Shell Scenarios

Sky

Decarbonizing the Industrial Sector

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WARNING: Uncertainties ahead

This presentation contains data from Shell’s new Sky Scenario. Unlike Shell’s previously published Mountains and Oceans exploratory scenarios, the Sky Scenario is targeted through the assumption that society reaches the Paris Agreement’s goal of holding global average temperatures to well below 2°C. Unlike Shell’s Mountains and Oceans scenarios which unfolded in an open-ended way based upon plausible assumptions and quantifications, the Sky Scenario was specifically designed to reach the Paris Agreement’s goal in a technically possible manner. These scenarios are a part of an ongoing process used in Shell for over 40 years to challenge executives’ perspectives on the future business environment. They are designed to stretch management to consider even events that may only be remotely possible. Scenarios, therefore, are not intended to be predictions of likely future events or outcomes and investors should not rely on them when making an investment decision with regard to Royal Dutch Shell plc securities.

Additionally, it is important to note that Shell’s existing portfolio has been decades in development. While we believe our portfolio is resilient under a wide range of outlooks, including the IEA’s 450 scenario (World Energy Outlook 2016), it includes assets across a spectrum of energy intensities including some with above-average intensity. We seek to enhance our operations’ average energy intensity through both the development of new projects and divestments, we have no immediate plans to move to a net-zero emissions portfolio over our investment horizon of 10-20 years. Although, we have no immediate plans to move to a net-zero emissions portfolio, in November of 2017, we announced our ambition to reduce our net carbon footprint in accordance with society’s implementation of the Paris Agreement’s goal of holding global average temperature to well below 2°C above pre-industrial levels. Accordingly, assuming society aligns itself with the Paris Agreement’s goals, we aim to reduce our net carbon footprint, which includes not only our direct and indirect emissions, associated with producing the energy products which we sell, but also our customers’ emissions from their use of the energy products that we sell, by 20% in 2035 and by 50% in 2050.

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Navigating 21st century turbulence

Demand growth
Coal remains popular
Efficiency rebound
Difficult Sectors
Stalled Technologies
Time

“A Better Life with a Healthy Planet”
In Sky, six big steps forward from now to 2070... illustrating the interplay of technology innovation, public policy, market forces, and human behaviour

- Carbon pricing
- Energy efficiency
- Electrification of final energy
- Growing new energy systems
- Carbon capture and storage
- Ending deforestation

...underpinned by a changing consumer mind-set and societal license for change.
Carbon pricing is an important driver for change in the industrial sector

**Carbon prices in Sky, $/tonne CO₂**

- **Unwavering acceleration and coordination:**
  - Market & fiscal mechanisms
  - Standards & mandates
  - Investments in infrastructure & technology

Source: Shell analysis, Sky scenario
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Sky sees a major ramp up in electrification, including within industry

**Electricity as a % of final energy use**

The transition in **Sky** is at least triple the historic rate

Historic electrification trend is ~2% points per decade

Source: Shell analysis, Sky scenario
Copyright of Shell International B.V.
Step 4 – New energy systems emerge
The major sources of primary energy shift in Sky

World total primary energy by source, EJ/year

Source: Shell analysis, Sky scenario
Copyright of Shell International B.V.
In Sky, deep electrification, but molecules remain important

Global end-use energy consumption, EJ/year

- **Solid Fuels**: Coal, Biomass
- **Gaseous Fuels**: Natural Gas, H₂
- **Liquid Fuels**: Oil, Biofuel
- **Electricity**

Source: Shell analysis, Sky scenario
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An incremental path for industry in Sky driven by carbon pricing

- Efficiency improves continuously
- Product substitution plays a role
- From 2020 to 2040, many light industries shift to electricity
- By 2050, hydrogen has also appeared in light industry
- From 2030, CCS appears in heavy industry
- After 2050, hydrogen emerges in the heavy industry sector, eventually backing out some CCS
- Remote sinks, such as BECCS, play some role for industry in the second half of the century
Hydrogen becomes significant in the second half of the century

A hydrogen based energy delivery system

Supply

Demand

Source: Shell schematic
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Hydrogen emerges at scale in the 2030s
The heavy industry story in Sky

Energy use, EJ per year

- Hydrocarbon use
- CO₂ captured
- Electricity use
- Biomass use
- Hydrogen use

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Hydrogen for iron ore smelting

BLAST FURNACE ROUTE

Fossil fuels → IRON ORE CONCENTRATE
Coal → IRON ORE PELLETS
Coke Plant → Coke
Hot Blast Coal, Oxygen → CO₂

IRONMAKING

CO₂

STEELMAKING

Oxygen → HOT METAL
CO₂

Hydrogen → SPONGE IRON

CRUDE STEEL

HYBRIT ROUTE

Non-fossil fuels → IRON ORE PELLETS

Hydrogen & water → Hydrogen
Hydrogen Plant → Hydrogen Storage
Electricity → Hydrogen
A man-made sink: Carbon capture and storage (CCS)

1. Capture
2. Transport
3. Storage
4. Measuring

2000m
Bioenergy with CCS has an important role to play

Energy crops
- High biomass yield
- Extensive availability

Biomass residues

Capture
- Compression transport

Geological storage

Carbon dioxide (CO₂)
- Combustion
- Fermentation
- Aerobic digestion
- Gasification

Fuel upgrading
- Gas cleaning
- Liquidation

Energy products
- Heat
- Biohydrogen
- Biomethane
- Synthetic biofuels
- Electricity

Non-energy by-products
- Saline aquifers
- Depleted oil and gas fields

Source: Shell schematic
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Sky: Achieving the balance

Net emissions
35.2 Gt
(all emissions are Gt of CO₂)

Fossil fuels
37.8 Gt

Bioenergy production and use
6.7 Gt

Photosynthesis
6.7 Gt

2.6 Gt

Source: Shell analysis, Sky scenario
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Sky: Achieving the balance

Source: Shell analysis, Sky scenario
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Sky: Achieving the balance

Emissions from biofuel use

2070

15.1 Gt

Fossil fuels

6.5 Gt

3.4 Gt

6.5 Gt

Geological storage of CO₂

6.1 Gt

0.4 Gt

21.6 Gt

Source: Shell analysis, Sky scenario

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Sky: Achieving the balance

- Fossil fuels: 13.7 Gt
- Geological storage of CO₂: 8.3 Gt
- Emissions from biofuel use: 16.1 Gt
- Photosynthesis: 26.1 Gt
- Net-negative emissions: 6.4 Gt

Source: Shell analysis, Sky scenario
Today – a fossil fuel backbone

- Oil
- Gas
- Coal
- Nuclear
- Biomass
- Solar
- Wind
- Electricity
- CCS
- Hydrogen
- Fossil fuel production
- Heavy industry
- Manufacture
Sky – an electricity backbone

- Oil
- Gas
- Coal
- Nuclear
- Biomass
- Solar
- Wind
- Electricity
- CCS
- Hydrogen
- Fossil fuel power
- Heavy industry
- Manufactured products

CO₂
Additional reading and the Sky dataset

www.shell.com/skyscenario