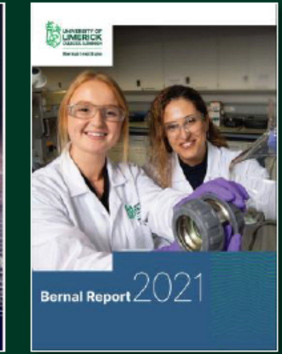

Purposing Irish Sustainable Carbon: Fuel, Fiber or Food ?

[redacted] [2,4]

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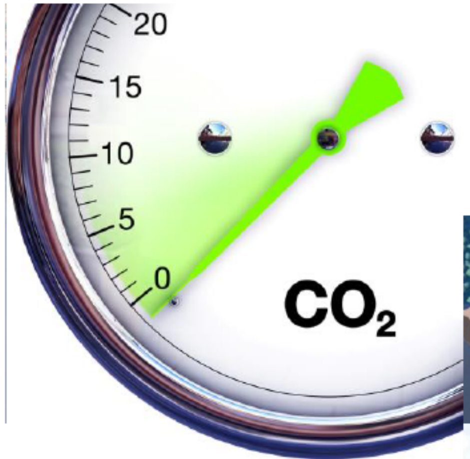
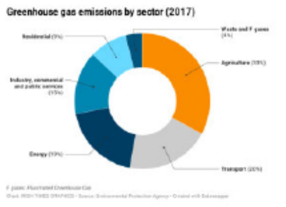
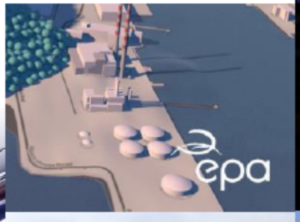
TU Delft [2] platform bio economie [3] Corbion [4]

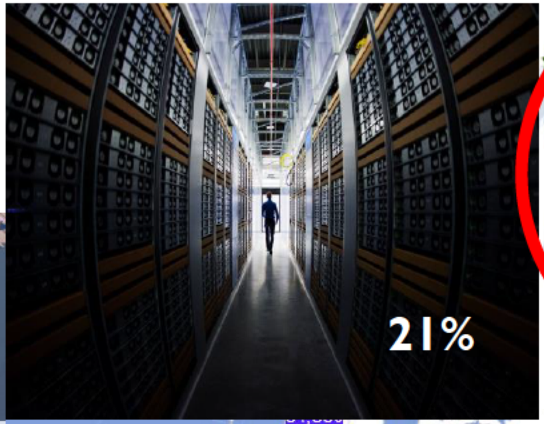
All Island Bioeconomy Summit, Tullamore IRL | 20221012

Current pillars under Irish economy emit carbon, yet some require carbon.



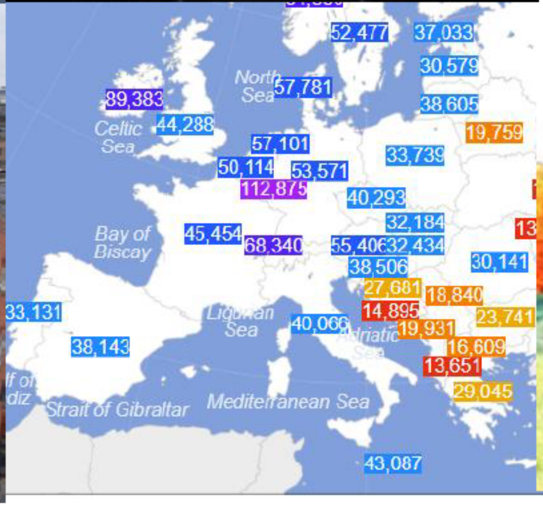






Elements

- aggressive carbon reduction (construction, food, transport)
- -55% EU target/mandates
- economic diversification
- high quality job creation
- nature & biodiversity



"… national biogenic CH4 emissions would need to be reduced by 30–79% for Ireland" *

GDP/capita (2021) IRL $83 800 USA $69 734
NL $58 252 UK $41 811

https://www.epa.ie/climate/communicatingclimatescience/whatisclimatechange/visualisingirelandsgreenhousegasemissions/

* Remi Prudhomme. Cathal O'Donoghue, Mary Ryan, David Styles. **J Environ Management** 295 (2021) 113058.

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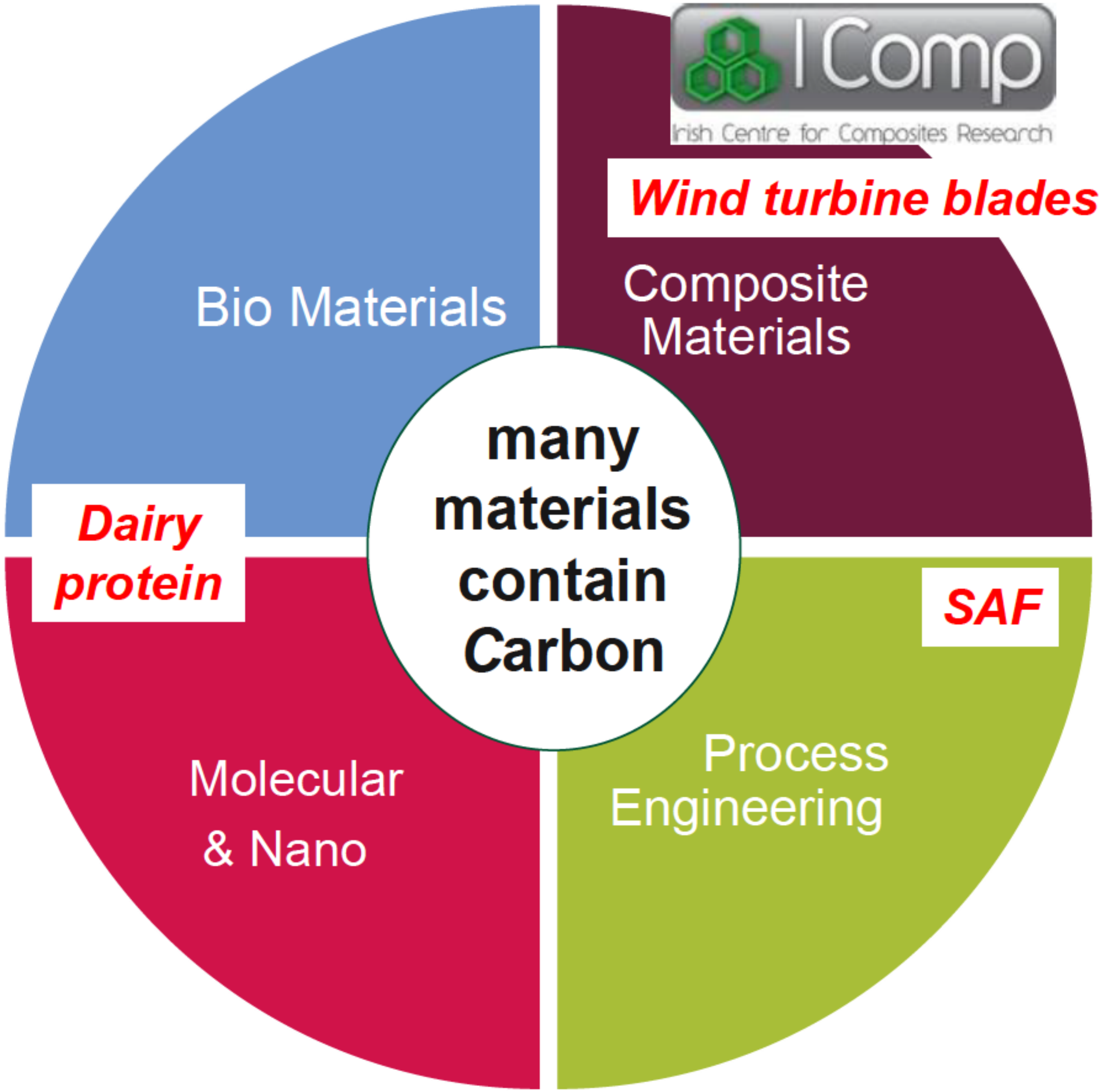
Bernal : structured materials research

