03 METHANOL PRODUCTION

Conventional Methanol Production

Methanol convertor

Steam(H_2O)

Natural Gas

Reformer

Fuel Gas

Natural Gas(fuel)

Synthesis gas

$CO+H_2$

$CO_2+ H_2$

Methanol Converter

H_2 Purge

To Burners

To H_2 consumers

Methanol/Water

CH_3OH/H_2O

Distillation

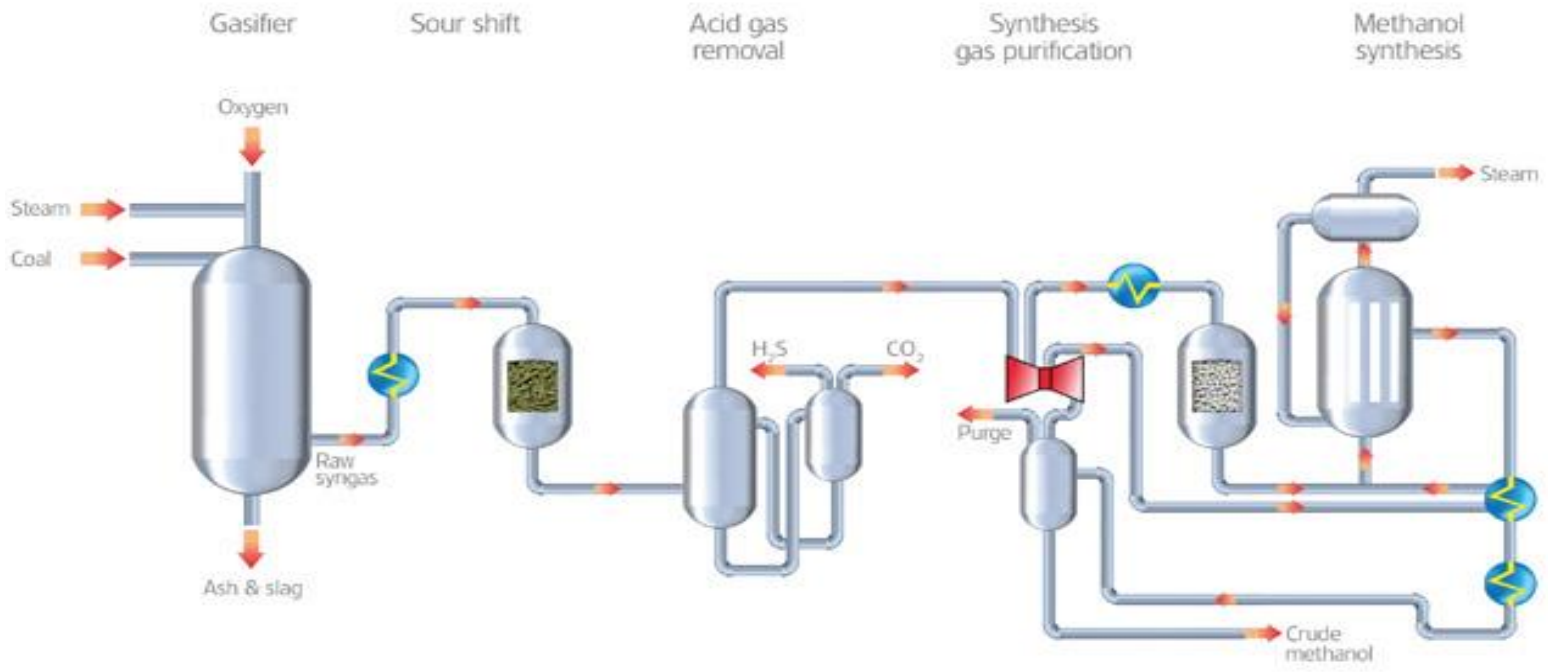
Methanol

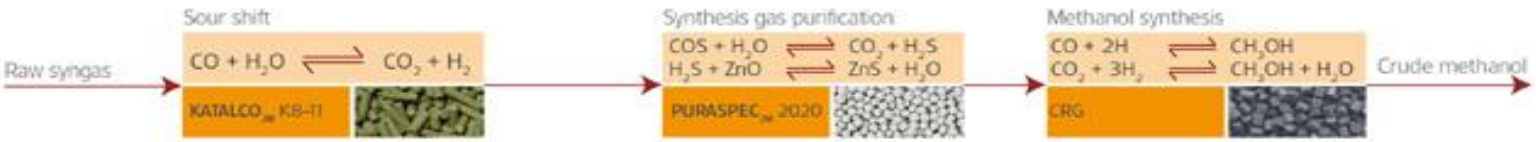
Water

Reformer

Distillation tower

Methanol Production – Coal Gasification





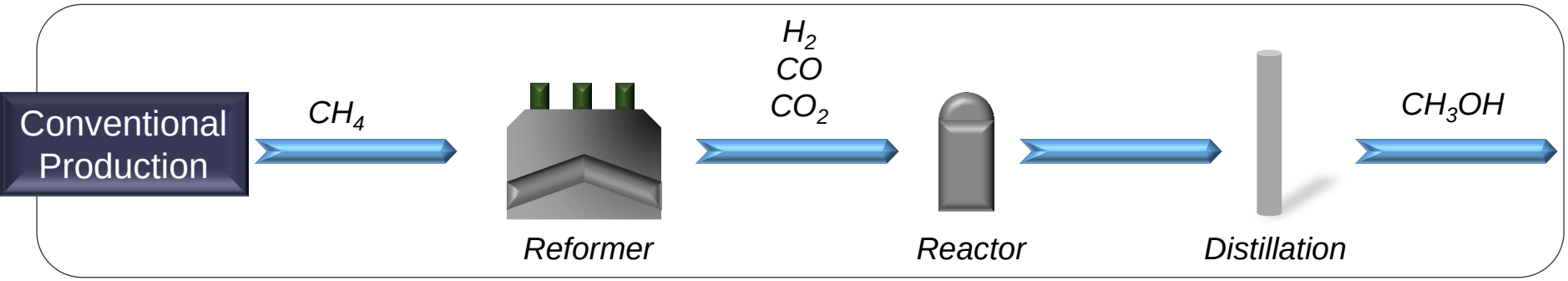
Source: Johnson Matthey

Methanol Production Bridge to Sustainability

- Methanol is a “future proof” molecule that can be made from conventional fossil sources and emerging renewable feedstocks.

- Expansion of energy markets for methanol builds demand for sustainably-sourced and locally-produced methanol.

