Carbon Capture and Sequestration – Implications and Opportunities for India

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Workshop on
"Awareness and Capacity Building in Carbon Capture and Utilization (ACBCCU-2018)"

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India – Energy vs Environment

- Primary Energy Consumption continues to grow at ~4.2% YOY
- Energy access essential to economic development
- India depends significantly (>80%) on crude oil imports
- Coal imports have declined due to improved grading and appropriate utilization – but power demand remains buoyant @4.6% CAGR
- Natural gas penetration increasing but limited by infrastructure

- Aggressive commitments in INDC under COP-21
- Air quality issues continue to persist

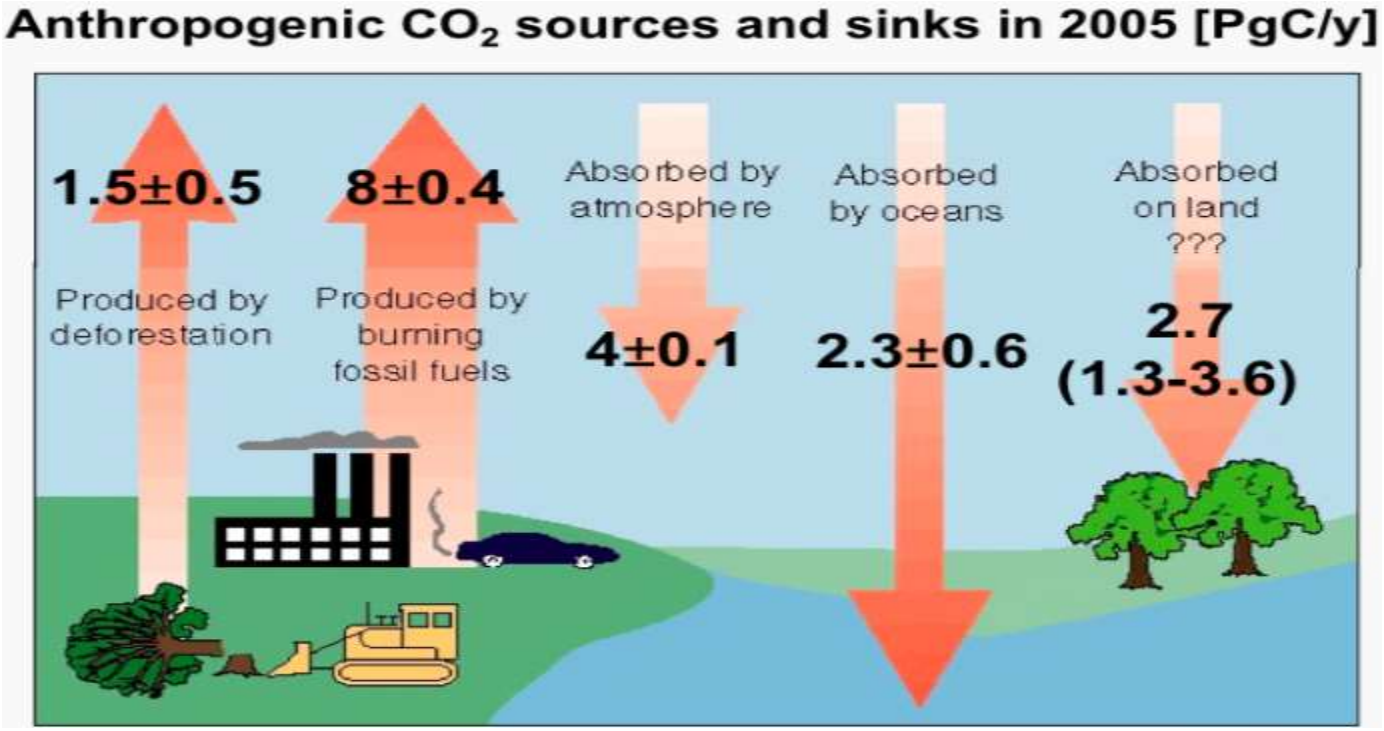
India - Energy vs Environment

	Level		Shares		Change (abs.)		Change (%)		Change (annual)*	
