Prediction of Syngas composition from Pyrolysis of Waste-derived feedstocks in the UK using Aspen Plus

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Project: Pre-commercial Pyrolysis Plant and Model

- AIM: Study advanced thermal conversion of waste material into high quality renewable products (i.e. clean syngas, oils and char)

- MEANS: a) Operation of 0.8 MWe facility processing ~1.14t/h RDF sourced from non-recyclable municipal solid waste

  b) Model in Aspen Plus of a Pyrolysis plant with similar characteristics to predict syngas composition as a function of feedstock and operating conditions

- Partnership between Cranfield University and Syngas Products Group Ltd (Syngas Products)

- Funding:

Innovate UK

EPSRC
Engineering and Physical Sciences Research Council

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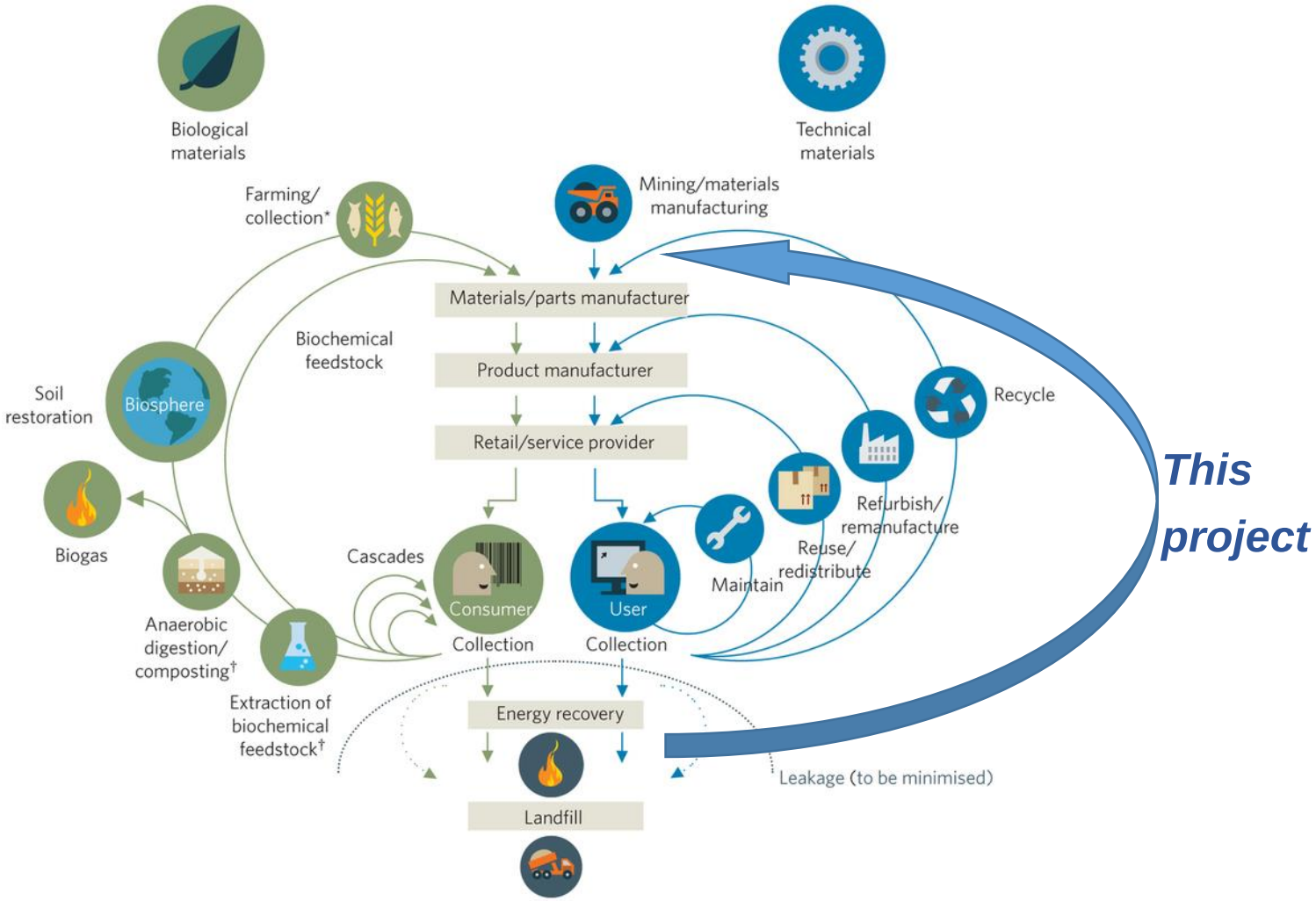
Circular Economy: Framework of this Project



