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Our commitment, your success

EU Renewable Energy Directive (RED II) and the EU refinery of 2030.
Navigating the world of residues and biofuel technologies.

November 2020

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REDII Transport Fuels (Article 25 to 28)

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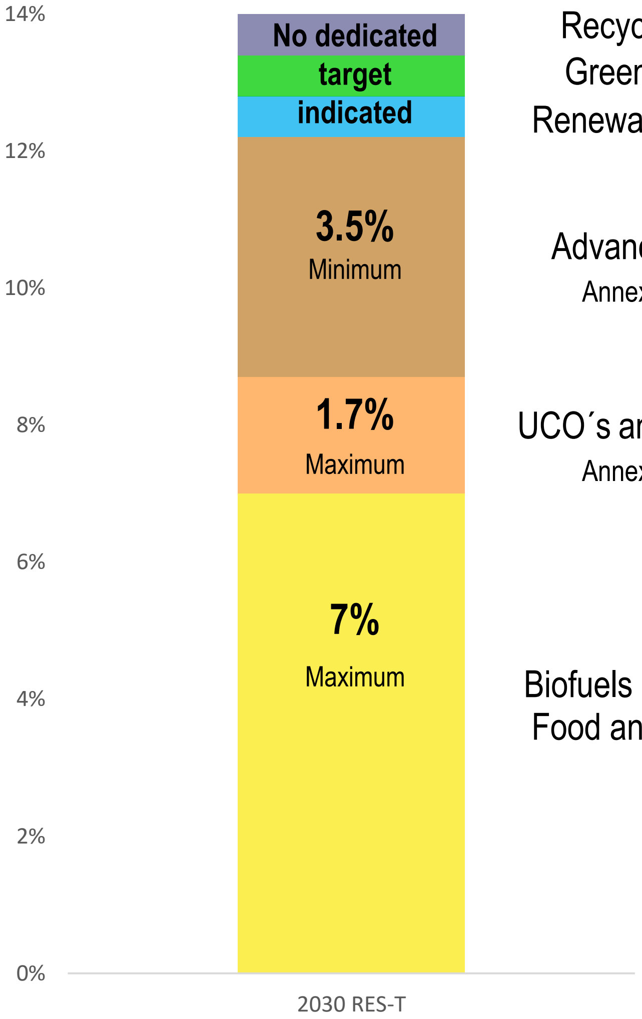
The EU directive requires at least **14% of transport fuels** in the EU to be of a renewable origin by **2030.**

Each member state may require increased targets.

With the multipliers the EU is clearly incentivizing electrification of the transport sector.



Recycled Carbon x1
Green Hydrogen x1
Renewable Electricity x4


Advanced Biofuels
Annex IX – Part A x2



UCO´s and Animal Fats
Annex IX – Part B x2


Biofuels produced from Food and Feed crops x1

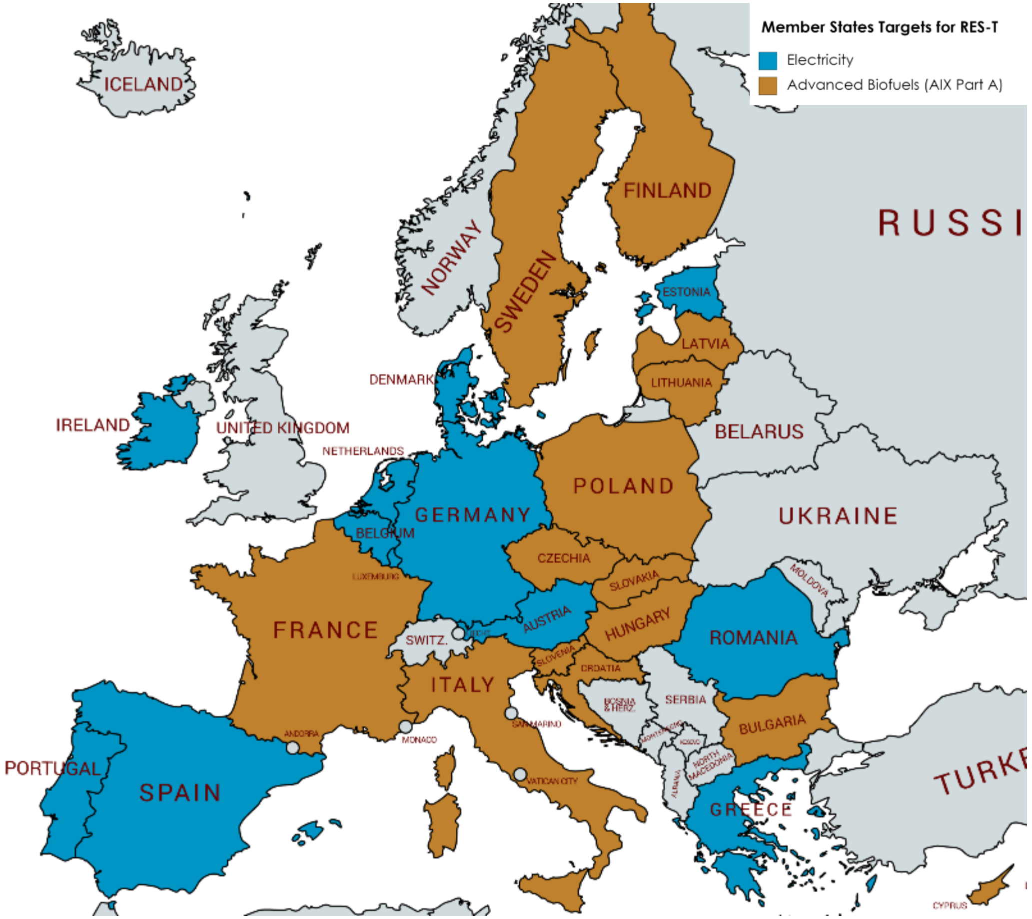

Member state commitments surpass 14% in **25 member states**, with ambitious targets such as **28% in Spain** and the highest commitment in **Sweden with 52%**

Advanced Biofuels Drivers

- Raw material availability / logistics cost
- Existing vehicle fleet mainly based on diesel
- Low population density & Size of Member state (km2)

Electrification Drivers

- Wind/PV/Hydro availability
- Existing Rail infrastructure for the transport of goods
- High population density in cities



Refiners have the same overall key drivers plus constraints related to refinery & products.

