Potential for Power-to-X in South Africa

Presentation at the 4th Conference on CO2 as Feedstock

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South Africa's Council for Scientific and Industrial Research (CSIR)

The CSIR's Executive Authority is the Minister of Science and Technology

The CSIR is a science council, classified as a national government business enterprise, with six sites across South Africa, headquartered in Pretoria

In numbers:

- **70** years (established 5 October 1945)
- Close to **3 000** total staff
- …of which **1 700** scientists, engineers and technologists
- …of which more than **300** doctoral qualifications
- **8** research centres/units, three implementation units
- **~ $ 200 million** total operating income per year
  (~30% government grant to invest into new topics, 70% through contract research)

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CSIR's six Research Impact Areas (RIAs) respond to the priorities as defined by South Africa's "National Development Plan (NDP)"

Core technologies & facilities

- Materials
- Sensors
- Photonics
- Robotics
- ICT
- Modelling
- Research facilities

Agenda

Background

Options for decarbonising of the South African industry

Power-to-Liquids export potential for South Africa

Summary

Background

South Africa's is a very carbon-intensive economy

- The South African energy system is based on domestic coal and on imported oil
- More than 50% of South Africa's CO2 emission is due to electricity production from coal (Eskom)
- ~16% of South Africa's CO2 emissions are due to production of synthetic fuels and commodity chemicals from coal (Sasol)

The South African Department of Energy is procuring new generation capacity and has already allocated a total of 8.1 GW of renewables (mainly wind & PV) for procurement from Independent Power Producers

- … of this, 6.3 GW have achieved preferred bidder status
- … of this, 4.0 GW have financially closed and signed the Power Purchase Agreements with Eskom
- … of this, ~1.8 GW are operational and feed energy into the grid as of end of June 2015

The renewables tariffs are now amongst the cheapest anywhere in the world – thanks to the excellent wind and solar resources combined with a highly successful, stringent & efficient procurement programme

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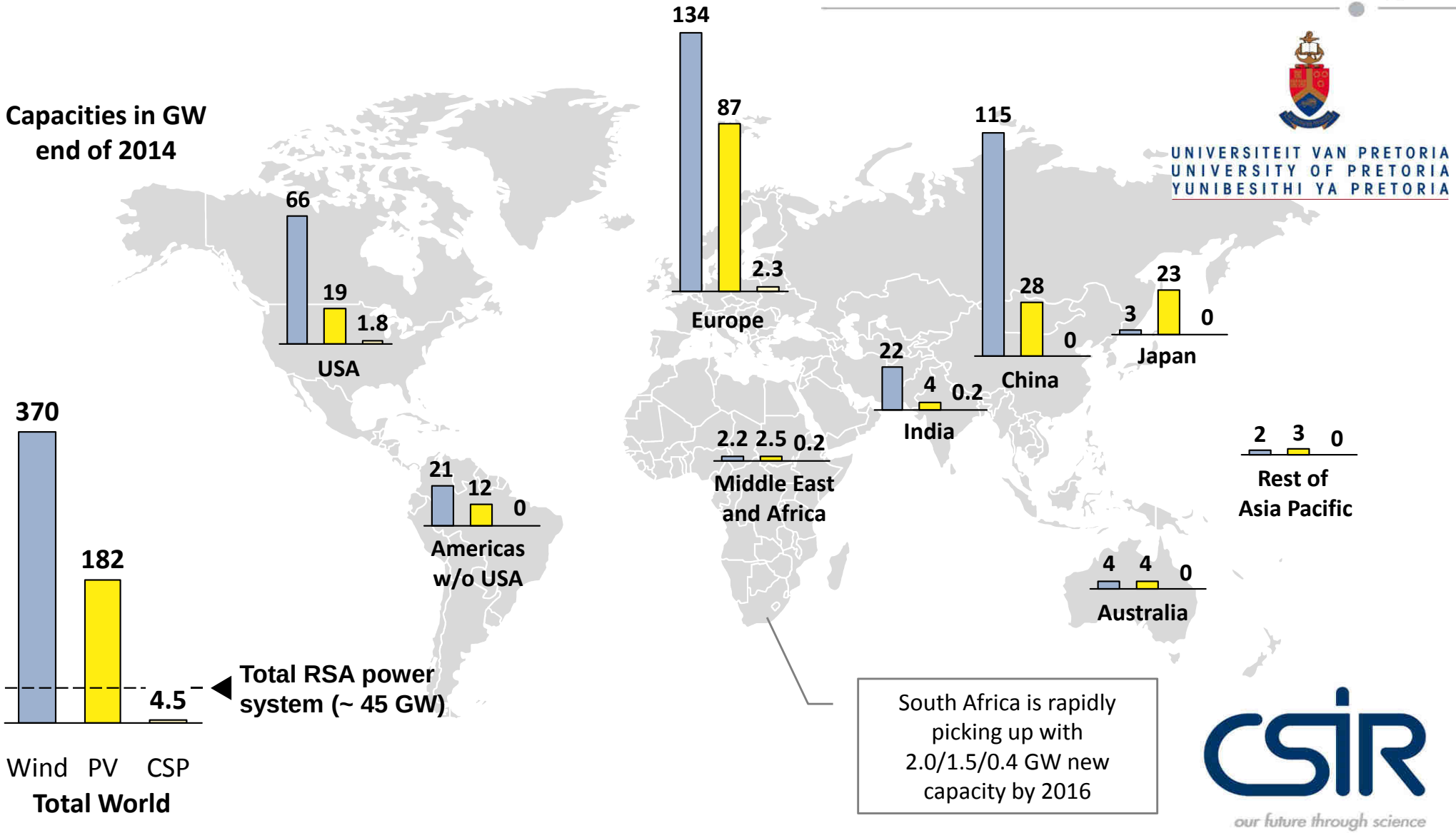
Sources: CSIR Energy Centre analysis

Renewables until today mainly driven by US, Europe and China

Globally installed capacities for three major renewables wind, PV and CSP end of 2014



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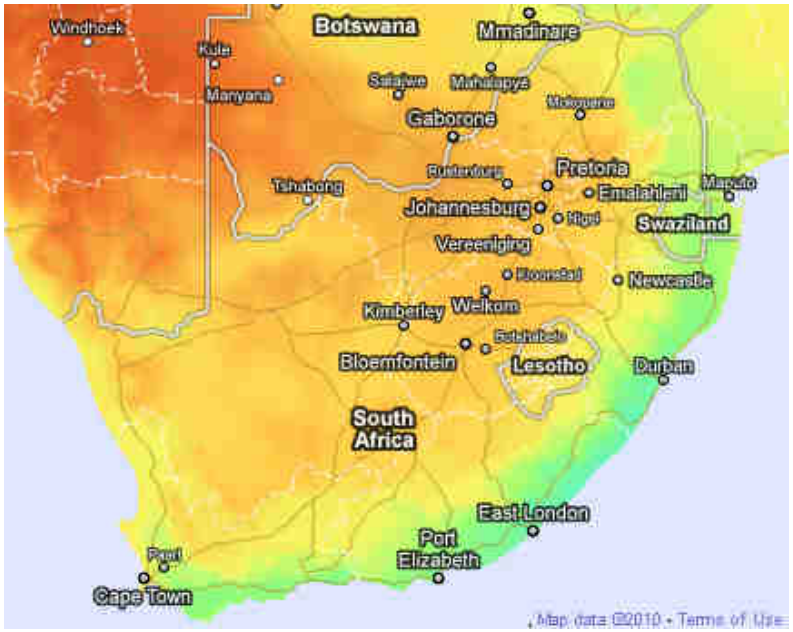
Sources: GWEC; EPIA; CSPToday; CSIR Energy Centre analysis

