Plenary Session 3:  
Disruptive technologies in energy sector:  
Impacts, challenges and preparation
Disclaimer

The observations presented herein are meant as background for the dialogue at the 7th Asian Ministerial Energy Roundtable. They have been prepared in collaboration with The Boston Consulting Group and should not be interpreted as the opinion of the International Energy Forum or The Boston Consulting Group on any given subject.
Introduction

Market context

• While energy technology is evolving, reliable energy sector transformation needs clear and predictable policy signals.

• The challenge is to maintain momentum in the cost effective uptake of new energy technologies without stranding investment in existing technologies.

• International collaboration needs to be enhanced to achieve globally shared objectives through new innovative technologies and adequate levels of investment to maintain energy security.

Session objectives

• Discuss how long-term policy and cooperation can better accommodate new technologies and improve efficient and sustainable resource management along energy transition pathways.

• How can Ministers set up policies that embrace energy innovation and disruption in support of multiple national energy policy objectives without eroding market stability?

• What forces drive technology changes in the Energy sector? How are ambitions for greater sustainability of new technologies translated into effective actions that strengthen energy security?

Key Question:
How can Ministers facilitate new technology deployment and investment to support national objectives, shared goals, and global energy security?
Contents

What is the role of technology in the energy sector?

What are the main levers promoting technological change?

Key questions and discussion
Technology is playing an increasingly important role in the energy sector
Strong commitment to innovation in the energy sector

Example: Mission Innovation

Mission Innovation to reinvigorate and accelerate public and private global clean energy innovation with the objective to make clean energy widely affordable (COP21 Conference, December 2015)

- **Double Governmental Investment in Clean Energy Innovation**: Each participating country will seek to double its governmental and/or state-directed clean energy research and development investment over five years
- **Private Sector and Business Leadership**: Investment in the earlier-stage clean energy companies that emerge from government research and development programs
- **Implementation**: Participating countries will implement Mission Innovation in a transparent, effective, and efficient manner
- **Information Sharing**: Each participating country commits to provide, on an annual basis, transparent, easily-accessible information

Source: Mission Innovation
The business community is fully aware of the need for action

1. "America needs a **consensus climate solution** that bridges partisan divides, strengthens our economy and protects our shared environment [including a] **gradually rising** (...) **carbon tax**"

2. "With solar panels on the roof, a micro CHP plant in the cellar, an electric car in the drive and an intelligent consumption control system, everyone can create their own **Energiewende**"

3. "**By definition we must move towards renewable energy**—how can people argue against that? To argue that is to say that eventually we will **run out of energy and die or civilization will collapse**"

4. "**Renewables** are no longer referred to as alternative energy, they are **traditional**"

5. "**50 percent of our energy consumption** – spanning heat, transport and electricity – to be met by **renewables** by 2030"

Source: Press releases
Investors acknowledge the risks associated with climate change

Investors are divesting from fossil-based assets and 'greening' their portfolios

- More than 400 institutions across 43 countries representing $2.6 trillion in assets have already committed to divest from fossil fuels
- Recent examples
  - Norway's largest pension fund decided to divest from all companies that earn >50% of their revenues from coal-based activities. Divestment: $9-10bn
  - Allianz will divest from any company that generates >30% of revenue by mining coal or bases >30% of its energy production on coal. Divestment: $4bn

Investors claiming for consistent data to assess financial risks associated with climate change

- BlackRock warns companies that "climate change has become an investment risk"
- Latest example: Exxon forced to report on Climate Change
  - A number of large institutional fund firms including BlackRock, the world’s largest asset manager, and Vanguard, supported a shareholder resolution calling on ExxonMobil to share more information about how new technologies and climate change regulations could impact the business of the world’s largest publicly traded oil company

Source: The investors guide to climate change, Press search
Technological change in energy is already a fact (I)

Change in power generation mix 2000-16

- Wind: 143 GW
- Natural Gas: 101 GW
- Hydro: 94 GW
- CSP: 10 GW
- Waste: 8 GW
- Nuclear: 3 GW
- Coal: 2 GW
- Solar PV: -16 GW
- Biomass: -37 GW
- Fueloil: -38 GW

New installed power capacity 2012-16

- EU-27:
  - 2000:
    - Conventional technologies: 99%
    - Wind: 5%
    - CSP: 5%
    - Solar integrated in buildings: 1%
    - Solar PV-Utility: 1%
  - 2012:
    - Conventional technologies: 50%
    - Wind: 40%
    - CSP: 12%
    - Solar integrated in buildings: 5%
    - Solar PV-Utility: 5%
  - 2014:
    - Conventional technologies: 45%
    - Wind: 23%
    - CSP: 20%
    - Solar integrated in buildings: 11%
    - Solar PV-Utility: 11%
  - 2016:
    - Conventional technologies: 35%
    - Wind: 29%
    - CSP: 25%
    - Solar integrated in buildings: 11%
    - Solar PV-Utility: 11%

