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International Solar Alliance Expert Training Course

PV Technology: Costing and Finance Models in Developing Environments

In partnership with the Clean Energy Solutions Center (CESC)

Carbon Trust

September 2019

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Overview of Training Course Modules

This Training is an additional module and focuses on the issue of Costing and Finance Models in Developing Environments

Agenda

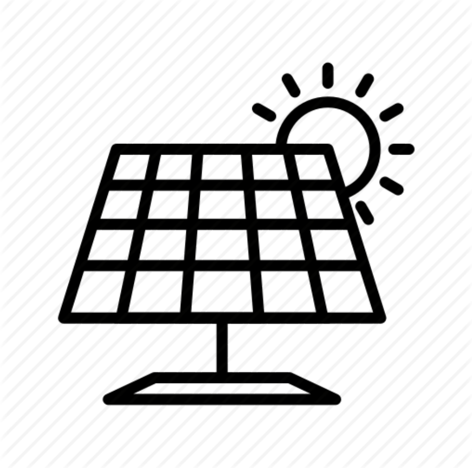
1. Introduction: Learning Objective
2. Investment Trends in Solar PV
3. Costs at Scale: Utility, Community & Residential
4. Traditional Finance Models
5. Alternative Finance Models
6. Developing Environments Case Studies
7. Conclusions

1

Introduction: Learning Objective

Objective

- Provide an overview of the **investment setting for solar PV projects** in developing environments and the **finance mechanisms** used to fund these projects.
- Understand the **cost and tariff structures** associated with solar PV at varying scales

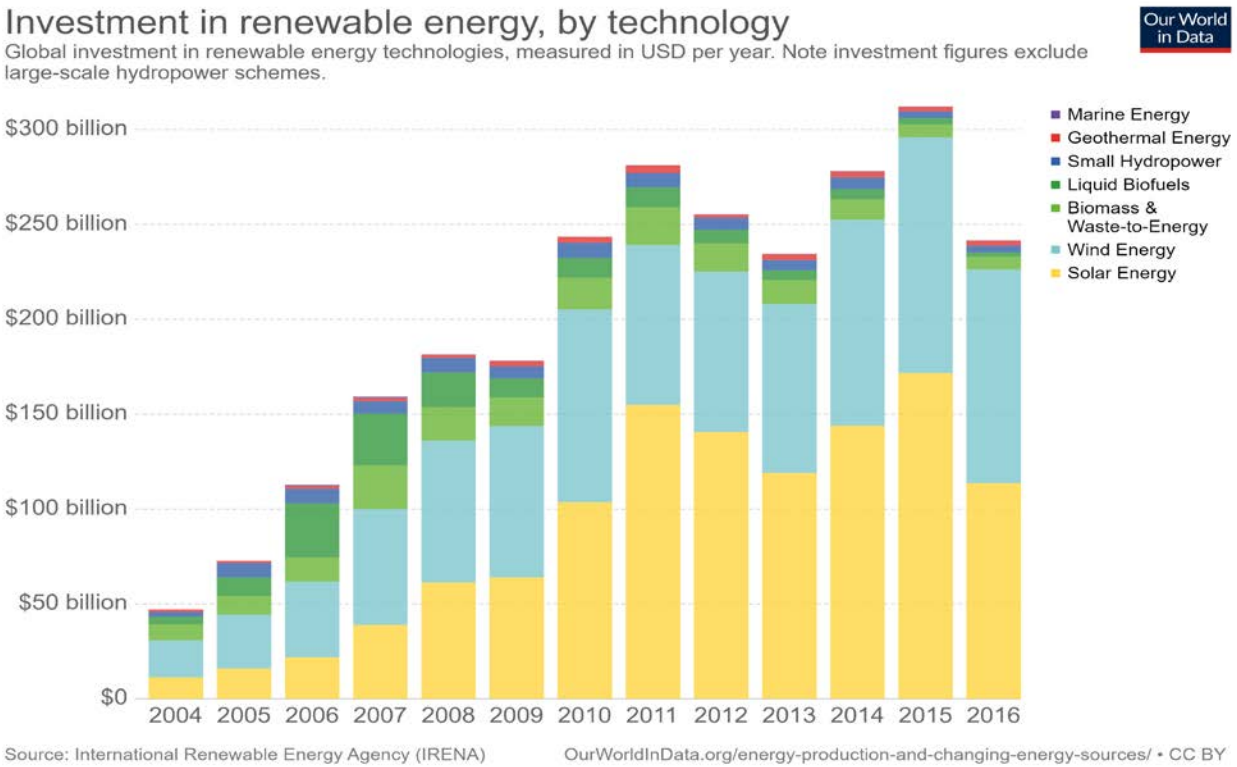




2

Investment Trends in Solar PV

Solar PV: Growing proportion of global renewable energy investment

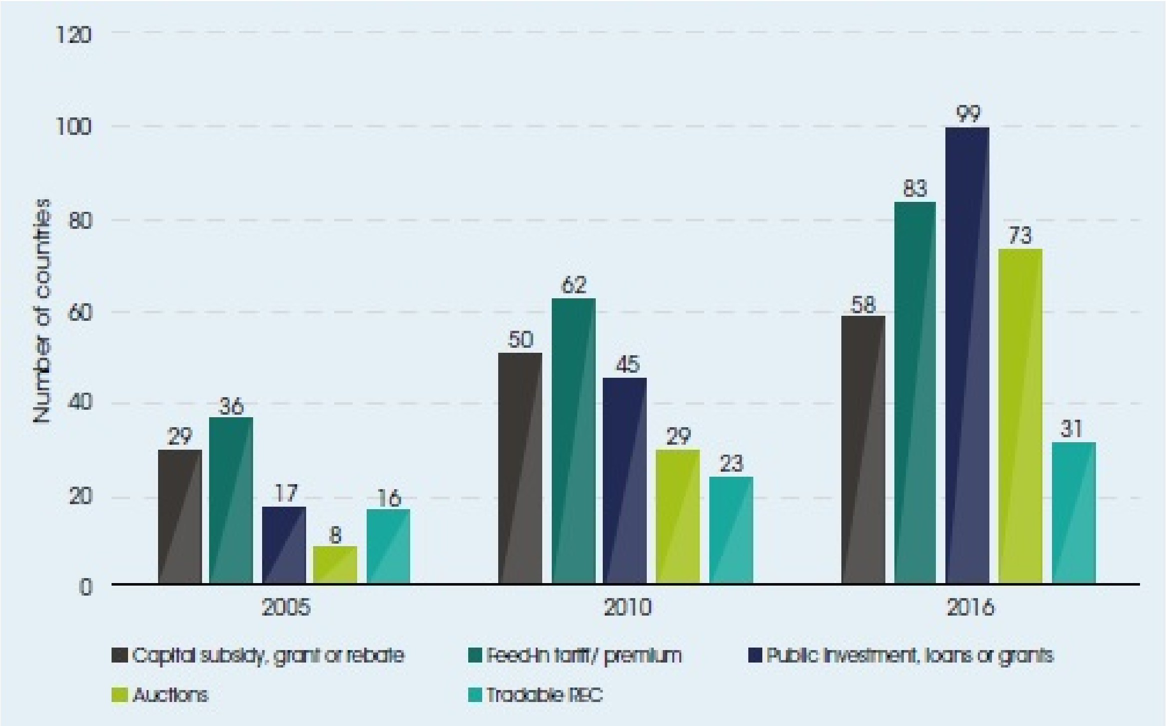
Global Renewable Investment 2004-2016



Our World in Data (2019)

- 2015 to 2016 saw a 17% decline in solar PV investment due to falling technology costs (reducing the amount of money needed per project) and a changing political landscape wherein the UK, Japan, and China began cutting subsidies in 2016.
- Capacity installed, however, reached a record high of over 65 GW globally.

