Process Model for Carbon Nanomaterials Production from Plastic Waste Using Agro/Animal Waste

PRESENTED BY : AYUSHI SINGH

Dual waste valorization: Plastic + Biomass → CNMs

INTRODUCTION AND THE CRITICAL PROBLEM

Why This Project Matters?
this project addresses two major global challenges simultaneously:
Plastic Waste Challenge:

- 360 million tonnes/year global production
- Only 20% recycled, 55% landfilled, 25% incinerated
- Microplastic pollution, GHG emissions, landfill depletion

Biomass Waste Challenge:

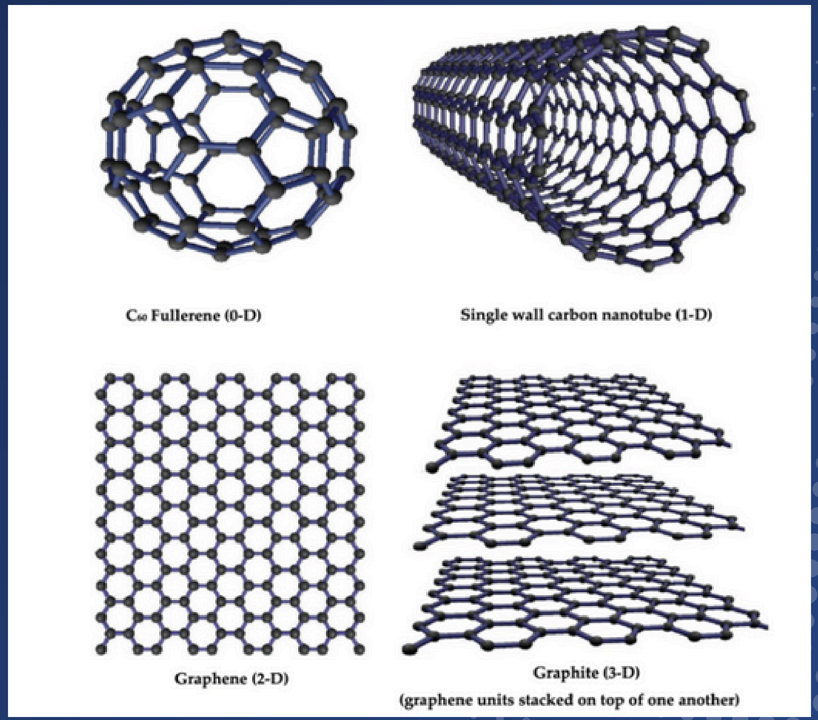
- >500 million tonnes/year in India alone
- Often burned openly → air pollution
- Wasted resource potential

Market Opportunity

- Carbon nanomaterials market projected to reach $9.8 billion by 2028
- Traditional CNM production relies on fossil fuels and expensive metal catalysts
- High energy consumption and significant CO_2 emissions

Our Solution: Transform waste into wealth by creating a circular economy pathway that simultaneously solves waste management problems and produces high-value advanced materials.

Turn Waste into Value!



