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Session VII: Impact and Land Use Modelling

THE KEY FINDINGS OF IPCC 4AR AND CLIMATE CHANGE IMPACT ADAPTATION / MITIGATION STUDIES IN INDIA

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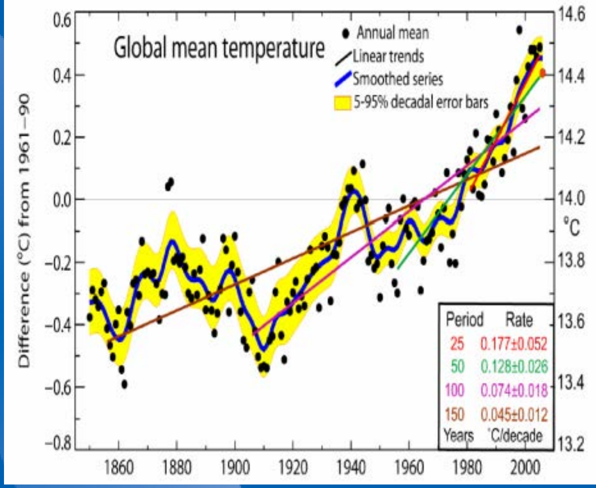
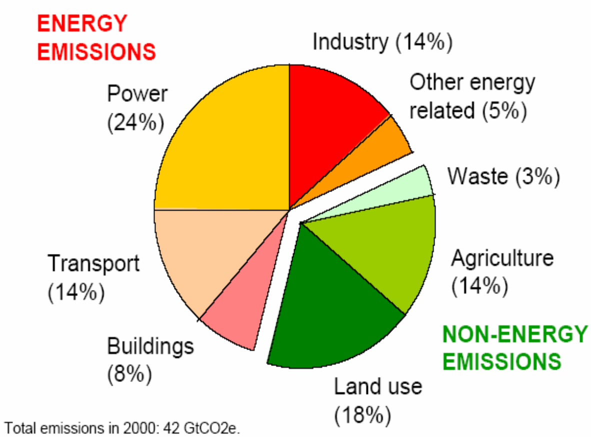
Greenhouse Gases & Climate Change

- ➢Since the industrial revolution we have seen an increase in greenhouse gas emissions that has caused the global climate to change. In the case of carbon dioxide this is around 30% more than pre-industrial levels.

- ➢This increase in greenhouse pollution is due to our continued reliance on energy technologies based on fossil fuels - a legacy of the industrial age.

- ➢Developing Countries are, with limited understanding of the issue and availability of resources, gearing up to adapt to climate change related risks





Total emissions in 2000: 42 GtCO2e.

Energy emissions are mostly CO_2 (some non-CO_2 in industry and other energy related). Non-energy emissions are CO_2 (land use) and non-CO_2 (agriculture and waste).

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IPCC 4AR - KEY FINDINGS FOR ASIA

- The Expansion of areas under severe water stress will be one of the most pressing environmental problems in South and Southeast Asia in the foreseeable future as the number of people living under severe water stress is likely to increase substantially in absolute terms

- Projected surface warming and shifts in rainfall in most countries of Asia will induce substantial declines in agricultural productivity as a consequence of thermal stress and more severe droughts and floods. The decline in agricultural productivity is likely to be more pronounced in areas already suffering from increasing scarcity of arable lands. The net cereal production in South Asia is projected to decline at least between 4 to 10% by the end of this century under the most conservative climate change projections

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IPCC 4AR - KEY FINDINGS FOR ASIA

- Increased risk of extinction for many flora and fauna species in Asia is likely as a result of the synergistic effects of climate change and habitat fragmentation. With average temperature increasing by 1°C the duration of wild fire season is likely to grow by 30%

- Rise in surface air temperature and decline in precipitation is likely to reduce pasture productivity in parts of Asia by the end of this century

- Increases in endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected in East, South and Southeast Asia. Increases in coastal water temperature would exacerbate the abundance and/or toxicity of cholera in South Asia

IPCC 4AR - KEY FINDINGS FOR ASIA

- Projected sea level rise is likely to result in many million additional people being flooded each year

- Sea water intrusion is likely to increase the habitat of brackish water fisheries but coastal inundation is likely to damage the aquaculture industry significantly. Changes in currents, water temperature, salinity, strength of upwelling and mixing layer thickness in the West Pacific and North Indian Oceans are expected due to climate change and sea level rise will exacerbate the already declining fish productivity in Asia

- Stability of wetlands including mangroves, and coral reefs around Asia is likely to be increasingly threatened

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ASIA - REDUCING THE VULNERABILITY

- Exploitation of natural resources associated with rapid urbanization, industrialization, and economic development in most developing countries of Asia has led to increasing air and water pollution, land degradation, and other environmental problems that placed enormous pressure on urban infrastructure, human well being, cultural integrity, and socioeconomic settings

Development and SD Mainstreaming policies through integration of indigenous knowledge and technological advances in national development initiatives is likely to reduce pressure on natural resources and improve management of environmental risks, which is likely to enhance the adaptive capacity and coping mechanisms in developing countries of Asia to reduce their vulnerability to climate change

ASIA – SUSTAINABLE DEVELOPMENT PATHWAYS

- The inclusion of sector specific climate proofing concept in the design and implementation of national development initiatives in most countries in Asia would be crucial in enhancing its climate change adaptive capacity

- Development of improved bio-energy systems in East, South and Southeast Asia is likely to have significant potential to contribute to climate change mitigation

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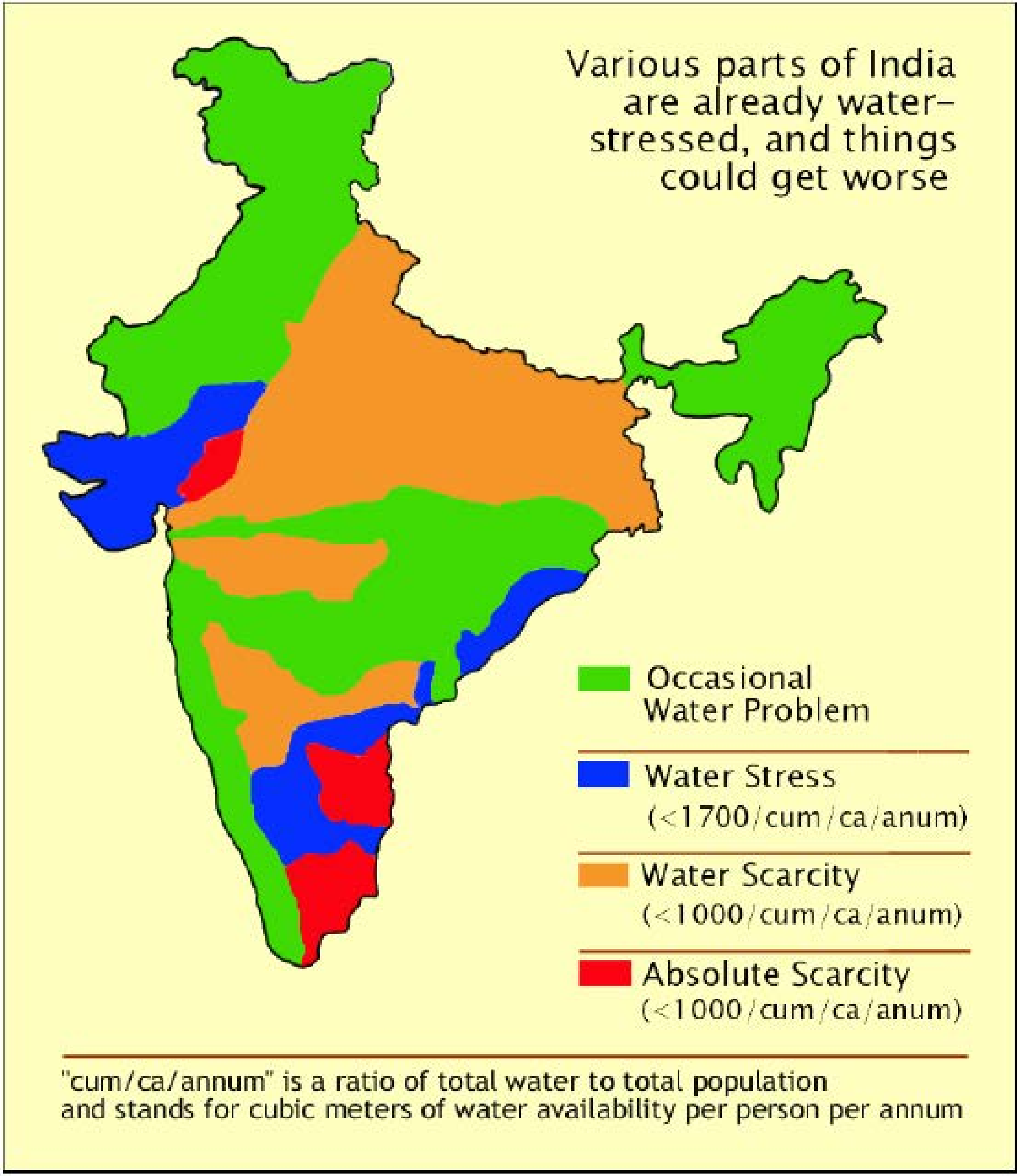
Climate Change Impacts Modeling Projects

