Analysis of the availability of sustainable, biogenic gasoline in Europe

Technical potential analysis

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Agenda

- **Considered biomass potentials:**

  Countries and sources, Boundary conditions

- **Technical potential of biomass:**

  Assumptions, Results

- **Sustainable alcohol potentials:**

  Production potentials, CO_2 saving potentials

- **Gasoline production:**

  Conversion pathways, Production potentials, CO_2 saving potentials

Consortium

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Energy and Bioproducts Research Institute (EBRI), Aston University, Great Britain

Institute of Technology, Hungarian University of Agriculture and Life Sciences, Hungary

Institute of Catalysis Research and Technology (IKFT), Karlsruhe Institute of Technology (KIT), Germany

Considered potentials – boundary conditions

- **Sustainable Sources** compliant with RED III Annex IX
- Only **domestic biomass** produced in Europe
- Only **second-generation** biomass considered
  → No interference with food supply

- **Theoretical Potential**: Entire amount of biomass that is produced in given area
- **Technical Potential**: Considers amount of realistically available biomass after accounting for other established purposes (e. g. animal feed, fodder, mushroom production)
  → Future demands not included

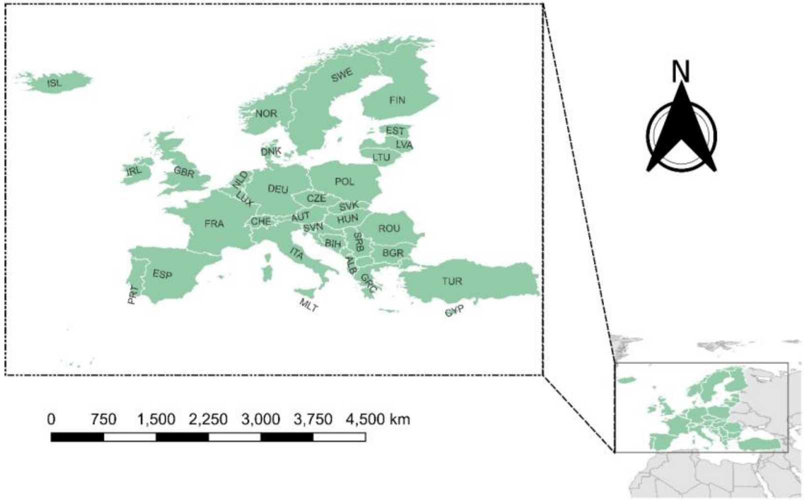
Considered potentials – countries and sources

Countries:

- EU27 + Iceland, Liechtenstein, Norway, Switzerland, Bosnia & Herzegovina, Montenegro, North Macedonia, Albania, Serbia, Turkey, Kosovo and UK
- Ukraine as a major agricultural contributor was not included

Biomass sources:

- Agricultural residues (straw)
- Perennial energy crops grown on marginal land
- Forestry byproducts
- Animal faeces, urine & manure
- Animal and mixed food waste, vegetal waste, organic fraction of household waste (processable waste)



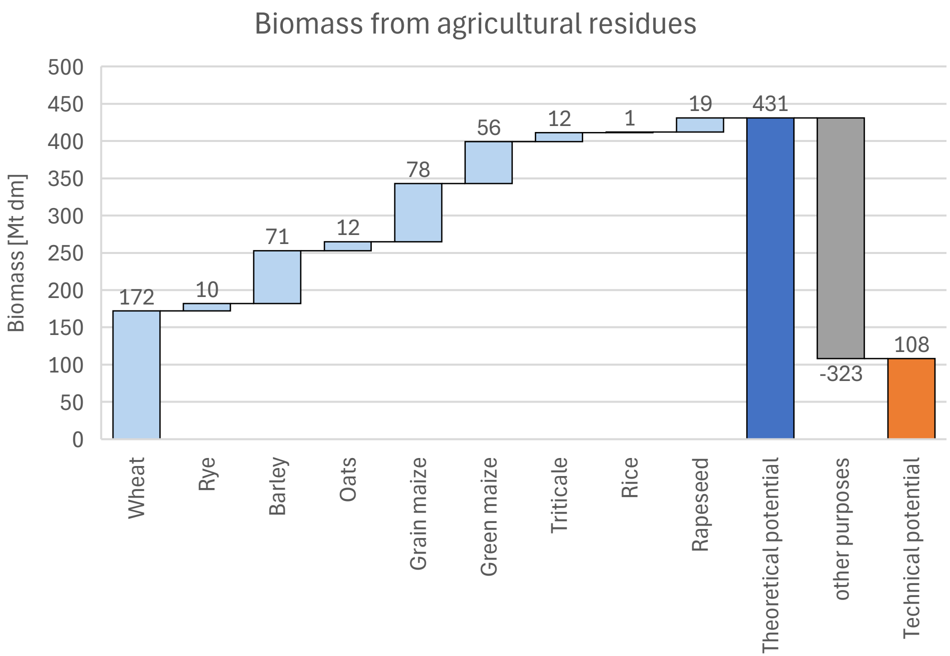
Technical Potential of Biomass – Assumptions (1)

