risk [c]Free CF pot. = Free cash flow potential
*statistically significant at 10%; **significant at 5%; ***significant at 1%

Steffen, B. (2018), The importance of project finance for renewable energy projects, Energy Economics (69), 280–294.

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



Key reason: small balance sheets of new players in industry

Results from regression analysis on rationales to use project finance

Negative financial synergies with existing business

- ~~1. Contamination risk~~
- 2. Debt overhang
- ~~3. Securitization~~

(Further) market imperfections

- ~~4. Information asymmetry btw. sponsor & lender~~
- 5. Agency owners & mgrs

Considerations regarding org. structure

- ~~6. Horizontal joint ventures~~
- 7. Independence civic prjcts

Steffen, B. (2018), The importance of project finance for renewable energy projects, *Energy Economics* (69), 280–294.

Agenda

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*

Egli, F., Steffen, B., Schmidt, T. S. (2018). A dynamic analysis of financing conditions for renewable energy technologies. Nature Energy.

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

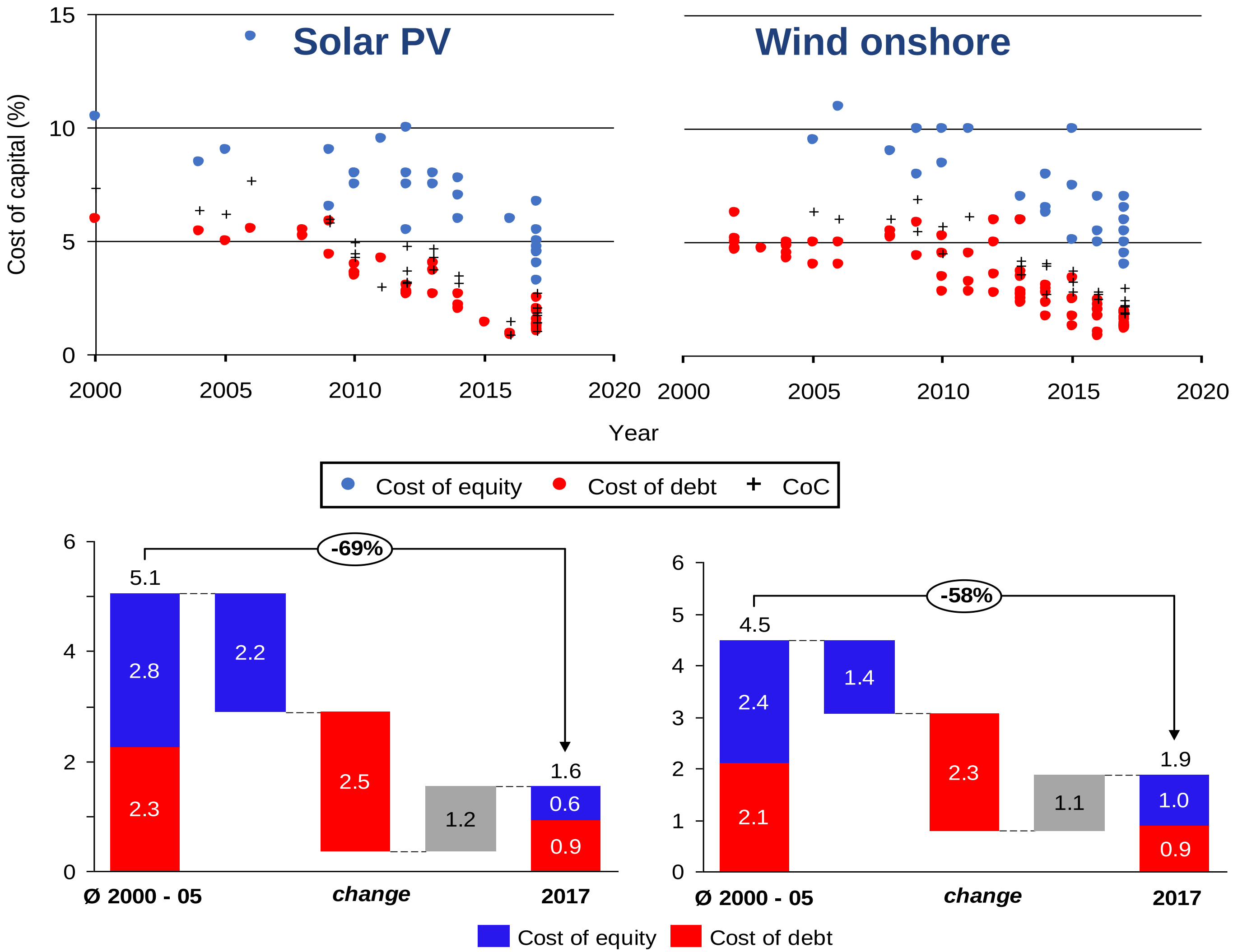
2. **Qualitative: Investor interviews to identify drivers for changes**
   - Semi-structured interviews, grounded theory-type coding of arguments

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

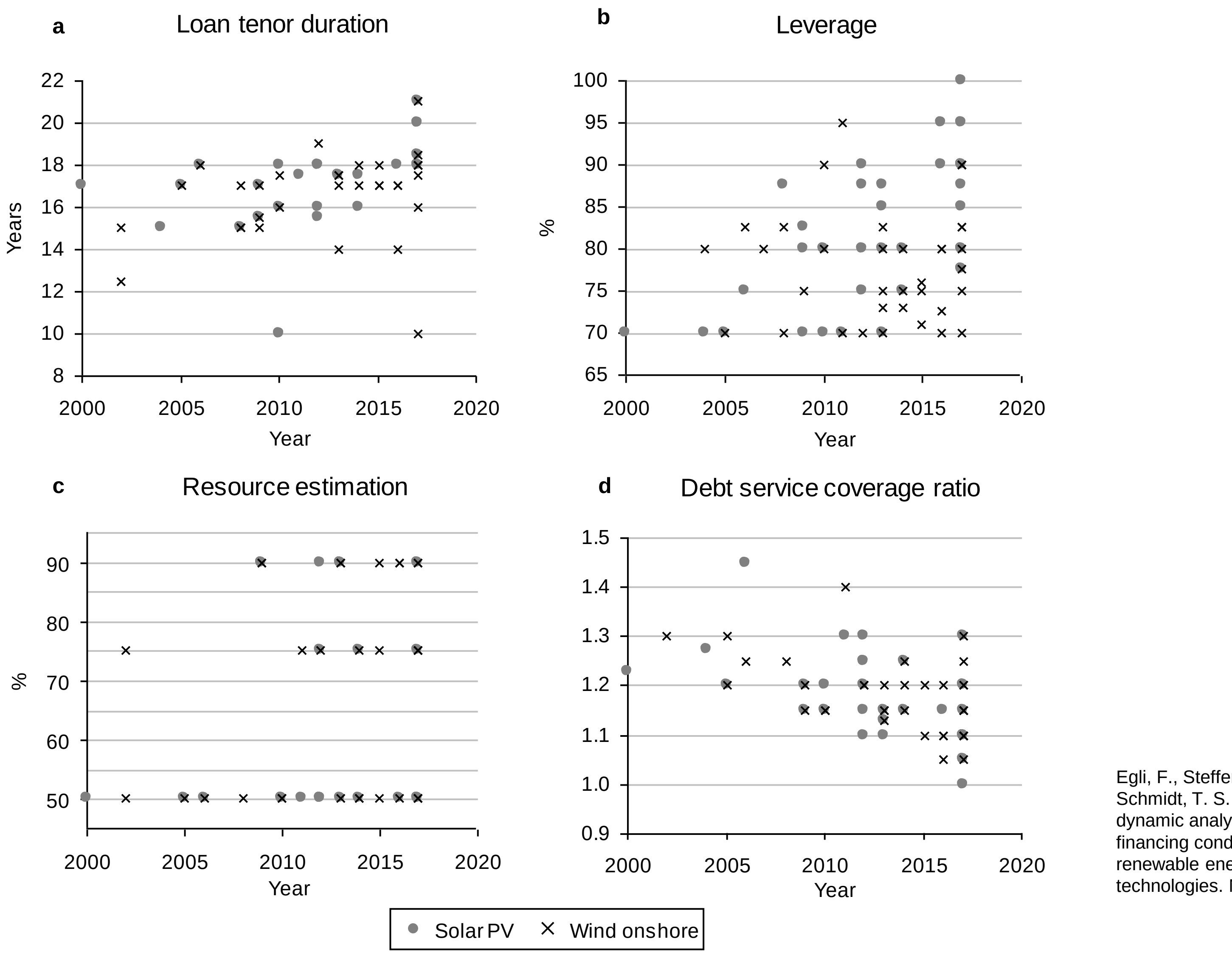
Egli, F., Steffen, B., Schmidt, T. S. (2018). A dynamic analysis of financing conditions for renewable energy technologies. Nature Energy.