Integration of pyrolysis in the circular economy (Modified from Ellen MacArthur Foundation system diagram)

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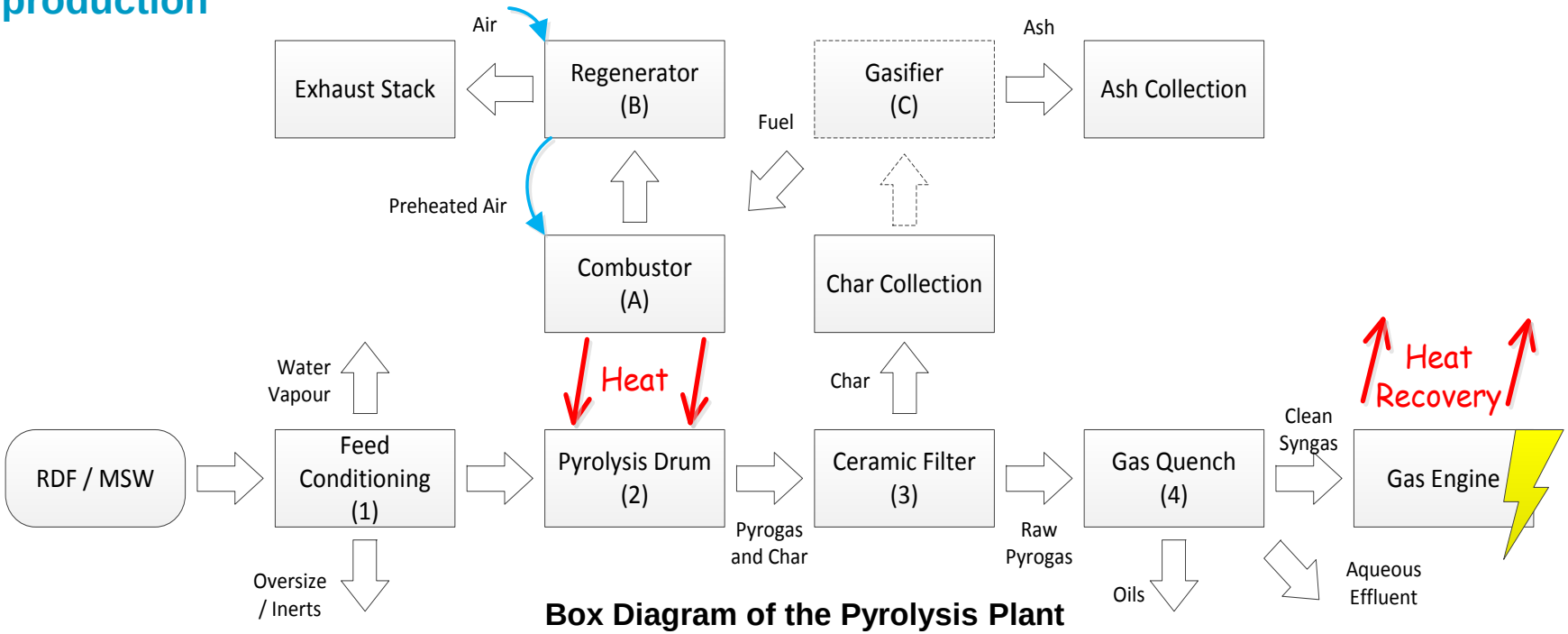
Syngas Products' Pre-commercial Pyrolysis Plant

Canford Energy Recovery Facility (South of England, UK) – Patented clean syngas production



