Lignocellulosic waste valorization by hydrothermal carbonization and anaerobic digestion

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Background

$2.2 \cdot 10^8$ t MSW year^{-1}

≈ 10% lignocellulosic biomass

Biowaste

47 % composting and recycling

28% energy valorization

25% landfill

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Background

Urban pruning waste

Energy resource

Industrial level

Home level

Background

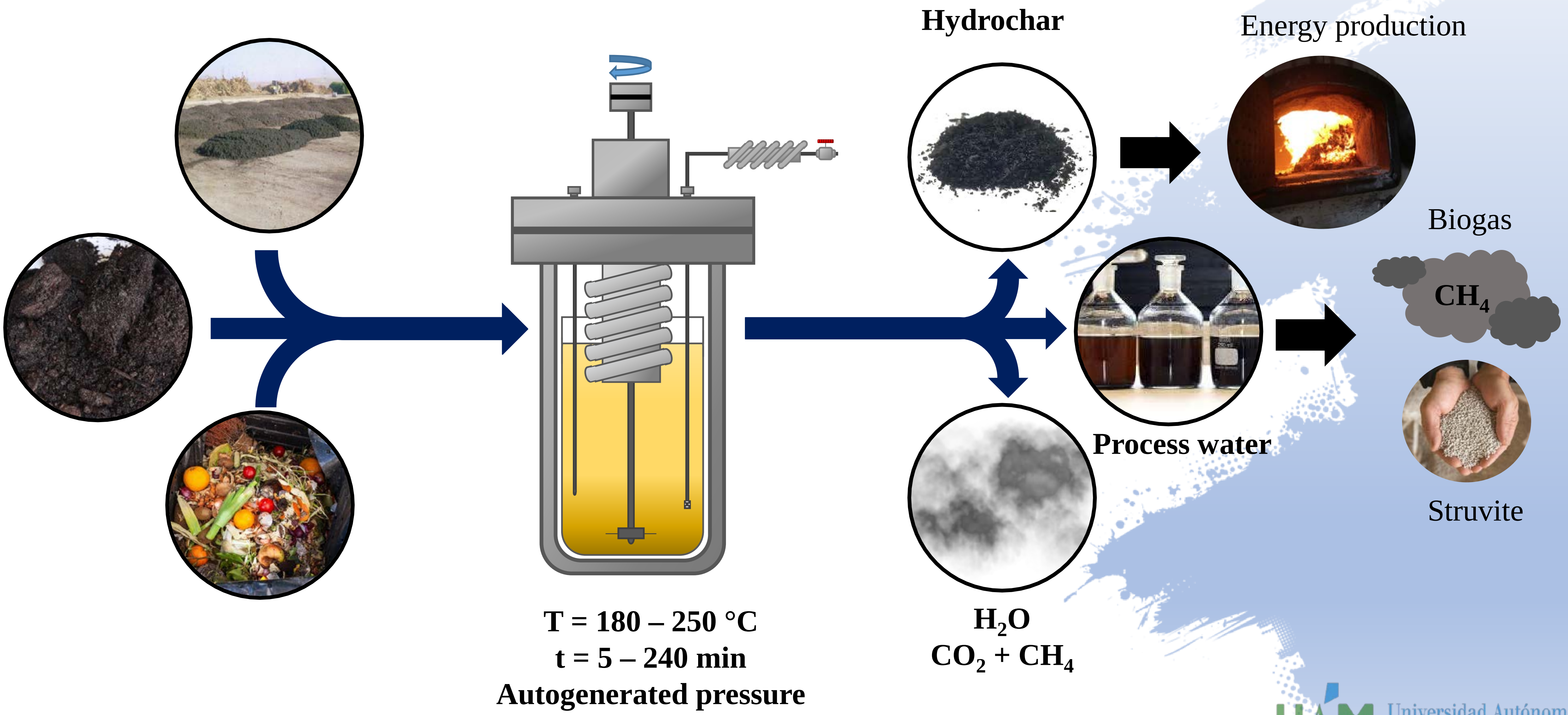
Urban pruning waste

Energy resource

Industrial level

Home level

Hydrothermal carbonization (HTC)



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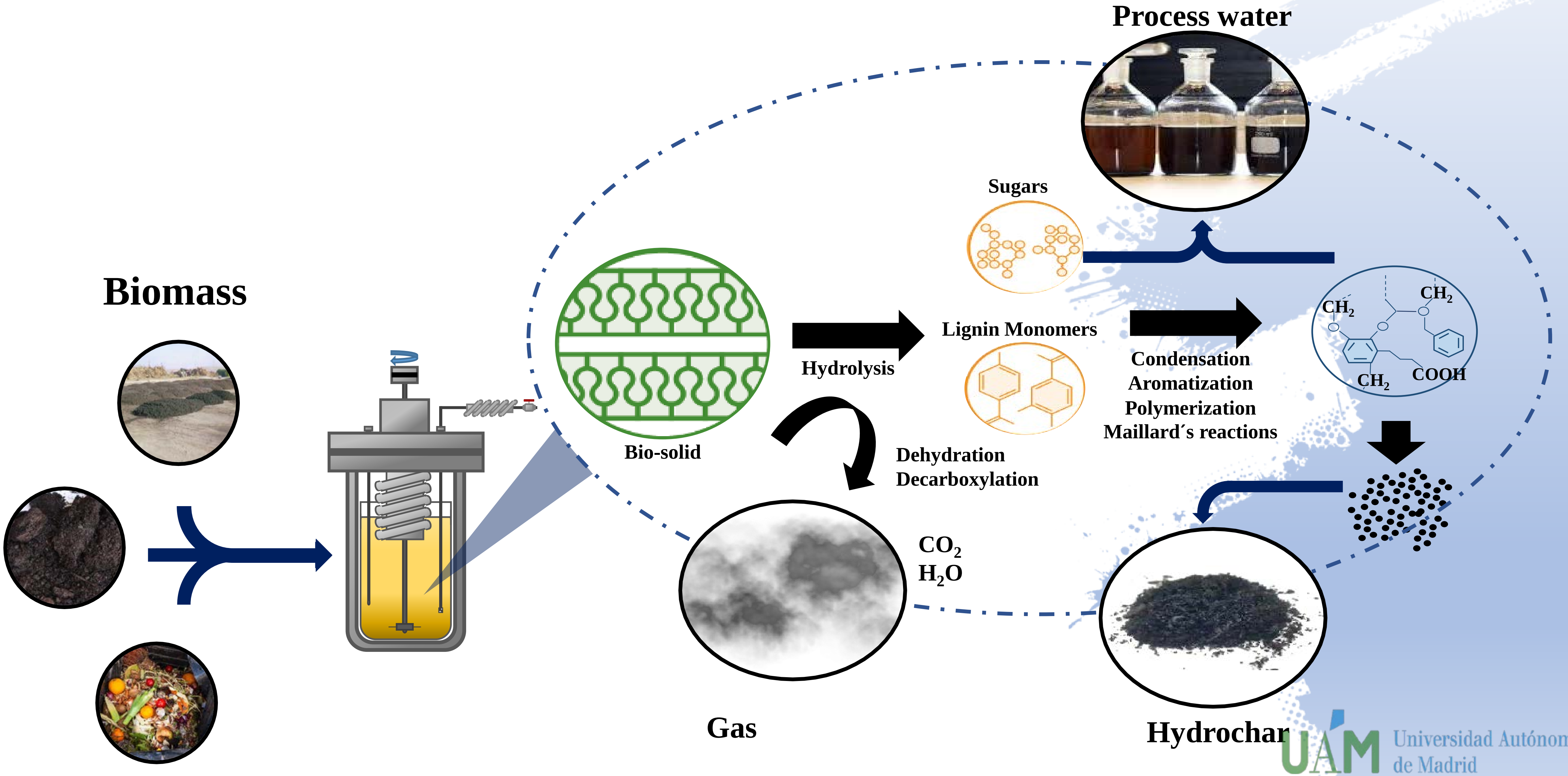
Hydrothermal carbonization (HTC)