Step 1: Historic development of the cost of capital



Egli, F., Steffen, B., Schmidt, T. S. (2018). A dynamic analysis of financing conditions for renewable energy technologies. Nature Energy

Step 1: The data (other financial indicators)



Egli, F., Steffen, B., Schmidt, T. S. (2018). A dynamic analysis of financing conditions for renewable energy technologies. Nature Energy

Step 2: The drivers

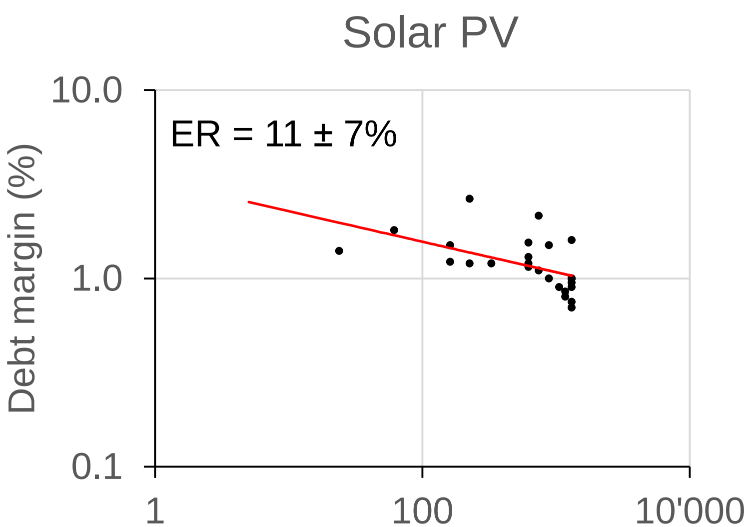
Level	Drivers of changes in financing conditions	
Economy	▪ **Capital markets:** Low-cost liquidity, few investment alternatives, low return expectations ▪ **Banks:** Low-cost refinancing, low bank fees, preference for project finance	*Drivers related to general economic development* — **control for**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

Egli, F., Steffen, B., Schmidt, T. S. (2018). A dynamic analysis of financing conditions for renewable energy technologies. Nature Energy.

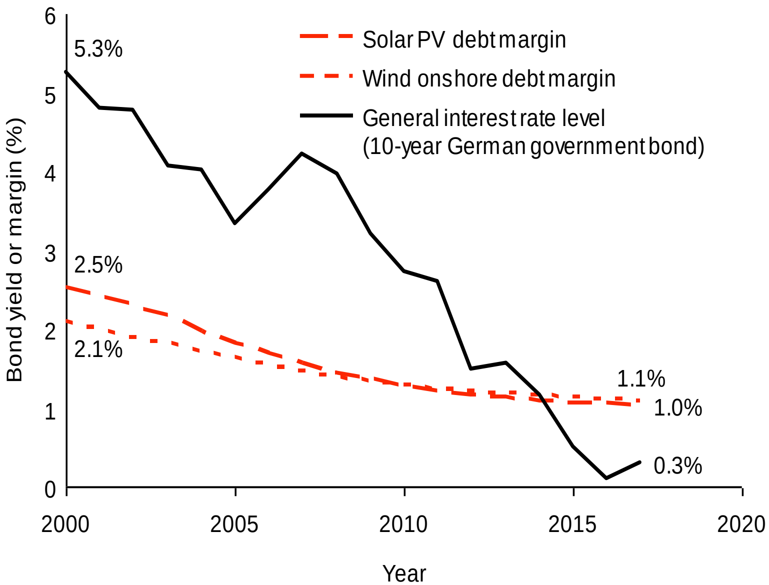
Step 3: Experience and general interest rate effects

Identification of experience effect:

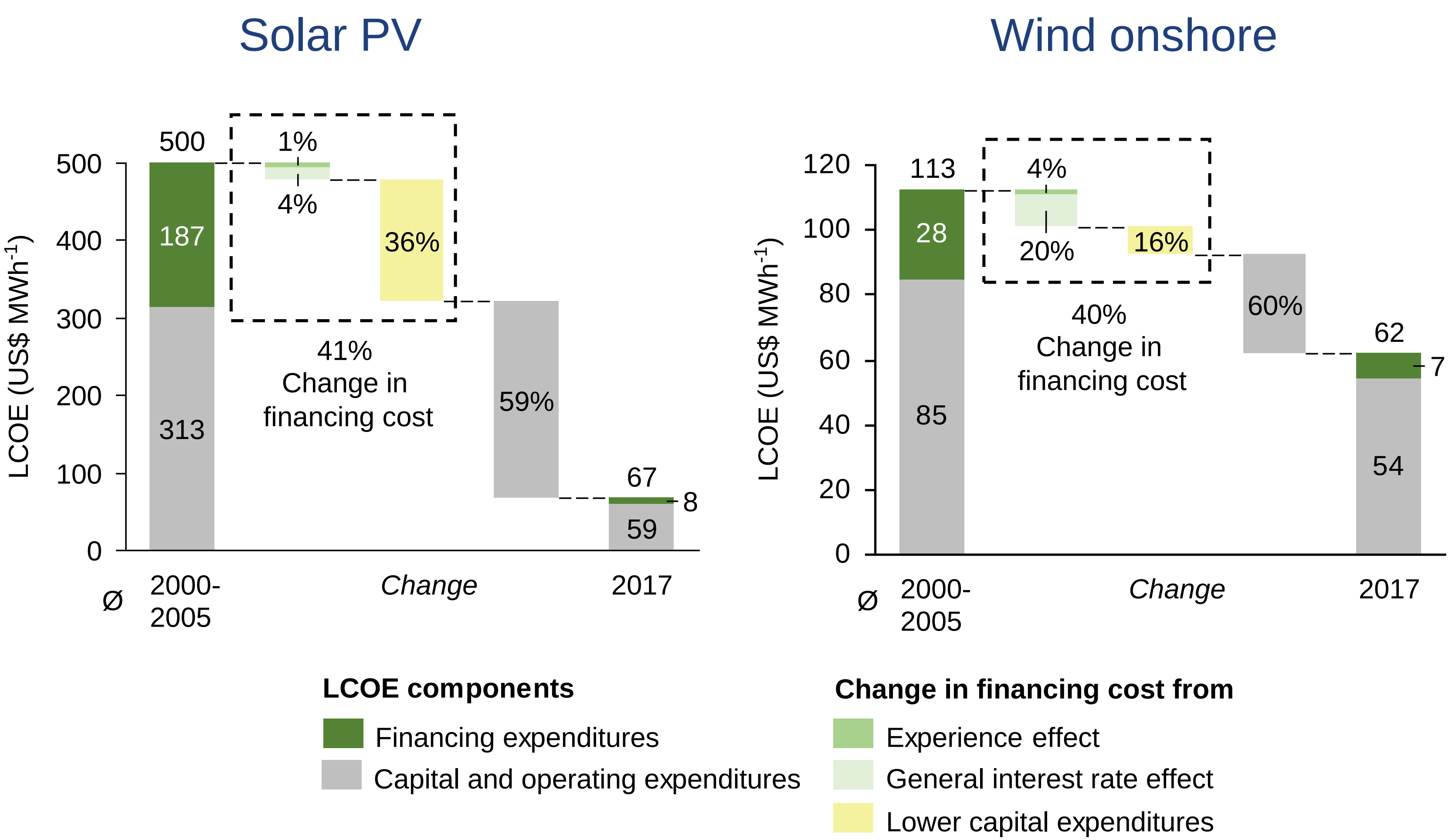
$$DebtMARGIN(I_t) = DebtMARGIN(I_0)\left(\frac{I_t}{I_0}\right)^{-b_1}$$