Box Diagram of the Pyrolysis Plant

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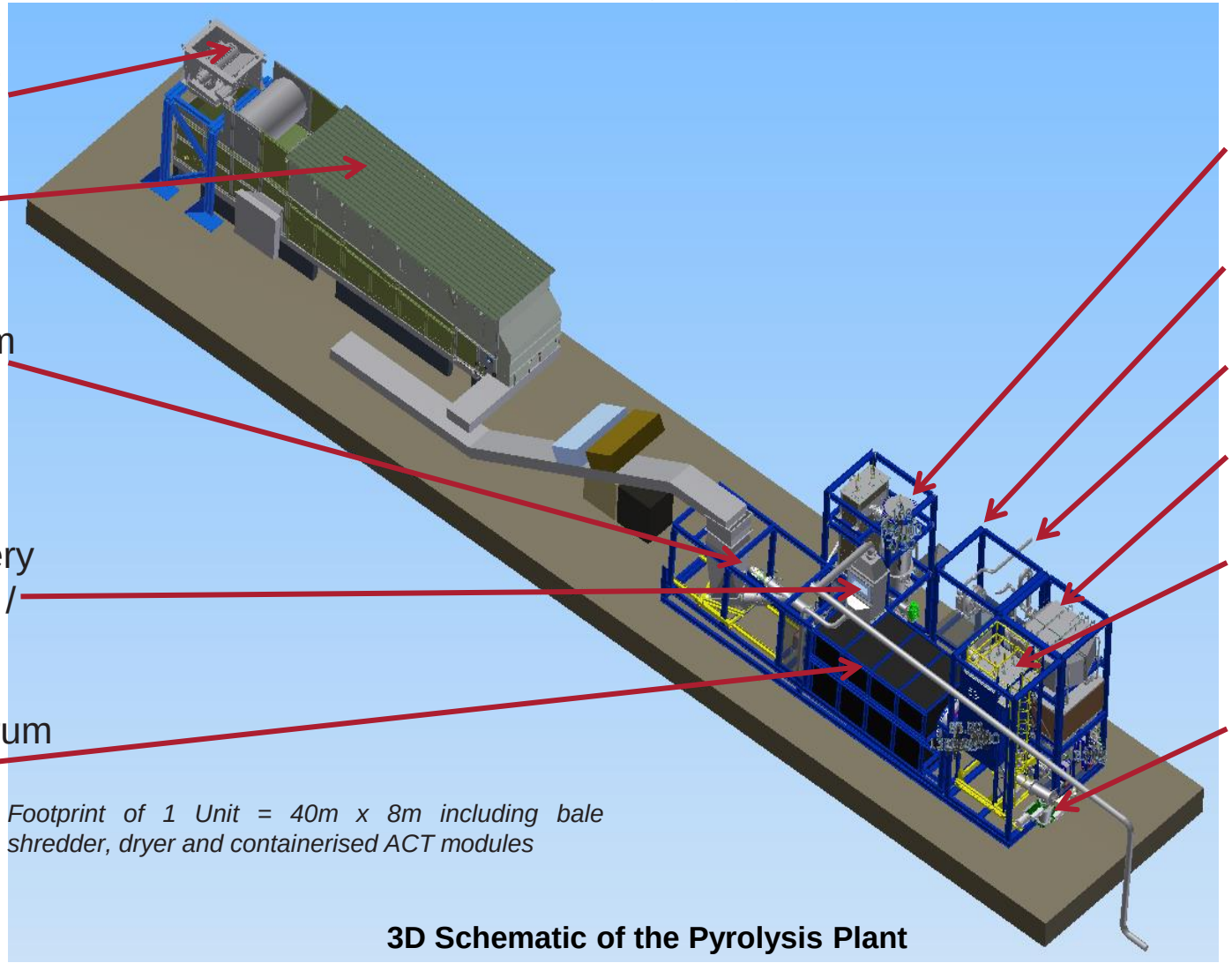
Syngas Products' Pre-commercial Pyrolysis Plant



3D Schematic of the Pyrolysis Plant

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Syngas Products' Pre-commercial Pyrolysis Plant