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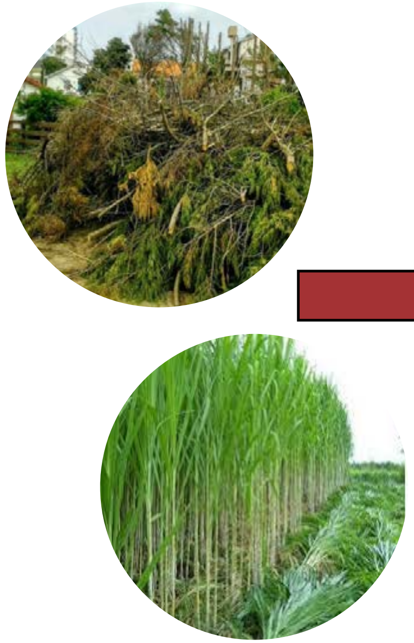
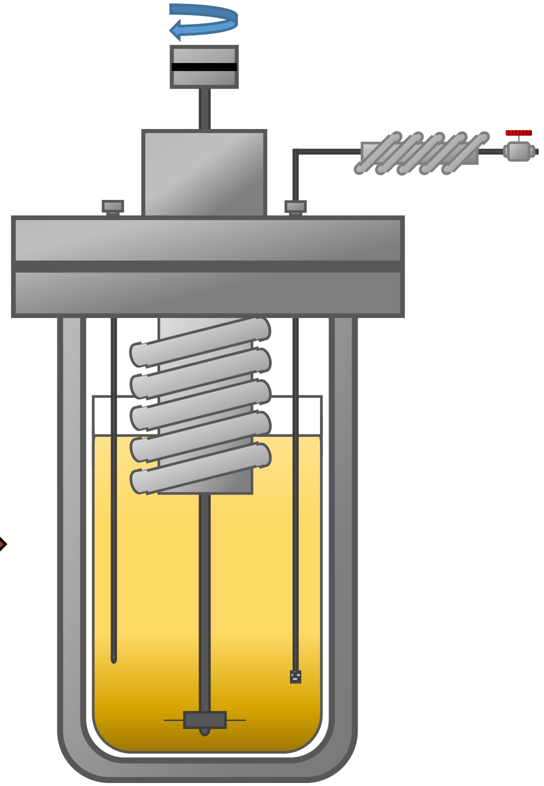
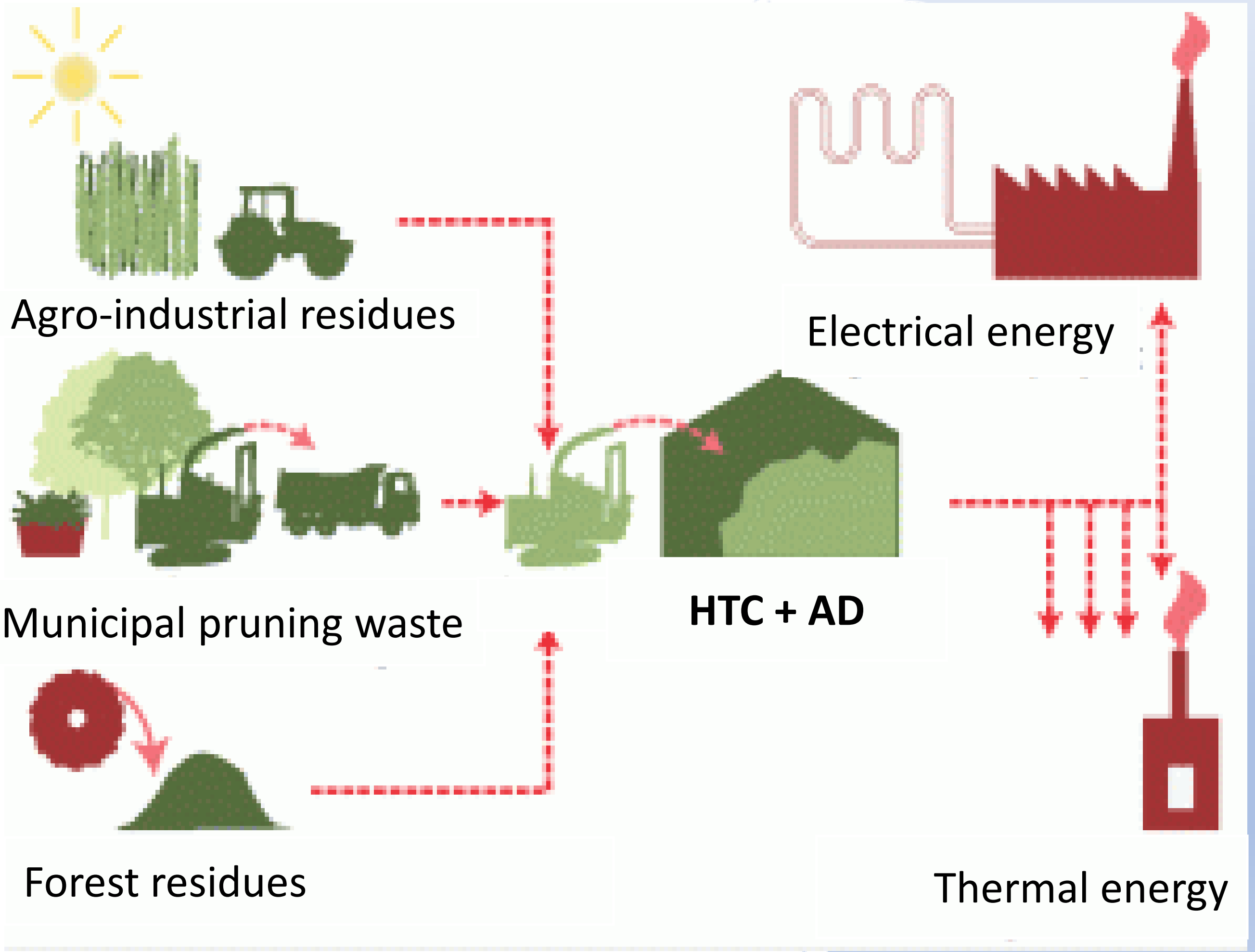
Objective





HTC

T = 180 – 210 – 230 °C
t = 60 min

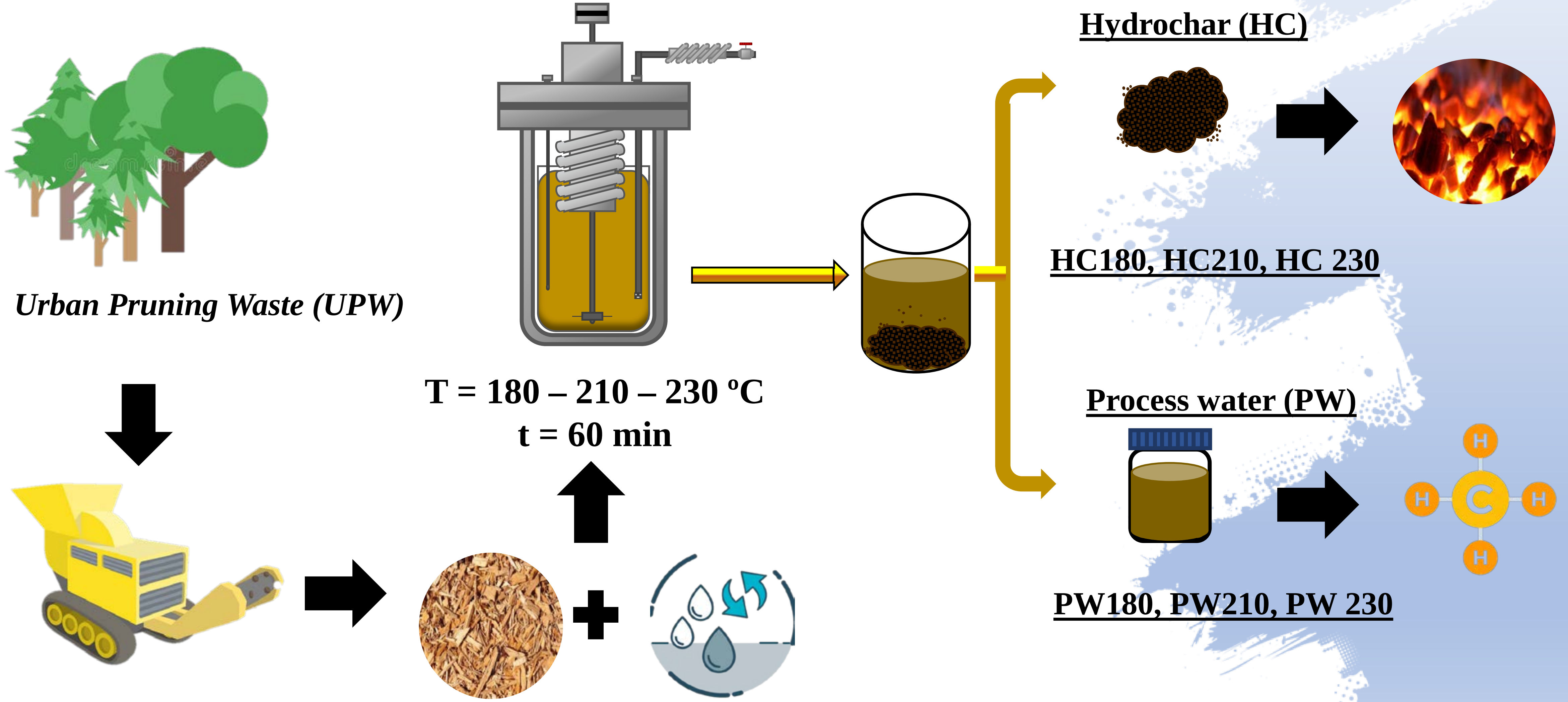


Characterization of urban pruning waste (UPW)

Urban Pruning Waste (UPW)

Characteristics	UPW
Moisture (%)	4.8 ± 0.2
C (%)	46.9 ± 1.1
H (%)	6.1 ± 0.4
N (%)	0.9 ± 0.1
S (%)	0.4 ± 0.2
O* (%)	40.6 ± 0.1
Volatile matter (d.b.%)	76.5 ± 0.1
Ash (d.b.%)	5.1 ± 0.1
Fixed carbon (d.b.%)	18.4 ± 0.1
HHV (MJ kg^{-1})	19.7 ± 0.1
H/C	1.55
O/C	0.65
NPK	0.9/0.1/0.5

