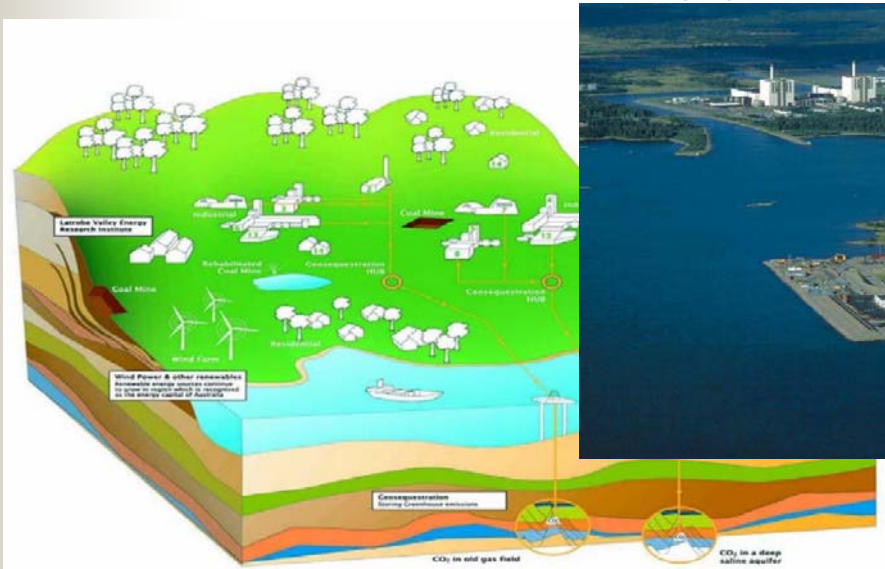
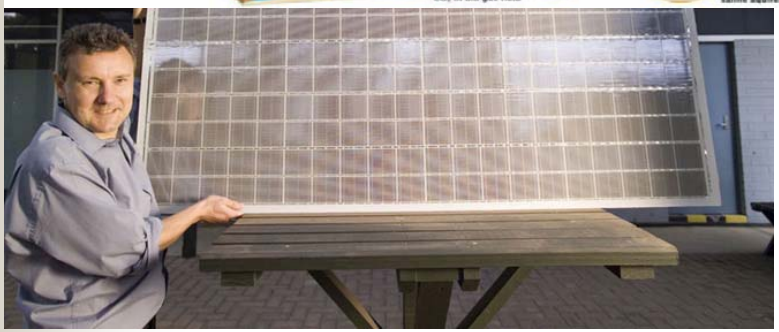
Energy Options in a Carbon Constrained World.





Martin Sevior, School of Physics, University of Melbourne

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Energy underpins our Civilization

