Reactor and Catalyst Development for Fischer-Tropsch Synthesis

APPLICABLE TO SMALL SCALE WOOD PROCESSING PLANTS IN NEW ZEALAND

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Objectives

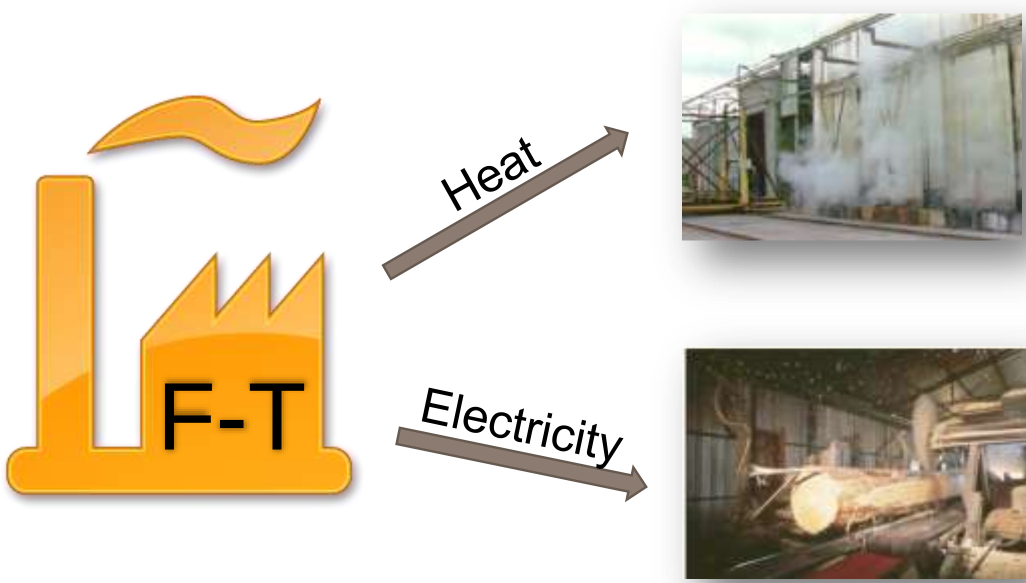
Make biomass based Fischer-Tropsch work in New Zealand!

- Plant configuration
- Reactor/Catalyst development

Plant Configuration

Think outside biomass supply vs. economy of scale squeeze

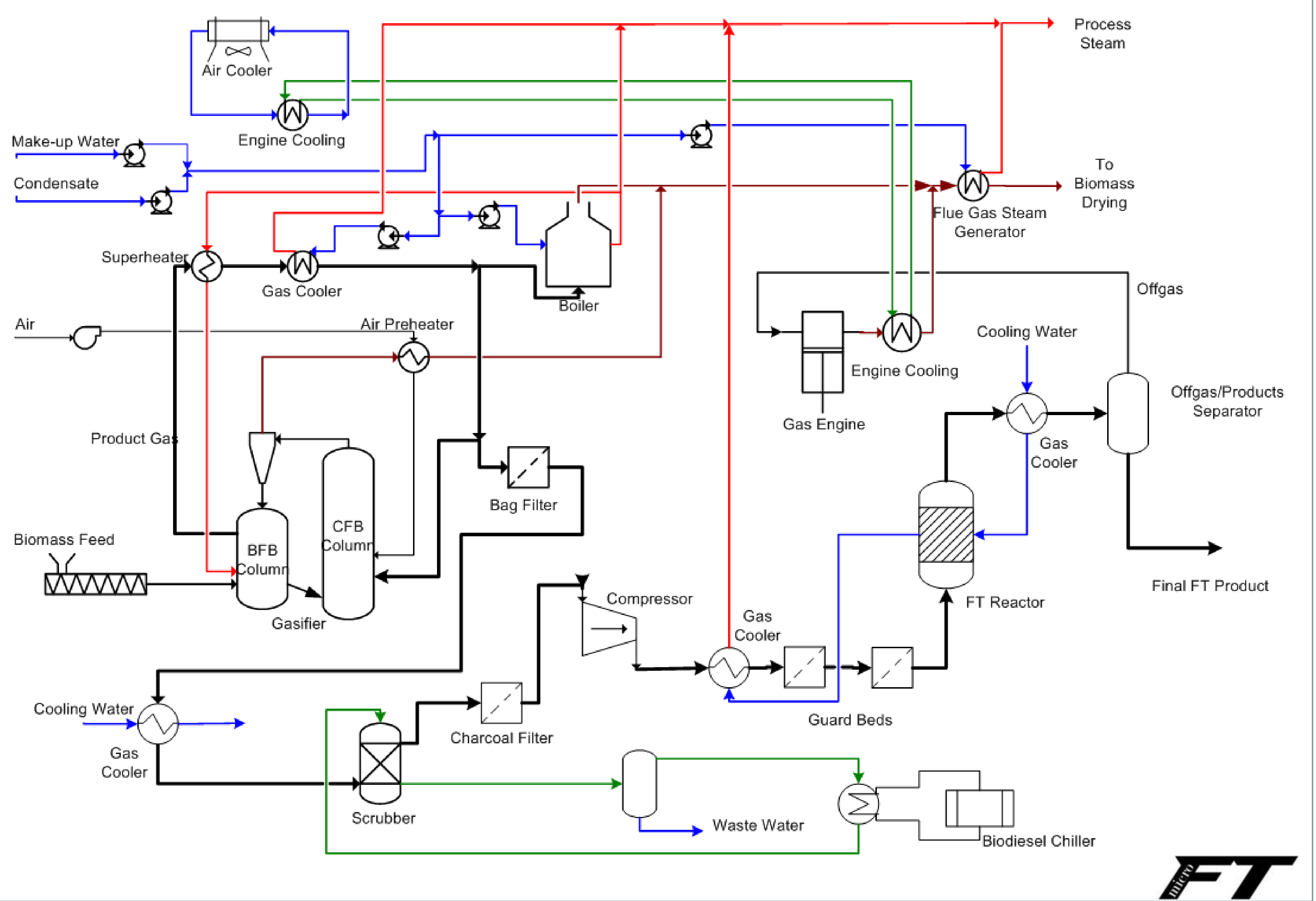
Sawmill Integration



Advantages

- Heat Sink
- Existing wood supply chain
- Electricity requirement
  - -Once through process

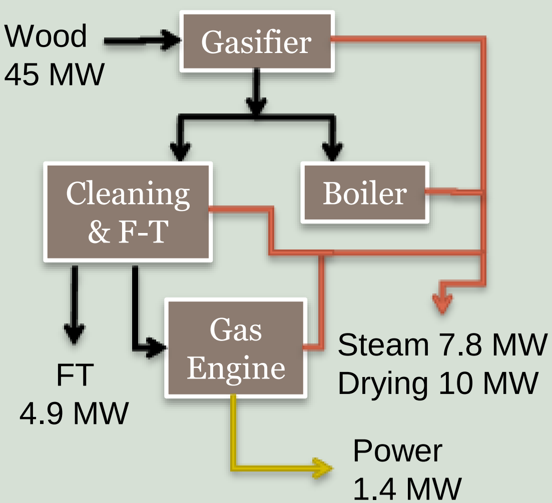
Sized on requirement, not on compromise!!!


