Performance Metric Framework (PMF): Synthesis and Opportunities to Add Value to the IEA Process

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Disclaimer

“The views expressed in this briefing are the personal views of the author, and do not represent the views of the U.S. Government or the U.S. Department of Energy”

Background

- **Metrics Successes**
  - **IEA collects regular data including:**
    - **Public investment in R&D**
    - **Deployment and generation/production progress**
    - **End-use efficiency, deployment, and intensity**
    - **Many additional metrics**
    - **Member countries and others when possible**
  - **This year: Significant expansion of countries and metrics**

Current Metrics Constraints

- **Some metrics difficult to collect**
- **Limited time to collect for each CEM**
  - **Some metrics may require multiple years to improve methodology/availability**
- **Many differences between countries' approaches to metrics and to fostering energy technology progress**
  - **Are state-owned companies included?**
  - **State/regional investments?**
  - **Subsidies?**
  - **IEA has solutions to many of these already, but new metrics will come with new differences**
- **Some countries do not report**

Objectives

- **This Meeting**
  - **Near Term: Provide Informed Input to IEA's ETP 2012 and its Section on "Technology Progress" to be Previewed at the Next Clean Energy Ministerial, London, in April 2012**
  - **Long Term: Contribute to Enhanced Framework of Metrics for Routinely Monitoring and Measuring Technology Progress**
- **PMF Objectives**
  - **Enable discussion of optimal metrics strategy**
  - **Work towards long-term, integrated set of metrics**
    - **For monitoring progress towards clean energy economy**
  - **Foster progress towards better metrics and data collection**
- **Presentation Objectives**
  - **Begin identifying high-priority metrics**
    - **Criteria for high-priority metrics**
    - **Background and limitations**
  - **Discuss limitations and usefulness of possible metrics, including definitions**
  - **Discuss possible initiatives to improve metrics**

Status of PMF

- Initial metrics outlined for 14 technology areas, five life cycle stages
- Initial selection of high priority metrics
- Initial selection of additional target metrics
- Remaining work
  - Refine draft metrics and priorities
  - Formulate proposal(s) to Secretariat

Criteria

- **Criteria for framework metrics**
  - Understandable
  - Relevant
  - Complete
  - Consistent
  - Quantitative
  - Accurate
  - Timely
  - Feasible

Leading Indicator	Years to Impact
1	12-25
2	5-12
3	3-5
4	0-3
5	-0.5 to 0
6	< -0.5

- **Criteria for high-opportunity framework metrics**
  - Strength: Degree to which this metric forecasts accurately
  - Forecasts further into future
    [Leading/Lagging (1 symbol)]
  - Not targeted by IEA (★symbol)
    - Partial: Collected for some technologies, or may be included in general policy review
- **Other factors of interest**
  - Data available for comparison
  - Accuracy/precision
  - Data availability

Data Availability	
A	Recent data already existing and available that is sufficient to quantify the metric
B	Partial and/or less-recent data is currently available
C	Data not readily available but could be gathered via research or other sources near term
D	Data not available and difficult to quantify metric, even by approximation, near term

Solar PV

Sample Metrics for Measuring Progress toward a Global Clean Energy Economy

Resources

- **Public RD&D investment in PV technologies($/yr) [1]** 1 ★
- **Private RD&D investment in PV technologies ($/yr) [2]** 2

Technology Readiness

- **Unsubsidized LCOE ($/kWh) and capital cost ($/kW) from new PV installations in a) utility, b) commercial, and c) residential sectors [3]** 4 ★
- Maximum PV efficiency (%) for next generation technologies achieved in lab and average annual improvement (%) [1] 3

Market Readiness

- **Total value of subsidies issued for PV ($/yr) [2]** 5 ★
- **Percent of G20 countries with grid integration policies for PV deployment (%) [1]** 3 ★
- Capacity and production of PV component manufacturing plants (MW/yr) [7] 4
- Share of PV power generation meeting a quota obligation system (%) [5] 4
- Funding for training and outreach to create an educated PV workforce among government planners, industry builders, consumers, etc. ($/yr) [1] 3

Market Transformation

- **Installed PV a) capacity (MW) and b) generation (TWh/yr) [1]** 5 6 ★
- Annual growth rates of PV a) capacity and b) generation (%/yr) [3, 5] 4
- Learning rate: cost reduction for each doubling of cumulative installed PV capacity (%) [3] 2
- Market capitalization of PV companies ($) 4

Impacts

- GHG emissions avoided (MtCO2e/yr) [1] 6
- Life cycle environmental impact score of PV systems [6] 3
- Number of employees in PV workforce (#) [1, 2] 4

PV Metrics Table, Representing Generation

Solar PV

Candidate Metric	Unit	Strength	Leading/Lagging	IEA Gathering	Comparison	Precision	Data Availability	Oppor-tunity
Public RD&D investment in PV technologies	**$/yr**	**Med-High**	**Leading-1**	**Yes**	**Roadmap**	**Medium**	**B**	
Private RD&D investment in PV technologies	**$/yr**	**Med-High**	**Leading-2**	**No**	**Roadmap**	**Low**	**B**	✓
Technology Readiness								
Unsubsidized LCOE ($/kWh) and capital cost ($/kW) from new PV installations in a) utility, b) commercial, and c) residential sectors	**$/kWh; $/kW**	**High**	**Leading-4**	**Partial**	**BLUE Map + Roadmap**	**Low-Med**	**B**	
Maximum PV efficiency (%) for next generation technologies achieved in lab and average annual improvement (%)	%	Medium	Leading-3	Yes	Roadmap	Medium	B	
Market Readiness								
Total value of subsidies issued for PV	**$/yr**	**High**	**Coincident-5**	**Yes**	**Trends**	**Med-High**	**C**	
Percent of G20 countries with grid integration policies for PV deployment	**%**	**Medium**	**Leading-3**	**Possible**	**Trends**	**High**	**C**	
Capacity and production of PV component manufacturing plants	MW/yr	Medium	Leading-4	No	BLUE Map	Med-High	C	
Share of PV power generation meeting a quota obligation system	%	Medium	Leading-4	No	Trends	Med-High	B	
Funding for training and outreach to create an educated PV workforce among government planners, industry builders, consumers, etc.	$/yr	Med-Low	Leading-3	No	Trends	Medium	C	
Market Transformation								
Installed PV a) capacity (MW) and b) generation (TWh/yr)	**MW; TWh/yr**	**High**	**Coincident-5,6**	**Yes**	**BLUE Map + Roadmap**	**High**	**A**	
Annual growth rates of PV a) capacity and b) generation	%/yr	High	Leading-4	Calculated	BLUE Map	High	A	
Learning rate (% cost reduction for each doubling of cumulative installed PV capacity)	%	Medium	Leading-2	Yes	BLUE Map	Med-High	B	
Market capitalization of PV companies	$	Medium	Leading-4	No	Trends	Medium	C	
Impacts								
GHG emissions avoided	MtCO2e/yr	High	Lagging-6	Calculated	BLUE Map	High	C	
Life cycle environmental impact score of PV systems	score	Medium	Leading-4	No	Trends	Med-High	D	
Number of employees in PV workforce	#	Low	Leading-4	No	Trends	Med-High	B	

