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Sustainable Energy:

Background & Transport

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What is Sustainable Development?

Definition of Sustainability

Some of the best-known (and memorable) definitions of Sustainability are:

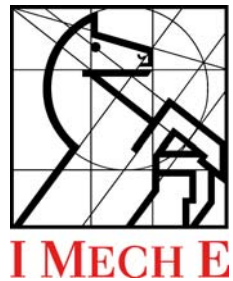
"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Bruntland Report (1987)

Or even more simply, "We have borrowed the present from our children."

Old African proverb

Definition of Sustainability

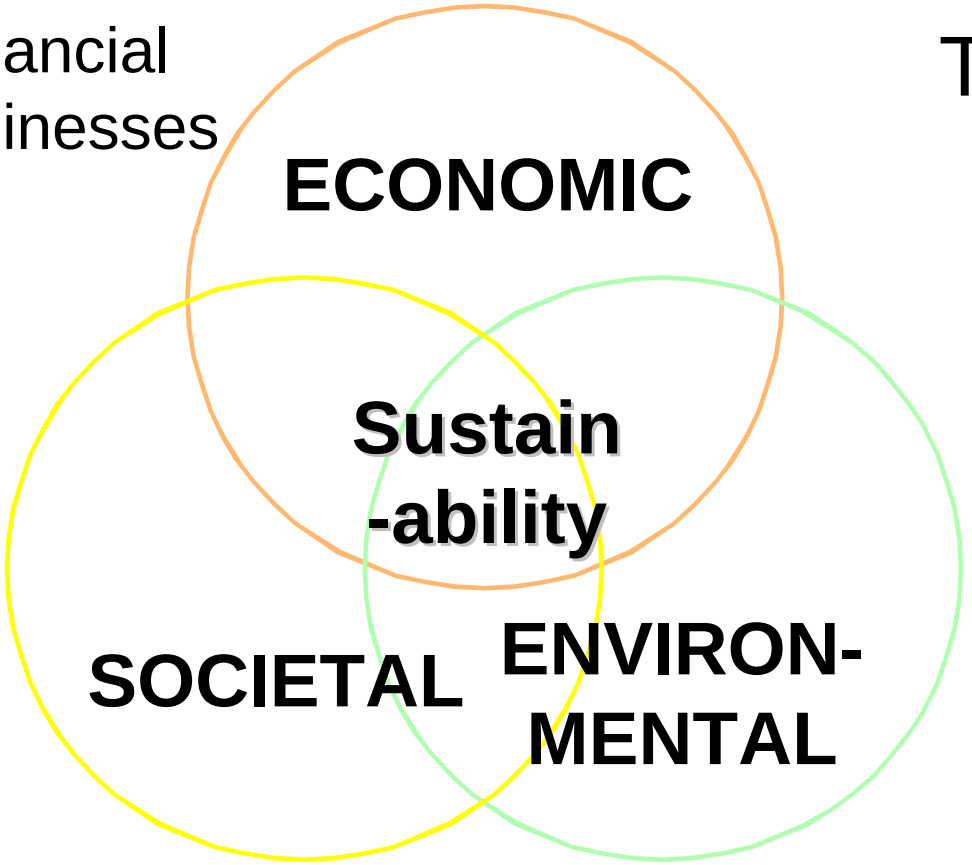


"The capacity for continuance into the long-term future. **Sustainability** depends upon maintaining and, where possible, increasing our stocks of certain assets, so that we manage to live off the income without depleting the capital. **Sustainable development** is the process by which, over time, we succeed in managing all the different capital flows in our economies on a genuinely sustainable basis."

The Engineer of the 21st Century Inquiry (2000)

Definition of Sustainability

Improving financial gains for businesses and society



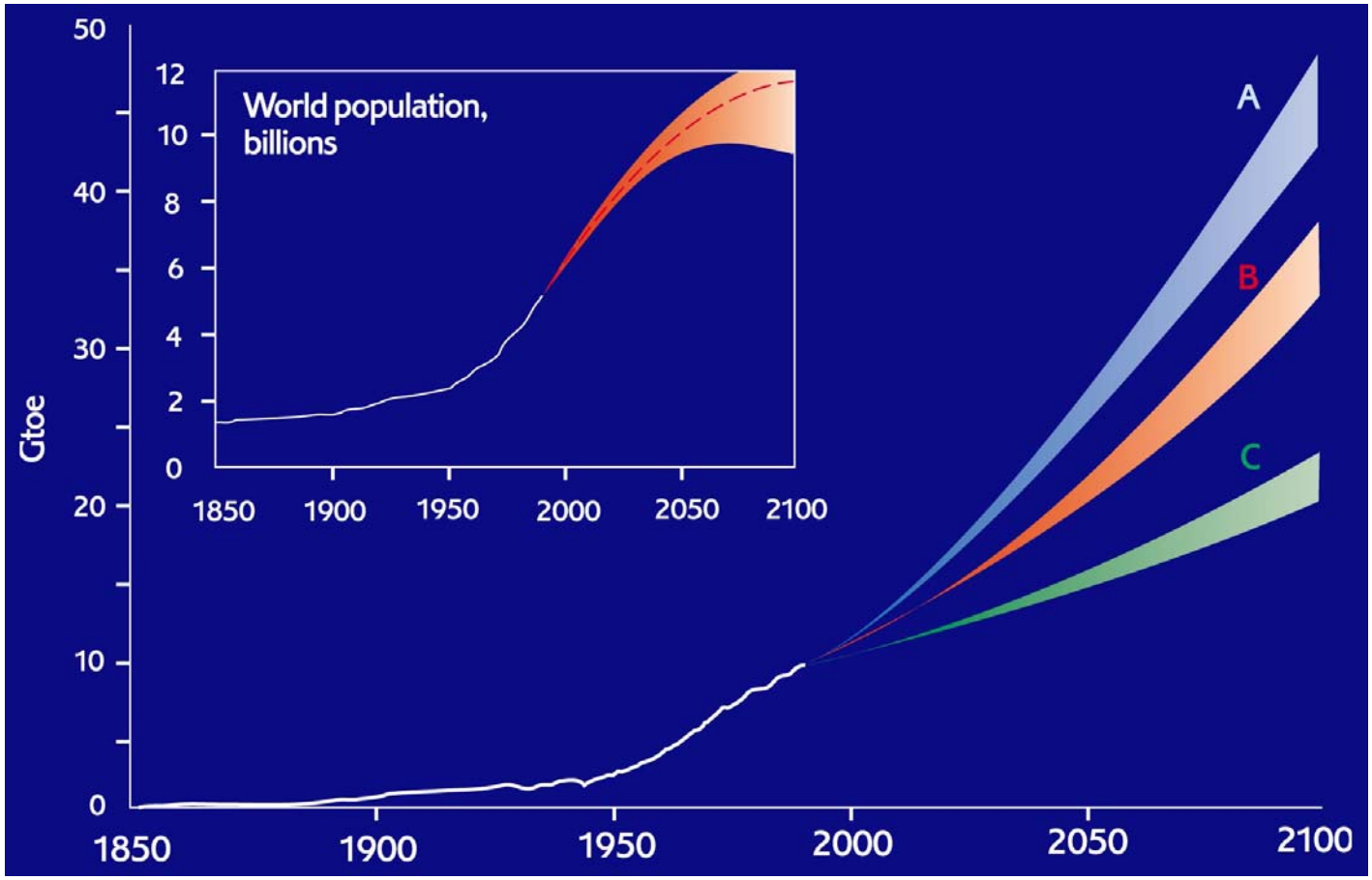
The 'Triple Bottom Line' Effect

Increasing quality of life

Positive impacts on environment and health

What is Sustainable Energy?

