5°) carbon capture and storage

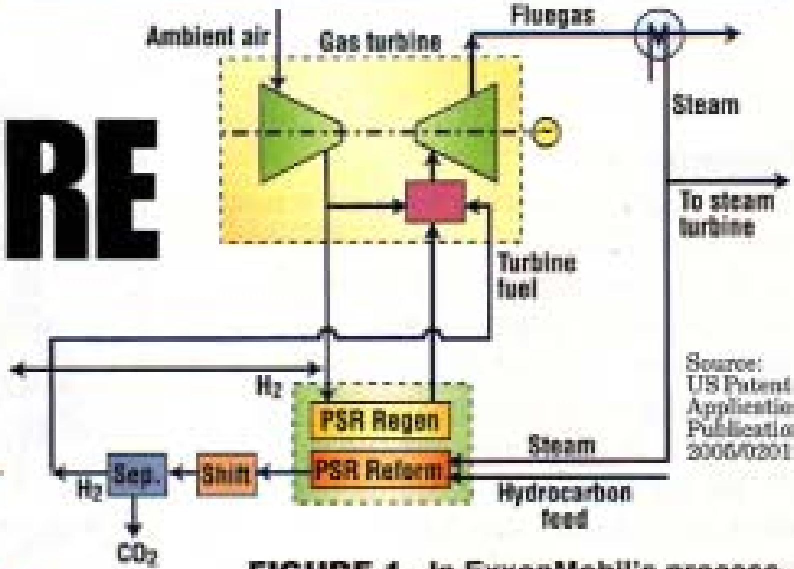
Technology Showcase

CARBON CAPTURE AND STORAGE

Whether a CPI company's interest is based on reducing its own CO_2 emissions or supplying technology to curb that of its potential customers, this growing field has implications for all

Michele M. Glessner and Jeffrey E. Young, Alston & Bird

PRODUCING HYDROGEN FUEL AND CAPTURING CO_2



Source: US Patent Application Publication No. 2006/0201939

FIGURE 1. In ExxonMobil's process, a hydrocarbon feed such as methane and steam are passed through a pressure-swing reformer (PSR) and converted to synthesis gas. In a shift reactor, the CO in the synthesis gas is converted to CO_2 and a hydrogen-enriched gas stream is produced. Hydrogen is separated from the CO_2 in a separation zone and used as fuel for a gas turbine

CHEMICAL ENGINEERING WWW.CHE.COM MAY 2008

CO2 A RAW MATERIAL
FOR SUSTAINABLE DEVELOPMENT

Cost of CO_2 from adsorption processes

(NH_3, MEA, Na_2CO_3 powder, zeolithe beads, cryogenic route)

between 20 – 60 $/T

(MIT evaluation science 27.02.09)

Investment for CO_2 adsorption on coal power unit of 1000 MW

1 – 2 billion$

Purity of CO_2 from adsorption processes **99 %**

Questions: **CO_2**

→ **Waste or raw material ?**

→ **New industrial processes ?**

technical aspects of the industrial CO_2 capture units

- gas- liquid adsorption systems
- gas_solid adsorption systems
- gas- liquid transformation through cryogenic process

carbone dioxide capture

European Parlement and European Commission have launched a program for CO_2 sequestration
STOA 2005-28 and 2008-01,and European set plan

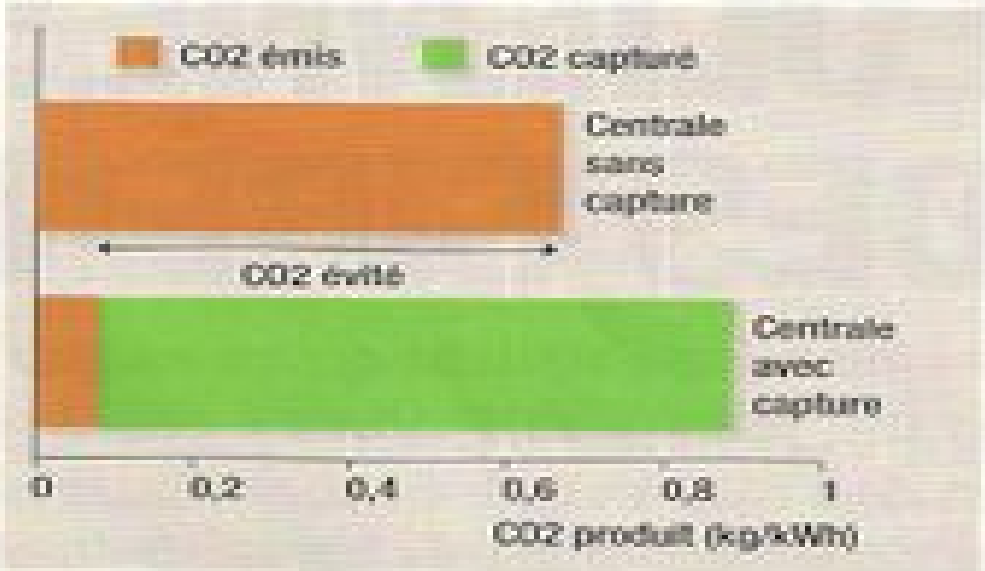
A new control of the gas out put from burning system

- °-Dow –Alstom (pilot plant 1800 T/Y) Dow'south Charleston W.Va)-amine CO_2 removal
- °-Alstom-Polish utility PGE Electrownia Belchatow (100.000T/Y) amine removal
- °-Air products CCS demonstrationin Schwarze Pumpe Germany built by Alstom operated by Swedish utility Vattenfall
- - Siemens with aquaous amino acid salt solution (ACS news 2011)

e gaz à effet de
de moyens de
n France,
ustrie lourde.

Le CO_2 est alors séparé de l'hydrogène, lequel peut être utilisé pour produire de l'énergie (électricité et ou chaleur) sans émission de CO_2.

Pour chacune des 3 grandes voies de captage il y a donc, à un moment donné, une séparation gazeuse : N_2/CO_2 (post-combustion), O_2/N_2 (oxycombustion) et CO_2/H_2 (pré-combustion). On dispose de tout un ensemble de technologies de séparation gazeuse. Certaines existent à l'échelle industrielle, d'autres ne sont disponibles qu'au laboratoire et nécessitent la réalisation de démonstrateurs. Toutes font encourir une pénalité énergétique qu'il faut réduire.



Main Financial Aspects of the EEC

- In order to start the capture of CO2 (CCS) the EEC has been decided to develop 10 industrial 1000MW coal power plants for learning step
- total amount of 12 billions euros
- goal: the scale up of that kind of industry
- For each plant :a capture of 5 millions tons of CO2 per year and cost 200 euros/T
- 2020 the goal is 300 CCS industrial Plants

