Coal: Social, environmental and economic concerns

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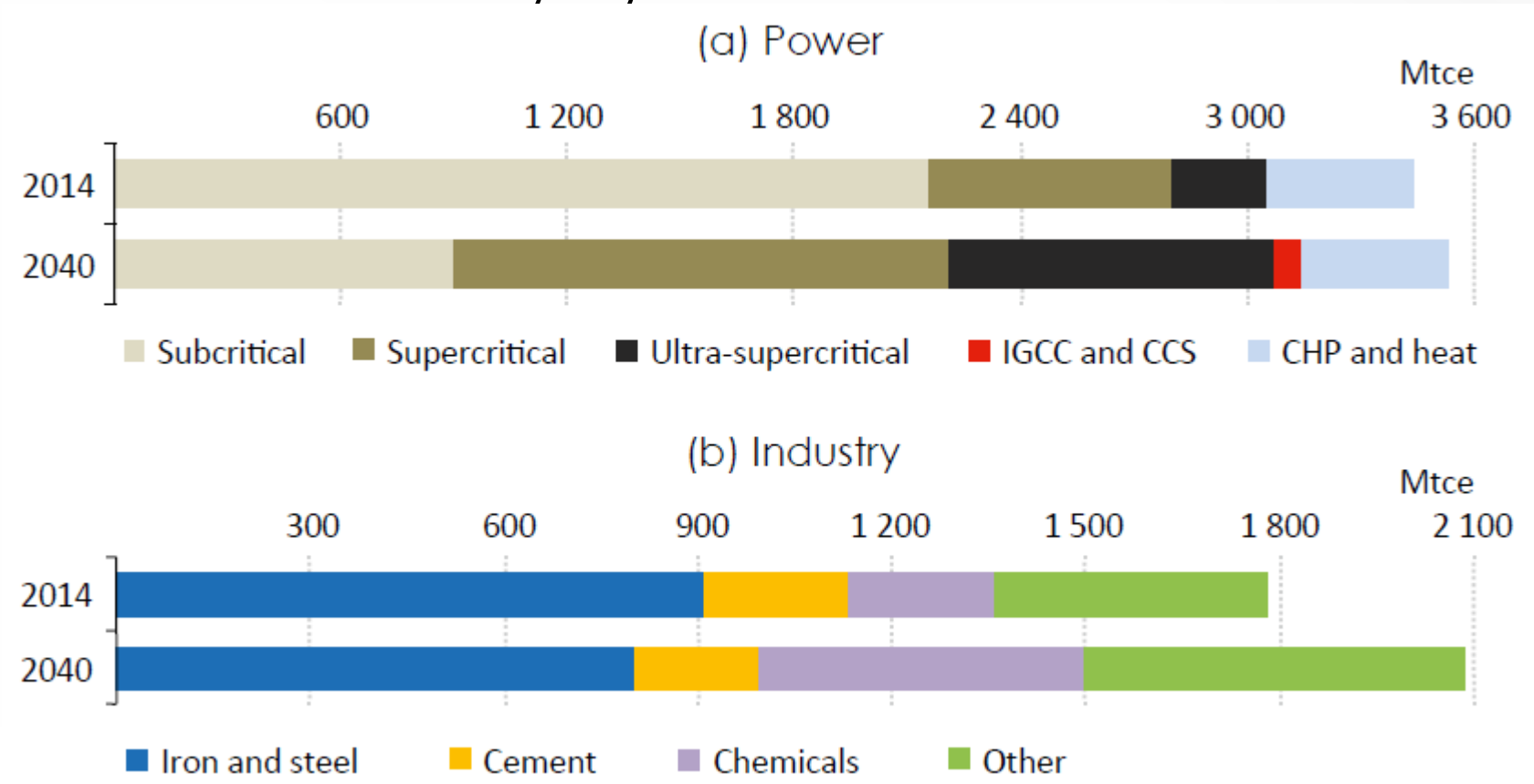
Introductory lecture – Energy commodities and technologies

