Europe's Long Term Vision on Abiotic Resources

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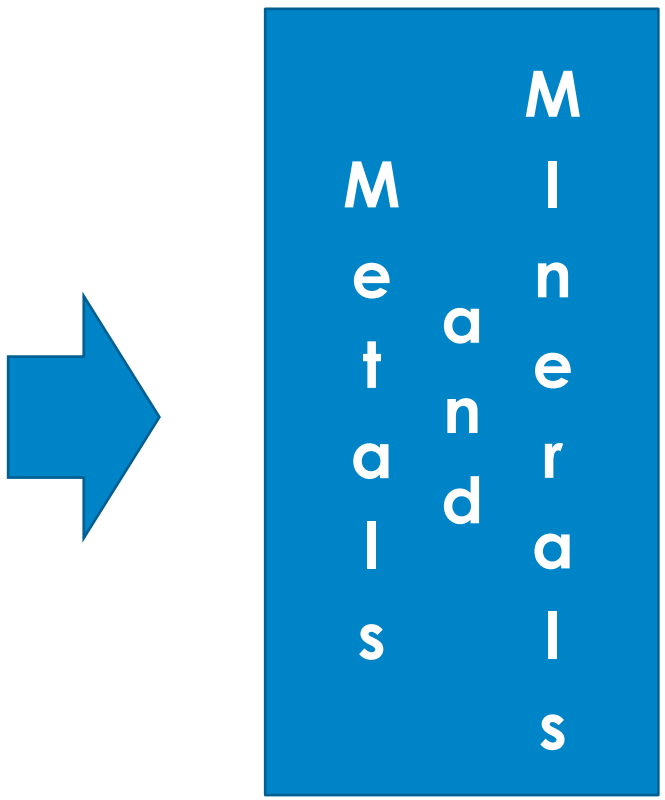
Veram Stakeholder Workshop
Brussels, June 2017

Four key global challenges till 2050

- **World population** is expected to grow by over a third, or 2.3 billion people, between 2009 and 2050 – **standard of living**
- **Food:** The projections show that feeding a world population of 9.1 billion people in 2050 would require raising overall food production by some 70 per cent between 2005/07 and 2050 (High Level Expert Forum - How to Feed the World in 2050, Italy 2009).
- **Water:** Nearly 1 billion people still do not have access to improved sources of drinking water and there are more people without access to tap water in cities today than there were at the end of the 1990s. (UN World Water Development Report, 2014)
- **Energy:** Energy demand projections (IEA, 2015)



Themes and challenges arising out of current resource management

- **Safety** (Challenge 1)
  - EHS requirements
  - Stability at greater depths
  - Energy consumption
- **Resource diversification** (Challenge 2)
  - New processes required
  - extending existing and making new deposits viable
  - Marine environment
  - Remediation and waste management
- **Resource efficiency and competitiveness** (Challenge 3)
  - automated mine
  - adapting conventional designs and operations to automation
  - new design layouts and operations to suit automation
- **Managing the resource from deposit to customer** (Challenge 4)
  - Digitisation
  - New materials for new industrial applications: Part of Industry 4.0
  - trace and track

Other challenges arising -2-

- Enabling the genius amongst us
- Fostering the uptake of new innovations for current operations
- Convincing the investor to invest in new concepts
- Further education for current personnel
- Training and education for future engineers:
  → KIC
- Capacity building :
  - skills and transfer knowledge and understanding within and beyond current practice for industry and authorities

- Social understanding and acceptance is a function of performance and communication

Technology transfer and adaptation: Taking the advantage of automation technologies

- Automation makes it possible to run a underground mine 24/7 and enhance the face utilization.
  - It is not unusual that the face utilization in underground mines is typical 25%. This usually due to reasons such as:
  - Blast ventilation, machine breakdowns, shift changes, lunch breaks and travel time within mine reduce face utilization
  - The complex sequencing of mine operation combined with a variable environment challenges optimization of production
  - Open pit mines and underground can optimize machine utilization .
- Automation can run any recycling operation 24/7 and increase efficiency.
- However, autonomous machines enables huge improvements but requires huge investments and takes time to implement.
- But automation also needs adaptation and coordination.