Very high solar irradiation in South Africa is a competitive advantage

Compared to Germany, where solar PV is now close to cost competitiveness with new coal and gas…

... South Africa's solar irradiation is very high



Yearly total of global irradiation on horizontal surface

750 — 1250 — 1750 — 2250 — 2750 [kWh/m²]

Average for Germany

Average for South Africa (2x)

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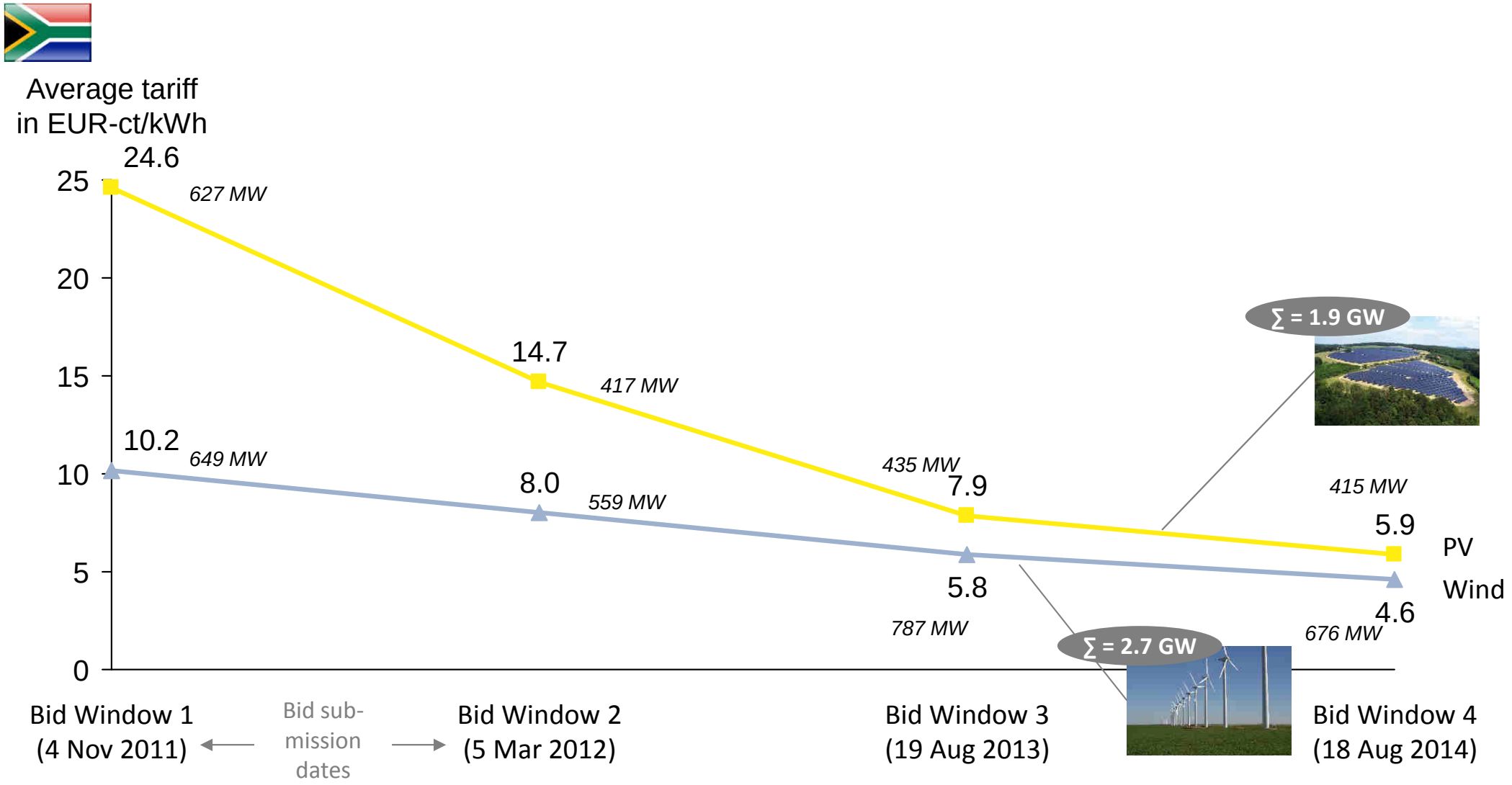
Source: Joint Research Center of the European Commission, PVGIS, BCG analysis

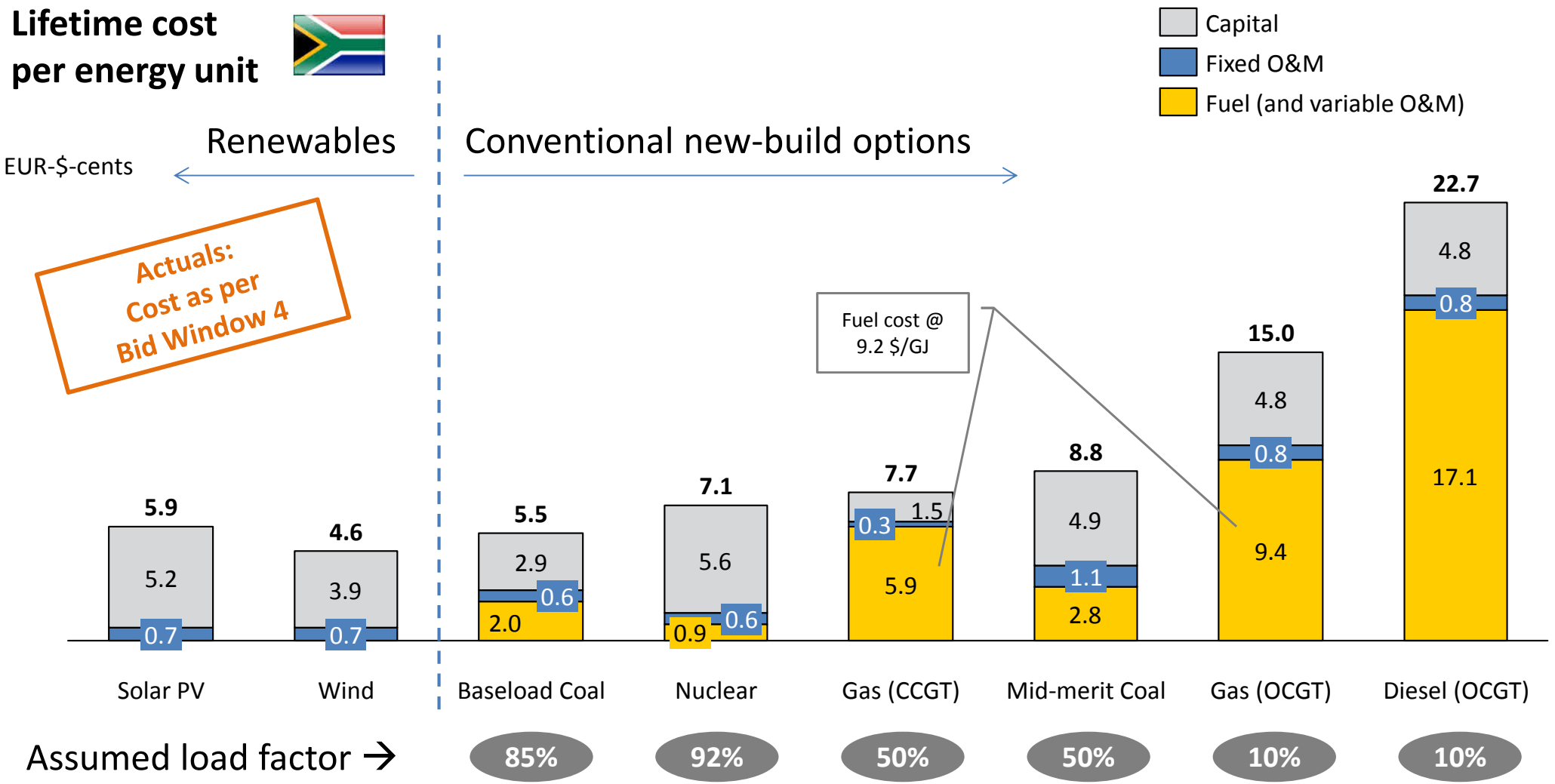
Actual results: solar PV & wind in South Africa cost competitive today