Hosted Centres
and associated clusters

SSPC

PMTC

DPTC



Membership Centres

Confirm Smart Manufacturing

Lero

AMBER

CONNECT

cúram

biorbic

MaREI

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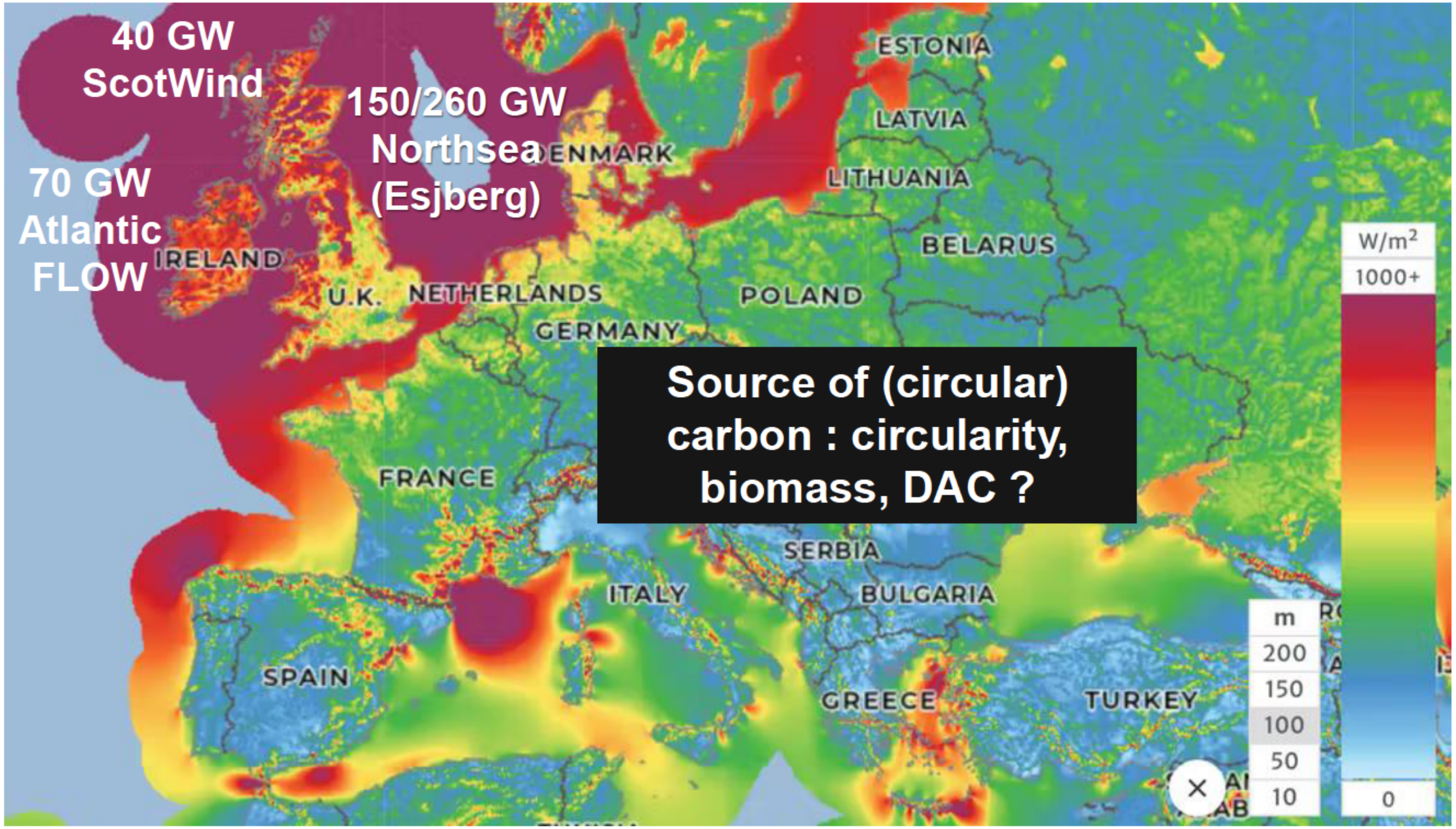
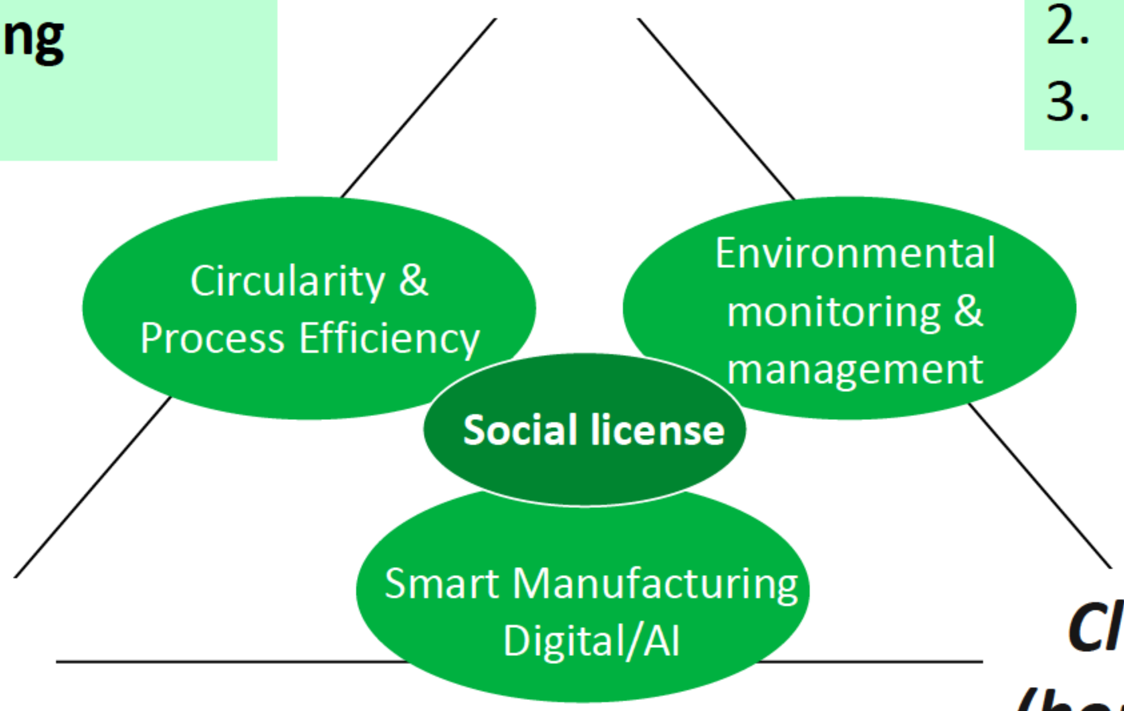
Renewable Wind Energy transforms NW Europe



Think Ireland 2050: driven by decarbonised wind renewable energy

Can we double (or more) future economic impact of carbon requiring sectors ?



Simplified future carbon needs

1. Food – alt proteins & cult meat
2. Fuel – Sust Aviation Fuels
3. Fiber – Atlantic turbine fleet

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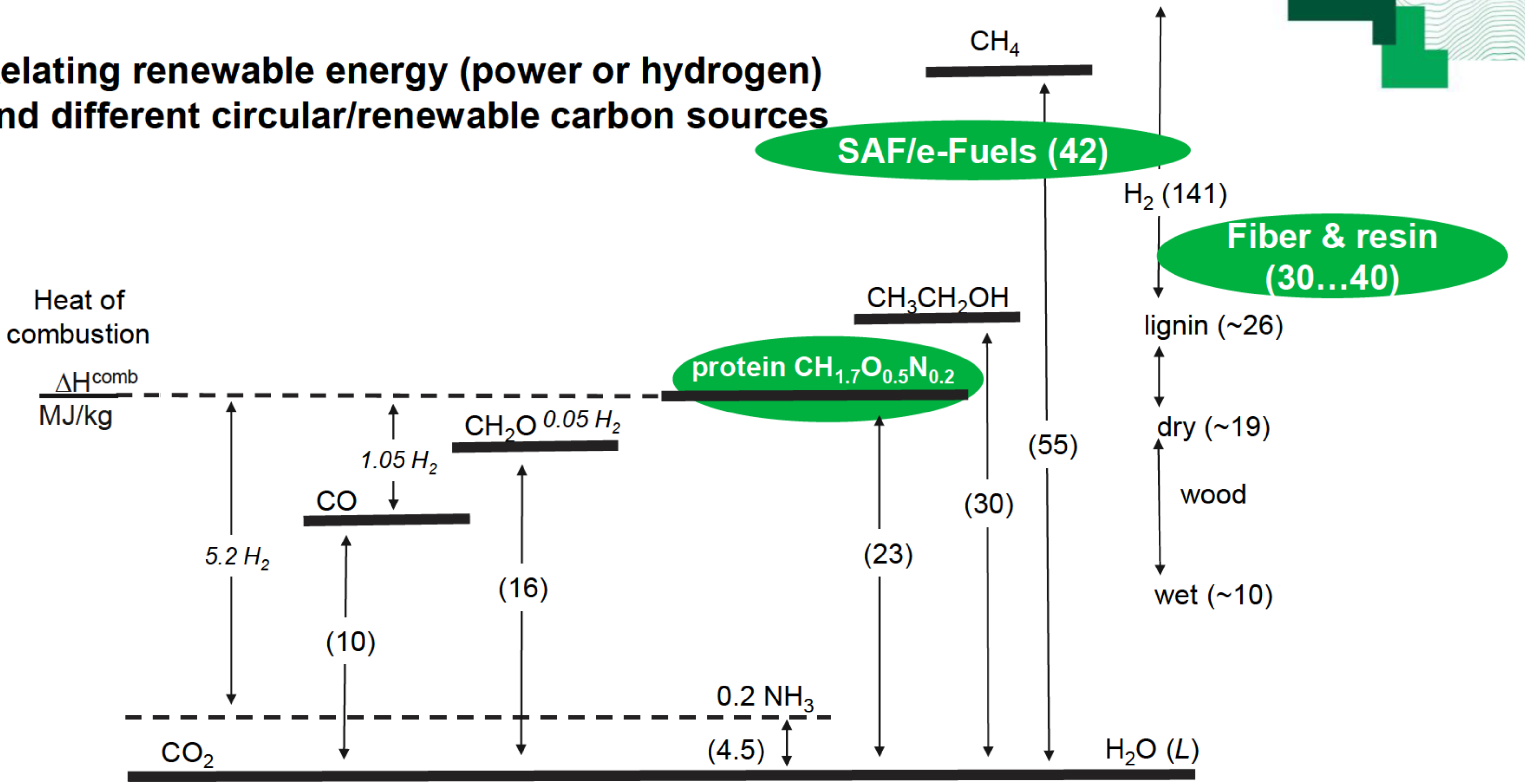
Thanks to:

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

Relating renewable energy (power or hydrogen) and different circular/renewable carbon sources