	2016	2040	2016	2040	1990-2016	2016-2040	1990-2016	2016-2040	1990-2016	2016-2040
Primary energy consumption (units in Mtoe unless otherwise noted)										
Total	724	1921			529	1197	271%	165%	5.2%	4.2%
Oil† (Mb/d)	4	10	29%	25%	3	6	269%	129%	5.2%	3.5%
Gas (Bcf/d)	5	14	6%	7%	4	9	315%	185%	5.6%	4.5%
Coal	412	955	57%	50%	302	543	275%	132%	5.2%	3.6%
Nuclear	9	44	1%	2%	7	35	493%	412%	7.1%	7.0%
Hydro	29	52	4%	3%	14	23	94%	80%	2.6%	2.5%
Renewables (including biofuels)	17	256	2%	13%	17	239	>1000%	>1000%	>10%	>10%

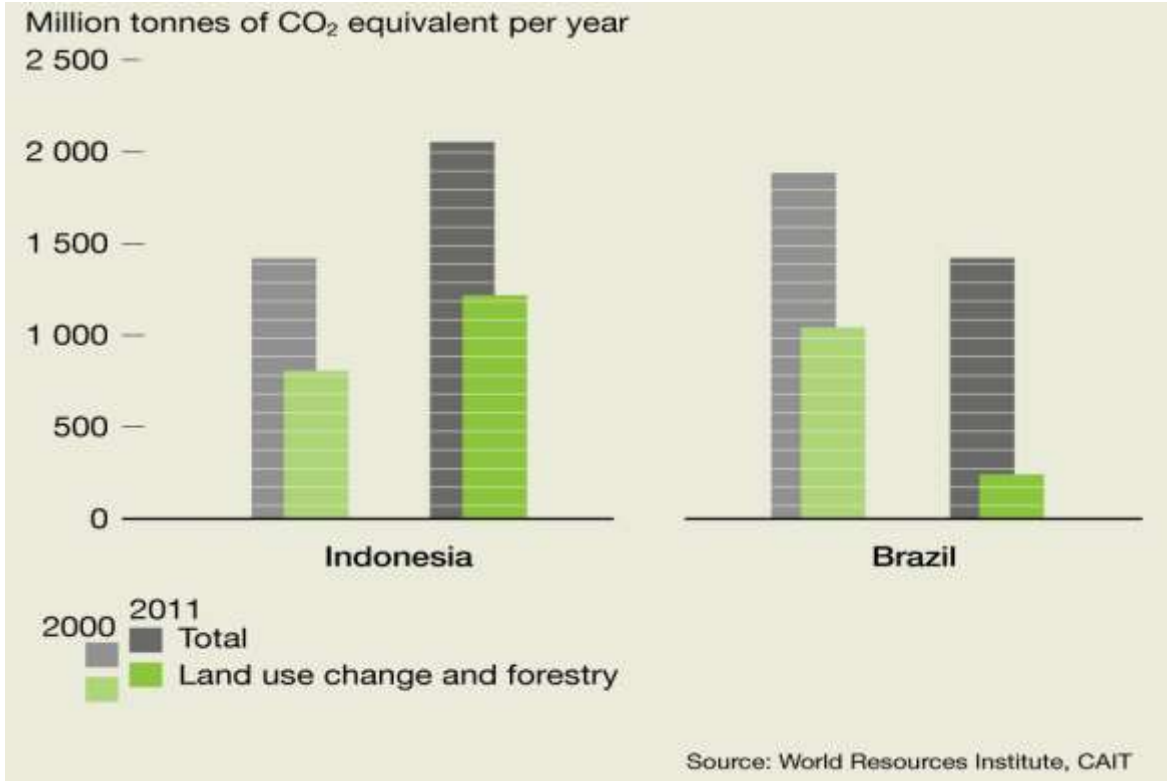
BP: Statistical Review of World Energy, 2018

Fossil Fuels continue to dominate future energy scenario

Anthropogenic Carbon



Khatiwala, Primeau and Hall, 2009



India – Carbon Imports (approx)

Commodity	Import, MMT/yr	% C	Imported C, MMT/yr
Crude Oil	220	85%	190
Coal	200	75%	150
Natural Gas	15	77%	11.6

