CCS FOR INDUSTRIAL SOURCES

Rouzbeh Jafari, Ph.D.
Development Engineer – Shell Cansolv

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University of Regina, Regina, Canada

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Reserves: Our use of the term "reserves" in this presentation means SEC proved oil and gas reserves.

Resources: Our use of the term "resources" in this presentation includes quantities of oil and gas not yet classified as SEC proved oil and gas reserves. Resources are consistent with the Society of Petroleum Engineers 2P and 2C definitions.

Organic: Our use of the term Organic includes SEC proved oil and gas reserves excluding changes resulting from acquisitions, divestments and year-average pricing impact.

Shales: Our use of the term 'shales' refers to tight, shale and coal bed methane oil and gas acreage.

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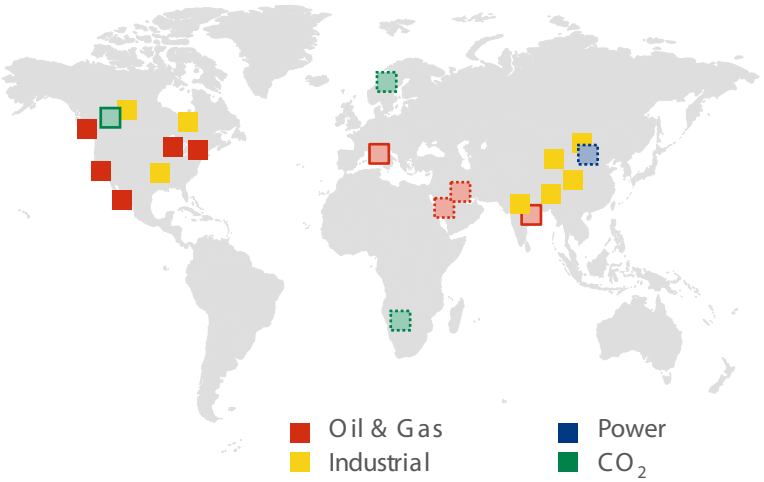
SHELL CANSOLV

- Founded in 1997
- Extensive experience with regenerable amine processes
- Track record of delivering commercial scale flue gas treating amine plants worldwide
- 20+ licenses, 15 plants in operation worldwide
- Part of Shell since 2008
- Based in Montreal, Canada and Beijing, China



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SHELL CANSOLV AT SASKPOWER'S CCS PROJECT UP TO 1MM TONNES/ YEAR CO_2 CAPTURE FOR EOR

- First commercial-scale post-combustion carbon capture system at a coal-fired power plant
- Demonstrates the viability of large-scale post-combustion CO_2 capture
- Uses Shell Cansolv CO_2 technology. Captures up to 90% CO_2, high or low SO_2 content
- Enables EOR with CO_2 from power plant flue gas
- Meets stringent CO_2 regulations
- CO_2 is permanently stored

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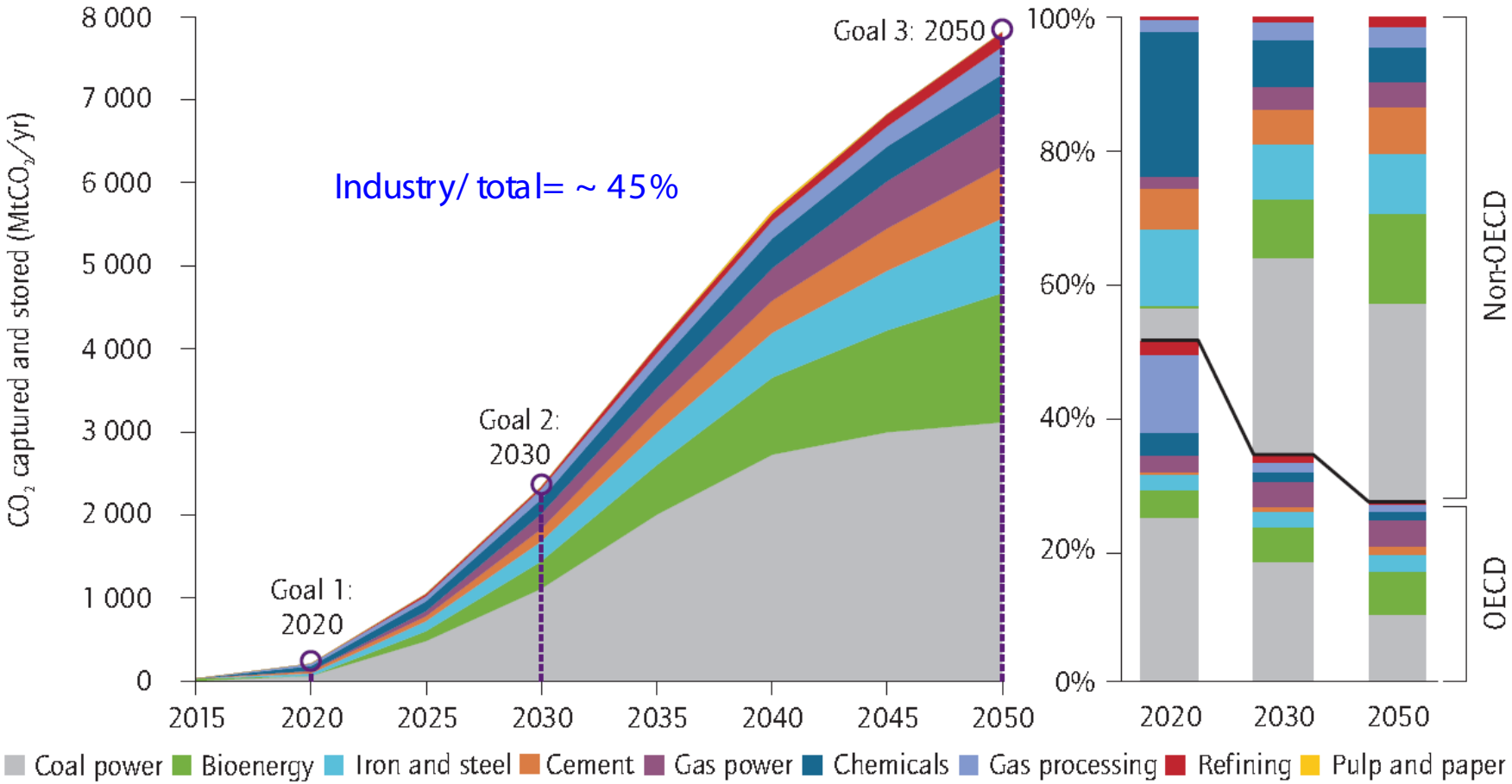
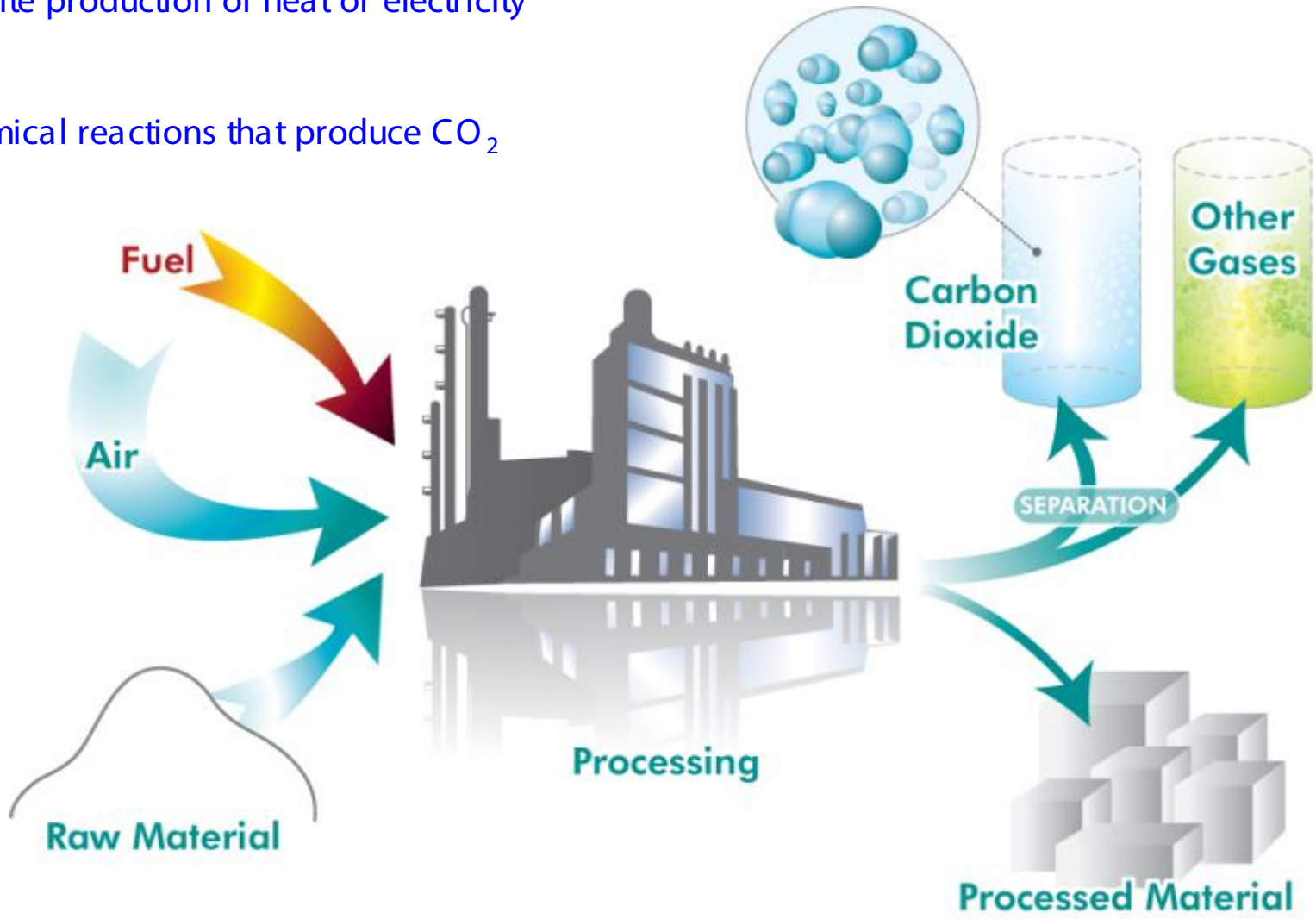
WHY IS INDUSTRIAL CO2 CAPTURE ESSENTIAL?