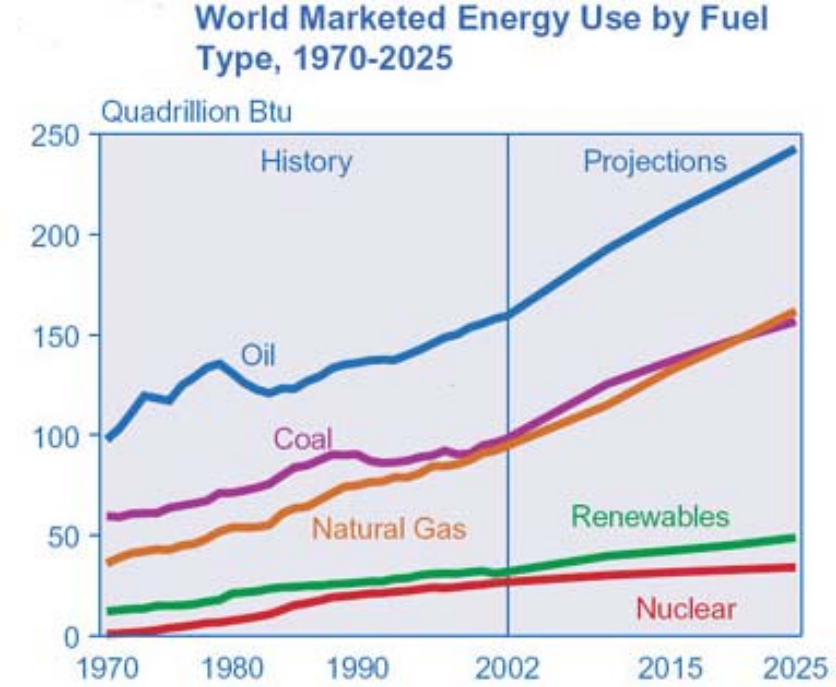
Imagine one week without Electricity

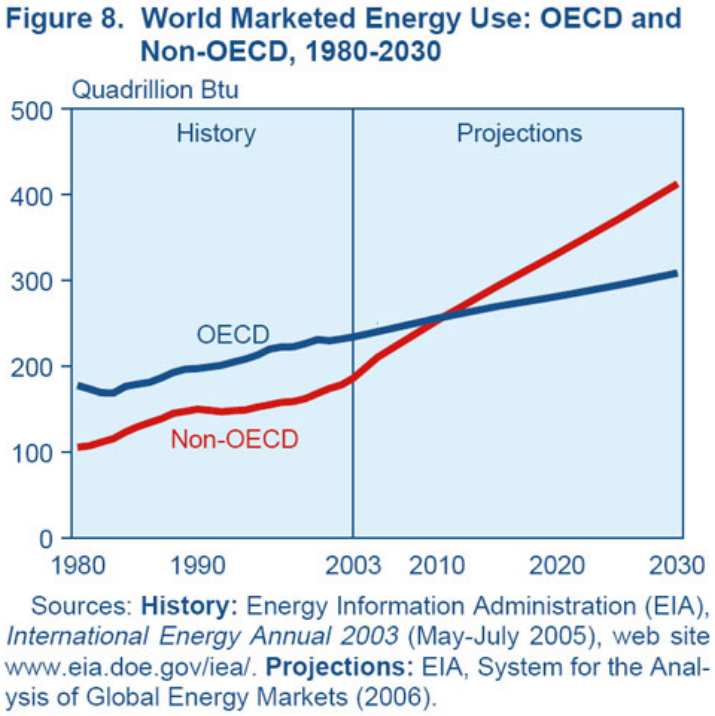
Imagine one week without Motorized transportation

We rely heavily on Fossil Fuels to provide the energy our civilization needs.

However our finite Earth constrains our future use of these.

Energy use without constraints

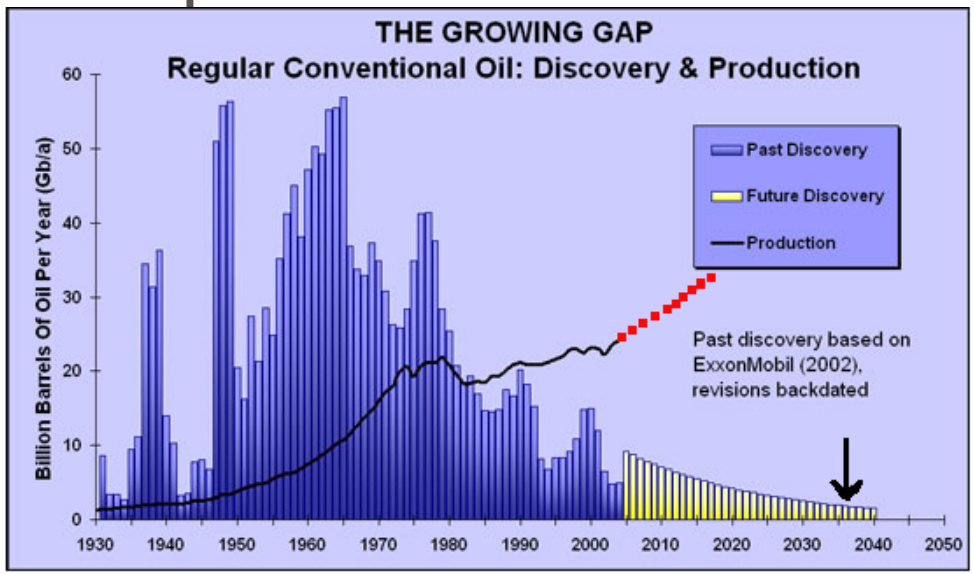




Non-OECD Countries are growing very quickly and are consuming an ever-increasing amount of energy.

How long can we keep using Oil?

- The rate of Oil usage is substantially greater than the rate of new Oil discoveries
- Developing Nations have become competitors for Oil



Simple extrapolation shows Oil exhausted by 2036

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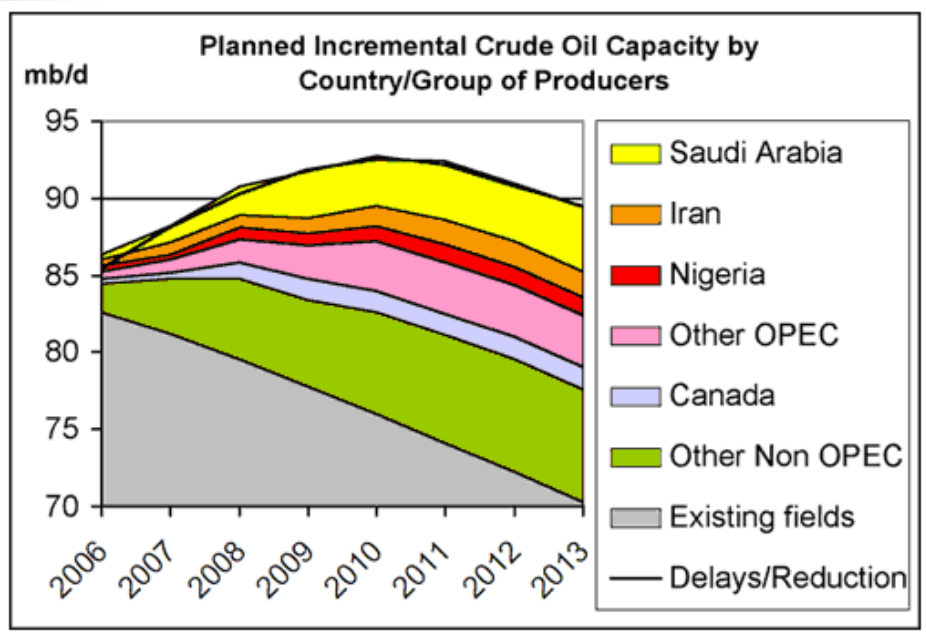
Is Oil coming up against a wall?

- Australia's Oil production peaked in 2000
- Will/When will World Oil production peak?



