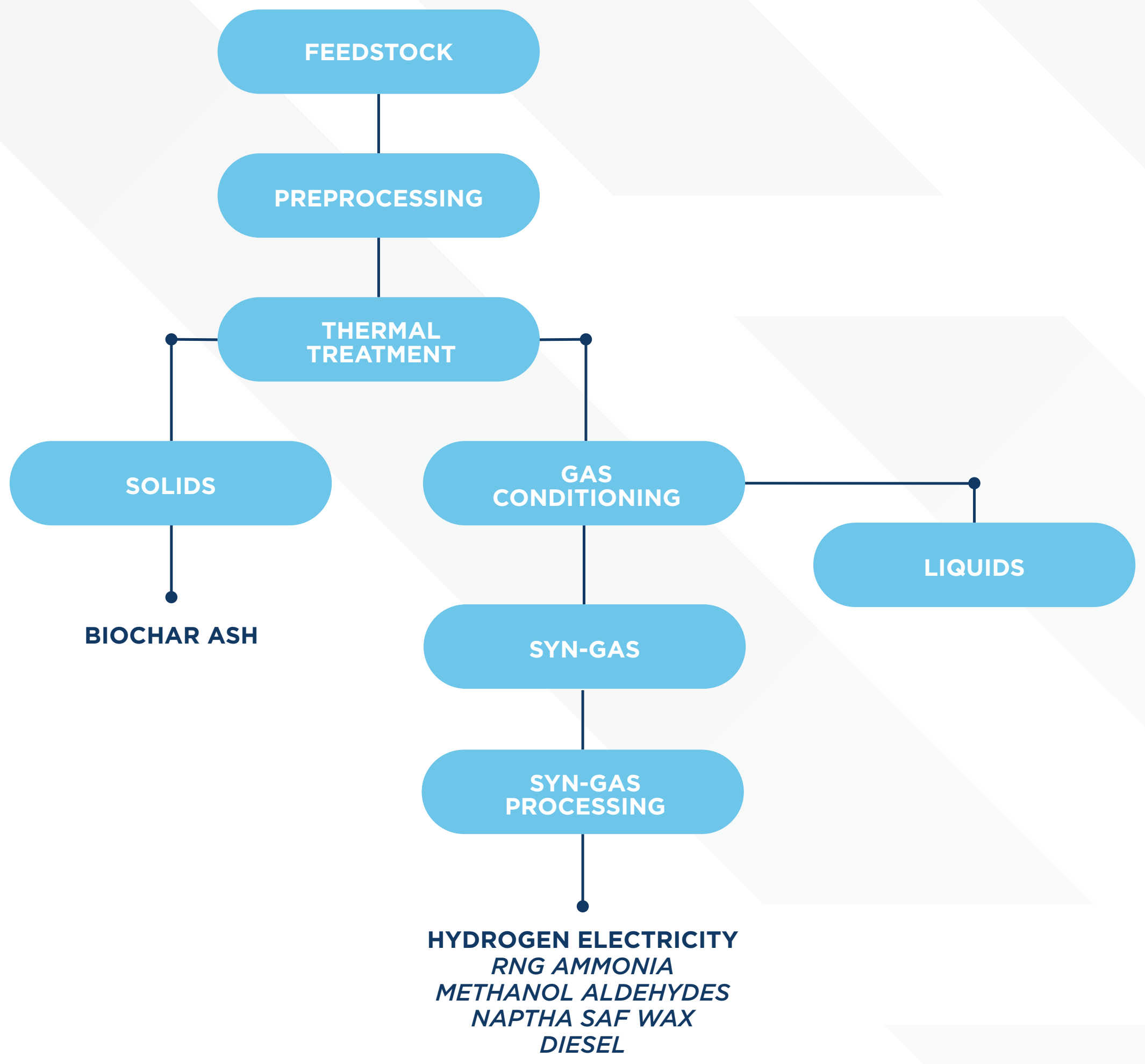
BURNS McDONNELL

IS THERMAL ENERGY WASTE PROCESSING THE NEXT STEP IN WASTE TREATMENT?

What is Thermal Waste Processing?