BASIC PRE-CONDITIONS FOR AUTOMATION

- Interoperability and
- compatability of systems

Why robotics is important to resource management?

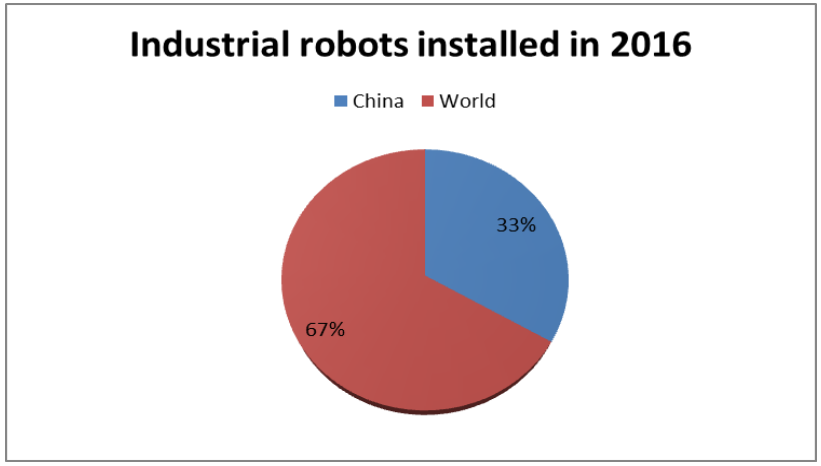
Robots will transform almost every industry and service sector!

Examples for extractive sector area.

1. Robots have the potential to provide cost effective services in environmental monitoring.
2. Their ability to map and monitor large spaces (underground, under water, and from the air) will provide a new and cost effective means to gather valuable information important for mining and smelting operations (monitoring of environmental pollution).
3. Robots provide the means to work in hazardous environments improving safety for emergency service workers, in mining and mineral extraction and in mine closure/decommissioning.
4. Robots will increase efficiency and safety of recycling facilties.

Policy measures required! Made in China 2025 Strategy: flagship is to mass-produce core robot parts

- Consumer of robots:
  - World's largest market for robots since 2013, in 2016 it installed 90.000 new industrial robots (1/3 of all robots in the world.



- Producer of robots:
  - It produced 72.400 in 2016 and plans to produce 100.000 in 2020.

AI and Communication technology

The future mine/processing/recycling plant will require

- the wide use of remote monitoring and controlling of all operations;
- remote controlled production for unmanned processes;
- mine-wide information network for all autonomous machines;
- design next generation of machines to operate remotely and autonomously;
- introduce integrated and intelligent monitoring and control systems
- Adapting 5G and real time operation management

BASIC TECHNOLOGIES FOR AUTOMATION

- Communication
- Localisation systems
- Road and Traffic Management

Europe's minerals-energy nexus

- Raw materials provide 97% of our current energy through fossil fuels, uranium and biomass (IEA 2010) (10).
- Global energy demand also continues to rise (IEA, 2014)

- The infrastructure of the energy sector requires the massive use of metals and minerals, in particular
  - (1) steel for ships, pipelines, mining equipment, power plants, refineries and exploration activities,
  - (2) copper for the electricity grid, generators and electric motors, and
  - (3) aluminium, primarily for the electricity grid, and
  - (4) a host of other metals and minerals including phosphorous, potassium and nitrogen for bio mass production.

  The remainder of the energy is produced through hydropower, wind and sunlight – which need huge amounts of concrete, steel and specialty metals (Hertwich et al. 2015).
- It is this low carbon energy supply that global leaders will seek to expand in order to transition to a low carbon society within the coming decades to counterbalance climate change.
- New energy technologies and their material needs should be assessed also in terms of **Circular Economy r**equirements.