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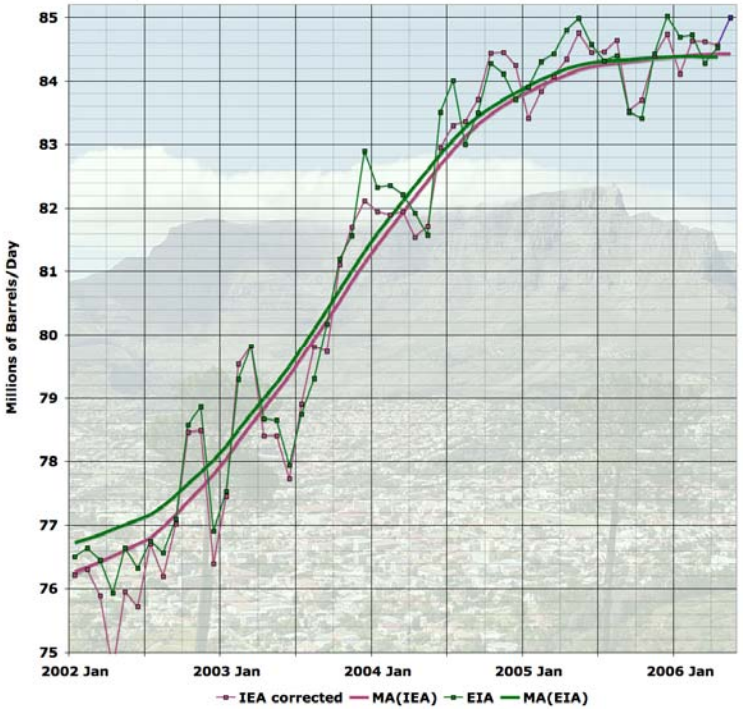

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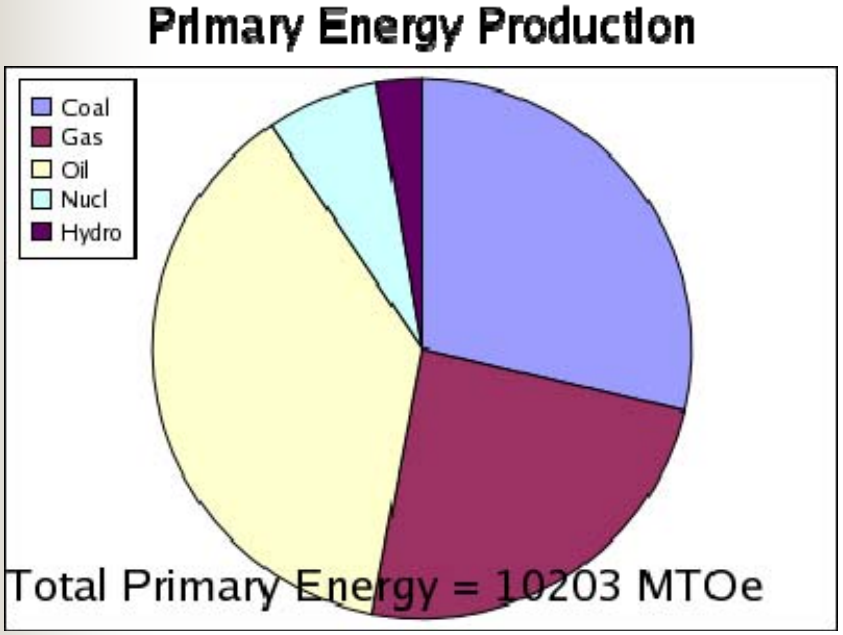
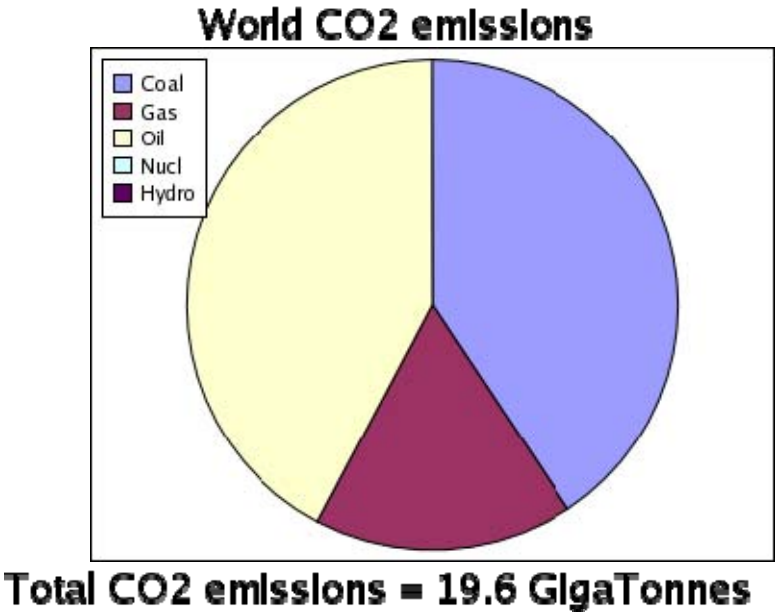
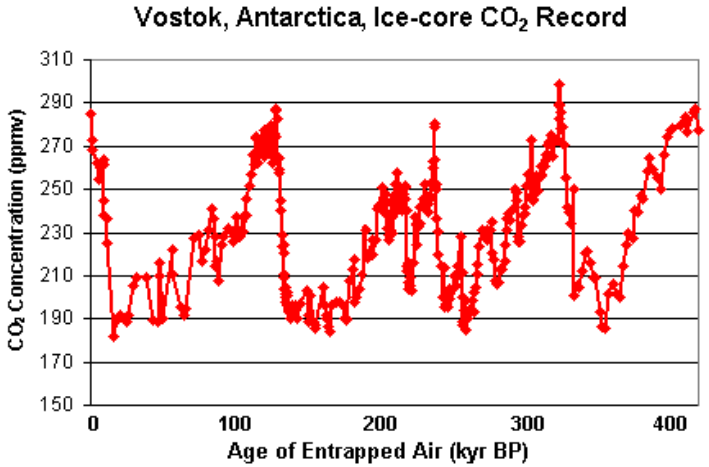
Energy Data from 2005