Process Steam
Air Cooler
Engine Cooling
Make-up Water
Condensate
To Biomass Drying
Flue Gas Steam Generator
Superheater
Gas Cooler
Boiler
Offgas
Air
Air Preheater
Cooling Water
Engine Cooling
Gas Engine
Offgas/Products Separator
Product Gas
Gas Cooler
Bag Filter
CFB Column
BFB Column
Biomass Feed
Gasifier
Final FT Product
FT Reactor
Compressor
Gas Cooler
Cooling Water
Gas Cooler
Guard Beds
Charcoal Filter
Scrubber
Waste Water
Biodiesel Chiller
microFT

Modelling – 3 scenarios

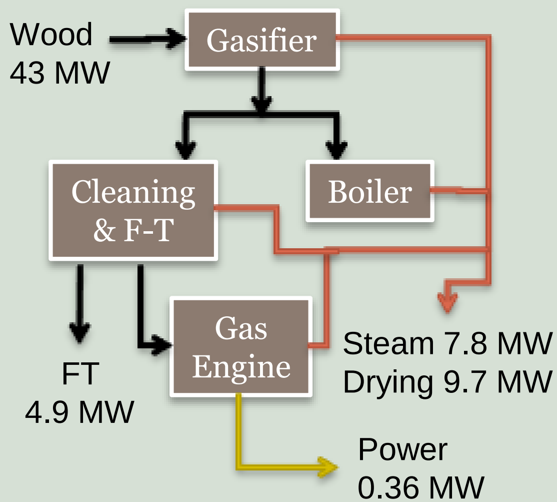
Scenario 1

- Meet all on peak mill electricity requirements
- Meet heat requirements
- Maximise FT production



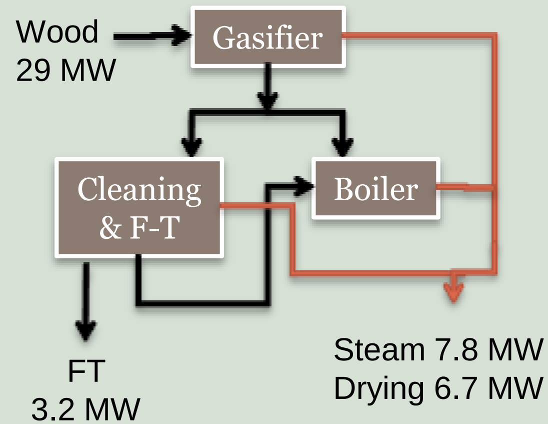
Scenario 2

- Meet off peak mill electricity requirements
- Meet heat requirements
- Maximise FT production

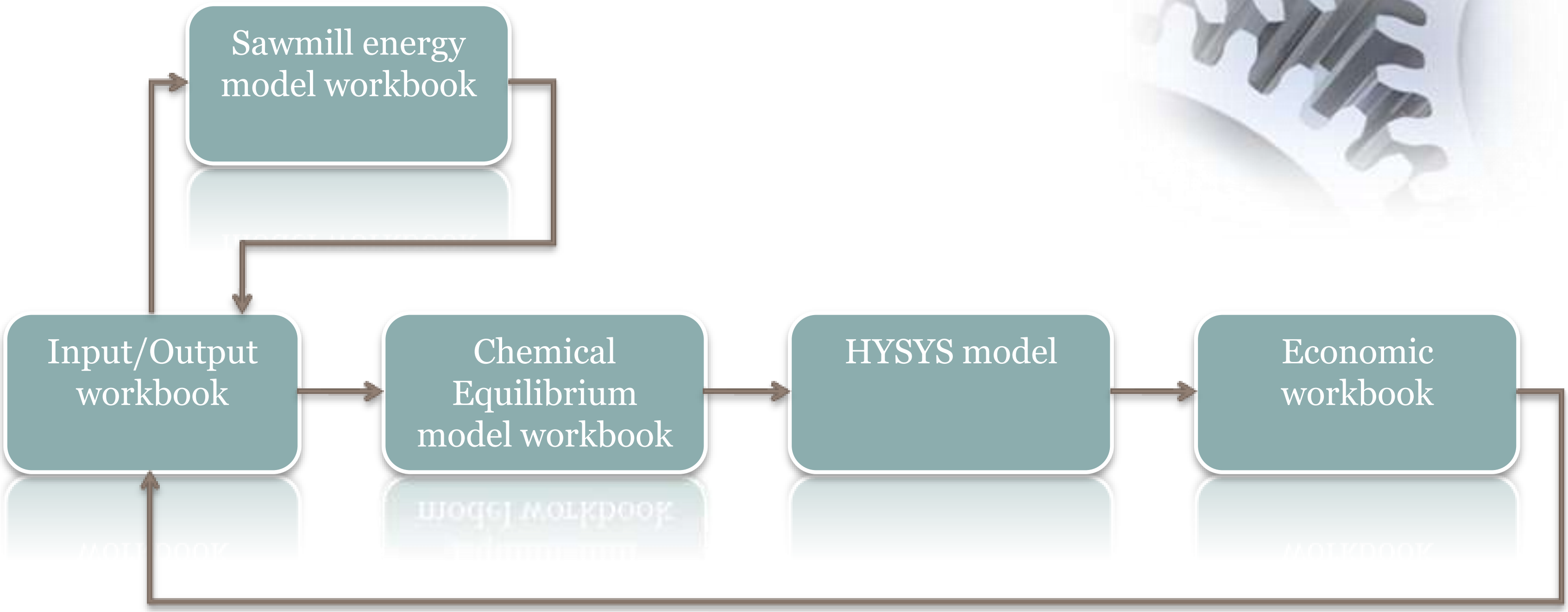


Scenario 3

- No Electrical Generation
- Meet heat requirements
- Maximise FT production



Modelling - Methodology



Modelling - Results

Scenario 1

•Meet all on peak mill electricity requirements

Capital Cost
$NZ 36 M

Breakeven
FT Crude Cost
$US 147 bbl

Production rate
74 bbl/day

Scenario 2

•Meet off peak mill electricity requirements

Capital Cost
$NZ 33 M

Breakeven
FT Crude Cost
$US 154 bbl

Production rate
75 bbl/day

Scenario 3

•No Electricity Generation

Capital Cost
$NZ 19 M

Breakeven
FT Crude Cost
$US 199 bbl

Production rate
49 bbl/day

-Based on wood cost of $10 odt, for $40 odt fuel price is $209 for Scenario 1
-Assumed error of +/- 25% for capital cost estimation

Modelling Conclusions

The breakeven prices for the FT crude are similar to peak oil prices of recent years

Scenario 1 and 2 are a better solution due to lower product production costs as well as protection from electricity price volatility

All scenarios are very sensitive to capital cost variations

Catalyst and Reactor Development

Reactor Selection

- High performance i.e. good catalyst utilisation and conversion
- Easily Scalable
- Suitable for smaller scale

Catalyst development

- Suitable for reactor choice
- Favourable α for maximum production from once through process

Microchannel Reactor

What is it?

Reactor with channels of dimensions between 0.1-5mm

Advantages

- Heat and mass transfer rates orders of magnitude higher than traditional reactors
- Effectively a small fixed bed reactor
- Easily scalable – number up rather than scale up
- Very suitable to small scale once through process

Microchannel Reactor

Reactor Design

Manufacturability

↓

-No exotic materials
-No specialised manufacturing techniques

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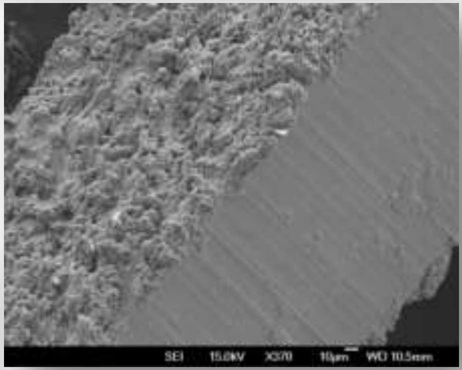
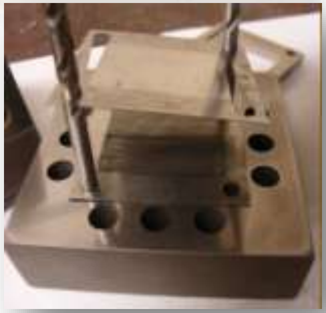
-Repeatable
-Scalable

