AMER8

The 8th
Asian Ministerial Energy Roundtable

Abu Dhabi | UAE

Plenary Session 1:

The Role of New Technologies for a More Competitive and Productive World Energy Mix

Background Paper

INTERNATIONAL ENERGY FORUM

BOSTON CONSULTING GROUP

Disclaimer

The observations presented herein are meant as background for the dialogue at the 8th Asian Ministerial Energy Roundtable. They have been prepared in collaboration with Boston Consulting Group and should not be interpreted as the opinion of the International Energy Forum or Boston Consulting Group on any given subject

Introduction

Market context

Innovation and new technology deployment change the global geography of energy. With new oil and gas flows emerging, a growing range of countries benefits from efficiency gains, new production and transportation techniques.

On the longer-term clean air, climate, and inclusive economic growth necessitate that the roll out of proven and new technologies accelerates and greater synergies between energy hydrocarbon, renewable, and nuclear sectors are achieved

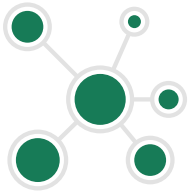
Session objectives

- What initiatives are considered to strengthen research and overcome market hurdles to new technology deployment?
- Which policy and market mechanisms have proven successful to leverage returns to shareholders and the public at large?
- How can policy safeguard predictable and transparent market conditions to mobilise investment timely and efficiently in the age of change?

Key Question

How can Ministers help create an environment conducive to the development of new technologies? How can this be harnessed to benefit host countries?

Strong rationale to develop new technologies in the energy sector …



Become a hub for the research, development and manufacturing of technology-intensive and renewable technologies, attract and develop best talent

Increase competitiveness of energy sector

Reduce the cost of energy production, both primary extraction as well as generation.

Increase competitiveness of energy intensive industries

Reduce CO2 emissions and environmental footprint of energy sector.

Make the energy sector future proof

Energy transitions pose new value propositions for industrial growth in Asia

… and in adjacent sector: Plastics have powered human progress but their disposal is becoming a complex challenge

From the excitement of Throwaway Living …

… to the reality of living with all the plastic we have thrown away

A Patch of Plastic Garbage in the Pacific Ocean Amounts to Twice the Size of Texas, a New Study Says

Ocean plastic waste set to triple within a decade, government scientists warn

Source: "Throwaway Living" copyright of Life Magazine, 1955; Plastic Oceans; Evening Standard; Time; Financial Times; National Geographic

Contents

Energy innovation has a material impact on competitiveness

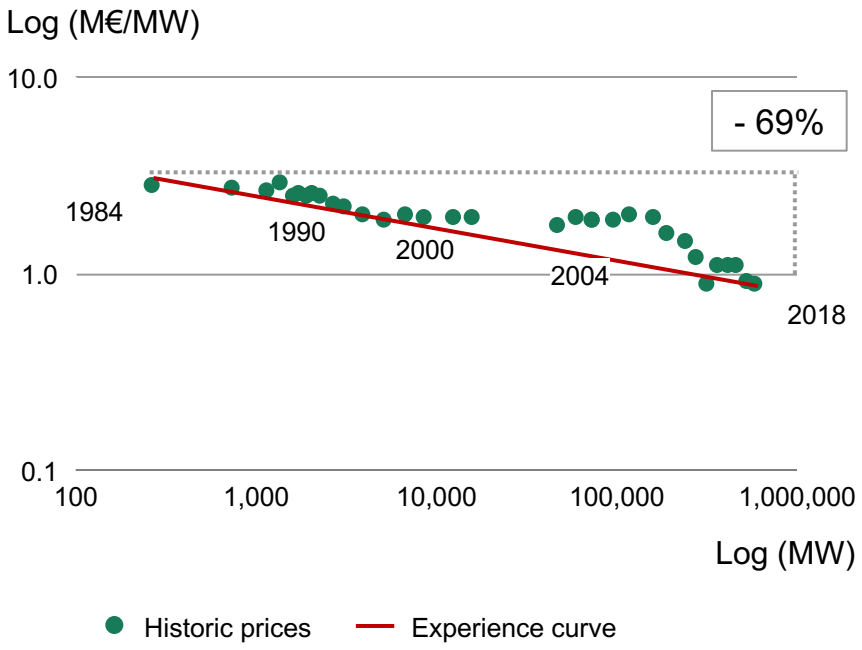
Digital in energy is the new wave of disruption

