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Power Sector Costing Study Update

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Rationale

- Assist government decision making
- Economics are a key decision factor
- The cost of renewables have declined rapidly in recent years
- Decision making is often based on outdated numbers
- Cost figures are often not fact based and therefore coloured by opinion of the author
- Cost data vary by project, country and over time

- IRENA strives to become a source of objective cost data that enable cost comparisons
- This will be complemented with an assessment of benefits for cost/benefit analysis
- Business perspective will be complemented with macro-economic perspective (PACB)

- 2011 power sector data, followed by transportation sector (2012) and stationary applications
- For the time being no cost competitiveness analysis

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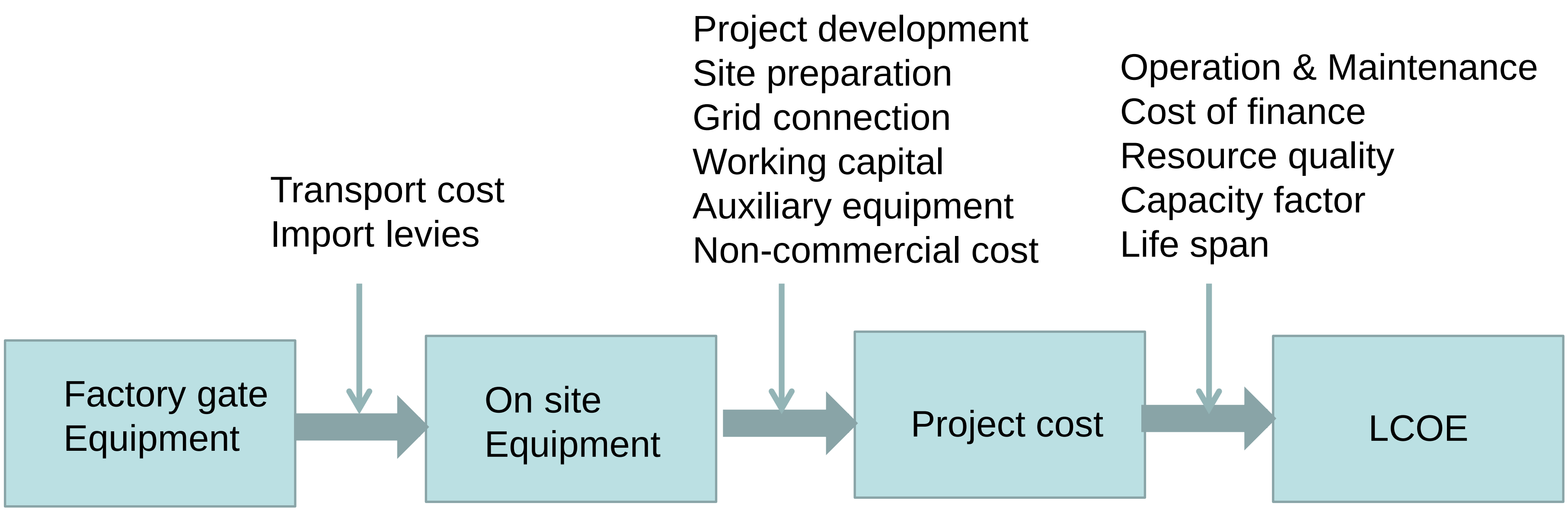
Cost indicators

- Cost can be measured in many ways
- A simple method is preferable
- Three indicators have been selected:
  - Equipment cost (factory gate FOB and delivered at site CIF)
  - Project cost
  - Levelized cost of electricity LCOE (ONE possible measure of attractiveness)
- Trends, most recent year and 5-year outlook (learning curves and market outlook)
- Available information is usually limited to prices
  - Strictly speaking *price* indicators
  - Long term, prices are a function of production cost
  - Short term, profit margins can vary and prices and cost may diverge



LCOE:
Levelized cost of Electricity
(Discounted cost equal discounted revenues)

Categorization

- Definition needed of technology categories:
  - Functionality
  - Quality (life, annual output per unit of capacity, maintenance needs)
  - Size
- System boundaries must be defined
- Allocation rules must be given (eg CHP cost)
- All these are arbitrary
- Depending on the choice, the outcome may differ

Technology Categories – 1st try 2011

- Solar PV rooftop and utility scale
- Solar CSP
- Wind onshore
- Wind offshore
- Large hydro >10 MW
- Small hydro < 10 MW
- Biomass co-combustion
- Biomass digestion gas engine
- Biomass steam cycle
- Biomass gasification
- *DRAFT working papers on PV, CSP and Wind have been completed. Hydro, Biomass under review.*

Data Sources

- General information
  - Business journals (eg Photon)
  - Business associations (eg GWEC, WWEA)
  - Consultancies (eg BNEF)
  - Auctions and tenders (eg Brazil)
  - Project design studies
- Questionnaire
  - Collect actual project data
  - Started with 12 countries, 10 projects by country
  - In cooperation with GIZ (in-kind contribution German govmnt)

Overall insights

- Price data are readily available, cost data less so: often mixed up while trends may differ
- Rapid cost & price reduction PV
- Less so for CSP
- For some years a price *increase* for wind, but declining again
- Project prices:
  - PV USD 2 000 - 3 000/kW (CF 10 - 20%)
  - CSP no storage USD 4 000 - 5 000/kW (CF 25%)
  - CSP 8 hrs storage USD 7 000 - 8 000/kW (CF 40 - 45%)
  - Wind onshore USD 1 500 - 2 000/kW (CF 20 - 35%)
    offshore USD 4 000/kW (CF 30 - 45%)
- Equipment cost account for half to three quarters of project cost
- Equipment cost in emerging economies generally lower
- Further significant cost reductions likely in the coming years for all three technologies
- Cost of financing is a critical issue

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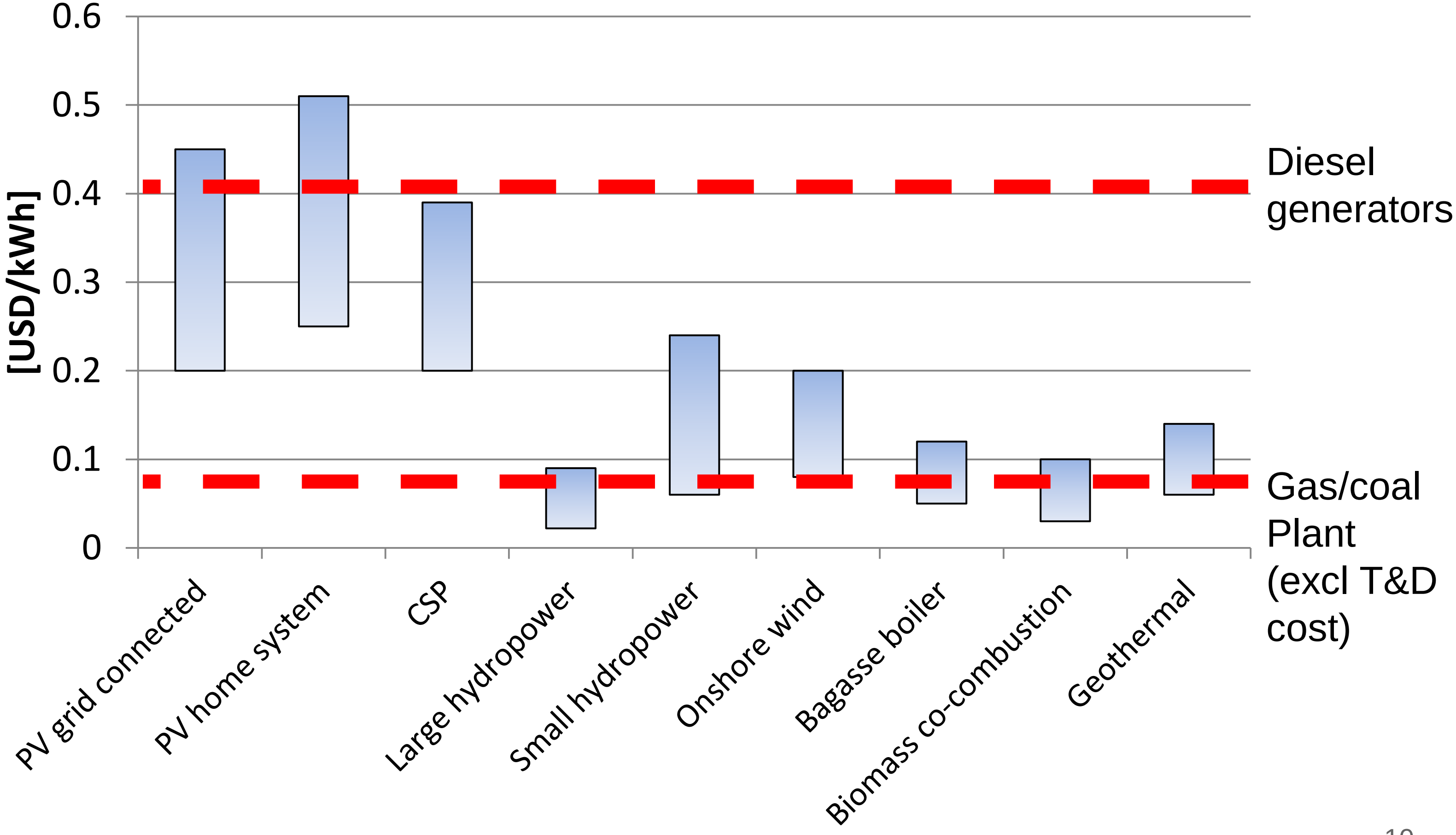
From investment cost to LCOE: key factors

- Cost of financing can vary widely (from zero to over 30 percent)
  - Should the same discount rate be applied for all technologies
- Capacity factors matter
  - PV 1000 – 2000 hours per year
  - Wind onshore 1800 – 4000 hours per year
- Operation and maintenance cost can account for a substantial share of LCOE
  - Available data suggest an even stronger decline than for investment cost