Methods



$UPW\ (20\%\ weight) + H_2O\ (80\%\ weight)$

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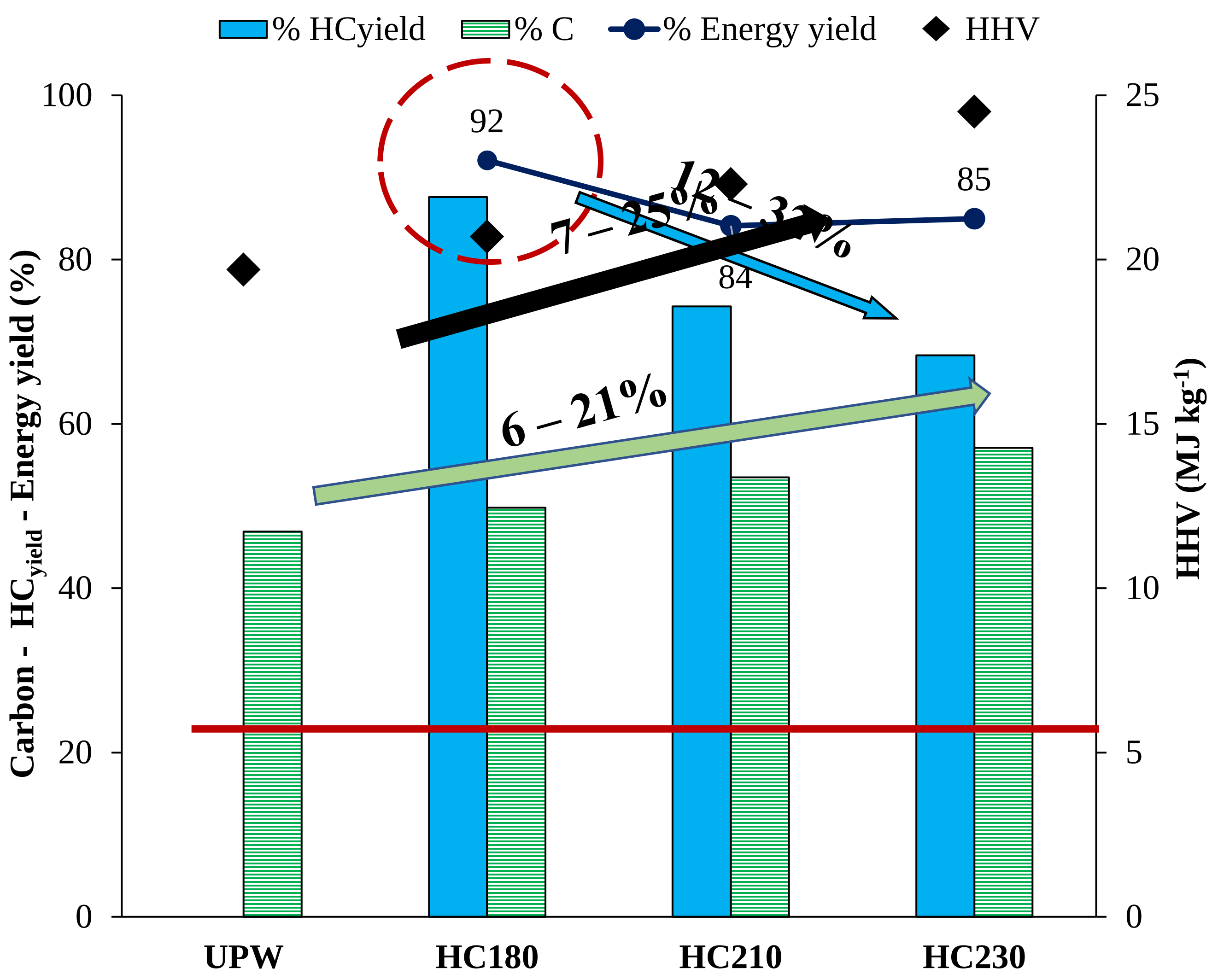
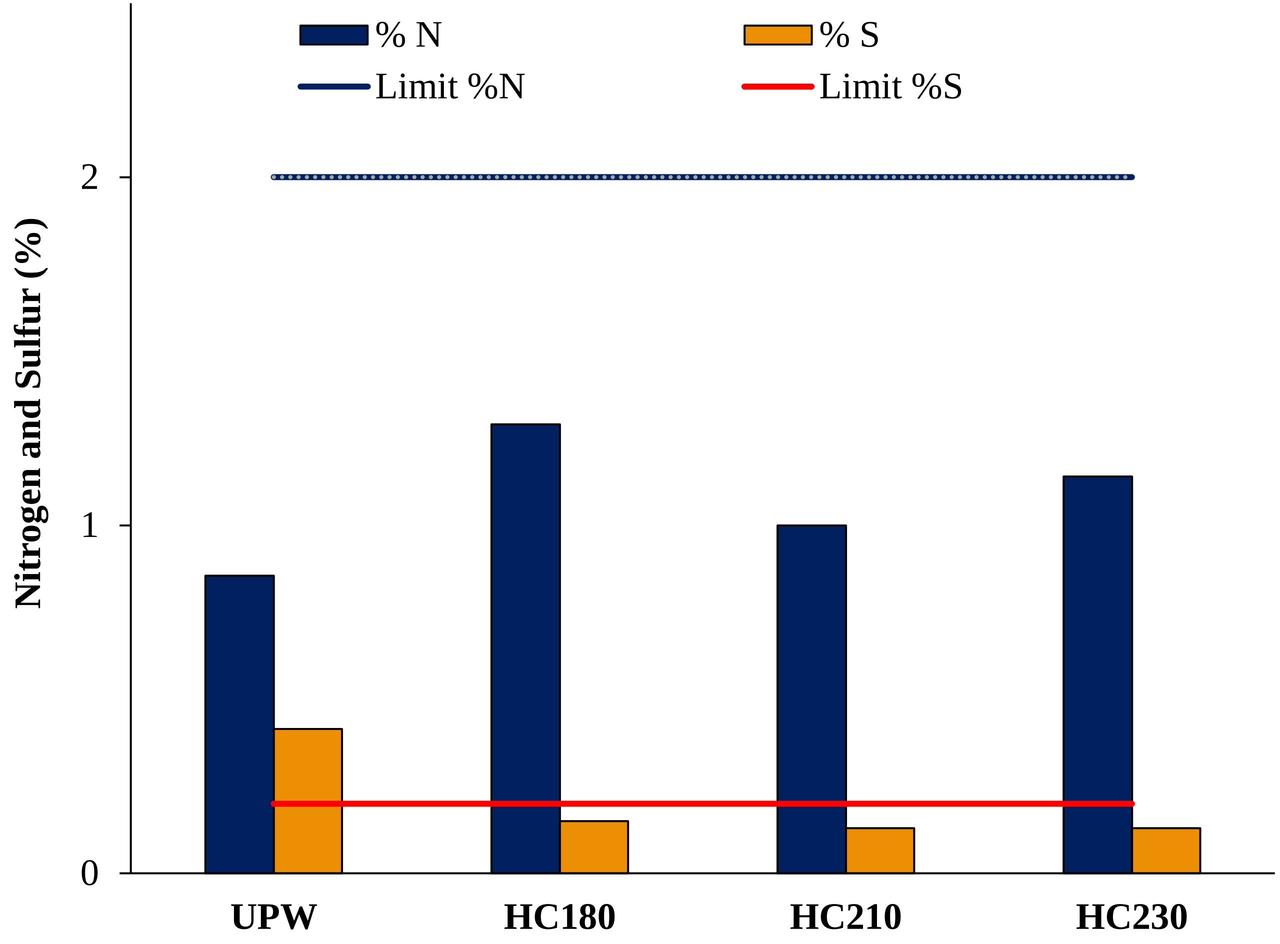
Results



ISO 17225
Graded thermally treated and densified biomass fuels

	UPW	HC180	HC210	HC230
HHV > 17 MJ kg^{-1}	✓	✓	✓	✓
Nitrogen < 3%				
Sulfur < 0.5%				
Volatile matter < 75%				

Nitrogen and Sulfur content



ISO 17225
Graded thermally treated and densified biomass fuels

	UPW	HC180	HC210	HC230
HHV > 17 MJ kg^{-1}	✓	✓	✓	✓
Nitrogen < 2%	✓	✓	✓	✓
Sulfur < 0.3%	✗	✓	✓	✓
Volatile matter < 75%				