- The 2DS suggests a steep deployment path for CCS technologies applied to power generation and a number of industries.



EMISSION OF CO_2 FROM INDUSTRIAL PROCESSES

- On-site production of heat or electricity
- Chemical reactions that produce CO_2



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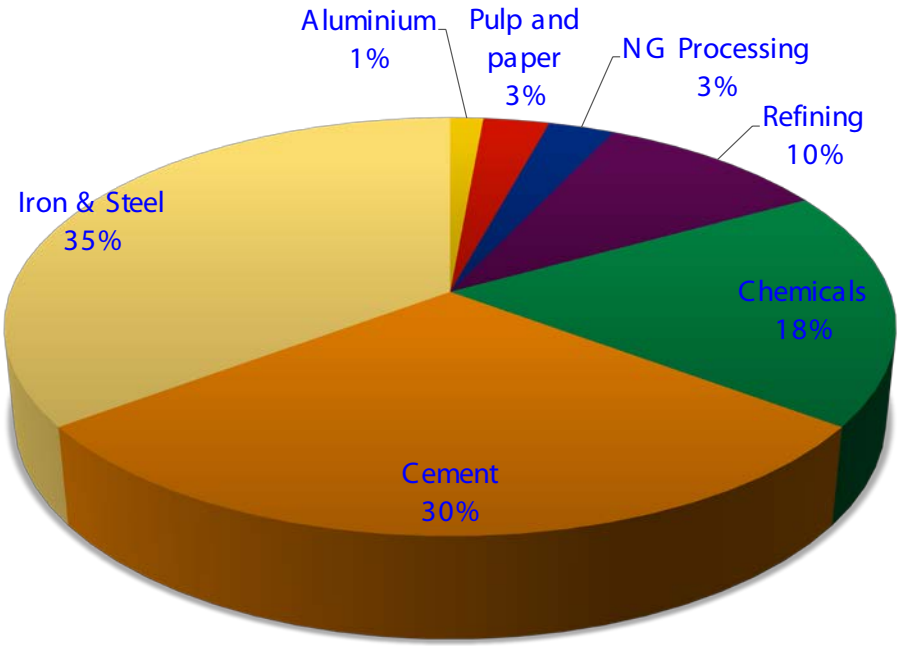
INDUSTRIAL CO_2 SOURCES
WHAT ARE THE MAJOR CONTRIBUTORS?

