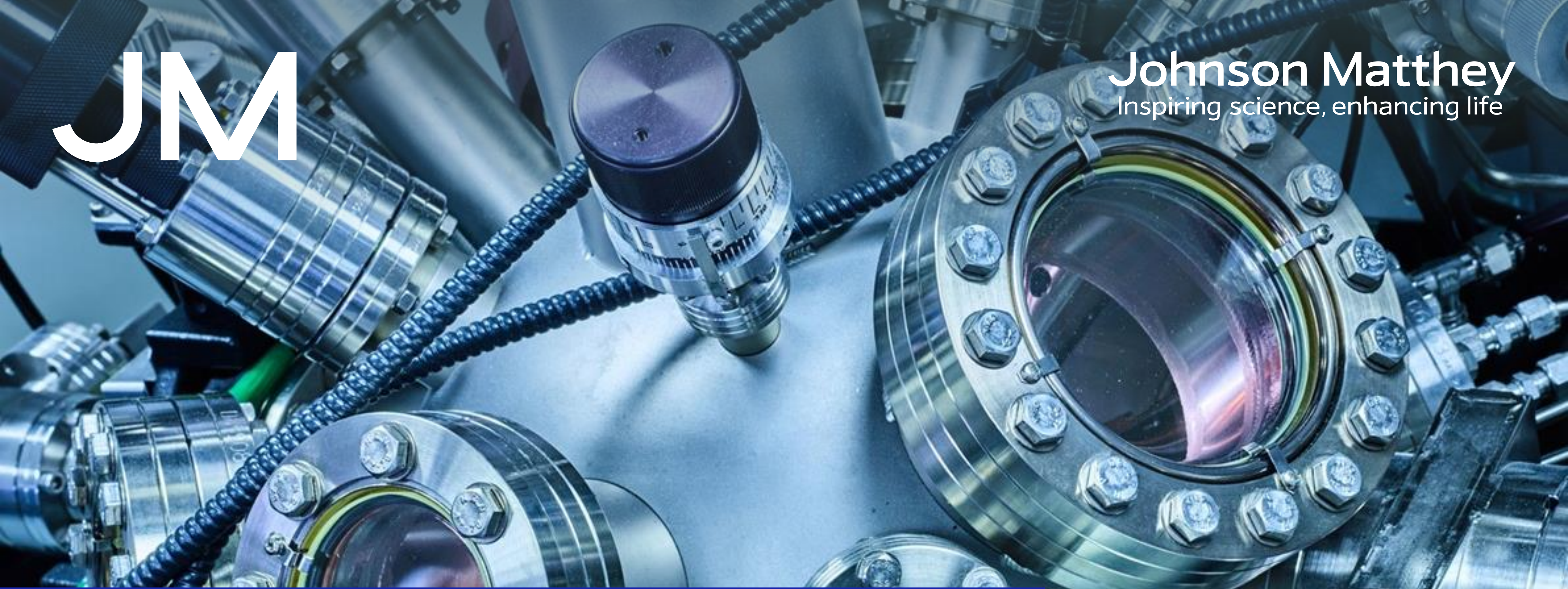

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Catalytic reforming in FLEXCHX

