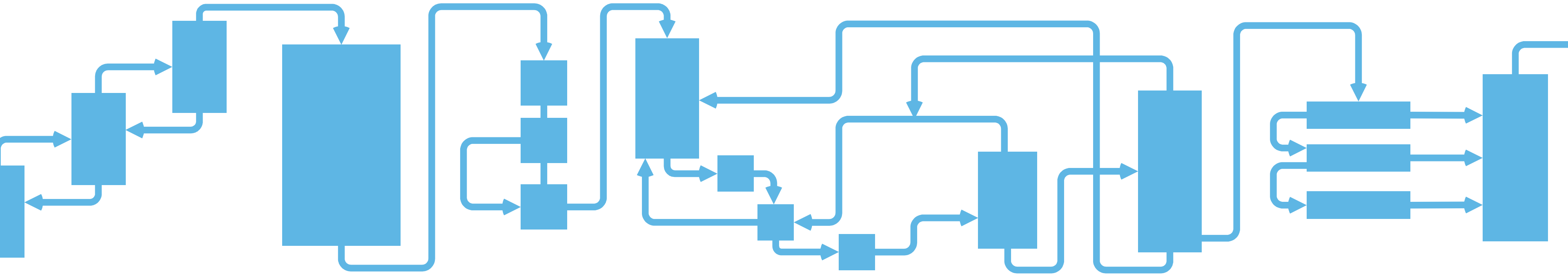


Syngas from renewables

Production of green methanol

Jim Abbott, JMPT

2015 European Methanol Policy Forum

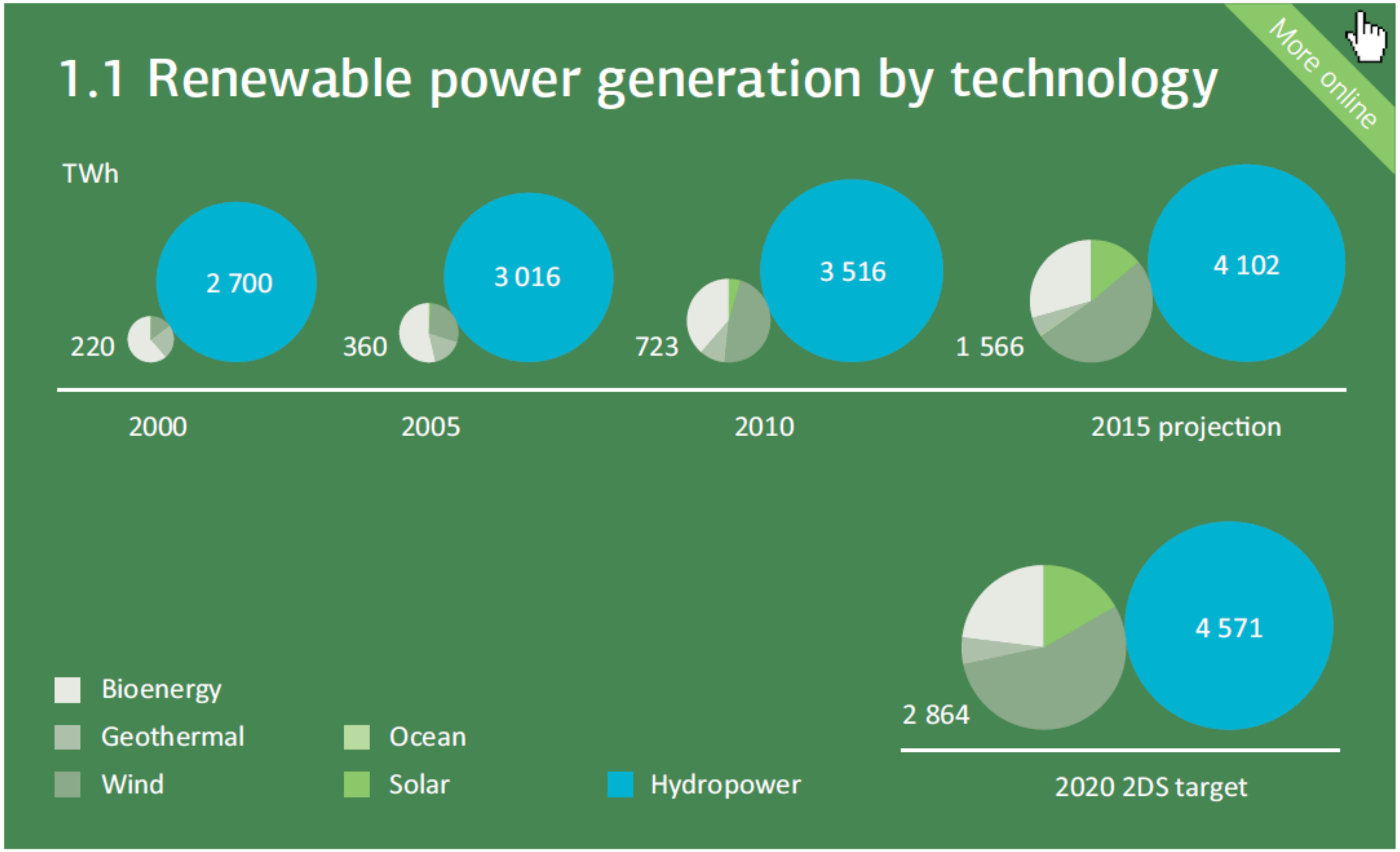
Brussels, 14 Oct 2015

JM

Johnson Matthey
Process Technologies

Renewable energy usage

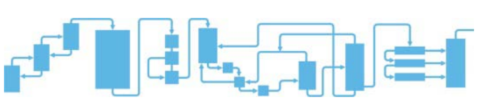
Johnson Matthey Process Technologies



14%
Annual growth of renewables 2000 - 2015

13%
Required annual growth of renewables to 2020

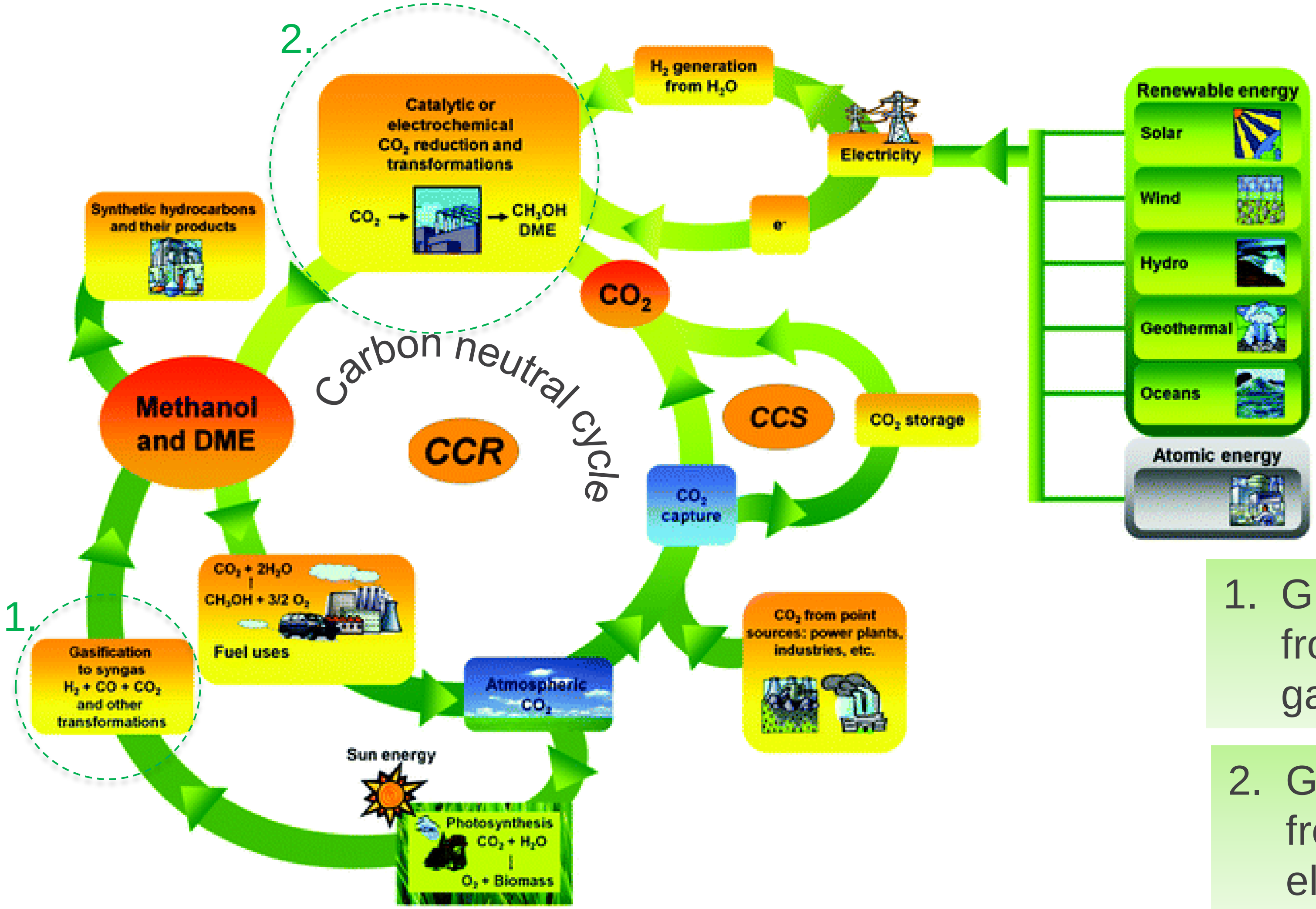
Progress of renewable power use towards 2020 2°C target [reproduced from Tracking Clean Energy Progress 2013, IEA]



- Legislated targets for ‘green’ fuels