More countries opting for public investment, auctions and feed-in tariffs



IRENA & CPI (2018, p29)

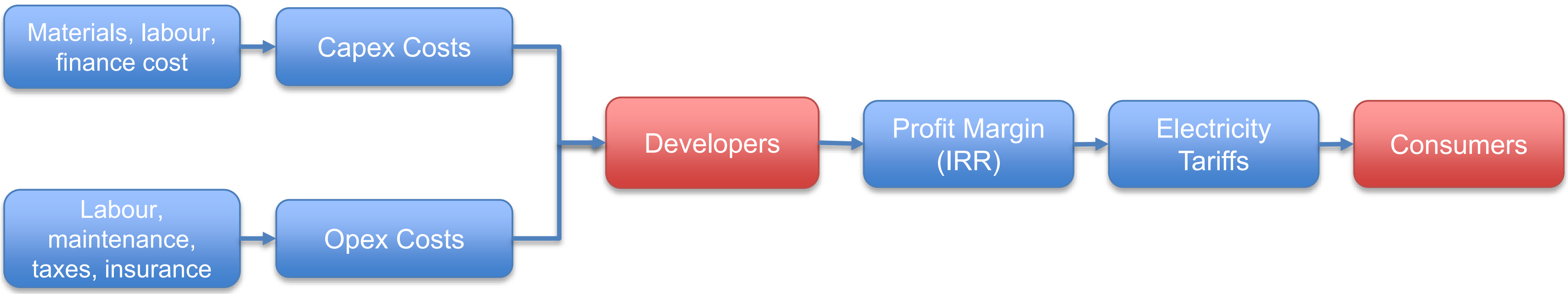
- Growing prevalence of auction-based renewable energy programmes is evident
- Case studies point to auctions increasing competition and delivering increasingly cheaper electricity
- Public investment is often seen in new entrant countries where private finance for renewables is still in its infancy

3

Costs at Scale: Utility, Community & Residential

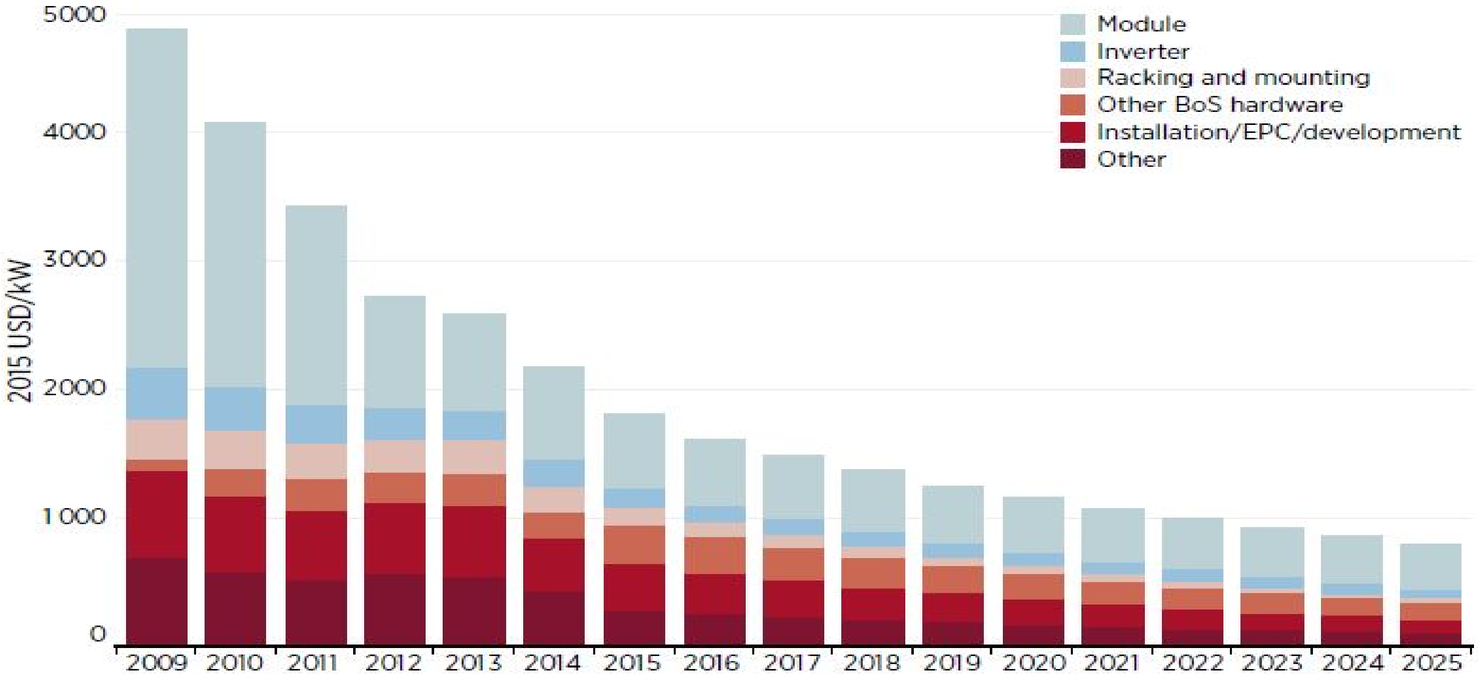
Developers incur cost of installation and operation, consumers cost of electricity

- The costs incurred in developing a solar PV project are borne by the project developer.
- Ultimately, the developer passes the costs associated with developing a project onto the consumer, who pays an electricity tariff which compensates the developer for all costs incurred plus a return margin for the risk taken.
- Costs for developers are therefore the upfront capital expenditure (Capex) and the operating expenditure (Opex). Costs for consumers are the electricity tariffs from the project.



Upfront costs have been predominated by PV modules, future declines to come from BoS reductions

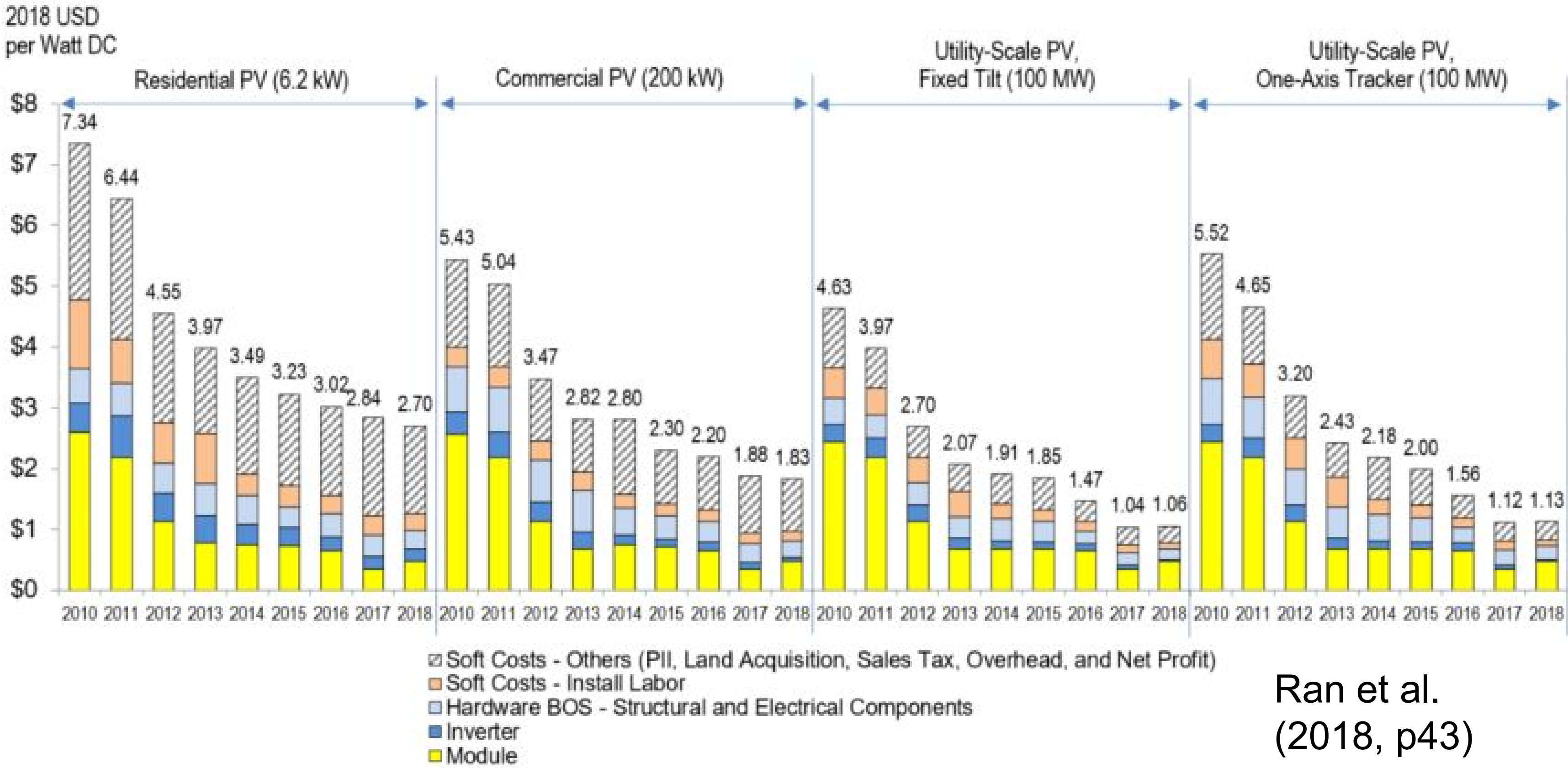
- Three major upfront cost components:
  1. Solar Module
  2. Inverter
  3. Balance of System (BoS): comprising non-module and inverter hardware, installation costs (EPC) and soft costs (permitting, finance costs, system design)