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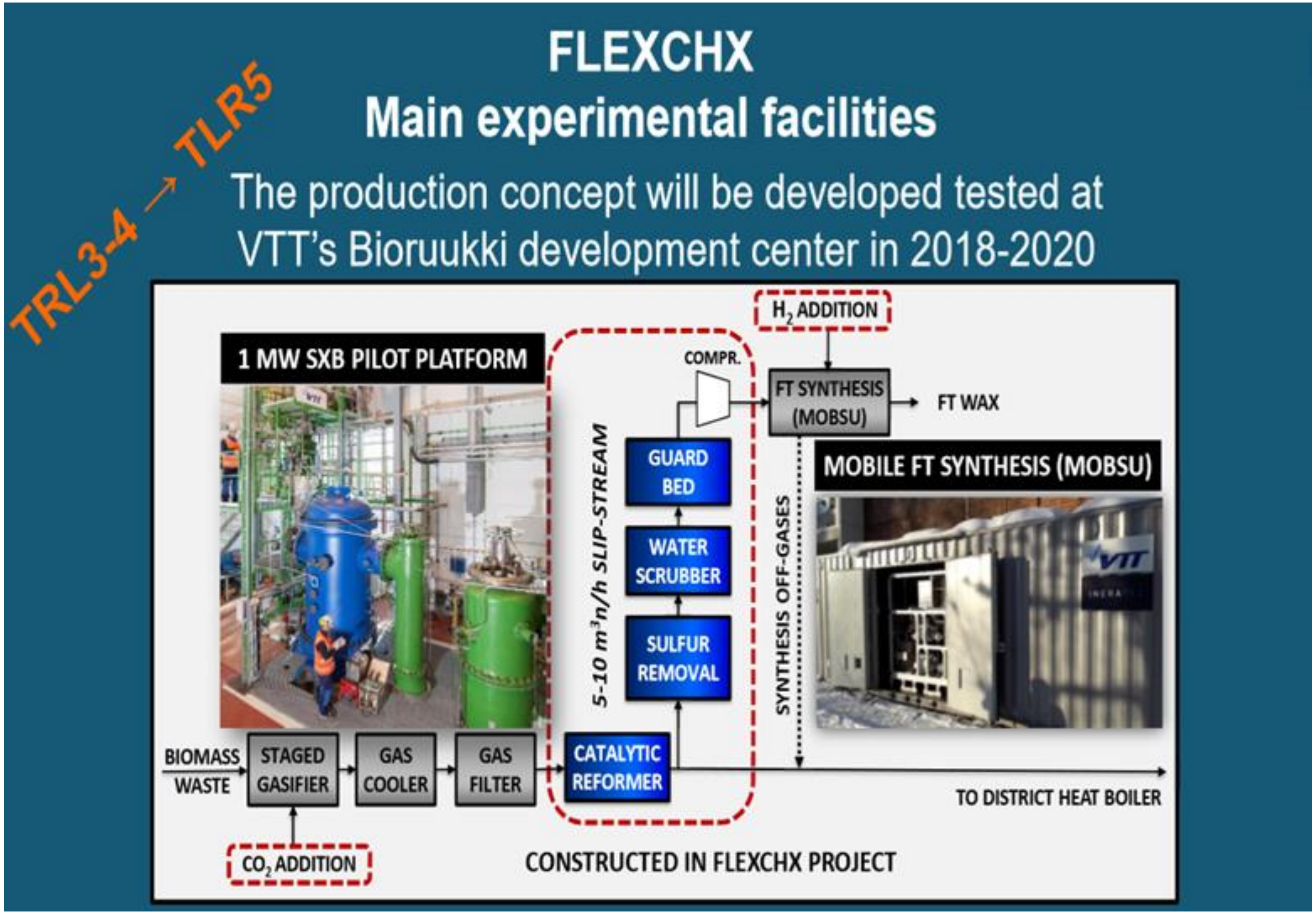
Steam reforming of tars and methane

- Biomass gasification produces syngas as well as heavy organic compounds, known as tar.
- These tars are typically aromatic compounds as well as benzene and naphthalene.
- Tar species quickly foul the machinery in a biomass gasifier and make the syngas unusable for applications such as fuel cells.
- A major part of the FLEXCHX project was to develop a robust and effective steam reformer catalyst to effectively convert this tar to additional syngas.

$$C_xH_y + xH_2O \longrightarrow xCO + (y/2+x)H_2$$

Typical steam reforming reaction equation

FLEXCHX pilot testing



The 1 MW SXB-gasifer plant, the 0.5 bbl/day MOBSU-FT unit located at VTT's Piloting Centre Espoo, Finland and the modifications to be executed in FLEXCHX.