What we made

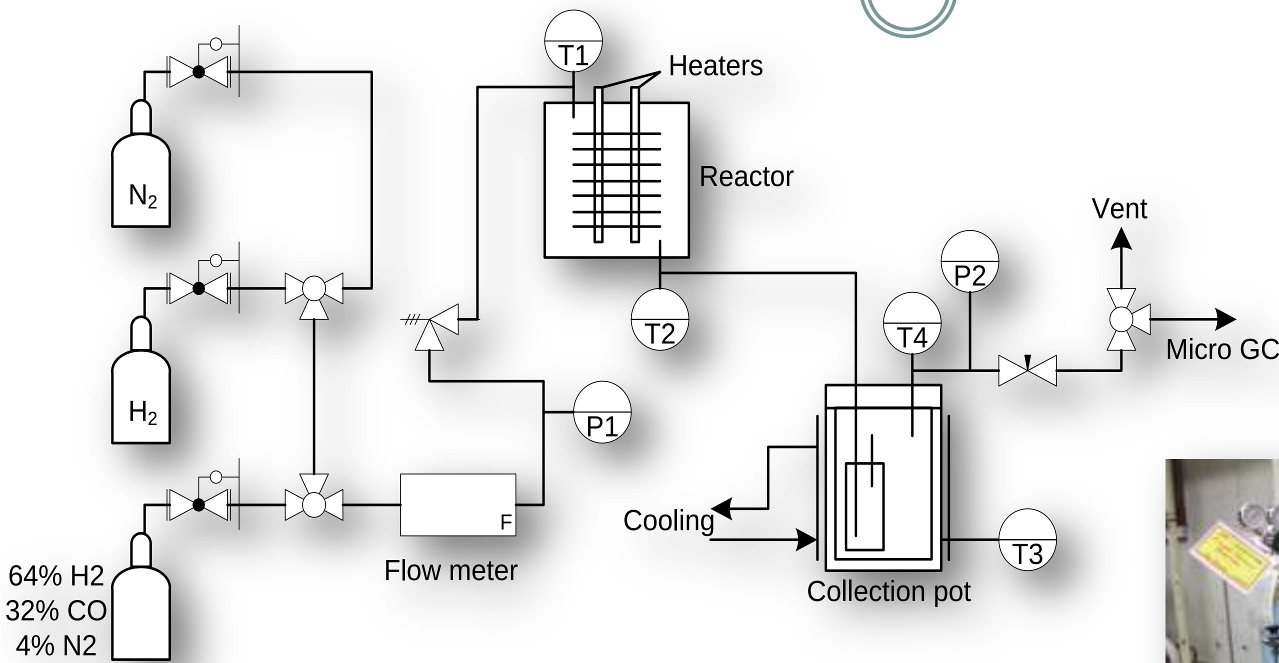
0.2mm 316ss shim
Wire cut channels 0.3mm x 50 per shim



-Aluminium foil gasketing
-25mm hardened tool steel top and bottom plates with cartridge heaters



Trial Rig

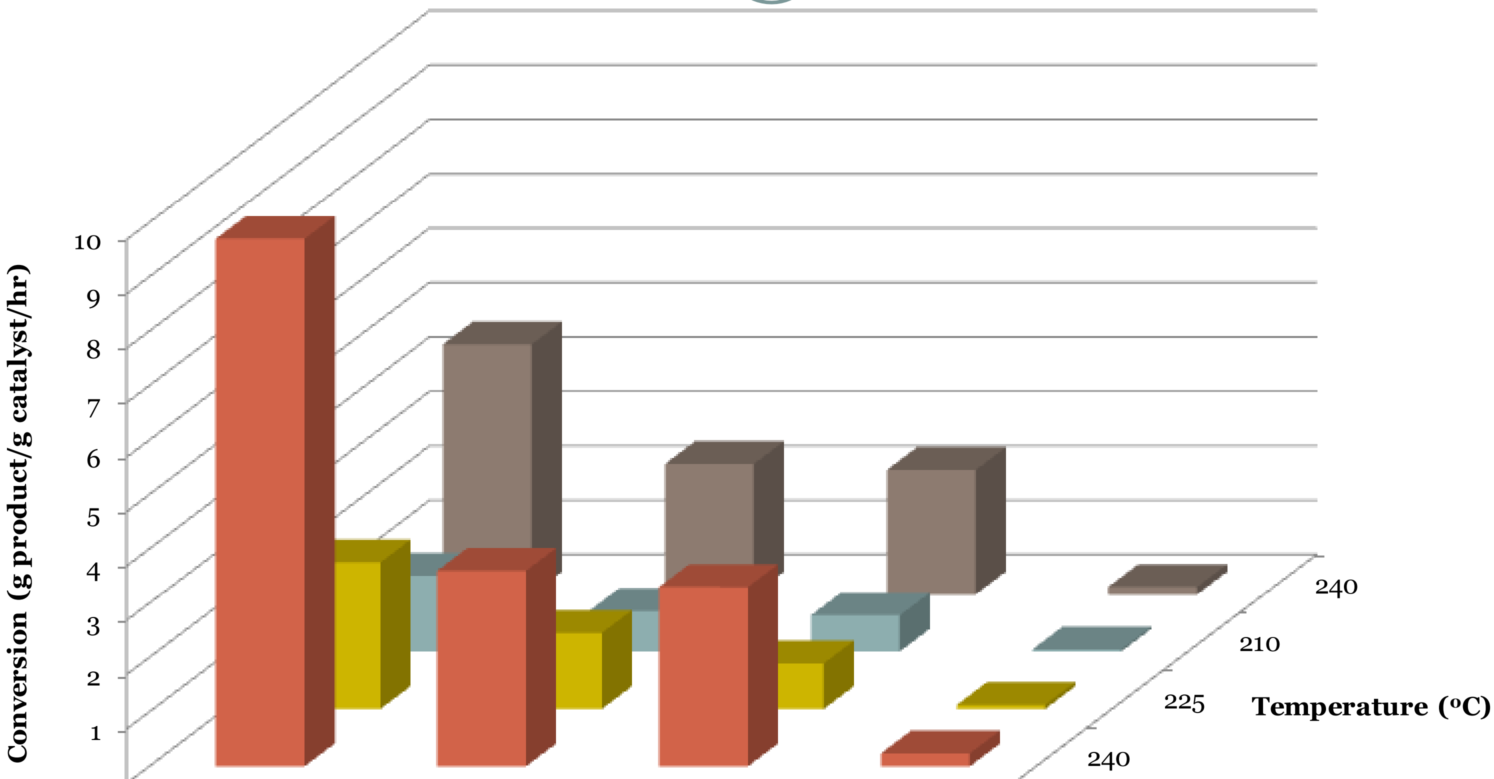


T1
Heaters
Reactor
N_2
H_2
64% H2
32% CO
4% N2
T2
P1
F
Flow meter
Vent
P2
T4
Micro GC
Cooling
T3
Collection pot

Microchannel reactor washcoats

Neat cobalt nitrate	Cobalt on titania	Combustion synthesis
-Simple -Easy to add solution -Repeatable	-More traditional -Expect less deactivation	-Expect tighter distribution of crystal size
-Potentially wasteful of cobalt -Deactivation	-Questionable repeatability	-Questionable repeatability