Source: EIA (DOE; US); EWEA; BCG analysis
Technological change in energy is already a fact (II)

Apple and Google will be 100% Renewables in 2017

Renewables procurement in 2016

<table>
<thead>
<tr>
<th>Company</th>
<th>2017</th>
<th>2017</th>
<th>n.a.</th>
<th>n.a.</th>
<th>n.a.</th>
<th>100% Renewables procurement year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>96</td>
<td>80</td>
<td>n.a.</td>
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<td>Microsoft</td>
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</tbody>
</table>

Source: Click Clean; BCG Analysis
An important environmental challenge ahead

Energy sector CO₂ emissions
- Moderate scenario-

G Tm CO₂

Source: IEA World Energy Outlook 2016: BCG analysis
Contents

What is the role of technology in the energy sector?

What are the main levers promoting technological change?

Key questions and discussion
Three levers are promoting technological change in the energy sector.

- Energy independence
- CO₂ emissions reduction
- Technological change
- Costs reduction
Renewables and Energy Efficiency are the most relevant technologies

<table>
<thead>
<tr>
<th></th>
<th>CO₂ emissions reduction</th>
<th>Energy independence</th>
<th>Cost reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewables (+ Storage)</td>
<td>![Green Circle]</td>
<td>![Green Circle]</td>
<td>![Yellow Circle]</td>
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<tr>
<td>Energy efficiency</td>
<td>![Green Circle]</td>
<td>![Yellow Circle]</td>
<td>![Yellow Circle]</td>
</tr>
<tr>
<td>Others (CCS, Hydrogen ...)</td>
<td>![Green Circle]</td>
<td>![Yellow Circle]</td>
<td>![Red Circle]</td>
</tr>
</tbody>
</table>
Renewables and Energy Efficiency accounted ~33% of global energy investments in 2016

Source: IEA Energy Investment Outlook
Investments in Clean Energy equal ~ B 300 $ yearly

1. Includes smart grid, electric vehicles and power storage
Source: BNEF. BCG Analysis
Onshore Wind and Solar PV are leading the race
Energy storage can be a game changer

Development status of the sector's technology

<table>
<thead>
<tr>
<th>Production cost</th>
<th>Emerging</th>
<th>Under development</th>
<th>Mature</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Tidal energy</td>
<td>Solar CSP</td>
<td>Geothermal energy</td>
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<tr>
<td>Moderate</td>
<td>Energy storage</td>
<td>Hydroelectric</td>
<td>Solar photovoltaic</td>
</tr>
</tbody>
</table>

Onshore wind and Solar photovoltaic are leading the race.
Energy storage can be a game changer.
Asia is leading Clean Energy investments worldwide

Renewable Investment by region and technology in 2016 (%)

% of total investment by technology

- Marine
- Biofuels
- Small Hydro
- Geothermal
- Biomass & Wastes
- Wind
- Solar

% of total Investment by region

Asia
Europe
North America
South America
M.E.
Oceania

(1) Data for Biomass & Waste estimated from preliminary 2016 data
Note: Investment includes Asset Finance, Corporate R&D, Government R&D, Public Markets, Reinvested Equity, Venture Capital / Private Equity
Source: BNEF. BCG Analysis
China is leading the investment in renewables in 2016

Top 10 countries in renewable Investment (2016)

(1) Data for Biomass & Waste estimated from preliminary 2016 data
Note: Investment includes Asset Finance, Corporate R&D, Government R&D, Public Markets, Reinvested Equity, Venture Capital / Private Equity
Source: BNEF. BCG Analysis
China is leading renewables investments in Asia-Pacific

Top 10 countries in renewable Investment in Asia-Pacific (2016)

- China: 78.3 B$
- Japan: 14.4 B$
- India: 9.7 B$
- Australia: 3.3 B$
- Thailand: 1.4 B$
- Philippines: 1.0 B$
- Singapore: 0.7 B$
- Vietnam: 0.7 B$
- Taiwan: 0.7 B$
- Indonesia: 0.5 B$

Note: Investment includes Asset Finance, Corporate R&D, Government R&D, Public Markets, Reinvested Equity, Venture Capital / Private Equity
Source: BNEF. BCG Analysis
Asia-Pacific will concentrate ~40% of global renewables investments until 2020