Several Renewable Production Pathways Exist



Option 1

New Life for Old Assets

Option 2

CO_2 Recovery & Utilization

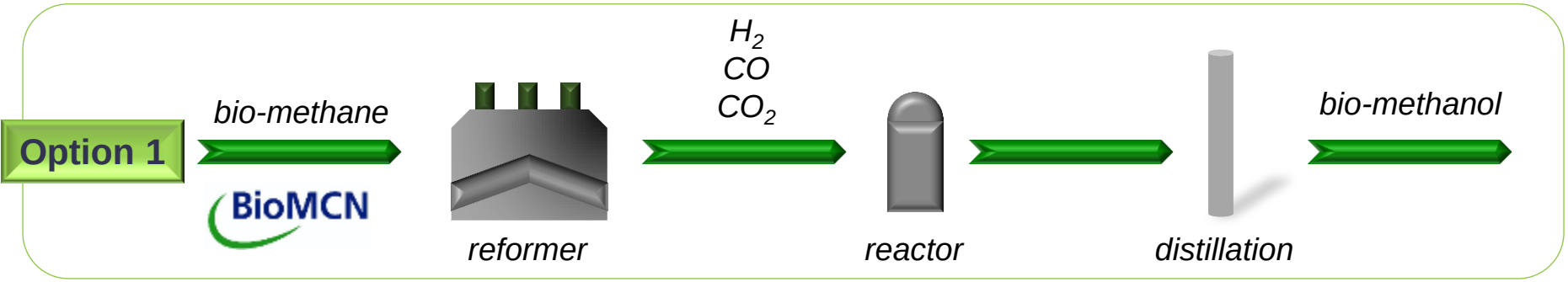
Option 3

Back to Basics

Option 4

Liquid Electricity

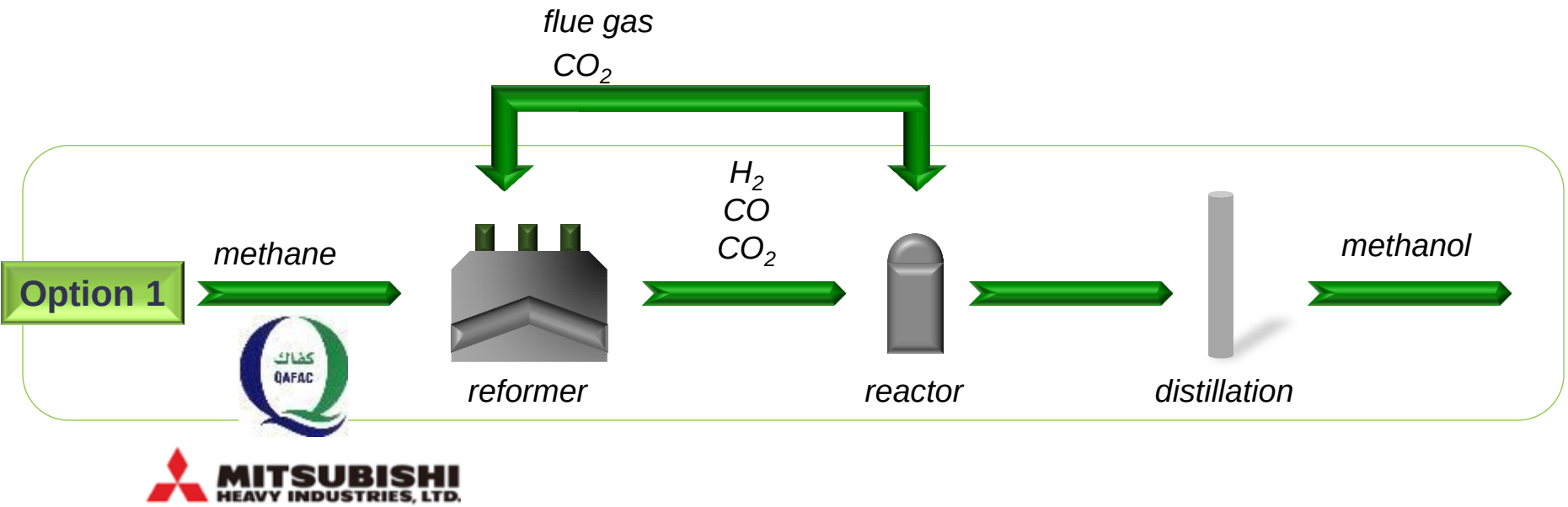
New Life for Old Assets



Option 1

BioMCN – Biomethane to Biomethanol