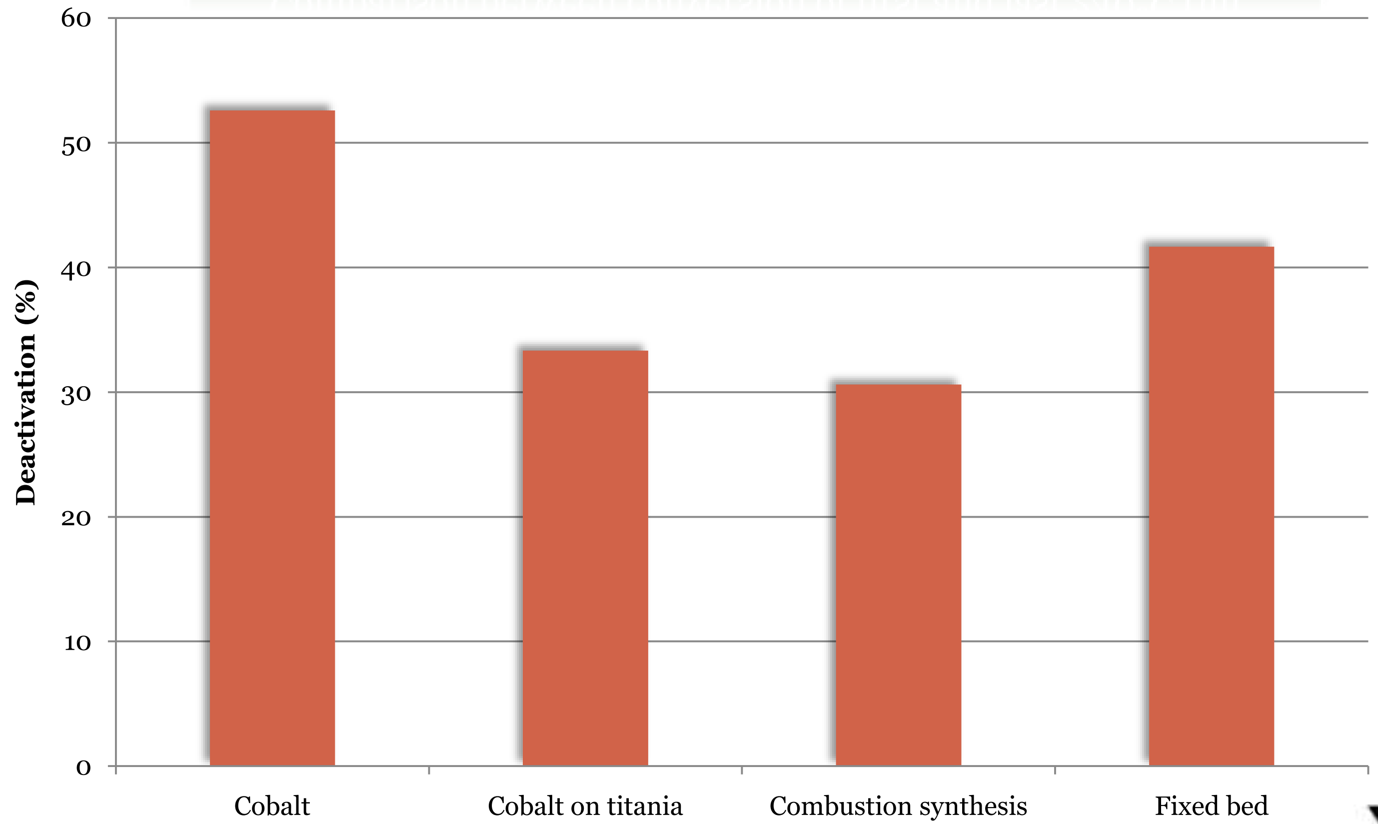
Results - Conversion



	Cobalt	Cobalt on titania	Combustion synthesis	Fixed bed
240	9.7	3.6	3.3	0.24
225	2.7	1.4	0.84	0.077
210	1.4	0.75	0.67	0.04
240	4.6	2.4	2.29	0.14