Wind onshore CAPEX by region

Solar PV CAPEX by region

Source: IRENA Capacity Statistics 2016 and IEA Renewable Medium Term Report
Storage will play a critical role in renewables full development

High-res. production forecasts
- Short-term / day ahead production output forecasting
- Connecting adjacent farms in data clusters to provide more accurate wind forecasts

Storage in wind farm batteries
- Storage in batteries at each wind farm to offer decentralized alternatives
- Use of more cost-efficient molten salt batteries (first prototypes)

Smart, predictive maintenance
- Fully automated scheduling of maintenance services based on analysis of big data

Smart warehouse concept
- Completely automated ordering and management of spare parts

Virtual power plants as the new standard
- Decentralized generation asset connections managed from one central control room
- Real-time monitoring of all data and production profiles

Smart / digital grids
- Balanced local grid production with an increased penetration rate of renewables
- Reactive capacity compensation

Source: BCG analysis
Storage market growth will be focused in Asia and Europe
Significant market uptake in the next 5 years

Global annual battery installations by country

<table>
<thead>
<tr>
<th>Year</th>
<th>Africa</th>
<th>USA</th>
<th>Canada</th>
<th>LATAM</th>
<th>Germany</th>
<th>Italy</th>
<th>UK</th>
<th>Rest of Europe</th>
<th>Middle East</th>
<th>China</th>
<th>Japan</th>
<th>India</th>
<th>South Korea</th>
<th>Australia</th>
<th>Rest of Asia</th>
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Current market status

- **Africa**: Strong market activity driven by favorable incentive schemes.
- **Middle East**: Strong market activity driven by favorable policies.
- **Rest of Americas**: One-off projects in Chile and Puerto Rico.
- **Rest of Asia**: Strong market activity driven by favorable policies.
- **South Korea**: Utility procurement program driving activity.
- **Italy**: Some tests and pilots. Strong interest in behind-the-meter market.
- **UK**: Test/pilot projects.
- **Germany**: Test/pilot projects.
- **USA**: Test/pilot projects.
- **Canada**: Test/pilot projects.
- **LATAM**: Test/pilot projects.
- **Rest of Europe**: Limited/no activity (more focus on off-grid).

1. Battery technologies considered are Lithium-Ion, Lead-acid, Sodium Nickel Chloride, Sodium Sulphur, Flow, Flywheels, Compressed Air (Alternative).

Source: IHS, 2015; BCG analysis

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Energy Efficiency is fostering technological development and new business models

**Central generation and storage**

**Transmission & distribution**

**Consumer**

- Distributed generation
  - Prosumers produce power for their own consumption
- Demand response
  - Consumers take advantage of new technologies to optimize consumption and reduce the cost of energy
- Integrated systems
  - Systems which include and coordinate distributed generation and smart consumption

**Smart grid**

Distributed generation

- Private microgrids and decentralized generation
- Smart consumption
Building sector represents 54% of global Energy Efficiency investment in 2015


- **Buildings** – 119 $B
- **Industry** – 40 $B
- **Transport** – 62 $B

Source: IEA Energy Investment Outlook

**Building sector** represents 54% of global Energy Efficiency investment in 2015.
Asia Pacific accounting ~30% of total Energy Efficiency investment in Buildings

Energy Efficiency Investment in Building sector by region (2016)

Source: IEA Energy Investment Outlook 2017
"Integrated decentralized solutions" are the next step

Decentralized technologies consist of generation, storage, and load ...

- Decentral generation
  - PV
  - Wind
  - CHP
  - Diesel

Energy management system (EMS)

- Storage

- Flexible loads
- Non-flexible loads

Grid

... and are applied across key customer segments

<table>
<thead>
<tr>
<th>Segment</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small utility</td>
<td>• IPPs, yieldcos, and / small utilities</td>
</tr>
<tr>
<td>Off-grid</td>
<td>• Mines in remote regions e.g. in Africa</td>
</tr>
<tr>
<td>Community</td>
<td>• Small cities, universities, military</td>
</tr>
<tr>
<td>Industrial</td>
<td>• Heavy industries e.g. a large steel plant</td>
</tr>
<tr>
<td>Commercial</td>
<td>• Retail stores e.g. IKEA</td>
</tr>
<tr>
<td>Residential</td>
<td>• One- or two-family homes</td>
</tr>
</tbody>
</table>
Broad number of Smart Home solutions and technologies

- Central control unit: SmartHome controller
- Actors & sensors: Wireless thermostats, SmartPlugs
- Automation rules
- 'Local control nodes': Personal computer, Remote control
- 'Remote control nodes': Mobile phone

... enabling convenience, energy savings & security

... on the move

Source: BCG and BCG DV analysis
Currently there are few incentives to capture and store CO₂

A costly technology hard to justify

"CCS suffers from a reputation of being a costly technology, due to its mismatch between short-term certain costs and long-term uncertain benefits."

