What is Hydrogen’s Role in the Energy Transition?

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Hydrogen science coalition

Contents

Hydrogen science coalition

A voluntary group of independent academics, scientists and engineers who aim to bring an evidence-based viewpoint to the hydrogen debate
(Initial focus on UK and Europe)

Members

Jochen Bard	Fraunhofer IEE, Germany
Tom Baxter	University of Strathclyde, UK
David Cebon	Cambridge University, UK
Bernard van Dijk	Univ Applied Sciences, Netherlands
Paul Martin	Spitfire Research, Canada
Johanne Whitmore	HEC Montreal

Principles

The only zero emissions hydrogen is renewable hydrogen

Decarbonize existing hydrogen first

Hydrogen shouldn't delay efficiency and electrification solutions

Blending hydrogen into the gas grid is a waste

Prioritize locally produced hydrogen

www.h2sciencecoalition.com

Hydrogen Production

Why is Hydrogen So Exciting?

It’s the most abundant element in the universe!

Just like fossil (“natural”) gas, you can move it in pipes and store it in tanks (sort of…)

Burn it (in a fuelcell) and get only water!

It can be made from (maybe even excess) renewable electricity!

It’s the “Swiss army knife” of the energy transition! You can use it in transport, heating, energy storage…

We make and use lots of it already! For important things like making fertilizer!

…well, at least we can use it in the “hard to decarbonize sectors” (what are those again?)

Hydrogen's Reality

Hydrogen is a global decarbonization problem, with GHG emissions larger than the entire aviation industry

Hydrogen is not a fuel but an energy carrier - it is made from other forms of energy

Currently, it is made almost exclusively from *fossil fuels* without carbon capture

Pure hydrogen has to be manufactured, which involves significant energy losses

Hydrogen's Reality

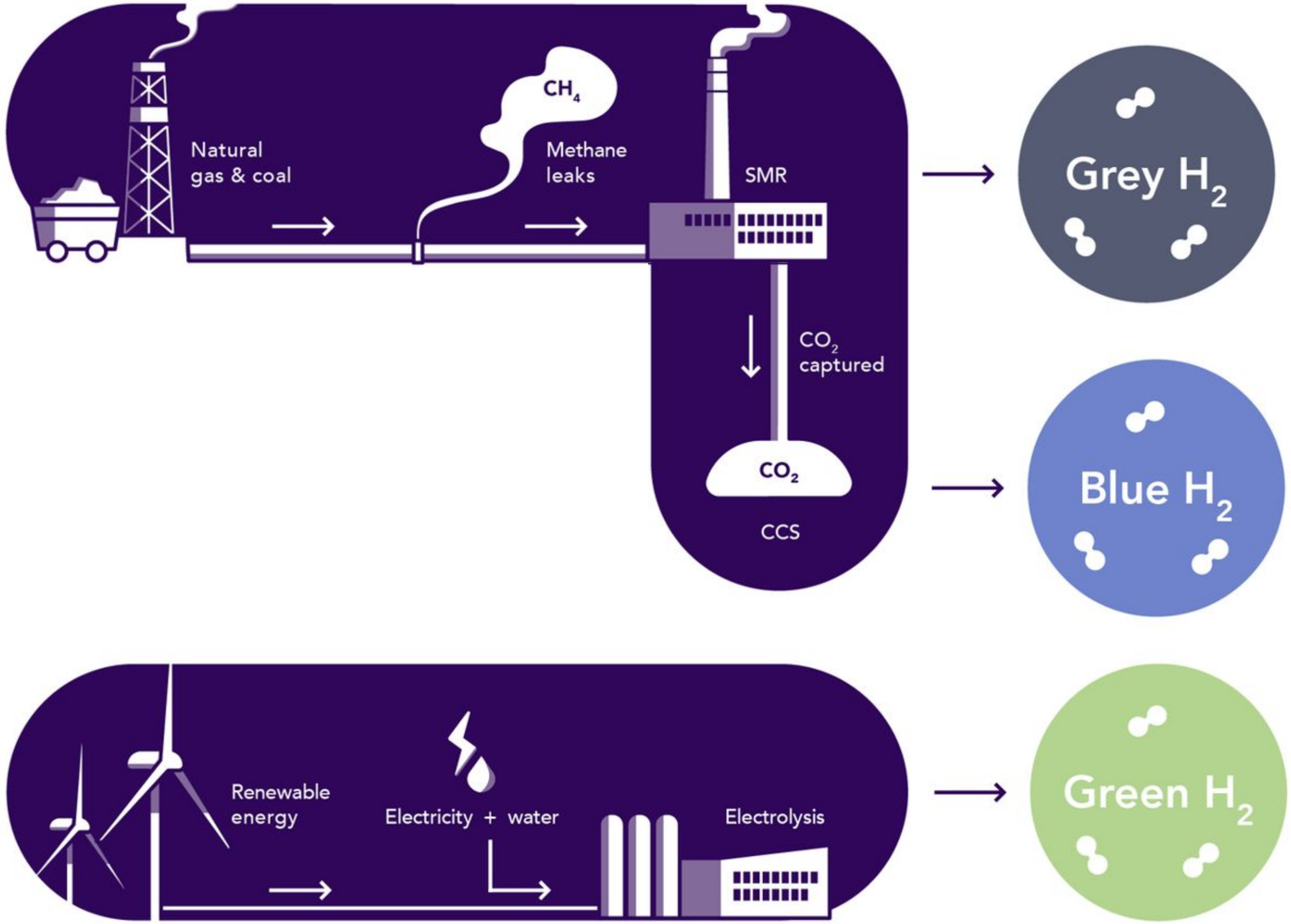
Hydrogen is a terrible battery: feed 3 kWh, get 1 kWh back

Difficult and expensive to move and store: energy density per unit mass is good, but per unit volume is *very poor*

Burning it in air creates NOx (nitrogen oxides) as well as water - documented respiratory & carcinogenic effects

Virtually every use case of hydrogen as a fuel is questionable on the basis of physics and economics