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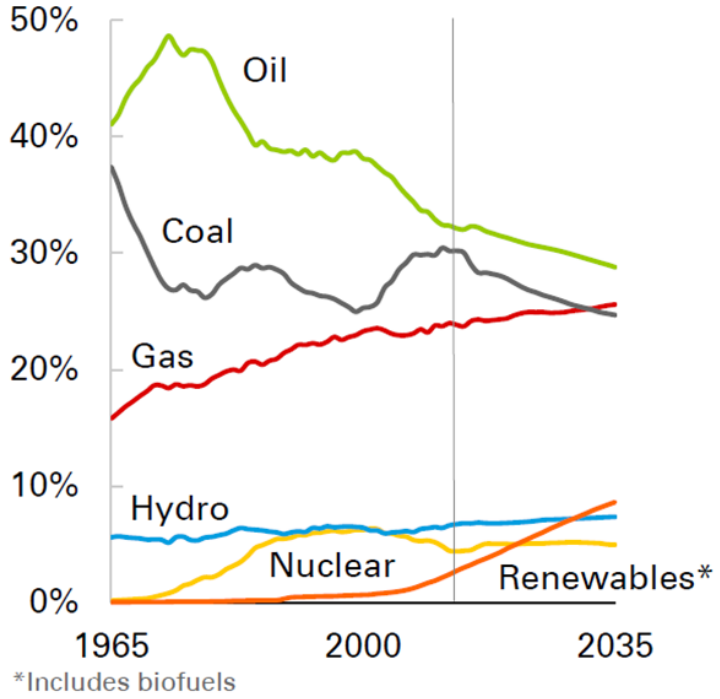
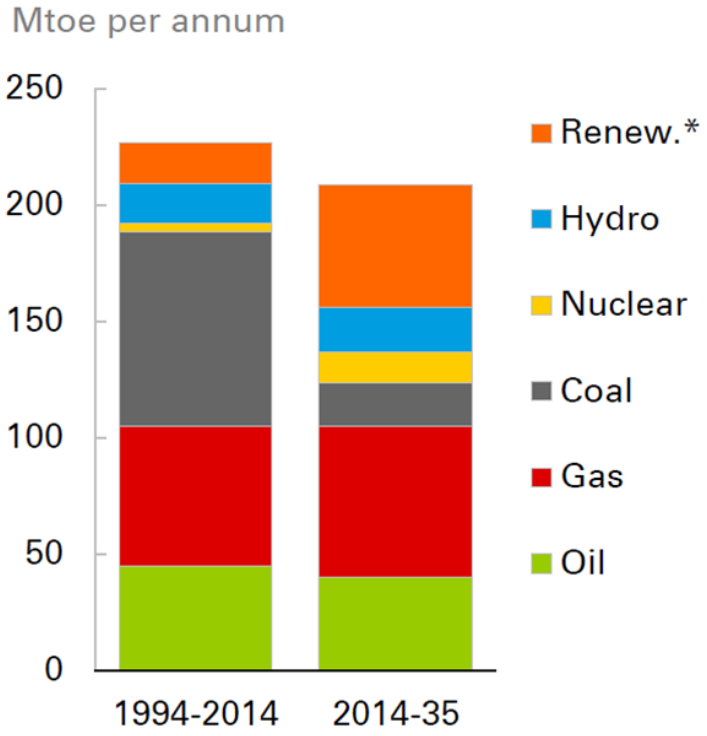
Shares of primary energy