Two reasons may explain government’s hesitation to providing enough funding

• Large CAPEX needed for funding, often costs above 1bn $.
• CCS suffers from having CO₂ avoidance as sole purpose, compared to other renewables which creates energy efficiency measures.

...and some more reasons for project developers:

• CO₂ prices / carbon taxes are not high enough to allow large development of CCS, and subsidies are not sufficient.
• Lack of clear signals for climate change mitigation policy, unclear framework for storage and risk of substitution by natural gas or renewables.

No incentive to pay for CCS

"In the European quota system a ton of CO₂ costs ~7-10$ – while typical purification costs lies in the area of 80-165 $/ton."

Source: BCG Research
Innovation implies costs reduction and new competitors

**Challenge**
- Energy independence
- Technological change
- CO₂ emissions reduction
- Costs reduction

**Measures**
- Renewables
- Energy Storage
- Energy efficiency

**Impact**
1. Costs reduction
2. New players emerging
Costs of green technologies are plummeting

**PV & wind auction prices has plummeted...**

Auction / PPA prices
($/MWh)

<table>
<thead>
<tr>
<th>Year</th>
<th>PV: Avg. price</th>
<th>Lowest price</th>
<th>Onshore wind: Avg. price</th>
<th>Lowest price</th>
<th>Offshore wind: Avg. price</th>
<th>Lowest price</th>
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<tbody>
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<td>2013</td>
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</table>

*2013-2016 development*

*Reported prices comprise a selection of recent announced long-term remuneration contract prices (e.g. PPA, auctions) for renewable power by date of announcement and to be commissioned over 2016-21. Values reported in nominal USD. UAE = United Arab Emirates. US values are implied excluding tax credits. Source: GTM, IHS, BCG analysis.*

**...Batteries on the same trend?**

Forecast of Ion-Lithium battery costs
($/kWh)

*Source: GM announcement of October 28th 2015 for 2016 (based on a cell of 145$/kWh)*

*Tesia claims or forecasts*
Power storage technology continues to ride the experience curve

Source: Nature Energy 2017 - The future cost of electrical energy storage based on experience rates
Innovation is driving efficiency and cost reduction

**Increasing capacity factors in wind**

- Wind speed (m/s)
- Efficiency (%)

**Improving solar PV cell efficiencies**

- Efficiency (%)
- Year

Source: IBA, Fraunhofer
## Digital Wind Farm: Big Data and Advanced Analytics as enabler for significant cost savings

### Operating environment
- > 100 Wind turbines

### Proof of concept
- Upload to cloud (Redshift)
- Data processing with Alterix
- Modeling with Python
- Visualizing with Tableau
- Machine learning with random forest model to predict breakdowns

### Potential impact
- Service costs are > 75% of OPEX
- Cost saving potential ~70% of service costs; plus 3% higher performance

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1. 54 continues signals/values including power and wind speed (10 min interval)
2. 366 different error/status codes
Source: BCG / DAAS / GAMMA analysis
Forecasts are consistently being surpassed

Global PV deployment forecasts

Estimated costs of batteries by 2020

Source: International Energy Agency, EPIA
"Utilities are crazy if they don't start offering customers innovative financing packages for solar and distributed generation...because others will."—Honda Executive

"New technologies mean new incumbents and new products"

Example: Distributed Generation and Demand Management
## High diversity of companies and business models

*Example: Distributed Energy*

<table>
<thead>
<tr>
<th>Distributed generation</th>
<th>Supply of DG systems</th>
<th>Leasing service - PPA</th>
<th>Rent-the-space model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Efficiency</strong></td>
<td>Energy services</td>
<td></td>
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<tr>
<td><strong>Energy Management Systems</strong></td>
<td>Supply of smart home solutions</td>
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<td><strong>Demand response service</strong></td>
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<td><strong>Integrated solution</strong></td>
<td>Virtual Power Plant</td>
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<td><strong>Microgrid</strong></td>
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</table>

**Note:** map of examples, not exhaustive

**Source:** BCG analysis

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**New Players**

- **Virtual Power Plant**
- **Microgrid**
- **Non-commercial pilot projects**
# High diversity of companies and business models