- Steel
- Cement
- Chemicals
- Refineries
- Gas processing
- Pulp and Paper
- Bio-fuels
- Gasification



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CO2 CAPTURE FROM INDUSTRIAL SOURCES

IRON AND STEEL PLANT




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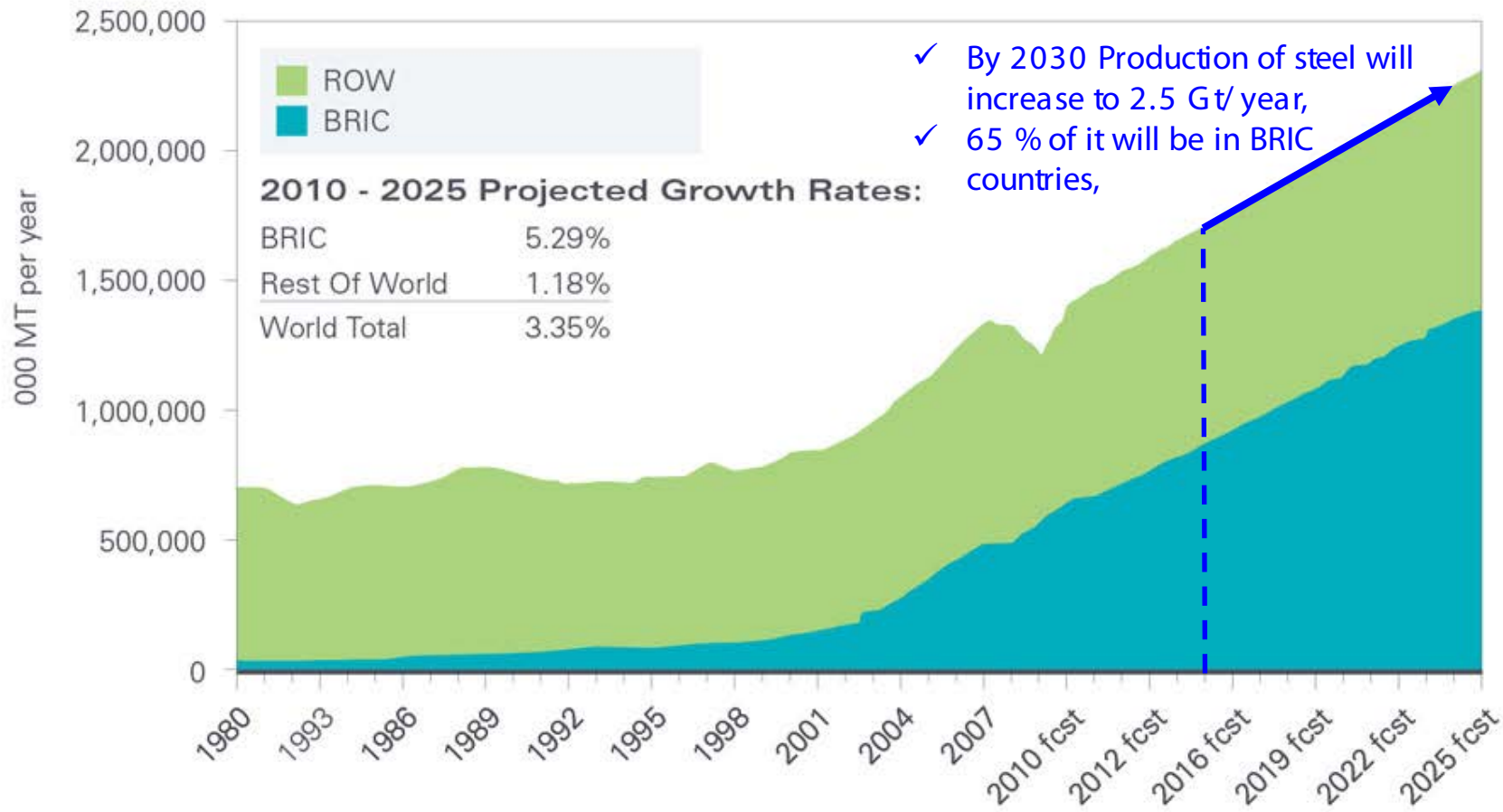
GLOBAL STEEL PRODUCTION

Global Crude Steel Production: 1980-2025



Source: Vanadium Market Fundamentals And Implications. Terry Perles/TTP Squared, Inc., Nov. 16, 2010

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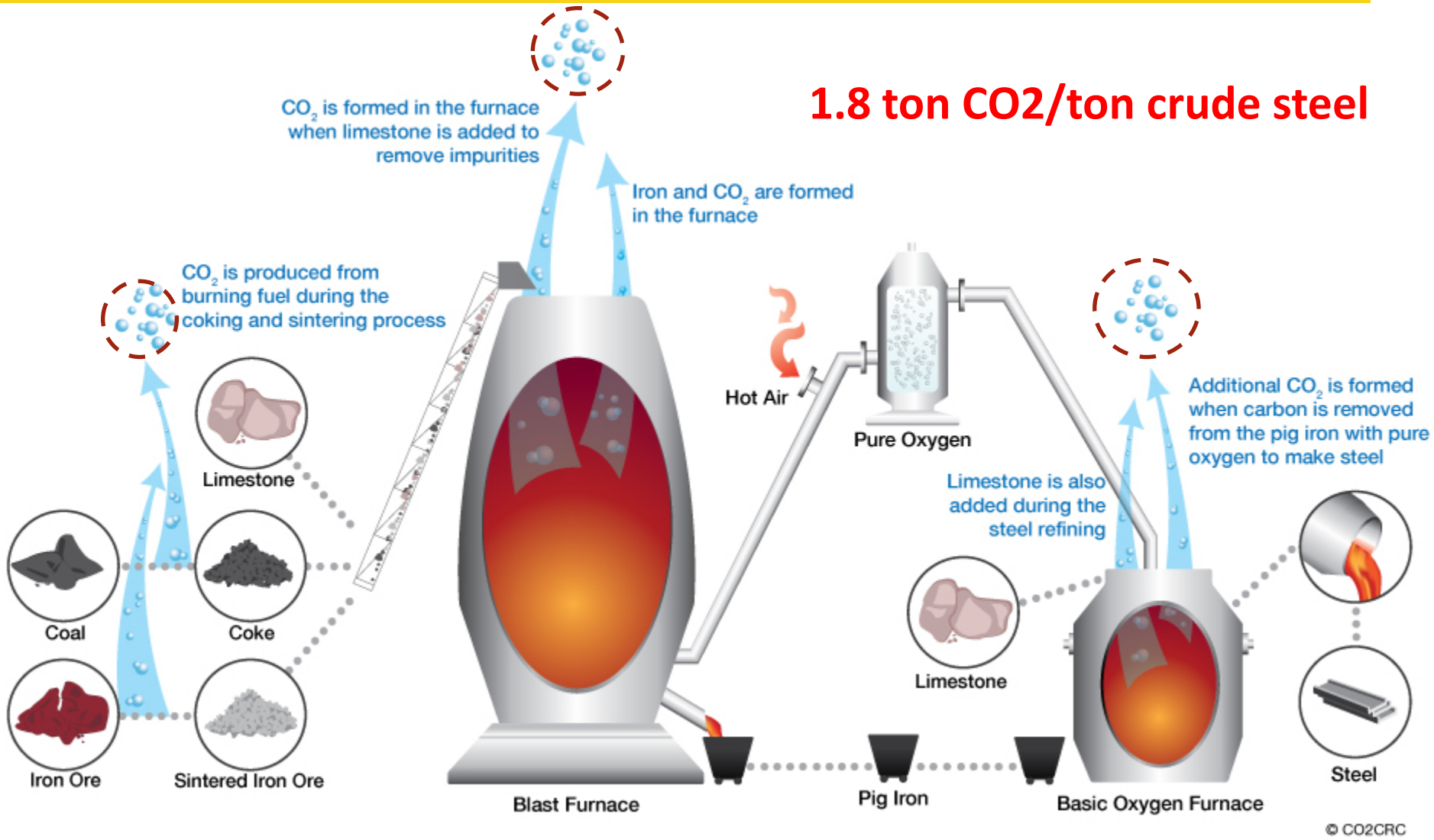
WHAT ARE THE SOURCES OF CO2 IN IRON AND STEEL PROCESS?

