Status - Renewable Bio-methanol Production

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Content

- Methanol being Green, Blue or Grey or Brown
- Projects and plans
- Production cost for renewable methanol
- Combinations of bio- and e-methanol
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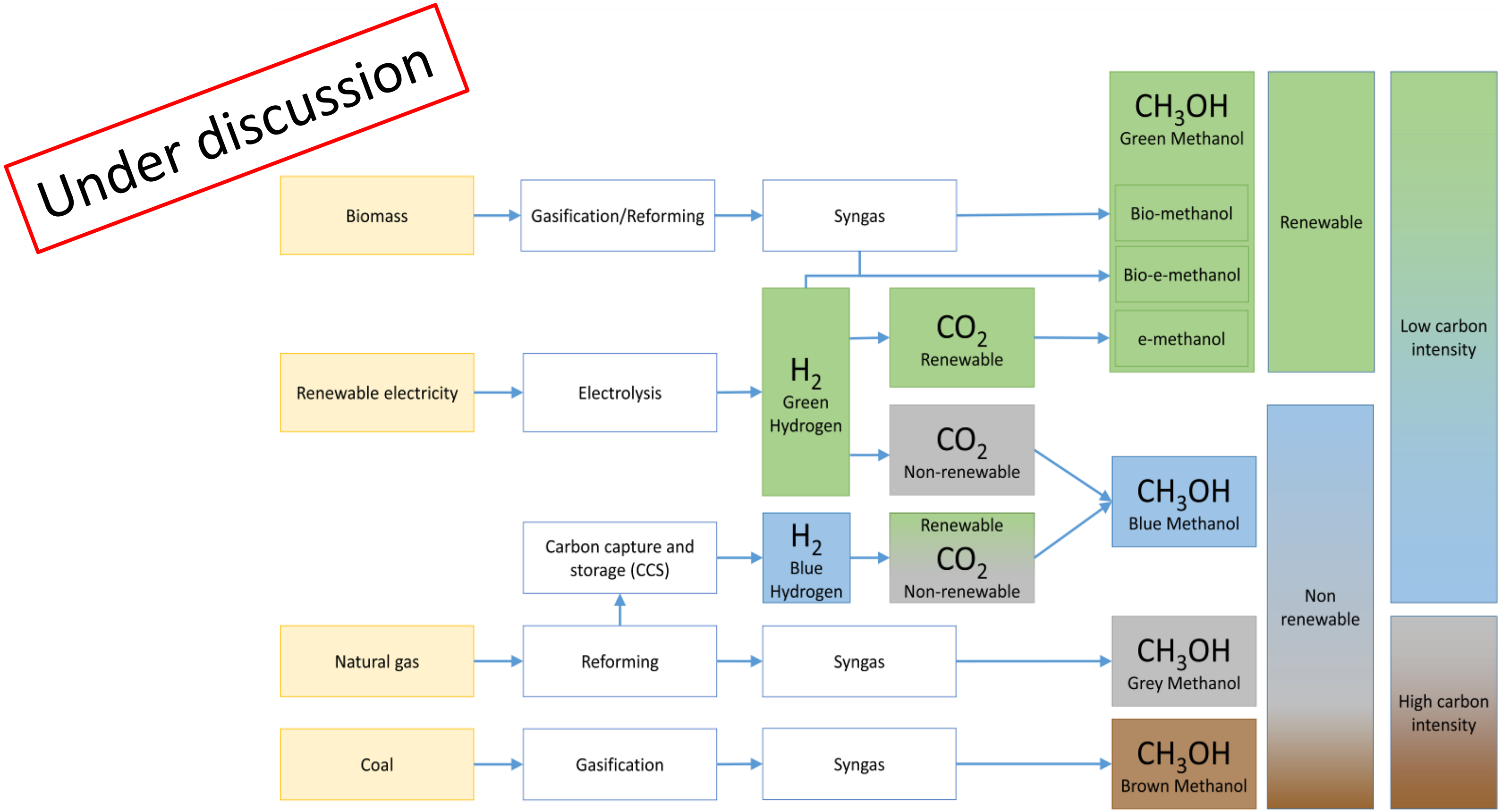
Methanol production pathways