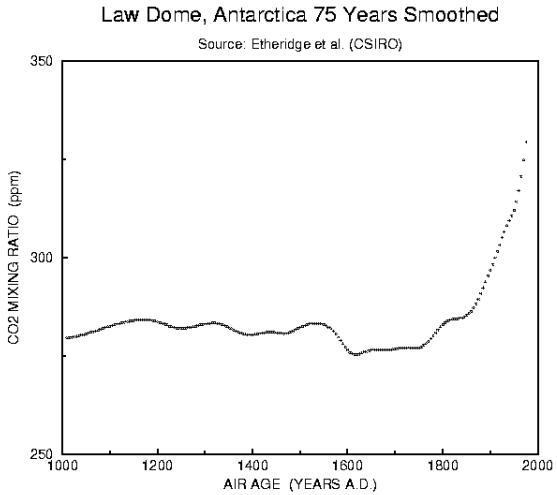
Burning Fossil Fuels produces CO2

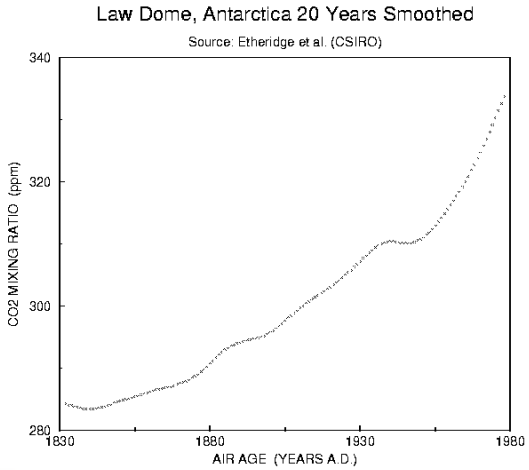




CO2 increase in the Atmosphere







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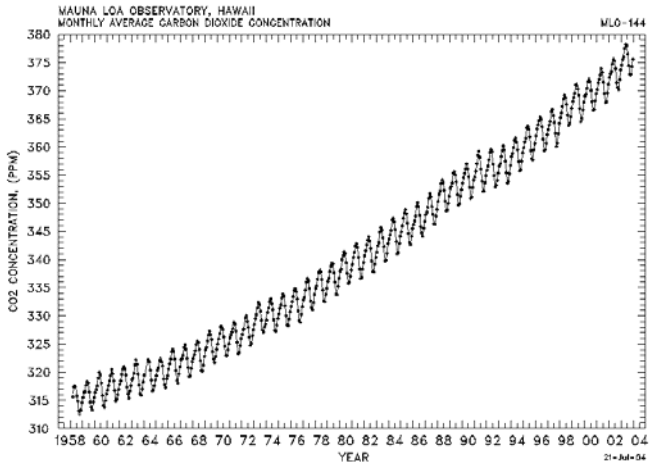

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Total World CO2 emissions

- Total world demand for energy is expected to at least double by 2050
- Much is this growth is in the third world which needs energy to escape poverty

“If we have to free our people from drudgery and ill-health, we need to address the issue of access to energy, particularly the need for rural masses”

Manmohan Singh, Prime Minister of India on plans to expand electricity generation capacity from 110 GW to 980 GW by 2030. (Australia has 40 GW of electricity generation.)

