The 7th Asian Ministerial Energy Roundtable

AMER7

Bangkok | Thailand

Plenary Session 3:

Disruptive technologies in energy sector:

Impacts, challenges and preparation

Background Paper

BCG ENERGY | IEF INTERNATIONAL ENERGY FORUM

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 polies 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?

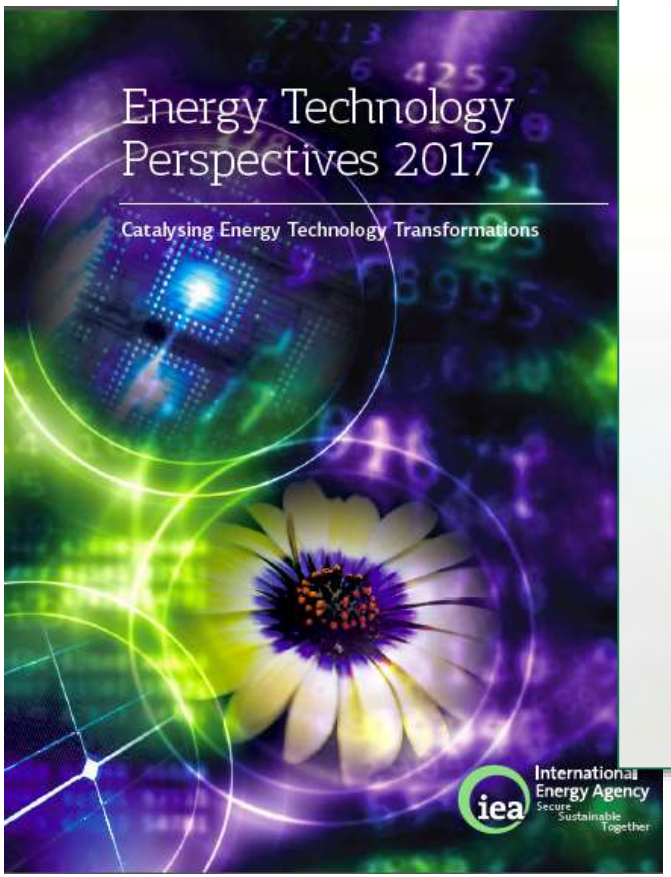
Contents

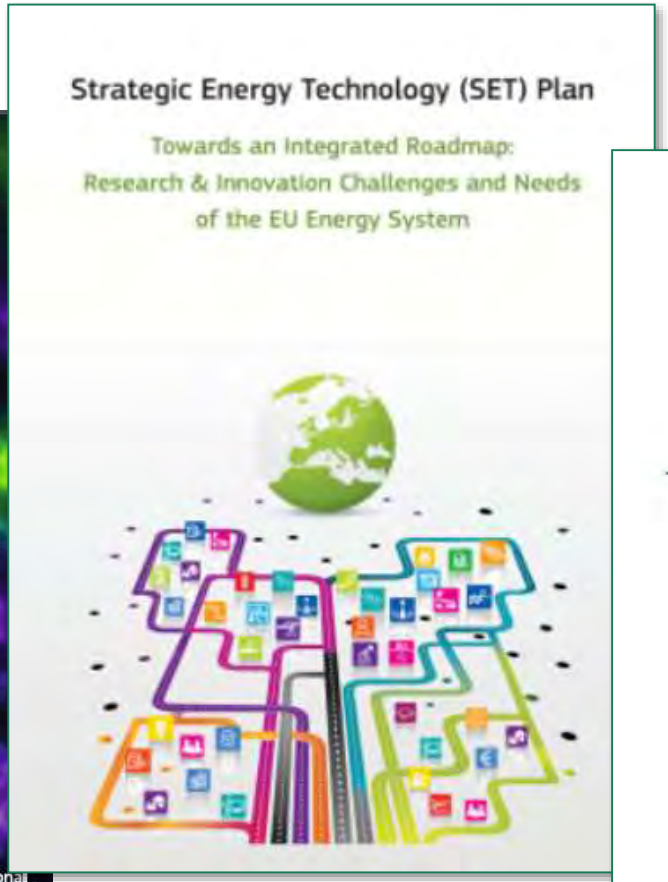
What is the role of technology in the energy sector?

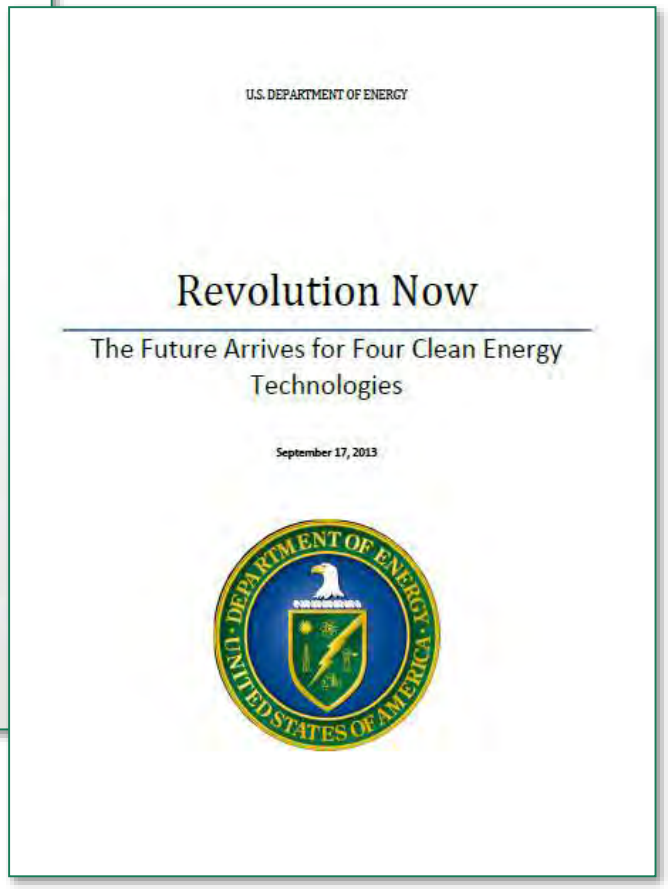
What are the main levers promoting technological change?

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

World leaders launch *Mission Innovation* at the United Nations Climate Change Conference 2015 (COP21) in Paris-Le Bourget, France, November 30, 2015.

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**"*	bp GM ExxonMobil TOTAL	**BP, ExxonMobil, GM, Shell, Total** (and others)
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**"*	e·on	**Johannes Teyssen, CEO**, E.ON
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**"*		**Elon Musk, CEO**, Tesla
4	***"Renewables** are no longer referred to as alternative energy, they **are traditional**"*		Andrei Teksler, **Deputy Energy Minister, Russia**
5	***"50 percent of our energy** consumption – spanning **heat, transport and electricity** – to be met by **renewables** by 2030"*		Nicola Sturgeon, **The First Minister, Scotland**

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

Norwegian Sovereign Wealth Fund

Allianz

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

BLACKROCK

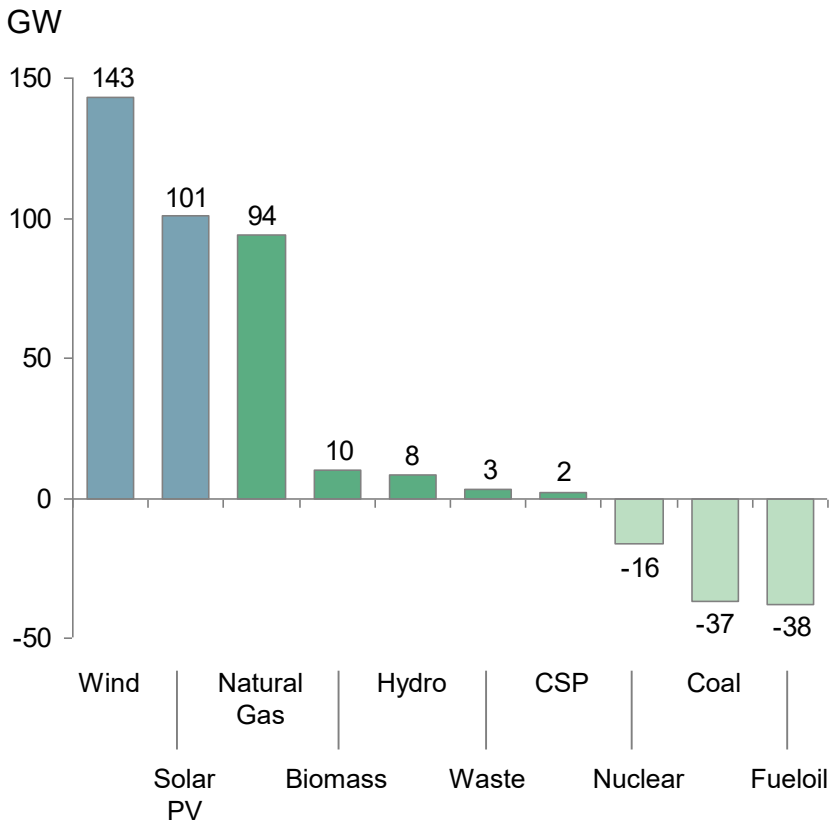
Vanguard

Source: The investors guide to climate change, Press search

Technological change in energy is already a fact (I)