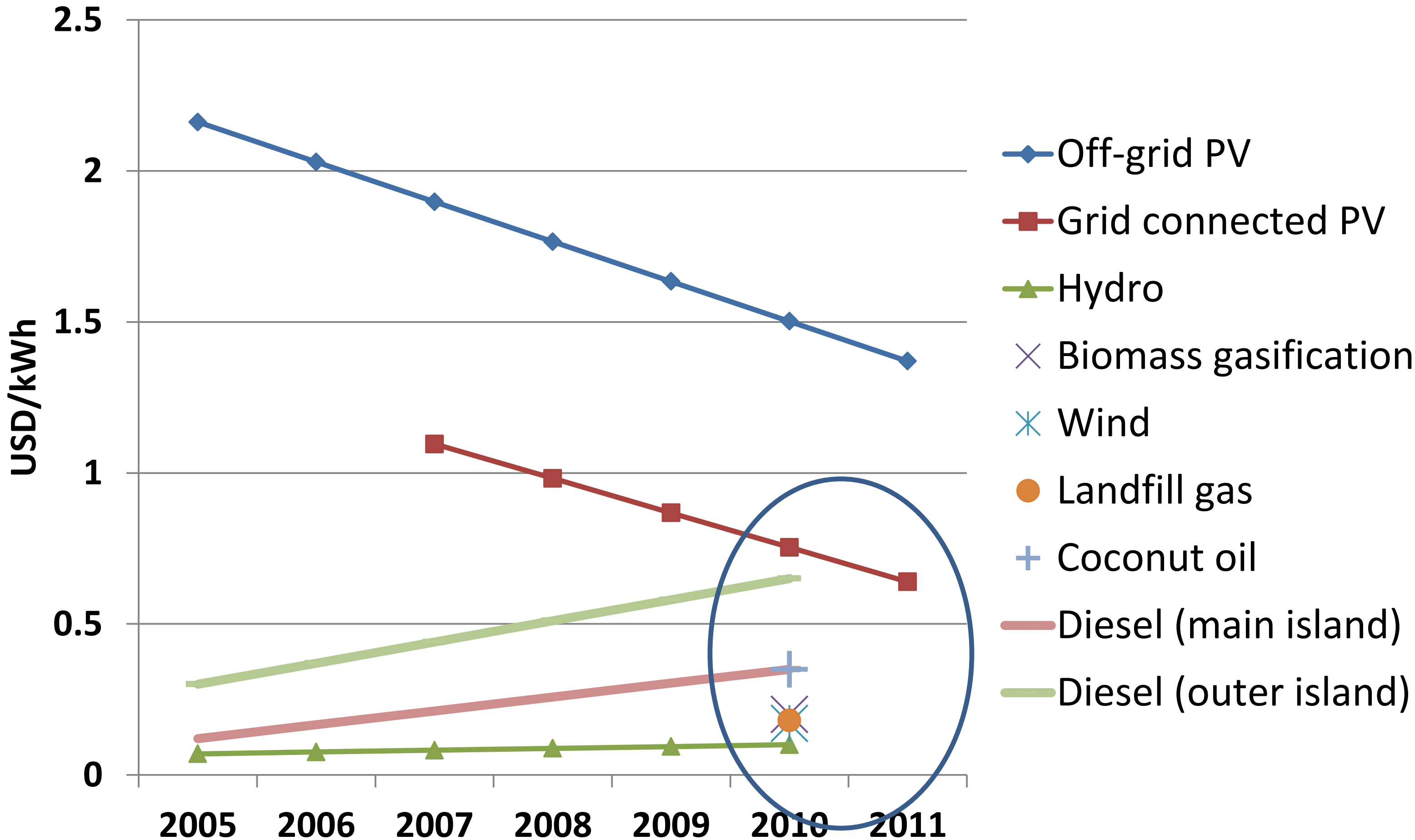
LCOE

African situation 10-20% cost of finance



LCOE Pacific Islands

Renewables have become competitive



Source: Syngellakis, 2011

SOLAR - PV

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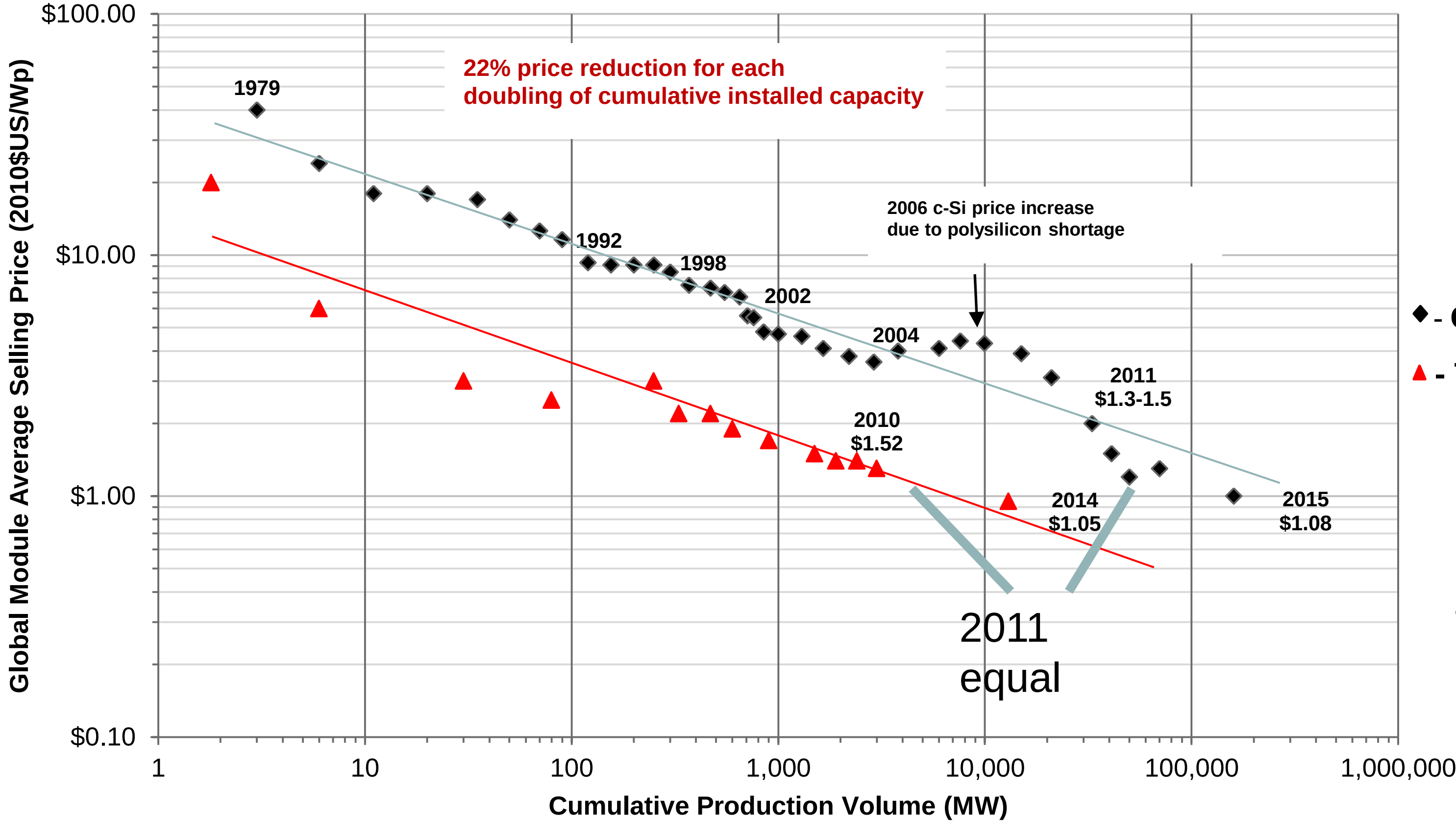
Rapid and predictable cost reductions for PV modules

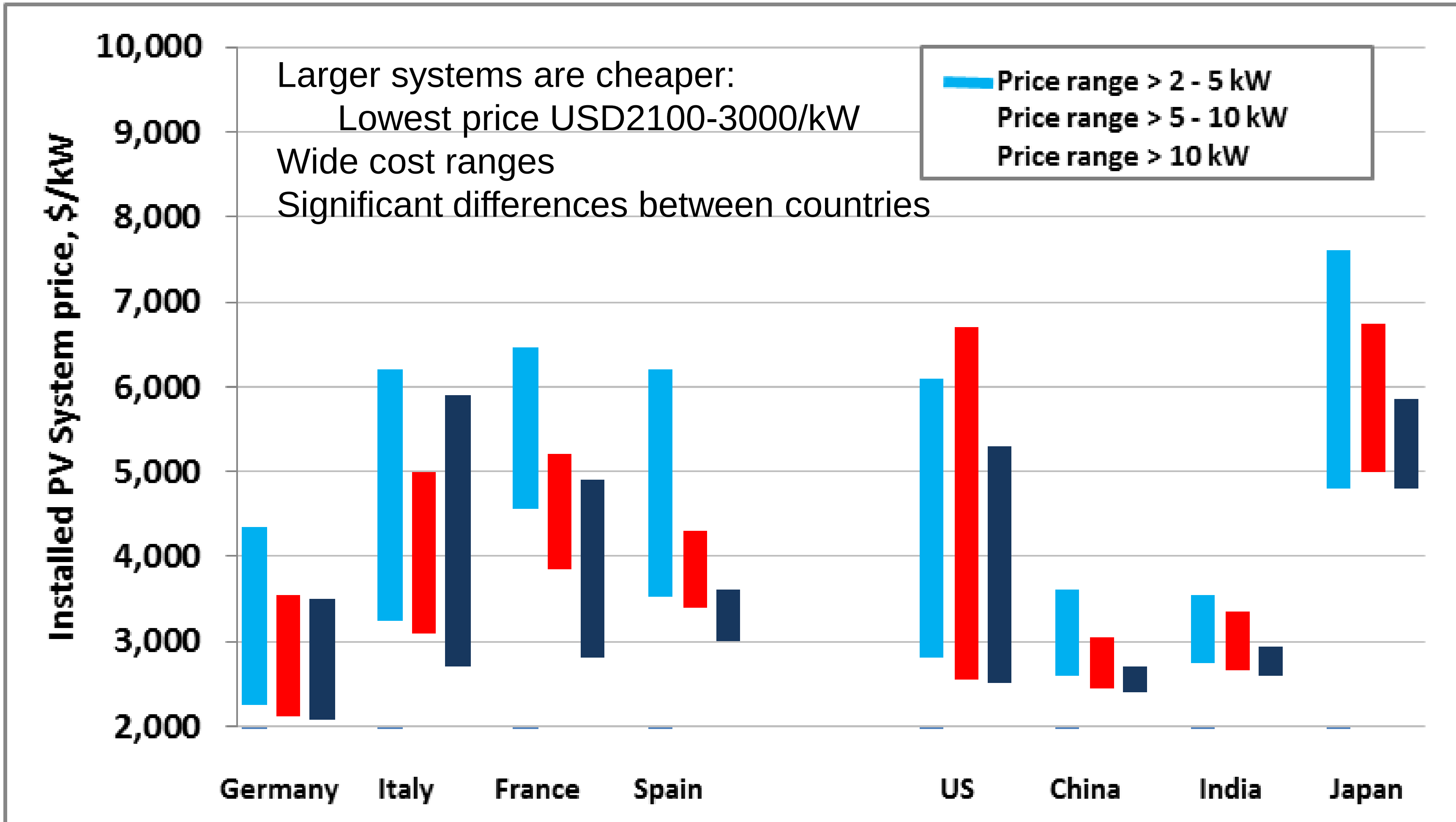
Learning curve: constant % cost reduction per doubling installed capacity



Next doubling
40 GW
(22% cost
reduction)