Energy companies are very active in technology development

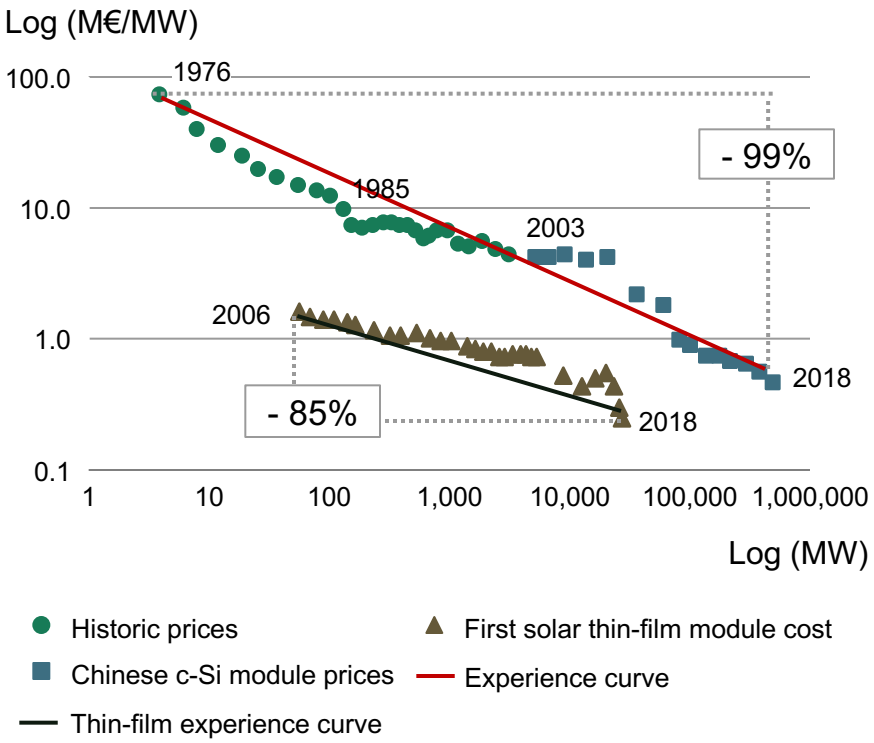
Key questions and discussion

We are experiencing steep price declines in renewable technology as we continue to ride the experience curve