1.8 ton CO2/ton crude steel



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CALCULATION

Steel plant: 1.8 ton CO_2/ton crude steel

Estimate of cumulative steel production from now to 2030 = 30.5 Gt

↓

Estimate of cumulative CO_2 emission from steel plant by 2030

55 Gt

Applying CCS on 15% of Steel production

8.3 Gt CO_2 Captured

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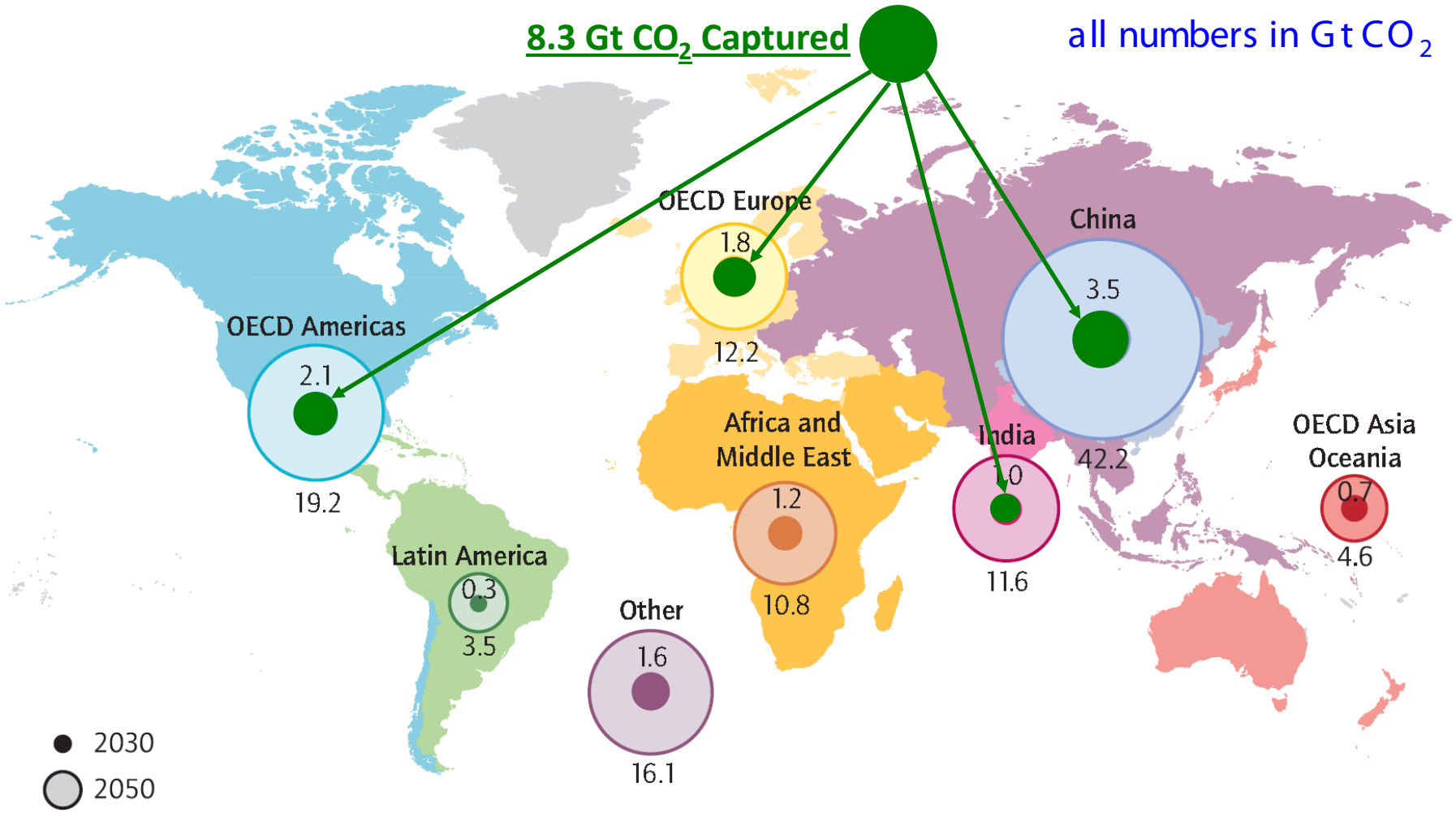
CUMULATIVE CO_2 CAPTURED 2015-2030 AND TO 2050, BY REGION IN 2DS – COMPARE WITH



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Ref: iea Technology roadmap, carbon capture and storage, 2013

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CO2 CAPTURE FROM INDUSTRIAL SOURCES

