Biomass Gasification, a Key Technology to Accomplish a Sustainable Energy System

tcbiomass2022

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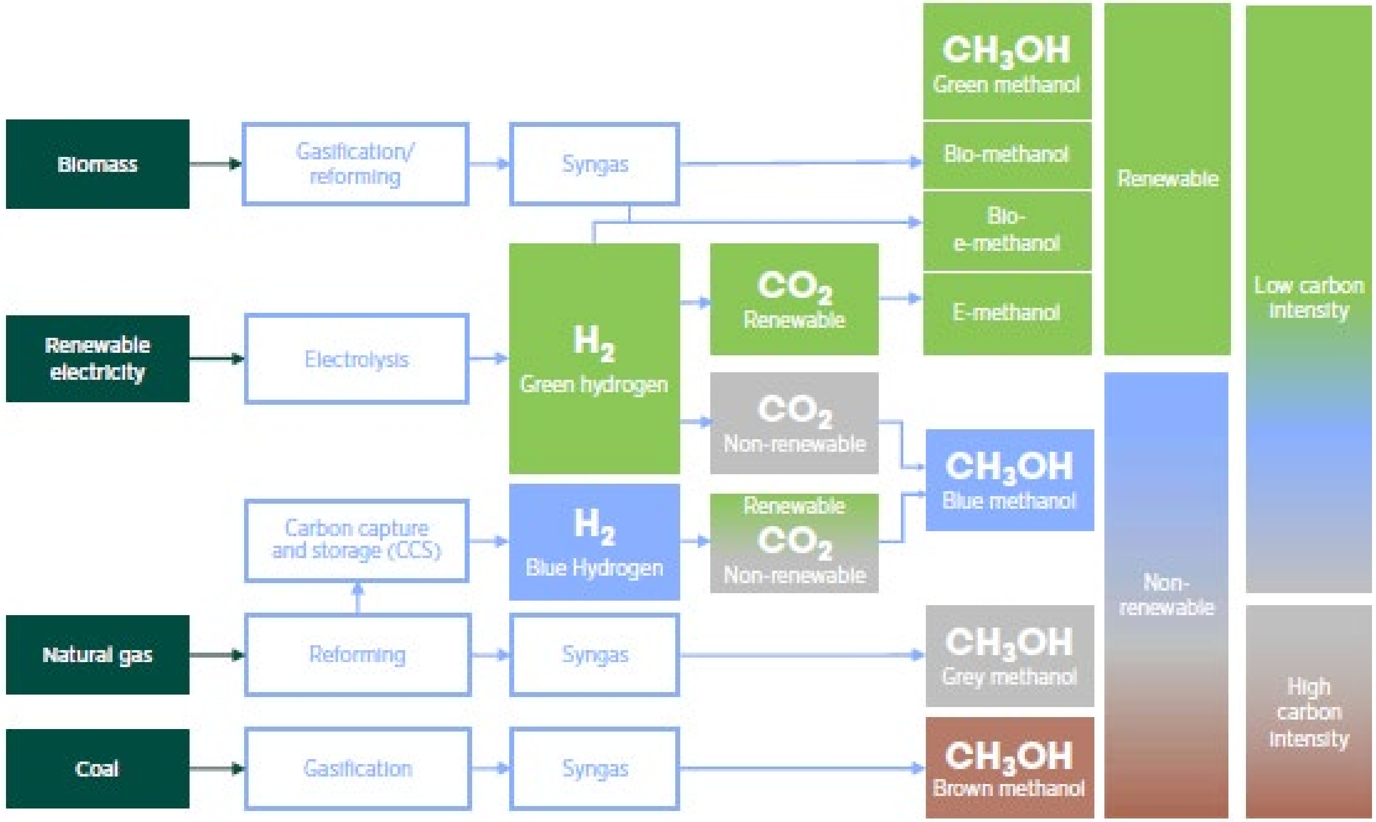
Presentation Addresses:

- Process overview
- Production costs
- Combined bio- and e-methanol production
- Market Pull scenarios

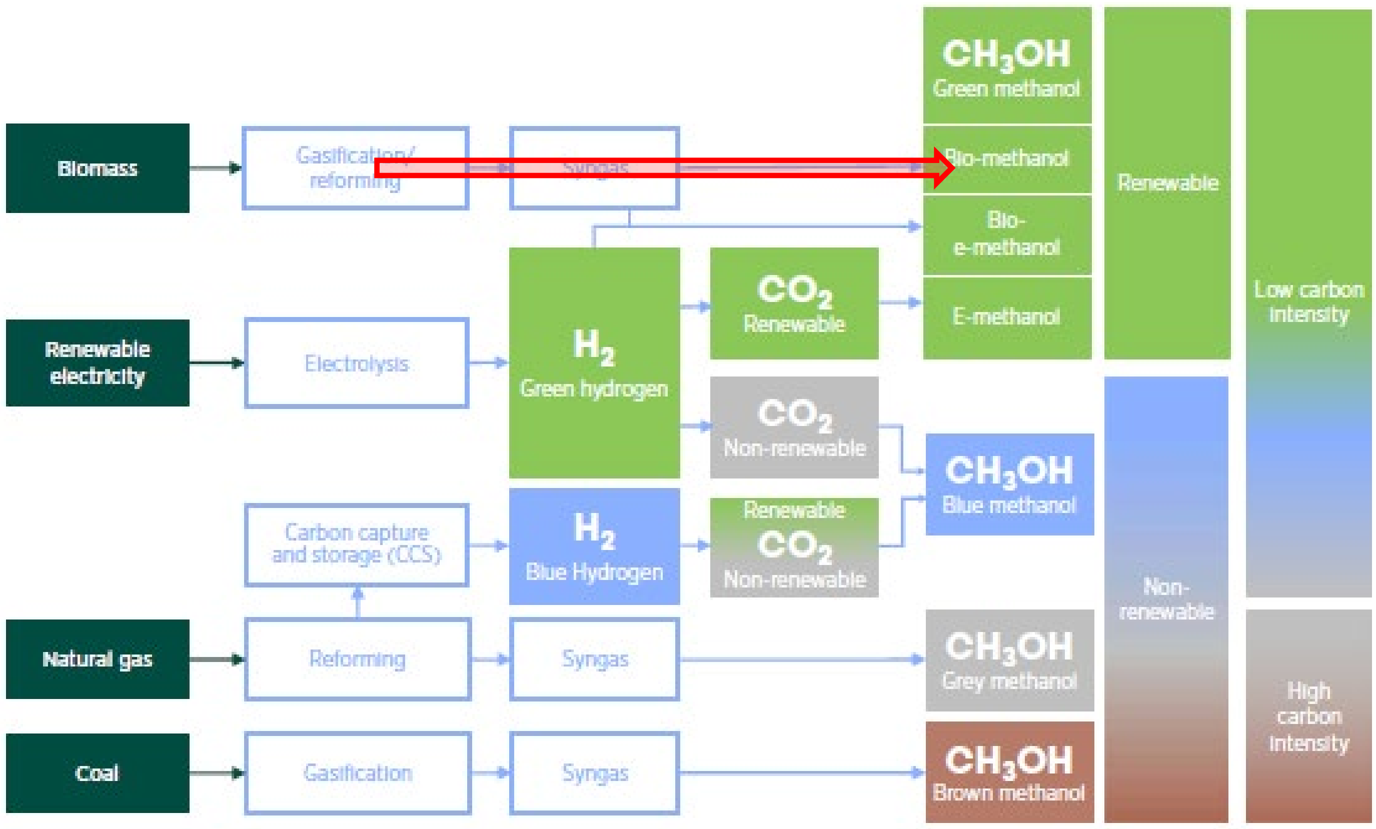
Process overview

Different Methanol Production Pathway
as presented in the IRENA-Methanol Institute Report 2021

