Chris Goodall

Overcoming the obstacles to Net Zero

Oxford Energy Seminar
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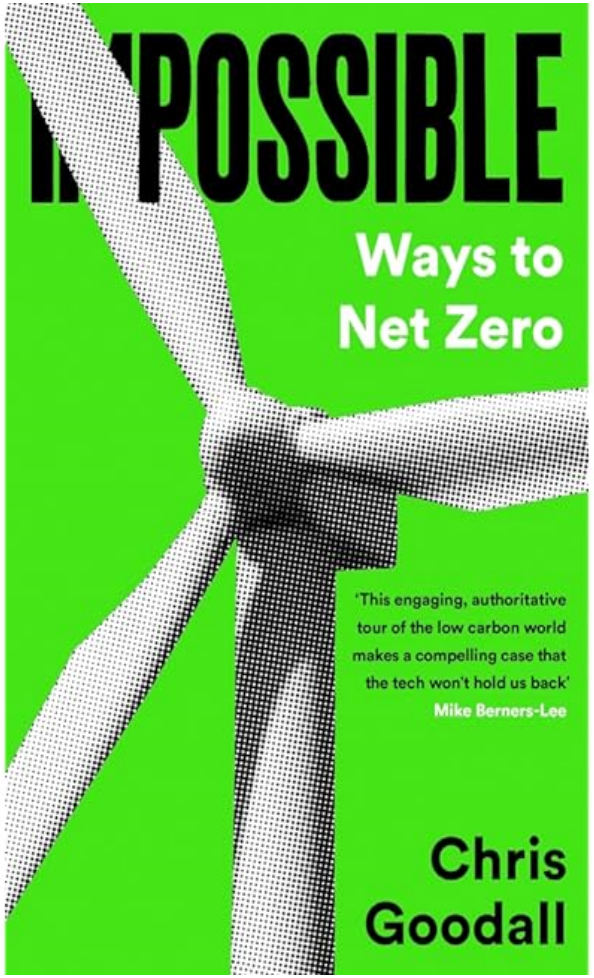


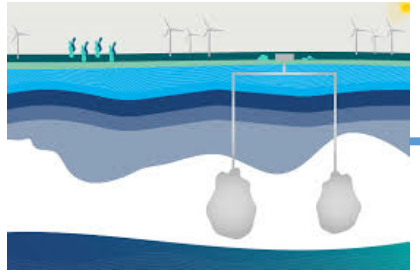
Renewables plus hydrogen/battery storage