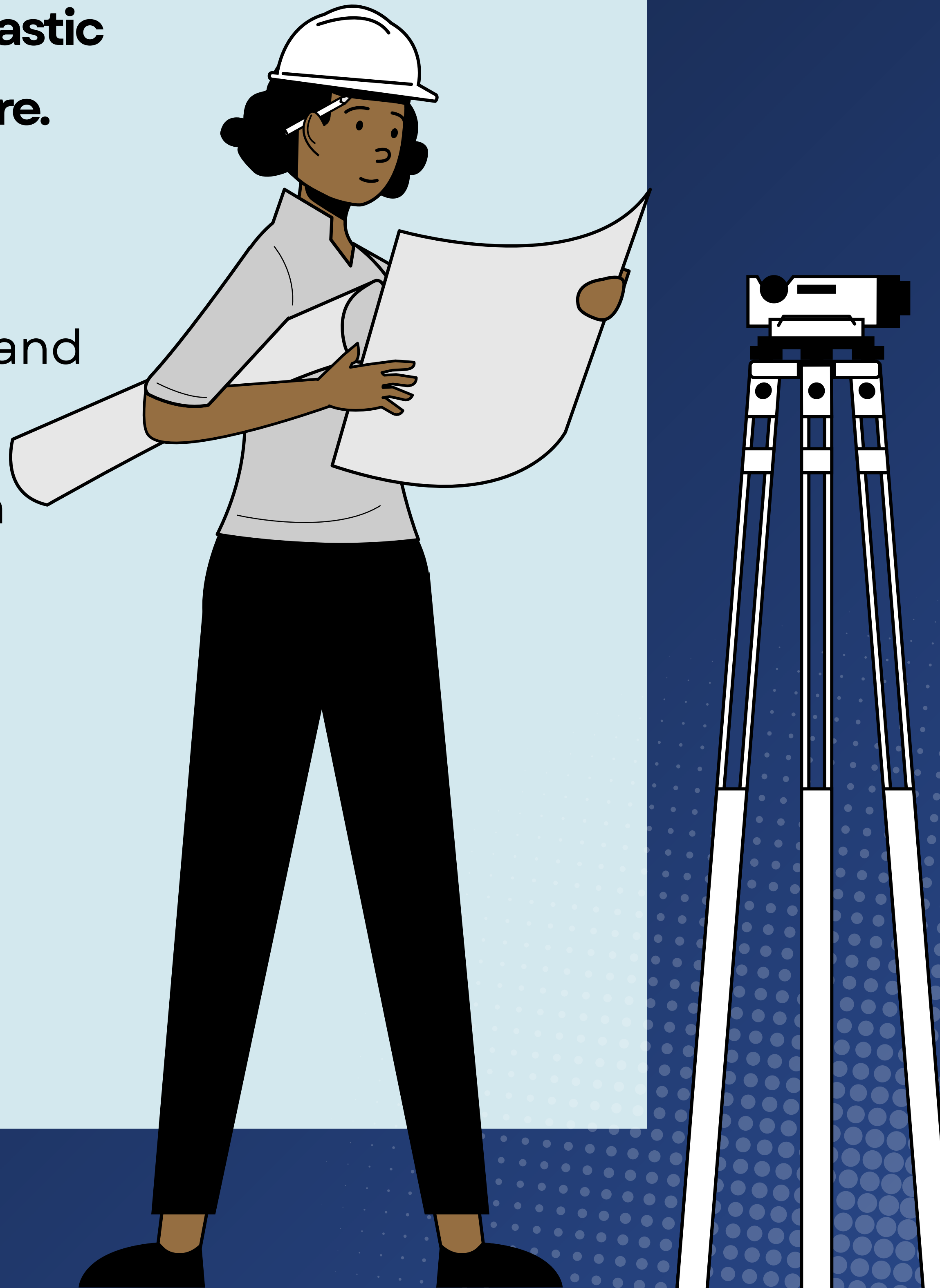
PROJECT OBJECTIVES

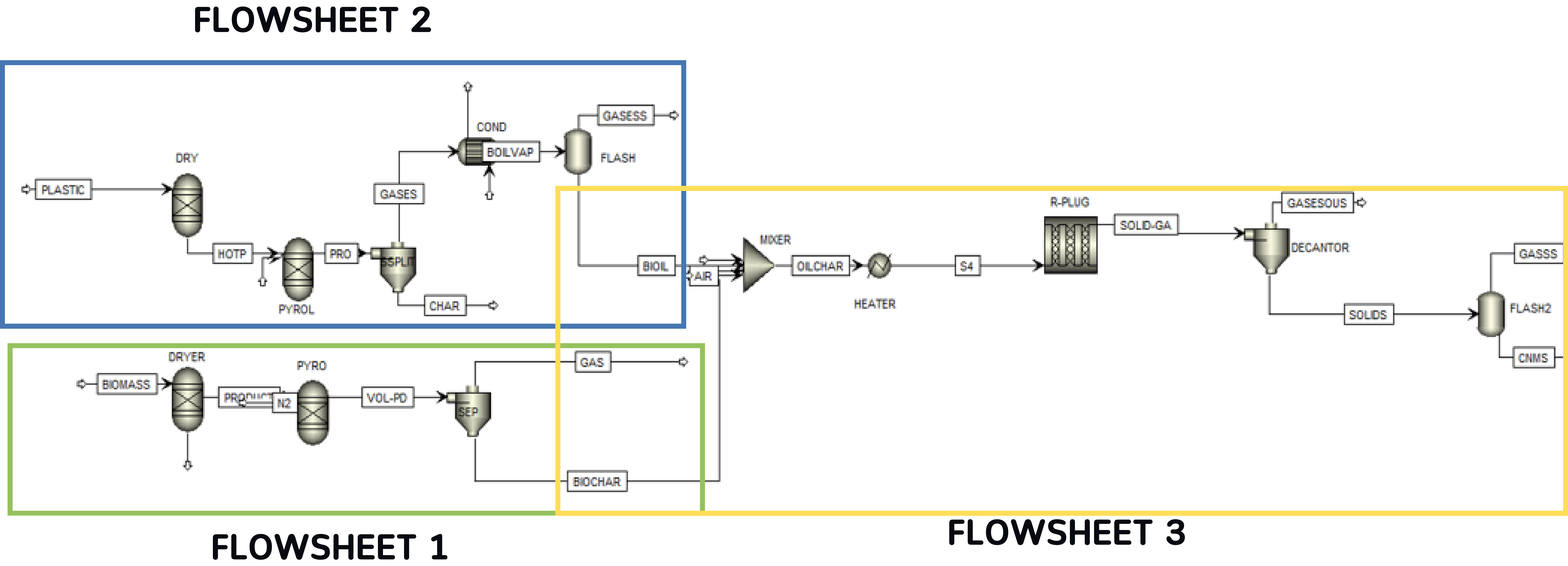
Primary Goal: Develop and simulate a comprehensive process model for converting plastic waste and biomass into carbon nanomaterials using Aspen Plus V14 simulation software.

The primary objectives of this project are:

Specific Objectives:

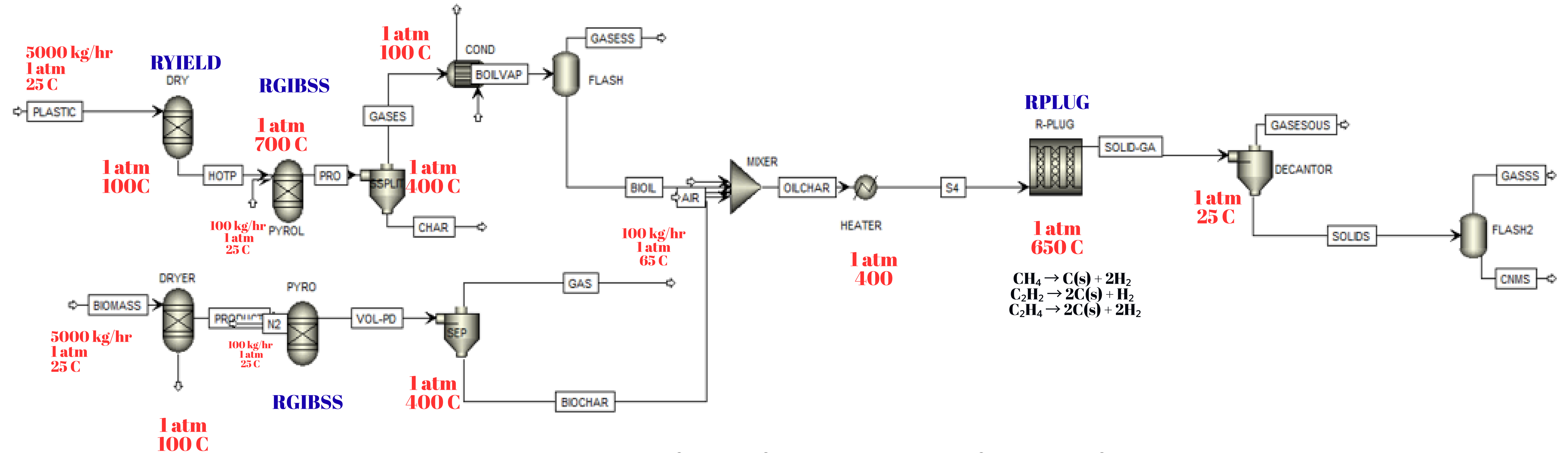
1. Create an integrated process combining plastic pyrolysis (bio-oil source) and biomass pyrolysis (biochar catalyst)
2. Model the complete system with thermodynamic equilibrium and reaction kinetics
3. Design appropriate reactors and separation units
4. Evaluate technical feasibility, product yields, and conversion efficiencies
5. Assess environmental benefits and economic viability
6. Demonstrate carbon capture and greenhouse gas reduction potenti