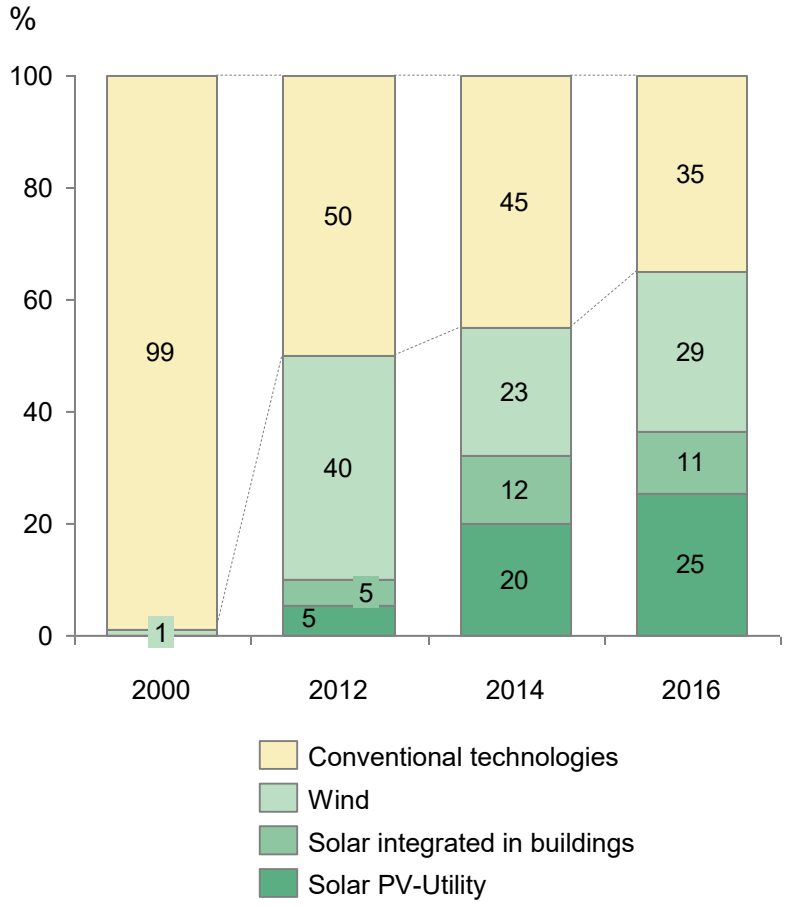
EU-27

Change in power generation mix 2000-16



US

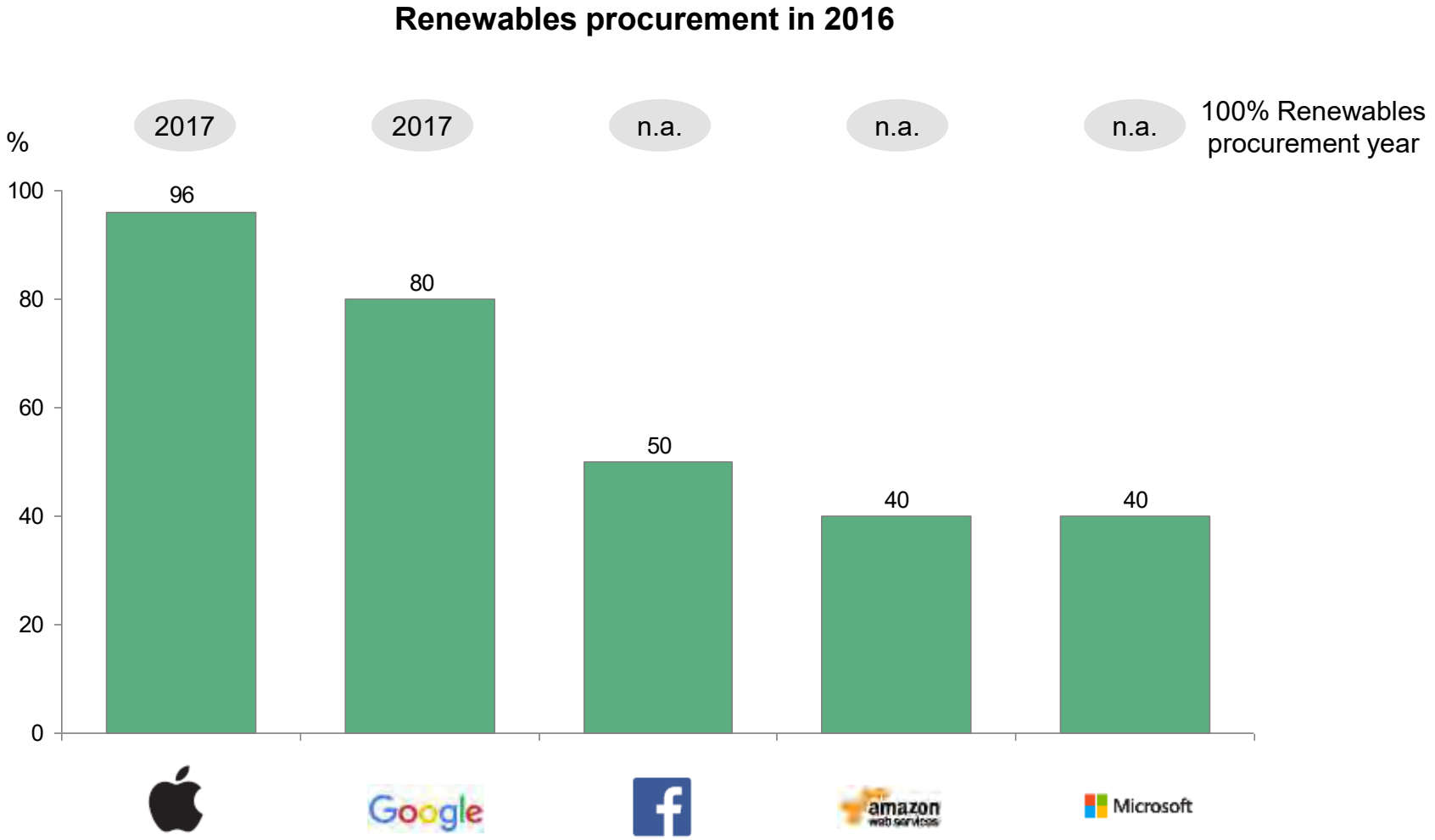
New installed power capacity 2012-16



Source: EIA (DOE; US); EWEA; BCG analysis

Technological change in energy is already a fact (II)

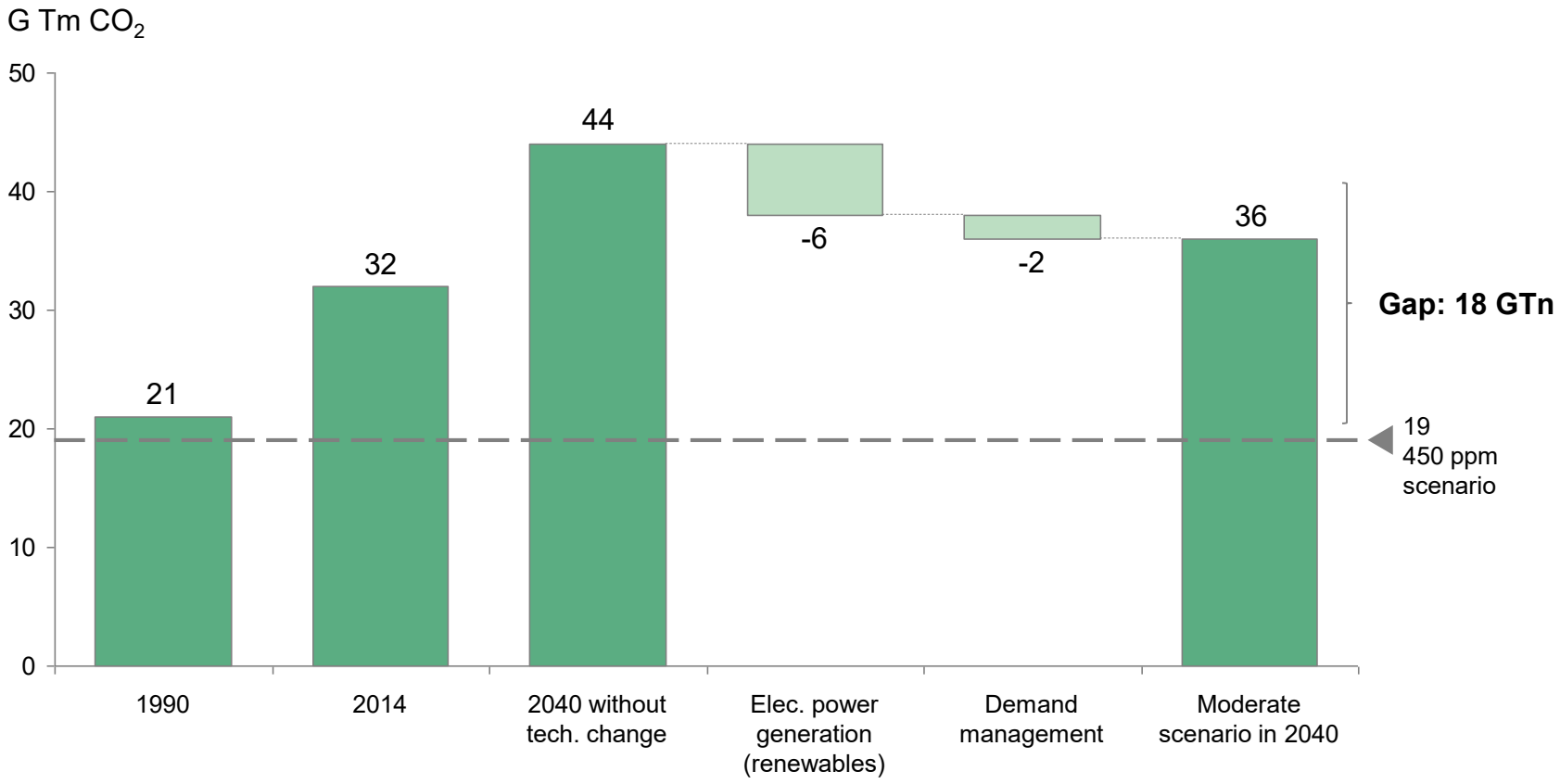
Apple and Google will be 100% Renewables in 2017



Source: Click Clean; BCG Analysis

An important environmental challenge ahead

Energy sector CO_2 emissions
- Moderate scenario-



Source: IEA World Energy Outlook 2016: BCG analysis

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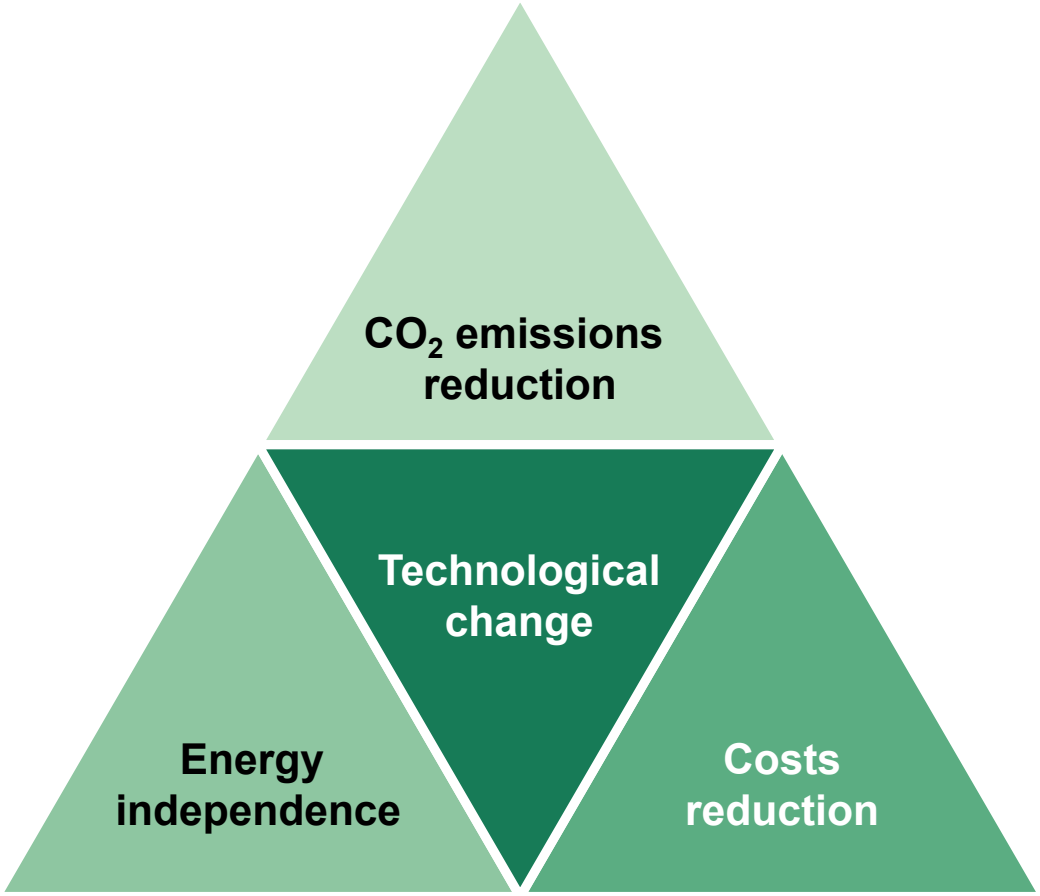
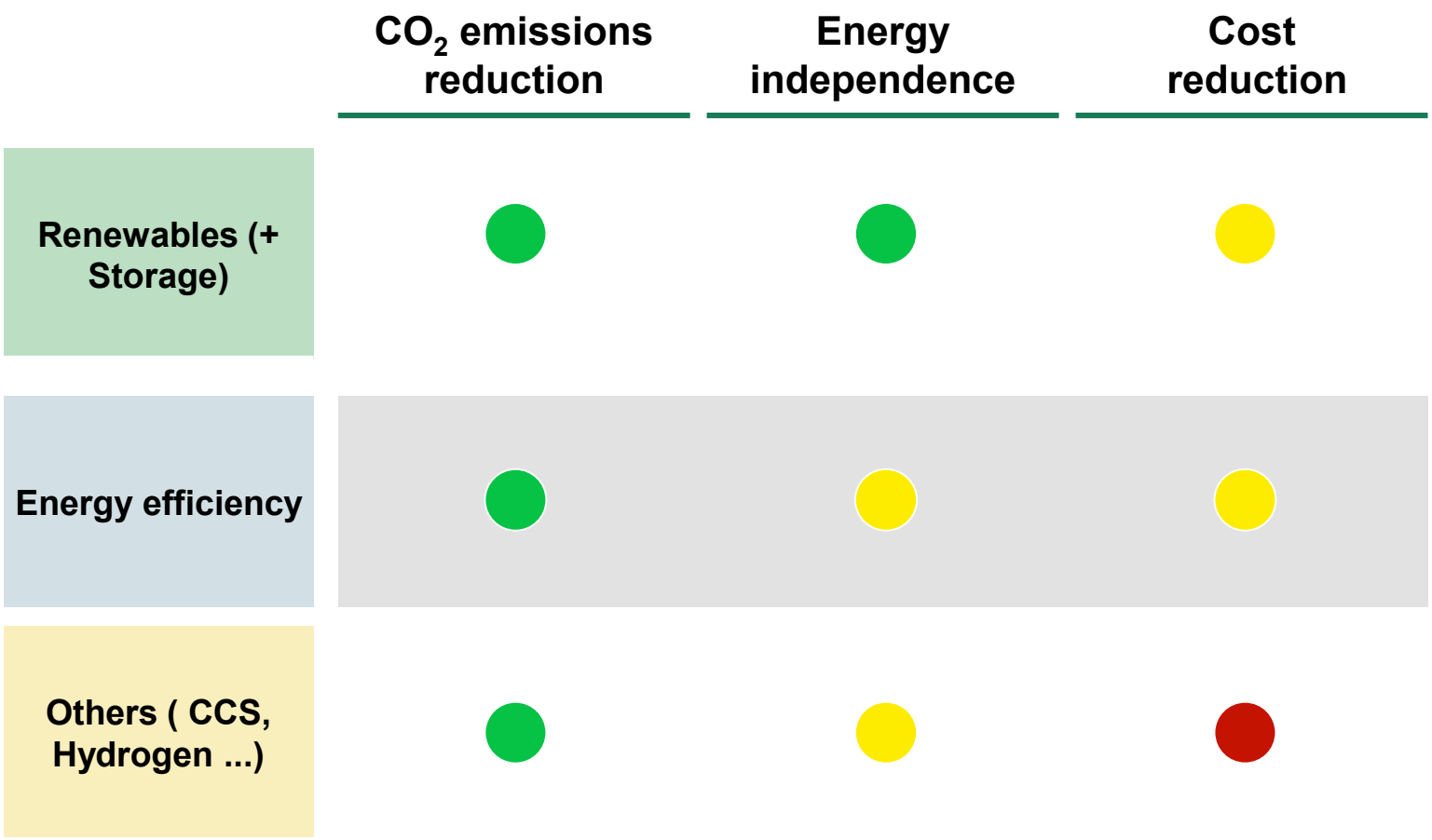
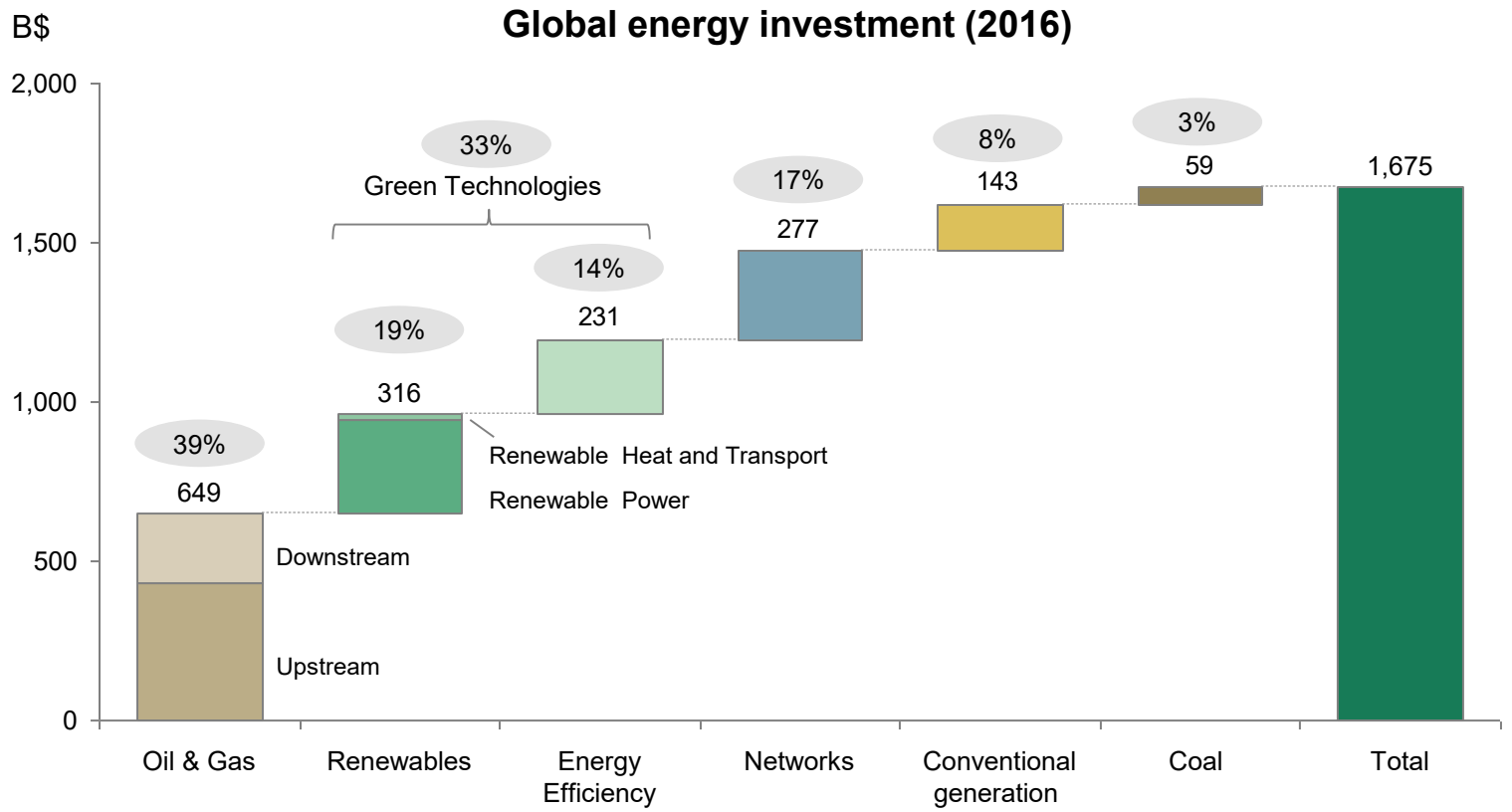
Three levers are promoting technological change in the energy sector