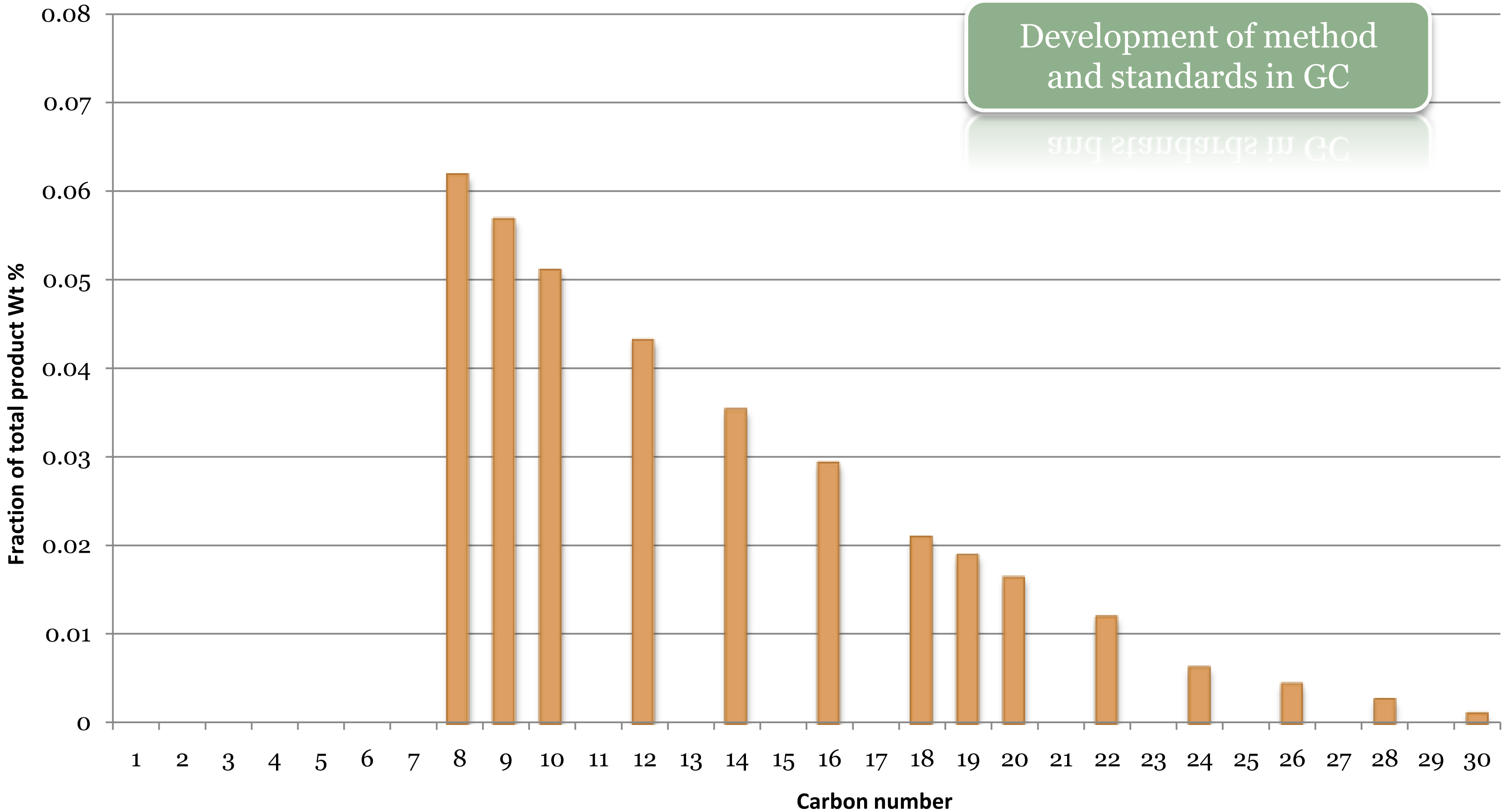
Results - Deactivation

Comparison between conversion of first and last 240°C run

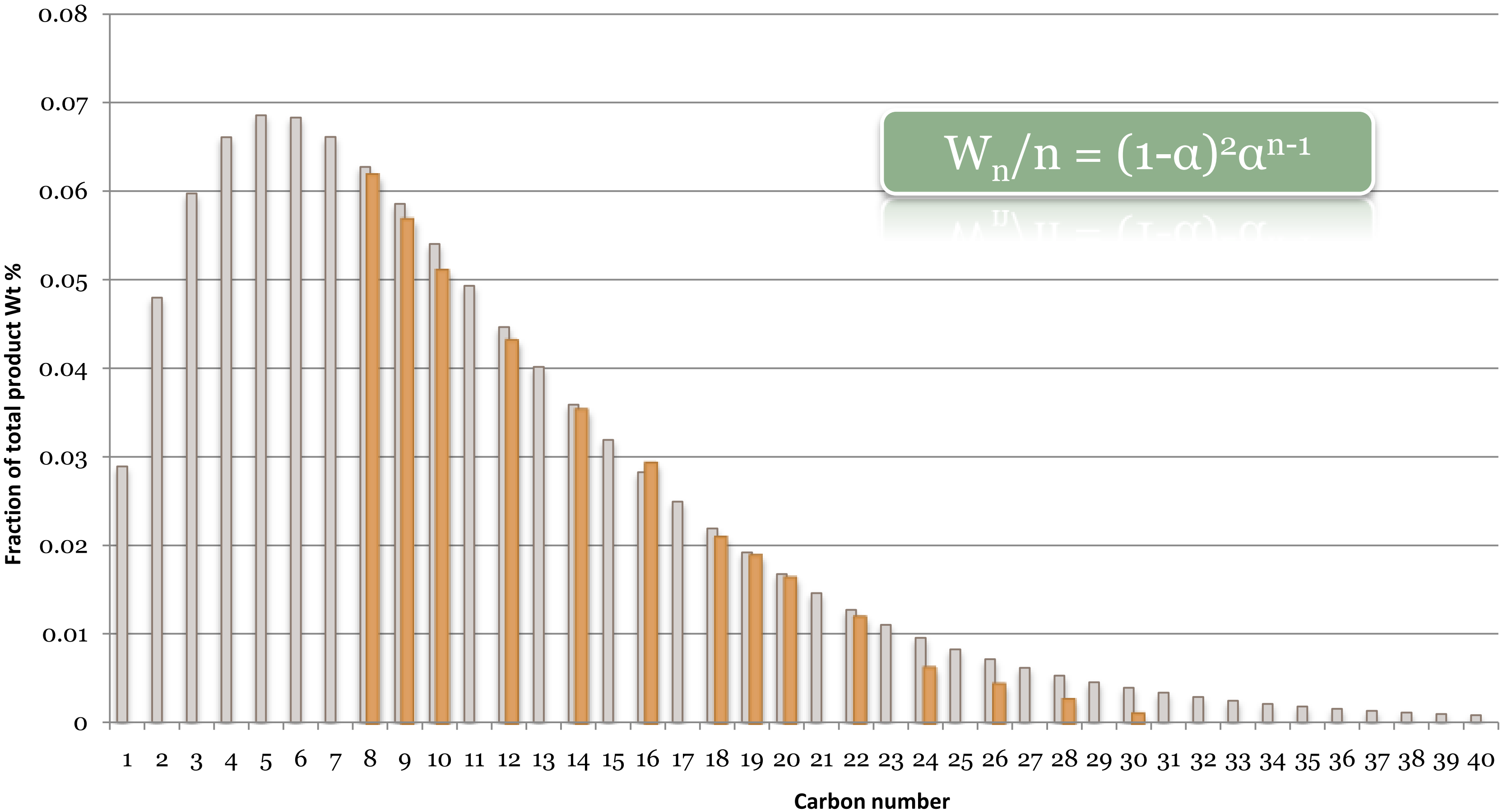


Methodology – Liquids analysis

Development of method and standards in GC

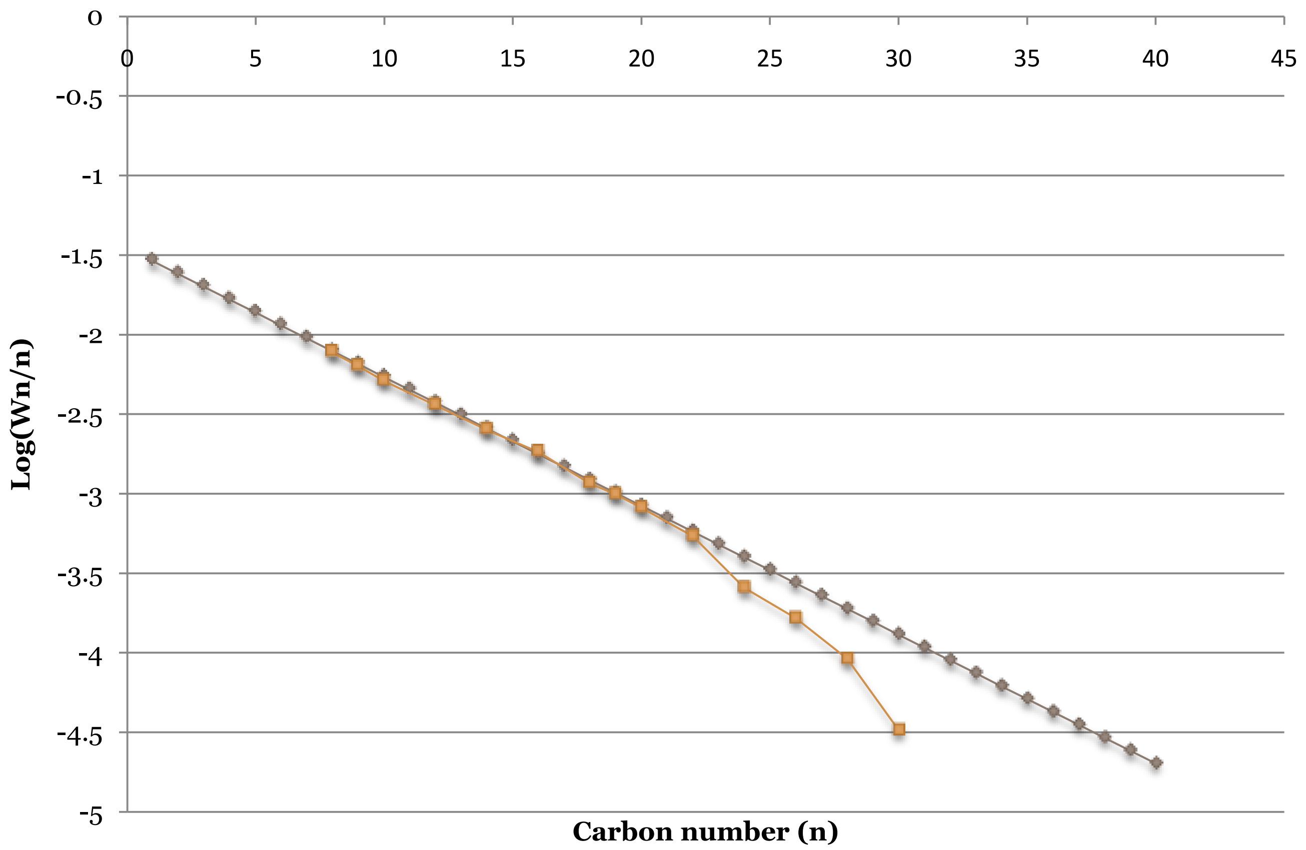


Methodology – Liquids analysis



