Electricity Technology Options Assessment Guide (ETOAG)

ETOAG Report

World Bank
Washington D.C.
June 2012

CHUBU ELECTRIC POWER CO. INC.
ECONOMIC CONSULTING ASSOCIATES LIMITED

Outline

1. Background
2. Purpose of ETOAG report and META
3. Representative countries
4. Power generation technology options
5. Power delivery technology options
6. Methodology and approach
7. Example results from ETOAG Report and META
8. Uncertainty analysis
9. Impact of environmental externality cost
10. Summary

Background

- Technical and Economic Assessment of Off-Grid, Mini-Grid and Grid Electrification Technologies (Dec. 2007)
- Study of Equipment Prices in the Power Sector (Dec. 2009)

➢ expand the list of generation technologies

➢ expand the list of T&D technologies

➢ take into account positive and negative externalities of power generations

- **E**lectricity **T**echnology **O**ptions **A**ssessment **G**uide (**ETAOG**)
- **M**odel for **E**lectricity **T**echnology **A**ssessments (**META**)

The purpose of ETOAG and META

- The main purpose of ETOAG and META is to provide information and a tool that allows users to evaluate electricity technology options

- ETOAG and META provide
  - Guide to the technologies and the capital, fuel and operating costs of each of the technologies
  - Generic estimates of the levelized cost per kWh of generating electricity and of electricity transmission and distribution
  - Curve showing levelized cost per kWh for a range of capacity factors from 10% to 90%.

Representative countries

Country	Broad Category
India	Developing
Romania	Middle-income
USA	Large developed

Outline

1. Background
2. Purpose of ETOAG report and META
3. Representative countries
4. Power generation technology options
5. Power delivery technology options
6. Methodology and approach
7. Example results from ETOAG Report and META
8. Uncertainty analysis
9. Impact of environmental externality cost
10. Summary

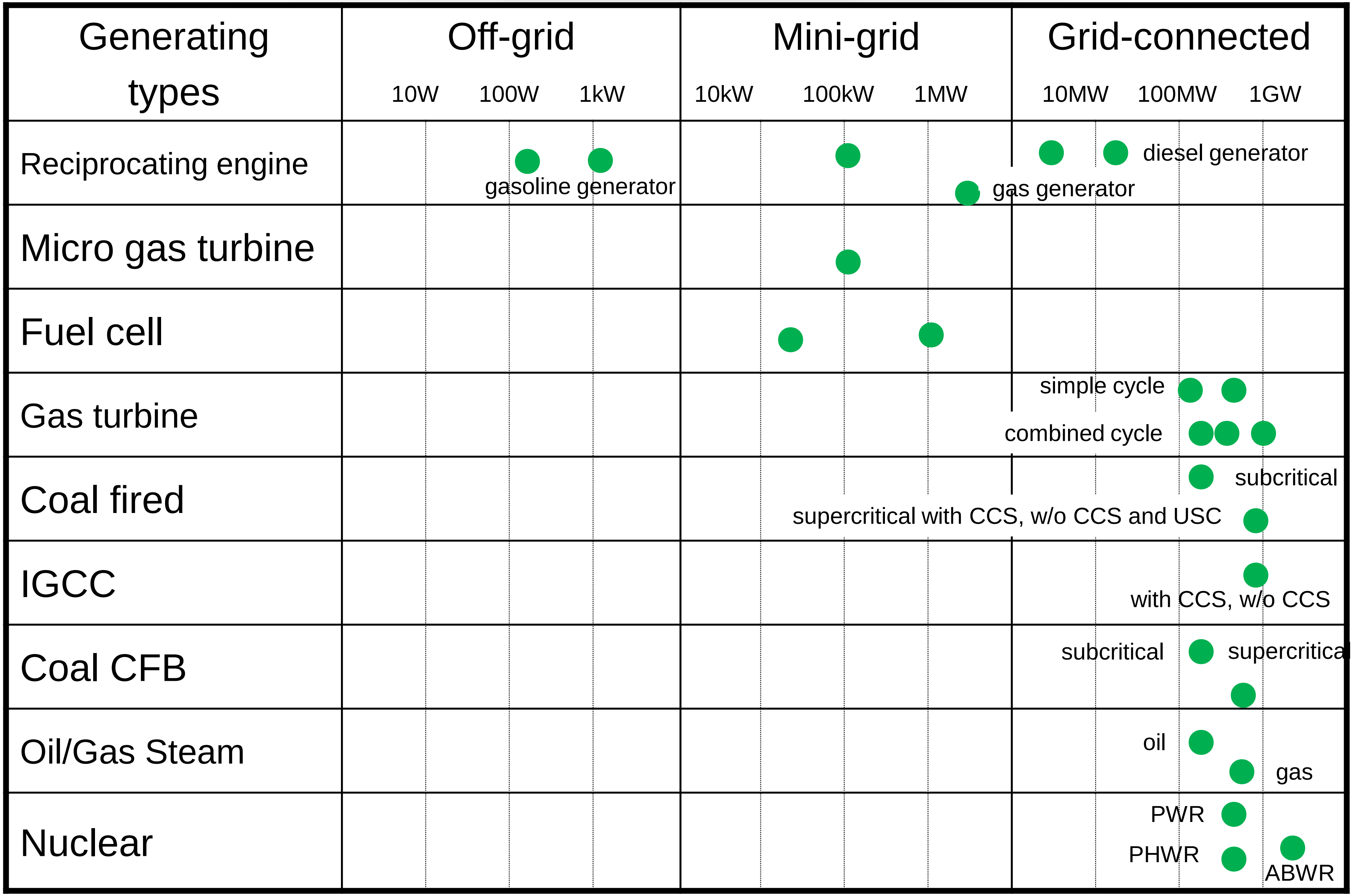
Power generation technology options

- Various power generation technologies
  - **Different technologies**
    Solar, Wind, Hydro, Thermal, Nuclear etc.
  - **Different sizes**
    Unit size range of 50W to 1,350MW
  - **Grid types**
    Off-grid, Mini-grid and Grid Connected

