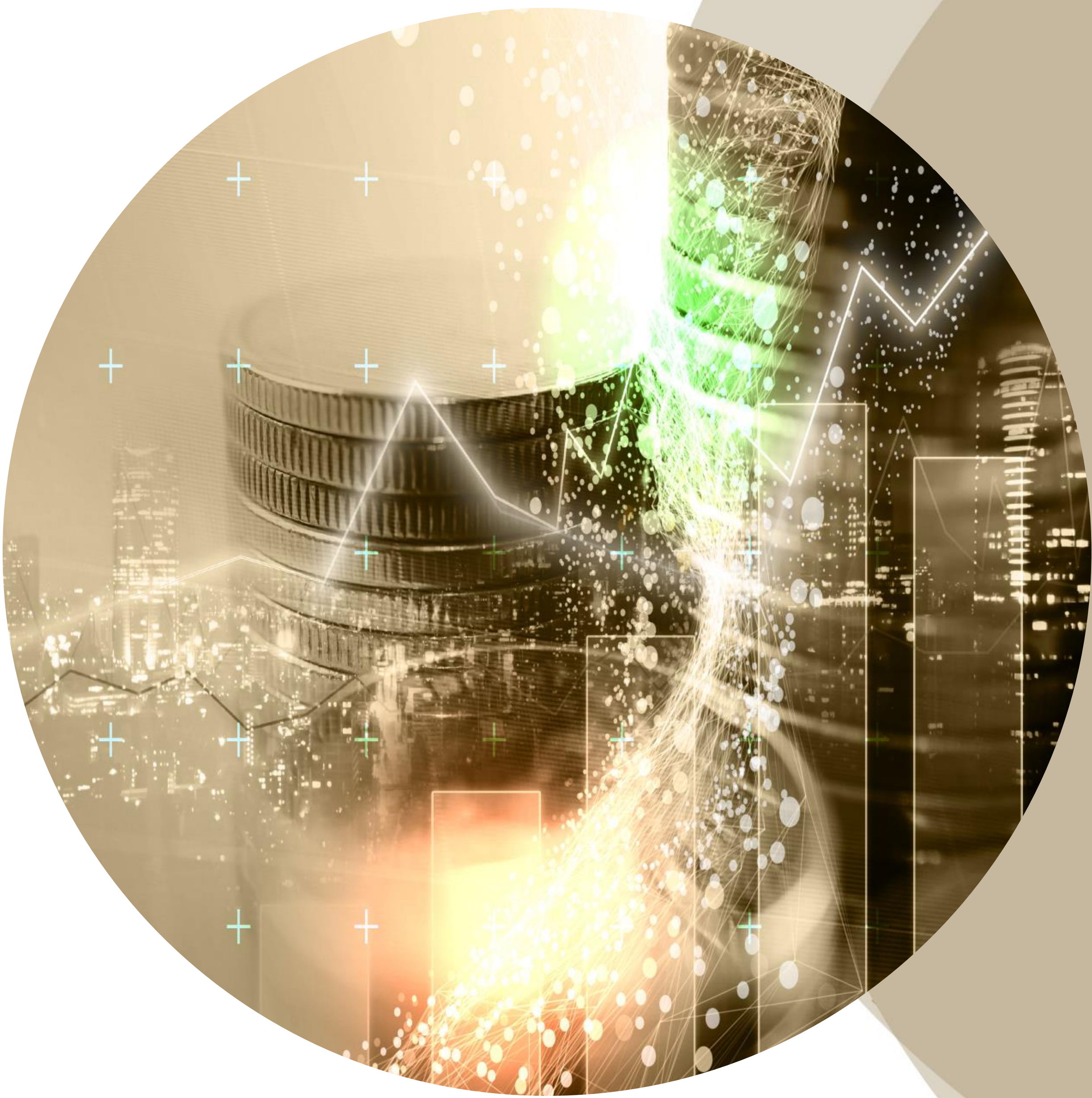

White Paper - Monetising Molecules

- An overview of the costs and drivers impacting grey, blue, and green hydrogen

September 2020

advisian.com

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Company details

Advisian Group Ltd.