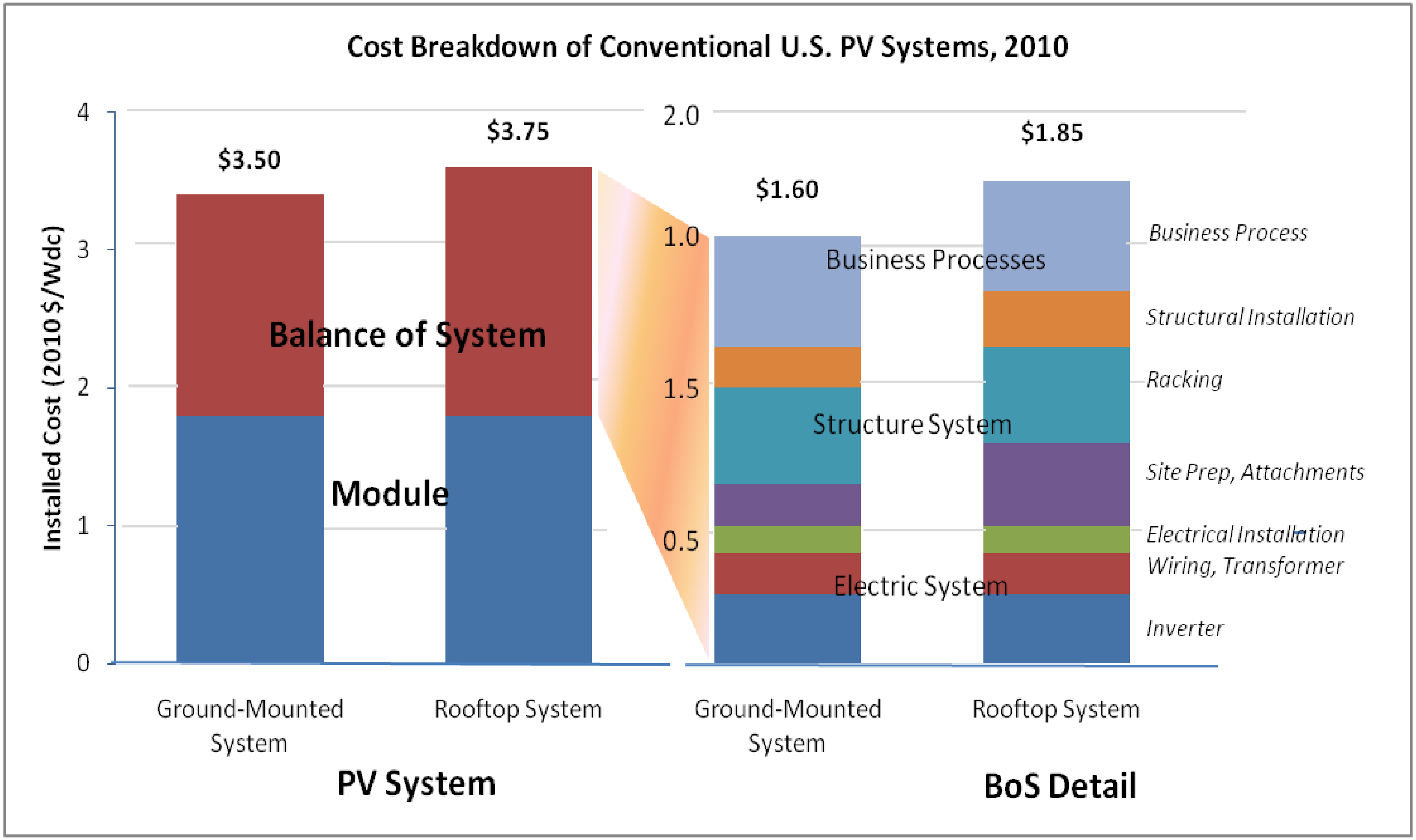
Source: Mints, Navigant, Bloomberg NEF, First Solar, NREL PV cost Model

Residential installed PV system prices, first half 2011



Source: IRENA Study, 2011

Module 60% of system cost, BOS other 40%



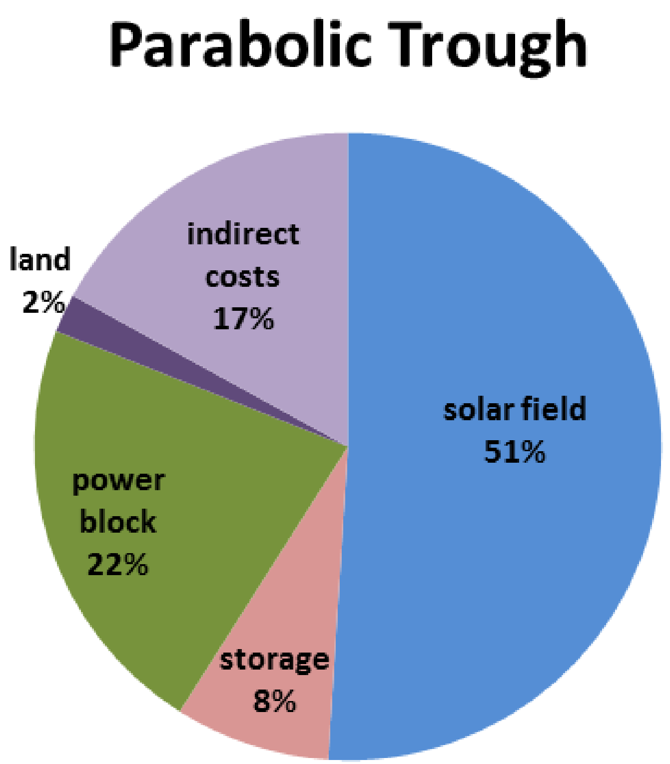
Source: Lionel Bony etc., Achieving Low Cost, Solar PV, 2010

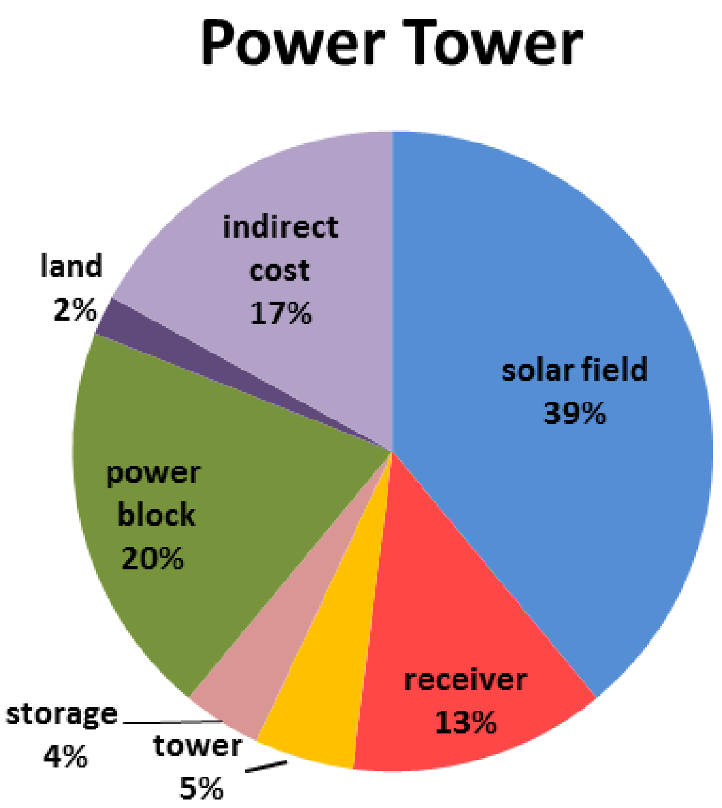
SOLAR CSP

In Fact a Set of Technologies

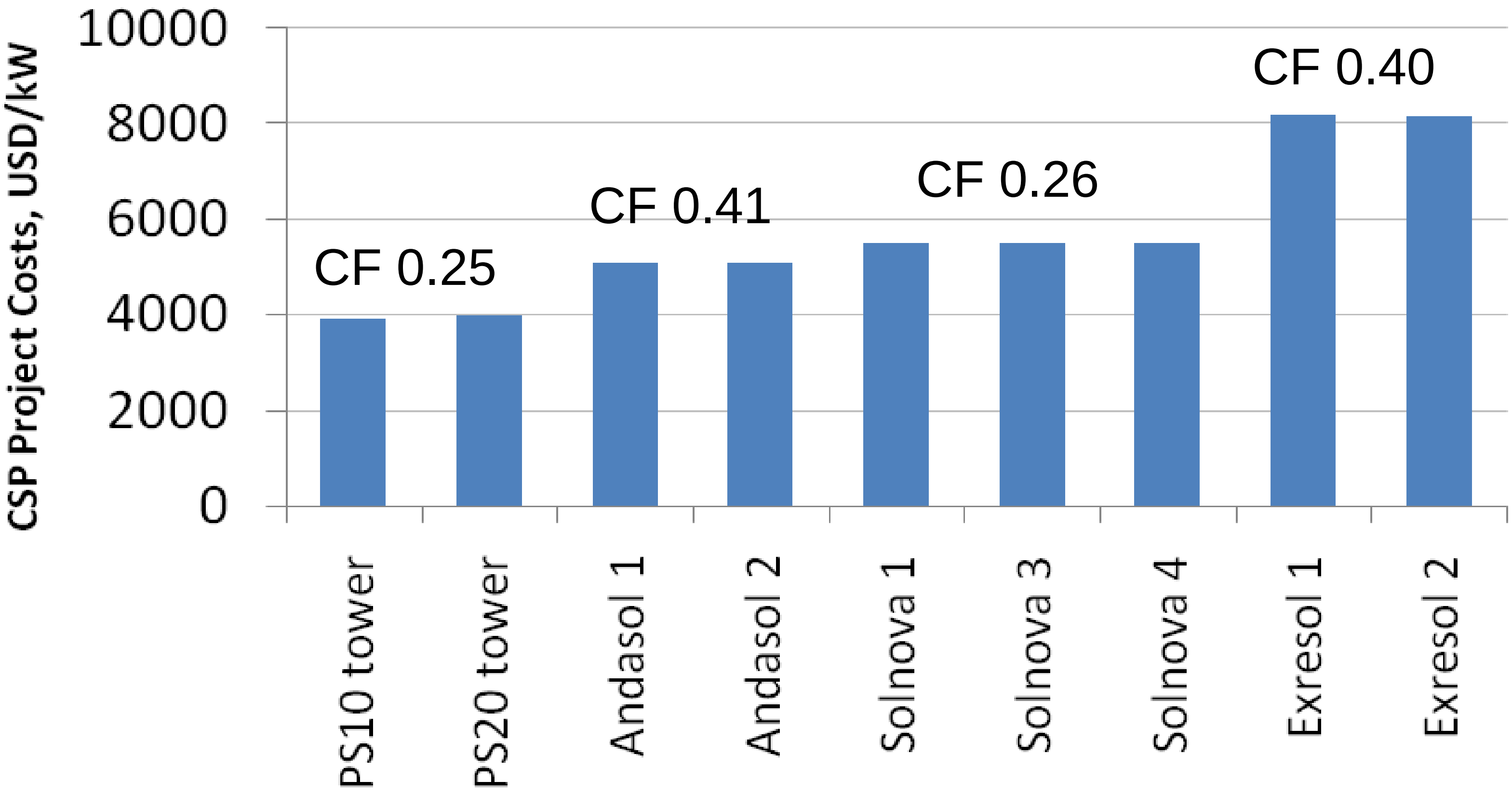
- Parabolic trough, Linear Fresnel, Solar Tower. Future Stirling systems is unclear.
- Thermal storage adds to cost range
- Storage increases electricity output and increases its value (evening peak)
- Significant investments in 80´s in California, nothing for 20 years
- Spain started again
- Worldwide installed capacity less than 1.5 GW
- More than 10 GW planned
- May grow rapidly – or not (PV competition)