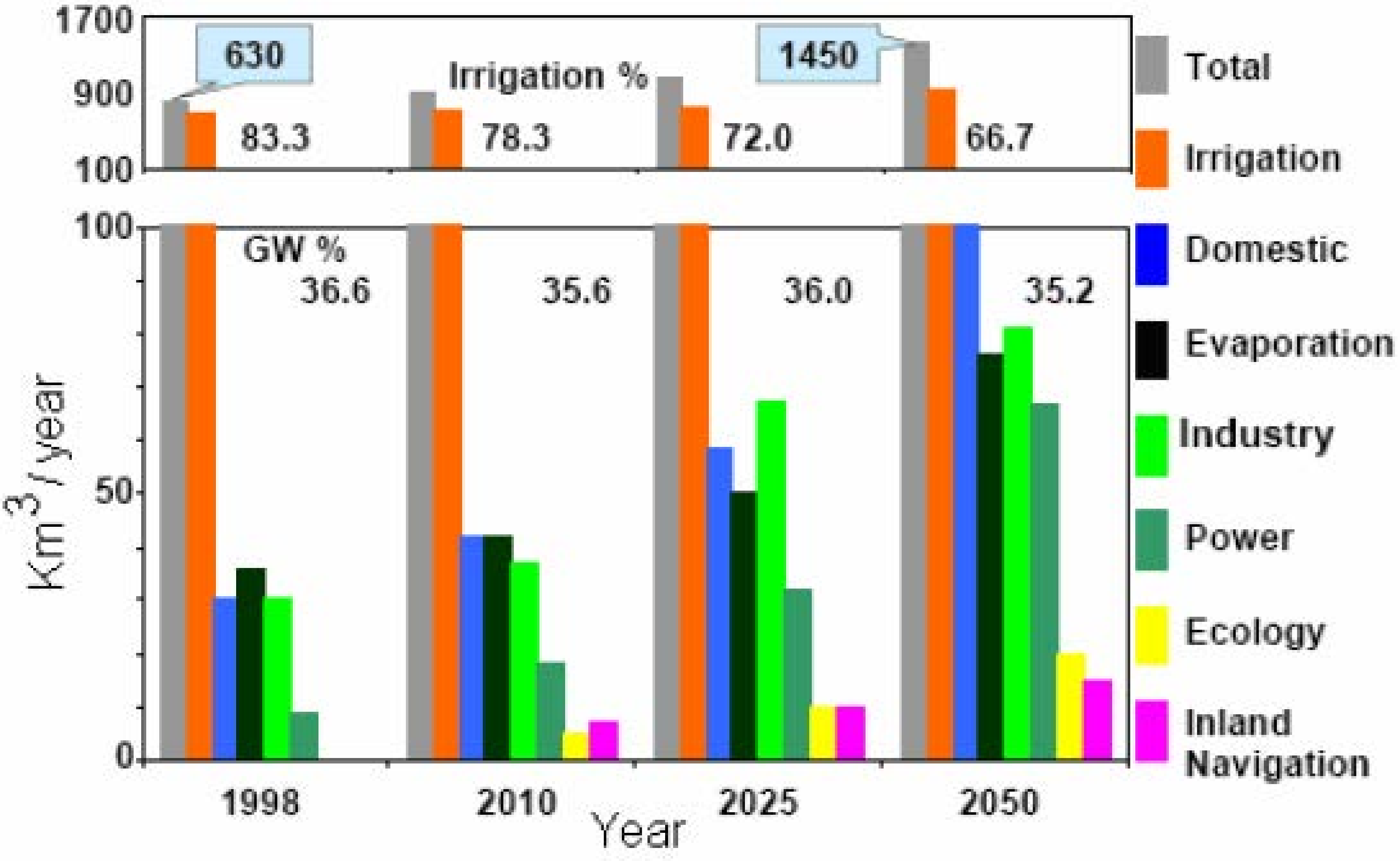
- **Modeling studies are underway to <u>develop confident climate change scenarios</u> at local and regional scale under Indo – UK collaboration.**
- **A host of modeling projects are currently underway at various institutions in India to assess the impacts of regional climate change on <u>food productivity and water availability</u> as part of its second National Communication to UN-FCCC**
- **Studies are also in progress to explore the impacts on <u>sea level rise and coastal inundation, health implications, terrestrial and marine ecosystems, and on urban infrastructure</u> including economic burden to India's GDP**

Water Resources in India



Sector Specific water Requirement in India

Total water need is expected to increase by ~120%



Basin Wise Projected Changes

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Plausible changes in water balance components and annual surface flow in major river basins of India by the mid-21st century due to climate change as simulated by a high resolution climate model

Major River Basins (within India's territorial border only)	Change in Annual Mean Rainfall / Snowfall (mm)	Change in Annual Mean Surface Runoff (mm)	Change in Annual Mean Evapo-Transpiration (ET) (mm)	Currently Reported* Average Surface Flow BCM / year	Likely Change in Annual Surface Flow by mid-21st Century (%)
Indus	+232	+114	-28	73	17.6
Brahmaputra	+148	+54	+35	586	8.4
Ganga	+165	+83	+74	525	9.7
Mahanadi	+217	+108	+49	67	11.1
Brahmani	+216	+137	+82	28	14.8
Godavari	+76	+42	+7	110	19.2
Krishna	+64	-38	+24	78	-6.3
Pennar	-51	-27	-9	7	-4.9
Cauvery	+43	-12	+39	21	-2.8
Luni	-124	-15	-94	15	-3.7
Tapti	-52	+14	-45	12	-0.6
Narmada	-229	+9	-22	46	-3.4
Mahi	-118	-36	-83	11	-8.1
Sabarmati	-212	-48	-126	4	-12.3

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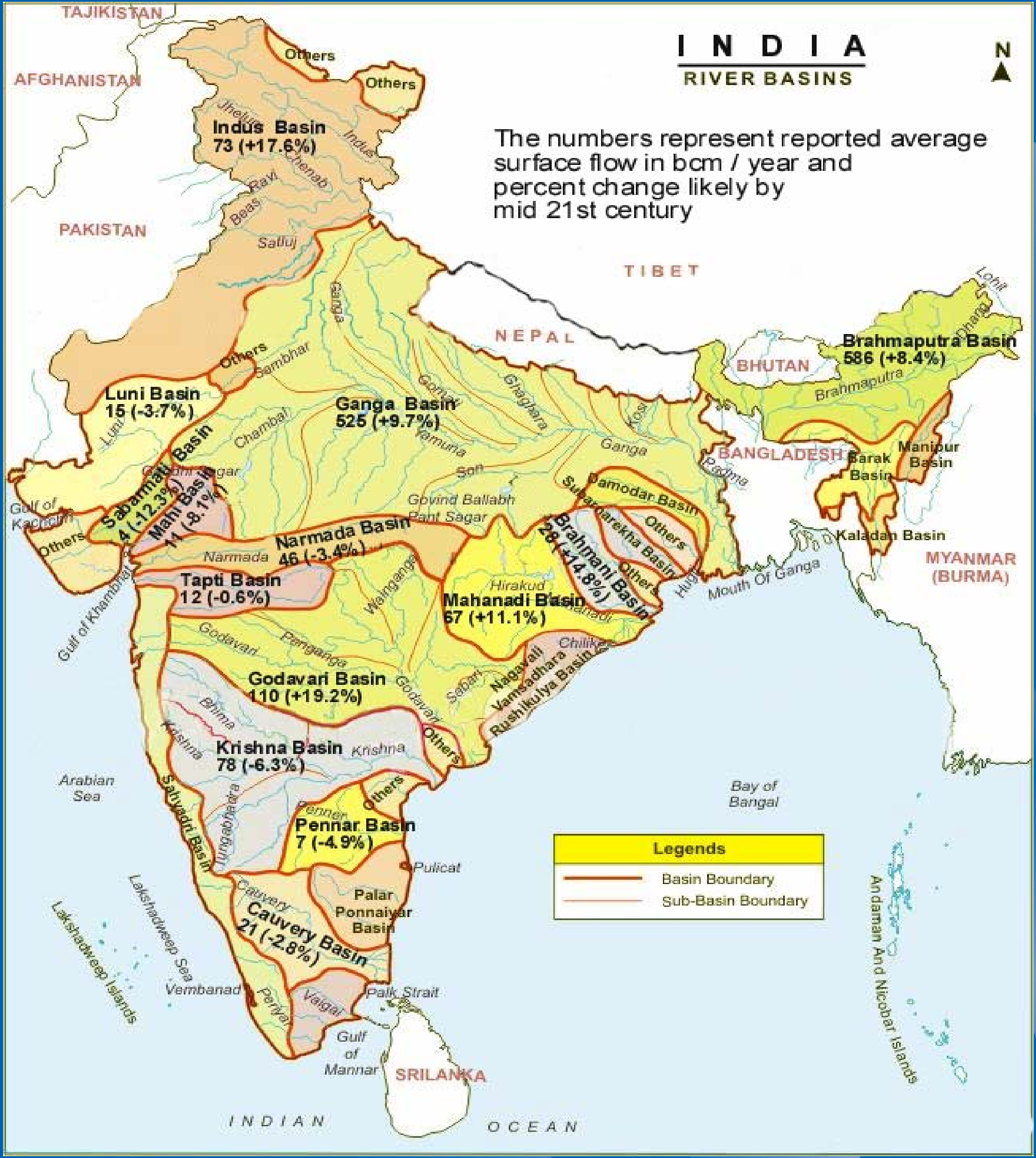
Basin Wise Projected Changes