NH_3 = 22.5 MJ/kg

Future carbon sources in Ireland

source	Amount (kta - kton/yr)	Technology	Price (€/ton)
Atmospheric (CO2)	Infinite at low concentration	DAC	500-1000
Combustion (CO2)	X (none or mobile)	Carbon capture amine/PSA	
Cement (CO2)	6 000 (70% lime stone, 30% current fuels), 30% conc.	Direct use or gas separation	0 ….. 100
Biomass (CH_2O)	forestry, sawdust, energy crops 498..2180 ktoe (1162-5087 kton)	Collect, depolymerise, hydrolyse or gasify	100-200 transport (400 as sugars)
Biomethane (*CH_4, CO_2)	Distributed digesters per farm or cooperation, MSW around cities 305..952 ktoe (230-720 kton)	Direct use or gas separation (or fatty acids after acidification)	Emerging market 400-660/2 *
Plastics / rubber (-CH_2-)	• 300 – packaging / diverse • **140 -** end-of-life wind turbines (75 GW FLOW)	Collect, decompose, depolymerise (polyesters) or gasify (polyolefins).	100 (syngas) …. 1500 (chem building blocks)

* anaerobic digesters produce equivalent amounts of CH_4+ CO_2

https://www.seai.ie/publications/Bioenergy-Supply-in-Ireland-2015-2035.pdf

Biogenic carbon availability in IRL (2020)

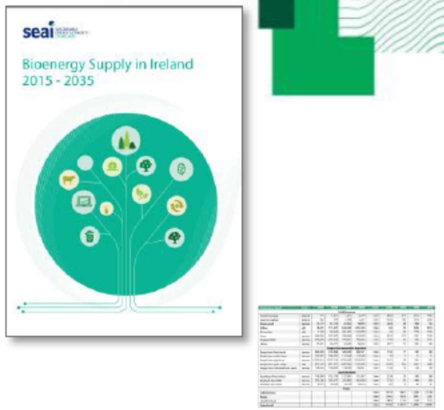
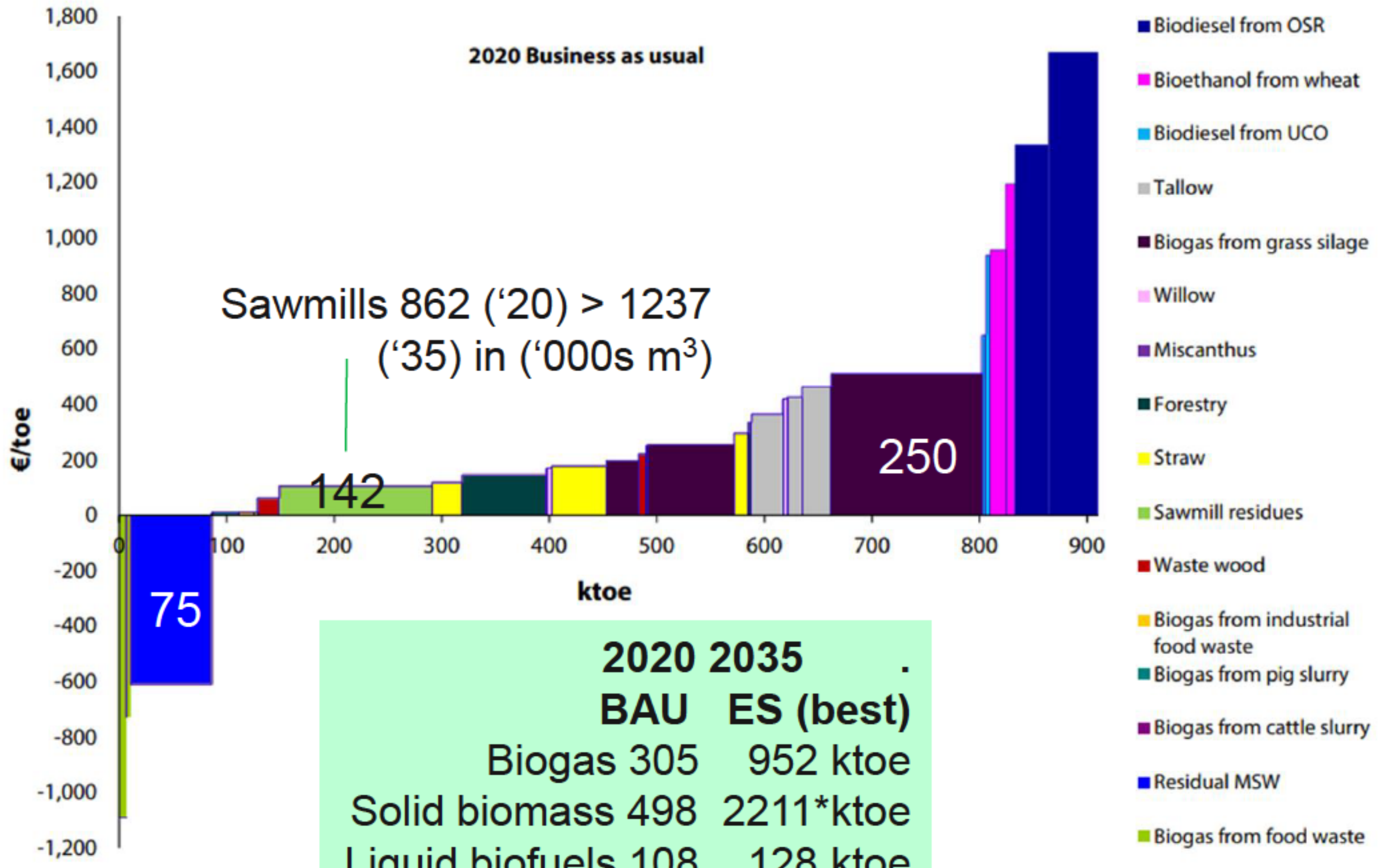


Figure 1.4: Supply curves for all resources in 2020 BAU scenario



	2020 BAU	**2035 ES (best)**
Biogas	305	952 ktoe
Solid biomass	498	2211*ktoe
Liquid biofuels	108	128 ktoe
Total	**910**	**3291 ktoe**

https://www.seai.ie/publications/Bioenergy-Supply-in-Ireland-2015-2035.pdf

toe ~ 42 GJ = 11.630 MWh

@ 18 GJ /ton wood

* Increase due to projected Forestry, Energy crops (willow, miscanthus) and grass silage

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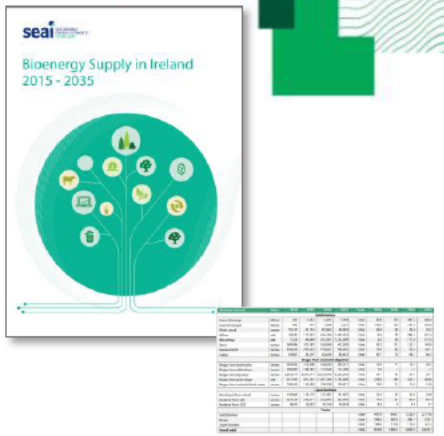
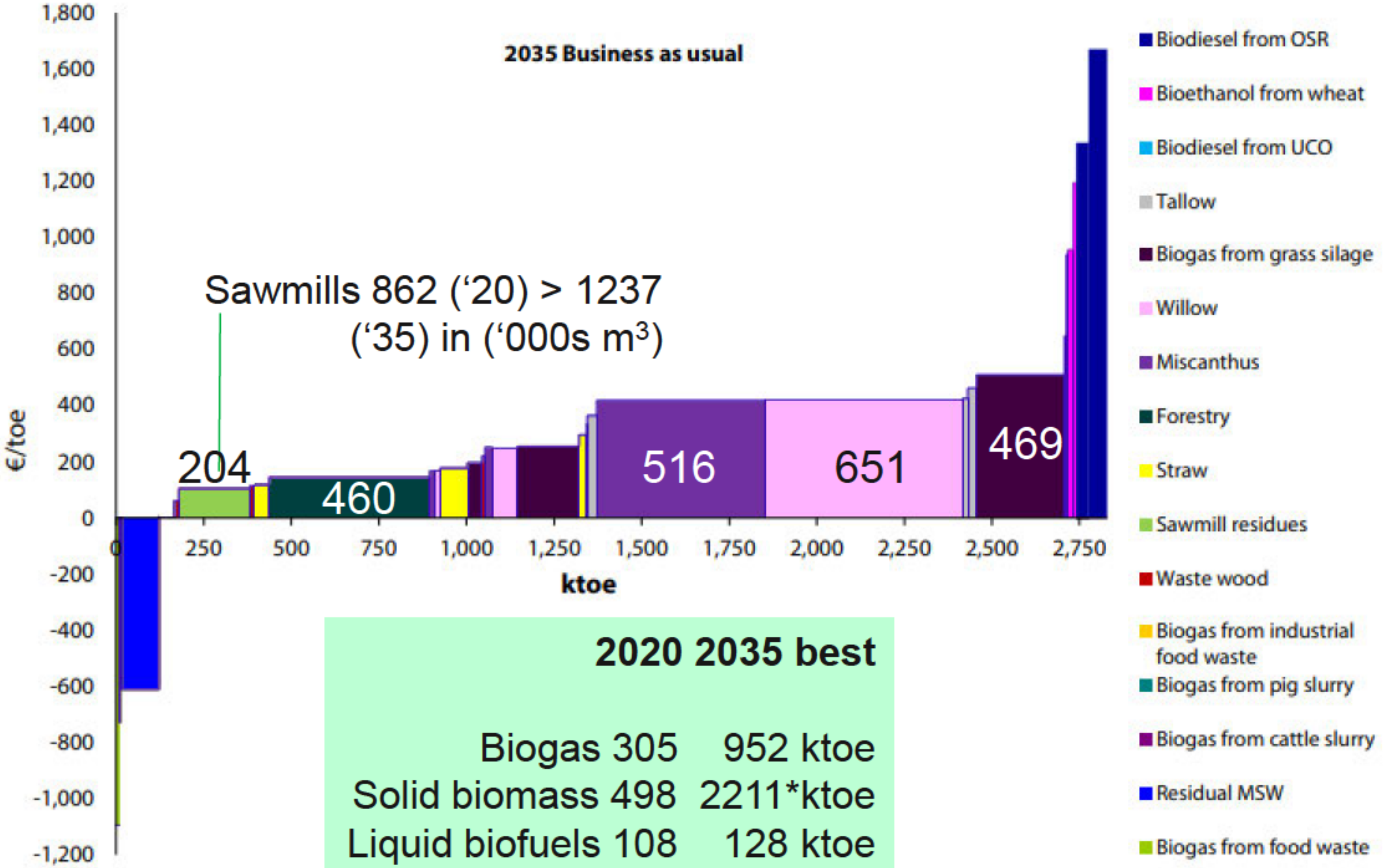
Biogenic carbon availability in IRL (2035)