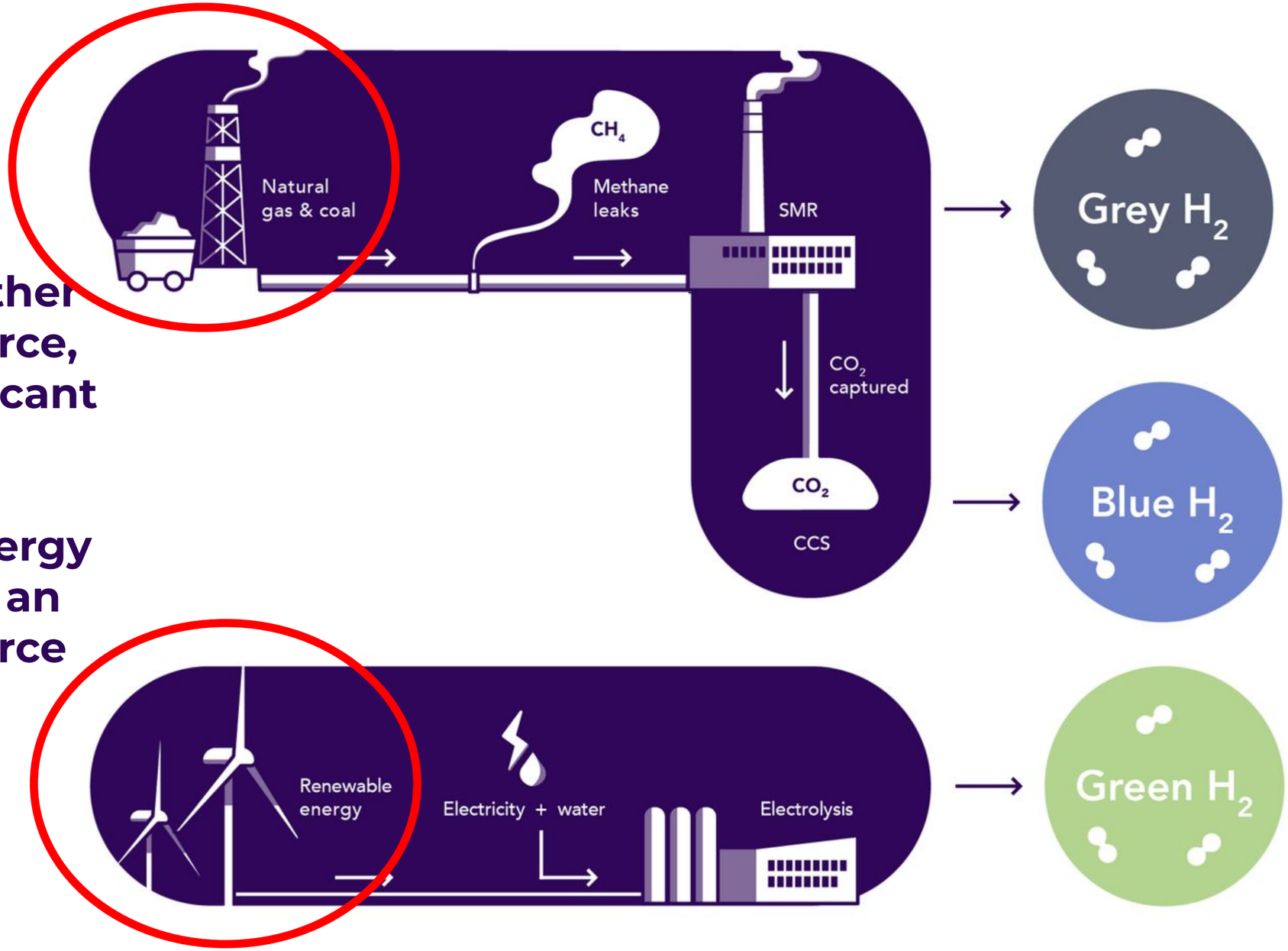
How is hydrogen made?



How is hydrogen made?

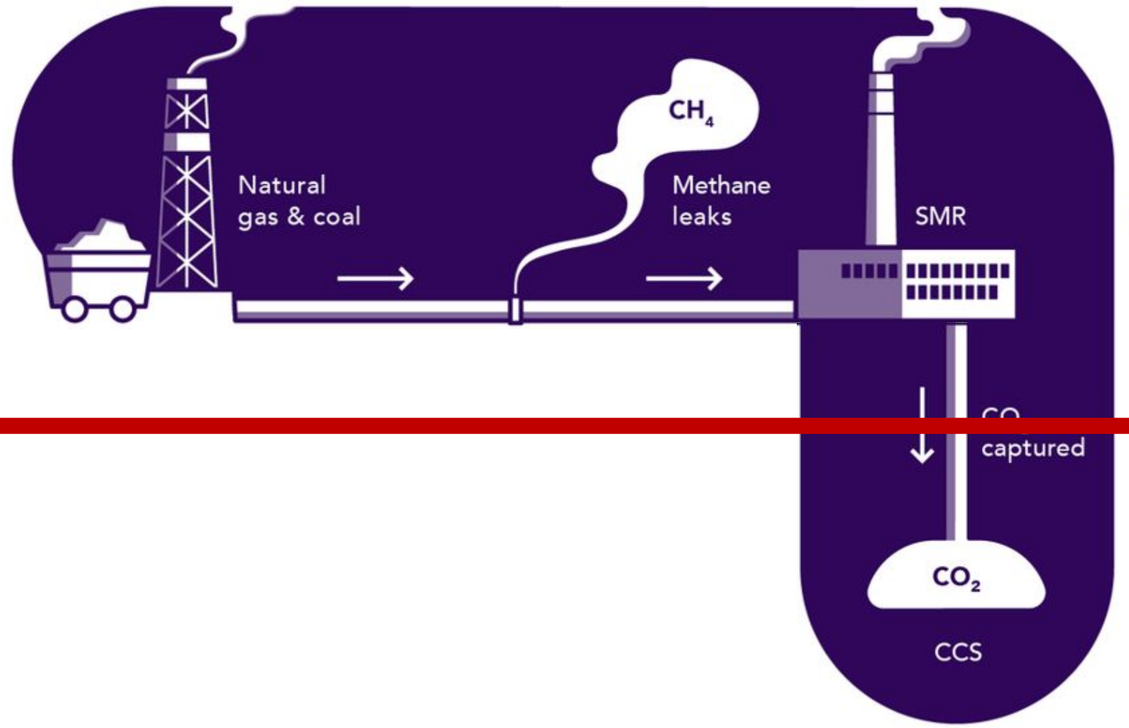
...from another energy source, with significant losses

H2 is an energy carrier, not an energy source



Overview of Hydrogen In Canada

How is hydrogen made in Canada?