IRENA (2016, p39)

Scale Influences Upfront System Costs

US costs data reveals how the scale at which solar PV is procured affects the overall cost of the project. For developing environments focusing on rural energy access, the average size of their projects will greatly influence the cost of the technology in their country. Residential-scale projects are the most expensive per unit.



Ran et al. (2018, p43)

The LCOE yields an electricity cost per unit figure across technologies

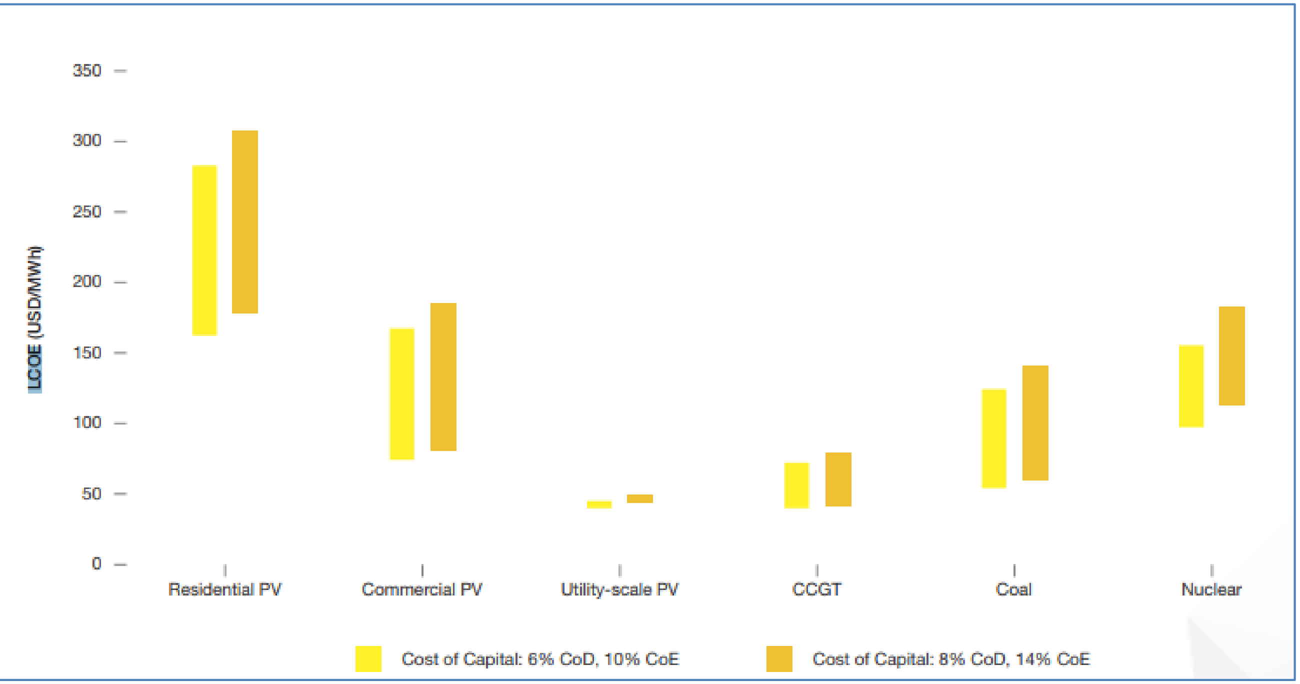
- The costs analysed in the previous slides represent the upfront or "Capex' costs of solar PV projects.
- Capex represents the majority of the overall project costs. Operation and Maintenance (O&M) accounts for between 20 and 25% of the overall cost of solar PV.
- A method called levelized cost of energy (LCOE) is often used to estimate the cost of energy technologies.
- Essentially, the LCOE sums the investment expenditures in the construction and O&M phase (discounting expenditures at future dates according to the country's discount rate) of the project, and divides this by the expected electricity produced by the project over its lifespan (discounting future electricity by the same discount factor).
- This yields a cost per unit electricity produced figure that can be used across technologies.

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + OM_t + F_t}{(1+DR)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+DR)^t}}$$

LCoE = Levelised cost of energy
I_t = Investment expenditures in the year t
OM_t = Operations and maintenance expenditures in the year t
F_t = Fuel expenditures in the year t
E_t = Electricity generation in the year t
DR = Discount rate
n = economic lifetime of the power plant

Ecofys (2014, p3)