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Electricity and Hydrogen - The starting point (Case Study Spain)

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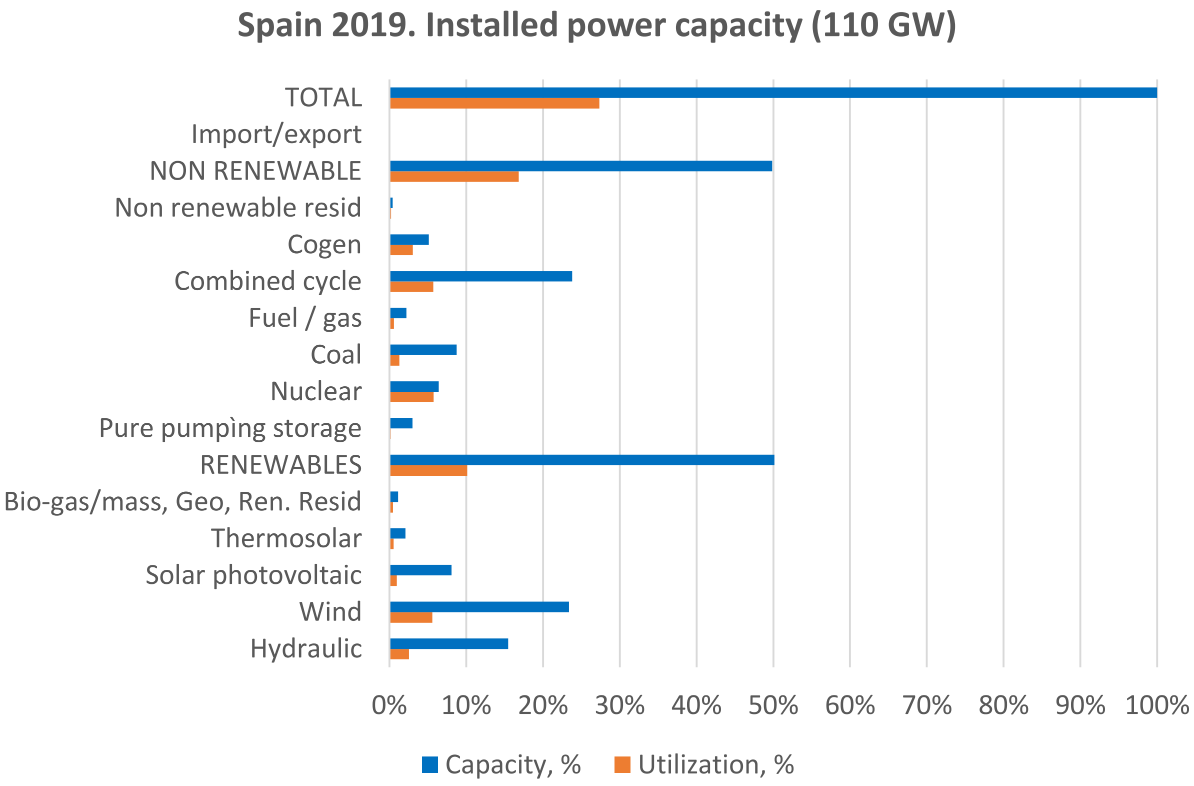
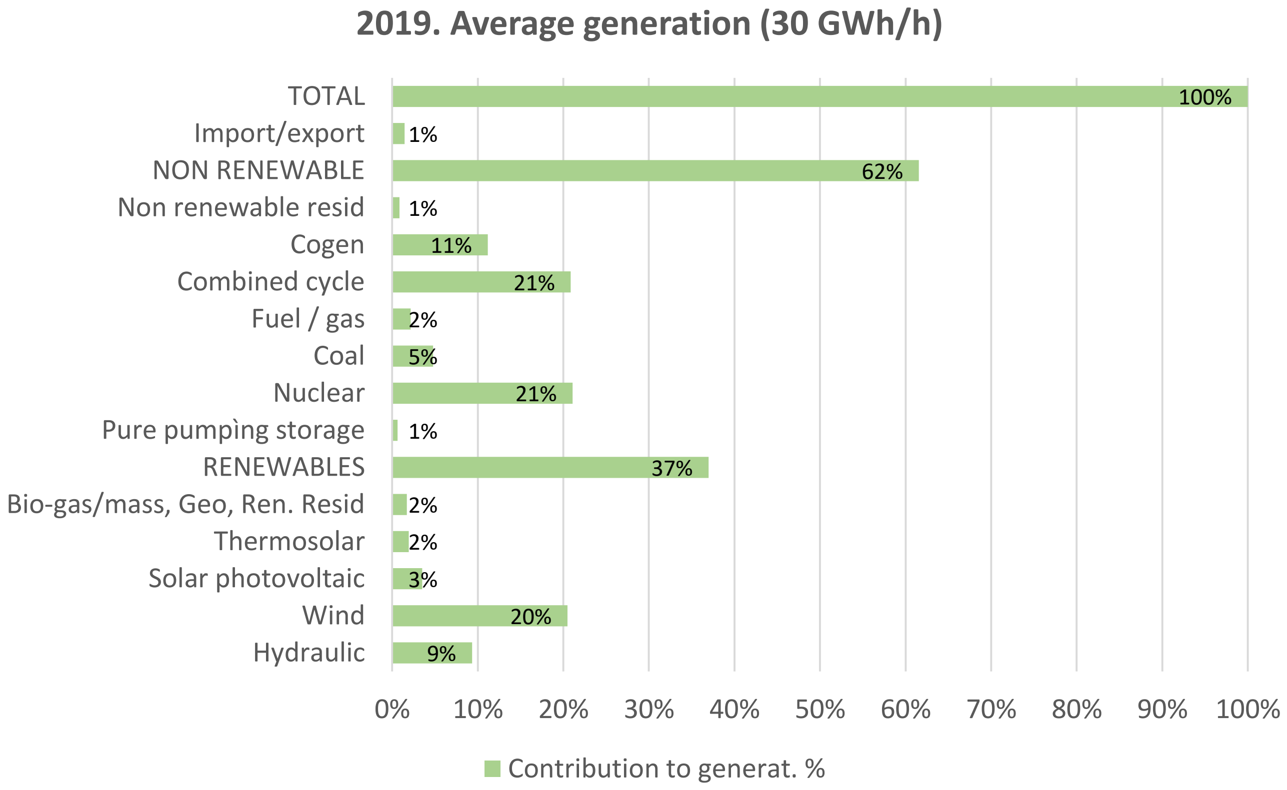
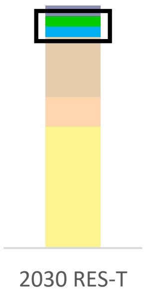


