CO_2 Capture to Avoid Dangerous Climate Change

Bryan Lovell Meeting 2019:
Role of geological science in the decarbonisation of power production, heat, transport and industry
21 – 23 January 2019

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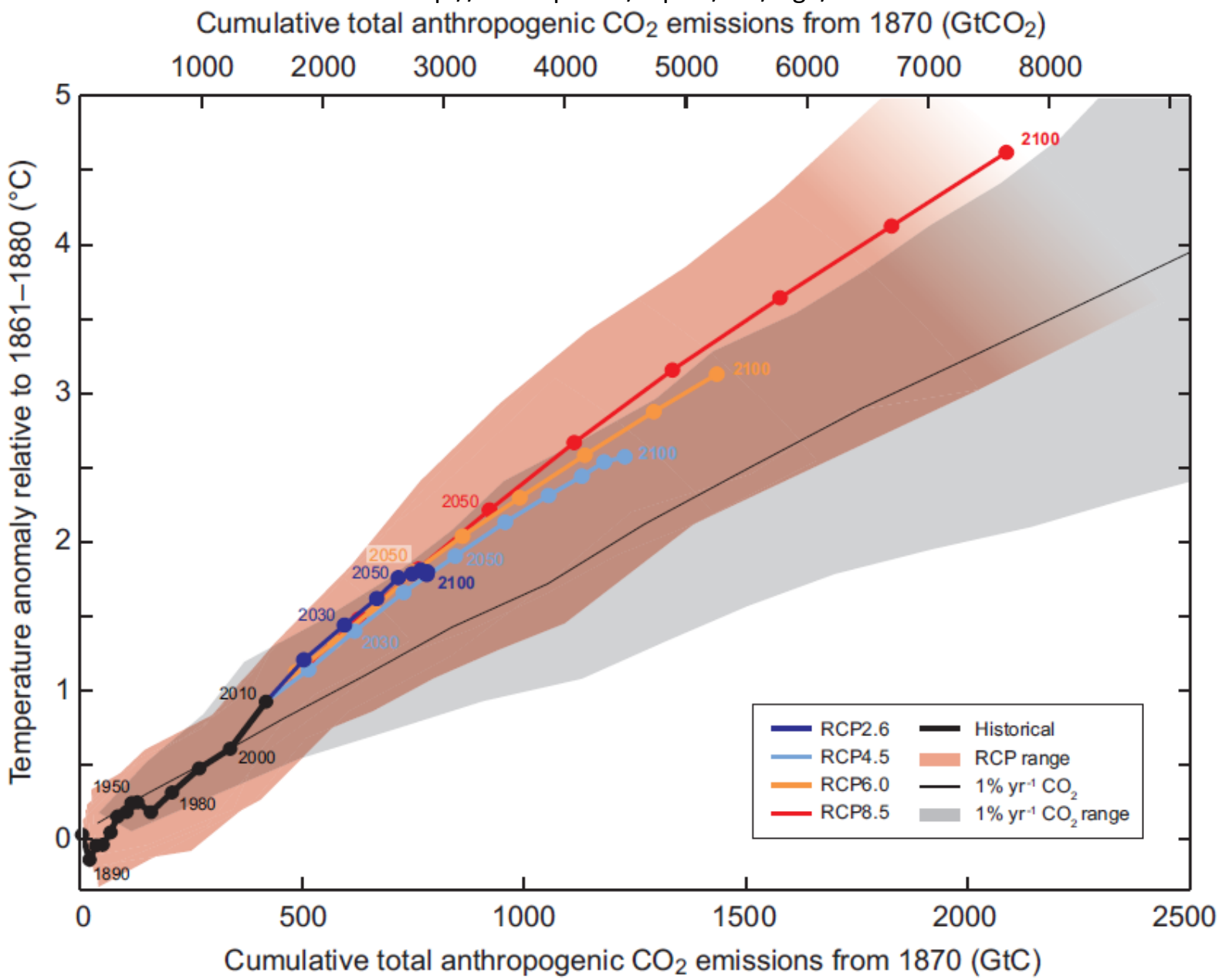
IPCC Climate Change 2013 'The Physical Science Basis'

http://www.ipcc.ch/report/ar5/wg1/



What do we need to achieve? A soft landing seemed possible in 2009.

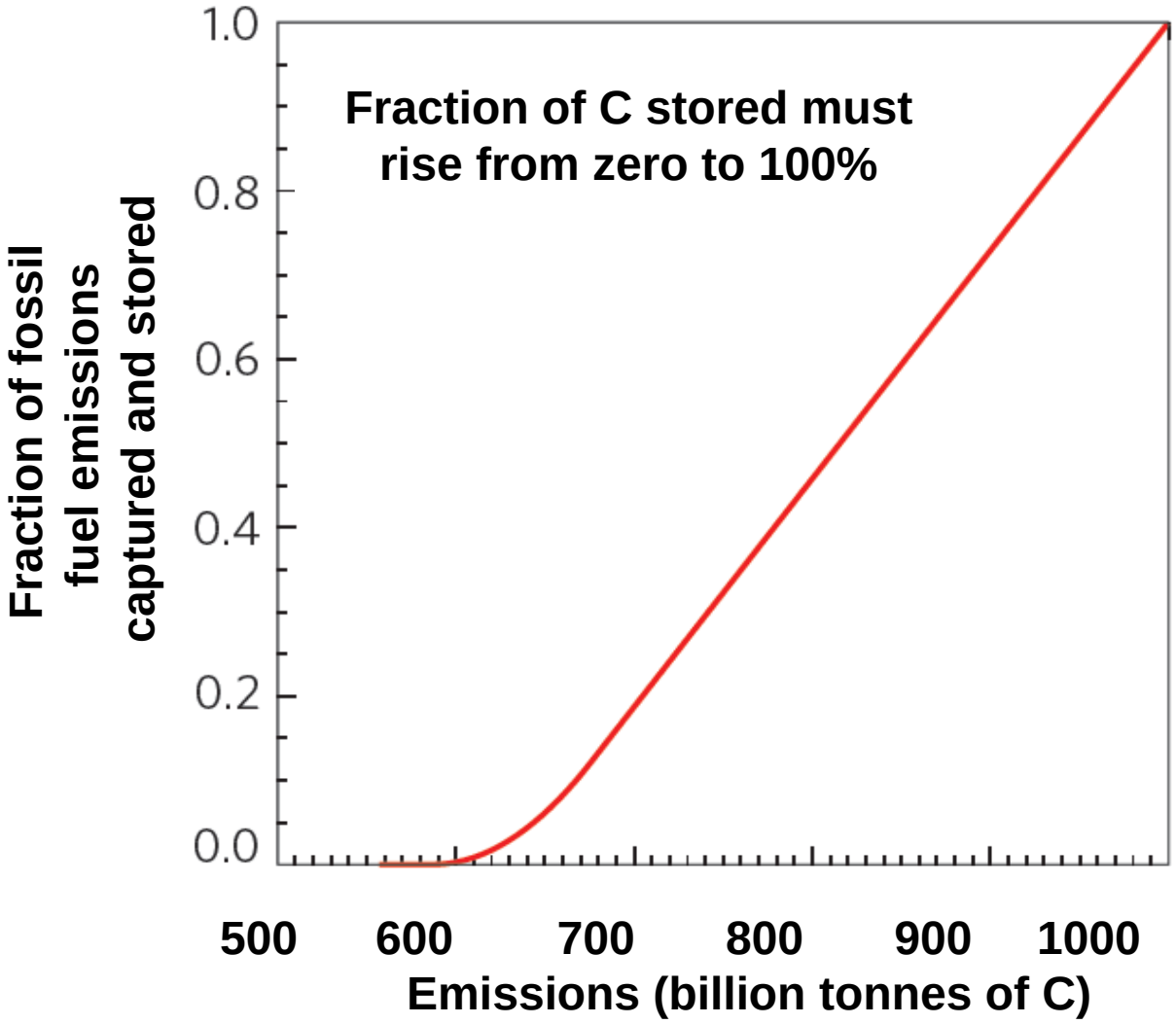
The prime climate objective is not to end the use of fossil fuels.

The prime objective is to develop and deploy 100% CCS in time to cap cumulative emissions of carbon at a safe level.

CO_2 EOR and other applications with partial overall capture should be seen as a stage in a path from zero CO_2 capture to 100% CCS.

They can be a move in the right direction from where we are now – emitting 100% of fossil carbon to atmosphere.

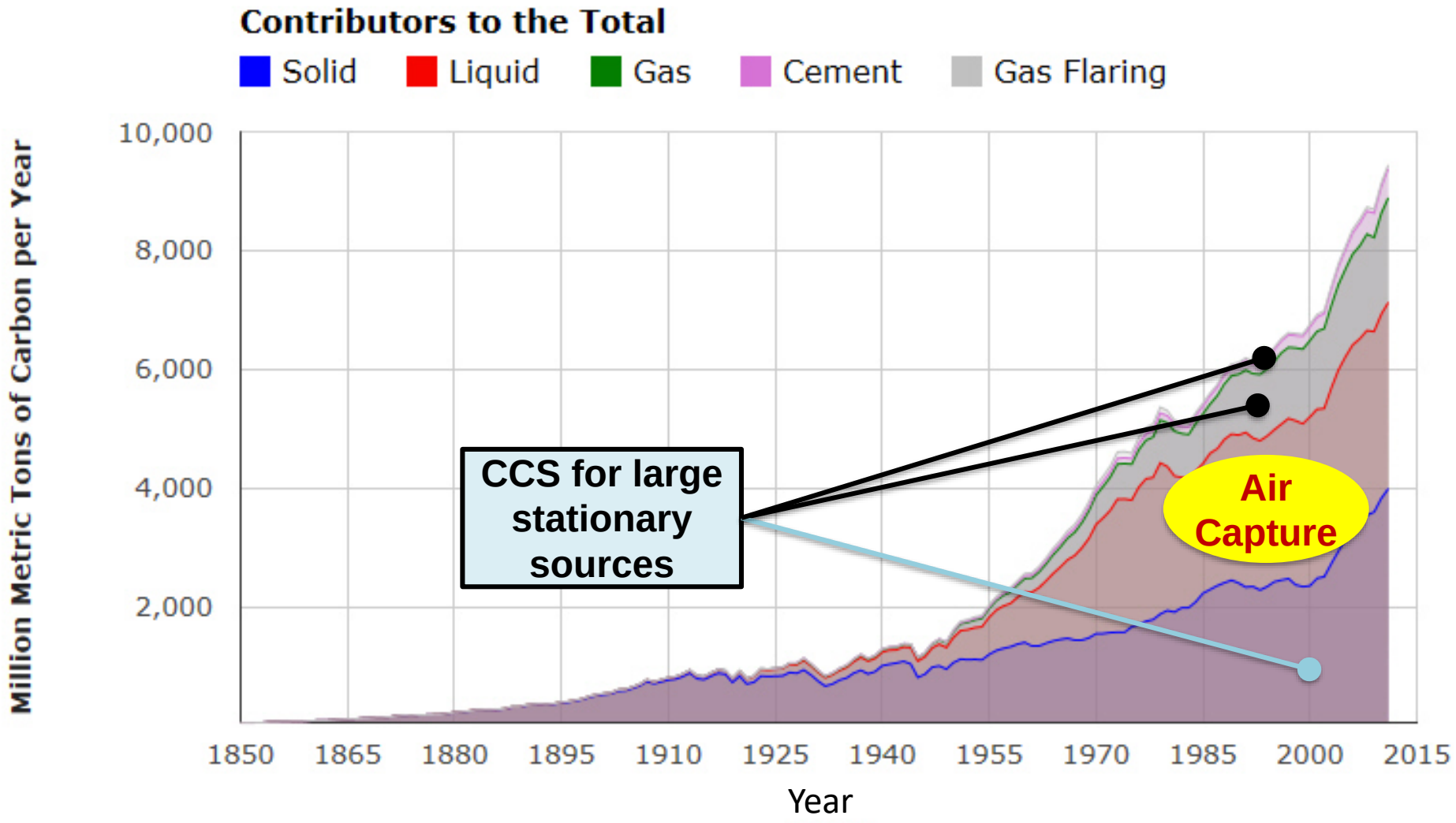
The key factor is the extent to which technologies and/or projects can readily be adapted to get higher fractions of CO_2 stored.