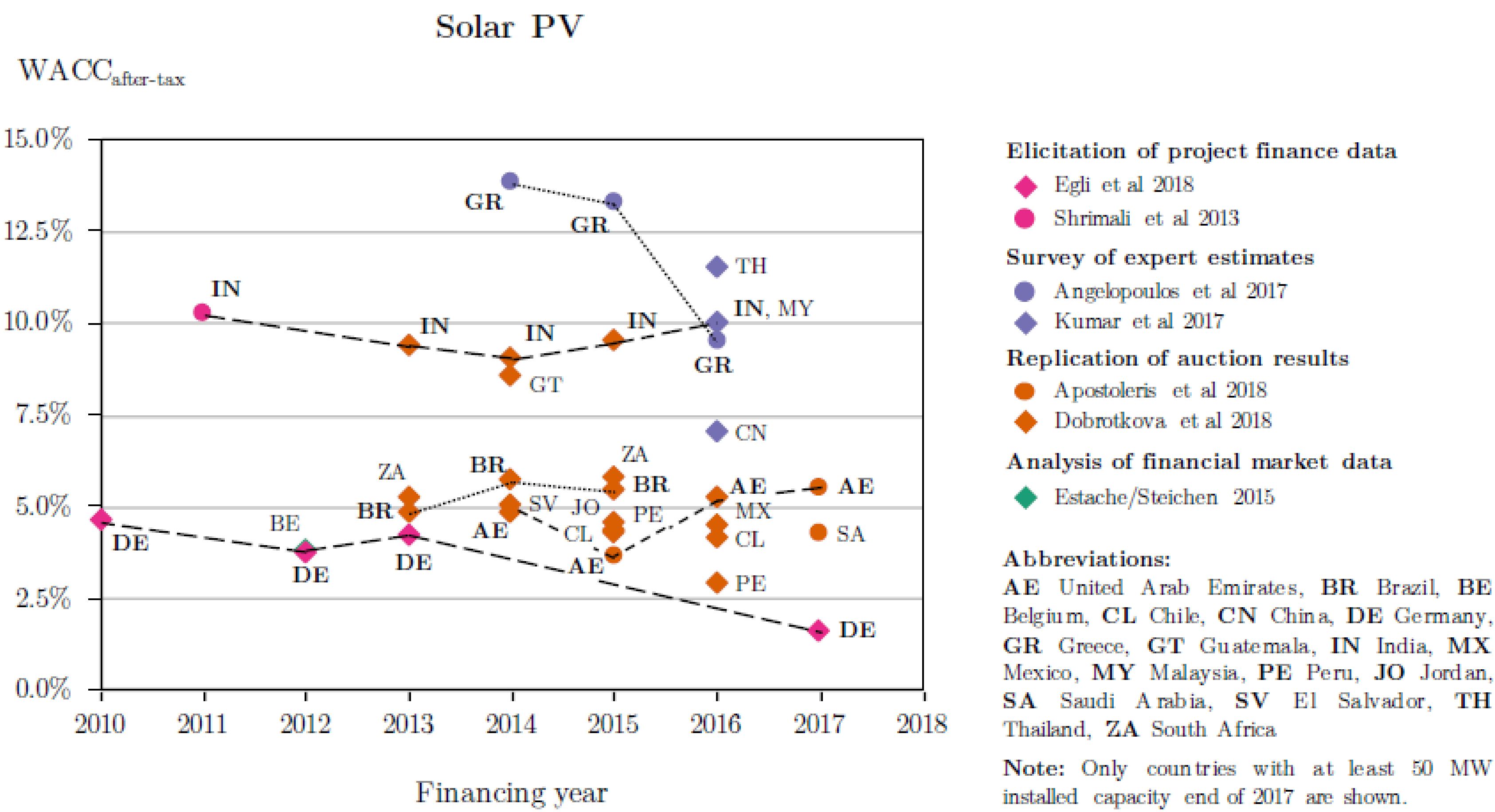
Comparison of experience effect and general interest rate level