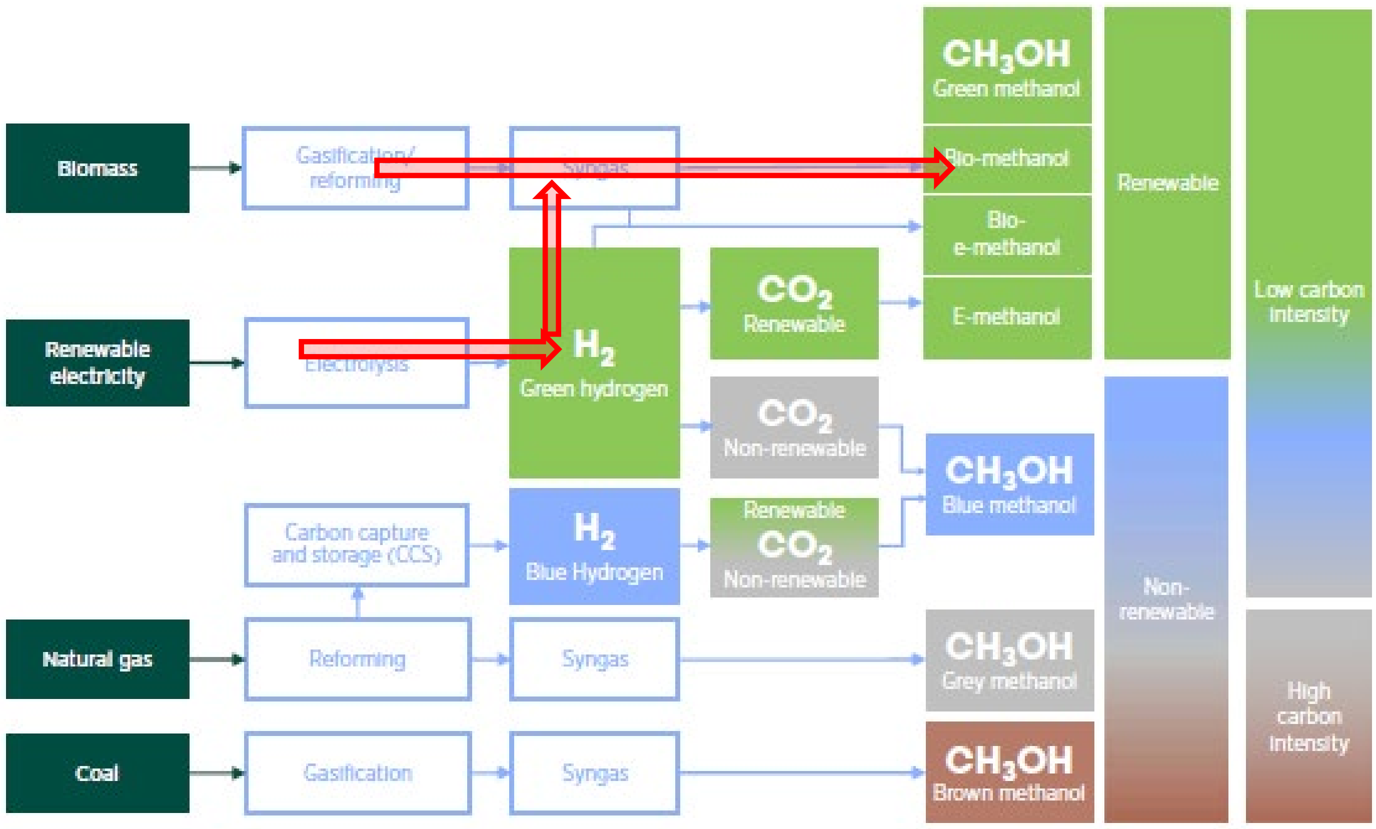


Bio-methanol production pathway

Green Methanol via Biomass gasification



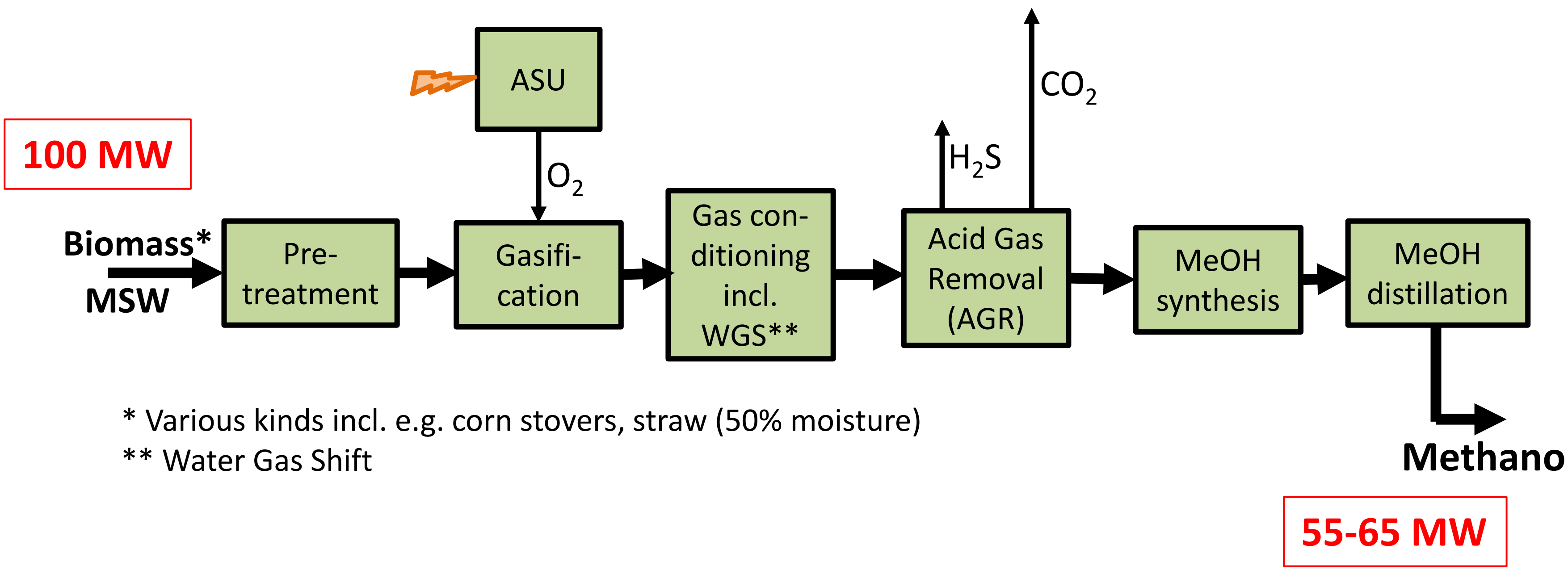
Combined Bio- and e-Methanol Pathway



Gasification-based Methanol Plant

Bio-Methanol via Biomass and MSW gasification