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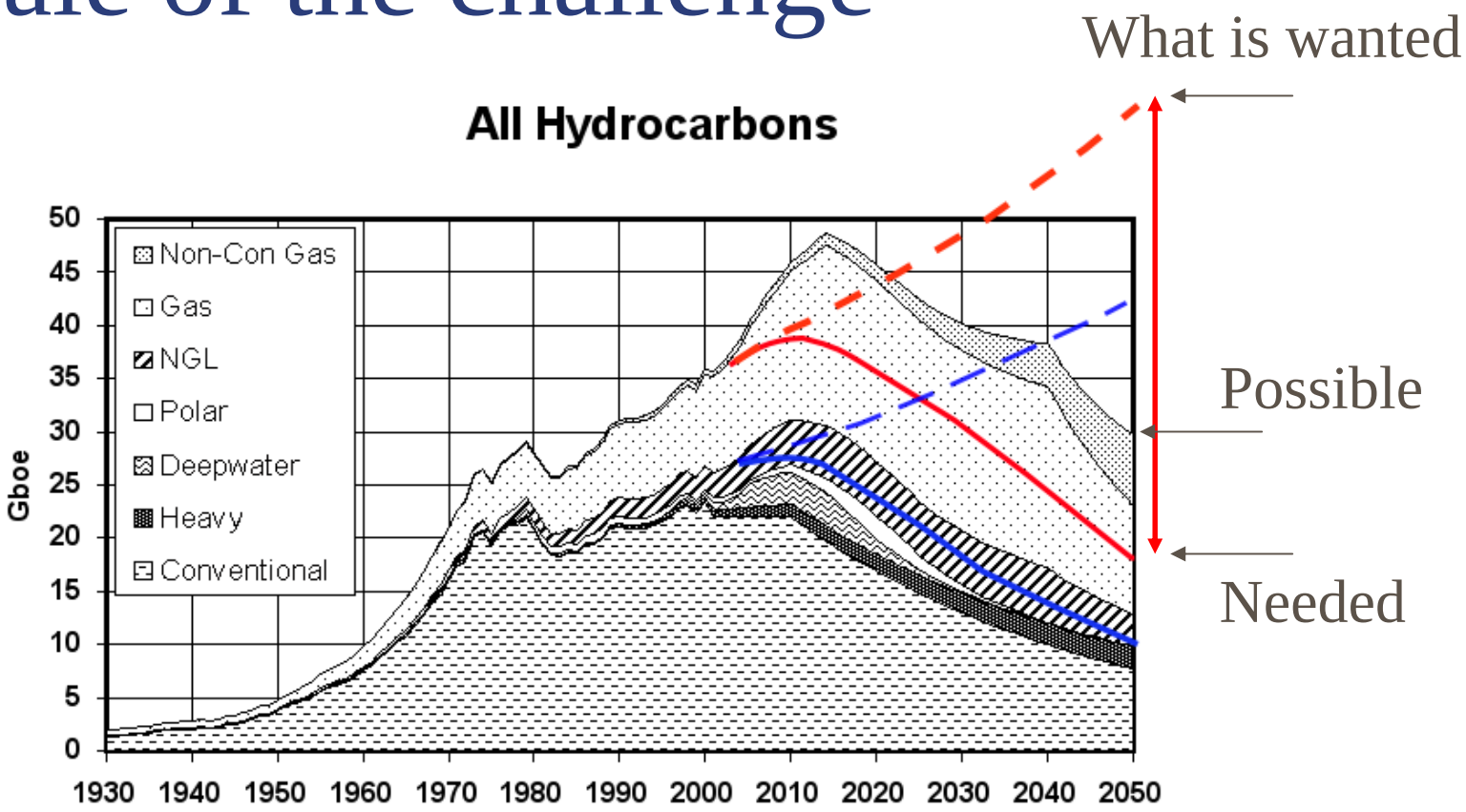
Greenhouse Emission targets

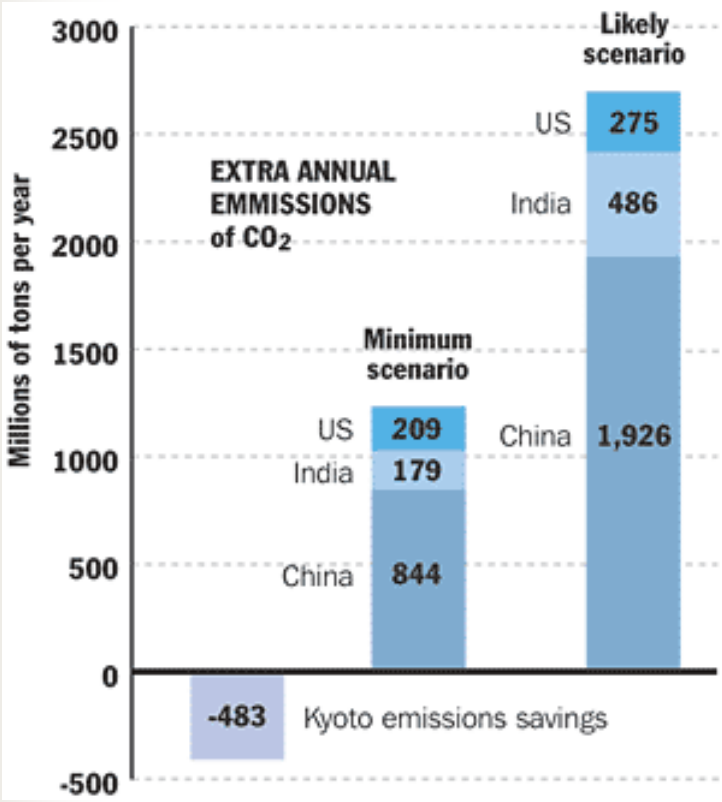
- Kyoto protocol
  - Reduce Greenhouse emissions by 5.2% from 1990 levels by 2008-2012
  - This is extremely hard. eg Canada has increased it's emissions by 20% since 1990
- Future
  - Reduce greenhouse emissions by **60%** from 1990 levels by 2050 to stabilize temperature rise to 2 C