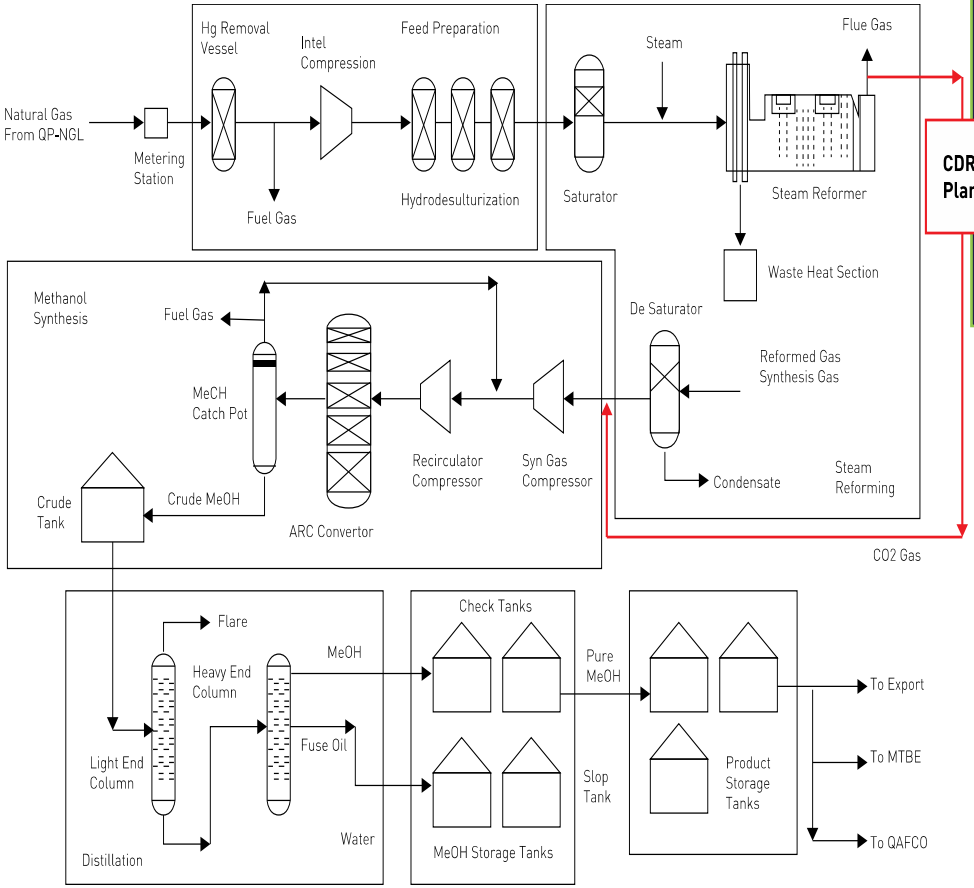
CO_2 Recovery & Utilization



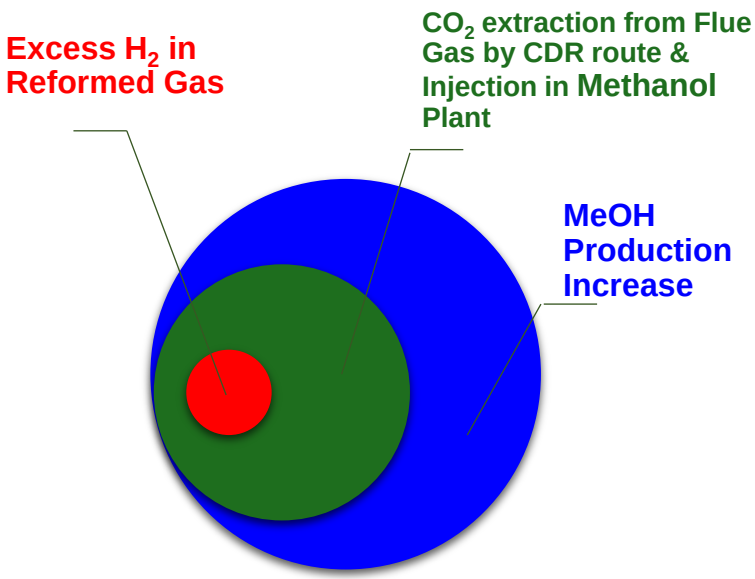
Option 2

CO_2 Recovery & Utilization

QAFAC Utilization of Recovered CO_2

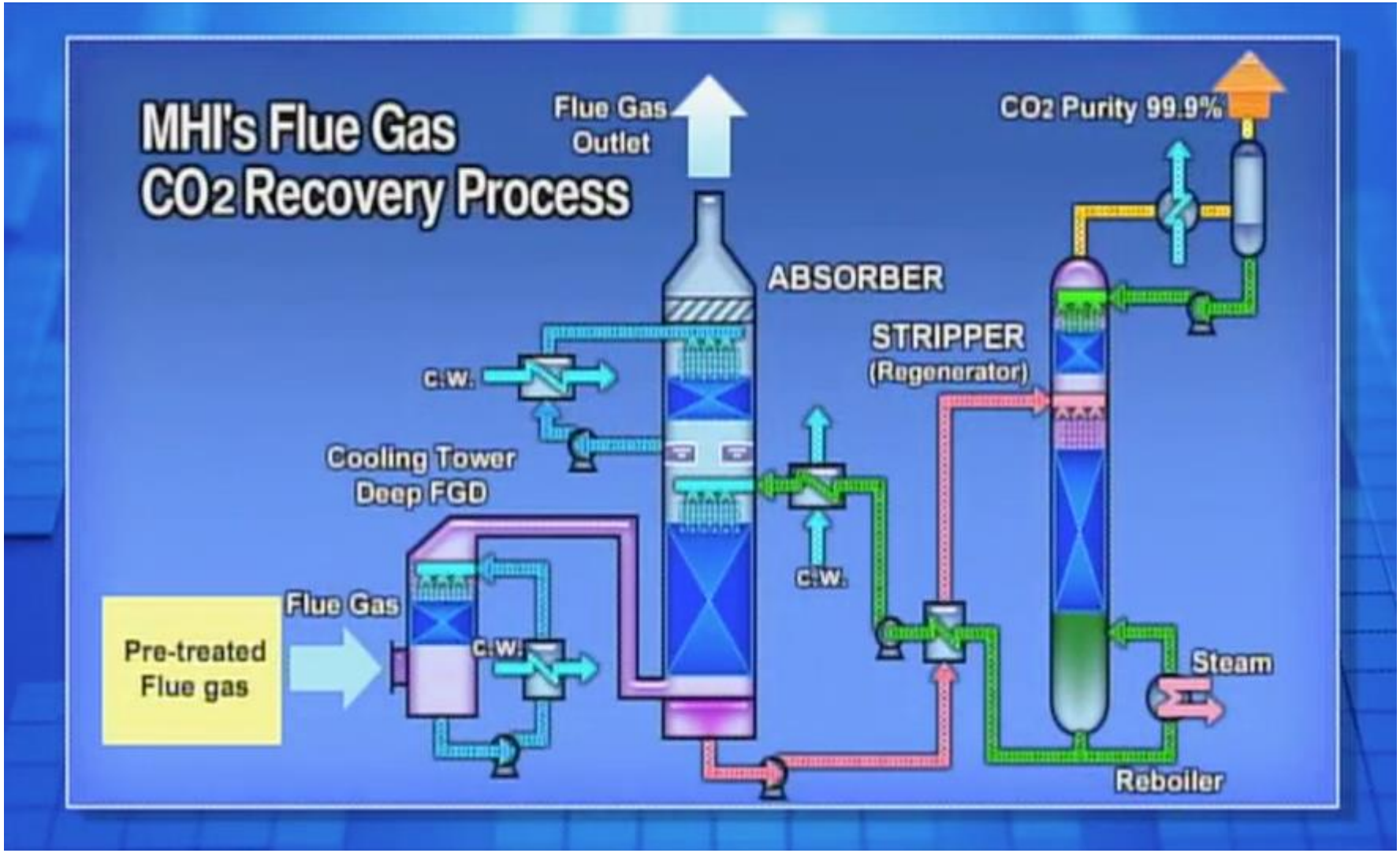


- 500 MTPD of CO2 is recovered from the flue gas using MHI's proprietary KS–1™ solvent and injected in synthesis loop for boosting Methanol production.
- The capacity of Methanol Plant has increased by 300 MTPD with addition of CO2 in synthesis gas mixture as excess H2 is available for the methanol reaction.
- Thus, QAFAC's Methanol Plant became Self–sufficient for raw material (CO2).