Canford ERF (South of England, UK) – Patented clean syngas production

- Extensive R&D test rig trials (2013-2015)
- Test rigs relocated, expanded and integrated in 2016
- 10ktpa & 0.8MWe pre-production unit operational
- Commissioning began Nov 2016 (incl. first power export)
- Validation trials set for 2017
- Phased scale-up planned for 2018-2019

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Syngas Products' Pre-commercial Pyrolysis Plant

Canford ERF (South of England, UK) – Patented clean syngas production

- Each module processes 10kt/a pre-dryer & 7kt/a post-dryer:
- Processes up to 1.5 t/h of baled feedstock (pre-dryer)
- Heat-only mode produces up to 2.7MWth usable heat
- CHP mode up 0.8MWe electricity and 0.7MWth usable heat
- Housed in standard container frames (easily transportable)
- Wider commercialisation planned for 2019+

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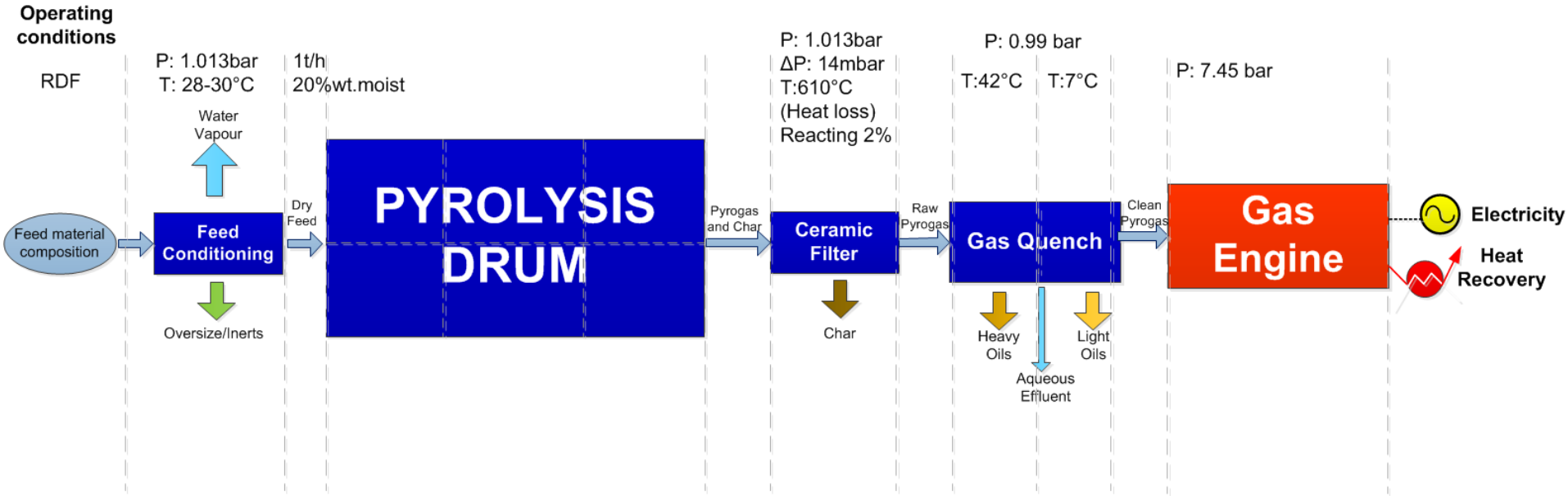
Pyrolysis Model in Aspen Plus