Renewables and Energy Efficiency are the most relevant technologies

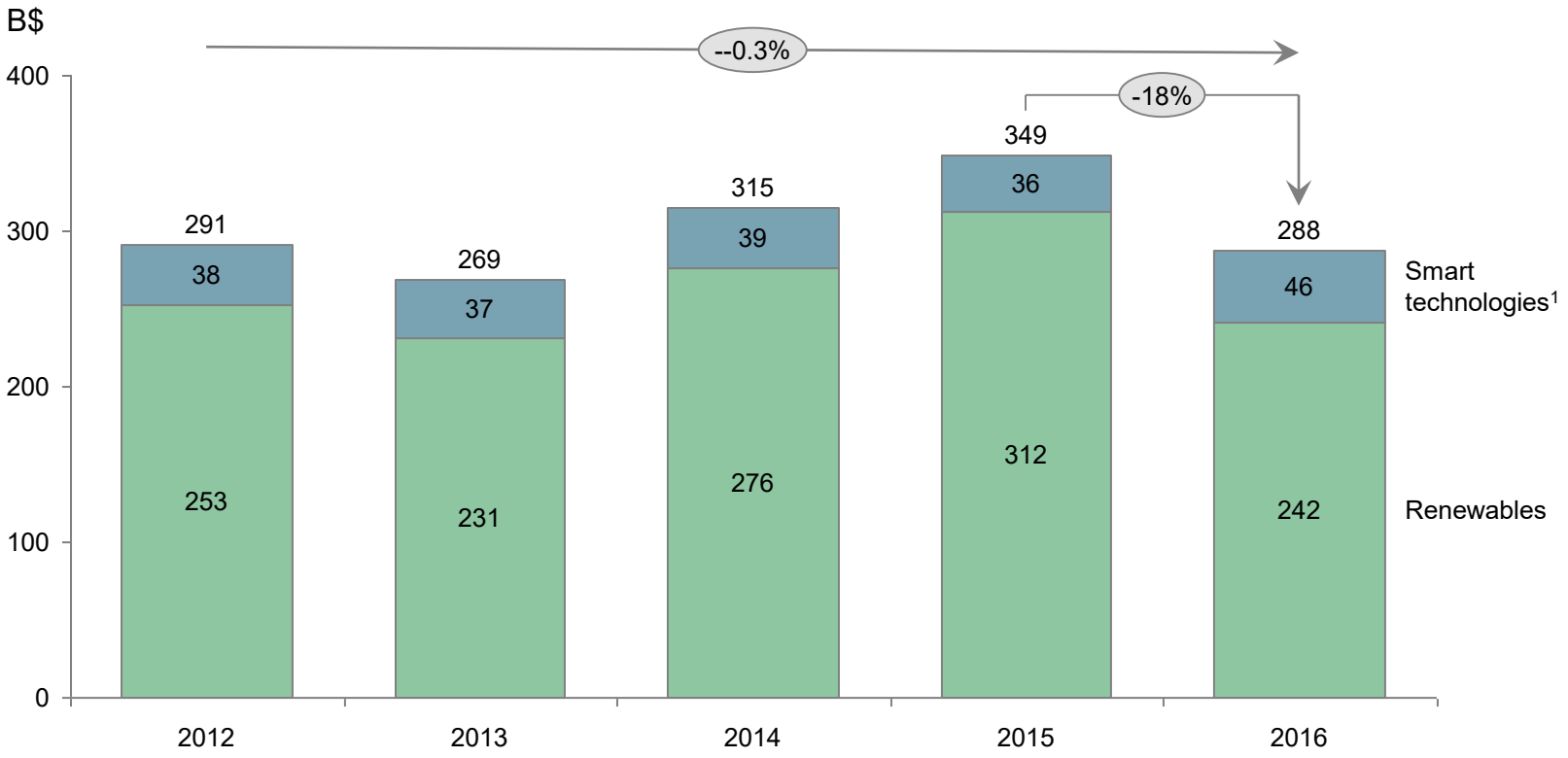


Renewables and Energy Efficiency accounted ~33% of global energy investments in 2016



Source: IEA Energy Investment Outlook

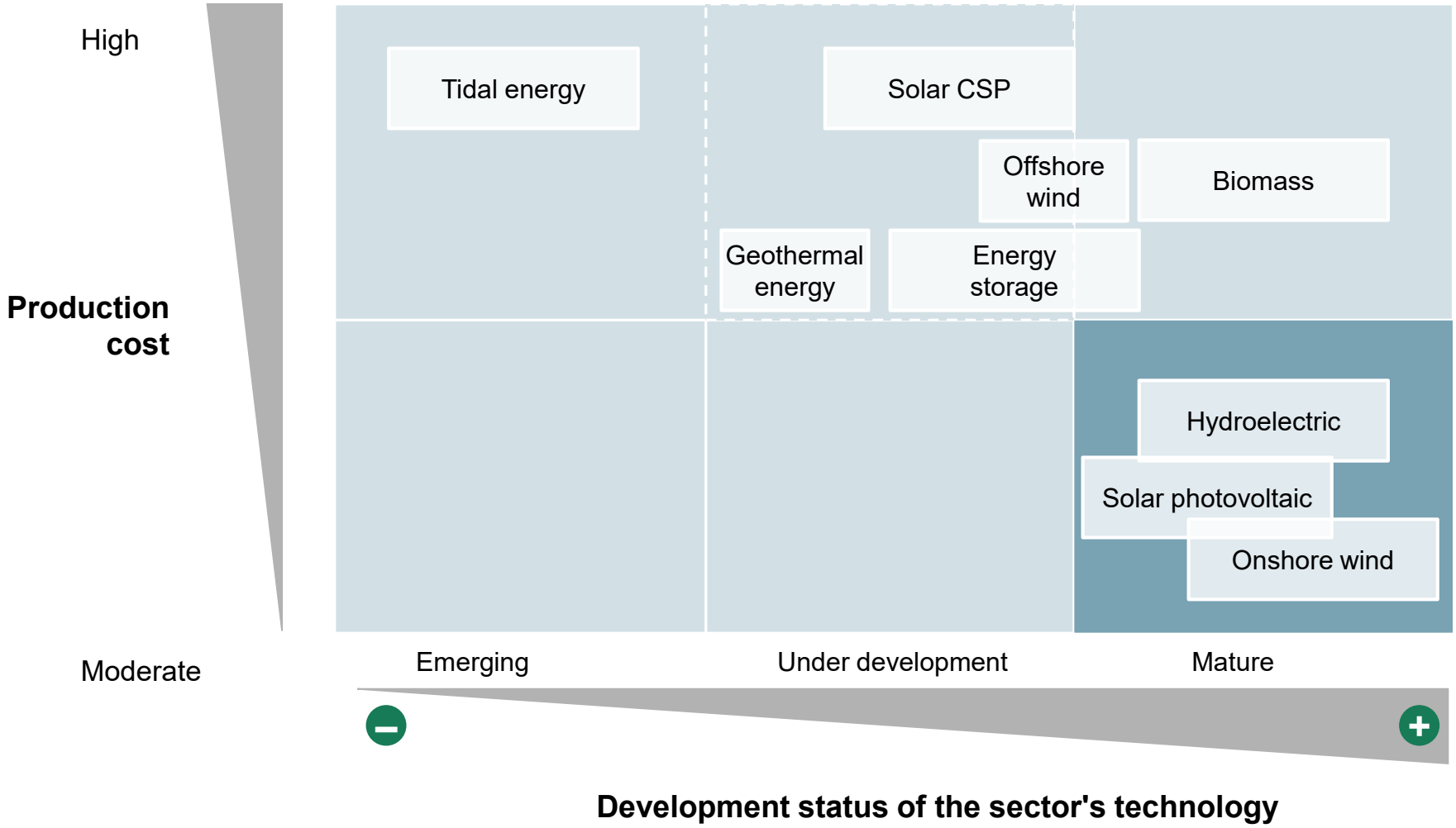
Investments in Clean Energy equal ~ B 300 $ yearly



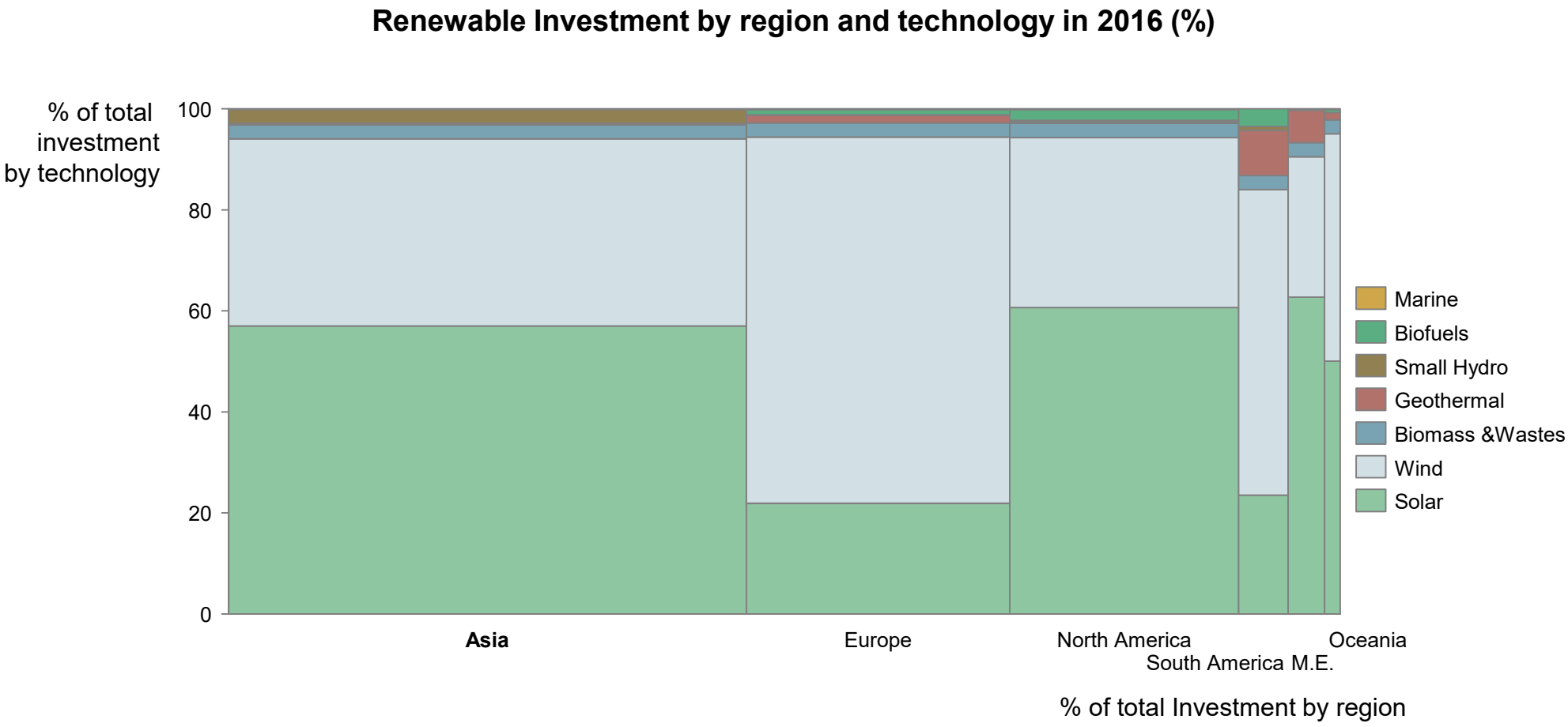
1. Includes smart grid, electric vehicles and power storage
Source: BNEF. BCG Analysis