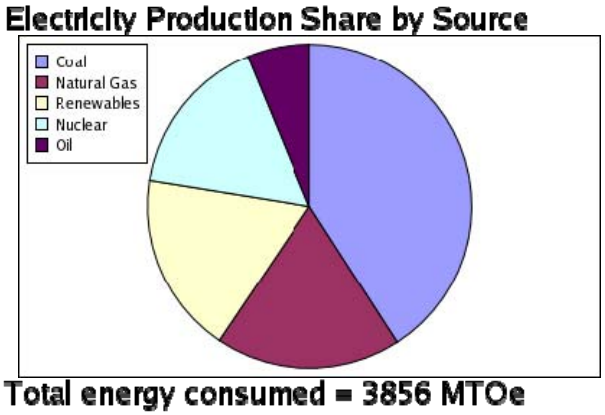
Scale of the challenge

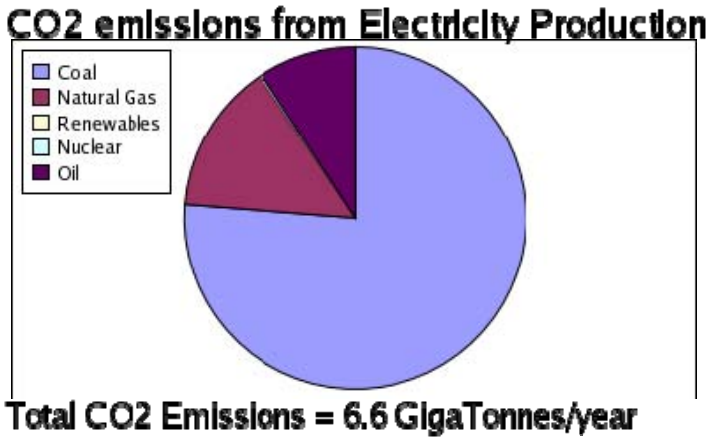


Conventional Oil and Natural Gas cannot keep pace with demand nor should they.

Default for Electricity is Coal







Additional CO2 emissions due to new Coal Fired Power Stations to 2020

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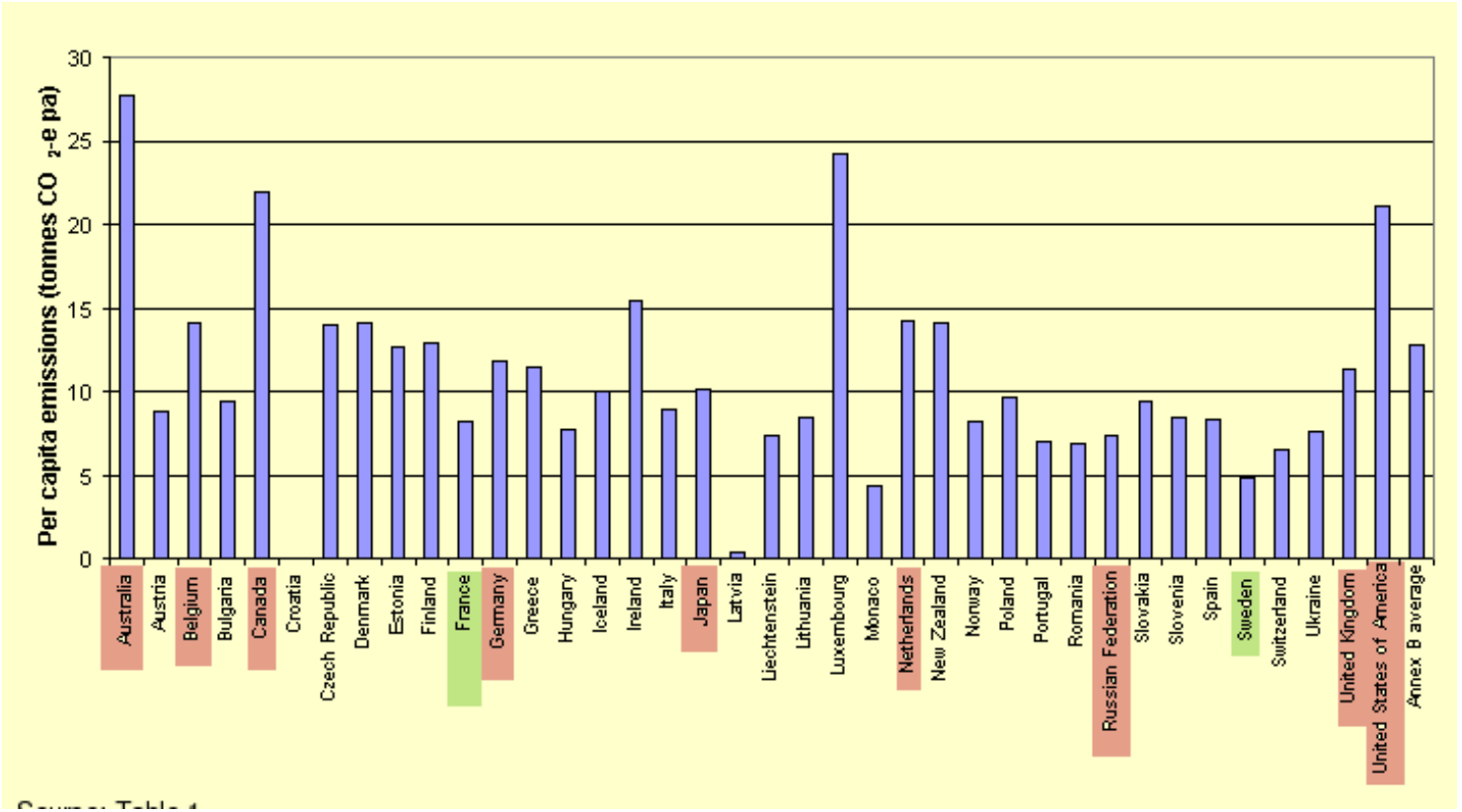
Australia's Challenges