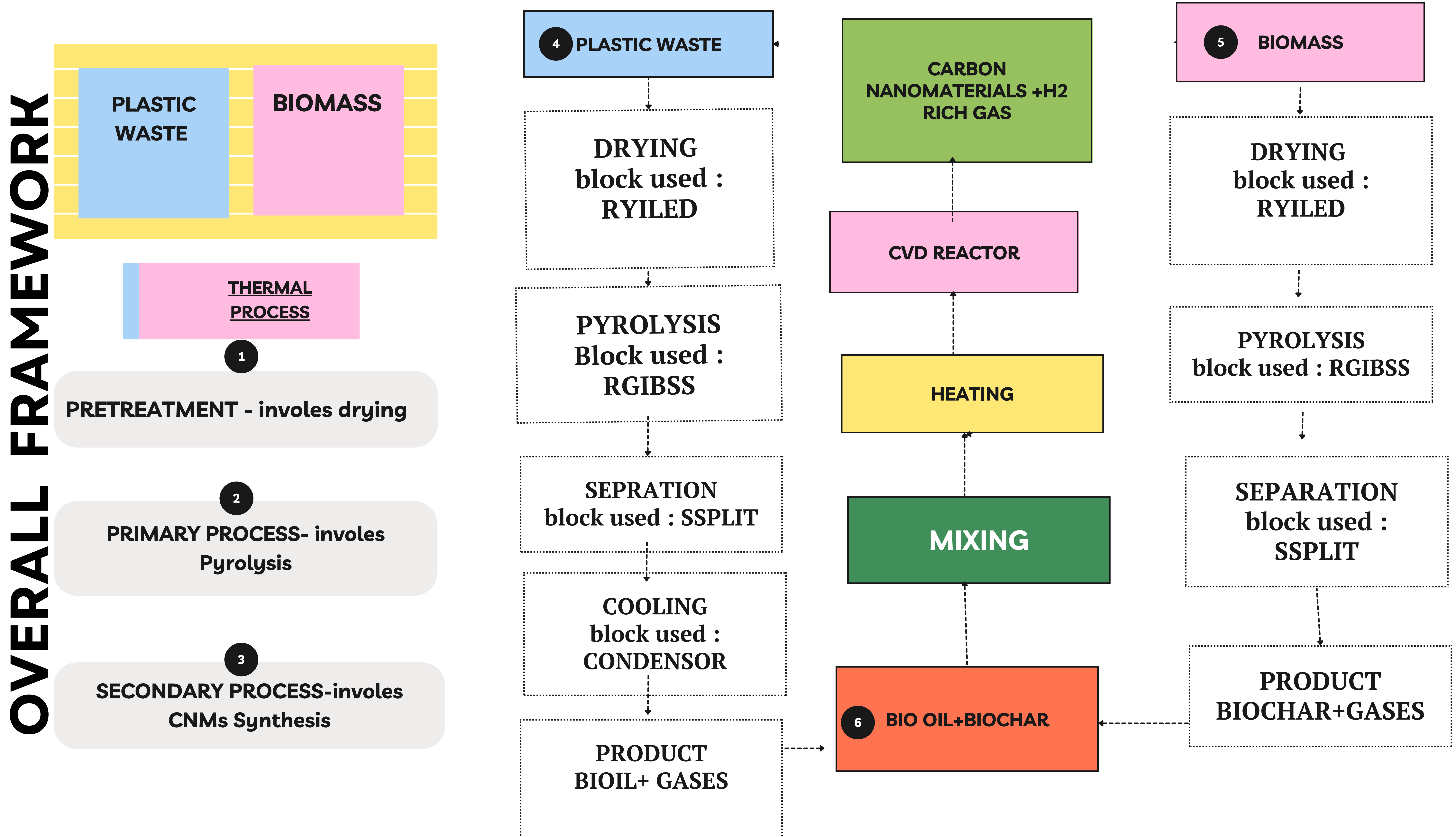
FLOWSHEET 2
PLASTIC
DRY
HOTP
PYROL
PRO
SSPLIT
GASES
COND
BOILVAP
FLASH
GASESS
CHAR
BIOIL
AIR
MIXER
OILCHAR
HEATER
S4
R-PLUG
SOLID-GA
GASESOUS
DECANTOR
SOLIDS
FLASH2
GASSS
CNMS
BIOMASS
DRYER
N2
PYRO
VOL-PD
SEP
GAS
BIOCHAR
FLOWSHEET 1
FLOWSHEET 3