Again, scale influences the LCOE but utility-scale solar is cost competitive

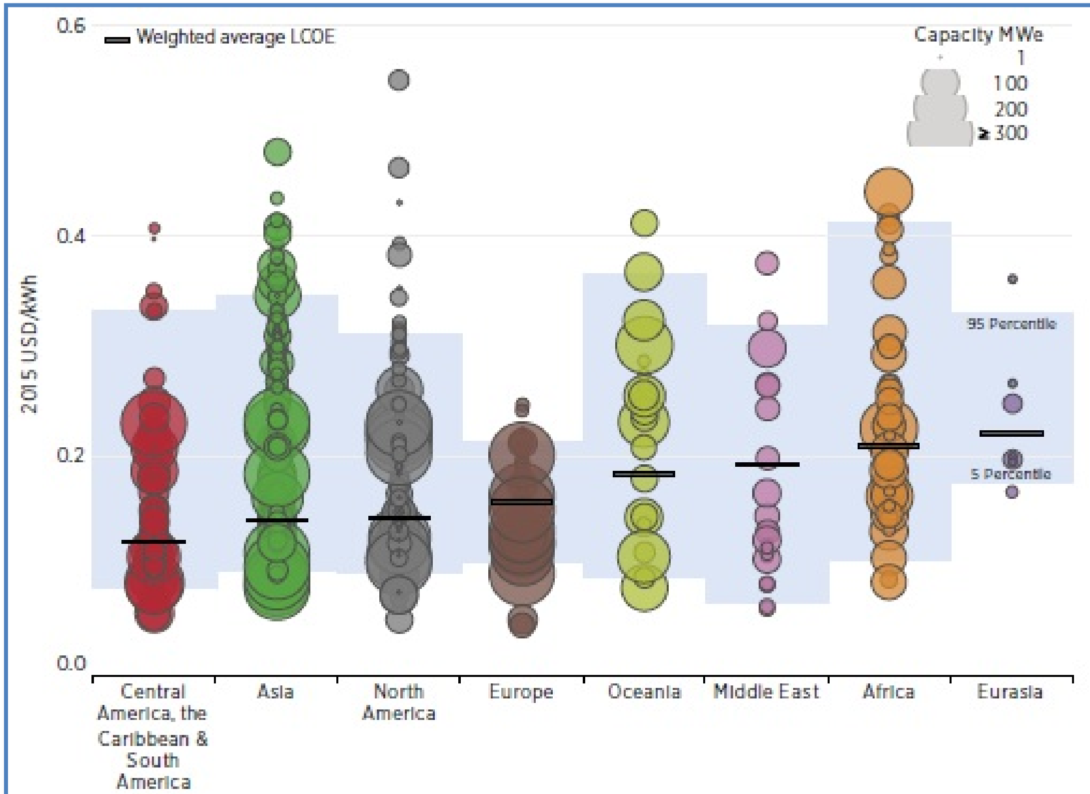


Solar Power Europe (2018, p9)

- LCOE thus heavily influenced by the following:

1. Capacity/load factor of the technology
2. Resource quality at project location
3. Weighted-average cost of capital (WACC)
4. Discount factor in project territory

Developing environments are producing competitive solar PV projects at utility-scales



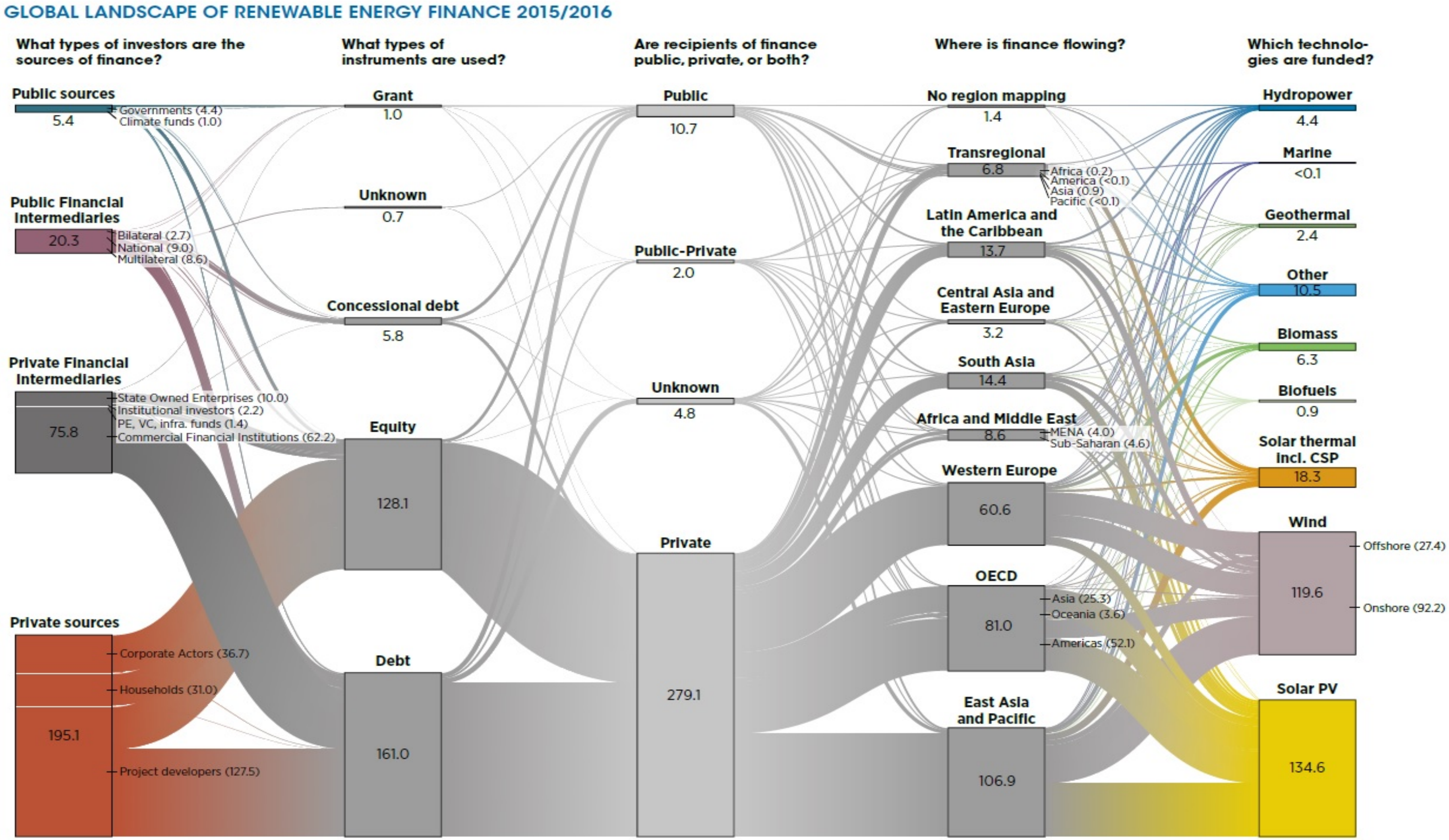
There are large variations in electricity prices from solar PV due to drastically different location, regulatory and economic settings

IRENA (2016, p36)

4

Traditional Solar PV Finance Models

Solar PV finance landscape shows the dominant role of private finance



IRENA (2018, p15)

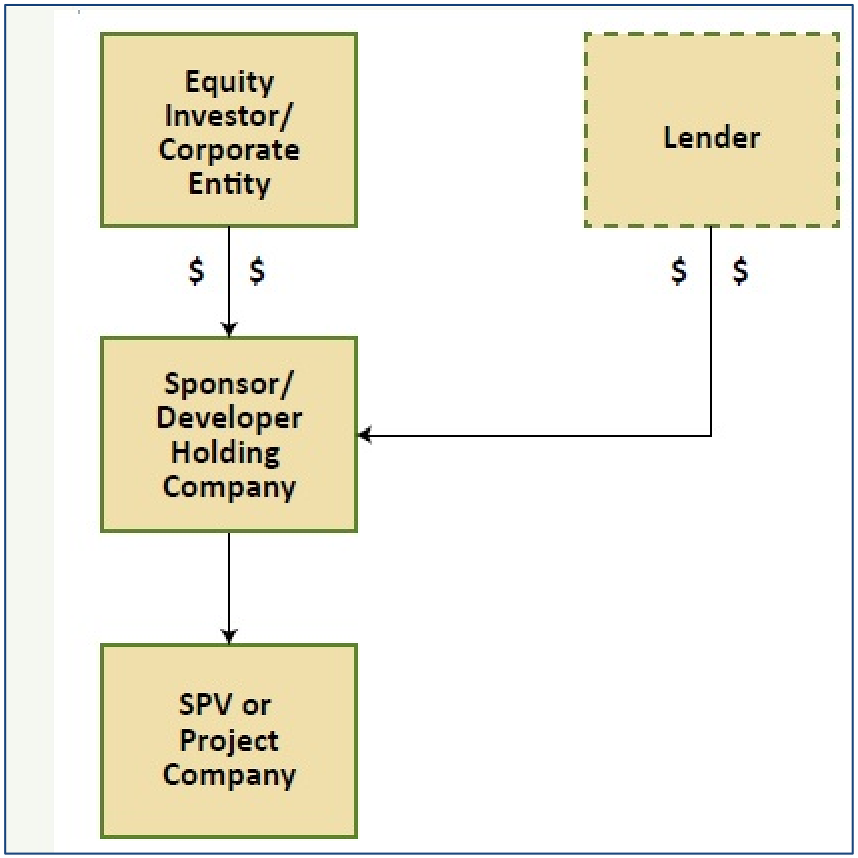
Finance instruments used for solar PV projects