First four bid windows' results of Department of Energy's RE IPP Procurement Programme (REIPPPP)



Note: BW = Bid Window; Sources: Department of Energy's publications on results of first three bidding windows http://www.energy.gov.za/IPP/List-of-IPP-Preferred-Bidders-Window-three-04Nov2013.pdf; http://www.energy.gov.za/IPP/Renewables_IPP_ProcurementProgram_WindowTwoAnnouncement_21May2012.pptx; StatsSA on CPI; CSIR Energy Centre analysis

Consequence of renewables' cost reduction: Solar PV & wind cheapest new-build options per kWh in South Africa



Note: Changing full-load hours for conventionals drastically changes the fixed cost components per kWh (lower full-load hours → higher capital costs and fixed O&M costs per MWh);
Assumptions: average efficiency for CCGT = 50%, OCGT = 35%; coal = 37%; nuclear = 33%; IRP cost from Jan 2012 escalated with CPI to May 2015; assumed EPC CAPEX inflated by 10% to convert EPC/LCOE into tariff; CSP: 50% annual load factor and full utilisation of the five peak-tariff hours per day assumed to calculate weighted average tariff from base and peak tariff
Sources: IRP Update; REIPPPP outcomes; StatsSA for CPI; Eskom financial reports on coal/diesel fuel cost; CSIR Energy Centre analysis

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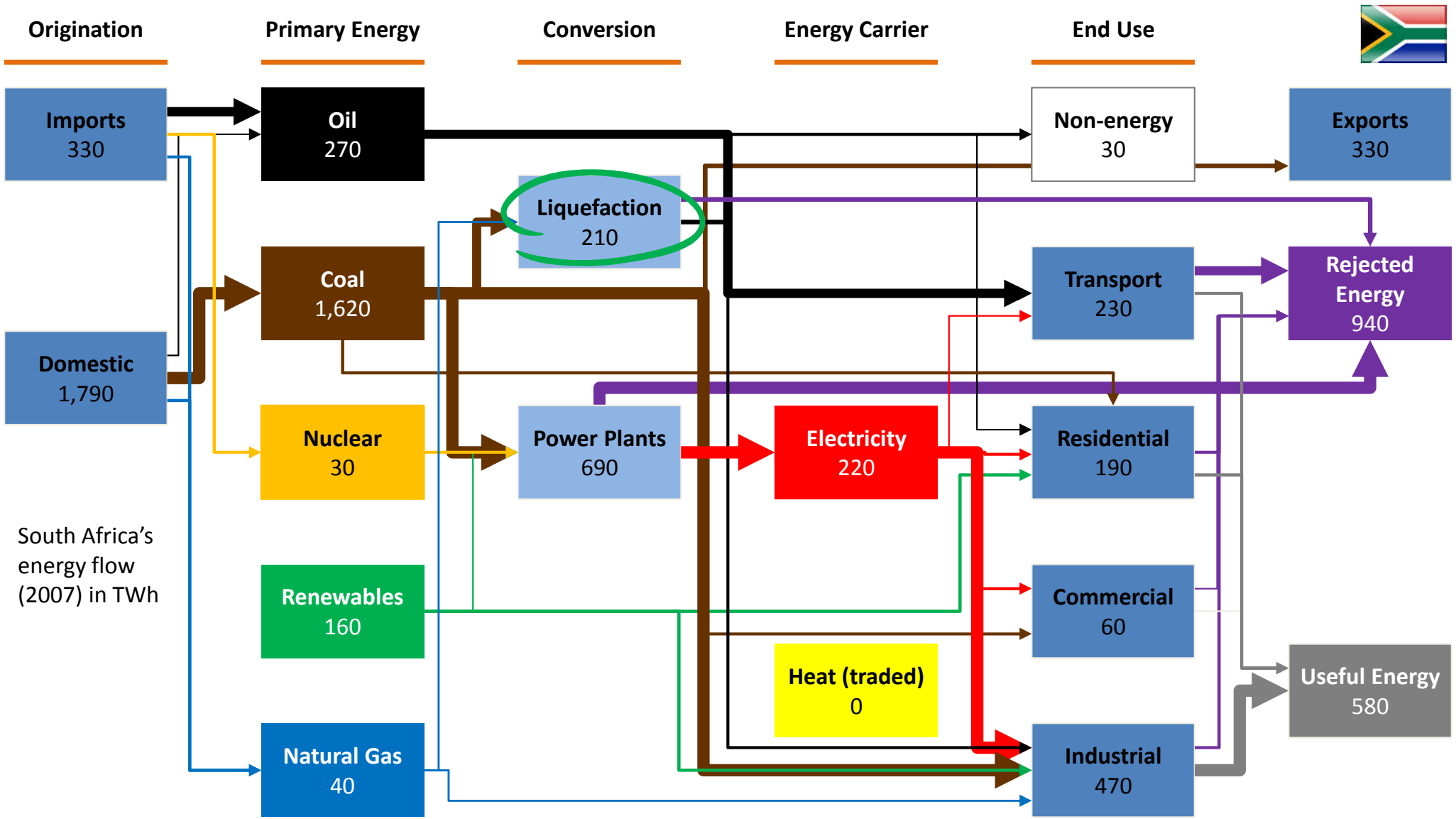
South Africa's energy system relies on domestic coal and imported oil

Energy-flow diagram (Sankey diagram) for South Africa in 2007 in TWh



Sources: Lawrence Livermore National Laboratory; World Nuclear Association; IEA; Eskom; StatsSA; CSIR design and analysis