Renewable Energy Generation Technology options

Generating types	Off-grid	Mini-grid	Grid-connected
	10W 100W 1kW	10kW 100kW 1MW	10MW 100MW 1GW
Solar PV	● ●	●	●
Wind	on-shore ●	on-shore ●	● ● on-shore, ● off-shore
PV-Wind Hybrids	●	●	
Concentrated Solar Power			● with storage, ● without storage
Geothermal		● binary	● binary, ● dual flush
Biomass MSW			●
Biogas Landfill Gas			●
Hydro	● ● pico	● micro, ● mini	large ●, ● pumped storage
Energy Storage		● lead acid battery, NaS ●	

Thermal Power Generation and Nuclear Generation Technology Options



Outline

1. Background
2. Purpose of ETOAG report and META
3. Representative countries
4. Power generation technology options
5. Power delivery technology options
6. Methodology and approach
7. Example results from ETOAG Report and META
8. Uncertainty analysis
9. Impact of environmental externality cost
10. Summary

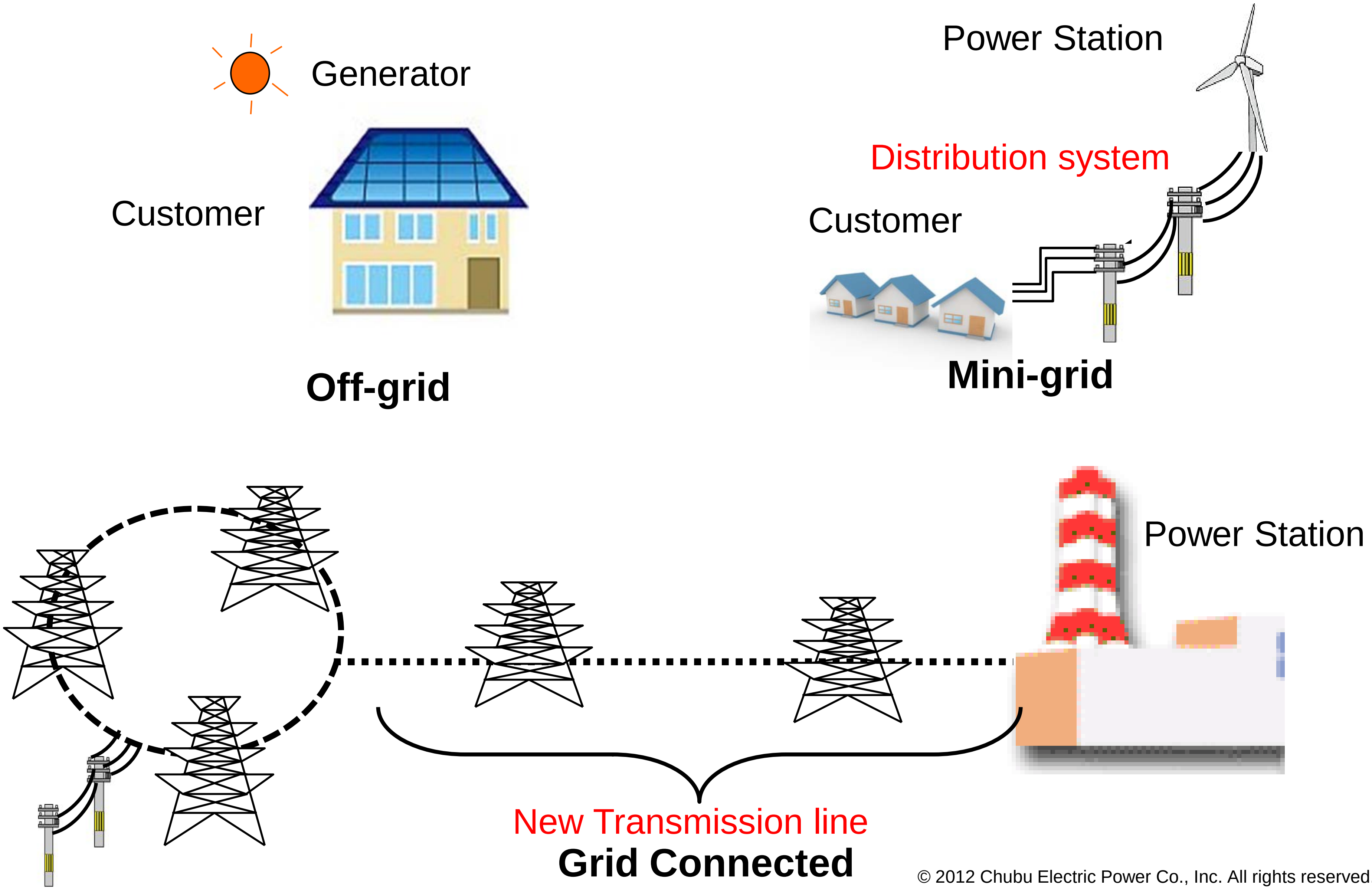
Power delivery technology options

- Transmission technologies include a range of transmission voltages and substation voltages.

Country	Transmission voltage		
	300 ~ 500kV	200kV ~	100kV ~
India	400kV	220kV	132kV
Romania	400kV	220kV	110kV
USA	345, 500kV	230kV	138kV

- Average distribution costs per kWh for each country are estimated.