Instruments	Grants		Equity		Debt	
Forms	Subsidies	Seed/Start-Up	Growth/Expansion	Infrastructure	Corporate	Project
Sources	• Governments • Donours/DFIs • Foundations	• Friends/Family • Angel Investors • Impact Funds	• Impact funds • Venture Capital Funds • Private Equity Funds	• Private Equity Funds • DFIs	• Local Banks • International Banks	• Commercial Banks • EXIM Banks • DFIs
Market Depth	+++	+	+++	++	+++	+
Risk Appetite	++++	+++	++	++	+	+
Typical Amount	$30k-10m	$100k-1m	$1m-5m	$10m+	$20k-10m	$15m+
Tenure	N/A	3-7 years	3-5 years	5-10 years	6 months - 5 years	7-15 years
Expected Returns	None	• Impact: 5-20% • Commercial: 30%+	• Impact: 5-20% • Commercial: 20%+	15-25%	16-24% (local currency)	6-12% (hard currency)
Provider Examples	• Governments • EEP S&EA • DFID/USAID	• Beyond Capital • Eleos Foundation • NovaStar	• Acumen • Bamboo • Khosla Impact	• Infraco • IFC • Frontier	• Barclays • EcoBank • StanCharter	• AfDB • Norfund • Nedbank

Adapted from RECP (2014)

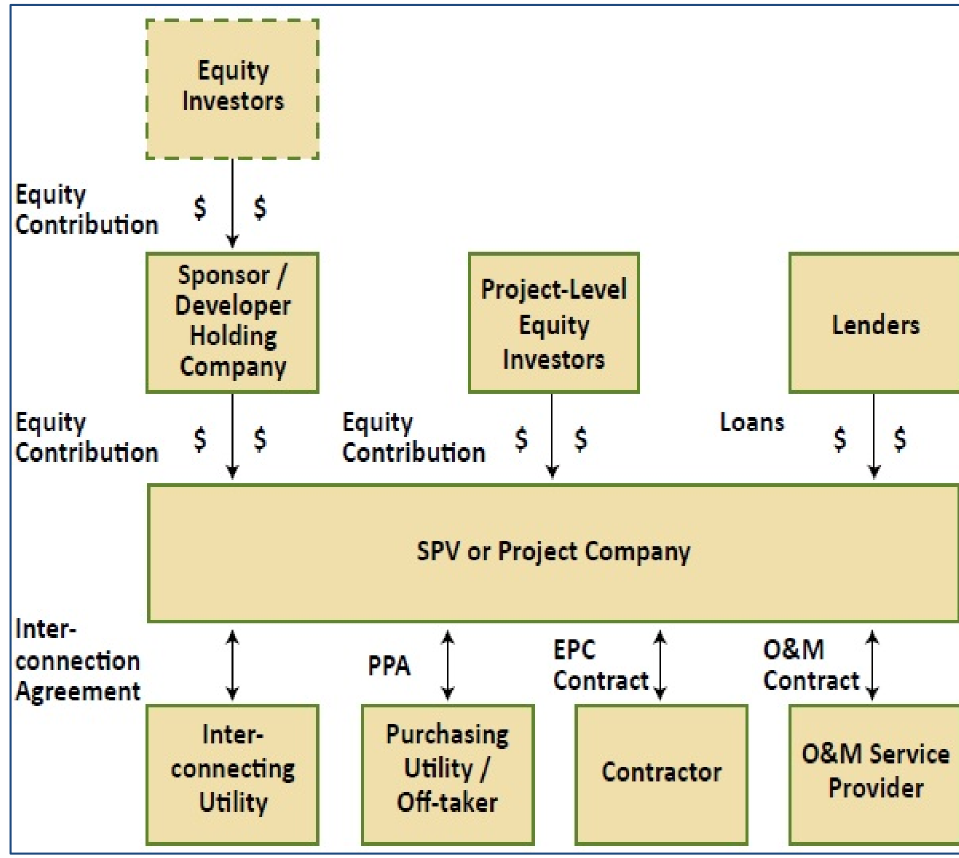
Traditional finance models: corporate and project finance

Corporate Finance Model



IFC (2015, p160)

Project Finance Model



IFC (2015, p162)

Barriers to solar PV finance in developing environments

- Solar PV funding profiles are long-term (greater than 5 years) with high Capex and low O&M costs.
- Low income countries are lacking long term funders (pension schemes) and those with reasonable long term capital prefer lower-risk assets such as government bonds.
- Low familiarity with new technologies such as solar PV, making funders more reluctant to invest in non-conventional assets.
- International commercial banks are not interested in projects less than $10 million in value
- WACC from funding institutions willing to lend to solar PV developers are upwards of 15% (16-18% in Nepal, 16.5% in Ethiopia)
- Equity financiers are less interested in small (<5 MW) projects in unknown environments and tend to focus on larger-scale utility projects in environments they are already operating in.
- Project locations are typically remote which requires transmission and distribution network expansions- resulting in lengthy negotiations and delays in project grid synchronisation.

Adapted from World Bank (2012)

Issues to be addressed for developing environments

Summary	Detail
• High upfront capital costs	• Renewable energy projects have far higher upfront (and lower operational) costs than traditional energy projects, which means that return on capital takes longer than a traditional project. • Loan tenures tend to be much shorter than is needed for off-grid energy projects.
• Revenue risk	• Customers have low purchasing power. • Off-grid energy suppliers are subject to revenue risk, even when using pay-as-you-go models, which mitigate credit risk. • Limited data is available on successful revenue models that enable the productive use of energy and mitigate revenue risk.
• Small ticket size	• Off-grid energy projects have much smaller ticket sizes than traditional energy projects, often below the lending threshold and capability of commercial and development banks.
• Limited operational data	• Off-grid electricity is a nascent area and lenders lack multiple successful precedents which give them confidence in their investments.
• Technology risk	• Technology is often imported from abroad and may not be fit for the local environment.
• Regulatory barriers and risk	• Existing barriers may include fiscal and import barriers; risks may include, for instance, the lack of protection for a mini-grid operator in case the main grid reaches its area of operation.
• Human resources	• Limited availability of employees with requisite skills to operate and repair the equipment.

Carbon trust (2017, p50)

- Debt funding is generally cheaper than equity funding; however, developing countries do not have sufficient capacity for long-term debt financing for these projects
- Debt finance is still too expensive in some developing countries making the projects uncompetitive.
- Sourcing funding remains a major barrier to solar PV deployment in developing countries.
- Developers need a supportive and cost-effective regulatory environment.