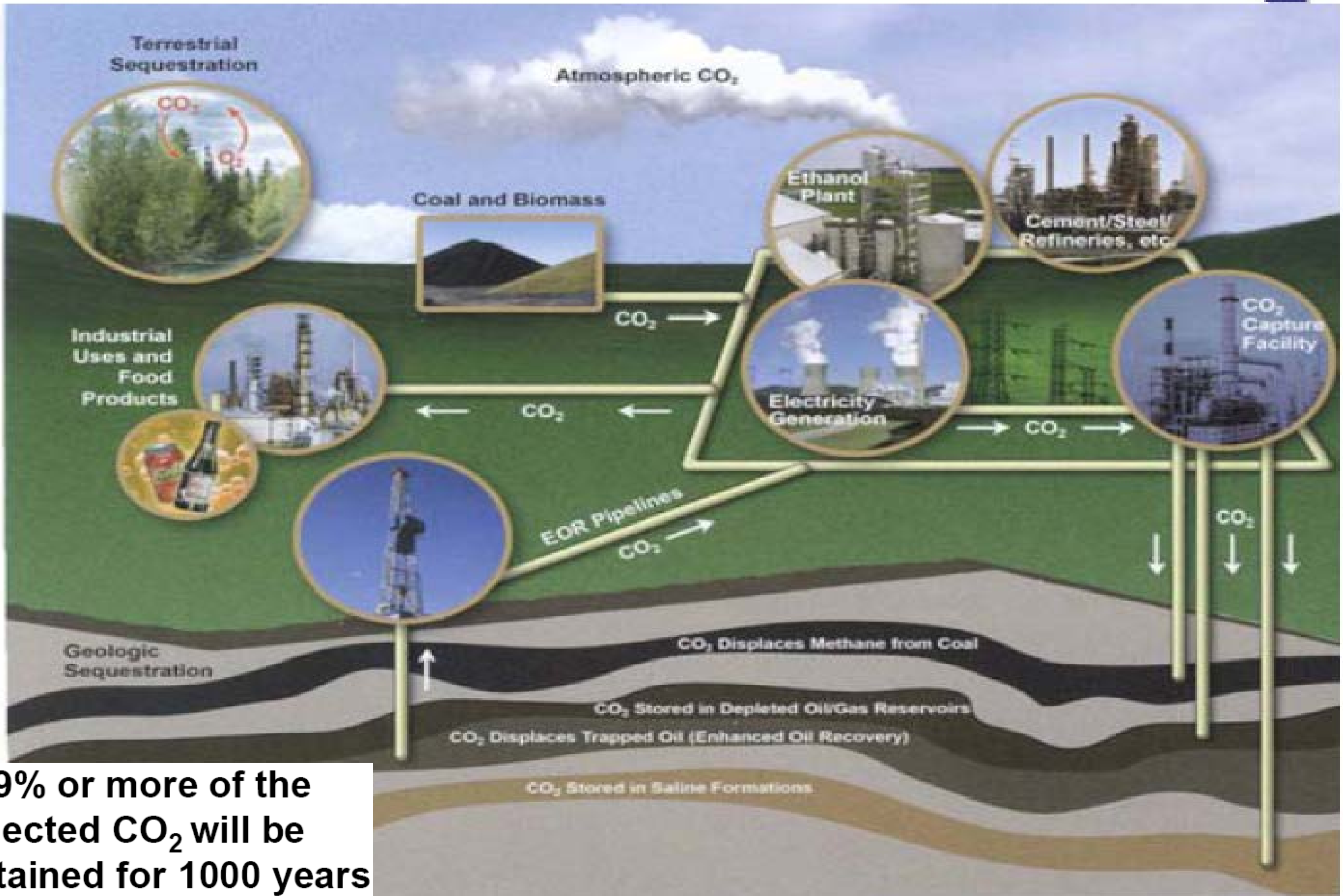


Carbon Capture and Storage Technology

- Alternative technologies that produce fewer greenhouse gases have, recently, been at the forefront of the debate on climate change.

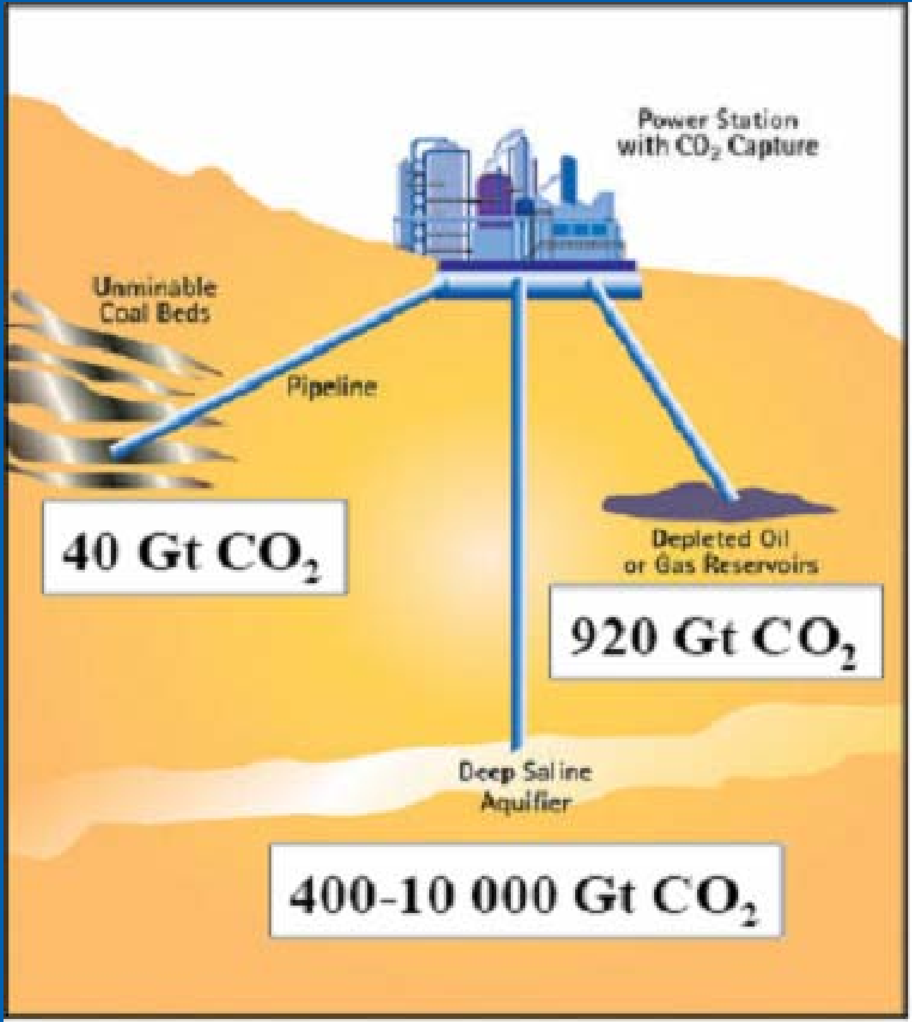
- Carbon capture and storage is the newest and perhaps the most controversial of those technologies currently being investigated.

What To Do With CO_2 ?