CEMENT PLANT




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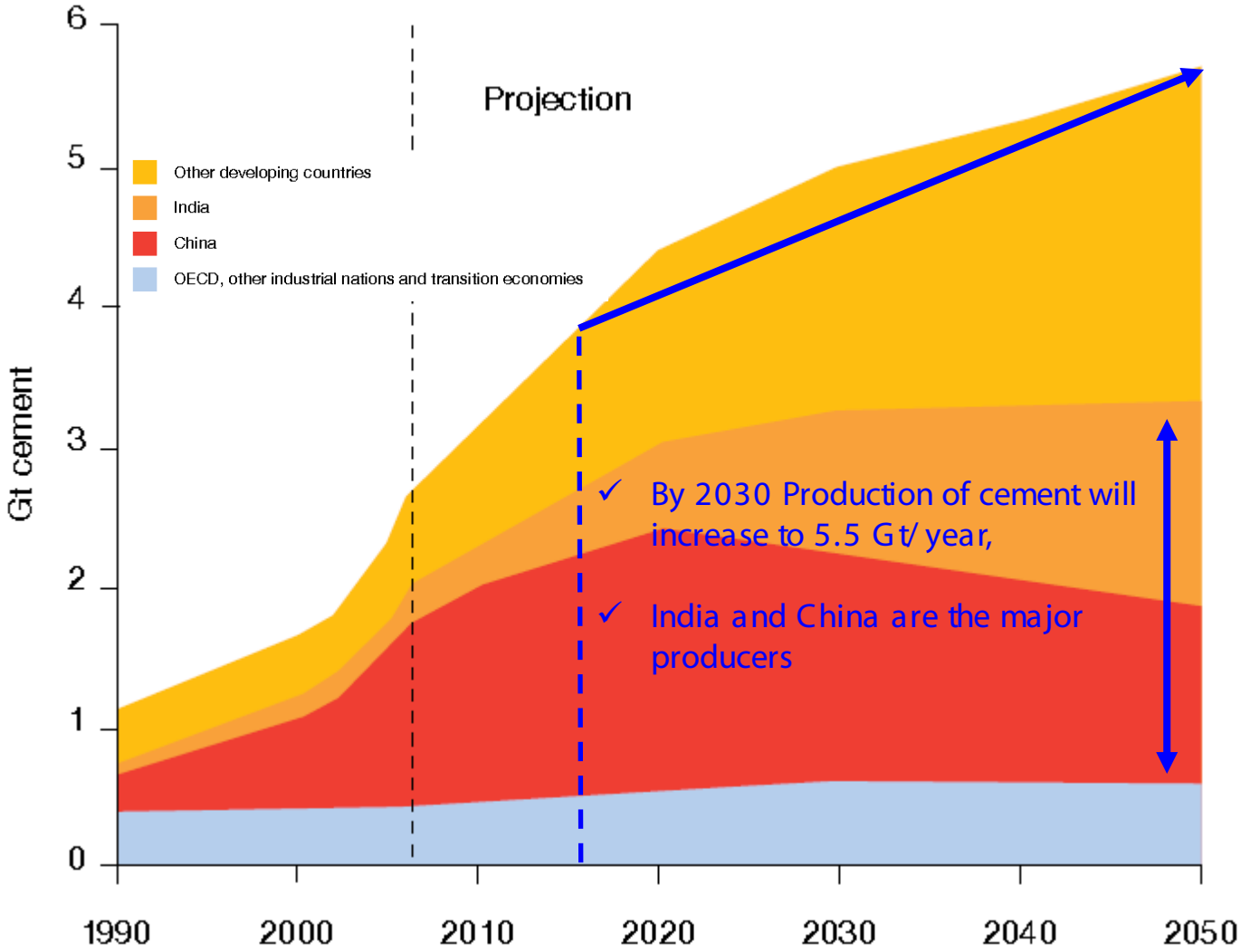
GLOBAL CEMENT PRODUCTION



Source: Nicolas Muller & Jochen Harnisch, A blueprint for a climate friendly cement industry

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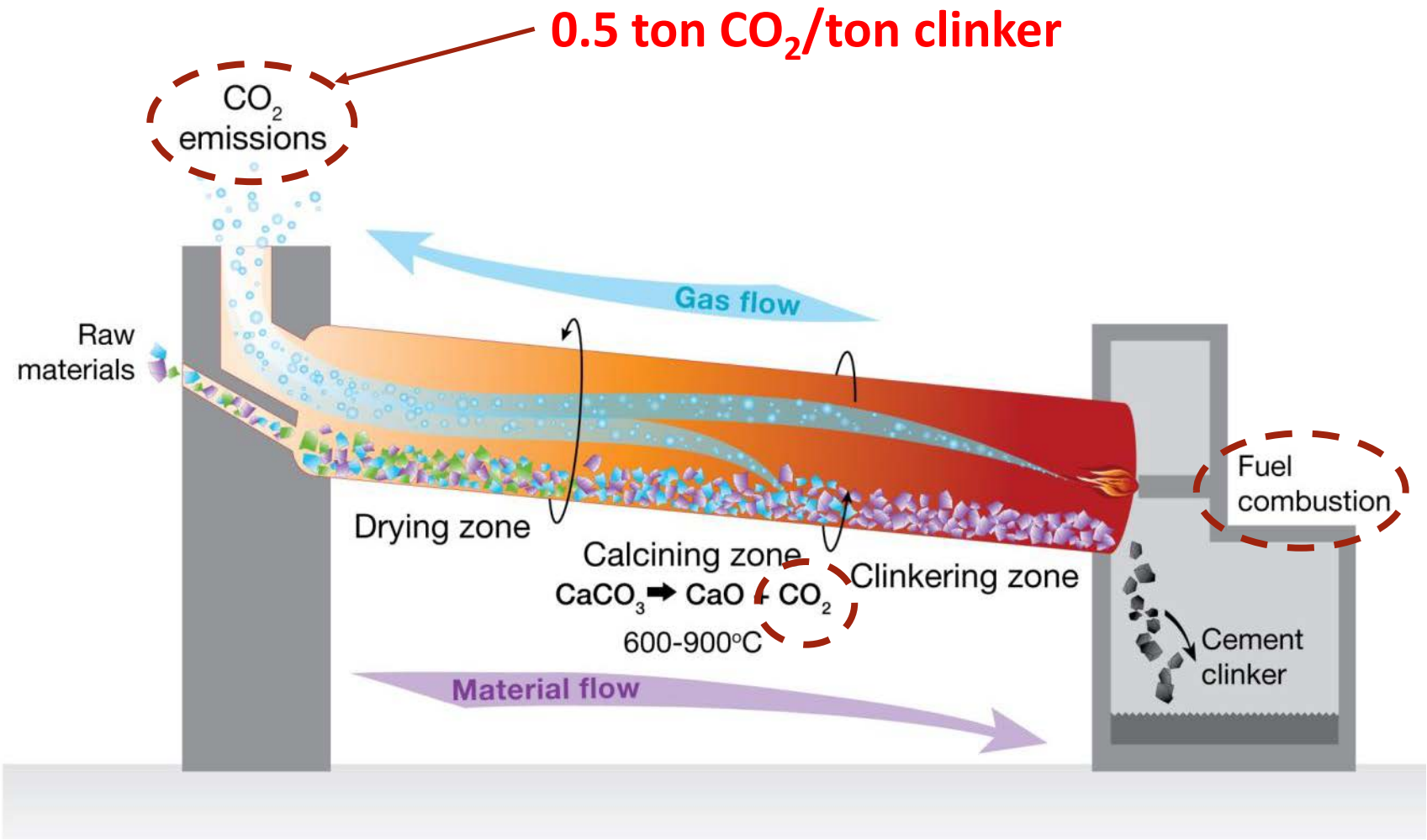
WHAT ARE THE SOURCES OF CO2 IN CEMENT PROCESS?