We need to find about 350 MMT of domestic carbon (on current basis) to fully replace our carbon imports

Domestic Carbon Sources (estimates)

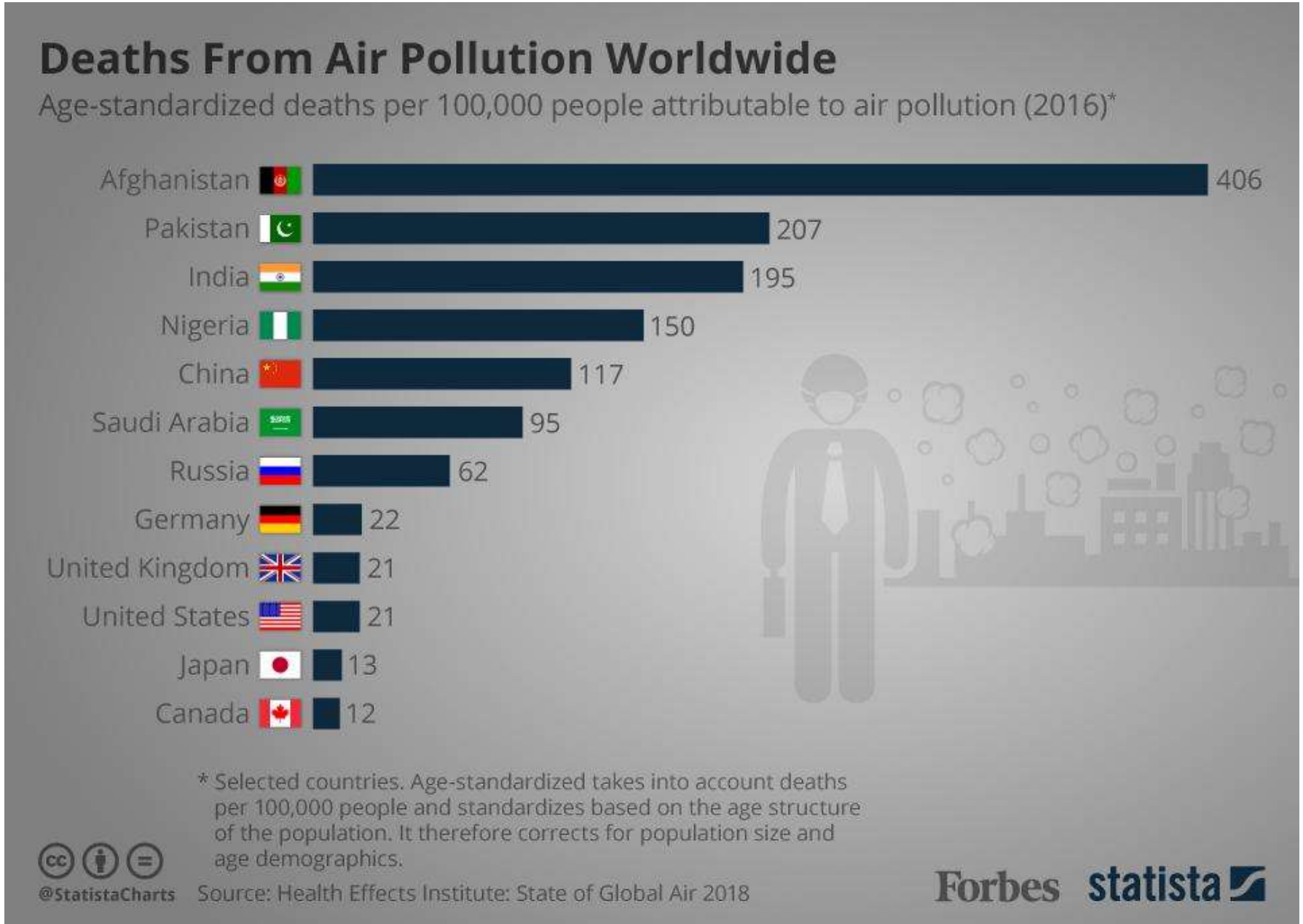
- India – Second most populous nation ~18% of World population
- Population growth and rapid urbanization drive increased MSW
- Land limitations in India constrain availability of landfill space and supply-demand economics of urban land planning
- In rural areas, fallow / mono-cropped / under-irrigated land offers upsides on carbon capture through farm activity