Myles R. Allen, David J. Frame & Charles F. Mason, The case for mandatory sequestration, Nature Geoscience 2, 813 - 814 (2009), doi:10.1038/ngeo709

A very significant fraction of fossil fuel use requires air capture

http://cdiac.ess-dive.lbl.gov/trends/emis/glo_2014.html



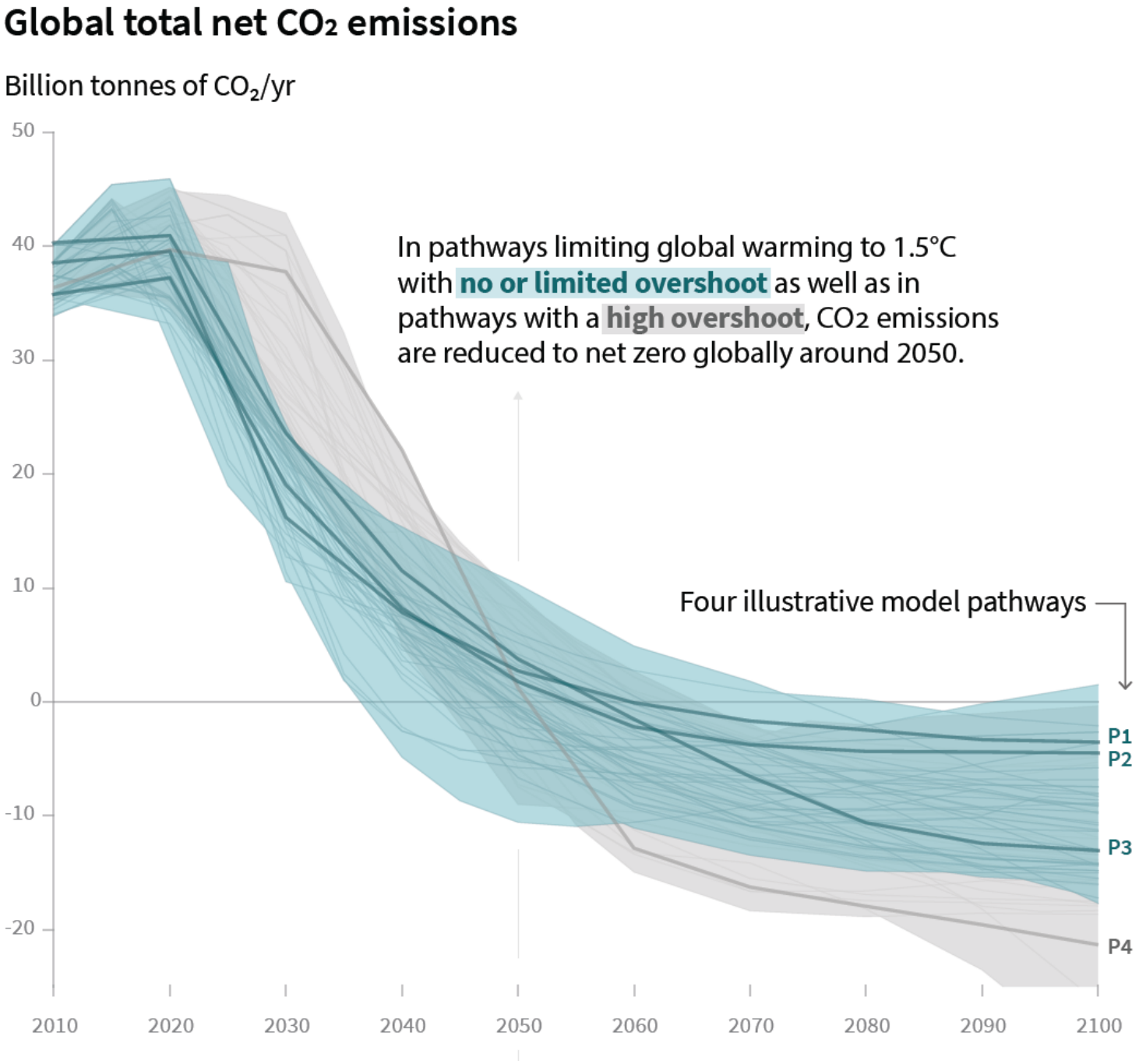
Source: Boden, T.A., G. Marland, and R. J. Andres. 2015. Global, Regional, and National Fossil-Fuel CO_2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi: 10.3334/CDIAC/00001_V2015.

Now a harder landing -

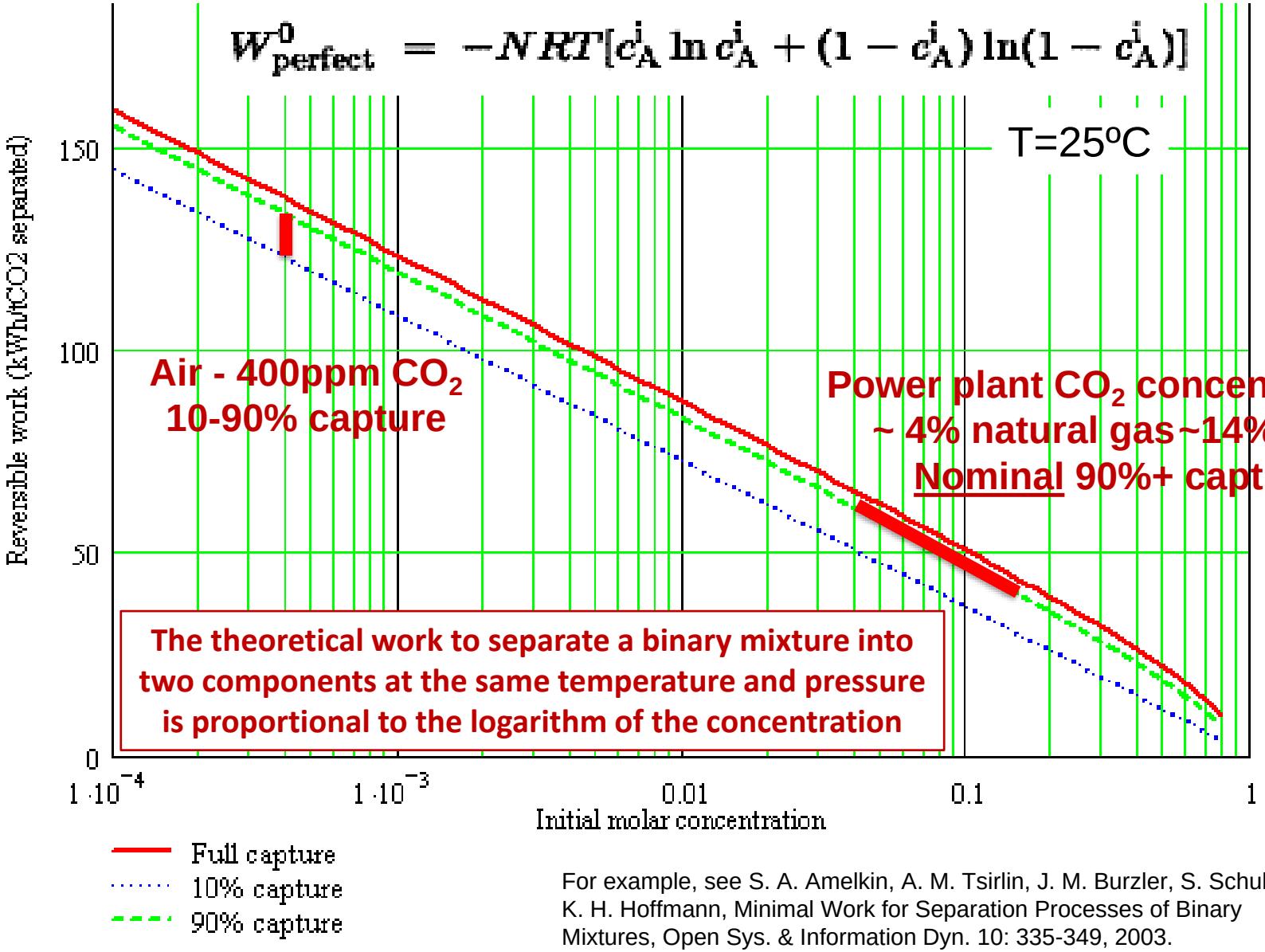
IPCC special report on global warming of 1.5°C, October 2018

Greenhouse Gas Removal technologies required to achieve even net zero emissions, as well as net negative CO_2 emissions

GGR includes BECCS and Direct Air Capture with CO_2 Storage (DACS or DACCS)