Energy efficiency: ~ 60%



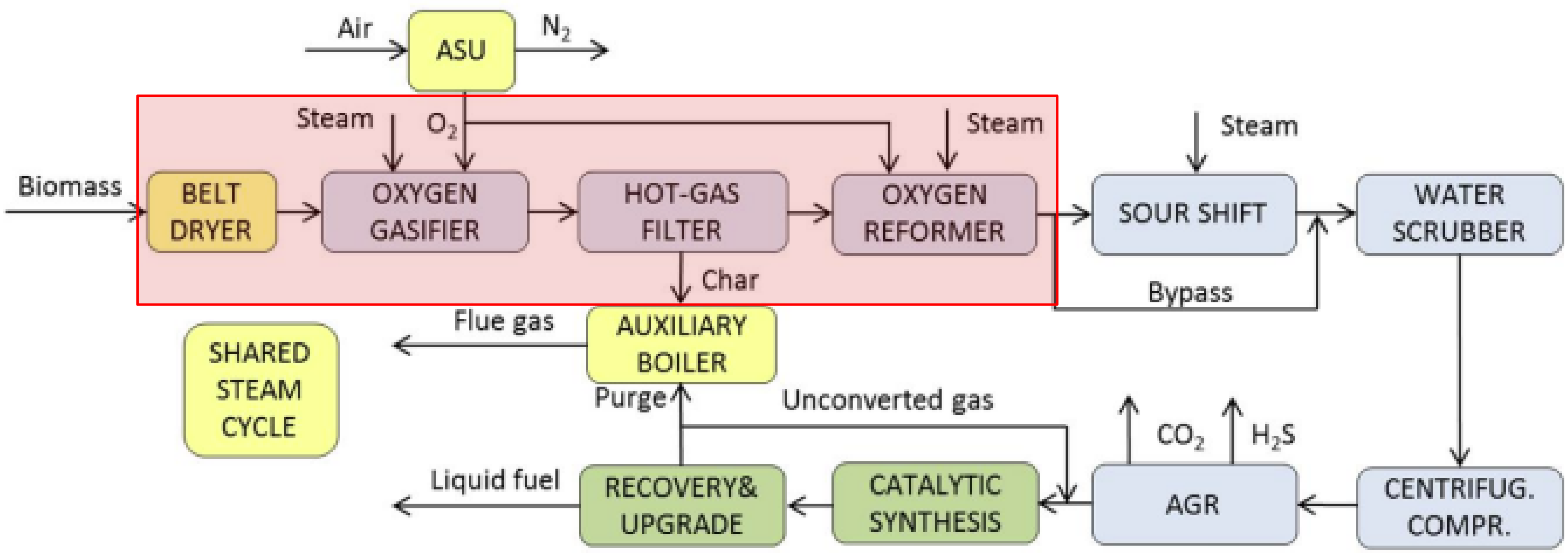
* Various kinds incl. e.g. corn stovers, straw (50% moisture)

** Water Gas Shift

Production Costs

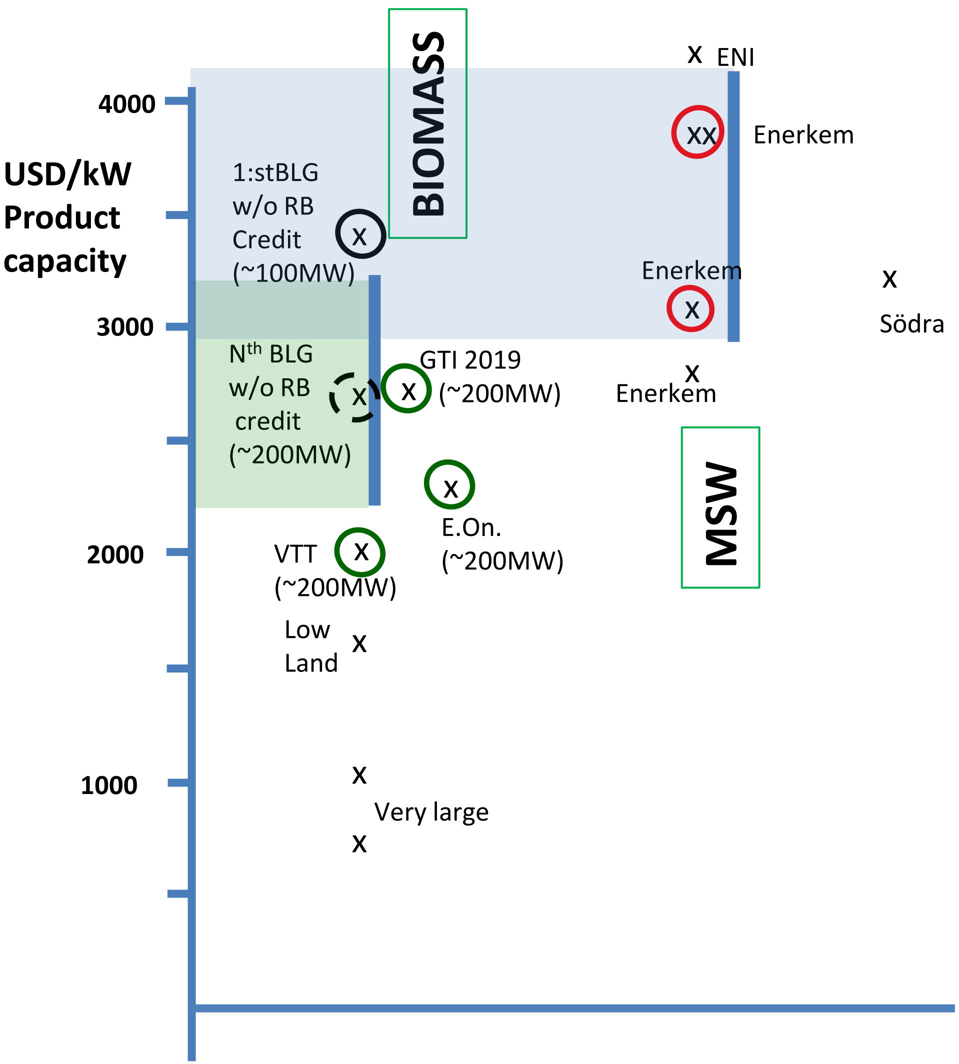
Generalized block diagram of a stand-alone biomass-to-methanol plant