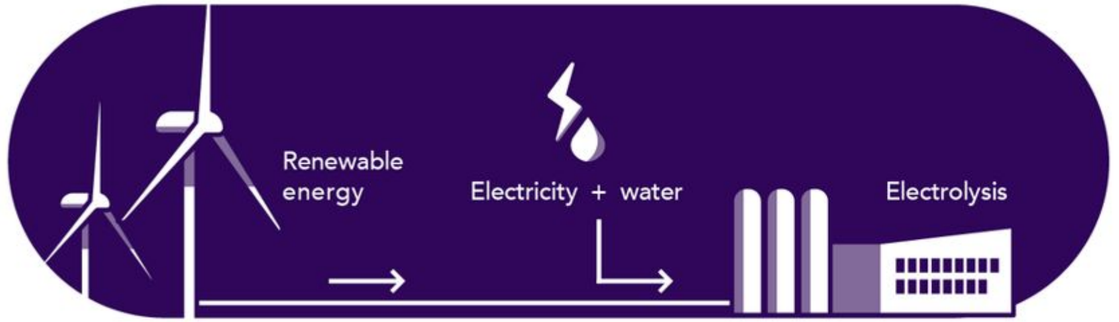
BLACK

Grey H_2

3 million tonnes/yr pure H_2 92% is "black" hydrogen

Blue H_2

0.23 million tonnes/yr "blue"-ish H_2 from Shell Quest



Green H_2

<<0.01% green H_2 made in Canada

How is hydrogen used in Canada?

The *vast majority* used to desulphurize fossil fuels before they are burned

At least 0.7 million tonnes / year (23%) is used to make ~3.9 MT/yr of ammonia (fertilizers)

A little is used in other industrial processes

Basically none is used as a fuel for heating or transport

Decarbonizing hydrogen in Canada

Greening existing H_2 uses would take 24% of Canada's electricity!

Hydrogen itself is a huge decarbonization problem, not a solution to anything.

There is no green hydrogen to waste- and won't be for a long time, if ever.

We make 3 million tonnes/yr of pure H_2

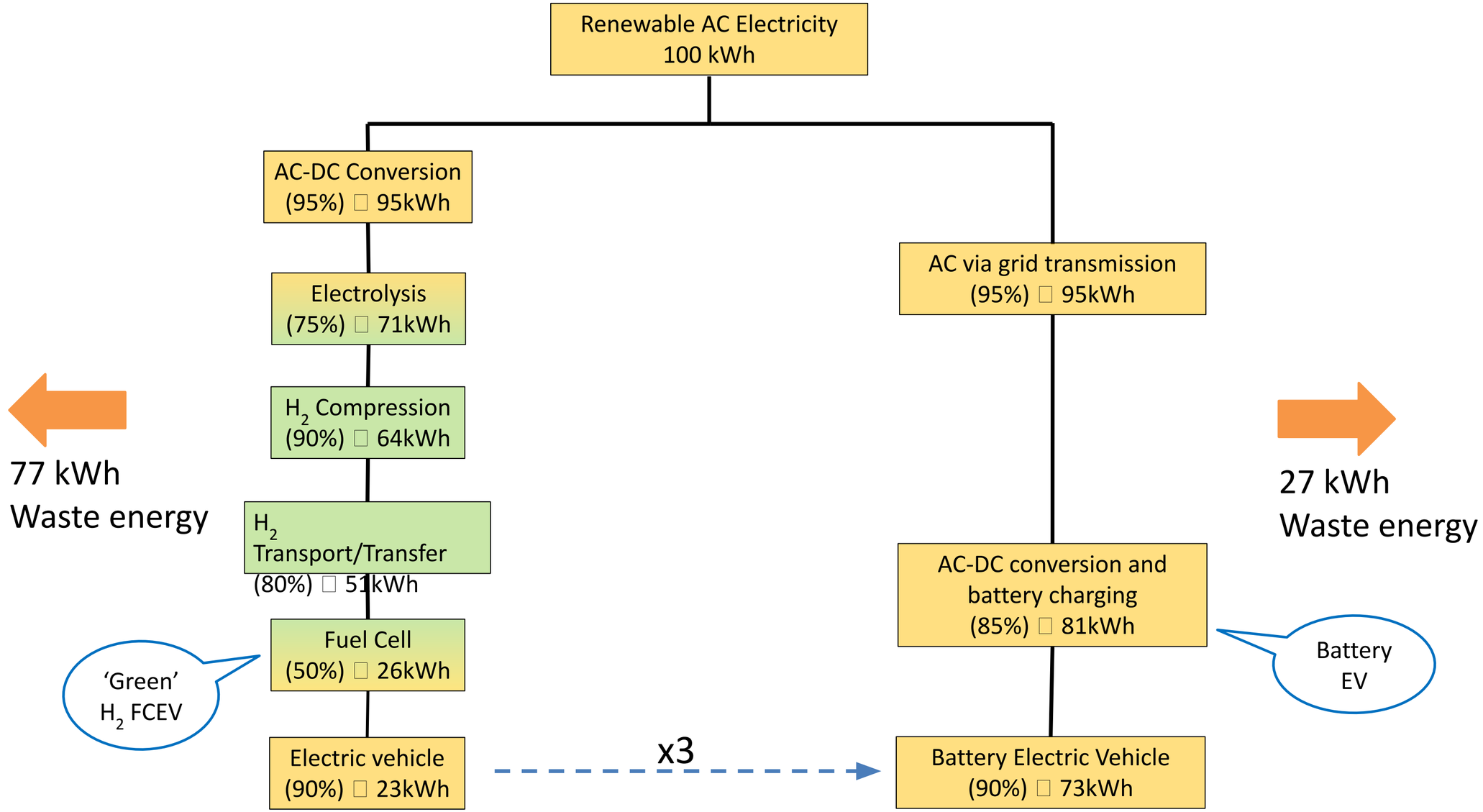
It takes ~ 50 MWh to make 1 tonne of H_2