- Market for ‘green’ chemicals

Methanol in a carbon neutral cycle

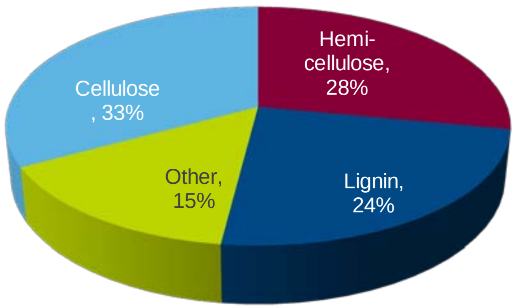
Johnson Matthey
Process Technologies

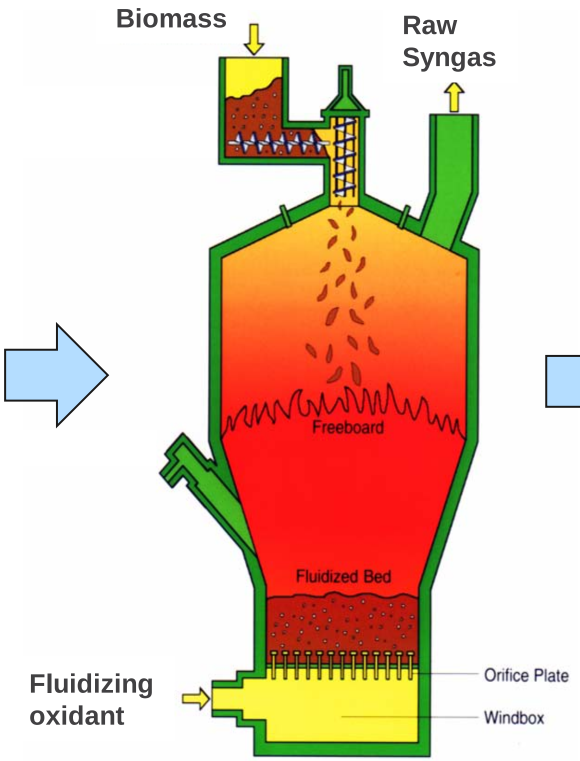


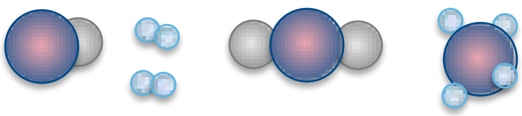
1. Green methanol from biomass gasification
2. Green methanol from renewable electricity

Beyond Oil and Gas: The Methanol Economy [Olah et al,, Wiley, 2011]

Syngas from biomass gasification







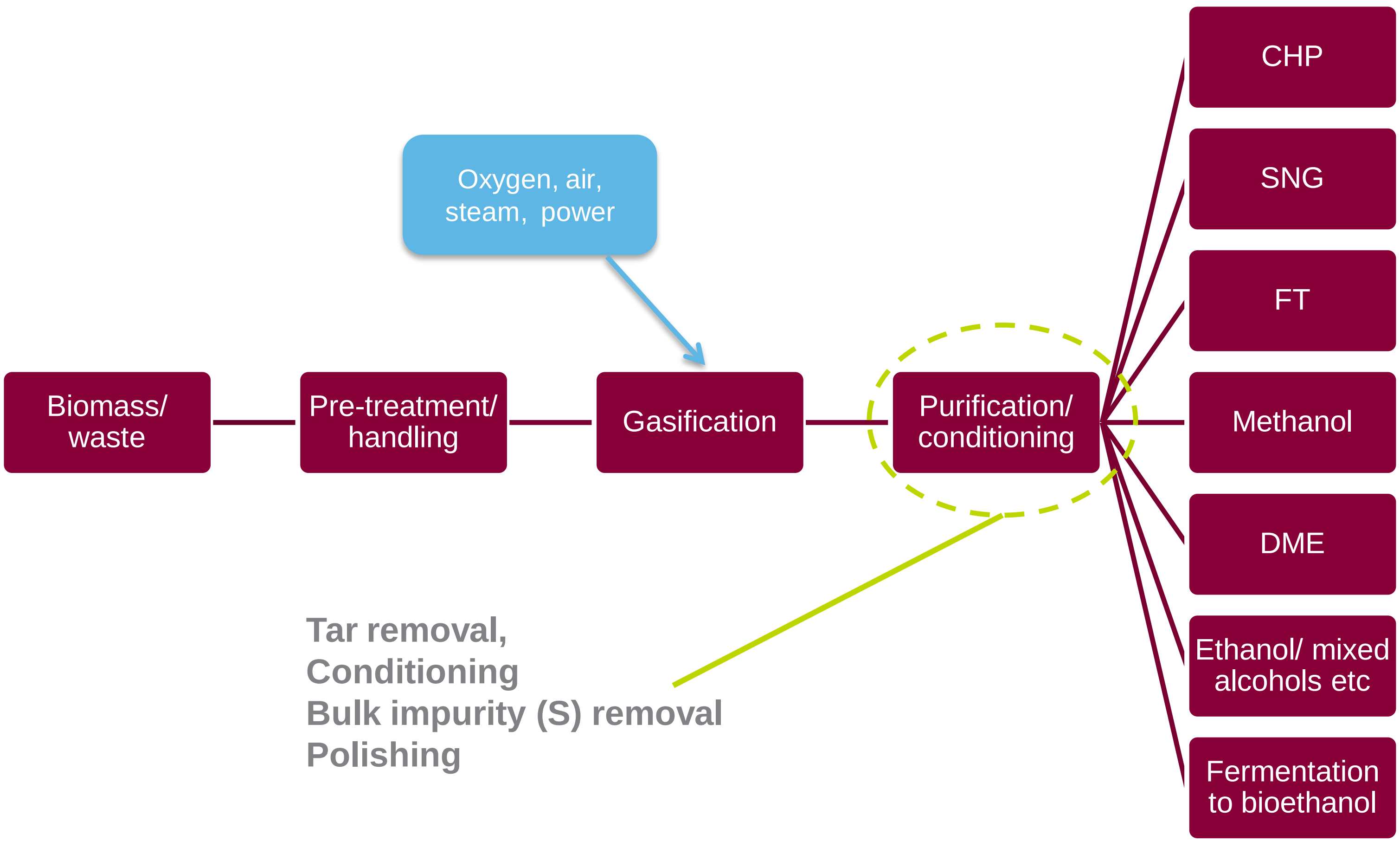
syngas

- High yield – uses 'not for food' biomass/waste resources
  - Efficient power production
  - Building block for chemicals, fuels – e.g. methanol