**Example: Energy Storage**

|----------------------|--------------------------|--------------------------|----------------------|---------------------|
| **Battery Manufacturing** | LG Chem, SAFT, Samsung, Tesla | • Massive capacity additions by incumbents  
• Growth of custom solutions for grid storage  
• Potential for disruptive innovation (e.g., Alevo) | ~5% | ~5% |
| **Power Conditioning Systems** | GM, Siemens, ABB | • Entry of low-cost competitors from solar  
• Limited ability to differentiate on technical capabilities | ~7% | ~5% |
| **Energy Storage Management Software** | Greensmith, Younicos | • Several players with established solutions (Greensmith, Younicos)  
• Perceived differentiation in market today, but capabilities being broadly developed  
• Differentiation will require enhancing capabilities | ~25% | ~20% |
| **Integration / Tech Provider** | Schneider Electric, Tesla, AES, NEC | • Increasing competition from upstream players moving downstream  
• Growing number of modular solutions on market; but value driven by customization | ~12% | ~8% |
| **EPC** | AES, RES, Mortenson | • Traditional EPC players building capabilities in energy storage market  
• High potential for cost reductions with experience; "typical" EPC markups likely | ~9% | ~7% |
| **Developers** | Invenergy, EDF, SolarCity, RES, AES | • Renewable energy developers taking larger position in energy storage market (often paired with renewables sites) | ~2% | ~4%² |

1. Identification of market leaders based on cumulative systems deployed in market today  
2. Increase in developer margins driven by addition of project financing capabilities  
Source: DOE, company websites, expert interviews, BCG analysis

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New technologies allow for new niche players
Example: wind and solar production forecasts

<table>
<thead>
<tr>
<th>Wind forecasts</th>
<th>Solar forecasts</th>
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<tbody>
<tr>
<td>Wind forecasts</td>
<td>Solar forecasts</td>
</tr>
<tr>
<td>• Combination of 12 meteorological models</td>
<td>• Combination of meteorological models and information from 800 stations and satellite</td>
</tr>
<tr>
<td>• Includes local input</td>
<td>• 0-228 hour forecasts</td>
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<tr>
<td>• High-resolution, particularly in the short term</td>
<td>• Resolution in 10 minutes</td>
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<tr>
<td>• Intra-hourly predictions</td>
<td>• 0-160 hour forecasts</td>
</tr>
<tr>
<td>• Short and long-term forecasts</td>
<td>• Management of uncertainty/probabilities</td>
</tr>
<tr>
<td>• 0-168 hour forecasts</td>
<td>• Information for all countries</td>
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<tr>
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<tr>
<td>• Prediction of velocity and direction</td>
<td>• Combination of meteorological models</td>
</tr>
<tr>
<td>• Extrapolations</td>
<td>• Data in the client's format</td>
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<tr>
<td>• Combination of meteorological models</td>
<td>• Combination of meteorological models</td>
</tr>
<tr>
<td>• Includes historical wind farm data</td>
<td>• Information for all countries</td>
</tr>
</tbody>
</table>

Source: Company websites
Summary

Technological change in the energy sector is a reality that will be much more relevant in the medium term

CO₂ emissions reduction, Energy independence and Cost reduction are key levers to develop new technologies

Three main technologies to face this energy sector challenge

• **Renewables**: Wind and solar power playing an important role
• **Storage**: To reduce costs and make affordable renewables
• **Energy efficiency**: new business models and entrants will compete with traditional utilities

Others technologies like CCS and Hydrogen/Fuel Cells already in development phase

New technologies mean constant costs reduction and new incumbents emerging
Contents

What is the role of technology in the energy sector?

What are the main levers promoting technological change?

Key questions and discussion
Challenges of promoting technologies in the Energy sector

Key questions

1. How can governments accelerate the deployment of new technologies as reliably and cost effectively as possible: Which approach holds the most promise:
   - Government mandates such as on the phasing out of ICEs over the next decades, or
   - Market regulation such as on carbon pricing mechanisms and performance standards?

2. What is the impact of new technology deployment on investment in existing technologies, how can governments help to:
   - Reduce risks to investment in existing technologies
   - Ensure adequate investment while portfolios adapt over time, to
   - Maintain energy security in energy sector transformations?

3. How can governments and industry accelerate the deployment of clean energy technologies in the fossil fuel sector such as CCUS, and increase carbon efficiency?

4. What new requirements do shared goals and new technologies impose on energy market data transparency: Where can the Joint Organizations Data Initiative play a role?

5. How can Ministers leverage the IEF platform to further enhance knowledge sharing on energy efficiency and facilitate trade and investment in new technologies?