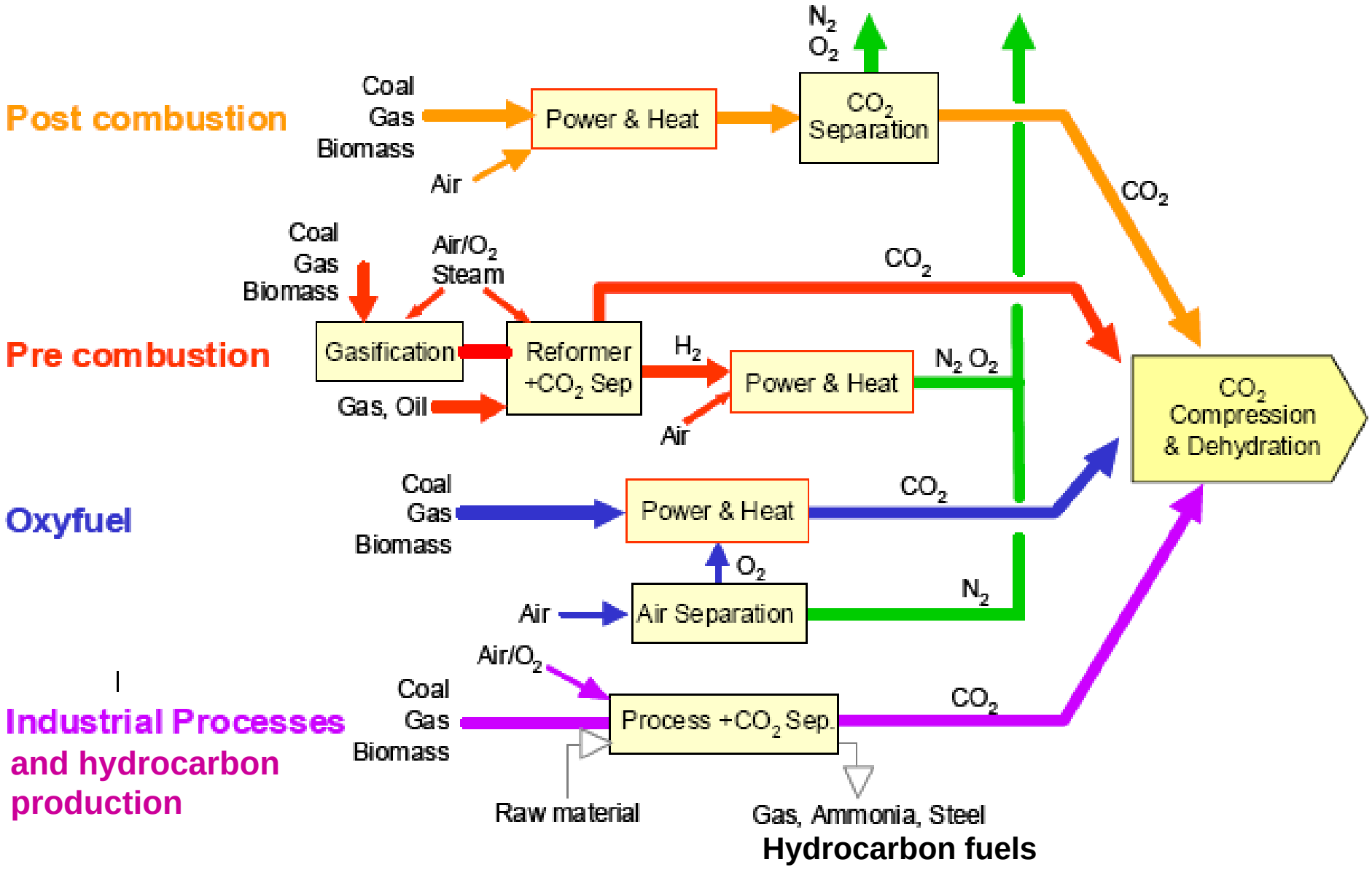


Direct air capture requires only about twice the theoretical energy input of conventional CO_2 capture from power plants – but who pays for it?



For example, see S. A. Amelkin, A. M. Tsirlin, J. M. Burzler, S. Schubert, K. H. Hoffmann, Minimal Work for Separation Processes of Binary Mixtures, Open Sys. & Information Dyn. 10: 335-349, 2003.

Types of Carbon Capture Technology



IPCC Special Report on CCS, 2004

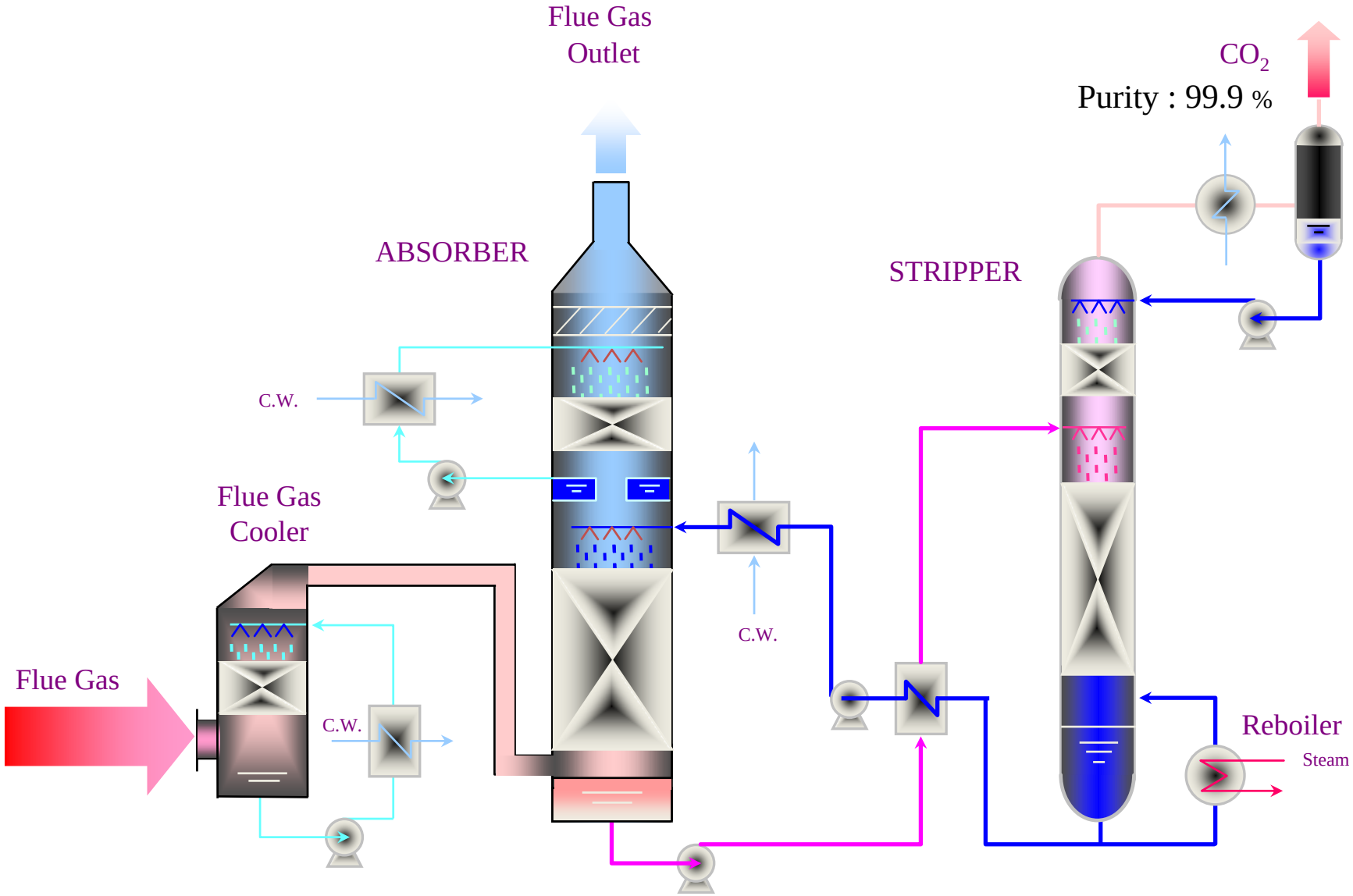
Post-Combustion Capture at Boundary Dam, Saskatchewan –

First Large-Scale CCS Project in the World on Coal Power

2014 SaskPower, Saskatchewan, Canada: Old power plant being rebuilt with a state-of-the-art turbine and a fully-integrated carbon capture system capable of cutting CO_2 emissions by up to 90%, or approximately one million tonnes a year.

http://www.saskpower.com

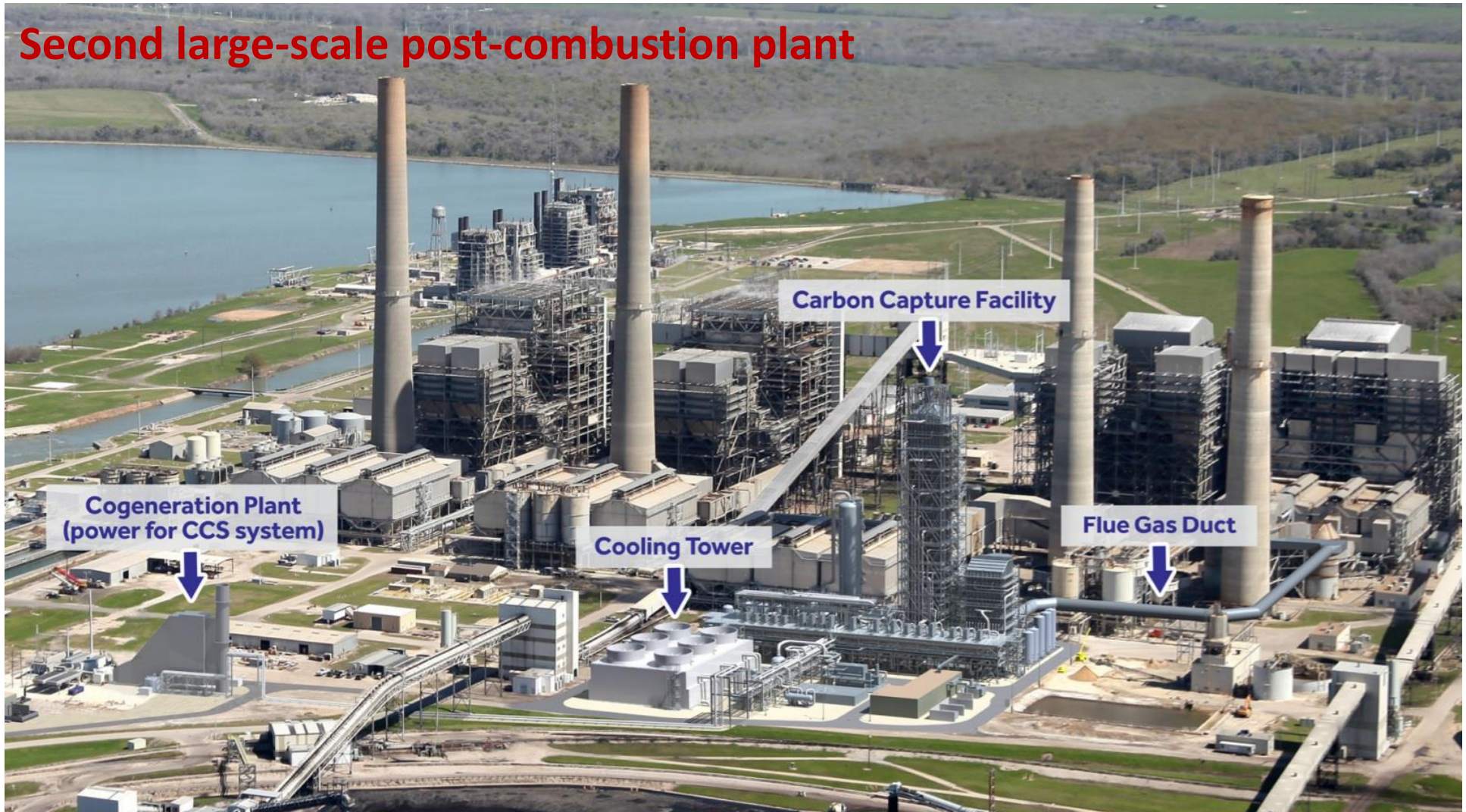
Process Flow for Post-Combustion Capture