Nominal Operating Conditions



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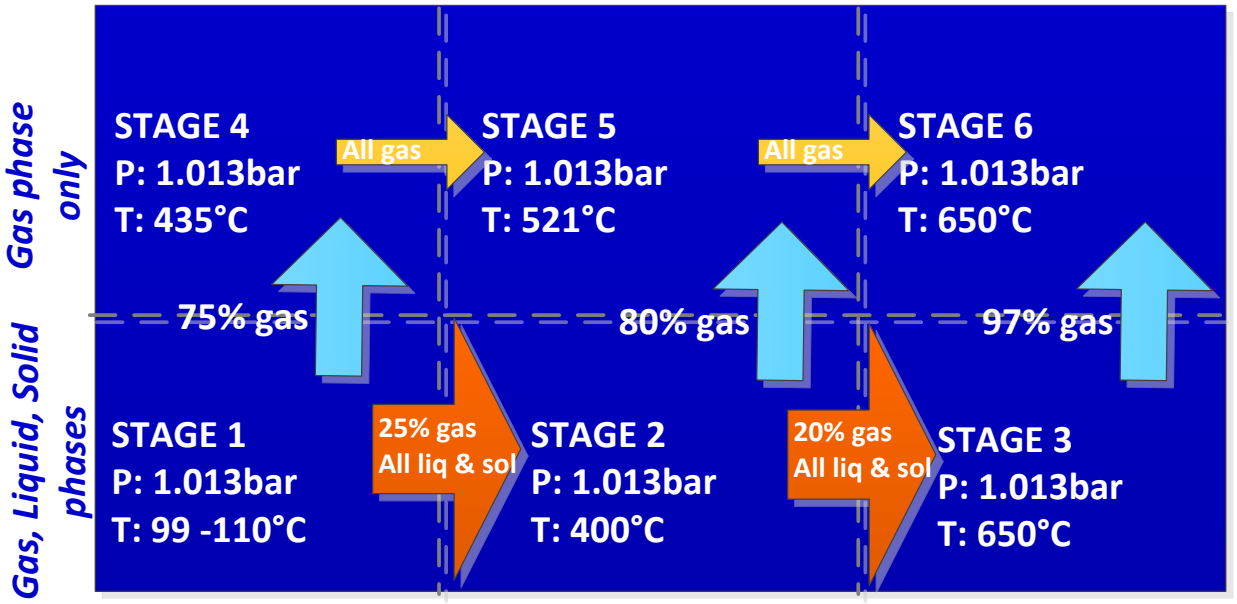
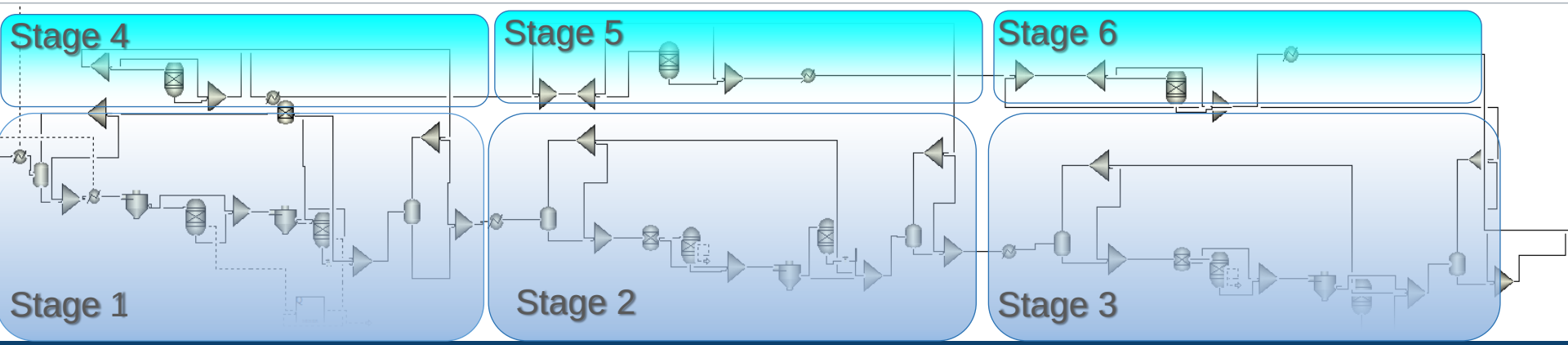
Pyrolysis Model in Aspen Plus

Novel approach : The pyrolysis is split into six separate zones





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Pyrolysis Model in Aspen Plus