Greening *existing* hydrogen production in Canada would take ~150 TWh of electricity- before we have any left over for new uses

Canada's electrical production in 2019 was 632 TWh

Hydrogen Uses

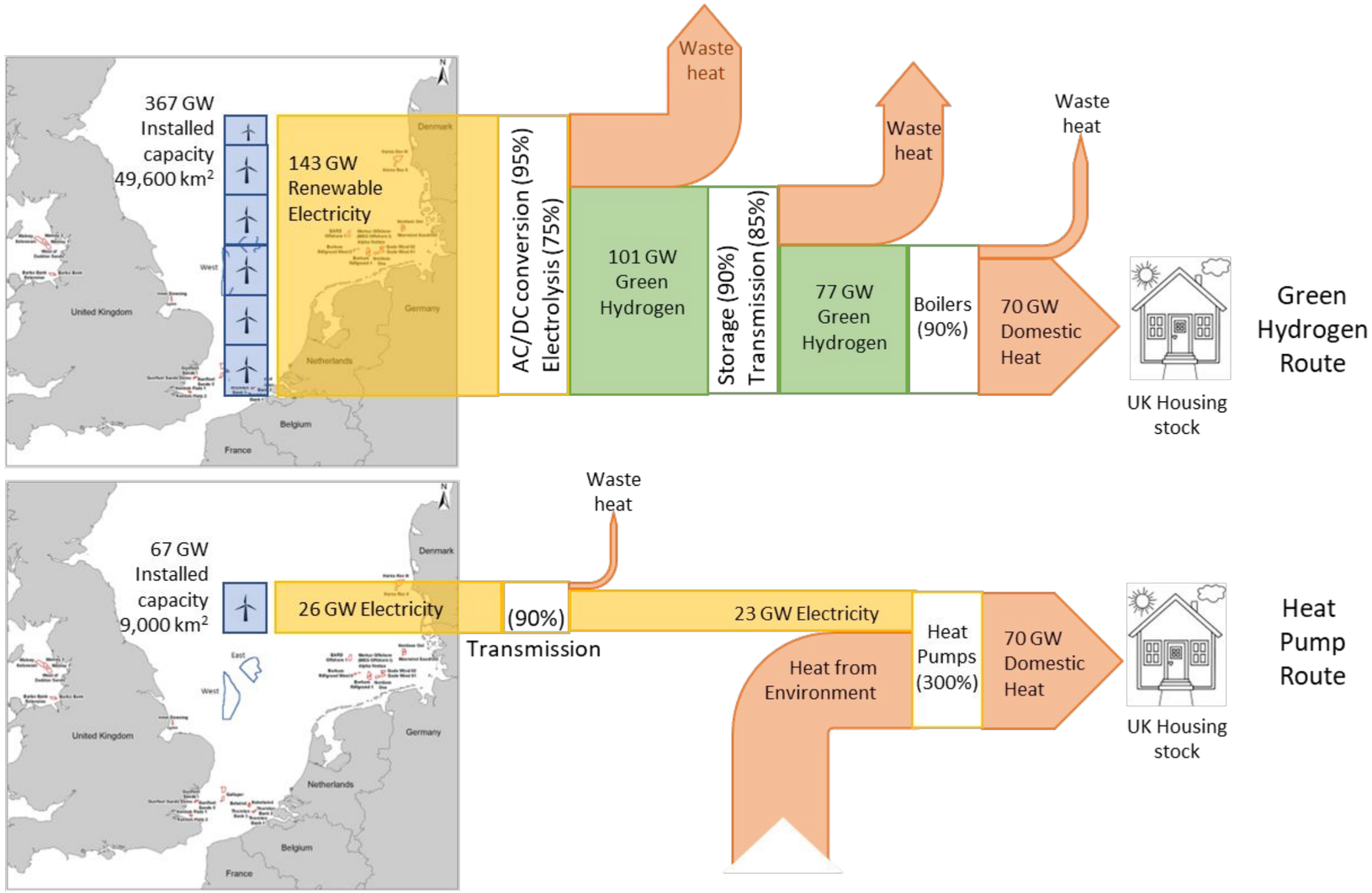
Inefficiency is the Achilles Heel of Hydrogen: Vehicles…



Conclusion:

- Efficiency is not just a geeky engineering concept.
- It takes 3x more renewable electricity to power a hydrogen FCEV than a Battery EV: **over** 3x cost!

Example: Heating the UK with Heat Pumps or Green Hydrogen



Conclusions:

1. Hydrogen processes are extremely inefficient
2. Heat pumps: the most important energy efficiency measure for the UK.
3. Green hydrogen heating 5.5 x more electricity than HP
4. Huge consumer subsidies needed for green hydrogen
5. Hydrogen heating serious economic mistake for UK.
6. Building sufficient green hydrogen production
   - not feasible before 2050/60/70.
   - prevent decarbonisation of rest of economy
7. Most of these issues translate to other countries
8. FF Industry knows all this!