Grid applications

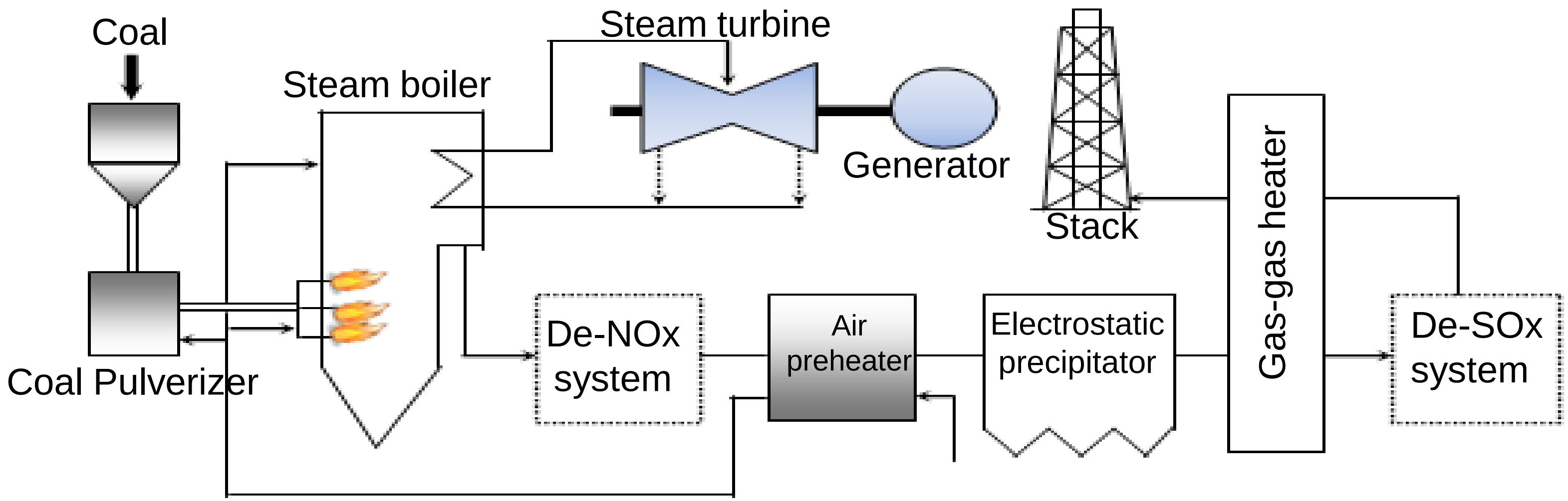


Outline

1. Background
2. Purpose of ETOAG report and META
3. Representative countries
4. Power generation technology options
5. Power delivery technology options
6. Methodology and approach
7. Example results from ETOAG Report and META
8. Uncertainty analysis
9. Impact of environmental externality cost
10. Summary

ETOAG – comprehensive guide & database

- Brief description of technology (e.g., Coal-fired)



- Design assumptions (capacity, life, storage capacity)
- Technology development status and prospects
- Levelized cost per kWh for each technology

Fundamental approach

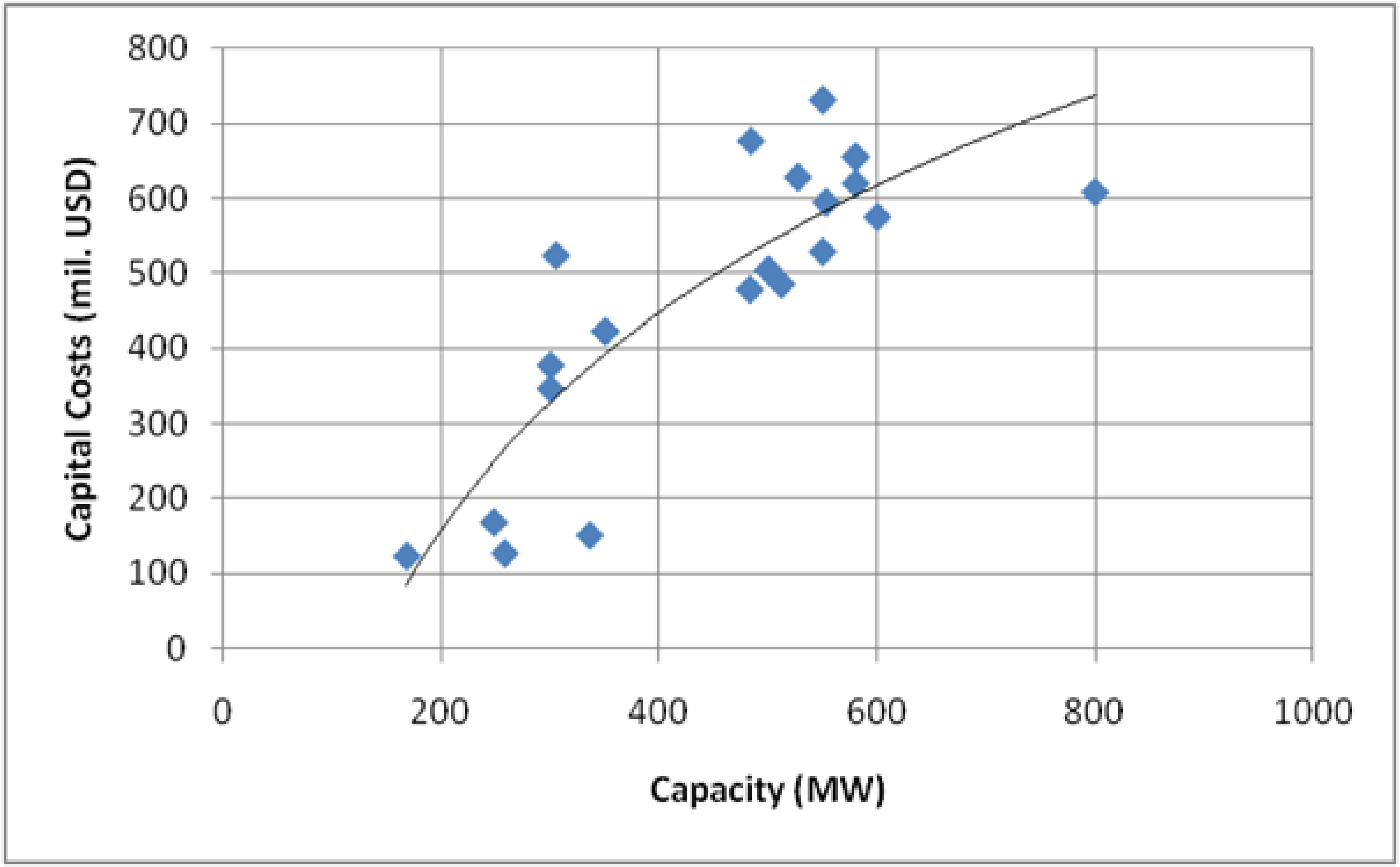
1. Collected cost and performance data from published documents, websites and Chubu's internal database

2. Calculated capital cost, O&M cost, fuel cost, environmental externality cost, and levelized cost per kWh in 2010 US$ price level

3. Project capital costs normalized to standard cost of generic plants using regression analysis

Normalization of capital cost

Regression Curve for Capital Cost of Combined Cycle Plant in USA



● Environmental control technologies

- Report/META take as an assumption that power generation plants comply with the stricter of the local environmental regulations or the World Bank environmental guidelines.
- The capital and operating costs and performance parameters include environmental control technologies.

 - FGD (Fuel-gas desulfurization)

 - SCR (Selective catalytic reduction)

- The User of META has the option to remove FGD and SCR and may evaluate the results.