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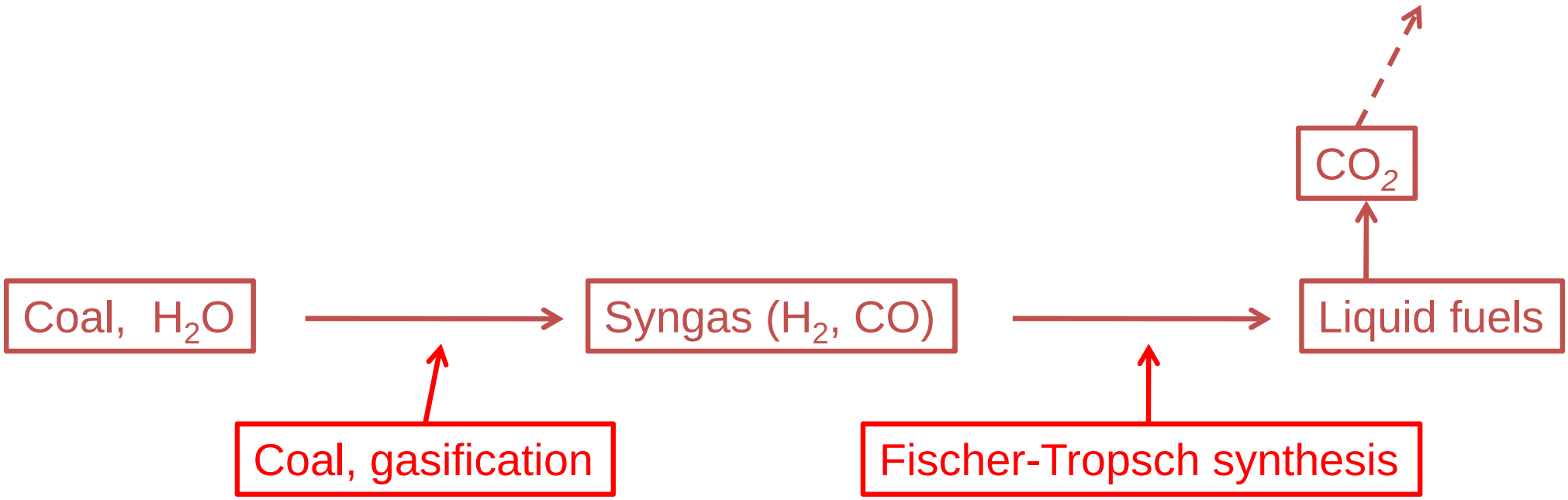
Options for decarbonising of the South African industry

Power-to-Liquids export potential for South Africa

Summary

Recycling clean CO2 to syngas at Sasol



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Sources: UP analysis

Recycling clean CO2 to syngas at Sasol

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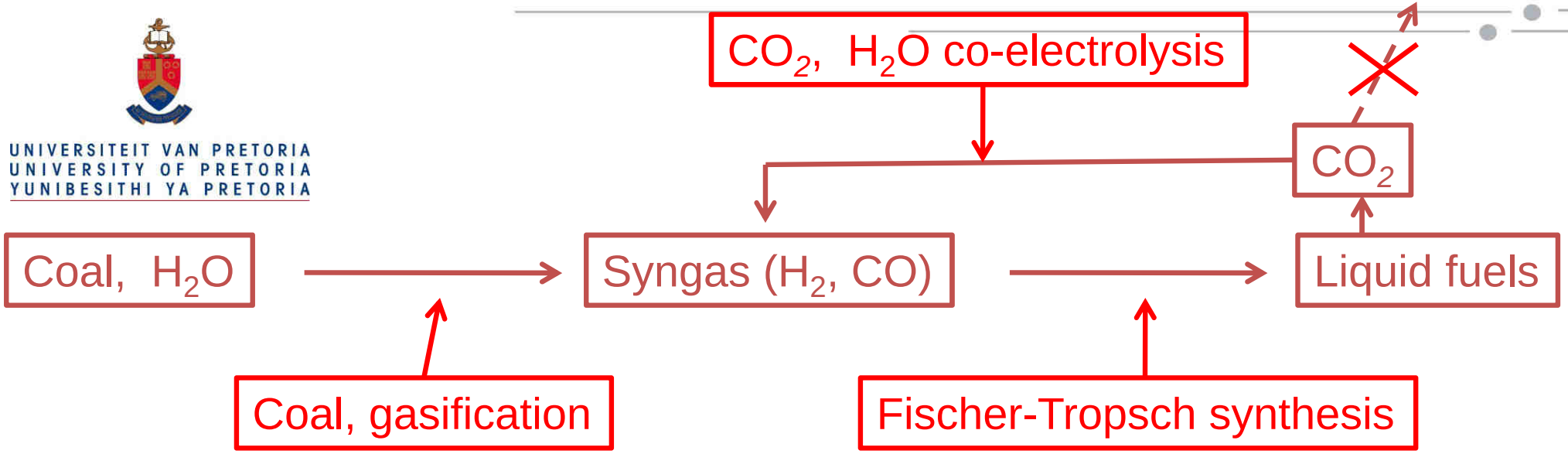
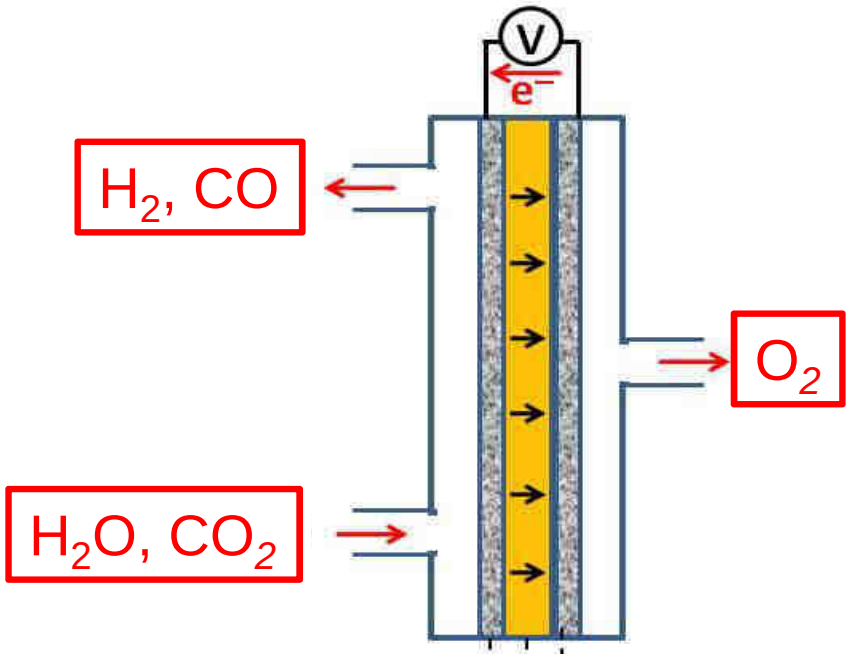


CO_2, H_2O co-electrolysis:
(Solid Oxide Electrolysis Cell, SOEC)

- Use photovoltaic electricity
- Two independent processes
- H_2/CO ratio flexible
- Operating temperature 700-900°