Step 4: Channels of improved financing costs

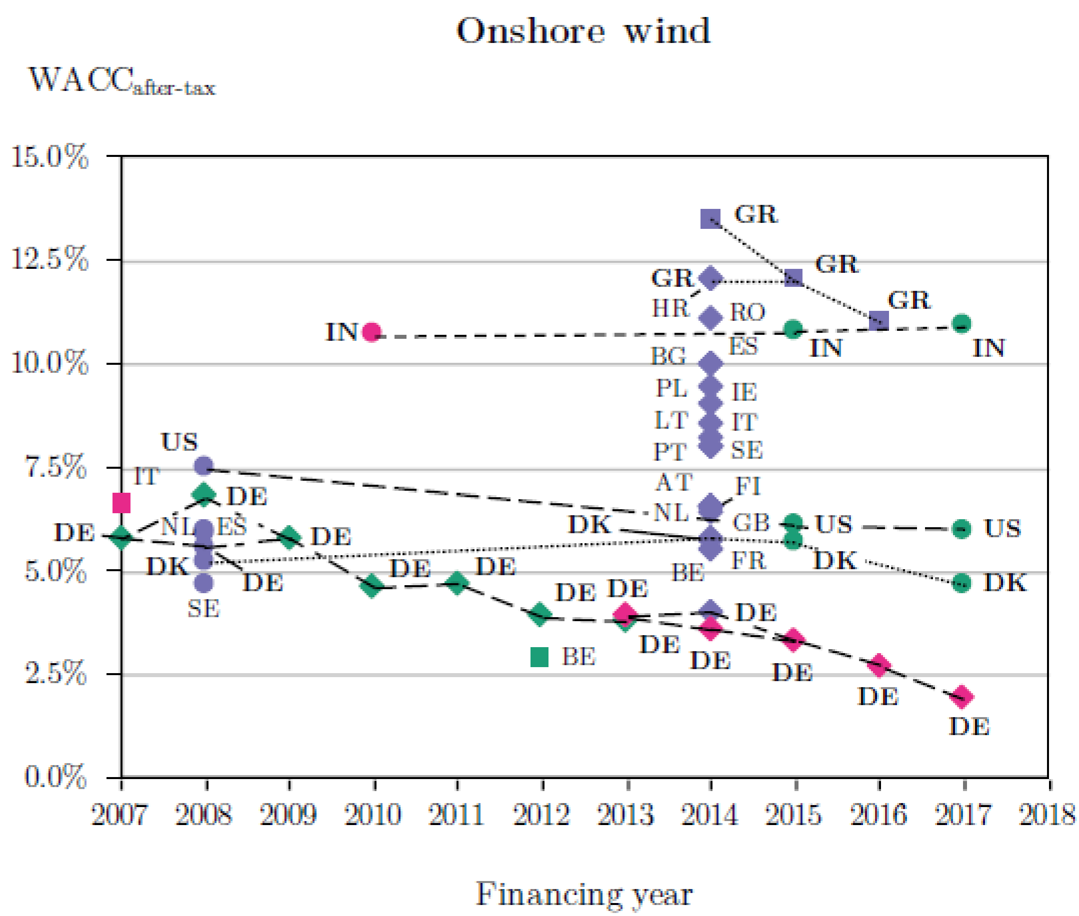


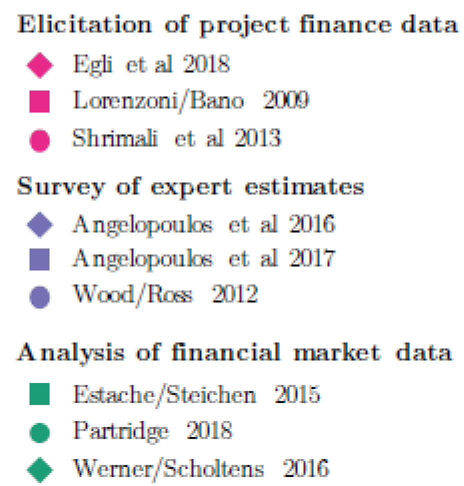
Side note: Cost of capital differs strongly between countries



Steffen B (2019), Estimating the Cost of Capital for Renewable Energy Projects. https://ssrn.com/abstract=3373905

Side note: Cost of capital differs strongly between countries





Abbreviations: **AT** Austria, **BG** Bulgaria, **BR** Brazil, **BE** Belgium, **DE** Germany, **DK** Denmark, **ES** Spain, **FI** Finland, **FR** France, **GB** United Kingdom, **GR** Greece, **HR** Croatia, **IE** Ireland, **IN** India, **IT** Italy, **LT** Lithuania, **NL** Netherlands, **PL** Poland, **PT** Portugal, **RO** Romania, **SE** Sweden, **US** United States

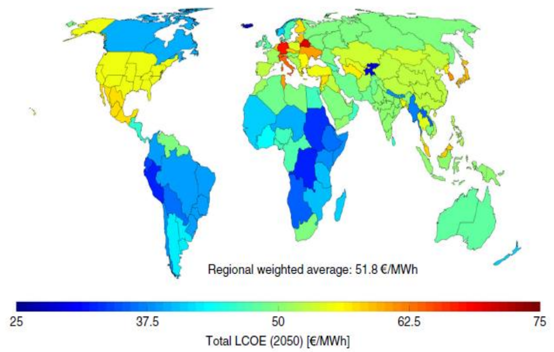
Note: Only countries with at least 50 MW installed capacity end of 2017 are shown.

Steffen B (2019), Estimating the Cost of Capital for Renewable Energy Projects. https://ssrn.com/abstract=3373905

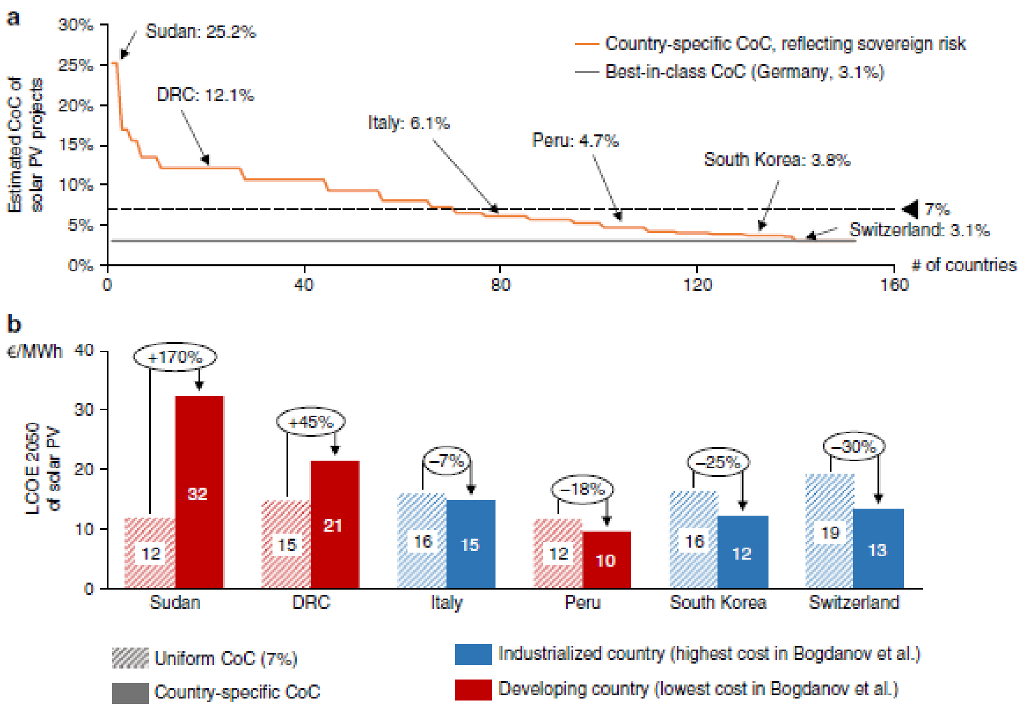
In models, CoC assumption is crucial for cost comparison

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]



1.. D. Bogdanov et al., "Radical transformation pathway towards sustainable electricity via evolutionary steps," *Nature Communications*, vol. 10, no. 1, p. 1077, Dec. 2019.

2. Egli F, B. Steffen, and T. S. Schmidt, "Bias in energy system models with uniform cost of capital assumption," *Nature Communications*, vol. 10, pp. 4588–4590, 2019.

Agenda

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?