Cost of various process units are well known except the ones processing biomass to raw syngas (red area)



Source: VTT (Hannula and Kurkela) 2013

Relative Investment Costs for Gasification based Plants with Biomass and MSW as Feedstocks
(USD/kW product capacity)



- With investment/kW product capacity as base unit, also other conversion routes can be compared with methanol producing plants, e.g. E.On.'s and GTI's project producing BioSNG
- GTI's project scaled to 200 MW gas, same size as E.On and VTT.
- Circles indicates data points judged as having a well developed investment base
- ENI project has a comparably complicated gas purification system
- The two low-cost bio-mass based plants seam to be too low data points although they benefit from economy of scale.
- Södra is an odd application (byproduct methanol extracted from the pulping cycle)

Bio-methanol:

Capital cost element in production cost

From biomass: 206-293 USD/t MeOH   ***From MSW: 264-367 USD/t MeOH***

CAPEX/y	From biomass		From MSW	
	Low	High	Low	High
USD/t MeOH	206	293	264	367
USD/MWh MeOH	37	53	48	66
USD/GJ MeOH	10.4	14.7	13.3	18.4

BIOMASS FEEDSTOCK

Specific investment:1 560-2 220 USD/t/y

Capital cost: 15 years/ 10% (annuity percentage of 13.2%)

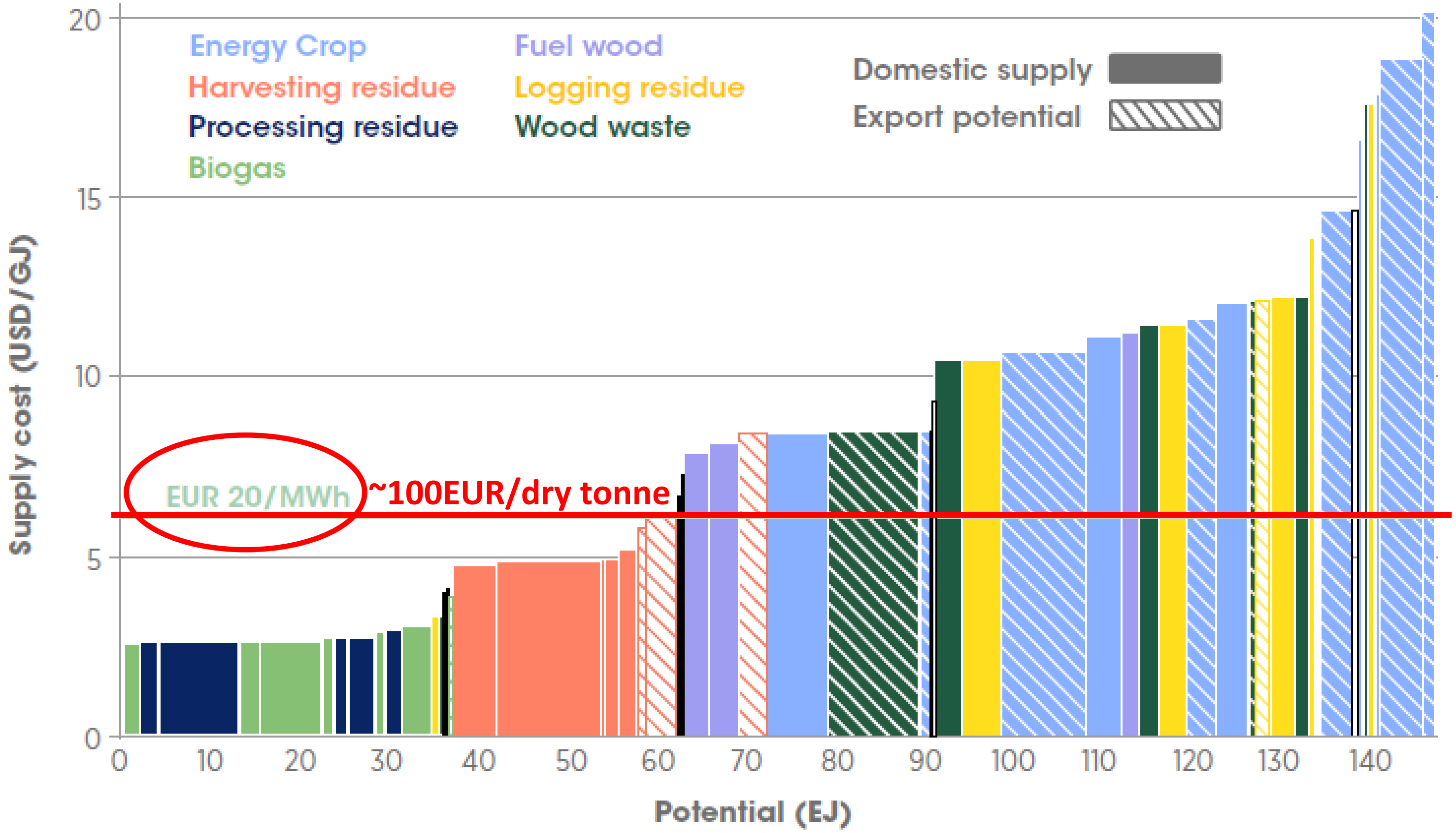
MSW FEEDSTOCK

Specific investment: 2000-2 780 USD/t/y

Capital cost: 15 years/ 10% (annuity percentage of 13.2%)

Global supply curve for primary biomass, 2030

60 EJ available under ~ 100 USD/t of dry biomass



Source: IRENA, 2014

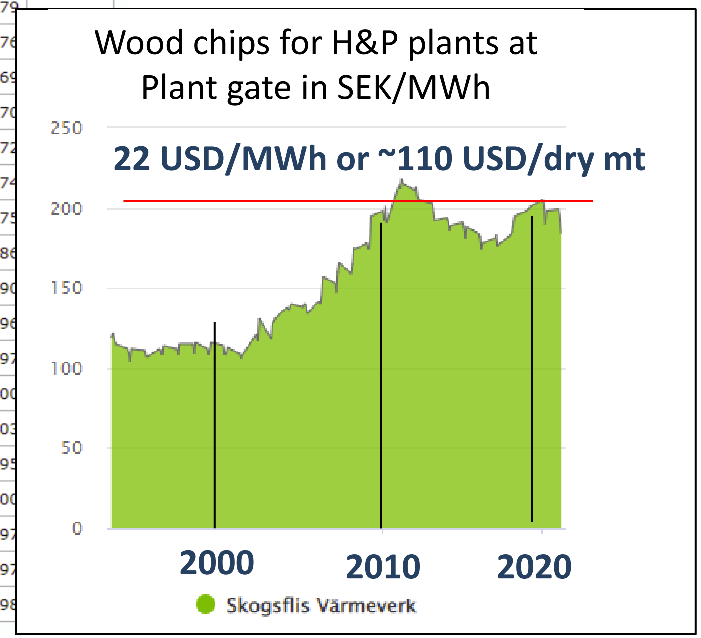
Various Swedish biomass prices at plant gate (SEK/MWh)