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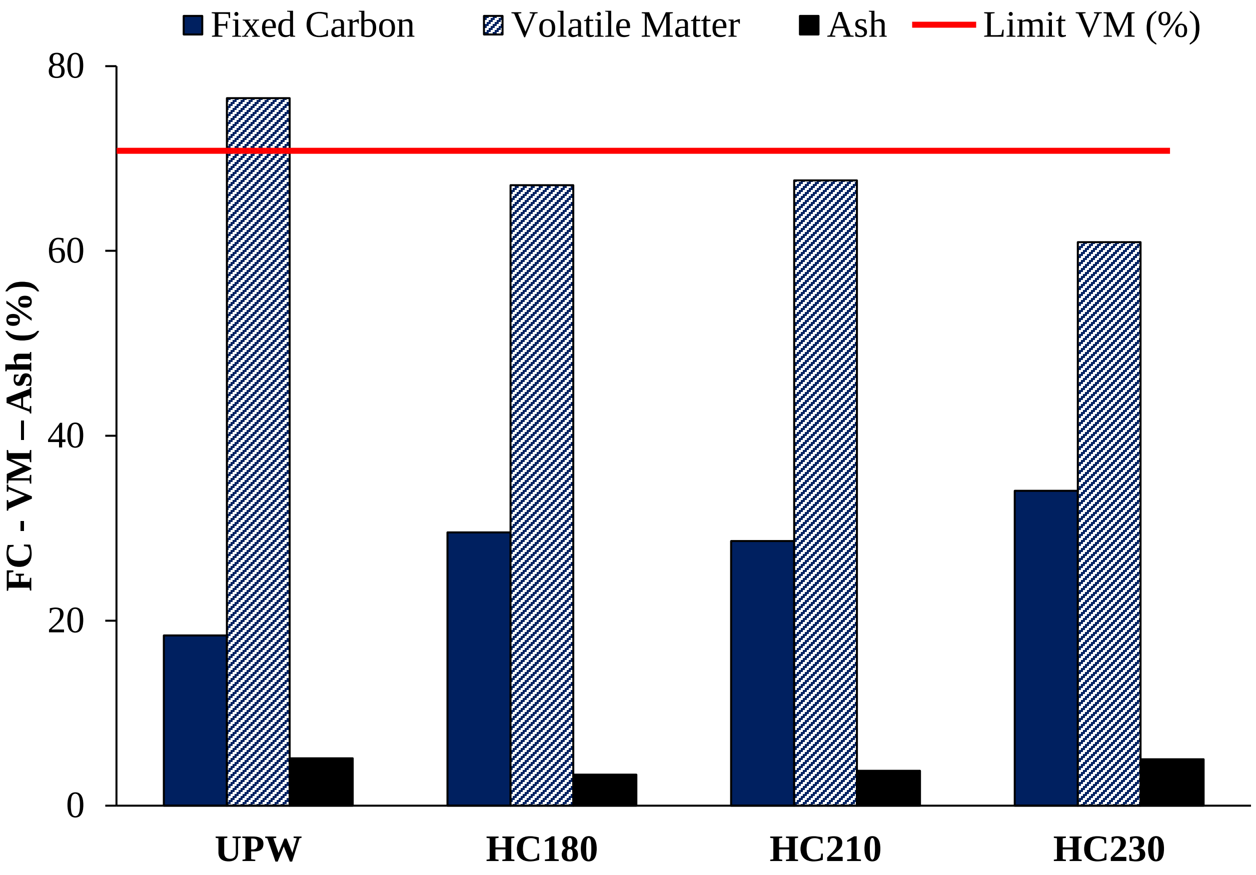
Proximal analysis



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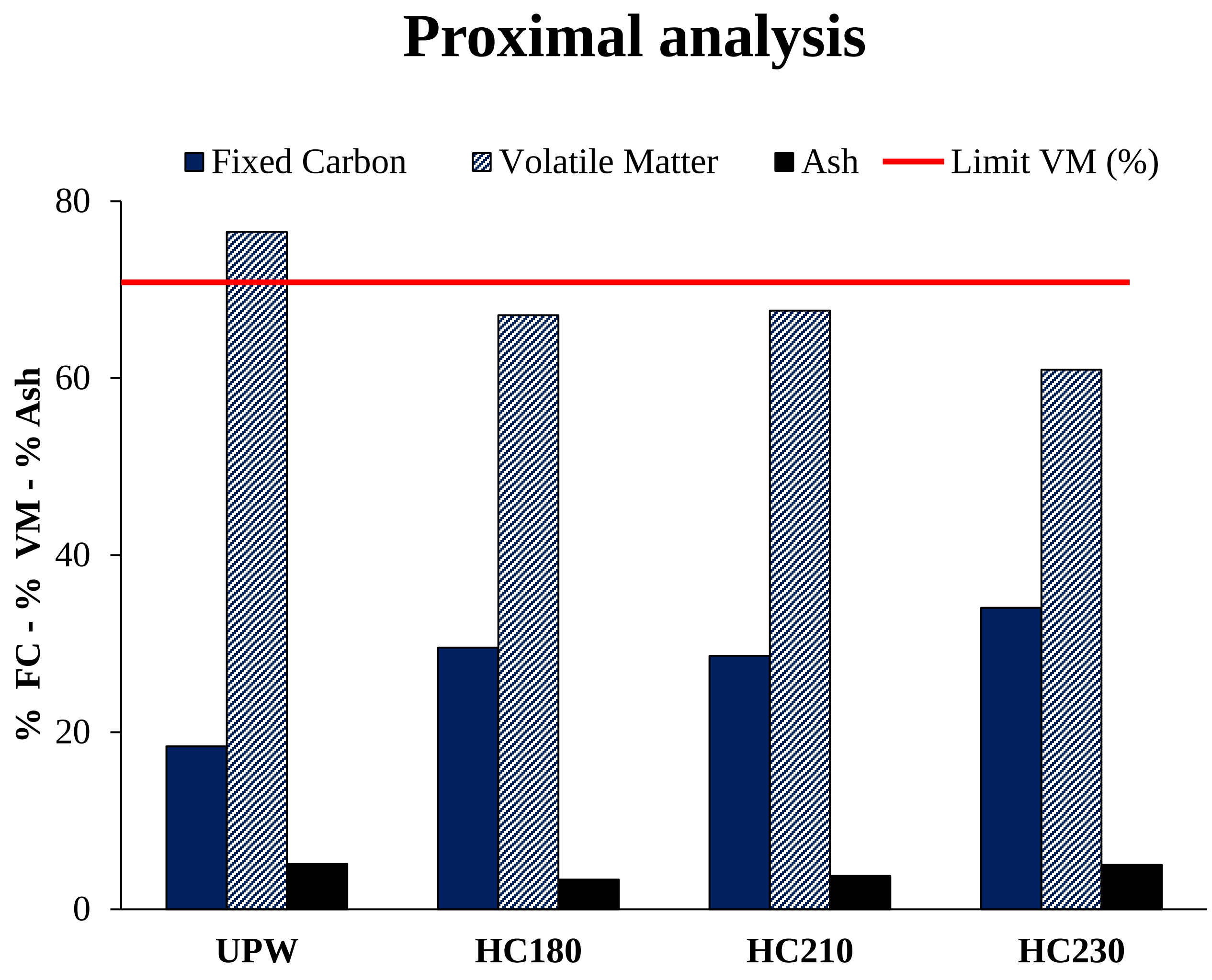
Volatile matter < 75%	✗	✓	✓	✓

Proximal analysis

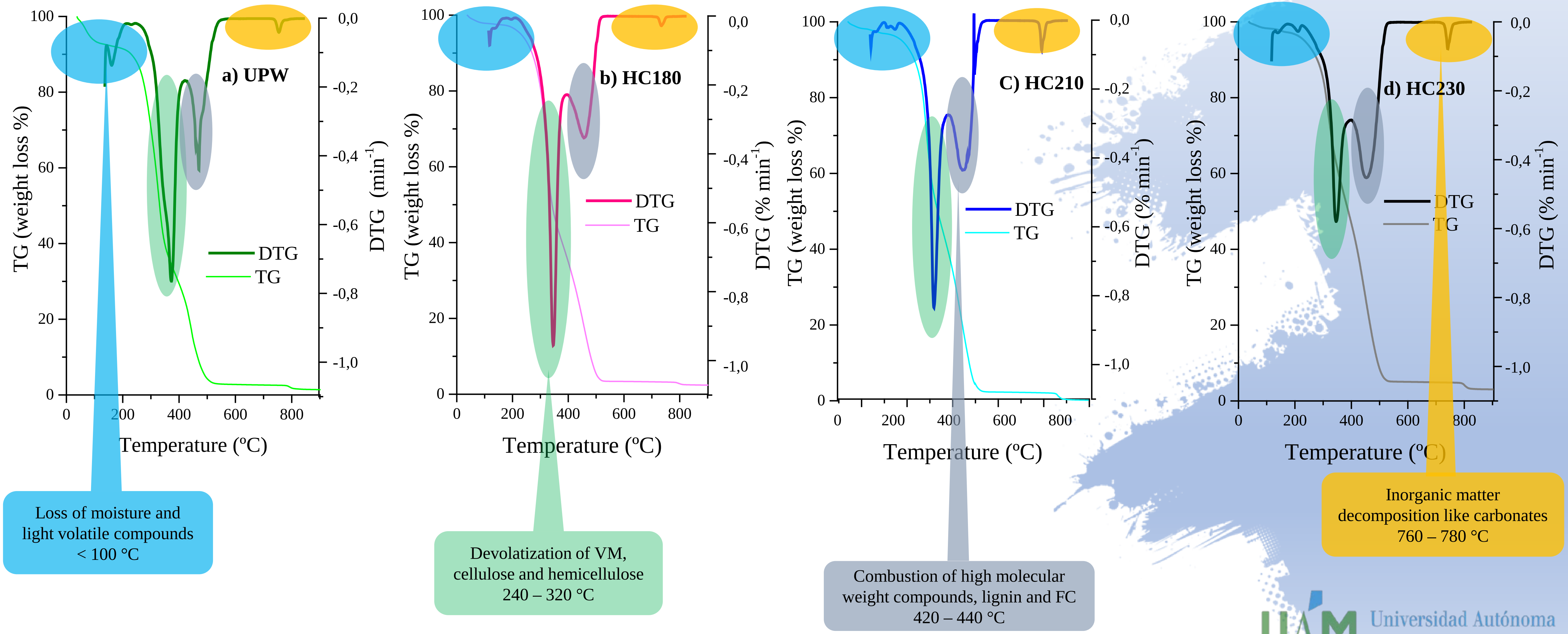


Ash content ↓ **5 – 35%**

SI < 0.3 Low
FI < 4 Medium
AI <0.2 Low

	UPW	HC180	HC210	HC230
$R_{b/a}$	1.3	1.0	1.2	1.2
SI	0.53	0.16	0.15	0.16
FI	7.47	3.08	2.56	2.08
AI (kg GJ^{-1})	0.30	0.09	0.07	0.07