CSP Project Cost Structure



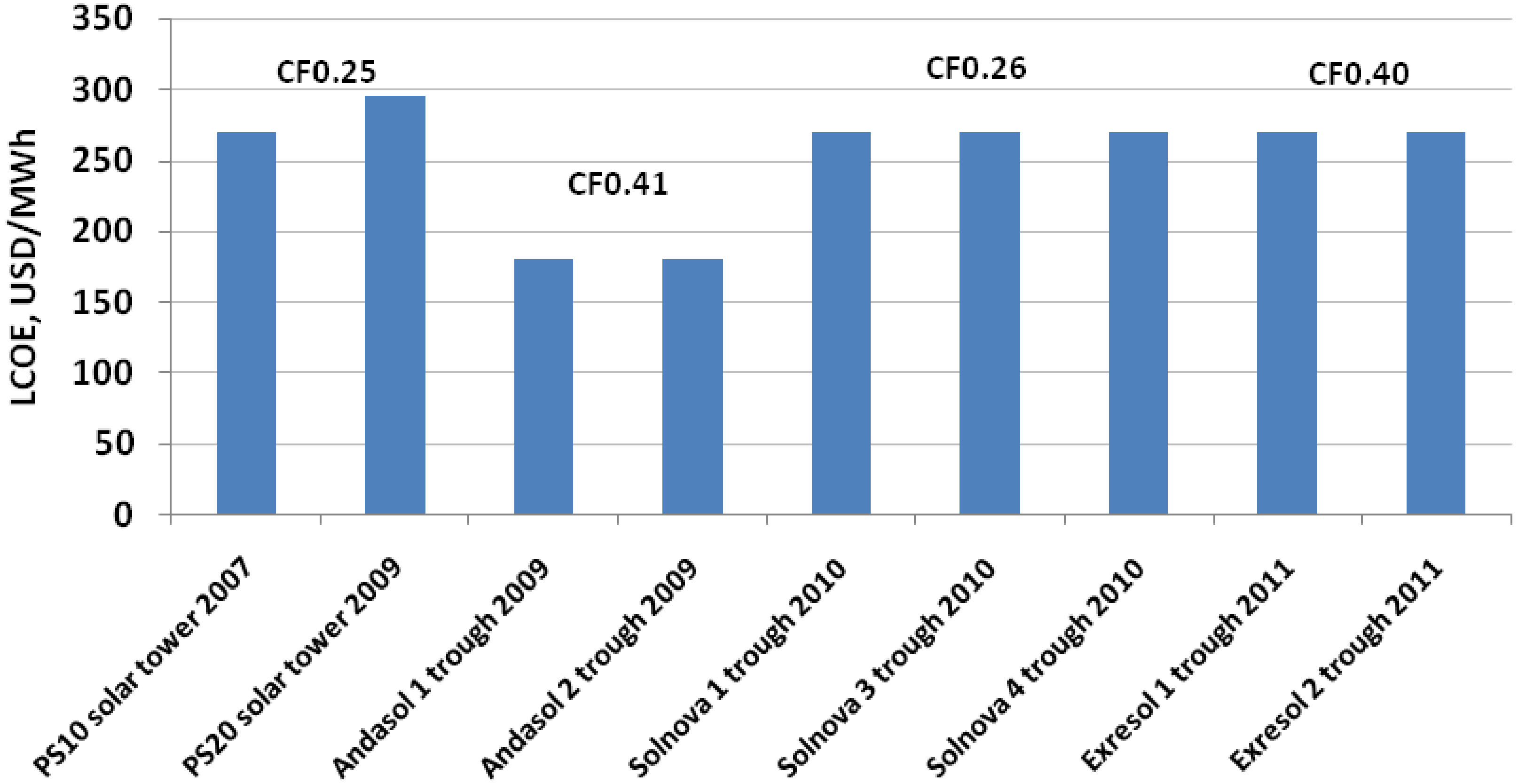


Project Investment Cost



Source: IRENA Analysis

LCOE



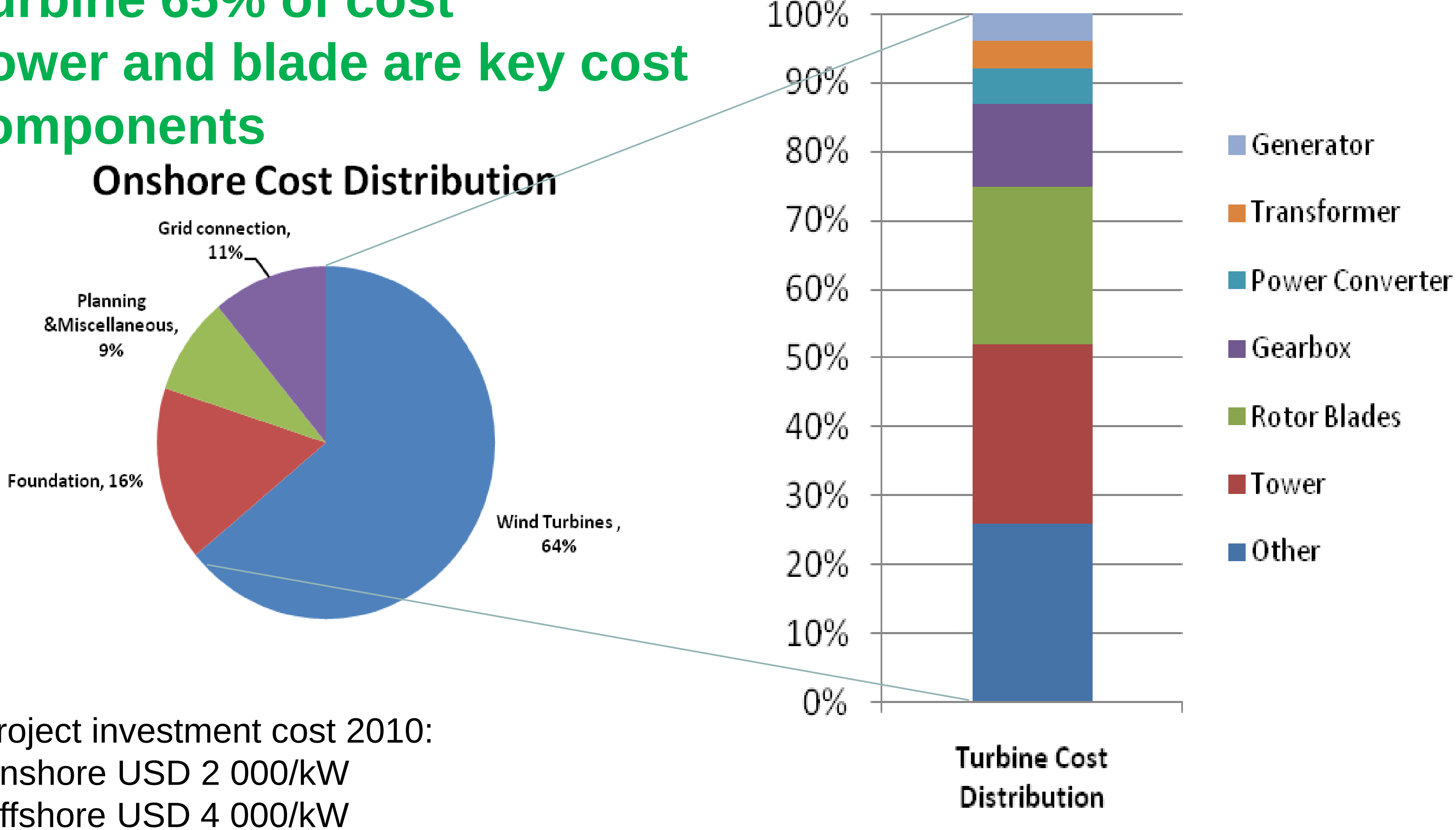
Source: IRENA Analysis

WIND ONSHORE

Typical wind project cost structure

Turbine 65% of cost

Tower and blade are key cost components



Project investment cost 2010:
Onshore USD 2 000/kW
Offshore USD 4 000/kW

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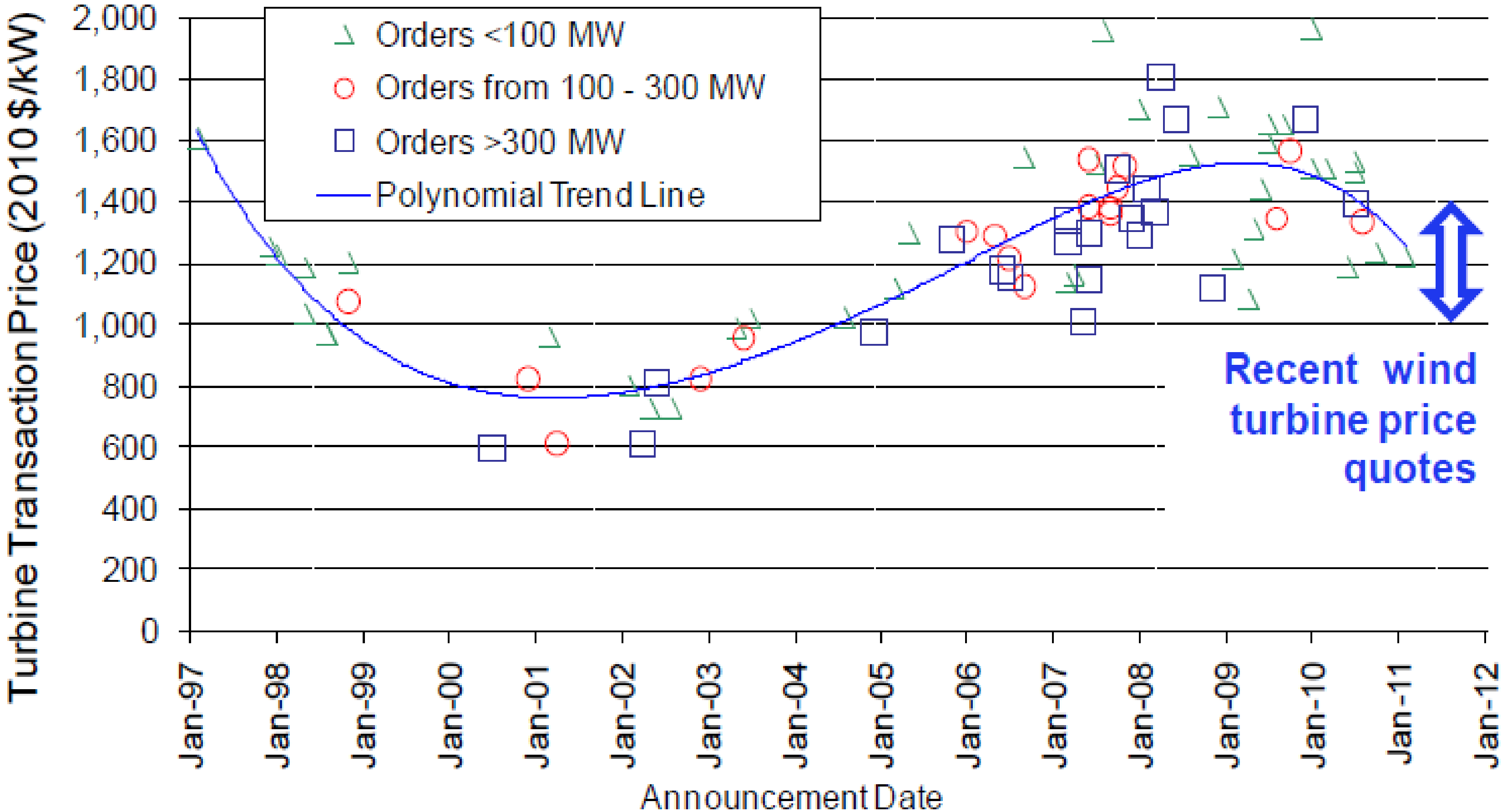
Wind turbine cost, US, 2001-2011