Onshore Wind and Solar PV are leading the race

Energy storage can be a game changer

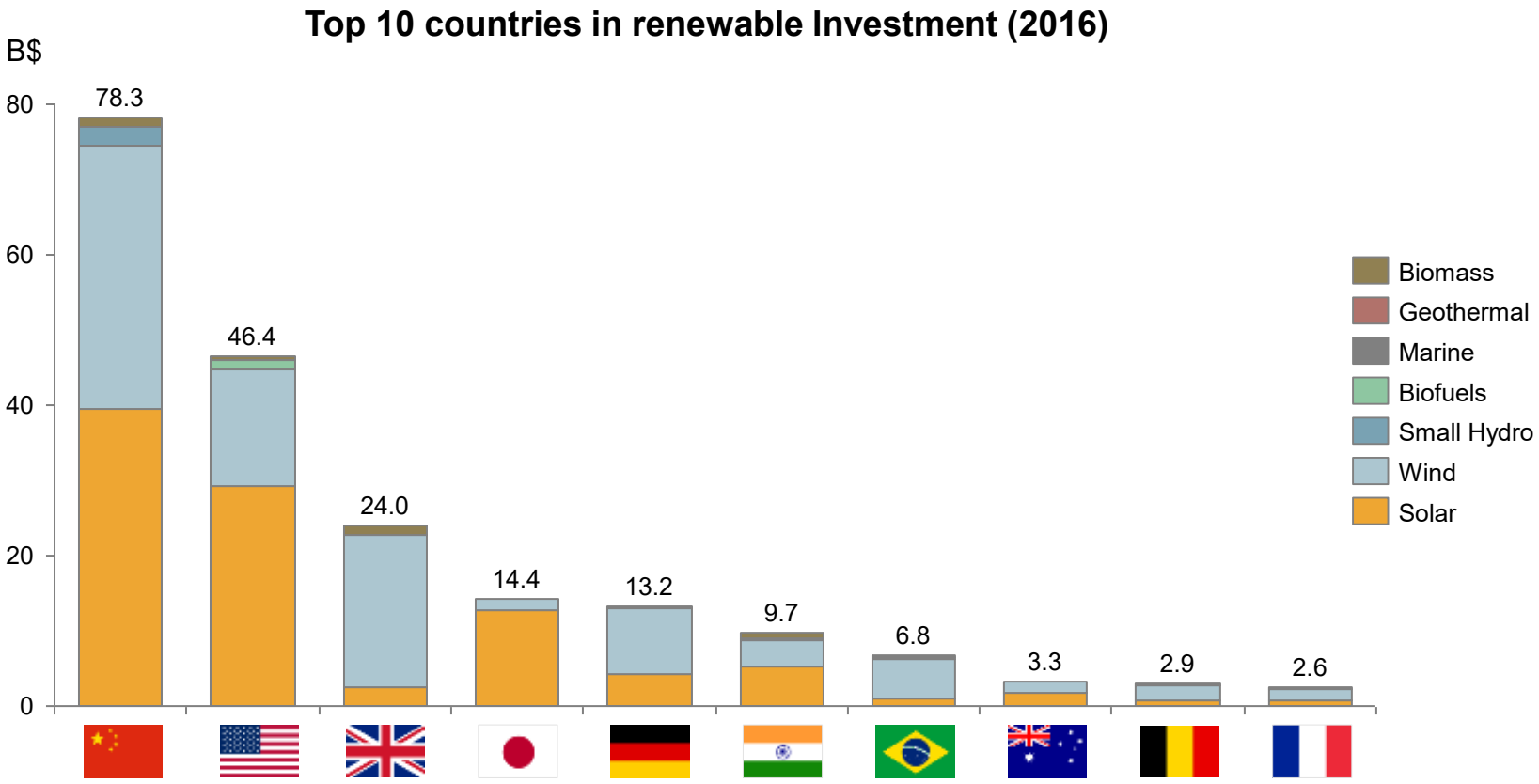


Asia is leading Clean Energy investments worldwide



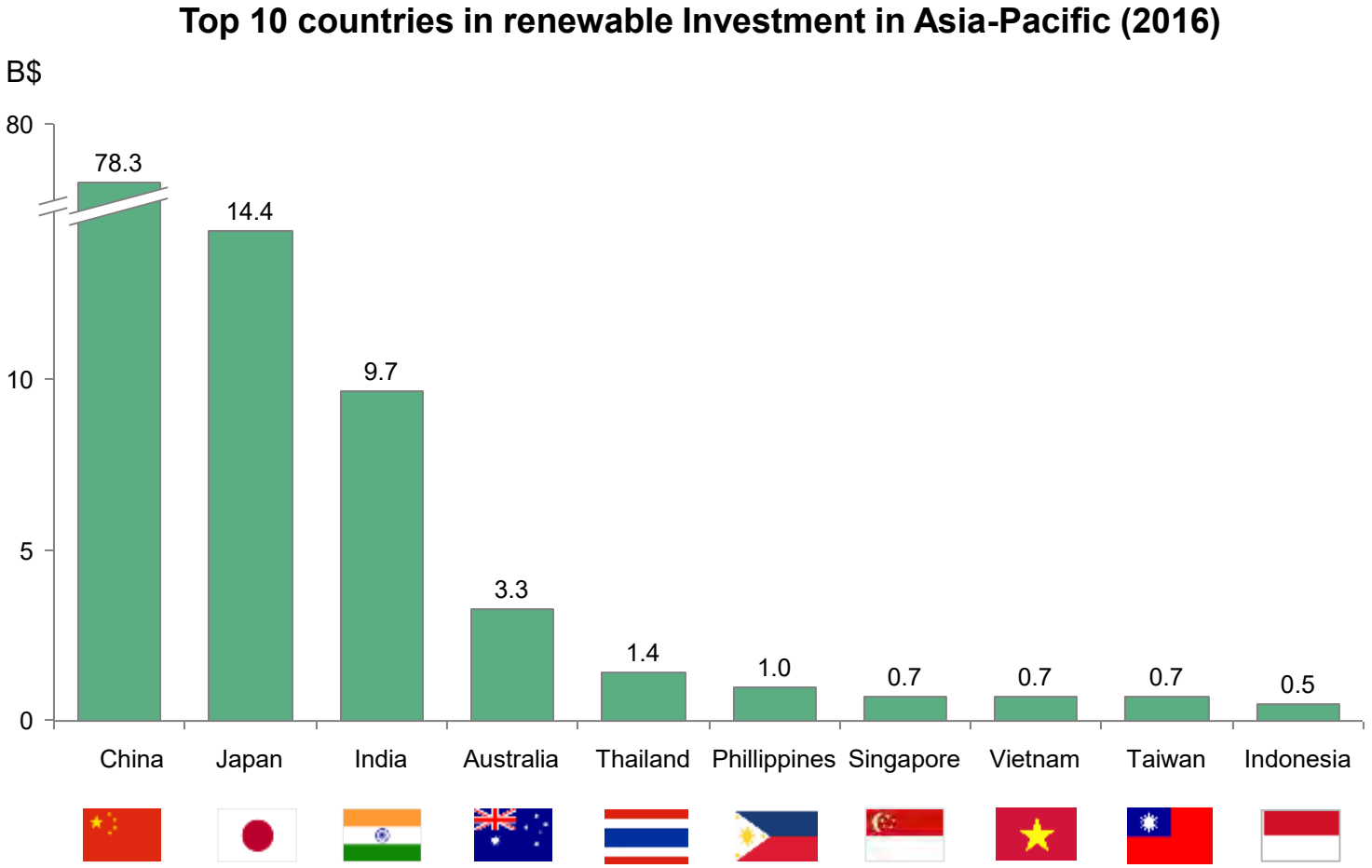
(1) Data for Biomass & Waste estimated from preliminary 2016 data
Note: Investment includes Asset Finance, Corporate R&D, Government R&D, Public Markets, Reinvested Equity, Venture Capital / Private Equity
Source: BNEF. BCG Analysis

China is leading the investment in renewables in 2016



(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

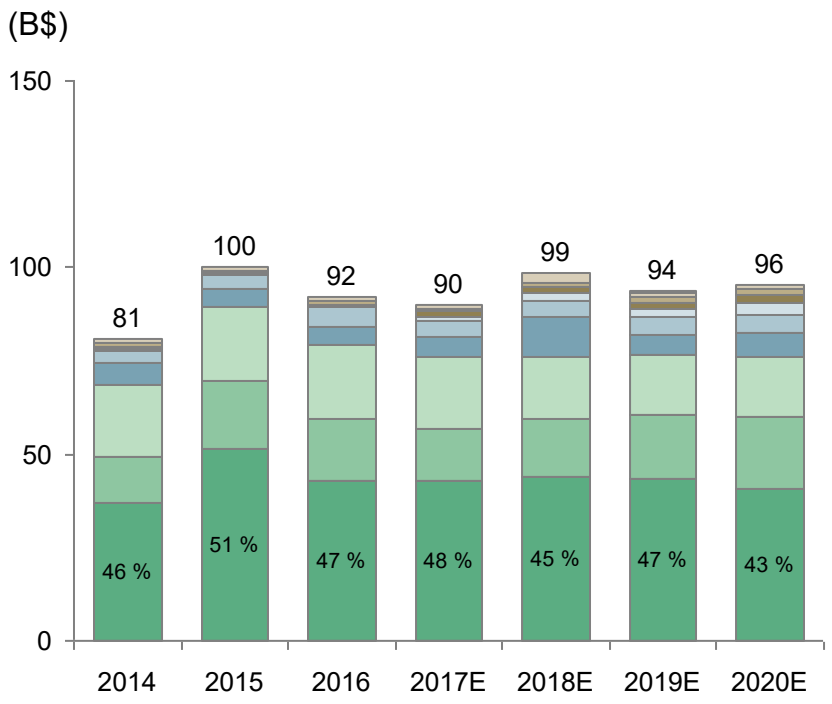
China is leading renewables investments in Asia-Pacific



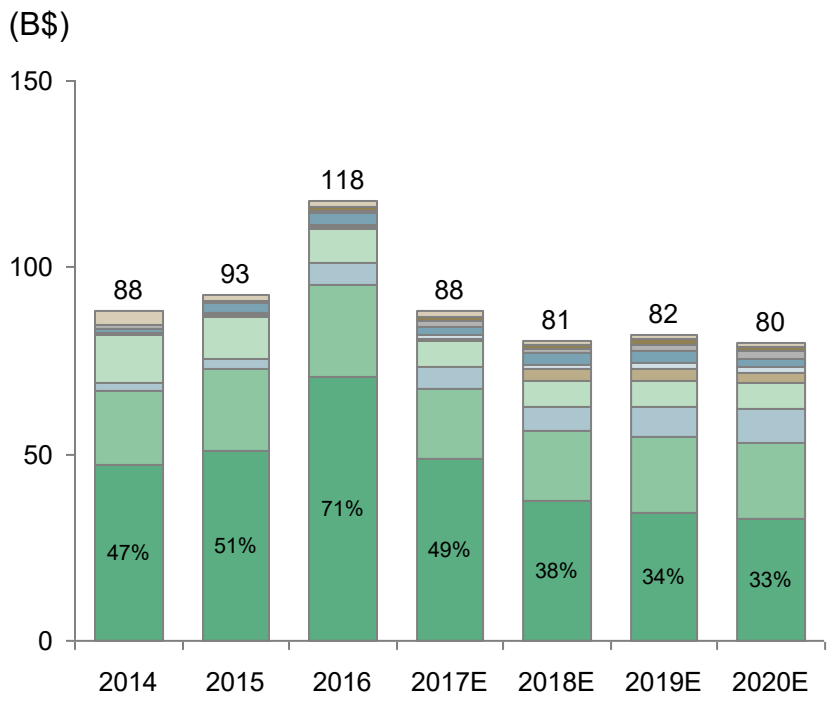
Note: Investment includes Asset Finance, Corporate R&D, Government R&D, Public Markets, Reinvested Equity, Venture Capital / Private Equity
Source: BNEF. BCG Analysis