Thermogravimetric and differential TG profiles



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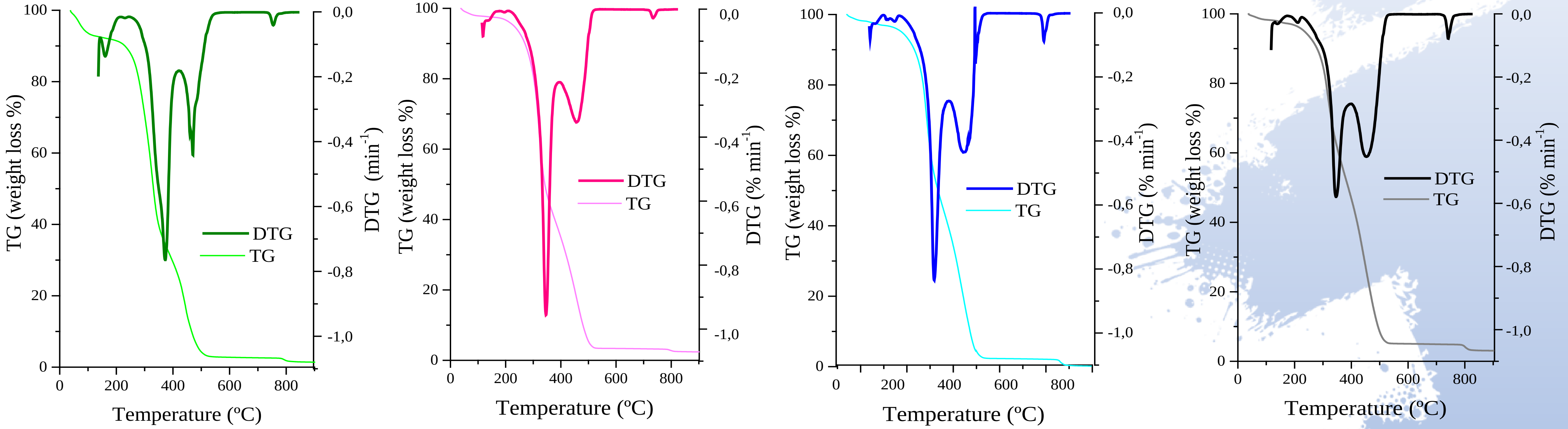
Thermogravimetric and differential TG profiles



	UPW	HC180	HC210	HC230
T_i (ºC)	239	242	251	254
T_m (ºC)	326	325	318	313
T_b (ºC)	533	528	528	536
CCI·10^{-7} (min^{-2} $ºC^{-3}$)	7.8	8.0	8.4	9.6
Z_i (% min^3)	8.6	10.6	11.4	11.6
H_j (% min^4)	0.2	0.3	0.4	0.4

HC combustion reactivity

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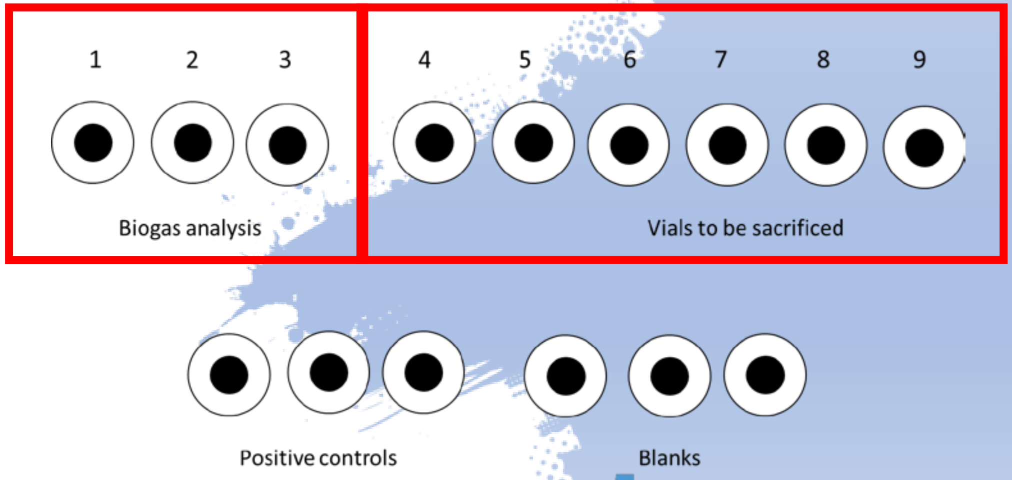
Process water characterization

	PW180	PW210	PW230
pH	3.5 ± 0.1	3.4 ± 0.1	3.5 ± 0.1
COD (g L^{-1})	51.1 ± 1.3	39.3 ± 0.5	44.9 ± 2.4
TOC (g L^{-1})	21.1 ± 0.1	17.0 ± 0.1	18.4 ± 0.1
TVFA (g L^{-1})	1.5 ± 0.0	0.9 ± 0.0	0.2 ± 0.0
TS (g L^{-1})	30.7 ± 0.3	19.3 ± 0.3	21.6 ± 0.4
VS (g L^{-1})	27.0 ± 0.4	16.1 ± 0.2	18.5 ± 0.3

Biochemical methane potential

ISR = 2
- 15 g VS L^{-1} granular anaerobic sludge
- 7.5 g VS L^{-1} substrate



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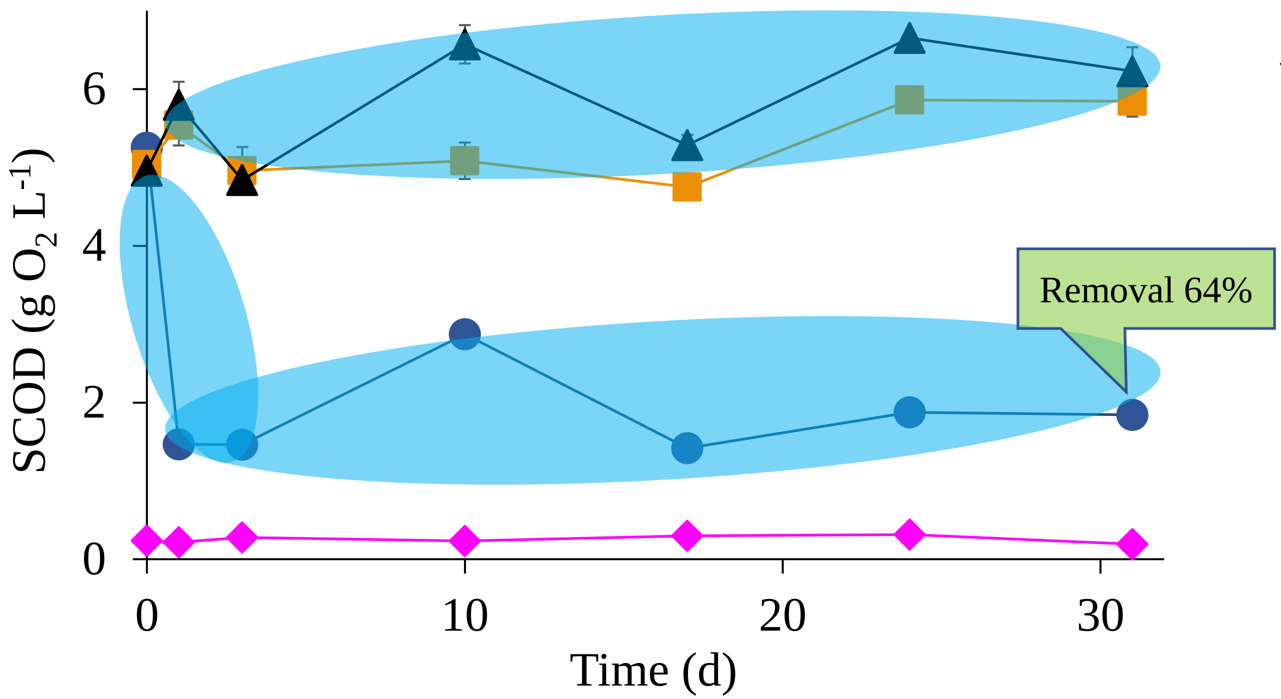
Biochemical methane potential