2016-2021 (left) and 2000-2021 (right)

Representative price for northern Europe: 100-110 USD/t at plant gate

	Förädlade		Skogsflis		Biprodukter		Stycketorv		Frästorv		Returträ	
	Värmeverk	Industri	Värmeverk	Industri	Värmeverk	Industri	Värmeverk	Industri	Värmeverk	Industri	Värmeverk	Industri
2016:1	278	..	184	184	153	161	157	..	170	..	94	..
2016:2	265	..	182	192	152	157	153	..	154	..	94	..
2016:3	270	..	174	185	149	156	143	..	154	..	81	..
2016:4	268	..	178	190	151	154	156	..	138	..	83	..
2017:1	267	..	181	183	159	154	152	..	143	..	86	..
2017:2	271	..	183	184	150	159	156	..	148	..	79	
2017:3	275	..	176	176	149	155	148	..	151	..	76	
2017:4	252	..	177	183	146	148	150	..	140	..	69	
2018:1	280	..	183	176	161	158	154	..	146	..	70	
2018:2	274	..	185	188	153	163	152	..	148	..	72	
2018:3	265	..	190	201	156	165	178	..	154	..	74	
2018:4	271	..	195	187	164	158	170	..	145	..	75	
2019:1	285	..	198	176	164	150	166	..	143	..	86	
2019:2	287	..	199	195	164	160	171	..	145	..	90	
2019:3	289	..	199	188	169	176	..	..	143	..	96	
2019:4	317	..	201	193	174	174	162	..	141	..	97	
2020:1	314	316	205	191	171	176	166	..	150	..	100	
2020:2	314	290	202	181	168	175	151	..	142	..	103	
2020:3	314	319	190	187	171	174	..	..	158	..	95	
2020:4	301	297	198	183	175	178	165	..	151	..	100	
2021:1	311	318	199	166	172	174	168	..	140	..	97	
2021:2	327	295	194	184	168	174	186	..	145	..	97	
2021:3	331	276	184	185	151	176	..	..	157	..	98	

1 SEK = 0.11 USD



Source: Swedish Energy Administration

Feedstock and other OPEX cost element in production cost

Biomass feedstock at 171-237 USD/t MeOH depending conversion efficiency

Other OPEX 78-278 USD/t MeOH depending on feedstock / maintenances intensity

Feedstock

Feedstock cost USD/GJ feedstock	Conversion efficiency, feedstock to methanol, %					
	50		60		70	
	USD/GJ MeOH	USD/t MeOH	USD/GJ MeOH	USD/t MeOH	USD/GJ MeOH	USD/t MeOH
15	30.0	597	25.0	498	21.4	426
10	20.0	398	16.7	332	14.3	284
6	12.0	239	10.0	199	8.6	171
3	6.0	119	5.0	100	4.3	85
1.5	3.0	60	2.5	50	2.1	43

20 EUR/MWh
~100EUR
/dry tonne

OPEX

			Biomass as feedstock		MSW as feedstock	
			Low	High	Low	High
CAPEX, USD/t MeOH/y			1 560	2 220	2 000	2 780
OPEX Low	5%	USD/t MeOH	78	111	100	139
OPEX High	10%	USD/t MeOH	156	222	200	278

Total production cost for bio-methanol from biomass and MSW

		Biomass as feedstock				MSW as feedstock			
		Low		High		Low		High	
CAPEX/y, USD/t MeOH		206		293		264		367	
Overall conversion efficiency, %		60	70	60	70	50	60	50	60
Feedstock cost element for methanol at various level, USD/t MeOH	At USD 15/GJ	498	426	498	426	-	-	-	-
	At USD 10/GJ	332	284	332	284	-	-	-	-
	At USD 6/GJ	199	171	199	171	-	-	-	-
	At USD 3/GJ	100	85	100	85	119	100	119	100
	At USD 1.5/GJ	50	43	50	43	60	50	60	50
	At USD 0/GJ [a]	-	-	-	-	0	0	0	0
OPEX at 5%, USD/t MeOH		78		111		100		139	
OPEX at 10%, USD/t MeOH		156		222		200		278	
Cost of methanol (USD/t MeOH)	Feedstock cost below USD 6/GJ	327-561		447-714		414-583		556-764	
	Feedstock cost at USD 6-15/GJ	455-860		575-1 013		-		-	
Carbon credit (USD/t MeOH)	At USD 50/t CO_2 [b]	-82		-82		-82		-82	
	At USD 100/t CO_2 [b]	-164		-164		-164		-164	

- Energy Efficiency varies from 50-70%
- Feedstock price varies from 0 to 15 USD/GJ
- Other OPEX varies from 5-10% of investment per year
- Carbon credit at 50-100 USD/t CO_2 corresponds to 82-164 USD/t MeOH

(Swedish carbon tax is about 125 USD/t CO_2. That applied would lead to cost competitive production today)

Total production cost for bio-methanol after potential cost reduction

IRR from 13.2 to 10.2%* & "learning curve" cost red. of 20%

*20 years/8%

		Biomass as feedstock		MSW as feedstock	
		Low	High	Low	High
Before cost reduction USD/t MeOH (from Table 17)	Feedstock below USD 6/GJ	327-561	447-714	414-583	556-764
	Feedstock at USD 6-15/GJ	455-860	575-1 013	-	-
CAPEX/y reduction, USD/t MeOH		-82	-118	-106	-147
OPEX reduction, USD/t MeOH		-18 to -36	-26 to -51	-23 to -46	-32 to -64
Cost of methanol (USD/t MeOH) at feedstock cost below USD 6/GJ < 20 EUR/MWh or 100 EUR/ dry tonne	With no carbon credit	227-443	303-545	285-431	377-553
	With a credit of USD 50/t CO_2 *	145-361	221-463	203-349	295-471
	With a credit of USD 100/t CO_2 *	63-279	139-381	121-267	213-389
Cost of methanol (USD/t MeOH) at feedstock cost at USD 6-15/GJ	With no carbon credit	355-742	431-844	-	-
	With a credit of USD 50/t CO_2 *	273-660	349-762	-	-
	With a credit of USD 100/t CO_2 *	191-578	267-680	-	-