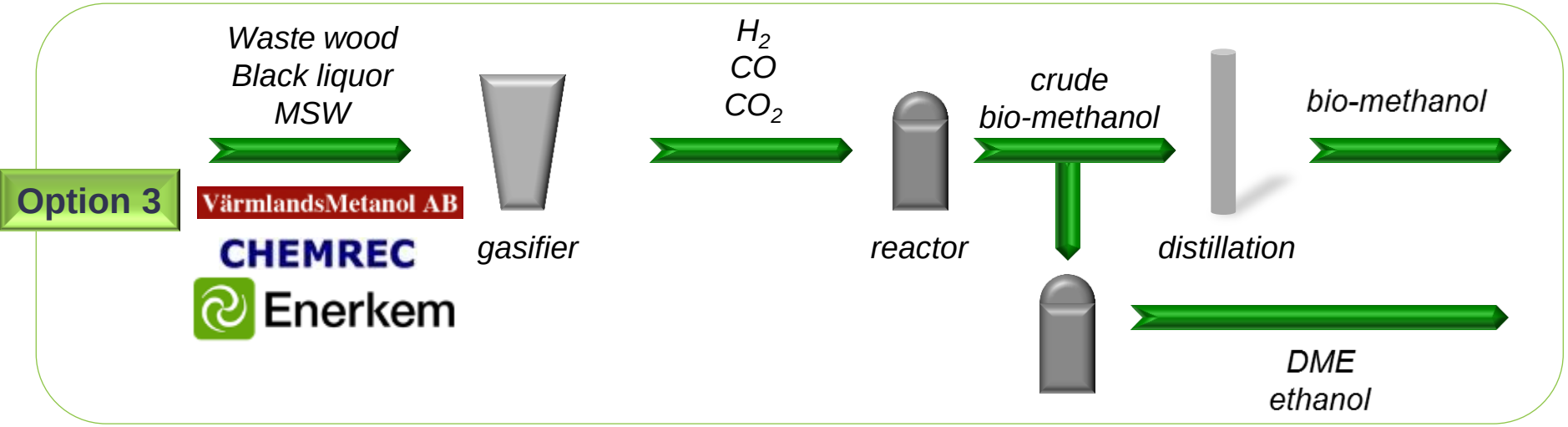


Option 2

CO_2 Recovery & Utilization



Back to Basics

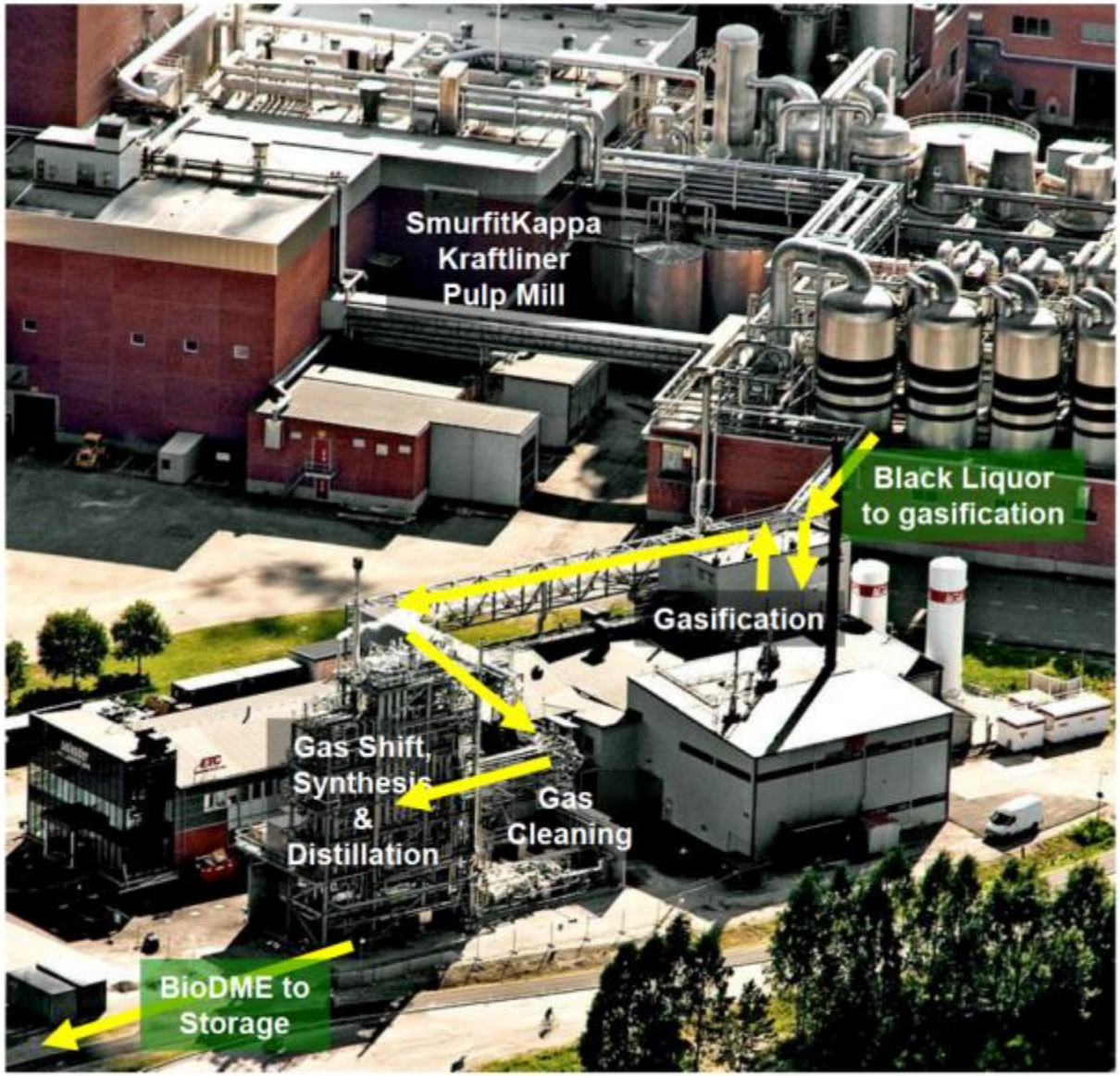


Enerkem – Waste to Methanol

Option 3

Option 3

Chemrec - From Black Liquor to Methanol to bio-DME



DME production capacity:	4 tons / d
Pipe installation:	~ 10 000 m
Hand valves & on/off valves:	~ 1400 pieces
Instruments:	~ 450 pieces
Vessels:	~ 30 pieces
Heat exchangers:	~ 25 pieces
Process Plant Foot Print:	20 x 30 m
Investment cost (excl gasification):	~ 22 million €

European Project BioDME