Wind turbine price index 1984–2018

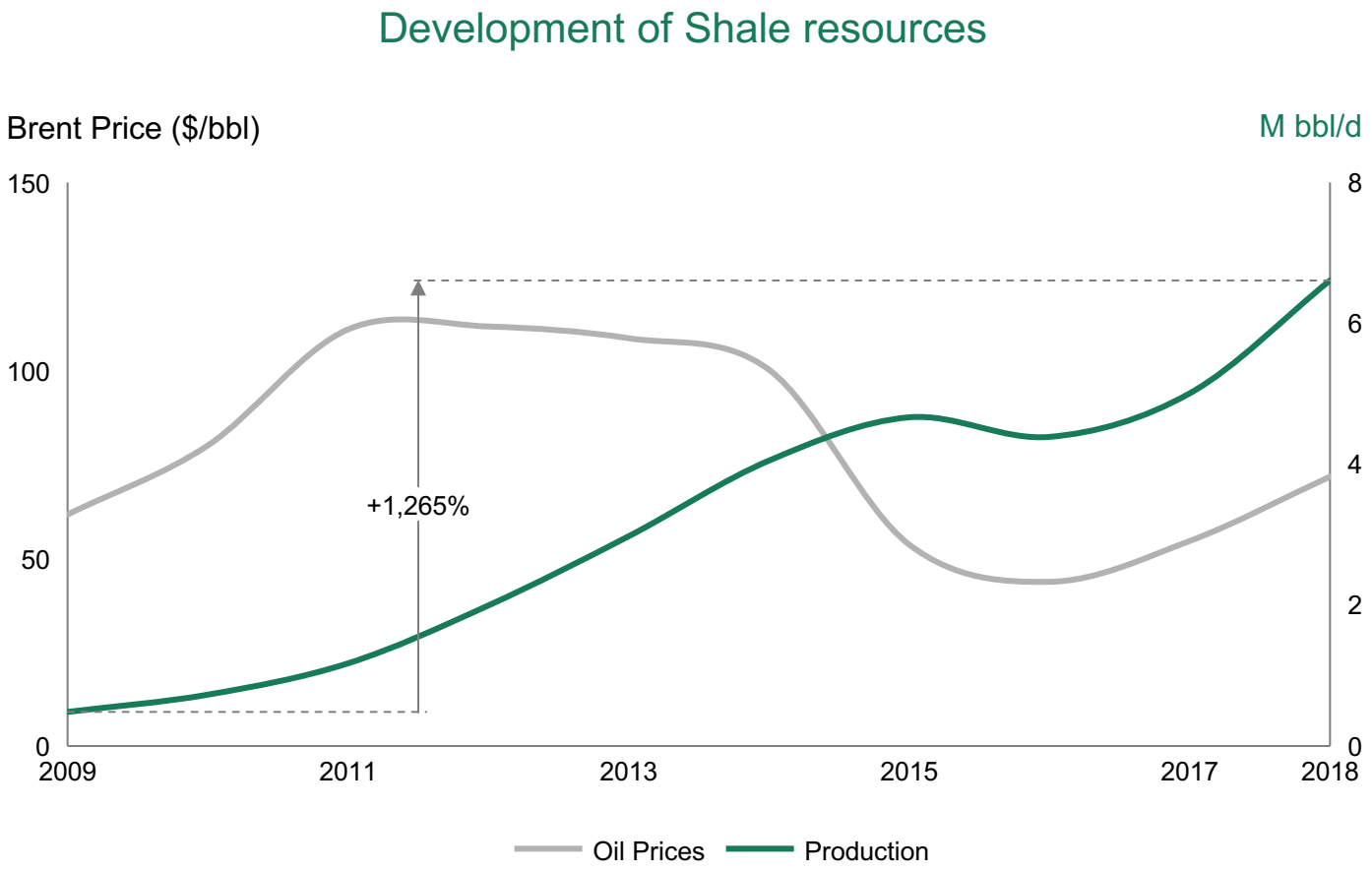


Solar PV module experience curve 1976–2018



Source: Bloomberg new energy finance; Lawrence Berkeley laboratory

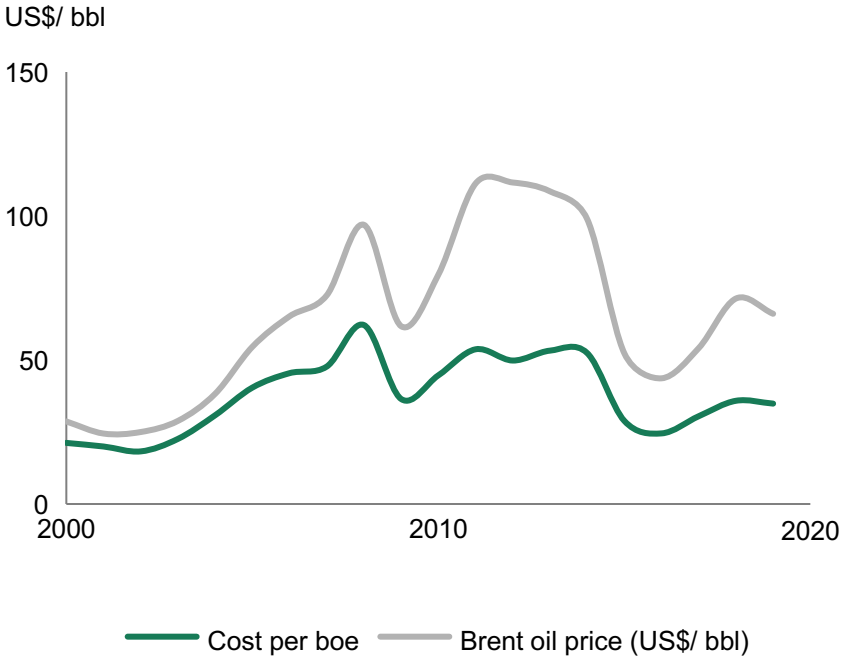
In conventional energy, high prices have also driven technology development



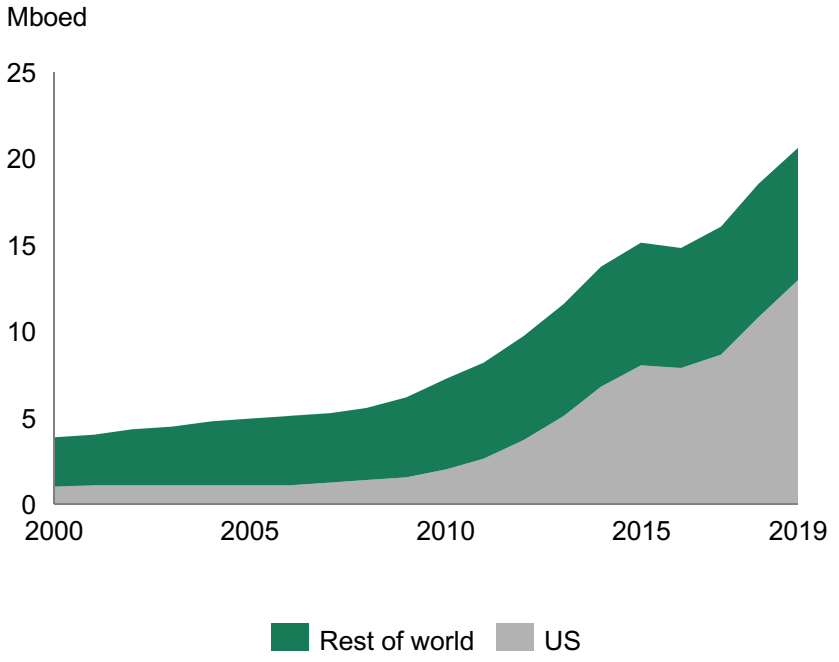
Note: Production analyzed includes crude oil only
Source: Rystad Energy (August 2019), BCG analysis

In fact, technological disruption also has a significant impact on unconventional energy

Price evolution of cost per barrel global unconventionals



Evolution of production from unconventionals



Note: Production analyzed includes crude oil only
Source: IEA, Rystad Energy (August 2019), BCG analysis

Example of innovation in unconventional production

Single-Well Pad (1 well)

- 1x Separator
- 5x Tanks
- 1x Flare/VRU

Total Cost: ~$0.5 – $0.7M
Cost/Well: ~$0.5 – $0.7M

Multi-Well Pad (6-8+ wells)

- 1x Test separator
- 9-12x Tanks
- 2x VRU
- **1x Manifold**
- **1x Bulk separator**

Total Cost: ~$3.0 – $4.0M
Cost/Well: ~$0.4 – $0.6

Centralized Tank Battery (18-40+ wells, 3-5 pads)

- 4-6x Test separator
- 27-60x Tanks
- 7-10x VRU
- 4-6x Manifold
- 2x Bulk separator
- **Pipeline**

Total Cost: ~$8.0 – 14.0M
Cost/Well: ~$0.3 – $0.5

Scale and consolidation driving efficiencies

Source: 2016 BCG UPD

Technology increasingly enabling reduction in emissions

ExxonMobil — Upgradation of 99% of high-bleed controllers to reduce methane emission

eni — 66% reduction in fugitive methane emissions in 2017 over 2014 levels

أرامكو السعودية saudi aramco — Low carbon intensity due to advanced efficient reservoir management technologies

REPSOL — Substituting 5,000 high-bleed pneumatic devices for low-bleed ones

TOTAL — 80% reduction in routine flaring between 2005 and 2017