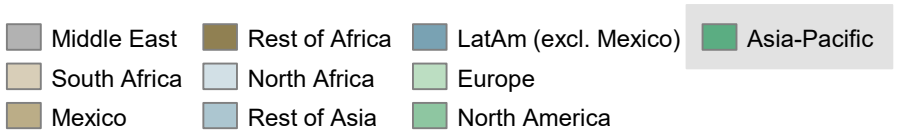
Asia-Pacific will concentrate ~40% of global renewables investments until 2020

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

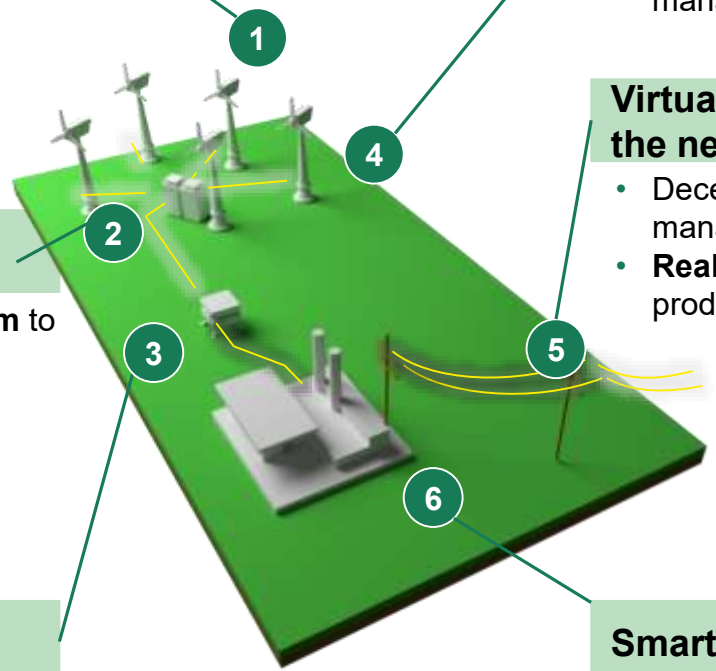
- Short-term / day ahead **production output forecasting**
- Connecting **adjacent farms in data clusters** to provide more accurate wind forecasts

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

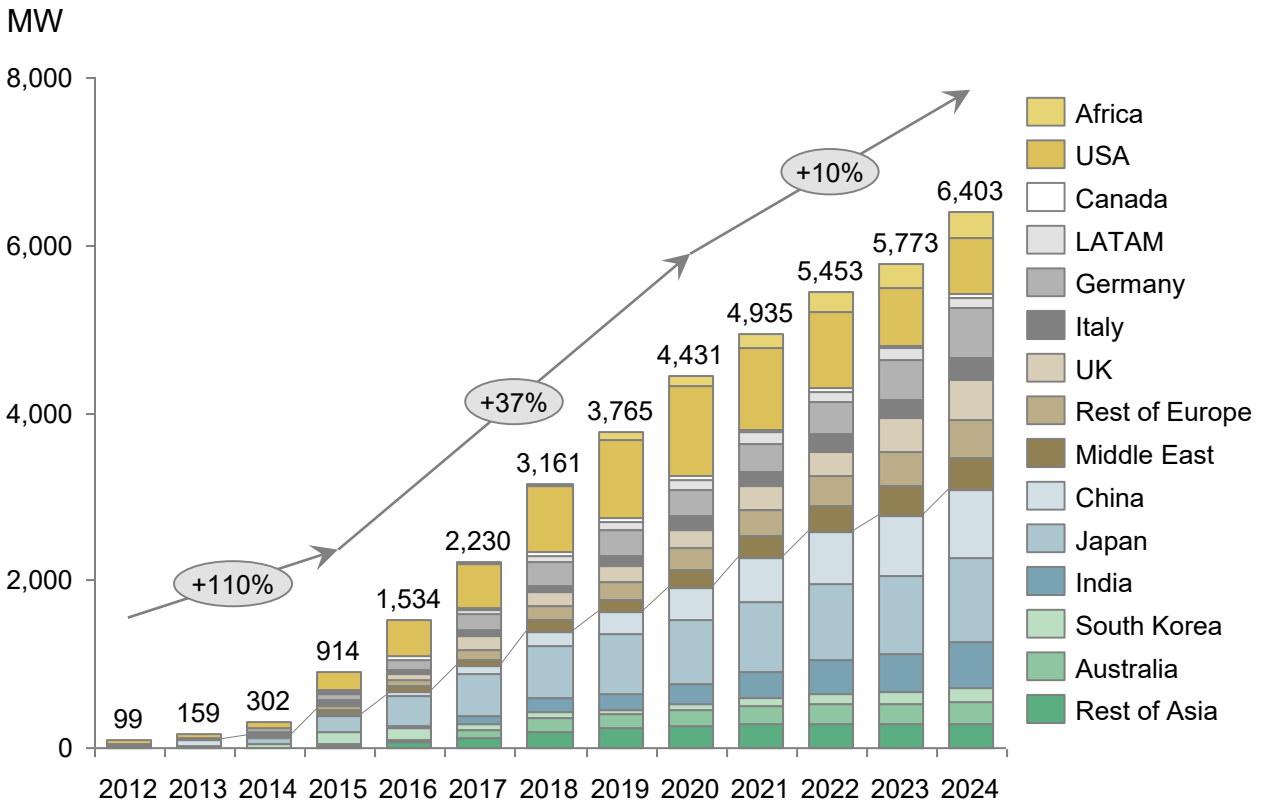
- **Balanced local grid production** with an increased penetration rate of renewables
- **Reactive capacity compensation**

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[1]

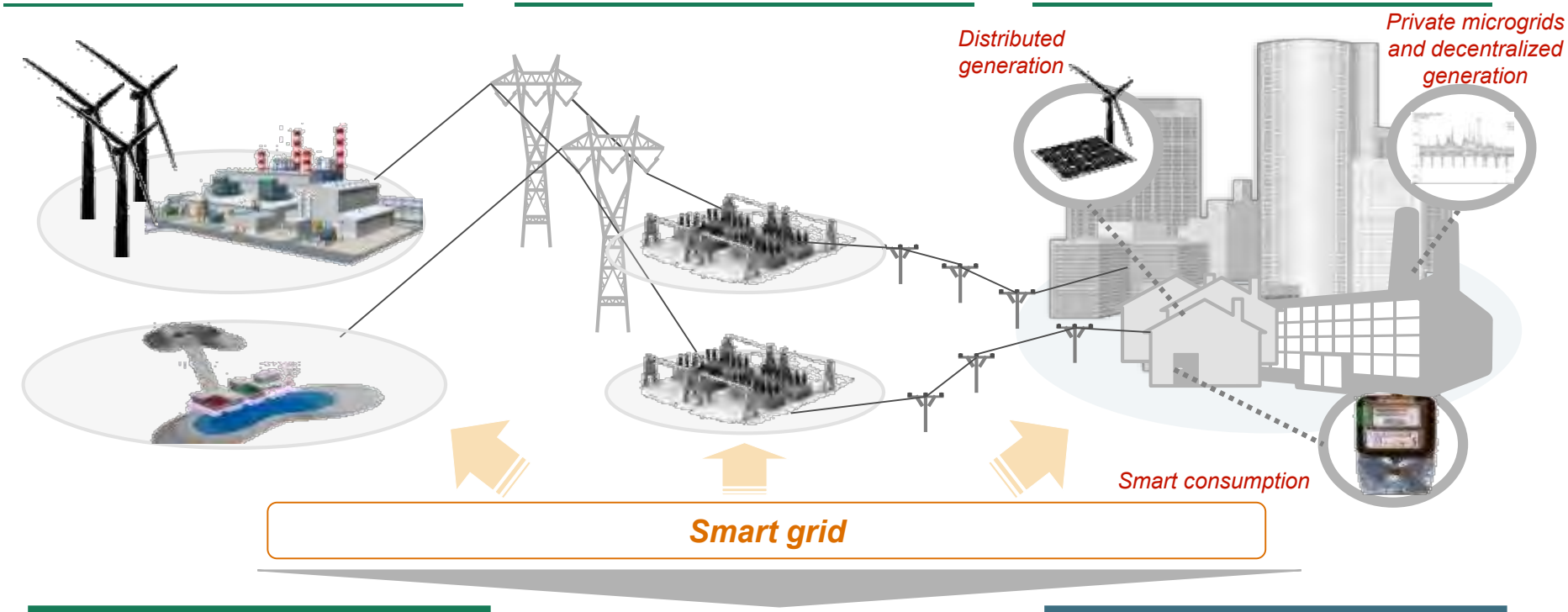


Current market status

	Strong market activity driven by favorable incentive schemes
	Test/pilot projects. Some activity in residential market.
	Test/pilot projects
	Majority of activity in France, driven by PV tender scheme
Africa	Limited/no activity (more focus on off-grid)
Middle East	Test/pilot projects
	Strong market activity driven by favorable policies
	Test/pilot projects
Rest of Americas	One-off projects in Chile and Puerto Rico
	Test/pilot projects
	Strong market activity driven by favorable policies
	Test/pilot projects
	Utility procurement program driving activity
	Some tests and pilots. Strong interest in behind-the-meter market
Rest of Asia	Test/pilot projects

1. Battery technologies considered are Lithium-Ion, Lead-acid, Sodium Nickel Chloride, Sodium Sulphur, Flow, Flywheels, Compressed Air (Alternative).
Source: IHS, 2015; BCG analysis

Energy Efficiency is fostering technological development and new business models



Distributed generation

Prosumers produce power for their own consumption

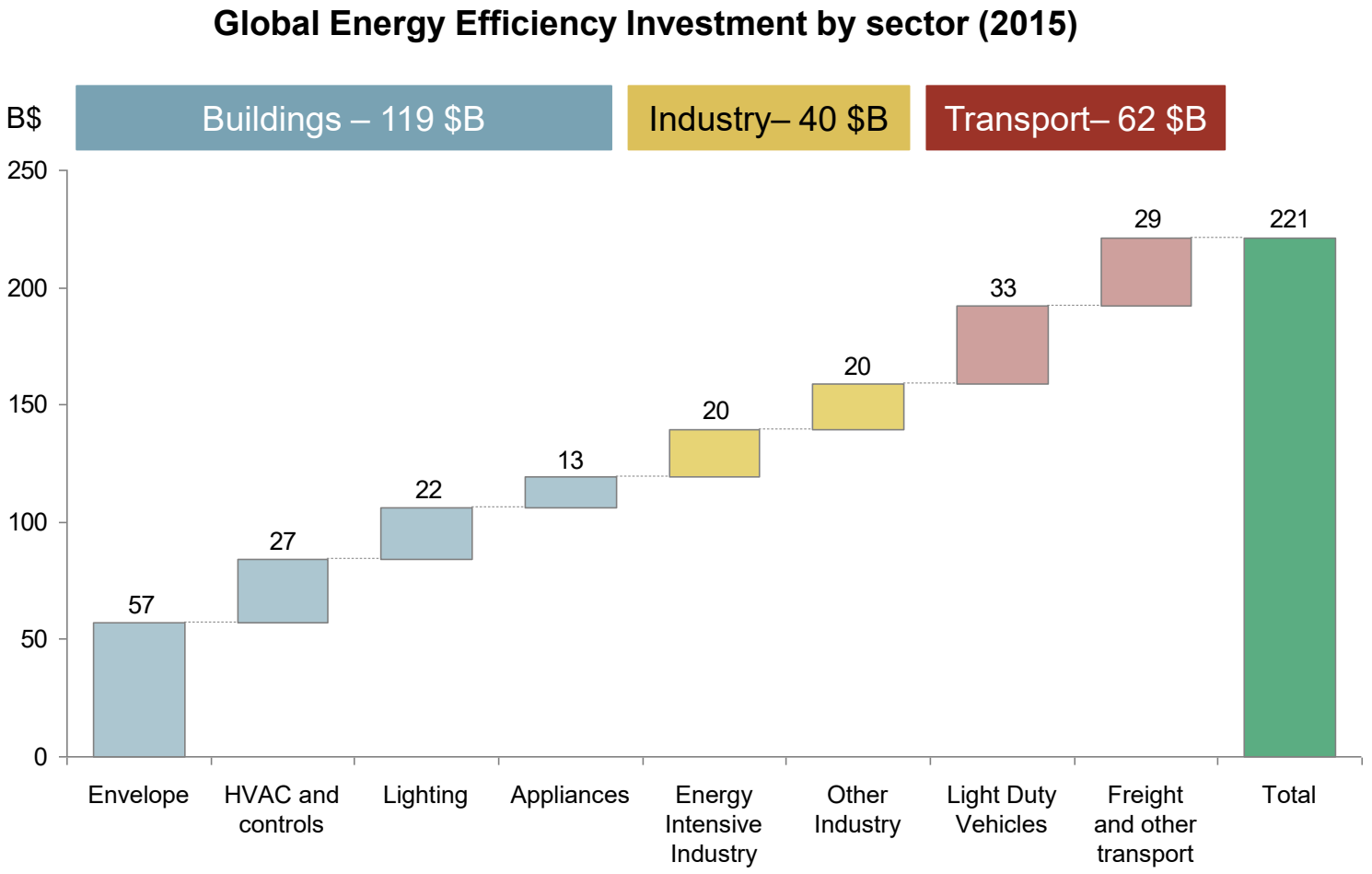
Integrated systems

Systems which include and coordinate distributed generation and smart consumption