Petra Nova is a joint venture between NRG Energy and JX Nippon Oil & Gas Exploration that became operational in early January 2017

http://www.ourworldofenergy.com/vignettes.php?type=coal-power&id=11

The largest post-combustion CCS project installed on an existing coal-fired power plant in the world. The project is designed to capture approximately 90 percent, or 1.6 million tons annually, of the CO_2 from NRG Energy's W.A. Parish 240 MW generating station southwest of Houston, Texas.



Carbon Capture System Site Layout

https://2w4set5pkcc374jjw3jbdf15-wpengine.netdna-ssl.com/wp-content/uploads/2017/10/5-Armpriester-Petra-Nova.pdf

Petra Nova Carbon Capture Site

nrg | JX
PETRA NOVA Carbon Capture

Wet flue gas cooling rather than dry cooling as at BD3, also has a conventional wet FGD upstream that will not be affected by fly ash

PACT: Pilot-Scale Advanced Capture Technology

A UK national facility managed by the University of Sheffield

https://pact.group.shef.ac.uk/

PACT is coordinating the International Test Center Network for 2 years

https://itcn-global.org/

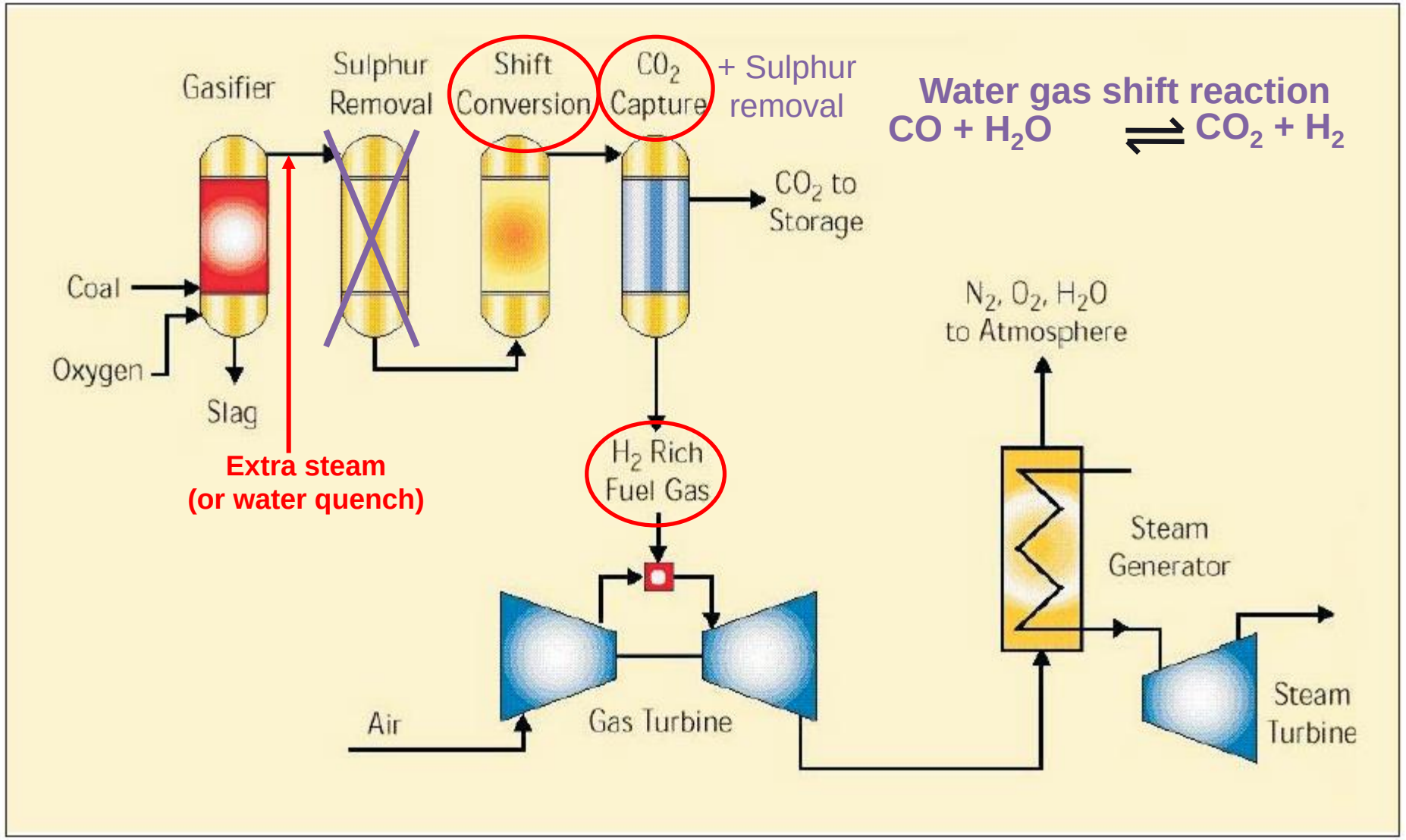
The Amine Capture Plant:

- Adsorption and desorption, a fresh & spent amine storage tanks, an electric boiler (steam for regeneration of the solvent)
- Other specific details include:-
  - Treats 100% of flue gas from the 165KW test facilities
  - Removes 1 tonne of CO2 per day using MEA (>85% capture)
  - Can Operates for extended test periods using synthetic gas option
  - 8m column height
  - 0.07MWe consumption (50kg/h CO2)
  - Multiple solvent sampling locations along the columns
  - Provisions for corrosion coupons and alternative materials test sites
  - Trace gas injection capability

ETI gas power with CCS, now OGCI ‘Clean Gas Project’

https://www.eti.co.uk/programmes/carbon-capture-storage/thermal-power-with-ccs

Pre-combustion capture with coal gasification

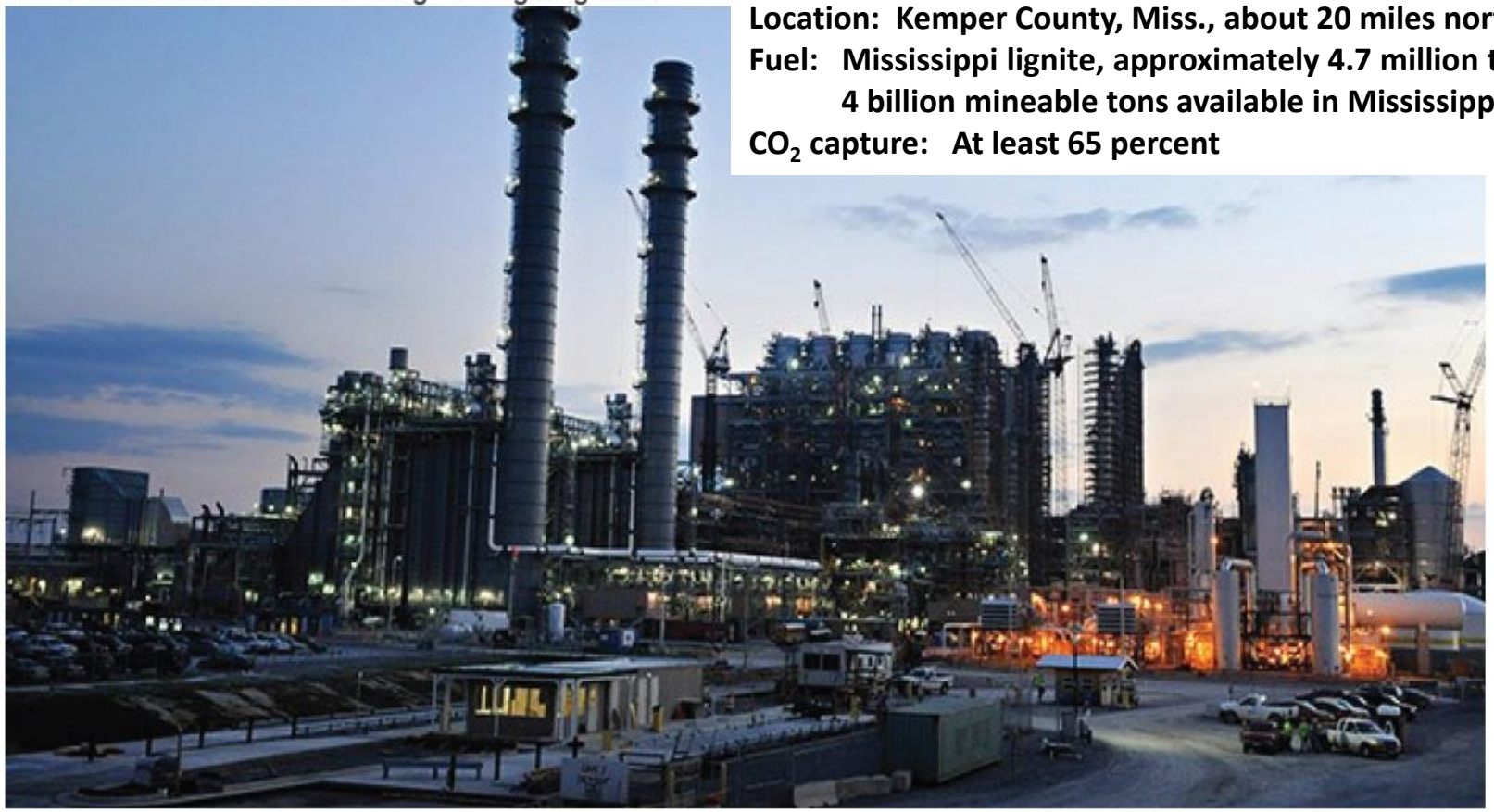


Based on IEA GHG www.ieagreen.co.uk

Jon Gibbins, New Europe, New Energy. Oxford, 27 Sep 2006

Kemper plant costs rise $496M due to startup delays

10/30/2014
By Jennifer Van Burkleo
Online Associate Editor Power Engineering Magazine



http://www.mississippipower.com/about-energy/plants/kemper-county-energy-facility/facts