Sources of electricity

Batteries

Grid

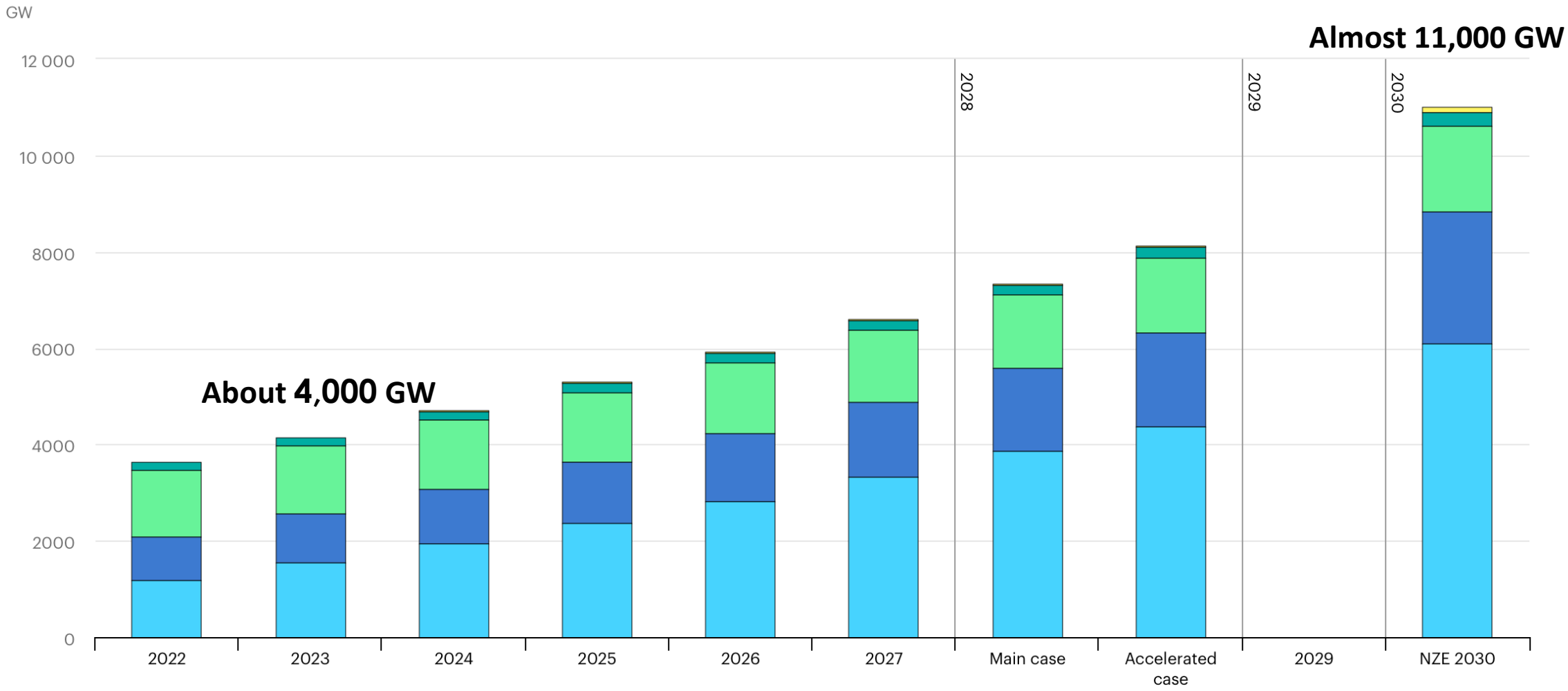
Consumer



Surplus to hydrogen store

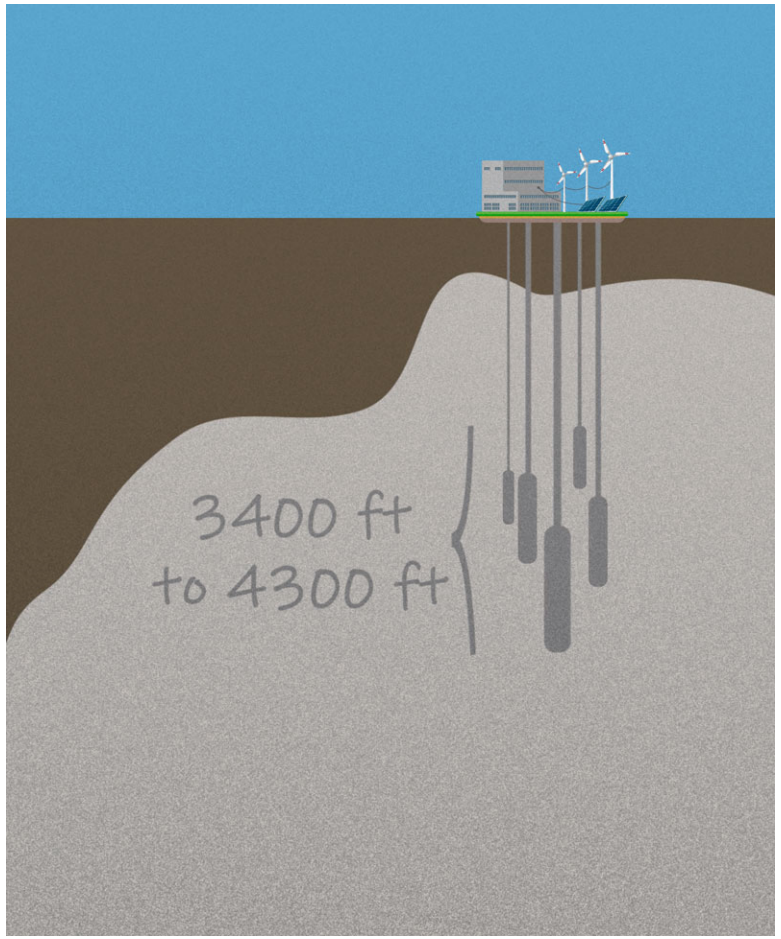
Hydrogen to electricity in times of deficit