CAPTURING CO_2 :Ammonia process

Efforts to find economical technology
to reduce CO_2 emissions are intensifying

exaust
burnin
g
gases

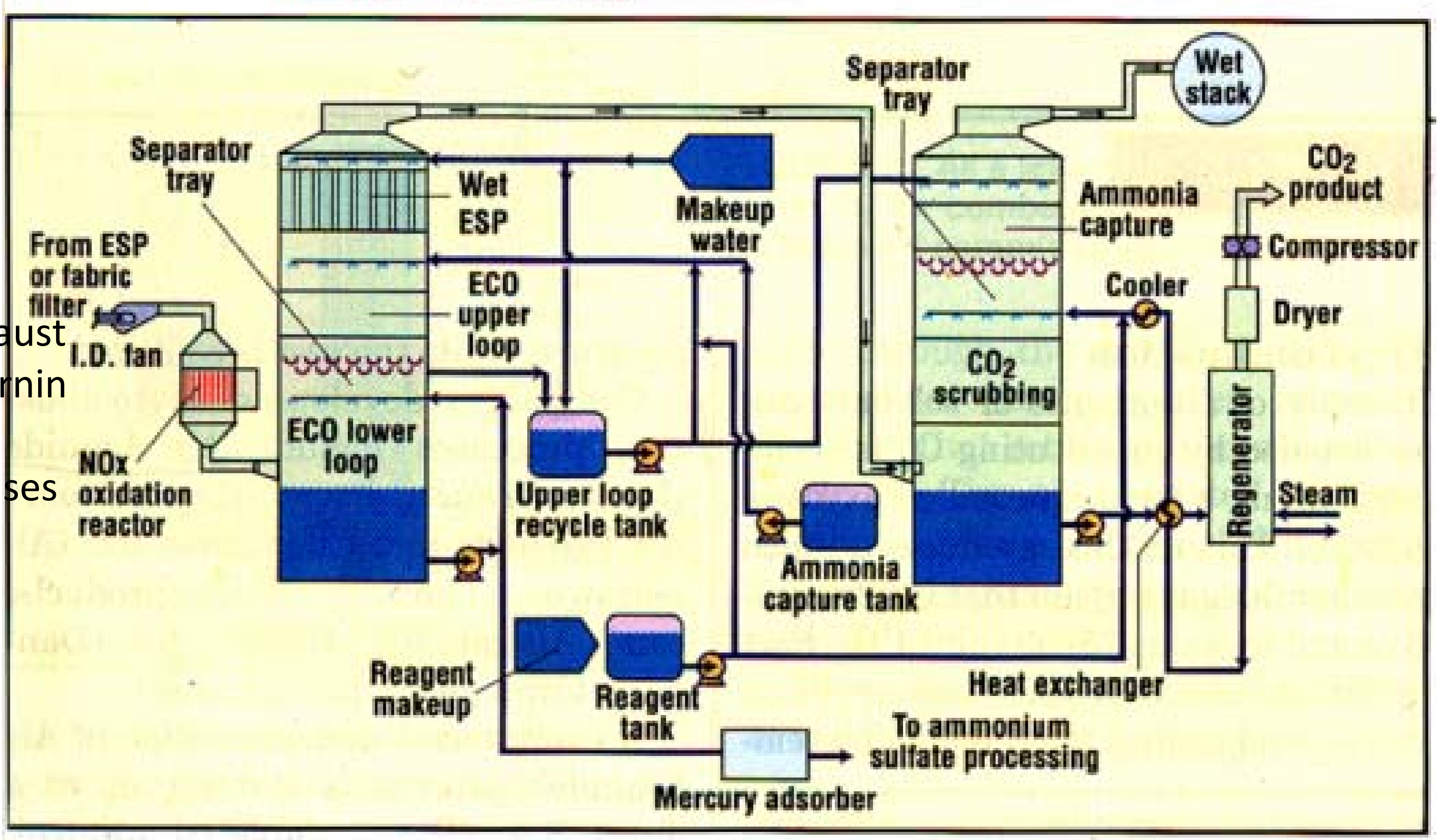
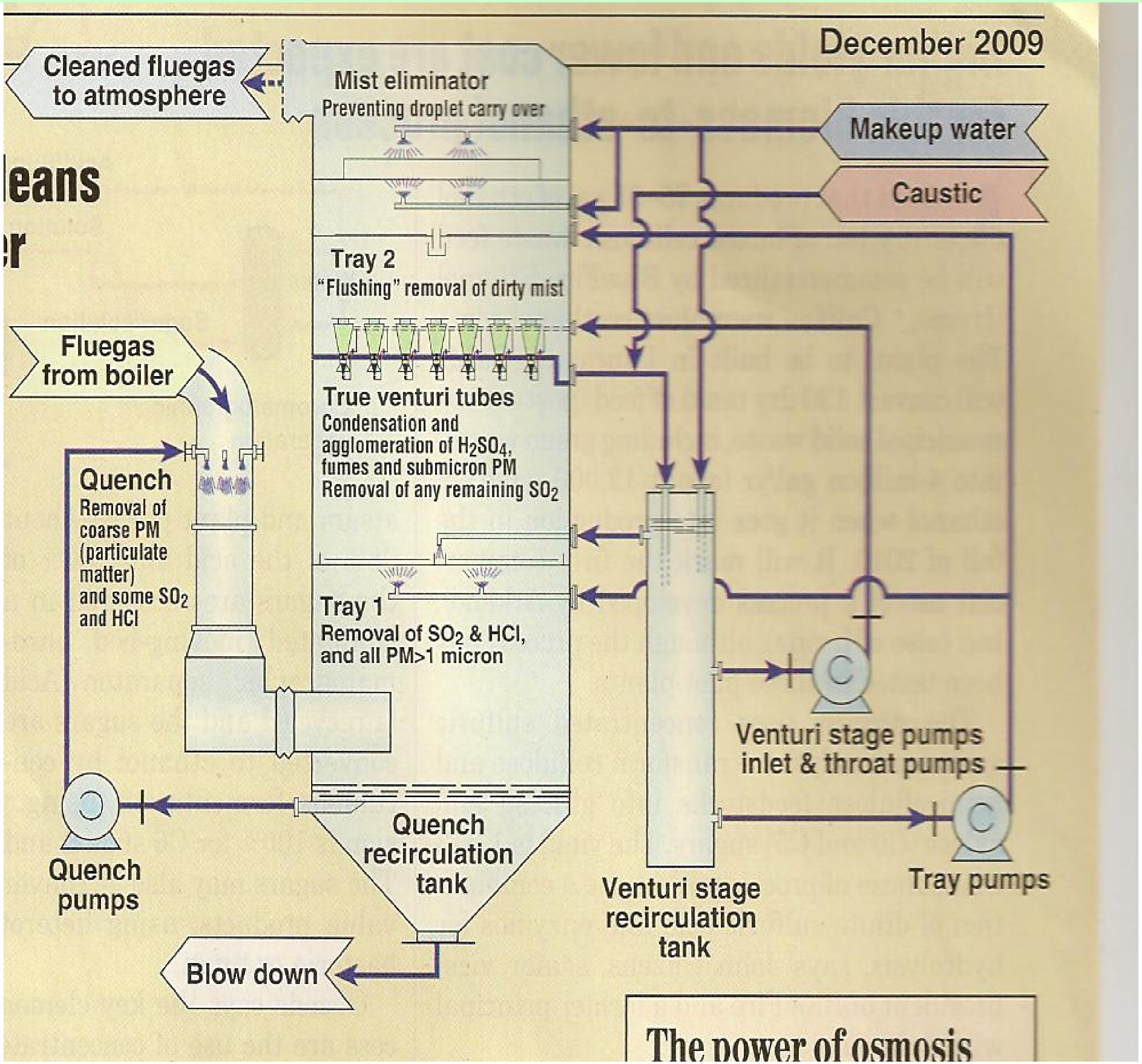


FIGURE 1. In this integrated version of Powerspan's ECO and ECO_2 processes, ammonia is recycled from the ECO_2 CO_2-absorber to scrub SO_2 in the ECO process