Energy Efficient Heating and Cooling Equipment

Sample Metrics for Measuring Progress toward a Global Clean Energy Economy

Resources

- **Public RD&D investment in energy efficient heating & cooling technologies ($/yr) [4]** 1 ★ 2
- **Private RD&D investment in energy efficient heating & cooling technologies ($/yr) [4]**

Technology Readiness

- **Typical payback period for retrofitting existing heating/cooling system with energy efficient system (yr) [4]** 4
- Maximum efficiency of a) electric heat pumps, b) gas-engine heat pumps, c) CHP, d) solar thermal, and e) chillers (%) [4] 3
- Capital cost of a) electric heat pumps, b) gas-engine heat pumps, c) CHP, d) solar thermal, and e) chillers [4] 4

Market Readiness

- **Percent improvement compared to 2000 of mandatory minimum energy performance standards for heating/cooling equipment sold in G20 countries (%) [1,4]** 3 ★
- **Number of G20 countries with labeling programs for heating and cooling equipment (#) [1,4]** 3 ★
- Average value of incentives issued per high efficiency heating and cooling unit ($/unit) [3] 5 ★

Market Transformation

- **Global sales of new energy efficient heating and cooling equipment (units/yr) [4,5,6]** 5 ★
- Learning rate: cost reduction associated with cumulative doubling in sales of high efficiency heating and cooling equipment (%) [2] 2
- Average energy use of new heating and cooling equipment sold (kWh/yr) [1] 4 ★
- Percent of households with high efficiency heating/cooling system (%) [4] 5

Impacts

- GHG emissions avoided from use of high efficiency heating/cooling equipment (MtCO2e/yr) [4] 6
- Number of employees in energy efficient heating and cooling workforce (#) 4

HVAC Metrics Table

Energy Efficient Heating & Cooling Equipment

Candidate Metric	Unit	Strength	Leading/Lagging	IEA Gathering	Comparison	Precision	Data Availability	Oppor-tunity
Resources								
Public RD&D investment in energy efficient heating and cooling equipment	**$/yr**	**Med-High**	**Leading-1**	**Yes**	**Roadmap**	**Medium**	**C**	
Private RD&D investment in energy efficient heating and cooling equipment	**$/yr**	**Med-High**	**Leading-2**	**No**	**Roadmap**	**Low**	**D**	✓
Technology Readiness								
Typical payback period for retrofitting existing heating/cooling system with energy efficient system	yr	High	Leading-4	No	BLUE Map + Roadmap	Medium	B	
Average installed efficiency of a) electric heat pumps, b) gas-engine heat pumps, c) CHP, d) solar thermal, and e) AC systems	**%**	**Med-High**	**Leading-3**	**Partial**	**BLUE Map + Roadmap**	**Medium**	**A**	✓
Installed costs of a) electric heat pumps, b) gas-engine heat pumps, c) CHP, d) solar thermal, and e) AC systems	**$/kW**	**High**	**Leading-4**	**Partial**	**BLUE Map + Roadmap**	**Medium**	**B**	✓
Market Readiness								
Percent improvement, weighted by energy usage, compared to 2000 of mandatory minimum energy performance standards for heating/cooling equipment sold in G20 countries	**%**	**High**	**Leading-3**	**Yes**	**Trends**	**High**	**C**	
Number of G20 countries with labeling programs for heating and cooling equipment, tracked by categorical, endorsement, and other	**#**	**Med-High**	**Leading-3**	**Yes**	**Roadmap**	**High**	**B**	
Average value of incentives issued per high efficiency heating and cooling unit	$/unit	High	Coincident-5	Yes	Trends	Med-High	C	
Market Transformation								
Global sales of new energy efficient heating and cooling equipment	**units/yr**	**High**	**Coincident-5**	**Yes**	**BLUE Map**	**High**	**B**	
Learning rate for capital costs (% cost reduction associated with cumulative doubling in sales of high efficiency heating and cooling equipment)	%	Medium	Leading-2	No	Trends	Med-High	B	
Average energy use of new heating and cooling equipment sold	kWh/yr	Medium	Leading-4	Yes	Trends	Medium	C	
Percent of households with high efficiency heating/cooling system	%	Medium	Coincident-5	Possible	Trends	Medium	C	
Impacts								
Energy demand and GHG emissions avoided from use of high efficiency heating and cooling equipment	MtCO2e/yr	High	Lagging-6	No	BLUE Map	High	C	
Number of employees in energy efficient heating and cooling workforce	#	Low	Leading-4	No	Trends	Med-High	D	

Energy Storage – Vehicle Batteries (EV, HEV, PHEV)

Sample Metrics for Measuring Progress toward a Global Clean Energy Economy

Resources

- **Public RD&D investment in battery technologies($/yr) [1]** 1 ★
- **Private RD&D investment in battery technologies ($/yr) [1]** 2

Technology Readiness

- **Incremental capital cost of EV, HEV, PHEVs compared to conventional ICE vehicle of comparable size and performance (%) [4,6,7]** 4
- **Average fuel economy difference compared to conventional ICE vehicle of comparable size and performance (light duty) (%) [7]** 4
- **Battery specific power (kW/kg) [4]** 3
- **Battery power density (kW/L) [4]** 3
- Battery life expectancy (cycles or yrs) [4] 3
- Average recharging time for EV and PHEVs (hrs/100 km) [4,7,8] 3
- Estimated cost of recharging infrastructure ($/car) [4] 3
- Cost of batteries in commercial production ($/kWh) [6,7] 3

Market Readiness

- **Average national fuel efficiency standards in G20 countries (light duty) (km/L) [5,7]** 2 ★
- Value of subsidies per electric drive vehicle (EV, HEV, PHEV) among G20 countries ($/vehicle) [5,6,7,8,10] 4 ★
- Number of nations with national EV/PHEV sales targets (#) [2,4,11] 3 ★
- Manufacturing capacity of batteries (units/yr) [6,7] 4
- Number of electric charging points among G20 countries (#) [7] 4