Global Primary Energy Use



Global primary energy use, historical development from 1850 to 1990 and in the three cases to 2100, in Gtoe. The insert shows global population growth, 1850 to 1990 and projections to 2100, in billion people. *Source: Bos et al., 1992*

Declining supplies of fossil fuels

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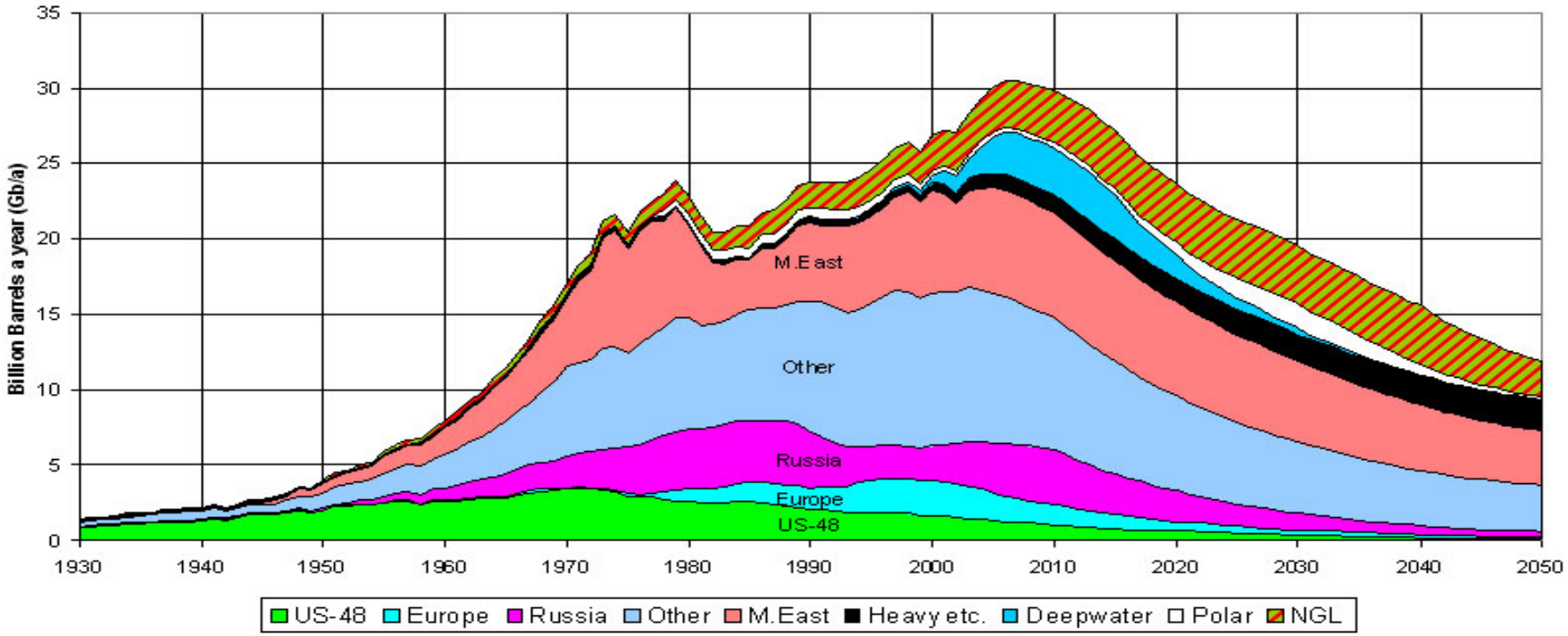
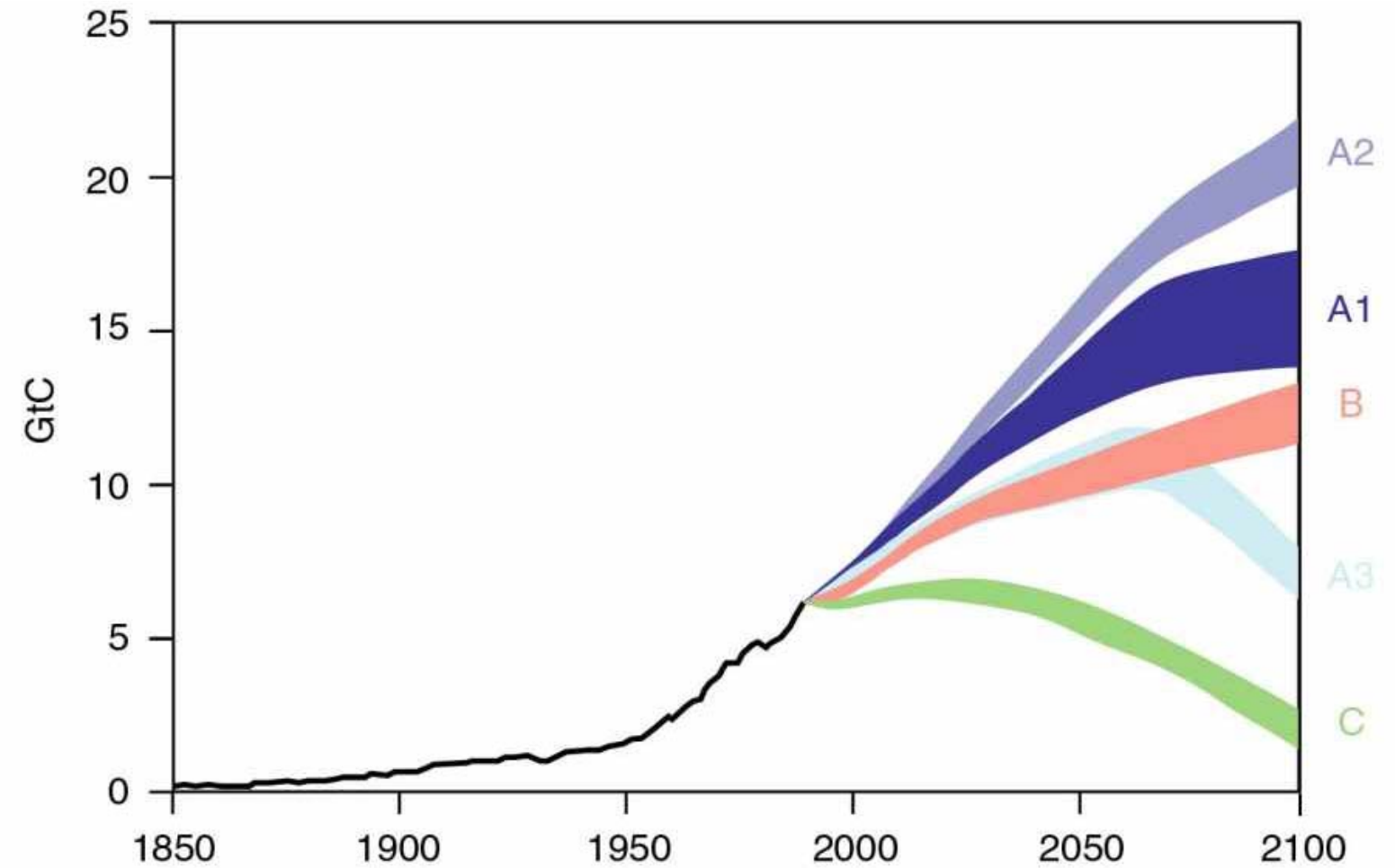
Depletion of finite natural resources, e.g. Uppsala Study (annual production of liquid hydrocarbons).