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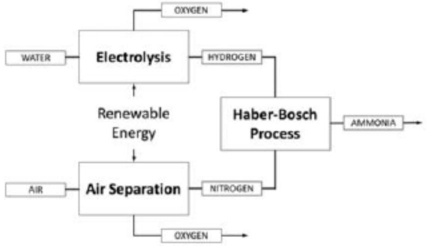
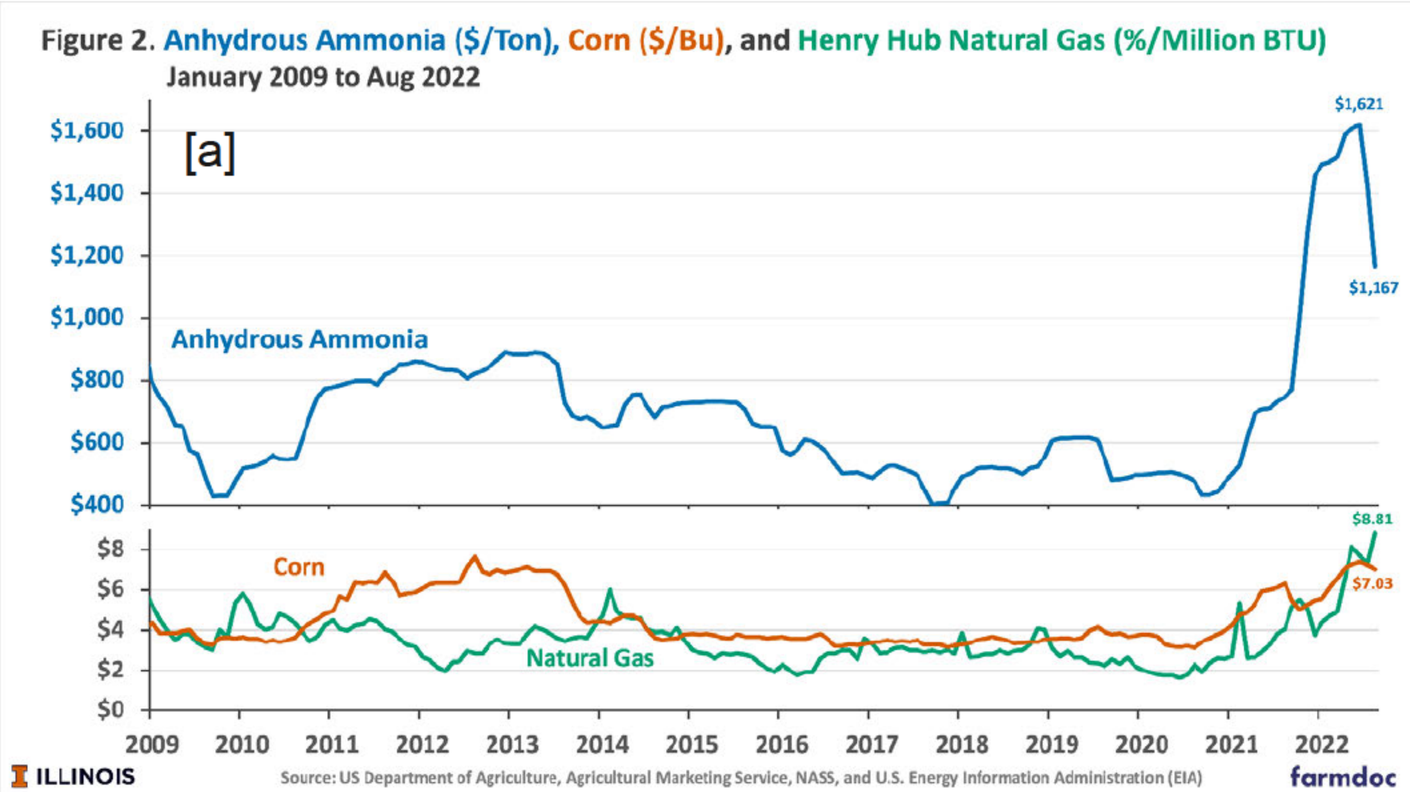
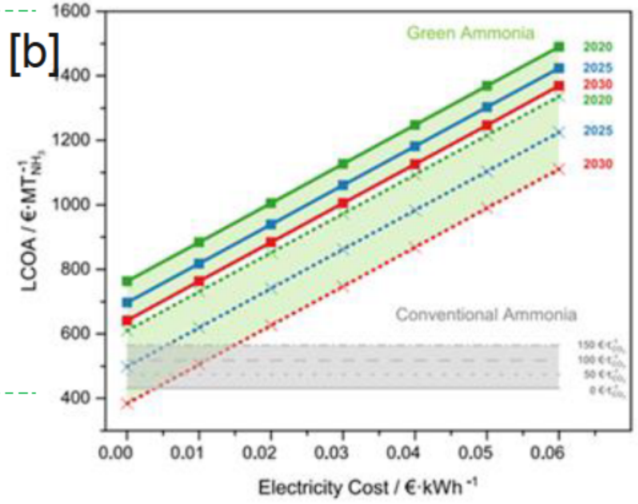
Historic/fossil and Electrolytic Ammonia prices

Pre-war: e-NH3 *'by CF's estimates, green ammonia will cost about $500 per metric ton to make, about three times as much as conventional ammonia'*. ([CE&N 3/'21](#))







Green hydrogen 2 .. **5** .. 8 €/kg

[a] Schnitkey, G., N. Paulson, C. Zulauf, K. Swanson and J. Baltz. "Fertilizer Prices, Rates, and Costs for 2023." farmdoc daily (12):148, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, September 27, 2022.

[b] Joana Sousa, Wendelin Waiblinger, and Kaspar Andreas Friedrich. Techno-economic Study of an Electrolysis-Based Green Ammonia Production Plant. Industrial & Engineering Chemistry Research 2022 61 (39), 14515-14530 (DOI: 10.1021/acs.iecr.2c00383)

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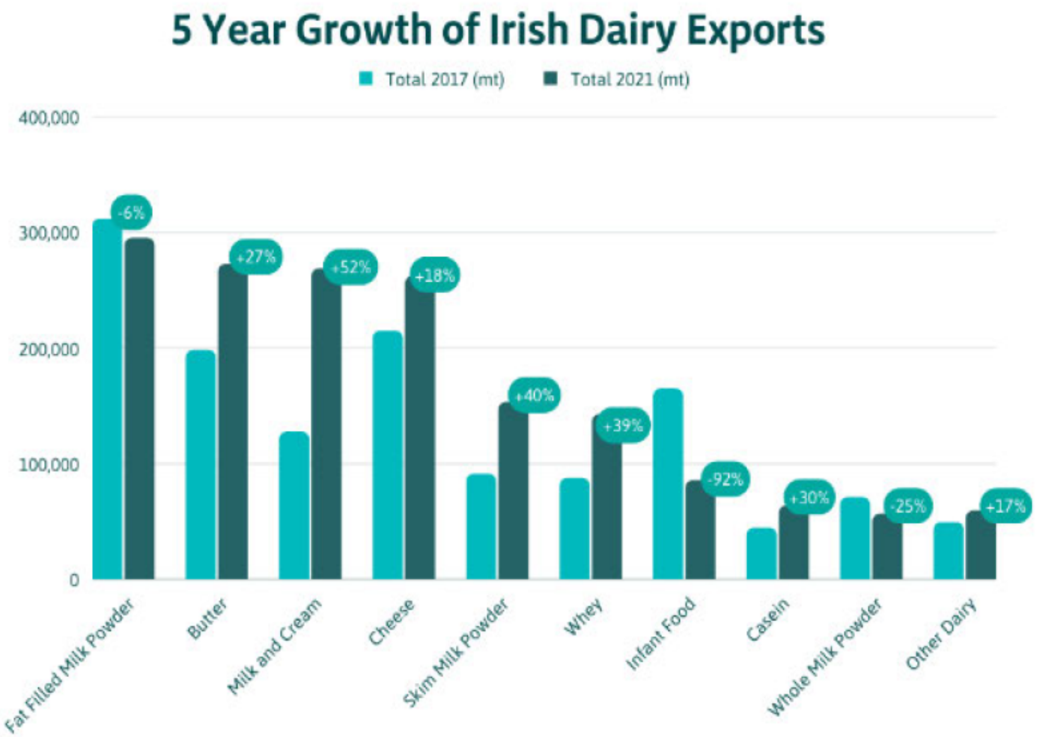
Dairy prot-economics

Republic of Ireland	protein kta	price €/kg
Population of 5m needs		
Protein @ 23 kg pp/yr (veg. & animal)	116	
Milk production (8750 kta @ 3.5% protein)	306	
Exports cheese (250 kta ~ € 1 bn)	100	10
Exports specialties (550 kta ~ € 3 bn)	165	18
Exports butter (270 kta ~ € 1 bn)	-	-
Milk : 9.5 kg CO2 / kg protein		



* https://www.bordbia.ie/industry/irish-sector-profiles/dairy-sector-profile/

Protein in cheese 40%, butter 0%,
milk powders & specialties 27…35%

Can dairy export potential be doubled (or more) at constant (todays) footprint ?