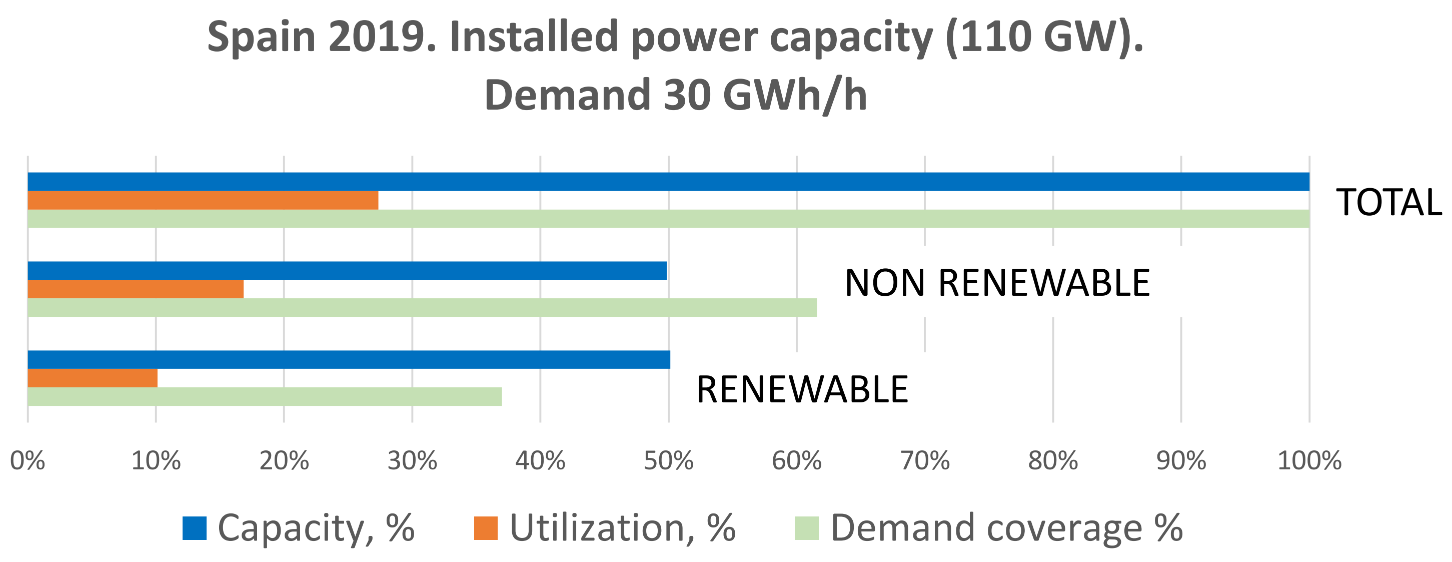


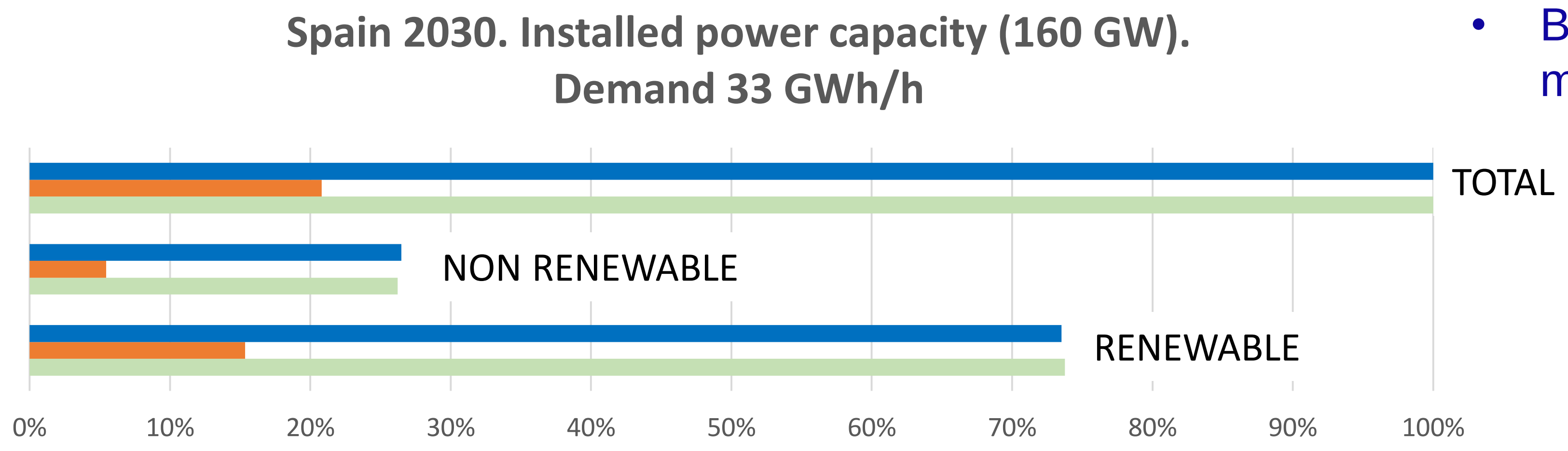
- Installed power capacity: 50% / 50% that leads to 63% / 37% generation (non-RES/RES)
- Overall average capacity utilization is around 27%
- Daily demand variability +/- 40%
- RES average utilization is about 20% of the installed capacity
- Wind daily utilization varies from 2% to 60% of its installed capacity



Electricity

x4 multiplier

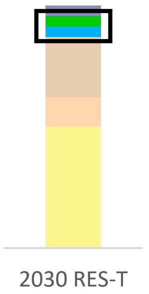




At least 185 GW of renewable power to be installed in the next 30 years. How much and at what rate?