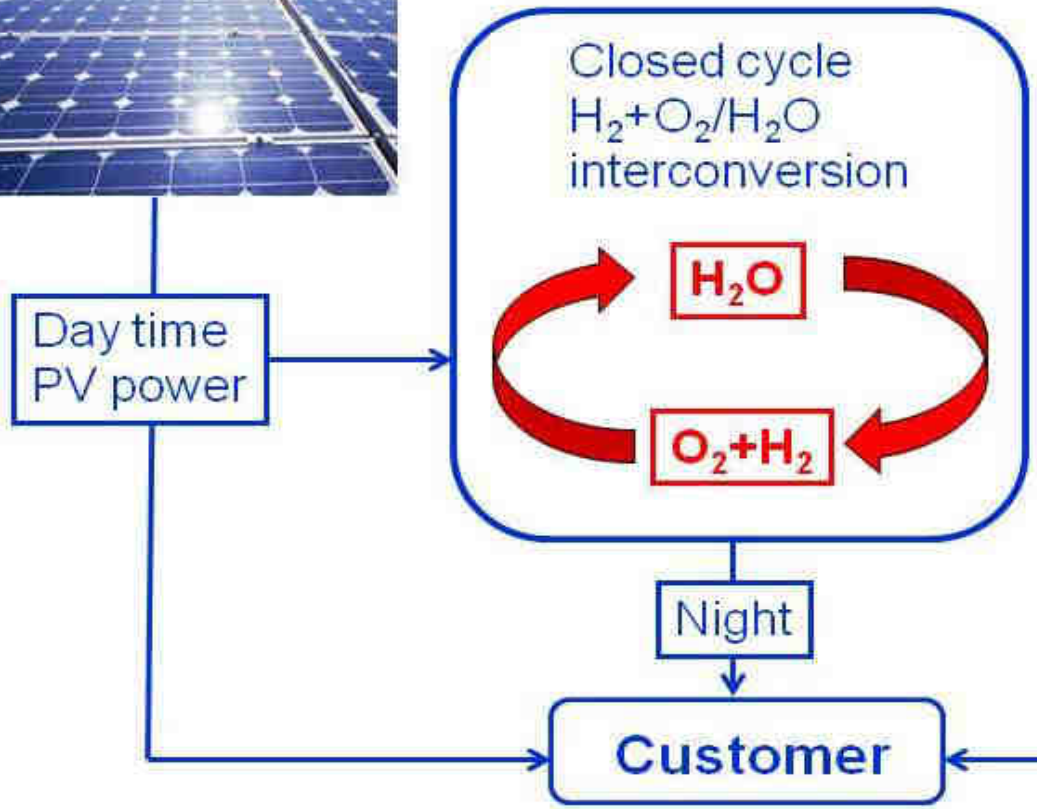


Sources: UP analysis

Short-time energy storage in form of H2 using SOEC/SOFC

Advantages:

- Flexible switching between H_2 production and H_2 use (minutes)
- High round-trip efficiency (need significant up-scale)



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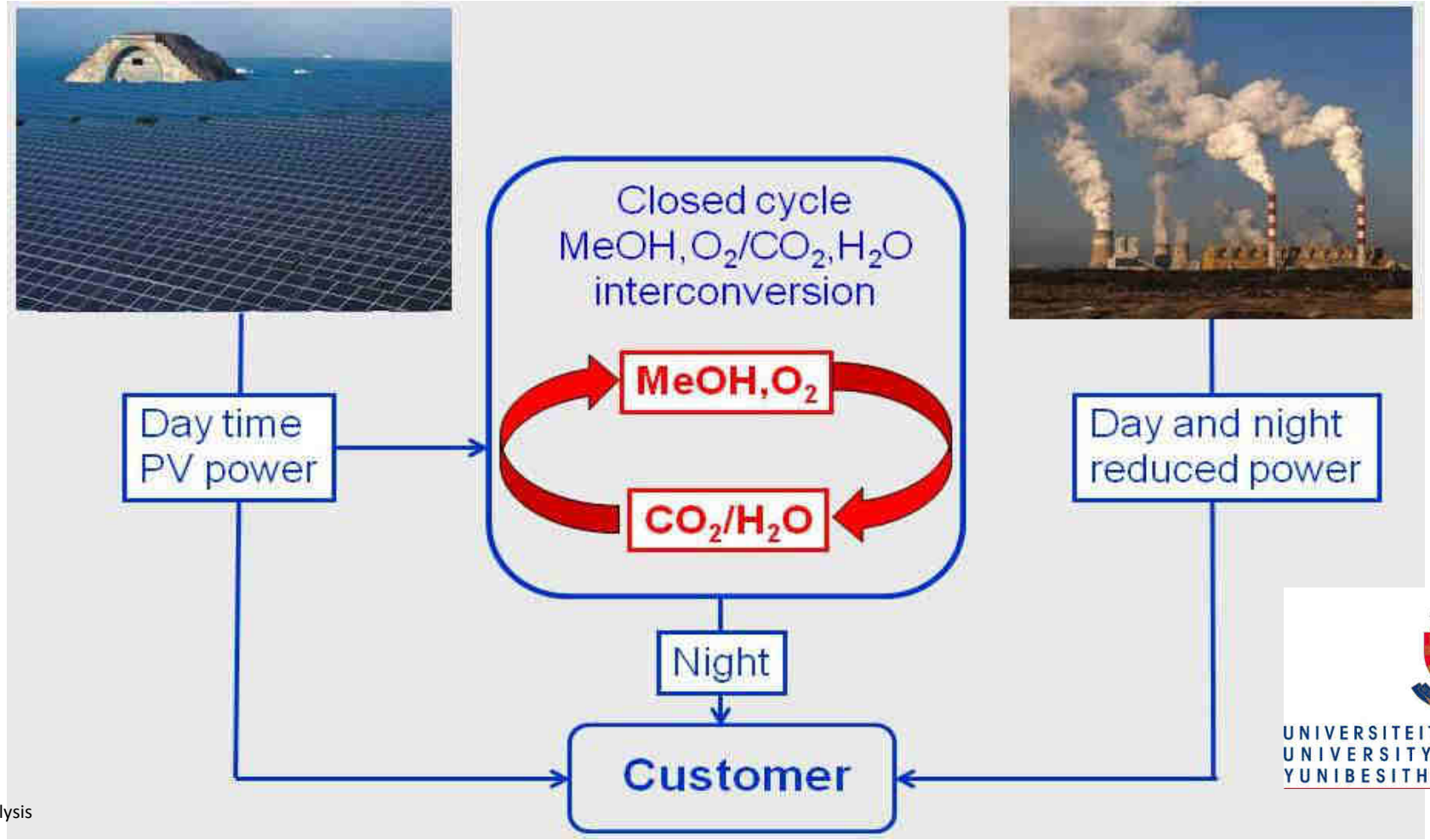
Sources: UP analysis

Medium/long-term: energy storage as liquid fuel

Advantages:

- Easy storage
- Transportable using existing technology
- Use by combustion or in PEM fuel cells

