Pacific Northwest
NATIONAL LABORATORY

HTL Developers perspective: main demos in EU and worldwide

John Holladay

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

MetroVancouver points out the need for water management, understanding opportunity cost

Objectives/questions:

- Can HTL perform better than AD?
- TEA considerations for full scale?

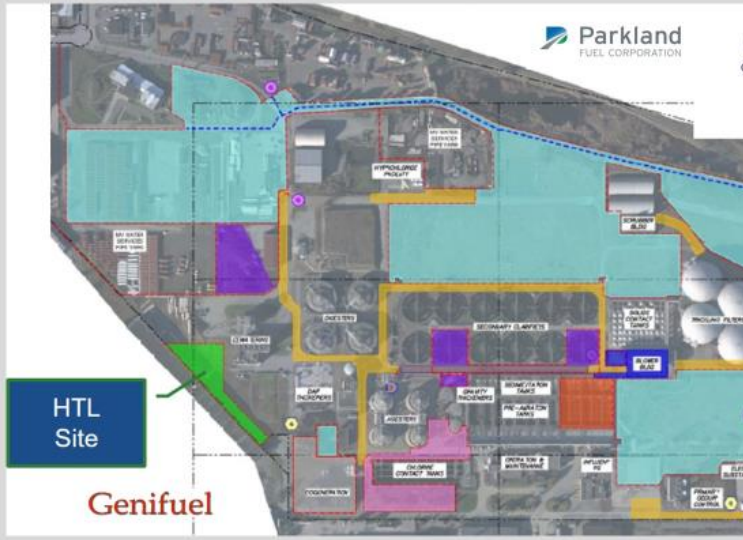
Science needs (Univ. British Columbia)

- Impact of HTL aqueous returned to i) headworks, ii) AD, iii) other?
- Required HTL aqueous pretreatment for i) NH4+, ii) phenols, iii) other?
- Required management of HTL precipitate
- Efficient phosphorus recovery or disposal?
- Fate of compounds of environmental concern (e.g. PFAS, other)?

metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGI

HTL Demonstration at Annacis Facility

- 10 m^3/d Facility
- ~2% of Annacis biomass
- Status:
  - ✓ FEED
  - ➢ Fabrication
  - ➢ Commissioning 2023
- Funding by MV and
  - Parkland; Prov. BC

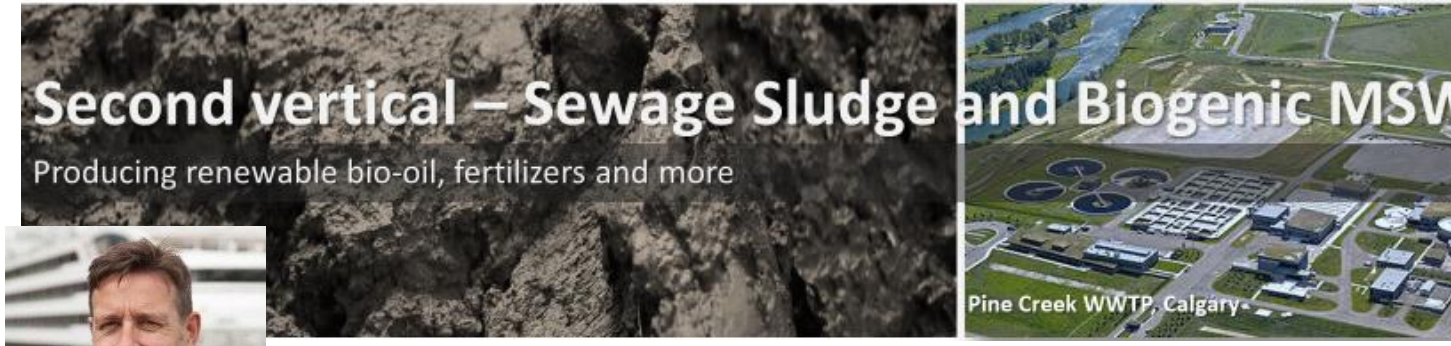


Paul Kadota

Steeper Energy Norway (wood) and Calgary (sewage sludge) point to H_2 use and links to refining

Questions to be answered:

- Attributes and direct markets for Hydrofaction® Oil;
- Utilization of the in situ renewable H_2 for cost-effective upgrading;
- Evaluation integration of bio-crude into existing refineries;
- Advancing understanding of chemical-linkers to improve compatibility of Hydrofaction® Oil with existing fuels; and,
- Developing economic pathways to 100% renewable: gasoline, diesel, jet-fuel, marine fuels, and fine chemicals.



