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Renewable Methane - The Next Step

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Overview – the case for renewable methane in Australia is very compelling….

- It is critical for Australia to invest in the development of renewable methane as we move more toward hydrogen development and its natural markets
- This can replace a massive fossil fuel energy trade ($50b/year just in LNG) that is totally at risk and will be very hard pressed to be replace by hydrogen for many reasons, and
- Ensure we can use the $billions we have sunk into existing gas transmission, distribution, major energy storage, LNG production and exports, and power generation assets, markets, regulation etc. – again all at risk of major stranding or requiring large scale investments.
- It will also mean we can have a green grid if we have green methane – game over - gas is the current transition fuel supporting the major uptake of renewables (just look at SA) and it just needs a clean green form of methane to cement the transition – to deliver the end point.
- The technology race has just begun and Australia is really well placed to be a leader – we are not already in other green technologies (solar, wind, batteries) – but we can be in renewable methane – and we have natural investors.
- **There needs to be a renewable methane strategy, program, road map, and support for its development – to add onto the gas strategy.**

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My background with hydrogen

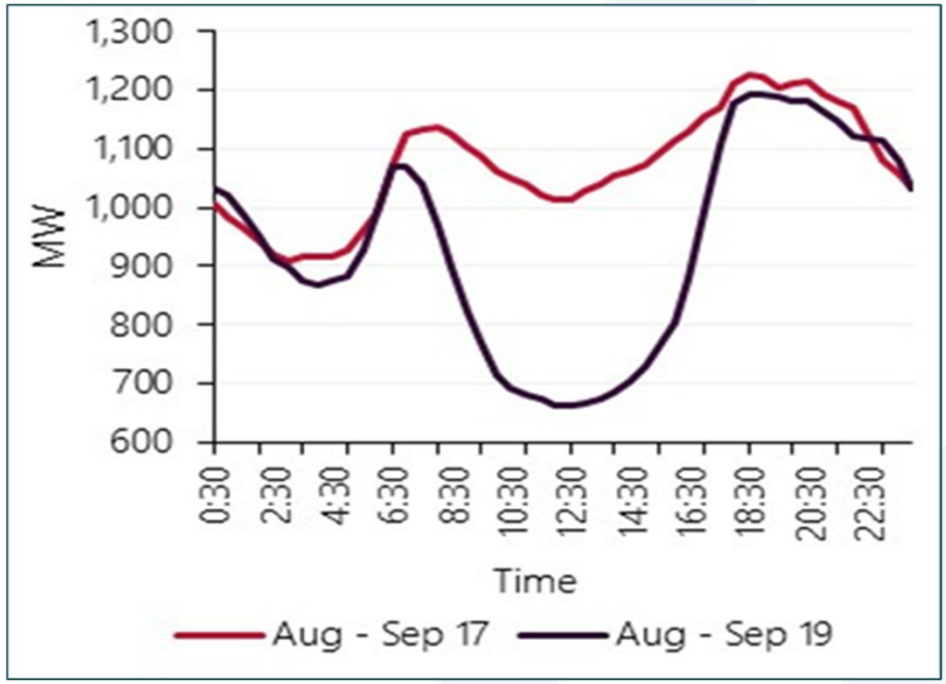
- After graduating in Chemical Engineering I started in the gas industry at AGL when “towns gas” was still produced and distributed in many places and was hydrogen based – prior to that I worked in an Ammonium Nitrate plant (Ammonia based) and at BHP steel works coke ovens
- I designed and built plant to produce hydrogen from steam reforming of naphtha and then natural gas - and then shut down the last coal to gas plant in Australia
- I also was heavily involved in building gas infrastructure and converting customers from the old hydrogen towns gas to natural gas – which was a huge and very expensive undertaking
- I moved on to marketing gas and then the economic regulation of gas markets, merges and acquisitions, market design, etc.
- I even had a period of expert work in the water and waste water industries which is not likely a key market for hydrogen (well oxygen and hydrogen as a by product)
- Hydrogen followed me still – I was heavily involved with brown coal gasification efforts in Victoria to deliver fuel for power stations as a commercial adviser and gas market expert
- Now I am working extensively on the development of the production and marketing of green gases – not just hydrogen