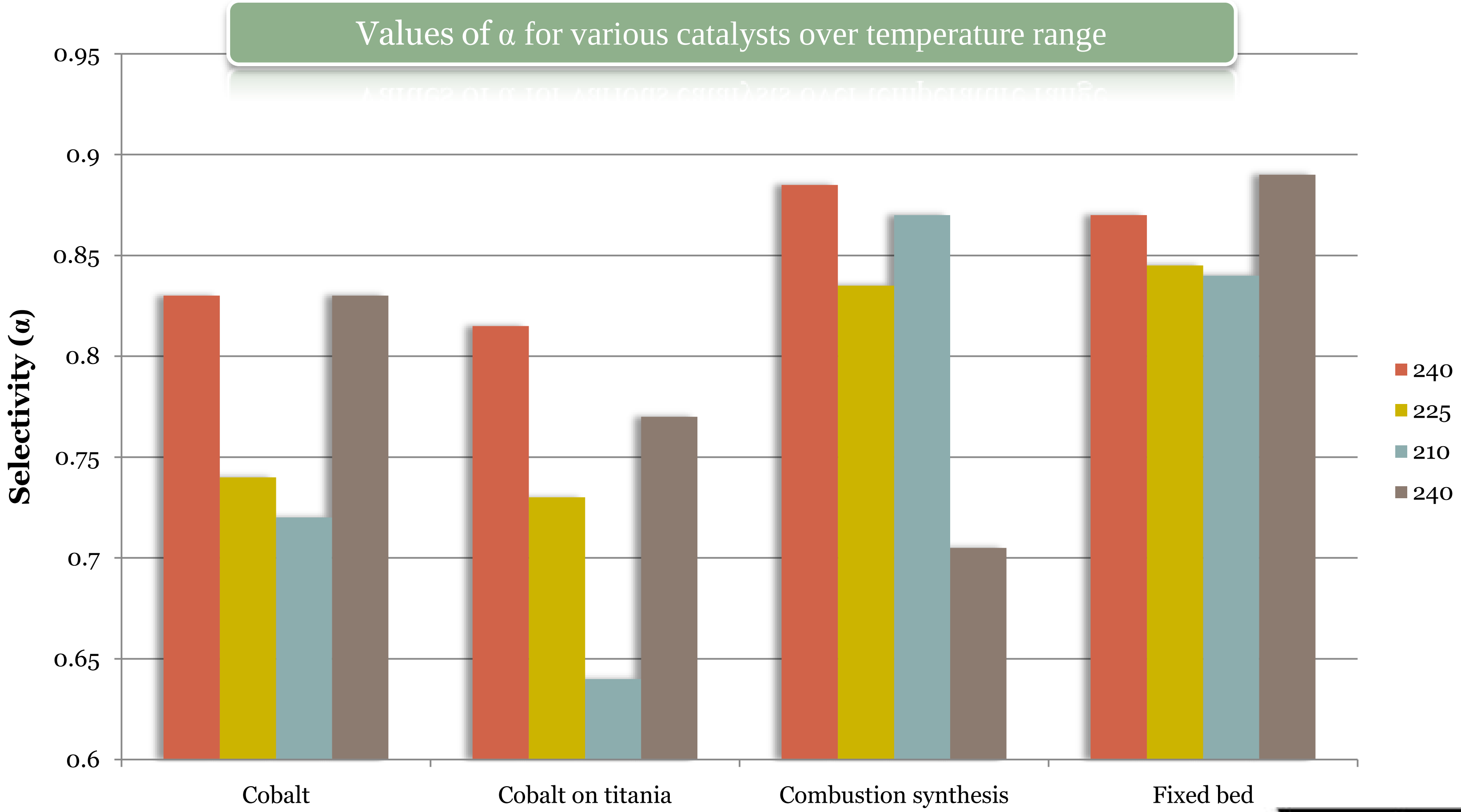
$$W_n/n = (1-\alpha)^2\alpha^{n-1}$$

Methodology – Liquids analysis

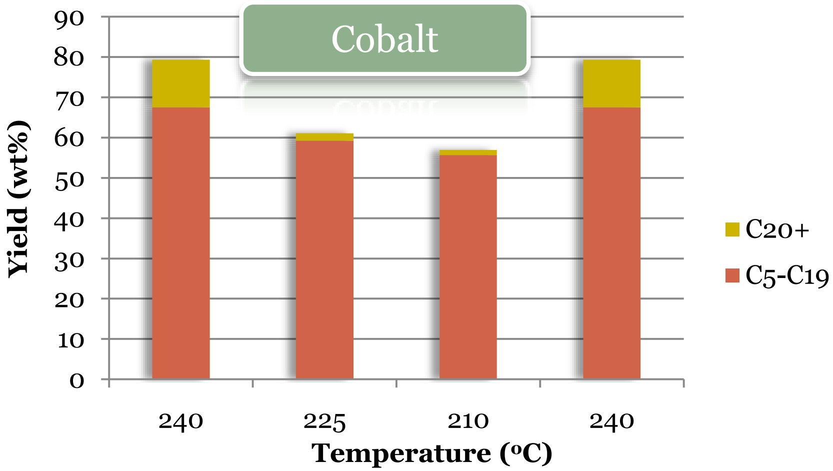


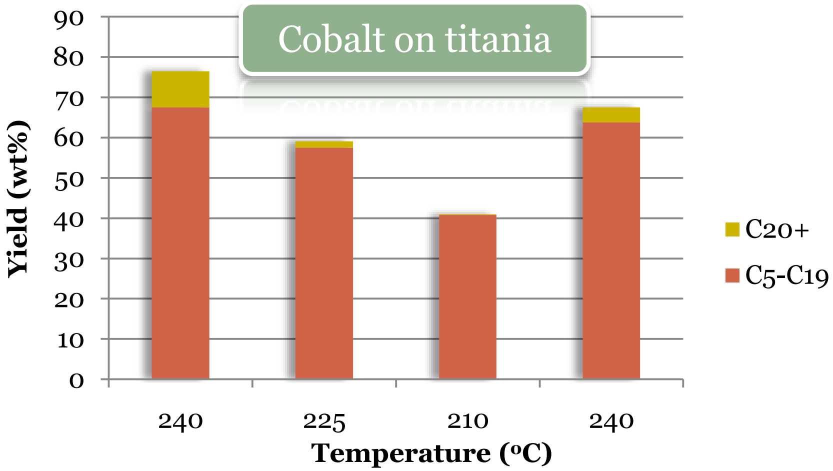
$Log(W_n/n)$

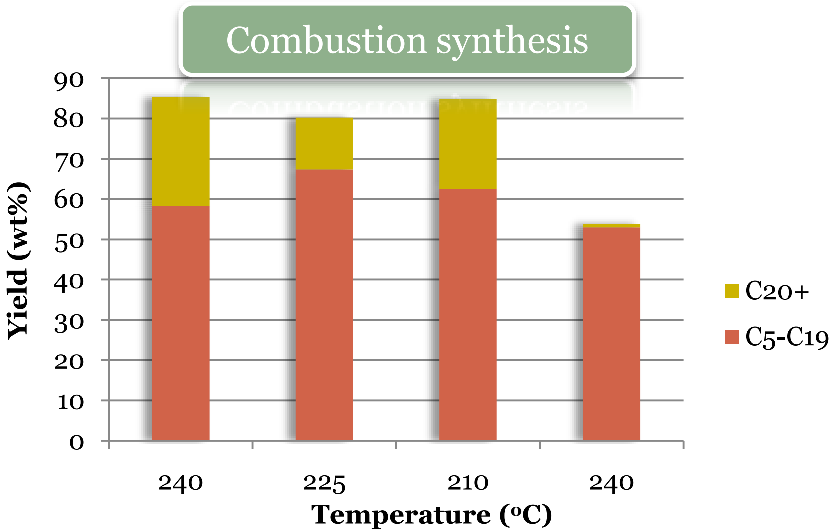
Results – Liquids analysis

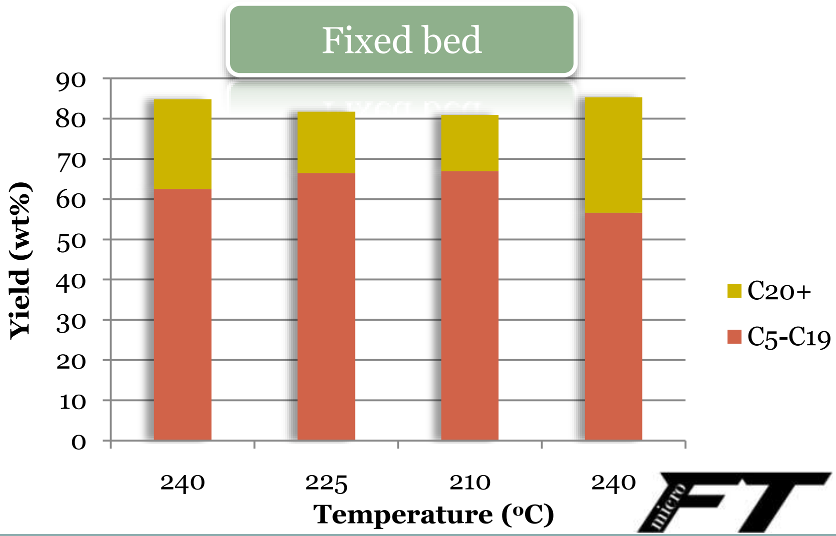