International Energy Agency – latest forecasts for renewable energy

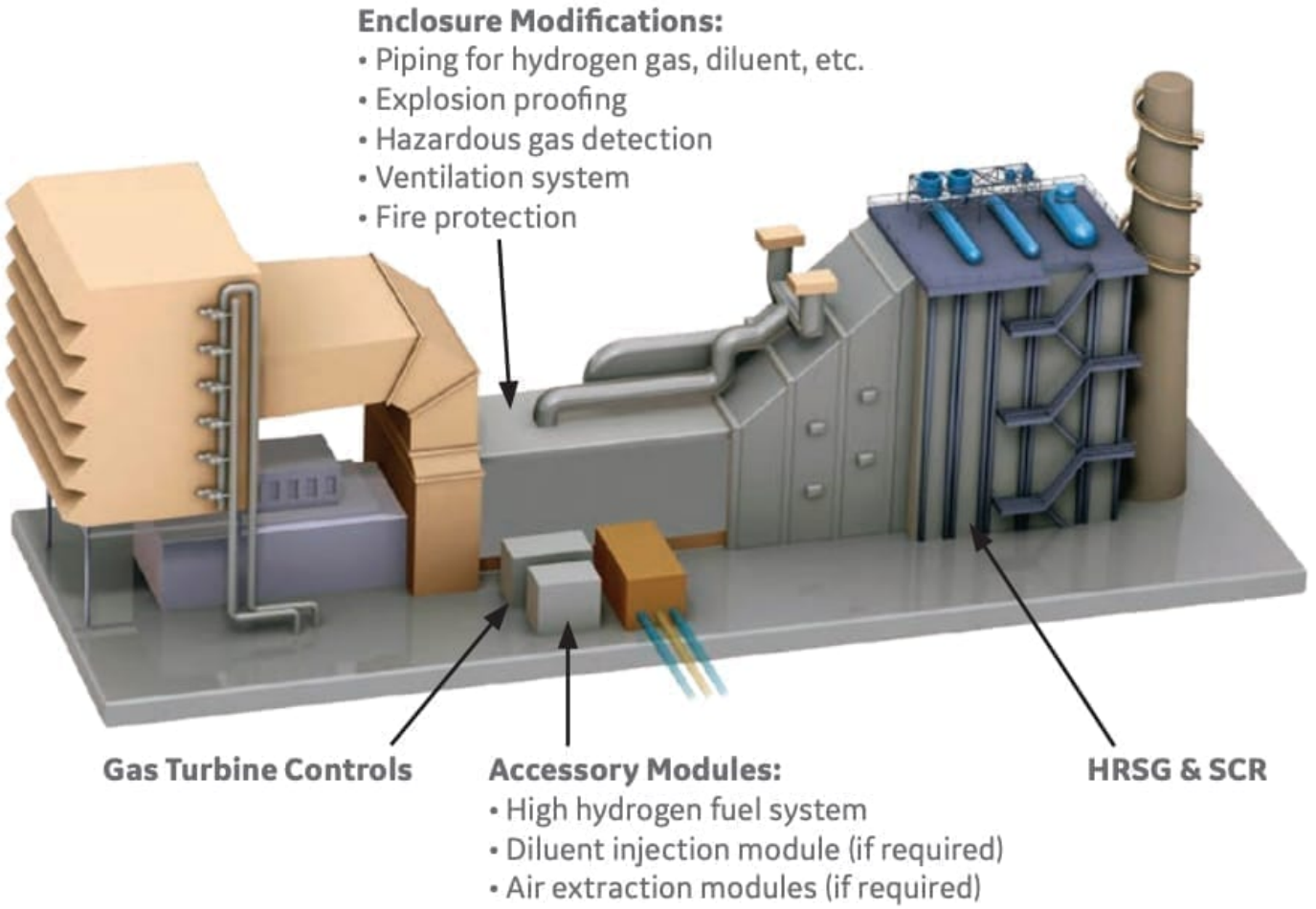


Intermountain Power Utah – a hydrogen power station

Salt cavern storage
underneath the power station



A power plant converted to running on H2



Efficiency of about 50% electricity-to-electricity

Grid

80% + efficient if supplied with heat

About 60% efficient

H2

Heat

Solid Oxide Electrolyser

Hydrogen Gas turbine

Transmission of electricity from lower cost locations

Xlinks Project – 3.4 GW

Or immediate conversion into hydrogen

Hydrogen made at German offshore wind

‘Renewables plus hydrogen’ solves most of the problem. What’s left?

Industries

- Steel
- Cement
- Fertiliser
- Heavy industry
- Trucks
- Shipping
- Aviation
- Plastics
- Clothing
- Agriculture

Capture and retention of carbon

- Direct air capture
- Improving soil carbon levels
- Recapturing CO2 from oceans

Wider issues

- Raw materials availability
- Capital shortages
- Carbon taxation
- Willingness of electorates to vote for the transition
- Grid upgrading

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FOCUS IN THIS PRESENTATION

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The ‘hard-to-abate’ industries can generally be decarbonised using a small range of alternative solutions

		Electricity	Hydrogen	CO2/CO/C	CCS	DAC	Recycling	Biomass
Steel		x	x				x	
Cement		x			x			
Fertiliser			x	x		x		
Heavy industry		x	x		?			
Trucks		x	?					
Shipping		x	x			x		
Aviation			x			x		x
Plastics		x	x	x		x	x	
Clothing			x	x			x	
Agriculture			x			x		x

Don’t trust these numbers, but the sectors do represent a large share of global emissions

Share of emissions		Sector
8%		**Steel**
7%		**Cement**
5%		**Fertiliser**
5%		**Heavy industry**
5%		**Trucks**
3%		**Shipping**
3%		**Aviation**
3%		**Plastics**
2%		**Clothing**
c.25%		**Agriculture**