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CO2 CAPTURE FROM INDUSTRIAL SOURCES

CHEMICALS




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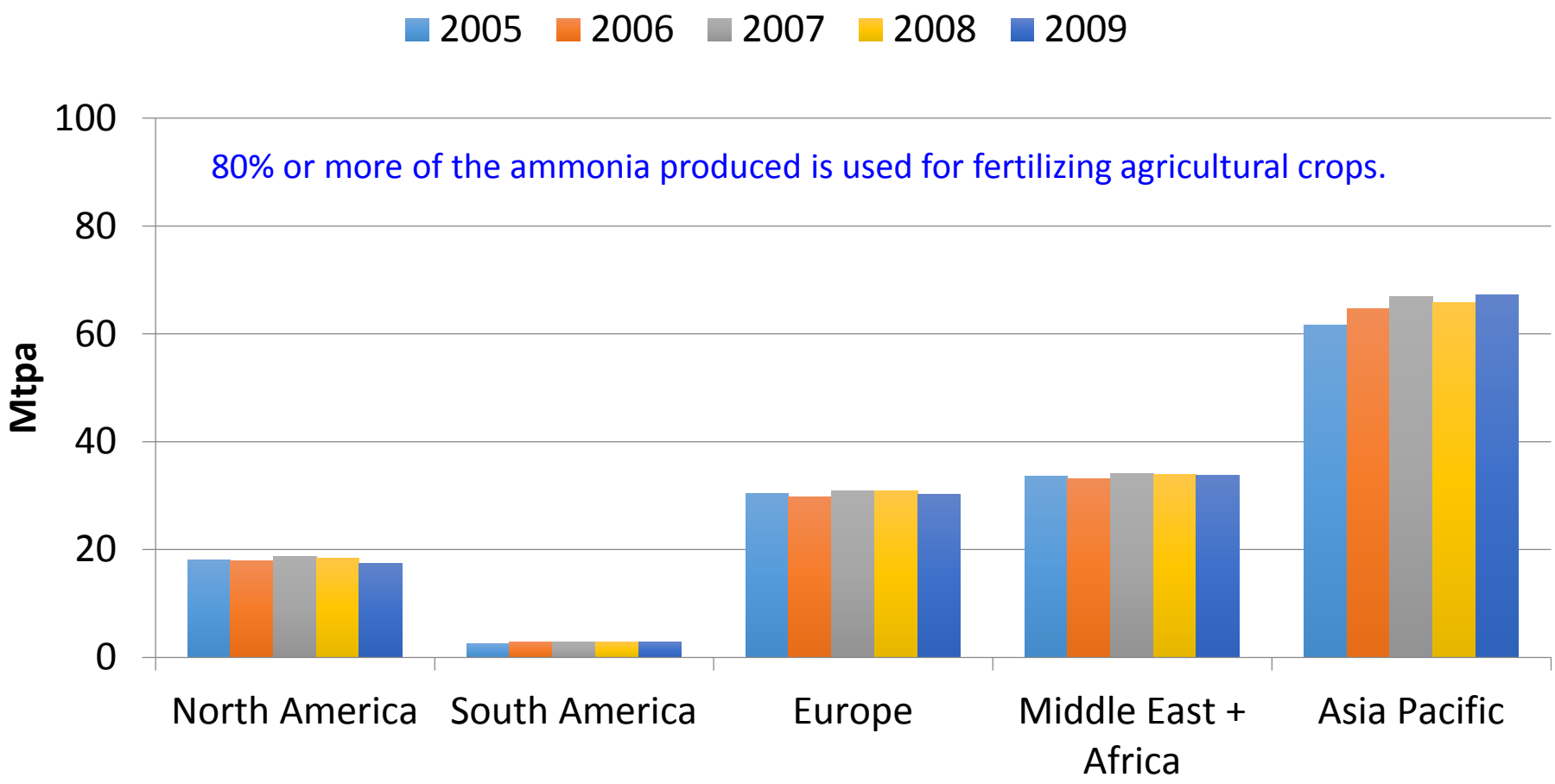
GLOBAL AMMONIA PRODUCTION

numerous large-scale **ammonia production** plants worldwide, producing equivalent to 159 million tonnes of ammonia in 2010

China produced 32.1% of the worldwide production, followed by India with 8.9%,



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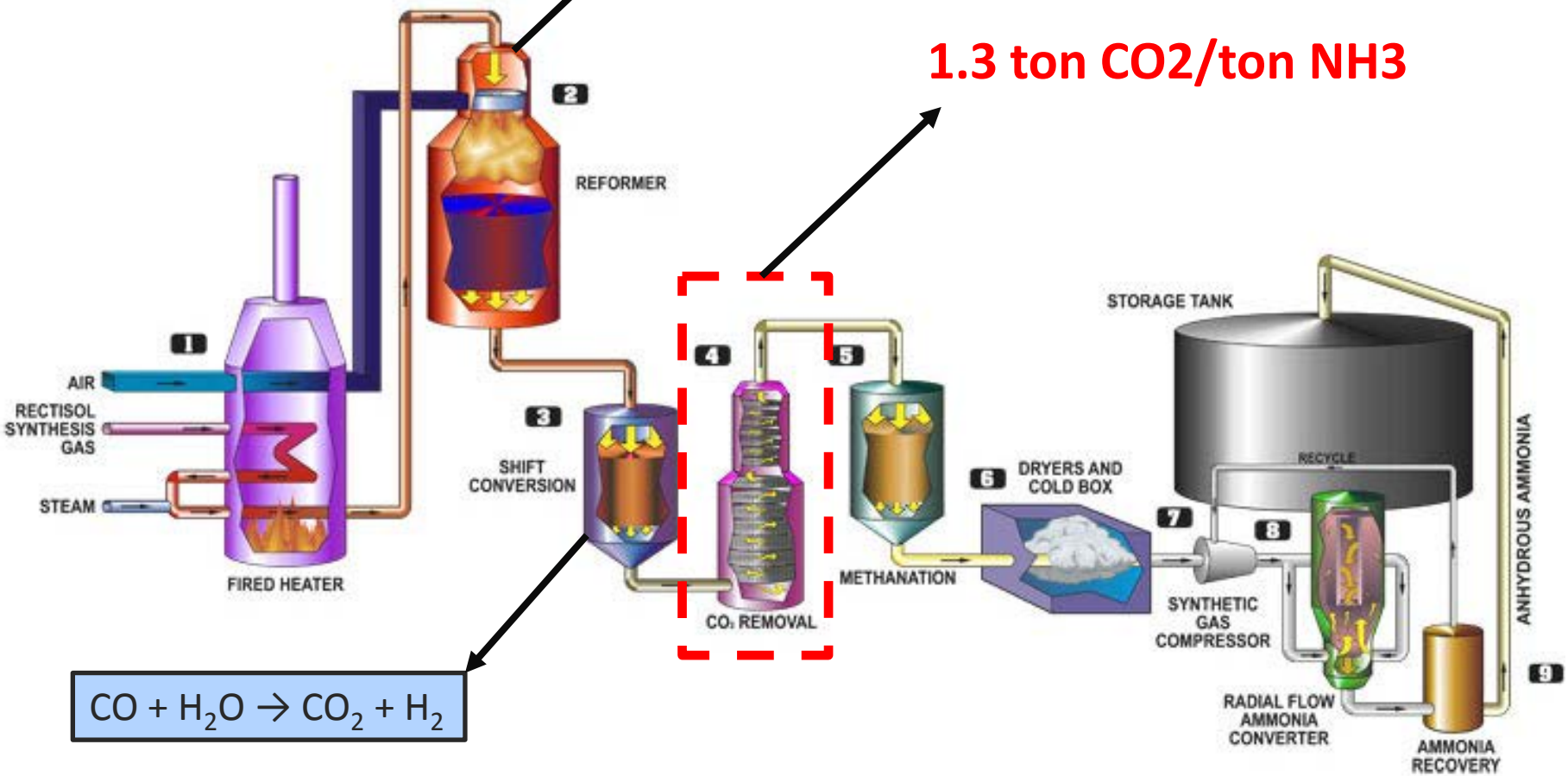
Source: www.indexmundi.com/ en/ commodities/ minerals/ nitrogen/ nitrogen_t12.html