Conventional Oil production is declining, we rely on imports

Our CO2 emissions are the largest per Capita in the OECD



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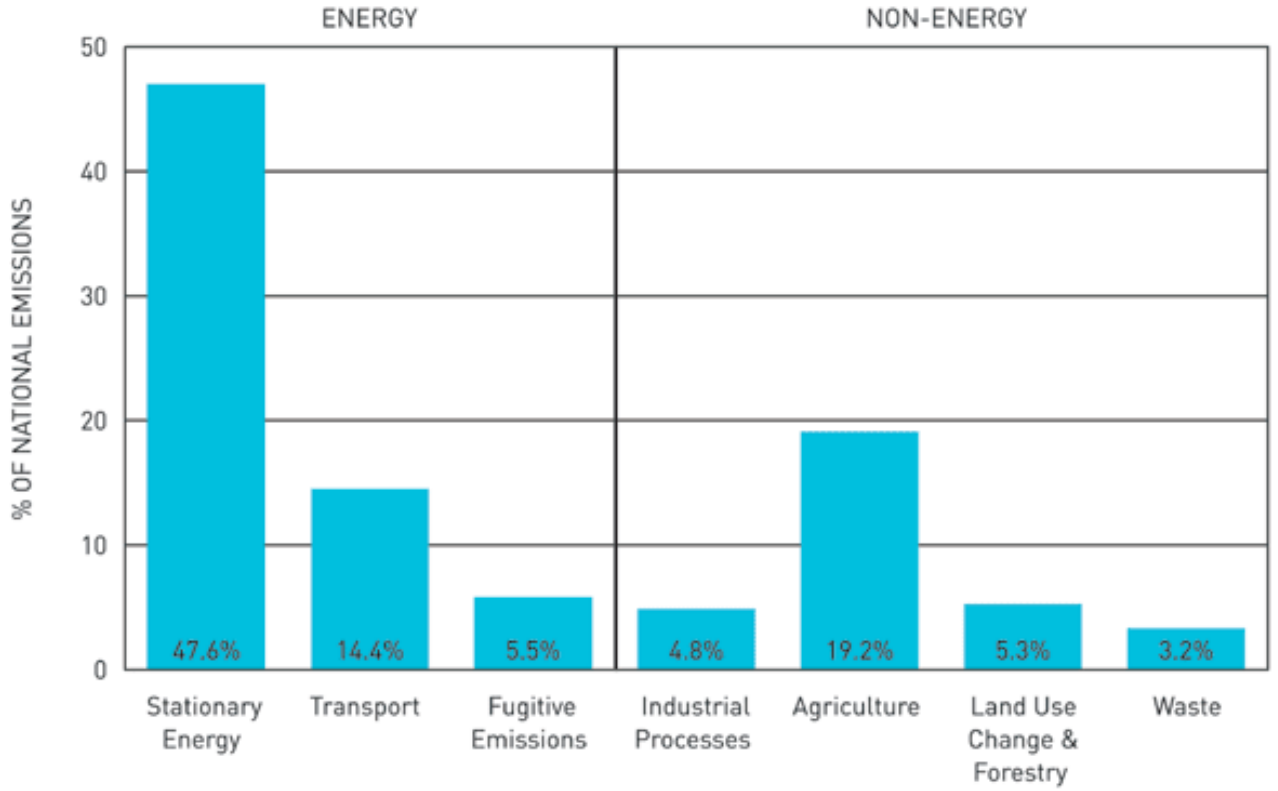
Australian CO_2 emissions

Around 50% of Australia's CO2 emissions are from electricity production.



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Options for Transport

Convert Coal to Oil (Monash Energy Project, being developed)

Convert Gas to Oil (under active Consideration)

Use LPG (well underway) or Natural Gas (not persued)

Rework our Cities, Public transport improvements

BioFuels – Ethanol, BioDiesel (May meet 10% of current demand)

More Efficient Vehicles

Transport can be far more efficient

Gasoline Engines are on-average 10% efficient

Modern Diesel Engines are 20% efficient

Fuel cells vehicles can reach 50% efficiencies

Batteries/Electric engines are 80% efficient

The electric route means same transport with 1/8th the energy.

Next generation batteries

0 – 100 km/hr in 4 seconds, 400 km range, available 2007

Cost US $100K

For the rest of us, Plugin Hybrids, (60 km range on electric) are likely to enable us to continue to use personal transportation post 2010

If sourced from electricity with low carbon emission technologies can substantially reduce world CO2 emissions

Electricity Generation

Our current coal-fired power stations provides us with cheap and reliable electricity.

Electricity costs vary depending on the coal quality and distance from mines.

Queensland Black Coal generates electricity at less than 3 cents per KW-Hr. Victoria generates electricity at 4 cents KW-Hr

But if we're to meet our target of 60% CO2 emissions, we must close many of them or at least not use them as much.

What can we do for Electricity?

Energy Efficiency

Over the past 5 years, Australia's electricity consumption has grown by 3.7% per year.

To some extent this reflects our very cheap electricity.

This are a variety of energy efficiency gains available throughout the economy. All require investment of time and money.

Achieving additional efficiency gains in addition to those made via "natural" processes, almost certainly requires higher prices.

Natural Gas

Natural Gas produces half the CO2 for the same amount of electricity.

Output can be altered quickly so it can be usefully paired with renewable energy sources such as wind and solar.

However, Natural Gas is also a finite resource and it's world-wide production rate is likely to peak within the the next 20 years.