Piloting a methane detector technology to continuously monitor methane emissions in shale sites

Product innovations also drive recycling and recyclability

BASF
We create chemistry

Additives and stabilisers to extend recycling lifecycle

Recycling requires process steps that consume thermal stabilizers originally in plastic materials. These steps can stress the plastic and limit further use

BASF offers a line of stabilizers targeted to recycled plastics to improve quality and applications of recycled plastics

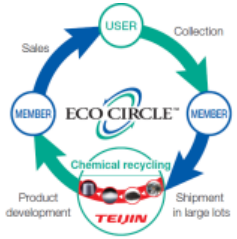
DOW

Mono-material pouches

- Up to 83% less plastic
- High recyclability thanks to its mono-material composition
- Consumes 54% less total energy
- Up to 90% less post-consumer solid waste

Ultimately these innovations help differentiate the portfolio and extract more premium value for the consumer

Efforts are underway to develop depolymerization technologies and secure economic feasibility



Teijin "ECO CIRCLE™" system

Developed its own technology (2002) and operated a manufacturing plant in Japan, but had to shut down the business in 2008 due to the rise in PET bottle prices. Shifted strategic focus to partnerships

Implemented a circular ecosystem by partnering with licensing client companies since mid-2000s (150+ partners)

Invested in building a plant in China with the new technology through JV with a Chinese player

Gr3n "DEMETO" Consortium

Depolymerization by microwave technology

- Reduced the reaction time using a microwave (180 min --> 10 min)

Easier to recycle fiber-based PETs such as carpets and textile fabrics which are difficult to recycle using conventional methods

Process is being tested based on EU plastics recycling fund/DEMETO consortium guidelines

- Participants: H&M, Coca cola, EUPC, Nestle, SUEZ, etc.