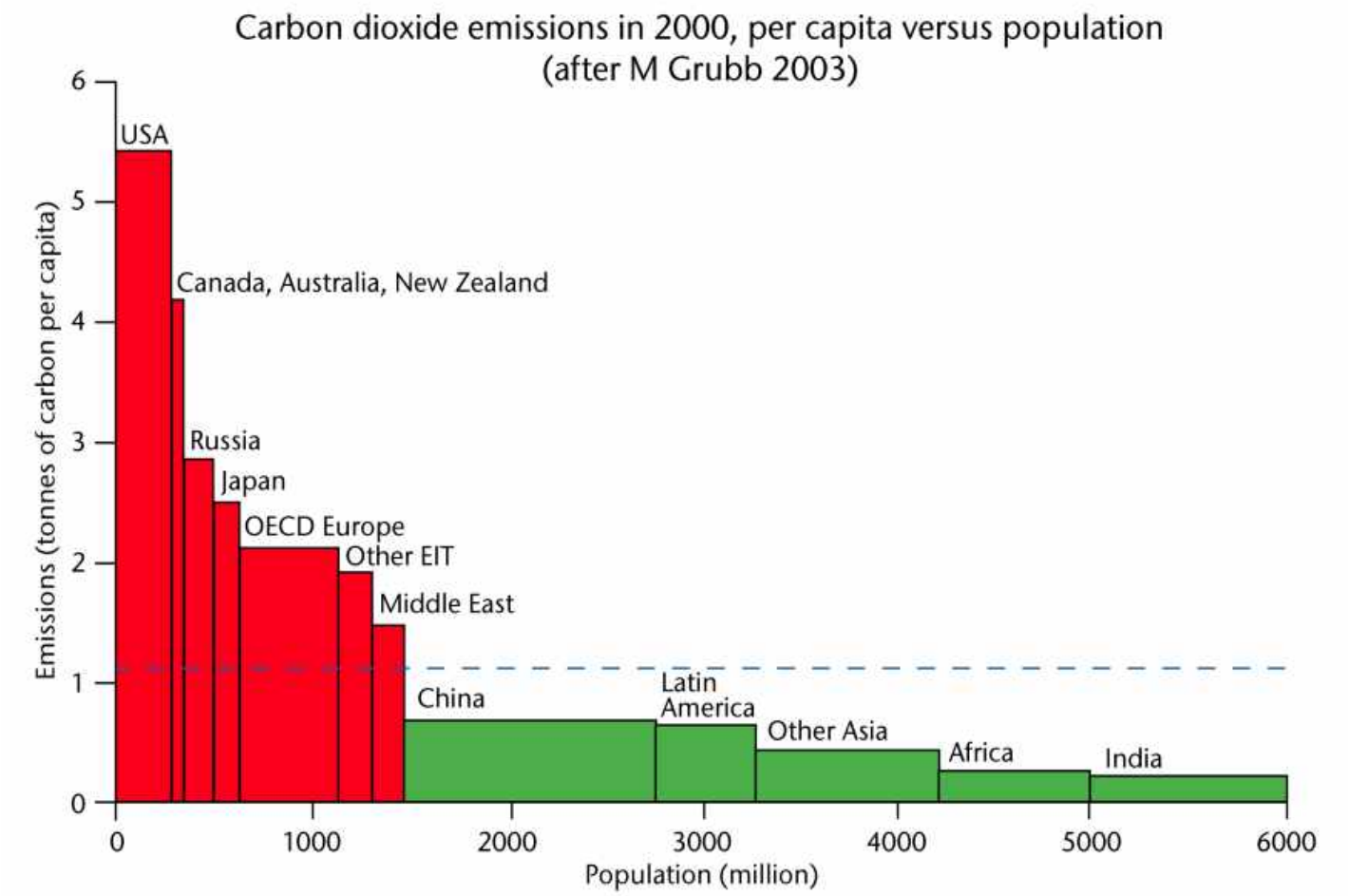


Global Fossil Fuel Carbon Emissions

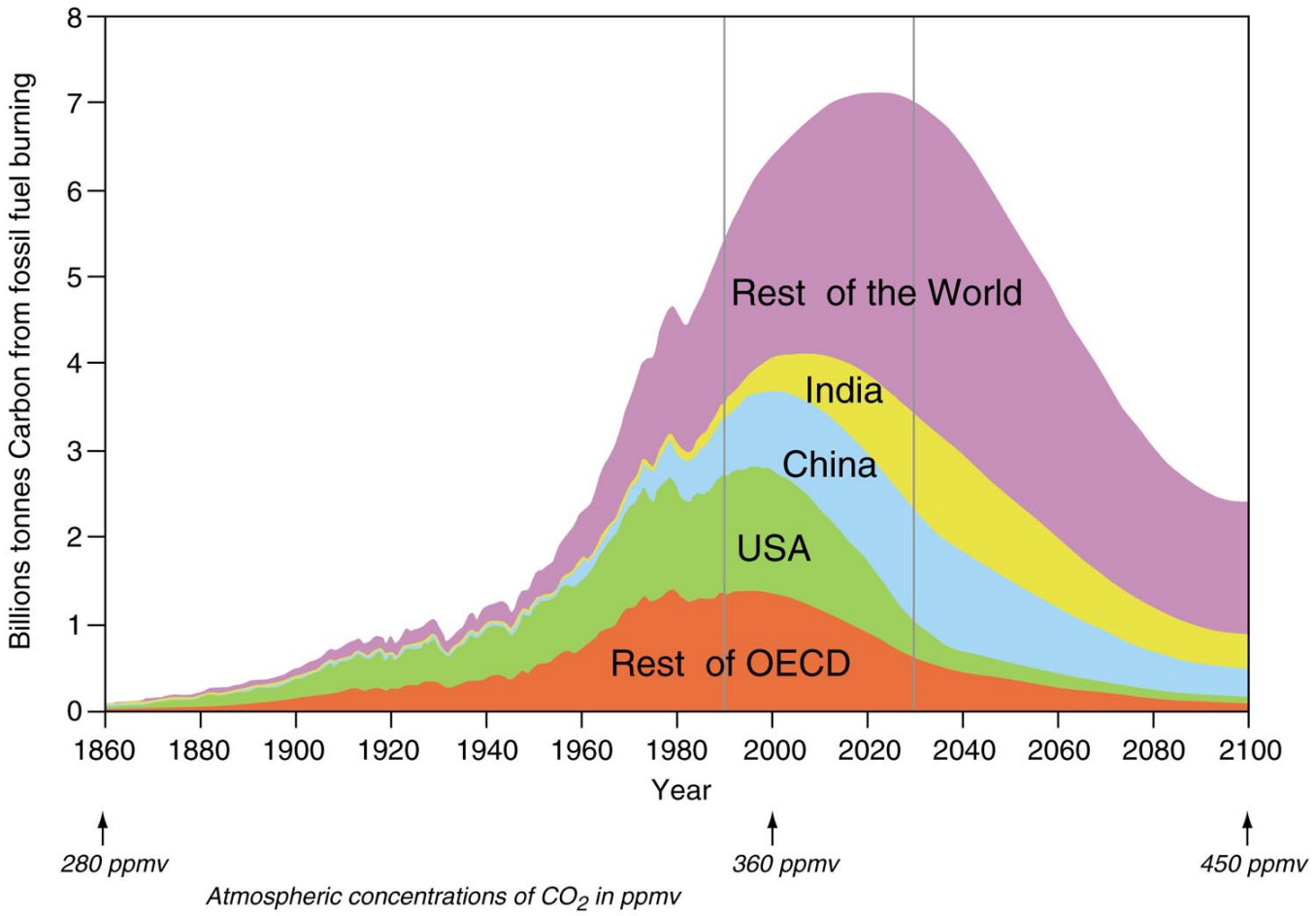


Source: World Energy Council (2000)

Carbon Emissions per Capita



CO_2 Contraction and Convergence



CO_2 contraction for 450 ppmv and convergence by 2030 to globally equal per capita emissions rights

Source: Global Commons Institute (2003)

www.imeche.org

Why the Transport Sector?