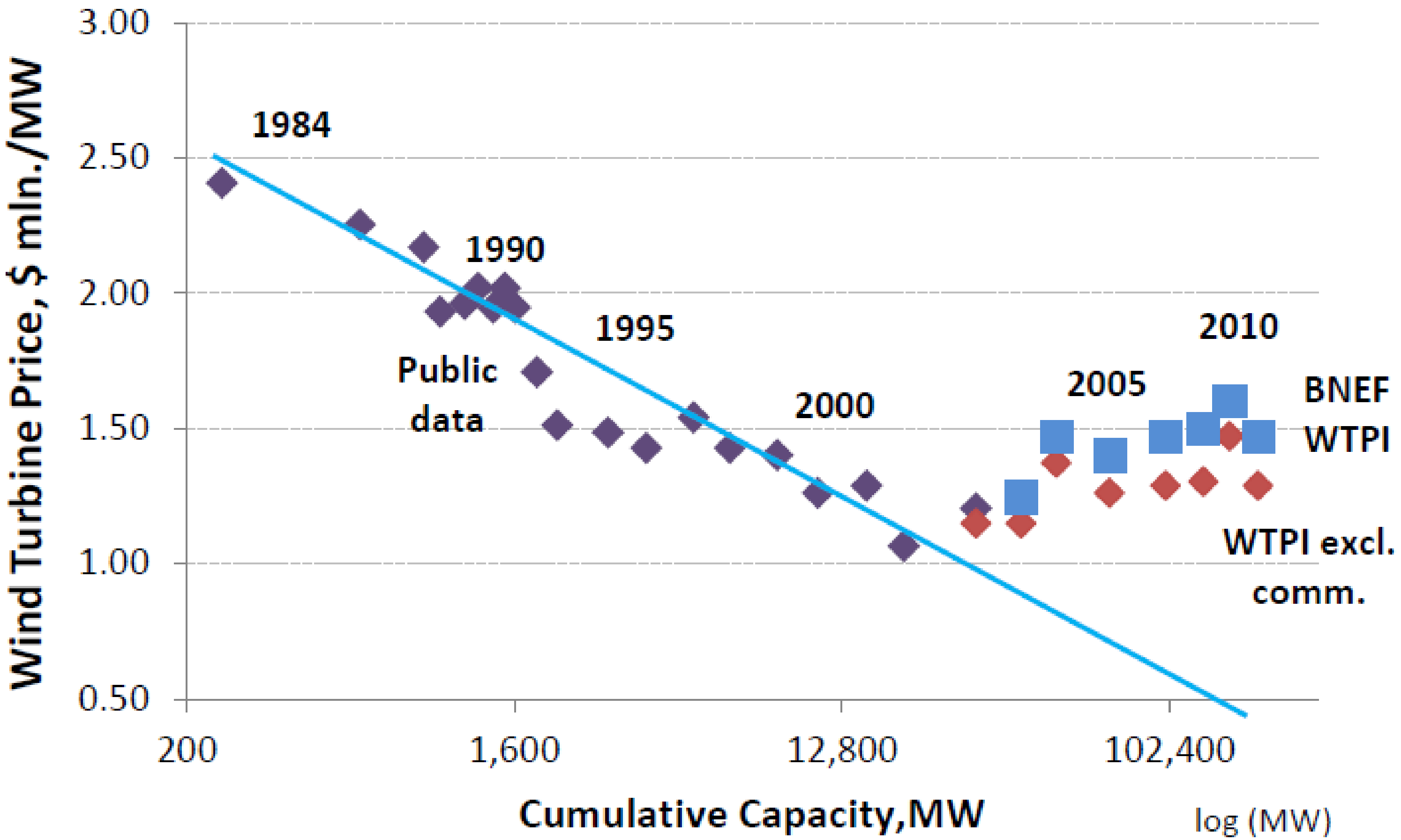
Rose by 67% in last 10 years



Source: 2010 Wind technologies market report, June 2011

Learning curve for turbines

Strong anomalies in recent years; further analysis needed



Commodity prices only part of the Explanation

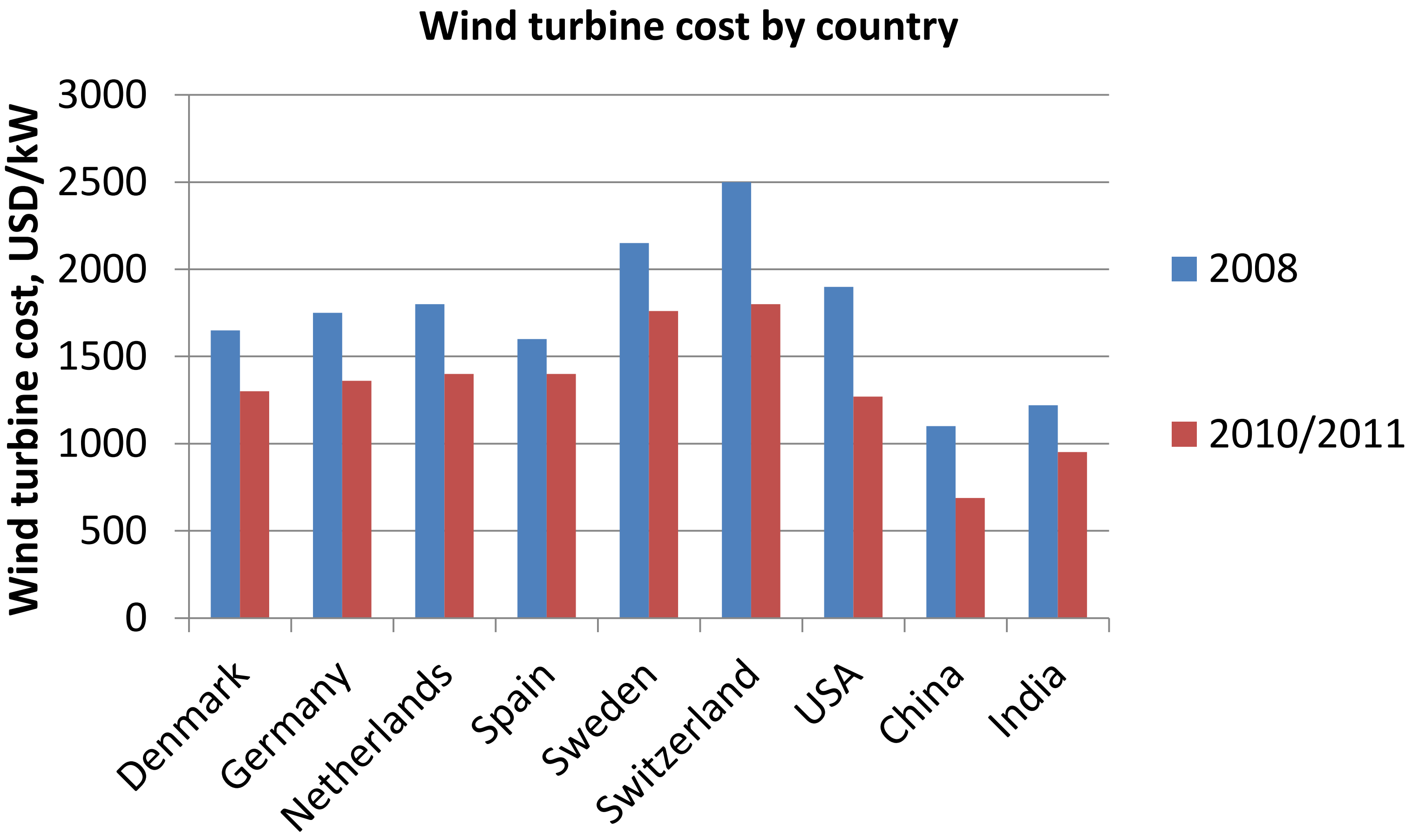
Higher turbines yield higher CF

Next doubling 200 GW (cost Reduction?)

Source: Bloomberg New Energy Finance, February, 2011

Wind turbine cost by country (2010/2011)