FLEXCHX pilot testing

Flexible hybrid process for combined production of heat, power and renewable feedstock for refineries

Authors: Kurkela, Esa [1]; Kurkela, Minna [1]; Frilund, Christian [1]; Hiltunen, Ilkka [1]; Rollins, Benjamin [2]; Steele, Andrew [2]
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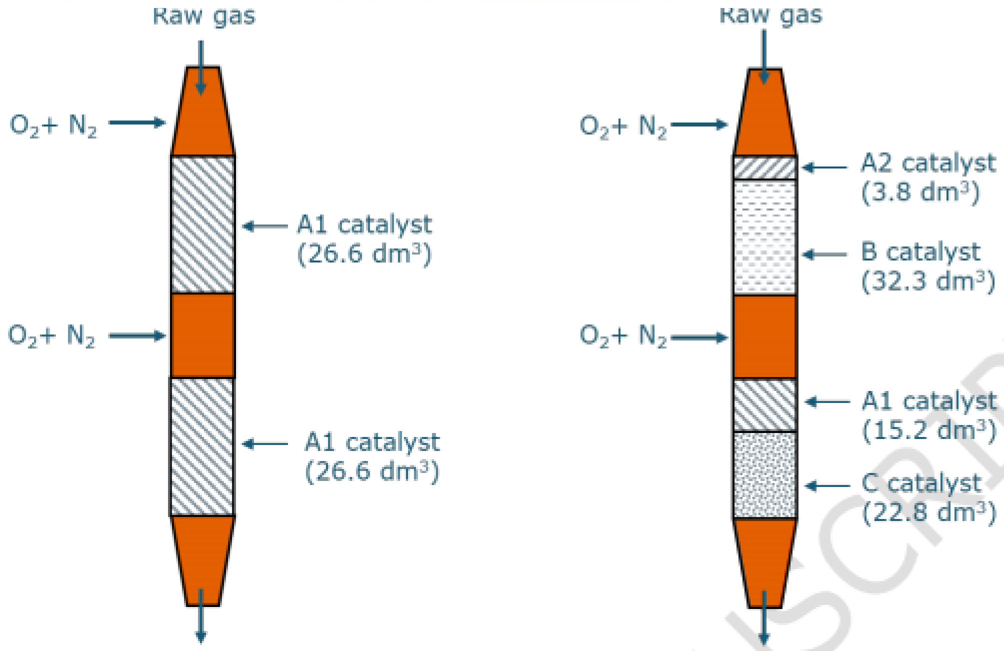


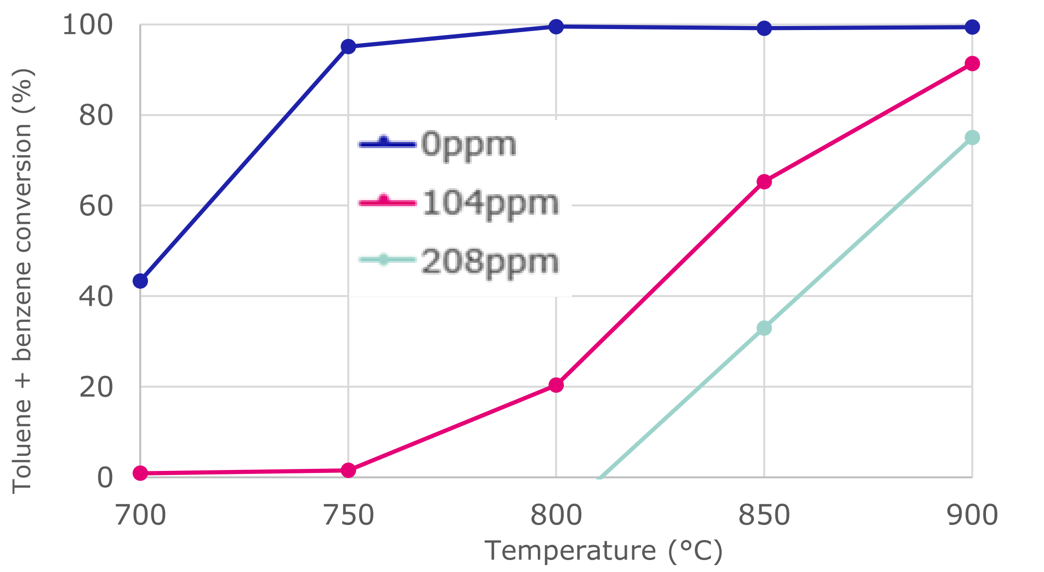
Fig 3. The reformer concepts and catalyst volumes used in the test campaigns.

Table 2. Feedstock analyses as used in the gasification campaigns of SXB pilot plant.