Commodity: global trends

- Demand
- Supply
- Resources

Demand

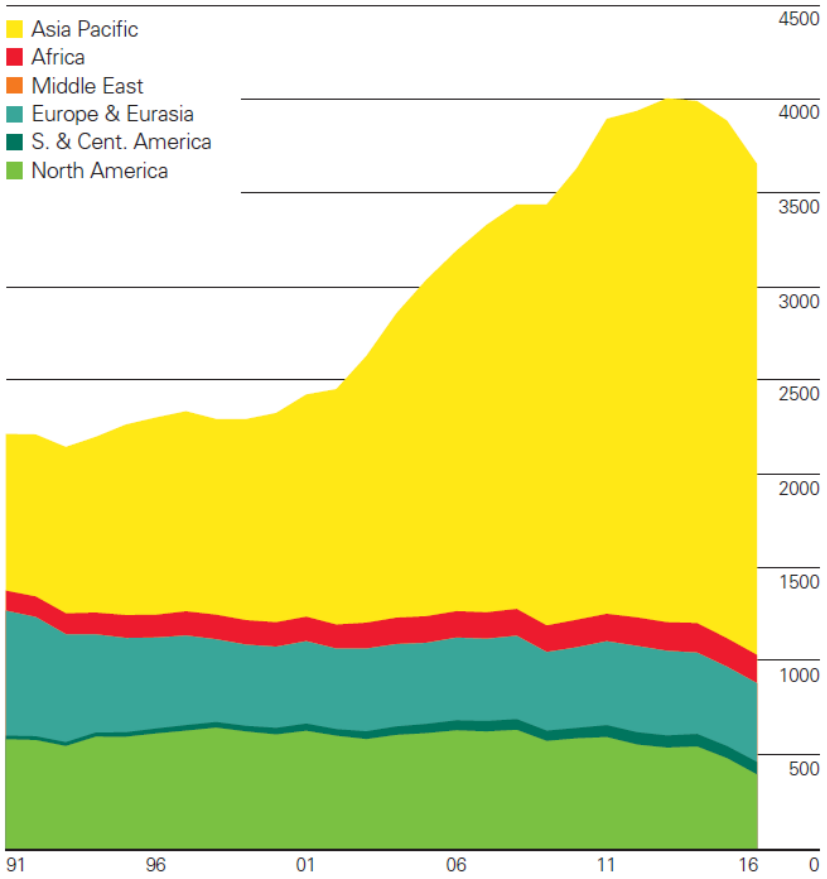
World coal demand by key sector in IEA New Policies Scenario



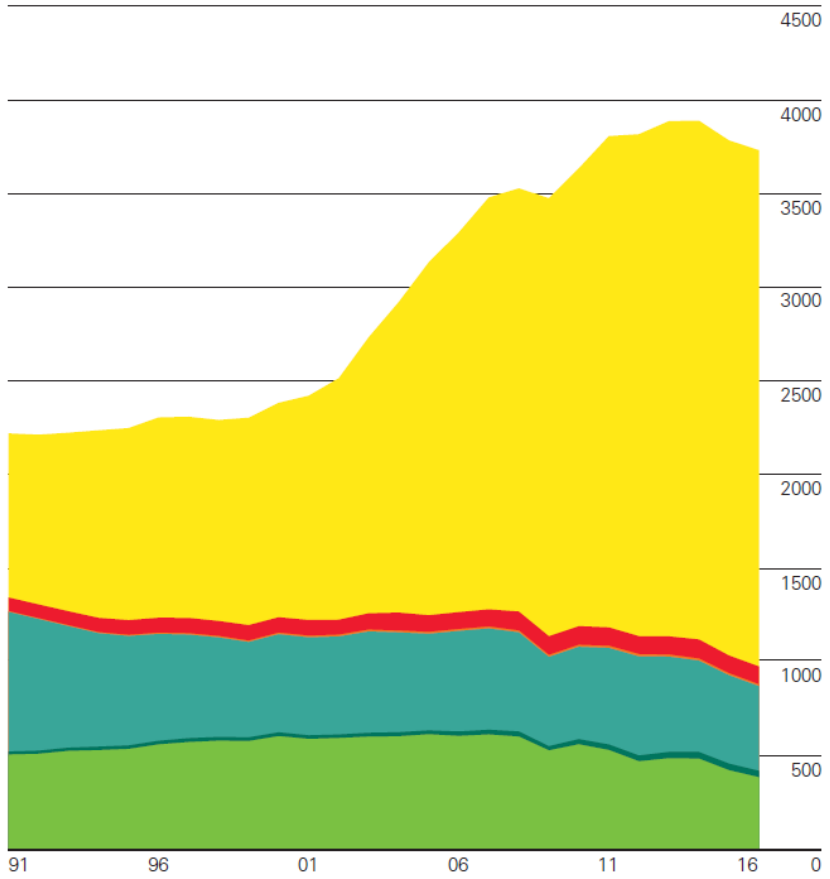
Source: IEA World Energy Outlook 2016.