7th Framework Programme

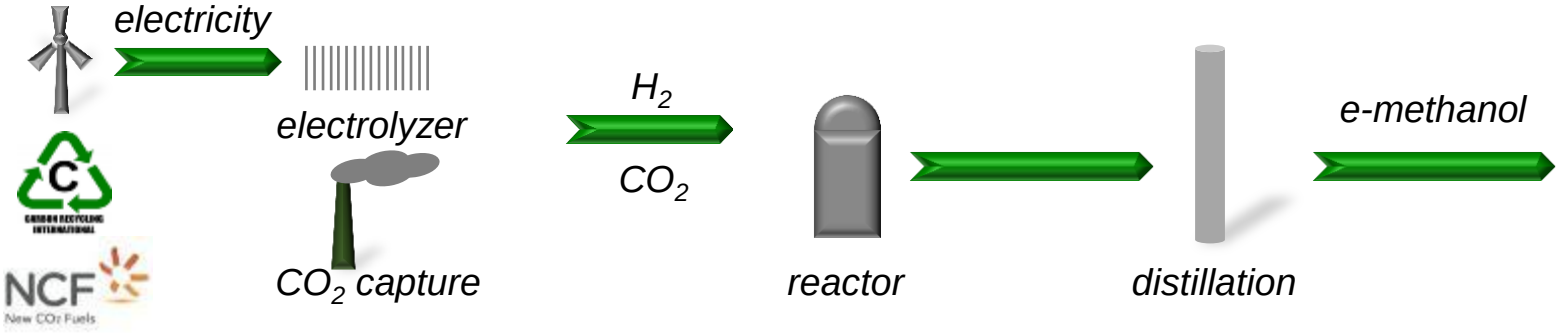
BIODME

Option 3

VärmlandsMetanol– Wood Based Methanol Project

Liquid Electricity

Option 4

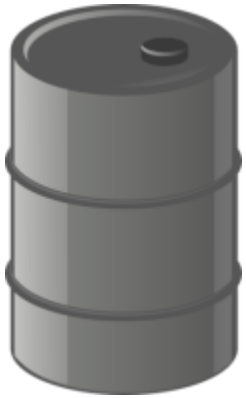


Option 4

CRI Power - CO_2 to Methanol

Option 4 Pathway to Storing Renewable Electricity

- Converting intermittent renewable power into ‘liquid electricity’ is an alternative option to e-mobility, while reducing CO_2
- The amount of energy stored in one cubic meter of methanol equals the storage capacity of 222 battery-electric BMW i3’s