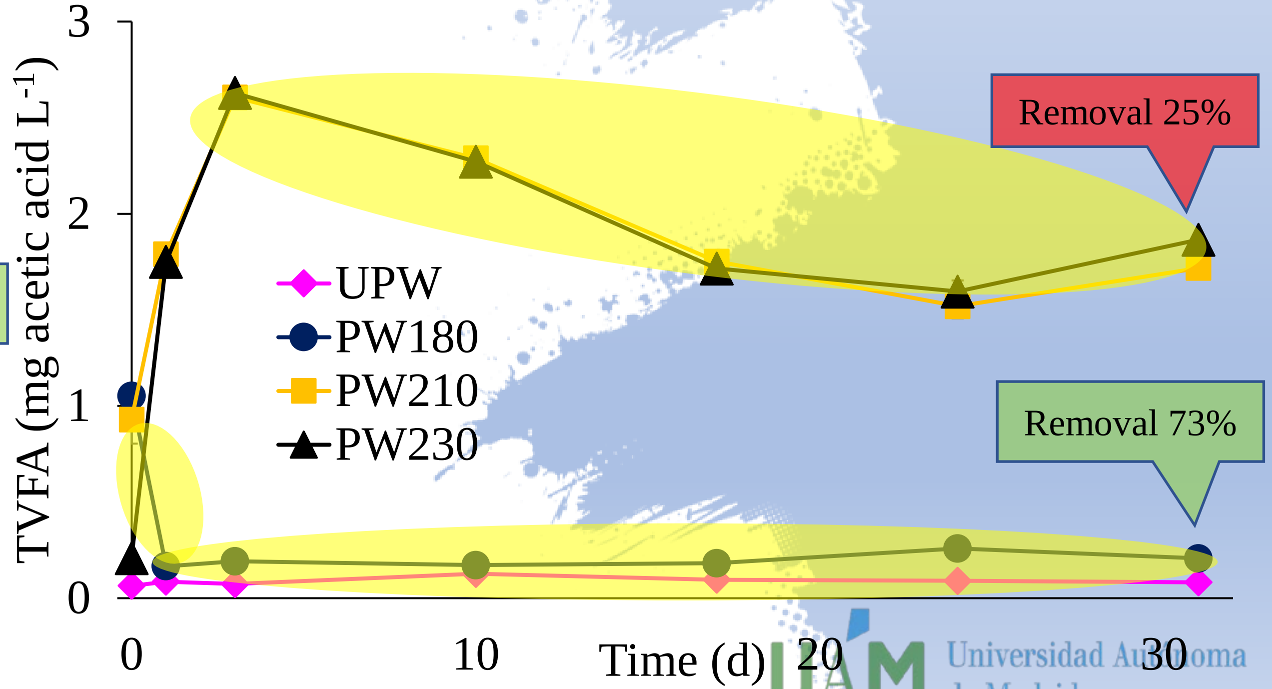
- ✓ pH (7.5 – 7.8)
- ✓ Alkalinity (> 2.5 g $CaCO_3$ L^{-1})
- ✓ Total ammonia nitrogen (1700 mg L^{-1} < inhibition values)

Adequate for the AD process

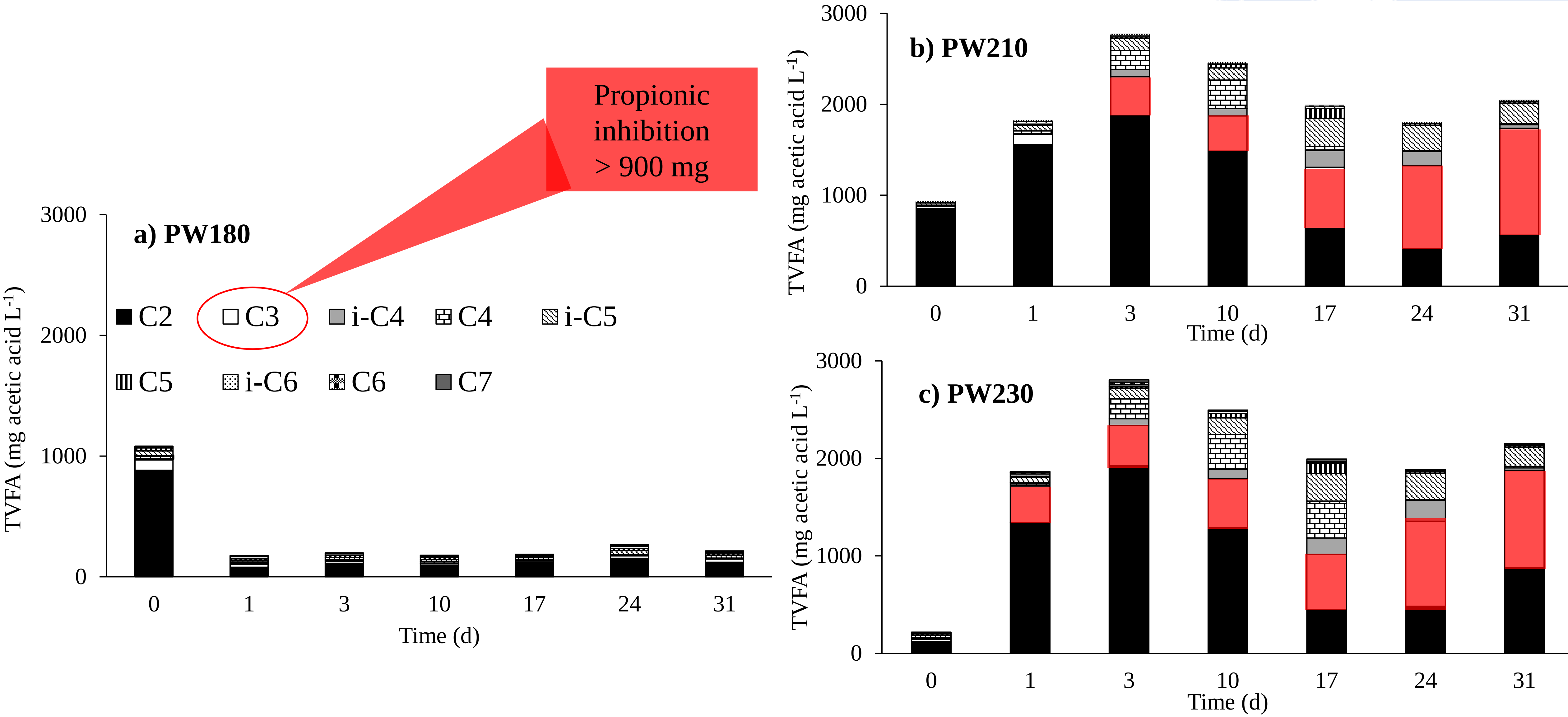
Soluble chemical oxygen demand (SCOD)



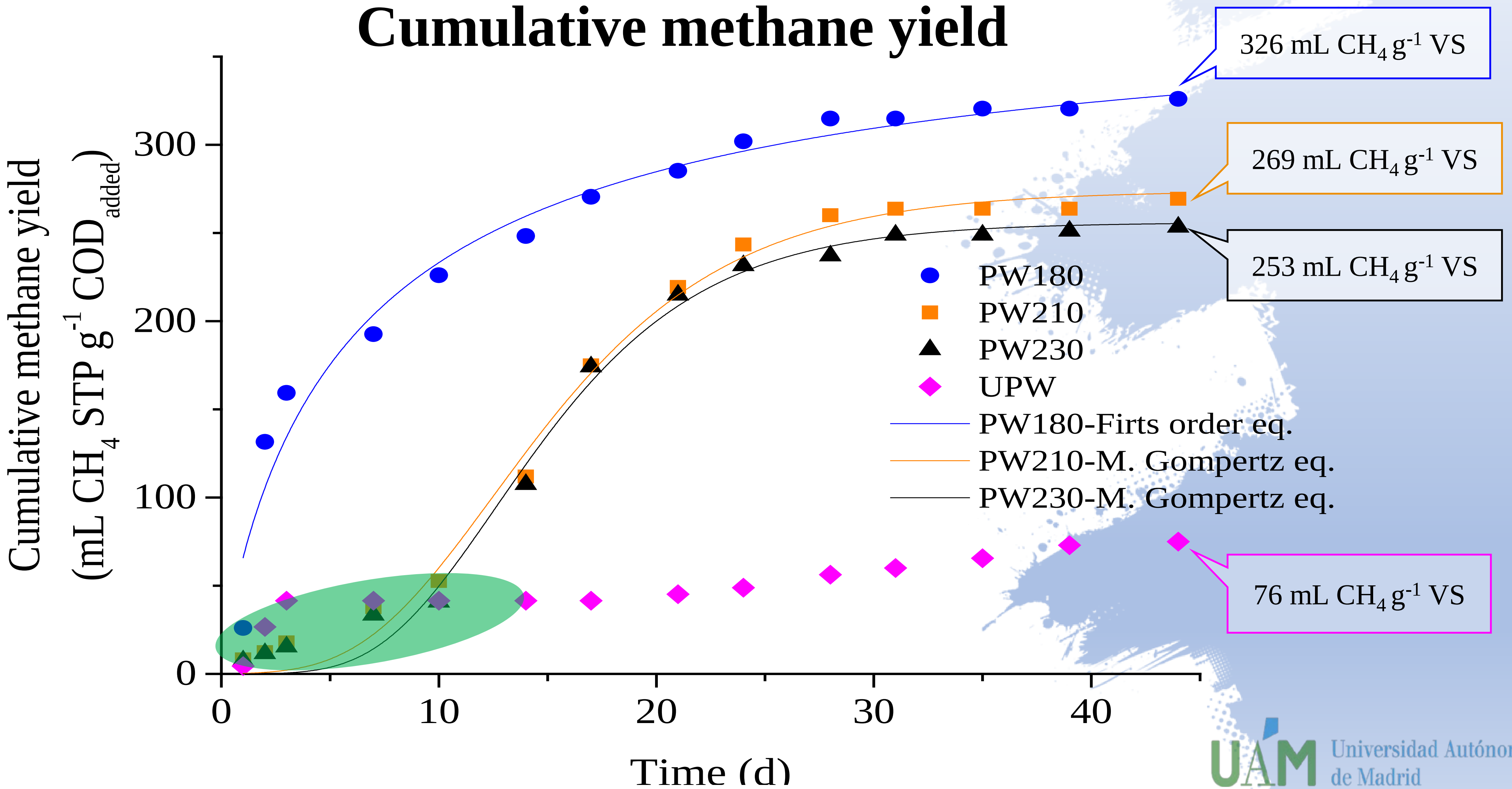
Volatile fatty acids (VFA)