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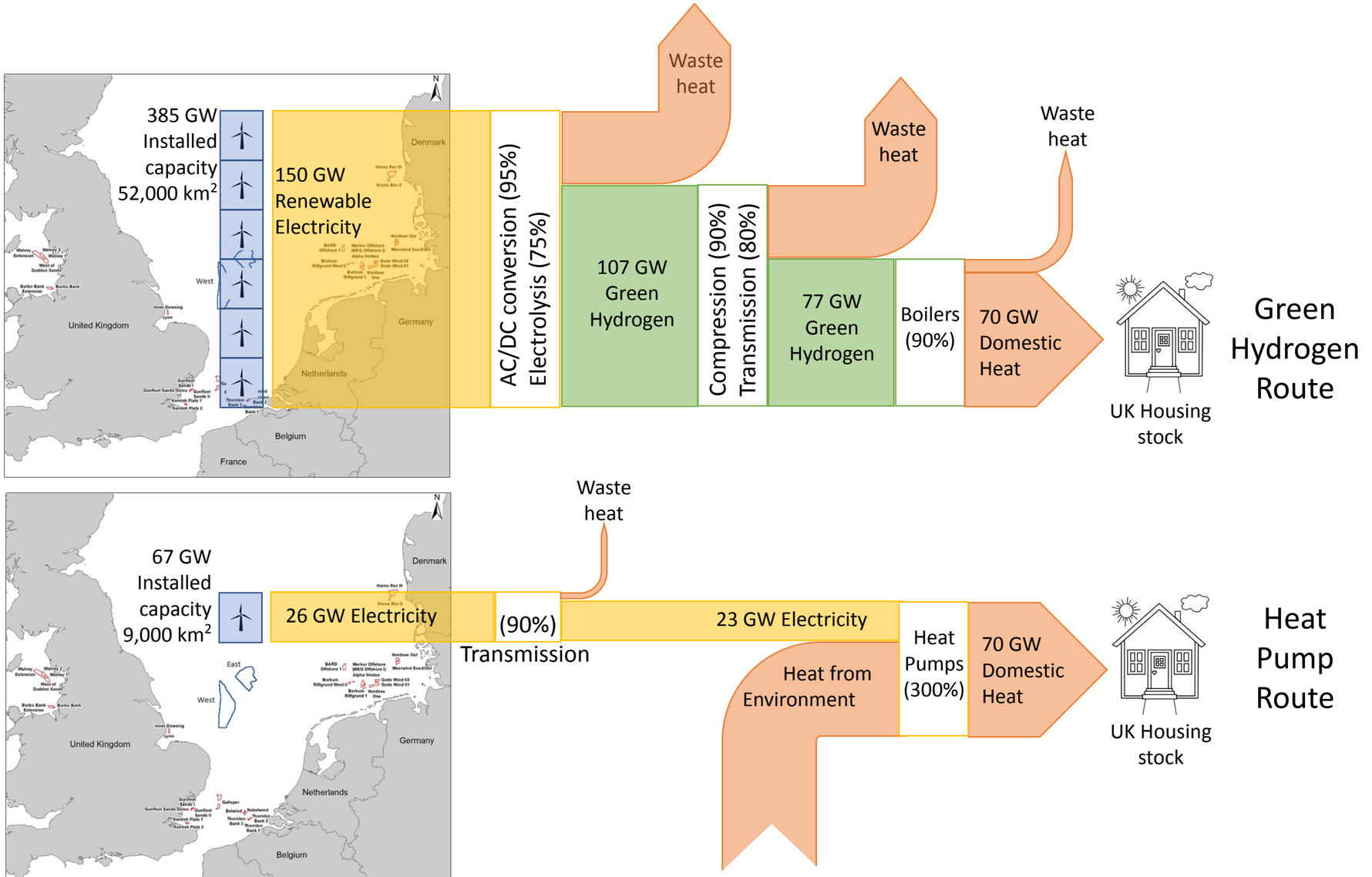