	Wood pellets	Bark pellets	Wood chips	Sunflower husk pellets
Particle size, mm	10-20	8	0-10	8
LHV MJ/kg (dry basis)	18.4	18.8	18.1	18.4
HHV, MJ/kg (d.b.)	19.8	20.1	19.5	19.6
Moisture, wt%	7.4	9.2	10.0	10.3
Proximate analysis, wt% d.b.				
Volatile matter (d.b.)	82.5	72.2	85.7	75.0
Fixed carbon (d.b.)	17.1	23.5	13.9	22.1
Ash, wt% (d.b.)	0.4	4.3	0.4	2.8
Ultimate analysis, wt% (d.b.)				
C	49.8	51.7	48.6	52.1
H	6.3	6.1	6.5	5.8
N	0.13	0.5	0.1	0.7
Cl	< 0.005	0,01	0.004	0.06
S	0.01	0.03	0.01	0.14
O as difference	43.7	41.7	44.4	38.6
Ash	0.4	4.3	0.4	2.8

Challenges facing reforming catalyst

- Reforming catalysts are typically based on nickel or PGMs such as platinum or rhodium.
- Nickel catalysts are cheaper but suffer more from issues surrounding coke formation and irreversible sulphide formation.
- PGMs are more expensive but typically have much better durability and can be used at lower loadings.
- Reforming is an endothermic process. There is a negative feedback as increases conversion lowers the gas temperature.



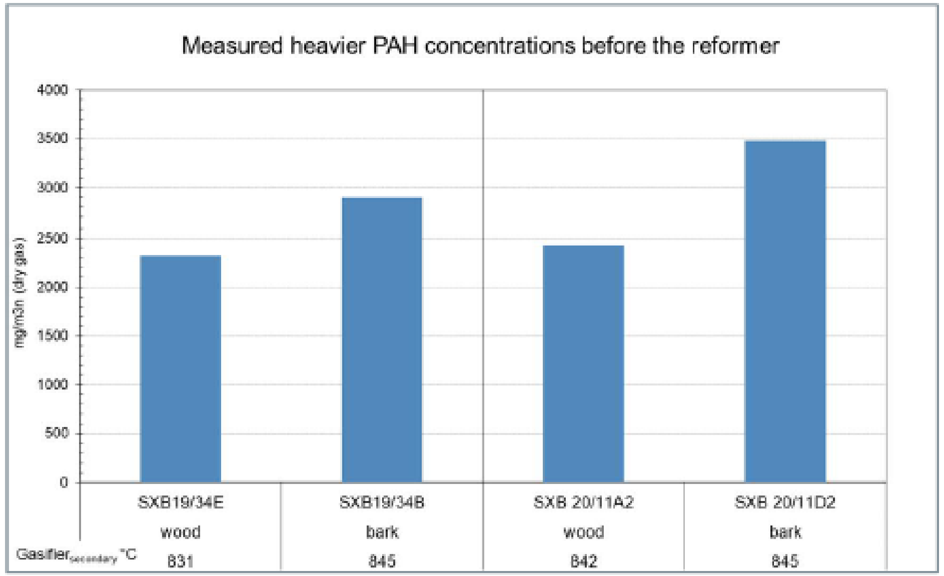
Conversion of toluene and benzene under identical conditions except for varying concentrations of H_2S for a rhodium based catalyst.