Going *green* in the Australian energy market context

- We have of over the last couple of years been engaged extensively in modelling and analysing the concept of moving in Australia to a low or net zero carbon environment – the transition, the impacts on electricity and gas markets and end use and various cost benefits analysis, participation of demand side.
- And the impacts are far more vast than are probably understood at the moment – particularly in terms of Australia's energy trade strengths - and domestic energy use and affordability
- Along the way we have been forming some views I will outline today – these are pragmatic - derived from a mixture of engineers and economists with industry experience – much of the current discussions are centred on more early development and scientific endeavour - but now we need to deal with scale
- To move to low or net zero carbon in the end a massive transition has to take place - scaling up technological options makes the reality of future choices just a little clearer – and the economics of this scale up adds another level of potential clarity to where the focus should be (again in our view).
- Lets look at the dominant issues – as our recent modelling has shown.

Death of base load power – and coal is being cannibalised

Gladstone Coal Fired Power Station – what just happened?



And now you can buy a "super cap" to cover these shoulder periods

- Renewables are swamping the network and eradicating baseload power – really fast
- The electricity supply system needs flexibility – in generation and load
- This graph says it all – it is of Gladstone (Coal) Power Station output and shows the impact of renewable generation over 2 years (yes just 2 years)
- By 2025/2026 the base will be zero for this power station if the renewables are built that are in actual planning and construction (all per AEMO)
- This is happening across the NEM – South Australia already gas and wind predominately
- Gas is chasing the load – **by default it is the transition fuel right now** – coal trying to turn down more but is on an inevitable death spiral due to lower run hours & higher costs

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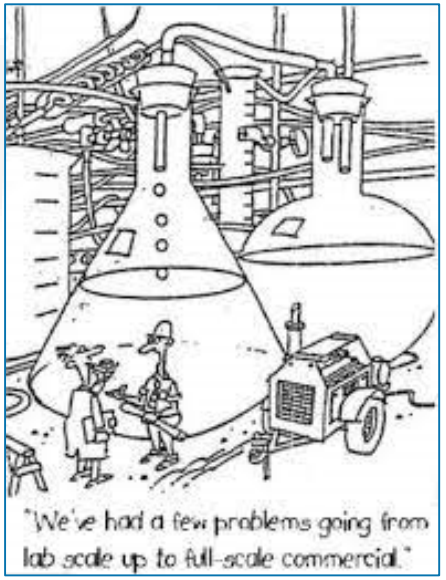
The rise and rise of energy storage and gas

- The gas power generation plants are needed for stability, for load following and to allow more renewables to flood into the market – their flexibility is the key – and we have some 10,000 MW of them already - more gas plants may be needed – **but gas is a carbon fuel** – we will come back to this
- The gas market is working to become a lot more flexible in its trading (and succeeding) – but still opaque with limited investor ownership in supply chain
- Without more grid renewables the pressure to put more in behind-the-meter will be more intense – it already is intense and causing angst for AEMO (and networks) – household batteries are still problematic on costs and utilisation
- Storage is required in the 2 to 4 hour band – this can displace peaking gas plant - and will/is in our view through lithium ion (e.g. AGL Wandoan Solar + Battery) – storage also creates no energy – just stores it (issues of utilisation abound).
- The large scale PHES if built will foreclose a lot of other technologies in that storage space and provide some longer term energy storage – smaller PHES has problems in execution and market risks – and again these technologies do not create new energy - just storage of renewable energy – which has its own implications for build of renewables