Chemical Engineering, Dec. 2003, p. 17, Power span Conf. Portsmouth, NH, USA

gas combustion cleaning before carbon dioxide adsorption



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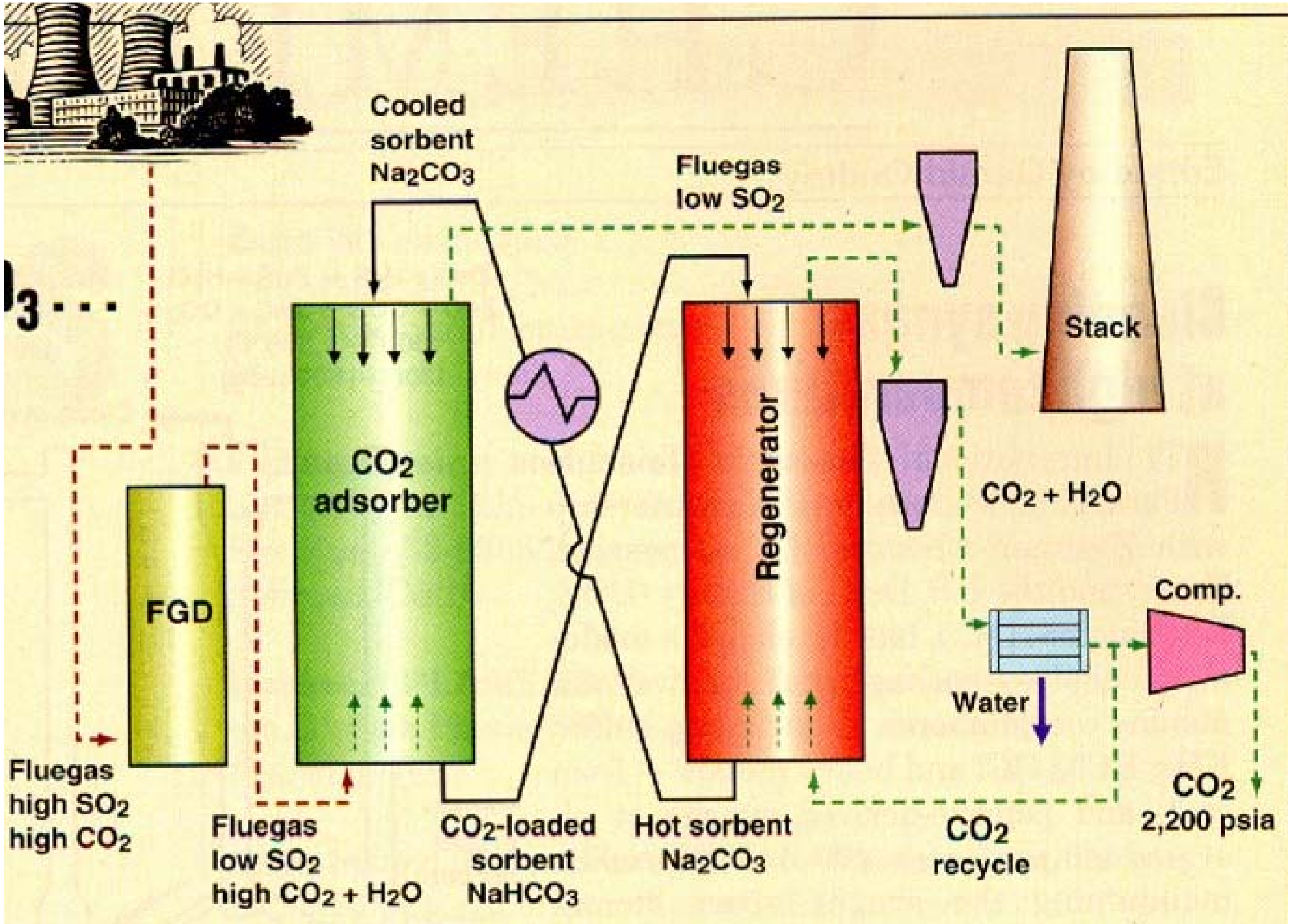
Two solid ways to remove CO_2 from fluegas, one based on Na_2CO_3 .



Chemical Engineering, Dec. 2008, p. 12, DOE support – Research Triangle Institute (RTI, USA)

CCS NH3 développé par ALSTHOM /USA

opment for Alstom.
er the CO_2 is cap-
Hilton says, the
ing mixture is then
ed to a regenerator.
it is heated to more
00 °C, and the bicar-
reverts to carbon-
l to CO_2, which is
ntrated under pres-
he intended result
h-pressure, 90%-
ream of CO_2 and
aration of ammonia
se.
CO_2 capture system
ot of energy, and
's target is to get
rgy use of the col-
system down to
of a plant's total
If successful, Al-
edicts, the system
up the cost of elec-
y 6 to 9 cents per
-hour—approxi-
oubling the current cost per kilowatt-hour.
has also joined in the technology development
and is working with Alstom to develop an ad-
mine-scrubbing technology.
nding on results, the trial may grow. American
Power and Alstom plan to install the technol-
ogy later this year at AEP's New
Haven, W.Va., electric plant and

WE ENERGIES (BOTH)

A consortium of investors have high hopes that a test at We Energies' 1,210-MW plant will remove CO_2 efficiently and inexpensively.

Commercial Demonstration of Ammonia CO_2 Capture

- Flue gas stream for 120 MW
- 1 million tons CO_2 removed
- $200 to $300 million in capital
- $25 to $35 per ton CO_2

Gary Loop

Great Plains SYNFUELS
DAKOTA GASIFICATION COMPANY

Antelope Valley Station (AVS)

SEEKING PATENTS ON ASPECTS OF CO_2 CAPTURE		
Invention title	**Patent or published application**	**Owner**
Method and apparatus for efficient injection of CO_2 in oceans	6,598,407	UT-Battelle, LLC
Device for removing carbon dioxide from exhaust gas	7,022,168	Alstom Technology LTD
Method for recycling carbon dioxide for enhancing plant growth	6,237,284	The Agricultural Gas Co.
Integration of hydrogen and power generation using pressure swing reforming	2005/0201929	ExxonMobil Research and Engineering
Removal of carbon dioxide from air	2006/0186562	Wright, et. al.
Efficient combined cycle power plant with CO_2 capture and a combustor arrangement with separate flows	2006/0112696	Statoil ASA
System and method for combined microseismic and tiltmeter analysis	2006/0081412	Pinnacle Technologies, Inc.

CHEMICAL ENGINEERING WWW.CHE.COM MAY 2008

SIEMENS CLAIMS CO_2 REDUCTION ADVANCE

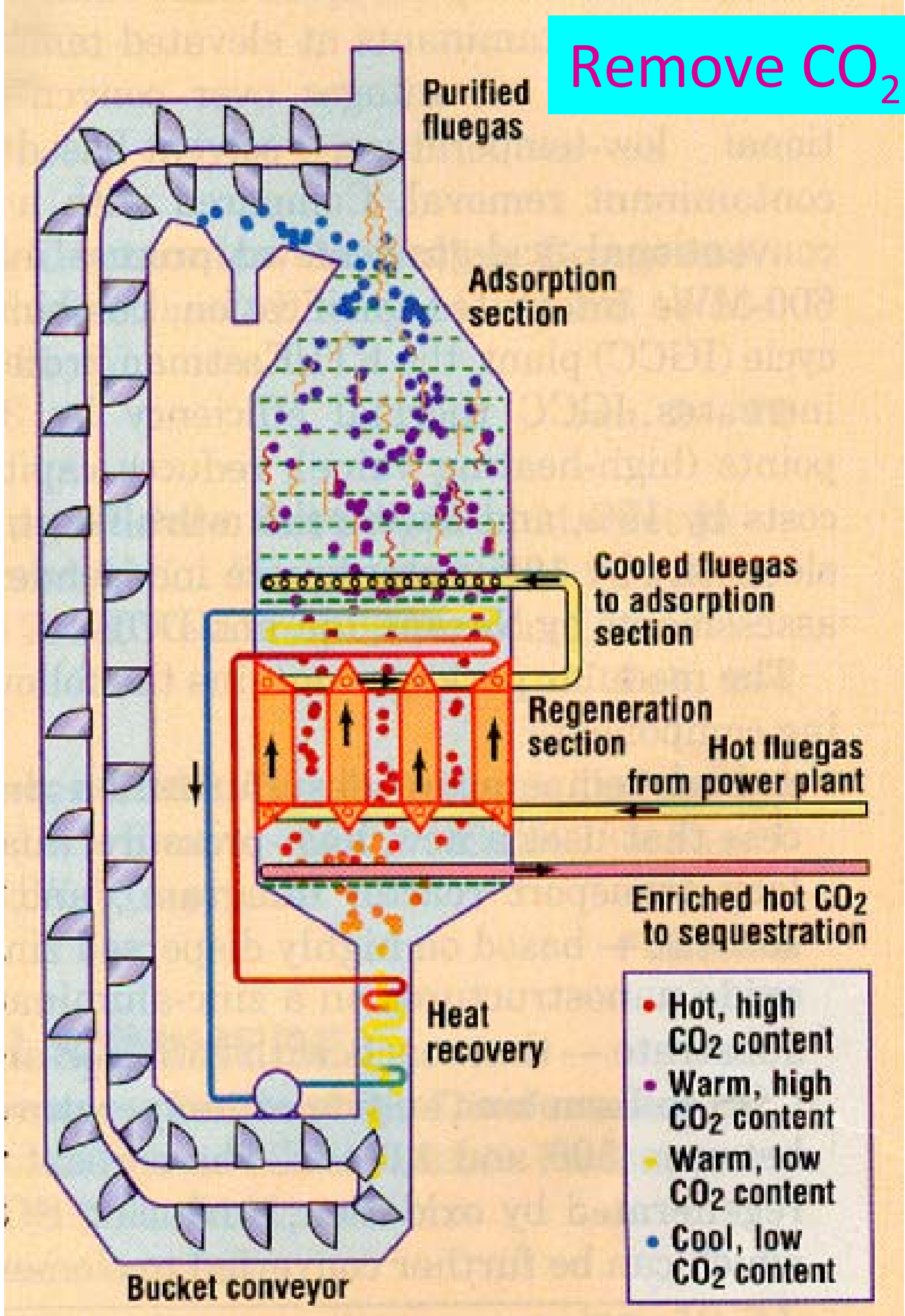
Siemens Energy claims that its CO_2 reduction technology has achieved a CO_2 capture efficiency of more than 90% in a pilot facility at a power plant owned by the firm E.ON