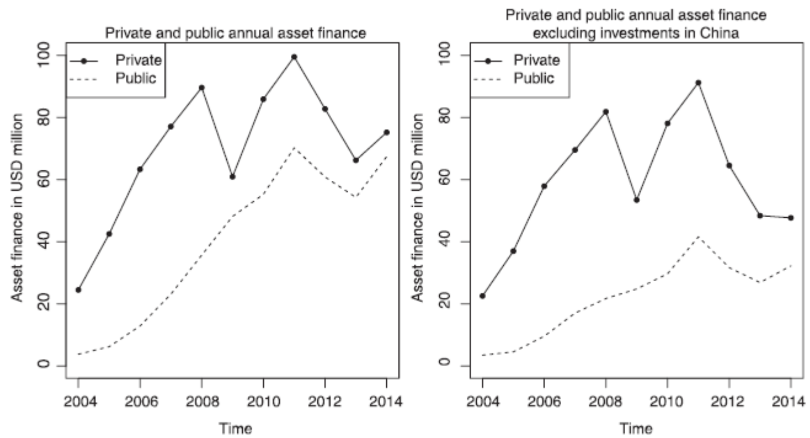


Fig. 4. Volume of annual public and global private asset finance (left panel) and excluding China (right panel).

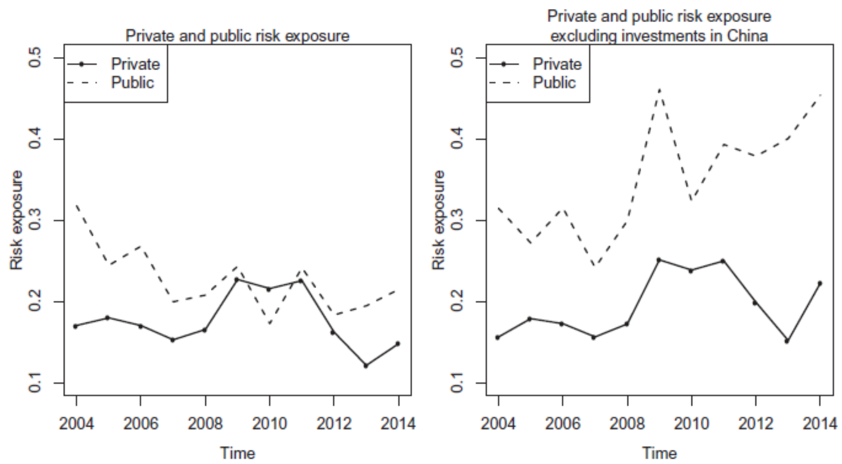
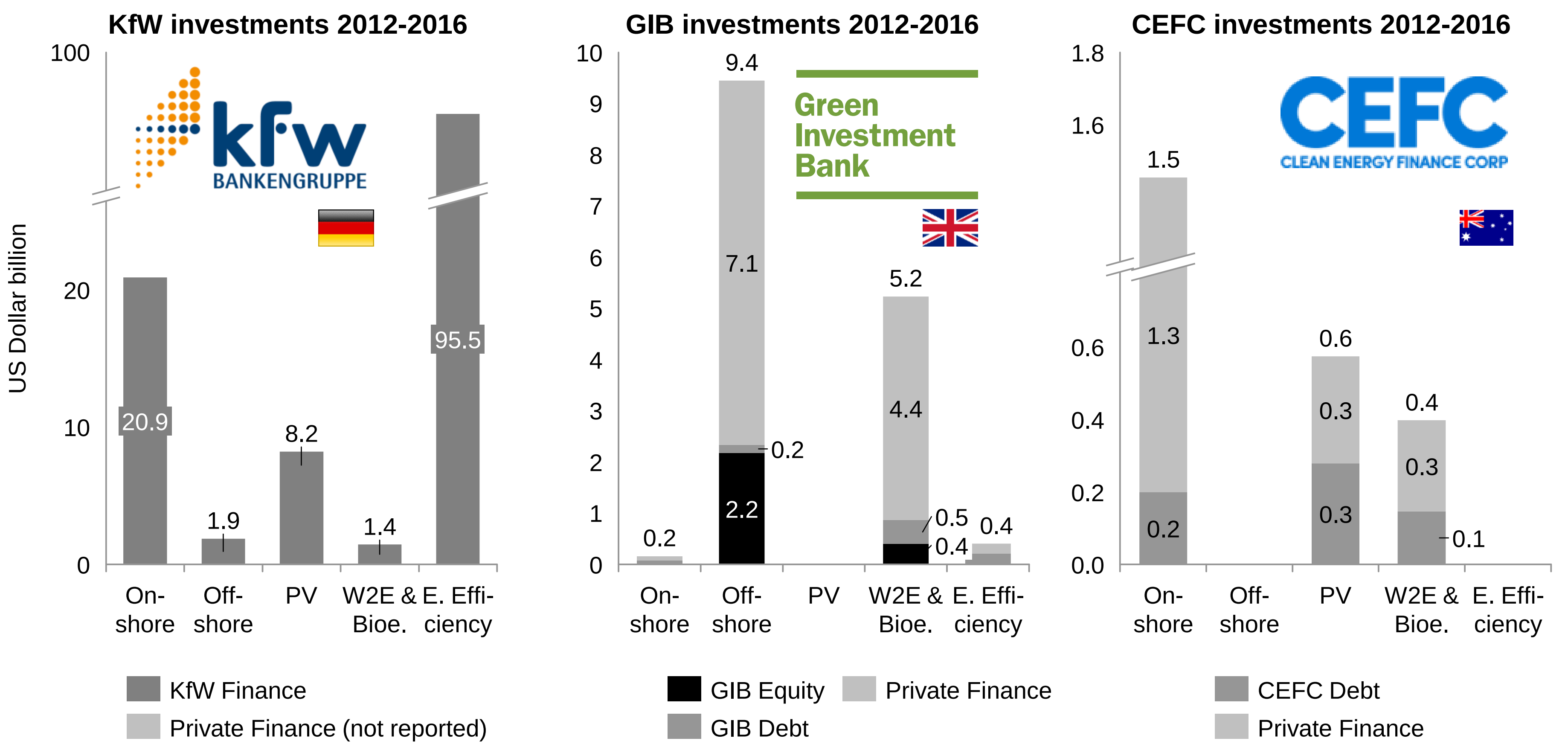


Fig. 5. Exposure to risk of annual public and private asset finance for global investments (left panel) and excluding investments made in China (right panel).

Sources: Mazzucato M, Semieniuk G: Financing renewable energy: Who is financing what and why it matters, Technological Forecasting & Social Change 127 (2018) 8–22

A market creating policy: (Green) state investment banks



Geddes, A., Schmidt, T.S., Steffen, B. (2018), The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany, *Energy Policy* 115, 158–170.