Perry Toms

Northern and Southern Oil Refineries (Australia), note capital and operating cost both need to come down

"It is not the return on my investment that I am concerned about; it's the return of my investment" - Will Rogers

- Completed detailed design of a 1t/h HTL process ($7M CAPEX)
- Financial model 16ML/annum, $28M CAPEX
- Feedstock tipping fee $160 – 285/dry tonne

David Lewis

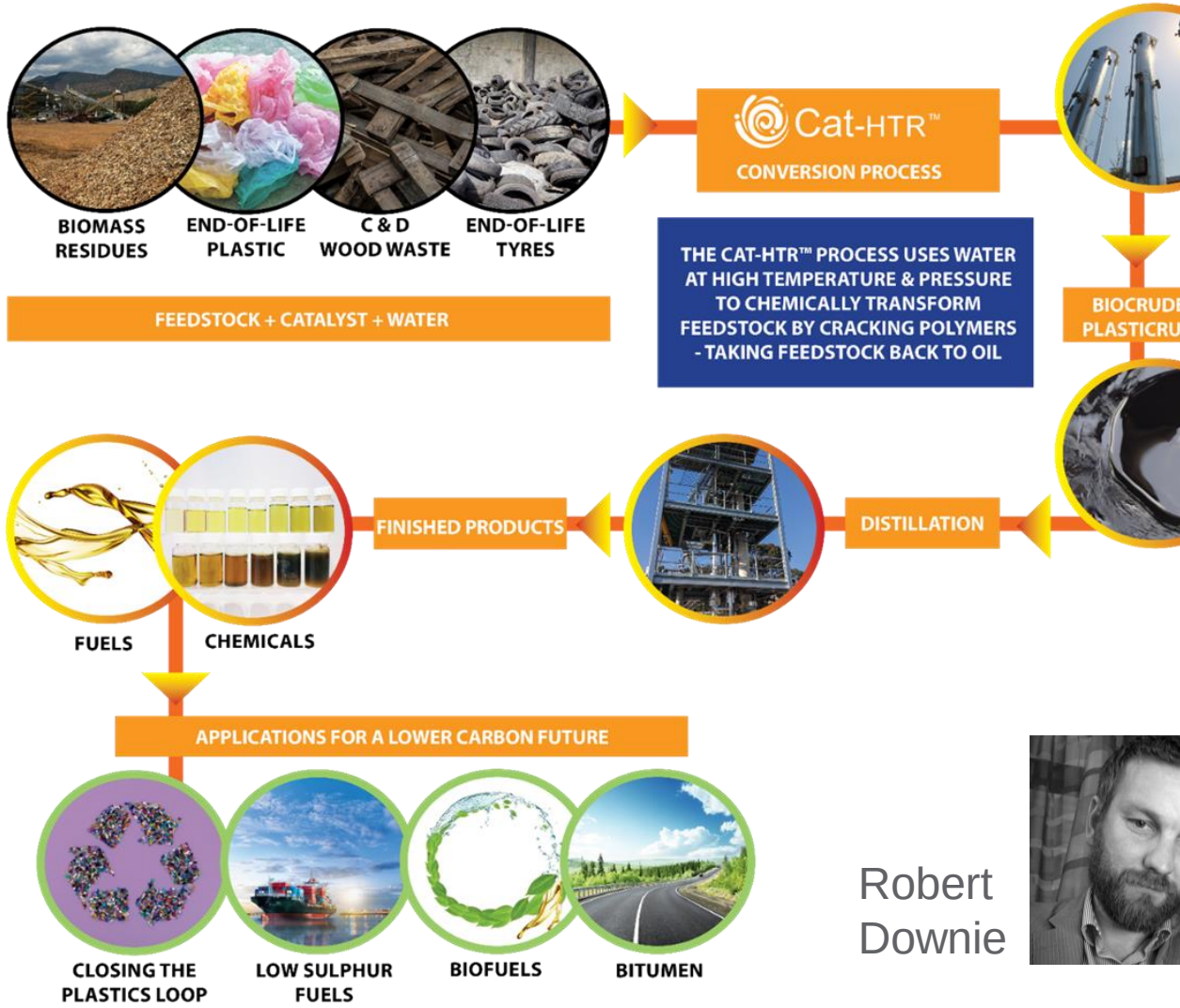
Licella catalytic HTL (Australia, UK and N. America) noted the importance of collaboration

Current focus

- End-of-Life Plastics in the UK with Mura
- Post consumer biomass in North America with Arbios.

Importance of collaboration

- access to large amounts of low-value feedstock without creating bidding wars
- Technology development companies and operational companies require different mindsets.
- Allows for synergies as each company can focus on their core competencies.