- 99% or more of the injected CO_2 will be retained for 1000 years

CO_2 Storage Potential

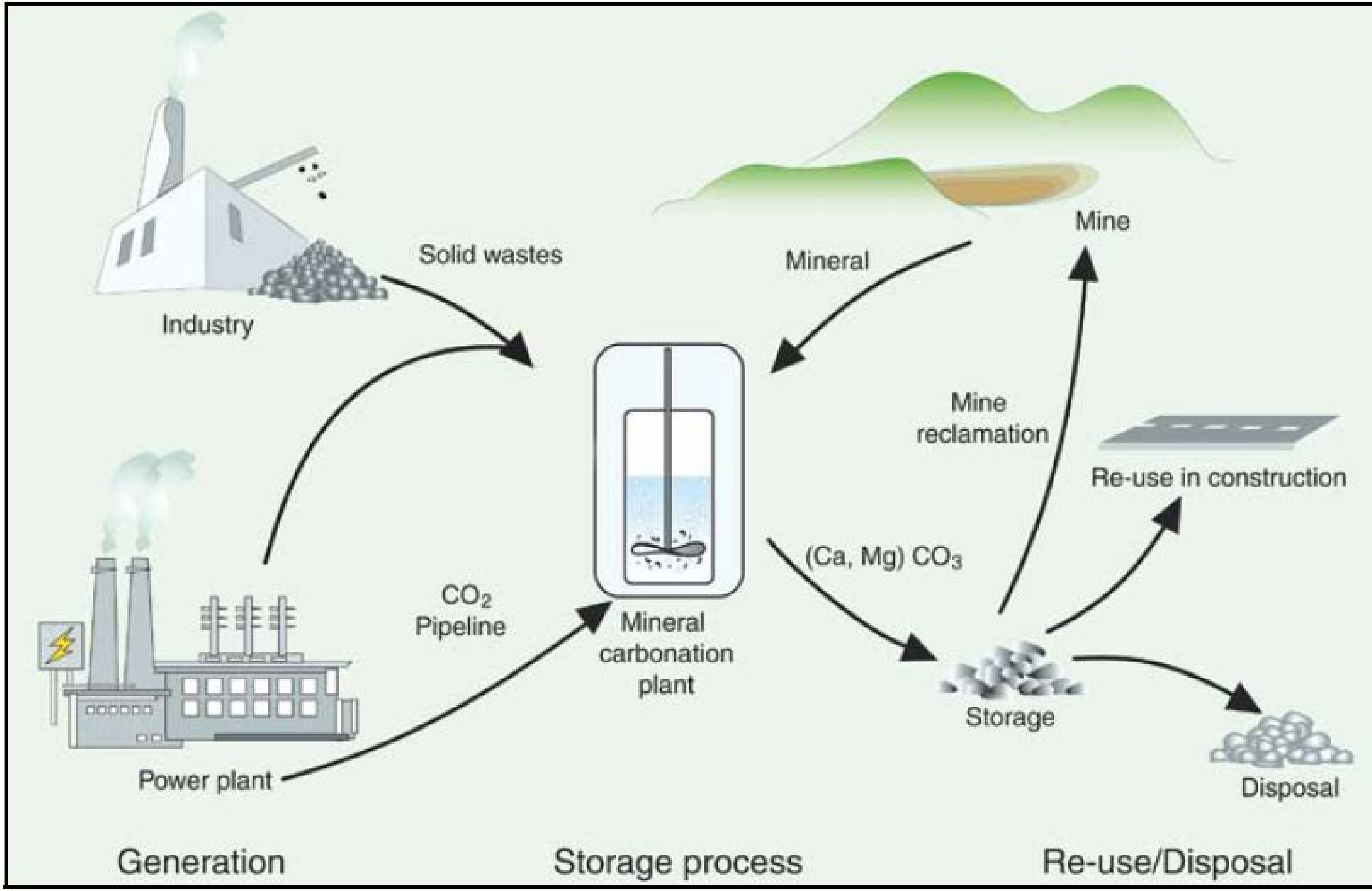


Source: IEA GHG R&D Programme

Global Potential:
1000 – 10.000 Gt CO_2

Potential in NL (160 Mton/yr):

- depleted gas fields: > 9000 Mt CO_2
- saline aquifers: 260-2600 Mt CO_2
- coal beds: 50-600 Mt CO_2



Material fluxes and process steps associated with the mineral carbonation of silicate rocks or industrial residues

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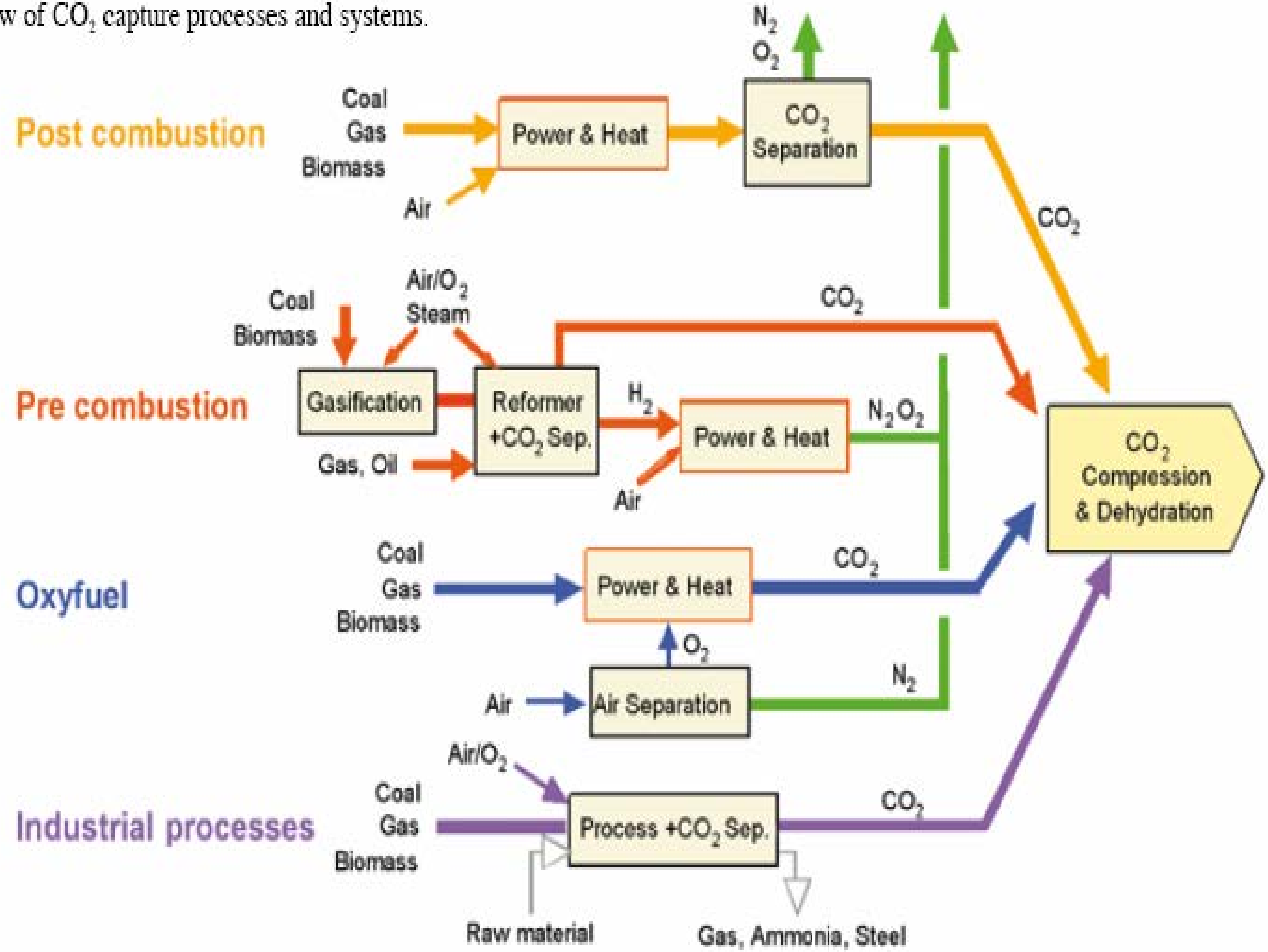
Greenhouse Gas Grave

Massive geo-sequestration projects are already underway in Australia… Is burying hundreds of tonnes of carbon dioxide underground - a novel way to reduce greenhouse gas emissions

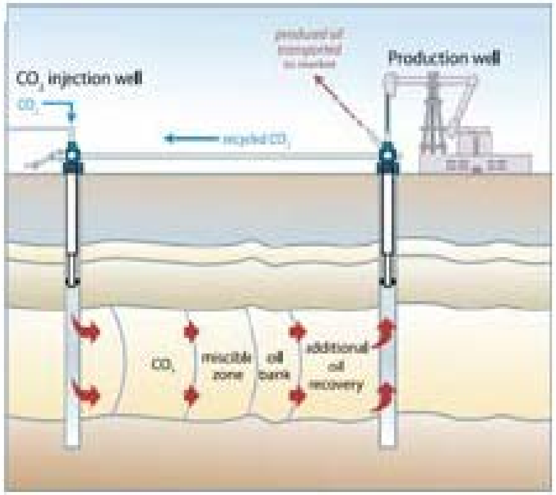
Workers at a power plant

Renewable energy would reduce our dependence on coal

Overview of CO_2 capture processes and systems.