SIEMENS

Workers confer inside the CO_2 capture facility at E.ON's power plant near Hanau, Germany.

near Hanau, Germany. Siemens says its scrubbing agent, an aqueous amino acid salt solution, provides better energy efficiency than amine-based agents offered by firms such as Dow Chemical and BASF. And because the salt is nonvolatile, practically no solvent emissions need to be scrubbed from power plant flue gas, Siemens says.—MM

Remove CO_2 with adsorbing beads



In a concept being developed by Adsorption Research, Inc. (ARI; Dublin, Ohio; www.adsorption.com), adsorbent beads are delivered to the top of an adsorber column by a bucket elevator and fall down through an adsorption section, counter to upflowing, cooled fluegas. The beads' passage is slowed by a series of perforated trays to provide a residence time of about 1-1/2 min for carbon dioxide adsorption.

Next, the beads drop through a heat-exchanger section, where they are indirectly heated to 400–600°F by incoming fluegas. The heat releases the CO_2, which is withdrawn through a perforated pipe. Simultaneously, the gas is cooled to about 125°F for the adsorption step.

In laboratory tests, using a zeolite or a proprietary adsorbent, the process has achieved 89% CO_2 recovery, with a purity of 99%, says Kent Knaebel, president of ARI. He adds that, unlike MEA adsorption, the process requires little parasitic heat or cooling energy and the adsorbent is not degraded by SO_2, NOx or O_2. He estimates that a commercial unit could process 15,000 tons/d of CO_2 from a 500-MW power plant for under $20/ton, compared with about $40/ton for MEA.

Mixing sea water and CO_2 for sequestration

Source: U.S. Patent No. 6,598,407

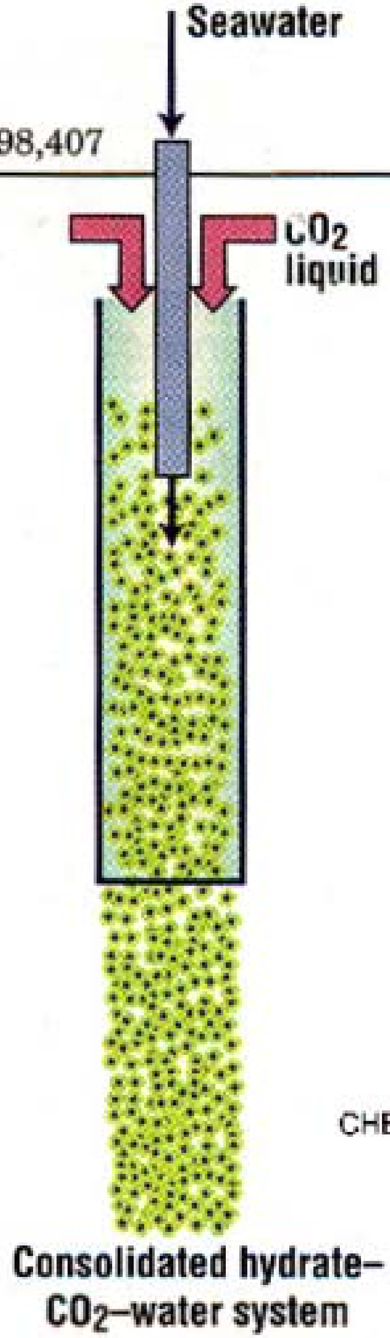
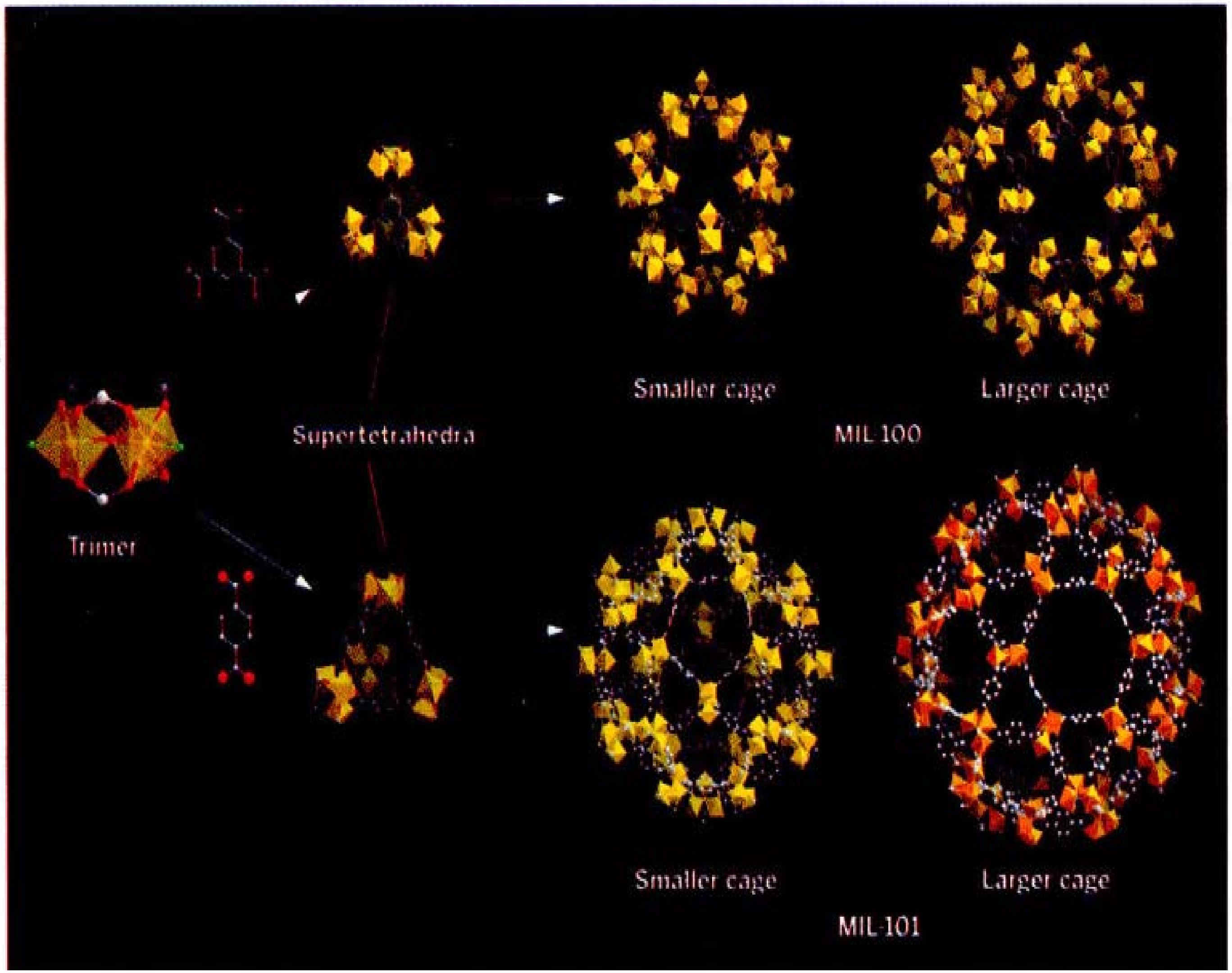


FIGURE 2. UT-Battelle's method of mixing seawater and CO_2 is claimed to increase efficiency, increase the residence time of CO_2 in the ocean, and decrease the cost of CO_2 sequestration, while reducing the negative effects of simply releasing CO_2 gas into ocean water

CHEMICAL ENGINEERING WWW.CHE.COM MAY 2008

GÉRARD FÉREY/UNIVERSITY OF



ROOM TO SPARE Chromium trimers (left center) and the carboxylate linkers trimesate (left top) and terephthalate (left bottom) combine to form supertetrahedra from which the framework compounds MIL-100 and MIL-101 are constructed. Each compound contains smaller and larger nanometer-sized cages, accessible via interconnecting windows. The MIL-100 small cage is 25 Å in diameter; MIL-100 large cage, 29 Å; MIL-101 small cage, 29 Å; MIL-101 large cage, 34 Å. Cr is yellow, C is white, O is red, and H_2O is green.