Plant: 582-megawatt electric power plant
Technology: TRIG™ Integrated Gasification Combined Cycle (IGCC)
Location: Kemper County, Miss., about 20 miles north of Meridian, Miss.
Fuel: Mississippi lignite, approximately 4.7 million tons used per year; 4 billion mineable tons available in Mississippi alone
CO_2 capture: At least 65 percent

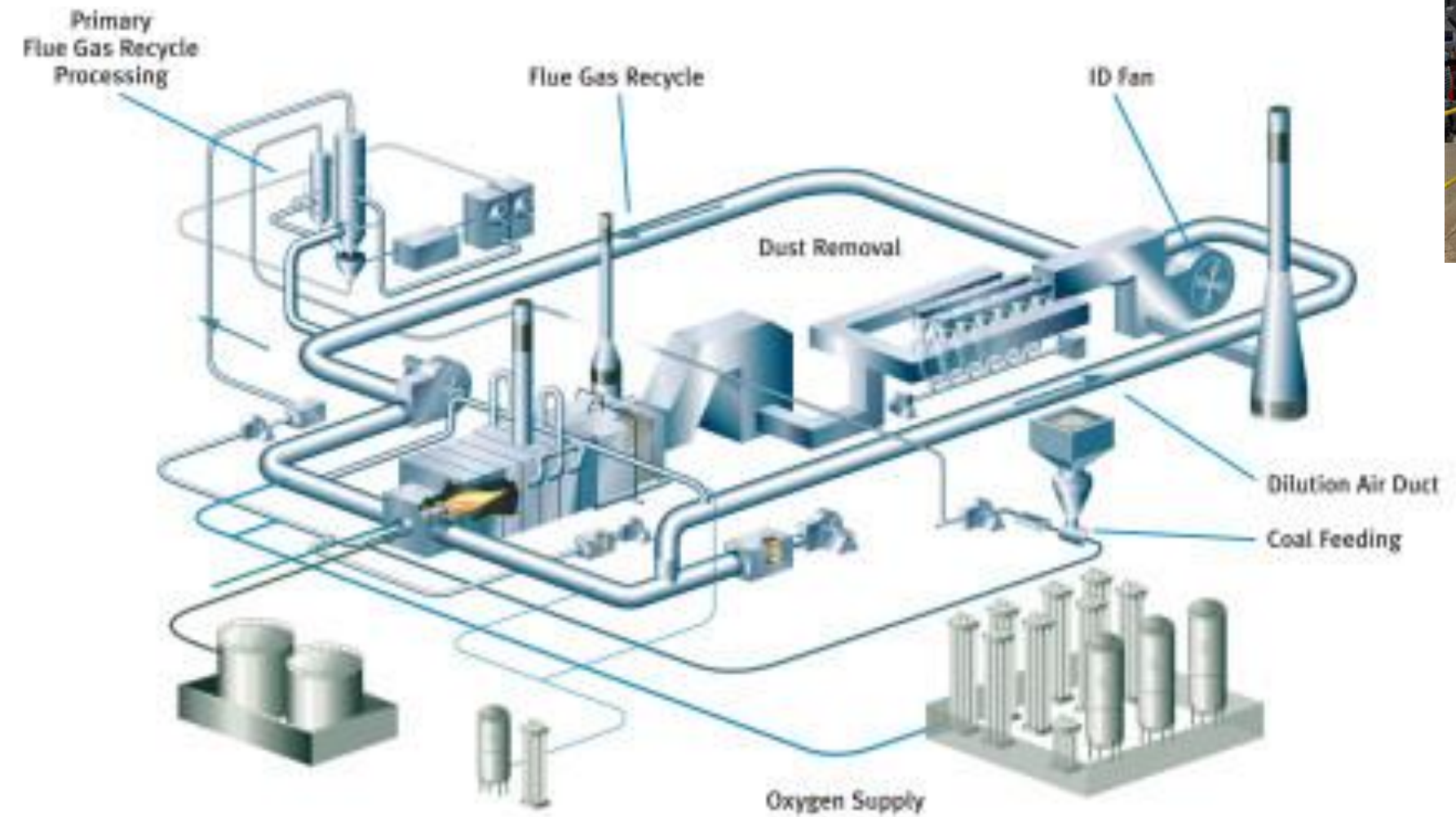
NOW CANCELLED

In the September monthly report filed by Southern Co. (NYSE: SO) to the Mississippi Public Service Commission and the Securities and Exchange Commission, the company said its subsidiary, Mississippi Power, will need an additional $496 million to extend the deadline to finish the Kemper Integrated Coal Gasification Combined-Cycle (IGCC) facility in eastern Mississippi. This total makes the overall cost of the plant reach more than $6.1 billion. The project was originally budgeted for $2.8 billion.

http://www.power-eng.com/articles/2014/10/kemper-plant-costs-rise-an-additional-496m-due-to-startup-delays-brings-total-cost-to-6-1b.html?cmpid=enl-%E2%80%A61/4

Oxyfuel capture from pulverised coal plants

Doosan Babcock Oxycoal Burner Test Rig, Renfrew, Scotland – 40MWth, equivalent to a single burner in a full-scale wall-fired boiler



OxyCoal™ Firing Demonstration Facility, Renfrew, Scotland

An indicative illustration of Drax Power Station (left) and the White Rose Carbon Capture and Storage Project (right)

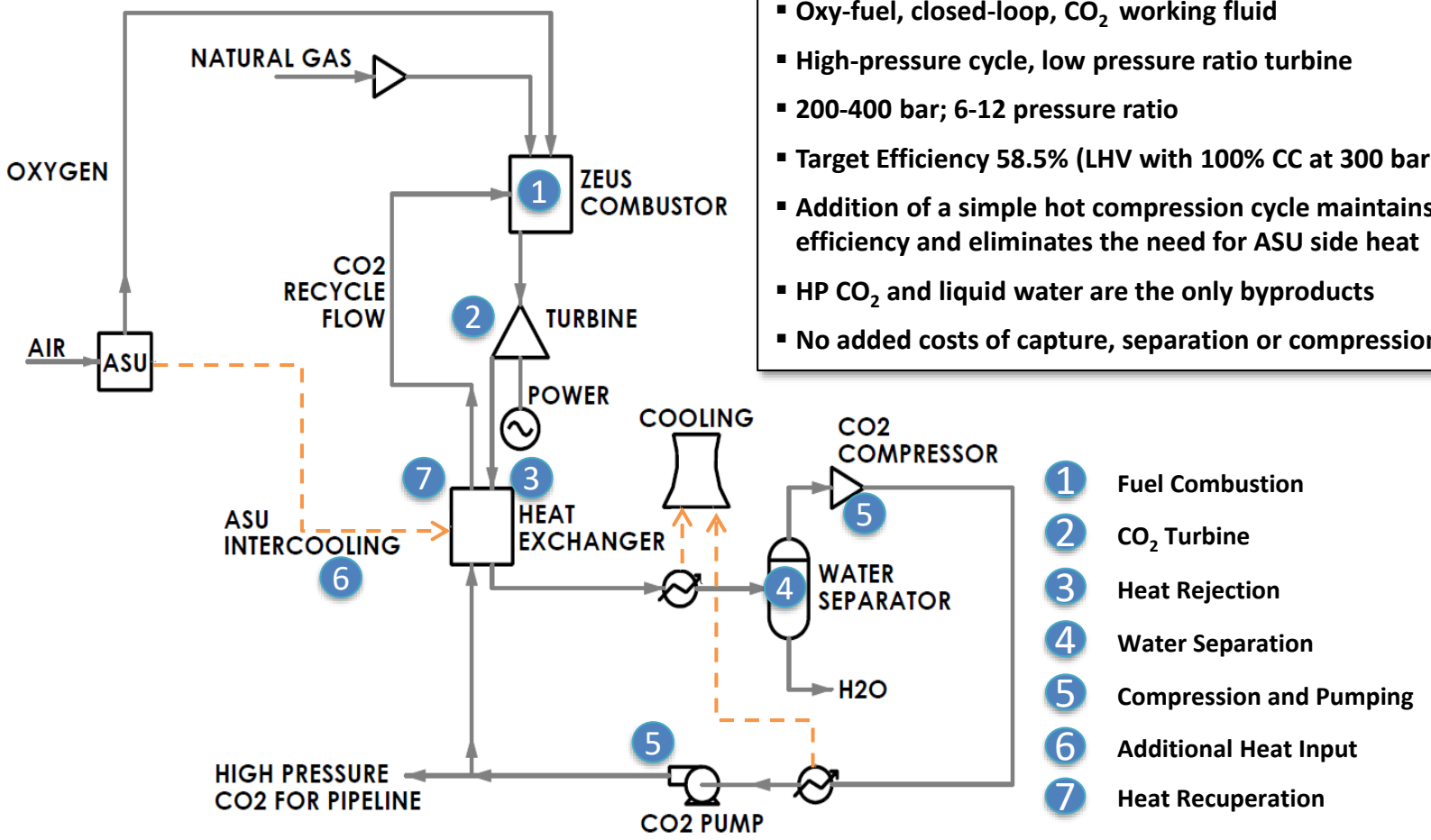
White Rose CCS Project

- New standalone power plant at the existing Drax Power Station site near Selby,
- State-of-the-art coal-fired power plant with the potential to co-fire biomass.
- 426MWe (gross) oxyfuel power and carbon capture and storage
- 90% of all CO_2 emissions captured
- Capturing approximately 2 million tonnes of CO_2 per year
- Anchor project for Yorkshire CO_2 transportation and storage network