- Role for power & CO_2 to protein (or microalgal/cyano bacterial) concepts ? (gas fermentations converting 3.3 ton CO_2 into 1 ton microbial protein)
- Sufficient sustainable carbon at point source (or distributed) ?

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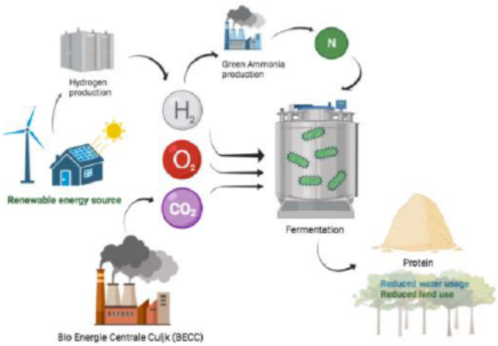
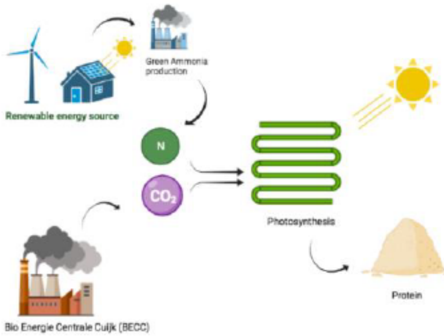
Bernal Institute
TU Delft

alternative protein plant bolted on CO2 point source



microbial gas fermentation



cyanobacteria/microalgal solar bioreactors

K Wattel, L Smulders, S. Sikrishnan, M Teke, A. Lazopoulou, D Goedhuis, J van Breugel, M Palmeros, LAM van der Wielen. H2Protein – 75 kta alternative protein plant based on Bioenergy Centrale Cuijk. Design Report TU Delft-BECC july 2022

See also https://www.tudelft.nl/en/2022/tnw/national-growth-fund-finances-cellular-agriculture

Bio Energie Centrale Cuijk

PHOTANOL

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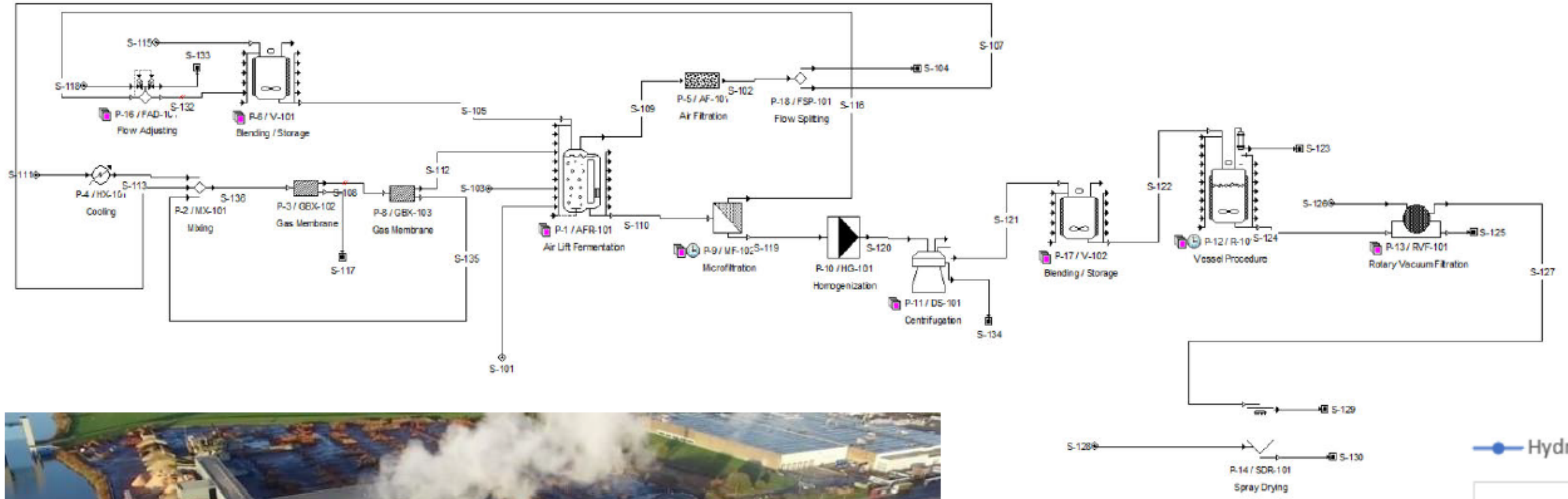
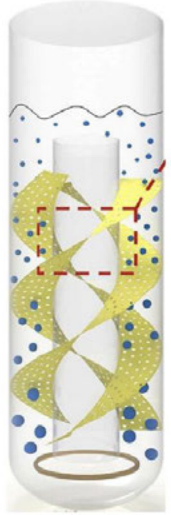
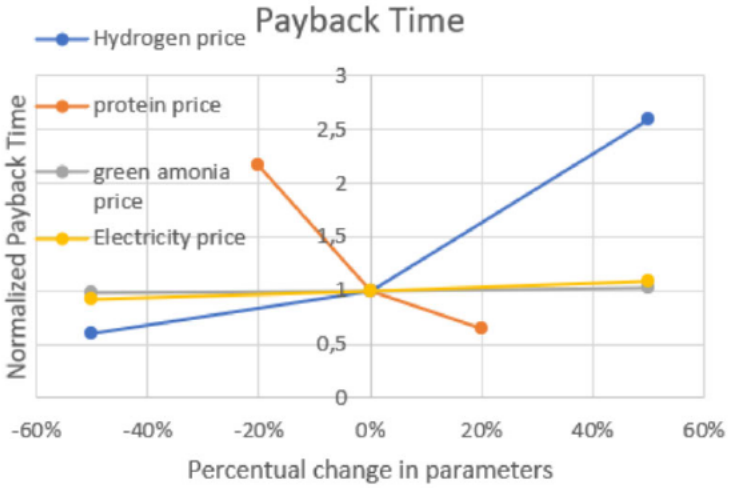
75 kta alternative protein plant bolted on BECC 20 MWe/20 MWth thermoelectric plant





doi: 10.1016/J.CEJ.2018.01.039.



K Wattel, L Smulders, S. Sikrishnan, M Teke, A. Lazopoulou, D. Goedhart, J van Breugel, M Palmeros, LAM van der Wielen. H2Protein – 75 kta alternative protein plant based on Bioenergy Centrale Cuijk. Design Report TU Delft-BECC july 2022

Investable payback time with several cost reduction options RE 14ct/kWh; hydrogen € 5/kg; ammonia €600 /ton CO2 – flue capture (€ -0.35/kg); protein selling price € 10/kg

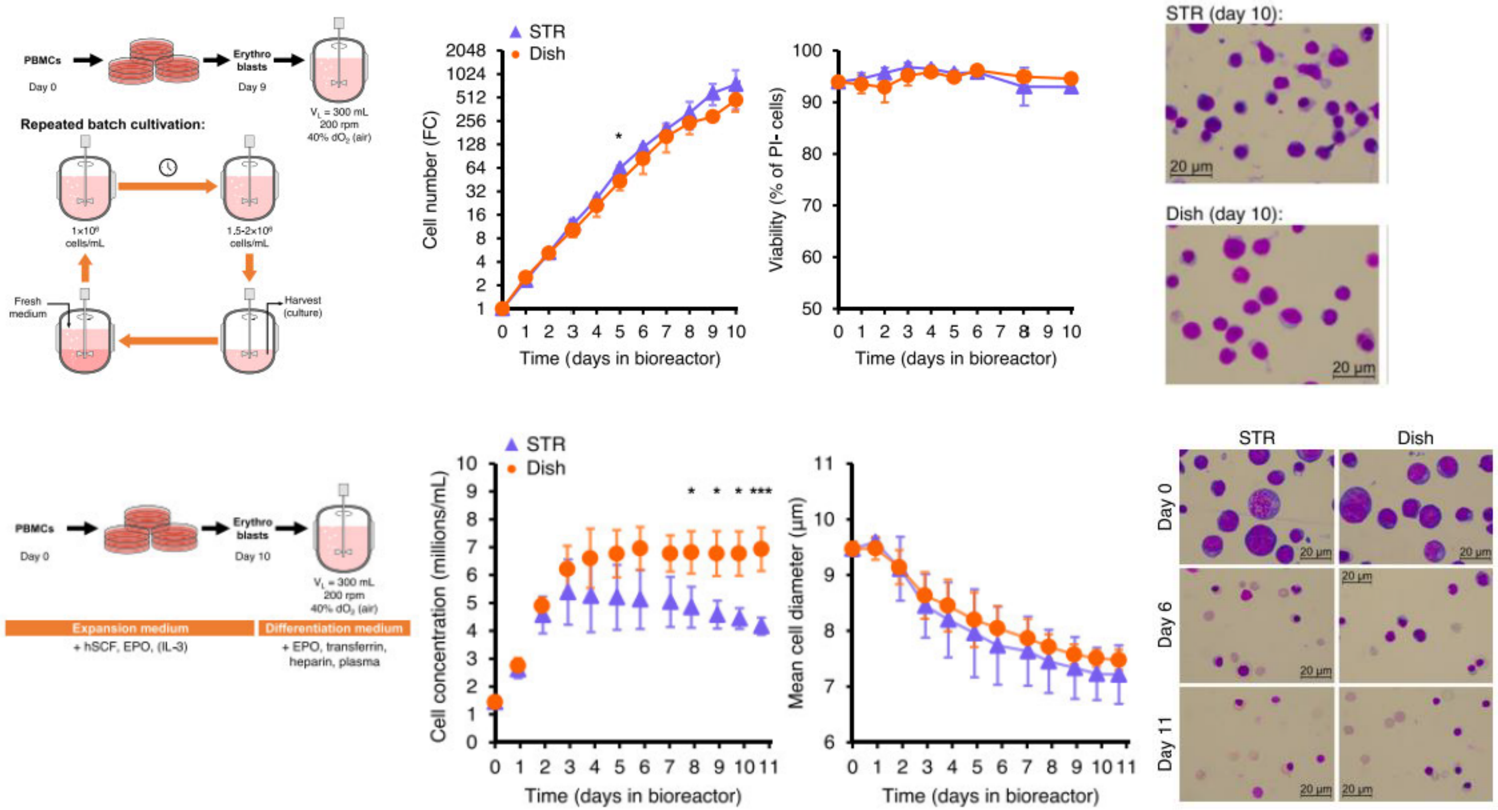
Also alternative cases: RWE/DSM/TU Delft.