[redacted]

C&EN Chemical &Engineering News august 25,2008 p13-16
MITCH JACOBY
Example: BASF MOFs- Rainer Zietlow –Muller-
CH4 store in MOFs for Eco Fuel World Tour ,
Volkswaggen caddy- 1500 miles between fill-up

metal organic framework

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C&EN Chemical &Engineering News august 25,2008 p13-16

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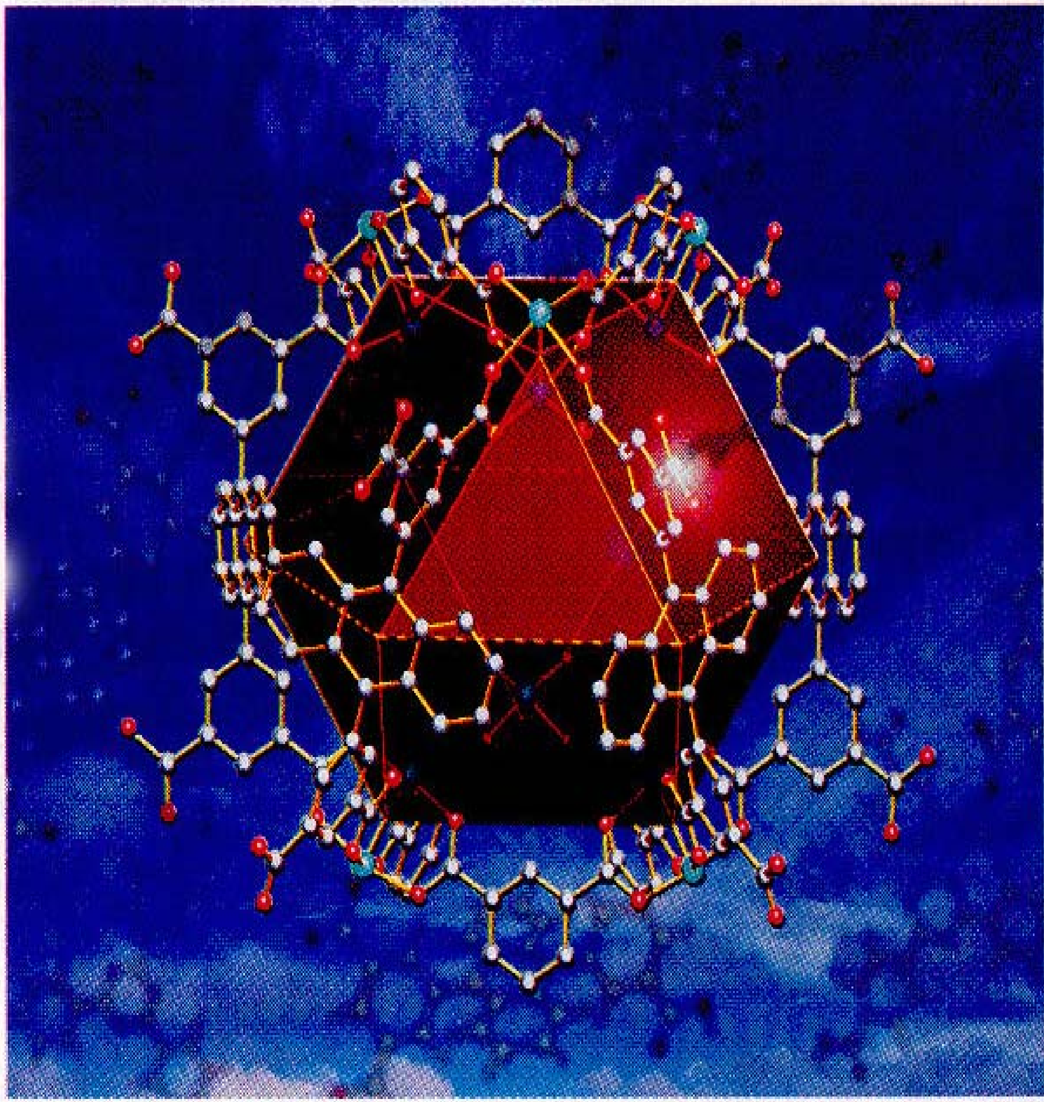

DAQIANG YUAN/TEXAS A&M

[redacted]

METHANE HOARDER This framework compound, dubbed PCN-14, is composed of dicopper paddlewheel units and linkers based on an anthracene derivative. Among porous materials, PCN-14 holds the record for methane storage. Cu is turquoise, C is gray, and O is red.

INT.CONf. RIO

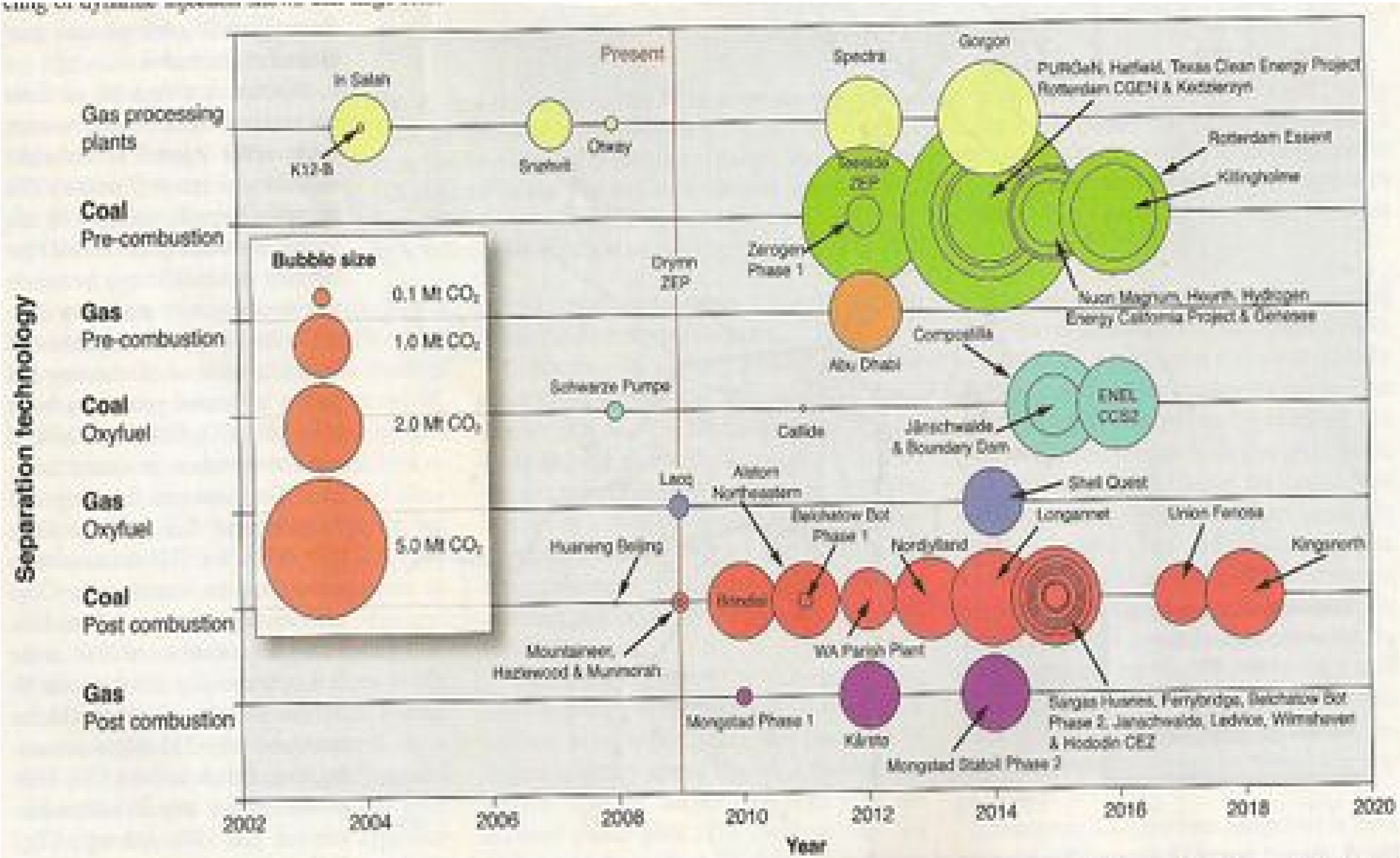

Fig. 4. Chart of large CCS demonstration projects planned worldwide, plotting calendar year against capture type and fuel. Coal and postcombustion power plants dominate. There is typically a 5-year lead time on design and construction (Fig. 2), so to operate these plants on schedule requires that projects commence spending on design now. Few of these projects have certain funding to assist construction, and even fewer have systems to enable commercial operation. National CCS targets with worldwide coordination and exchanges of learning are needed. [Compiled by Y. Bushby (15)]