Types of Feedstock

Nominal case-study: Refused-derived fuel

Component	Component (Aspen Plus)	% (w/w)
Cellullose	C6H10O5	23.2
Glutamine	GLUTA-01	2.7
Citric acid	CITRICAC	7.0
Methionine	METHI-01	1.0
Carbon	CARBON	3.9
$Ca_5(PO_4)$	CA5(PO4)	0.2
Ethene	ETHENE	6.2
Polyvinyl	POLYVINY	0.5
SiO_2	SIO2	3.4
TiO_2	TIO2	0.1
Al_2O_3	AL2O3	1.1
Fe_2O_3	FE2O3	0.5
H_2O	H2O	39.2
$CaCO_3$	CACO3	1.3
PET	PET	0.6
Propylene	PROPY-01	0.9
Fe	FE	3.4
Al	AL	0.4
P_2O_5	P2O5	0.2
Na_2O	NA2O	0.4
K_2O	K2O	0.3
MgO	MGO	0.3
CaO	CAO	3.2

Composition of RDF

Other potential feedstocks to be used:

Tyres, dry waste water sludge, etc.

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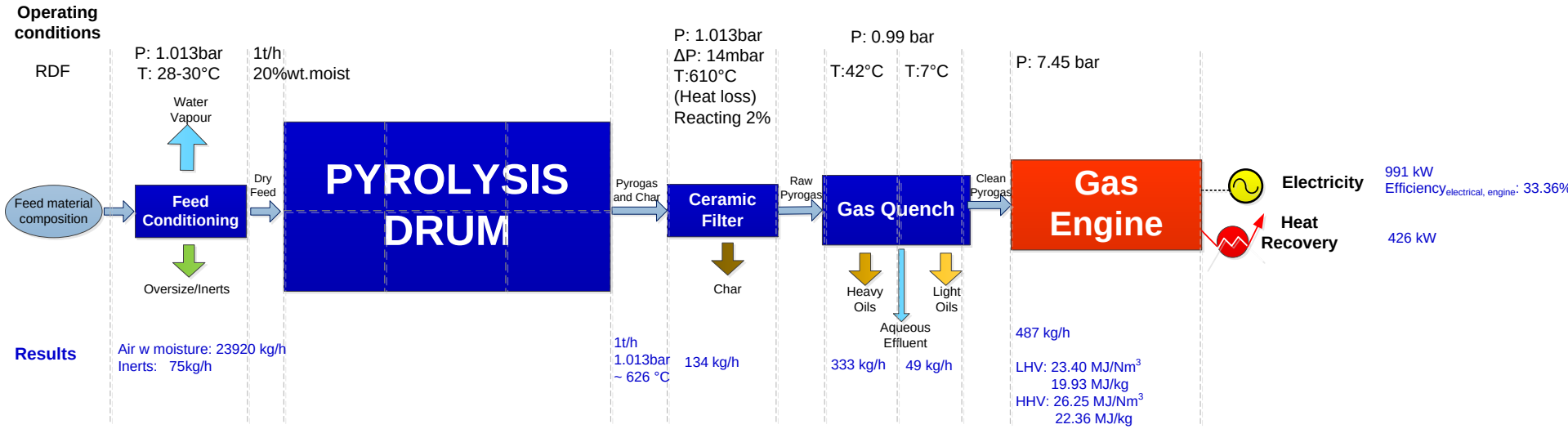
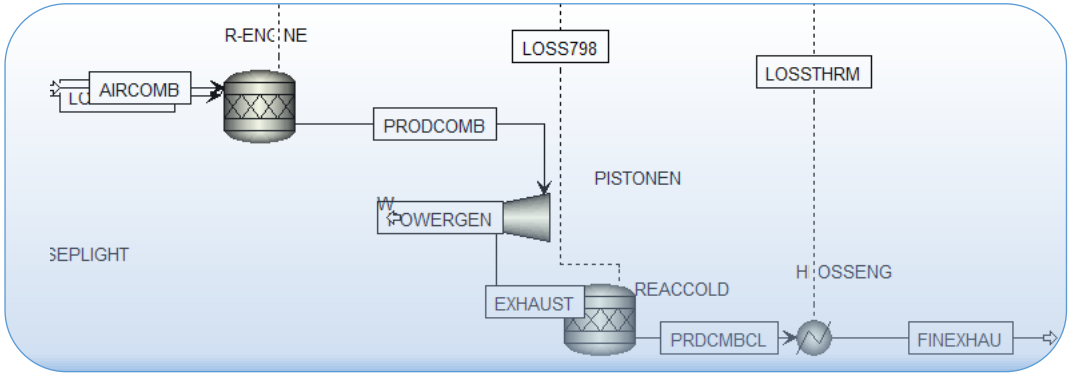
Pyrolysis Model in Aspen Plus