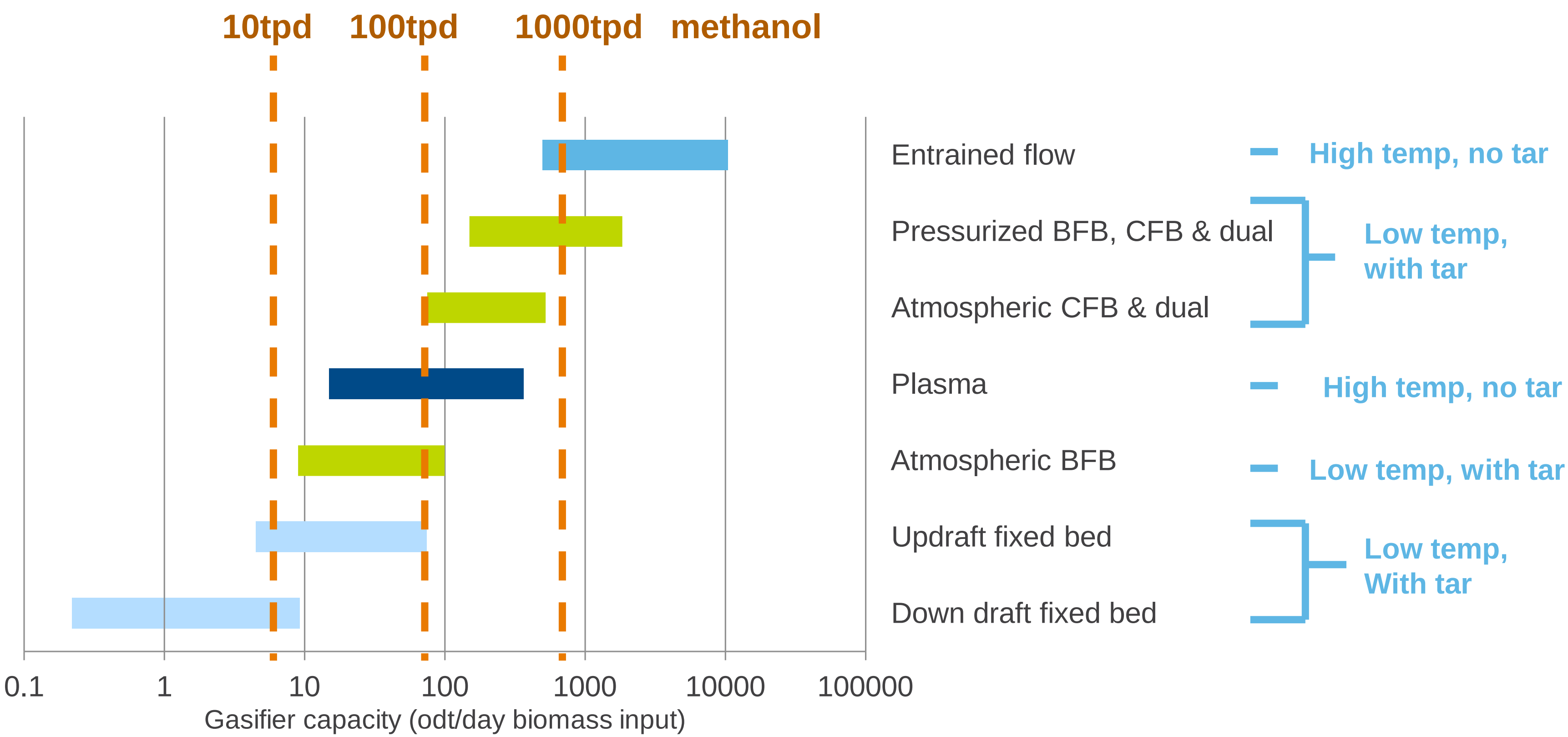
Production and use of bio-syngas

Johnson Matthey
Process Technologies

Gasification is a flexible process to convert a wide range of biomasses to syngas from which useful chemicals can be efficiently produced



Bio-syngas from gasification



Review of technology for the gasification of biomass and wastes, E4Tech, June 2009

Low temperature gasifiers

- Low pressure, inexpensive
- Particulate feed

High temperature gasifiers

- High pressure, expensive
- Powder feed – difficult for biomass

Syngas from low temperature gasifiers

JM Johnson Matthey Process Technologies

Component		Unit
CH_4, C_2+	2-15	%
CO	10-45	%
CO_2	10-30	%
H_2	6-40	%
NH_3	0.2	%
C_6H_6/tars	1-40 (0.009-0.37)	g/Nm^3 (oz/scf)
H_2S*	20-200	ppmv
Dust	0-10 (0-0.93)	g/Nm^3 (oz/scf)
Temperature	550-900 (1022-1652)	°C (°F)
Pressure	1-5 (14.5-72.5)	Bara (psia)

On 'dry' and 'N_2' free basis
* + other contaminants
halides, alkali metals , HCN

Tars & aromatics

- Downstream fouling and poisoning
  - Equipment & catalysts
- Downstream effluents
- Represent loss of product

Methane and light hydrocarbons

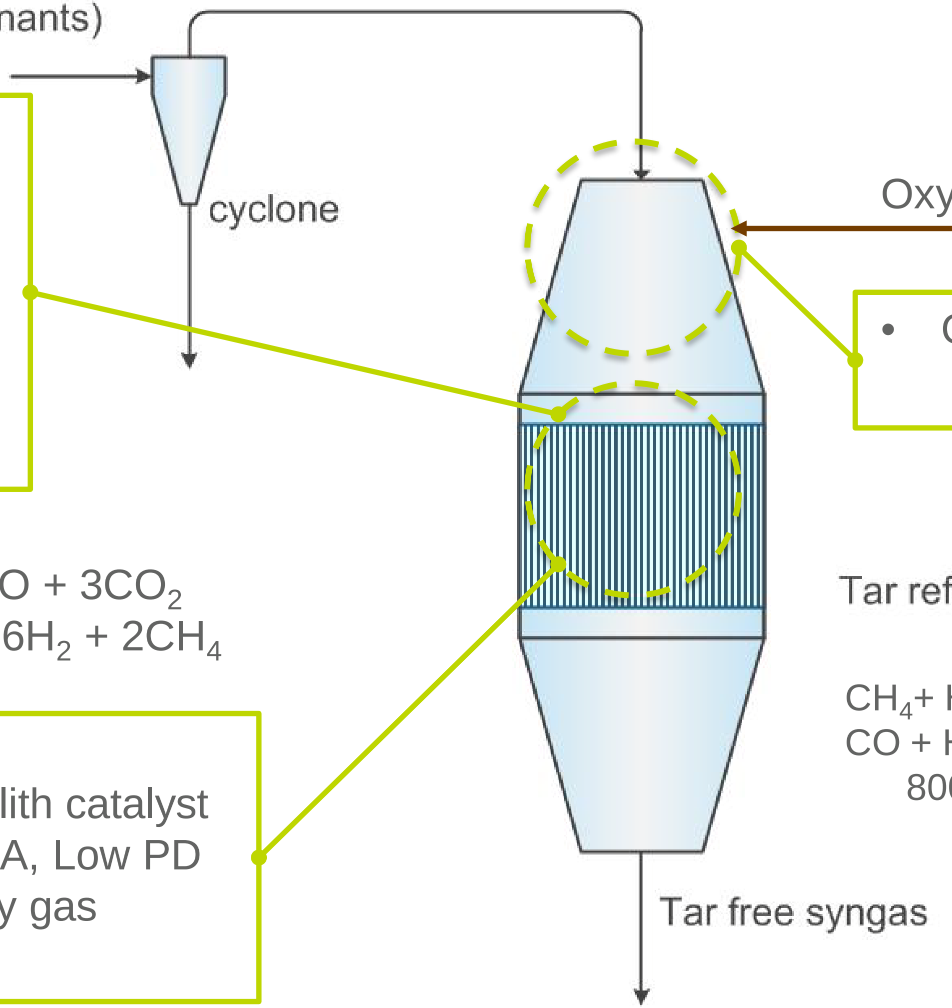
- Represent loss of product
- Represent inerts in downstream syngas conversion processes