Supply

Coal production (Mtonned oil equivalent)



Coal consumption (Mtonnes oil equivalent)



Source: BP Statistical review of World Energy 2017.

Resources

- Coking coal: derived from bituminous coal, by destructive distillation. It is hard and dark/greyish, it has few impurities and high carbon content and it is used particularly as a fuel in the industry (e.g. iron).
- Steam coal: (also called thermal coal) all other hard coal that is not Coking coal. It is commonly used for power and heat generation, ground to a powder.
- Lignite: (often called brown coal) soft coal with relatively low carbon content (60-70%), derived from compressed peat. Mostly used for power generation, but also for gasification and in ammonia-based fertilizers.

Resources

Coal resources (billion tonnes)

	Coking coal	Steam coal	Lignite	Total resources*	Share of world	Proven reserves	Share of world	R/P ratio**
OECD	**1 676**	**7 303**	**2 317**	**11 297**	**49%**	**459**	**47%**	**227**
Americas	1 036	5 842	1 519	8 396	37%	262	27%	264
Europe	155	330	343	827	4%	83	8%	154
Asia Oceania	485	1 132	456	2 073	9%	115	12%	232
Non-OECD	**1 732**	**7 550**	**2 387**	**11 669**	**51%**	**525**	**53%**	**92**
E. Europe/Eurasia	757	2 254	1 441	4 452	19%	238	24%	390
Asia	920	4 984	920	6 824	30%	260	26%	55
Middle East	19	23	-	41	0%	1	0%	1 256
Africa	34	263	0	297	1%	13	1%	48
Latin America	3	27	25	55	0%	13	1%	131
World* **	**3 408**	**14 853**	**4 705**	**22 966**	**100%**	**985**	**100%**	**127**

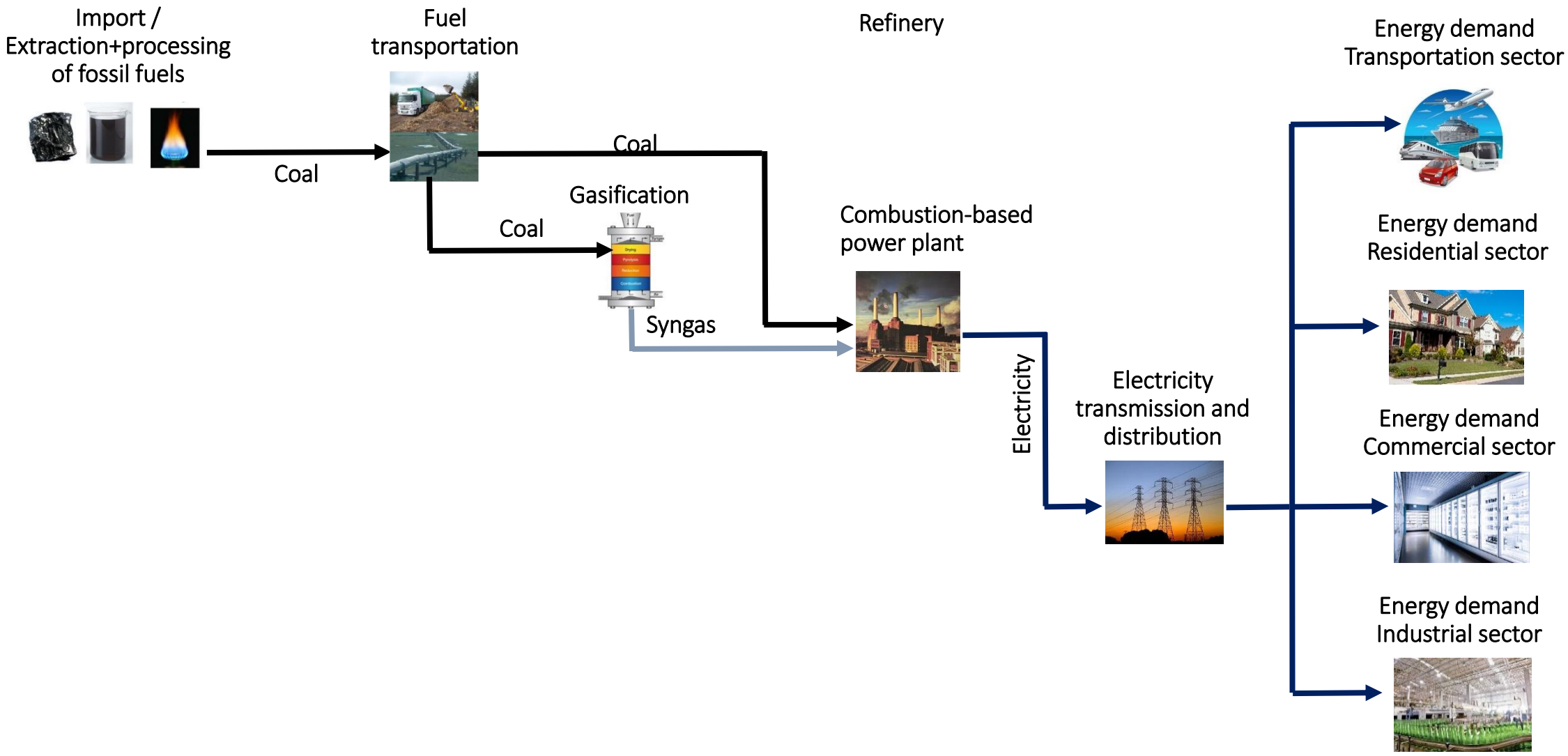
Source: IEA World Energy Outlook 2016.