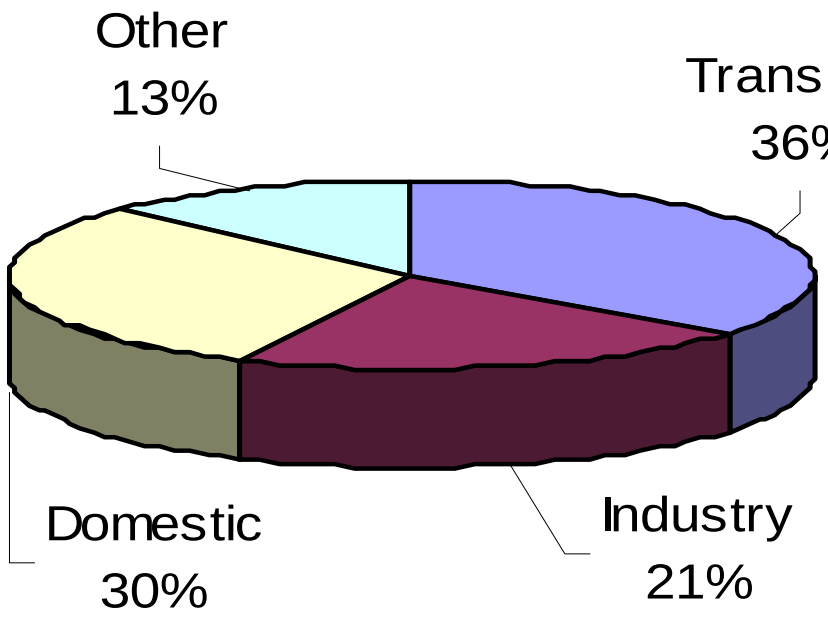
Why the Transport Sector?

In this context, the transport sector includes:

Each of these sub-sectors is using energy at a rate which is considered to be “unsustainable”. To avoid impending global disaster and total depletion of fuel supplies, more sustainable forms of transport must be developed.

Why the Transport Sector?

In the developed world (OECD), which is, by far, the greatest user of global energy, the largest consumer of energy is the transport sector. This pie chart shows energy use by sector in the United Kingdom:



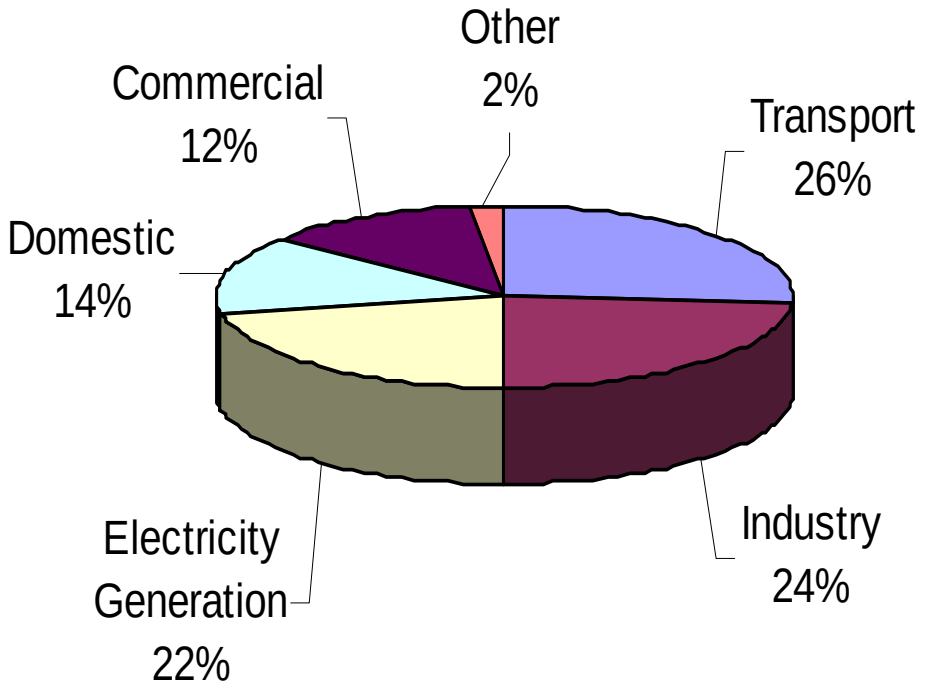
Energy Use by Sector, UK 2004

Why the Transport Sector?

Similarly, this pie chart shows Carbon Dioxide emissions by sector in the United Kingdom (note that the transport sector is already the largest and is the fastest growing sector):

Source: Dr Malcolm Kennedy, PB Power, Dec 2004

Percentage of Total UK CO_2 Emissions

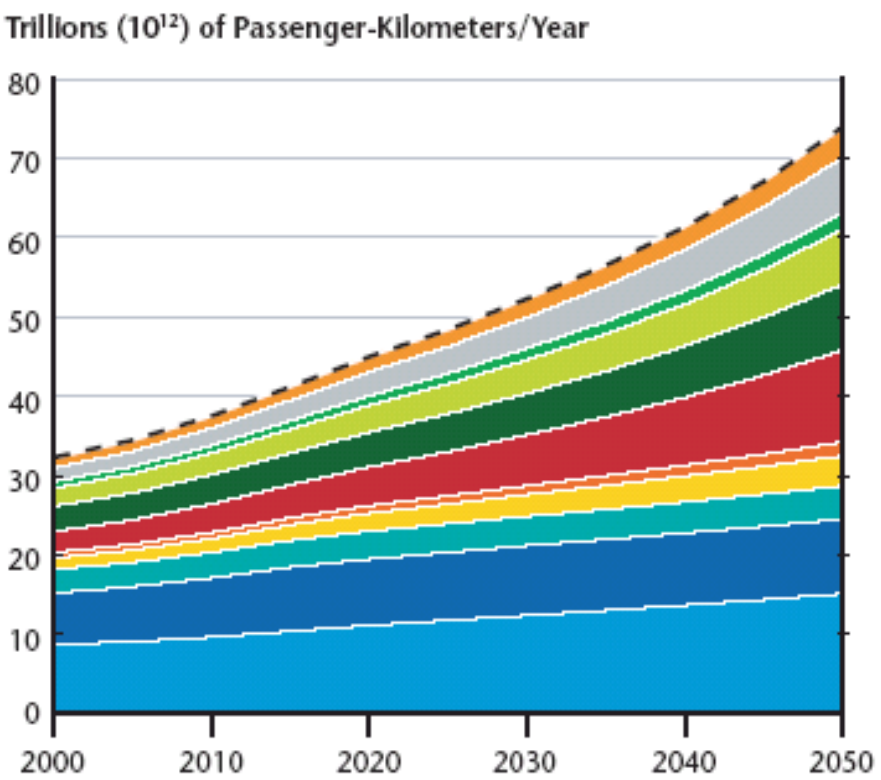


What's the problem?

What's the problem?

Personal mobility is rising rapidly, driven by growing wealth.