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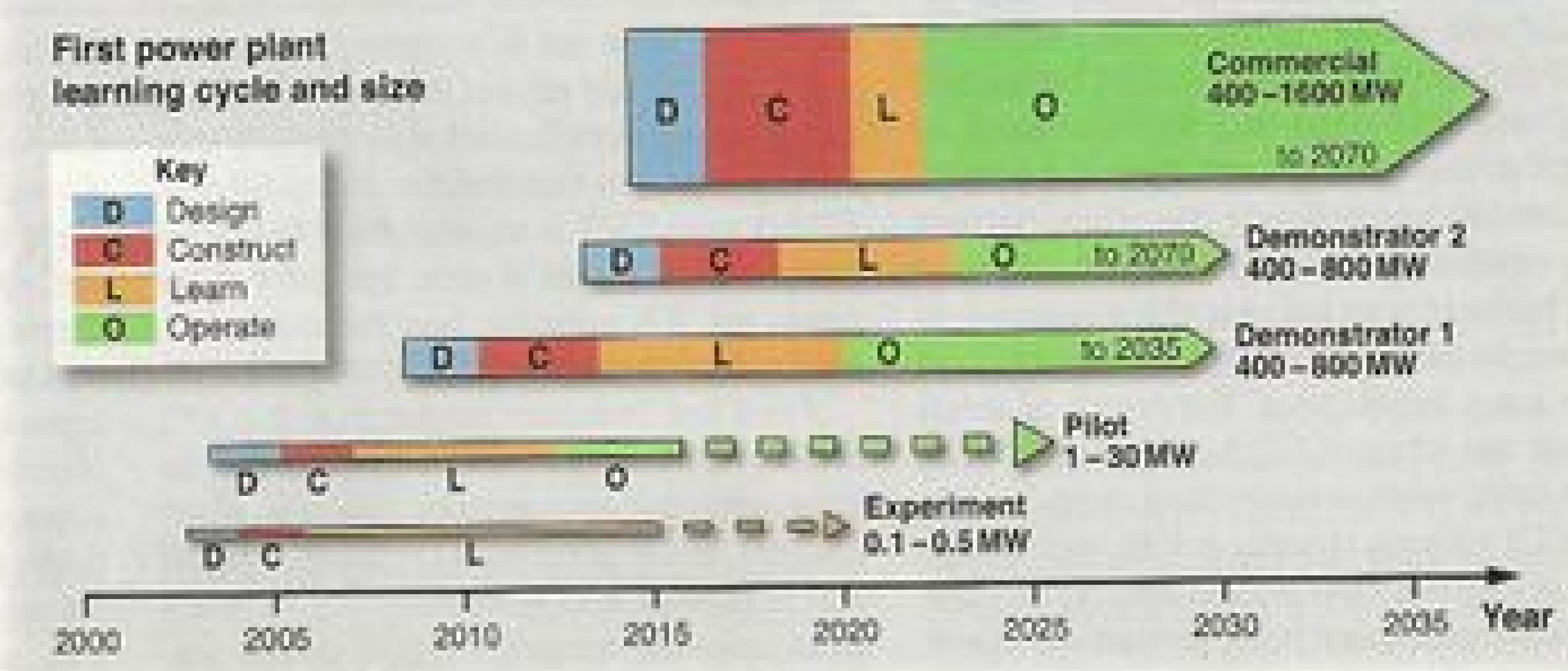


Fig. 2. Time chart showing how a CCS power plant can be increased to reliable and cost-effective commercial size by 2020, by means of progressively larger experimental equipment. Rapid information flow on the vertical axis is important from learning to subsequent design. This depends on industrialized nations providing financial support for CCS plant during the pilot and demonstration phases. Tens of large CCS demonstrators need to be built worldwide from 2009. Incentive systems (for instance, premium payments for decarbonized electricity) are needed to enable introduction, operation, and establishment from 2014 to 2020.