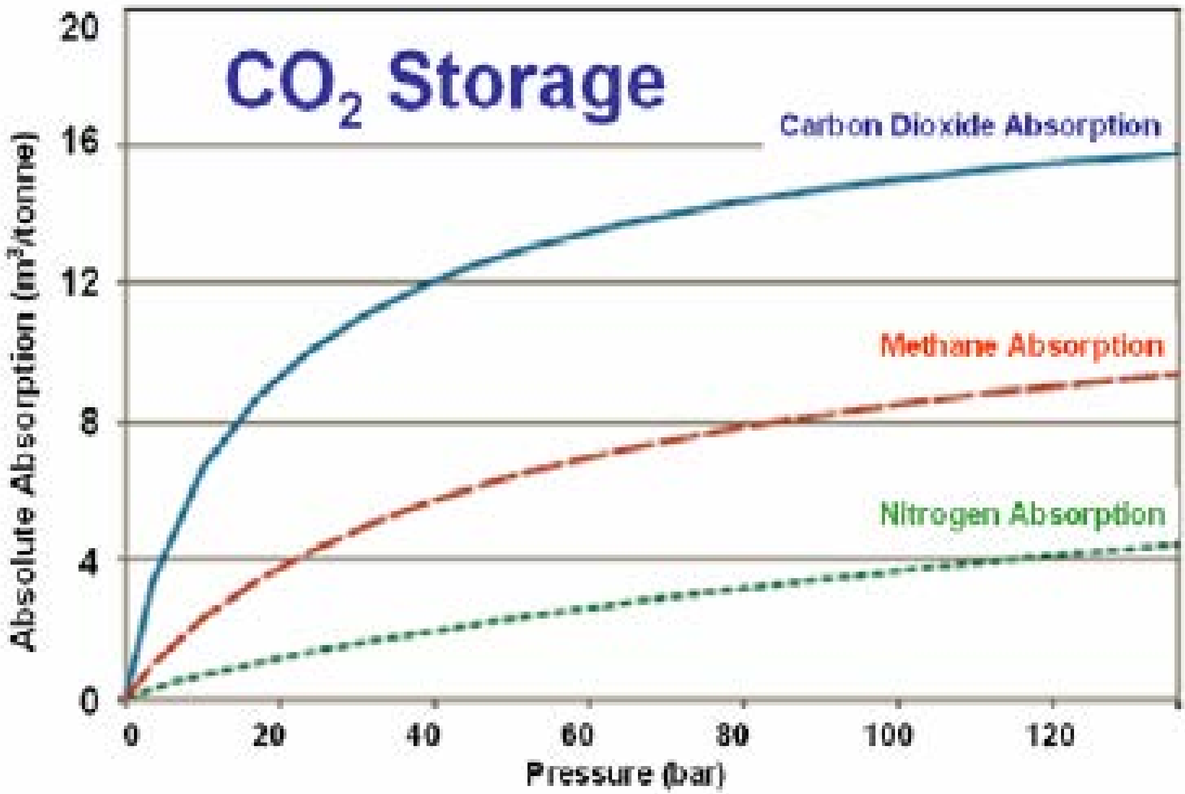
CO_2 Storage & Enhanced Oil Recovery



Small amounts of CO_2 dissolve in the oil, increasing the bulk volume & decreasing the viscosity, so facilitating flow

Average of 13% of the original oil in place, OOIP, is produced from **Enriched Oil Recovery (EOR)**

Enhanced Coal Bed Methane



Coal has very large number of micro pores & can absorb many gases, the most common among them being methane. Absorption refers to binding of gaseous or liquids to solid surfaces

One ton of Coal may contain up to 25 m^3 of methane. CO_2 has higher affinity to coal than methane. This property is exploited to extract methane from coal seams by injecting CO_2

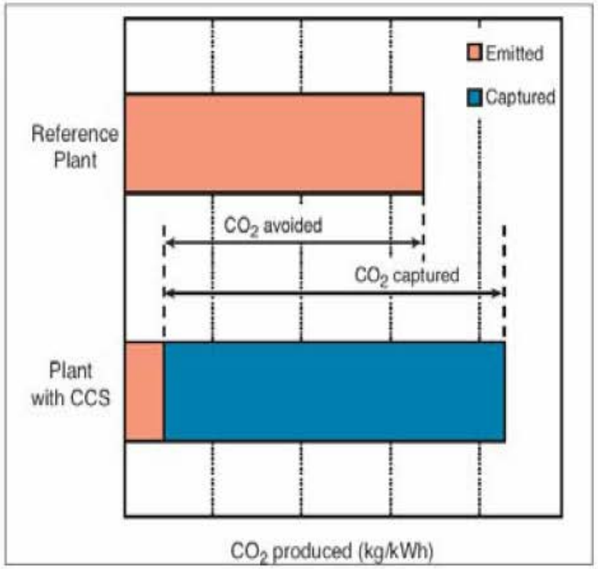
(a)

(b)

(a) CO_2 post-combustion capture at a plant in Malaysia. This plant employs a chemical absorption process to separate 0.2 $MtCO_2$ per year from the flue gas stream of a gas-fired power plant for urea production (Courtesy of Mitsubishi Heavy Industries).

(b) CO_2 pre-combustion capture at a coal gasification plant in North Dakota, USA. This plant employs a physical solvent process to separate 3.3 $MtCO_2$ per year from a gas stream to produce synthetic natural gas. Part of the captured CO_2 is used for an EOR project.

A power plant equipped with a CCS system would need:



- 10–40% more energy than a plant of equivalent output without CCS, of which most is for capture and compression.
- A power plant with CCS could reduce CO_2 emissions to the atmosphere by approximately 80–90% compared to a plant without CCS

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Capture & Storage Economics

Carbon Capture & Storage = CCS

Cost of Electricity = COE

Percentage increases in COE with CCS:

Pulverized Coal Power Plant	44-90%
IGCC Power Plant	24-52%

Cost of Electricity 2005 Estimates US$/MWh	Pulverized Coal Power Plant	Integrated Coal Gasification Combined Cycle Power Plant, IGCC
Without CCS	**43-52**	**41-61**
With CCS	**62-99**	**51-93**

India's Environment & CCS

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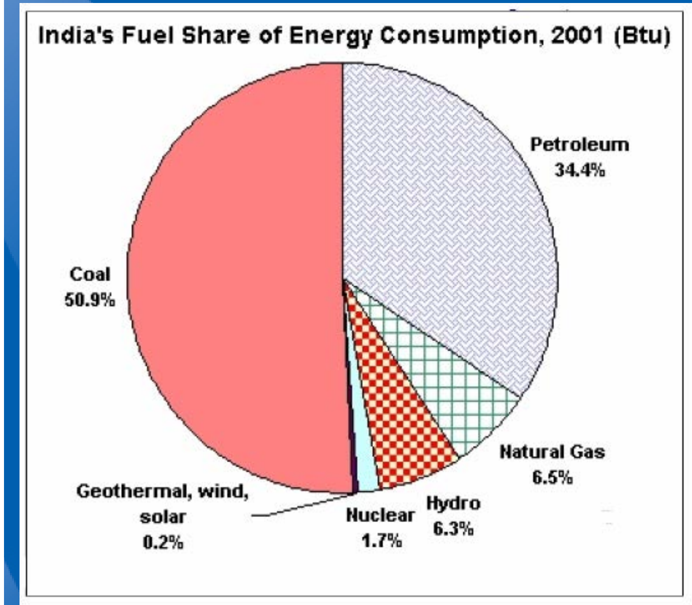
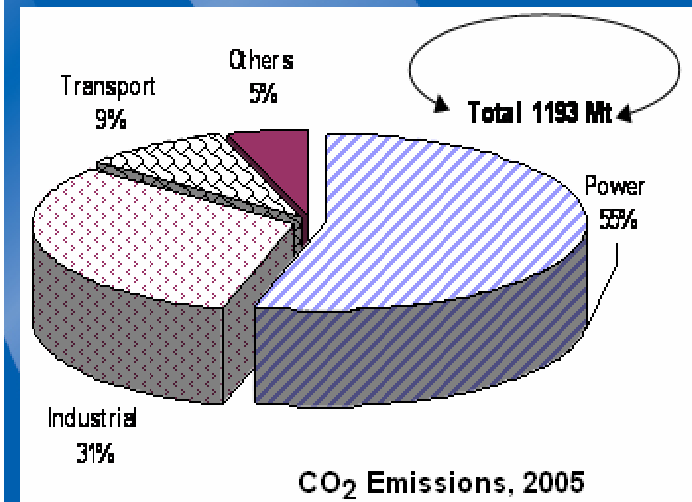
India's large reserves of coal are a major asset to the country, accounting for 70% of it's current production of electricity. However, excessive use of this form of energy production—especially without the use of strategies to mitigate its effects—will deteriorate the quality of the country's air, land, and water resources.