Source: Mobility 2030, WBCSD

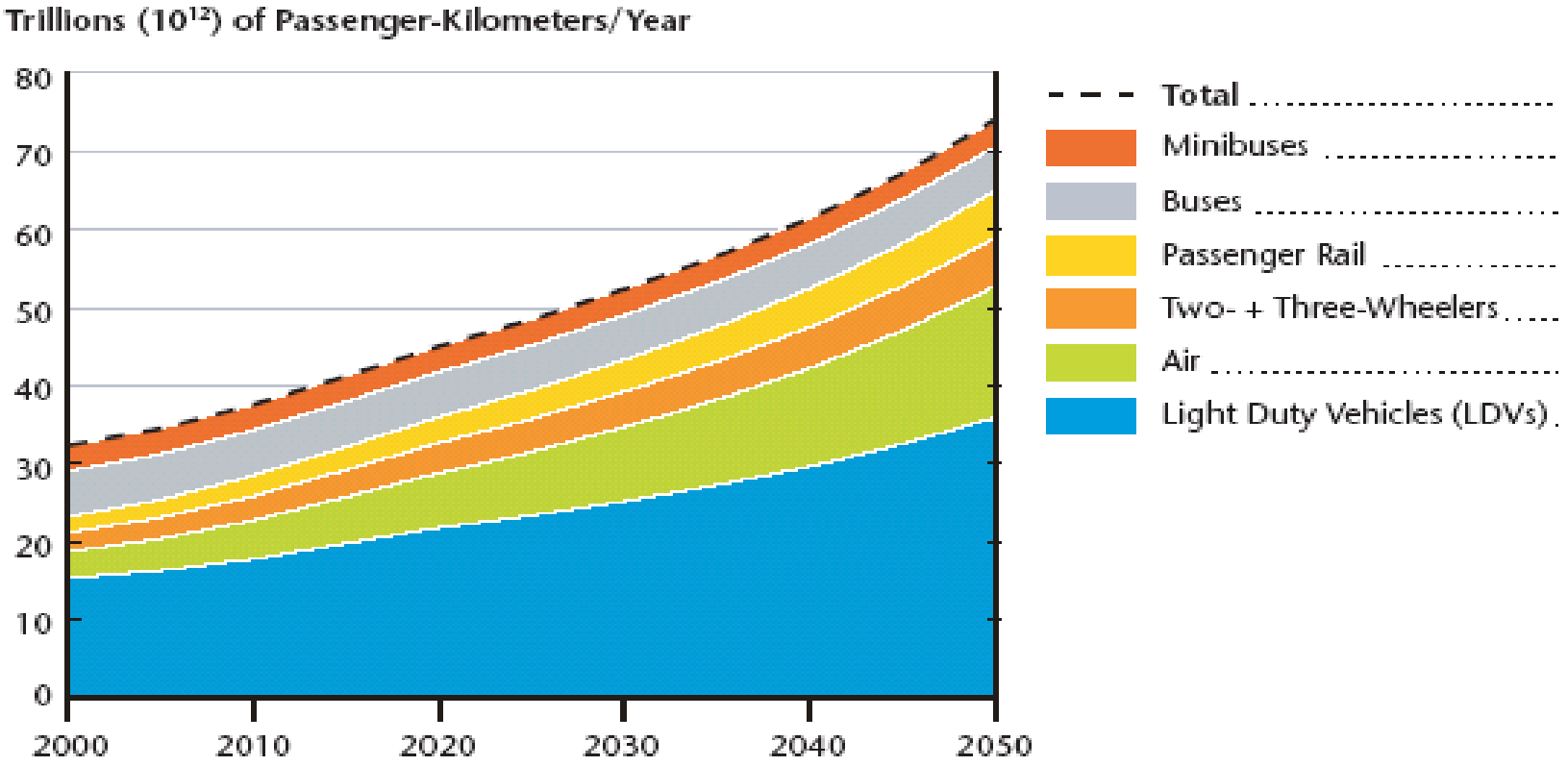


Average Annual Growth Rates	2000-2030	2000-2050
Total	1.6%	1.7%
Africa	1.9%	2.1%
Latin America	2.8%	2.9%
Middle East	1.9%	1.8%
India	2.1%	2.3%
Other Asia	1.7%	1.9%
China	3.0%	3.0%
Eastern Europe	1.6%	1.8%
Former Soviet Union	2.2%	2.0%
OECD Pacific	0.7%	0.7%
OECD Europe	1.0%	0.8%
OECD North America	1.2%	1.1%

What's the problem?

Huge growth likely in car use and air travel across the globe.

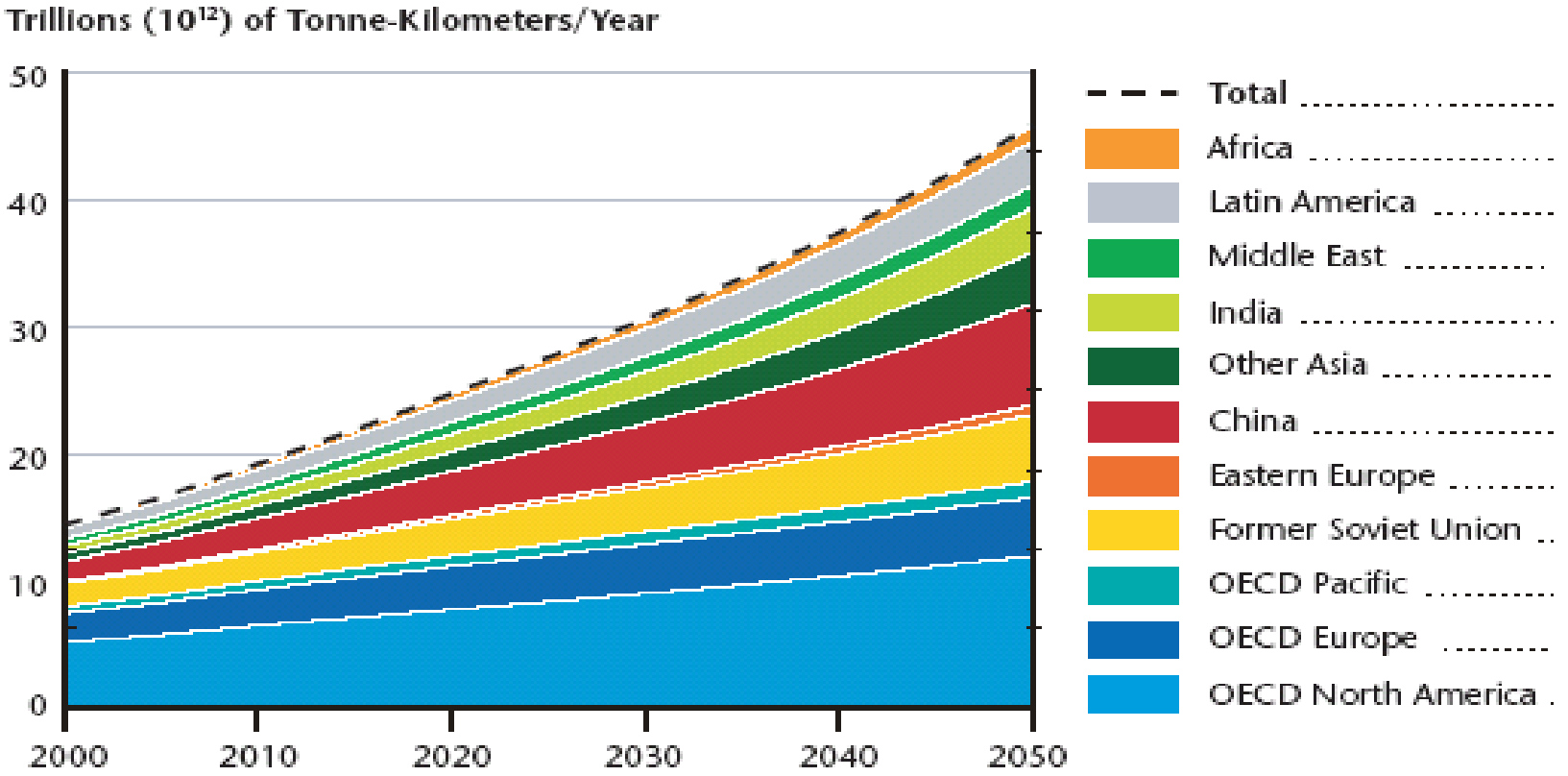
Source: Mobility 2030, WBCSD



What's the problem?