Nominal Operating Conditions





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Pyrolysis Model in Aspen Plus

RESULTS: Gas composition, Heating Values and Power Generated

Gas Composition		Experimental	Model
Component	**Formula**	**% (Vol.)**	**% (Vol.)**
Oxygen	O_2	2	4.12
Nitrogen	N_2	12	0.86
Carbon dioxide	CO_2	22	9.73
Carbon monoxide	CO	20	20.29
Methane	CH_4	18	20.36
Hydrogen	H_2	14	14.70
Ethylene	C_2H_4	9	9.95
Ethane	C_2H_6	2.3	3.02
Propane	C_3H_8	0.5	1.71
Benzene	C_6H_6	0.2	0.89

Main chemical components considered for evaluation of model predictions

Heating Values	Experimental	Model	
	MJ/Nm³	**MJ/Nm³**	**MJ/kg**
HHV	29.55	26.25	22.36
LHV	27.28	23.40	19.93

Comparison for heating values

Engine $\eta_{electrical}$		
	Experimental	**Model**
%	36.0	33.3

Comparison for efficiencies of the power island

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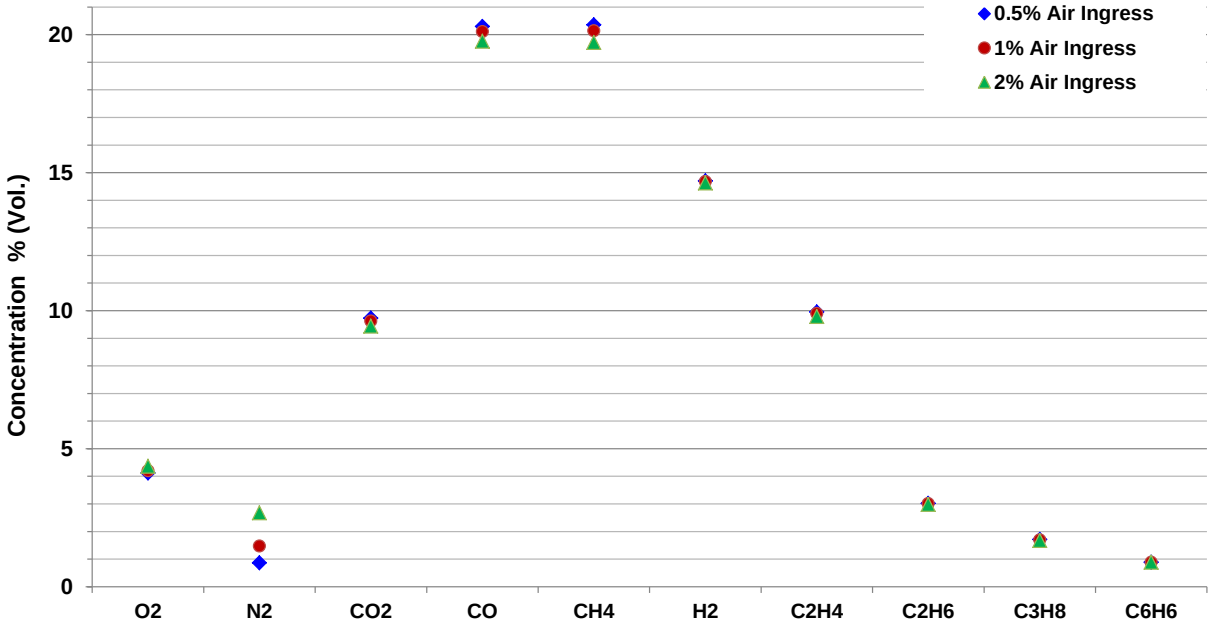
Pyrolysis Model in Aspen Plus

Effect of Air Ingress on Gas Composition of Pyrogas



Effect of Air Ingress on Heating Value of Pyrogas

Model Results	0.5% Air Ingress	1% Air Ingress	2% Air Ingress
HHV (MJ/Nm^3)	26.25	26.07	25.69
LHV (MJ/Nm^3)	23.40	23.24	22.90
Engine $\eta_{electrical}$ (%)	33.36	33.43	32.77