Loop™ Industries

'Zero energy depolymerization' technology that decomposes PET into DMT/MEG monomer under ambient temperature and pressure

Planning to build a pilot plant and test commercialization through JV with Indorama ('18)

- 21kt size plant to begin operation in 2020

Partner with global consumer goods firms including Pepsi, Nestle, Danone/Evian for future supply plans

Source: Company IR, Press search

Big value potential to develop and commercialize technology across all recycling methodologies

60+ technology providers globally at different levels of maturity

apc Agile Process Chemicals LLP
CARBIOS Reinvent Polymers Lifecycle
loop INDUSTRIES
TYTON BioSciences
Enerkem
Resynergi evolutionary energy recovery systems
GARBO your innovative partner
nexus FUELS
CreaCycle GmbH
Ioniqa Technologies
worn again technologies
PYROWAVE CLOSING THE LOOP
agilyx Reduces. Produces. Creates.

agilyx Reduces. Produces. Creates.

Companies are also participating in multiple part of chain

- Founded in 2004, Agilyx began as a thermal conversion technology provider converting mixed plastics into liquid oil products.
- Volatile and low oil prices inspired Agilyx to adapt technology to develop a Polystyrene-to-Styrene Monomer (PSM) System (chemical feedstocks)
- They now have a dual revenue model of producing both chemicals and fuels

"Alliance to End Plastic Waste" advances circular economy solutions

ALLIANCE TO END PLASTIC WASTE

AEPW is an alliance formed in Jan 2019 by 25+ companies to minimize plastic waste and promote solutions for used plastics

Founding members include

DOW, SCG, Shell, BASF We create chemistry, TOTAL, NOVA Chemicals, sabic, Mitsui Chemicals, lyondellbasell, 台塑企業, MITSUBISHI CHEMICAL, SUMITOMO CHEMICAL Co., Ltd., Chevron Phillips Chemical Company LP, ExxonMobil, sasol

Key actions to date

- Funding of The Incubator Network, to build ecosystems of waste management and recycling innovators
- Partner with cities like Project Stop in Indonesia to design, implement and scale circular economy solutions to marine plastic pollution
- Supporting Renew Oceans to capture plastic waste before it reaches the ocean from the ten major rivers

AEPW has committed over $1.0B with the goal of investing $1.5B over the next five years to help end plastic waste in the environment

Inaction is not an option - We should act now to adapt to new market and regulation needs

Tajikistan to abandon use of plastic bags

04 July 2018 - 18H13

Chilean court ratifies plastic bag ban after appeal

WorldViews

Mumbai's plastic ban carries costly fines and jail sentences for offenders

RECYCLING

IKEA U.K. and Ireland to Ban Single-use Plastic Straws

U.S. NEWS 07/16/2018 11:28 am ET | Updated 1 day ago

Adidas Pledges To Only Use Recycled Plastic By 2024

Polyester, which is made from plastic, currently makes up about 50 percent of the material in Adidas' products.

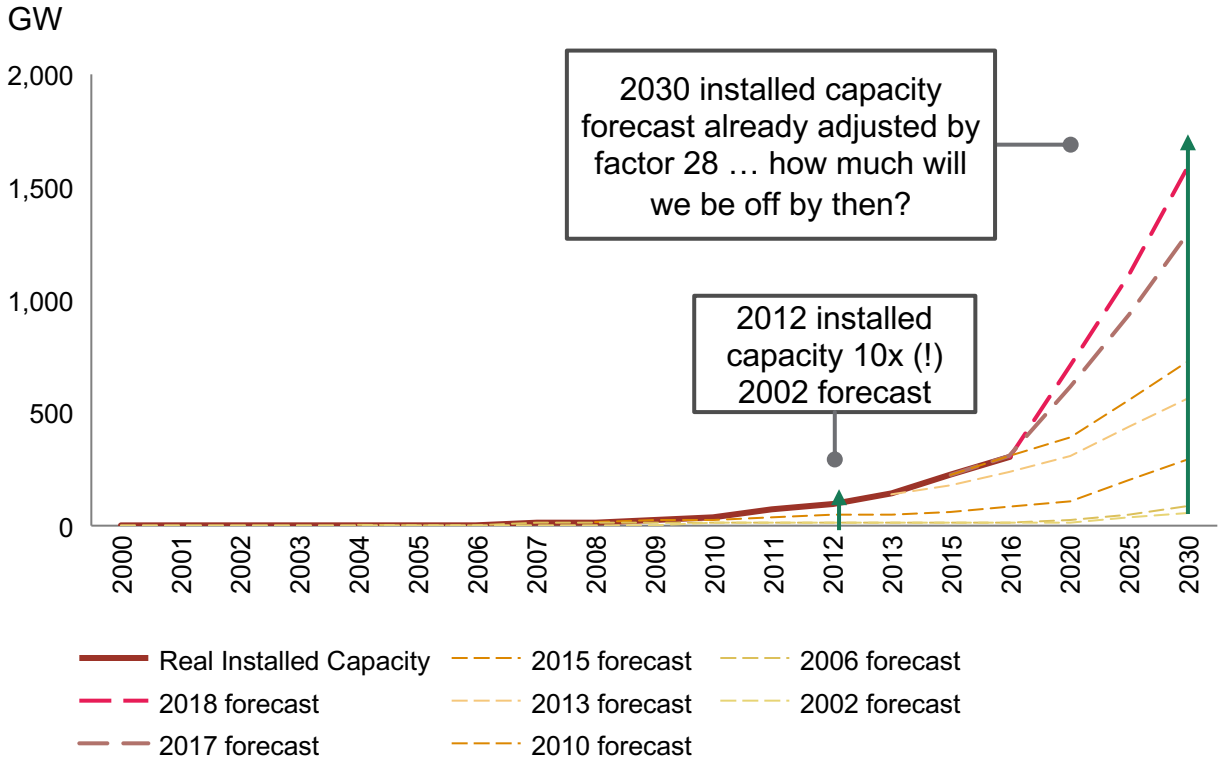
Why Starbucks, Seattle, and Tom Brady are all shunning plastic straws