Green – Blue – Grey - Brown

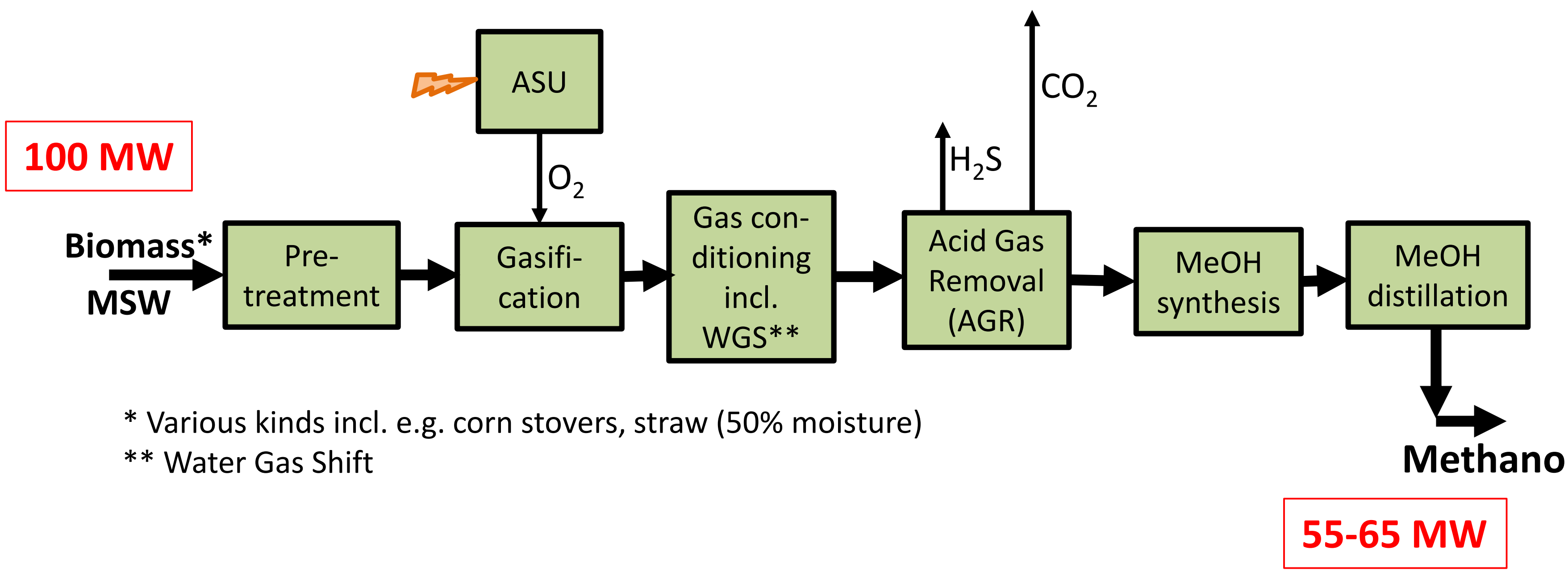


CO_2 Renewable: from bio-origin and through direct air capture (DAC)