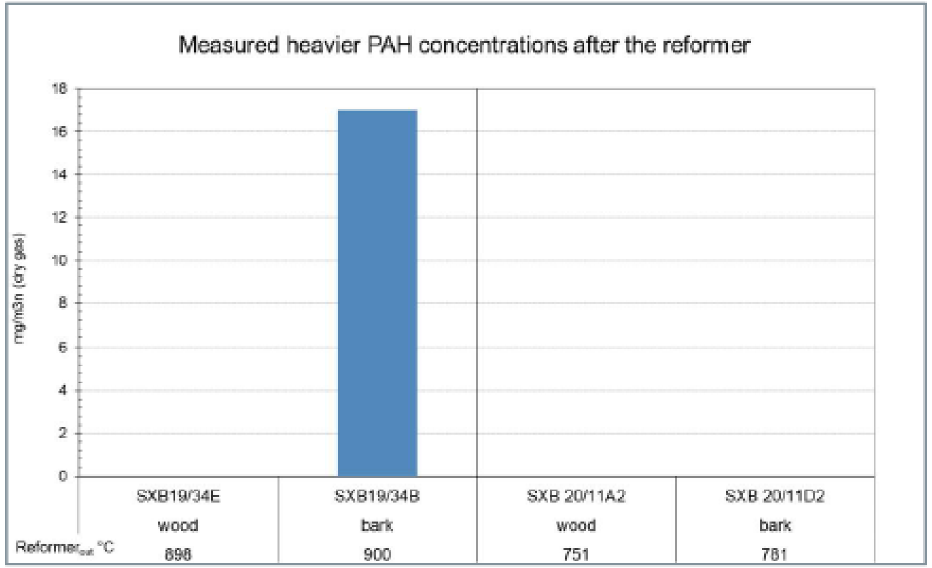
Steam reforming catalysts

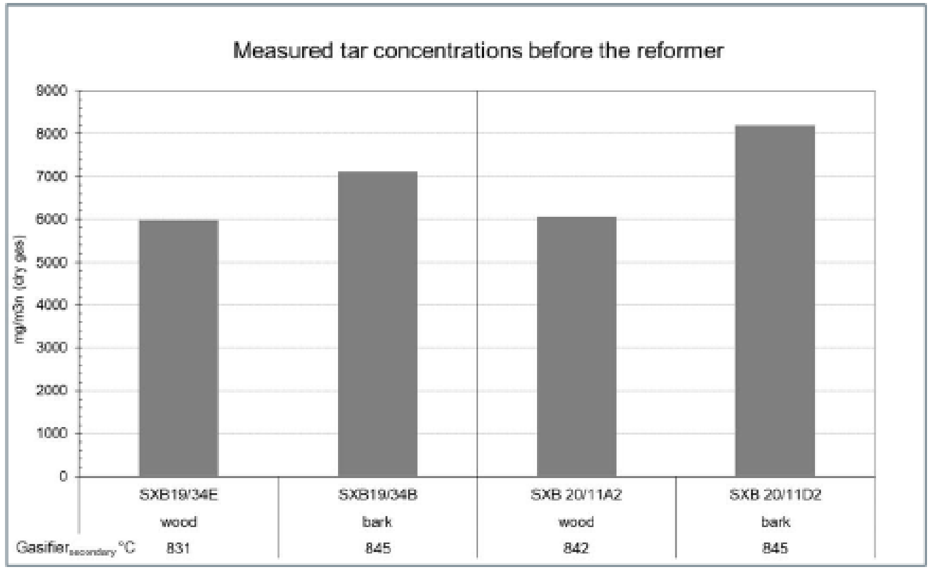
- A variety of different catalysts were supplied as part of the FLEXCHX project.
- Each served a different purpose.
- Screened in JM test rig.
- Initial, bulk tar reforming was carried out with a rhodium based catalyst, this catalyst has good thermal stability and activity.
- Later methane reforming was carried out with catalysts containing platinum which has a higher methane conversion.
- Nickel based catalysts were also included as a heat shield for the PGM catalysts.

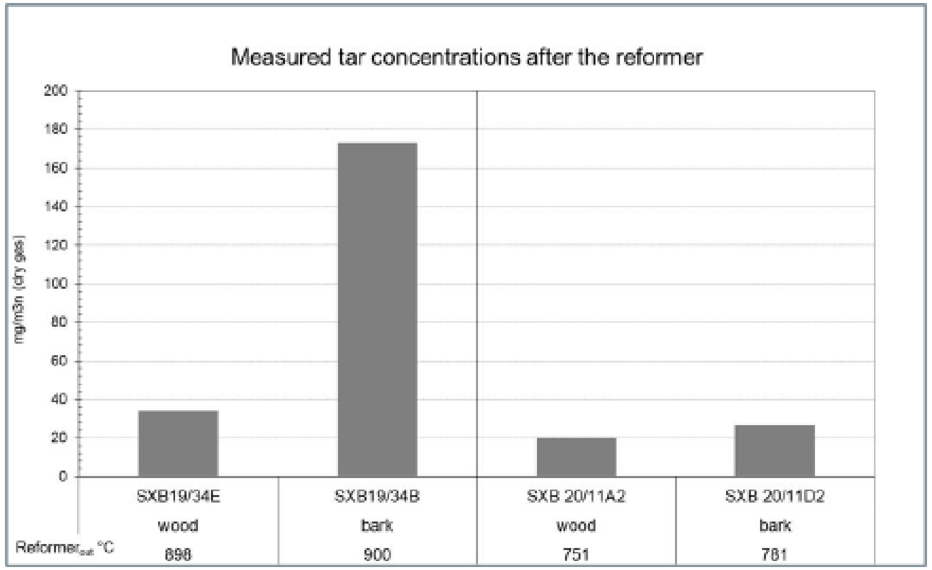
A selection of PGM and nickel based reformer catalysts.