Annual demand growth by fuel



Source: BP Energy Outlook 2016

Energy supply & demand: The Big Picture

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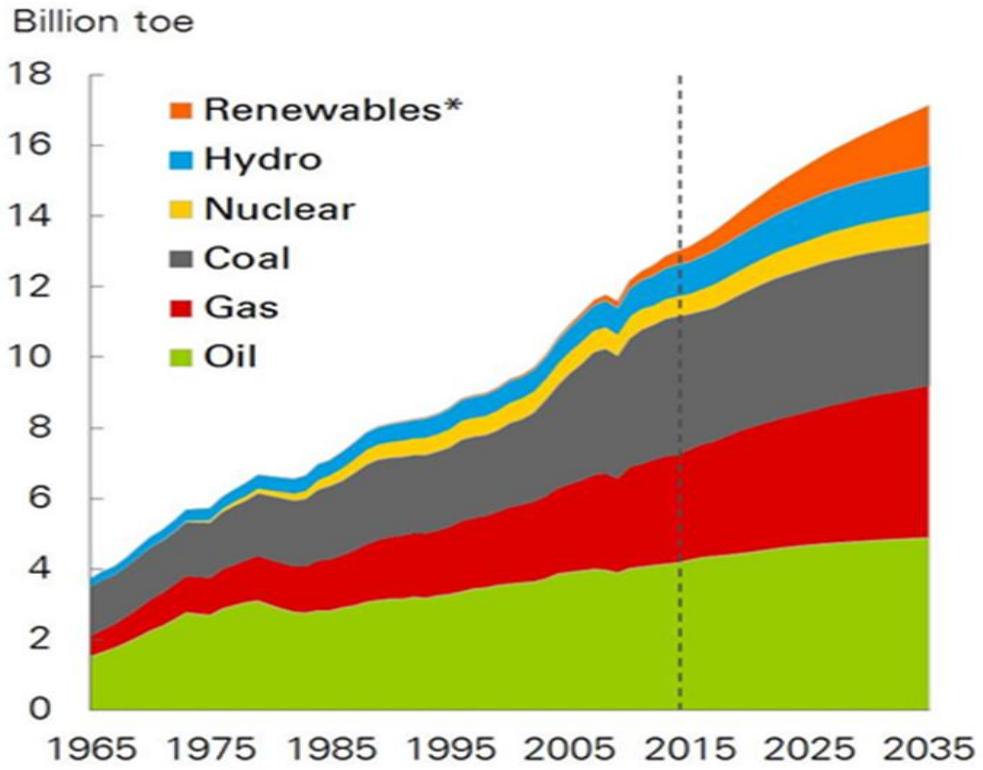

BP Energy Outlook
2017 edition

25 January 2017

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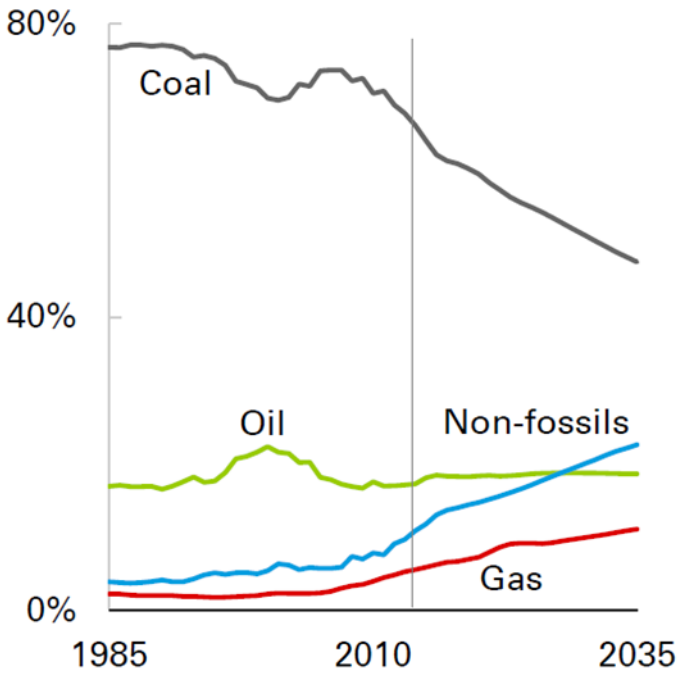
Shares of primary energy in China



Source: BP Energy Outlook 2016

- China's rise in gas demand to 2035
- Slowing GDP = China's energy demand to grow by <2% p.a. (was 8% since 2000)
- Fuel mix likely to change significantly, driven by changing economic structure, environmental and climate policies
- Non-fossil fuels and gas expected to increase rapidly, with combined share in China's energy mix more than doubling to around a third by 2035.

Rise in gas output to 2035
5.6% growth in shale gas
(to almost 25% share)