Environmental externality costs

- Report/META incorporates the cost of environmental externalities from emissions of CO_2, SO_2, NOx and PM_{10}.
- Report/META do not consider all potential externality costs; e.g., habitat and biodiversity loss due to changes to river flows (hydropower), disruption of migrating birdlife due to windfarms.
- Users of META have the option to add a premium to the capital and operating costs in order to reflect their assessment of impacts.

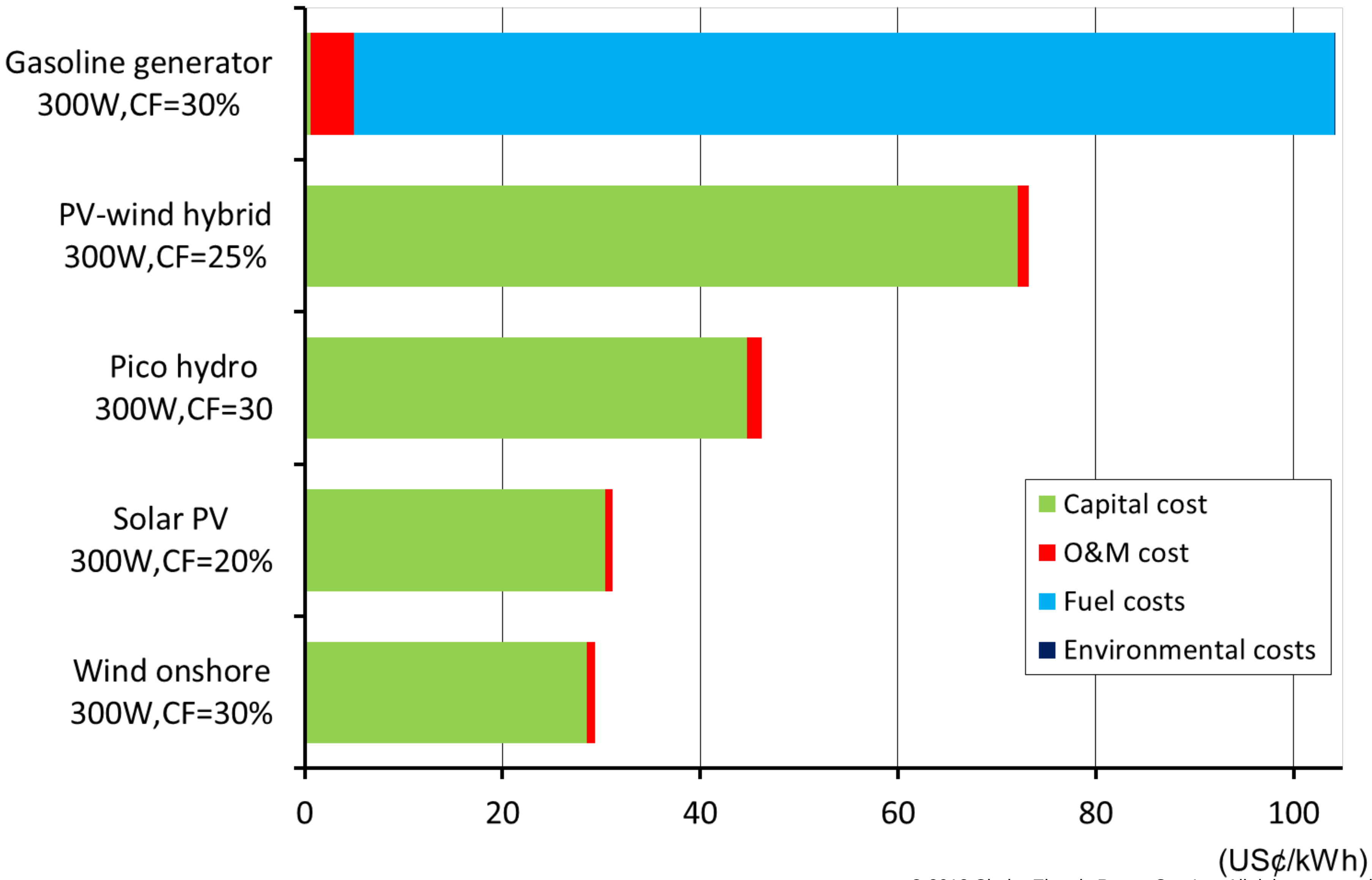
Major economic & design premises

- **Overnight costs**
  - Report/META use overnight costs in order to avoid the impact of project specific financing cost.
  - The user can use META to calculate and add IDC to the overnight cost along with financing expenses