Comparison for heating values and electrical efficiency

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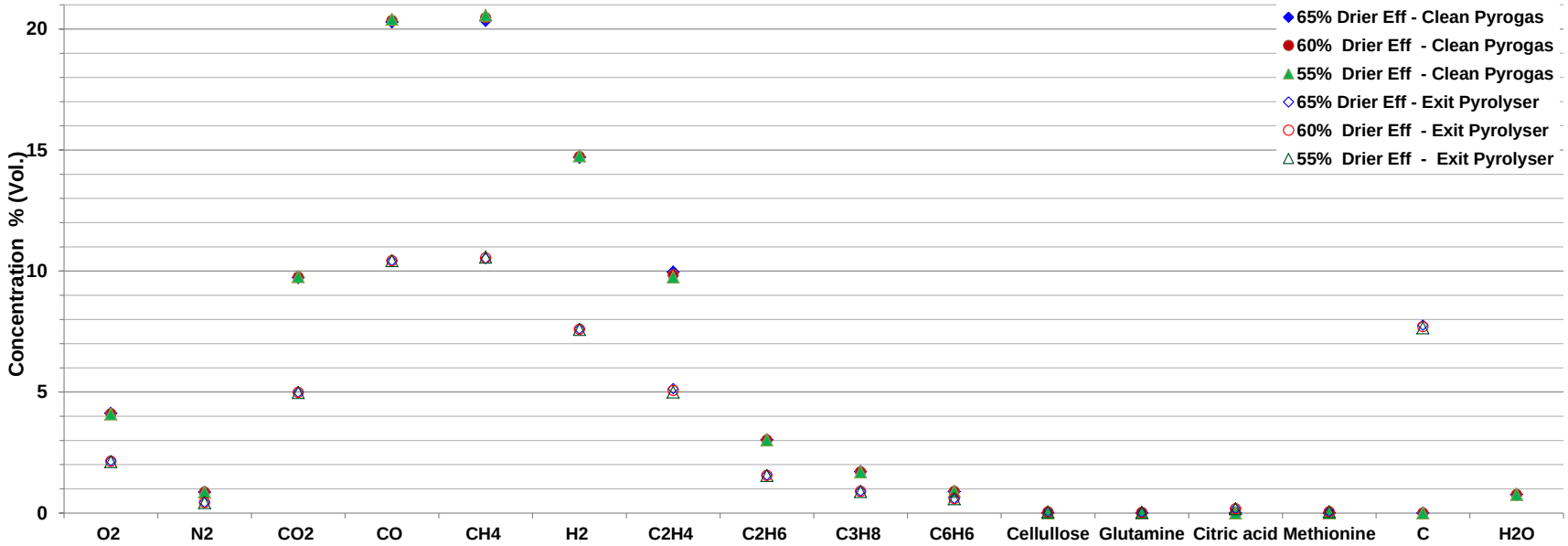
Pyrolysis Model in Aspen Plus

Effect of Drier efficiency on Gas Composition of Pyrogas



Effect of Drier efficiency on Heating Value of Pyrogas

Model Results	65% eff (200kg$_{H2O}$/h)	60% eff (220kg$_{H2O}$/h)	55% eff (240kg$_{H2O}$/h)
HHV (MJ/Nm^3)	26.25	26.21	26.18
LHV (MJ/Nm^3)	23.40	23.37	23.33
Engine $\eta_{electrical}$ (%)	33.36	33.36	33.42

Comparison for heating values and electrical efficiency

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FUTURE WORK

- Use the model for other sensitivity analyses . E.g.:
  - ✓ How the temperatures applied in the stages of the pyrolyser affects the composition of the pyrogas;
  - ✓ Optimise the integrated process to compensate for the heat needed in the first steps with heat removed in the last stages
- Explore other feedstocks to study how the model responds
- Validate new model predictions using different feedstocks with experimental data
- Add char gasifier to the model

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SYNGAS PRODUCTS

The eighth international conference on
Clean Coal Technologies

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