Increased wealth also drives increased freight transport.

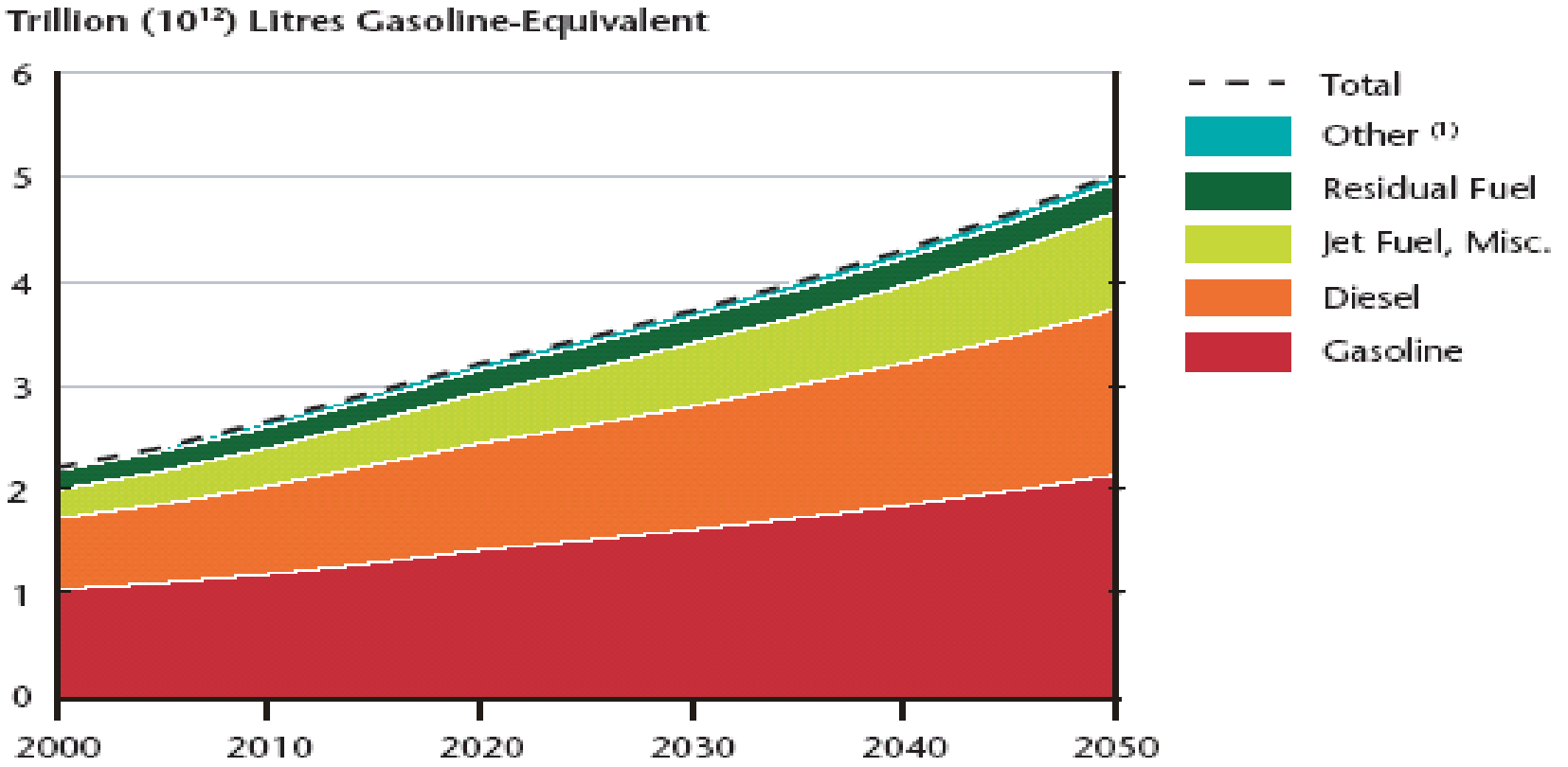
Source: Mobility 2030, WBCSD



What's the problem?

More transport means more (fossil) fuel use, worldwide.

Source: Mobility 2030, WBCSD



What's the problem?

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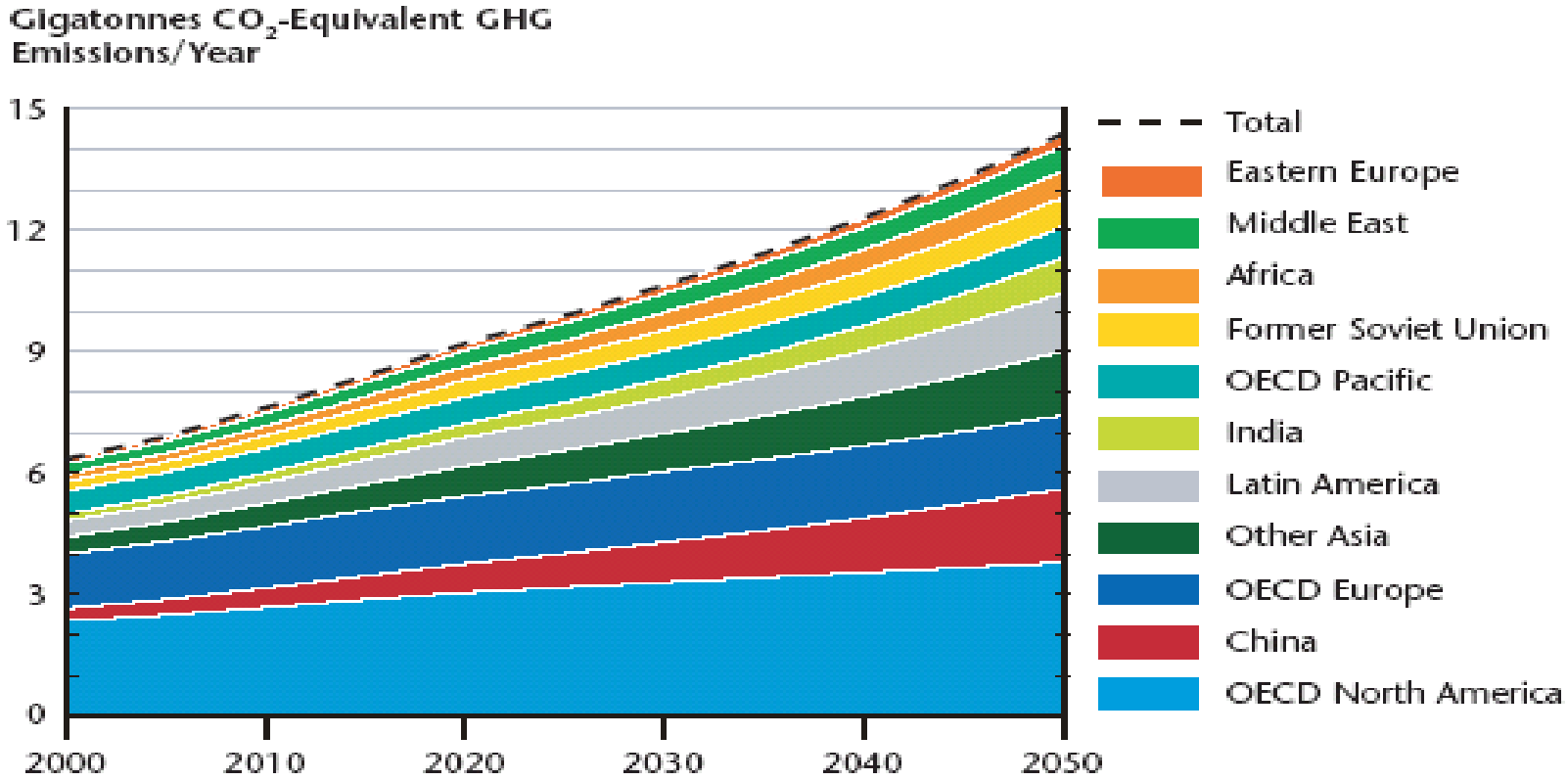
More (fossil) fuel use means more Greenhouse Gas Emissions.

