SDU
LIFE CYCLE ENGINEERING

Dilemma 1: Produktion

- hvad skal det danske jordbrug producere?
- hvordan sikrer vi tilstrækkelig og bæredygtig produktion af både fødevarer, materialer og energi?

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Dansk Bioøkonomi Konference 2021
Maribo, 27. oktober, 2021

Estimerede behov for kulstofholdige brændsler og råvarer efter maximal elektrificering

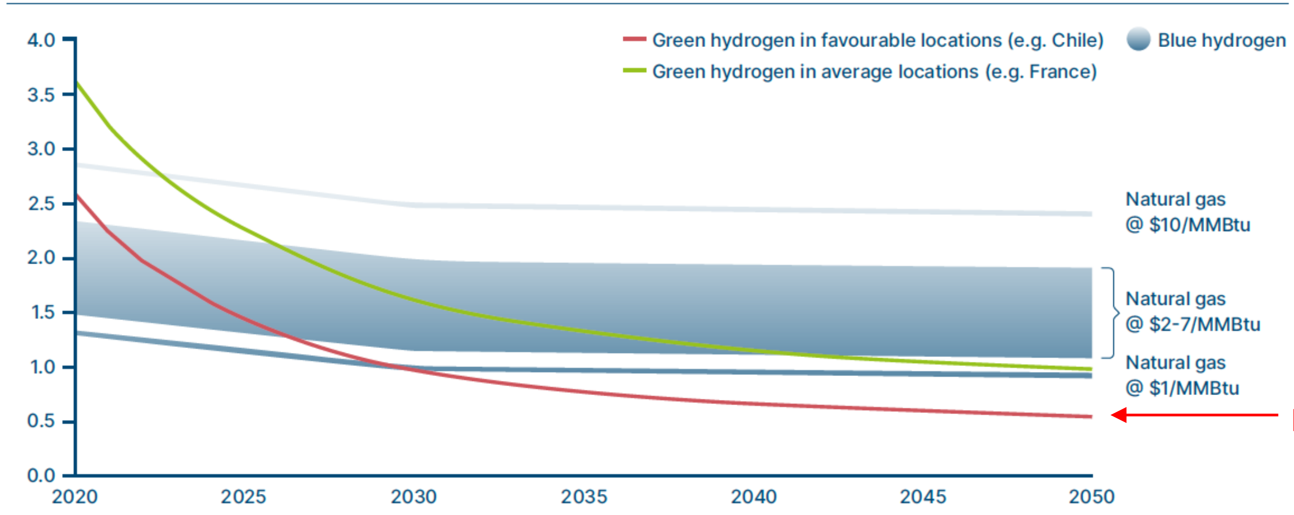
Sector	Demand 2050 (EJ/y) Low	High	Alternatives to fossil fuels and feedstock	Comments
Steel	5	20	Hydrogen, biomass/bio-coke, CCS,	Focus on hydrogen in Germany. Hydrogen-based technology being developed by Thyssen-Krupp
Cement	0*	30	Waste (SRF), waste from landfill mining, CCS, bio-methane, wood chips	Can take dirty, waste-based fuels. Ålborg Portland mentions landfill mining as potential future option. Also focus on CCS. * = 0 presumes all on landfill mining or CCS. Concrete re-absorbs CO_2 during its lifetime. Landfill mining + CCS + enhanced re-absorption => cement/concrete can have a very large negative carbon footprint
Plastic + other chemicals	60	120	Mechanical & chemical recycling, electrification, bio-plastic, e-naphta	According to LEGO, Dow and Shell work on electrification of crackers. Around 75 % of of processing energy for plastic making judged to be electrifiable
Buildings	30	40	Bio-insulation e.g. PUR More timber in construction	Main demand for biomass in buildsings judge to be in floors, ceilings, kitchens, furniture. Growing population and living standars judged to be main driver for increase
Industry	20	40	Electric boilers, bio-methane, e-methane	Electric biolers possible in many cases, but not for high temperature and flame
Peak load heating	30	50	Electric boilers, heat pumps, CCS, bio-methane	Peak load heating calls for low investment cost/MW => fuel based
Electricity balancing	10	20	Bio-methane, wood chips, CCS, ammonia, hydrogen	Electricity balancing calls for low investment cost/MW => bio-methane
Road transport	5	10	Bio-methane, biofuels, e-fuels, hydrogen	
Jetfuel	15	20	Electrification, hydrogen, HVO type bio-fuel, HTL, pyrolysis/gasification, e-fuels	Airbus claims focus on hydrogen. ATAG claims more than 50 % needs kerosens type. Due to slow fleet transition => min 75 % needs keroseene type by 2050
Marine fuel	0*	20	Hydrogen, ammonia, bio-methanol, e-methanol, bio-methane, e-methane,	End fuel demand = 20 EJ/y by 2050 + conversion losses. * = 0 presumes all on non-carbon based propulsion like electricity, hydrogen or ammonia
Food/feed/meat	(45)	(50)	Animal feed from BMP from CO_2, N_2 + H_2	Also a competitor for land/biomass. Demand not included in summation 'Total'
Total	175	370		BAU scenario says total primary energy demand by 2050 = 900 EJ/y (WEC, 2013) Availability = 150-200 EJ/y by 2050 – newest study from ETC says 40-60 EJ/y