- Marginal profitability of the installed capacity
- Gasoline and diesel 2019 demand is about 49% of the oil demand (LPG, jet, primary sector diesel, bunker, fuel,… excluded)
- Beyond 2030 plans, energy storage is a must for the system to be feasible

Investments (2021-2030) 91 billion € renew. & 58 billion € networks and electrification…announced (80% private).



Electricity and Hydrogen - Supply follows Demand but does Demand follow Supply?

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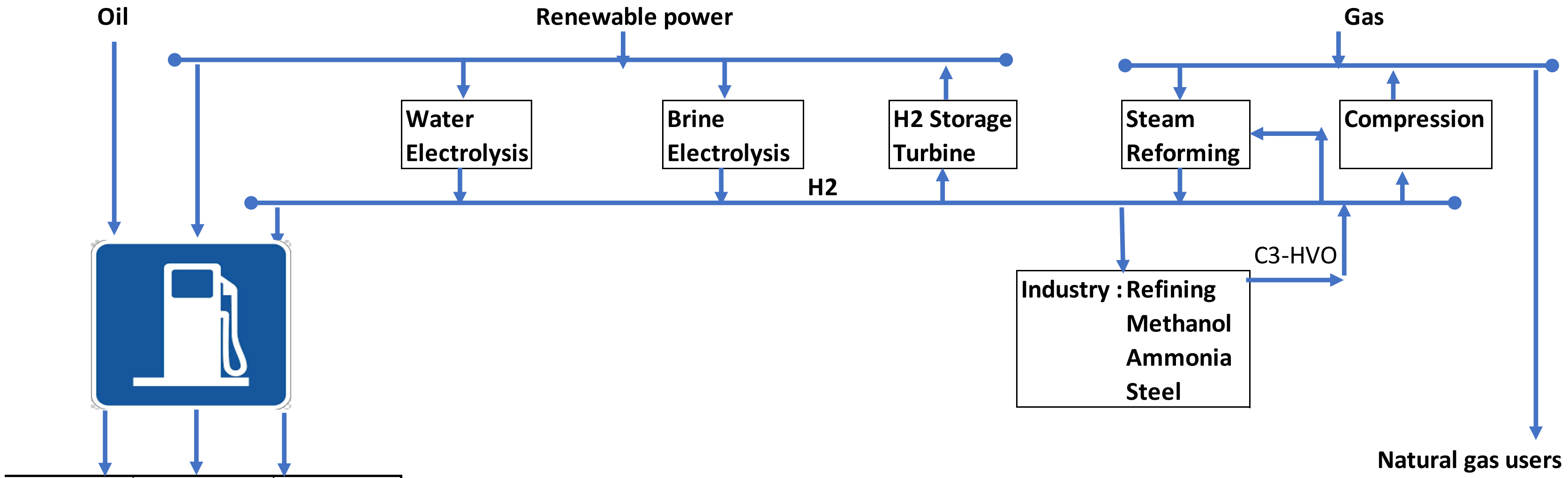

Diesel/Gas.	Electricity		H2	
30-60	30-60		65-85	Cost of vehicle (thousand €)
Wide	Wide		Small	Choice
7 l	15 kWh		1 kg	Fuel Consumption/100 km
1,5	0,1	0,5	11	Cost (€/unit) Home night fare/Street charge
1575	225	1125	1650	Cost €/year, (15.000 km)
Base	Base - 50%		Base - 10%	Maintenance cost
700	250-580		500	Autonomy /refill (km)
5	60 - 500		5	Fueling time (min)
Good	Limited		Poor	Fueling infraestructure
No	Limited		No	Charger at home

Opportunities

- Integration. The industry case.
- Integration. The gas case.
- Green H2 from brine electrolysis
- HVO C3 to produce:
  - Green H2
  - Biopropane
  - Petrochemical feed

- Neither too soon, nor too late refiners (and gas operators) could consider this as an opportunity.
- Hydrogen demand from industry has an advantage. Creating further demand is critical.
- Hydrogen hubs and Hydrogen fueling stations need careful design.

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Current Landscape – Food & Feed Crops

Food & Feed Crops

- Maximum 7%, w/o multipliers & capped

FAME from Food & Feed Crops

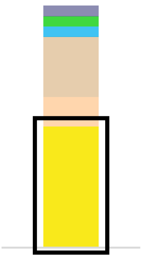
- Overall similar properties
- CO2 emissions are similar
- FAME has poor cold properties

HVO from Food & Feed Crops

- HVO products include Renewable Jet Fuel
- HVO produces drop-in fuels

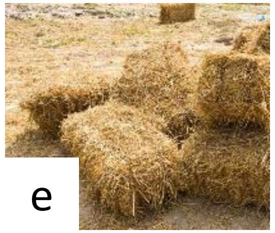
Property	Units	HVO	FAME	Diesel EN 590
Density at 15 °C	kg/m3	775–785	885	835
Viscosity at 40 °C	mm2/s	2.9–3.5	4.5	3.5
Distillation 90 vol.%	°C	295–300	355	350
Cetane number		84–99	51	53
Cloud point	°C	−5 to −30	−5	−5
Cold Filter Plugging Point	°C	−20 to −50	0 to −20	−10
Lower heating value	MJ/kg	44	38	43
Polyaromatic content	wt-%	0	0	4
Oxygen content	wt-%	0	11	0
Sulfur content	mg/kg	~0	<10	<10

Refiners must consider that feedstocks are and will be further limited.