CO_2 Non-renewable: from fossil origin, industry

Gasification-based Methanol Plant

general scheme



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

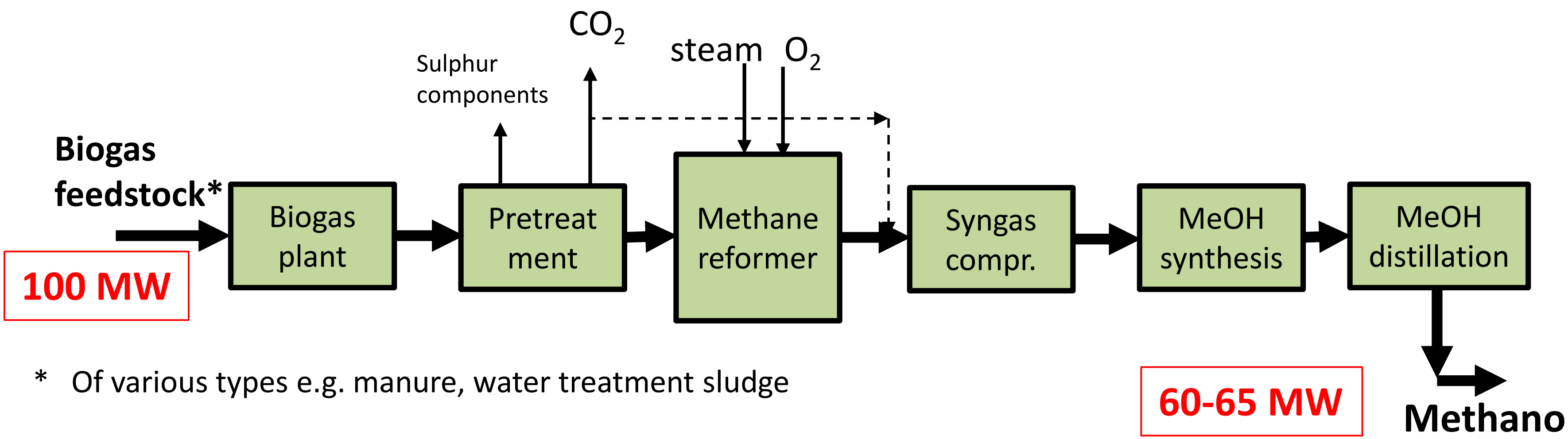
List of Methanol Projects

in various stages of planning

#	Project / study	Status	Capacity (tpy)	CAPEX (Million Euros)	CAPEX (EUR/ tpy)	CAPEX (EUR/kW)	Source
1	Trans World Energy (TWE), Florida (USA)	FEED done, Startup 2Q 2023	875 000	385	440	640	TWE
2	ENI Refinery, Livorno, Italian (I)	Basic Engineering ready 3Q,2020	115 000	300	2610	3850	NextChem
3	LowLand Methanol (NL)	Startup early 2023	120 000	120	1000	1455	LowLand Methnaol
4	Södra (SE)	Operation	5000	10	2000	2909	Södra
5	Enerkem, Rotterdam (NL)	Engineering	215 000	520	2420	3460	Enerkem
6	Enerkem, Tarragona (SP)	Engineering	215 000	520	2420	3460	Enerkem
7	VTT		265 000	347	1309	1866	VTT
8	Chemrec, Domsjö	Prel. Eng.	147 000	350	2380	3060	Chemrec
9	Chemrec, n^{th} plant	Concept	290 000	490/240*	1690/828*	2465/1290*	Chemrec
10	New Hope Energy, Texas (USA)	Investment decision 4Q,2020	715 000	450	630	915	New Hope Energy