Estimates are largely based on extrapolation of Danish system design studies on electrification possibilities applied to world scale

Pris/omkostnings-udvikling for biomasse og brint

Biomass type	Price ab supplier €/GJ	Global biomass supply EJ/y	Reference
Straw	4.3	80	EA Energianalyse, 2011
Wood chips (DK)	5.9	80	EA Energianalyse, 2011
Wood pellets	10.3	80	EA Energianalyse, 2011
Woody biomass ab forest	21	170	Frank et al., 2021 (IIASA – GLOBIOM model)

Cost of hydrogen production from different production routes (excluding transport & storage costs)
$/kg H_2



Electricity cost at $10/MWh by 2050 (= 6 øre/kWh)

Energy Transitions Commission, 2021
BloombergNEF, 2021

NOTES: Blue hydrogen production: i) forecast based on SMR+CCS costs (90% capture rate) in 2020 transitioning to cheaper ATR+CCS technology in the 2020s; Green hydrogen production: i) favorable scenario assumes average LCOE of PV and onshore wind of lowest 33% locations (falling from $22/MWh in 2020 to $10/MWh in 2050) and average scenarios assumes median LCOE from lowest 75% locations (falling from $39/MWh in 2020 to $17/MWh in 2050) from BloombergNEF forecasts, ii) additional 20% (favorable) and 10% (average) LCOE savings included due to directly connecting dedicated renewables to electrolyser, iii) 18 % learning rate for favorable & 13 % for average scenario. Electrolyser capacity utilization factor: 45%. Comparison to BloombergNEF most favorable ($0.55/kg) and average ($0.86/kg) and Hydrogen Council favorable (ca. $0.85/kg) and average (ca. $1.45/kg) in 2050.

SOURCE: BloombergNEF (2021), *Natural gas price database* (online, retrieved 01/2021), BloombergNEF (2020), *2H 2020 LCOE Data Viewer*; BloombergNEF (2021), *1H2021 Hydrogen Levelised Cost Update*; Hydrogen Council (2021), *Hydrogen Insights*