OPEX assumed to follow the investment reduction

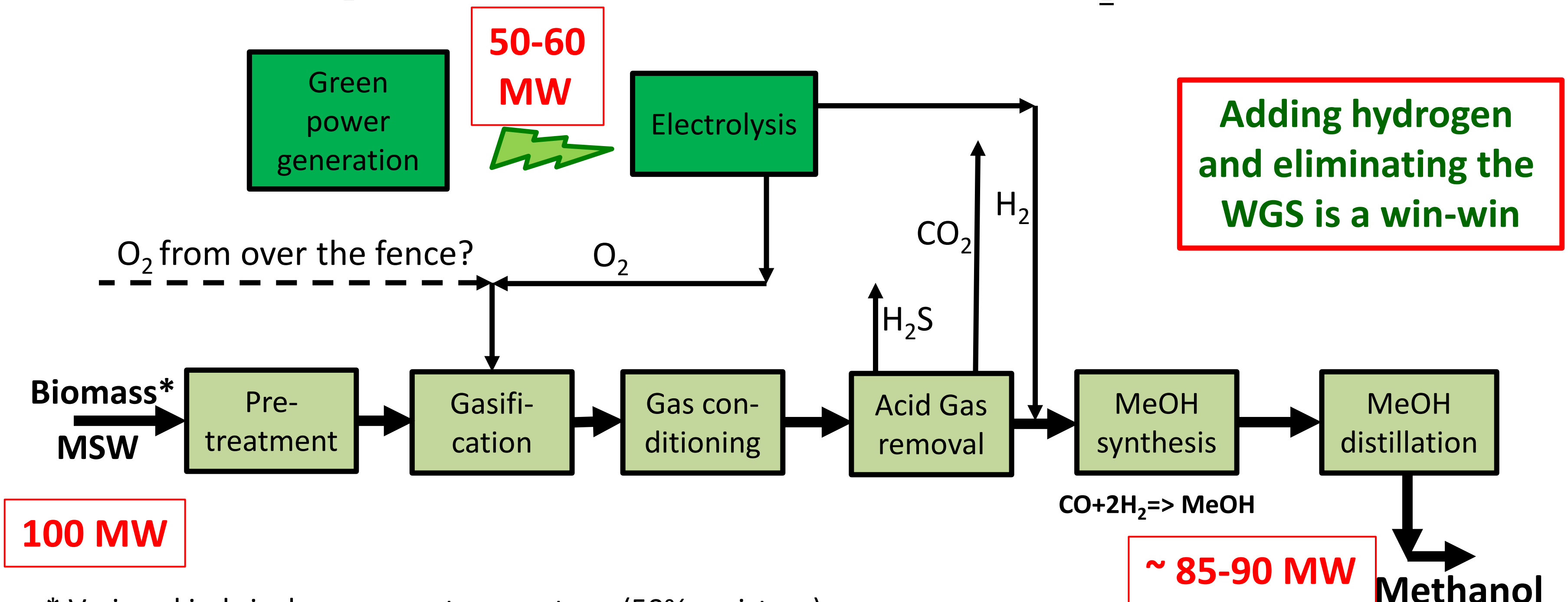
Even without carbon credit methanol production cost can compete with today's methanol prices

Combined Bio- and e-Methanol Production

Combined Bio- and e-Methanol, Step 1

(WGS** is replaced by imported hydrogen)

- Increased methanol production from the same amount of feedstock
- Simpler & more efficient process scheme because:
  - No WGS => increased syngas by 5-6%
  - Lower CO_2 emission
- No oxygen plant (potentially)
- No HP steam demand for WGS
- No new process developments
- Very efficient use of hydrogen
- Use of all CO in raw syngas
- <u>2 mole H_2 per recovered mole C in CO</u>

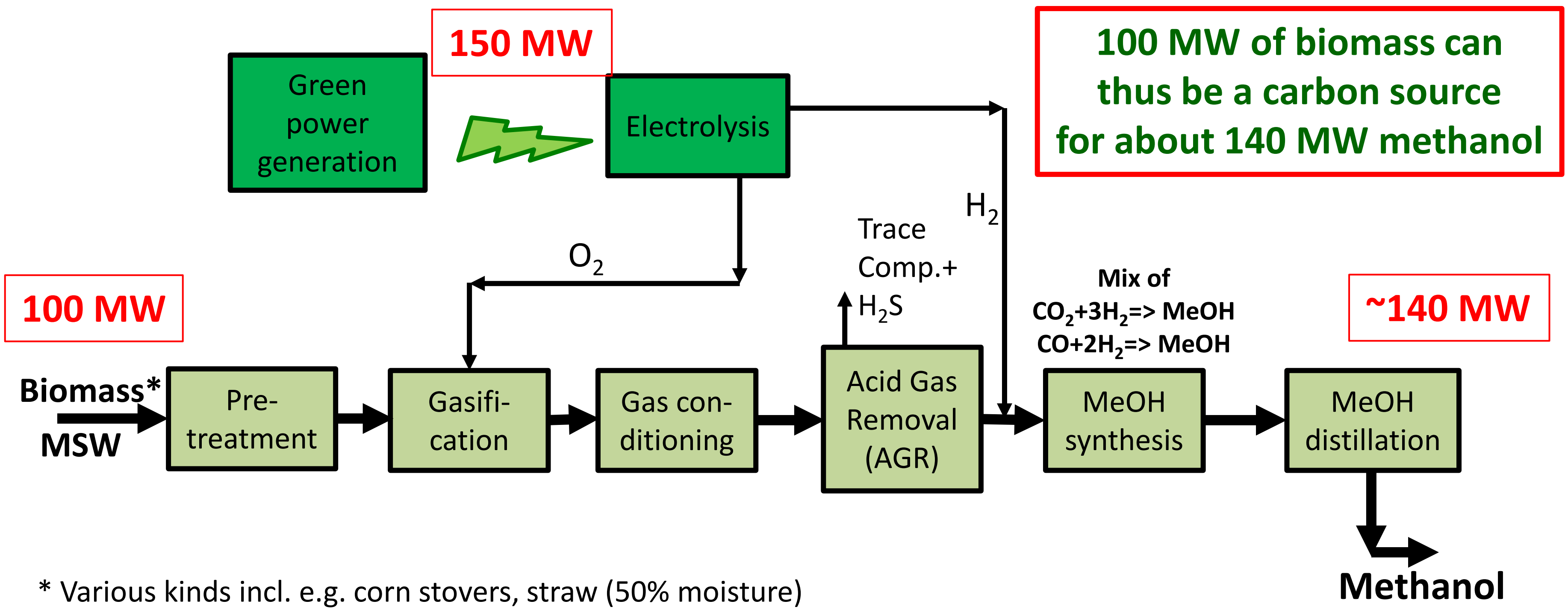


* Various kinds incl. e.g. corn stovers, straw (50% moisture)