* Credited for avoiding recovery boiler replacement

Reformer-based Methanol Plant
general scheme

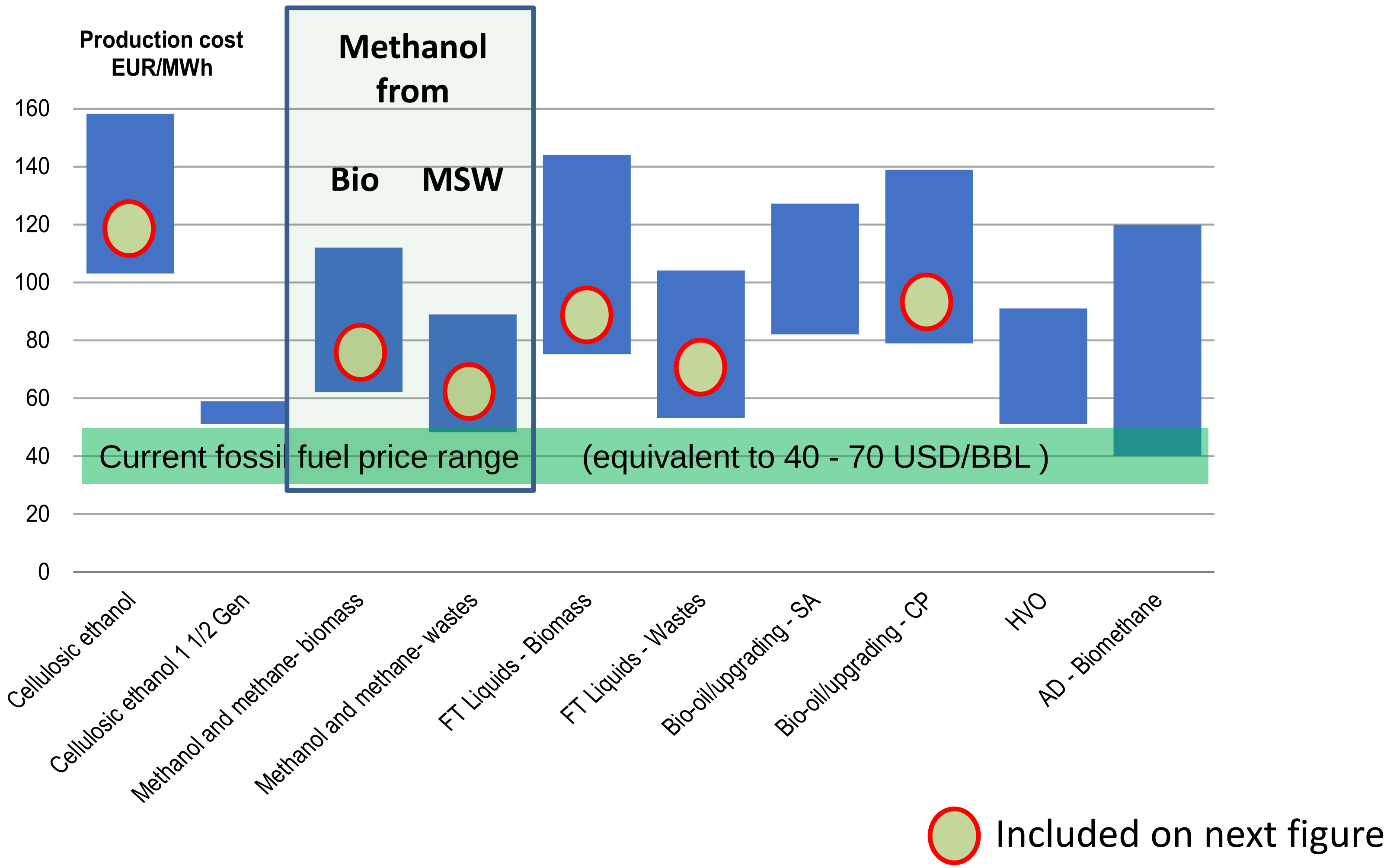


* Of various types e.g. manure, water treatment sludge

Technology	Feedstock	Project, reference	Project phase	Product	Plant capacity
Steam reforming	Natural gas/ biomethane	BASF, Ludwigshafen (DE)	Operational	methanol	480 kt/y* (2009)
Steam reforming	Natural gas/ biomethane	OCI/BioMCN Groningen	Operational	methanol	60 kt/y**

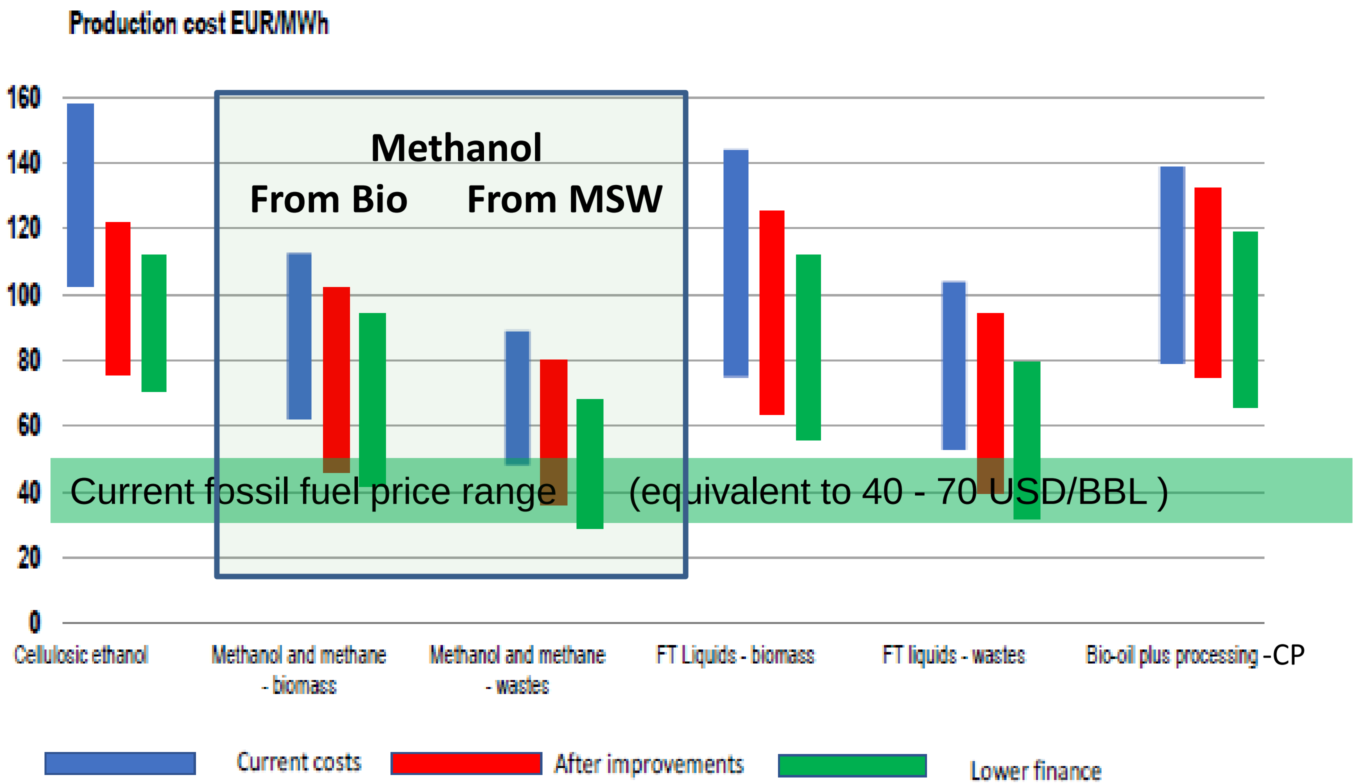
Production cost for various Advanced Biofuels