Market Transformation

- **Annual sales of electric vehicles (EV, HEV, PHEV) (#/yr) [3,4,5,9]** 5 ★
- Learning rate for capital costs: cost reduction associated with cumulative doubling in sales of vehicle batteries (%) 2
- Share of vehicle fleet that is electric (EV, HEV, PHEV) (%) [3,5,11] 5

Impacts

- GHG emissions avoided from use of electric vehicles (EV, HEV, PHEV) (MtCO2e/yr) [3] 6
- Reduction in petroleum consumption for transportation (bbls/yr) 6
- Number of employees in vehicle energy storage workforce (#) [1] 4

Vehicle Batteries Table

Energy Storage - Vehicle Batteries (EV, HEV, PHEV)

Candidate Metric	Unit	Strength	Leading/ Lagging	IEA Gathering	Comparison	Precision	Data Availability	Oppor-tunity
Resources								
Public RD&D investments in battery technologies	**$/yr**	**Med-High**	**Leading-1**	**Yes**	**Roadmap**	**Medium**	**B**	
Private RD&D investment in battery technologies	**$/yr**	**Med-High**	**Leading-2**	**No**	**Roadmap**	**Low**	**D**	✓
Technology Readiness								
Incremental capital cost of EV, HEV, PHEVs compared to conventional ICE vehicle of comparable size and performance (light duty)	**%**	**High**	**Leading-4**	**Possible**	**BLUE Map**	**Med-High**	**B**	✓
Average fuel economy difference compared to conventional ICE vehicle of comparable size and performance (light duty)	**%**	**Med-High**	**Leading-4**	**Possible**	**BLUE Map**	**Medium**	**B**	✓
Battery specific power	**kW/kg**	**Med-High**	**Leading-3**	**Possible**	**Trends**	**Med-High**	**B**	✓
Battery power density	**kW/L**	**Med-High**	**Leading-3**	**Possible**	**Roadmap**	**Med-High**	**B**	✓
Battery specific energy	**kWh/kg**	**Med-High**	**Leading-3**	**Possible**	**Roadmap**	**Med-High**	**B**	✓
Battery energy density	**kWh/L**	**Med-High**	**Leading-3**	**Possible**	**Roadmap**	**Med-High**	**B**	✓
Estimated cost of recharging infrastructure	$/car	Med-High	Leading-3	No	Trends	Medium	B	
Average recharging time for EV and PHEVs	hrs/100 km	Medium	Leading-3	No	Roadmap	Med-High	B	
Battery life expectancy	cycles; yrs	Medium	Leading-3	Possible	Roadmap	Med-High	C	
Cost of batteries in commercial production	$/kWh	Med-High	Leading-3	Possible	Roadmap	Medium	A	
Market Readiness								
Average national fuel efficiency standards in G20 countries (light duty)	**km/L**	**Medium**	**Leading-2**	**Yes**	**BLUE Map**	**High**	**B**	
Value of subsidies per electric drive vehicle (EV, HEV, PHEV) among G20 countries	$/vehicle	High	Leading-4	Yes	Trends, BLUE Map	High	B	
Number of nations with national EV/PHEV sales targets	#	Med-Low	Leading-3	Yes	Trends	High	B	
Manufacturing capacity of batteries	units/yr	Medium	Leading-4	Yes	BLUE Map	Med-High	C	
Number of electric charging points among G20 countries	#	Medium	Leading-4	No	Trends	Med-High	C	
Market Transformation								
Annual sales of electric vehicles (EV, HEV, PHEV)	**#/yr**	**High**	**Coincident-5**	**Yes**	**BLUE Map**	**High**	**B**	
Learning rate (% cost reduction associated with cumulative doubling in capacity)	%	Medium	Leading-2	No	Trends	Med-High	C	
Share of vehicle fleet that is electric (EV, HEV, PHEV)	%	Medium	Coincident-5	Calculated	BLUE Map	High	B	
Impacts								
GHG emissions avoided from use of electric vehicles (EV, HEV, PHEV)	MtCO2/yr	High	Lagging-6	Calculated	BLUE Map	High	A/B	
Reduction in petroleum consumption for transportation compared to BAU	bbls/yr	High	Lagging-6	Calculated	BLUE Map	High	B	
Number of employees in vehicle energy storage workforce	#	Low	Leading-4	No	Trends	Med-High	C	

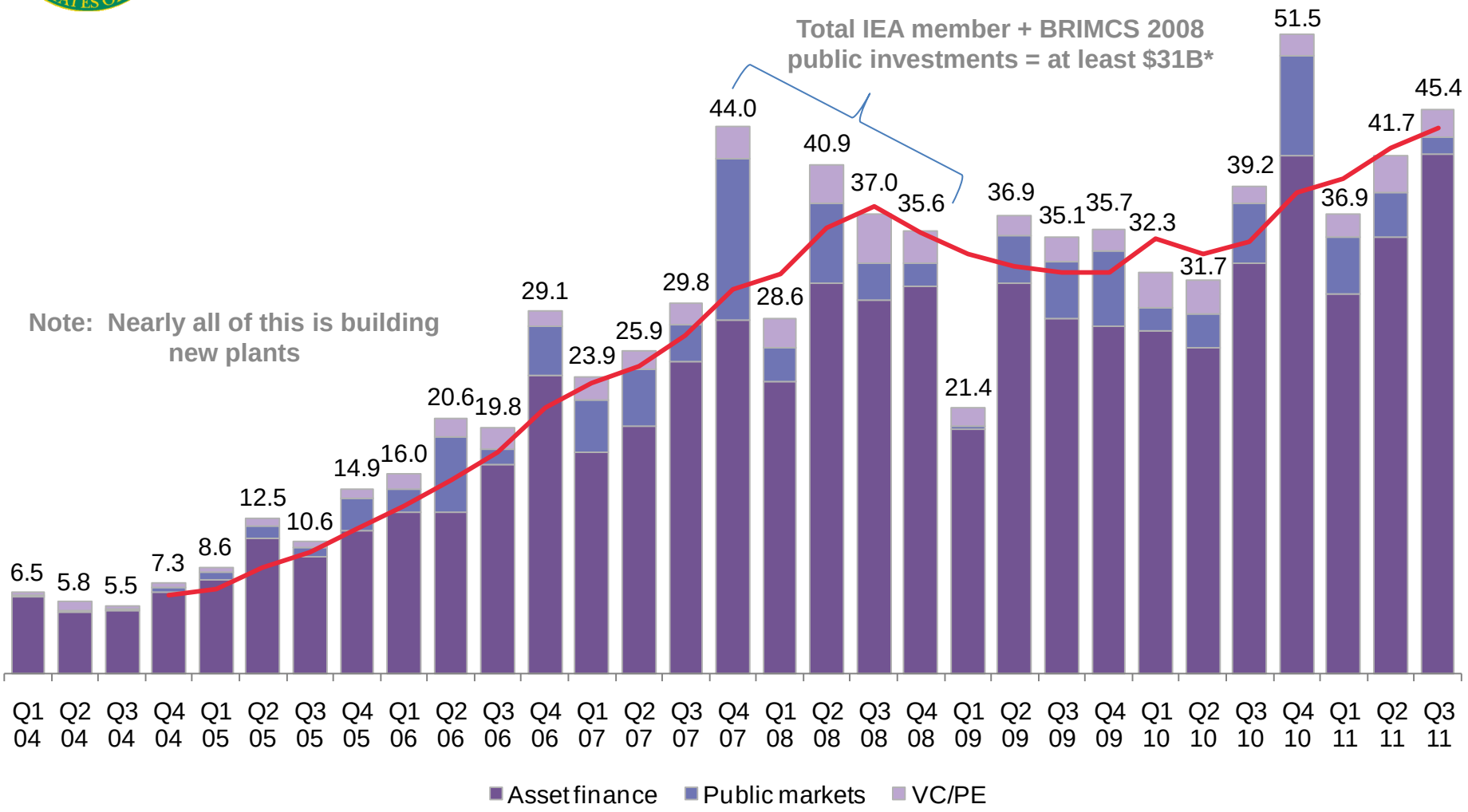
Additional Information On:

- Private investment
- Technology costs
- Possible additional metrics

Private Investment Metrics Problems

- **Private Energy R&D estimates**
  - **Battelle: $12B and growing worldwide**
  - **Bloomberg: $14B+ "Corporate RD&D" vs $7B to $21B "Govt R&D"**
  - **NSF: $5.3B in 2007 in US**
- **Problem:**
  - **We get mostly demonstration and deployment metrics**
  - **Why?**
    - **Publicly-held companies report single R&D number, if that**
      - **What part is related to clean energy?**
      - **What clean energy technologies?**
      - **What stage of RDD&D?**
    - **Privately-held companies report nothing**
    - **Government-owned company reporting varies**
    - **Demonstration and deployment frequently announced publicly**
- **Other issues: Sovereign wealth funds ($3.9 Tril)**
  - **Do they fund energy R&D? Are their contributions included?**

New Investment in Clean Energy



Note: Excludes corporate and government R&D, and small distributed capacity. Not adjusted for re-invested equity

Source: Bloomberg New Energy Finance
*Source: "Trends in investments in global energy research, development, and demonstration", Gallagher, et. al.

UNEP/Bloomberg Joint Project

FIGURE 29: CORPORATE AND GOVERNMENT R&D RENEWABLE ENERGY INVESTMENT BY TECHNOLOGY, 2010, AND TOTAL GROWTH ON 2009, $BN

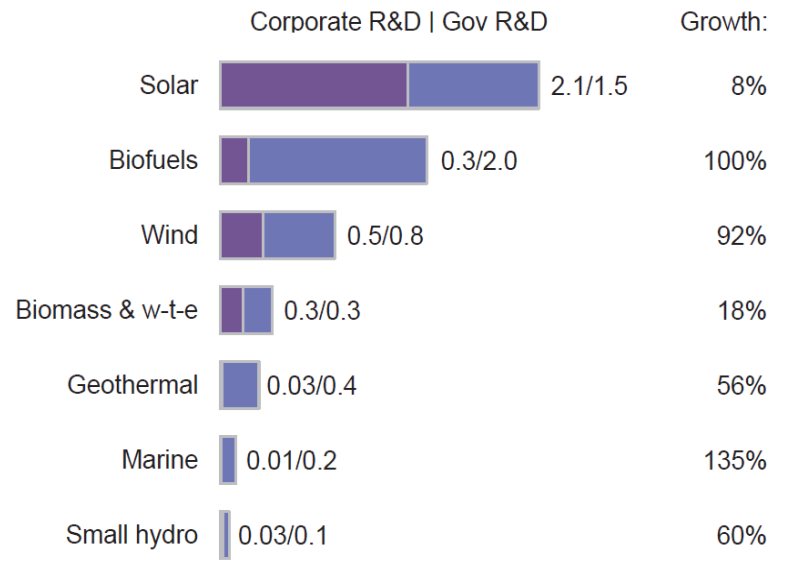
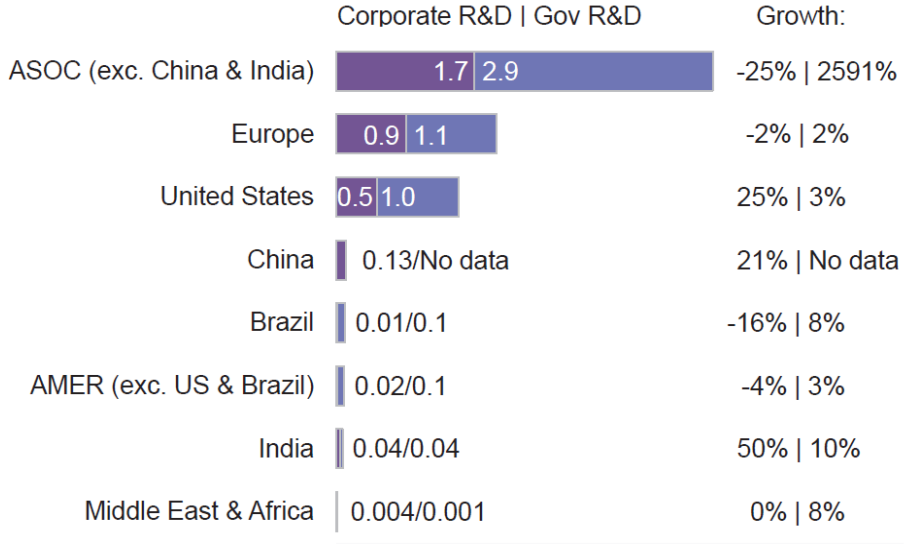