Steel

		Electricity	Hydrogen	CO2/CO/C	CCS	DAC	Recycling	Biomass
Steel		X	X				X	

Steel - circa 8% global emissions

Primary Steel Manufacture

Around 70% global steel production

Steel recycling

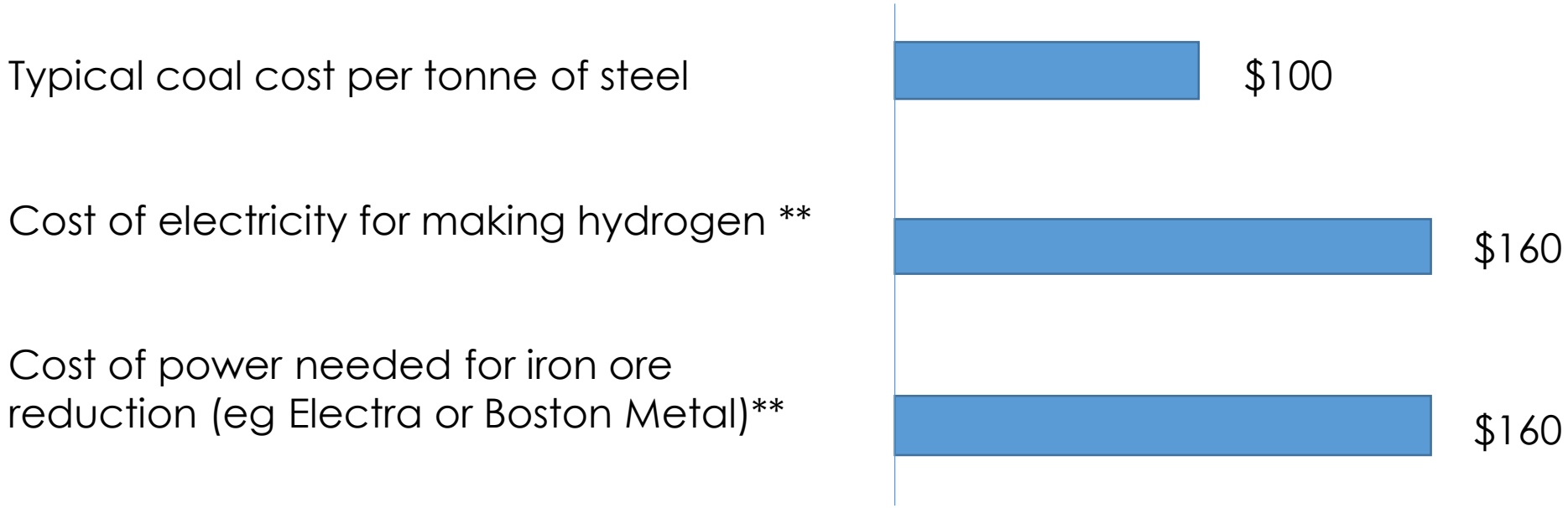
Around 30% global steel production

H2 Green Steel – visualisation of plant in Northern Sweden

Electra iron – passing electricity though iron ore in an aqueous solution

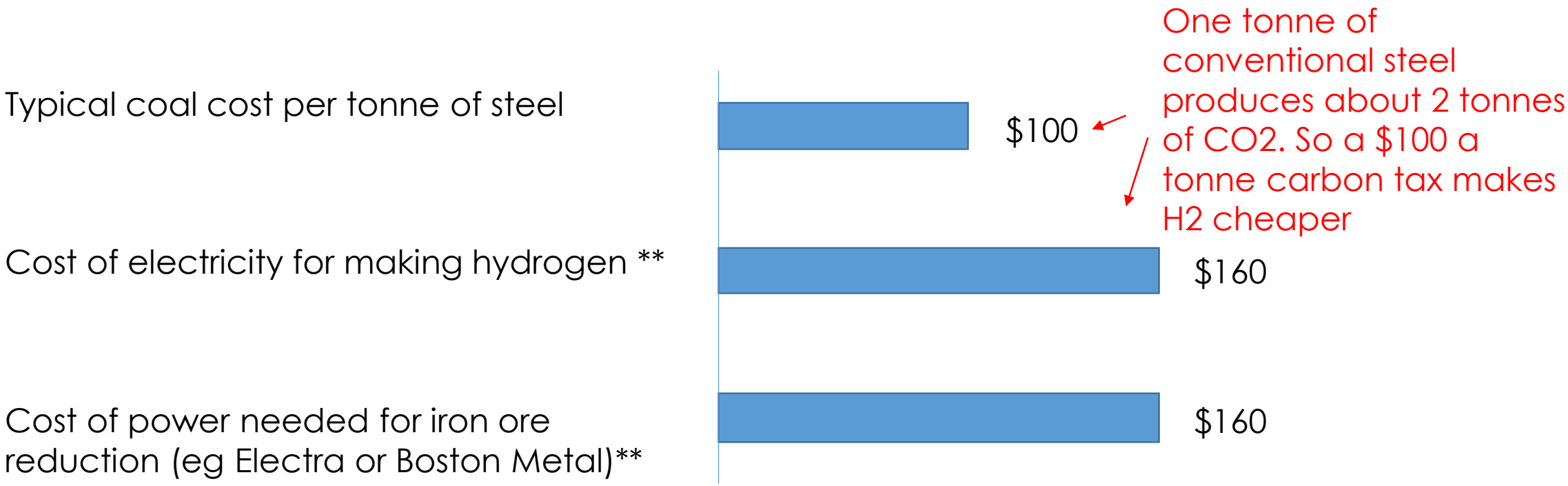
Pyrochar – replacing coke with torrified biomass

The first problem – higher manufacturing costs *



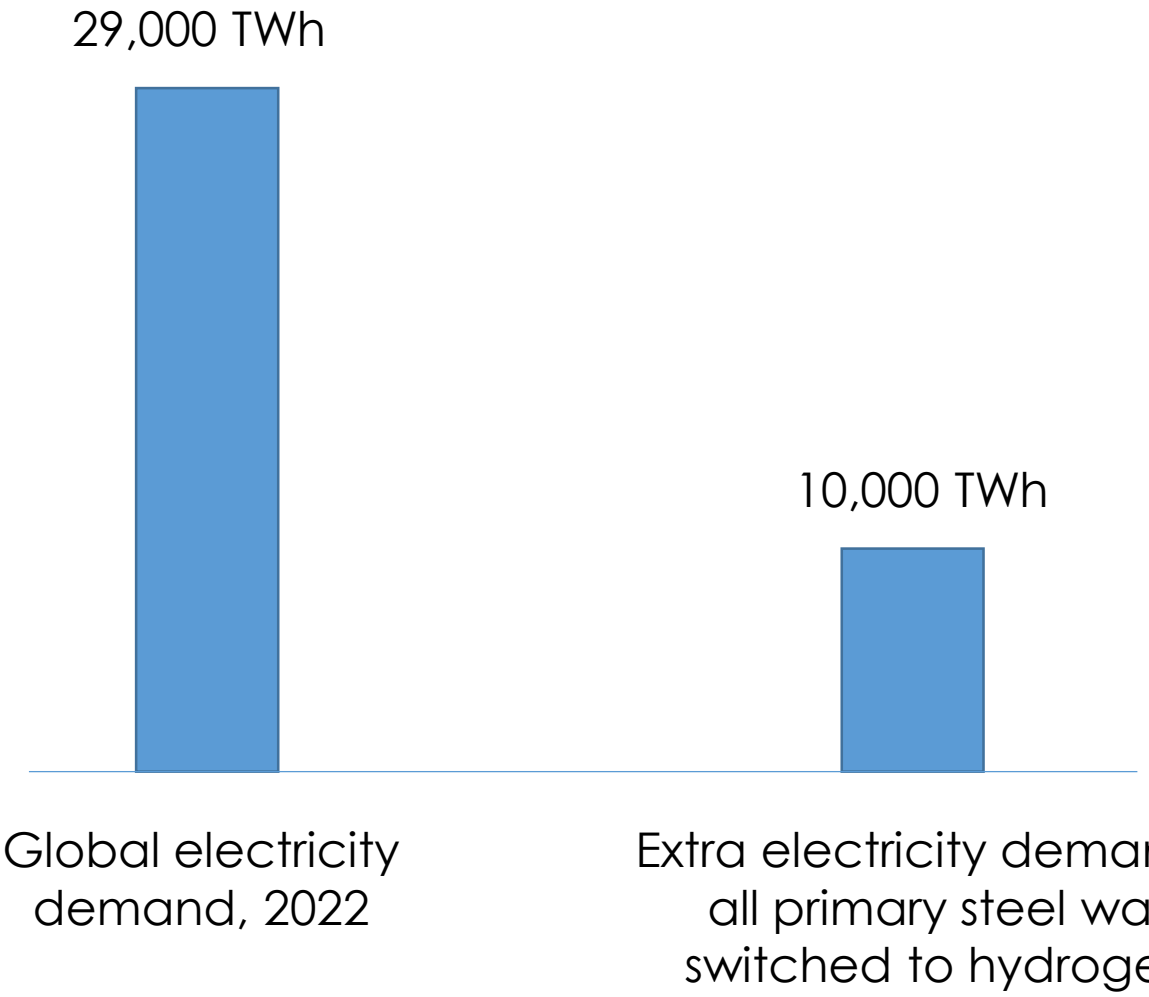
* The price of finished steel in China is approximately $350/tonne today
** At $40/MWh