Source: IEA Bioenergy report 2020



Production Cost Reduction Potential

Source: IEA Bioenergy report 2020



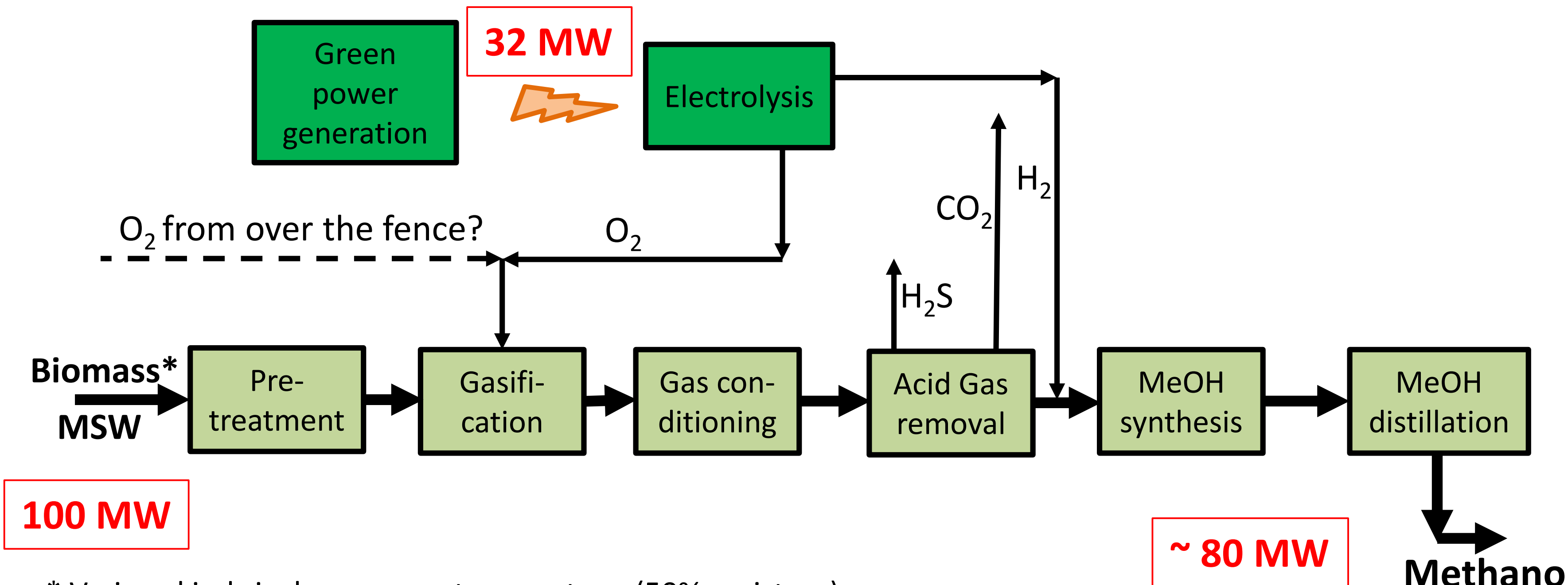
Improvements => 25-50% on CAPEX and 10-20% on OPEX (depending on pathway)

Lower finance costs => 22% lower capital cost (IRR from 13.1% to 10.2%)

Combined Bio- and e-Methanol, Step 1

(WGS** is replaced by imported hydrogen)

- Increased methanol production
- Simpler & more efficient process scheme because:
  - No WGS
  - 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