The "BaU" Scenario without significant changes in power sector policy in India will produce 775 million metric tons of CO_2 emissions/year by 2015 (as compared with 1,000 million metric tons/year now produced by power generation in the entire EU). However, India will be producing SO_2, NOX, particulate emissions, and ash at three times the current levels and ash disposal facilities around power plants will require 1 square meter of land per person.





India's Environment & CCS

Currently the power sector in India is on the verge of fundamental and significant reforms (a more liberal system with market prices, competition, a greater role for the private sector, and commercial incentives) that have profound implications for environmental management.

It has been suggested that, in India, carbon emission from thermal power plants can be brought down from 0.73 tonnes per megawatt hour (MWh) of electricity generated to 0.49 tonnes per MWh through greater efficiencies.

During this time of transition, it is critical to determine how best to take advantage of the technological innovations and opportunities it presents to protect our environment and avert threats to public health.

Carbon Capture & Storage

- **Advanced technologies will play a critical role in achieving significant greenhouse gas reductions.**
- **The adoption of advanced technology such as carbon capture and sequestration has to be made economically attractive.**
- **The dynamic factors that influence technology adoption and diffusion include <u>technology, regulatory policy and framework, business cycles, industry structure, and corporate strategy</u>.**
- **The regulatory and legal frameworks that may affect adoption include <u>underground injection regulation, relevant international and national laws, treaties and guidelines, property rights, and liability concerns</u>.**

CCS – Is there a viable Choice for India?

Should investors in new coal-based power generation pre-design their facilities so as to be carbon dioxide “capture-ready”?

Is it commercially viable to pay an upfront premium to pre-engineer the power plant such that the investor has the option - i.e. the right, but not the obligation - to retrofit carbon dioxide capture equipment in the future?

These questions provide the investor with three choices:

- Build a pulverized coal-fired power plant today (lowest initial investment, but highest cost to retrofit with CO_2 capture).
- Build a standard Integrated Coal Gasification Combined Cycle (IGCC) power plant
- Build an Integrated Coal Gasification Combined Cycle (IGCC) power plant with pre-investment to ease retrofit to CO_2 capture (highest initial investment, but lowest cost to retrofit with CO_2 capture).

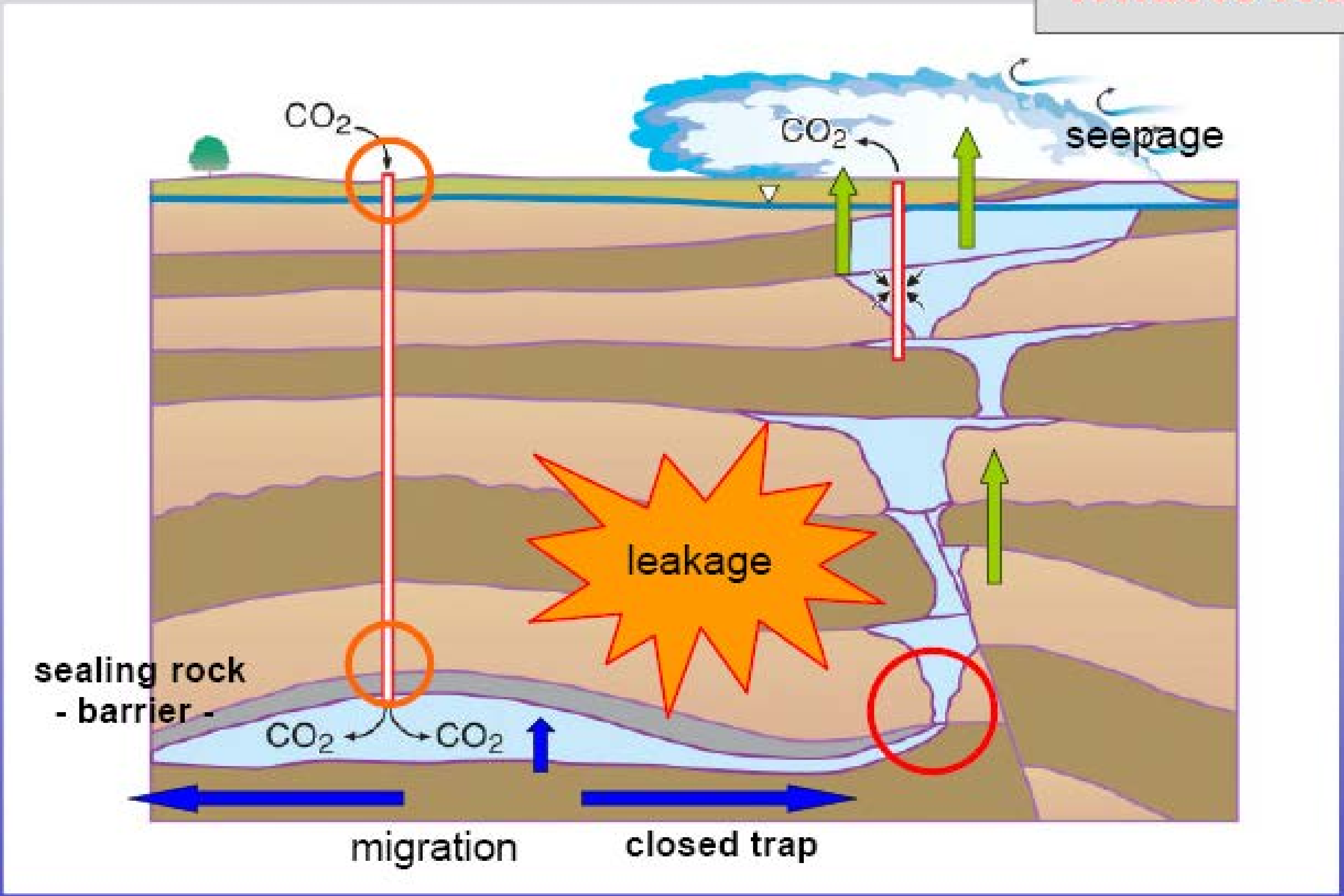
Key Concerns about Carbon Capture & Storage

➢**Doubts as to whether CO_2 storage can really be made permanent.** **While oil and gas fields are reasonably well understood over periods of a few decades, the long-term performance of seals and the character of other formations such as saline aquifers / deep sea (biology & impacts) is much less well understood.** ***CO2 would need to be trapped permanently - meaning at a minimum for tens of thousands of years (long-term liability for the storage site)*****.**

➢**Continuing our dependence on fossil fuels. There are many other problems associated with fossil fuels, from the exploitation of developing countries to health problems from air pollution, from oil spills to the propping up of dangerous regimes.** ***Even if carbon capture and storage helps solve the climate problem, it may delay the uptake of renewable energy sources that offer a more sustainable future*****.**

➢**Health effects. Slow leakage through soils and catastrophic leaks from pipelines can all affect** ***human and ecosystem (acidification and pCO2 impacts) health. Carbon dioxide in high concentrations asphyxiates*****.**

What is leakage ?



Escape of an injected fluid from a storage site

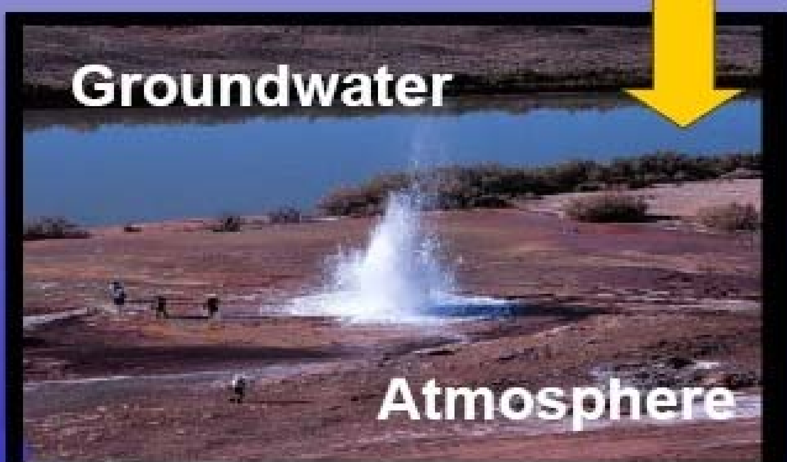
(CO_2 or a brine)

Pathways for CO_2 or displaced brines

- through bore holes — *fast process - catastrophic release*
- diffusion through overlaying rocks — *slow process - constant small release*
- through fractures (induced e.g. by injection or earthquakes)

Not today, tomorrow, 100 or 1000 years ...