2030 RES-T

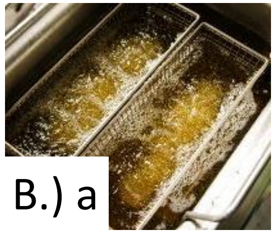
Part A — 3.5% min & x2 multiplier

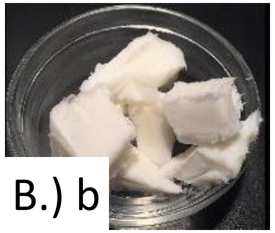
(a) Algae
(b) Biomass fraction of mixed municipal waste
(c) Biowaste from private households
(d) Biomass fraction of industrial waste
(e) Straw;
(f) Animal manure and sewage sludge;
(g) Palm oil mill effluent and empty palm fruit bunches;
(h) Tall oil pitch;
(i) Crude glycerin;
(j) Bagasse;
(k) Grape marcs and wine lees;
(l) Nut shells;
(m) Husks;
(n) Cobs cleaned of kernels of corn;
(o) Biomass fraction from forestry,
(p) Other non-food cellulosic material;
(q) Other ligno-cellulosic

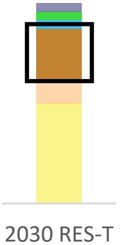


Part B — 1.7% max & x2 multiplier

(a) Used cooking oil;
(b) Animal fats







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Availability and logistics

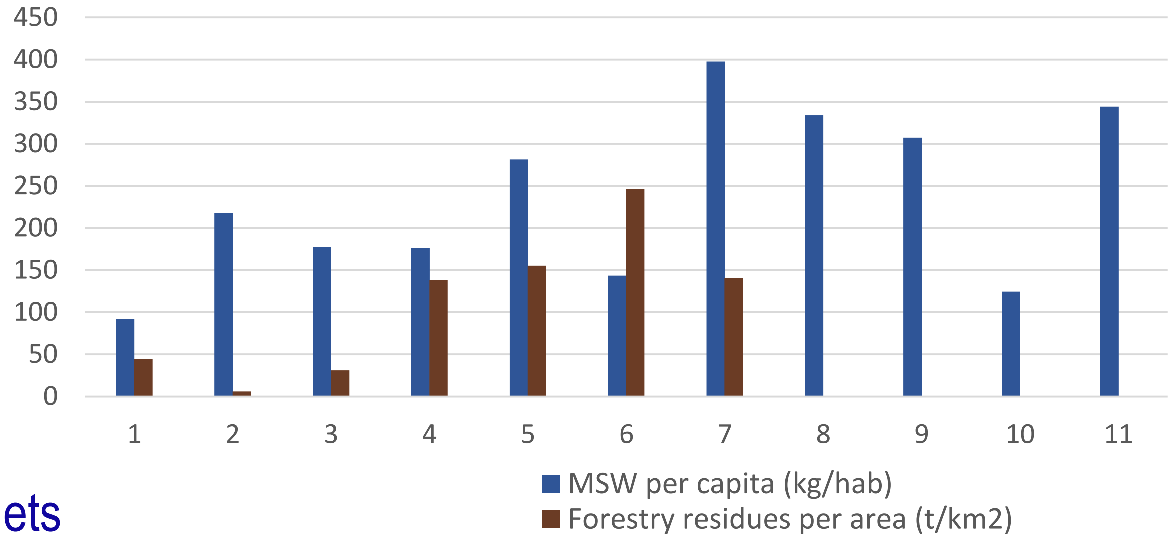
- Dispersion & Distance to advanced biofuels plant
- Density & Feedstock Pretreatment
- Annex IX-A feedstocks are sector & geography specific
- Macro vs micro availability analysis is very important

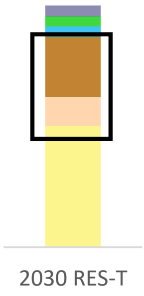
Characterization

- Desired Product (gas, liquid, solid)
- Product yield to achieve desired contribution to RES-T targets
- Renewable energy share estimations to reach RES-T target

Other Considerations

- Feedstock Owner: Public authorities vs. private companies





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Technologies

			FAME	HVOs	Anaerobic Digestion	Fermentation/ Hydrolysis	Pyrolysis	HTL	Gasification	Reverse shift reaction
Feedstocks		Recycled Carbon					X	X	X	
Feedstocks		CCU (CO2)								X
Feedstocks	Advanced Biofuels (Annex IX Part A)	Aquatic Biomass				X		X		
Feedstocks	Advanced Biofuels (Annex IX Part A)	Biomass from resiudes			X	X		X	X	
Feedstocks	Advanced Biofuels (Annex IX Part A)	Mixed Urban Residues					X	X	X	
Feedstocks	Advanced Biofuels (Annex IX Part A)	Lignocellulosic (LC)			X	X	X	X	X	
Feedstocks	Advanced Biofuels (Annex IX Part A)	Tall Oil	X	X						
Feedstocks		UCO's and Animal Fats (Annex IX Part B)		X						
Feedstocks		Food & Feed Crops	X	X	X	X				
Products	Intermediates	Char coal (bio-coal)					X			
Products	Intermediates	Torrefied pellets					X			
Products	Intermediates	Bio-oil (bio-crude oil)					X			
Products	Intermediates	BioSyngas					X		X	X
Products	Drop-In	BioGas		X	X		Methanation		X	
Products	Drop-In	Bio-alcohol/Biogasoline				X	Distillation/FT	Upgrading	FT	
Products	Drop-In	Renewable Diesel	X	X			Distillation/FT	Upgrading	Upgrading	
Products	Drop-In	BioKerosene (Jet Fuel)		X			Distillation/FT	Upgrading	Upgrading	

Hydrotreated Vegetable Oil (HVO) – Considerations

PROCESS CONDITIONS
P: 50 bar
T: 250-350°C

YIELD 65-85%

FEEDSTOCKS
- Food & Feed Crops
- Used Cooking Oils (UCOs)
- Animal Fats
- Tall Oil

PRODUCTS
- Renewable Diesel (HVO)
- Renewable Jet Fuel (HEFA-SPK)
- By-products of the process: Propane, Butane, Pentane, Naphtha, Acid Gases, Hexane.