The rise and rise of energy storage and gas

- The two renewable gases are **hydrogen and renewable methane** – hydrogen ostensibly from electrolysis of water and methane from reacting hydrogen and carbon dioxide – both do not emit (net) harmful greenhouse gases (as long as the carbon dioxide is taken from the atmosphere) – and displace fossil fuel emissions
- These gases have enormously different characteristics from an engineering perspective – and these differences are critical
- **Hydrogen is expensive to compress, store and transport any distance and best produced close to source – and large scale hydrogen storage is a petrochemical industry type issue (think not in my back yard) – distributed (community embedded) hydrogen is therefore extremely difficult (it is a dangerous good) – current gas infrastructure issues (H2 transmission problematic) – and hydrogen on a volume basis is 1/3 the energy of natural gas**
- The alternative capabilities of renewable methane are far more enticing as it is a direct replacement for existing natural gas – and frankly **renewable methane is a must do technology for Australia** if it remains on this pathway to net zero carbon - the major issue is **infrastructure and associated technology scale up**



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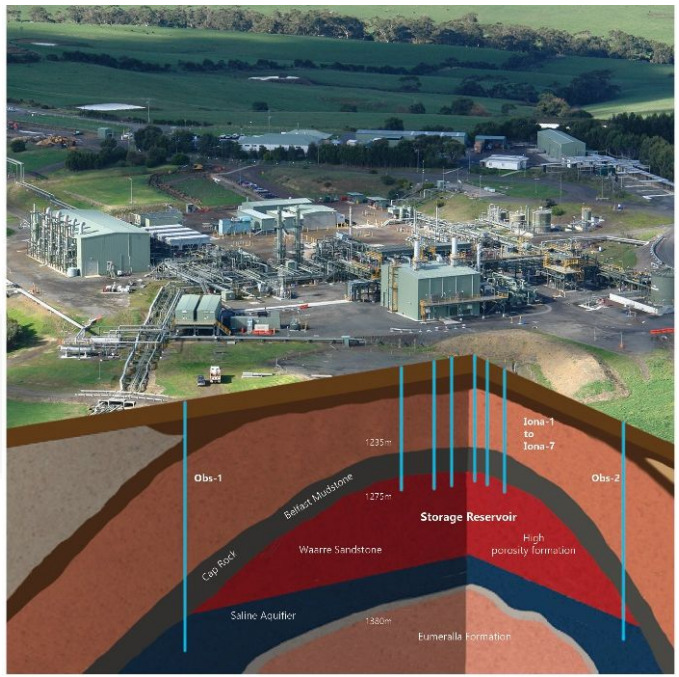
Storing renewable energy as gas

Renewable gases produced from renewable electricity (hydrogen and methane) are an excellent form of renewable energy storage:

- On the east coast of Australia there is some 150 PJ of natural gas storage for market use (>200 PJ in total – mostly underground) - this is more than **40,000 GWh of electricity storage equivalent (20,000 GWh from a CCGT)** Snowy 2 = 336 GWh for comparison – for no additional investment.
  - This storage can easily take renewable methane – less so hydrogen (1/3 of the energy storage if feasible to inject underground)- it is also very cheap –cheaper than PHES, batteries or hydrogen storage
- Renewable methane based gases can be readily converted to LNG in existing LNG plants and shipped overseas – Australia is the largest LNG exporter in the world currently at **$50 billion/year** and this trade (like coal exports) **is totally at risk** if not replaced with renewable gas for export.
  - LNG import and regasification facilities can also act as storage in Australia, close to the key capital city markets for market peaks – 3 to 5 such facilities being planned currently.



Storing renewable energy as gas

- There are some **35,000 km of natural gas transmission mains in Australia** – these can not be replicated with hydrogen – technical issues, reduced energy throughputs at much reduced pressures, certification issues and expensive
  - These are key energy arteries in Australia **shifting more energy than produced in the NEM each year** – very good interconnected grid now on the east coast – a **major strategic asset for Australia**
  - Many other sunk assets – gas distribution systems feeding some 5 million households and 10,000 MW plus of gas generation – all would either not be useable, de-rated significantly and/or require expensive conversions when trying to use hydrogen – it isn't easy being green…
- Gas markets in Australia are also very well defined, regulated (laws and regulations nationally and at state level) and reasonably competitive in each of these applications – domestically and internationally for LNG exports
  - The changes required here would be major/profound if natural gas becomes banned from production, export and end use – a very expensive exercise