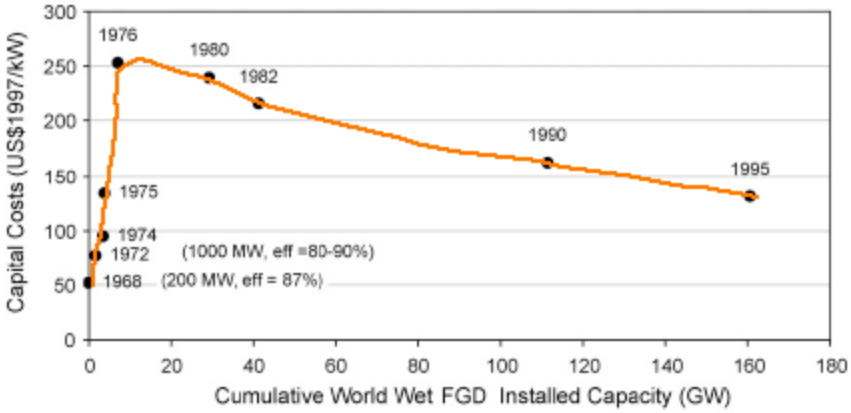
FIGURE 30: CORPORATE AND GOVERNMENT R&D RENEWABLE ENERGY INVESTMENT BY REGION, 2010, AND GROWTH ON 2009, $BN

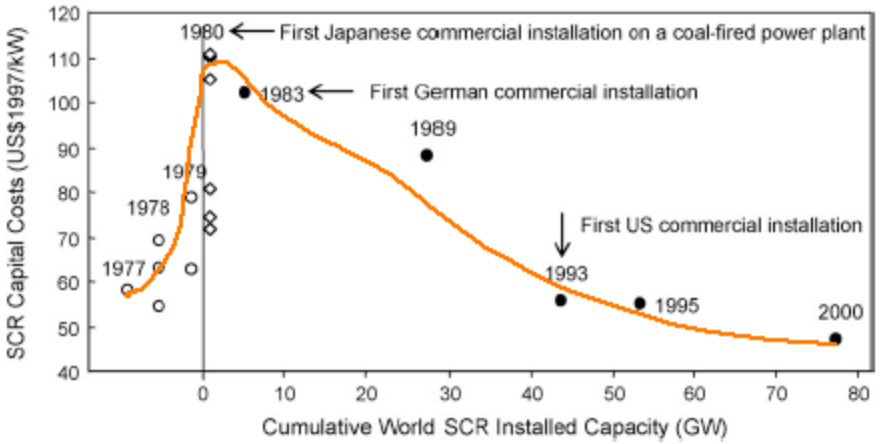


Source: Global Trends in Renewable Energy Investment 2011, UNEP/BNEF

Technology Costs

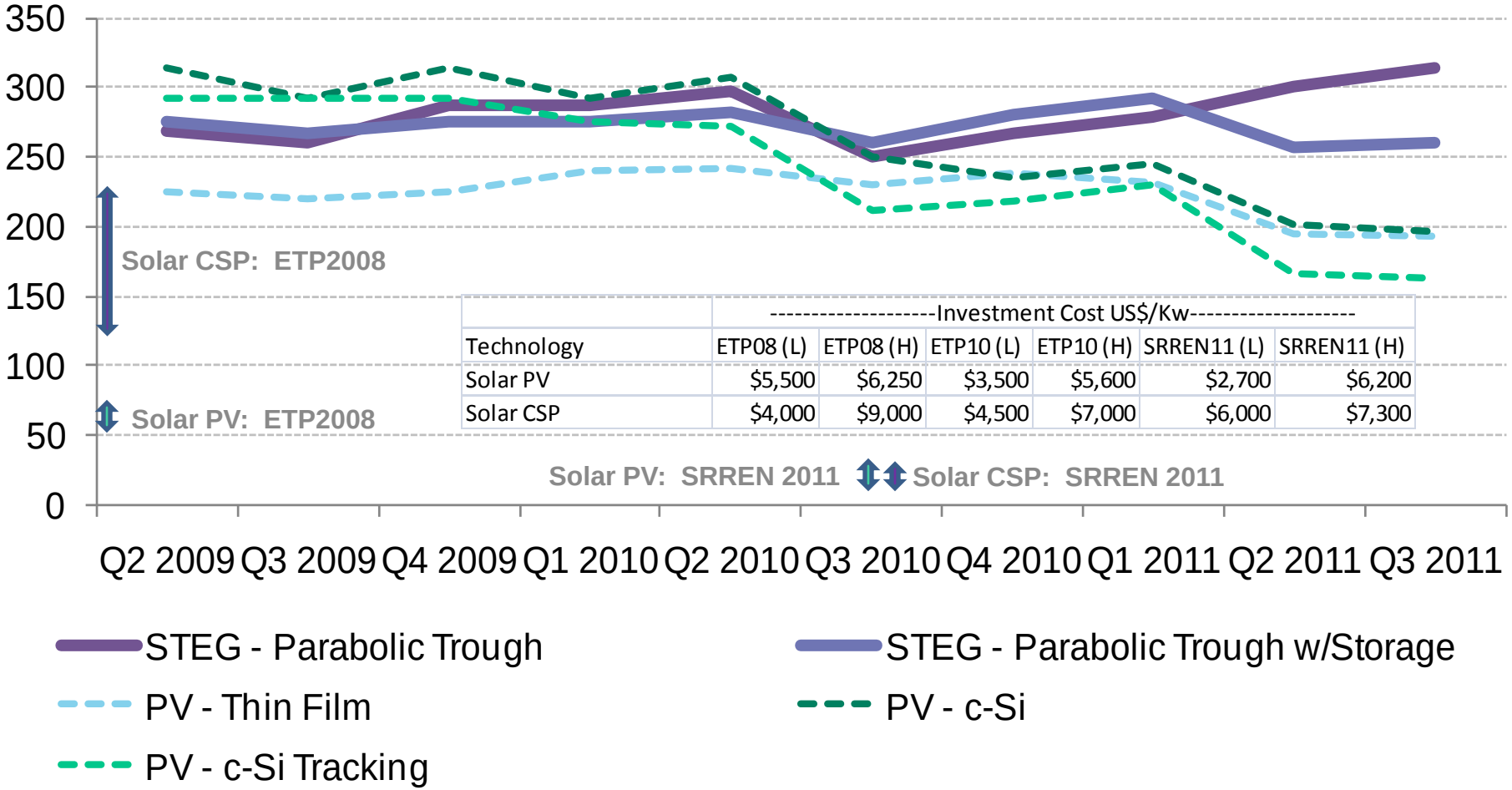
- **Factors affecting costs**
  - Learning curves, deployment
  - R&D expenditures
  - Commodity prices
    - Steel up 5-8%/yr (US)
    - Cement up 2-3%/yr (US)
  - Business cycles
  - Technology life cycle





Source: Rubin et al.; IJGGC, 2007

Solar Technology LCOEs (USD/mWh)