Biochemical methane potential



Biochemical methane potential



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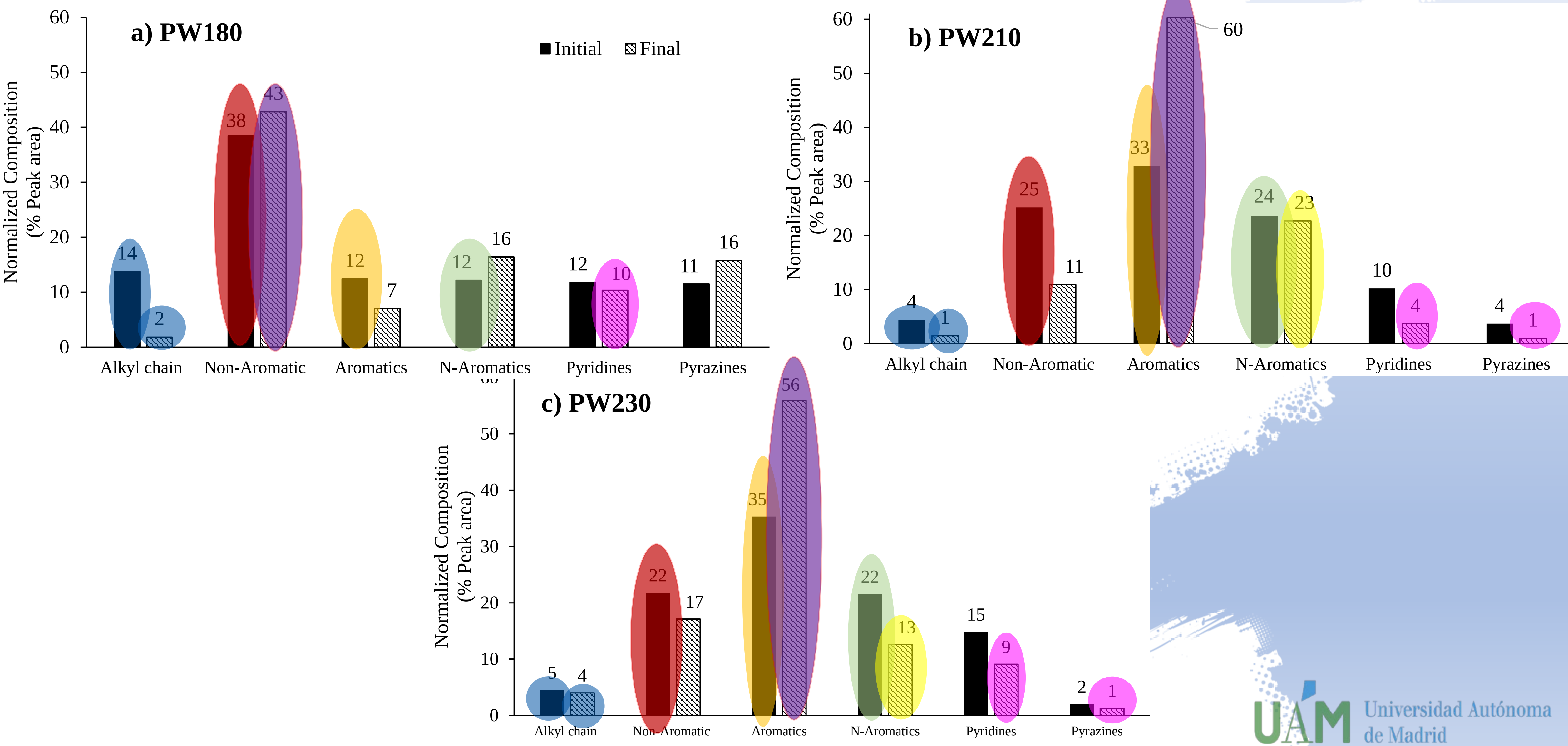
Biochemical methane potential



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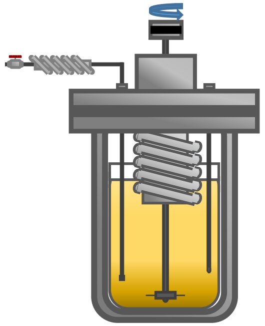
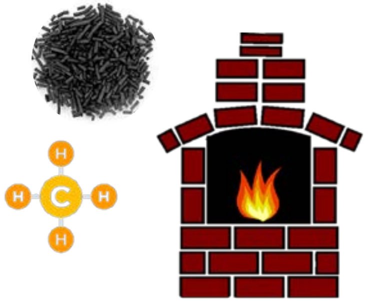
Energy synergy