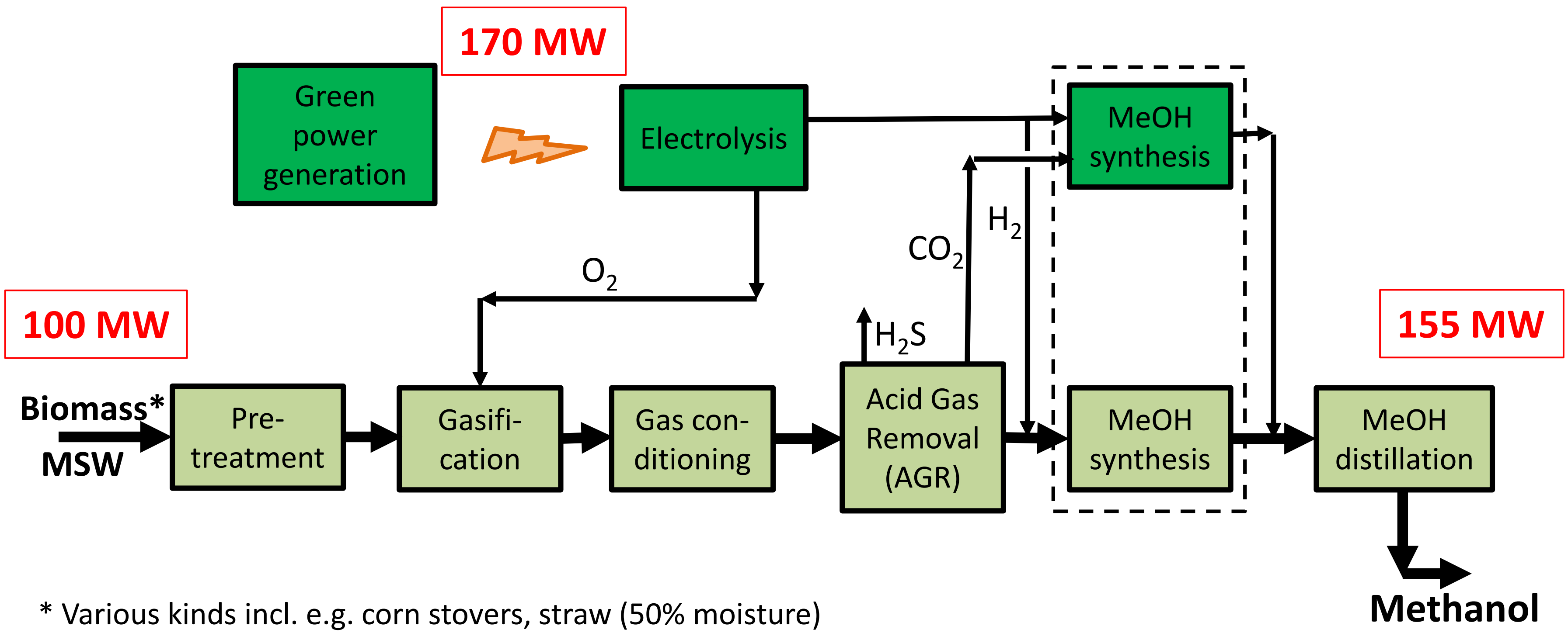


* Various kinds incl. e.g. corn stovers, straw (50% moisture)

** Water Gas Shift

Combined Bio- and e-Methanol, Step 2

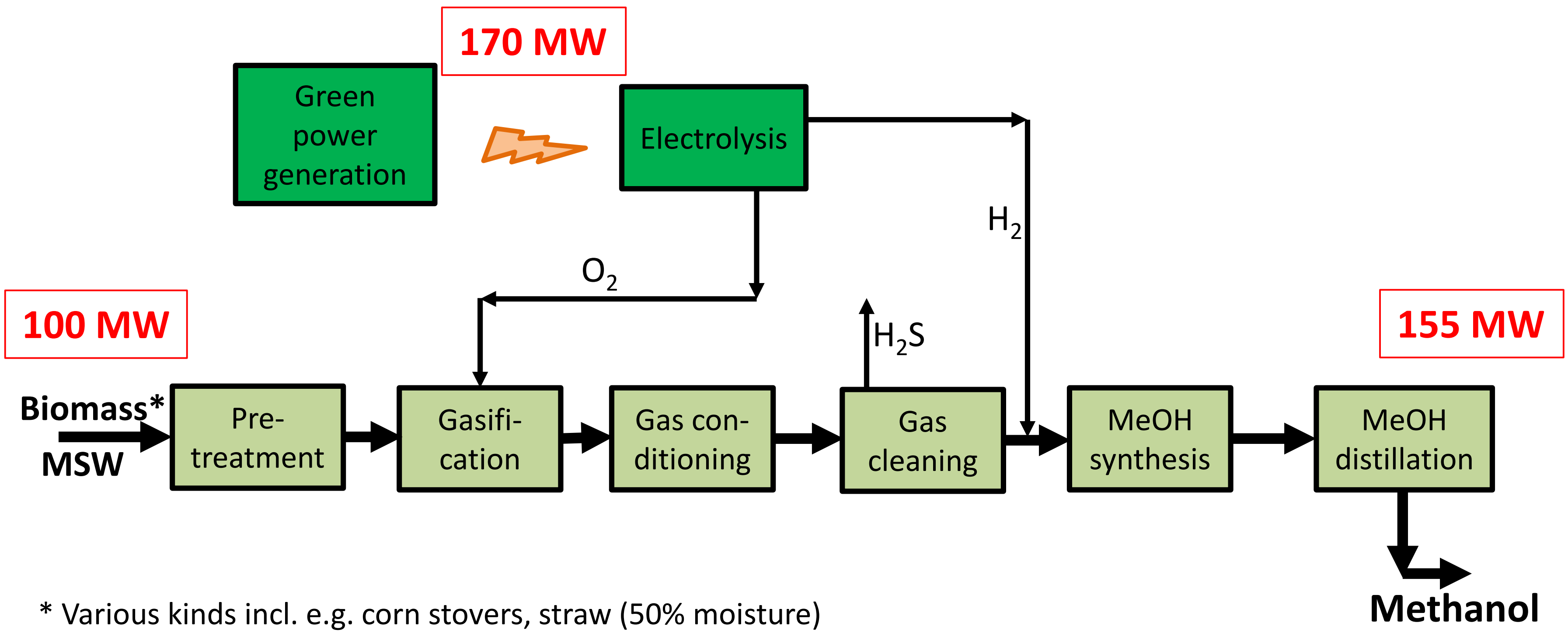
- A second methanol plant fed with CO_2 from AGR and H_2
- Combined methanol distillation
- No oxygen plant
- Close to all carbon in biomass converted to methanol =>
  More energy in produced methanol than in biomass feedstock
- E-methanol part produced with direct available, concentrated renewable CO_2