Commodity	Scope, MMT/yr	% C, approx	Potential C, MT/yr
Agri-residue (surplus)	120	40%	48
Forest residue	150	42%	63
Bio-gas excl landfill	800	45%	360
MSW	40	25%	10
UCO	5	85%	4

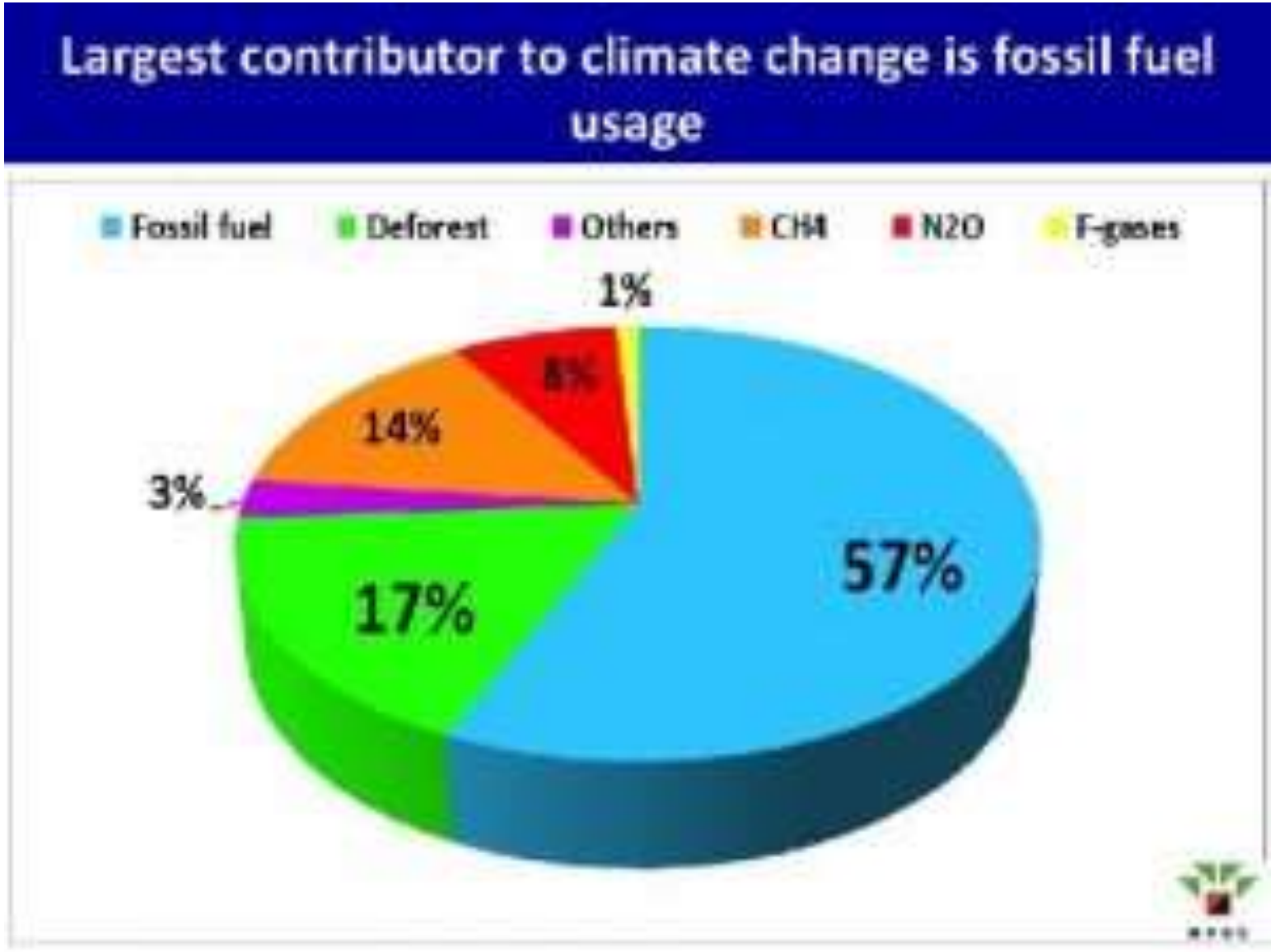
485 MMT of carbon excluding CO/CO2/landfill CH4 !