The problem – higher manufacturing costs *

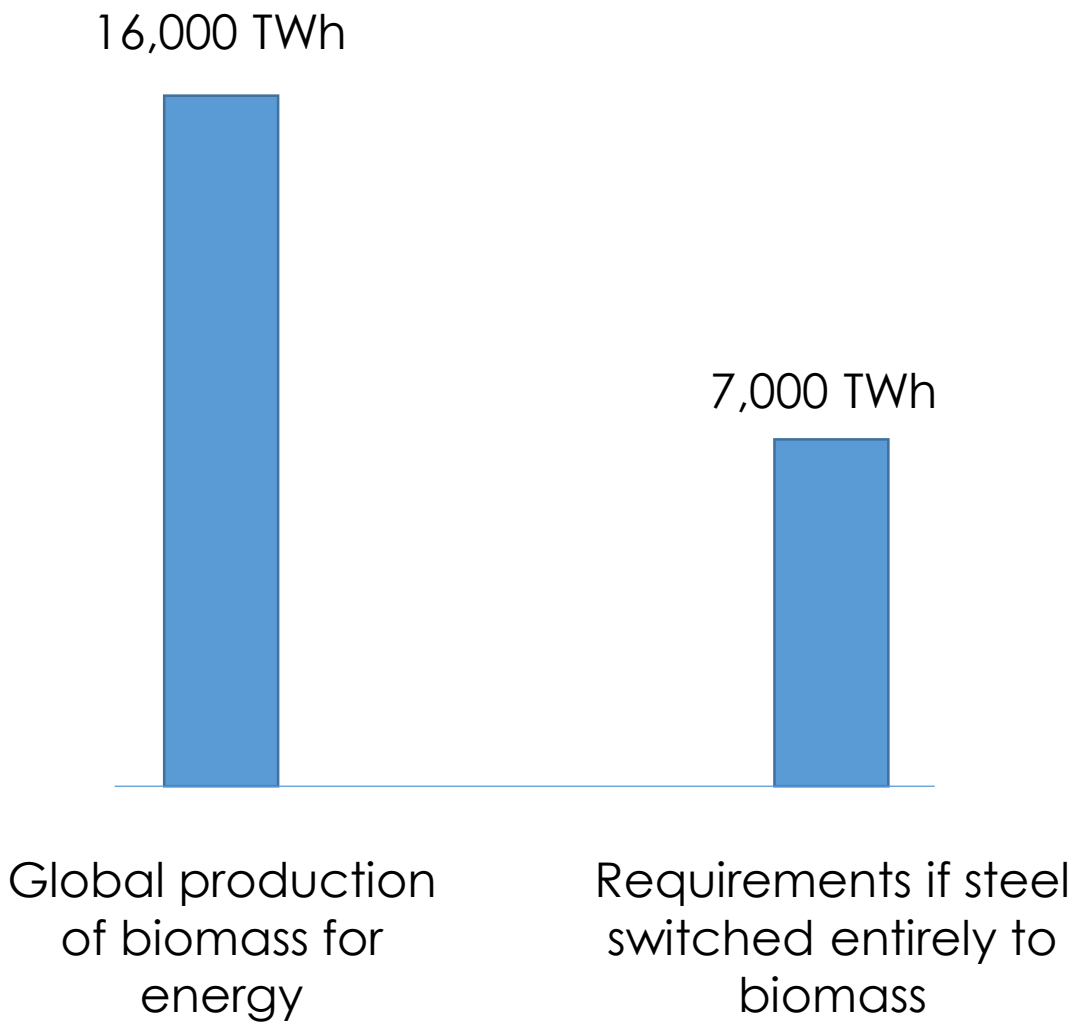


* The price of finished steel in China is approximately $350/tonne today
** At $40/MWh