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

Combined Bio- and e-Methanol, Step 3

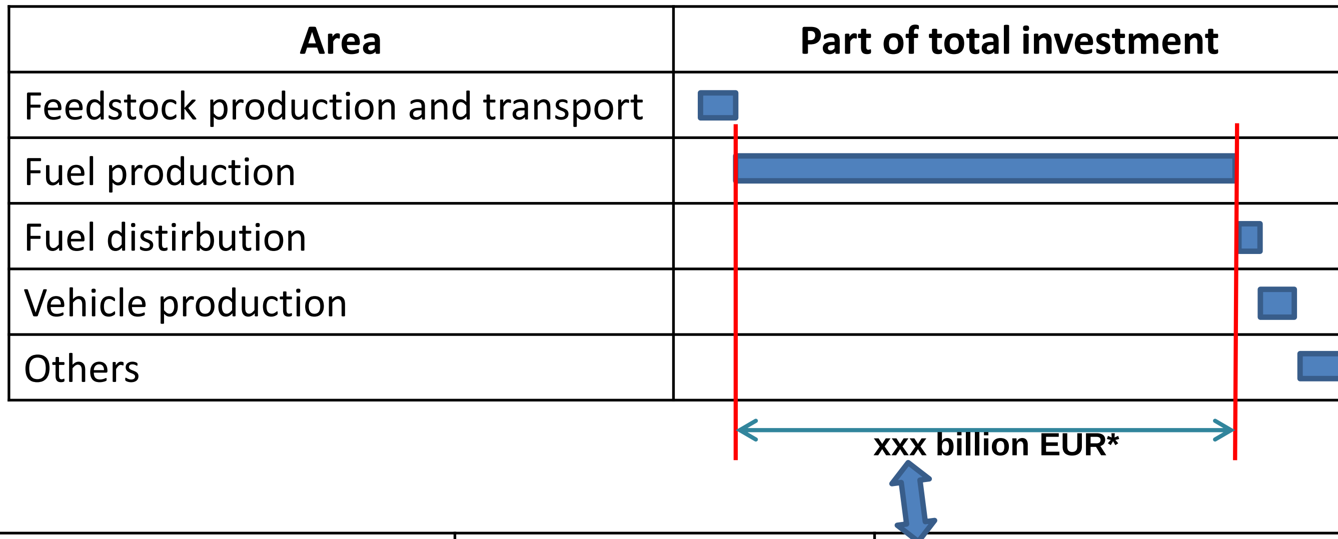
- Modified methanol catalyst converting both CO and CO2 with H2 to methanol
- Gas cleaning which only removes impurities like sulphur components
- Close to all carbon in biomass converted to methanol =>
  More energy in produced methanol than in biomass feedstock
- E-methanol part produced with in situ available renewable CO_2



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

By far the MAIN INVESTMENT requirement when changing to a renewable fuel system IS IN THE FUELS PRODUCTION

(Example Sweden with a need of 60 TWh of fuel for transport)