All the carbon we need is available within our borders

Impact of Fossil Fuel Combustion – Air Quality



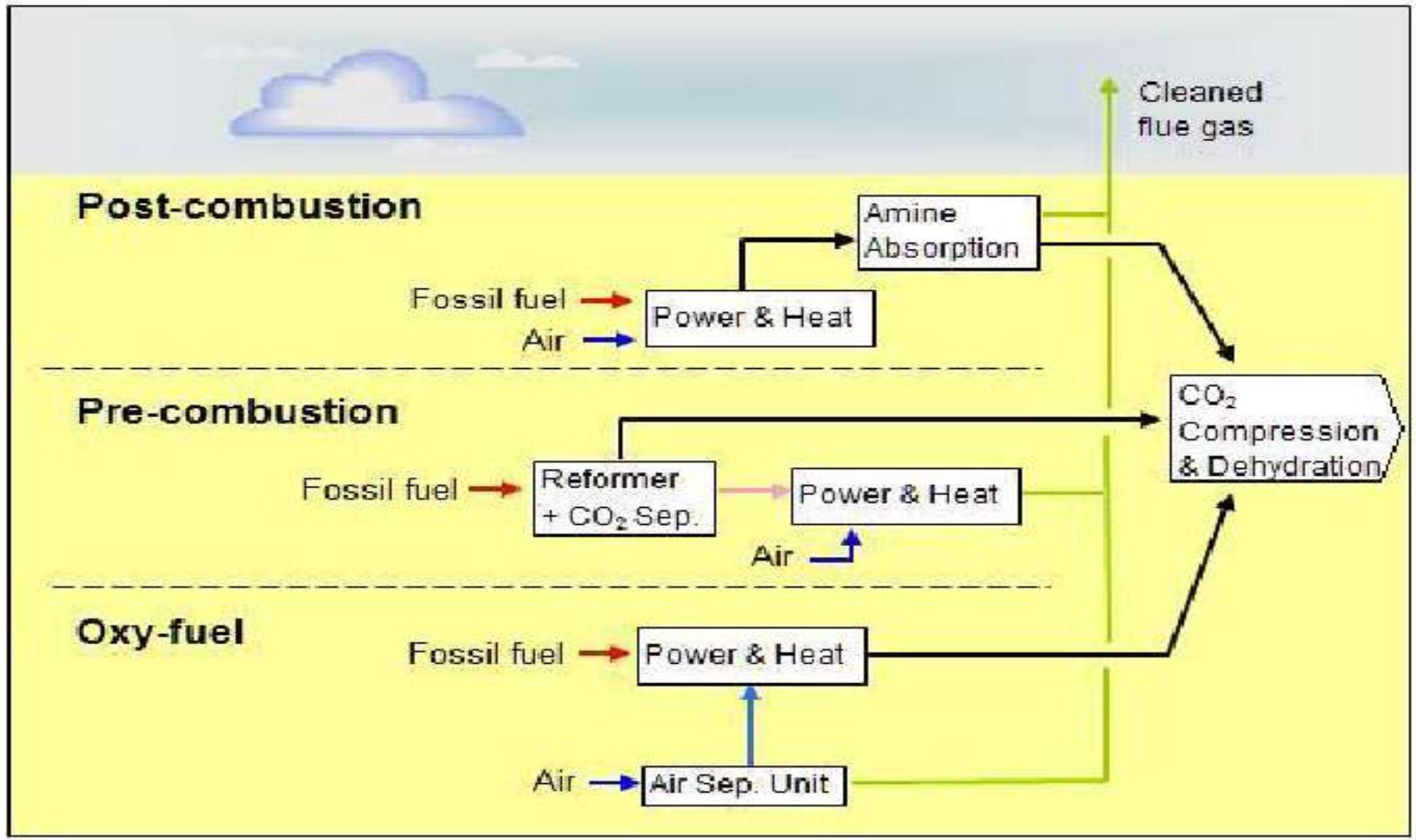
Impact of Fossil Fuel Combustion – Climate Change