China is the lowest, declining trend



Source: IRENA Analysis

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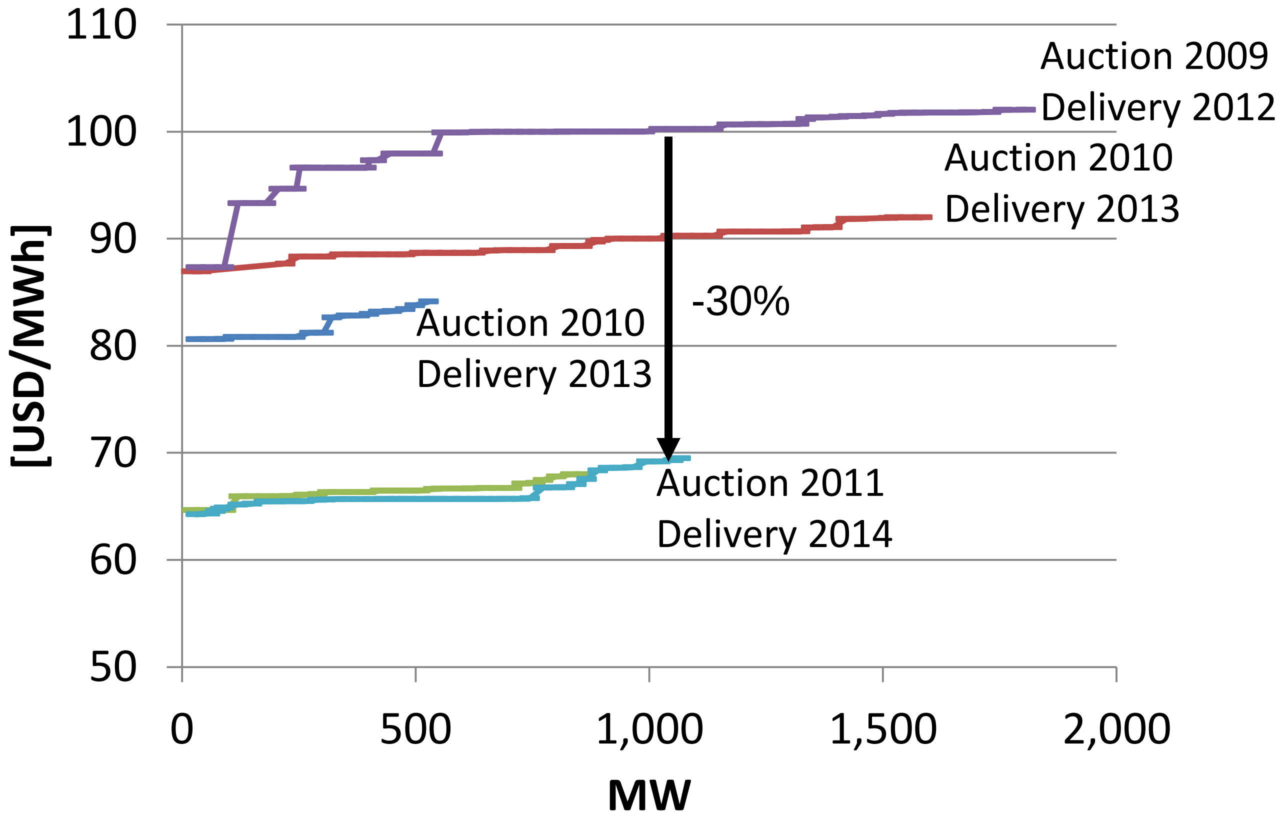
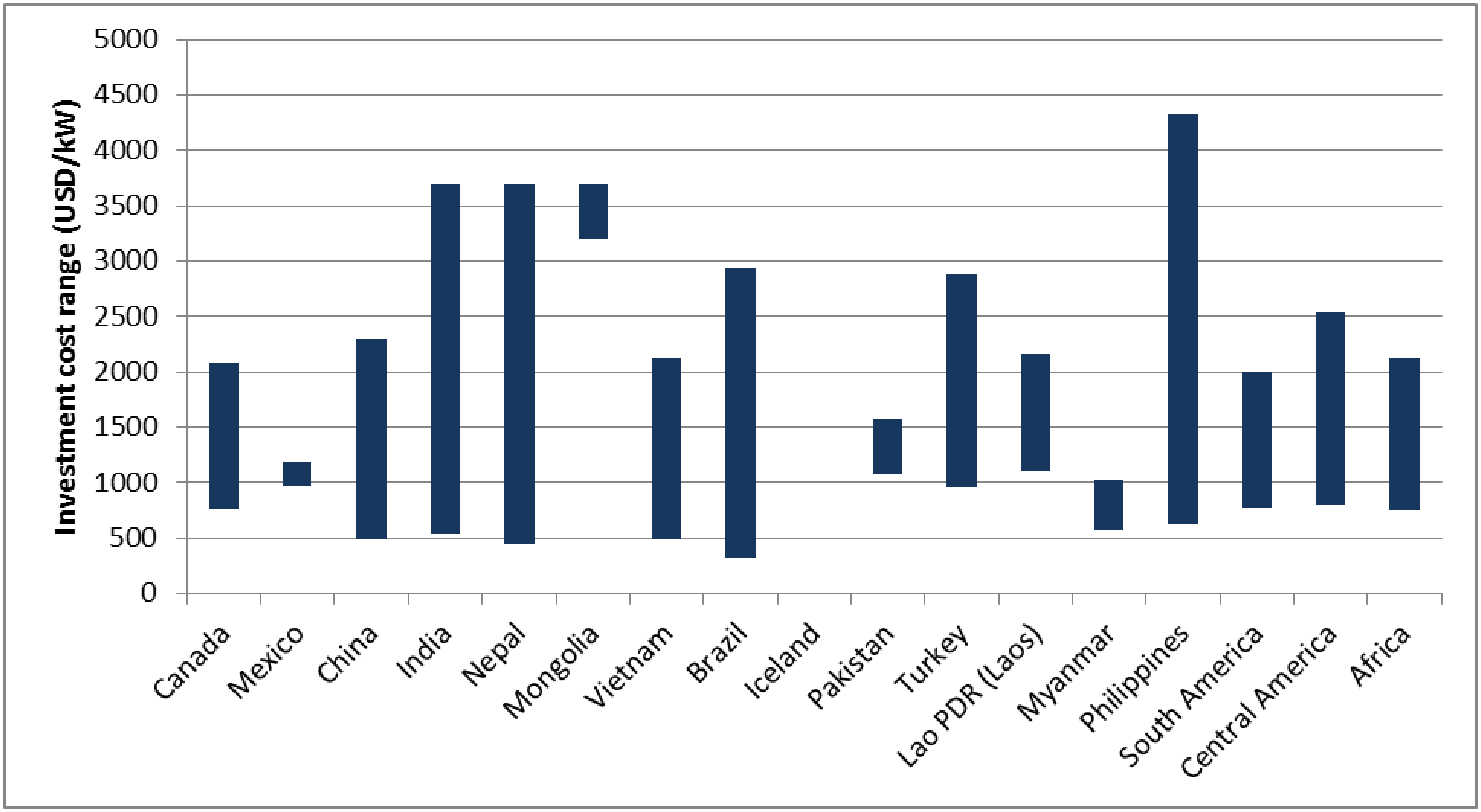
Wind Auctions Brazil



HYDRO

Cost of Hydropower Projects by Country



Source: IRENA Survey, 2011

Hydropower Investment Cost by Plant Type

Hydropower Technology	MW Range	Installed Cost (USD/kW)
Conventional Large Hydro	50 (average)	1,000 - 5,000
Microhydro	< 0.1	4,000 - 6,000
Run of River	< 10	1,500 - 6,000
Pumped Storage	>100	1,000 - 4,500

Source: Financing Renewable Energy in the European Energy Market, Final Report, Jointly prepared by Ecofys, Fraunhofer ISI, TU Vienna EEG and Ernst & Young, 2011, p.12-13

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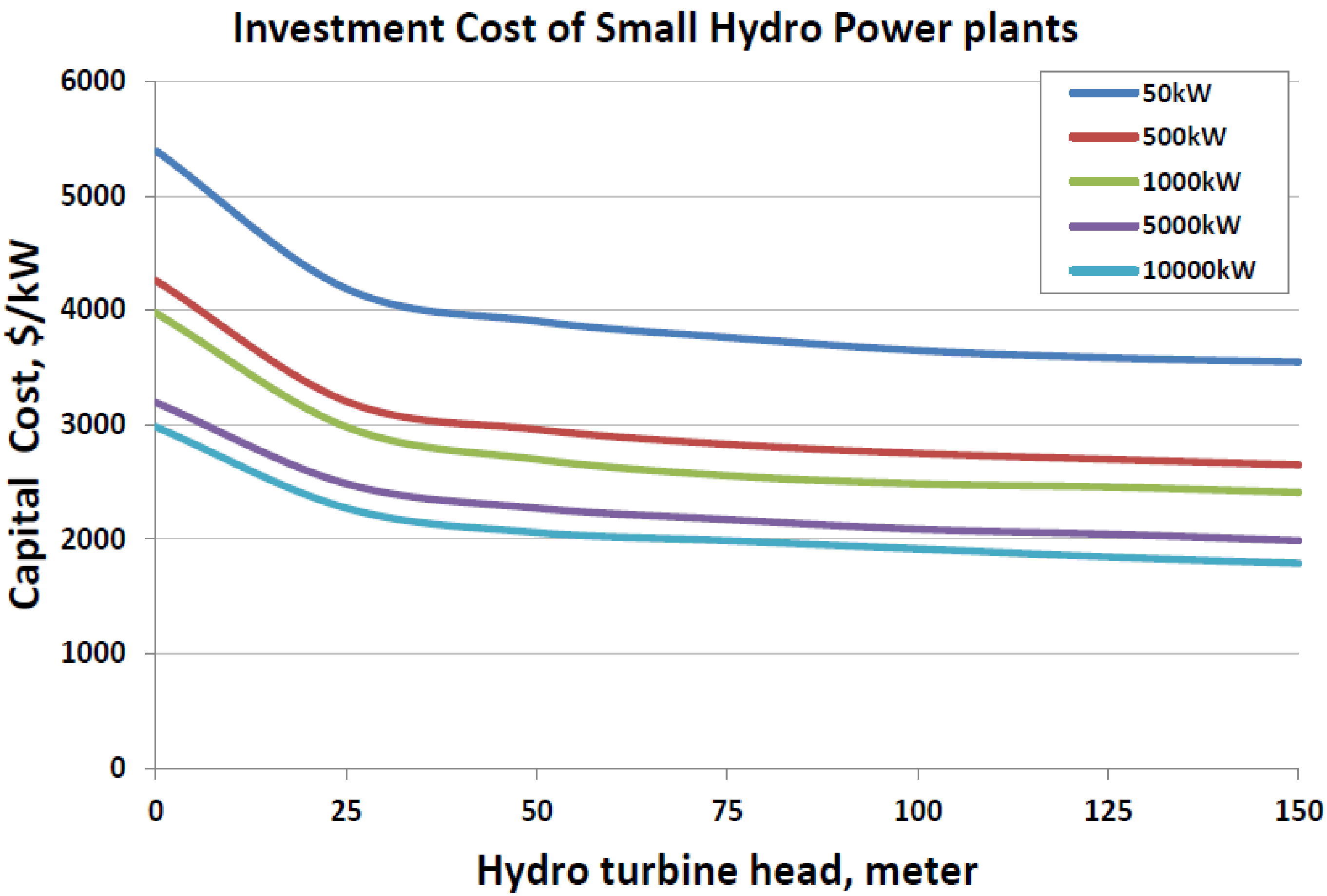
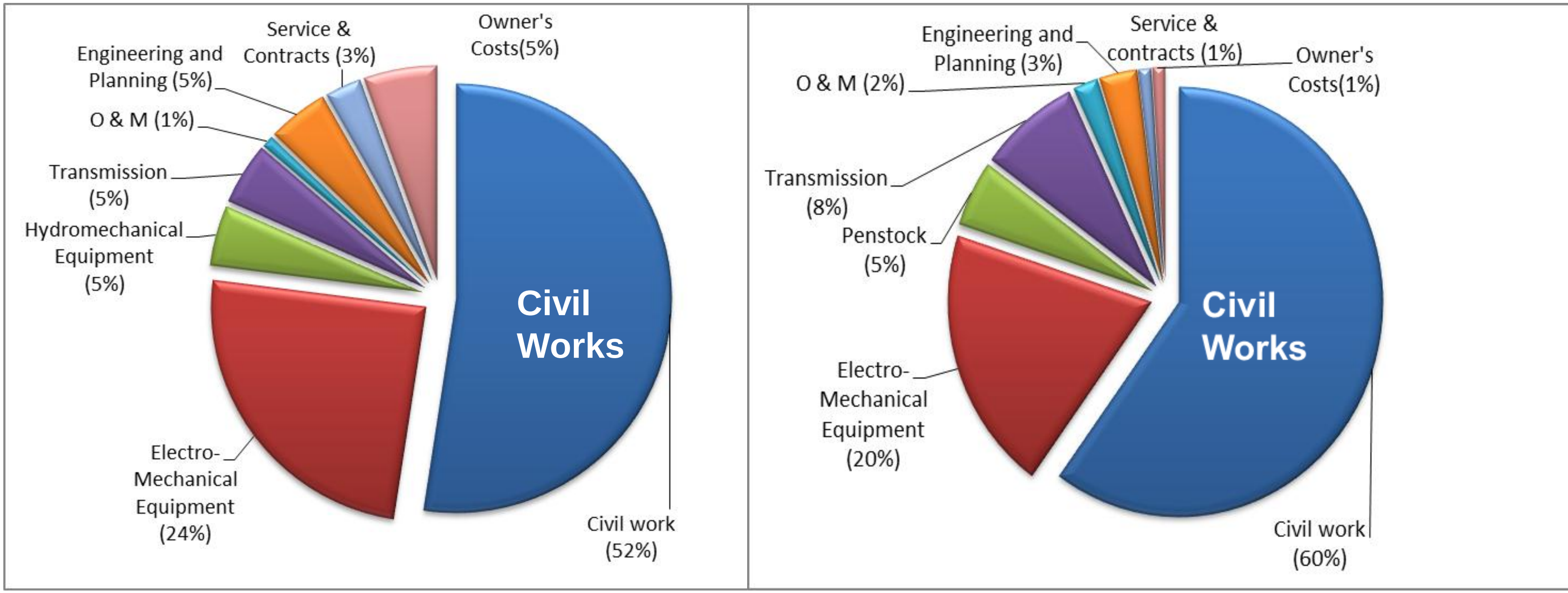
The investment cost of hydropower plants come down as turbine head and installed capacity rise



Cost Breakdown of a Typical Hydropower Project



Large hydropower | **Small hydropower**

Source: Overcoming the Barriers to Hydropower, Report No. 53719-PE Energy Unit Sustainable Development Department Latin America and the Caribbean Region,The World Bank, May 2010

Cost breakdown of a typical small hydropower project

About 2/3 of the SHP project costs are location dependent (civil works and transmission infrastructure).