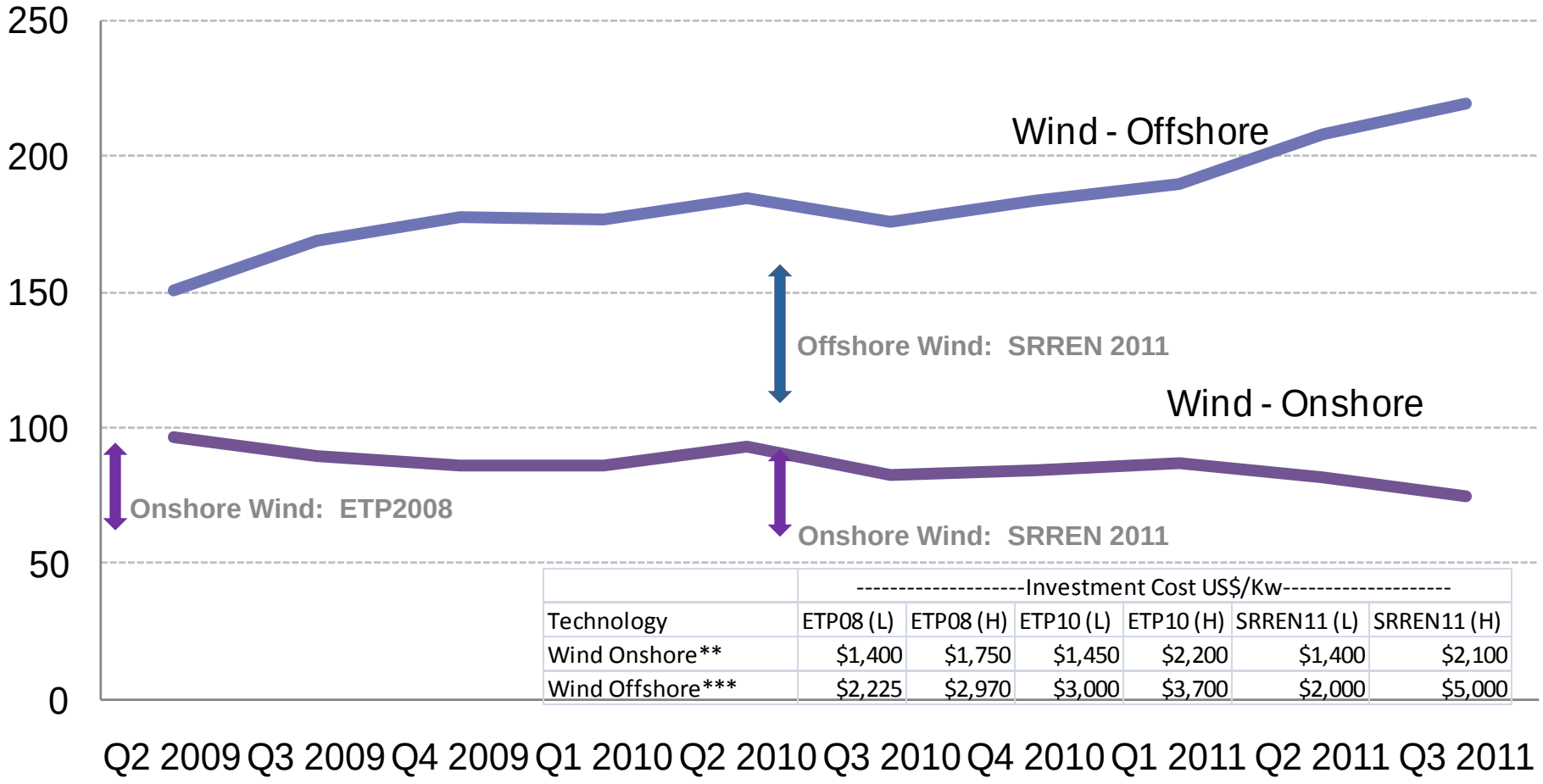


	Investment Cost US$/Kw					
Technology	ETP08 (L)	ETP08 (H)	ETP10 (L)	ETP10 (H)	SRREN11 (L)	SRREN11 (H)
Solar PV	$5,500	$6,250	$3,500	$5,600	$2,700	$6,200
Solar CSP	$4,000	$9,000	$4,500	$7,000	$6,000	$7,300

Prices are in nominal dollars

Source: Bloomberg New Energy Finance,
Except ETP, SRREN ranges
SRREN data in 2005$, data from 2009, 2010

Wind Technology LCOEs ($/mWh)