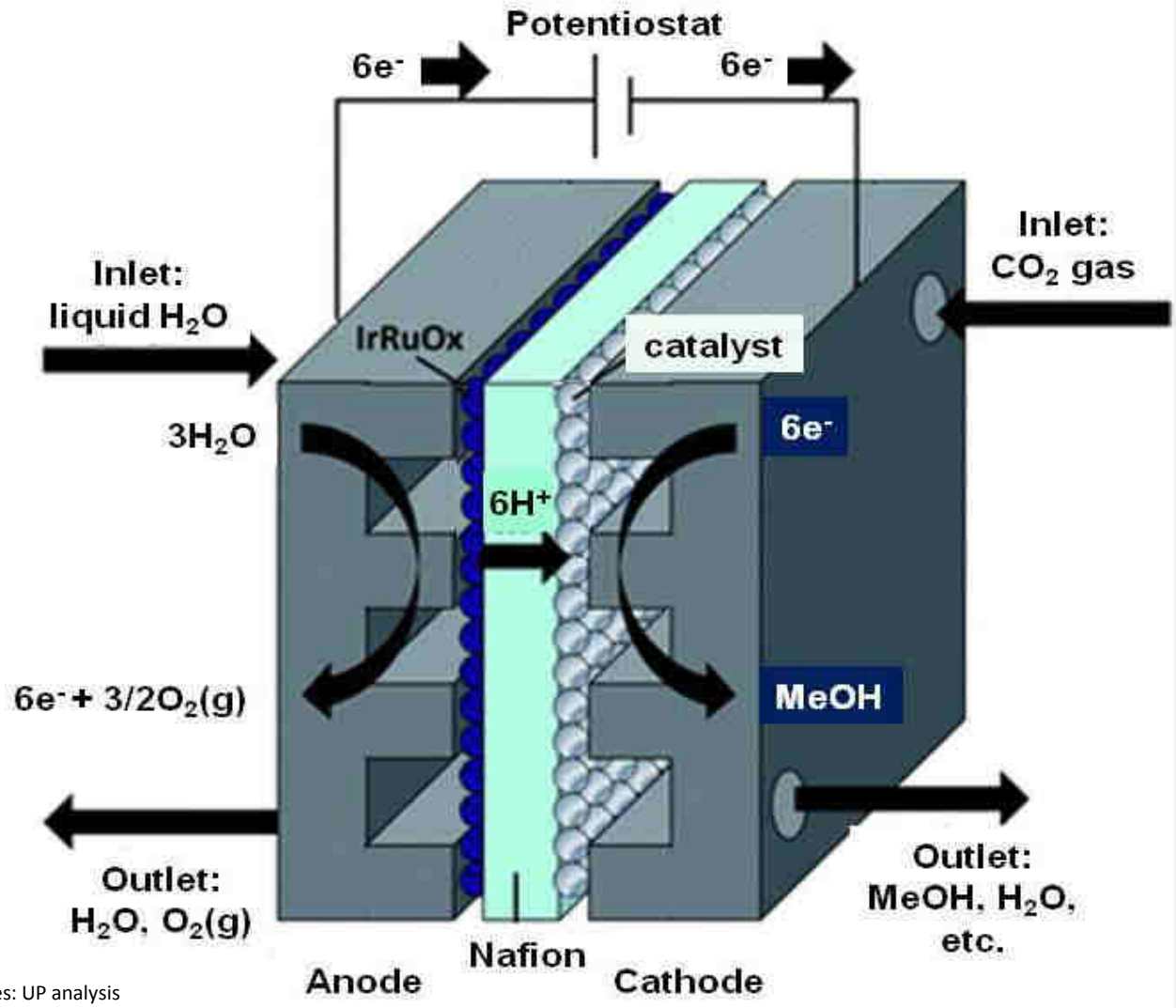


Sources: UP analysis

MeOH production by co-electrolysis of CO2 and water near 25° using inverse Direct Methanol Fuel Cell (DMFC)

Challenge:

Need cathode catalyst with better efficiency and selectivity



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Sources: UP analysis

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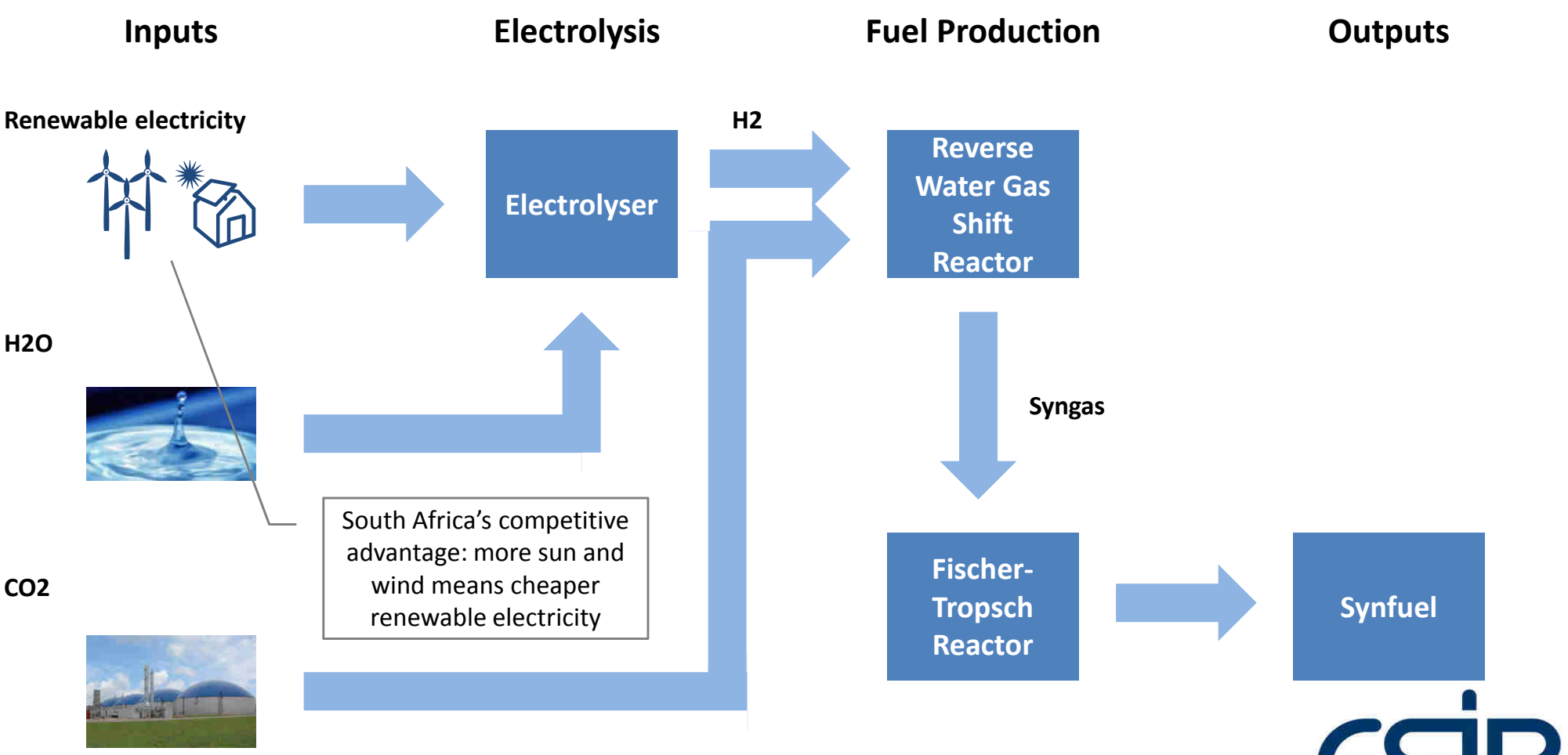
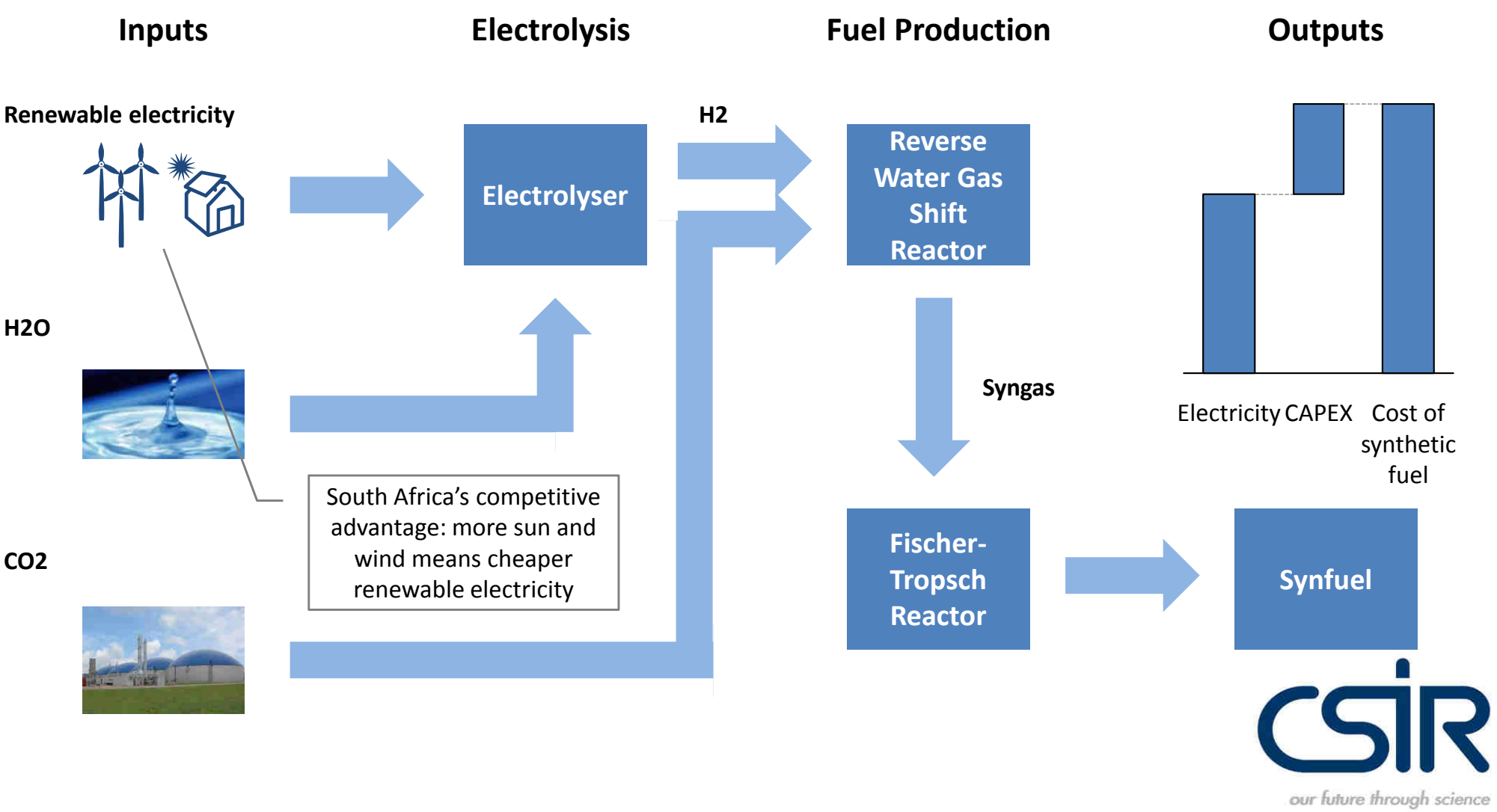
Producing carbon-neutral synthetic fuels from cheap renewable power could be a business case for South Africa …