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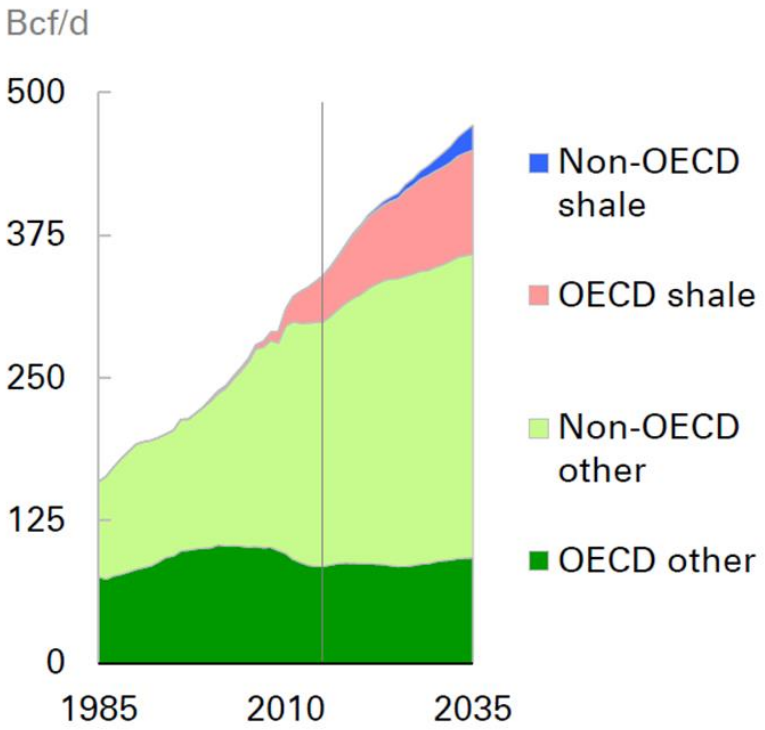
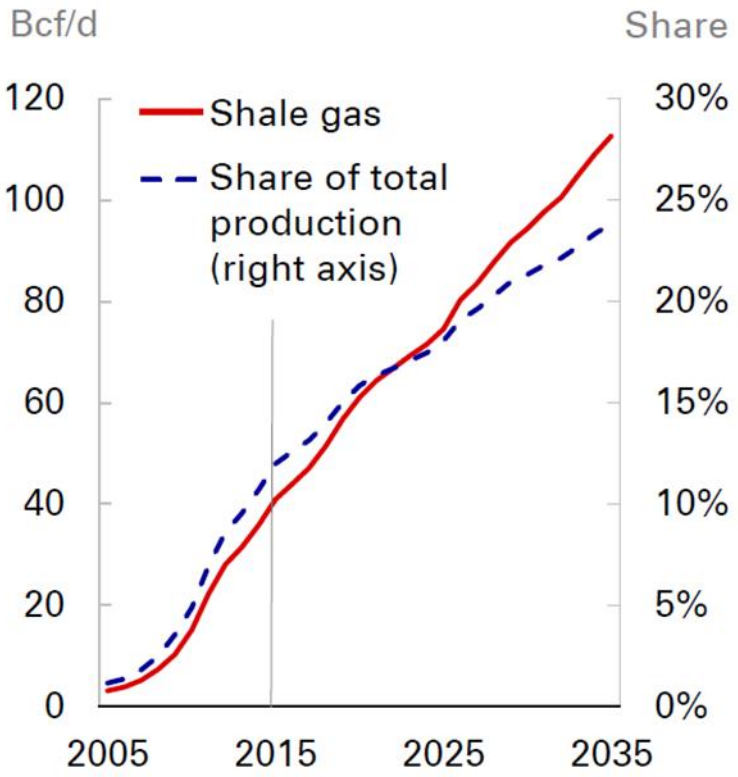
Gas production by type and region



Source: BP Energy Outlook 2016

Global shale gas production



Requirements of selected metals in different power generation technologies relative to the metal demand of the current mix (Kleijn et al. 2011)