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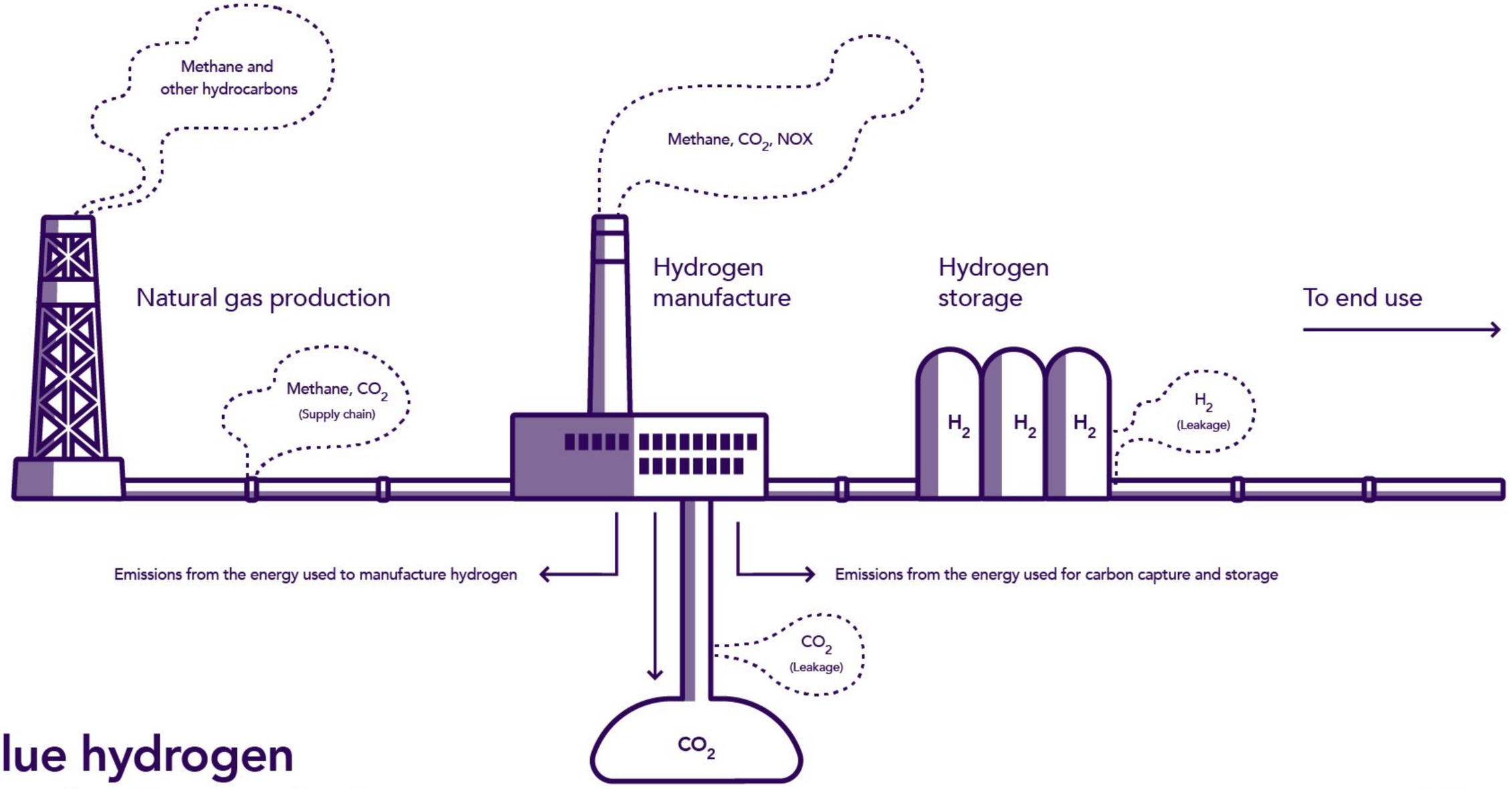
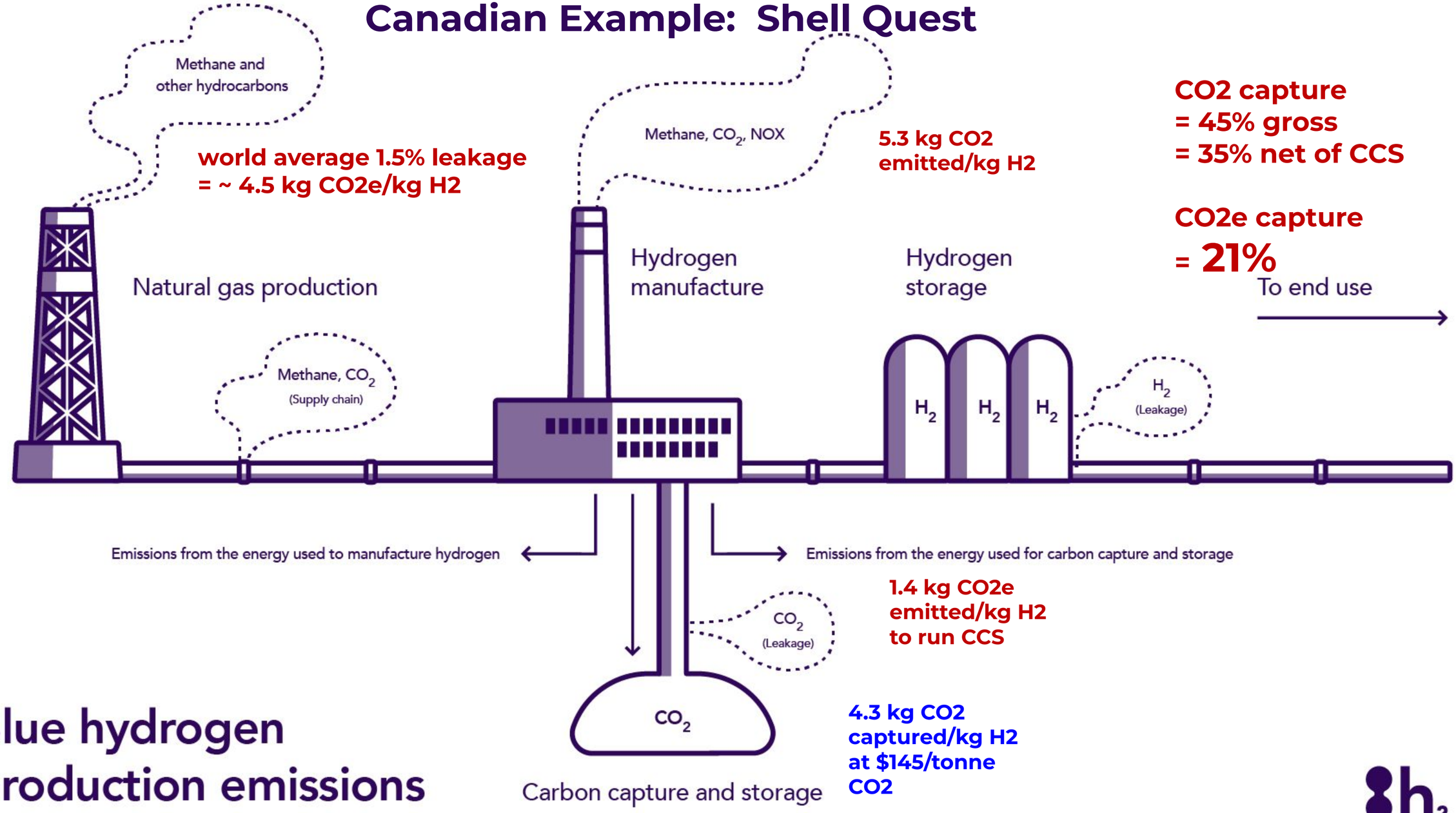


Blue hydrogen production emissions

Canadian Example: Shell Quest



Blue hydrogen production emissions

sources: Shell Quest public figures + HSC calculations

5 Principles of Clean Hydrogen

The only low emission hydrogen is green hydrogen...

1. **Blue hydrogen:**
   - **releases 10%-50% CO_2 of grey hydrogen**
   - **generates high fugitive methane emissions**
   - **requires large-scale, non-existent CCS**
   - **See HSC's definition* of clean H_2**
2. **Using grey hydrogen generates significantly higher CO_2 emissions than burning fossil fuels.**
3. **Green hydrogen is much cleaner, but requires a lot of renewable electricity.**

* https://h2sciencecoalition.com/briefings/clean-hydrogen-definition/

Decarbonise grey hydrogen first…

1. **Grey hydrogen is at least 2% of world CO_2 emissions… same as aviation**

2. **Start where grey hydrogen is used today as a chemical feedstock:**
   - **Fertilizer**
   - **Petrochemical processing (NOT fossil fuel desulphurization)**
   - **Direct iron reduction (to replace syngas)**

   - **Other niche use cases ….not hydrogen as a fuel!**

Hydrogen should not be used to delay electrification

1. **When electricity can be used instead of hydrogen, it is:**
   - **More efficient**
   - **Lower cost**
   - **Lower CO_2**
   - **A more mature solution: quicker to deploy**
2. **Green hydrogen solutions need massive renewable energy generation**
3. **Blue hydrogen solutions are not clean**