5995 Rogerdale

Houston

Texas 77072

USA

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Acronyms and Abbreviations

Acronym/abbreviation	Definition
AEM	Anion Exchange Membrane
ATR	Autothermal Reforming
BEV	Battery Electric Vehicle
CAPEX	Capital Expenditure
CCU	Carbon Capture and Utilization
CCU/S	Carbon Capture, Utilization / Storage
CO_2	Carbon Dioxide
COMAH	Control Of Major Accident Hazards
DEVEX	Development Expenditure
EPCm	Engineering Procurement and Construction Management
FEED	Front End Engineering Design
GW	Gigawatt
axH_2	Hydrogen
HSE	Health, Safety, and Environment
HTSE	High Temperature Steam Electrolysis
IEA	International Energy Agency
IRR	Internal Rate of Return
LNG	Liquified Natural Gas
LOHC	Liquid Organic Hydrogen Carrier
MW	Megawatt
O&G	Oil and Gas
OPEX	Operational Expenditure
PEM	Proton Exchange Membrane
PPA	Power Purchase Agreement
PV	Photo Voltaic
P2G	Power to Gas
SMR	Steam Methane Reforming
TIC	Total Investment Cost
TRL	Technology Readiness Level
WACC	Weighted Average Cost of Capital
WEC	World Energy Council

Executive summary

Low carbon hydrogen is increasingly viewed as one of the key pillars of the energy transition. With markets ranging from spacecraft to heating for homes, from shipping to decarbonizing of steel, the pressure on the low carbon hydrogen industry to step up and be a change agent is immense.

To prevent another hype cycle on the opportunities this represents, clarity of information and analysis is needed on the costs of production, the energy required to produce the hydrogen, impact of the water as a feedstock and the time it will take to move from a predominately gray hydrogen market to predominately low carbon hydrogen market.

With the proliferation of advocacy-based reports purporting to show a race to the bottom in terms of cost of production of low-carbon hydrogen, these increasingly must be taken in context, of what they do, and do not represent. For example, water costs, land costs, and installation costs can be implicitly dropped out of any cost analysis. And conversely where factors such as land push up the cost of production, they also often ignore salvage value, which can impact the overall economic value. For PEM electrolysers, especially which contain precious group metals (PGMs) the potential salvage value can have a positive net impact on the overall lifetime cost of production.

In such an early stage market, these aspirational prices can have a damaging effect when developers come to translating reports into deployment. It for this reason that ACRIS has developed an engineering-based hydrogen cost of production mode and is developing further modules on cost of distribution and market demand. These models are designed to allow the users to vary key inputs to assess the impact on cost of production. This tool can be found in the ACRIS website under “Insights.”

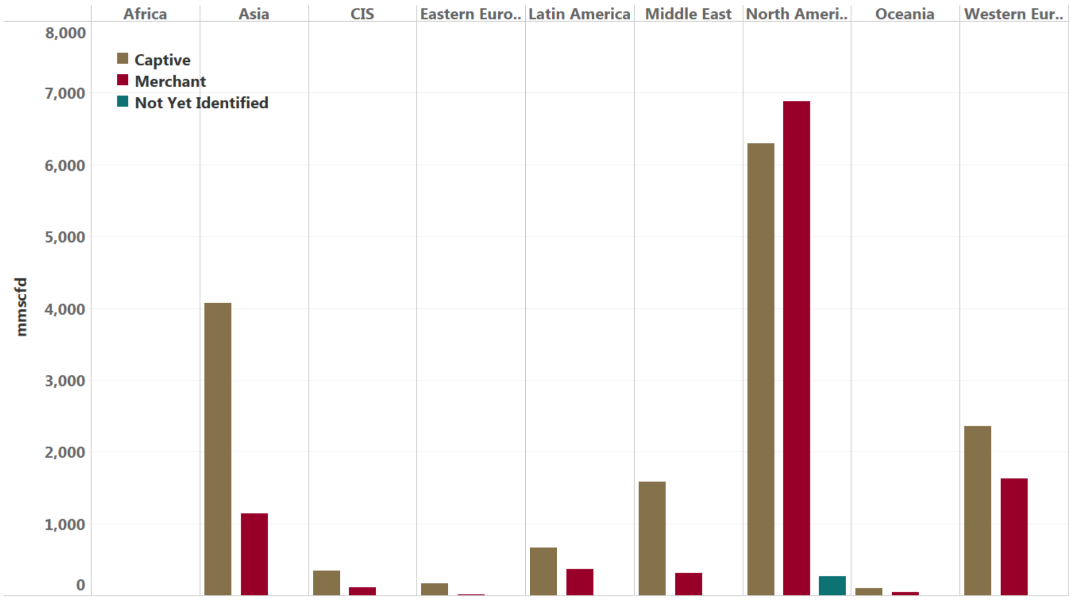
> *“The world in the 21st century must transition to widespread low carbon energy use. Hydrogen is an indispensable resource to achieve this transition because it can be used to store and transport wind, solar and other renewable electricity to power transportation and many other things,”*
>
> *Takeshi Uchiyamada, Chairman of Toyota Motor Corporation and former co-chair of the Hydrogen Council.*
> (Hydrogen Council, 2017)

1 Introduction

1.1 ACRIS Hydrogen Model Introduction

Low carbon hydrogen – referred to in the rest of this report as hydrogen - is anticipated to be an important energy source in the transition away from hydrocarbon-based fuels and greenhouse-gas intensive manufacturing.