Hydrogen suits some markets very well – but not others

- Hydrogen is looking best suited to applications that do not require high levels of storage or transport, or any expensive conversions for customers to use it as would be the case for households for example
  - The key market would be as a feedstock for syngas based plants such as ammonia based chemicals (ammonia nitrate for example) – and we think this is viable if sufficient cost reductions can be made in hydrogen production - which we think will occur – and these plants are already "petrochem" style used to storing and handling dangerous goods (especially gases)
  - Hydrogen can also be converted to green ammonia as a form of storage and transportation (energy carrier), as well as a traded commodity (20 mt/y)– or hydrogen can be liquified for transport – however this would require significant additional investment in infrastructure (unlike renewable methane), development of new markets, etc.
  - Green products: Steel – Whyalla plans are based on local production

Gas as a transition fuel for a renewable electricity system

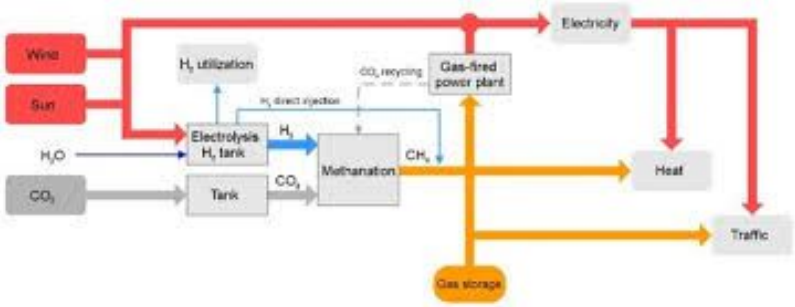
All the flags point toward developing renewable methane technology as a **key priority for Australia**

- Natural gas can and is becoming a transition fuel for renewable power generation and this is concerning environmentalist – they are moving rapidly to try and retard this (fracking, Narrabri, ACT gas bans, etc.) – and **in the end zero emission energy means natural gas has to go**, however
  - The development of largescale energy storage with high flexibility is problematic – and being able to produce renewable energy 24 hours per day is very appealing – especially with large scale storage to back it up
- Something has to give – it makes sense for Australia to explore the development of renewable methane technology – economically and environmentally – **hydrogen alone is not enough – we need to go further**
- So lets look where this is at – because the answers lie in **process integration** – a skill Australia has in great depth and is not directing well at all – and yet we could be world leaders
  - For most of the other technologies we will be customers buying other countries – in renewable methane we could have our own Elon Musk's…

The technology challenge(s)

- One of the key cost issues for hydrogen and renewable methane is the utilisation of the production technologies — it seriously effects the economics of the production plants – you really **need 24 hour grid based green power**
  - The other critical factors are renewable energy prices and capital costs – if capex comes down and utilisation is high for example renewable electricity cost then dominate – it is a pricing triangle
- So it will be still critical to develop sufficient say **8 to 16 hour renewable energy storage** and renewable wind and solar plant **overbuild** to be able to provide this 24 hour stream of renewable energy for renewable gas production – they are complementary
  - But due to large scale gas storage it does not have to be overly reliable as we can supplement it with gas generation at anytime once we have the storage – and in reality this will happen a lot in summer for example
  - The development of renewable zones will likely require additional transmission assets to be built or reinforced
- And we can continue to use gas

Synthetic methane production



The intriguing and appealing factor with methanation is that the chemistry is very well known (over 100 years) and has been undertaken in refineries for many, many years based on fossil fuel refining and conversion, but

- Process integration with renewable power and air borne carbon dioxide is more embryonic – and is an engineering challenge not one of basic chemistry – it is a process (chemical) engineering challenge and Australia is really well placed to develop this technology – we have good skills in this regard
- And while the hydrogen production chemistry requires continuous energy input (endothermic) the methanation process produces heat once it commences (exothermic) - **It is not well appreciated that "electrolysis" uses less electricity if heat can be added to the process (and pressure in the reactors).**
- This makes them complementary processes (thermally) and ripe for process integration to achieve high conversion efficiencies within one reactor or process plant (not as most would think in terms of producing hydrogen first and then methane) – and to cause in the reactor **High Temperature Steam Electrolysis** [HTSE] – 85% maybe attainable
- The process also calls for the extraction of carbon dioxide from the atmosphere, and again there are well know methods for doing this (stripping carbon dioxide from other gases including air), but these have not be advanced in terms of their engineering as their has been little demand for this particular use of the processes.
- The Europeans are advancing renewable methane technology as a priority