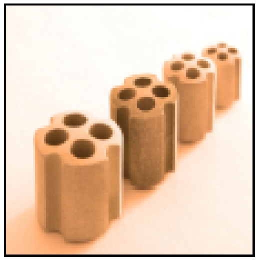
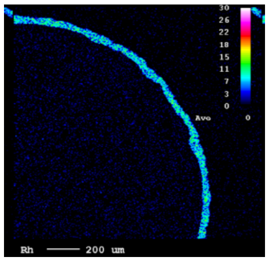
Critical to convert (or remove) tars

Highly desirable to steam reform
Methane and light hydrocarbons
For downstream conversion processes

The amazing tar reformer

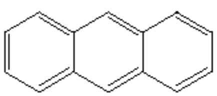
Johnson Matthey
Process Technologies



- Coated, Shaped catalyst
    - High GSA, Low PD

- Oxygen burner
    - Good mixing



Anthracene

$$+ 15H_2O \rightarrow 9CO + 3CO_2 + 16H_2 + 2CH_4$$

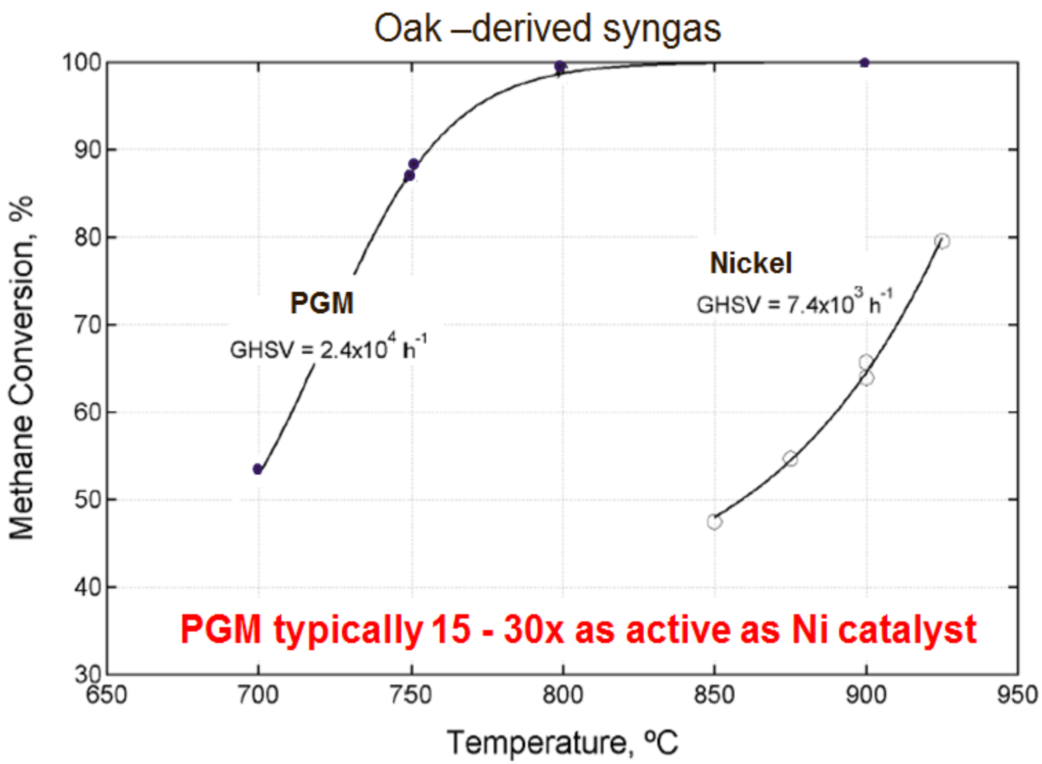
650-850°C

$$CH_4 + H_2O \rightarrow CO + 3H_2$$
$$CO + H_2O \rightarrow CO_2 + H_2$$

800 - 1000°C

- Coated monolith catalyst
    - High GSA, Low PD
    - For dusty gas

Tar reforming catalyst