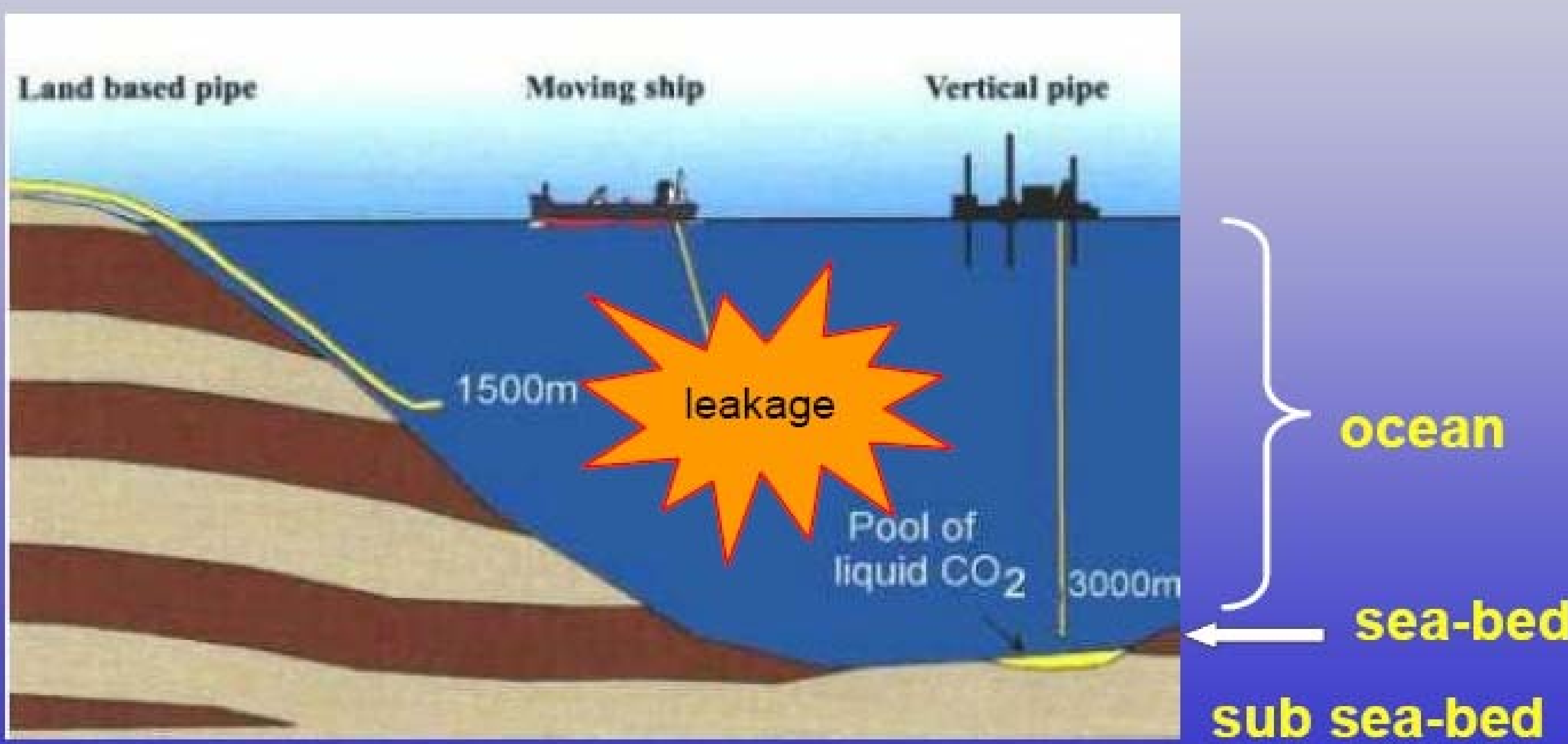
Upward migration of CO_2 finally reaching the ...



... or the Ocean ...

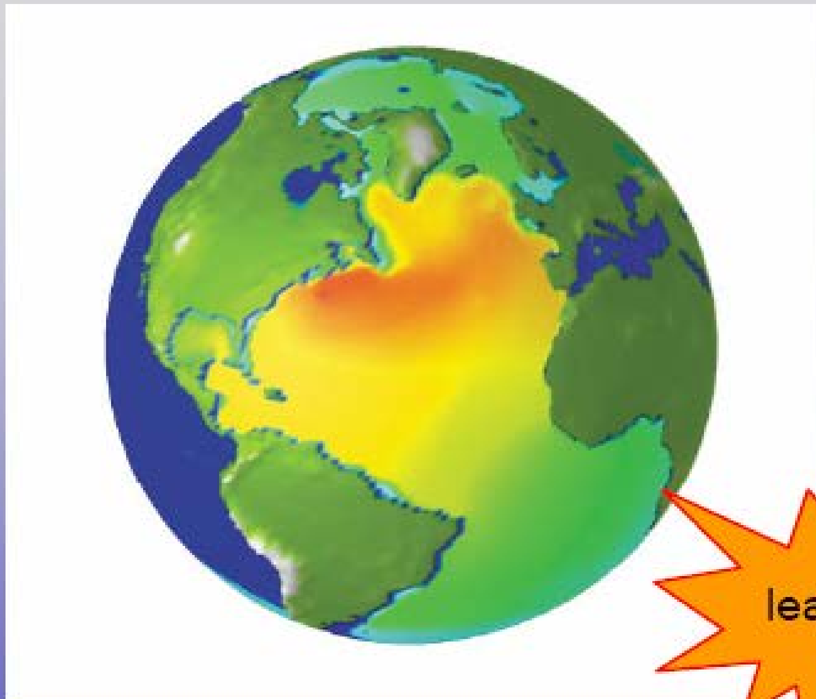
Ocean storage - direct pathways for CO_2

Escape of an injected fluid from a storage site



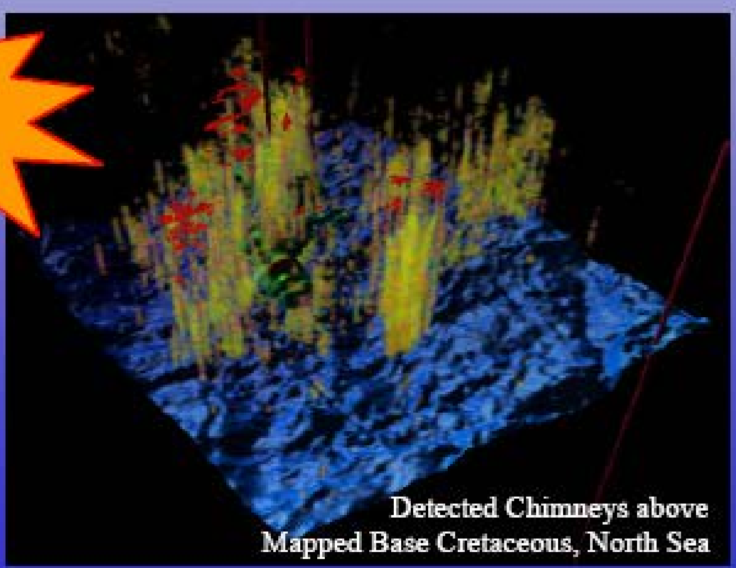
Environmental impacts of leakage

... ocean storage ...



- Increase of pCO_2 of sea water - more CO_2 partitioned to atmosphere in equilibrium
- Decrease of pH of sea water (more acidic) - mortal for organisms, benthic fauna
- Increase of CO_3^{2-} - less saturated in respect to $CaCO_3$ shells that some organisms form - dissolution of $CaCO_3$