Renewable energy procurement mechanisms affect the cost of electricity

	Price-based Instruments	Quantity-based Instruments
Investment-focused	Investment subsidies Tax incentives	
Generation-focused	Feed-in premium Feed-in tariff Net metering Net billing Tax incentives	Quota obligation Tender scheme Auctions

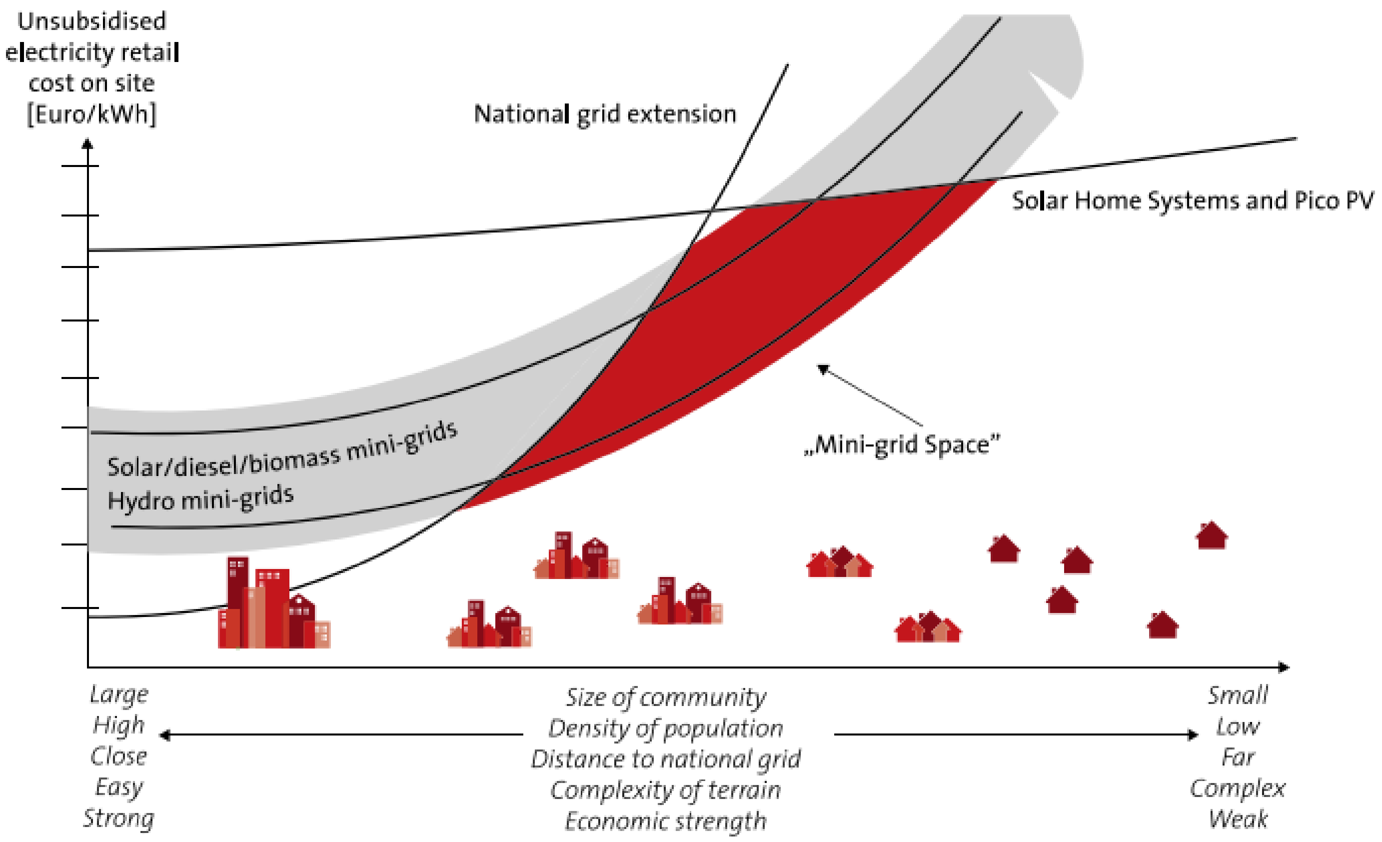
Tantiwechwuttikul & Yarime (2018, p2)

- Governments choose which support instruments to use to facilitate the proliferation of renewable energy in their country.
- Governments and DFIs can reduce the Capex burden and finance difficulties through subsidies, grants and/or concessional loans with repayment periods suited to solar PV projects.
- Price-based instruments are aimed at aligning the price of renewable technologies with the current grid prices so as to balance the needs of the developers (sufficient compensation for cost burden) and the electricity consumers (affordable electricity). There is therefore regulation on the price-side but the quantity is not expressly restricted.
- Quantity-based instruments regulates the quantity (capacity) which is procured. With auctions, for example, the government often allocates each technology a capacity limit per tender window and developers compete with each other on the price.

5

Alternative Solar PV Finance Models

Mini-grids & Microgrids fit in where there is low population density and no grid network



RECP (2014, p18)

Mini-grids: small-scale (10 KW -10 MW) electricity generation and distribution to a limited number of customers that operates in isolation from the national electricity grid. The electricity is provided at grid quality level. Microgrid: similar to a mini-grid but at a scale of 1-10 KW. RECP (2014)

Models of Mini-grid ownership and operation depend on the project setting

"The major hurdles in the success of mini-grids are not technology-related. There are no significant technology barriers that hinder mini-grids whether they are powered by diesel generators, renewable energy or a combination of both (hybrid systems). Rather, since supply to remote villages with low income is not economically viable, financial sustainability is the key challenging factor. Compounding the problem is the fact that there is no "one-size-fits-all" solution." (World Bank, 2014)

- Utility Operator Model: national utility is responsible for commissioning and operation. Funding is sourced from government or national treasury in the form of grants or concessional loans. Electricity tariffs are similar to grid prices, and are cross-subsidised by the utility.
- Private Operator Model: private entity responsible for commissioning and operation. Funding is sourced from private equity and/or commercial debt and often government support via subsidies, grants and guarantees. Revenues need to be sustainable which prompted the Anchor-Business-Community (ABC) approach. Private operators invest where there is an anchor customer such as a factory providing reliable cash flows. Thereafter, mini-grid is expanded to high potential businesses and the residential customers are seen as 'top-up' revenue due to their variable and low consumptive nature.
- Community-based Operator Model: the community owns and operates the mini-grid, sourcing finance predominantly from grants and concessions.
- Hybrid Operator Model: combination of the above models

Off-grid funding innovations: microfinancing, PAYG, fee-for-service

- Solar home systems (SHS) in previously unelectrified areas provide basic electricity access for lighting, charging and other low-intensity uses.
- Pay-as-you-go (PAYG) funding: consumers purchase the SHS using debt finance or pre-pay for electricity from the mini-grid. For SHS, consumers pay a deposit (~30 USD) and then a daily rate depending on the size of SHS purchased. Costs are competitive with older technologies for lighting such as kerosene. For mini-grid PAYG, a flat-rate or connection fee may be required in addition to the consumptive tariffs.
- Fee-for-service: the assets are not transferred to the customer. Finance is provided by investors who own the solar assets. Investors lease the assets to the consumer or sell the electricity directly to the consumer for a predetermined price. Investors bear all the risk but insure the asset accordingly.

MULTI-TIER FRAMEWORK (MODIFIED‡)	POWER CAPACITY	DELIVERY MODEL	RETAIL PRICE	DEPOSIT	DAILY FEE	MONTHLY COST
Tier 0.5‡	~ 0.5Wp	Retail	5.5 - 10$			-
		Fee for Service		0 – 1.2$		0.3$
Tier 1	3Wp	Retail	30 - 60$			-
Tier 1.5‡	~ 8 - 15Wp	PAYG		19 – 35$	0.2 – 1.25$	6 – 38$
		Fee for Service		6 – 9$	0.15 – 0.2$	4.5 – 6$
Tier 2	~ 30 – 50Wp	PAYG		62$	0.6$	18$
		Consumer Financing (via FI)	400$		0.8 – 1$	25 – 30$
Tier 2.5‡	~ 80 – 200Wp	PAYG		18 – 25$	0.8 – 1.2$	25 – 35$
		Fee for Service		55 – 80$	0.2 – 0.5$	7 – 14$
Tier 3	up to 400Wp	Fee for Service		90$	0.6 – 0.7$	18 - 20$

Klunne & Muchunku (2016)

6

Developing Environments: Case Studies

Scaling Solar: Large-Scale solar PV auctions using DFI Finance

The Challenge

Solar power has enormous potential as a quick-to-build electricity source in emerging markets, where needs are great. Even though prices have fallen dramatically over the past years, many countries have struggled to develop utility-scale solar plants due to challenges that include:

INSTITUTIONAL CAPACITY: Many governments have limited capacity to manage, structure and negotiate private power concessions.