** Water Gas Shift

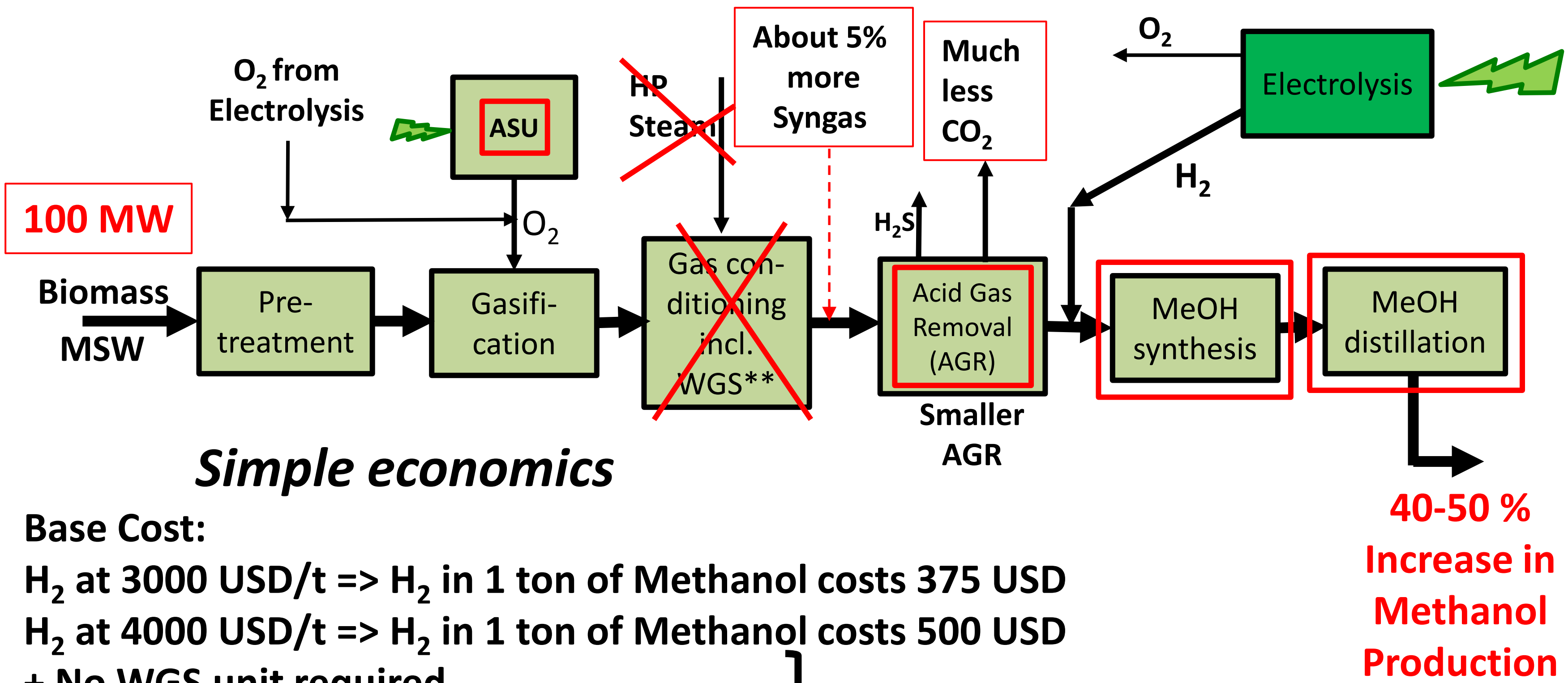
Combined Bio- and e-Methanol, Step 2

- Methanol plant fed with a mixture of CO, CO_2 and H_2 .
- Altered methanol catalyst
- CO_2 is kept at syngas pressure.
- AGR only removes sulphur components and other traces
- No oxygen plant
- Close to all carbon in biomass converted to methanol => More energy in produced methanol than in biomass feedstock
- <u>3 mole H_2 per recovered mole C in CO_2</u>



* Various kinds incl. e.g. corn stovers, straw (50% moisture)

Combined Bio- and e-Methanol, Step 1: *Simple economics*



Simple economics

Base Cost:

H_2 at 3000 USD/t => H_2 in 1 ton of Methanol costs 375 USD

H_2 at 4000 USD/t => H_2 in 1 ton of Methanol costs 500 USD

+ No WGS unit required
+ No HP Steam required
+ Approx. 5% more syngas required
+ Smaller AGR unit
+ Small or no AGR unit
- Larger Methanol synthesis and distillation

Assume + vs – equals about Zero

∑: Cost of increased methanol production will be the cost of added H_2

Market Pull Scenarios

“Market Pull” examples

Jeans-vd:n: ”Viljan måste finnas hos H&M:s ägare”

Plagg i din garderob kan vara gjorda av nässlor och alger. Men enligt jeansföretaget Nudies vd Joakim Levin gäller det att storbolagen vågar låta klimatomställningen belasta kvartalsvinsten.

Om Ikeas nya energiroll: ”Sverige nära brytpunkt”

Från glada entusiaster till en blåslampa på energibolagen – makten över framtidens elproduktion ligger i konsumentens händer. Men det finns en risk som kan få allt att haverera. Det säger Anna Wolf, civilingenjör och expert på framtidens energisystem.

Amazon vill leda klimatkampen

Amazon ska bli klimatneutralt till år 2040, och nyttja enbart grön energi redan 2030. Bland åtgärderna finns en jätteorder på eldrivna leveransbilar. Planen beskrivs som ett epokskifte i USA.

TT
Publicerad 2019-09-20

Jeff Bezos i Washington. Foto: Pablo Martinez Monsivais

– Vi vet att vi kan göra det och vi vet att vi måste göra det, säger näthandelsjättens vd Jeff Bezos på en presskonferens i Washington.

RE 100 ABOUT RE100 PARTNERS GOING 100%

More than 350 companies today

Going 100%

Requirements of RE100 companies

Companies joining RE100 make a global, public commitment to **100% renewable electricity.**

To achieve this goal, they must match 100% of the electricity used across their global operations with electricity produced from renewable sources – biomass (including biogas), geothermal, solar, water and wind – either sourced from the market or self-produced.

RE100 companies can achieve 100% renewable electricity through:

Companies

204 RE100 companies have made a commitment to go '100% renewable'. Read about the actions they are taking and why.

IKEA®

The INGKA Group (formerly IKEA) is a home furnishing company with 336 stores in 28 countries. The company has committed to produce as much renewable energy as the total energy it consumes in its buildings by 2020. Alongside Swiss Re, IKEA Group is a founding partner of the RE100 campaign.