Agricultural Residues:

- Straw-to-grain ratio for each crop is similar for all countries
- Use as animal feed, fodder and in mushroom production considered
- Some straw is left or ploughed into the soil to maintain soil quality

→ **25 % of theoretical potential can be technically used**

Source: https://www.bundesregierung.de/breg-de/mediathek/weizen-auf-einem-feld-2040206



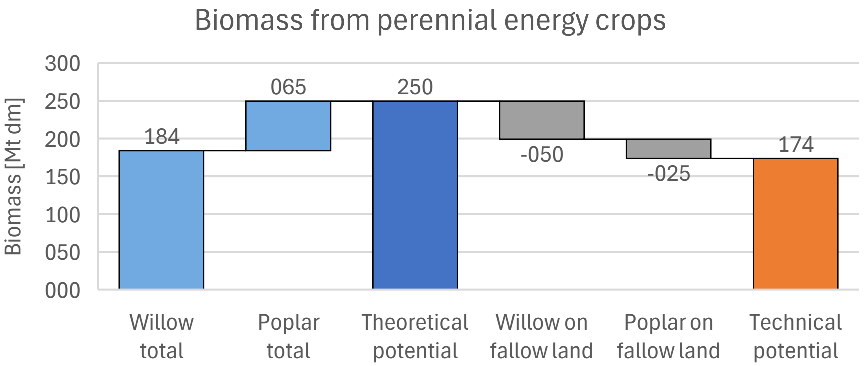
Technical Potential of Biomass – Assumptions (2)

Energy Crops on Marginal Land:

- Marginal land (44.62 Mha) and fallow land (14 Mha) are considered in theoretical potential
- **Technical potential excludes fallow land due to rest periods for soils**
- Willow and poplar are the most promising energy crops common to all projects
- 60 % of land usable for willow and 90 % for poplar

→ For potential estimation: **60 % of land** used for **willow** (higher yield) and **30 %** for **poplar**

Perennial energy crop	**Assumed yield** for considered land area in tonnes of dry mass per hectare [t DM/ha]	**Percentage of land suitable** for considered perennial energy crop	Total **technical biomass potential** on poor and very poor soils (44.62 Mha)	**Technical potential** in **assumed scenario**
Willow	5	60 %	133.8 Mt dm	**174 Mt dm**
Poplar	3	90 %	120.5 Mt dm	



Technical Potential of Biomass – Assumptions (3)

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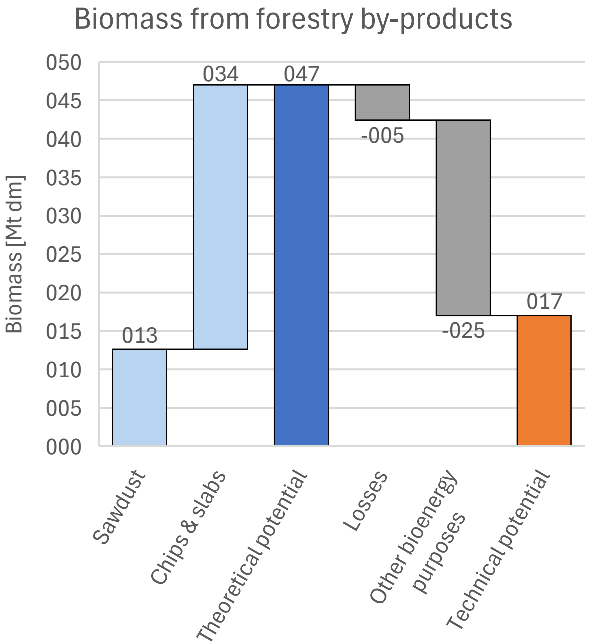
Forestry By-products:

- Calculated from wood production
- **41 % of processed woods** ends up **as residues**
- 11 % sawdust
- 30 % chips and slabs
- 4 % loss due to shrinkage and others

Source: https://wallenius-sol.com/en/enabler-magazine/impact-forest-industry

→ 37 % **of wood residues** available after accounting for already established bioenergy purposes

→ **Technical potential: approx. 15 % of overall processed wood**



Technical Potential of Biomass – Assumptions (4)

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Animal Faeces, Urine & Manure:

- Use as organic fertilizer considered

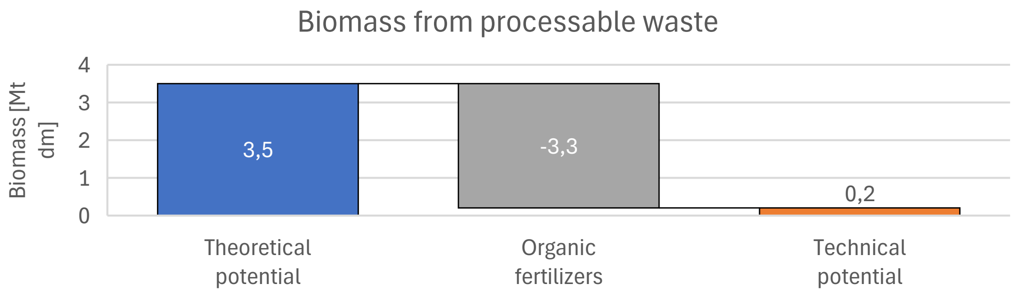
→ **Technical potential: 6.3 %** of theoretical potential

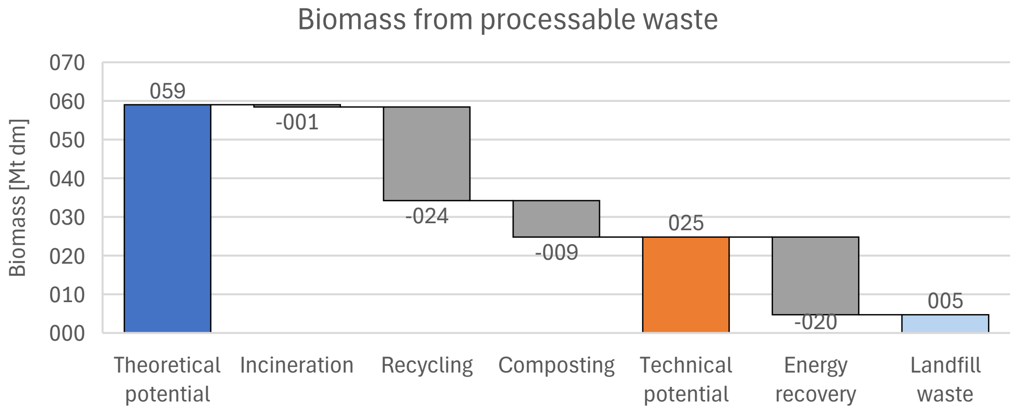
Processable Waste:

- Considering recycling, incineration, composting and energy recovery

→ Technical potential: 8 % of theoretical potential.

- If **‘landfill’ waste** and **‘energy recovery’ waste** are **diverted to produce alcohol,** the **technical potential increases to 42 %**





Biomass potentials

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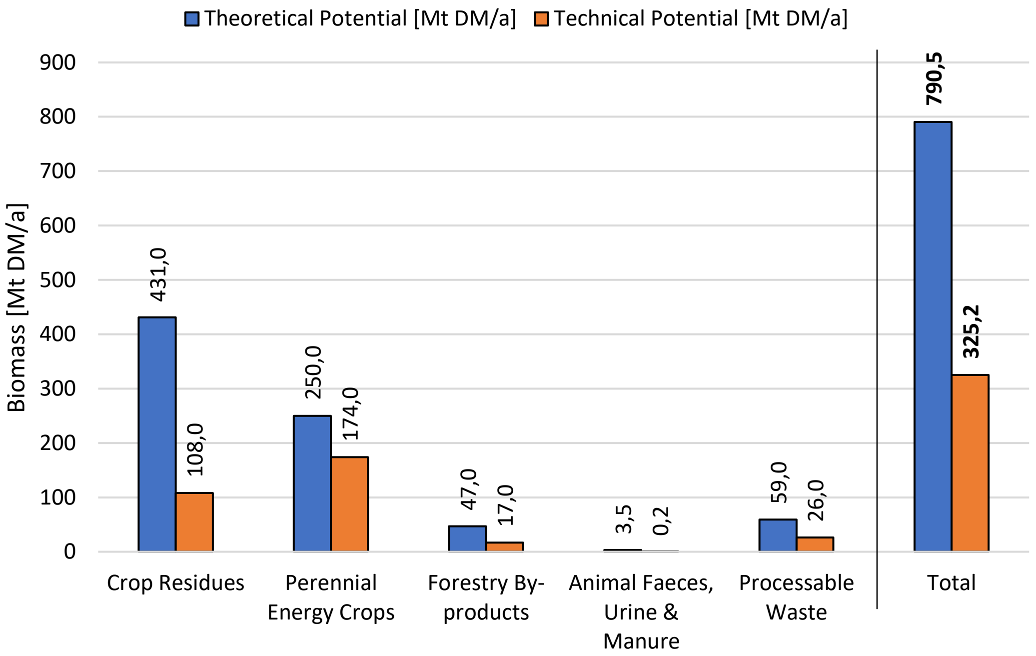
Summary:

- Values in million tonnes dry mass/year (Mt DM/a)
- Energy crops on marginal lands account for ~50 % of the total technical potential
- Crop residues account for another ~30 %

→ **325.2 Mt DM/a of biomass** could be **technically** produced

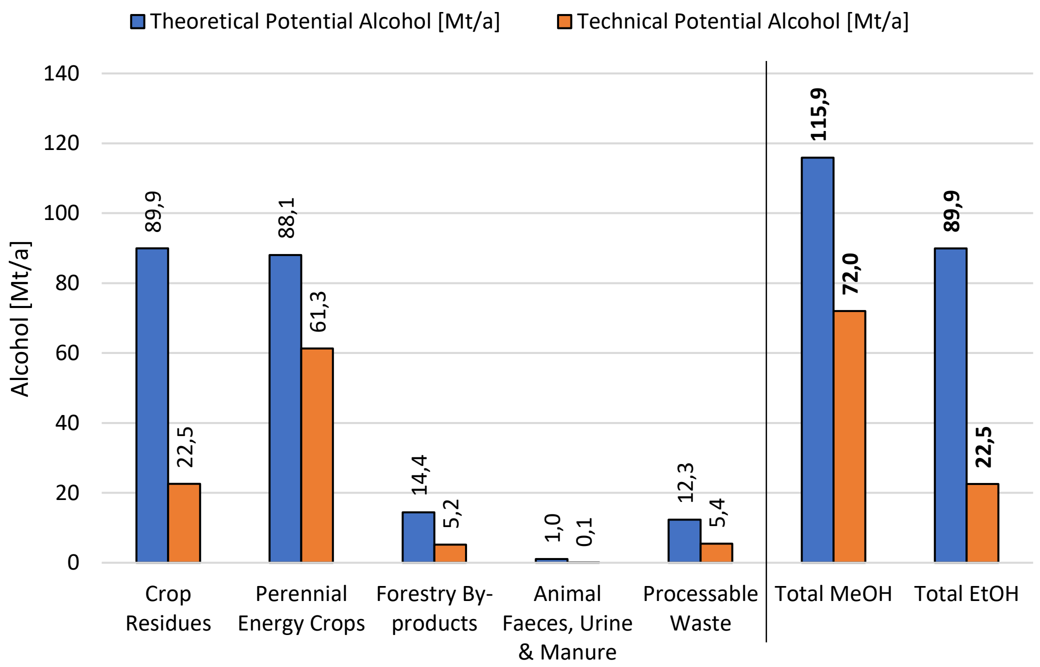


Alcohol potentials

Typical process pathways (RED II Annex V):

- **Crop residues** are converted to **EtOH**
- **Other sources** are converted to **MeOH**
- **Assumed conversion efficiency** of plants from biomass to alcohol: **40 %**

→ **72.0 Mt/a MeOH** and **22.5 Mt/a EtOH** could be **technically** produced (Methanol/ethanol share is adjustable)



Conversion pathways to gasoline

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Processes:

- Methanol to gasoline
- Ethanol to gasoline
- Methanol to Olefins + Oligomerization
- Ethanol to Olefins + Oligomerization