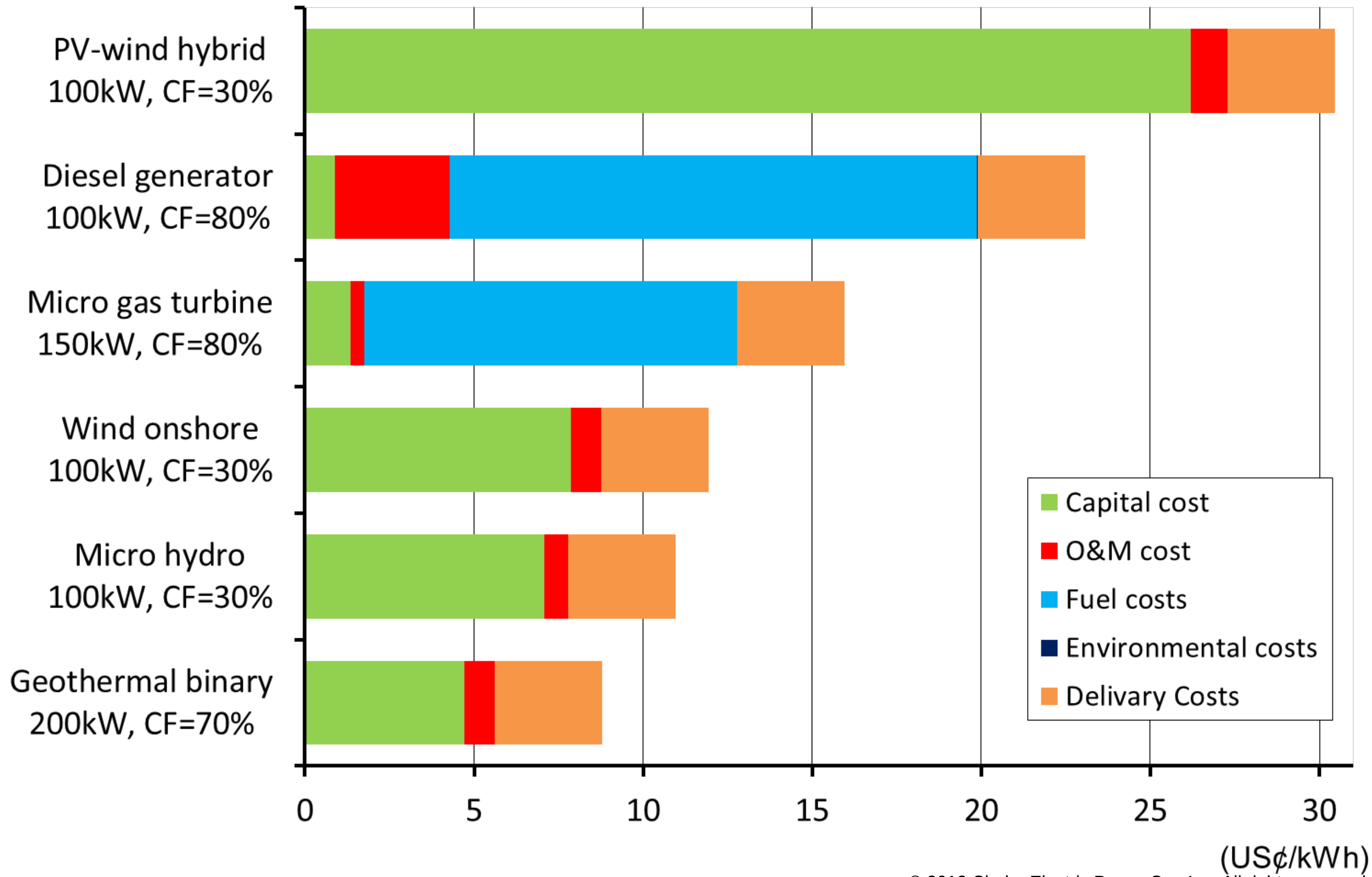
Outline

1. Background
2. Purpose of ETOAG report and META
3. Representative countries
4. Power generation technology options
5. Power delivery technology options
6. Methodology and approach
7. Example results from ETOAG Report and META
8. Uncertainty analysis
9. Impact of environmental externality cost
10. Summary