	Capital cost, USD/kW	Share of total cost,%	O&M cost, ¢/kWh	Total generation cost, ¢/kWh
Civil Works & Transmission	**900-2800**	**60-70**		
Engineering and Planning	**75-400**	**50-10**		
Electro-mechanical Equipment	**375-1400**	**25-35**		
Total	**1500-4000**		**1.5-2.0**	**4.3-9.5**

Source: Emerging Hydropower Technologies R&D in Canada: A Strategy for 2007-2011,2007

BIOMASS POWER

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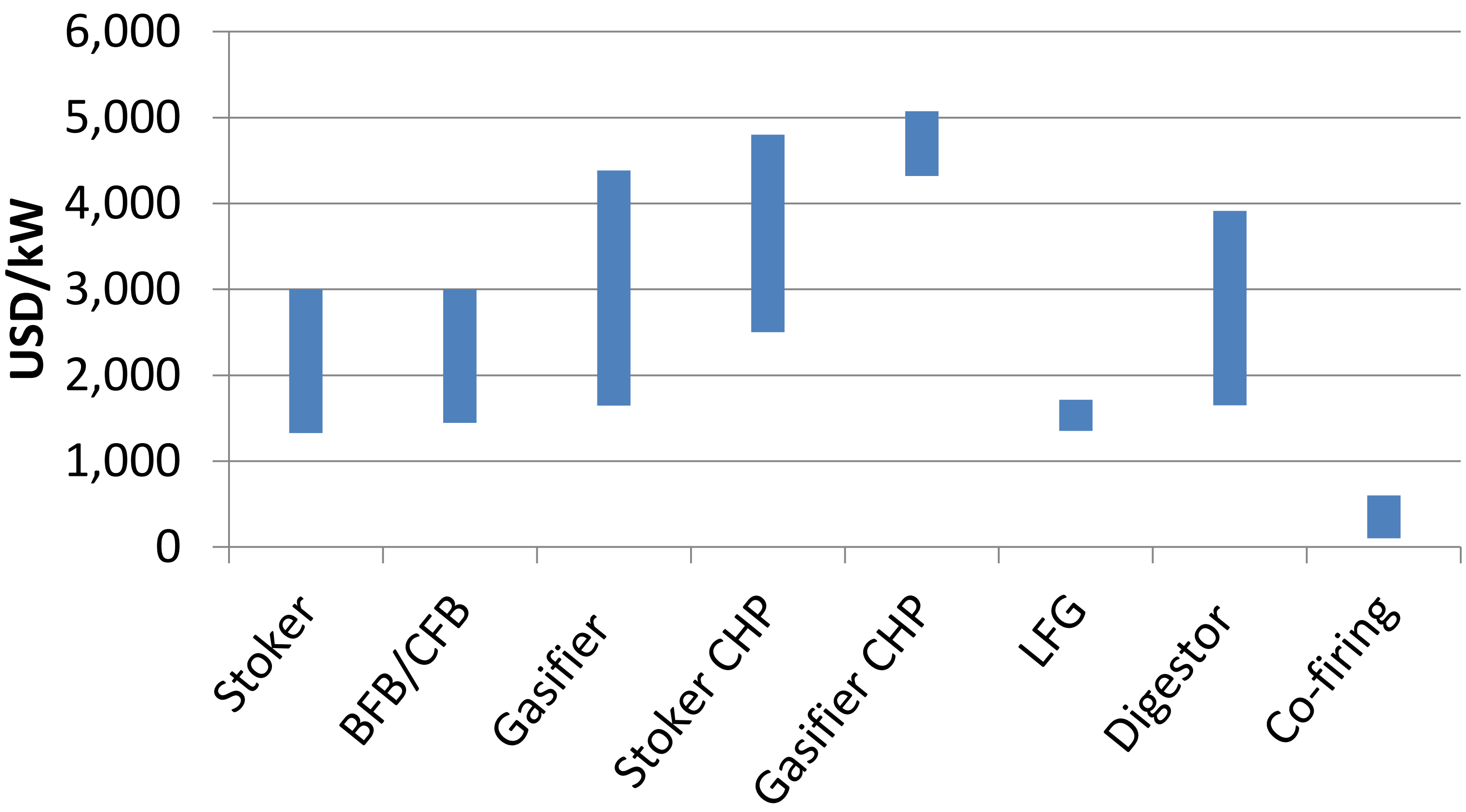
Set of Technologies:

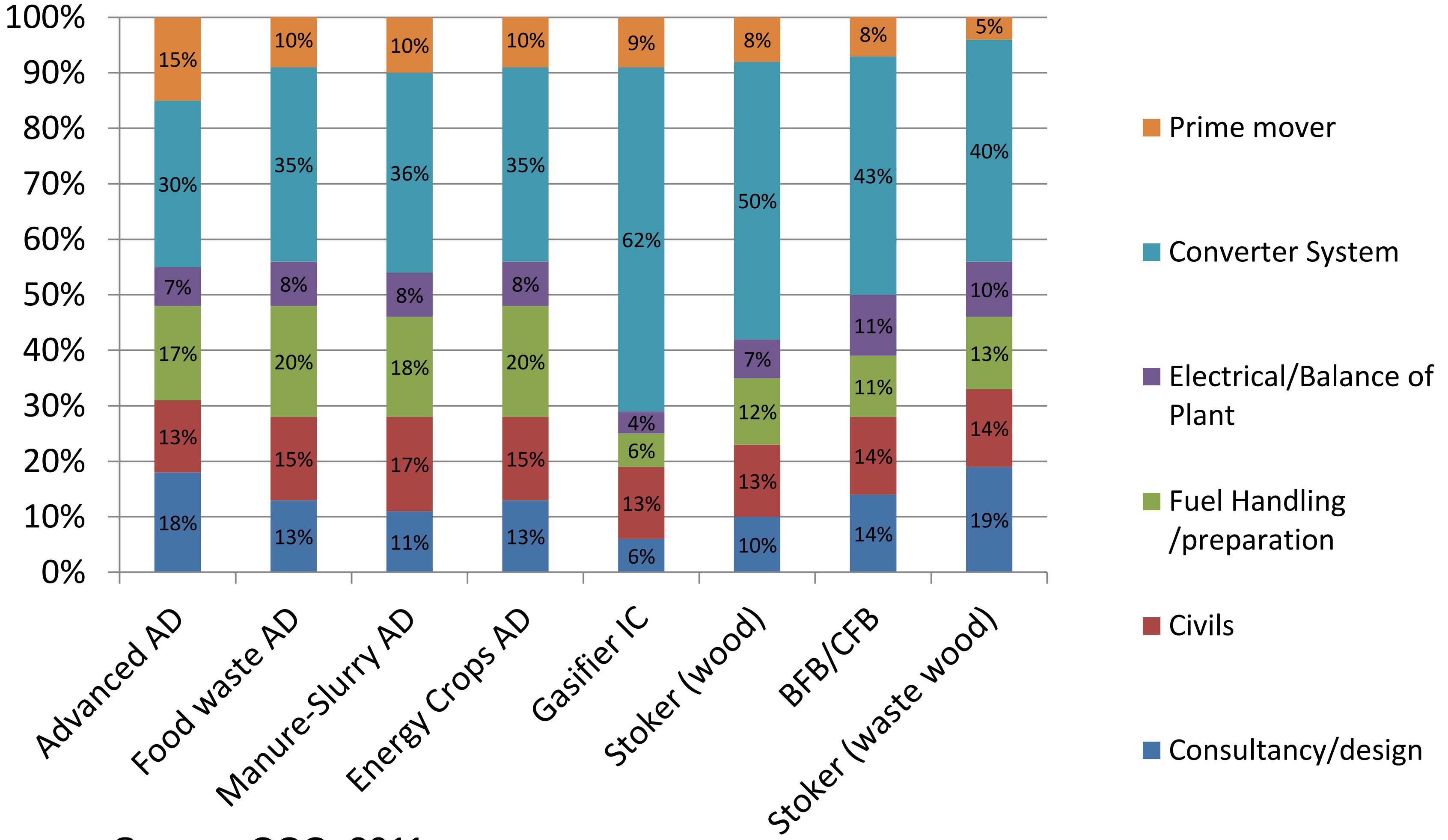
- Stoker boiler, Gasification, Digester, LFG (LandFill Gas, Anaerobic digestion)
- Feedstock cost account for a large share of the total cost
  - Biomass feedstock prices depend on quality, quantity, availability, moisture content
  - Biomass handling cost can have a high impact on final cost
- A market for pellets and woodchips has emerged in recent years
- Biopower plants require long term contracts for agricultural and forest residue supply
- Biomass co-generation systems are usually linked to industrial, agricultural and crop processing plant where the waste heat can be used in the process