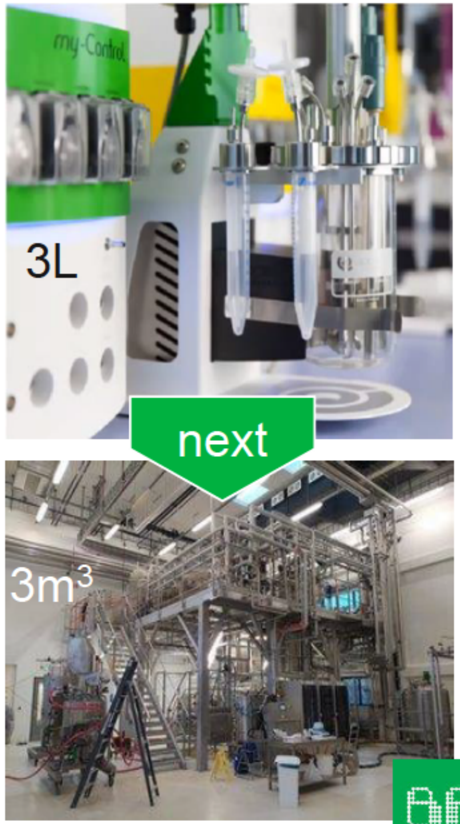
Towards cultured meat & donor-free cell therapy

Successful scale-up (1000x) of (A) manufacturing of erythroblasts ('red blood cell stem cells') and (B) differentiation to mature erythrocytes ('red blood cells') from mL to standard 3L bioreactors.

(A)

(B)





Joan Gallego, Giulia Iacono, Luuk A. M. van der Wielen, Emile van den Akker, Marieke von Lindern, Aljoscha Wahl Expansion and differentiation of ex vivo cultured erythroblasts in scalable stirred bioreactors. Biotechnol Bioeng. 2022;1–21. DOI: 10.1002/bit.28193

Sanquin
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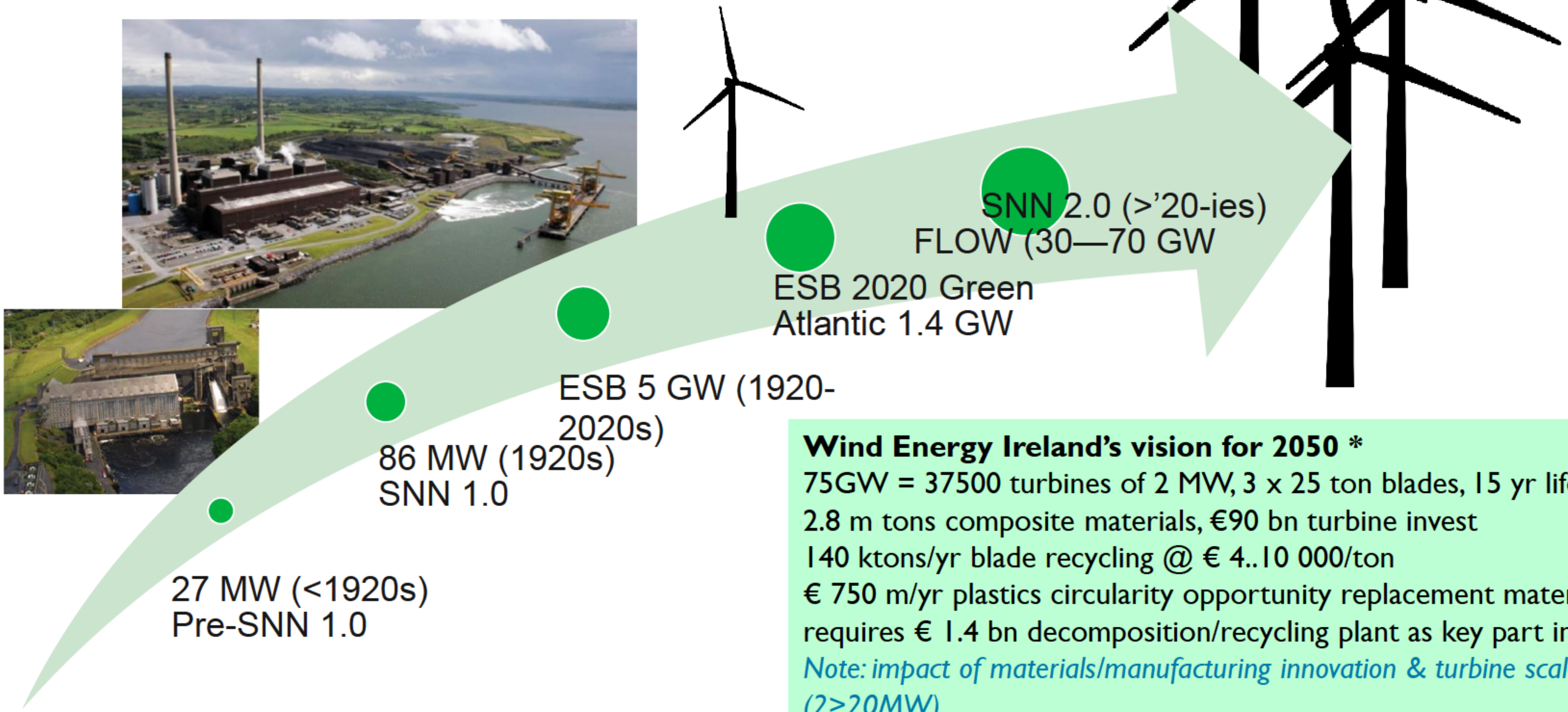
TU Delft

75 GW Atlantic Floating Offshore Wind FLOW enables Plastics Circularity Economic Opportunity



Wind Energy Ireland's vision for 2050 *

75GW = 37500 turbines of 2 MW, 3 x 25 ton blades, 15 yr lifetime;
2.8 m tons composite materials, €90 bn turbine invest
140 ktons/yr blade recycling @ € 4..10 000/ton
€ 750 m/yr plastics circularity opportunity replacement materials
requires € 1.4 bn decomposition/recycling plant as key part in
Note: impact of materials/manufacturing innovation & turbine scale-up (2>20MW)

* WEI (July'21) *Revolution: A vision for Irish floating wind energy*
download - https://windenergyireland.com/policy/reports-position-papers