Sources: CSIR Energy Centre analysis

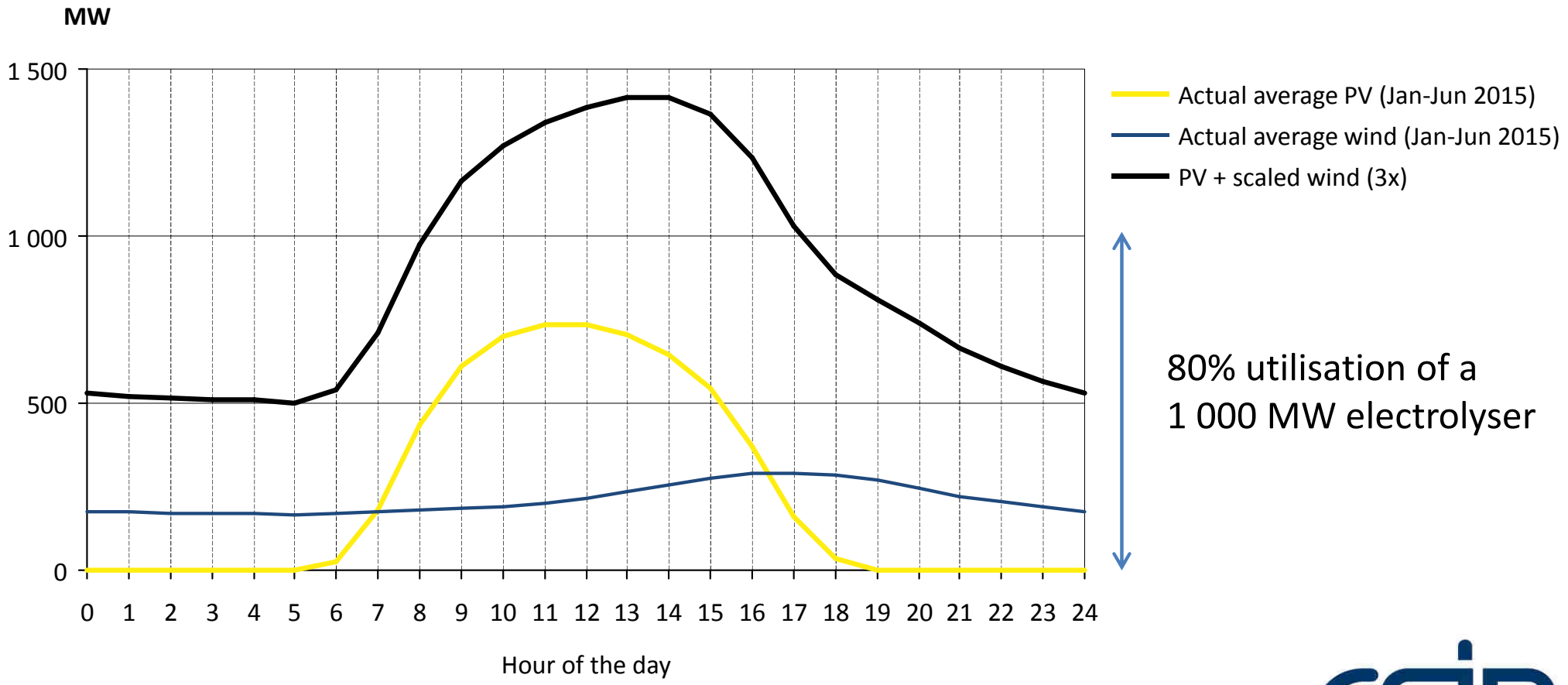
… because the main cost driver is cost of renewable electricity input



Sources: CSIR Energy Centre analysis

Solar PV and wind combined lead to very high load factors

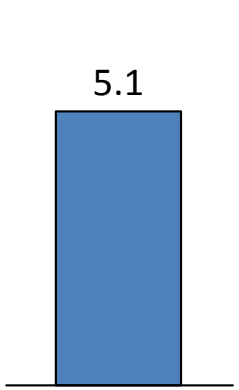
Actual average daily solar PV and wind production profile in South Africa from Jan-Jun 2015



Already at today's renewable electricity cost in South Africa, PtL is not far from competitiveness with production cost of biofuels

Actual average wind/solar PV tariff in South Africa today

EUR-ct/kWh



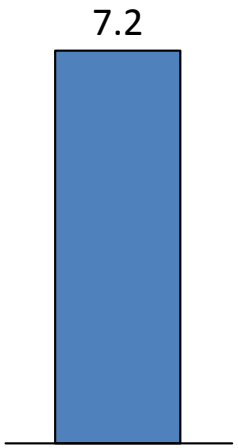
Solar/wind cost

./.