WHAT ARE THE SOURCES OF CO2 IN AMMONIA PROCESS?

$CH_4 + H_2O \rightarrow CO + 3H_2$

1.3 ton CO2/ton NH3



$CO + H_2O \rightarrow CO_2 + H_2$

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CO2 CAPTURE FROM INDUSTRIAL SOURCES

REFINING




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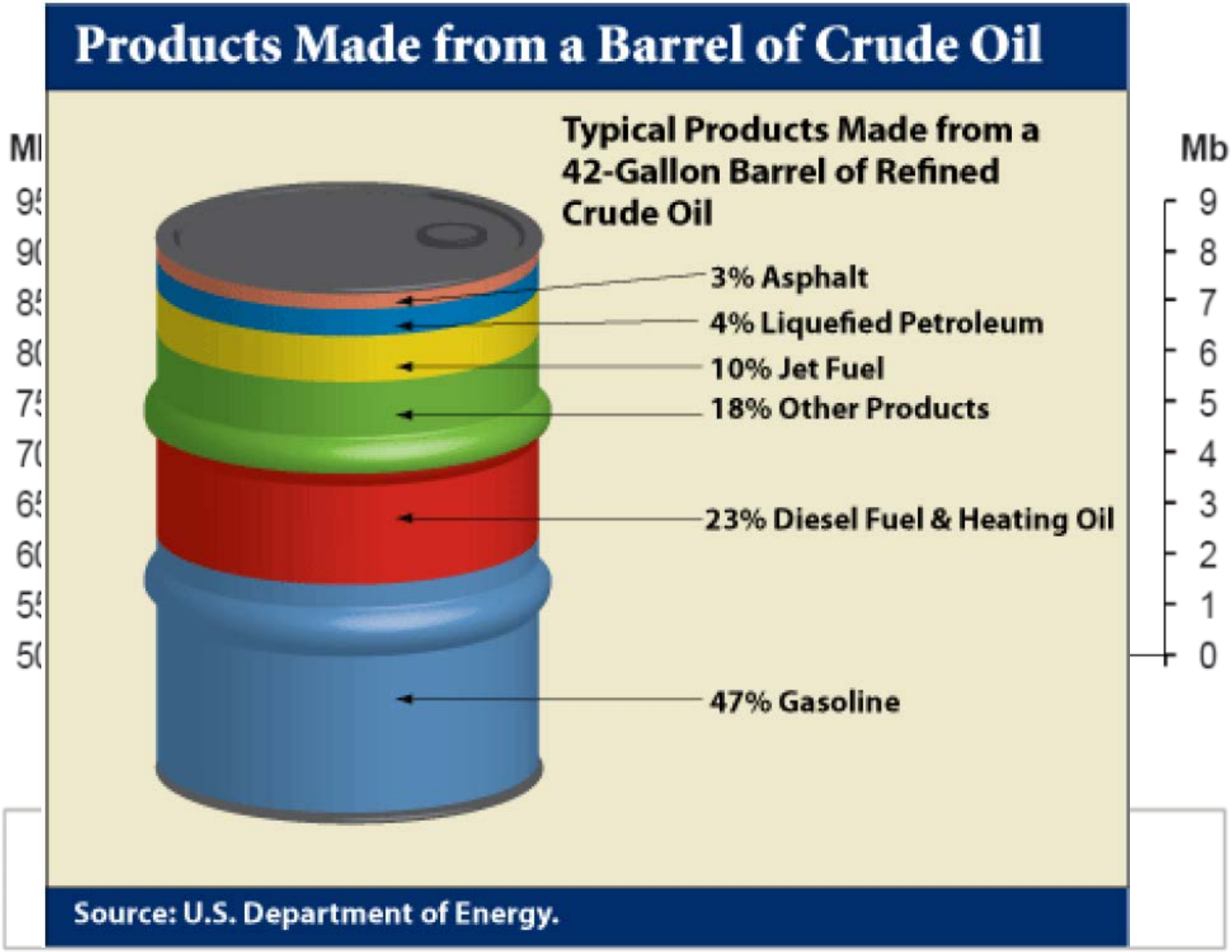
GLOBAL OIL REFINERY PRODUCTION



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Source: www.ibtimes.com/ articles/ 85678/ 20101125/ oil-crude-us-dollar-ireland-china-al-naimi-us-fed-eia-oil-price-outlook-100-mark-70-90-range-oil-tec.htm

WHAT ARE THE SOURCES OF CO2 IN TYPICAL COMPLEX REFINERY?

CO_2 emitter	Description	% of total refinery emissions
Furnaces and boilers	Producing heat and steam	30–60%
Utilities	Electricity and steam	20–50%
Fluid catalytic cracker	CO_2 as by-product	20–35%
Hydrogen manufacturing	CO_2 as by-product	5–20%

Source: Staerlen et. al. CO2 capture for refineries, a practical approach

International Journal of Green House Gas control, 2010, 4 (2), 316-320

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CO2 CAPTURE FROM INDUSTRIAL SOURCES

CHALLENGES OF DEPLOYING CO_2 CAPTURE PROCESS




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CHALLENGES → HIGHER COST FOR CCS

Characterization of inlet gas to capture process	Steel and Iron	Cement	Chemicals (Ammonia plant)	Refinery
CO2 Concentration (% vol.)	20-30	20-40	~8	5-15
Temperature (C)	~150	100-150	200-250	200-300
Pressure (Mpa)	0.1	0.1	0.1	0.1
Contaminations	dust	dust	---	SO3, NO2, dust
Size and location				
Distributed or concentrated	Distributed	Distributed	Distributed	Concentrated
Plant capacity	< 1Mton CO2/year	< 1Mton CO2/year	< 1Mton CO2/year	> 1Mton CO2/year
Other items				
Low grade heat available on site	Yes	Yes	Yes	Yes
Availability of the water	No	No	Yes	Yes

Source: Flue Gas Analysis in Industry, http://www.testo350.com/downloads/Flue_Gas_in_Industry_0981_2773.pdf

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IS CCS THE ONLY OPTION?