Source: Mobility 2030, WBCSD



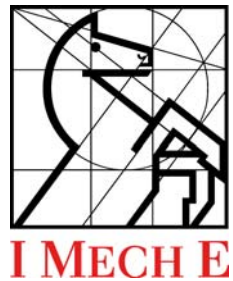
What's the problem?

Other issues:

- Increased congestion, local pollution and noise.
- More deaths and injuries, particularly in the developing world.
- Increased use of materials, land and energy.
- Growing inequities, especially for the elderly, poor and disabled; less access to transport and higher exposure to noise and pollutants.
- Growing inequity between developed and developing world.

The Energy Hierarchy

The ‘Energy Hierarchy’



1 – Energy Conservation

∇

2 – Energy Efficiency

∇

3 – Renewable, Sustainable Energy Supplies

∇

4 – Other Low Carbon Energy Supplies

∇

5 – Conventional Energy Supplies

The ‘Energy Hierarchy’

1 – Energy Conservation (do not use as much energy)

∇

2 – Energy Efficiency (find more efficient ways of supplying/using energy)

∇

3 – Renewable, Sustainable Energy Supplies (least environmental impact)

∇

4 – Other Low Carbon Energy Supplies (other GHG-reducing supply sources)

∇

5 – Conventional Energy Supplies (the way we currently do it)

What are the potential solutions?

What are the potential solutions?

Following the principles of the Energy Hierarchy we must first consider how to reduce transport requirements to use less energy:

- Live close to work and walk or cycle
- Use tele- and video-communications for meetings and conferences
- Where possible, use Rail rather than Road Transport and either rather than Air
- Avoid ‘food-miles’ – use locally-produced food and produce

What are the potential solutions?

Many potential technical solutions exist, many already proven. All will need the innovative application of engineering skills to make them work:

- New fuels and propulsion systems for vehicles
- Other transport solutions, e.g. materials, ITS, commercial vehicle systems
- Rail, Air & Marine
- Transport Integration

What are the potential solutions?

Before we look at the many new technologies now available, consider existing solutions:

"The United States could reduce its oil use by approximately 800 million gallons and carbon dioxide emissions by eight million tons a year if Americans bought diesels at the same rate as Europeans."

Dr Dieter Zetsche, President & CEO of Chrysler Group (2002)

What are the potential solutions?

Alternative fuels using existing infrastructure

- Fischer-Tropsch (FT) diesel. Derived from natural gas, high cetane number, free of sulphur and aromatics, giving high engine efficiency, low emissions.
- Conventional biofuels. Include methanol and ethanol for gasoline engines, and biodiesels, e.g. fatty acid methyl esters (FAME). Can be blended with fossil fuels or, potentially, used on their own.
- Advanced biofuels: higher yield crops, biomass gasification and F-T process.

What are the potential solutions?

Alternative fuels needing new infrastructure

- Liquefied Petroleum Gas (LPG). Derived from crude oil and natural gas condensate. Lower emissions than gasoline. Already fairly well established.
- Compressed Natural Gas (CNG). Very good emissions characteristics, similar to modern diesel systems. Reduces reliance on crude oil! Infra-structure more complex.
- Hydrogen (NB. Not really a 'fuel'). Zero tailpipe GHG emissions, but currently made from fossil fuels, and major infrastructure issues.

What are the potential solutions?

Gasoline Direct Injection

- Lower octane requirement allows higher compression ratio and, therefore, higher efficiency.
- Freedom of injection timing allows stratified mixtures to be used and, therefore, ultra-lean burn and unthrottled engine operation.
- Downsized engines deliver same performance characteristics as larger conventional engines, e.g. 1.1 litre replacing a 1.6, and providing ~ 20 % better fuel economy.

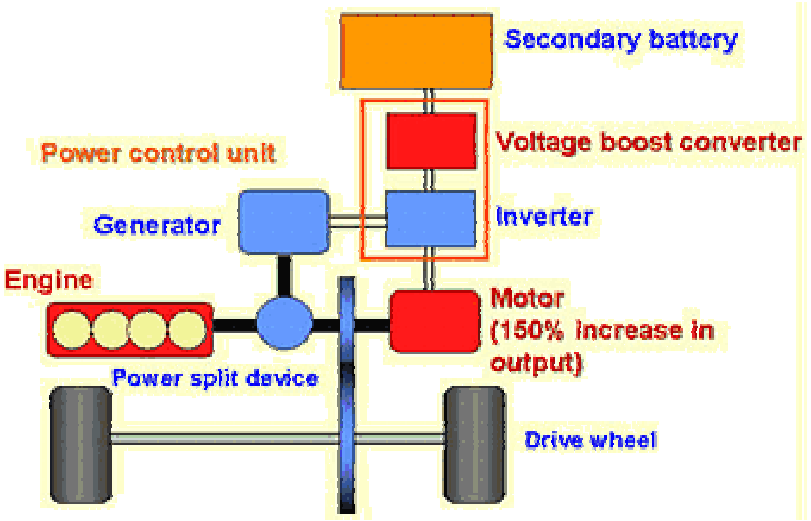
What are the potential solutions?

Direct Diesel Injection & HCCI

- Fuel injected directly into the cylinder, allows greater injection pressures and combustion efficiencies.
- Homogeneous Charge Compression Ignition (HCCI) has potential to give very high efficiency and very low emissions (NOx and particulates).

What are the potential solutions?

Hybrid systems



- Systems that combine ICE with one or more electric motors.
- ICE can be turned off when vehicle stationary or low speed.
- Electric motor(s) can be used at low speed.
- Engine and transmission systems can be optimised.
- Electric motor(s) can also function as generators.
- Regenerative braking systems also help overall efficiency.

What are the potential solutions?

Electric cars

- Power provided by rechargeable batteries
- Ideal for urban/city driving, e.g. G-Wiz!
- Speeds and ranges increasing (>300 km)
- Many mainstream OEMs now developing electric cars, e.g Mitsubishi ú
- Zero tailpipe emissions, zero carbon if charged by zero carbon electricity.
- High initial costs (batteries), but much lower running costs.