leakage

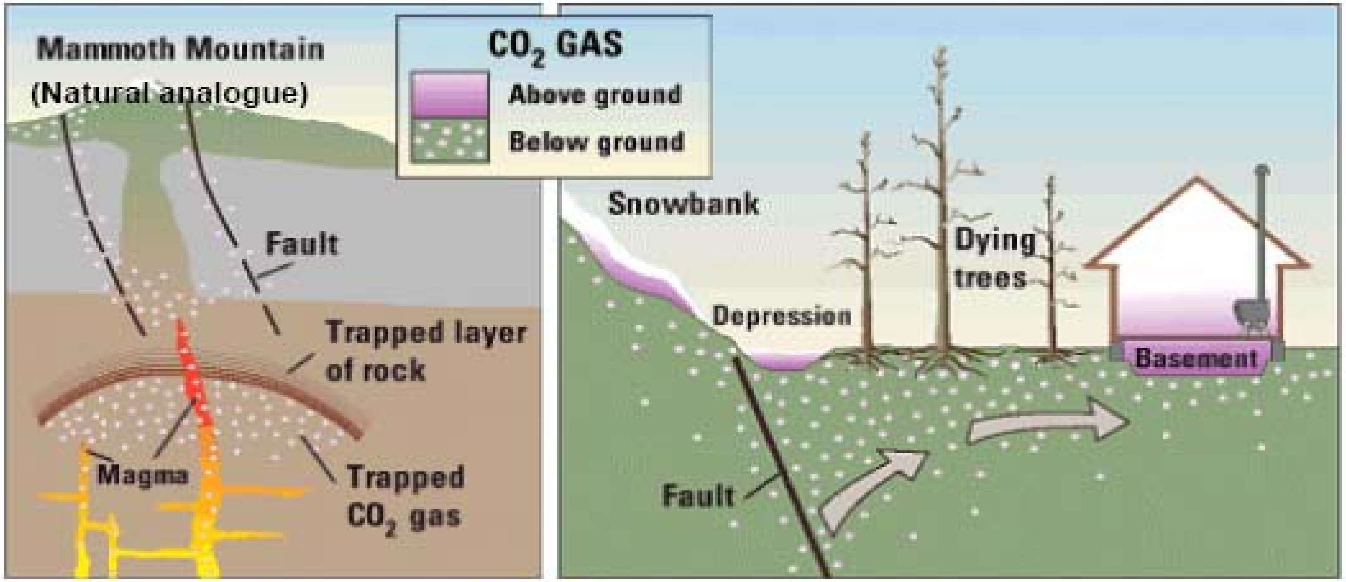


Simulated distribution of carbon dioxide after 100 years of continuous injection at 700 m depth off the coast of New York City (LLNL/DOC) for the DOE Center for Research on Ocean Carbon Sequestration (DOCS).

CO_2/CH_4 chimneys above oil/gas fields in the North Sea.

Environmental impacts of leakage

... geological storage ...



CO_2 enters a much more biologically active area

Soil gas usually contains 0.2-4% CO_2

- at 5 % dangerous for vegetation
- above 20% phytotoxic

At Mammoth Mountain soil gas contains 20 - 95% CO_2

CO_2 in the Groundwater (or brine) - pollution of fresh water, loss of water for drinking or irrigation purposes

CO_2 in the Surface (soil) - die-off of vegetated areas, root anoxia animals in the soil are affected

CO_2 in the Atmosphere - affected are animals and humans climate

Environmental impacts of leakage

- Humans tolerate up to 1% CO_2 in the air with no adverse effects
- Significant effect on respiratory rate and physical discomfort at 3-5% CO_2 in the air
- Death imminent at >30% CO_2 in the air for several minutes

CO_2 is 50% denser than air, it tends to sink downwards.

Health, safety and environmental risks depend on

local risk global risk

- Type of CO_2 release (e.g. catastrophic or slow but permanent)
- Type of vegetation (e.g. a desert or an agricultural area)
- Type of populated area (rural or dense)
- Wind speed, rainfall, season ...
- Engineering security, monitoring ...

If a storage site is selected carefully...

Likelyhood of impacts from leakage

Releases that are quickly dispersed in the atmosphere provide little hazard

... at least for humans

... is low ...

However, if leakage occurs it can be difficult to stop the release (except at well bores). It doesn‘t matter whether CO_2 is quickly dispersed or not.

The environment cares that CO_2 is coming back.
The environment also cares that CO_2 is stored (in the ocean)

The atmosphere does not care whether release is slow or catastrophic, whether CO_2 is quickly dispersed or not.

Climate cares how much CO_2 is reduced and is coming back.

Does low mean it can not happen?

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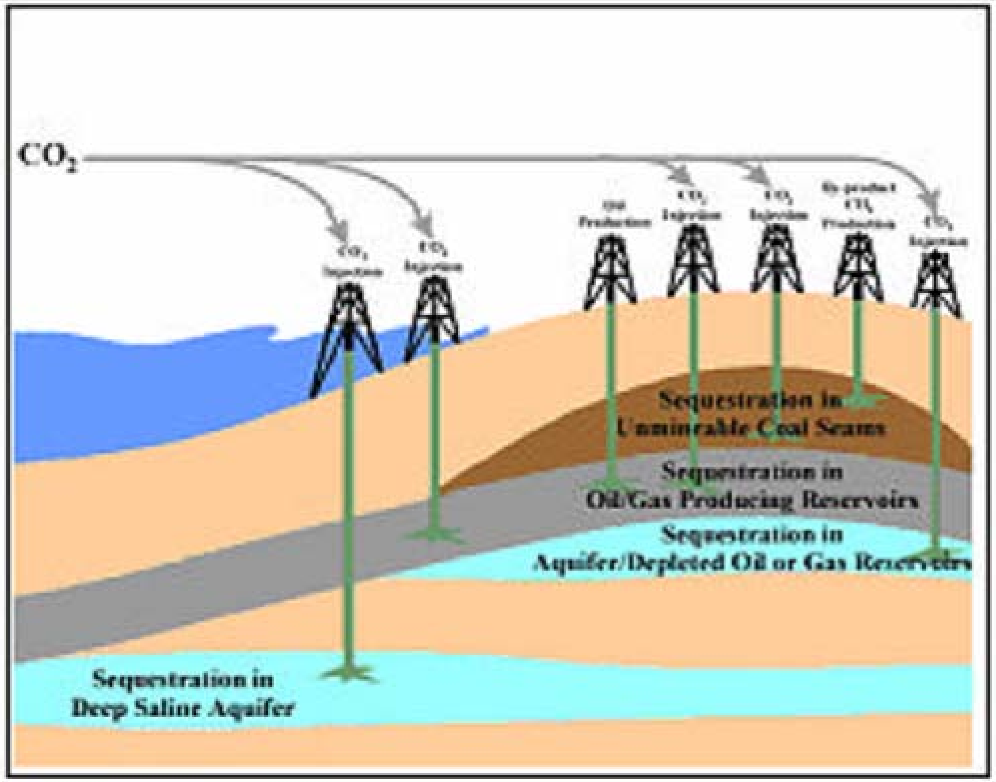
Environmental impacts of leakage

Recorded impacts exist for a number of CO_2 releases from natural analogues - mainly of volcanic origin

- At Dieng, in Central Java, Indonesia a large outflow of pure CO_2 from an existing volcanic vent and a reopened fracture occured in 1979. Sheets of dense gas flowed down from the volcano. 142 people were engulfed by the gas sheets and killed almost instantly.
- At Lake Nyos, Cameroon, a huge mass of concentrated CO_2 was emitted in 1986. The lethal concentration of the gas reached a height of 120 m above the lake surface and the total volume of the gas cloud may have been up to 1.3 km^3. The gas flowed down a topographic slope, killing more than 1700 people in a thinly populated area as far as 14 km away from the crater lake.
- At Poggio dell'Ulivo 200 t/day CO_2 are discharged from diffuse soil degassing. At least 10 people have been reported to have died from CO_2 releases in the region of Lazio in the last 20 years and CO_2 asphyxiation prompted the death of 30 cows in a heavily populated area near Rome in 1999.
- At Mammoth Mountain in eastern California / USA, surface CO_2 emissions of magmatic origin have killed approximately 0.6 km^2 of forests, and early signs of human asphyxia were reported in affected areas.
- An engineered CO_2 (EOR) injection facility at Rangely USA disperses 170-3800 t of CO_2 and 400 t of CH_4 annualy depending on the season (23 Mio t have been injected so far). - No casualities
- Natural gas storage facilites beleived to be safe also release gas (by accident - e.g. in Berlin, Germany six weeks ago, three workers were injured, large area had to be evacuated)



Various geological sequestration options - source: IEA GHG

Is leakage acceptable ?

- Benefit : Impact -

<u>If leakage (rate/a) would be accepted:</u>

... The more CO_2 is stored the more CO_2 will be released

0.1% leakage (= retention rate of 99,9%) from 1 Mio t CO_2 is less than 0.01% leakage from 100 Mio t stored CO_2.

... The more CO_2 is stored the smaller a leakage rate must be.

The current political situation is one of a „business as usual“ - backing more fossil fuel use instead of reducing it.

Conclusions

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Reliance Energy is committed to keep the environment clean and safeguard the society against any risks and hazards including the health impacts from thermal power plants while ensuring that India's development is not constrained due to gaps between energy production and demand.

Reliance Energy understands that *CCS technology is still under R&D mode and robustness of available technologies need to be ascertained before these are introduced in practice*.

India falls under moderate seismic zone and any geological storage in Assam, Maharastra or Gujarat region poses *serious risks to its population, agriculture and ecology in case of any unforeseen leakage episodes*.

The *application of captured CO_2 in EOR or in extraction of CBM also needs to be critically evaluated for risks and hazards* it might pose; cost - benefit analysis needs to be conducted for commercial utilization of the available technology to contain COE affordable to public.

Reliance Energy is willing to *collaborate with international technology producers to explore application of newer and robust technology for CCS including Integrated Coal Gasification Combined Cycle*.

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Feedback and Comments are welcomed !