Process related:

- Feed pre-treatment and Reactor guard beds are **key** to ensure reasonable run-lengths.
- Lack of experiences can drive conservative metallurgy usage
- Flexibility for both jet or diesel-oriented units

Products related:

- H2/C3 **recovery** from H2 purge and stripper off-gas
- Diesel can **improve** aromatic/cetane constrained diesel pools in FCC Coking schemes or multi-refinery
- Amine selection/regeneration tradeoffs for existing refineries




Anaerobic Digestion – Considerations

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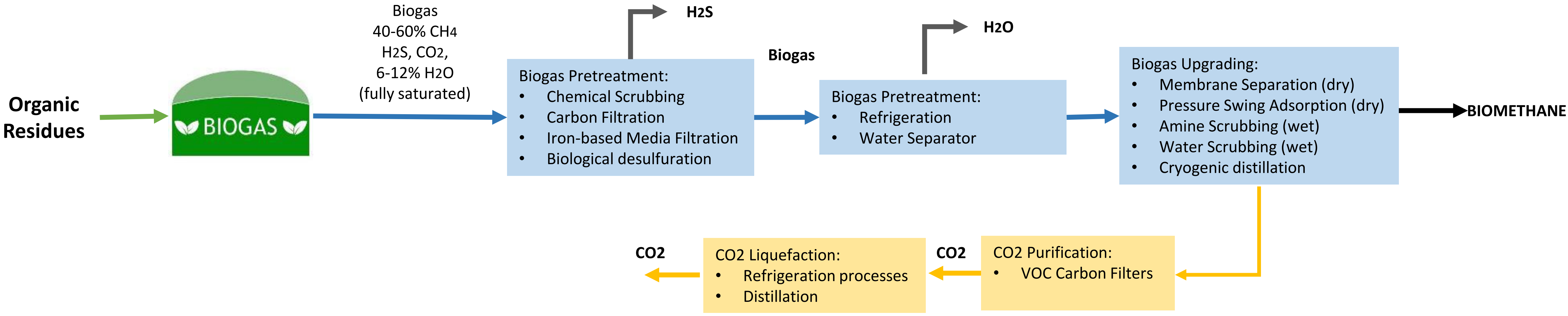

Process related:

- Waste characterization: stable concentration and composition, moisture content, fermentable material
- Two anaerobic digestion types: Dry and Wet
- Storage and pretreatment for impurities elimination

Products related:

- Biogas treatment: H2S, H2O and CO2 removal to obtain CH4 (biomethane)
- Byproducts: liquid (fertilizer) and solid digestate (RDF – Annex IX, Part A feedstock)

Pyrolysis – Considerations

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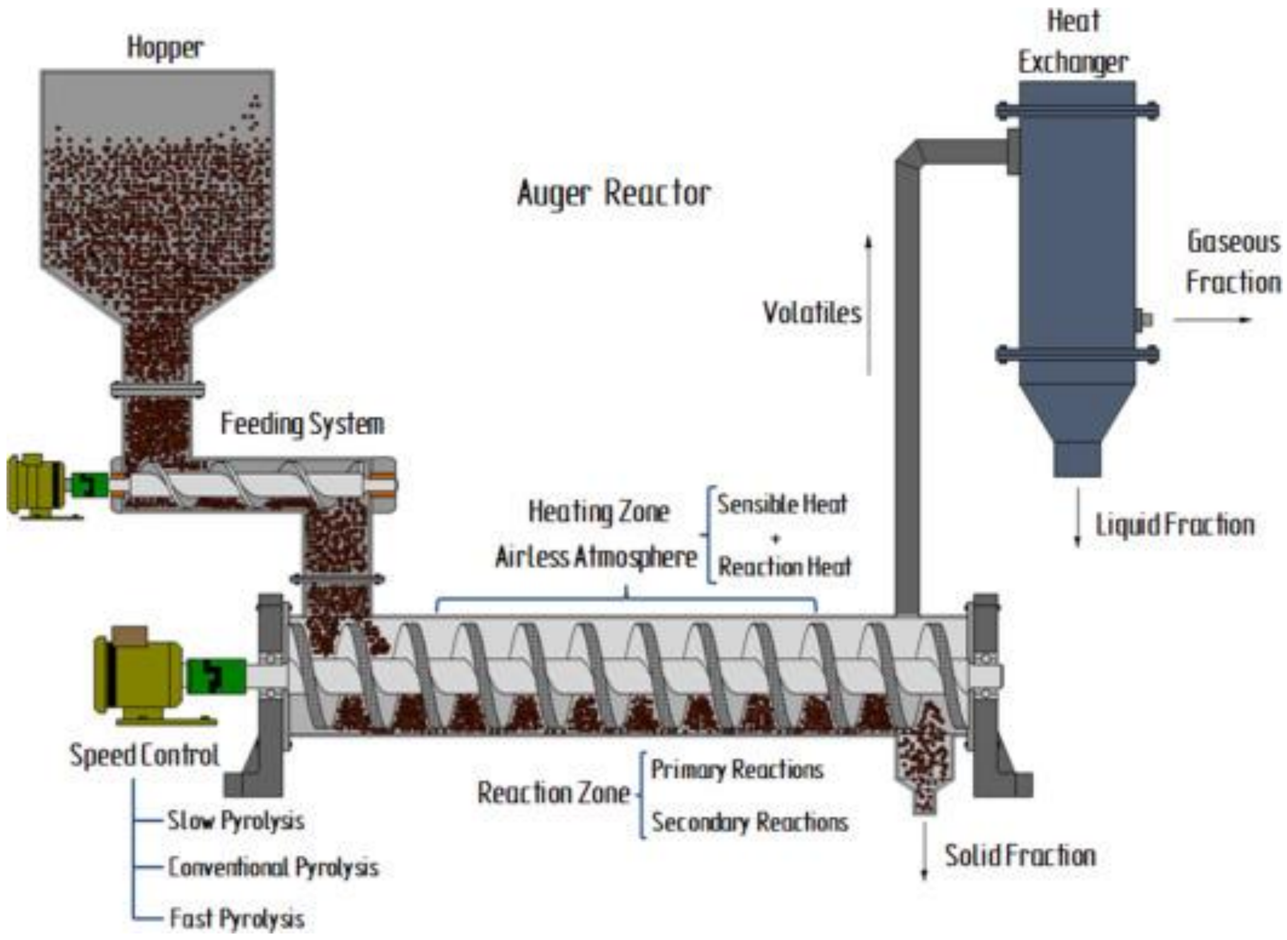
PROCESS CONDITIONS
P: 1 bar
T: 250-700°C

YIELD Bio-oil 15-65%

FEEDSTOCKS
- Dry lignocellulosic material
- Residues
- Plastic waste (recycled carbon)