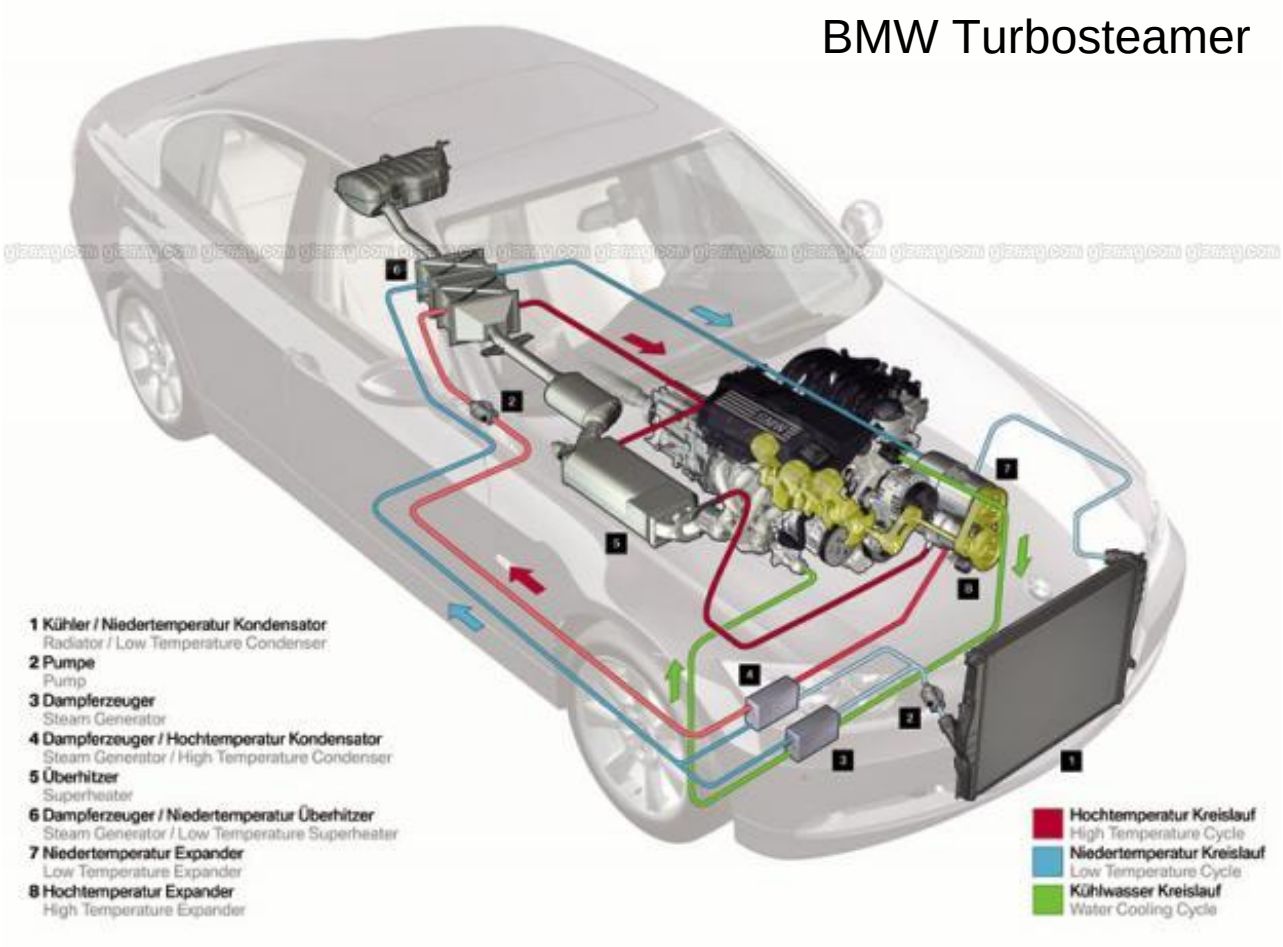
What are the potential solutions?

Fuel cells

- Potential for near zero emissions throughout lifetime of vehicle, and high efficiency. GHG emissions only zero if hydrogen comes from carbon neutral sources
- Currently, greater GHG reduction from using hydrogen to upgrade existing fuels (main hydrogen demand)
- Proton Exchange Membrane (PEM) systems currently most promising. On board storage of hydrogen, material costs, packaging and decommissioning issues are major obstacles.

What are the potential solutions?

BMW Turbosteamer



Waste Heat Recovery

- Recovers waste heat from vehicle exhaust and cooling circuit
- Produces steam to generate electricity using expanders

What are the potential solutions?

Other (mainly road) transport solutions

- Weight reduction, e.g. by use of aluminium, magnesium, and consequent smaller (lighter) engines. 30% weight savings are possible, ~ 15% fuel saving.
- Intelligent Transport Systems (ITS). Potential to improve traffic flow and safety, e.g. lane support, safe following, enhanced vision, electronic guidance.
- Lower and constant speeds give less drag and dramatically improved fuel consumption.
- Greater propulsion system efficiencies and aerodynamic drag reduction improve fuel consumption.

What are the potential solutions?

Rail

- Can make a positive contribution to sustainable transport.
- UK data: ½ C-emissions per pax-km compared with car, ¼ compared with air.
- Capacity to move people and freight using little energy and producing low emissions, safely, reliably and quickly.
- Particularly suited to urban areas (commuting, metro, light rail), inter city travel (< 1000km) and bulk freight.
- Not so good at low load factors, wide distribution tasks or short urban journeys.

What are the potential solutions?

Rail

- AC power systems have already delivered significant energy savings, also more reliable. Modern diesels also much more efficient.
- Potential for fuel cells to provide auxiliary power for diesel locomotives, and for hybrid-electric systems to further cut emissions and fuel use.
- Investment needed – e.g. in capacity, passenger comfort, interchanges (esp. car-rail), electrification, traffic management, cleaner fuels and weight reduction.

What are the potential solutions?

Rail

Low Weight Railcar (JPN)

Low Emissions Diesel Hybrid (USA)

What are the potential solutions?

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Air

- Fuel efficiency has improved dramatically over recent decades.
- Difficult to balance CO_2, NO_x and noise.
- Potential for further improvements in aircraft design, e.g. blended wings, improved engines.
- Fuel savings possible through better management systems, e.g. reduced stacking at airports, improved approach control.
- Possible climate change benefits through lower cruise altitudes and fewer very long haul flight stages. More research needed!

What are the potential solutions?

Marine

- Seaborne trade expanding rapidly, in line with export/manufacturing growth, particularly in China and SE Asia.
- Growth in new shipbuilding, especially oil tankers, large container ships and LNG carriers.
- Negligible levels of ship demolition.
- Pressure for new ships to be bigger and faster.
- Major innovations in hull design and propulsion systems to improve efficiency, e.g. electric motors.
- Development of alternative fuels, e.g. LNG

What are the potential solutions?

Transport Integration

- Reduce car dependency and control traffic growth
- Invest in bus, rail, tram and information networks.
- Better co-ordination between land use and transport planning, especially regionally.
- Exploit alternatives to travel.
- Encourage walking and cycling.
- Improve interchange systems, e.g. provisions for bikes on trains.
- Other countries much better at this than UK.

UK Transport Statistics

Energy Usage in Freight Transport:

Sea	0.11	MJ/t.km
Barge	0.83	MJ/t.km
Rail	0.86	MJ/t.km
Truck	0.9-1.5	MJ/t.km
Air	8.3-15	MJ/t.km

UK Transport Statistics

Traffic Volume and Carbon Emissions

Transport Mode	pax-km or t-km	Carbon Emissions
Passenger cars	86.4%	88.8%
Passenger rail	5.4%	3.5%
Domestic aviation	1.3%	2.8%
Buses	6.1%	4.2%
Motorcycles	0.8%	0.7%
Total passenger transport	**100.0%**	**100.0%**
Road freight (LDV and HGV)	67.1%	89.7%
Rail freight	8.6%	2.3%
Shipping	24.3%	8.0%
Total freight transport	**100.0%**	**100.0%**

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Sustainable Energy:

Background & Transport

Thank you for your attention during this presentation

My colleague Brian Robinson will now continue with:
Sustainable Energy
Power and Buildings