Synthetic methane production - Europe

The development of this technology has commenced in Europe and Australia – Europe has a road map for this development as synthetic methane can utilise existing infrastructure which is a major issue in Europe – and they have huge gas storage capacity = 1,131,000 GWh – with 22 GWh/day delivery. Demand is some 16,000 PJ/annum (4,400 TWh) for gas.

- The European technology development is indicative – HELMETH (TRL 4-5)
- High efficient Power-to-Gas (PtG) process – prototype that combines pressurised high temperature steam electrolysis with a carbon dioxide methanation module. Produces a synthetic natural gas (SNG) compatible with existing natural gas infrastructure.
- A significant advantage of the HELMETH PtG technology in contrast to PtG plants with low temperature electrolysis modules is its higher efficiency resulting in considerably lower electricity demand per SNG output.

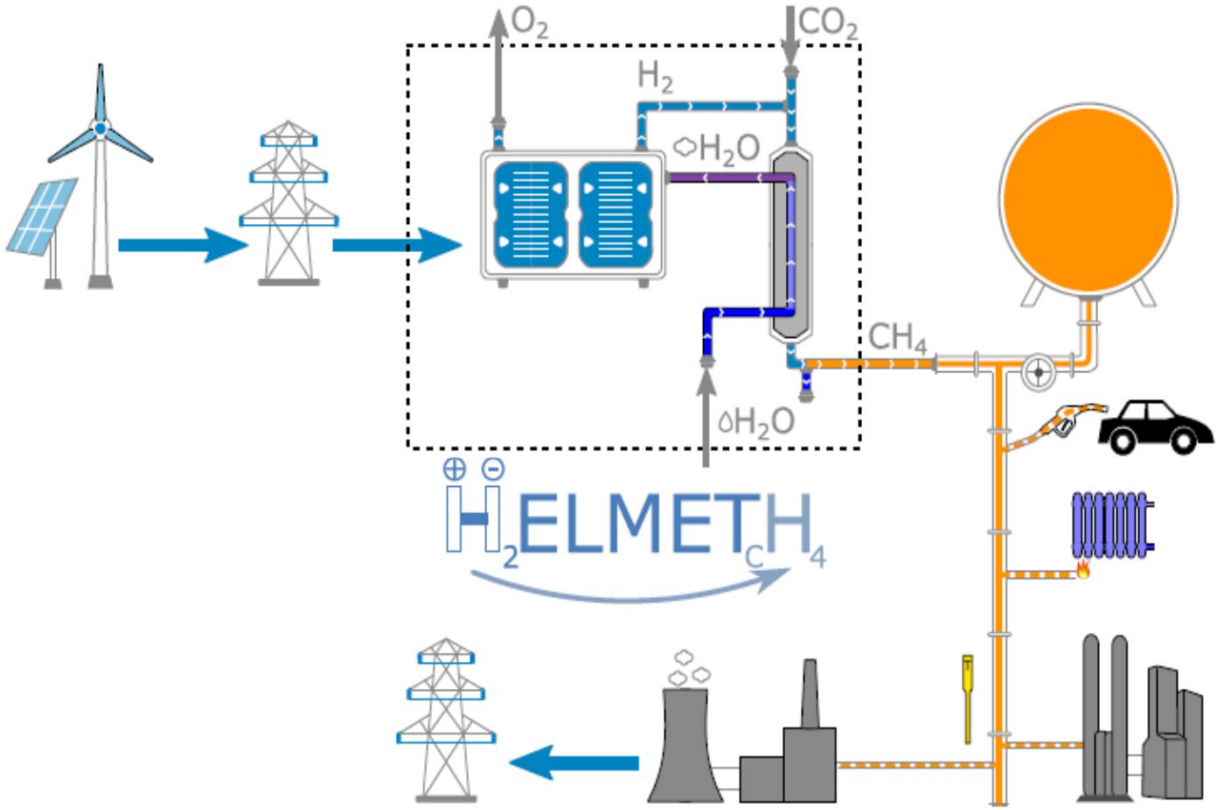


Figure 1: Schematic HELMETH PtG process, which enables an efficient conversion and storage of energy from fluctuating renewable sources