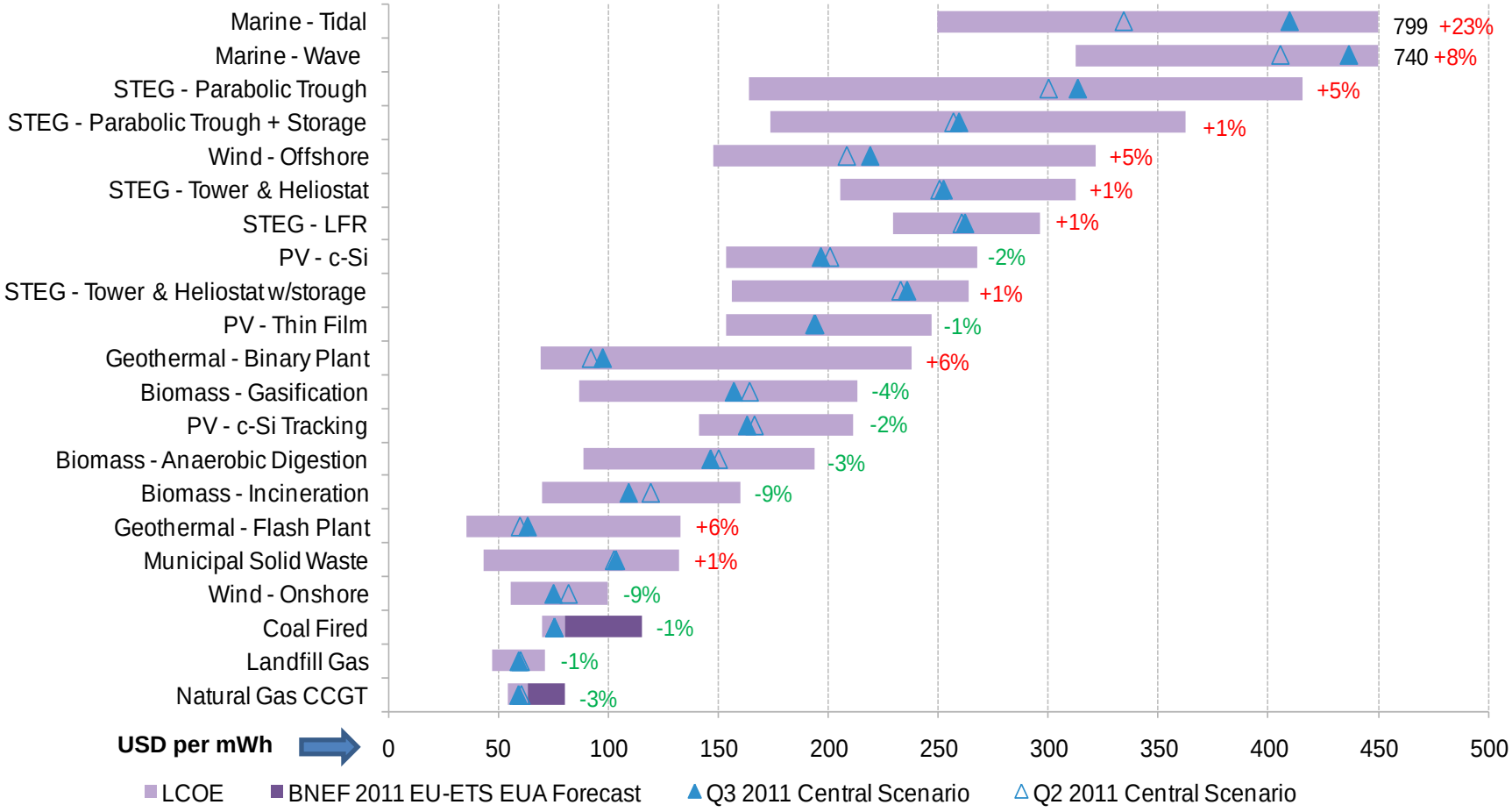


	----------Investment Cost US$/Kw----------					
Technology	ETP08 (L)	ETP08 (H)	ETP10 (L)	ETP10 (H)	SRREN11 (L)	SRREN11 (H)
Wind Onshore**	$1,400	$1,750	$1,450	$2,200	$1,400	$2,100
Wind Offshore***	$2,225	$2,970	$3,000	$3,700	$2,000	$5,000

Prices are in nominal dollars

Source: Bloomberg New Energy Finance,
Except ETP, SRREN ranges
SRREN data in 2005$, data from 2009, 2010

Dealing with Variability



Carbon forecasts from the BNEF European Carbon Model with a 2020 horizon $74/tCO2. Coal and nat gas prices from the US Department of Energy EIA Annual Energy Outlook 2011. % change represents change in mid from Q2 2011.

Source: Bloomberg New Energy Finance

Ernst & Young Attractiveness Indices

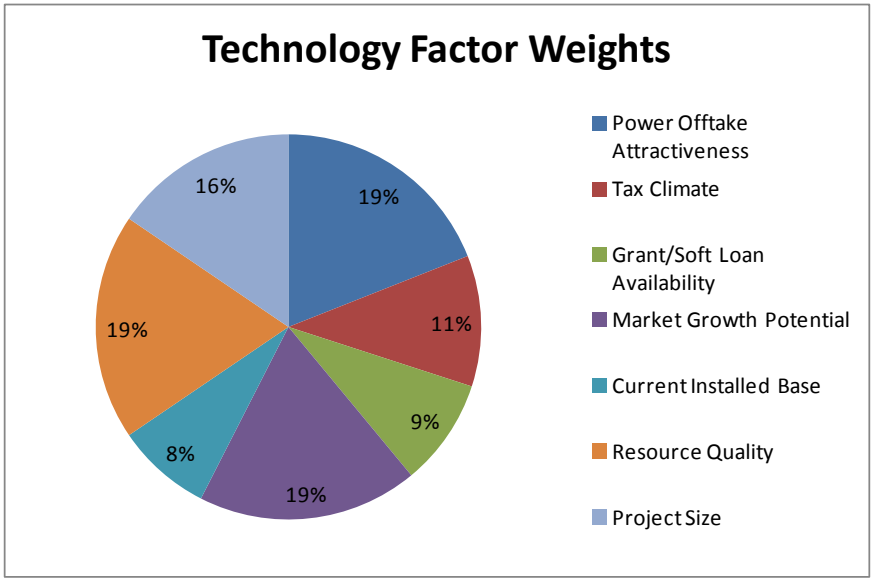
	Technology Attractiveness--Selected Countries					
Country	Solar PV	Solar CSP	Onshore Wind	Offshore Wind	Biomass	Geothermal
China	67	47	79	70	59	51
USA	75	78	70	56	62	68
Germany	49	0	64	77	64	56
India	64	52	70	42	58	44
UK	36	0	61	77	57	37
Italy	56	43	62	51	54	63
Denmark	40	0	44	56	45	32
Average	55	55	64	61	57	50

Relatively Poor Scores, But Not Valid To Compare To Other Technologies

Little Geothermal Resource

Too far north

Best Sites Already Taken



- **Each country's score independent of other countries**
- **Compare country to country, but not technology to technology**
- **See http://www.ey.com/GL/en/Industries/Power---Utilities/Renewable-energy-country-attractiveness-indices**
- **Not part of the framework, but could have good effects on CEM**