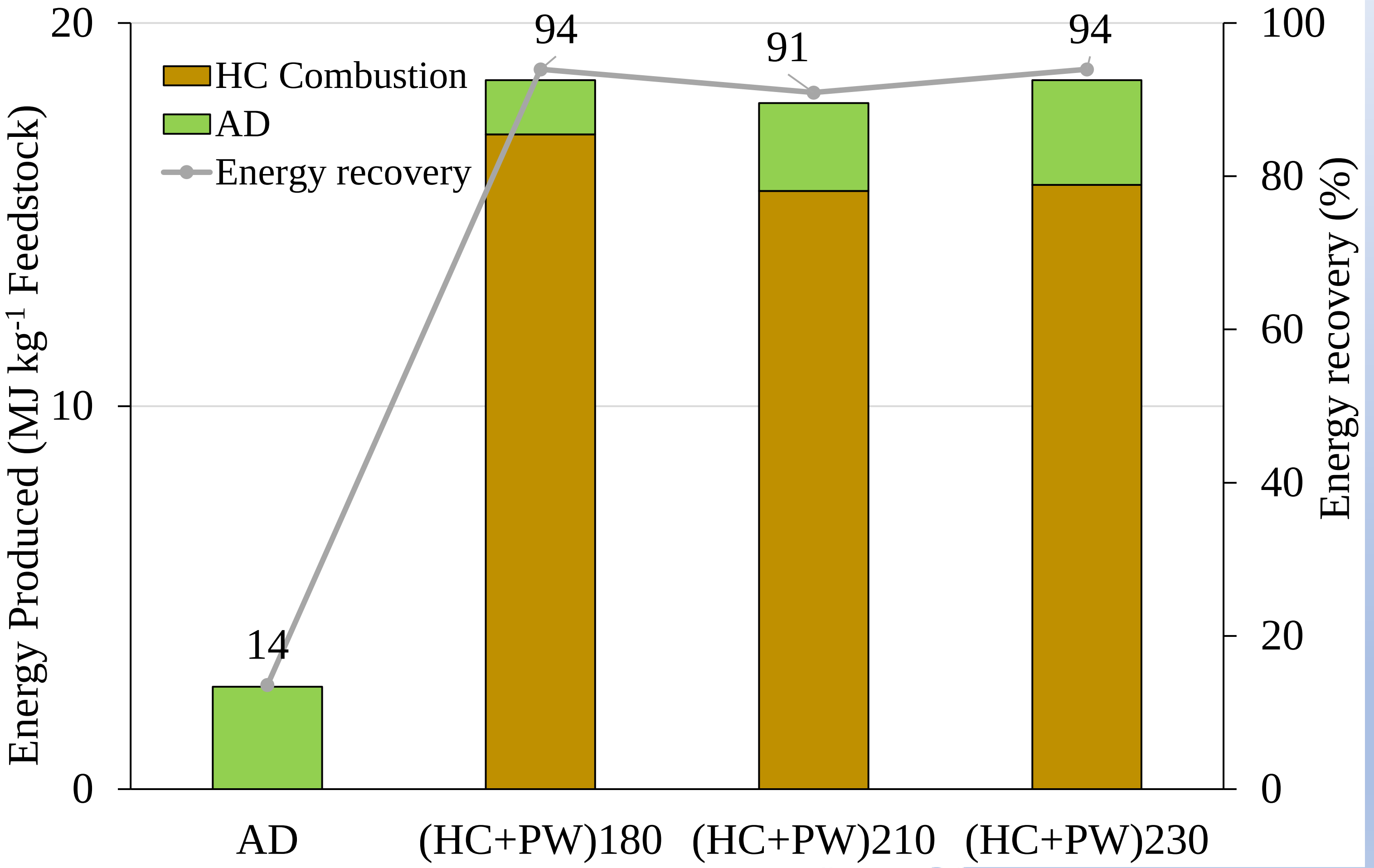
Energy recovery

HC

CH_4







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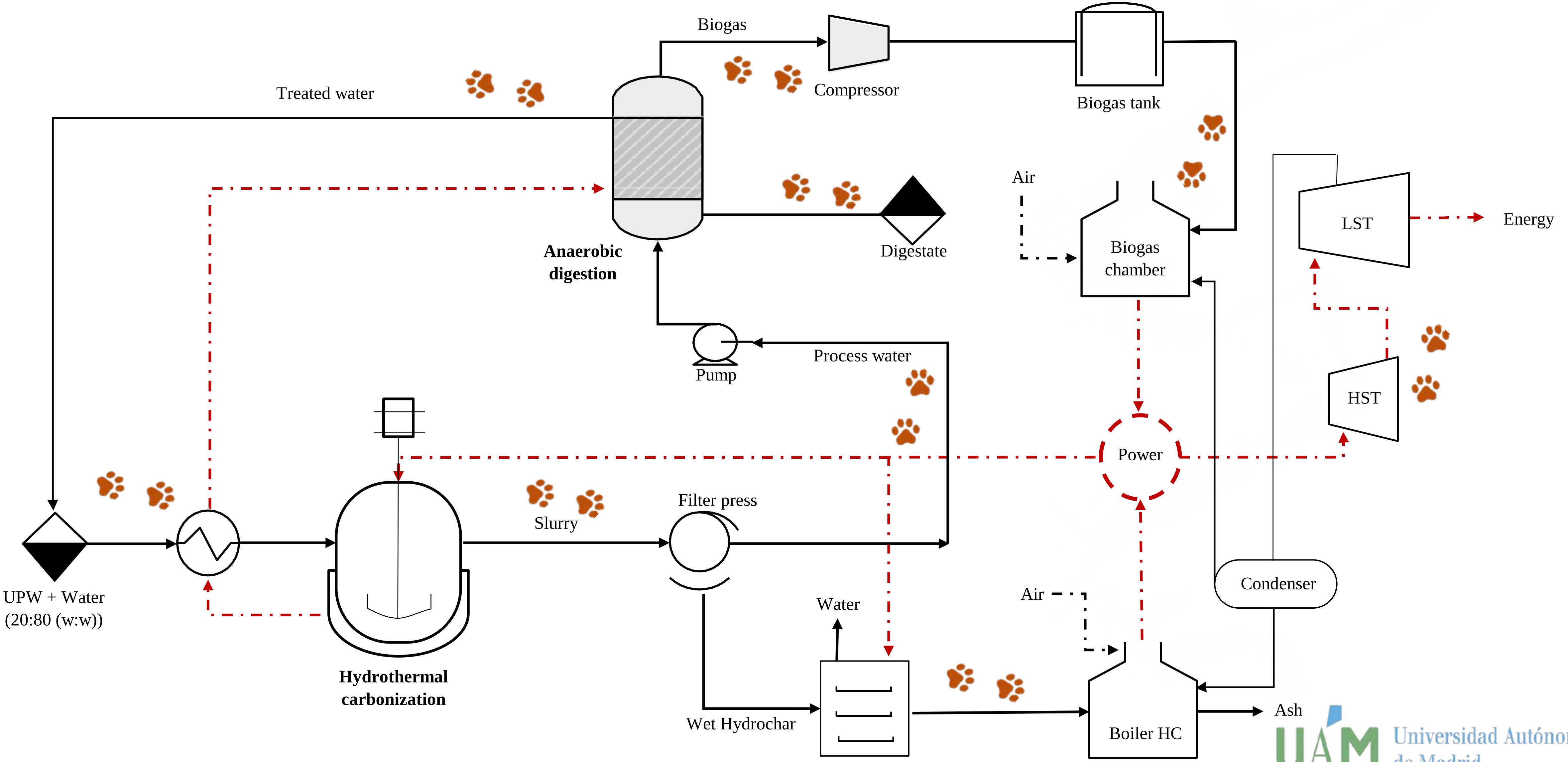
HTC + AD process



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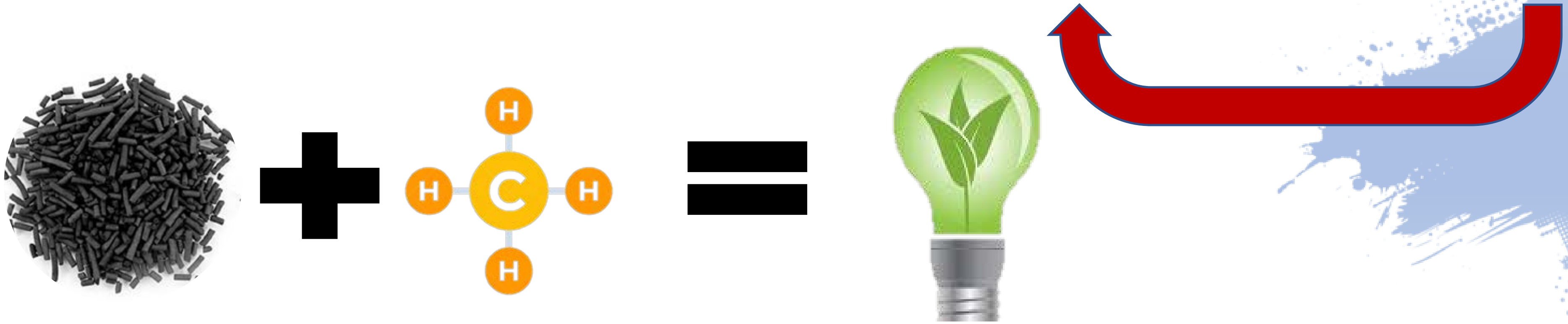
Energy balance

	Energy Input (kWh $t^{-1}_{feedstock}$)						Energy Output (kWh $t^{-1}_{feedstock}$)			η (%)
	HTC reactor	Dewatering	Thermal dry	Pelletizer	Pump	**Total input**	Energy HC	Energy CH_4	**Total output**	
HTC180	364	8	82	9	7	**469**	1008	79	**1086**	56
HTC210	505	9	65	7	13	**599**	921	128	**1048**	41
HTC230	462	9	63	7	14	**555**	930	152	**1082**	48



Conclusions

Hydrochar

- Higher energy densification
- Better physical and chemical properties
- Higher combustion reactivity and behavior
- Fulfill the requirements for energy production at industrial level

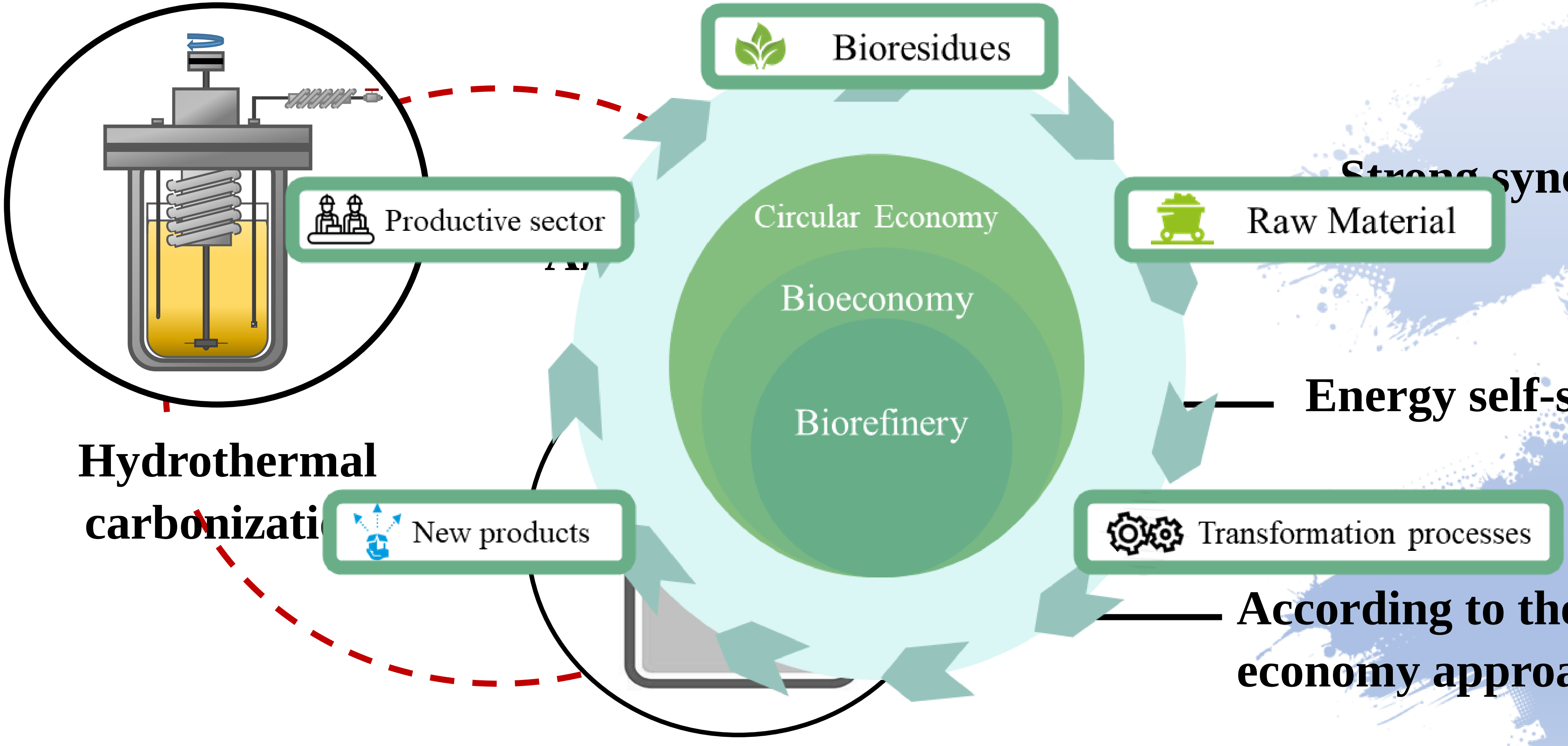
Process water

- Higher organic carbon content

Anaerobic digestion

- Higher methane potential yield
- Higher organic removal in PW at lower temperatures

Conclusions



Hydrothermal carbonizati

Strong synergy

Energy self-sustainability

According to the circular economy approach

Acknowledgements

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“Nothing is impossible for the person who fights ”

R. P. Ipiales