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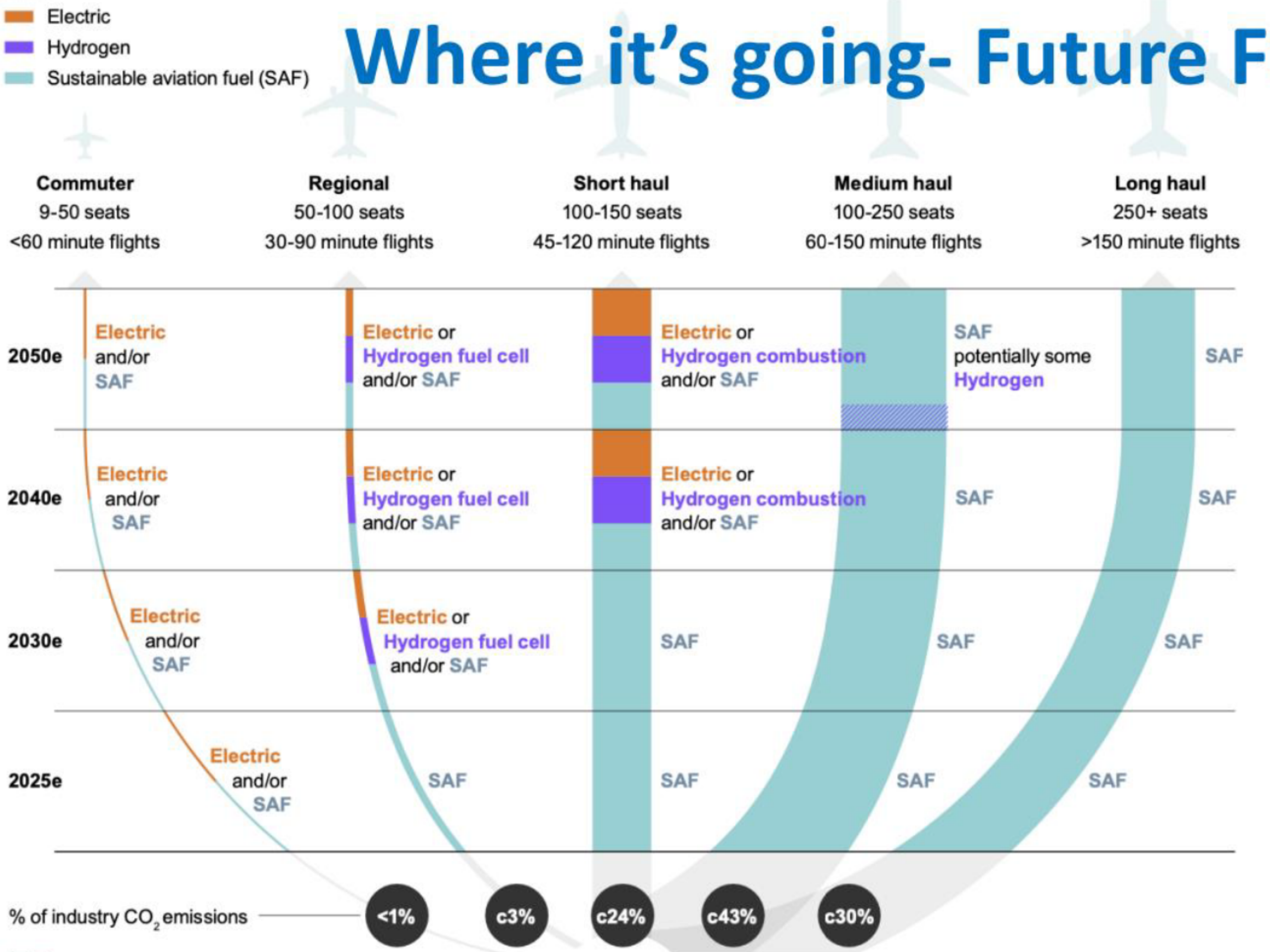
Example

Where it's going- Future Fuels:



Medium and Long haul aviation will depend on SAF for the foreseeable future.

Regional will only see the introduction of alternatives from mid-late 2030

Source: HSBC Global Research & ATAG ("Waypoint 2050" report)

[redacted]

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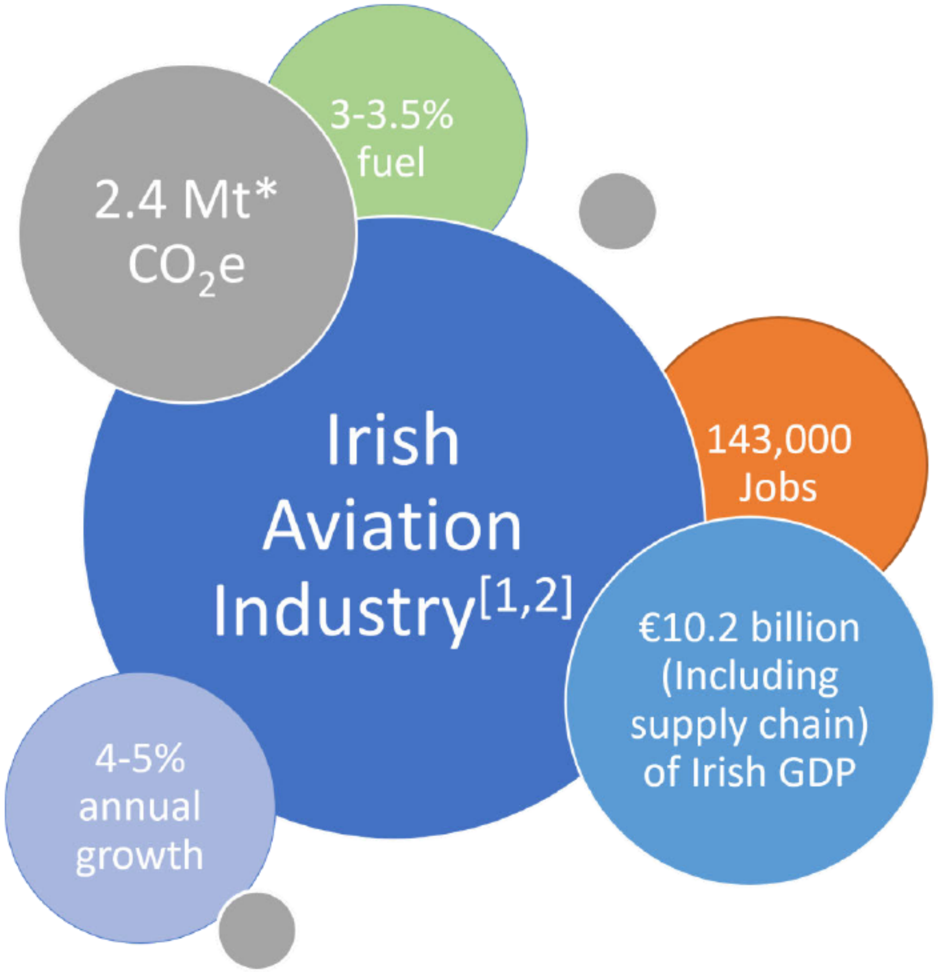
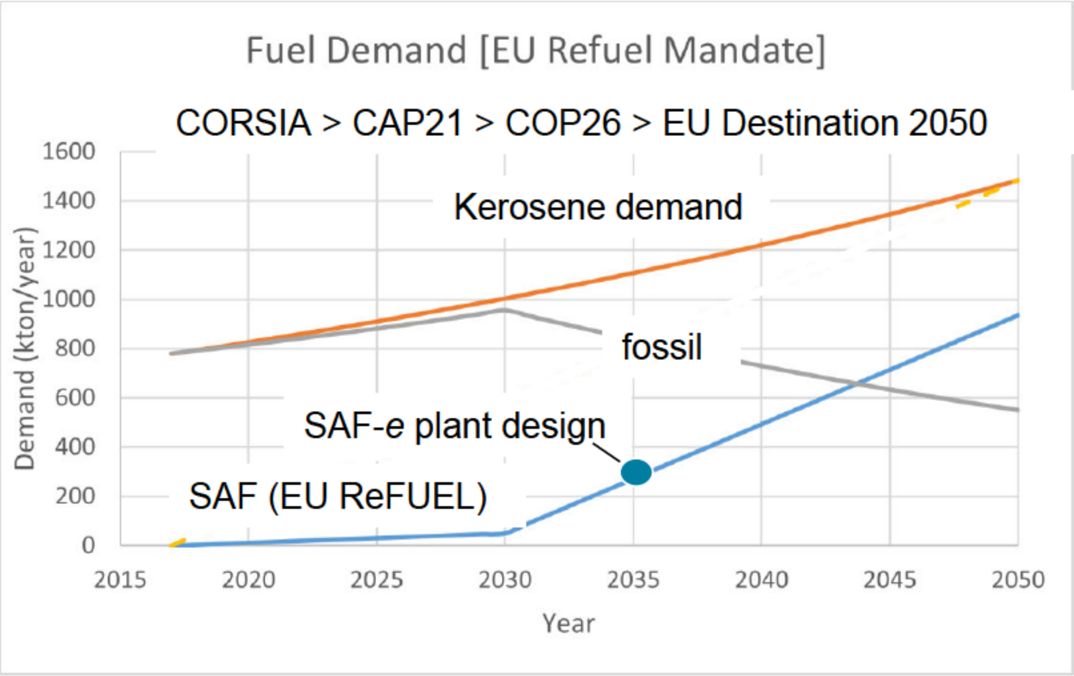
[redacted]