PRODUCTS
- Gas: H_2, CO, HC
- Liquid: biooil / pyrolysis oil
- Solid: ash, char

- Product yield highly dependent on feedstock characterization
- Focus on liquid or gaseous yield drives feedstock selection



Gasification – Considerations

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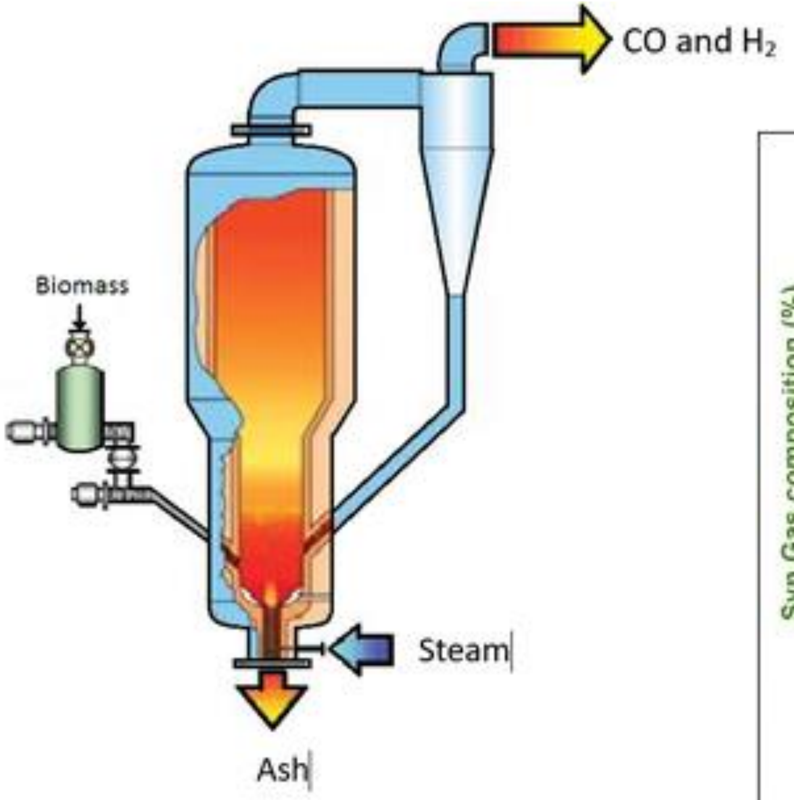
PROCESS CONDITIONS
P: Low Pressure
T: 800-1400°C

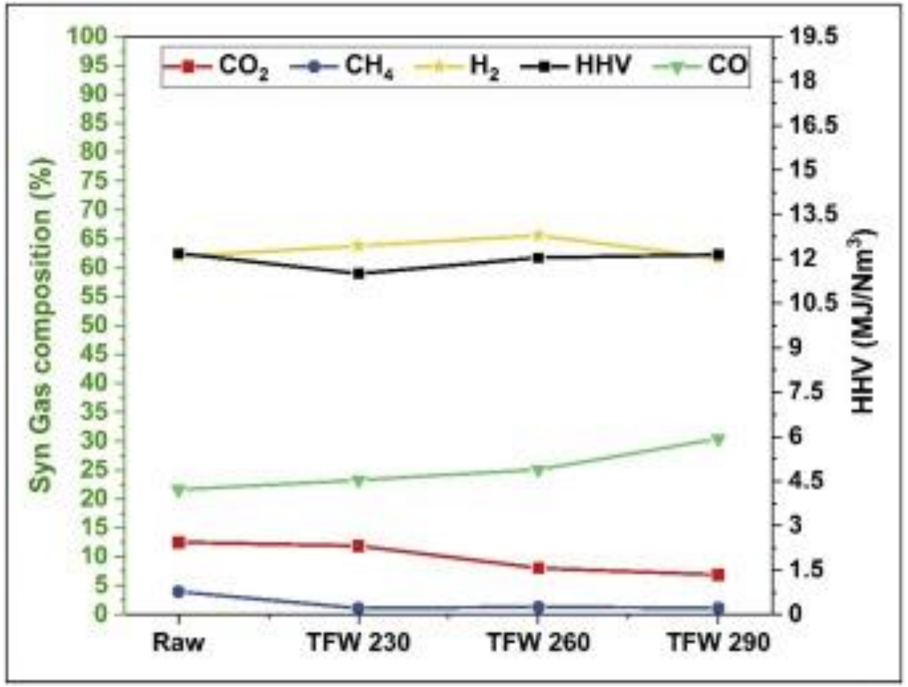
YIELD
Gas production: 1-4 m3/kg feedstock
Carbon conv. efficiency: 40-90%

FEEDSTOCKS
- Dry lignocellulosic material
- Residues
- Plastic waste (recycled carbon)

PRODUCTS
- Gas: CO, CO2, H2, H2O, CH4
- Solid: ash, slag

- Requires steam and O2 consumption (stoichiometric ratio < 1)
- High energy consumption for heat input