TATA MOTORS

AkzoNobel

GM

AstraZeneca

Carlsberg Group

Goldman Sachs

Coca-Cola European Partners

Walmart

H&M

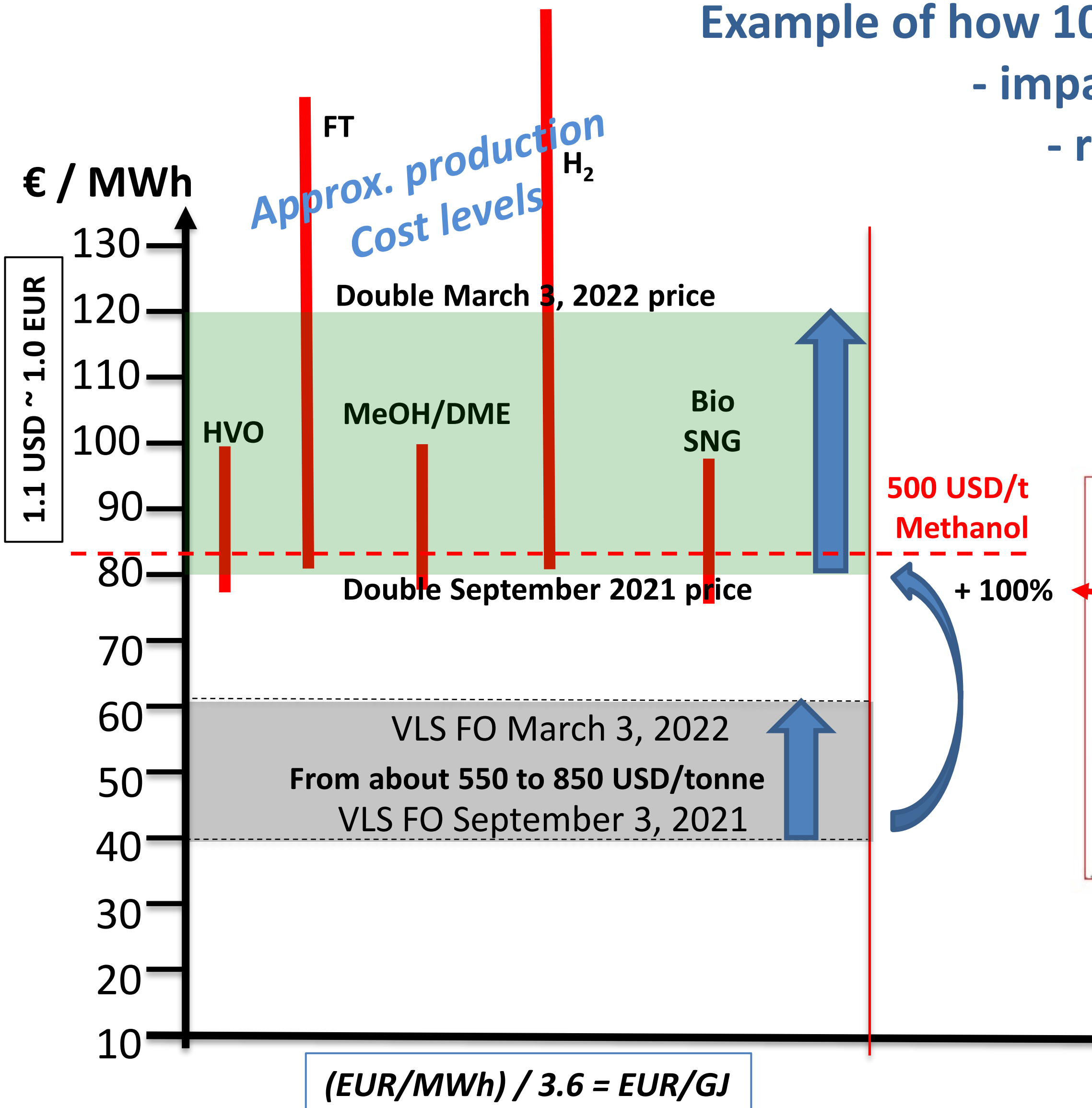
BARCLAYS

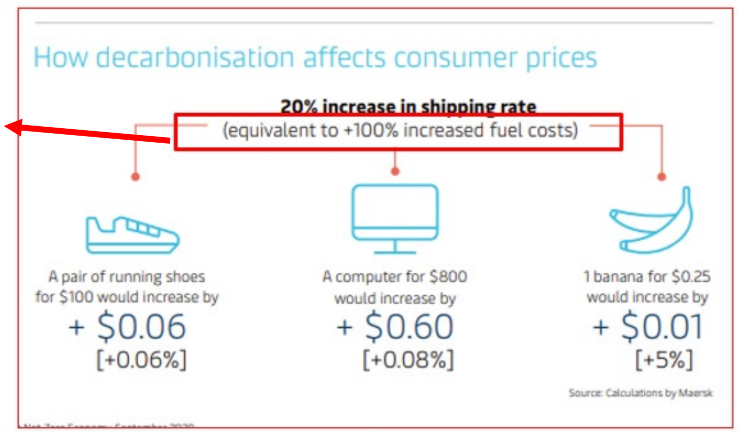
Illustration of a market pull scenario for the marine sector

Example of how 100% increase in bunker fuel price

- impacts on price of transported gods

- relates to cost of renewable fuels





Source: Maersk

19 April 2022

In summary:

- Biomass gasification technologies in the process of being scaled to commercial size – some are there!
- Production cost of bio-methanol well understood and at “acceptable” levels
- Combined bio- and e-methanol production looks very attractive, a win-win
- Vast amounts of biomass available in many parts of the Word.
- Long term off-take agreements for bio-methanol with strong partners within reach

Thank you!

I would like to acknowledge my co-authors:

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&
***Seungwoo Kang* and**
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from IRENA
&
Greg Dolan
from Methanol Institute

EXTRAS

Recent reports covering today's topic

Where to Find the Reports

- **Cost of Biofuels (SGAB):** https://publications.europa.eu/en/publication-detail/-/publication/13e27082-67a2-11e8-ab9c-01aa75ed71a1/language-en/format-PDF/source-71250236
- **Methanol as a renewable Fuel – A knowledge Synthesis (f3):** https://f3centre.se/en/research/methanol-as-a-renewable-fuel-a-knowledge-synthesis/
- **Tech Brief: Production of bio-methanol (IRENA):** https://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP%20Tech%20Brief%20I08%20Production_of_Bio-methanol.pdf
- **Advanced biofuels – Potential for Cost reduction (IEA Bioenergy):** https://www.ieabioenergy.com/wp-content/uploads/2020/02/Screenshot-2020-02-11-at-11.36.35.png
- **Innovation outlook: Renewable Methanol (IRENA):** https://www.irena.org/publications/2021/Jan/Innovation-Outlook-Renewable-Methanol