Proven reserves = 90% probability to be extracted profitably

Technologies in the coal chain

- Mining and preparation
- Transportation
- Gasification
- Combustion-based power plants
- Economic, Environmental and Social concerns

Sample Reference Energy System



Mining and preparation

Two mining methods exist:

Undergroung mining: it accounts for 60% of mining worldwide and includes 1) room-and-pillar methods, 2) long-wall methods

Surface mining: used in Australia and US, particularly

The preparation (or cleaning) consists in removing impurities, such as sulphur, ashes and rocks. Two main methods:

Physical cleaning: most used, mechanical separation based on density.

Chemical cleaning: more expensive.

Key characteristics	
Capital cost	51.3-7155 M$
FOM cost	-
VOM cost	14.3-71.6 $/t
Energy use	0.391 GJ/ton mined
CO2 Em. factor	5.1-10.1 kgCO2eq/GJ

Transportation

It accounts for a large part of the total cost of the delivered product. It usually occurs via:

- Railways;
- Barges on inland waters;
- Large vessels through oceans;
- Pipelines as a mixture of coal and water;
- Trucks (for short distances).

Key characteristics	
Sample values for maritime vessels	
Capital cost	-
FOM cost	-
VOM cost	0.1-0.9 $/GJ
Energy use	-
CO2 Em. factor	5-16 gCO2/ton-km

Gasification

Used for coal, biomass and oil residues. It produces 'syngas' rich in H2, CO, CO2. Core process is pyrolysis, i.e. oxydation at T>400 C under Oxygen shortage. Main technologies:

Moving-bed: oldest and simplest, with fuel slowly moving downwards for gravity and being oxydized. High steam consumption.

Fluidized bed: fuel and oxydizer moving upwards together. Faster, but output more impure.

Entrained flow: fuel and oxydizer moving downwards together. Highly pure output.

Key characteristics	
Capital cost	13.5-17.2 $/GJ output
FOM cost	0.7-1 $/GJ output
VOM cost	1.4-1.6 $/GJ output
Fuel cost (coal)	0.9-1.3 $/GJ
Availability	90%
Lifetime	20
Efficiency	73-75%
CO2 Em. factor	55 kt/PJ

Combustion-based power plants

Two main technologies dominate the scene of coal-fired power supply, and they traditionally cover *base load*:

- **Super-critical pulverised coal (SCPC)** or its evolution, Ultra-Super-Critical pulverised coal (U-SCPC). It is like a traditional steam cycle, where the steam is brought to super-critical conditions.
- **Integrated Gasification Combined Cycle (IGCC)**. Here, the coal undergoes a gasification reaction and is turn into a gaseous mixture of H2, CO2 and CO. The gas is then burnt in a Gas Turbine and the exhaust feeds a Heat Recovery Steam Generator (HRSG).