Carbon Capture and Storage

- Possible primarily to capture centralized combustion CO2
  - **Power stations**
  - **Some industrial plants**
- Capture – compress – channel - compartmentalize
- Could add ~ upwards of Rs 2 per unit to cost of thermal power – *possibly much more initially*
- **Storage –** Where? How?
  - depleted gas fields, defunct oil fields, deep saline aquifers…..
- Major issues: Safety, Reliability, Cost
- Capture typically reduces efficiency by up to 10 percent
- How to account for carbon credits? Who pays?

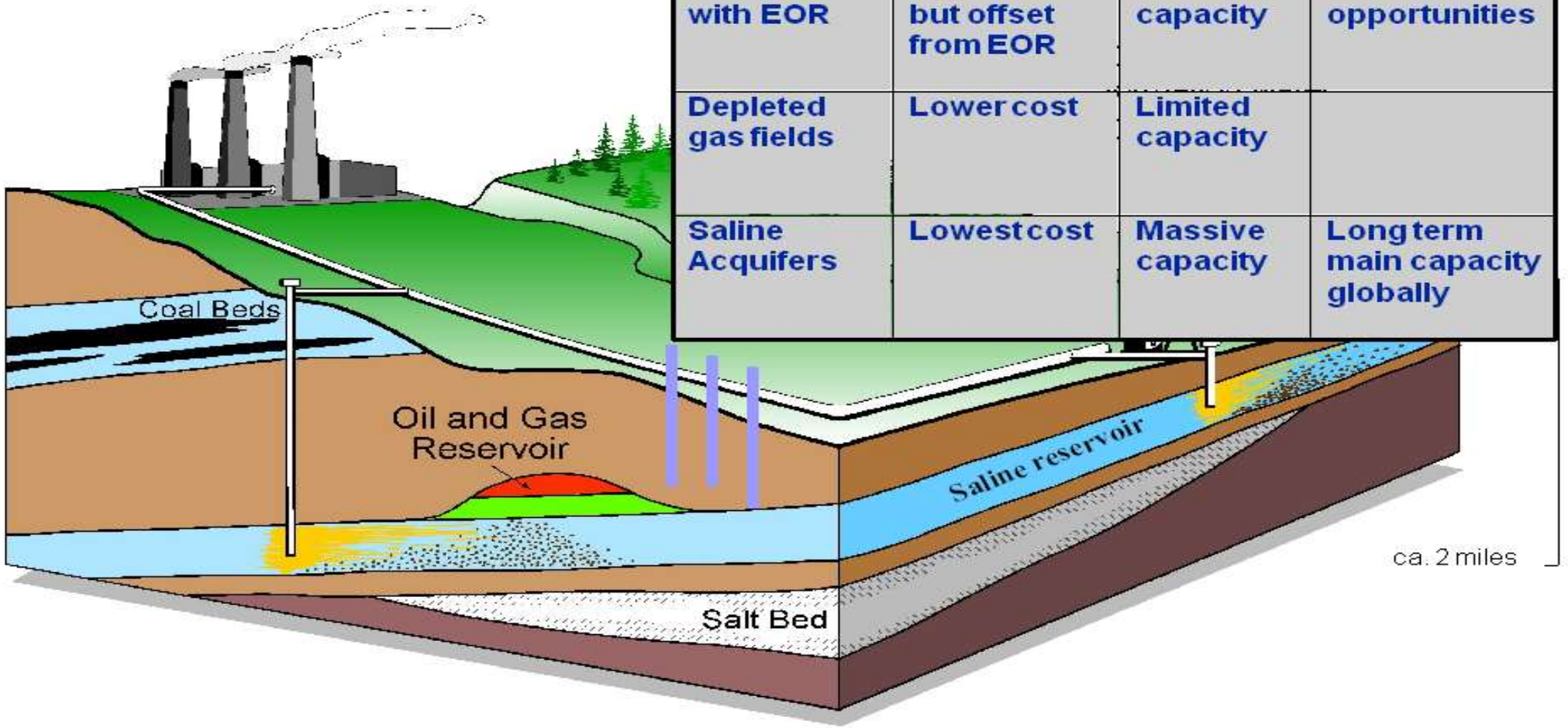
Carbon Dioxide Capture Technologies



After capture, compress (>70 atmos → liquid) transmit and store (>700m):