Demand response

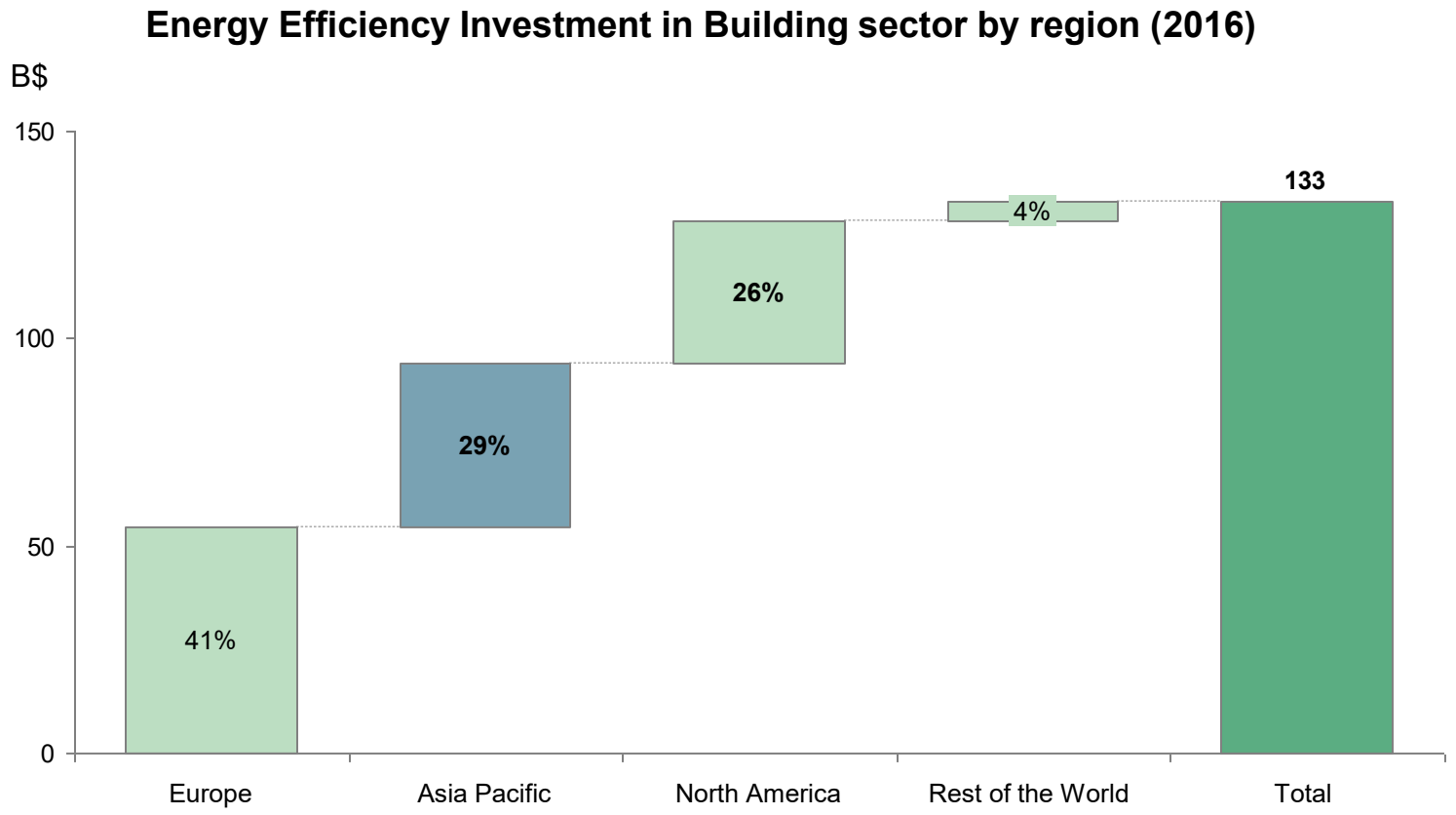
Consumers take advantage of new technologies to optimize consumption and reduce the cost of energy

Building sector represents 54% of global Energy Efficiency investment in 2015



Source: IEA Energy Investment Outlook

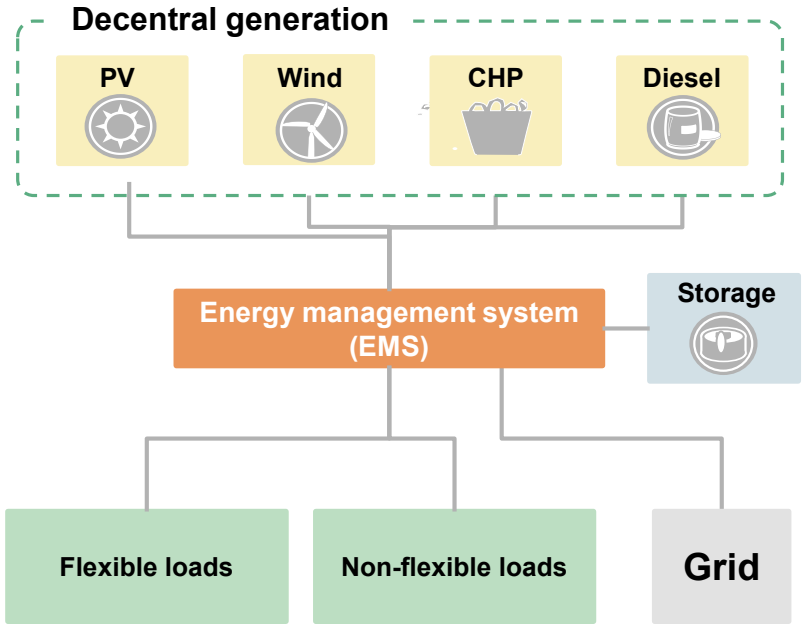
Asia Pacific accounting ~30% of total Energy Efficiency investment in Buildings



Source: IEA Energy Investment Outlook 2017

"Integrated decentralized solutions" are the next step

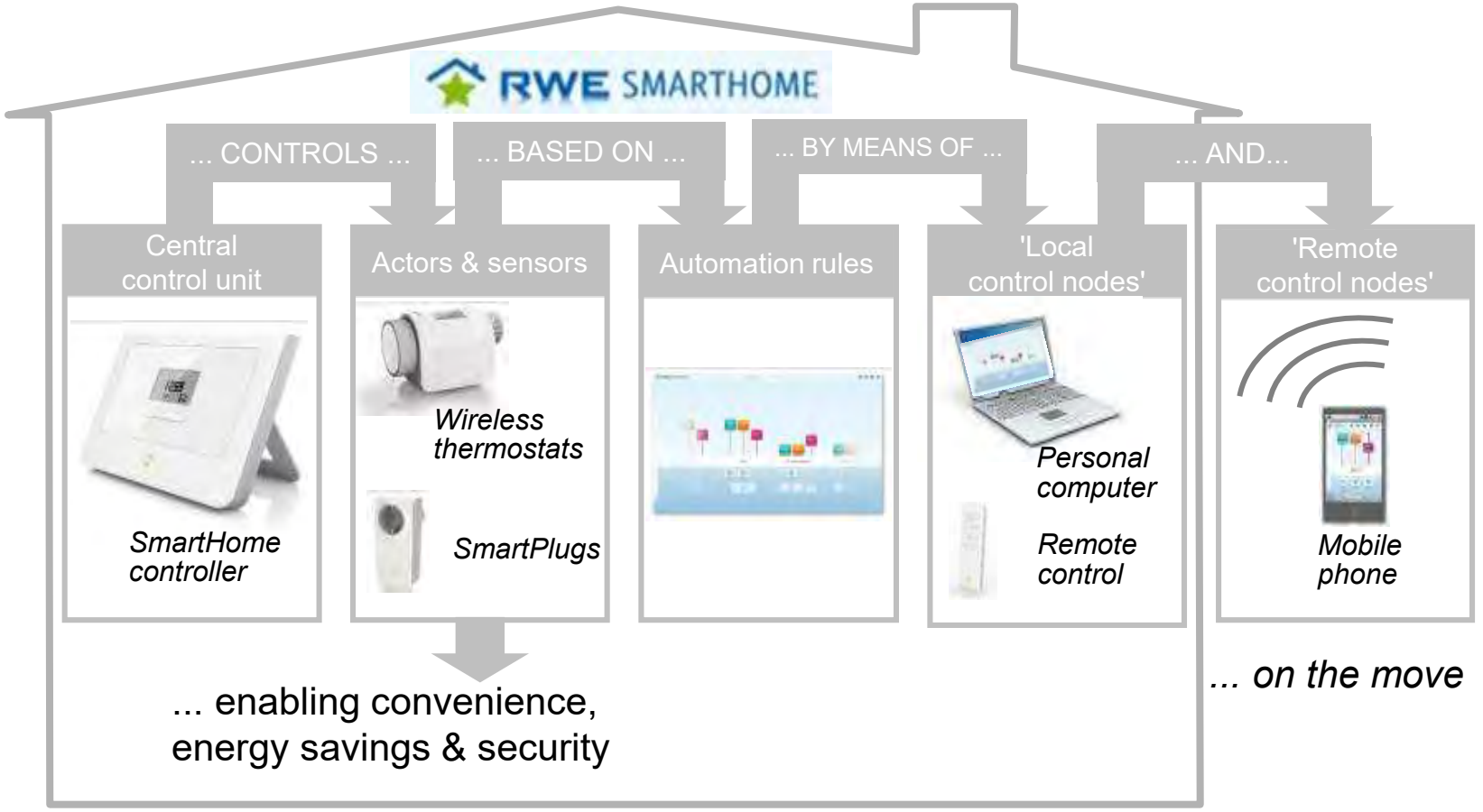
Decentralized technologies consist of generation, storage, and load ...



... and are applied across key customer segments

Segment		Example
Small utility		• IPPs , yieldcos, and / small utilities
Off-grid		• Mines in remote regions e.g. in Africa
Community		• Small cities, universities, military
Industrial		• Heavy industries e.g. a large steel plant
Commercial		• Retail stores e.g. IKEA
Residential		• One- or two-family homes

Broad number of Smart Home solutions and technologies



Source: BCG and BCG DV analysis

Currently there are few incentives to capture and store CO_2

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

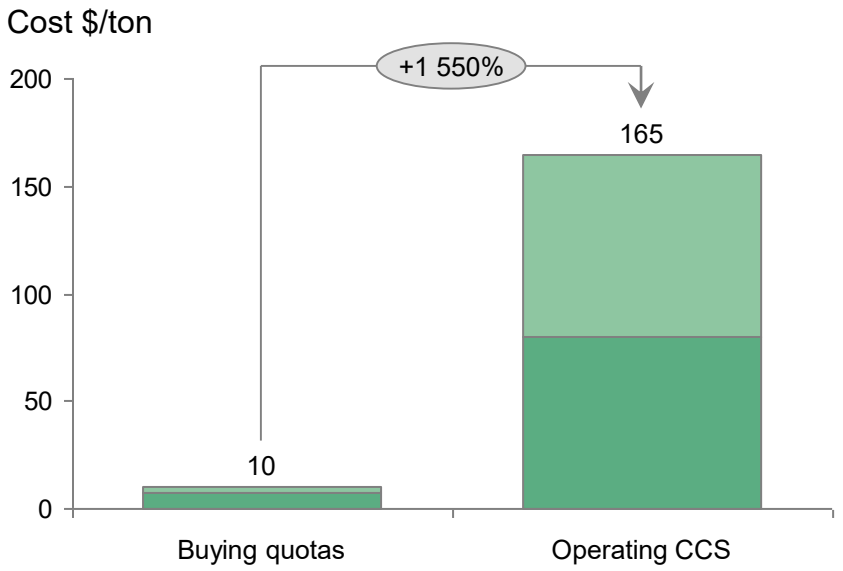
- Large CAPEX needed for funding, often costs above 1bn $
- CCS suffers from having CO_2 avoidance as sole purpose, compared to other renewables which creates energy efficiency measures

...and some more reasons for project developers:

- CO_2 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

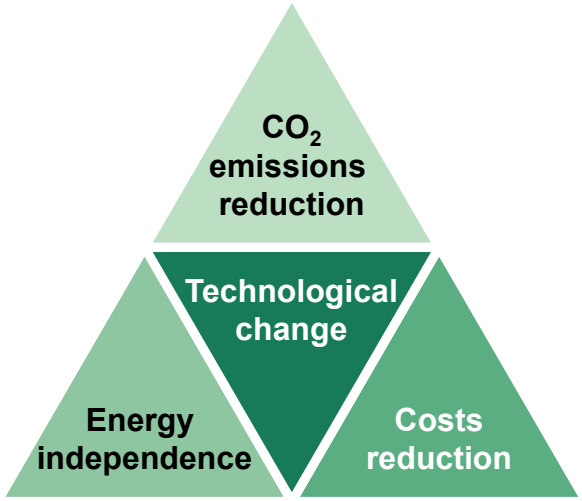
"In the European quota system a ton of CO_2 costs ~7-10$ – while typical purification costs lies in the area of 80-165 $/ton"