http://www.whiteroseccs.co.uk

Oxyfuel on Gas - the Allam Cycle

The NET Power Natural Gas System

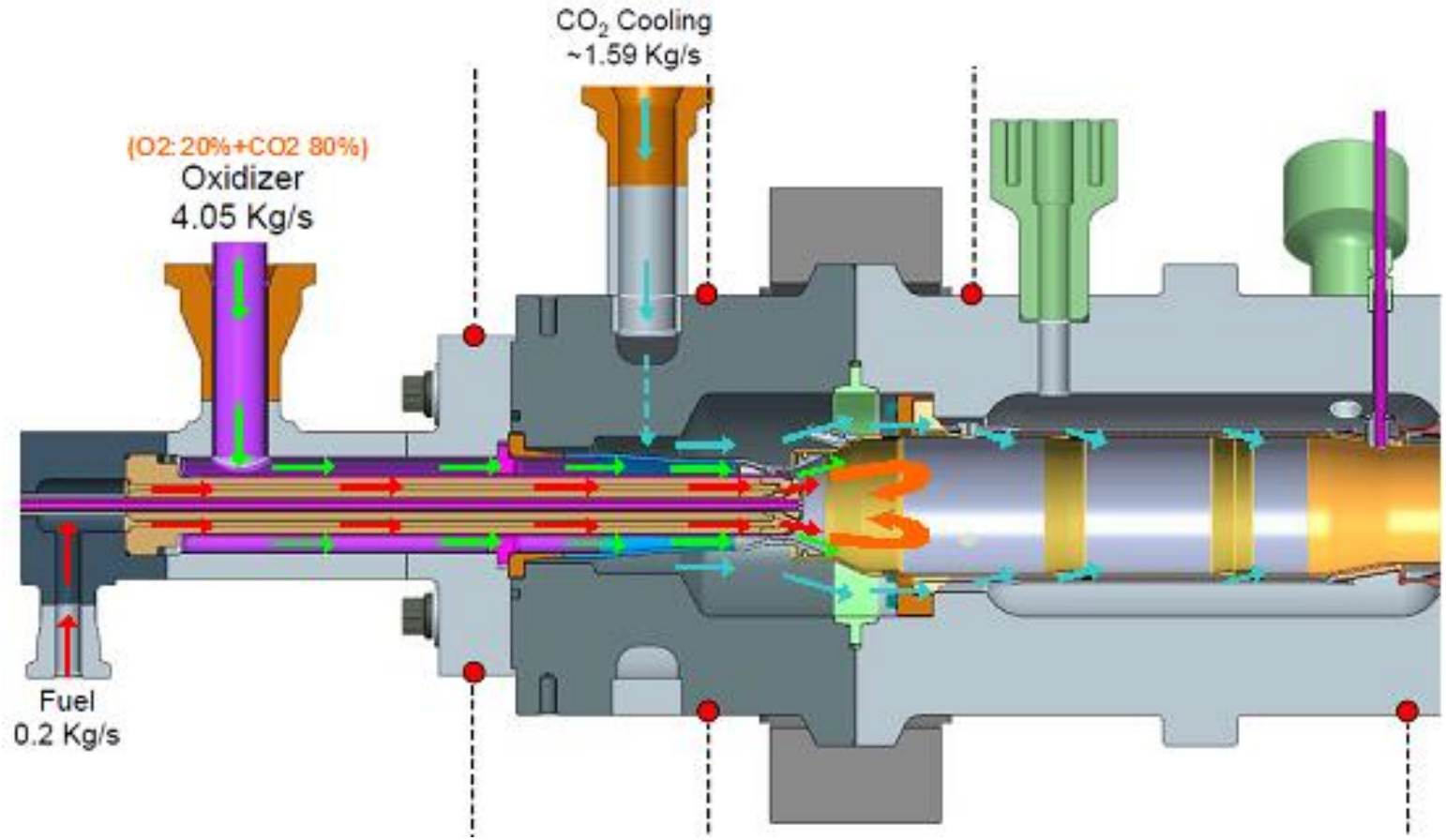


- Oxy-fuel, closed-loop, CO_2 working fluid
- High-pressure cycle, low pressure ratio turbine
- 200-400 bar; 6-12 pressure ratio
- Target Efficiency 58.5% (LHV with 100% CC at 300 bar)
- Addition of a simple hot compression cycle maintains efficiency and eliminates the need for ASU side heat
- HP CO_2 and liquid water are the only byproducts
- No added costs of capture, separation or compression of CO_2

Hideo Nomoto, Toshiba Corporation, Rodney Allam, NET Power, Presentation to 7th Trondheim Carbon Capture and Sequestration Conference, June 5, 2013

Pressurized Oxy-Combustion for High Pressure Cycles

Pressurized oxy-combustors use purified oxygen combined with a temperature moderator to burn fuels at high pressure. In place of the nitrogen found in air, CO_2 and/or steam are used as the temperature moderator and also subsequently as a working fluid that is expanded through a turbine to generate power. The combustor pictured here is a high-pressure (300 bar) oxy-combustor for use with gaseous fuels using CO_2 as the temperature moderator.



From: Mission Innovation, Carbon Capture Innovation Challenge, Report of the Carbon Capture, Utilization and Storage Experts' Workshop, September 26–28, 2017, Houston, Texas.

NetPower 50MW test site, now commissioning

Recently received support from Occidental Petroleum Corporation

Greenwire: Tuesday, January 16, 2018

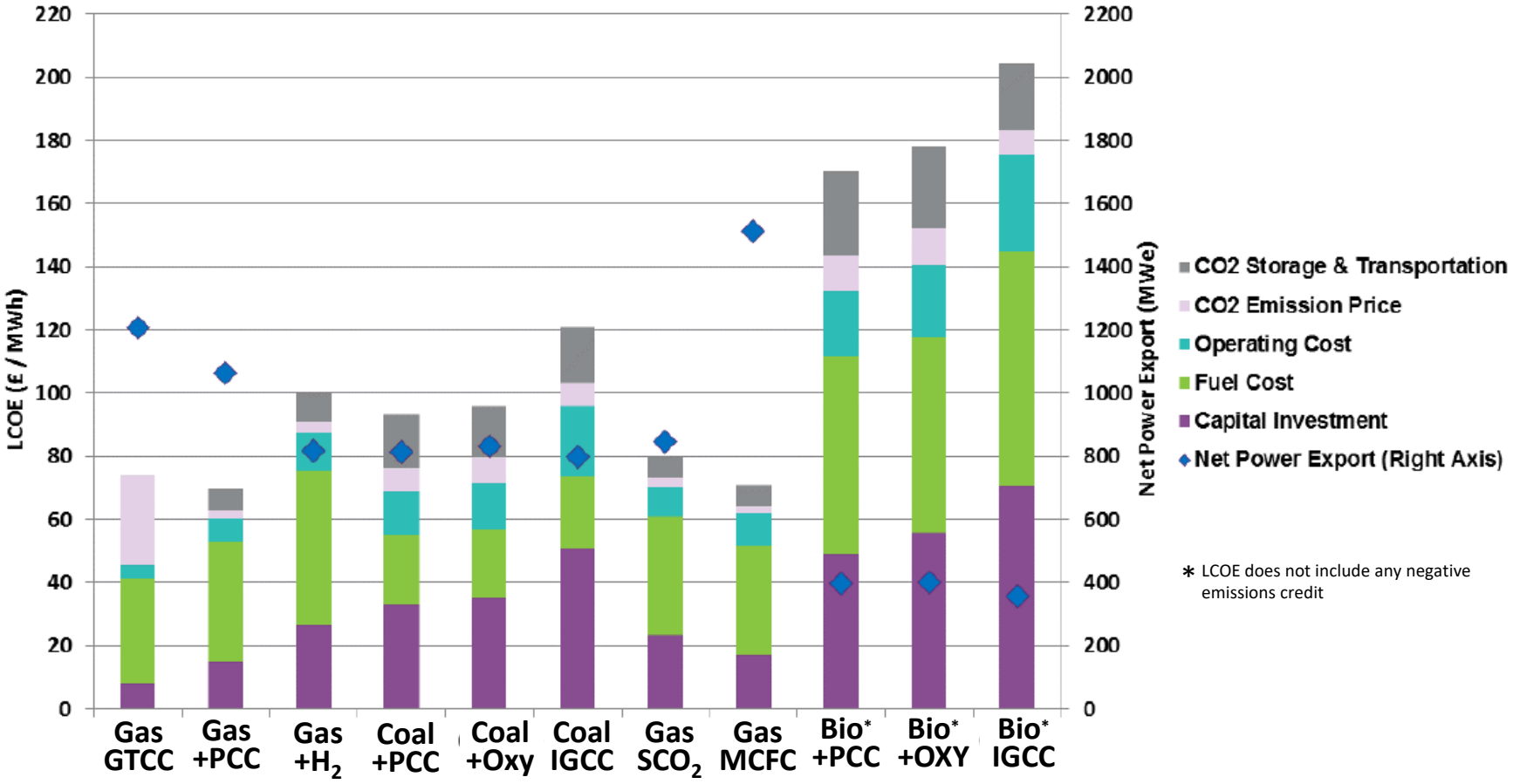
The NET Power project in Texas is the world's largest attempt to use carbon dioxide as a working fluid. NET Power and CB&I

https://www.eenews.net/stories/1060071081

UK cost estimates for a range of fuels and technologies

Study for BEIS by Wood, formerly Amec-FW https://www.gov.uk/guidance/funding-for-low-carbon-industry

- Post-combustion capture appears competitive – also allows retrofit
- Supercritical CO_2 cycles also being developed
- Urgent to accelerate learning by doing for all technologies to reduce costs



Direct Air Capture (DACS/DACCS) and Bioenergy with CCS (BECCS) can capture CO_2 for storage to offset fossil fuel emissions or for synthesis of hydrocarbon fuels using non-fossil energy sources

- BECCS is 'conventional' CCS using biomass as the fuel, but there is concern about biomass availability at the scales required