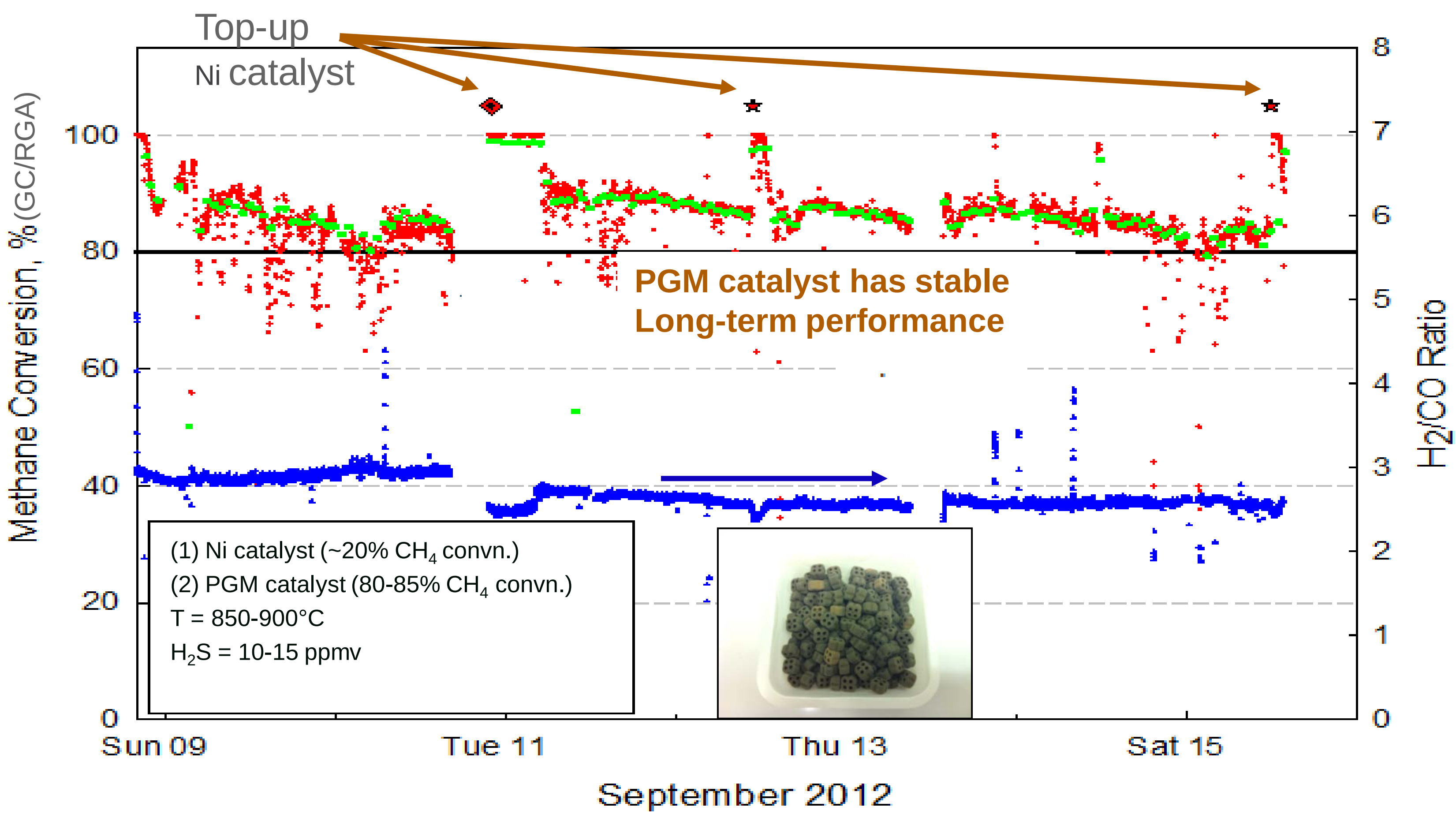


Catalysis Today 214 (2013) 74-81,
[Steele, Poulston, Magrini-Blair, Jablonski]

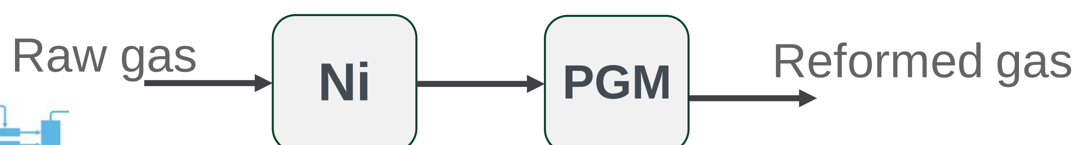
Advantages of PGM

- Faster inherent kinetics
- Slower sintering of metal crystallites
- Much superior resistance to sulphur
- Precision coating
  - Applies metal only where effective
- Recovery and recycle of PGM
- Regenerable

Methane conversion – oak derived syngas



NREL data unpublished – K. Magrini-Blair, W.Jablonski et al.



JM Johnson Matthey
Process Technologies

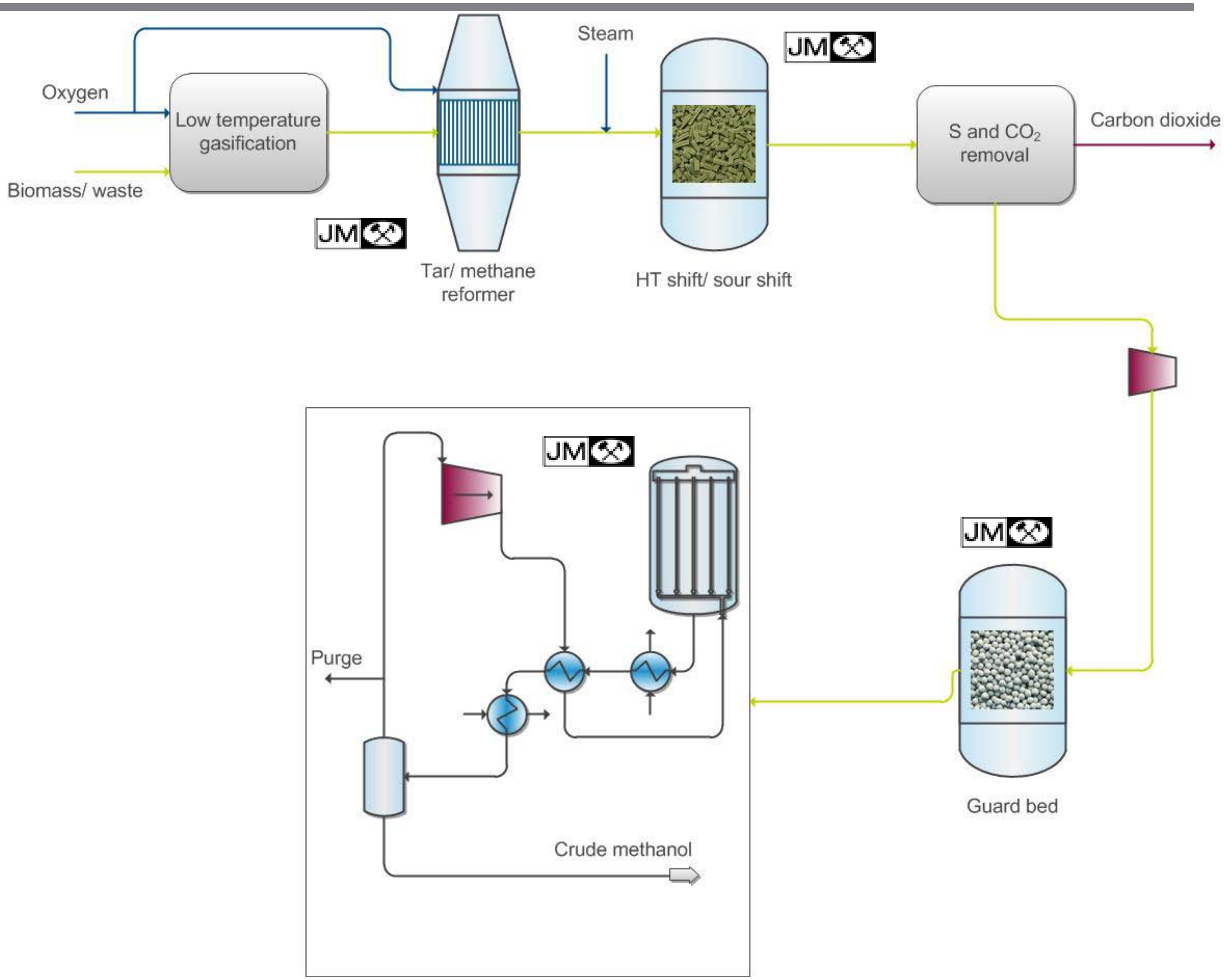
Industrial application of tar reforming

- Tar reforming in CHP
  - Market developing now
  - Typically smaller scale
  - 0.5 – 20 MW_{el}