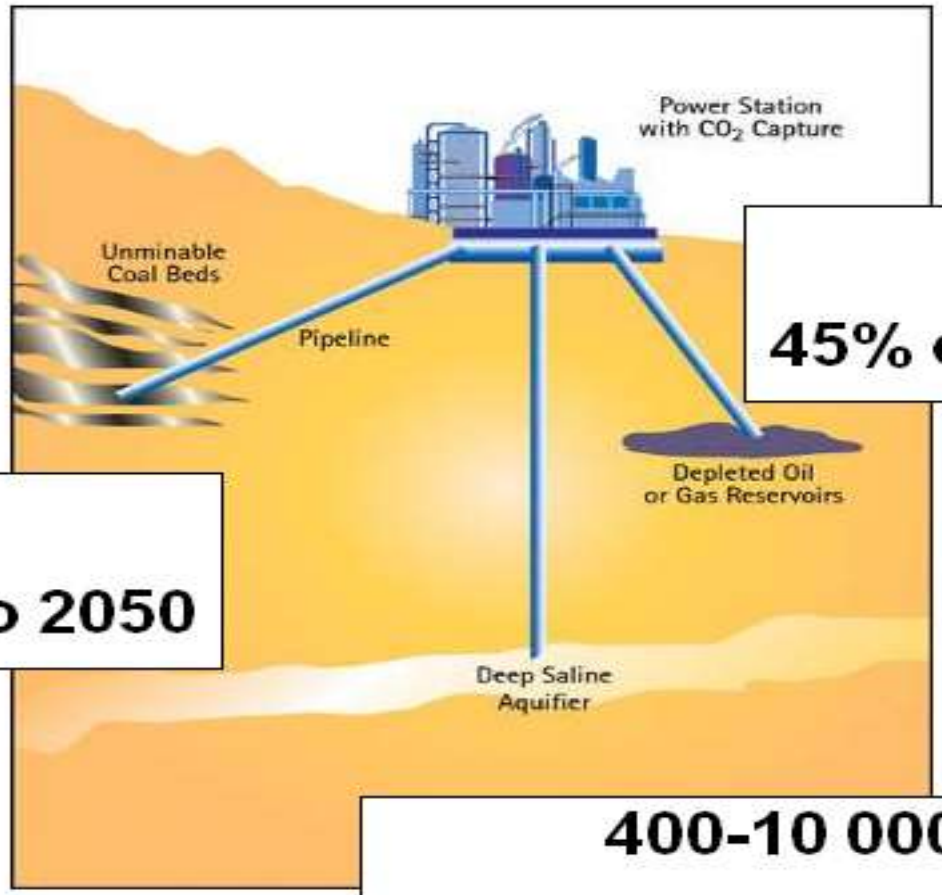
CO_2 storage options

	Cost	Capacity	When
Oil – fields with EOR	Higher cost but offset from EOR	Limited capacity	Earliest opportunities
Depleted gas fields	Lower cost	Limited capacity	
Saline Acquifers	Lowest cost	Massive capacity	Long term main capacity globally