Figure 1: 2020 Hydrogen Supply by Market Model[1]



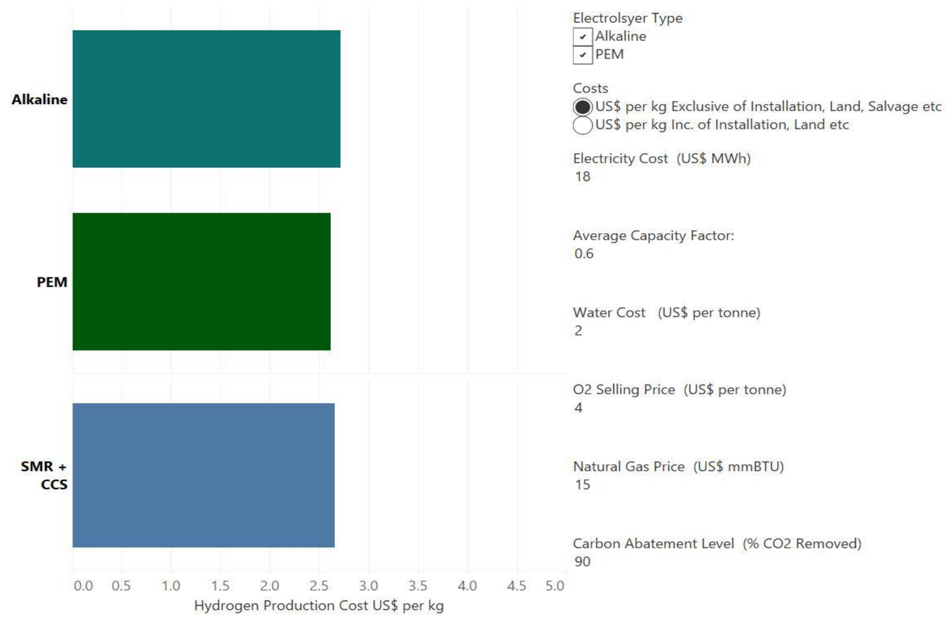
The reasons for this increasing move to use hydrogen are well documented by a range of agencies and advocacy groups but at their core centre around its potential to be a multipurpose energy vector produced at a near zero or low carbon intensity.

There are, however, a few challenges that must be overcome if hydrogen is to become a low-carbon fuel for the future, not least of which is the avoidance of a further hype cycle!

In terms of costs, the current crop of advocacy-based reports are keen on highlighting the potential to produce green hydrogen[2] at a cost equivalent to, or lower than, blue hydrogen, and longer-term gray hydrogen. Whilst the chart below, taken from the ACRIS hydrogen cost of production model, show that this is possible, for blue hydrogen, this is under very specific conditions, including having a market value for the oxygen produced via electrolysis, and a relatively high natural-gas price and a relatively low electricity price.

[1] Data from the Advisian Hydrogen Market dataset, data as of August 2020
[2] In this report we follow the consensus that for Hydrogen to be classed as green hydrogen it is produced from renewable energy, not grid electricity or nuclear power.

Figure 2: 2020 Hydrogen Supply by Market Model[3]



The hydrogen cost model allows a user to model hydrogen from renewable energy and blue hydrogen under a varying set a range of inputs.

This module is an engineering based full cost model. It includes land cost, installation costs, salvage value, project internal rate of return (IRR) and specific CAPEX costs. These values combine with the user inputs to generate a realistic value of the current cost of production.

Some of the key variables / differences in the model are tabulated below:

Table 1: Top Level Key Fiscal Variables in the Advisian Hydrogen Cost Model

	PEM Electrolyser	Alkaline Electrolyser	Blue Hydrogen
Debt / Equity Ratio	A higher equity to debt ratio		A higher debt to equity ratio
WACC	8%		
IRR	12%		
CAPEX	Data point from one manufacturer in 2020		Industry average capex
Salvage Value	Higher than alkaline electrolyser based on PGM value	Low	Low

For green hydrogen, this does not include any additional compression or any onsite storage and distribution. For blue hydrogen, this does not include removal of the CO_2 or long-term storage. The battery limits to this component of the model are important to understand.

[3] Data from the Advisian Hydrogen Market dataset, data as of August 2020

The remainder of this report is accessible to subscribers.