Second problem: switching to hydrogen will add about 35% to global power needs



Switching to charcoal as a source will not avoid a resource problem



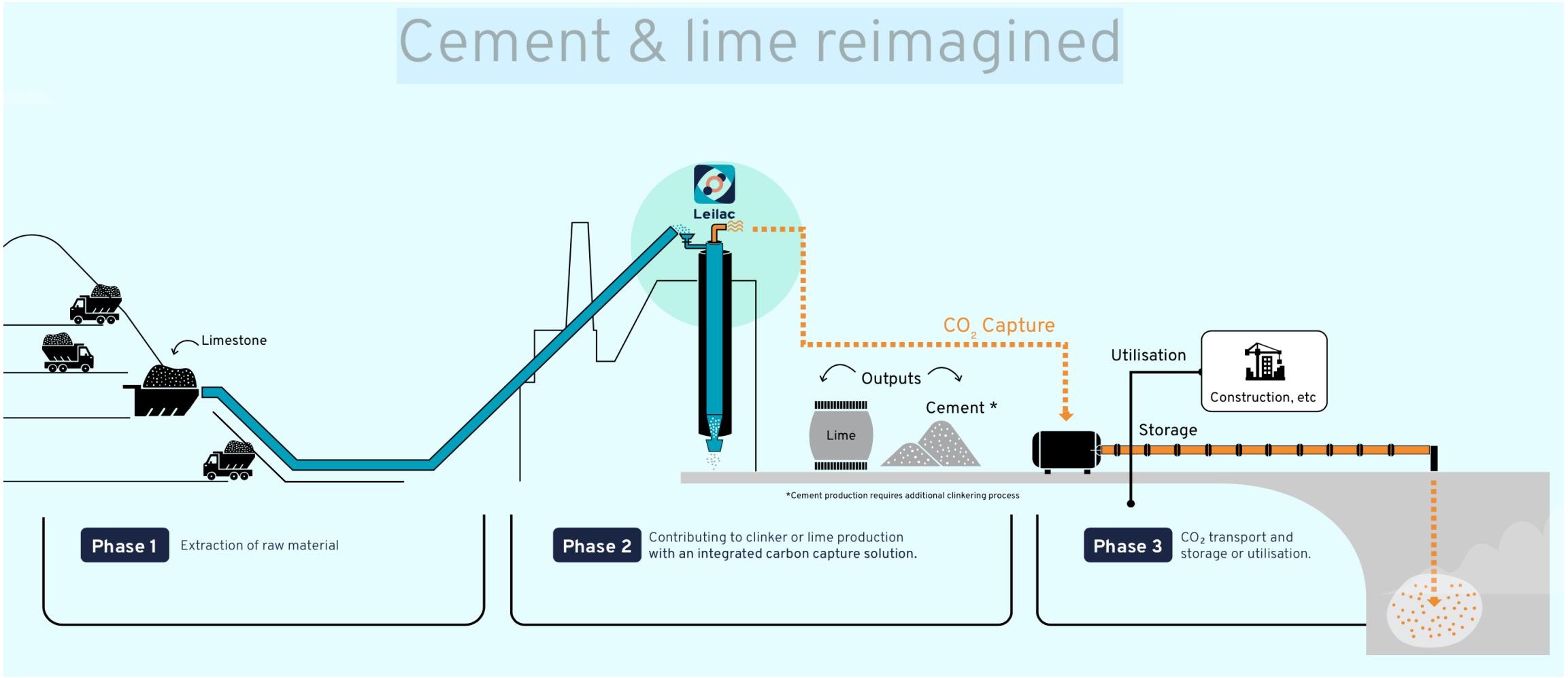
Steel

- Low carbon manufacturing options are clearly available
- But imply a current cost disadvantage in a world of low carbon taxation. (H2 Green Steel talks of 30% penalty).
- Whether using hydrogen directly or hydrogen, the amounts of extra power required represent a significant fraction of today's global output
- Biomass will not be widely used because of a unavoidable scarcity of resources
- Lastly, global industry will have to be completely re-equipped and will probably move location to regions with access to very low cost electricity

Cement – about 8% of global emissions

		Electricity	Hydrogen	CO2/CO/C	CCS	DAC	Recycling	Biomass
Cement		x			x			

The Calix process heats the limestone with electricity in a vacuum. Pure CO2 is driven off and stored