Geological Storage Potential

Courtesy of IEA GHG R&D Programme



920 Gt CO_2

45% of Emissionsto 2050

40 Gt CO_2

<2% of Emissionsto 2050

400-10 000 Gt CO_2

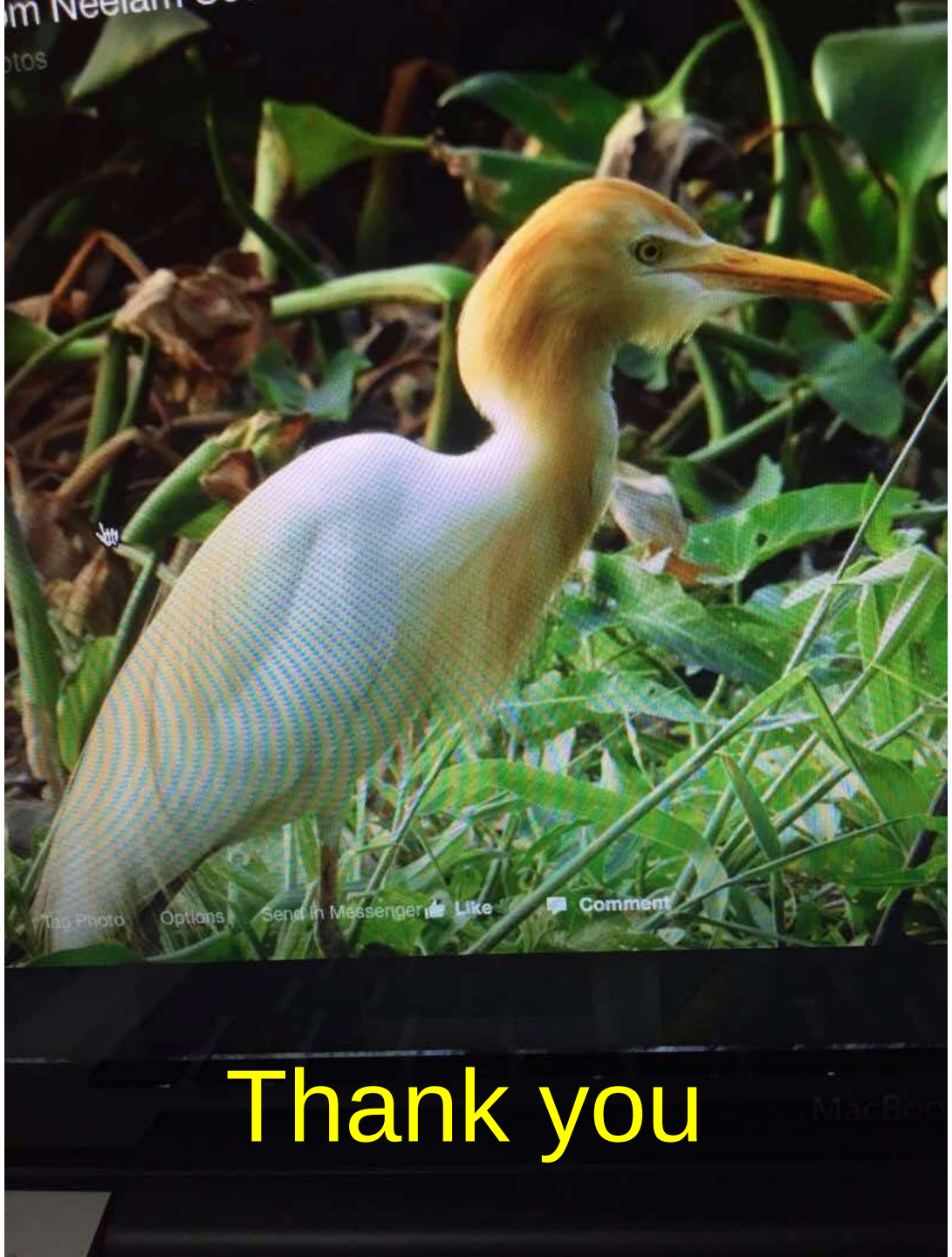
20-500 % of Emissionsto 2050

substantial storage potential

In Summary…

- Replace carbon energy with non-carbon energy where possibe
- Replace imported carbon with domestic carbon
- Map and quantify opportunity in saline aquifers
- Establish large scale demonstrations quickly

- Learn, don't reinvent the wheel
  - EU Zero Emissions Power strategy proposes 12 demonstration plants
- Make all thermal plants 'capture ready (post-combustion or oxy-fuel)
- Build carbon sinks aggressively – not just Geo-CCS but also positive afforestation, algae, CO2-reactive chemical plants (no single magic bullet)
- Set policy mechanisms for pricing of carbon



Thank you