- science vol 325 25 sept 2009 p 650

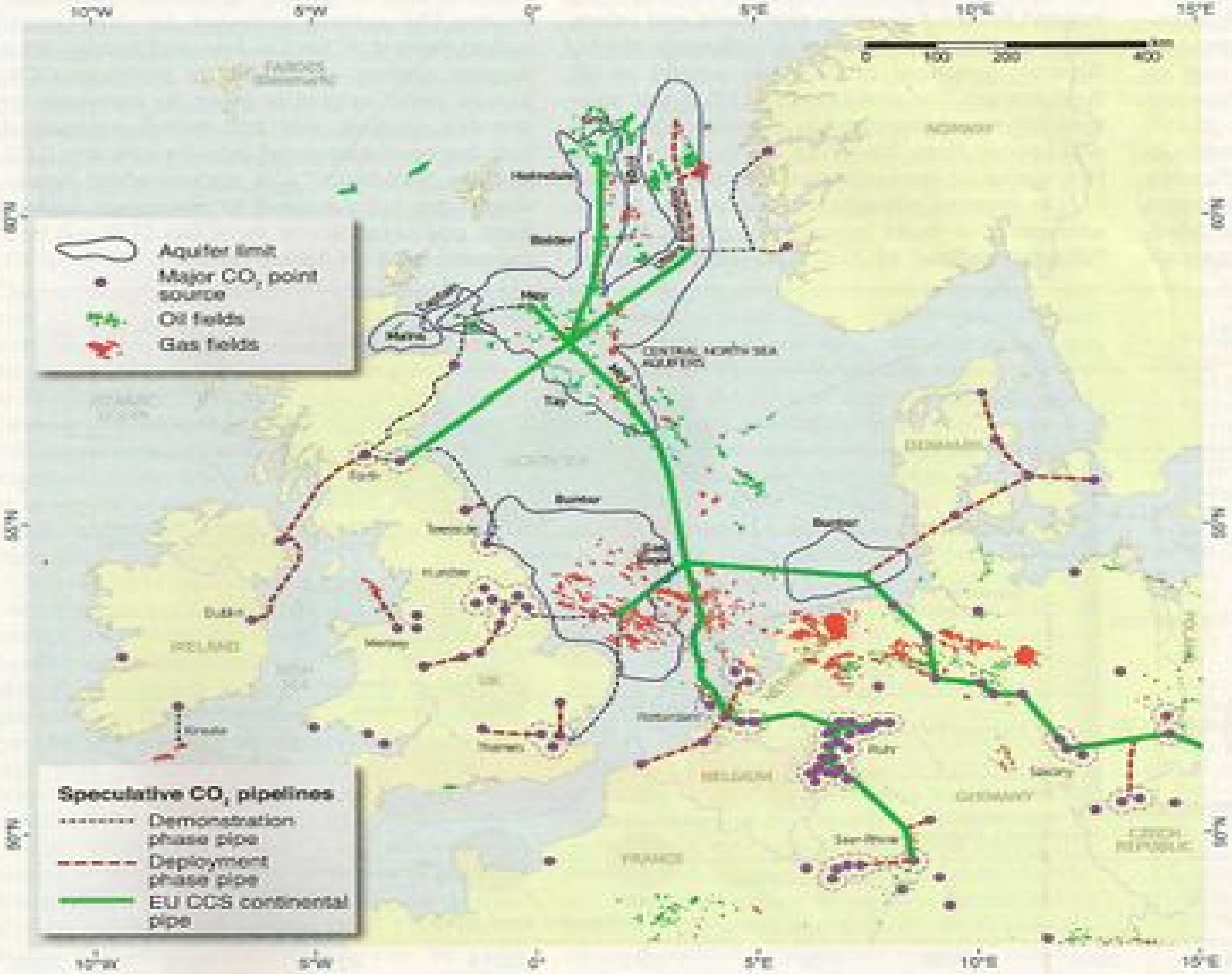
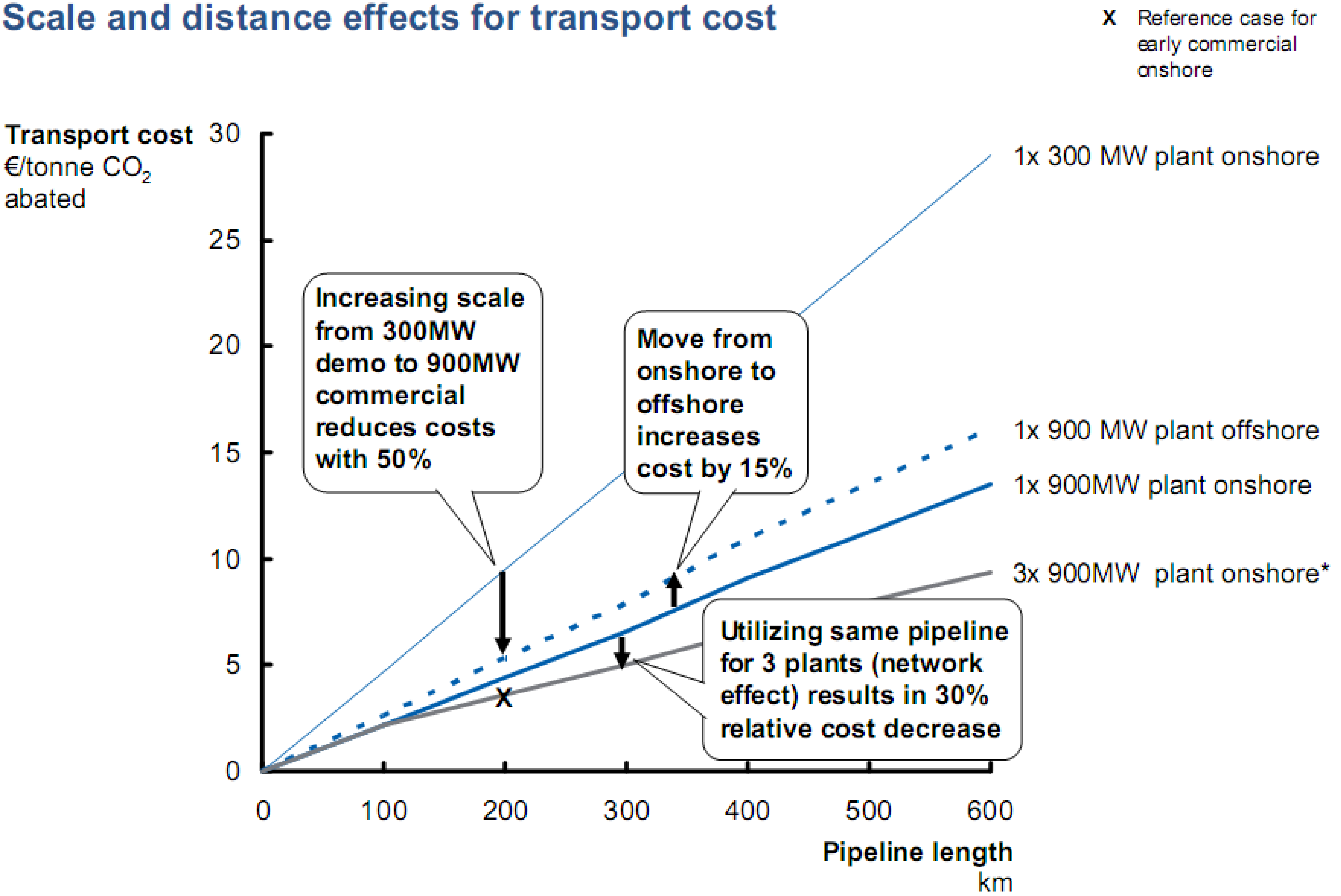


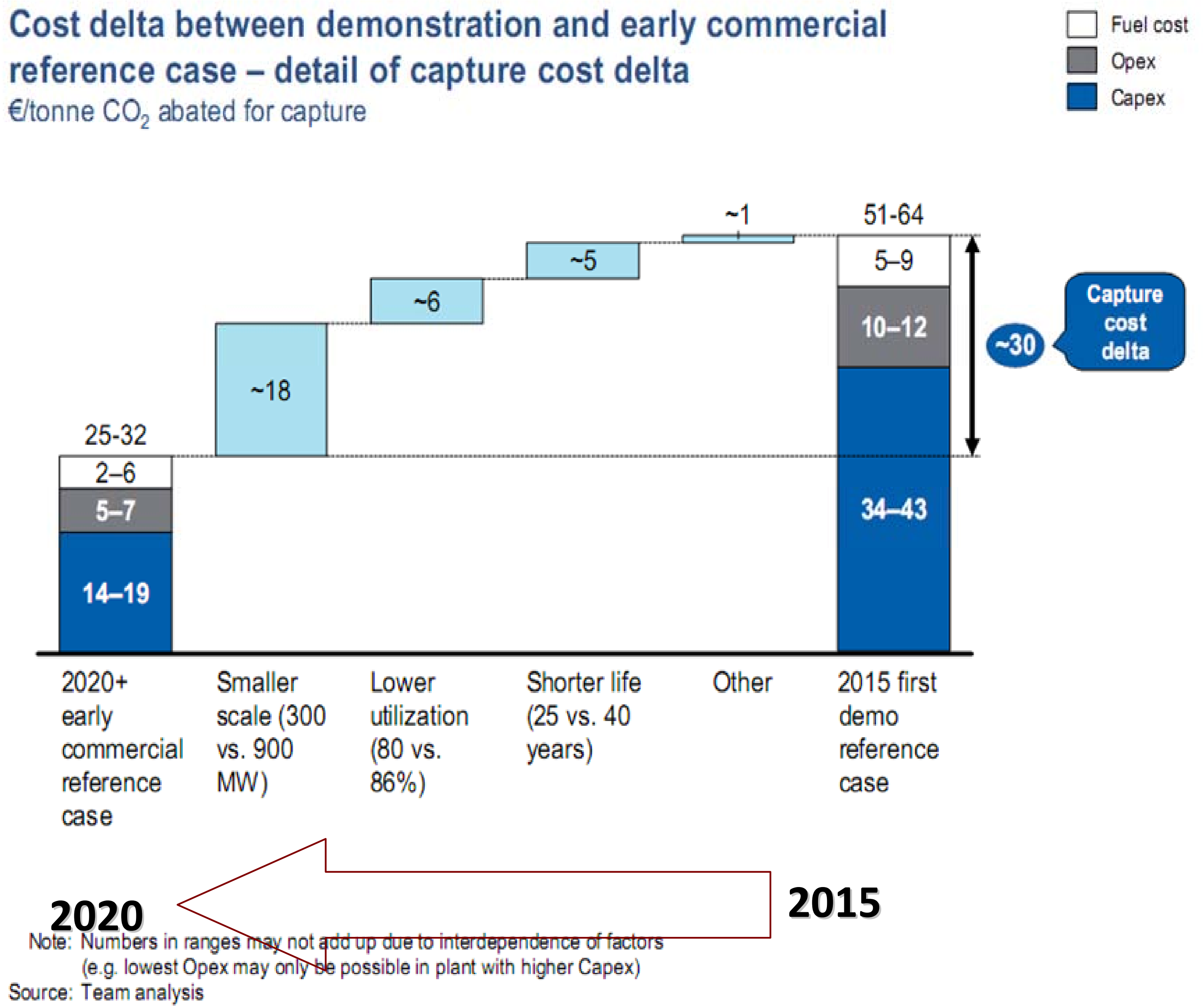
Fig. 3. Map of northwest Europe, showing sites of emissions, saline formations, gas fields, and oil fields. CO_2 can be collected from clusters of large power plants and transported to storage. This transport scenario visualizes pipelines built to offshore hubs accessing large-scale storage beneath the North Sea. Such sites can be evaluated with the use of legacy hydrocarbon data and may prove to be more reliable to develop and monitor than onshore storage. [Basemap of hydrocarbon fields supplied by M. Ricketts, Wood Mackenzie]