- Alternative materials → with lower carbon foot options,
  - Material of construction,
  - Chemicals,
- Process improvement:
  - Efficient energy consumption
  - Different chemistry and reaction pathway to eliminate CO_2 as a by product
- Onsite CO_2 utilization
  - Example: Cement curing at cement plant

- Alternative solutions will reduce CO_2 emission but can not replace CCS,

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SUMMARY

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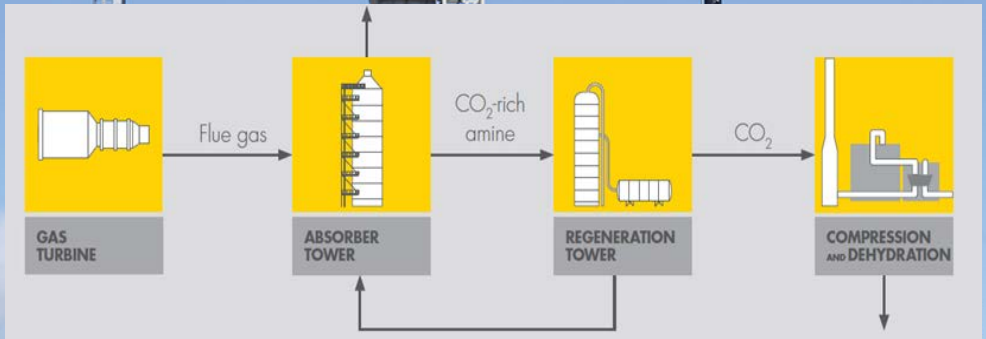
CCS ELEMENTS ARE PROVEN

Capture

- Capture-related technology has been utilised in industry for decades
- Most mature technology uses amine solvents for CO_2 Capture
- Emerging capture technologies build on industrial processes e.g. gas/ solid fluidised beds & membranes.



- CCS will play major role for CO_2 emission reduction from industrial sources

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CCS PROJECTS ARE OPERATIONAL BUT MORE ARE NEEDED

15 large scale projects in operation globally, a further 7 under construction

Capacity to prevent 40 million tons of CO_2 per annum from reaching the atmosphere

Source: Global CCS Institute, 2016

Most projects are associated with O&G industry and using CO_2 for EOR

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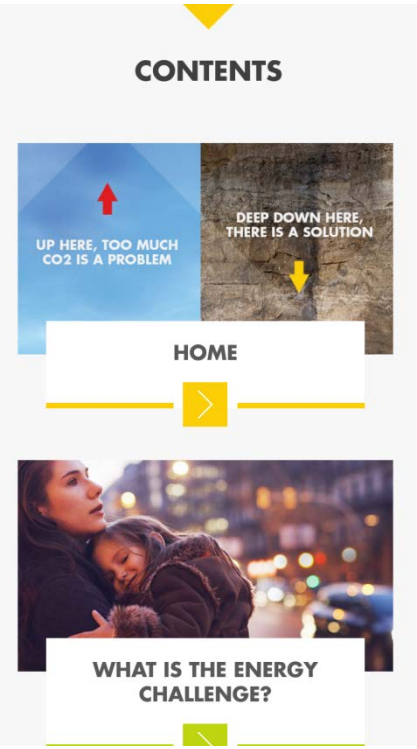
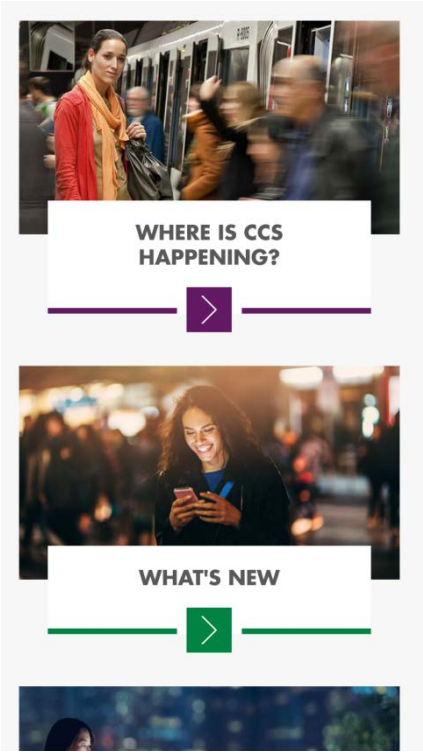
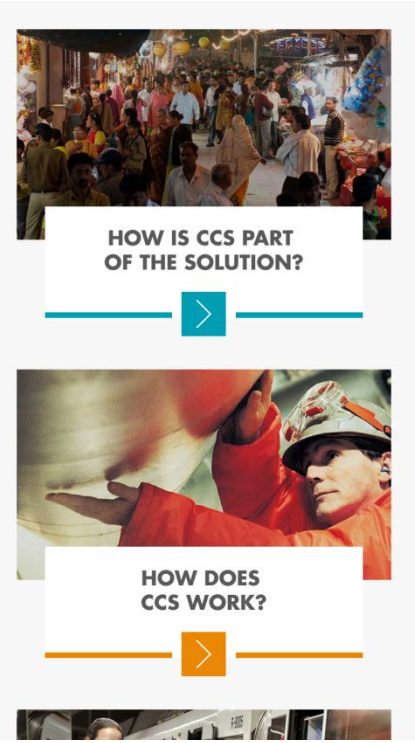
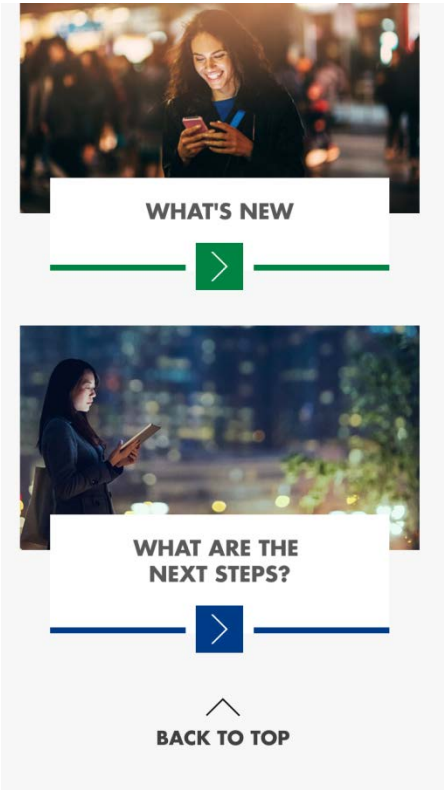
SHELL CCS APP.









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Q&A

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