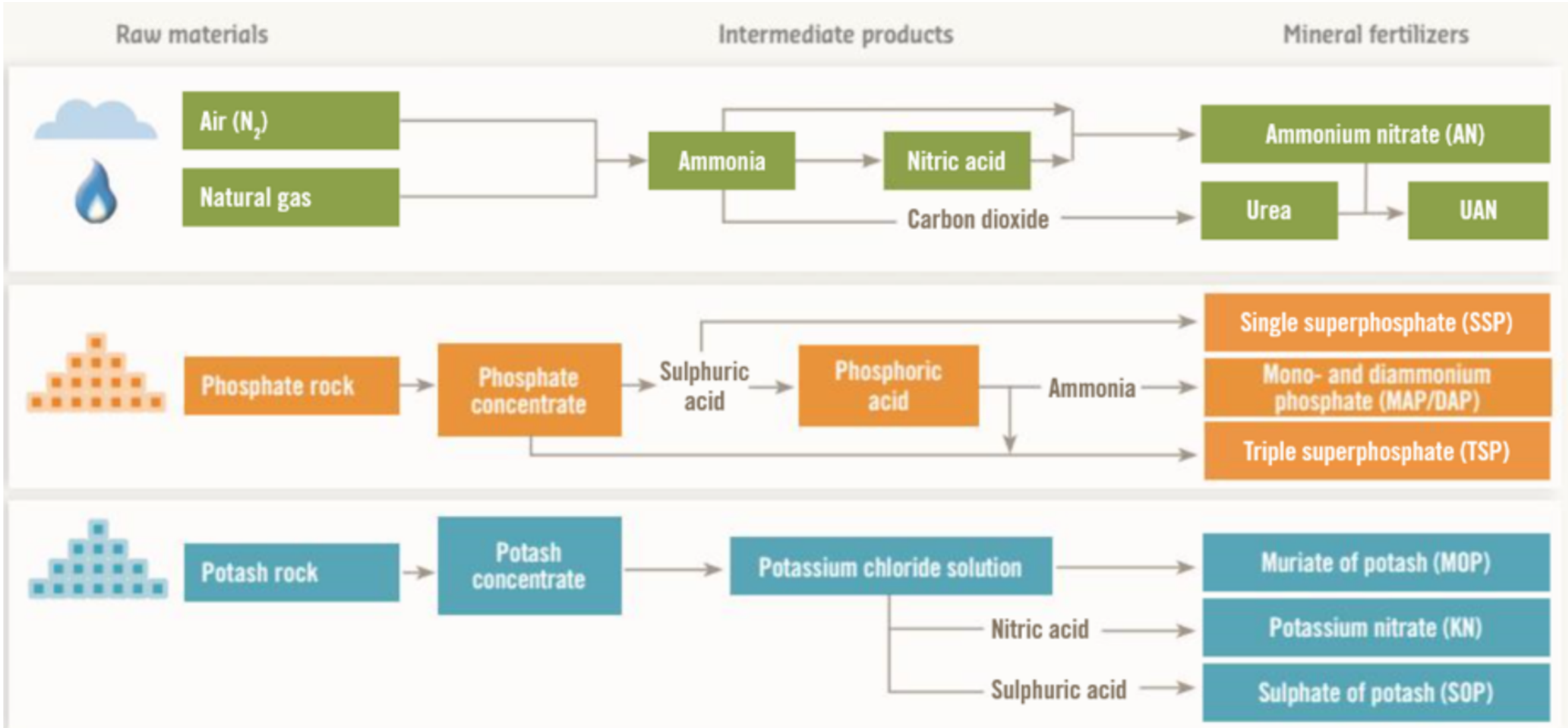


Brimstone: a US startup that makes cement from calcium silicates, not limestone (calcium carbonate)

Fertiliser manufacture – up to 5% of world emissions

		Electricity	Hydrogen	CO2/CO/C	CCS	DAC	Recycling	Biomass
Fertiliser			x	x		x		

Fertiliser manufacture – a complicated series of processes



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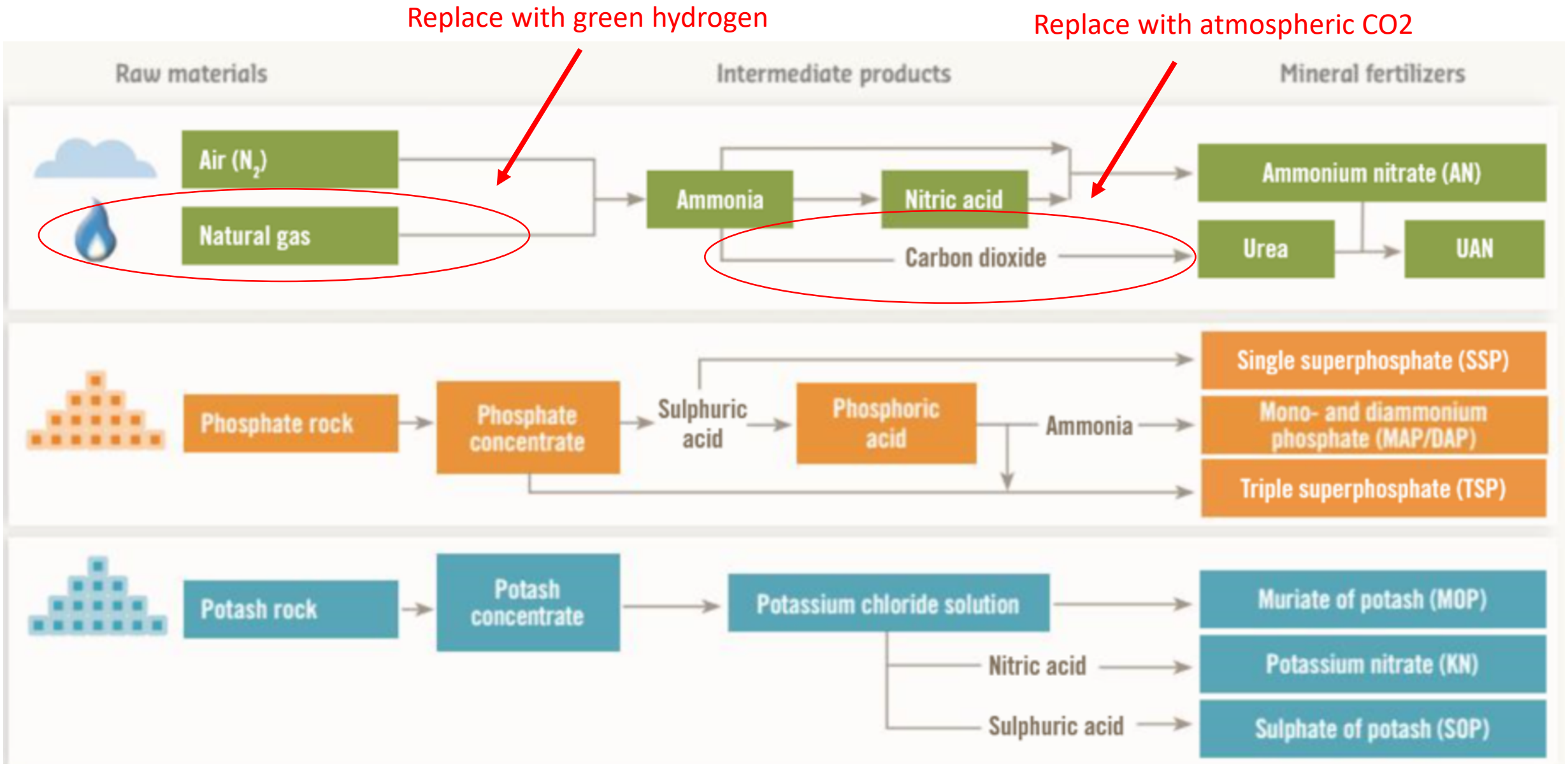


The Iberdrola hydrogen plant feeding a Fertiberia fertiliser factory in Spain

Iberdrola Hygroden Plant: One of the world's largest hydrogen production plants with 20 MW using electrolysis powered by 100% renewable sources (Image: © Iberdrola)

Heavy industry – about 5 per cent of global emissions

		Electricity	Hydrogen	CO2/CO/C	CCS	DAC	Recycling	Biomass
Heavy industry		x	x		?			