Source: BCG Research

Innovation implies costs reduction and new competitors

Challenge



Measures

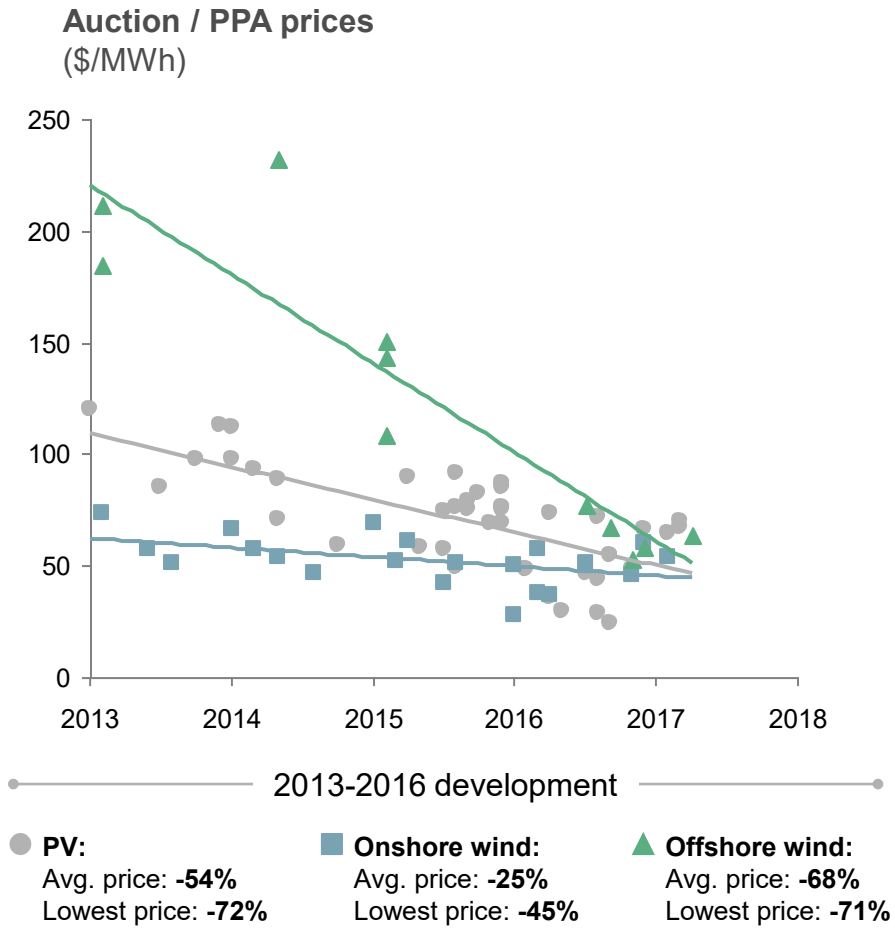
- Renewables
- Energy Storage
- Energy efficiency

Impact

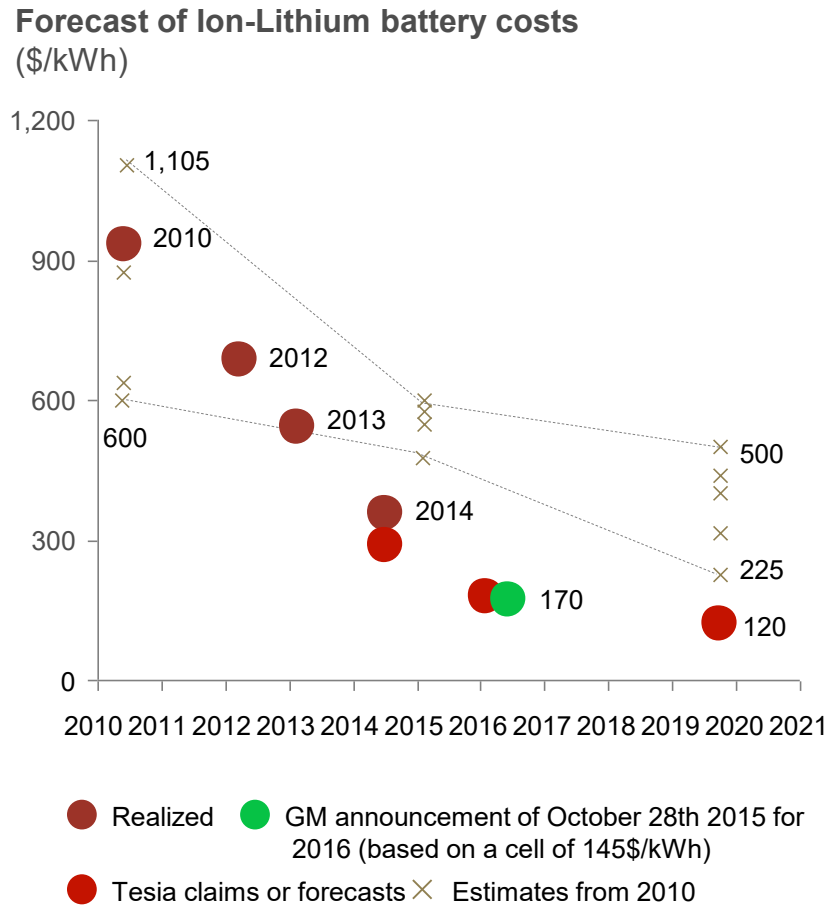
1. Costs reduction
2. New players emerging

Costs of green technologies are plummeting

PV & wind auction prices has plummeted...

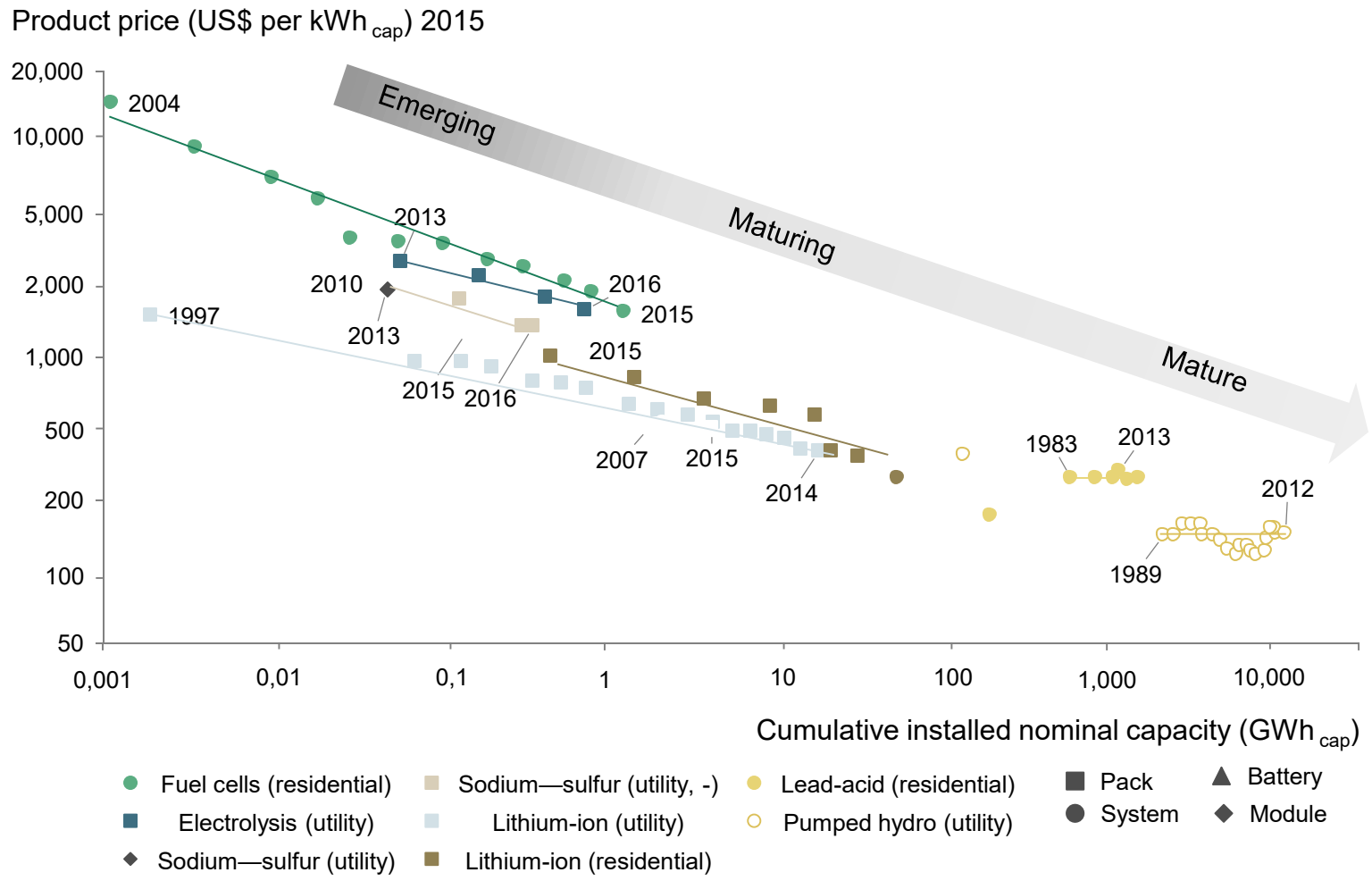


...Batteries on the same trend?



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

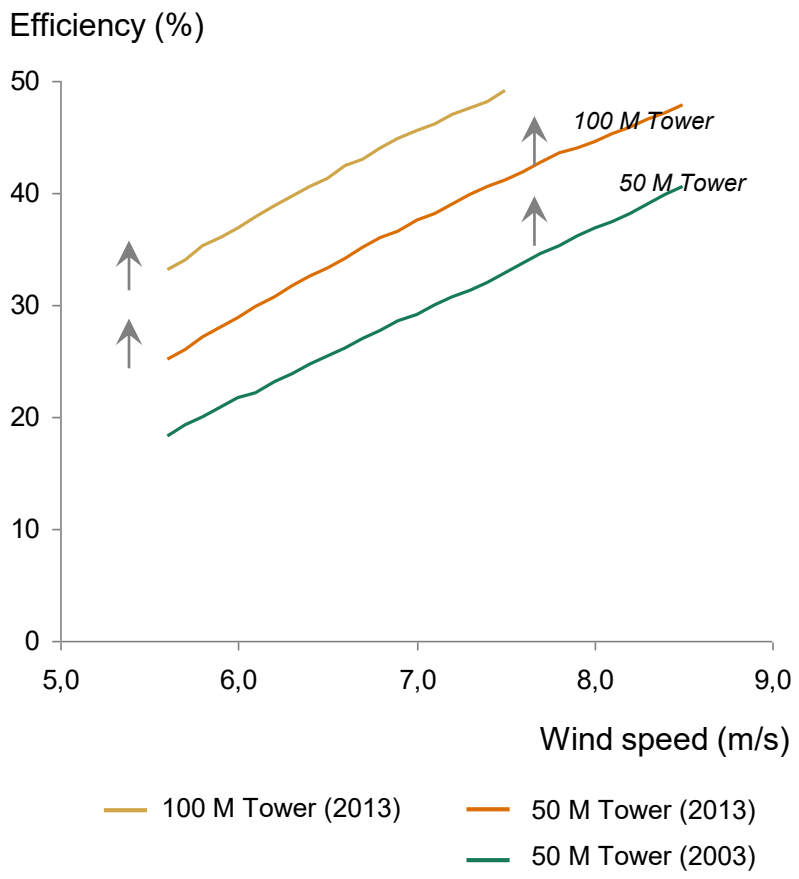
Power storage technology continues to ride the experience curve



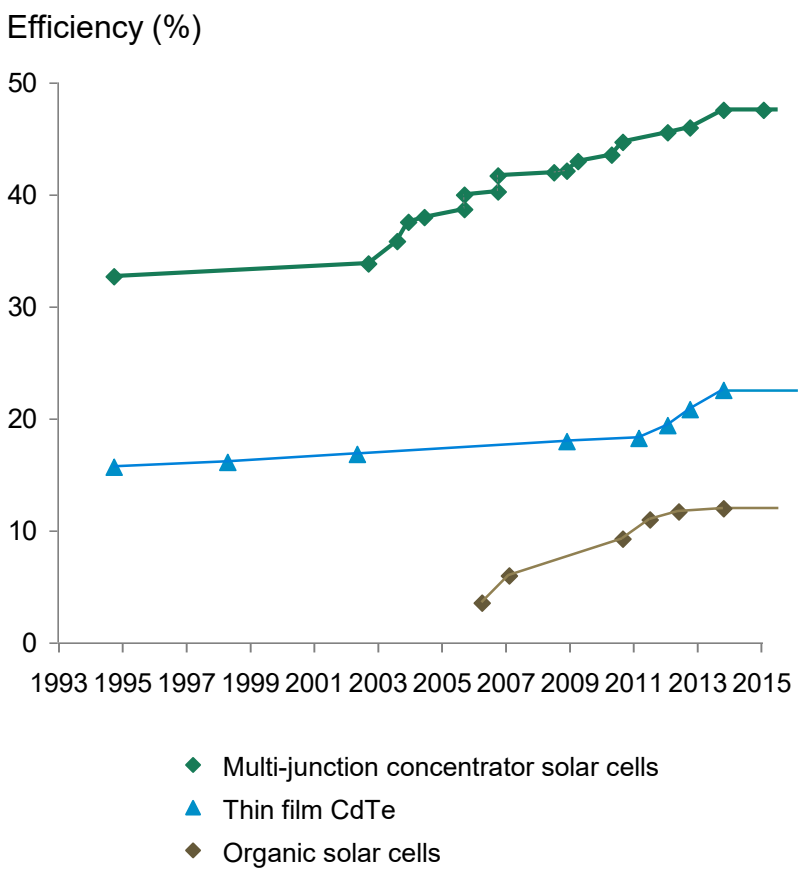
Source: Nature Energy 2017 - The future cost of electrical energy storage based on experience rates