Opportunity Summary

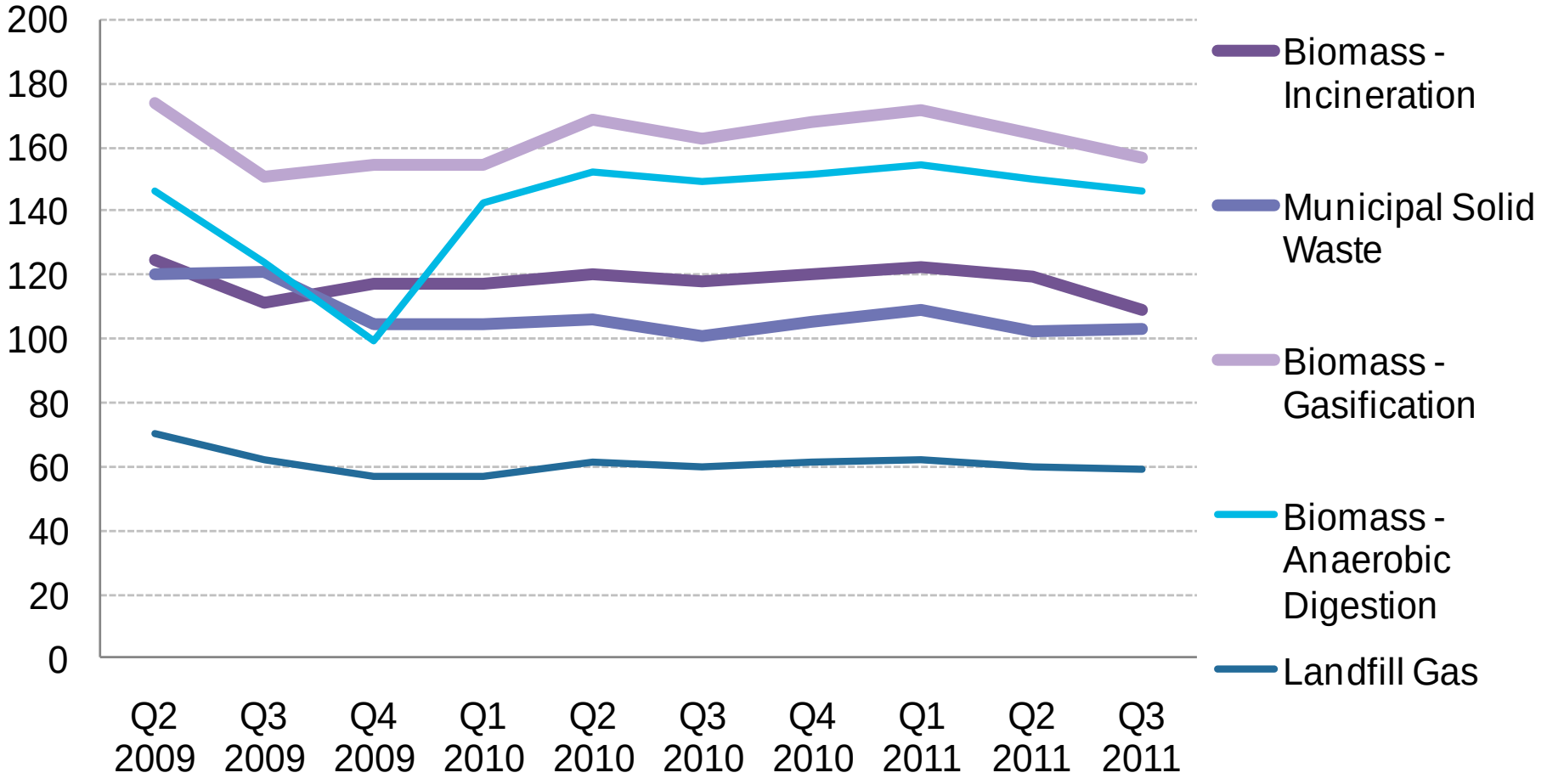
- **Additional metrics:**
  - **Private R&D investment by technology**
    - **Consider private sources/partners**
  - **Cost/benefit measures for non-generation technologies**
    - **HVAC costs and efficiency**
    - **HEV/EV/PHEV additional cost and savings metrics**
  - **Battery technology metrics**
- **Partnering with private industry**
- **Steps to the Future**
  - **Pick small set of high-priority metrics**
  - **Document methodology, assumptions, definitions**
  - **Develop strategy for data collection**
  - **Present to IEA in summary form**

Questions for Discussion

- What metrics are best indicators of progress?
- What are the elements of a framework?
  - Integrated/effective
  - Monitoring, evaluating, communicating progress
- What can we learn from the private sector?
- What approaches are most effective
  - Communicating progress evaluation
  - Accomplishing change in investment
  - Achieving desired outcomes

DETAILS

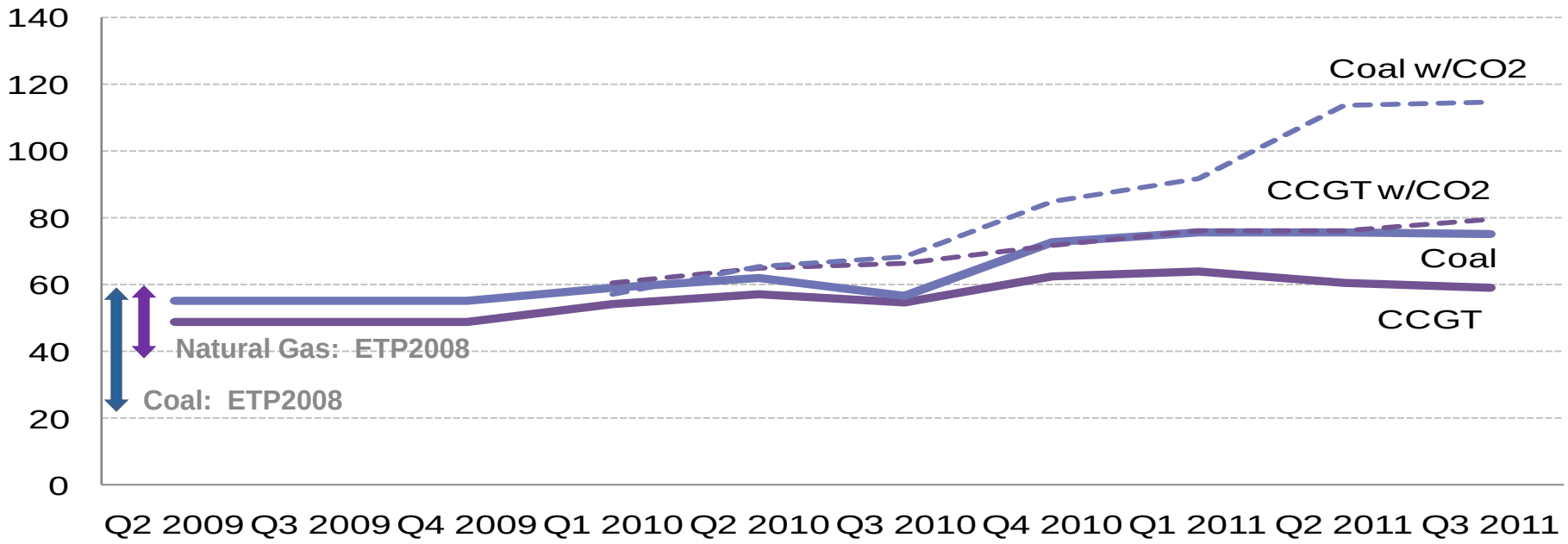
Biomass Technology LCOEs ($/mWh)



Prices are in nominal dollars

Source: Bloomberg New Energy Finance

Fossil Technology LCOEs ($/mWh)



Prices are in nominal dollars

Prices are in nominal dollars

Source: Bloomberg New Energy Finance,
Except ETP, SRREN ranges
SRREN data in 2005$, data from 2009, 2010

- **Necessary Improvements to Our Metrics:**
  - **Standard, open methodology**
  - **Documented assumptions**
  - **Quantified uncertainty, variability**