BUSINESS • BRANDS

Marriott Will Stop Using Plastic Straws in all of its Hotels by 2019

In the past, forecasts of global solar capacity growth have underestimated the reality by a factor of 28 …

Evolution of Global PV forecasts, 2002–2018



Source: International Energy Agency, IRENA, GTM

Implications

- In the last years, **global silicon oversupply** and regional push for capacity build-up (e.g., China) resulted in comparably **low silicon prices**
- But **volumes higher than expected** by many analysts even on one year time horizon, even more so on 5-10y time frame
- Thus silicon plant planning time horizon (>3y) with **risk to take conservative investments**
- Therefore **undersupply situation can develop** again, even though 2008 will not repeat itself

Contents

Investments will foster the expansion of new technologies

Big data and analytics

Cloud computing

Sensors

3D scanning

Mobile connectivity

Collaborative tech. platforms

Real-time comms & tracking

Additive manufacturing

Virtual reality

Unmanned aerial vehicles

Robots and automation

Cyber-security and blockchain

Time is right for the oil and gas industry to unlock the full potential of IoT

Continued cost pressures

Recent volatility and downward pressure on Oil and Gas prices has forced companies to improve operational efficiency, one way being the improved data collection and management of their assets and operations

Increased operations complexity

The search for new Oil and Gas reserves has led to an increased number of operations in more remote locations and growing challenges to find new resources, making it necessary to increase and improve data gathering and analytics

Growing pressure on CAPEX

The current size of O&G companies' asset portfolio requires better insights into equipment performance and health in order to keep capital costs in check in today's highly competitive environment

Growing lack of skilled labor

The decreasing numbers of skilled Oil and Gas professionals are forcing companies to find new ways of optimizing operations and reducing the need for on-site experts

Heightened HSE awareness

The high potential for environmental harm and risk of hazards for on-site workers have resulted in increased public scrutiny and demands for better oversight and prevention through data management

All of the above require innovative digital solutions that feed from data generated along the value chain

E&P companies are getting serious about digitalization

Established digital center of excellence

Looks to big data to help weather weak oil price

Partnership with microsoft to fuel digital transformation

Launching second plant 4.0 start-up incubator

Created new digital ventures

Digital can unlock significant value

Exploration	Field development	Drilling[1]	Operations/Production
Accelerate interpretation with machine learning	Fully optimize field architecture with smart and integrated modeling Synchronize project build using Digital Twins and BIM[2] Optimize for constructability and cost	Faster well delivery with closed loop automation Optimize well design using data analytics	Optimize production with real time data and advanced models enabled by IIoT[3] Optimize uptime using predictive maintenance and Digital Twins
50-60% reduction in interpretation time and cost	(up to) 70% reduction in engineering hours and higher value field concepts	20-30% Faster well delivery and more productive wells	3-5% Increased production[4] 20-40% Reduced maintenance cost

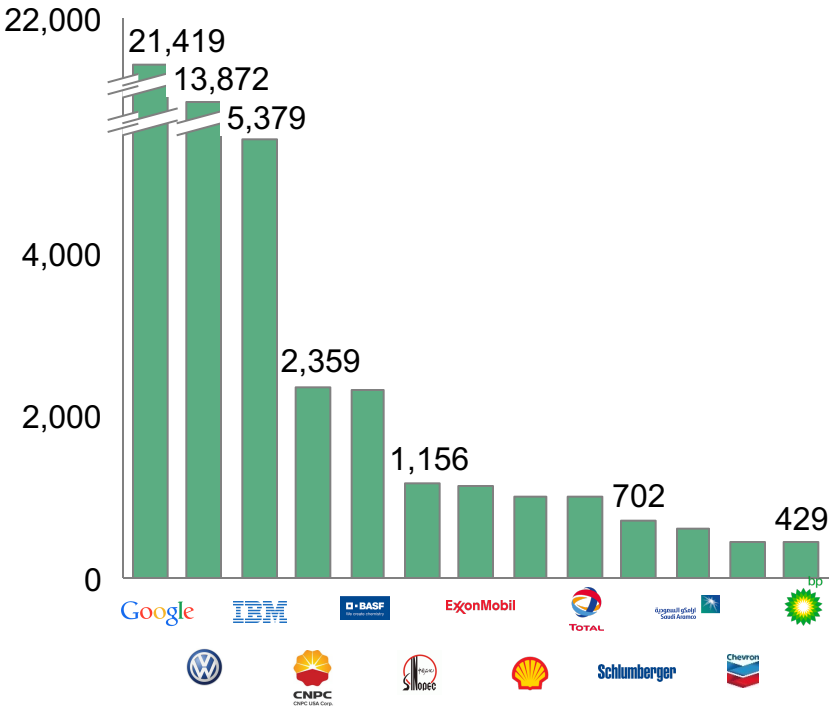
1. Drilling covers E&A and Development/Infill drilling 2. Building Information Modeling 3. Industrial internet of things 4. Assuming marginal value of US$50 per additional bbl
Source: BCG project experience, BCG Analysis