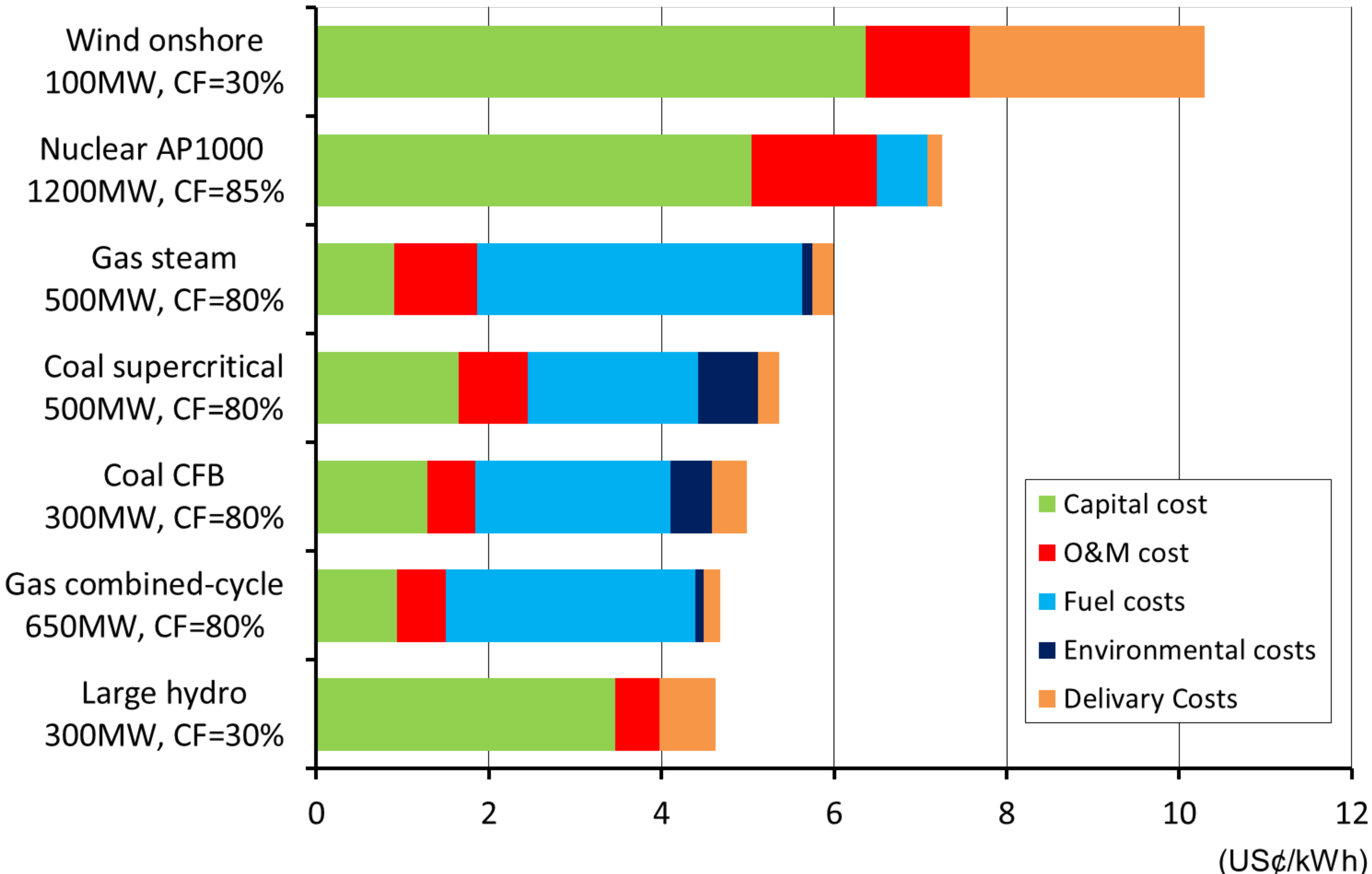
Off-grid Generation Cost in India



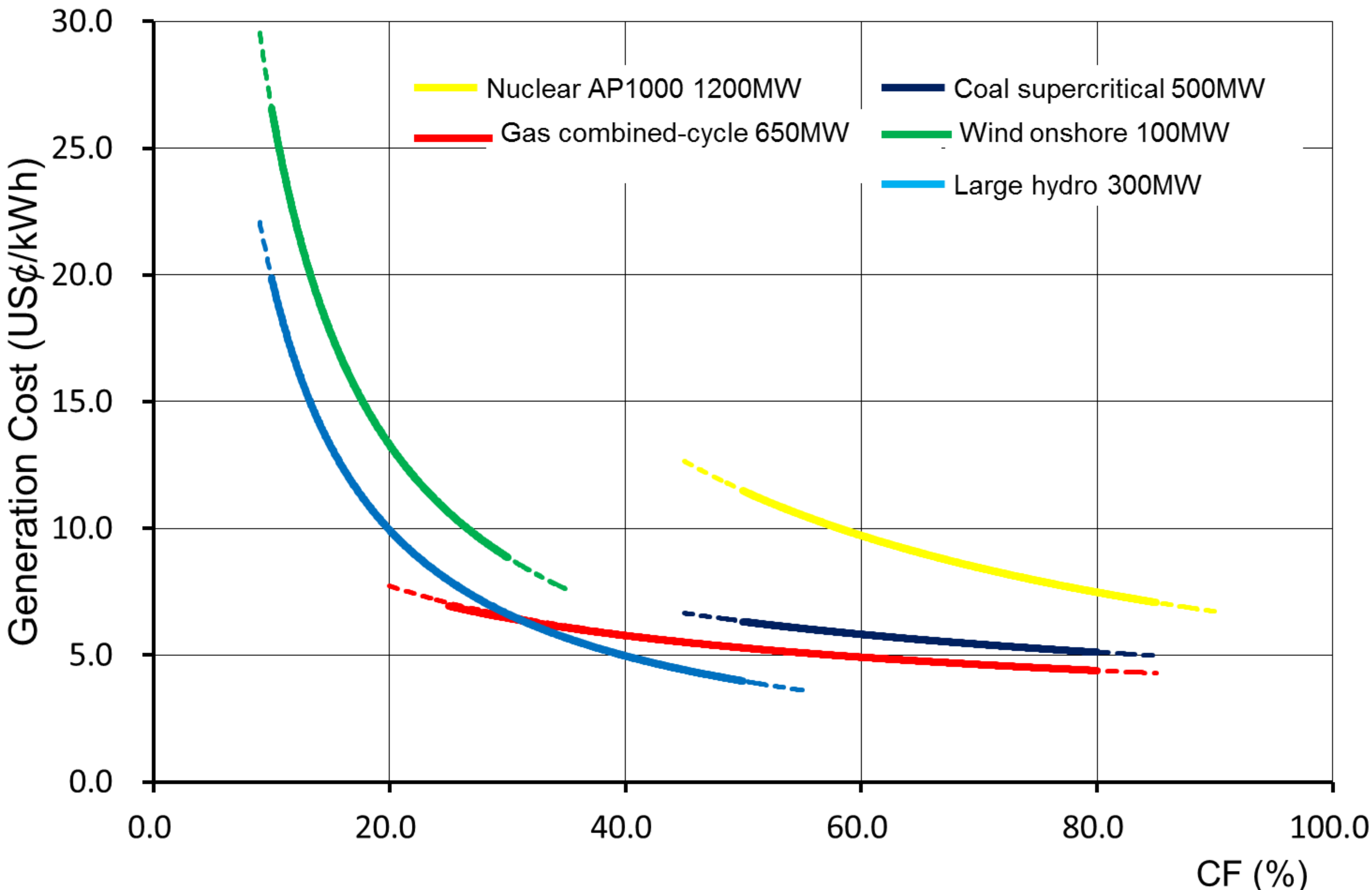
Mini-grid Generation Cost in India



Grid-connected Generation Cost in USA



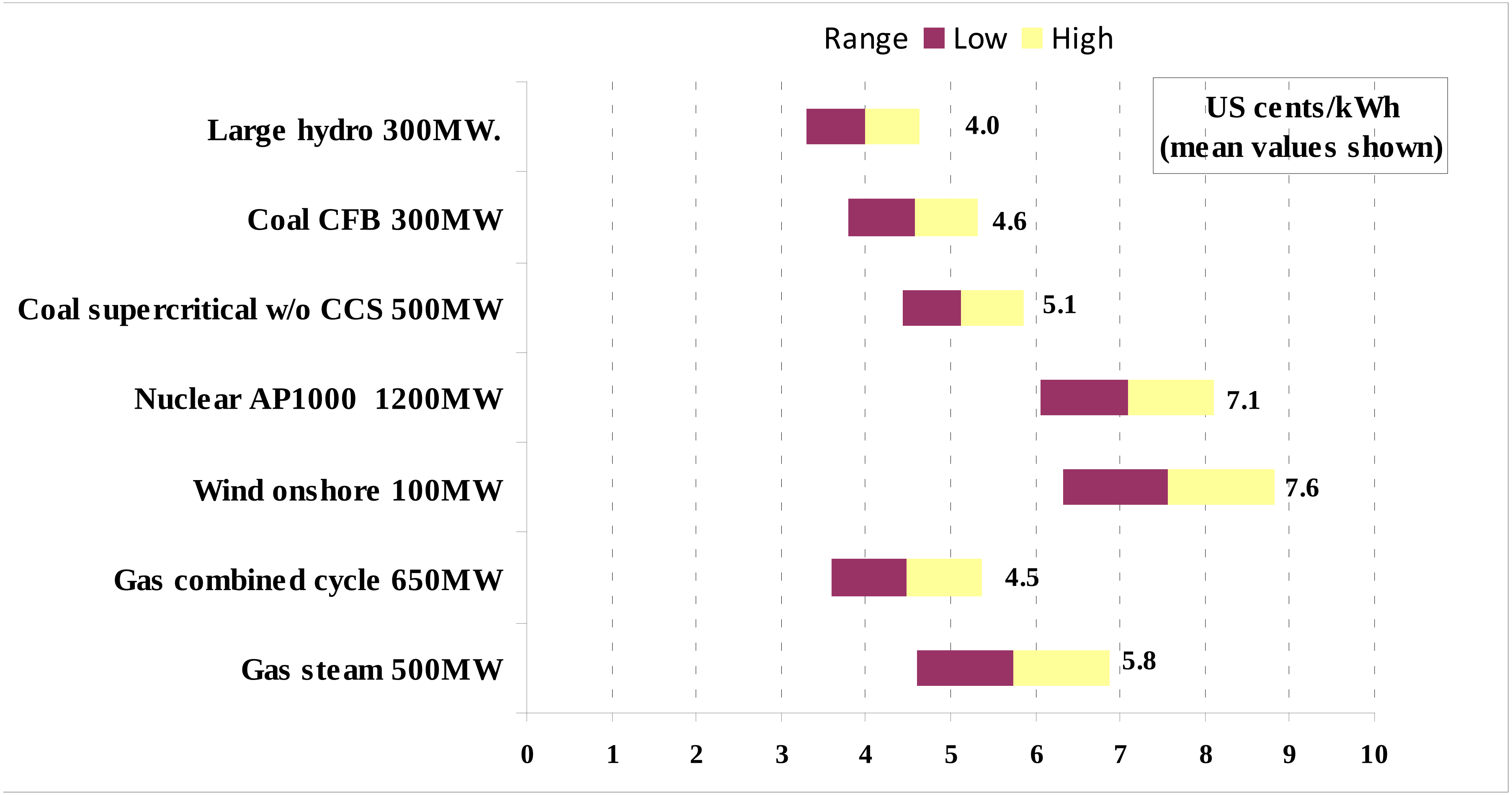
Screening curve analysis for USA



Outline

1. Background
2. Purpose of ETOAG report and META
3. Representative countries
4. Power generation technology options
5. Power delivery technology options
6. Methodology and approach
7. Example results from ETOAG Report and META
8. Uncertainty analysis
9. Impact of environmental externality cost
10. Summary

Illustration of uncertainty analysis



Grid connected, USA, 2010

Outline

1. Background
2. Purpose of ETOAG report and META
3. Representative countries
4. Power generation technology options
5. Power delivery technology options
6. Methodology and approach
7. Example results from ETOAG Report and META
8. Uncertainty analysis
9. Impact of environmental externality cost
10. Summary

External costs

- Types of external costs analysed
  - global (greenhouse gas emissions (GHG)
  - local/regional (SO_2, NOx, PM_{10})
- Emissions depend on:
  - generation technology, fuel, FGD/SCR
- Impacts of emissions and the types of cost
  - global warming → economic, health, environment
  - air quality → illness, death, environment
- External costs are added to other costs