Results – Liquids analysis



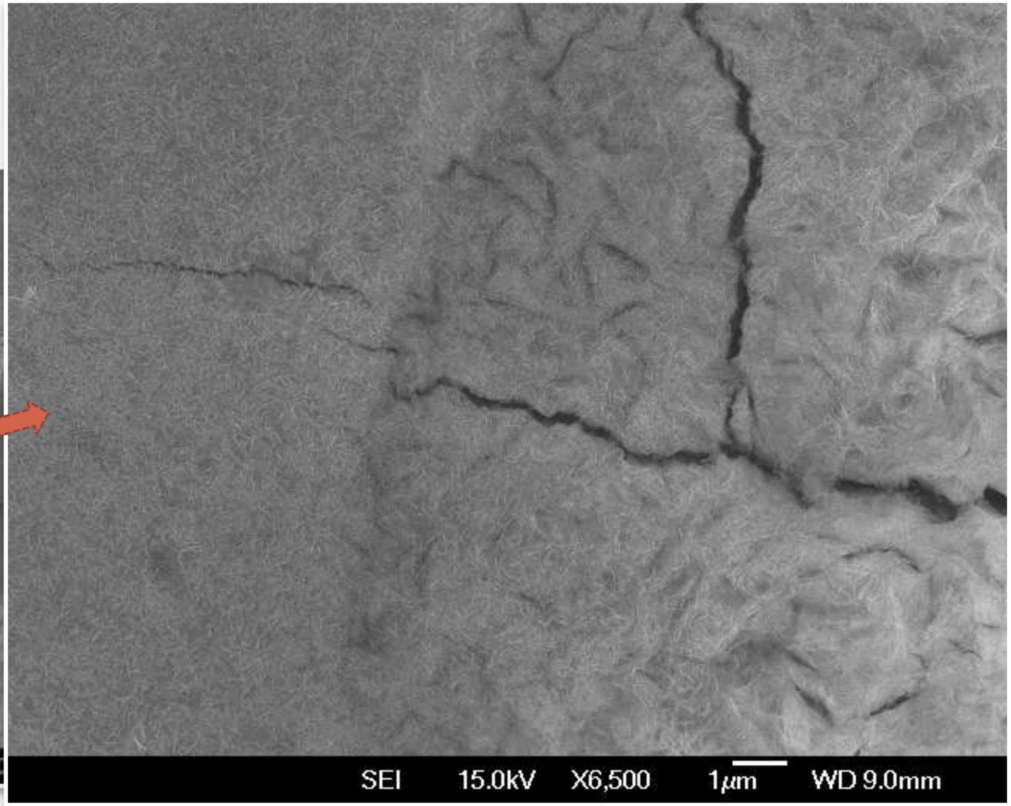




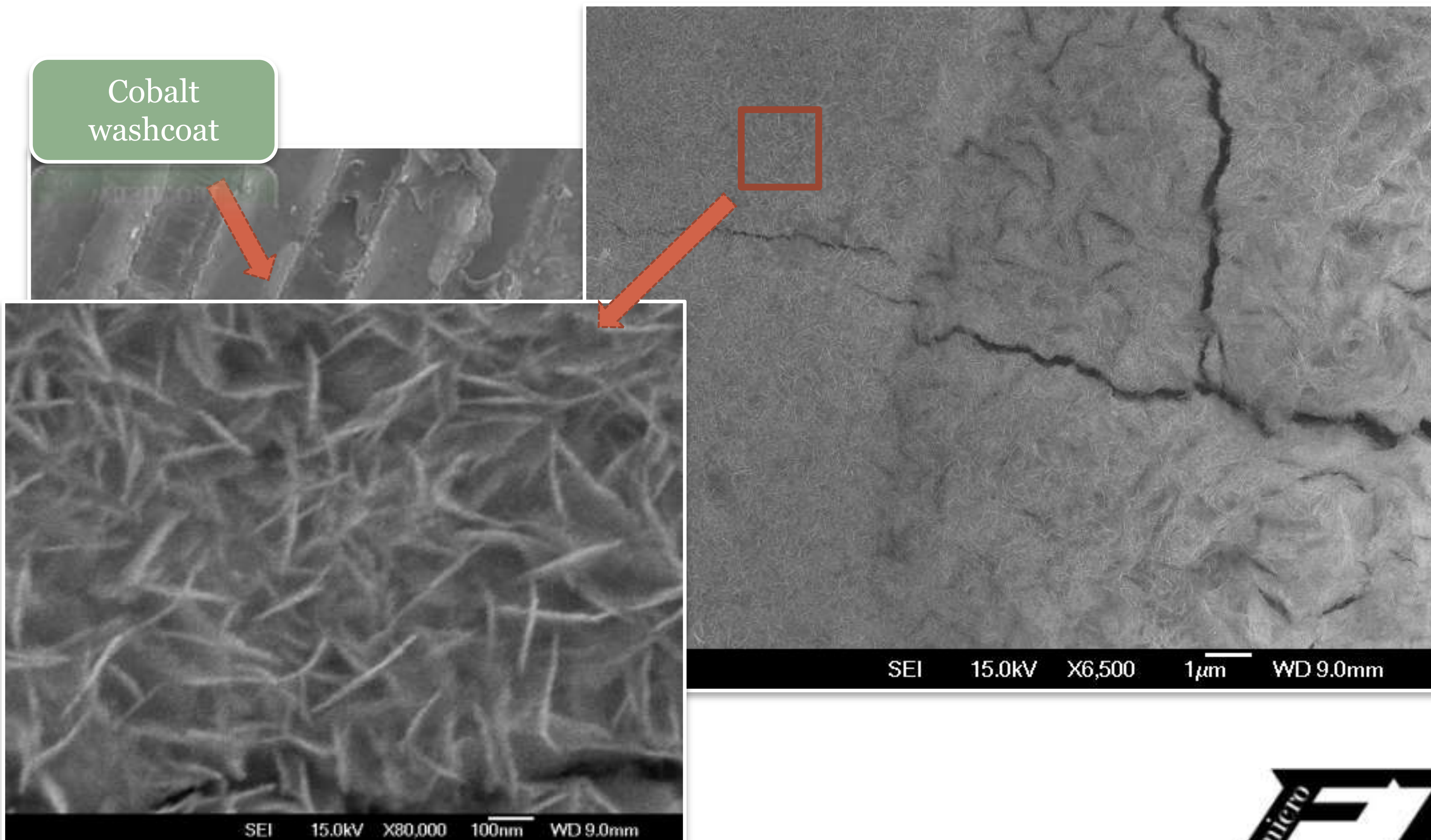


microFT

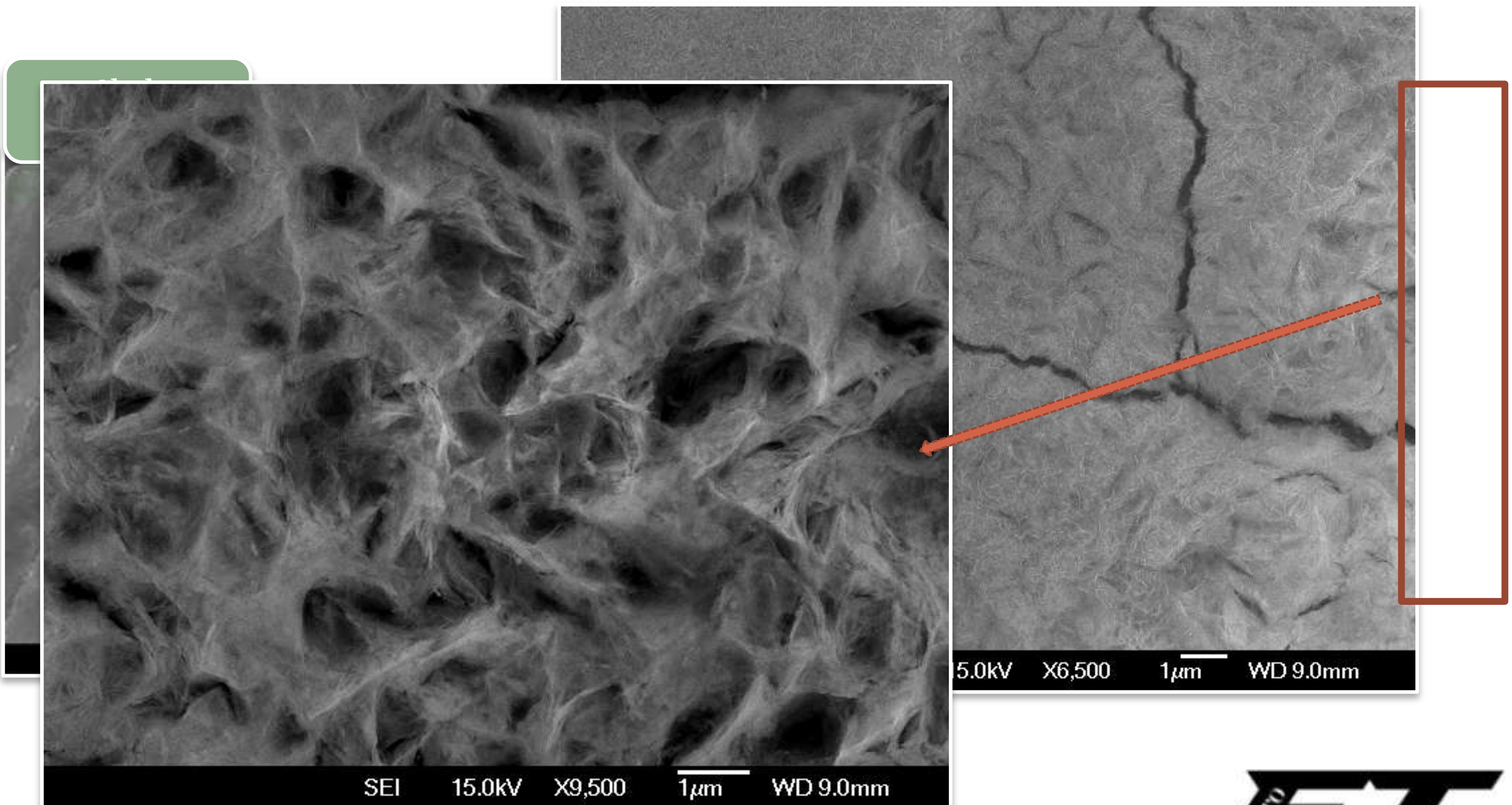
Results – SEM analysis



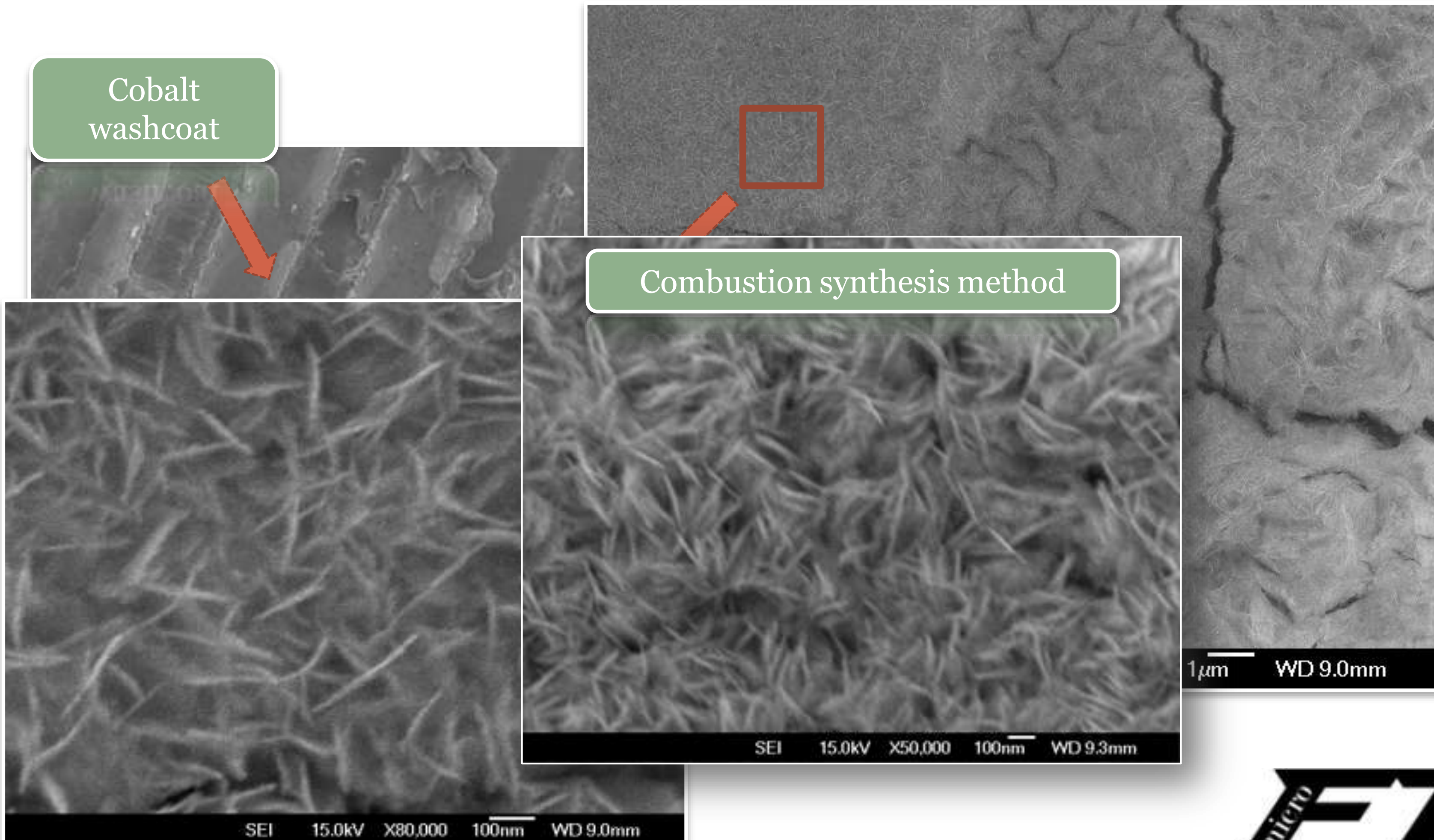
Results – SEM analysis



Results – SEM analysis



Results – SEM analysis



Where to from here?

Further SEM analysis

Further testing

-Longer runs
-More conditions

-Select conditions for optimisation of small scale FT i.e. pressure effects

Modelling of microchannel reactor

Stretch goal – incorporate FT rig with lab gasifier

Acknowledgments

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And Thank You for Listening!!