Contents

Major E&P players invest actively in R&D

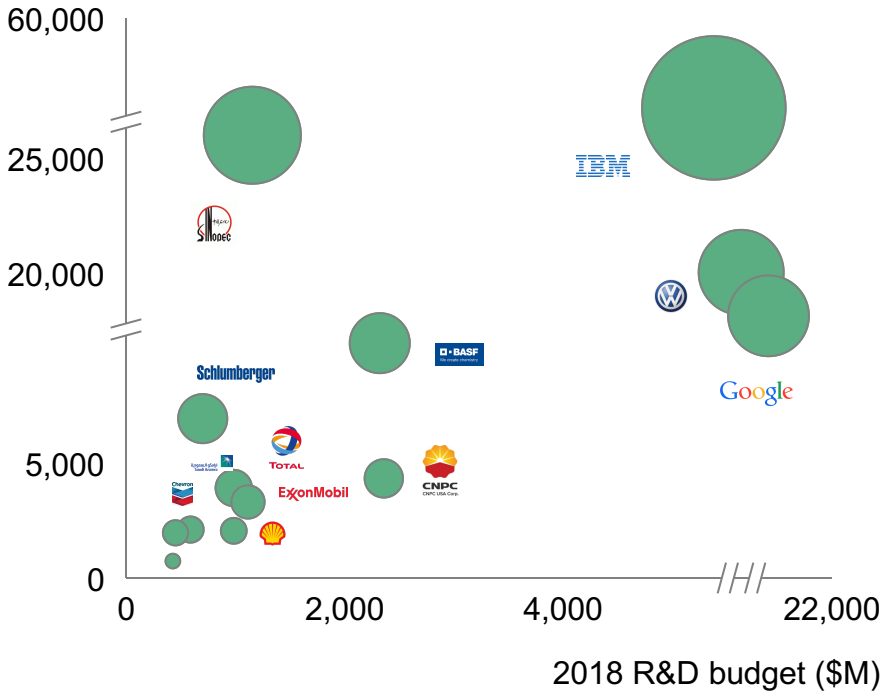
They spend ~$1B on average annually …

2018 R&D budget ($M)



… and have amassed a formidable IP base

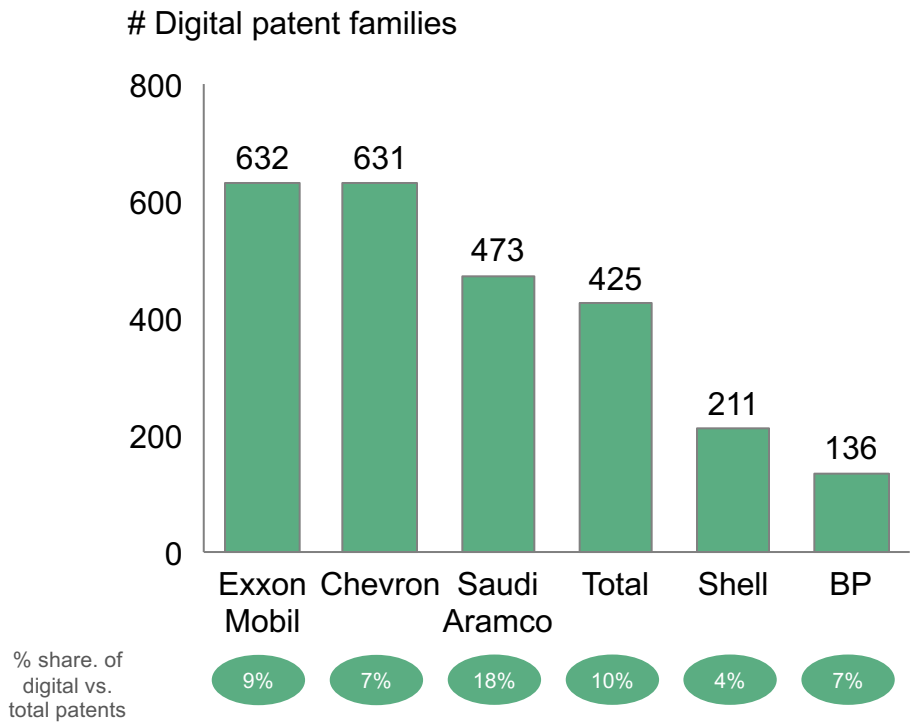
No. of patent families1,2 2013-2019



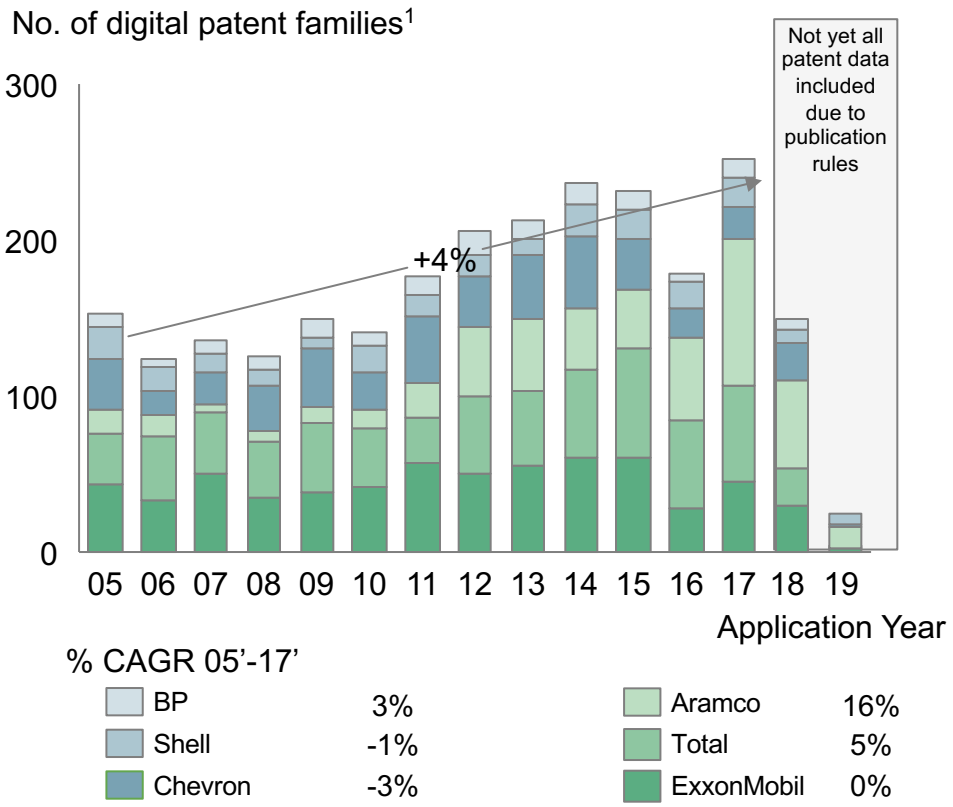
1 A collection of patent records that relate to the same innovation. For example, a patent describing a single innovation by the same group of inventors is filed in multiple jurisdictions and published at multiple stages. A patent family groups these records and selects one representative of the family; Analysis is based on R&D budget for 2018 and patents filed since 2013 for players of interest.
Source: Capital IQ, Derwent Innovation; BCG Analysis

Digital patents by oil companies continue to grow

Digital patents account for around 10% of total patents for Oil & Gas companies



..but this number continues to grow



1 A collection of patent records that relate to the same innovation. For example, a patent describing a single innovation by the same group of inventors is filed in multiple jurisdictions and published at multiple stages. A patent family groups these records and selects one representative of the family; Analysis is based digital patents filed by O&G players of interest since 2005.
Source: Capital IQ, Derwent Innovation; BCG Analysis

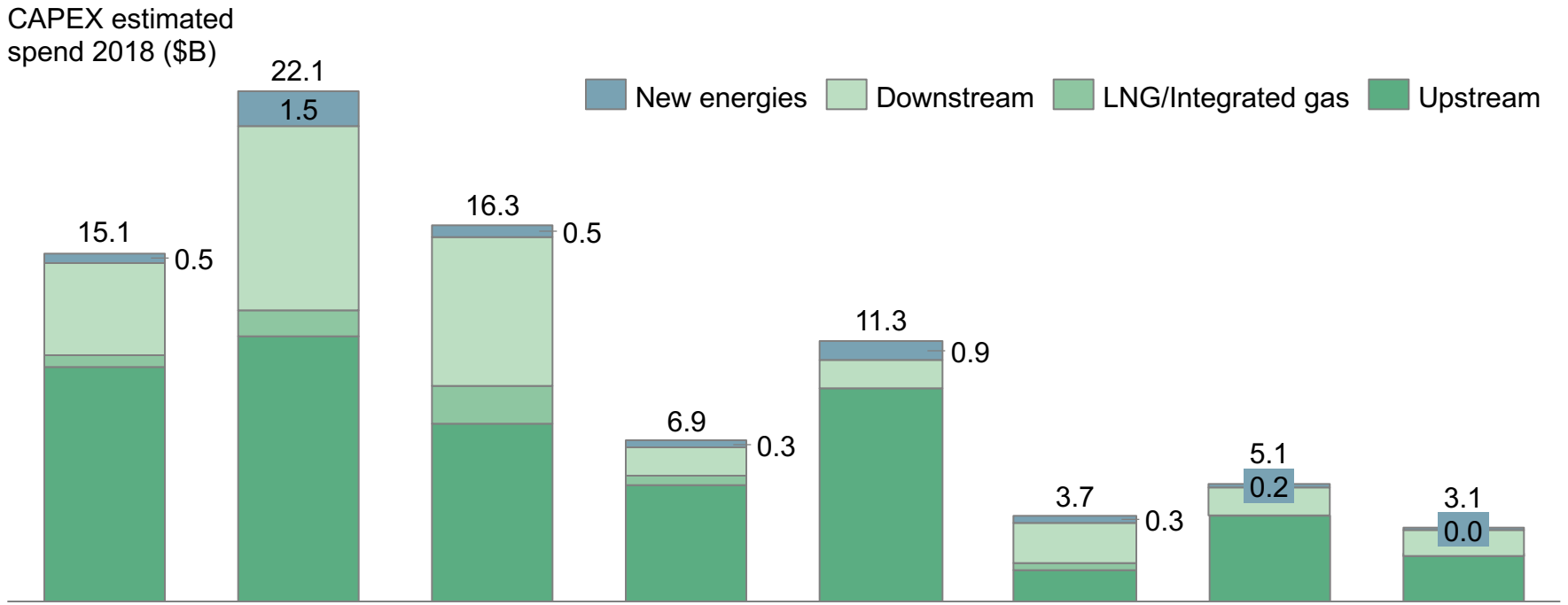
O&G companies are expanding into energy efficient and green technologies