Innovation is driving efficiency and cost reduction

Increasing capacity factors in wind



Improving solar PV cell efficiencies



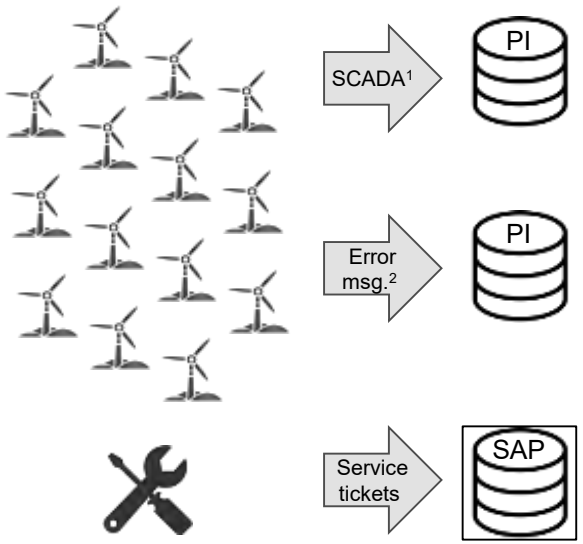
Source: IBA, Fraunhofer

Digital Wind Farm: Big Data and Advanced Analytics as enabler for significant cost savings

Project example

Operating environment

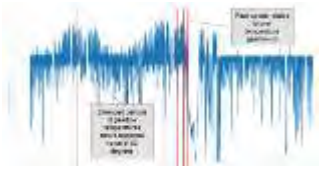
- > 100 Wind turbines



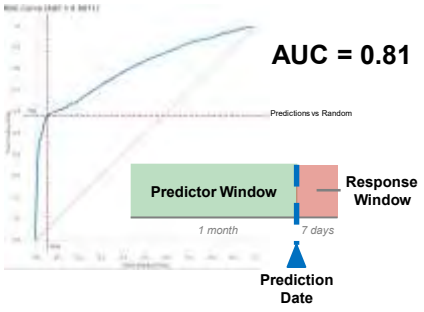
Proof of concept

- Upload to cloud (Redshift)
- Data processing with Alterix
- Modeling with Python
- Visualizing with Tableau

>9TB



- Machine learning with random forest model to predict break downs



Potential impact

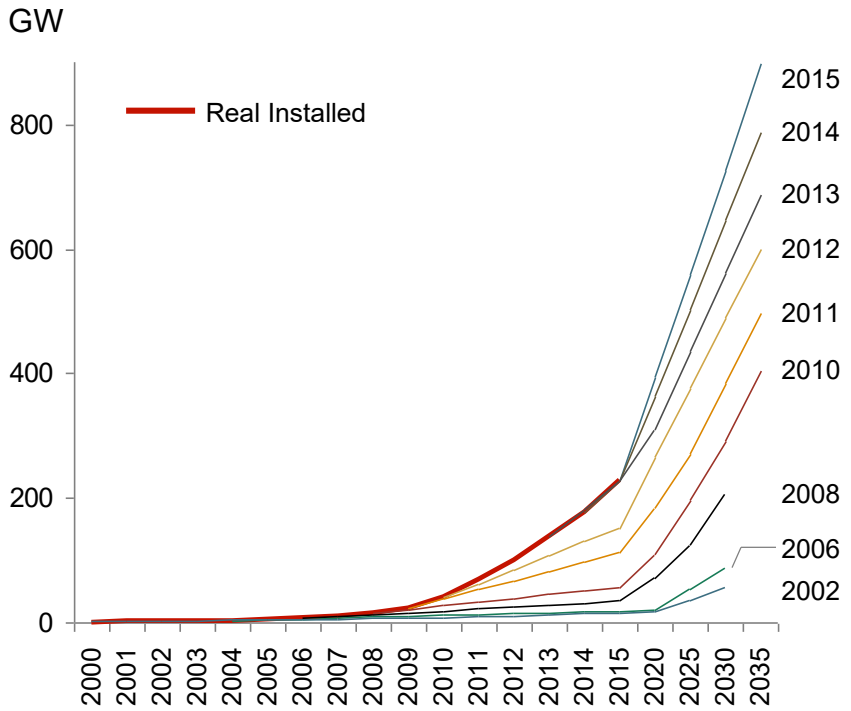
- Service costs are > 75% of OPEX
- Cost saving potential ~70% of service costs; plus 3% higher performance

1. 54 continues signals/values including power and wind speed (10 min interval)
2. 366 different error/status codes

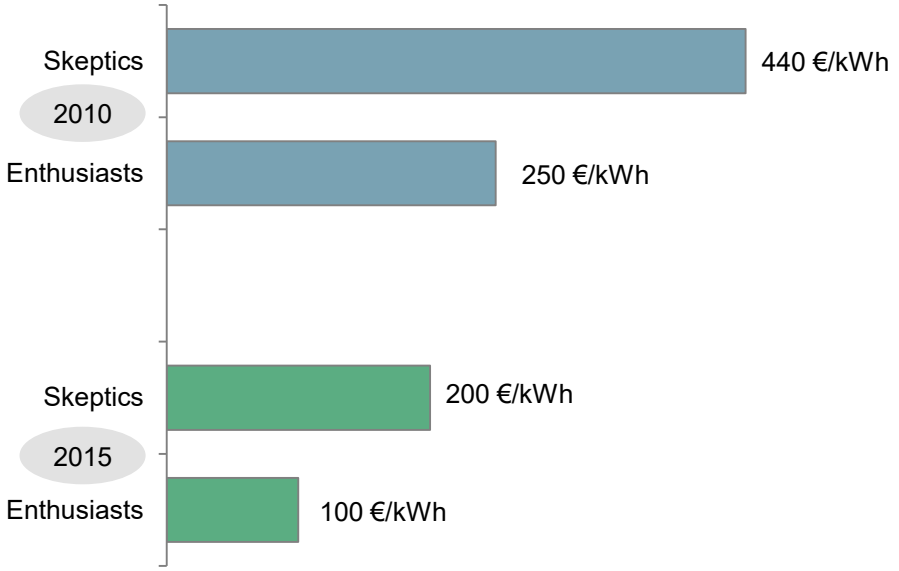
Source: BCG / DAAS / GAMMA analysis

Forecasts are consistently being surpassed

Global PV deployment forecasts



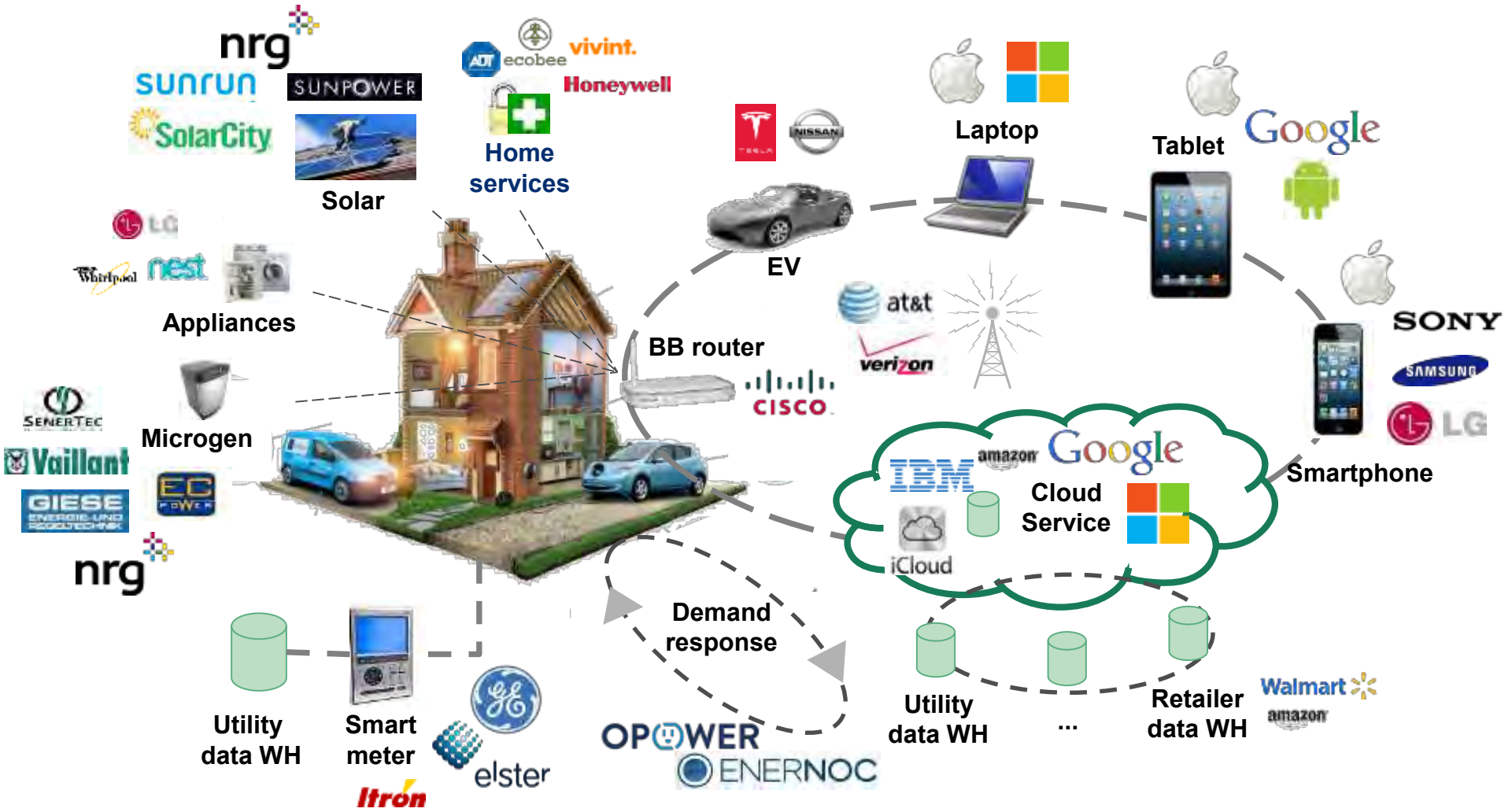
Estimated costs of batteries by 2020



Source: International Energy Agency, EPIA

New technologies mean new incumbents and new products

Example: Distributed Generation and Demand Management



"Utilities are crazy if they don't start offering customers innovative financing packages for solar and distributed generation…because others will."—Honda Executive

High diversity of companies and business models

Example: Distributed Energy

Note: map of examples, not exhaustive
Source: BCG analysis

High diversity of companies and business models

Example: Energy Storage

	U.S. Market Leaders[1]	Other / Emerging Players	Evolution of competition	Current Margins (2016)	Proj. Margins (2020)
Battery Manufacturing	LG Chem, SAFT, BYD, NEC	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	Parker, S&C, Eaton	SMA, ABB	• Entry of low-cost competitors from solar • Limited ability to differentiate on technical capabilities	~7%	~5%
Energy Storage Management Software	Greensmith, Younicos, AES, NEC	1energy, TESLA, S&C, res	• 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	BYD, S&C, Greensmith, AES, res	Schneider Electric, GE, Lockheed Martin	• Increasing competition from upstream players moving downstream • Growing number of modular solutions on market; but value driven by customization	~12%	~8%
EPC	S&C, AES, res *Highly fragmented today*	FJ, Mortenson	• Traditional EPC players building capabilities in energy storage market • High potential for cost reductions with experience; "typical" EPC markups likely	~9%	~7%
Developers	res, AES, Invenergy, NextEra Energy	EDF renewable energy, SolarCity	• Renewable energy developers taking larger position in energy storage market (often paired with renewables sites)	~2%	~4%[2]

Developer margins significantly higher if not acquiring system hardware

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

New technologies allow for new niche players

Example: wind and solar production forecasts

	Wind	Solar
meteomedia	**Wind forecasts** • Combination of 12 meteorological models • Includes local input • High-resolution, particularly in the short term	**Solar forecasts** • Combination of meteorological models and information from 800 stations and satellite • 0-228 hour forecasts • Resolution in 10 minutes
WEPROG	**Wind forecasts** • Intra-hourly predictions • Short and long-term forecasts • 0-168 hour forecasts • Information for all countries	**Solar forecasts** • 0-160 hour forecasts • Management of uncertainty/probabilities • Information for all countries
Fraunhofer IWES	**Wind forecasts** • Prediction of velocity and direction • Extrapolations	--
GL Garrad Hassan	**Short-term forecasts** • Combination of meteorological models • Includes historical wind farm data	**Short-term forecasts** • Combination of meteorological models • Data in the client's format

Source: Company websites

Summary

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

CO_2 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?**