Scale and distance effects for transport cost



* A network of 3 plants of 900 MW connected to shared large pipeline

Source: Team analysis

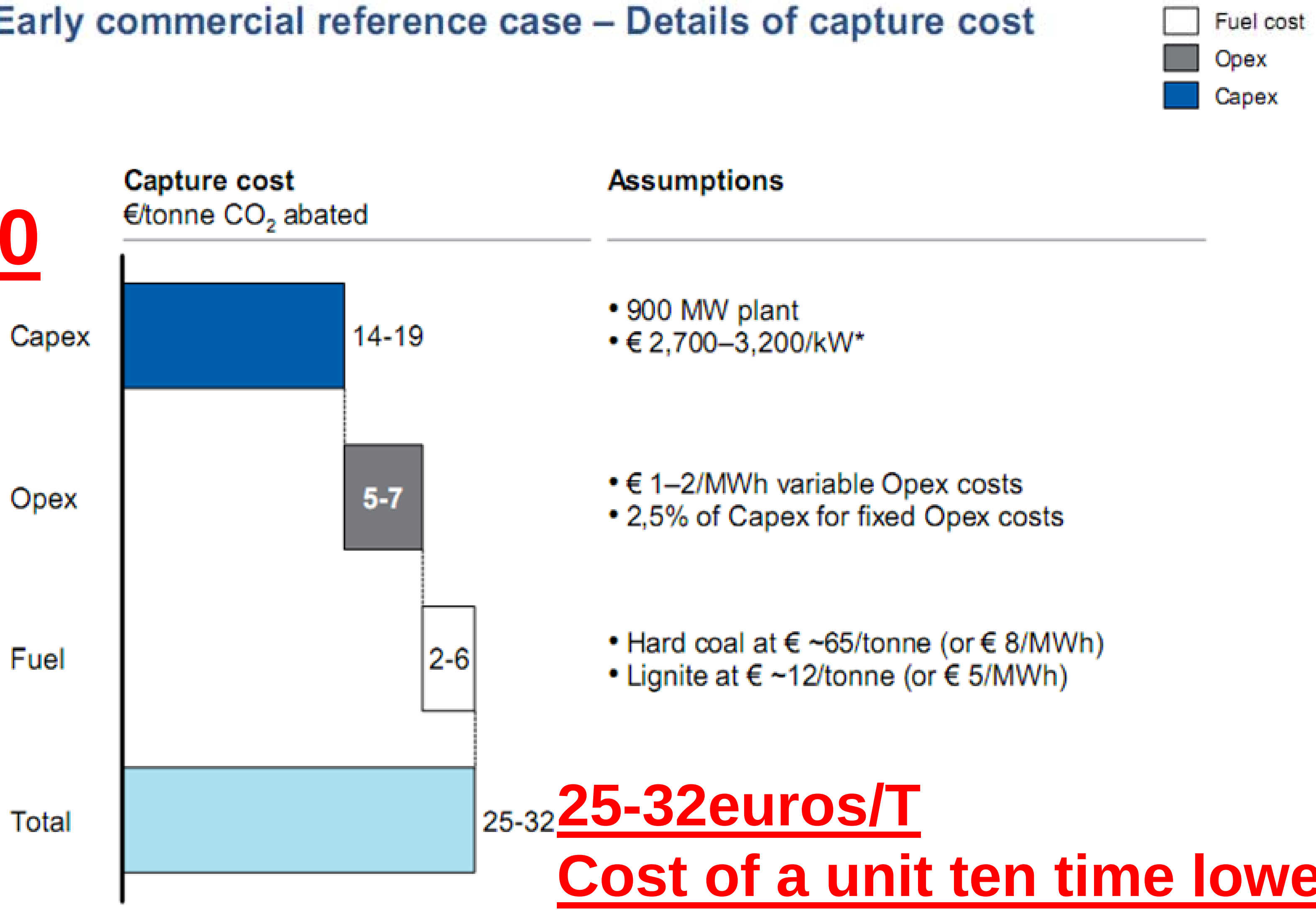


CCS assessing economicMac Kinsey 2009

1 Early commercial reference case – Details of capture cost

2020

Capture cost
€/tonne CO_2 abated



Assumptions

- 900 MW plant
- € 2,700–3,200/kW*

- € 1–2/MWh variable Opex costs
- 2,5% of Capex for fixed Opex costs

- Hard coal at € ~65/tonne (or € 8/MWh)
- Lignite at € ~12/tonne (or € 5/MWh)

25-32euros/T
Cost of a unit ten time lower

* Assuming industrialized CCS equipment production process
Source: Team analysis

CCS assessing economiic
Mac Kinsey 2009

CCS in CHINA

- China's biggest coal producer :Shenhua Group ,propose to capture and sequestre 3.6 millions tons of CO2 per year in oil reservoirs where pressure of CO2 and its solvant properties will force hard to get oil to the surface

- Science 25 sept 2009 vol 325 p 1646

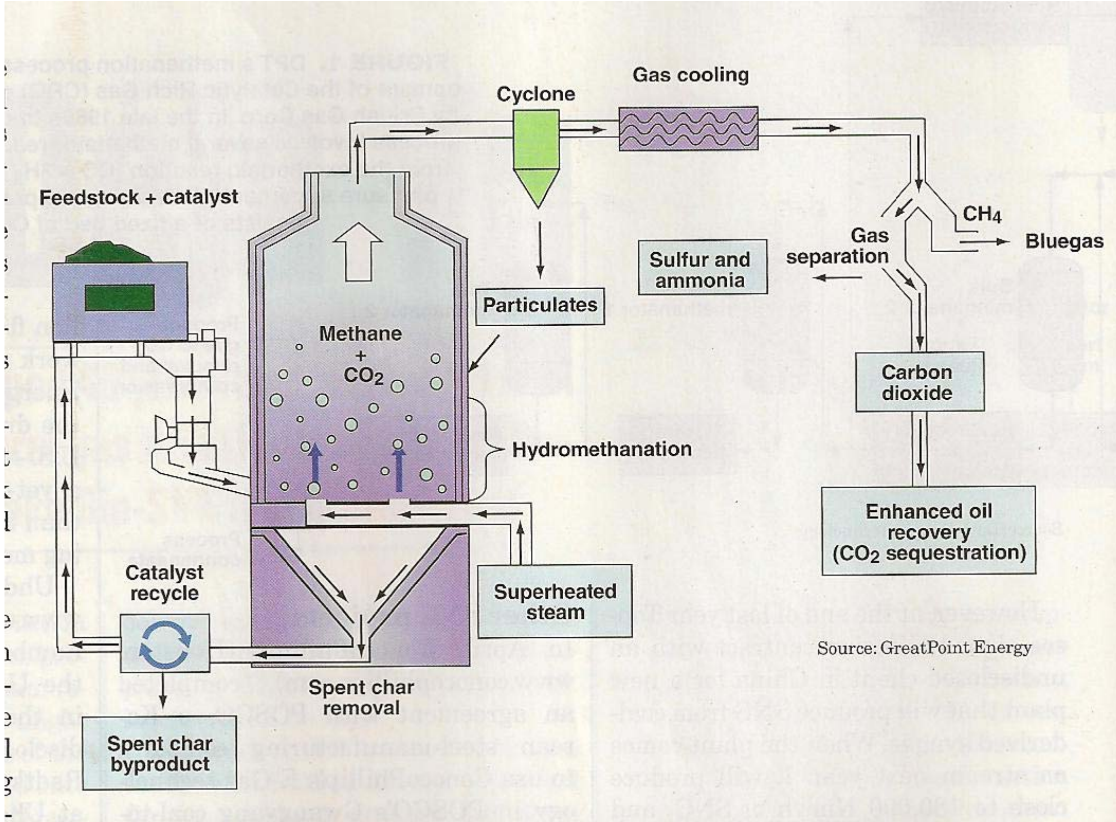


FIGURE 2. GreatPoint Energy's Hydromethanation process directly produces CH_4 and CO_2 by the reaction of steam with carbonaceous solids, such as coal, petcoke and biomass