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

Category		Organisation[a]	Technology Focus[b]	Country[c]	Interviewee's Role
Developer	1	Project Developer	Wind, Solar PV	AU	Head of Business Development
	2	Project Developer	WtE	AU	Chief Executive Officer
	3	Project Developer	WtE	AU	Managing Director
	4	Project Developer	WtE	AU	Managing Director
	5	Project Developer	Bioenergy, WtE	GB	Independent developer
	6	Project Developer	Wind, Bioenergy	GB	Managing Director
	7	Project Developer	WtE	GB	Managing Director
	8	EPC, OEM	Wind, Solar PV	AU	Business Development Manager
	9	IPP	Wind	AU	Executive General Manager
	10	IPP	Wind, Hydro	AU	Executive Manager, Development
	11	IPP	Renewables	AU, GB, DE	Chief Financial Officer
	12	IPP	Solar PV	DE	Project Developer
	13	IPP	Bioenergy	GB, DE	Independent developer
	14	IPP	Wind, Solar PV	GB, DE	Manager, ESG
	15	IPP	Wind, Solar PV	GB, DE	Executive General Manager
	16	IPP	WtE, Bioenergy	GB, DE	Head of Origination
	17	OEM	Wind, Solar PV	AU	Head Structured Finance
	18	OEM	Small-scale wind	AU, GB, DE	General Manager
	19	OEM	Renewables	AU, GB, DE	Sales Manager, Renewables
	20	OEM	Renewables	AU, GB, DE	Senior VP Project Development
	21	OEM	Wind	GB, DE	Senior Investment Manager
	22	Utility	Renewables, FFs	DE	Managing Director
	23	Utility	Renewables, FFs	DE	Head Business Development
	24	Utility	Wind, Solar PV	GB, DE	Business Development Manager
	25	Utility	Wind, Solar PV	GB, DE	Managing Director
Investor	26	Commercial Bank	Renewables, FFs	AU	Executive General Manager
	27	Commercial Bank	Renewables, FFs	AU	Senior Consultant
	28	Commercial Bank	Renewables, FFs	AU, GB, DE	Director Corporate Clients
	29	Commercial Bank	Renewables, FFs	AU, GB, DE	Consultant, Green Banking Expert
	30	Commercial Bank	Renewables, FFs	GB, DE	Consultant, Innovative Finance
	31	Gov't funding entity	Renewables	AU	Transactions and Development
	32	Green Bank	Renewables	GB, DE	Relationship Manager, Arranger
	33	Invest. Advisors	Renewables	AU	Principal Financial Advisor
	34	OEM investors	Renewables, FFs	AU, GB, DE	Managing Director
	35	Invest. platform	Renewables	GB	Managing Director
	36	SIB	Renewables, EE	AU	Division Director
	37	SIB	Renewables, EE	AU	Researcher
	38	SIB	Renewables, EE	AU	Department Director
	39	SIB	Renewables, EE	AU	Associate Director
	40	SIB	Renewables, FFs	DE	Department Director
	41	SIB	Renewables, EE	GB	Department Head
	42	SIB	Renewables, FFs	GB, DE	Investment Officer
	43	SIB	Renewables, FFs	GB, DE	Project Assessor
	44	SIB	Wind, Renewables	GB, DE	Team Head, Wind Power
	45	Sustainable Bank	Renewables	GB, DE	Chief Financial Officer
	46	VC Investor	Renewables, FFs	AU, GB, DE	Director
Expert[d]	47	Consultancy	Renewables	AU, GB, DE	Arranger, Due Diligence
	48	Consultancy	Renewables, FFs	GB, DE	Associate Principal, Energy
	49	Consultancy	Wind	GB, DE	Senior Consultant, Power Market
	50	Consultancy	Wind	GB, DE	Partner, Energy and Resources
	51	Energy Think-tank	Renewables	GB	Director, Finance, Energy Policy
	52	Envir. Consultancy	Renewables, FFs	GB, DE	Principal Consultant
	53	Envir. NGO	Renewables, FFs	AU, GB, DE	Director of Strategy and Finance
	54	Legal Consultancy	Renewables	AU	Partner, Project Finance, Energy
	55	Legal Consultancy	Renewables	AU	Senior Associate, Project Finance
	56	Legal Consultancy	Renewables	AU, GB, DE	Partner, Arranger

Geddes, A., Schmidt, T.S., Steffen, B. (2018), The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany, *Energy Policy* 115, 158–170.

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)

C. Signaling Role

- SIB reputation crowding-in private equity and debt
- "SIB participation signal" with effect on financing cost

B. Educational Role

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

D. First or Early Mover

- Early movers with respect to new technologies (in the country), new deal structures, new manufacturers and developers

Geddes, A., Schmidt, T.S., Steffen, B. (2018), The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany, *Energy Policy* 115, 158–170.

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

Global

WORLD BANK GROUP

WB/IFC/MIGA

IsDB

Regional

AfDB

EIB

ADB

AsDB

EBRD

CAF

CAF

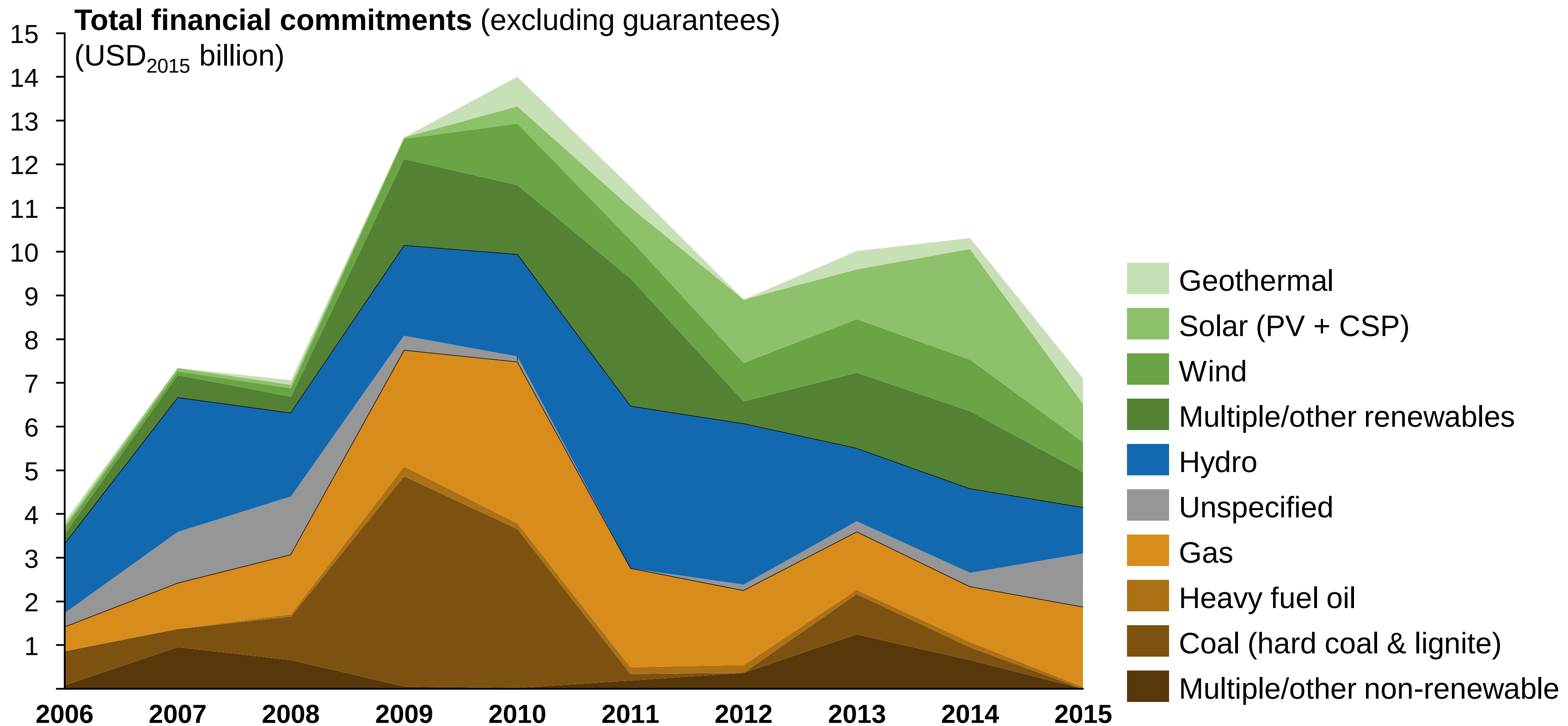
IDB Improving lives

IADB

«South-South»

Source: Steffen, B.; Schmidt, T.S. (2018). A quantitative analysis of 10 multilateral development banks' investment in conventional and renewable power-generation technologies from 2006 to 2015. *Nature Energy*.