Pilot plant reformer results

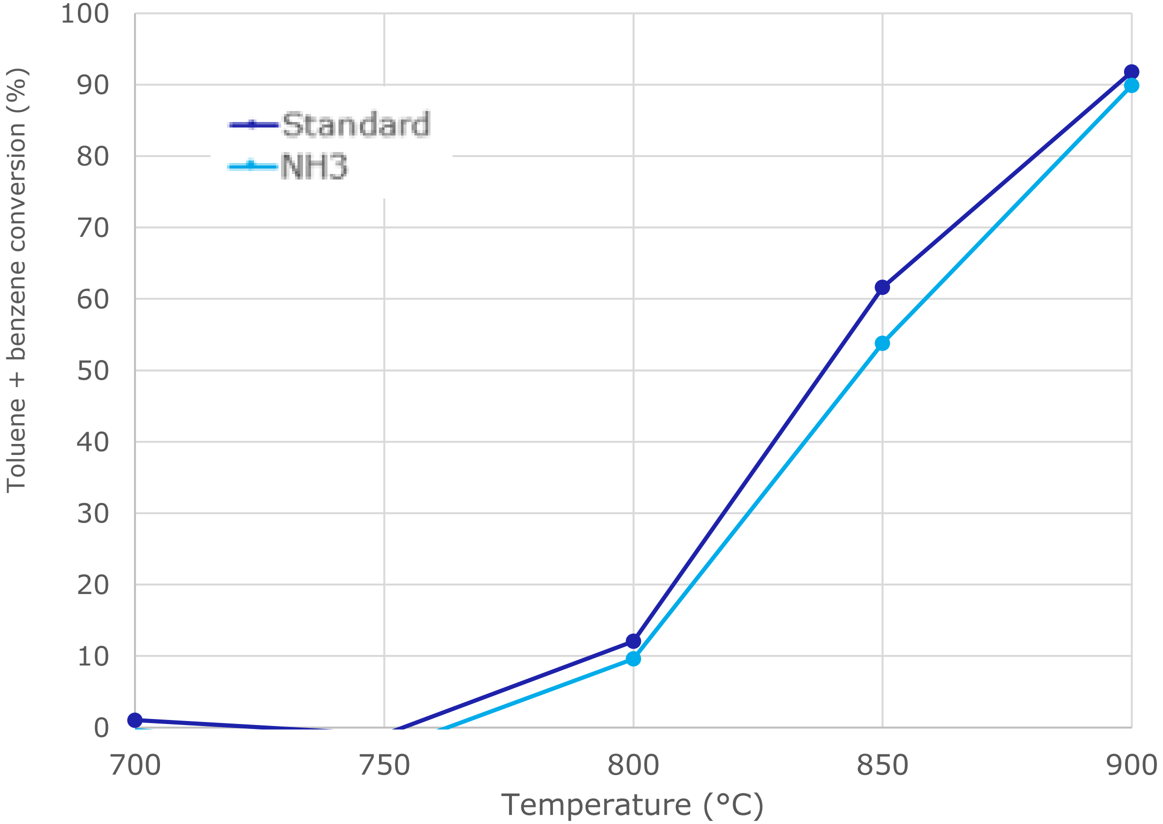


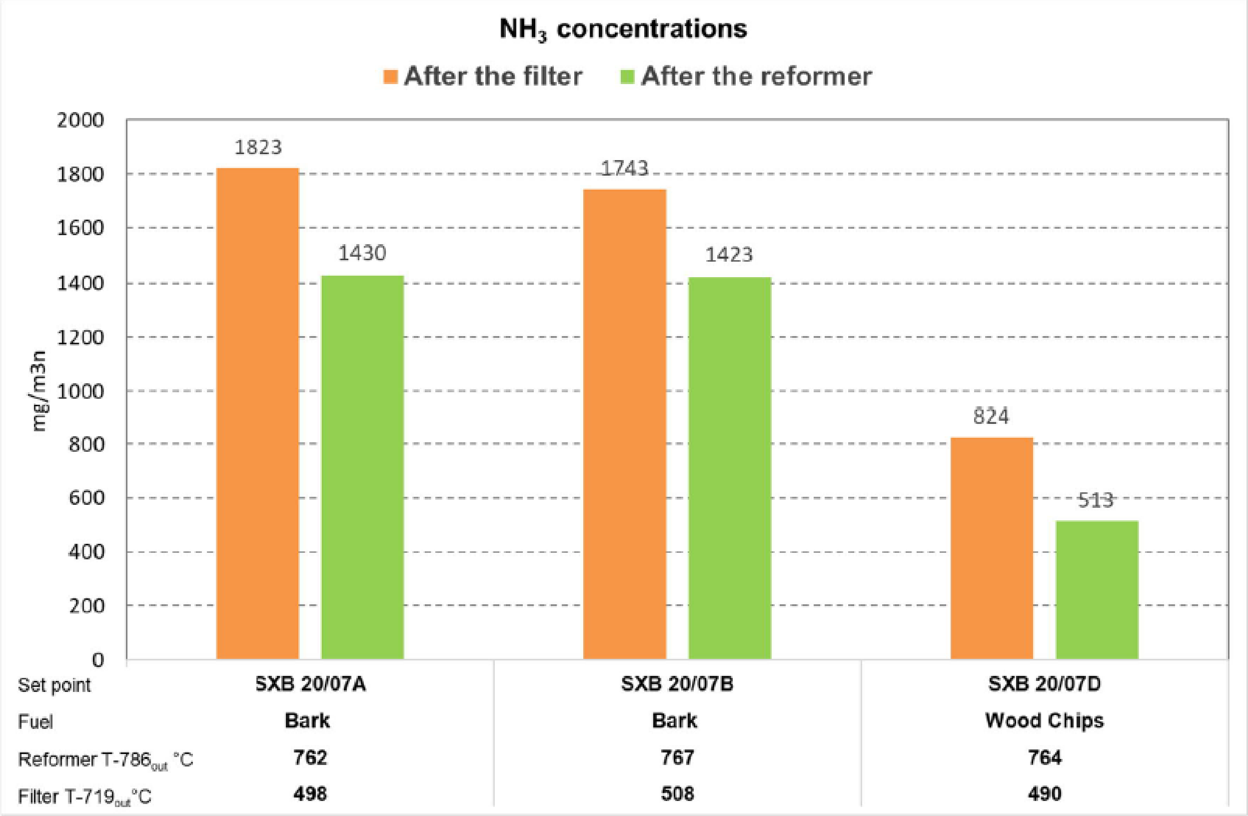






Pilot plant reformer results – effect of poisons





- The presence of ammonia doesn't seem to affect the conversion of tars but it still need to be removed before Fischer Tropsch synthesis unit.

- The reformer catalyst helps to remove some ammonia before the gas purification system.

Impact of FLEXCHX

Technical Impact:

- JM have strengthened their competencies of the reforming of hydrocarbons in bio-syngas.
- The effect of temperature and poisons on durability has been extensively studied.
- Catalyst cost models have been refined.
- Highlight: JM materials used throughout the reforming process flowsheet.

✓ OVERALL: JM reforming catalyst has been demonstrated for > 160 hrs @ 1MW scale.

Material and science Innovation:

- Developmental catalysts have been successfully tested at pilot-plant scale (providing a reference).
- Novel reforming opportunities investigated.
- Use of PGM catalysts helps mitigate the effects of H_2S poisoning and provides durable, highly active catalysts.

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