LACK OF SCALE: Navigating small and distinct power markets can deter investors and small grids can only absorb small projects.

LACK OF COMPETITION: Many power projects are not competitively tendered.

HIGH TRANSACTION COSTS: Individually negotiated contracts have high transaction costs.

HIGH PERCEIVED RISK: Poor credit utility off-takers and political risks increase the cost of capital, driving up tariffs.

The Solution

Scaling Solar is a "one stop shop" solution for governments to rapidly mobilize privately funded grid connected solar projects at competitive tariffs. This proven program is based on a templated approach to create viable markets for solar power in each client country and brings together a suite of World Bank Group services under a single engagement, including:

ADVICE to assess the right size and location for solar PV power plants in a country's grid and to prepare and develop sites for tender.

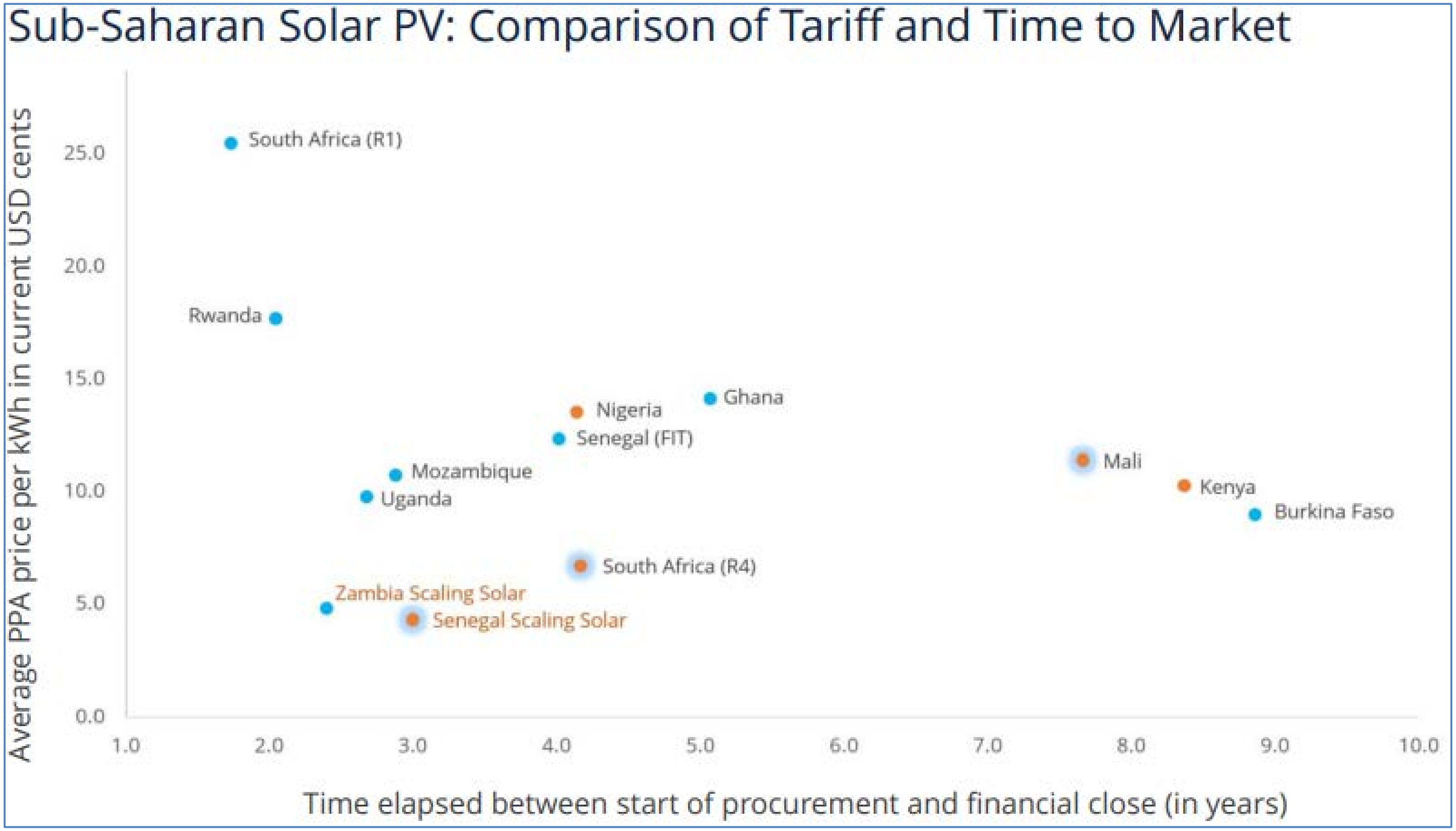
SIMPLE AND RAPID TENDERING to ensure strong competition from committed industry players.

FULLY DEVELOPED TEMPLATES of bankable project documents that can eliminate negotiation.

COMPETITIVE FINANCING AND POLITICAL RISK INSURANCE attached to the tender and available to all bidders.

RISK MANAGEMENT AND CREDIT ENHANCEMENT PRODUCTS to lower financing costs and tariffs.

Scaling Solar: Large-Scale solar PV using DFI finance highly cost-competitive



Scaling Solar (2019)

The REIPPPP: Large-scale solar PV auctions using mainly private finance

- Utility-scale, competitive auction-based procurement programme for multiple technologies.
- Finance sources: local commercial debt and equity, local development finance, international debt and equity.
- Mandated Ownership Structure: BEE (black-owned) ownership of >12%; Local Community (<50km radius of project site) >2.5%.
- Debt:
  1. 68% of the total debt was on commercial terms from local commercial banks (at an interest rate of 12% in local currency over 20 years) (Baker, 2015).
  2. 19% of total debt from DFIs.
  3. 88% of the projects were Project Financed
- Successes:
  - ➢ Well-established and deep capital markets
  - ➢ Socio-economic targets set by the government to encourage local content and job creation
  - ➢ Government guaranteed power purchase agreements (PPAs)
  - ➢ Quantity capped, developers compete on tariff (electricity price) and socioeconomic performance. Saw 74% decline in solar PV tariffs