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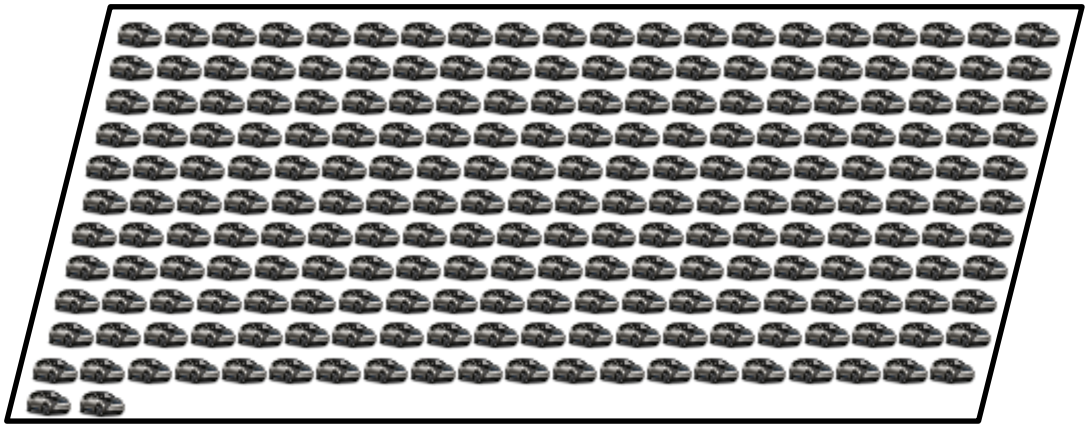


*Storage capacity BMW i3 = 21,6 kWh

Source: BSE engineering

04 NEW MARKETS

Methanol Fuel Examples Around the World

Application	Current Methanol Demand (2015E, -000-Tons)	Potential Market Demand (-000- Tons)
Alternative Fuels		
- Gasoline	11,571	40,000-50,000
- Biodiesel	1,197	25,000-40,000
- DME	4,970	10,000-15,000
- Power Generation & Others	>1	40,000-60,000
Fuel Cells	8	3,000-8,000
Methanol-to-Olefins	16,683	30,000-40,000
Methanol-to-Gasoline	250	15,000-35,000

Methanol in Gas Powered Turbines

In 2011, Israel Electric Corp (IEC) & Dor performed trial conversion at Caesara power plant located in valley in Eilat

Previously used diesel-fuelled turbine for peak power. Limited to 300 hours of operation annually; no pipeline natural gas access

June 2014 commercial operation of 100% methanol-fuelled Pratt & Whitney FT4C Twin Pack 50 MW gas turbine.