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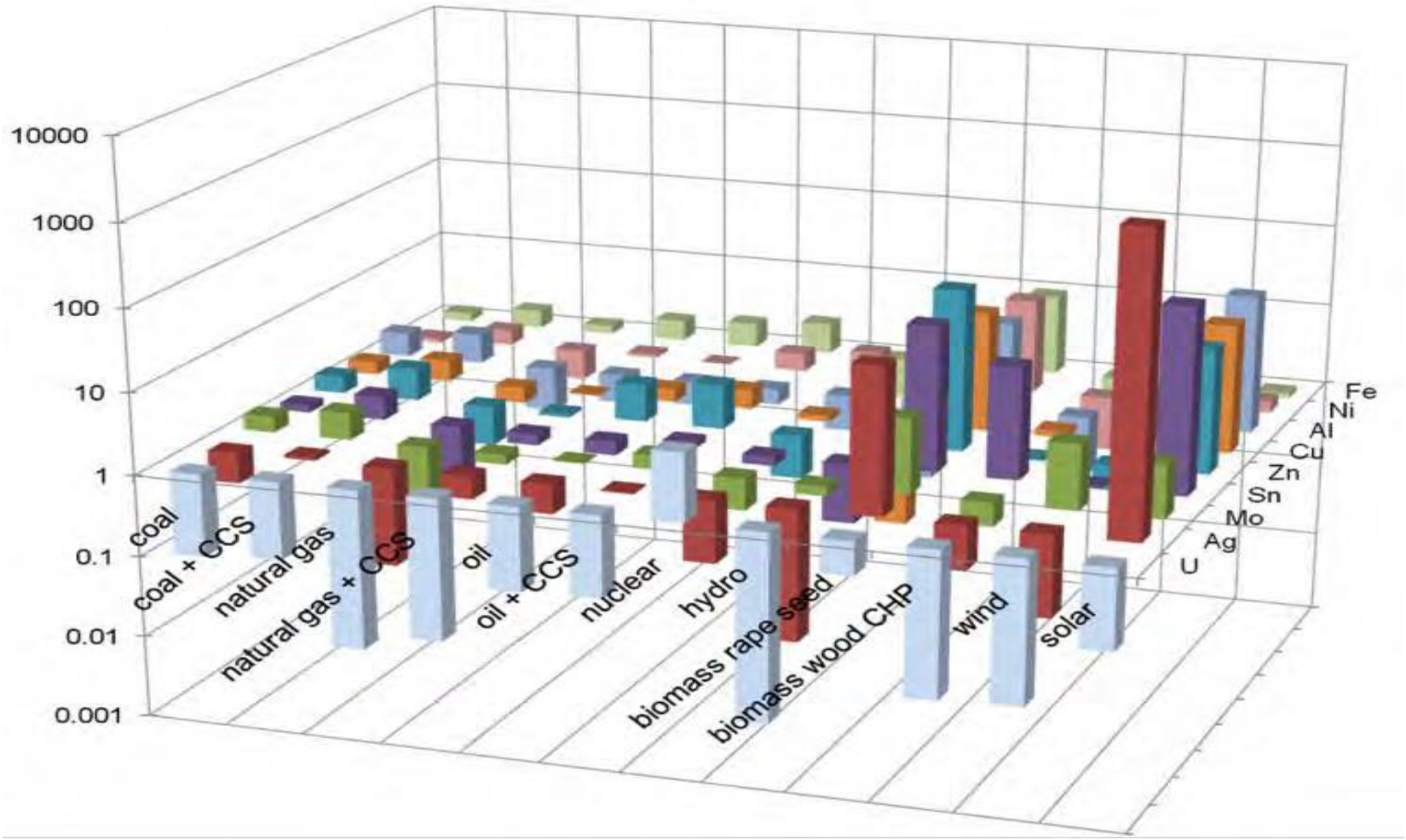
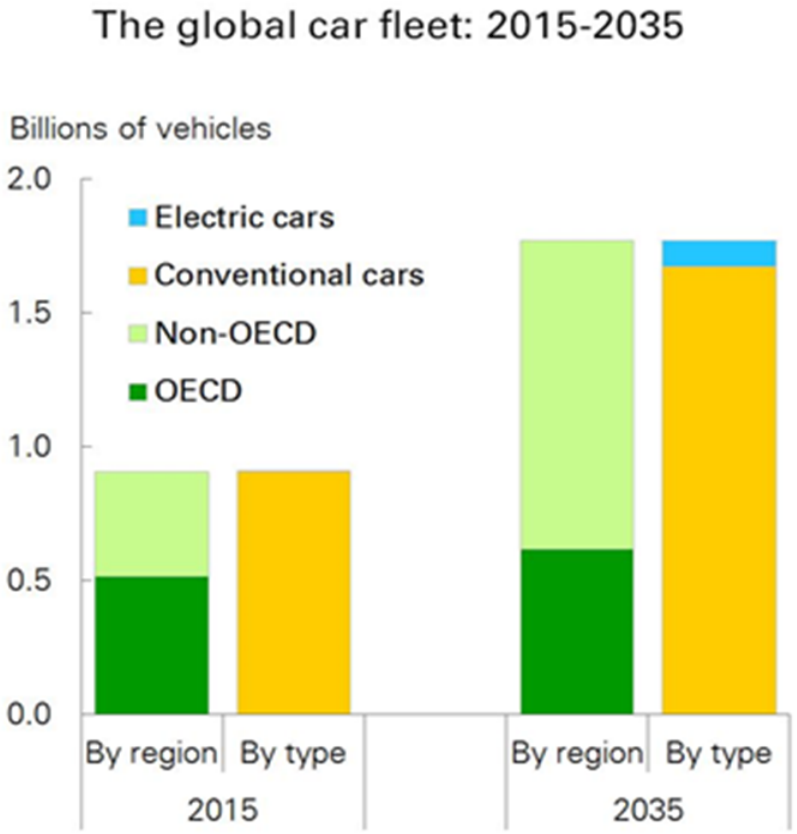
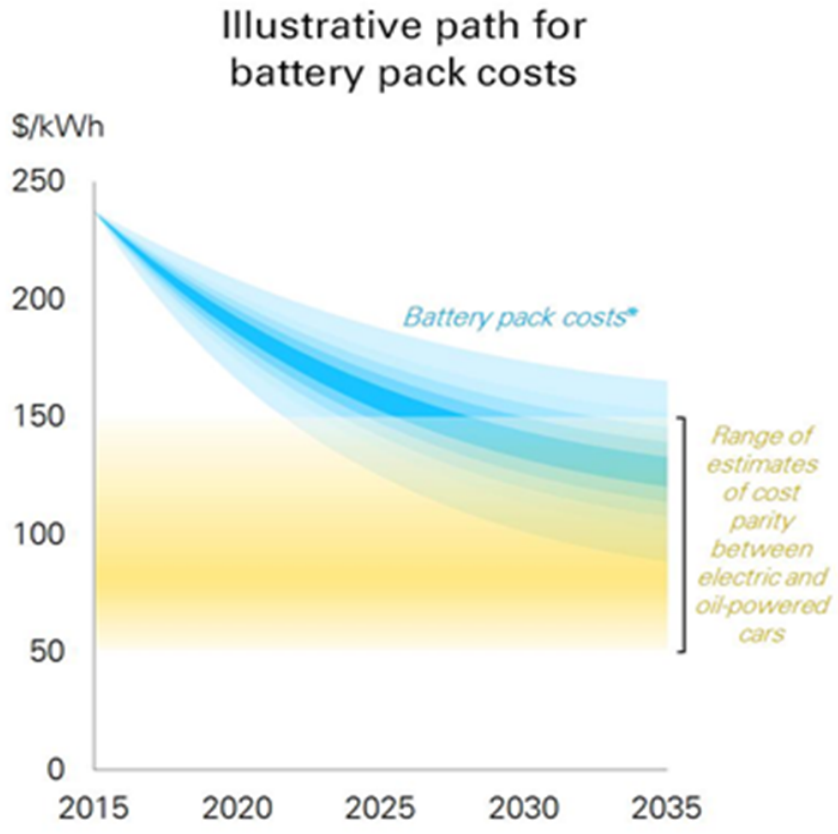


The minerals-transportation nexus





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Haulage and logistics

- Being able to transform mining haulage and logistics, automation now has the potential to revolutionise extraction processes also for European mines.
- Operating 24 hours a day
- From trucks to trains, technology can now in the driving seat.
- Precision GPS, radar and laser sensors

But we are still hauling around dead-weight

New concepts are needed to get to grips with transportation or no transportation

Water: OECD Environmental Outlook to 2050

The effective management of water resources and water services remains a major challenge for many OECD and non-OECD countries and pressures on water resources continue to mount.

- **Increasing competition for access to water (driven by population and economic growth),**
- **decreasing water quality,**
- **the continued need to expand access to sustainable water and sanitation in many parts of the world,**
- **deteriorating groundwater supplies, and**
- **the threat posed by climate change as major concerns for water management.**

The scale of the challenge related to water risks that can be monetised (excluding environmental risks) is estimated to be USD 500 billion annually (Sadoff et al., 20151).

In addition, inadequate water supply and sanitation costs USD260 billion per year according to (ibid.).

Thank you for your kind attention

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