Blending hydrogen into the gas grid is a waste…

1. **Max 20% hydrogen blend into the gas grid before major retrofits needed**
2. **Burn 14% more blend for the same heat energy as gas**
3. **Only 7% CO_2 savings**
4. **Higher cost for same energy**
5. **Blending green hydrogen into the existing gas grid makes no economic sense**

Prioritize Locally Produced Hydrogen

1. **Moving hydrogen by land, sea or pipeline is inefficient and costly (which is why industry doesn't do it today!)**
2. **Liquifying hydrogen consumes 30% of energy**
3. **Liquid hydrogen boils-off and has to be vented or burned**
4. **~18 hydrogen tube trailers to move same energy as 1 diesel tanker**
5. **Alternative: Ammonia… Highly toxic and dangerous to ship**
6. **Gaseous hydrogen is difficult and expensive to pump**
   - ✔ **Leaks through metals, plastics and pipe joints**
   - ✔ **11-33 x GWP of CO_2 … leakage causes global warming**
   - ✔ **Embrittles steels**
   - ✔ **High pumping energy**

Exporting Hydrogen

Hydrogen Exports?

Abundant potential wind energy resources in Eastern Canada - how can we profit from them?

Liquid hydrogen exports are totally impractical

Ammonia to the rescue! 50% more hydrogen per unit volume than hydrogen itself!

Ammonia is a very toxic gas, but more practical to transport than liquid hydrogen

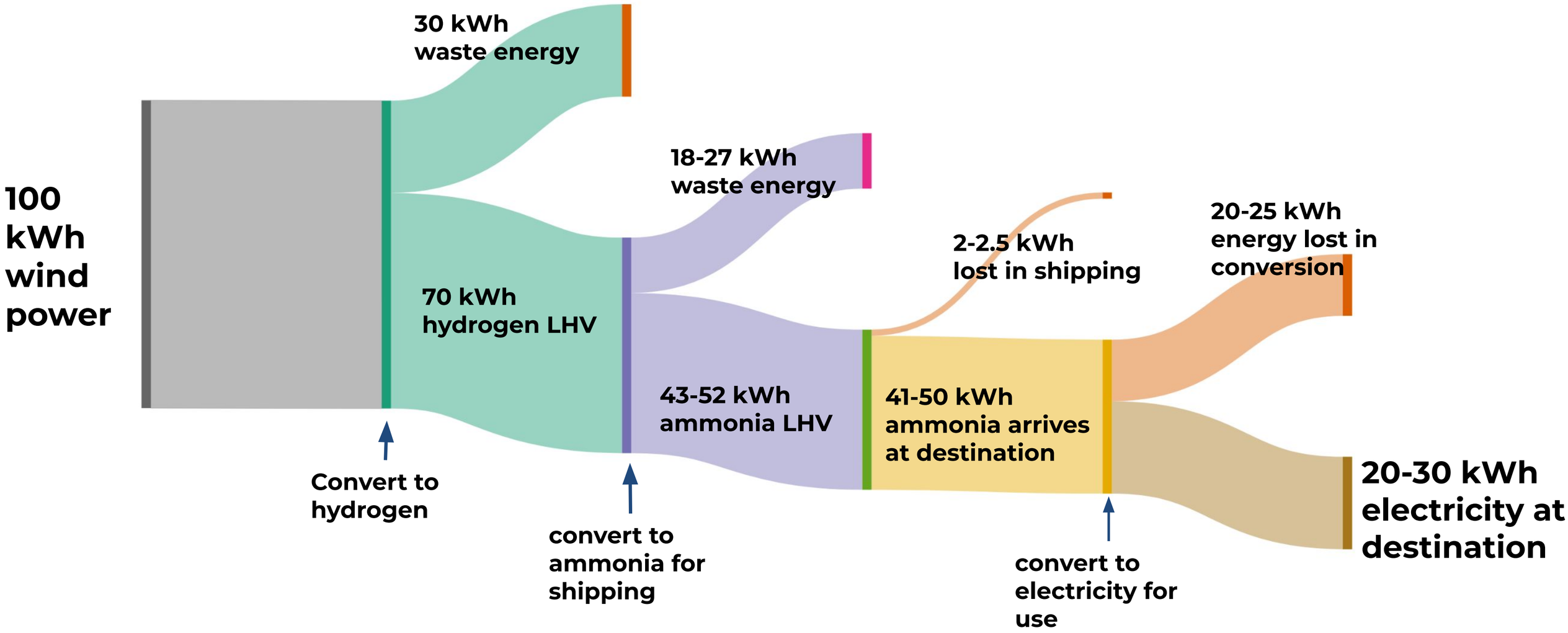
Hydrogen Exports?

The GRID in Nova Scotia is 76% fossil fuelled (52% coal)...

...and in New Brunswick is 30% fossil fuelled (15% coal)

So...why are we not prioritizing the decarbonization of these grids first?

Hydrogen (ammonia) Exports?



Source: Giddey et al, Ammonia as a renewable energy transportation media, ACS sustainable chemistry and engineering, 09/27/2017