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

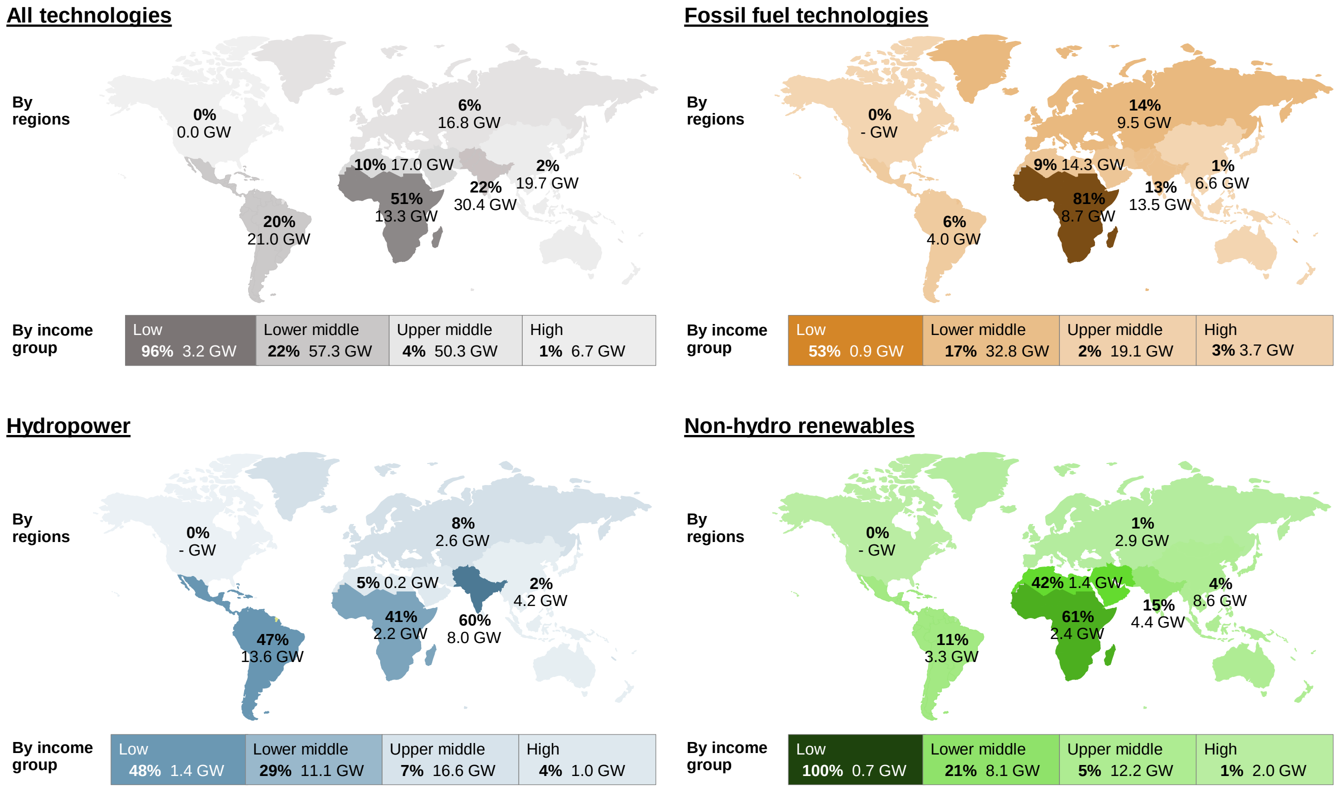


Share (%)										
Renewables	55%	51%	38%	36%	46%	76%	73%	62%	74%	56%
Renewables excl. hydro	**13%**	**9%**	**11%**	**20%**	**29%**	**44%**	**32%**	**45%**	**56%**	**42%**

Source: Steffen, B.; Schmidt, T.S. (2018). A quantitative analysis of 10 multilateral development banks' investment in conventional and renewable power-generation technologies from 2006 to 2015. *Nature Energy*.

Impact: Estimated 118 GW new capacity 2007–2015

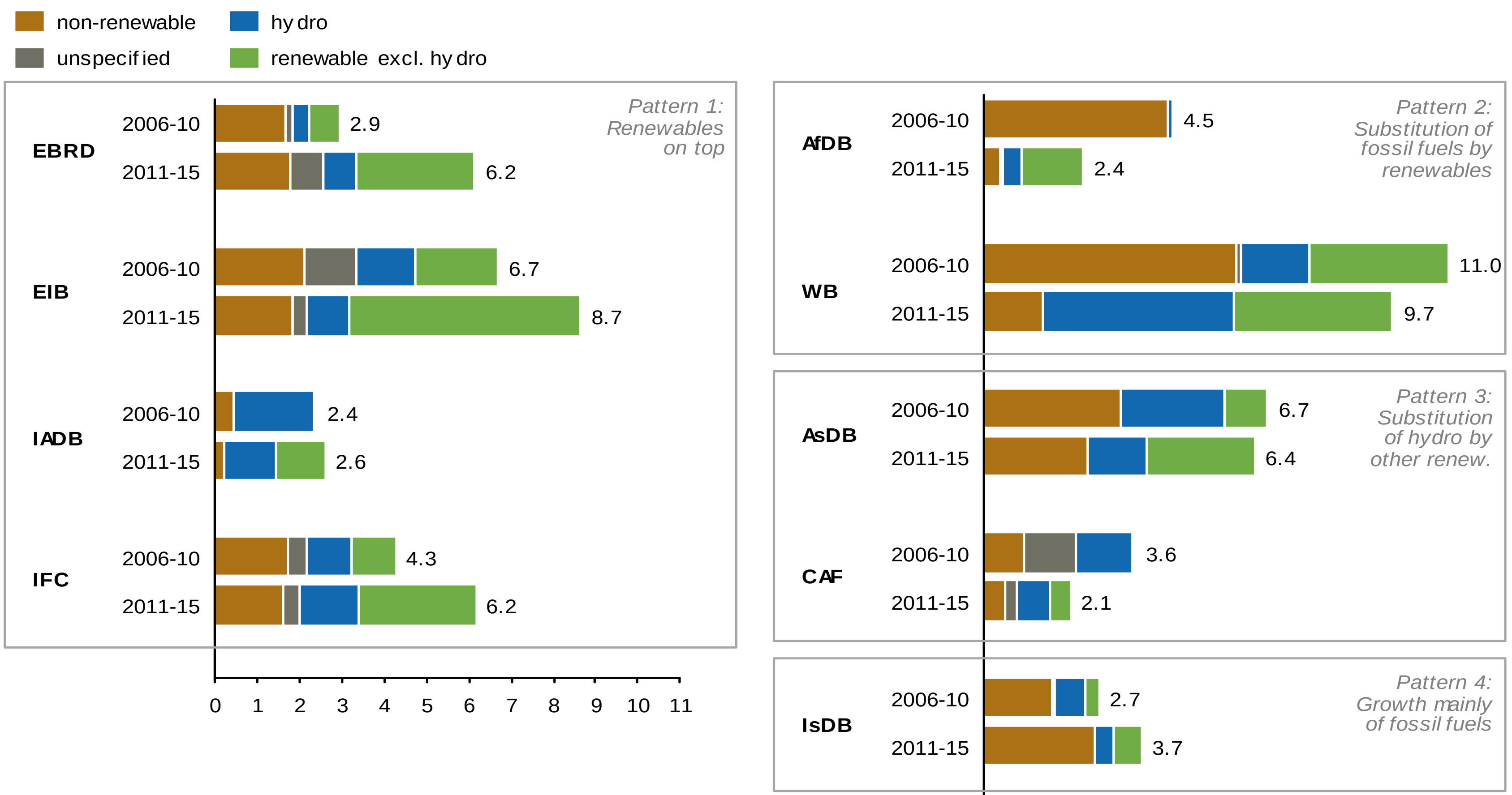
Share of power-generation capacity added during 2007–2015 through projects with MDB participation
(Estimate based on assumptions)