JM tar reforming catalyst installed in Ecorel 1MW_{el} biomass CHP plant

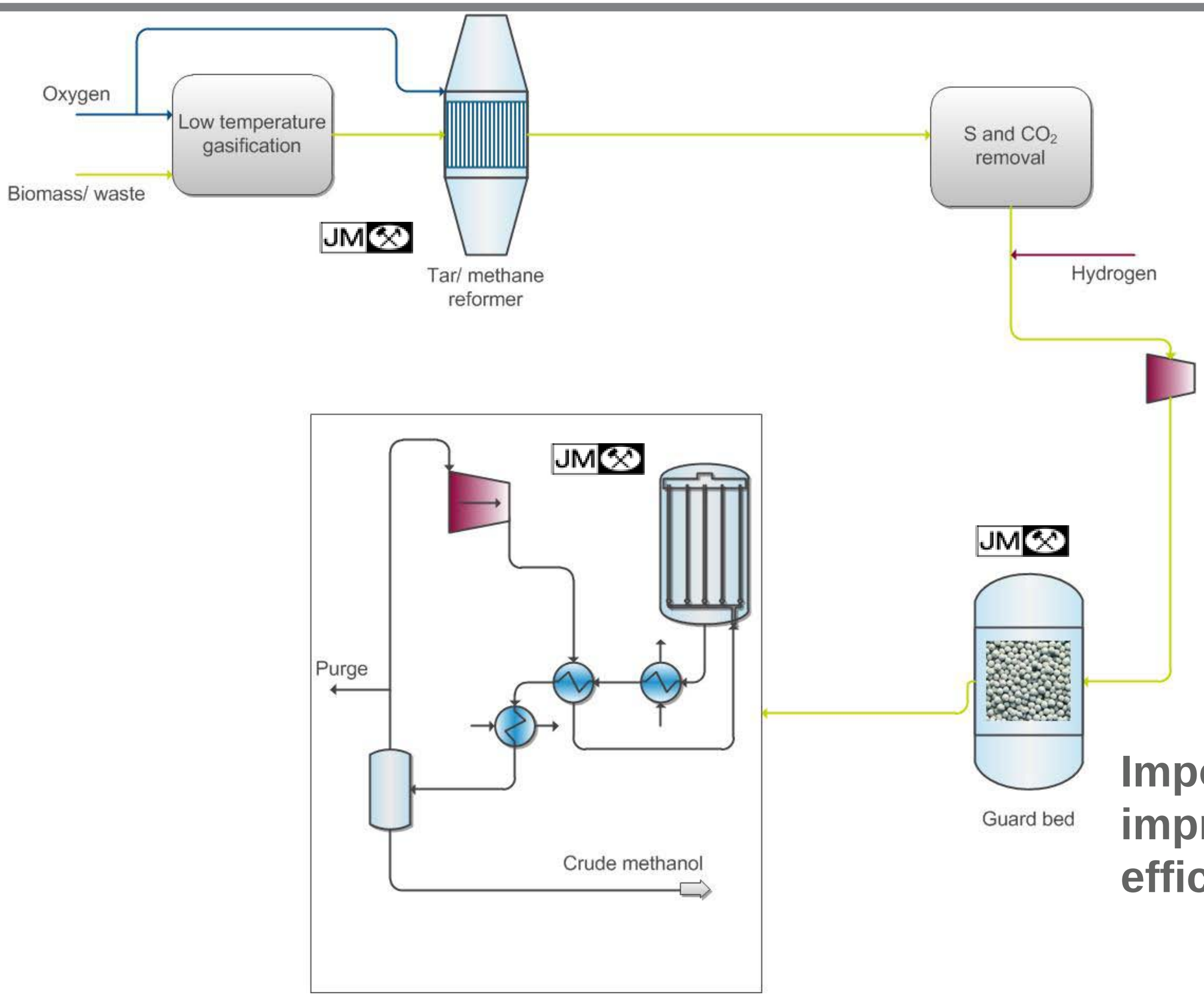
Methanol from bio-syngas

Johnson Matthey
Process Technologies



Methanol from bio-syngas

Johnson Matthey
Process Technologies



Import of hydrogen improves carbon efficiency

Methanol case study

Johnson Matthey
Process Technologies

- Basis - 4300 odtd wood feed & low temperature gasification
- Flowsheet
  - Tar scrubbing comparison vs tar & methane reforming with Ni or pgm catalyst
  - Water gas shift and carbon dioxide removal

Catalyst	Tar removal process	Temperature	Oxygen	Methanol
		°C	MTPD	MTPD
None	Solvent washing	n/a	0	1334
Nickel	Tar & CH_4 reforming	950	496	1760
PGM	Tar & CH_4 reforming	775	286	1877

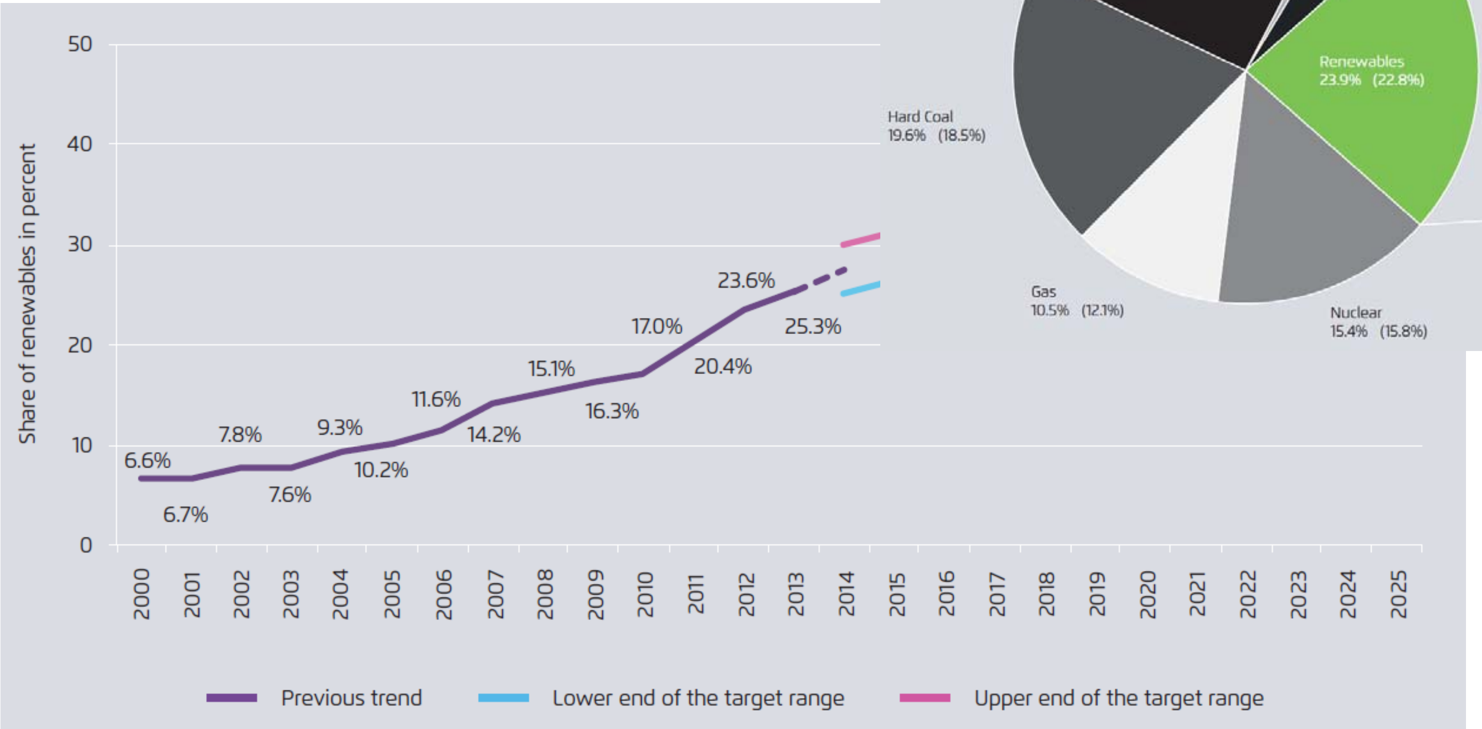
Catalysis Today 214 (2013) 74-81, [Steele, Poulston, Magrini-Blair, Jablonski]