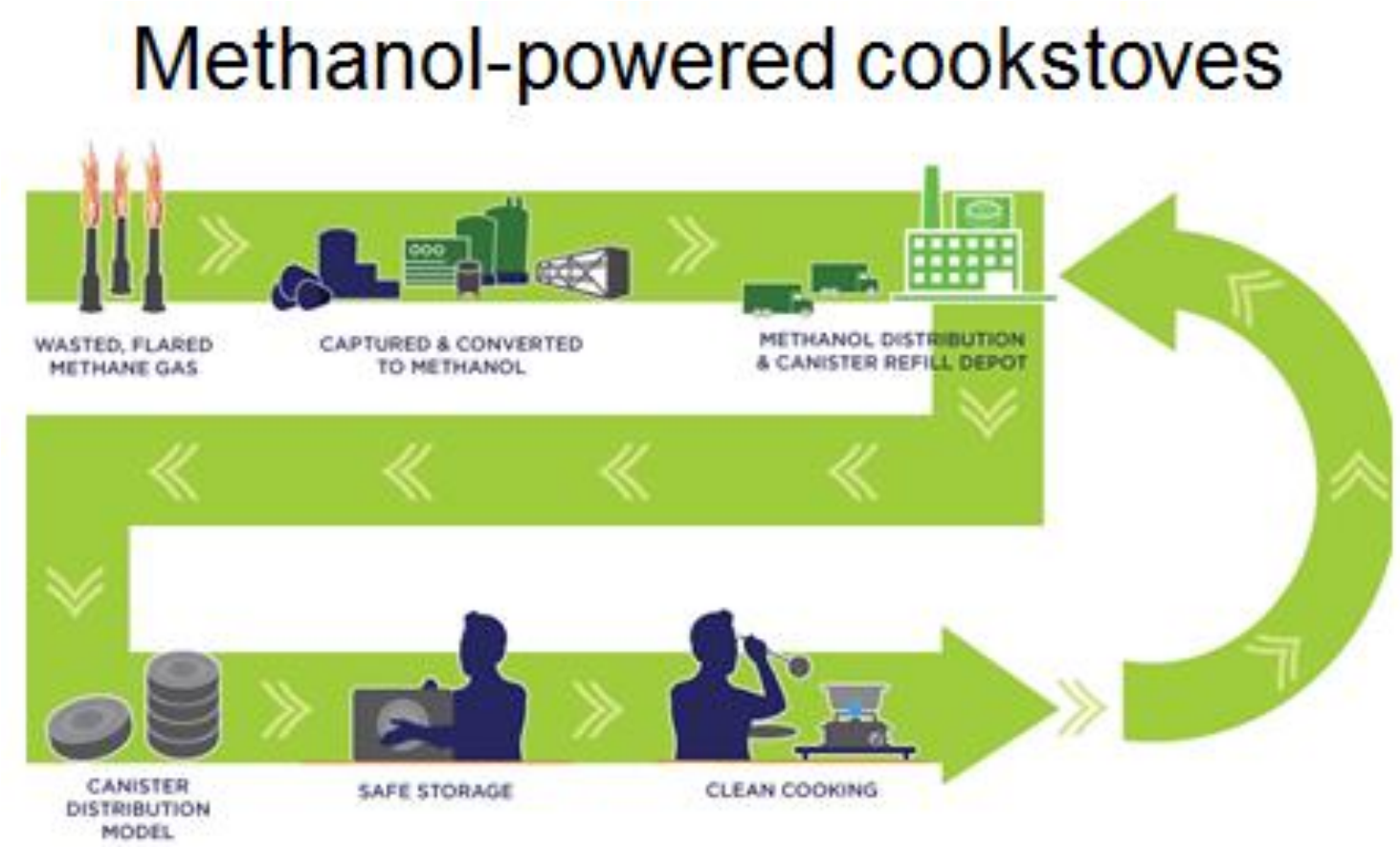
Dor Findings

- Low-cost fuel system retrofits to methanol, with this initial project costing $5 million.
- Yields significant NOx, SO2, and particulates emission reduction, without affecting performance.
- Unit now permitted to operate for 2,000 hours per year.
- Methanol consumption is *30 tons per hour*.
- This technology (*first of its type in the world*) can be adopted in many other places (mainly Islands) where due to no natural gas supply, are currently using polluting fuels.

Methanol in Cooking Stove Applications

- Traditional cooking fuels (wood/charcoal, dung, kerosene, paraffin, diesel, coal, LPG) can emit significant CO2 and harmful particulates, potential fire hazards.
- Nigeria (kerosene stoves), South Africa (paraffin), China (coal).
- Project Gaia pilot project and studies in Nigeria since 2005.
- Distributed fuel already in canister: no handling of fuel by beneficiaries; results very successful.

Methanol in Cooking Stove Applications



Methanol in Cooking Stove Applications

China is Leading the World

- Methanol for cooking applications in China since 1983
- Potential for large amounts of methanol needed for future cooking applications in China.
- Use of alcohol in cooking fuels could reduce annual direct coal burning by 3,172 MW and CO_2 emissions decrease of 8.25 billion tons.

Methanol Fuel Cells

Methanol important in fuel cells as an environmentally-friendly hydrogen carrier fuel

TWO TYPES OF FUEL CELLS

Direct Methanol Fuel Cells (DMFCs):

- Subcategory of proton exchange fuel cells
- Liquid MEOH used as the fuel.
- Easy to transport, energy-dense/stable
- Low efficiency
- Good for portable power
- Waste: CO_2 & water vapor

Reformed Methanol Fuel Cells (RMFC) / Indirect Methanol Fuel Cells (IMFCs):

- Methanol reformed to hydrogen gas before being fed into fuel cell.
- Higher efficiency, smaller cell stacks, better operation/storage at low temps.
- Heat mgt/insulation systems required

Primary Applications for Fuel Cells

Charging/Replacement of batteries

- Forklifts (Oorja Protronics)
- Camper vans (SFC Energy)

Provision of off-grid or grid-support power

- Backup power supply to telecoms towers
- Remote communities
- Desalinization plants
- Off-grid mining

Major Global Methanol Fuel Cell Producers

- **Ballard Power Systems** (Canada)
- **Horizon Fuel Cell Technologies** (Singapore)
- **Oorja Protonics** (United States)
- **Panasonic** (United States)
- **SFC Energy** (Germany)
- **Toshiba** (Japan)

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