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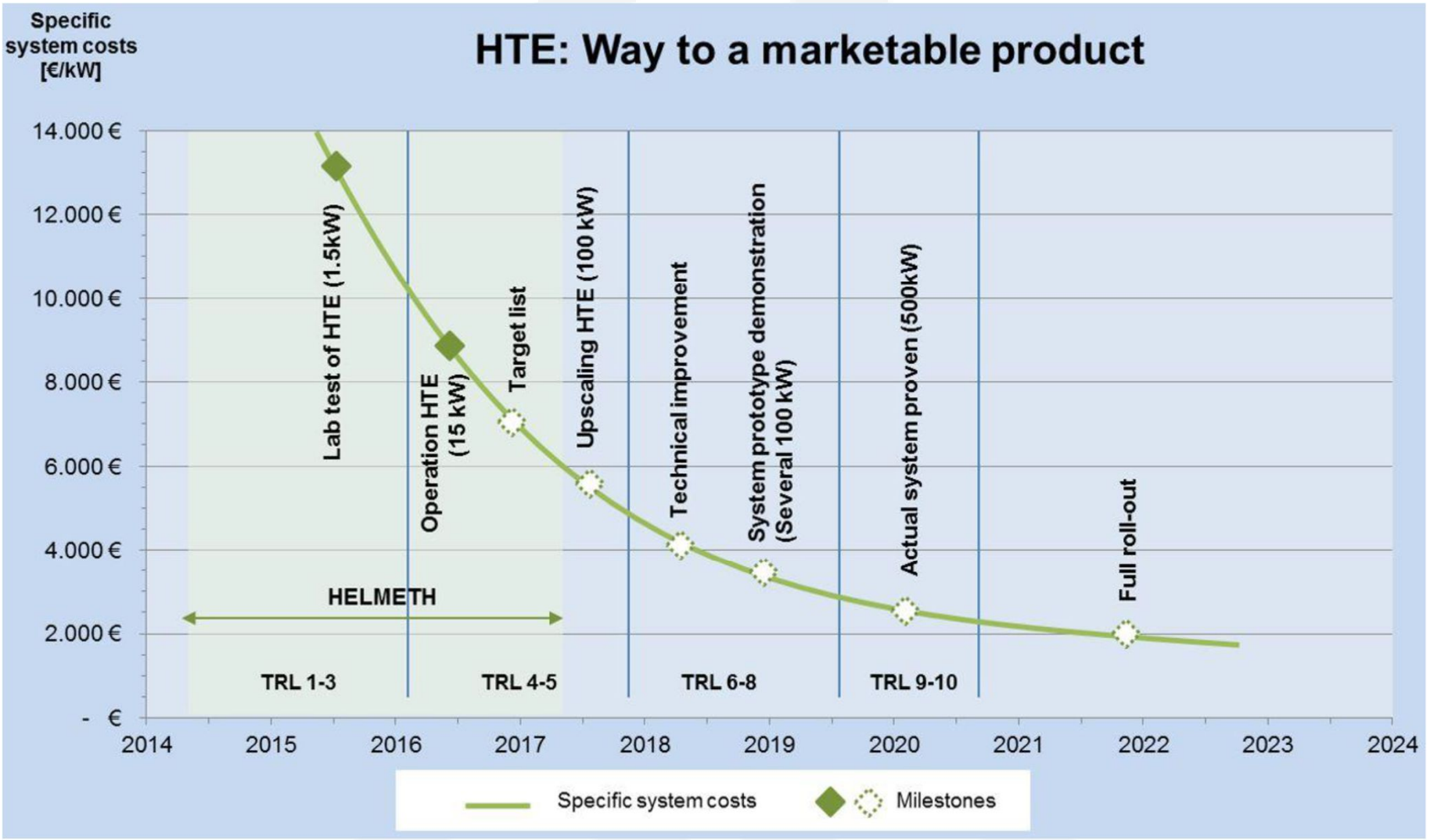
Synthetic & biogas methane production costs