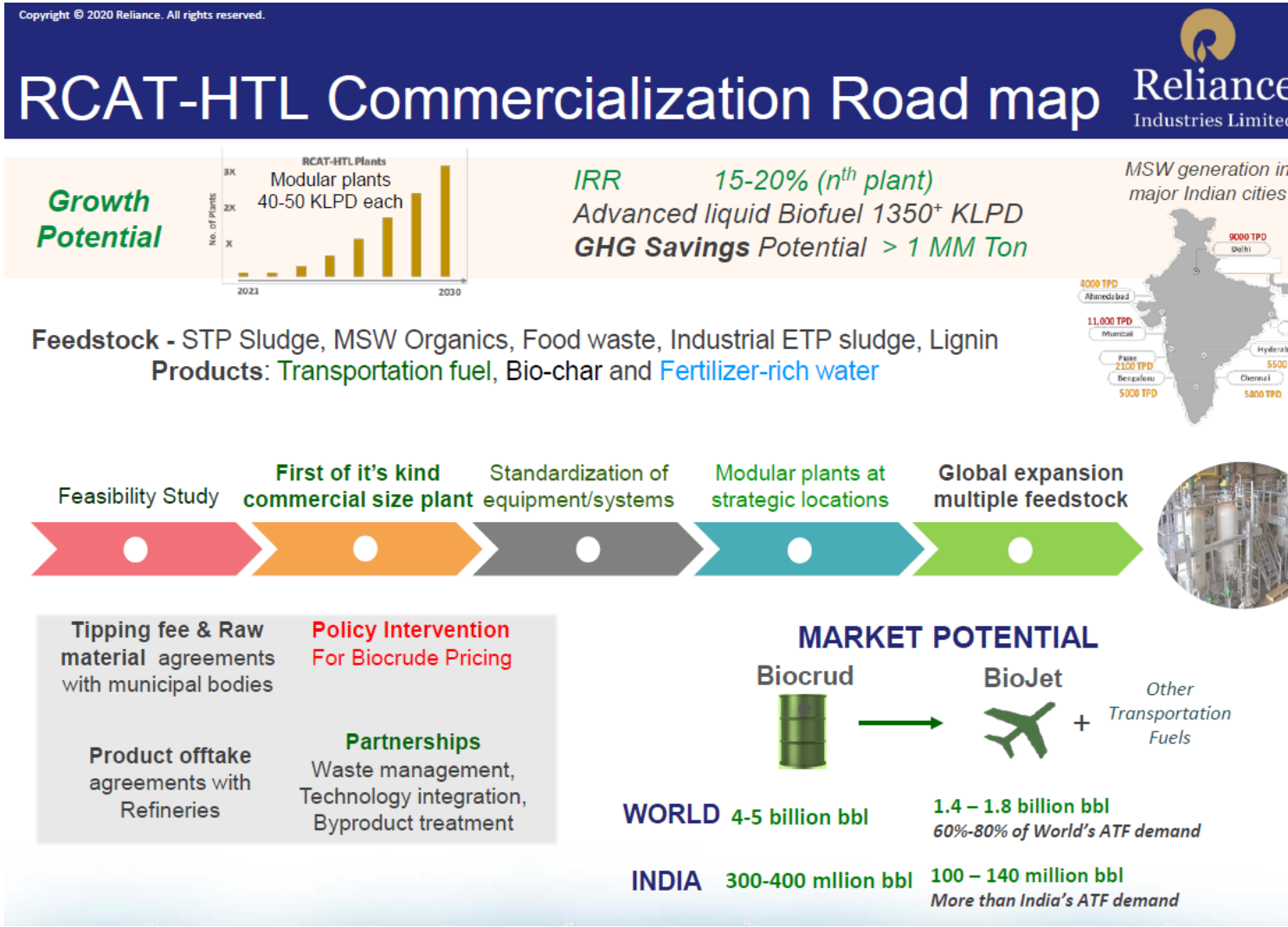
Robert Downie

Reliance (India) point at the need to demonstrate robustness at scale to reduce risk

Next Steps

- Technology and Engineering robustness *at scale*
- Roadmap for Economical viability
- Investor confidence in building "First of it's kind" precommercial plant

Ramesh Bhujade



Resource: https://ec.europa.eu/energy/sites/ener/files/documents/24._ramesh_bhujade_rileu_indiab2b-_rcat-htl02mar2020.pdf

RE-CORD (Politecnico di Torino) notes the need for co-liquefaction as well as co-refing