- Results are based on process simulations

	MtG	MtO+O	EtG	EtO+O	Unit
Inputs					
alcohol used	Methanol		Ethanol		
alcohol feed rate	1000	1000	1000	1000	kg/h
hydrogen feed rate	4.03	7.40	0.40	0.74	kg/h
total electricity demand	260.10	458.40	78.10	155.00	kW
Outputs					
gasoline	331.40	367.50	442.20	513.00	kg/h
water	556.30	562.50	392.10	410.00	kg/h
LPG	91.80	-	114.70	-	kg/h
fuel gas	22.00	-	51.30	-	kg/h
kerosene + diesel fuel	-	33.60	-	78.00	kg/h
energy efficiency	67.10	72.90	72.10	80.90	%
alcohol demand for gasoline	3.02	2.72	2.26	1.94	kg alcohol/ kg gasoline

Overall sustainable gasoline potential

Gasoline Potential:

- Input from total technical MeOH potential (72 Mt/a) and EtOH potential (22.5 Mt/a)

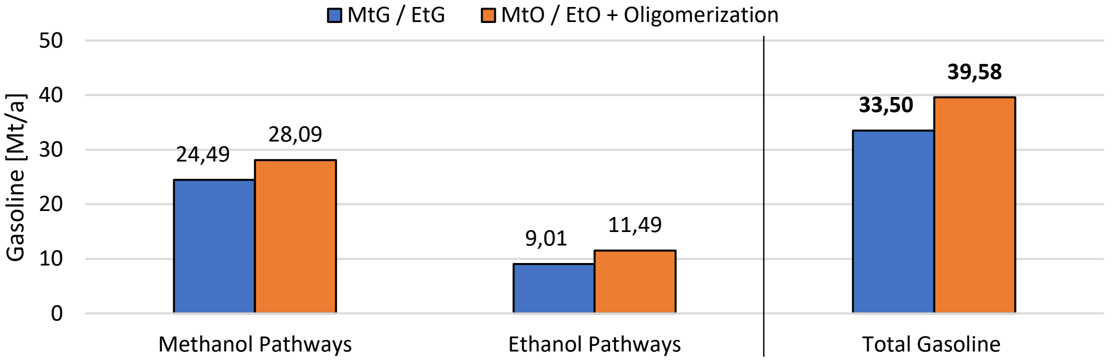
→ **MtO and EtO + Oligomerization** pathway leads to **higher sustainable gasoline output** than MtG and EtG pathway

Cost assessment:

- Share of alcohol costs in overall production costs increases with plant scale

→ Significant **decrease of overall production costs with upscaling** of production plants

Mass potentials:



Production costs:

Alcohol feed rate [Mt/a]	0.008	1	4
	Cost of resulting gasoline		
MtG (green methanol)	5.51 €/l	1.95 €/l	1.86 €/l
MtO (green methanol)	5.41 €/l	1.52 €/l	1.47 €/l
EtG (2nd generation ethanol)	4.43 €/l	3.02 €/l	2.70 €/l
EtO (2nd generation ethanol)	5.08 €/l	2.58 €/l*	2.47 €/l

* Significant decrease with future ethanol prices expected (1.52€/l)

CO_2 reduction potential of sustainably produced gasoline

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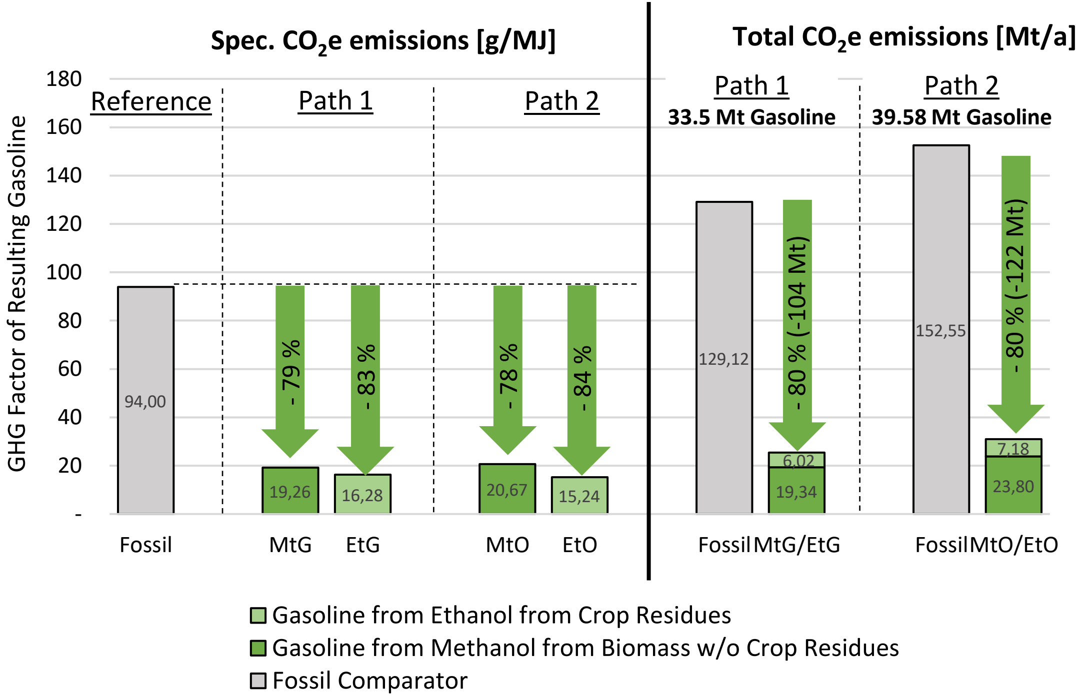
Values based on:

- CO_2 reduction of alcohols (typical values from RED II Annex V for **crop residues**, **energy crops** and **forestry by-products**)
- CO_2 reduction for **animal faeces, urine & manure and processable waste** is based on [1]
- Shares of gasoline from production processes
- Fossil comparator is 94 g/MJ (RED II Annex V)

→ **Similar reduction** potentials for the **different pathways**

→ **Higher absolute potential** for **MtO+O** and **EtO+O** processes



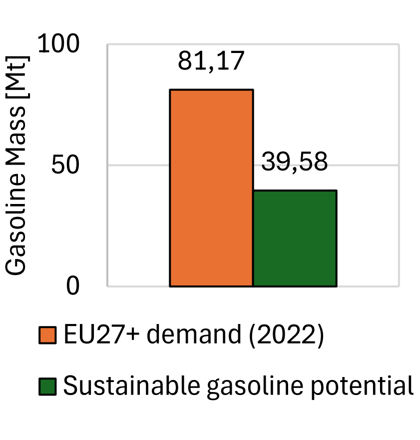
Conclusion & exemplary scenario

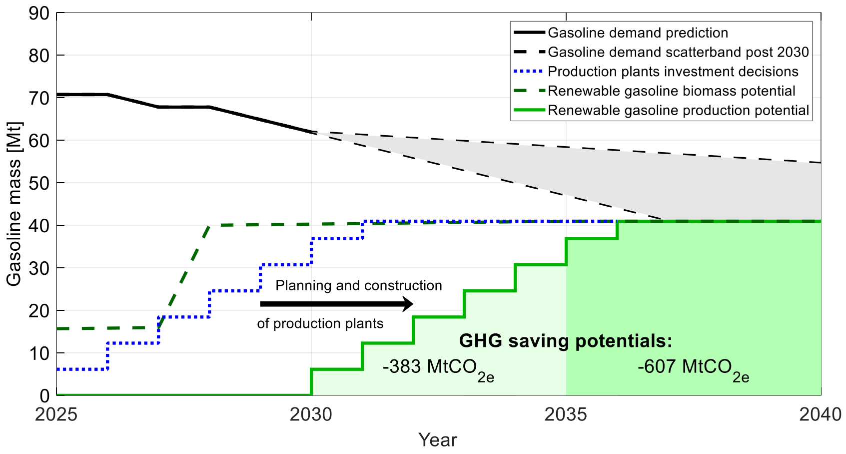
Sustainable potential:

- **~ 40 Mt** gasoline

→ **49 %** of the overall fuel consumption

→ **79 million vehicles** (667 litres per year and car)





→ Long term market demand, **no interference with E-Mobility** ramp up

→ Energy supply is fully based on European resources, **biomass availability** is **not a limiting factor**

→ **Quicker investment** decisions lead to **higher GHG saving** potentials

→ Flexibility of processes allows fuel production for different markets and applications → **investment security**

Thank You!

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References

Graphic title:

https://cordis.europa.eu/article/id/442119-in-pursuit-of-decarbonised-fuels-in-the-transport-sector

1) S. Puricelli *et al.*, "Life Cycle Assessment of innovative fuel blends for passenger cars with a spark-ignition engine: A comparative approach," *Journal of Cleaner Production*, vol. 378, p. 134535, 2022, doi: 10.1016/j.jclepro.2022.134535.