	Shell	Total	Equinor	BP	Repsol	Chevron	Eni	ExxonMobil
Power	• Acquisition of First Utility for 200M$ • Trading power in US and UK	• Acquisition of Direct Energy for $1.7 bn			• Buyout of Viesgo, Spanish utility		• Target: 2M power & gas clients in 2021 • 50M$ in Nuclear	
RES	• Investor on wind and solar projects in USA and EU	• Developer of more of 400 MW of solar PV in Asia	• Leading offshore wind industry • Funding 10M$ on solar cell research	• 1.5 GW of wind in US • Owner of Lightsource, PV developer	• Owns a stake in Principle Power, offshore wind platforms EPC	• Key global player in geothermal development	• PV/Wind projects in Italy, Africa and Middle East	
DER	• Acquisition of Demand Response company MP2 • 60M$ finance in Sonnen (home battery solutions)	• Owner of SunPower and Saft (battery OEM)	• Investment in Convergent energy storage developer	• Research on fuel cells through its New Ventures division				
BIO/ Synthetic fuels	• JV with Raizen, Brazilian sugar cane produced 2 bn liters ethanol in 2017	• Le Mede refinery, conversion to biofuel from oils		• JV with Bonsucro Brazilian sugarcane prod. • JV with Dupont developing Butamax	• Owns several refineries for processing HVO and Algae biofuels	• Attempts have been non-commercial	• Primary producer of green diesel in Europe	• Investing in second generation biofuels (Algea) 1B$
CCS	• Quest CCS in Alberta; Technology Center Mongstad	• R&D	• World leader in CCS	• Owner of Solida, use of CO_2 for processing concrete		• Gorgon and Quest CCS investment totaling $1.1B		• Participated in 1/5 of the global CCS capacity
Advanced mobility	• Consortium with German Govt. to develop 400 hydrogen fuel stations • Investing in fast charging solutions	• JV with Clean Energy Fuel for developing of NG trucks • Acquisition of PitPoint provider of clean fuels in Europe	• Investment in ChargePoint world's largest EV charging network	• Acquisition of StoreDot (20 M$) OEM batteries for use in EVs	• 50% IBIL, operating 700 Charging points			
EE and carbon sinks	• Small VC investments through Shell Ventures			• Research on carbon Management through its New Ventures division				• Development of energy efficient tyres, lubricants and plastics

Level of activity — High — Medium — Low — None

Source: Companies websites, Clean Energy Pipeline; BCG analysis

New energies investment of ~5% done by global majors every year



New Energies %)	3.3	6.8	3.1	4.3	7.5	6.8	2.9	1.0

Source: Rystad Energy, company reports/presentations and estimates based on available information

Majors are increasingly investing in renewables technology

2016	2017	2018
Saft–Batteries	MP2 Energy–Demand Response Solutions	Silicon Ranch–Solar power
Lampiris-Natural gas and renewable power	New Motion–EV charging	Husk Power System-Distributed energy, mini-grids
United Wind–Small wind turbines	SolarNow-Off-grid solar	British Solar Renewables-Solar power
Convergent-Energy storage	SteamCo-Smart meters	First Utility-Energy and broadband
Oxford PV–Solar power	Eren RE–Renewable power	Direct Energy-Residential power
ChargePoint-EV Charging	Greenflex–Energy efficiency	StoreDot–EV batteries
	Lightsource–Solar power	Chargemaster–EV charging
		Common Fusion Systems-Fusion power

Source: BCG energy practice

Majors have set up corporate venture capital funds to invest in energy efficiency and renewable energy

	Fund Name	Total Investment[1]	Year of Setup	Focus Technologies
bp	AE Ventures	$200M	2006	Biofuels, O&G and energy efficiency
Chevron	Chevron Technology Ventures	$250M	1999	O&G, alternative energy, advanced materials, energy transition
	Future Energy Fund	$100M	2018	Energy efficiency, alternative fuels, grid management
ConocoPhillips	Energy Technology Ventures	$300M	2011	Renewables, smart grid, energy efficiency, fossil energy, nuclear, water
TOTAL	Total Energy Ventures	$175M	2016	Renewable energies, energy efficiency, waste management
equinor	Equinor Technology Invest	$135M	2000	Upstream O&G, renewable energy
	Equinor Energy Ventures	$200M	2016	Renewable energy, energy storage, EV charging, solar, wind
ارامكو السعودية Saudi Aramco	Saudi Aramco Energy Ventures	$120M p.a.	2012	O&G, renewable energy, energy efficiency, water

1. Investment over the period: BP - 2006-13; Chevron – $250M since 1999, $100M since 2018; ConocoPhilips – since 2011; TOTAL – as of 2016; Equinor – $135M 2000-16 and $200M 2016 onwards for 4-7 years; Saudi Aramco – up to $120M per year since 2012
Source: BCG Energy Practice

Oil and gas climate initiative OGCI was launched in ‘16

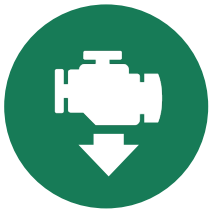
A $1B investment vehicle

OGCI CLIMATE INVESTMENTS

OIL AND GAS CLIMATE INITIATIVE

Carbon capture, utilization, and storage (CCUS)

Reducing methane emissions



Reducing transport emissions

Improving energy efficiency in industry

Chevron · eni · Shell · bp · equinor · REPSOL · OXY Occidental Petroleum · PETROBRAS · PEMEX · CNPC · أرامكو السعودية saudi aramco · TOTAL · ExxonMobil

Source: OGCI

Contents

Challenges of promoting technologies in the energy sector

Key questions

1. What initiatives are considered to strengthen research and overcome market hurdles to new technology deployment?

2. Which policy and market mechanisms have proven successful to leverage returns to shareholders and the public at large

3. How can policy safeguard predictable and transparent market conditions to mobilise investment timely and efficiently in the age of change?

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

AMER8

The 8th
Asian Ministerial Energy Roundtable

Abu Dhabi | UAE

Plenary Session 1:

The Role of New Technologies for a More Competitive and Productive World Energy Mix

Background Paper

IEF INTERNATIONAL ENERGY FORUM

BCG BOSTON CONSULTING GROUP

AMER8