Co-Liquefaction

- Enhanced feedstock availability

Water management

- Recycle, Cat HTG, AD, H_2 production

Co-refining

- Stabilization + HDO + co-refining), but less oxygenated crude

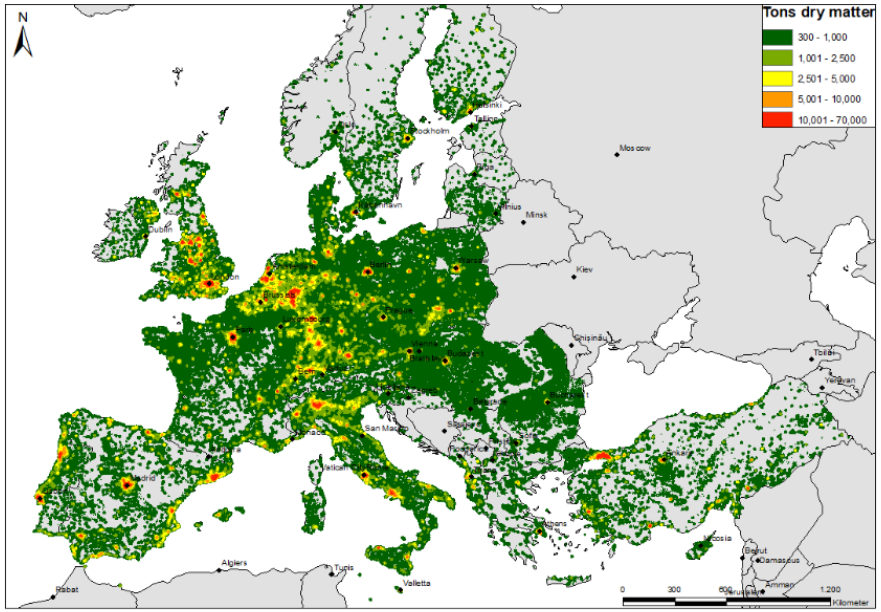
Biocrude sCO_2 fractionation

- extraction yields above 50%, low water and metal content, reduced acidity, moderate oxygen content reduction.

David Chiaramonti

HyFlexFuel note, among other things the need for understanding feedstock supply chain and valorization

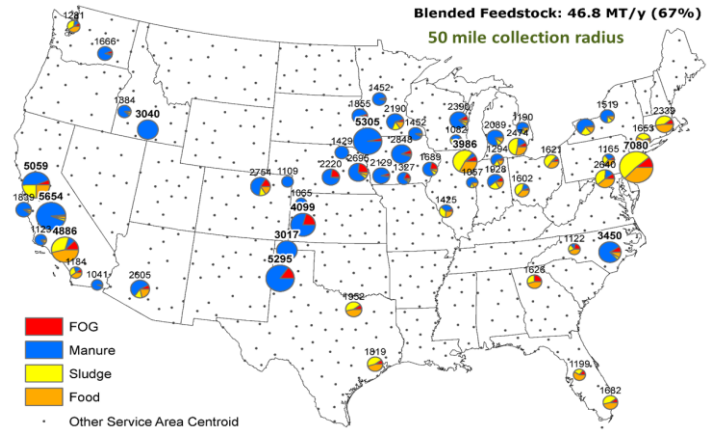
- Spatial analysis of residue and waste availability in Europe
- Feedstock density maps
- Energetic valorization of aqueous phase
- Nutrient recovery (phosphates)



Valentin Batteiger

PNNL notes the importance of blends (urban and rural), as well as increasing catalyst life in upgrading

- Address capital
  50% of capital cost is in heat exchangers—big opportunity
- Feedstock
  blends based on different regions
- Co-refining
  refiners question using feed with the N-content of biocrude
- Upgrading
  greatly improved catalyst life (untreated biocrude)
- Improved HTL efficiency and hydrotreater catalyst life
- Blending and co-processing



Feedstock blends (50 mi radiu

- **Urban wet waste compositi**

40% food / 50% sludge / 10% FO

- **Rural wet waste compositic**

50% Manure / 20% food / 25% sludge / 5% FOG

Upgrading

- **Major strides in biocrude upgrading**
- **Hydrothermal gasification remains a challenge**

Summarizing R&D gaps

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Materials

Feedstocks
- Waste Sludge
- Sewage
- Manure

Intermediates
- Biocrude
- Aqueous
- Gases
- Solids

Final products
- SAF
- Marine
- Diesel

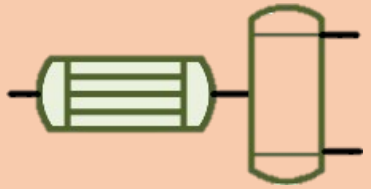
Sustainability
- Social
- Environmental
- Economic

Research areas

Sourcing, transporting & formatting

Liquefaction

Upgrading & refining



Value added

Major* R&D gaps

- feedstock availability
- feedstock blending
- water management
- large scale pumping

- time on stream
- heat exchanger
- scale/modularization
- higher liquid yields

- N and O removal
- Fe and mineral removal
- catalyst life
- ASTM specification

- nutrient recovery
- water clean up
- avoiding landfill
- eliminate pathogens

* Not full list of gaps