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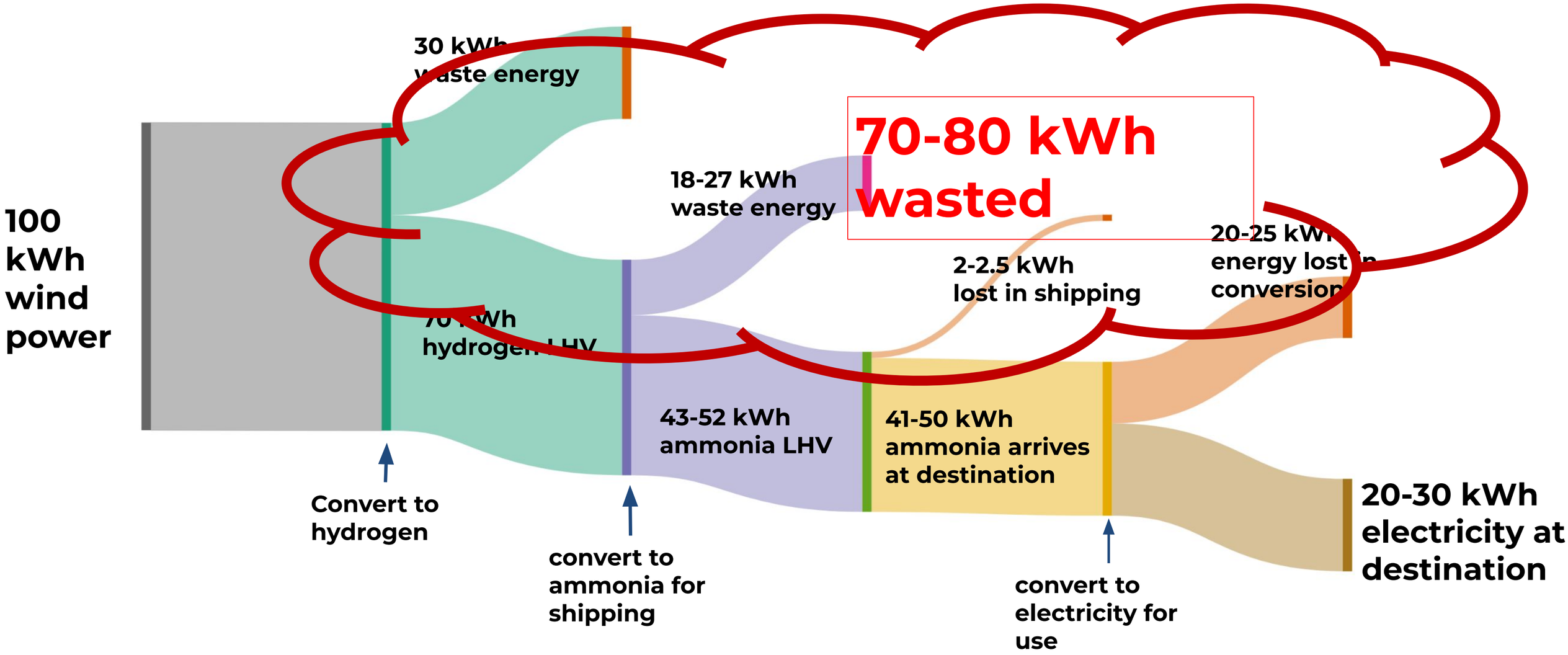

20-30% efficient **In the case of Germany: Buy 10 kWh in Canada, get 2-3 kWh in Germany, best case**

Source: Giddey et al, Ammonia as a renewable energy transportation media, ACS sustainable chemistry and engineering, 09/27/2017

Hydrogen Economics: Newfoundland Example

Production costs

Electrolyzer plant costs 1.5 million per megawatt

~ 50 MWh to make 1 tonne of H_2

Run 100% of the time, an electrolyzer plant will make about 475 kg of H2 per day

Newfoundland

Wind might be 45% capacity factor

475 x 45% = 214 kg H2 per day

Western Australia

Wind + solar hybrid = 70% capacity factor

475 x 70% = 333 kg H2 per day

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The same investment of money makes 50% more hydrogen in Australia than in Newfoundland…and solar is cheaper than offshore wind

“Hydrogen-Ready” LNG infrastructure

We can’t build any more fossil fuel infrastructure and keep to our climate change goals…

But we want to build LNG terminals to help Germany wean itself from Russian gas!

How do we do both?

No problem! We don’t need to feel bad about building LNG terminals- because we’ll convert them to ship liquid hydrogen later!

Is this too good to be true?

“Hydrogen-Ready” LNG infrastructure

The molecules are too different.

Hydrogen	LNG
Must be made where it is liquefied. Gas pipelines can’t practically be re-used	Moved to the liquefaction plant by existing gas pipelines
Liquid at -253 °C (24° above absolute 0)	Liquid at -163 °C
30% of its energy lost in liquefaction	8% of its energy lost in liquefaction
Would require 4x shipping & storage for same energy	
Stored in vacuum insulated, spherical tanks	Stored in flat-bottom insulated tanks

The land and the port can be reused, but *none of the equipment will be re-used*

“~~Hydrogen~~ Ammonia Ready” LNG infrastructure

OK, so we’ll use LNG terminals for ammonia!

But…in reality the ammonia plant will be built next to the hydrogen source, because ammonia is cheaper to ship than hydrogen

In Canada, that likely means Alberta- where (black) ammonia is made and used already

The ammonia plant already requires liquefaction equipment as part of the process- there is no need to duplicate it at a port

There is no meaningful re-use potential of LNG terminals for ammonia

Conclusions for Canada’s Energy Transition

Hydrogen in Canada: the cautious view

- **Canada isn't a low cost green hydrogen producer and never will be. We lack the high capacity factor wind + solar hybrids necessary to make cheap green H_2.**

- **Canada's hydroelectricity has a ready market in the US where it offers considerably greater decarbonization potential.**

- **Canada's hydrogen play is clearly "blue" (bruise-coloured) hydrogen made from fossil gas with CCS - but what/who will ensure that the produced hydrogen is "clean"?**

- **Canadian green hydrogen to ammonia for export projects don't appear to be an economic reality. Decarbonizing Nova Scotia's grid is a higher value use for wind power than green hydrogen is.**

Great things Canada can do instead!

- **Decarbonize transportation in Canada by electrification, either directly or via batteries. Take advantage of Canada's (80%) clean electrical grids!**

- **Use our awesome hydro resources to provide storage for wind power, without the losses involved in hydrogen**

- **Focus on decarbonizing the dirtiest grids in Canada: Alberta, Saskatchewan, Nova Scotia and New Brunswick**

Once grids and transport are decarbonized:

- **Encourage green fertilizer production to replace black ammonia- after the local grid is decarbonized**

- **Switch home heating in population centres to heatpumps**

Why is this important?

1. Hydrogen for heating and road transport is inefficient and will increase costs and fuel poverty and damage economies
2. Blue hydrogen will create high emissions - unless done within very strict regulatory controls (the dirtier it is, the more money they make!)
3. Generating green hydrogen will require massive renewable electricity and will delay decarbonization of grid electricity itself;
4. Hydrogen must only be used where there are no other alternatives…
   - Fertilizer, chemicals, iron reduction
   - Not heating, Not heavy trucks, Not electricity storage, Not aviation…
5. Confusion and uncertainty created by hydrogen lobby will delay international decarbonization

www.h2sciencecoalition.com!