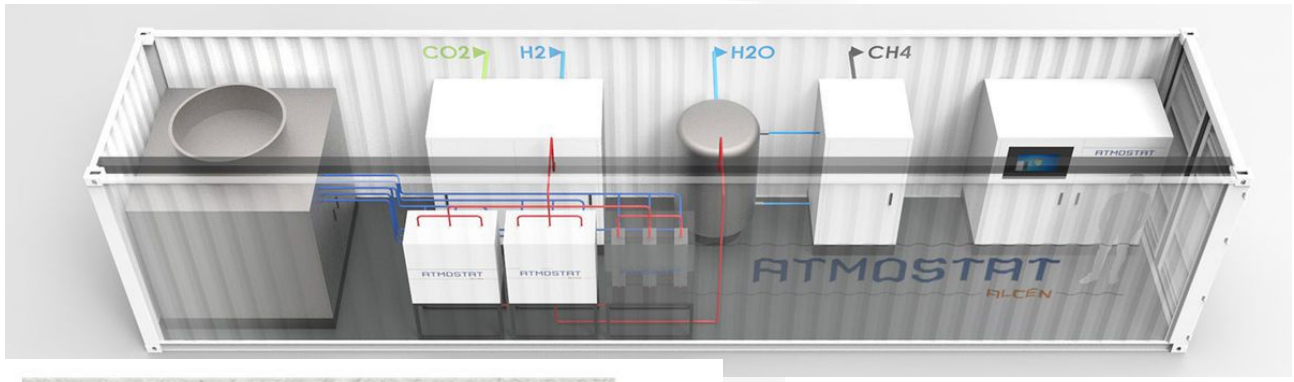
Development Steps for HT electrolysis on its way to a marketable product

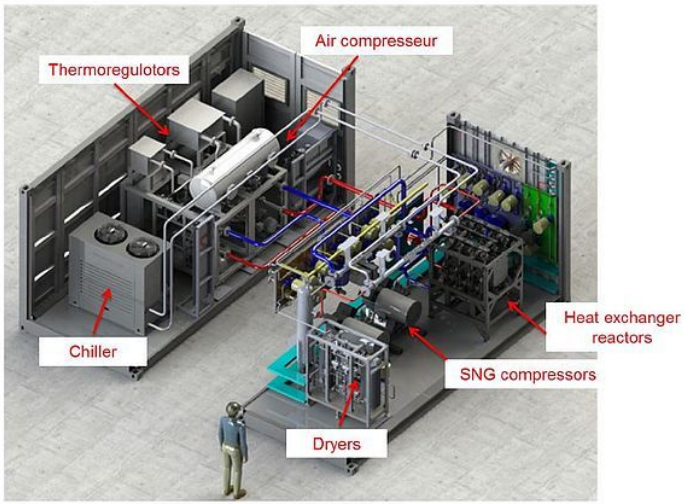
Synthetic methane production - Europe

The STORE&GO project tested different available power-to-gas technologies in three different European countries – Germany, Switzerland and Italy, and thus under different regulatory frameworks.