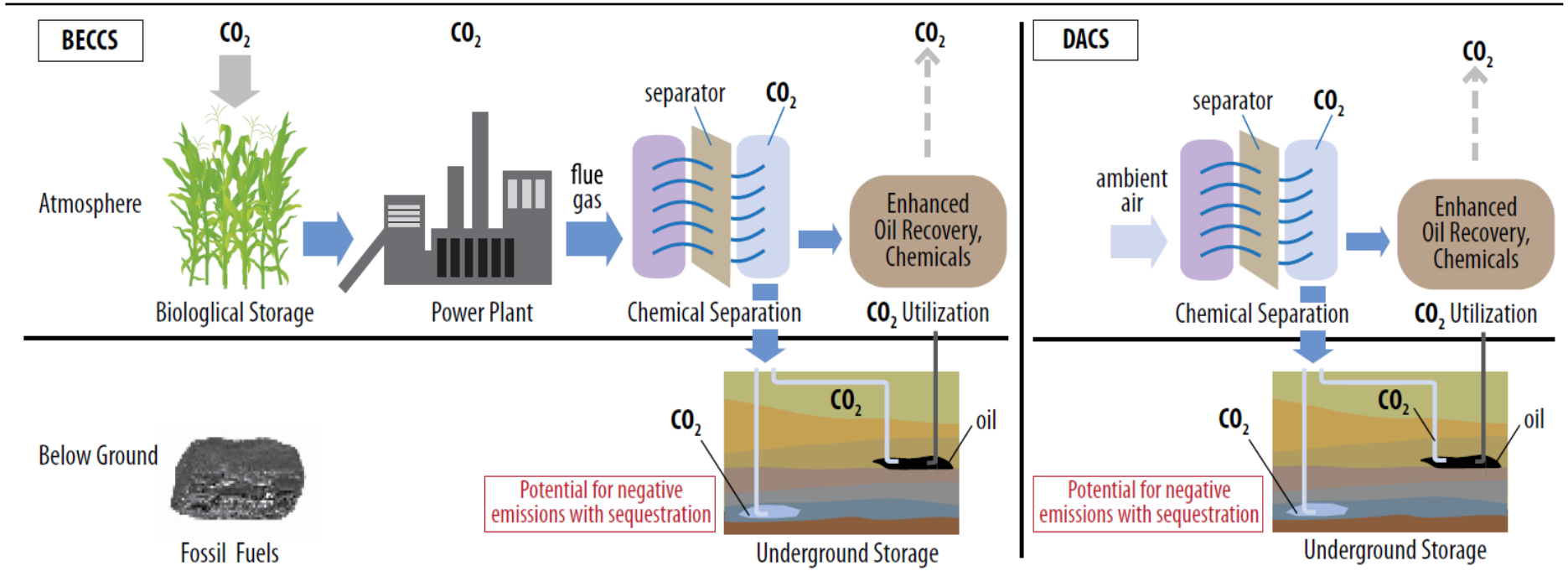


Figure 1. *In Bioenergy with Carbon Capture and Sequestration (BECCS, shown on left), crops such as corn or switchgrass take up carbon dioxide from the atmosphere as they grow. The crops can be burned in power plants to produce electricity, and the carbon dioxide generated is captured and sequestered underground. In Direct Air Capture and Sequestration (DACS, shown on right), carbon dioxide can be removed from the atmosphere as air passes through air filtering structures and is sequestered underground. Block arrows represent fluxes of carbon (as fuel or as carbon dioxide); dashed arrows indicate residual carbon dioxide emissions.*

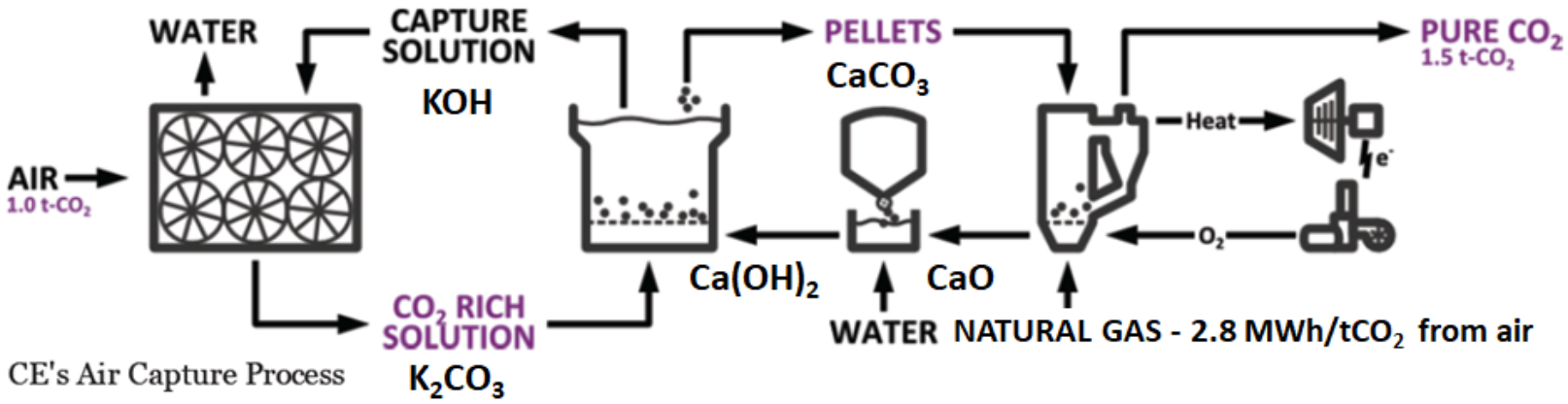
http://nas-sites.org/americasclimatechoices/

Air Capture: Carbon Engineering air capture process

Detailed 2018 engineering and cost analysis for a 1 Mt-CO_2/year direct air capture plant by Carbon Engineering reported levelized costs of $94 to $232 per ton CO_2 from the atmosphere ($42 to $102 on a barrel of oil).

https://www.cell.com/joule/fulltext/S2542-4351(18)30225-3

http://carbonengineering.com/



Squamish demo plant site construction

Running 2015, ~500 tCO_2/yr scale

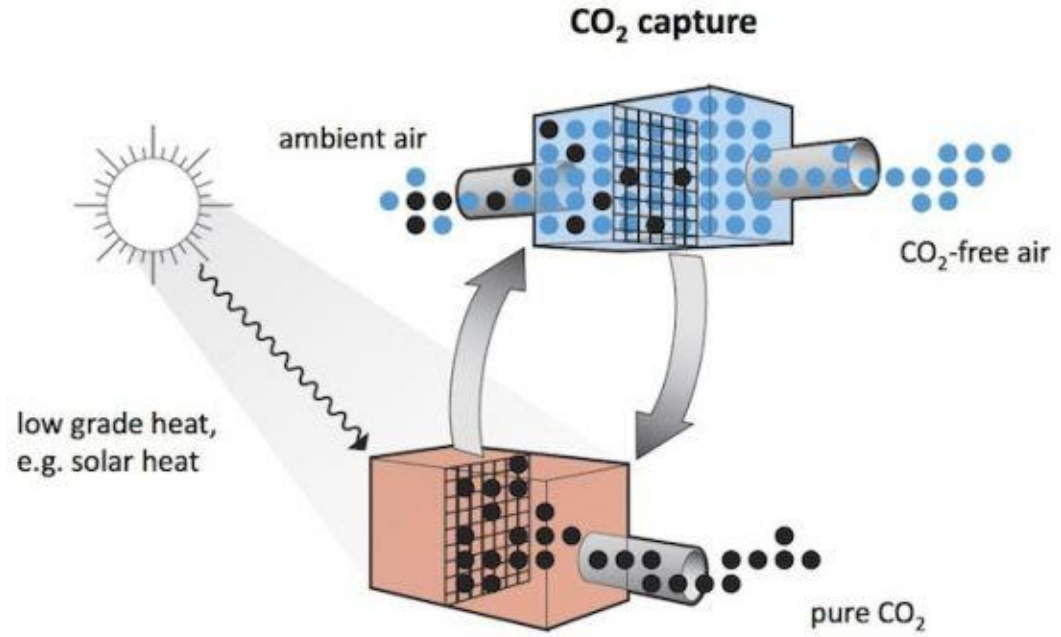
Design for 'slab' air contactor

100,000tCO_2/yr scale

Air Capture: Climeworks air capture process

CLIMEWORKS

http://www.climeworks.com



Based on a cyclic adsorption / desorption process on a novel filter material ("sorbent"). Scalable in multiples of 300 tCO_2/yr, in shipping container sized units.

Energy demand per ton of CO_2 :

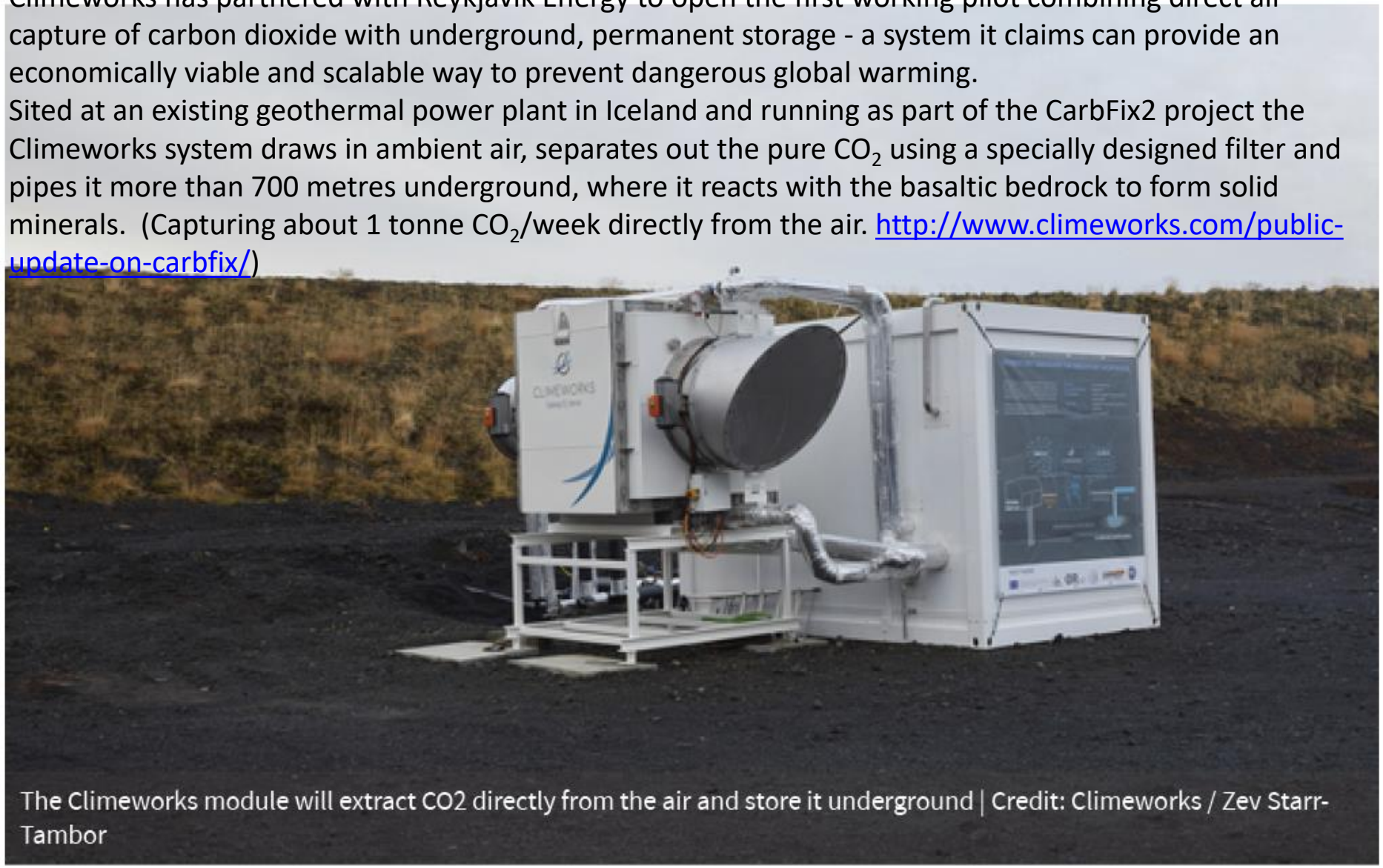
- 1.5 – 2.0 MWh heat at 100 °C
- 0.2 – 0.3 MWh electricity