Iris Ceramica in Italy - using hydrogen for process heat for ceramic tiles

Many heat intensive industrial processes can be converted from gas to electricity

Almost half of fuel consumed for energy can be electrified with technology available today.

Share of total estimated fuel consumption for energy, 2017, %

	Examples of processes	Technology status
Other (potential not assessed[1])		
Very-high-temperature heat (>1,000°C)	Melting in glass furnace, reheating of slab in hot strip mill, and calcination of limestone for cement production	Research or pilot phase
High-temperature heat (400–1,000°C)	Steam reforming and cracking in the petrochemical industry	Available today
Medium-temperature heat (100–400°C)	Drying, evaporation, distillation, and activation	Available today
Low-temperature heat (≤100°C)	Washing, rinsing, and food preparation	Available today

Source: McKinsey

Heavy freight transport – about 5% of world emissions

		Electricity	Hydrogen	CO2/CO/C	CCS	DAC	Recycling	Biomass
Trucks		x	?					

A Volvo electric truck for transporting containers

Shipping – about 3% of global emissions

		Electricity	Hydrogen	CO2/CO/C	CCS	DAC	Recycling	Biomass
Shipping		x	x			x		

One of the first large methanol ‘dual-fuel’ container ships

Aviation – about 3% of world emissions

			Electricity	Hydrogen	CO2/CO/C	CCS	DAC	Recycling	Biomass
	Aviation			X			x		X

The proposed DG Fuels plant in Louisiana using bagasse

The proposed Norsk eFuel plant in northern Norway using DAC and electrolysis

Plastics - about 3% of global emissions

	Electricity	Hydrogen	CO2/CO/C	CCS	DAC	Recycling	Biomass
Plastics	x	x	x		x	x	

Carbios – world leader in ‘chemical’ recycling of plastics

Clothing – about 2% of global emissions

			Electricity	Hydrogen	CO2/CO/C	CCS	DAC	Recycling	Biomass
	Clothing			x	x			x	x

Spiber – making clothes from 'brewed protein'

Agriculture – by some counts, 25% of global emissions

		Electricity	Hydrogen	CO2/CO/C	CCS	DAC	Recycling	Biomass
Agriculture			x			x		x

The Solar Foods manufacturing process

Electrolyser for H2

Direct Air Capture for C

Small amount of other nutrients

Brewery

Vegan ice cream

Direct Air Capture

Because there'll be some remaining GHGs, as well as the industries that need the carbon

The Climeworks illustration of what a large DAC plant might look like

Two alternative approaches – cheaper per tonne?

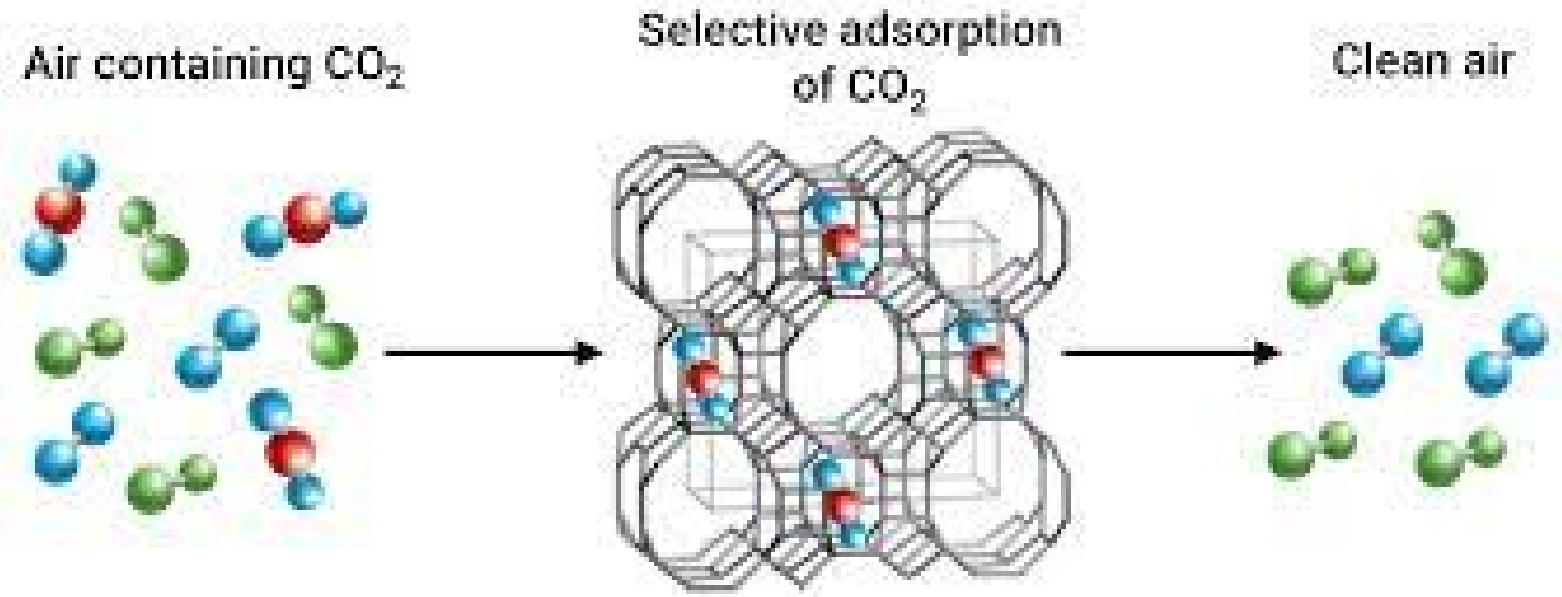
Avnos

'Water swing absorption'

Airhive

Fluidised bed

Zeolite absorption



ZeoDAC – catching CO2 in 'molecular cages'

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