- Utilizing thermal energy to break down feedstocks into new forms for processing into value-added products
- Feedstock $\xrightarrow{\text{HEAT}}$ Volatiles + Char
- Application of heat to treat and decompose waste materials through different approaches


FEEDSTOCK
PREPROCESSING
THERMAL TREATMENT
SOLIDS
GAS CONDITIONING
LIQUIDS
BIOCHAR ASH
SYN-GAS
SYN-GAS PROCESSING
HYDROGEN ELECTRICITY
RNG AMMONIA
METHANOL ALDEHYDES
NAPTHA SAF WAX
DIESEL

Types of Thermal Waste Processing

HEAT

Incineration (800˚C-1200˚C)

- Forced air with flame touching the feedstock
- Full feedstock decomposition to mineralized solid products (ash)
- Produces: Low solids (ash)

Gasification (800˚C-1200˚C)

- Oxygen is minimally introduced into the feedstock environment to facilitate decomposition
- Flame does not touch the feedstock
- Produced: high syngas, some solids and low liquids

CHAR

Pyrolysis (350˚C-600˚C)

- Absence of oxygen and/or inert environment
- Flame does not touch the feedstock
- Produces: some syngas, some solids (char) and high liquids (tars/pyro oils)

Torrefaction (200˚C-350˚C)

- Absence of oxygen and/or inert environment
- Flame does not touch the feedstock
- Produces: low syngas, high solids (char) and some liquids (tars/pyro oils)

Kinetic and Thermodynamic Foundation

Degree of Conversion:

$$\alpha = \frac{m_0 - m_t}{m_0 - m_f} \text{ x } 100\%$$

First Order Reaction Kinetic Equation:

$$\frac{d\alpha}{dt} = k \cdot f(\alpha)$$

Arrhenius Equation:

$$\ln k = \ln A - \frac{E_a}{RT}$$

Heating Rate:

$$\beta = \frac{dT}{dt}$$

General Equation

$$(\alpha) = \int_0^{\alpha} \frac{d\alpha}{f(\alpha)} = \frac{A}{\beta} \int_{T_0}^{T} e^{\frac{-E_a}{RT}} dT$$

Iso-Conversional Method Equation:

$$\text{`}\ln\left[\beta_i \left(\frac{d\alpha}{dT}\right)_{\alpha,i}\right] = \ln[f(\alpha) \cdot A_\alpha] - \frac{E_\alpha}{RT_{\alpha,i}}$$

Pre-Exponential Factor:

$$A = \beta \cdot E_a \cdot e^{\left(\frac{E_a}{RT}\right)\big/_{RT^2}}$$

Change in Enthalpy:

$$\Delta H = E_a - RT_\alpha$$

Gibbs Free Energy:

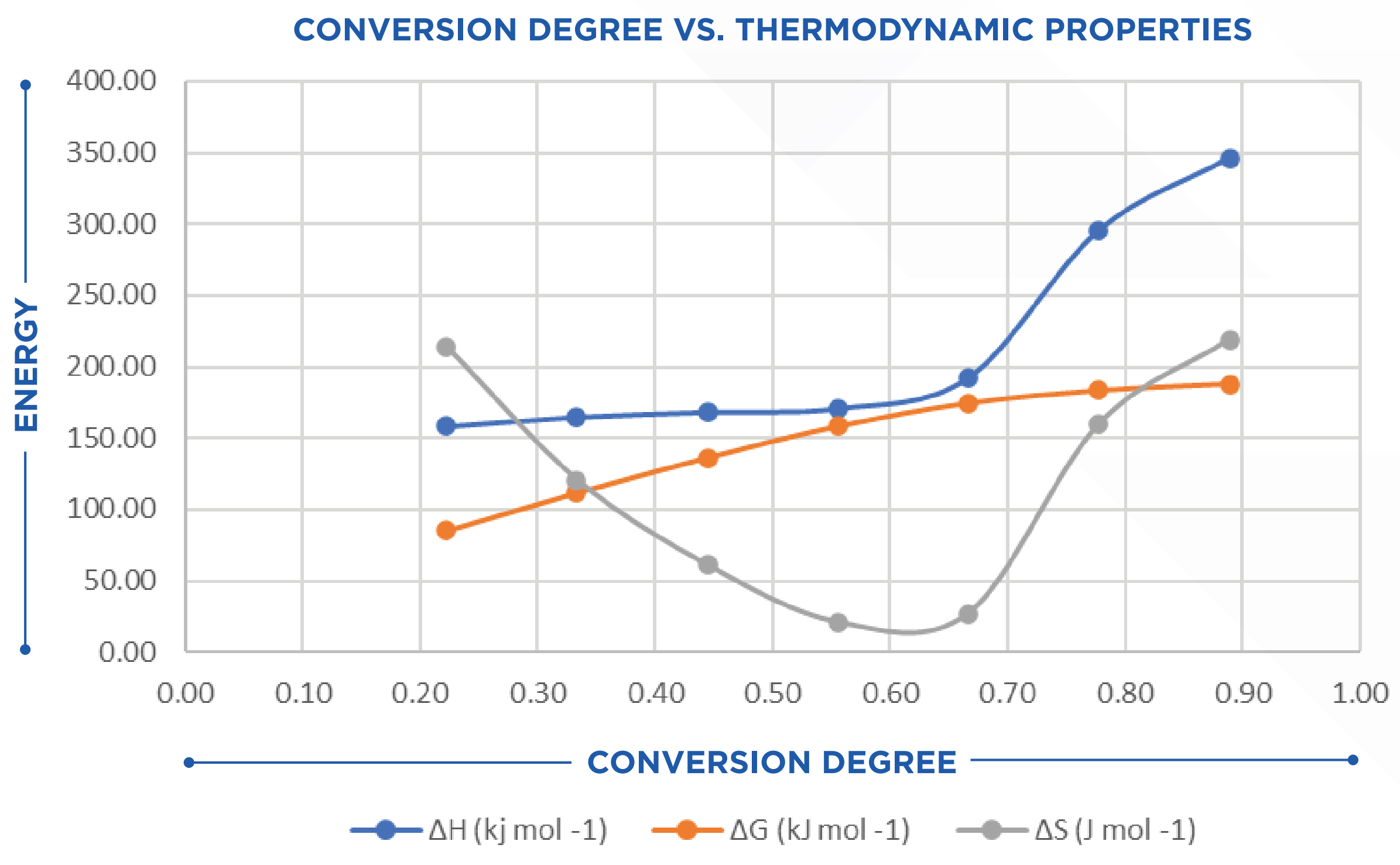
$$\Delta G = E_a + RT \cdot ln\frac{K_B \cdot T}{h \cdot A}$$

Entropy:

$$\Delta S = \frac{\Delta H - \Delta G}{T}$$

Kinetic Equation: Rate of Mass loss per unit volume:

$$-r_m = \frac{dm}{dt} = k_m(m_t - m_f)^n$$


CONVERSION DEGREE VS. THERMODYNAMIC PROPERTIES

Emerging Opportunities — Feedstock

Feedstocks without a viable disposal pathway

Agricultural wastes

- Anaerobic digestate
- Manures
- Nut shells

Woody biomass and wastes

- Forest slash
- Orchard trimmings

End of life batteries

- Cobalt
- Lithium recovery

Residential and industrial waste streams

- End of life plastics
- Municipal solid waste
- Plastics Types 3-7
  - Consumer plastics
  - Flexible packing
  - Plastic beverage cups
  - Plastic film
  - Styrofoam

Emerging Opportunities — Feedstock

- Fossil fuel utilization avoidance
- Production of renewable power, heat, fuels, chemicals from syn-gas
  - Conversion of otherwise disposed of carbon into a valuable product or material
  - Syn-gas conversion into carbon-negative fuels
    - Sustainable aviation fuel (SAF)
- Biochar
  - Carbonized waste biomass

What Will it Take to Get There?

- State and federal incentives
  - Long-term planning
- Economic syn-gas conditioning technologies
- Pathways for thermal liquids conversion/use
- Syn-gas conversion technologies
  - Reach beyond GSHV methane reforming and
  - Fischer-Tropsch process
- Solid byproducts (Biochar) market development