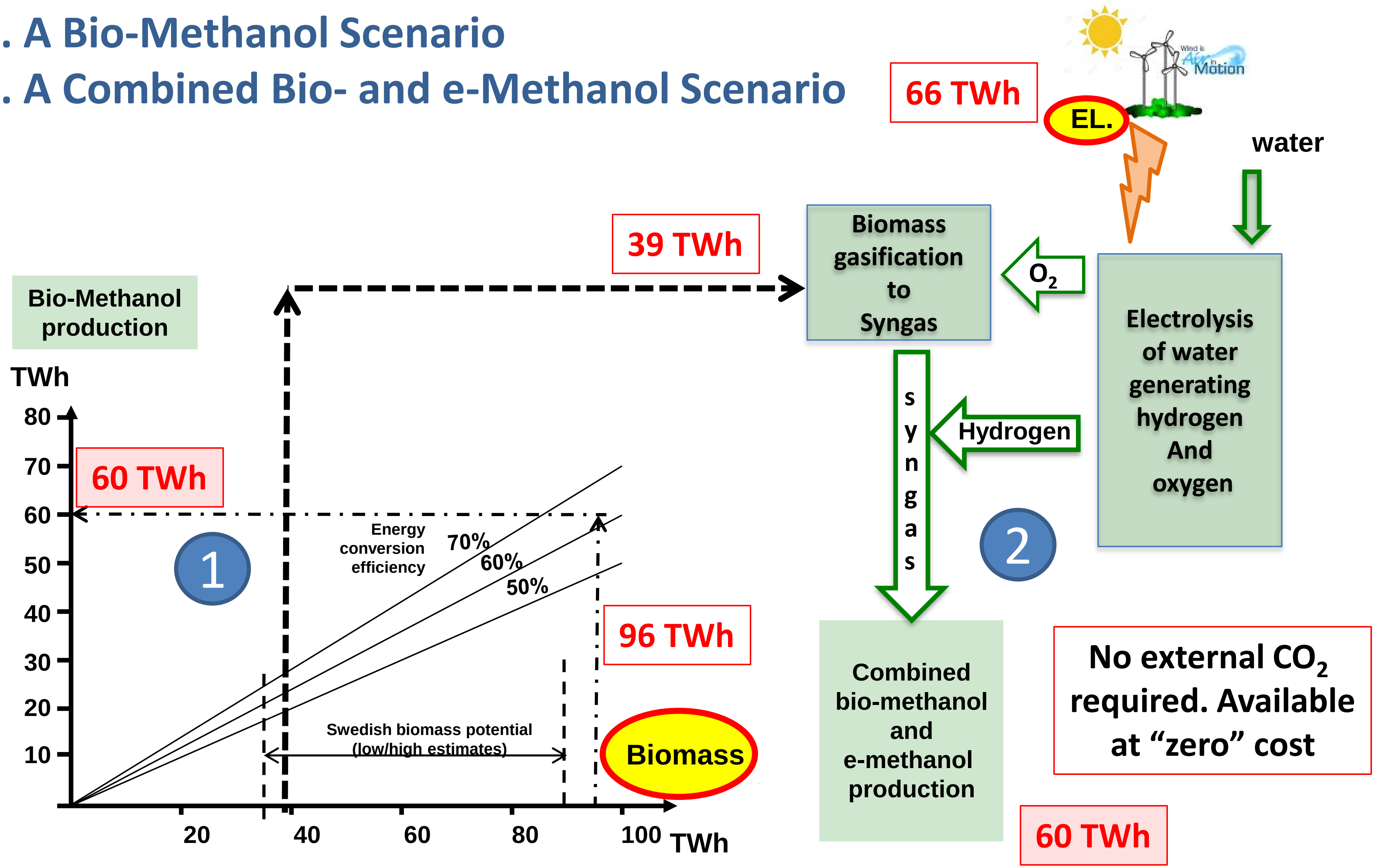
Pathway	Investment intensity (EUR/kW fuel production capacity)	xxx: Investment for 60TWh (Billion EUR)
Methane, MeOH, DME	1500-2000	11-15*
Cellulosic ethanol	2500-3000	19-23*
FT-liquids	2500-3000	19-23*

* Can be compared to an investment in high speed trains connecting Stockholm – Jönköping – Malmö – Gothenburg. This investment is calculated to about 23 billion EUR.

Generation of 60 TWh Renewable Methanol

1. A Bio-Methanol Scenario

2. A Combined Bio- and e-Methanol Scenario



Summary

- Currently there is only a limited amount of renewable methanol produced in the World
- Methanol production technology, its cost and performance is well known because most process steps are already practiced in commercial methanol production today. The key technology needing further development to become commercially available is the gasification step.
- Methanol has one of the lowest production costs compared to other renewable fuel alternatives
- Combination of bio- and e-methanol production pathways is efficient and leads to that (close to) all available carbon in the biomass feedstock becomes carbon in the renewable methanol.
- Use of available global biomass resource estimated for 2030 and beyond and utilizing the combined bio- and e-methanol concepts can contribute substantially to the world-wide effort of bringing down fossil GHG emissions towards zero by 2050.

THANK YOU!