Typical range of equipment costs



Typical Project Cost Structure

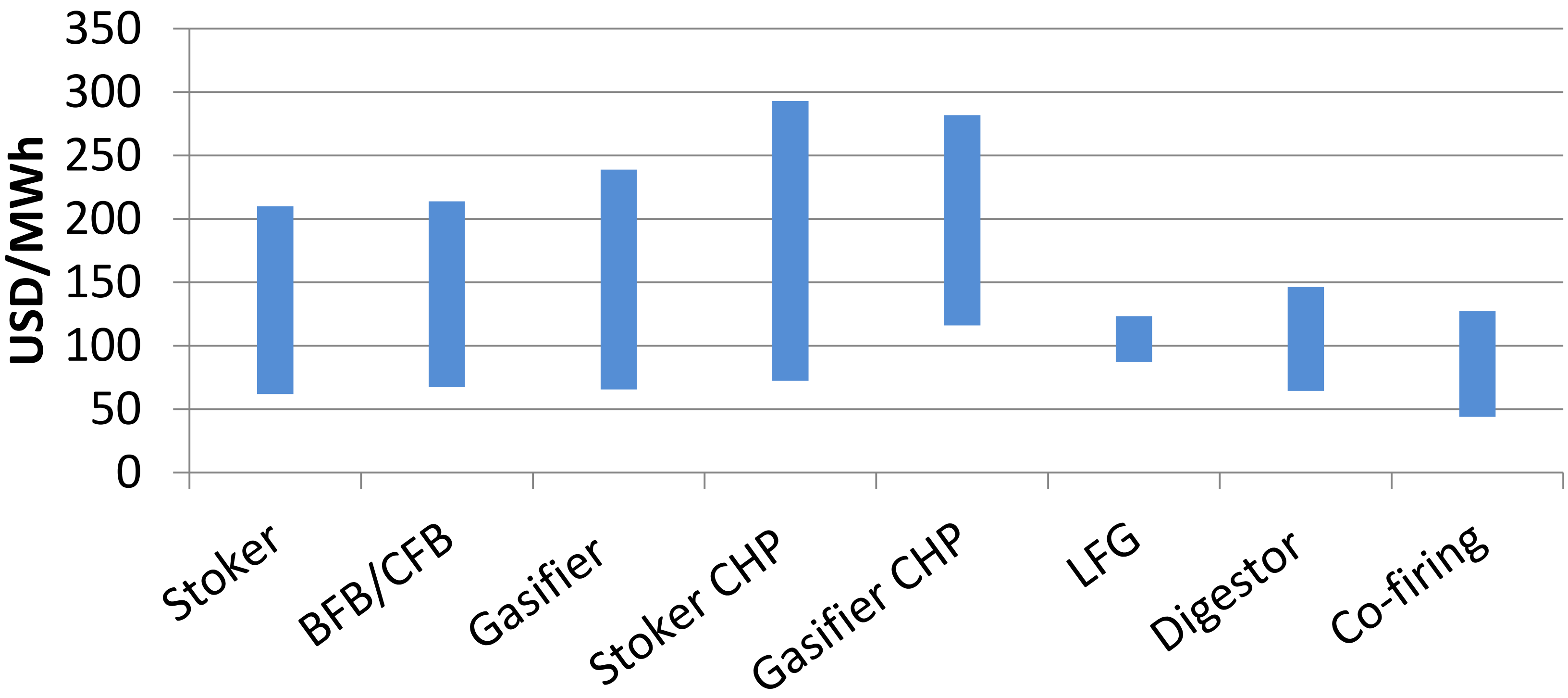
Equipment cost account for 45%- 70% of total cost



Source: CCC, 2011

Typical LCOE ranges

Feedstock from 10$/ton (9 GJ/ton) to 160 $/ton (17 GJ/ton)



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Part 2: Questionnaire

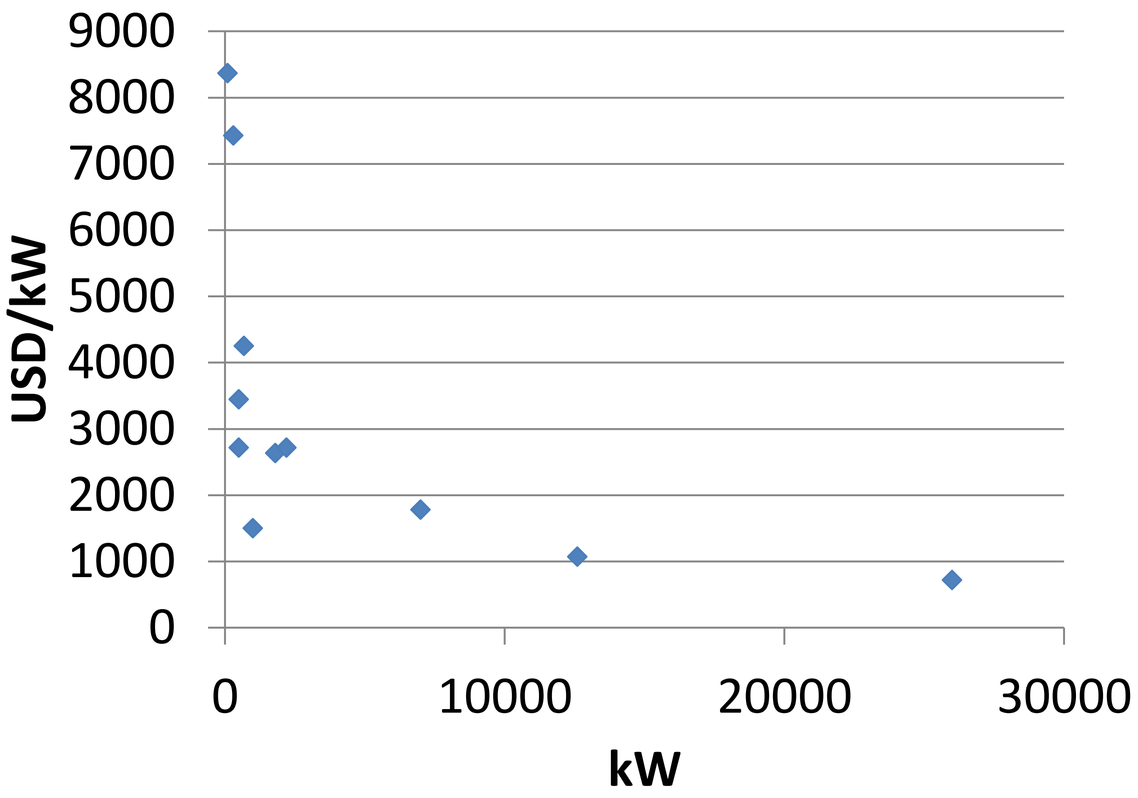
Status of country data collection (Jan 1st 2012)

- Twelve countries approached, objective is to collect 10 projects per country
  - Capex, Opex, project financing characteristics
- Data received for 57 projects
  - 15 hydro, 19 PV, 2 CSP, 7 wind, 4 biomass, 10 hybrid
  - Egypt, Morocco, Bangla Desh no data received so far
  - China - 1 hydro
  - Rwanda - 2 PV, 5 hydro
  - South Africa - 1 wind, 4 PV, 3 hydro
  - Kenya - 2 wind, 1 PV, 1 hydro, 2 biomass
  - Ethiopia - 2 PV, 1 hydro
  - Senegal - 2 wind, 2 PV, 1 biomass, 9 hybrid
  - Nigeria – 1 wind, 6 PV, 1 biomass, 1 hybrid
  - Uganda – 2 hydro
  - India – 1 wind, 2 PV, 2 hydro, 2 biomass, 2 CSP

Insights so far

- It is possible to gather detailed project cost data
- Many countries and project owners are reluctant to share information
  - Better to engage member countries directly
- Information needs to be checked carefully
- Typical project cost in many cases higher than data from literature
  - Economies of scale. Especially very small projects tend to show a wide cost spread.
  - Infrastructure needs vary
  - Some development aid projects select not based on cost
- Majore differences in financing conditions can make a factor two difference for LCOE
  - Equity:debt ratio between 80:20 to 20:80
  - Typical average cost of capital in Africa more than 20%

Hydropower Investment Cost: Economies of Scale



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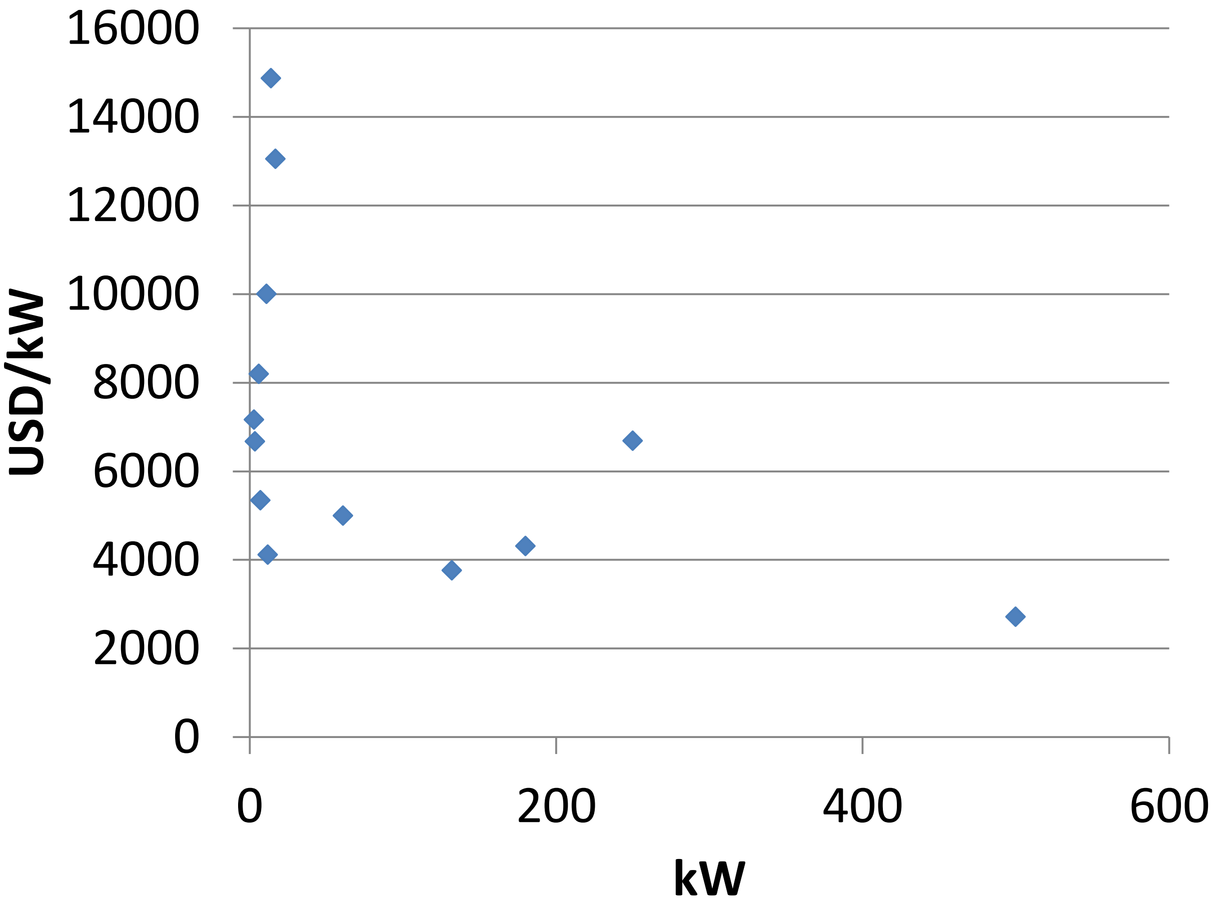
Solar PV Investment Cost: Economies of Scale



Next steps

- Complete questionnaire
- Issue working papers
- Prepare a report with summary of working paper findings and questionnaire
- Make a start with cost data collection for transportation fuels
- Develop a software based system to facilitate data roundup with the help of member countries

Thank you !

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Share of Feedstock Cost in LCOE