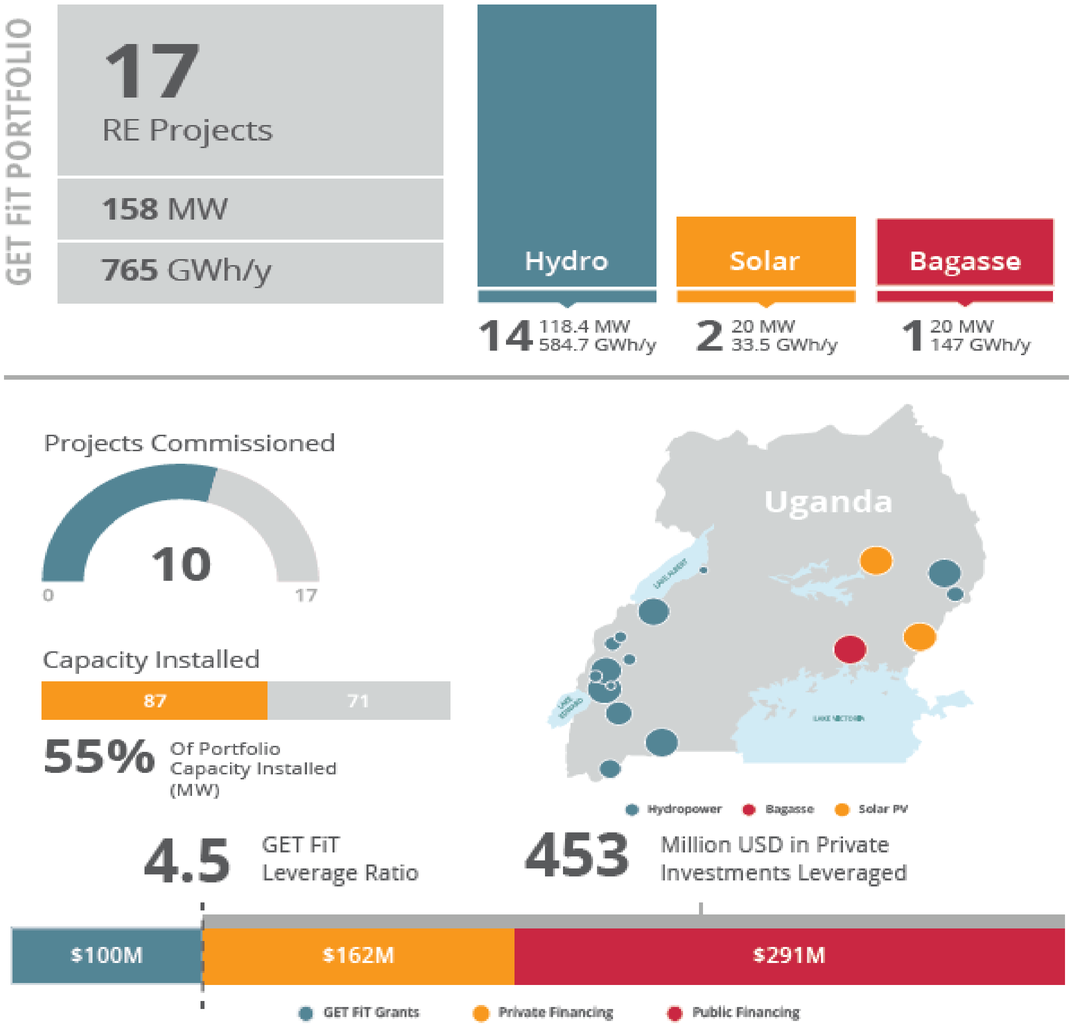
Adapted from Eberhard & Naude (2017)

The REIPPPP: Utility-scale auction-based procurement results

Solar PV Projects under the REIPPPP

Parameter	Bid Window 1	Bid Window 2	Bid Window 3	Bid Window 4
Total Investment (USD million)	2,945	1,743	826	1378
Debt (%)	73,5	72,6	77,5	75,4
Equity (%)	26,5	27,4	22,5	24,6
Average Tariff (USDc/KWh)	35	21	10	7
Capacity Procured (MW)	627	417	435	813
Date of Procurement	November 2012	May 2013	November 2013	April 2015

GET FiT Uganda: Leveraging grant funding using Feed-in tariffs



- Programme Date: May 2013
- Support Mechanism: Feed-in Tariff with a Feed-in Premium.
- Finance Sources: Capital grants ($100m), private debt and equity, public concessionary financing
- Partial-risk guarantee provided by the World Bank to assist projects acquire private funding

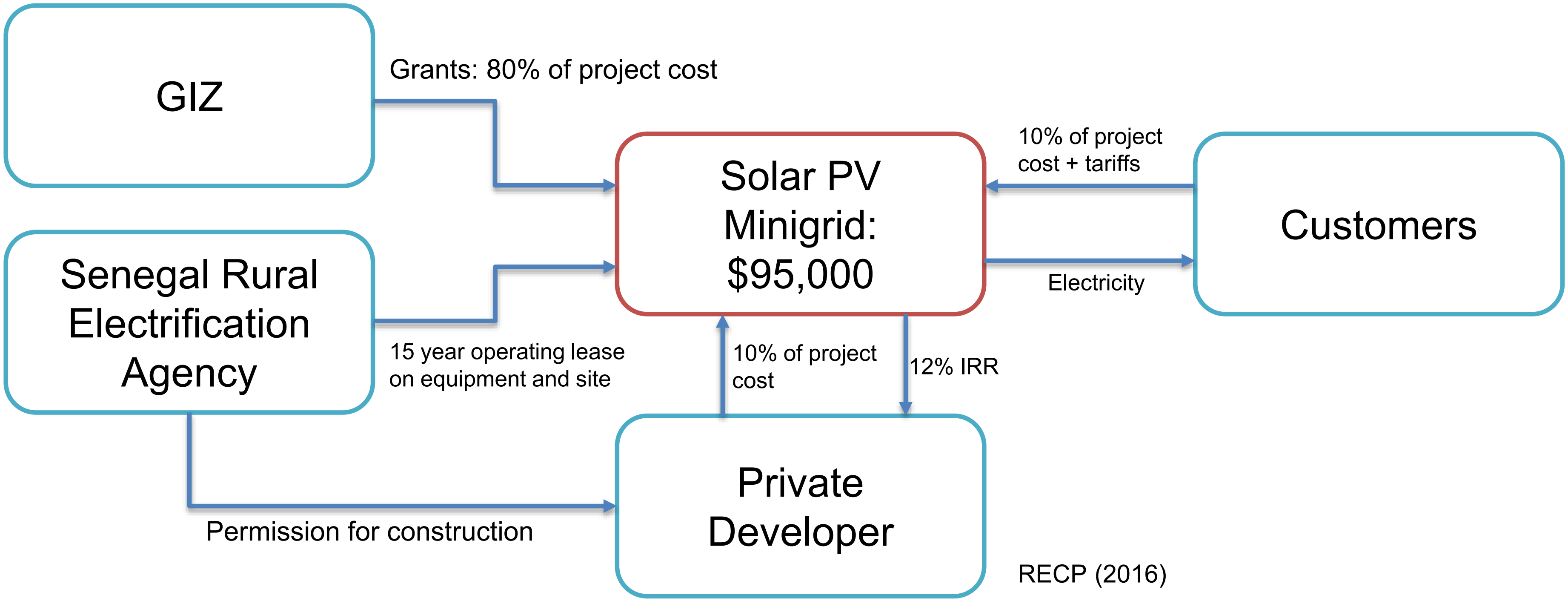
- Two 10 MW solar PV projects procured to date.
- Total Solar PV investment: $34 million
- Solar PV Tariff: 16.4 USDc/KWh

- Feed-in Premium is paid by development finance institutions (DFIs). 50% of the Premiums are paid to developers upon COD and the remainder paid over 5 years against performance criteria (electricity delivered)

KFW & Multiconsult (2018)

Senegal ERSEN project achieving rural electrification through hybrid utility-private operating models

- Solar PV/Hybrid with battery back-up supplying 18-24 hours of electricity per day.
- Date: Phase 1 2005-2009; Phase 2 May 2009
- Operator Model: Hybrid Utility-Private Model
- Capacities: 5 KW Solar PV, 10 KW Diesel with 800 Ah battery back-up.



RECP (2016)

Off-Grid financiers and microfinancing instruments

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Type of finance	Finance Providers
Crowdfunding	econeers, citizenergy, sunexchange (powered by SUNEX)
PAYG	BBOXX, M-KOPA SOLAR, fenix intl, d.light SOLAR
Fee-for-Service	FRES foundation RURAL ENERGY SERVICES, ZOLA ELECTRIC

7

Conclusion

Final Remarks

- We have seen consistent increases in solar PV capacity globally coupled with rapidly decreasing costs.
- Renewable energy auctions and FiT are the most popular procurement mechanisms in recent times for large-scale projects. The proliferation of mini-grids and microgrids has enabled remote locations to receive affordable electricity access in developing countries.
- The types of finance used to date has included a mix of debt and equity primarily from private investors, as well as grants and subsidies from public sectors. Innovations such as PAYG, microfinancing and crowdfunding have catalysed off-grid and microgrid solar PV development.
- The role of governments, as finance providers, regulatory bodies and procurement designers has become integral to the successful expansion of solar PV capacity globally.
- The role of innovative finance solutions has allowed solar PV to penetrate into untapped (unelectrified) markets and overcome the higher per unit costs associated with projects at a micro-scale

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