Hydrothermal Liquefaction (HTL) – Considerations

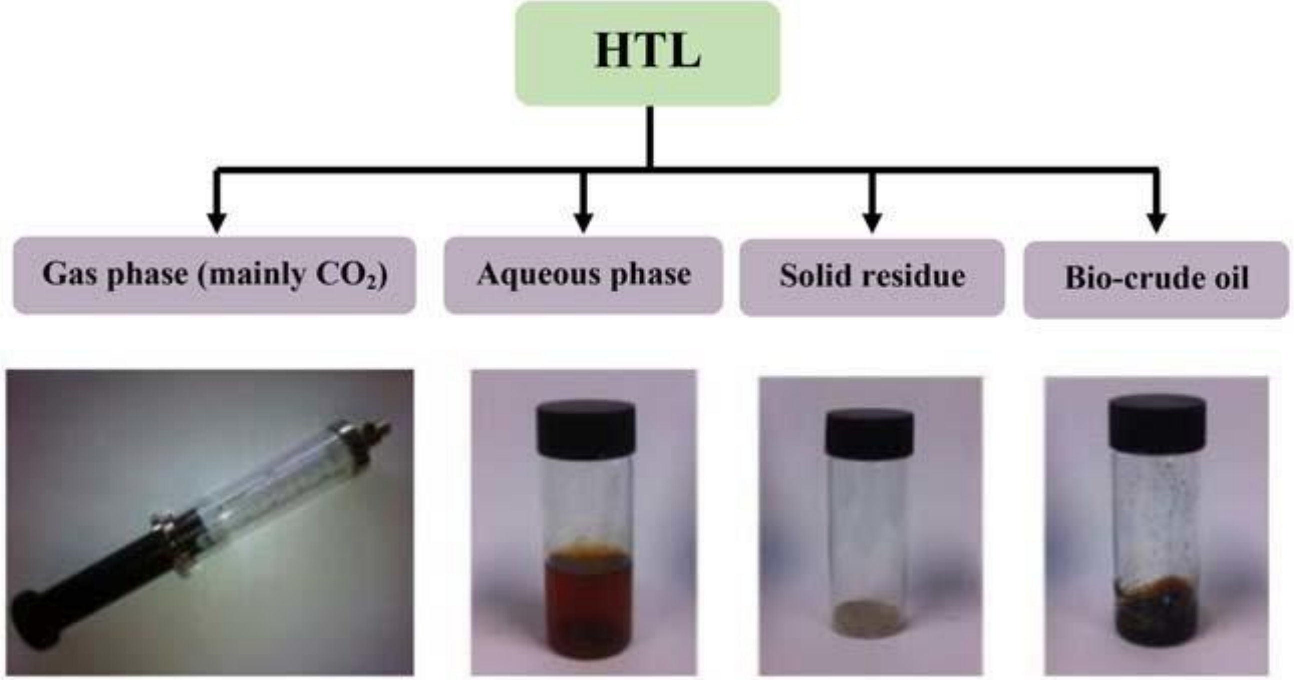
PROCESS CONDITIONS
P: 50-350 bar
T: 250-450°C

YIELD Biooil 30-70%

FEEDSTOCKS
- Wet lignocellulosic material
- Biomass from residues
- Plastic waste (Recycled carbon)

PRODUCTS
- Gas: mainly CO2
- Liquid: biooil, H2O
- Solid: char

- More flexibility in feedstock: wet feedstock suitability
- Less energy supply is required due to lower temperatures
- Catalysts are needed (KOH, Na_2CO_3, Pd/C, Zeolite, NiMo, …)



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Summary

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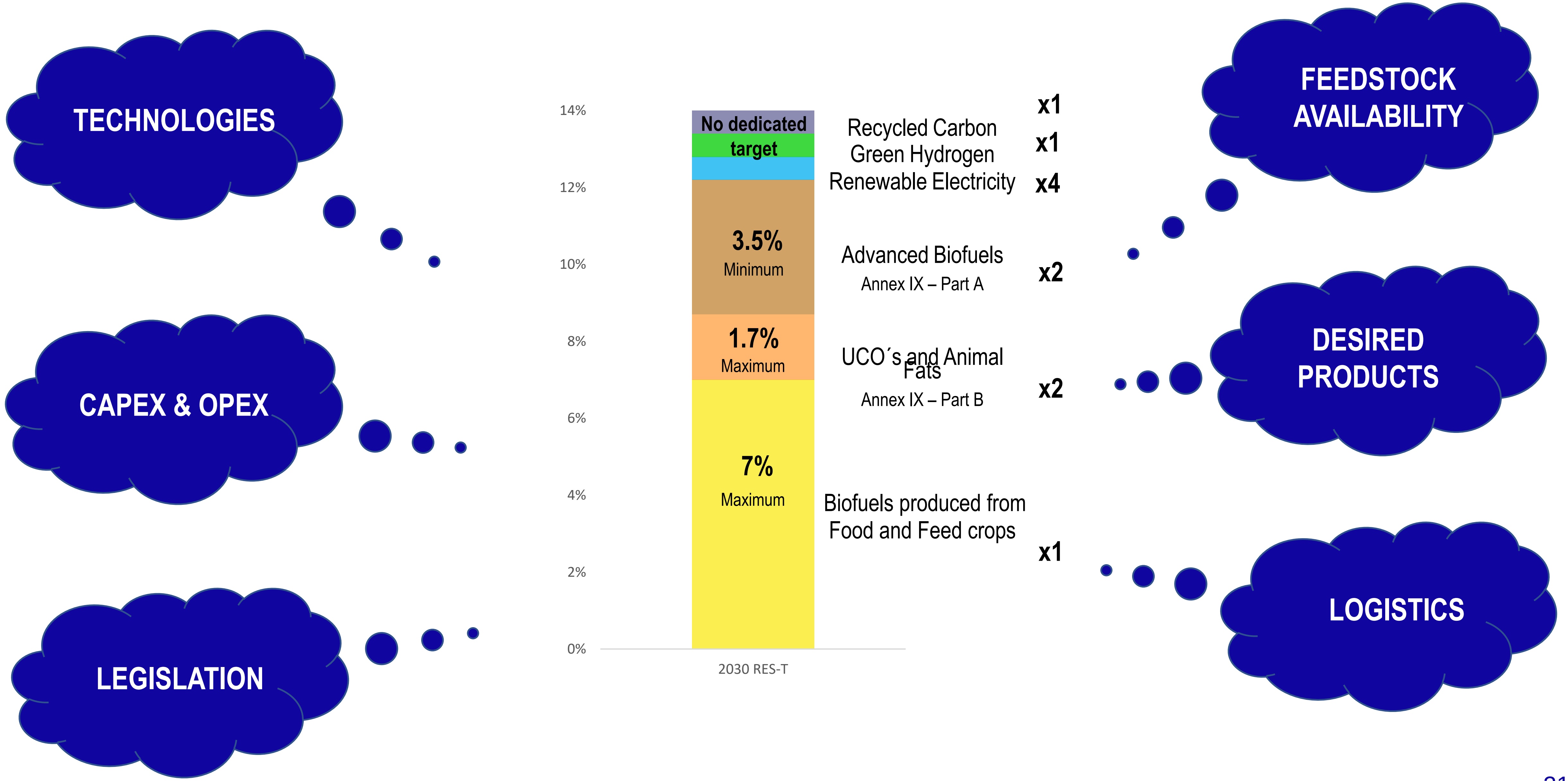

Thanks for Your Attention

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