SAF-*e* project



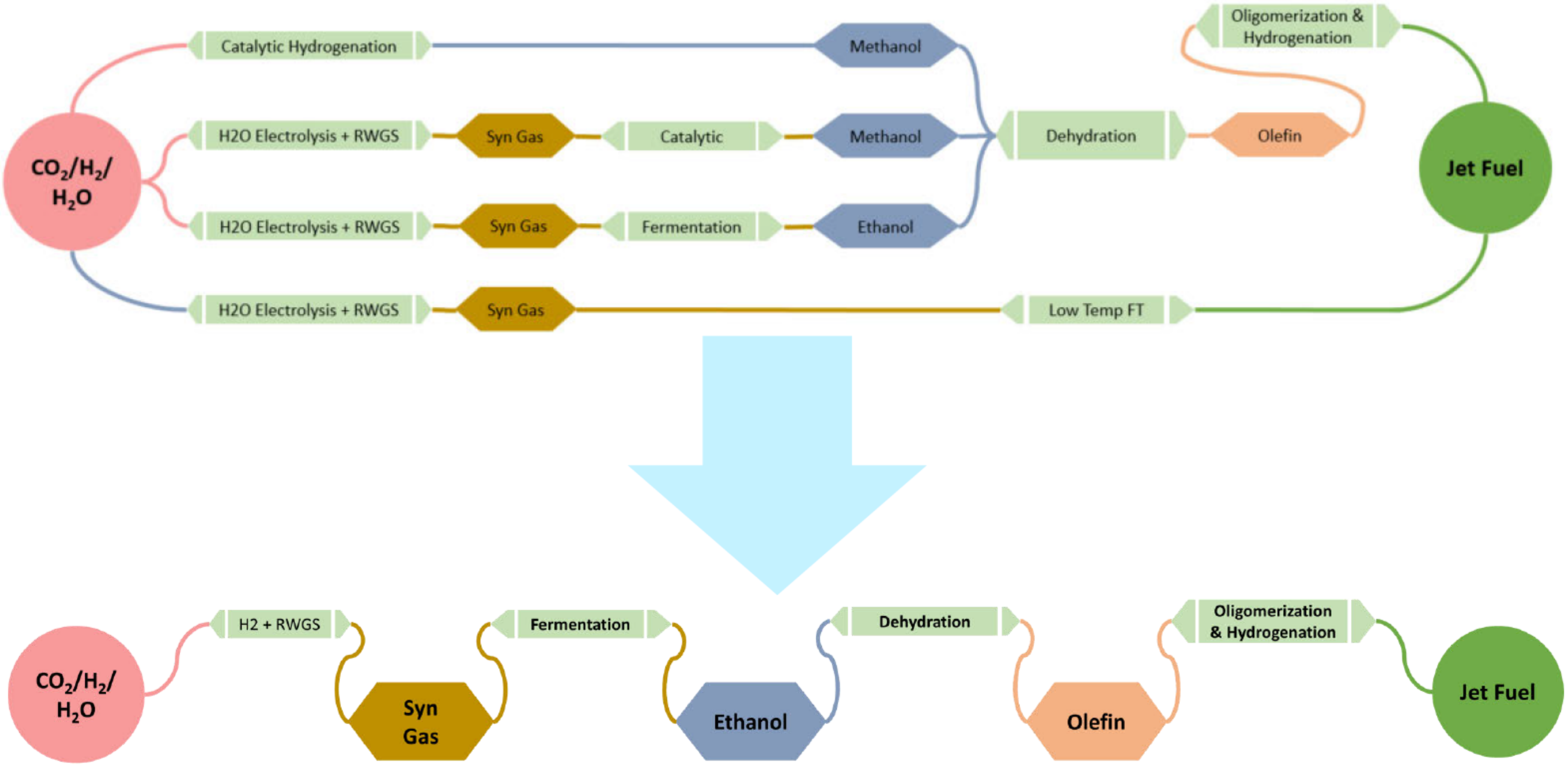
* Estimated from fuel consumption in 2017



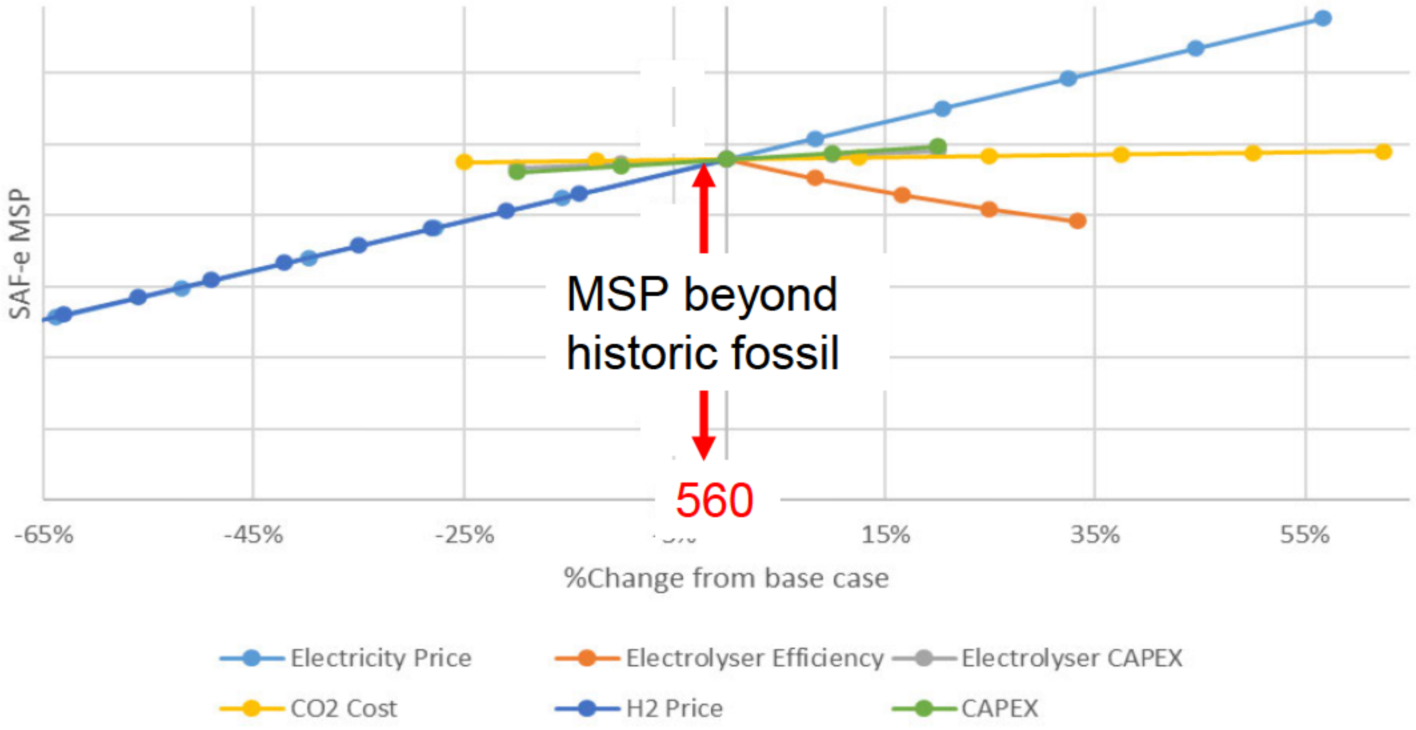
Plant Location	**Near CO_2**
Plant Capacity*	**350 kta SAF-e**
Plant Production rate incl byproducts	490 kta
Operational hours	8000 hrs
Operation mode	Continuous

Capacity is based on 1750 kta CO_2 Supply

Process Inventory and Selection



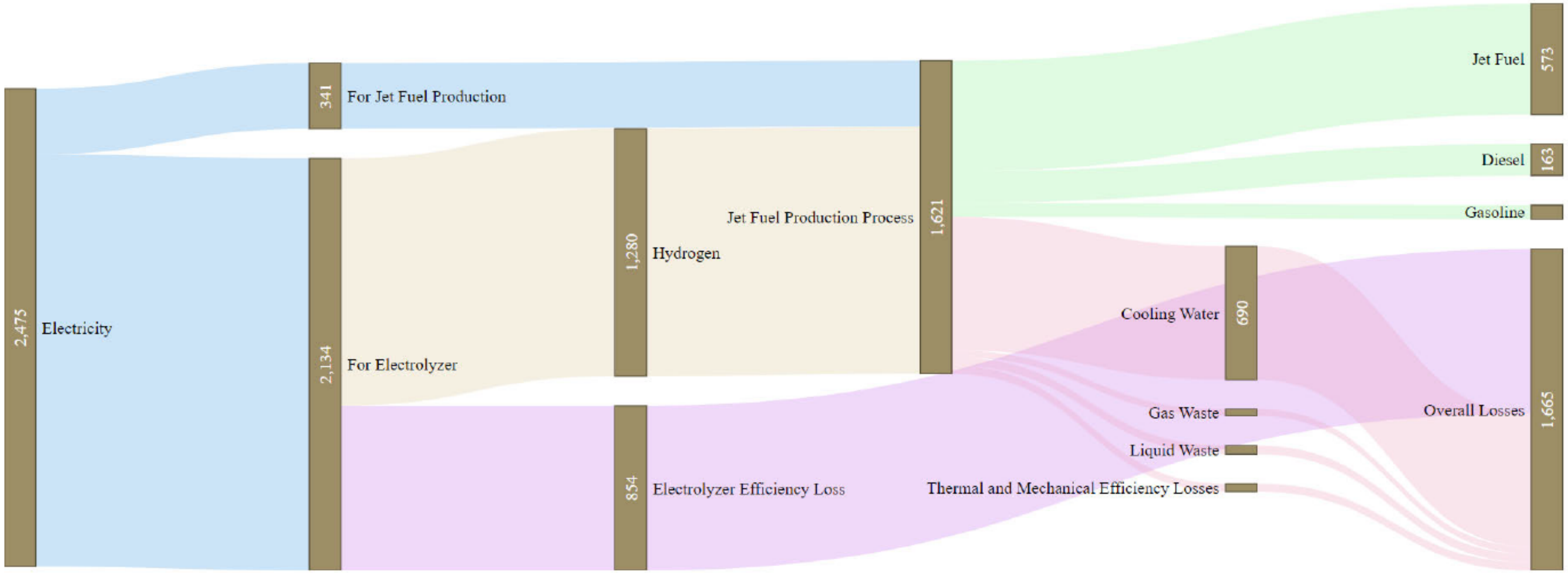
Minimum selling price



H_2 (manufacturing) main cost driver.

Project Background
Project Objectives
Basis of Design
Process Design
Heat & Mass Balance
TEE
LCA
Scenario Analysis
Scale Up Aspects
Conclusion
Recommendations

Scenarios: Energy Optimization



Units in MW

Significant cost and GHG reduction opportunities by further process integration.

TU Delft

Biogenic carbon use in 2050-ies Ireland

Low Carbon Ag/Foods

Future carbon needs	economics	environment	scale
1. Food – alt proteins & cult meat	√√√√	√√√√	100s-1000s kta
2. Fuel – Sust Aviation Fuels	~ √	√√	1000s kta
3. Fiber – Atlantic turbine fleet	√√	√√√	100s kta

Circular Materials

Clean Energy & Transport (homes, data, people, goods)

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