Carbon Capture and Sequestration (CCS) can be applied.

Key characteristics	
U-SCPC	
Capital cost	2200 $/kW
VOM and FOM cost	88 $/kW/a
Capacity Factor	75-80%
Efficiency	46%
CO2 Em. factor	730-850 kg/MWh
IGCC	
Capital cost	3700 $/kW
VOM and FOM cost	148 $/kW/a
Capacity Factor	75-80%
Efficiency	46%
CO2 Em. factor	700-750 kg/MWh

What more could you want in a fuel… Right?

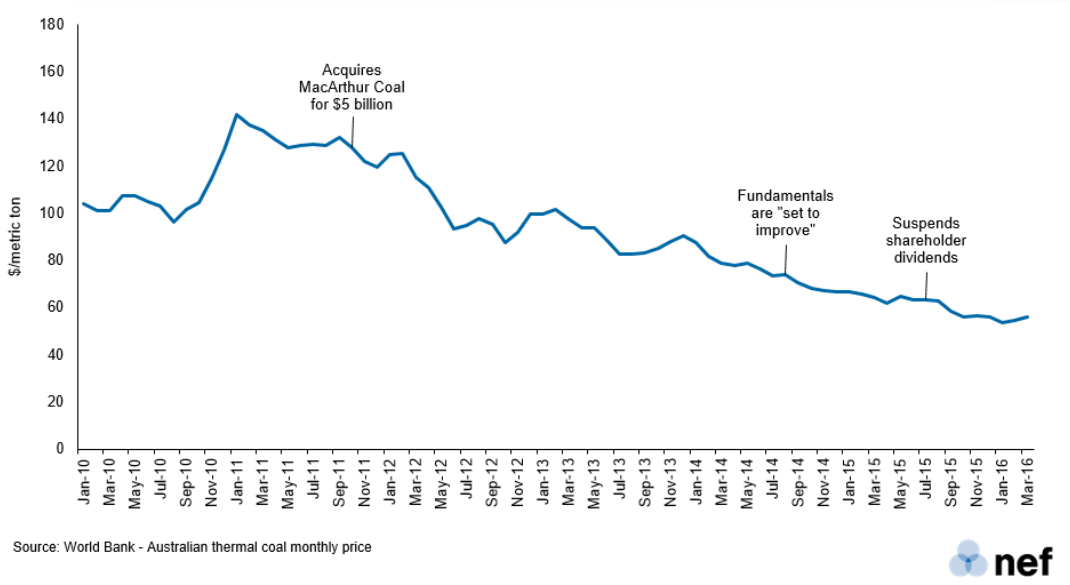
- Abundant
- Relatively inexpensive
- Simple to extract and transport
- Mature technology for power generation
- Located in politically stable regions and abundant in many countries
- Price not determined by ‘cartels’ – but by industry consumers (mining, steel, power…)

BUT

- Extremely polluting, adversely affecting the most critical life-sustaining systems on the planet (air, water, land)

Economic concerns

- Cheapest source of energy
- Coal pollution costs the EU €43 billion each year (health impacts from especially air pollution)
- Carbon pricing and regulation are imperative to control pollution and limit generation from inefficient units.



Environmental and social concerns

Climate

Source: Grist, davipt

Land-use

Source: Top News

Water

Source: National Geographic

The combustion of coal is the largest contributor to the human-made increase of CO_2 in the atmosphere.

Environmental and social concerns

Climate/Air	Land-use	Water
CO_2 emissions	Degradation of vegetation	River water alkalinity (and 'sodicity' – sodium salts)
SO_2-related acidification of ecosystems	Loss of wildlife habitats	Fly ash stored in *impoundment ponds*
Mercury emissions (concentration at higher levels of food chain)	Damage due to mine collapses	Degradation of aquatic habitats
Acid rain	Loss of topsoil leads to infertile wastelands	Cooling water requirements

Conclusions

- The continuing trend of year-on-year growth in coal-fired power needs to be reversed to meet ambitious CO_2 targets.
- Policy incentives such as carbon pricing and regulation are imperative to control pollution and limit generation from inefficient units.
- New coal power units should achieve best available efficiency and, if not initially installed, should be CCS-ready to have the potential to reduce the impact of coal use

References and reading material

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Changelog and attribution

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