70% efficiency (optimally)

Pure electricity cost of PtL plant fed with South African wind/PV power

EUR-ct/kWh

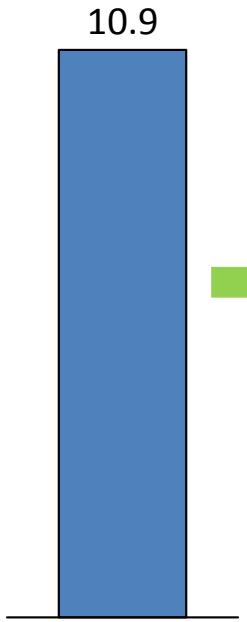


PtL electricity cost component

→ **Electricity approx. 2/3 of total cost**

Total PtL production cost

EUR-ct/kWh



Total PtL cost

Below 1 EUR/litre

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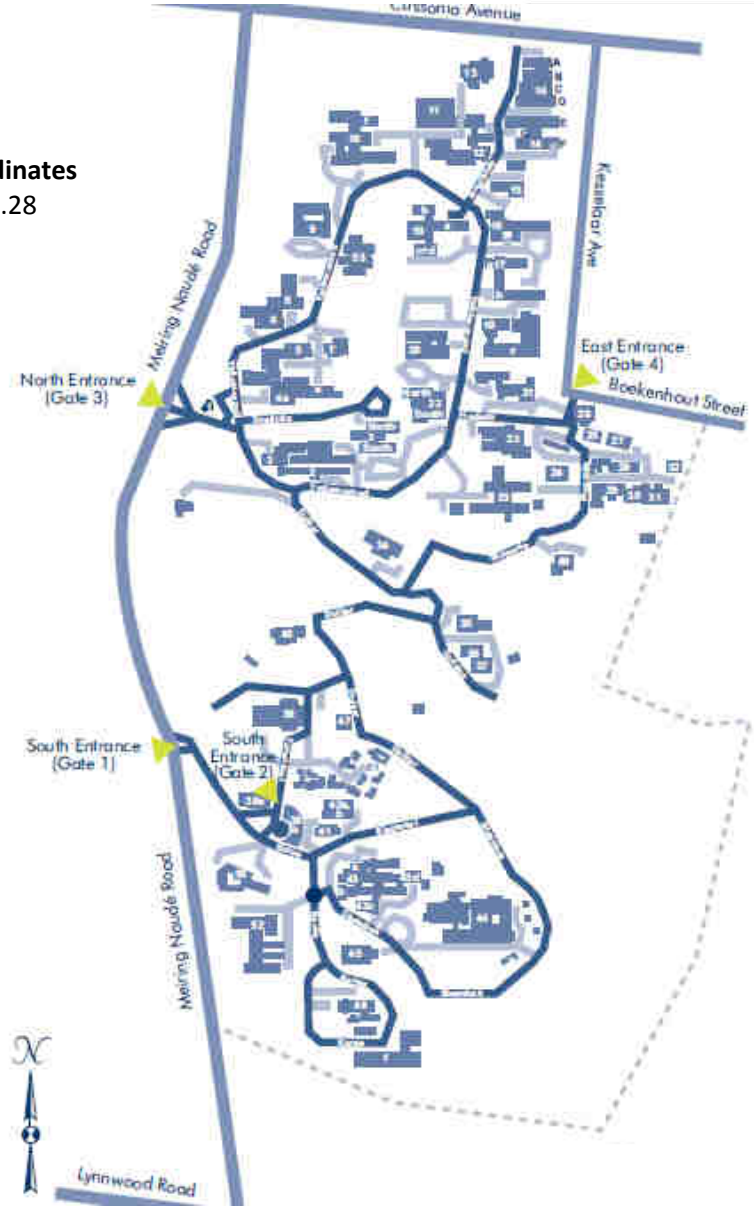
Sources: CSIR Energy Centre analysis

Today: CSIR's main campus in Pretoria is a large electricity consumer

GPS coordinates
-25.75, 28.28



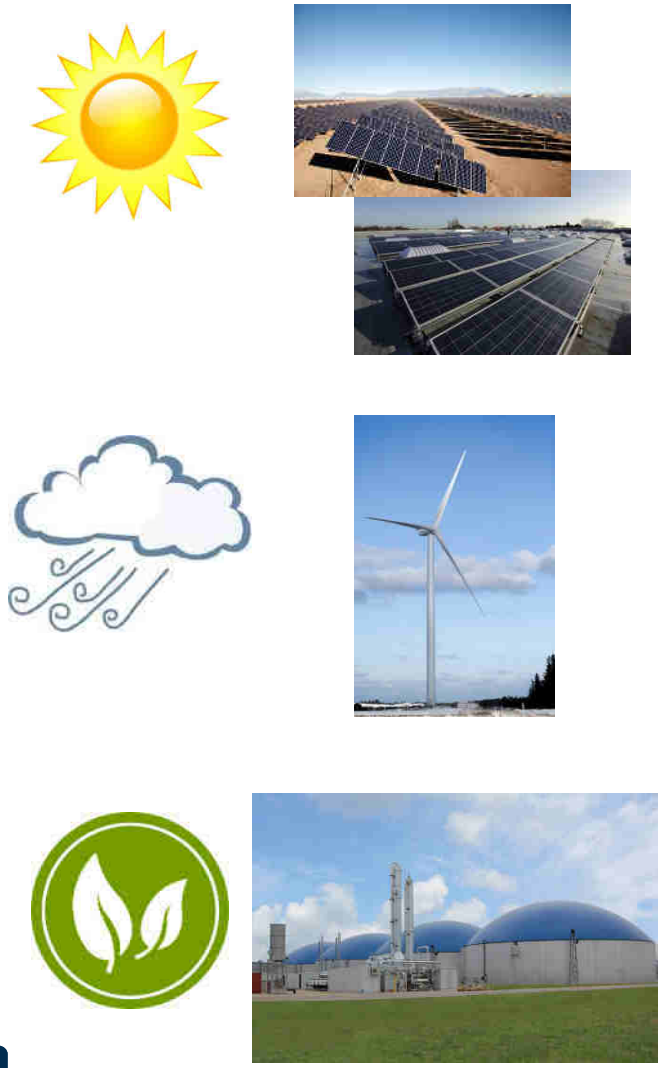
CSIR Campus today

- *52 buildings*
- *150 ha*
- *30 GWh/yr electricity demand*
- *3 MW base load*
- *5-6 MW peak load*

Equivalent of 7 500 German 4-person households

Sources: CSIR Energy Centre analysis

Future: renewables-based synfuels will be piloted at the CSIR's campus as part of the already initiated "CSIR Energy-Autonomous Campus"



Sources: Enertrag; modified and expanded by CSIR

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Power-to-X provides a huge potential for South Africa

South African renewable electricity will always be cheaper than in most other countries in the world

- Excellent solar & wind resources let South Africa achieve some of the world's lowest renewables tariffs
- Cheapest renewable electricity is a competitive advantage that will always be there

In addition, South Africa has vast experience in the creation of synthetic liquid fuels

- The country gets roughly 1/3 of its liquid fuel demand from Coal-to-Liquid
- Sasol is one of the largest Coal-to-Liquid producers globally

This combination provides a huge opportunity for South Africa to commercialise renewable-electricity-based, carbon-neutral synthetic fuels from Power-to-Liquid processes

The EU has started to create the market for such fuels via its mandatory biofuels blending requirements

The CSIR will together with the University of Pretoria pilot a Power-to-Liquid plant on its campus to help commercialise the technology in South Africa

We are looking for partners in this endeavour

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Thank you!