Source: Steffen, B.; Schmidt, T.S. (2018). A quantitative analysis of 10 multilateral development banks' investment in conventional and renewable power-generation technologies from 2006 to 2015. *Nature Energy*.

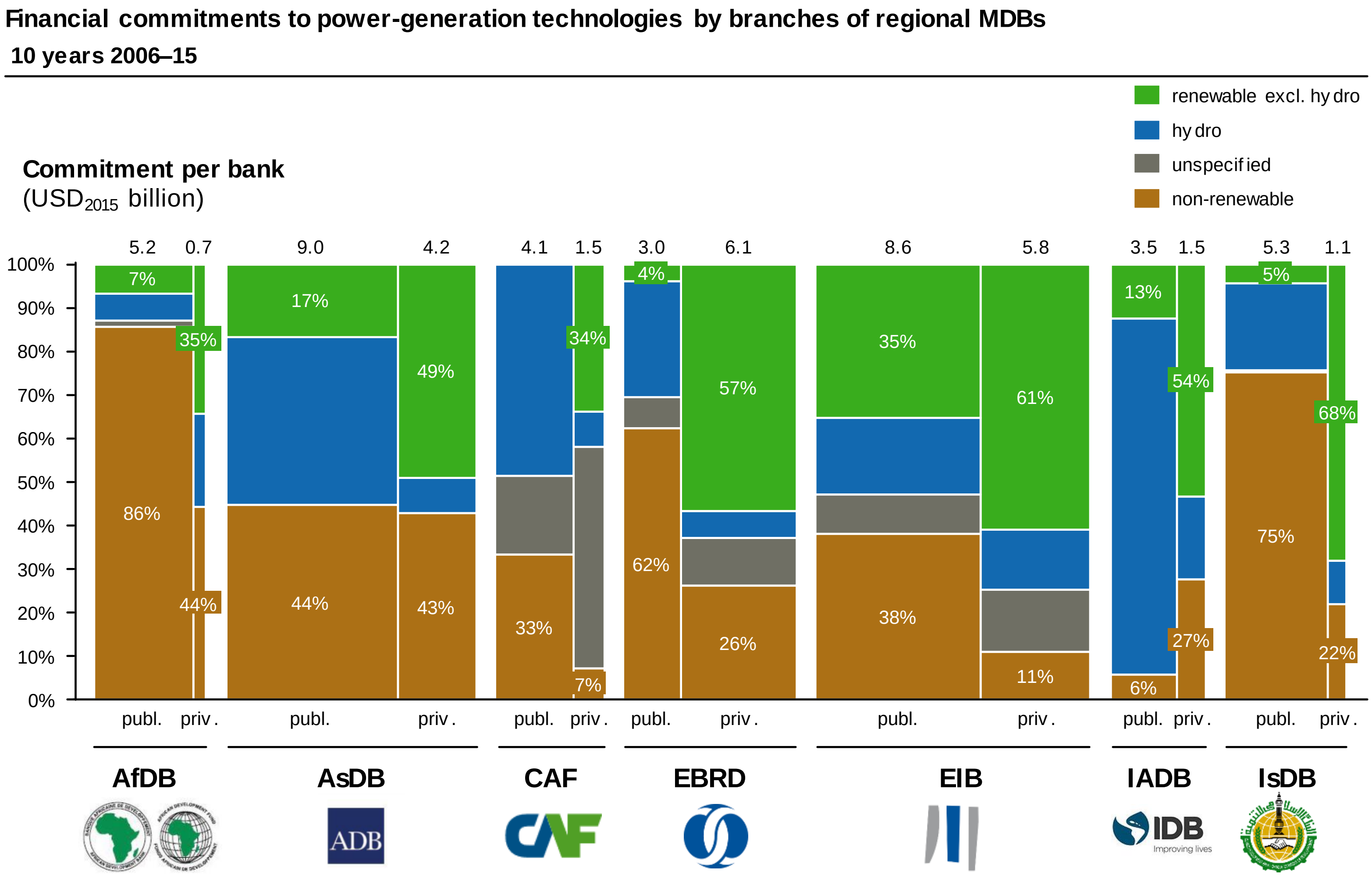
Different patterns – often RE invest "on top" of conventionals

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



Source: Steffen, B.; Schmidt, T.S. (2018). A quantitative analysis of 10 multilateral development banks' investment in conventional and renewable power-generation technologies from 2006 to 2015. *Nature Energy*.

Stark differences between public and private sector branches



Source: Steffen, B.; Schmidt, T.S. (2018). A quantitative analysis of 10 multilateral development banks' investment in conventional and renewable power-generation technologies from 2006 to 2015. *Nature Energy*.

Agenda

Related papers (and underlying datasets) from our group

1. Steffen, B. (2018). The importance of project finance for renewable energy projects. *Energy Econ*. *69*, 280–294.
2. Egli, F., Steffen, B., and Schmidt, T.S. (2018). A dynamic analysis of financing conditions for renewable energy technologies. *Nat. Energy 3*, 1084–1092.
3. Schmidt, T.S., Steffen, B., Egli, F., Pahle, M., Tietjen, O., and Edenhofer, O. (2019). Adverse effects of rising interest rates on sustainable energy transitions. *Nat. Sustain*. *2*, 879–885.
4. Egli, F., Steffen, B., and Schmidt, T.S. (2019). Bias in energy system models with uniform cost of capital assumption. *Nat. Commun*. *10*, 4588–4590.
5. Steffen, B. (2019). Estimating the Cost of Capital for Renewable Energy Projects. https://ssrn.com/abstract=3373905
6. Geddes, A., Schmidt, T.S., and Steffen, B. (2018). The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany. *Energy Policy 115*, 158–170.
7. Steffen, B., and Schmidt, T.S. (2019). A quantitative analysis of 10 multilateral development banks' investment in conventional and renewable power generation technologies from 2006 to 2015. *Nat. Energy 4*, 75–82.

See also:

8. F Polzin (2017), Mobilizing private finance for low-carbon innovation – A systematic review of barriers and solutions, *Renewable and Sustainable Energy Reviews* 77, 525-535.

Thank you for your attention!

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INNOPATHS