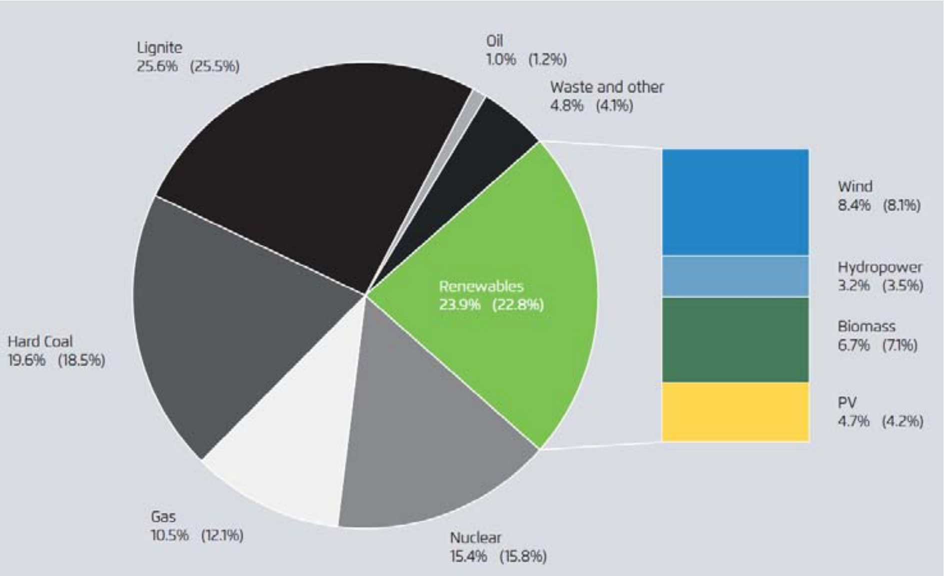
- Tar and methane reforming delivers 30-40% more methanol
  80% methane conversion
- PGM vs nickel catalyst
  45% less oxygen
  5-10% more methanol

The growth of power from wind and solar

Johnson Matthey Process Technologies

Share of renewables in German electricity consumption



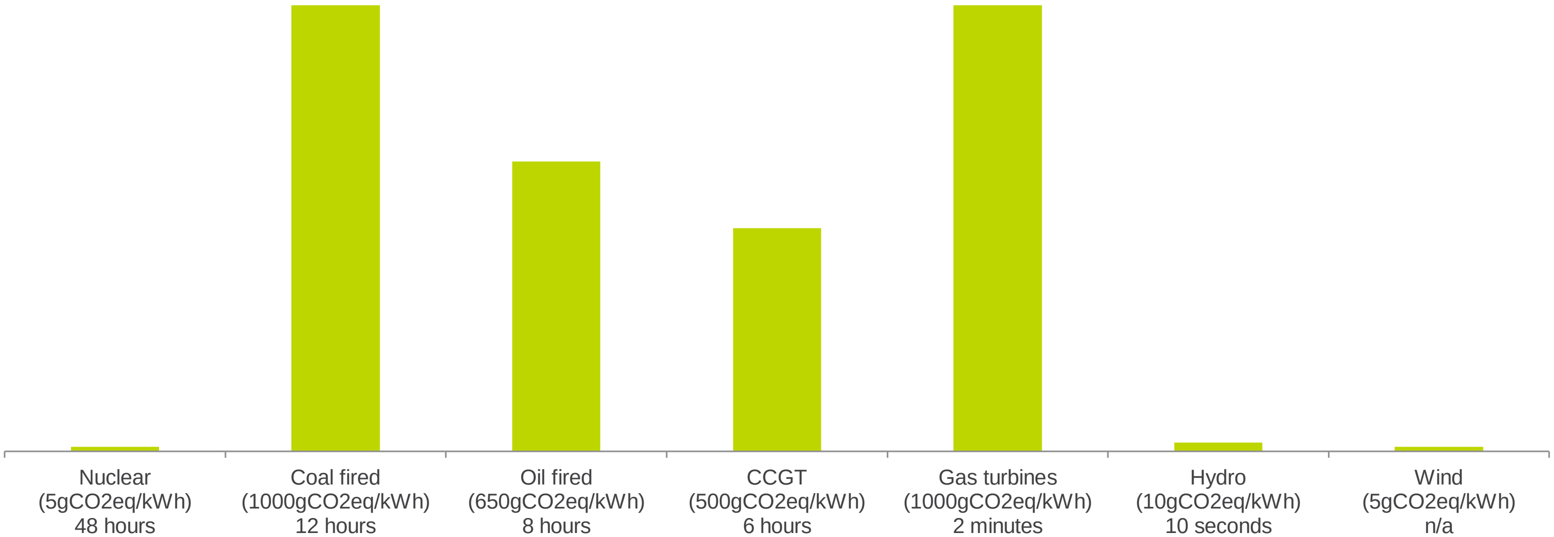


German power generation mix 2013

The German Energiewende and its climate paradox – causes and challenges [Agora Energiewende, Graichen, Berlin]

Power balancing: the supply side

Johnson Matthey
Process Technologies

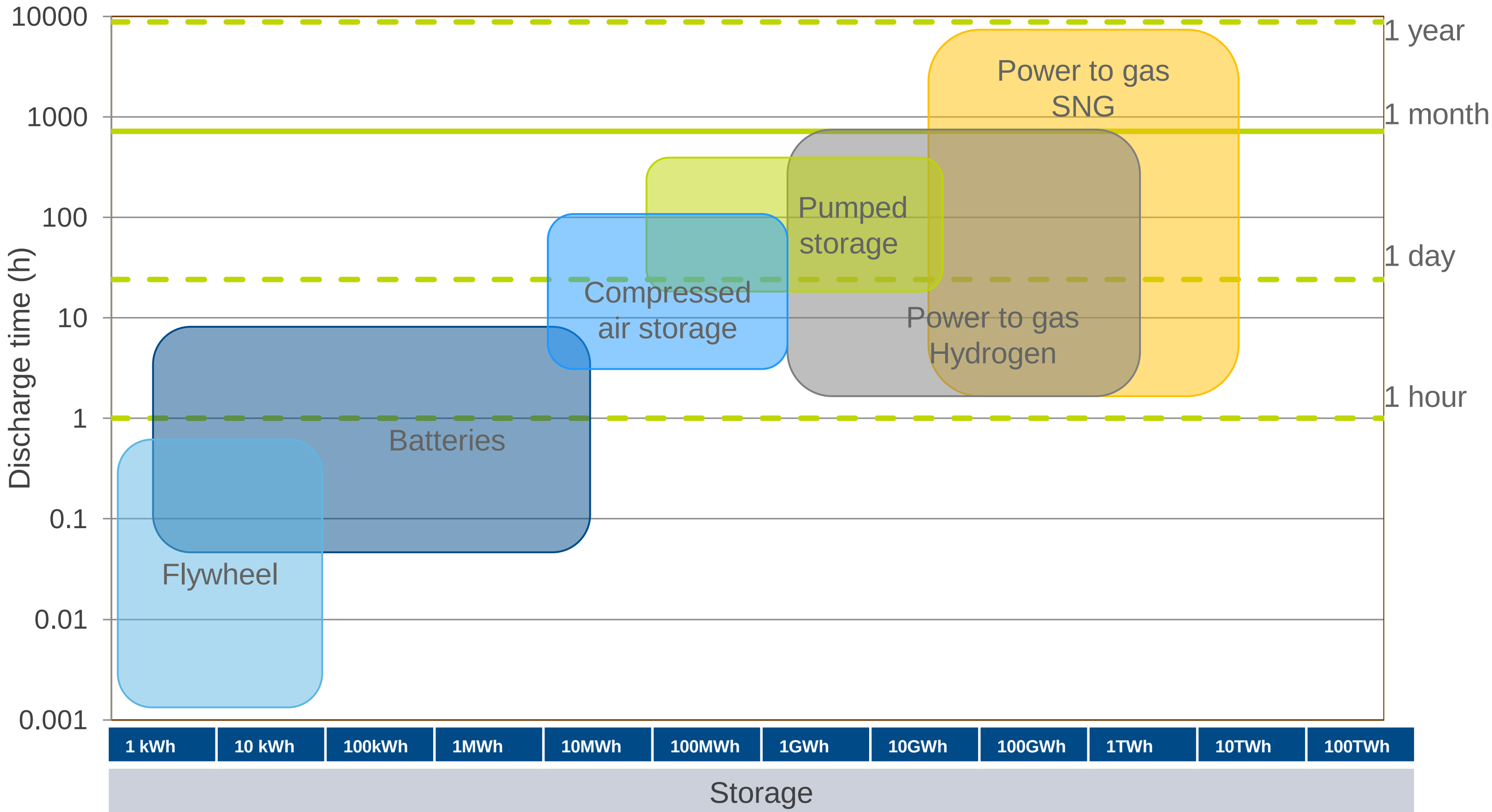


Recreated from Rapid Response Electrolysis [ITM Power, 2013, Hannover]