Estimates of external costs of “local” emissions (€/tonne)

Study	SO_2	PM10	NOx
Croatia, Zagreb	13,483	24,218	19,265
Representative EU ExternE	10,450	15,400	15,700
Portugal, ExternE	4,959	5,975	5,565
EU DG Environment (BeTa Database)	5,200	14,000	4,200
World Bank, Six Cities Study	96	1,723	255
ESMAP, China, Shanghai	390	1,903	454

Local external costs - caveats

- **Dominated by health costs**
- **Very wide variation in cost estimates**
- **Costs depend on a huge range of factors:**
  - ➢ stack height
  - ➢ population concentrations
  - ➢ prevailing wind direction
  - ➢ ambient air quality
- **Do not depend heavily on generic cost estimates**

Greenhouse gas emissions

- **Value of CO2 emission reduction:**
  - determined by willingness-to-pay to avoid emissions
- **First UNFCCC "Commitment Period" ends 2012**
- **Beyond 2012**
  - CDM credits recognized post 2012, but no buyers?
- **Default assumptions (US$/tonne of CO_2e):**
  - USA – US$30 from 2020
  - Romania – US$20 in 2010, rising to US$30 in 2020
  - India – no carbon cost before 2020

External cost defaults (US$/tonne)

All years	SO_2	PM10	NOx
India	120	2,240	330
Romania	6,450	7,770	7,230
USA	8,870	18,280	7,460

CO_2 equivalent	2010	2015	2020
India	0	0	0
Romania	20	25	30
USA	0	0	30

Illustration of use of the tools: Technology costs with externalities

(default external value for SO_2 of US$120/tonne for India)