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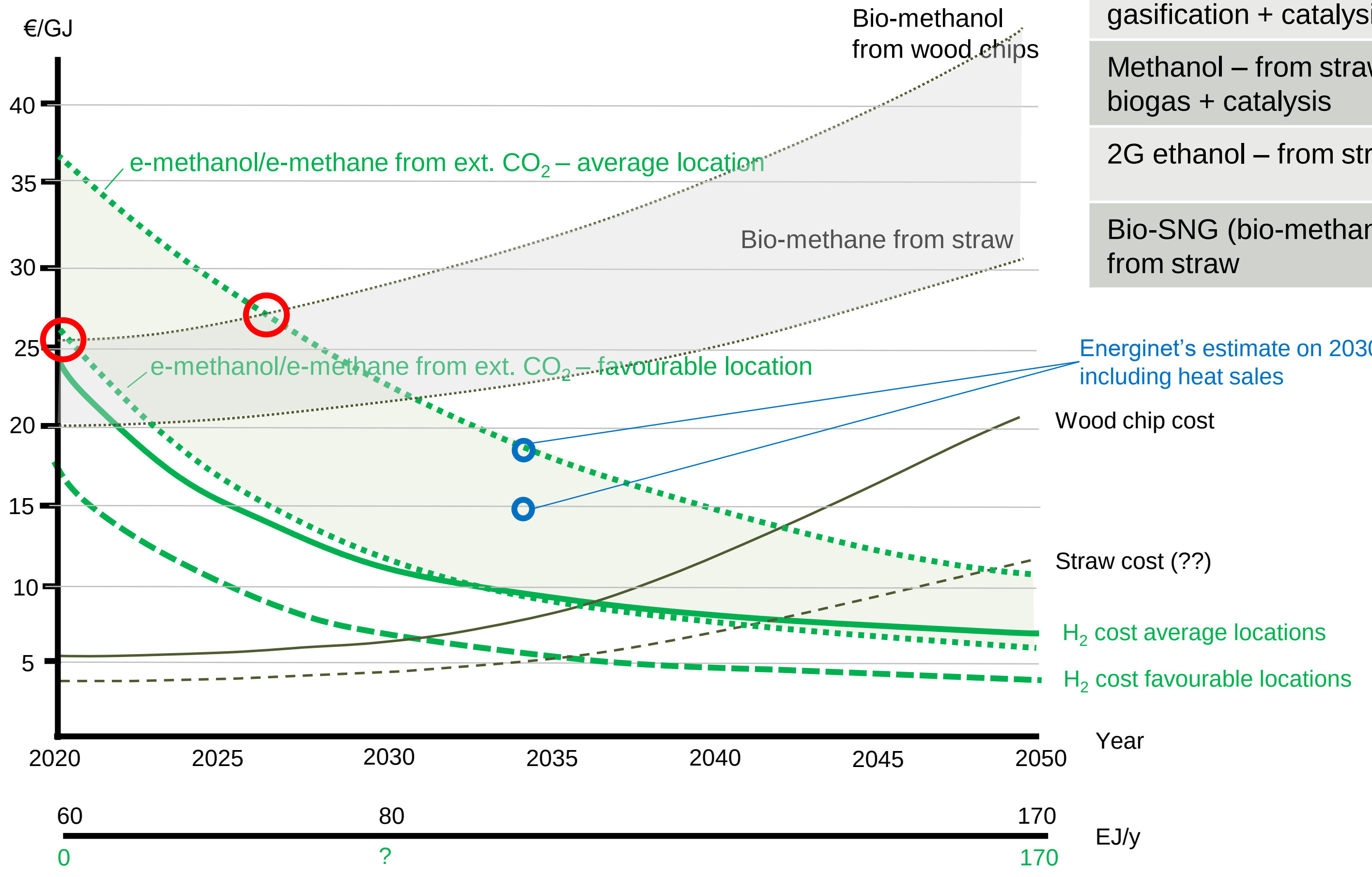
Forventet breakeven pris for bio-fuels og e-fuels



Fuel type & pathway	Straw €/GJ	Wood chips €/GJ	Biofuel[1] €/GJ	Biomass conversion share
Diesel – from wood chip gasification + FT	-	5.9	37	84 %
Methanol – from wood chip gasification + catalysis	-	5.9	26	77 %
Methanol – from straw based biogas + catalysis	4.3	-	26	83 %
2G ethanol – from straw	4.3	-	38	89 %
Bio-SNG (bio-methane) – from straw	4.3	-	20	78 %

[1]EA Energianalyse & SDU, 2016

E-methanol

- CO2 cost ca. 30 % of fuel cost towards 2050
- Conversion cost almost paid by heat sales – let's say +5 %
- Hydrogen cost thereby around 65 % of fuel cost = 2/3

⇒ e-methanol cost ≈ 150 % of hydrogen cost
⇒ Share of conversion + CO2 = 33 % by 2050

E-methane

- From biogas-CO2: e-methane cost ≈ 105 % of hydrogen cost

⇒ Share of conversion + CO2 = 5 %

- From external CO2: a little cheaper than e-methanol, e.g. 140 % of hydrogen cost

=> Share of conversion + CO2 = 28 %

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Konklusion

- Tilgængeligheden af kulstof er begrænset i forhold til behovet i et fossilfrit samfund. Biokulstof forslår til under halvdelen af behovet
- Der er derfor behov for Direct Air Capture, når de ikke-elektrificerbare dele af vores behov for energi, materialer og kemikalier skal forsynes med kulstofholdige råvarer
- Jordbruget vil primært komme til at producere fødevarer, foder og andre højværdi-produkter, hvor den biologiske oprindelse og produktets særlige egenskaber begrunder dette
- Kulstof til energi og materialer vil primært være side-produkter til ovenstående – jordbruget kommer ikke til at producere kulstof/bulk biomasse som råvare til energi og materialer som hovedprodukt
- Fx kommer jordbruget ikke til at producere råvarer til metan, metanol, flybrændstof eller plastik som andet end restprodukter fra føde/foder produktionen

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