Gas produced electricity, at current international prices of $6 per GigaJoule, costs around 7 cents/KW-Hr

Wind Power

Wind is the leading renewable energy source.

Cost is 7 – 9 cents/KW-Hr but is unlikely to decrease.

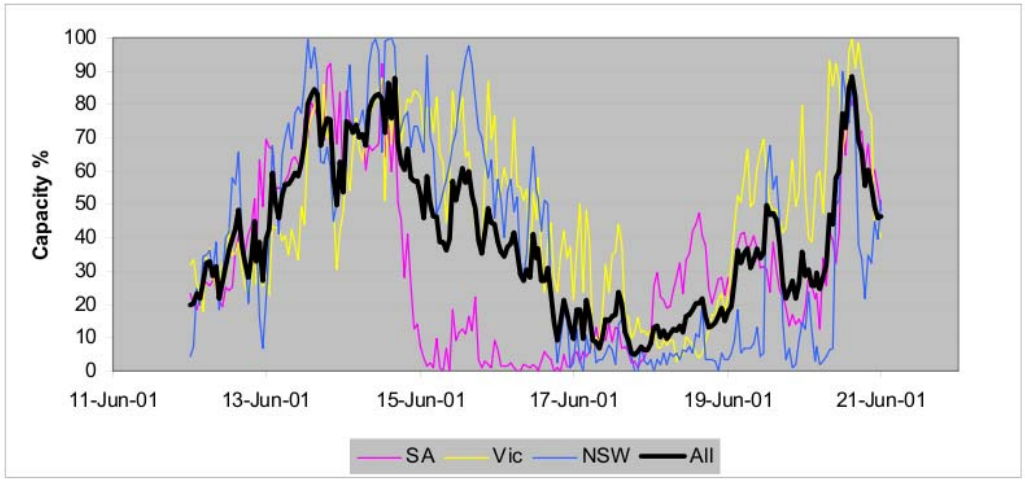

Figure 18 Estimated power production – extended calm in South Australia (winter)

Intermittency and variability of output mean diminishing returns after 10% – 20% of total capacity.

The problem with variability

In order to make a difference in CO2 outputs, you have to actually turn off (or down) coal-fired generators.

Victoria's goal of 10% Renewable by 2015 if met by wind requires about 2 GW of peak output

Output from wind can vary by 90% over 1 hour

Baseload generators require 6 hours to ramp through 80% of their output.

At higher percentages the problem gets worse, 30% wind in Victoria requires 6 GW of peak output.

Solar Energy

Fundamentally factor of 20 higher flux than wind.

Commercial PV systems currently provide electricity at 25-50 cents per KiloWatt-Hour

Solar works at small scale, so can compete at the retail level of 10 –14 cents/KW-Hr

Huge potential for improvements (factor 4 – 10 decrease in price).

eg Sliver Cells (developed at ANU), Nanosolar (California) rolls of thin film CIGS (400 MW factory), SolarSystems (Vic.) concentrators

The Nanosolar factory is costed at **$100 million** and expects to produce product worth **$2 billion / year**.

Variability and intermittency issues remain after costs are reduced – needs storage.

Carbon Capture and Storage

Coal is gasified into CO and H2 streams.

If combusted in pure O2, a pure CO2 stream emerges.

This can be reinjected into underground reservoirs. Intensely challenging – cubic kilometers of CO2 per year!

The coal gasification process depends on the properties of the coal (moisture content, sulphur and other impurities).

The CO2 storage procedure depends on the properties of the local site. All need detailed modeling

Appears feasible in Victoria's Latrobe Valley but more study is needed. Late 2010's – 2020.

Electricity cost is expected to increase by 1 – 4 cents/Kw-Hr

Nuclear Power

A “drop in” replacement for coal-fired base-load generation.

When used at world-best practice, emits about 1% of the greenhouse gases of fossil-fuel plants.

Fuel is abundant and will last for centuries.

New plants expected to produce electricity in the range 4-7 cents KW-Hr

Need considerable operating and regulatory expertise which does not yet exist in Australia

Needs additional infrastructure for Waste Disposal

Fierce Opposition from some in the community.

Others

Hydro – almost fully exploited already in Australia

GeoThermal – Immature and of limited availability

BioMass:

Useful for small scale local developments to utilize waste. (eg Saw Dust and Bagasse)

Large scale usage faces significant environmental challenges and transport issues.

Leading technologies

Technology	Cost	Potential
Carbon Capture and storage Unproven technology	6-10 cents/KW-Hr	Substantial scientific questions for each site.
Natural Gas. Good for Peaking demand. Still emits large amounts of CO2	5-7 cents/KW-Hr	Likely to increase in Price.
Nuclear Power “Drop in” replacement for Coal	4-7 cents /KW-Hr	Large potential for improvements
Wind Power Currently best renewable option	7 – 9 cents/Kw-Hr	Limited future potential
Solar Power Can compete at retail level. (10 –14 cents/KW-Hr)	25 – 50 cents/KW-Hr	Huge potential. Works well at small scale and retail.

Concluding remarks

Without storage, intermittency and variability of wind and solar likely to limit penetration to 30%.

Solar energy is worth direct Government support.

Achieving 60% reduction in CO2 emissions while growing electricity consumption requires replacing our existing Coal fired power stations with Nuclear or Carbon Capture.

Nuclear Power has proven track record of delivering large amounts of reliable electricity.

All options are more expensive than current coal.