- Germany – isothermal catalytic honeycomb reactor technology – converting renewable energy with reactors enabled methanation processes with improved heat management
- Switzerland – biological methanation - waste water conversion through biological methanation – another major opportunity in Australia
- Italy – modular milli-structured catalytical reactors – converting purified water through milli-structured methanation and capturing carbon dioxide from air and liquify the resultant gas to LNG.

https://www.storeandgo.info/





Discussion: Investigation of the potential from waste water for renewable methane needs to be undertaken

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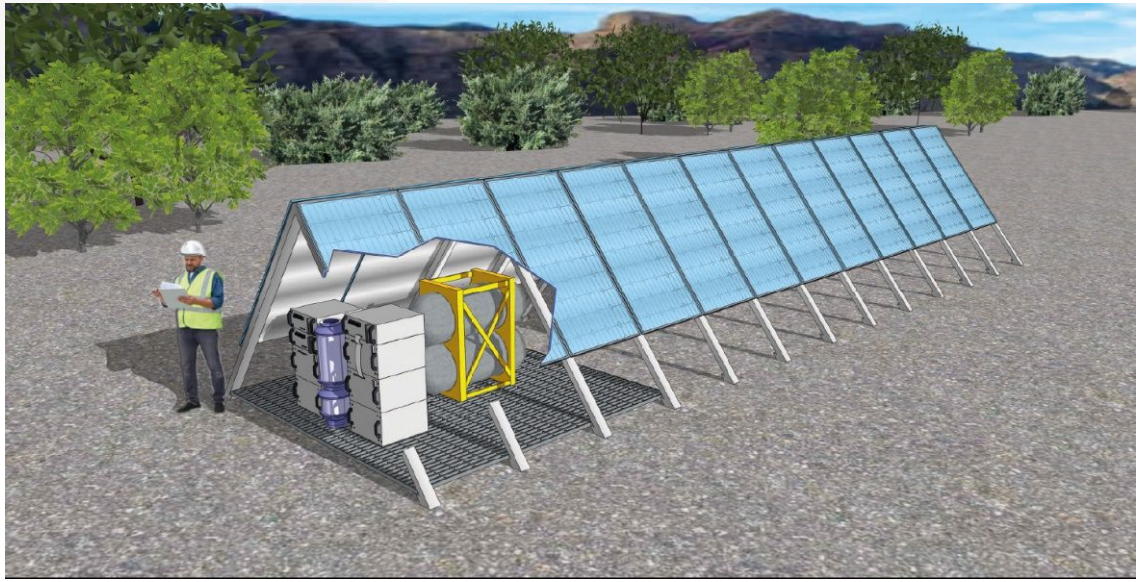
Synthetic methane production - Australia

The APA group and ARENA co-funded renewable methane pilot project – development partner is Southern Green Gas.

- The collaboration on this project aims to demonstrate the technical and commercial benefits of an integrated hydrogen electrolysis and renewable methane production system. The project will generate cost and technical data to be used to assess the feasibility of larger, commercial scale, renewable methane production.
- This unique project is the first step in testing whether it is possible on an industrial scale to create methane using solar-generated electricity, water and CO2 from the atmosphere.
- ARENA CEO Darren Miller said:
- *"Renewable methane is in effect indistinguishable from the methane that currently fills our natural gas pipelines. The gas network is expected to play a key role in supporting the decarbonisation of Australia's energy system."*



Commenting on the initiative, SGG's Managing Director Rohan Gillespie stated:

"The reason we have chosen methane as the carrier for renewable energy is the ability to utilize the existing gas infrastructure system. The existing gas pipeline network allows us to access customers here in Australia, as well as export customers such as Japan and South Korea, through the existing liquefied natural gas (LNG) system. We believe renewable methane offers the best solution to creating a major new export industry for Australia, leveraging its globally competitive advantage in solar energy."

In conclusion

- There needs to be a more holistic view of these technologies as the infrastructure costs can not be ignored
- Then there is this huge Australian energy export market to be concerned about in the longer term – it is totally at risk – coal and LNG
- If renewable natural gas production can deliver on economics it solves the whole equation – for energy used in Australia and what we export – and for manufacturing
- The challenge is process driven which we excel at in Australia and the development cycle is still very early – we have time to develop this and a range of natural partners – pipeline companies (transmission and distribution), LNG exporters, gas producers, etc.
- **There needs to be a renewable methane strategy, program, road map, and support for its development**
- These presentations and getting this type if narrative out there is currently critical – OGW trying its best with a workshop tomorrow – suspect it needs more than us…..

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