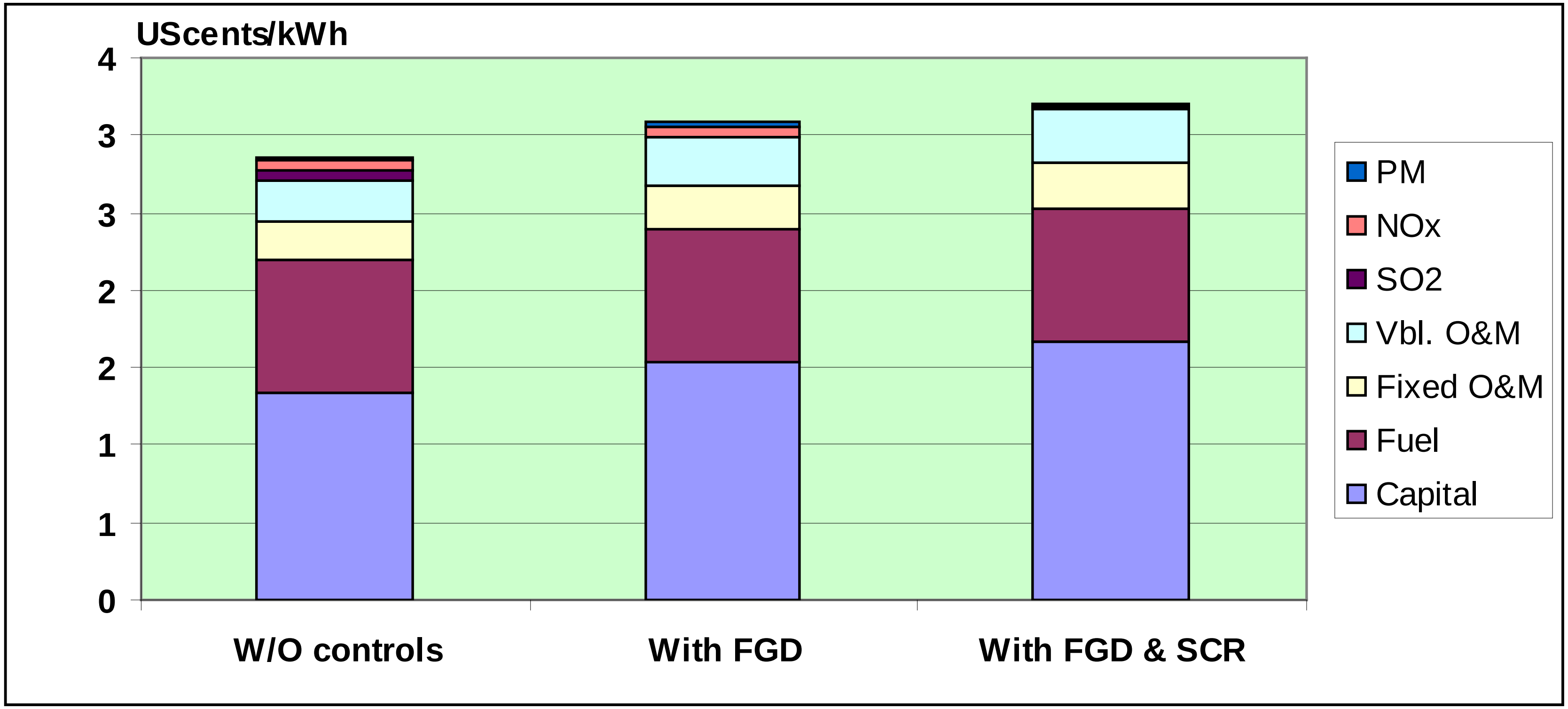
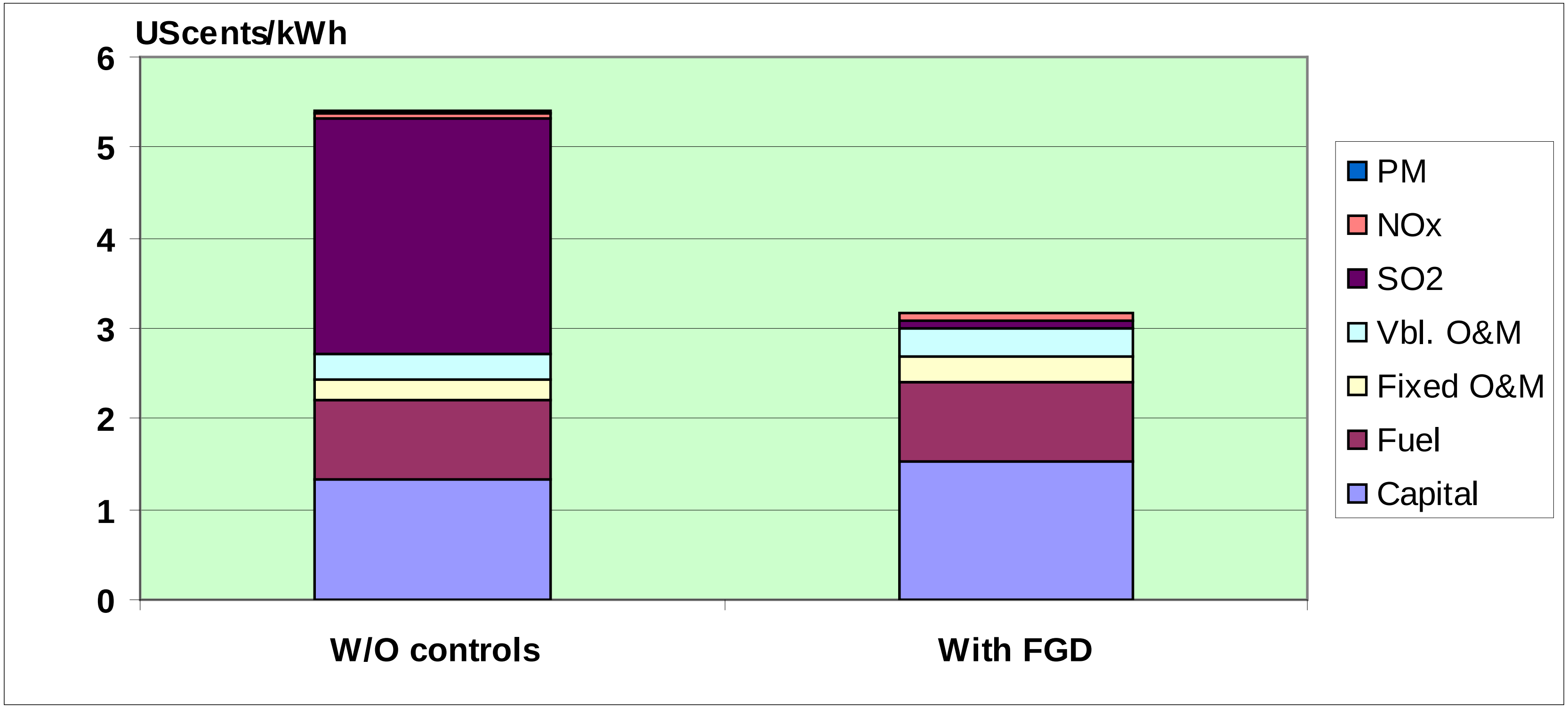


Illustration of use of the tools

Technology costs with externalities

(external value for SO_2 of US$5,000/tonne)



Summary of the ETOAG tools

- Purpose: information, database and a model to evaluate diverse electricity technology options
- Three countries (India, Romania and USA) provide default values
- Performance and cost estimates for 54 generation technologies and selection of T&D technologies
- For each technology: description, design assumptions, technology status and prospects
- Major economic & design premises: cost and performance data obtained from various sources – adjusted and normalized by Chubu engineering team
- An output is the levelized cost per kWh for the defaults

Examples of questions that ETOAG can help answer

- Is the lifetime cost of project A lower than projects B, C, D, ..?
- How do lifetime costs compare when environmental costs are incorporated? How sensitive are the results to environmental cost assumptions?
- Are environmental controls cost-effective? Are environmental damage costs greater than control costs?
- Is a distributed generation option w/o distribution costs cheaper than large-scale generation with distribution?
- What happens to electricity costs if international fuel prices rise in the future?
- etc...