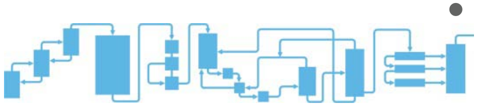
- Grid balancing and stability problems occur typically when share of renewables is >20%
- This leads to curtailment of power

Electricity storage technologies

Johnson Matthey
Process Technologies



Recreated from Power to gas webinar [ITM Power, 2014]



- Power to chemicals/fuels (gas, liquids) is an efficient, bulk energy storage process

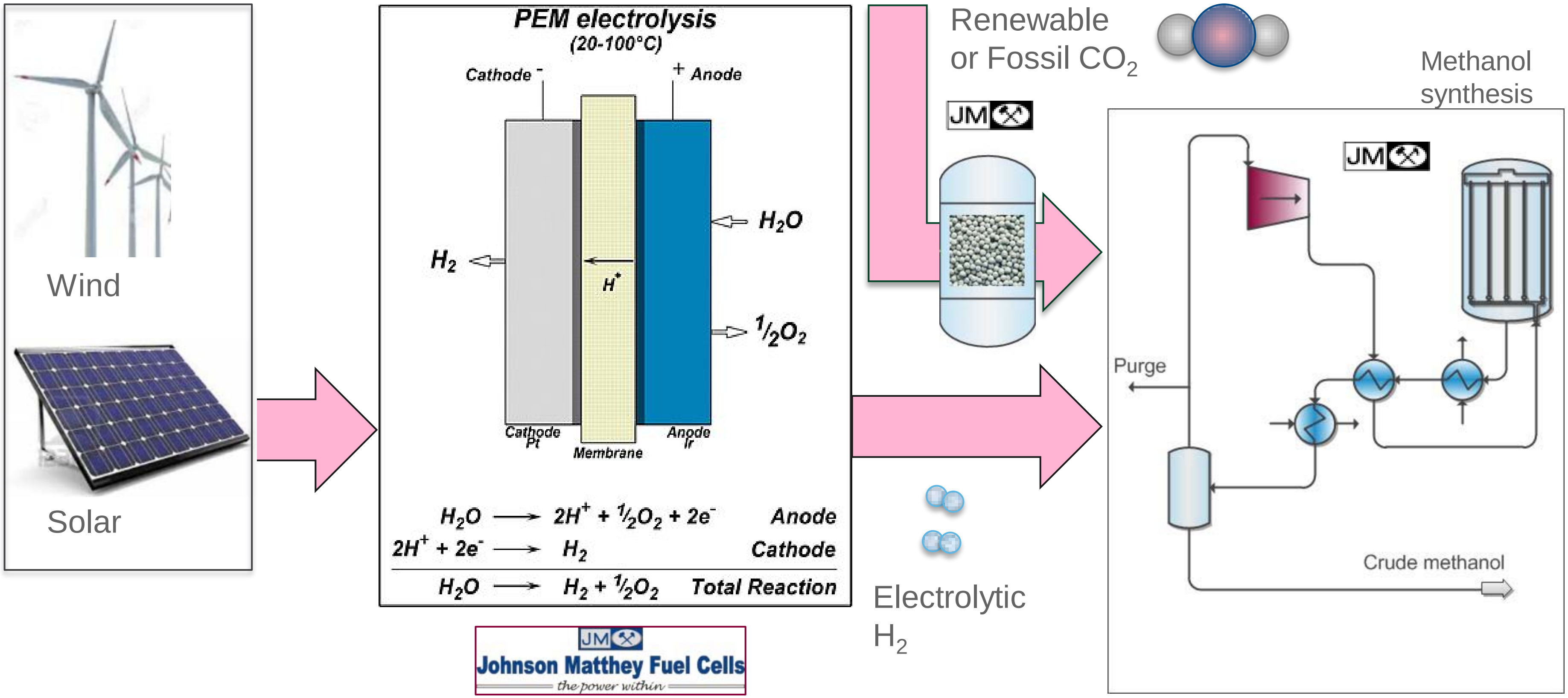
Electrolysis features (PEM*)

- Dynamically responsive (seconds)
- Can be operated to provide H_2 at high pressure
- High efficiency, low temperature process
  - 75-80% of electrical energy used to split water
- Now scaled up to 1-2MW modules
- Projected costs (p/kWhr consumed) falling
  - Larger scale equipment
  - Increasing manufacturing capacity

* Proton exchange/ polymer electrolyte membrane

H_2 from green power by electrolysis

Johnson Matthey
Process Technologies

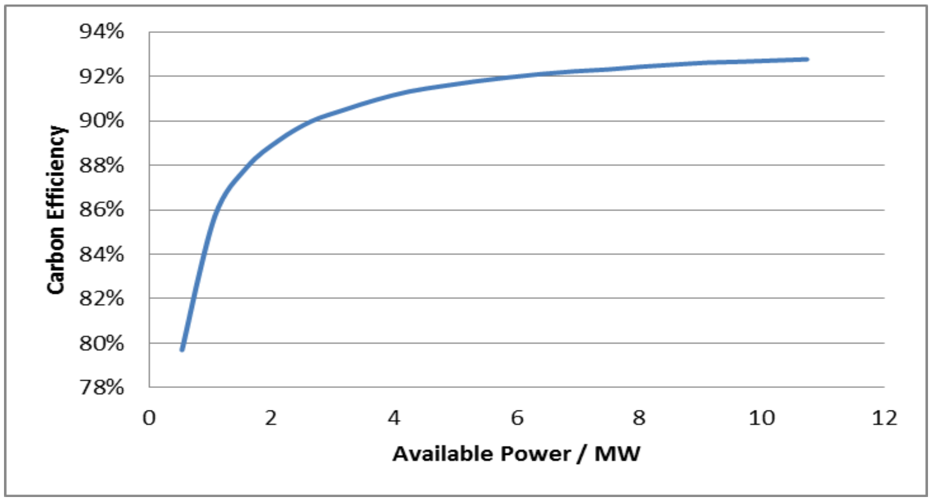


- Methanol synthesis from H_2 and CO_2
  - JM industrial experience
- Purification of CO_2 required

Methanol from renewable H_2 and CO_2

JM
Johnson Matthey
Process Technologies

- Technology requirements
  - Optimized designs and catalysts
    - Methanol from CO_2/H_2 only



Carbon conversion for an agile loop

- Flexibility/agility
  - For fast load change
  - High conversion over wide operating range

CRI methanol plant
[www.carbonrecycling.is]

- Reduced CAPEX for small scale
  - 10 – 100 MTPD methanol
  - Skid mounting & miniaturization

Summary

- Low carbon energy and fuels continue to be a key requirement for 2020 sustainability targets and beyond.
- Technologies to produce green power, fuels and chemicals are developing
  - From renewable power via electrolysis and carbon dioxide recovery
  - From biomass-derived syngas.
- Johnson Matthey is developing catalysis & technology
  - In bio-syngas purification and conditioning
  - For methanol production from renewable power