Climeworks CO_2 Kollektor

Design for Climeworks CO_2 Capture Plant

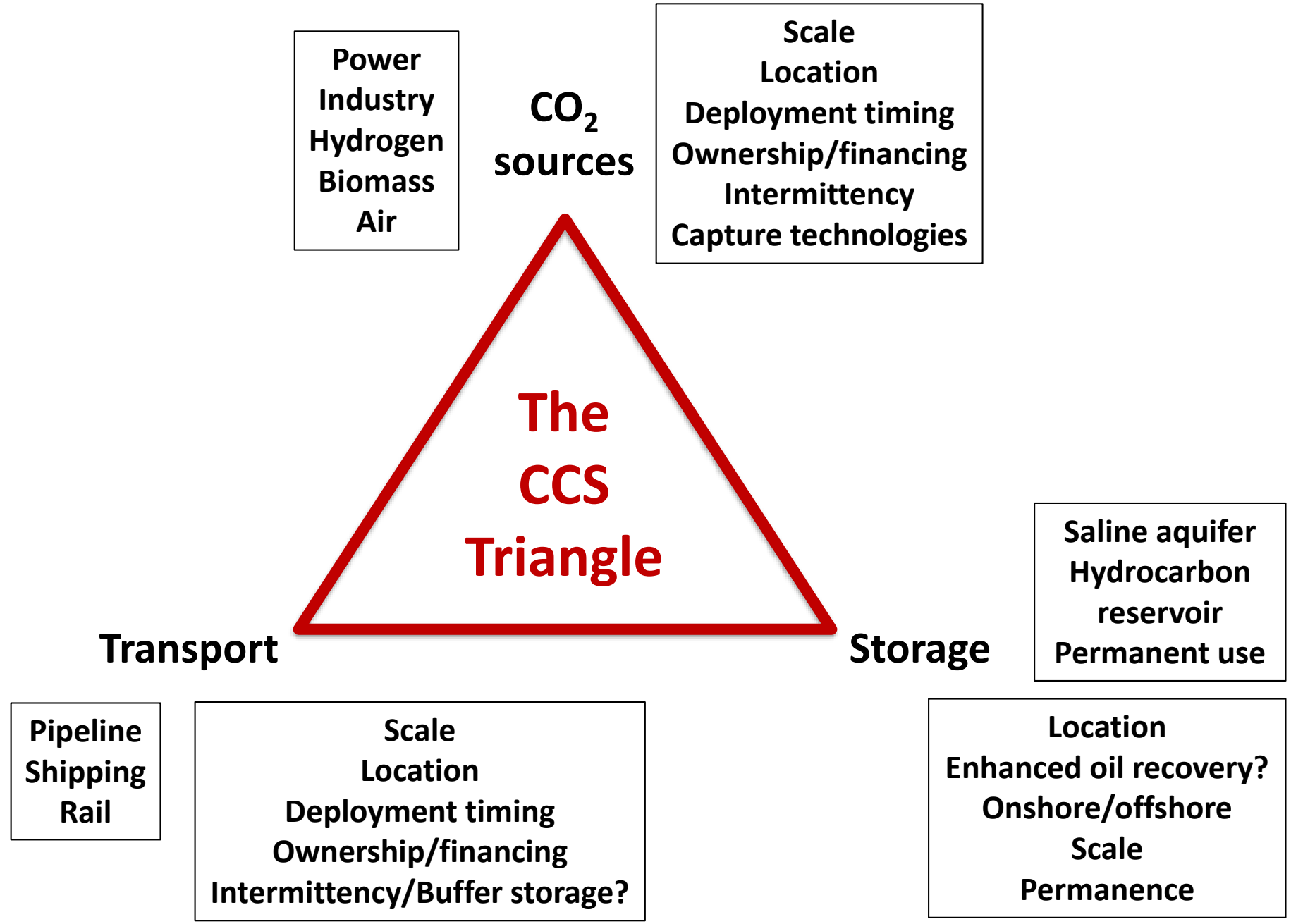
Climeworks flicks switch on 'world first' atmospheric carbon capture plant

Climeworks has partnered with Reykjavik Energy to open the first working pilot combining direct air capture of carbon dioxide with underground, permanent storage - a system it claims can provide an economically viable and scalable way to prevent dangerous global warming.
Sited at an existing geothermal power plant in Iceland and running as part of the CarbFix2 project the Climeworks system draws in ambient air, separates out the pure CO_2 using a specially designed filter and pipes it more than 700 metres underground, where it reacts with the basaltic bedrock to form solid minerals. (Capturing about 1 tonne CO_2/week directly from the air. http://www.climeworks.com/public-update-on-carbfix/)



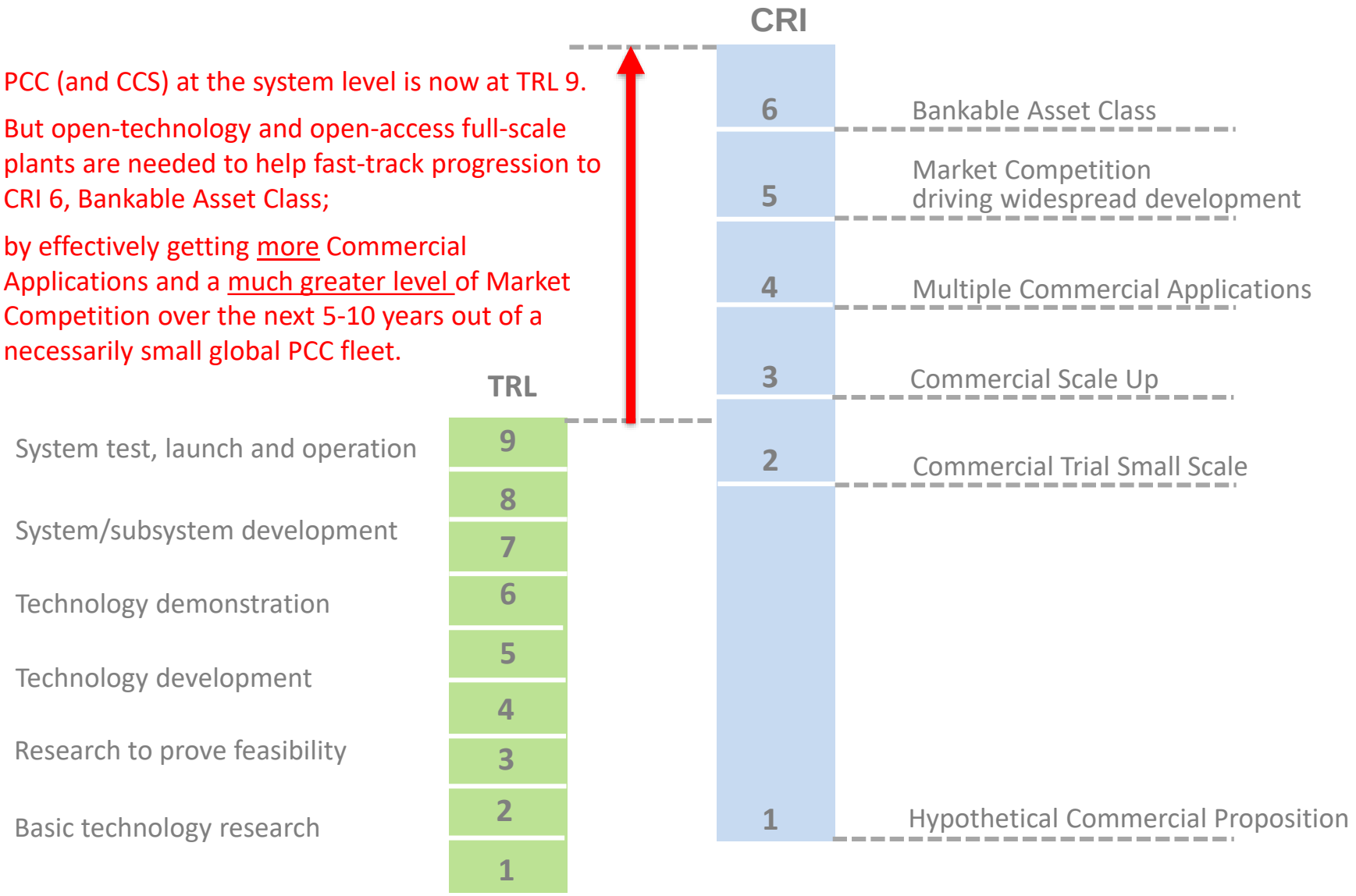
The Climeworks module will extract CO2 directly from the air and store it underground | Credit: Climeworks / Zev Starr-Tambor

Capturing about 1 tonne CO_2/week directly from the air.


Power
Industry
Hydrogen
Biomass
Air
CO_2 sources
Scale
Location
Deployment timing
Ownership/financing
Intermittency
Capture technologies
The CCS Triangle
Transport
Storage
Saline aquifer
Hydrocarbon reservoir
Permanent use
Pipeline
Shipping
Rail
Scale
Location
Deployment timing
Ownership/financing
Intermittency/Buffer storage?
Location
Enhanced oil recovery?
Onshore/offshore
Scale
Permanence

Open-technology and open-access full-scale projects are needed to drive Commercial Readiness Index (CRI) and reduce costs

- PCC (and CCS) at the system level is now at TRL 9.
- But open-technology and open-access full-scale plants are needed to help fast-track progression to CRI 6, Bankable Asset Class;
- by effectively getting more Commercial Applications and a much greater level of Market Competition over the next 5-10 years out of a necessarily small global PCC fleet.



From Bruce Adderley, Jeremy Carey, Jon Gibbins, Mathieu Lucquiaud and Richard Smith, "Post-Combustion Carbon Dioxide Capture Cost Reduction to 2030 and beyond", Faraday Discussion on CCS, July 2016. http://pubs.rsc.org/en/Content/ArticleLanding/2016/FD/c6fd00046k#!divAbstract

Renewables have taken over 40 years to develop, driven by oil and gas prices as well as by climate

Renewables started on large-scale deployment driven by ‘70s, ‘80s and particularly 2000s oil price rises while interest in, initially, new coal power with CCS started in only in the 2000s.

Google News hits by year (compiled 2008)