STAGE 1: PRETREATMENT **STAGE 2: PRIMARY PROCESS PYROLYSIS** **STAGE 2: SECONDARY PROCES CNMS SYNTHESIS**

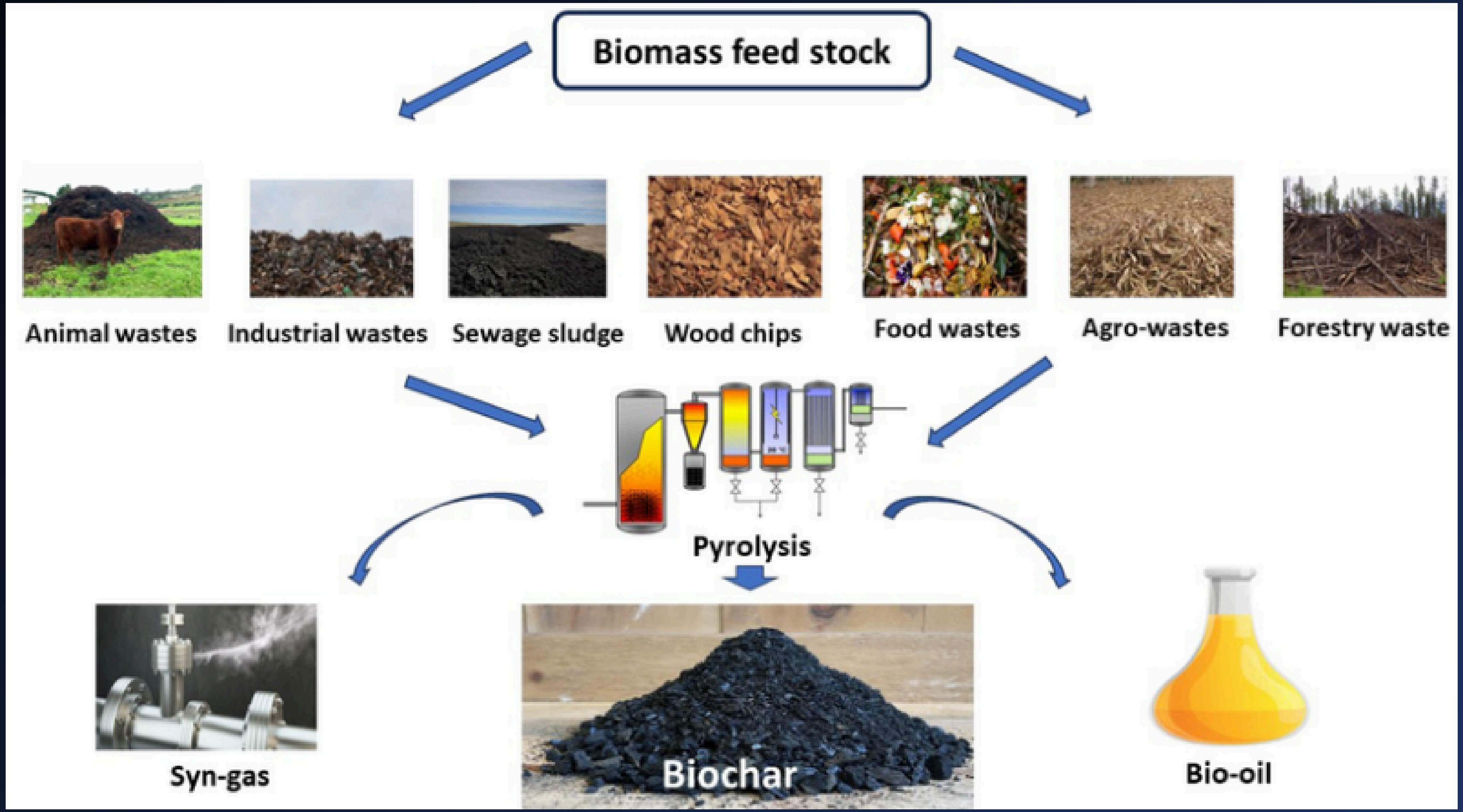


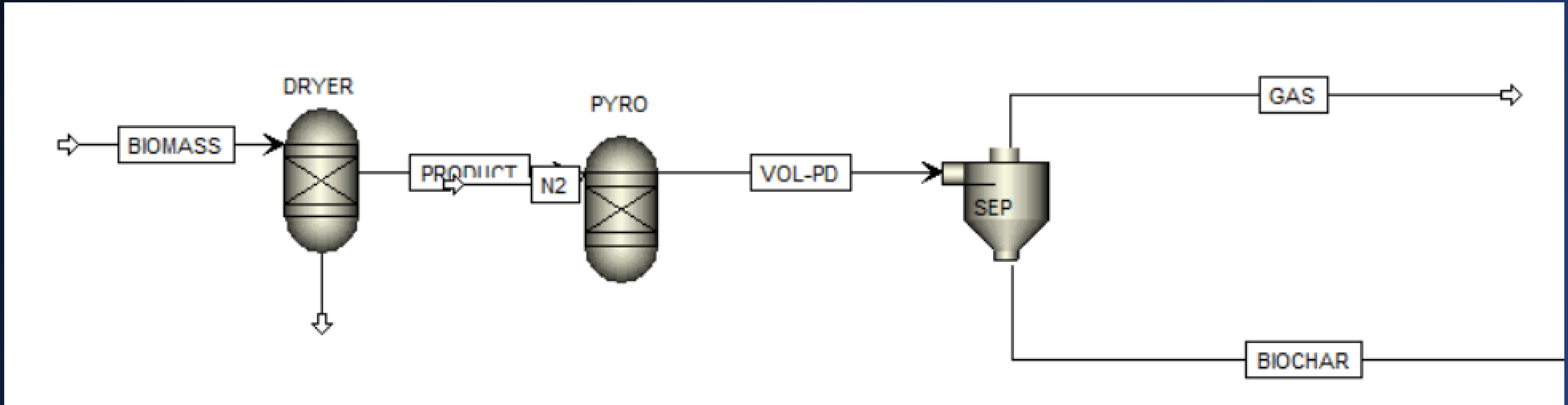
Dual waste valorization: Plastic + Biomass → CNMs

- RYIELD for non-stoichiometric decomposition,
- RGIBBS for equilibrium gas-phase reactions, and
- R-PLUG for catalytic plug flow deposition (CVD).
- This combination gives both realistic process behavior and computational stability in Aspen Plus.”


OVERALL FRAMEWORK
PLASTIC WASTE
BIOMASS
THERMAL PROCESS
1
PRETREATMENT - involes drying
2
PRIMARY PROCESS- involes Pyrolysis
3
SECONDARY PROCESS-involes CNMs Synthesis
4 PLASTIC WASTE
DRYING block used : RYILED
PYROLYSIS Block used : RGIBSS
SEPRATION block used : SSPLIT
COOLING block used : CONDENSOR
PRODUCT BIOIL+ GASES
CARBON NANOMATERIALS +H2 RICH GAS
CVD REACTOR
HEATING
MIXING
6 BIO OIL+BIOCHAR
5 BIOMASS
DRYING block used : RYILED
PYROLYSIS block used : RGIBSS
SEPARATION block used : SSPLIT
PRODUCT BIOCHAR+GASES

ASPEN PLUS SIMULATION FLOWSHEETBIOMASS TO BIO-CHAR





MY APPROCH

ASPEN PLUS SIMULATION FLOWSHEETBIOMASS TO BIO-CHAR

FEED TREATMENT

- **Feed:** Biomass (wood chips, crop residue, sawdust, etc.)
- **Reason:** Raw biomass contains high moisture, which reduces pyrolysis efficiency.
- **Action:** Feed composition (C, H, O, N, S, ash, moisture) defined via proximate/ultimate analysis.

PRETREATMENT
Block: DRY (RYIELD)

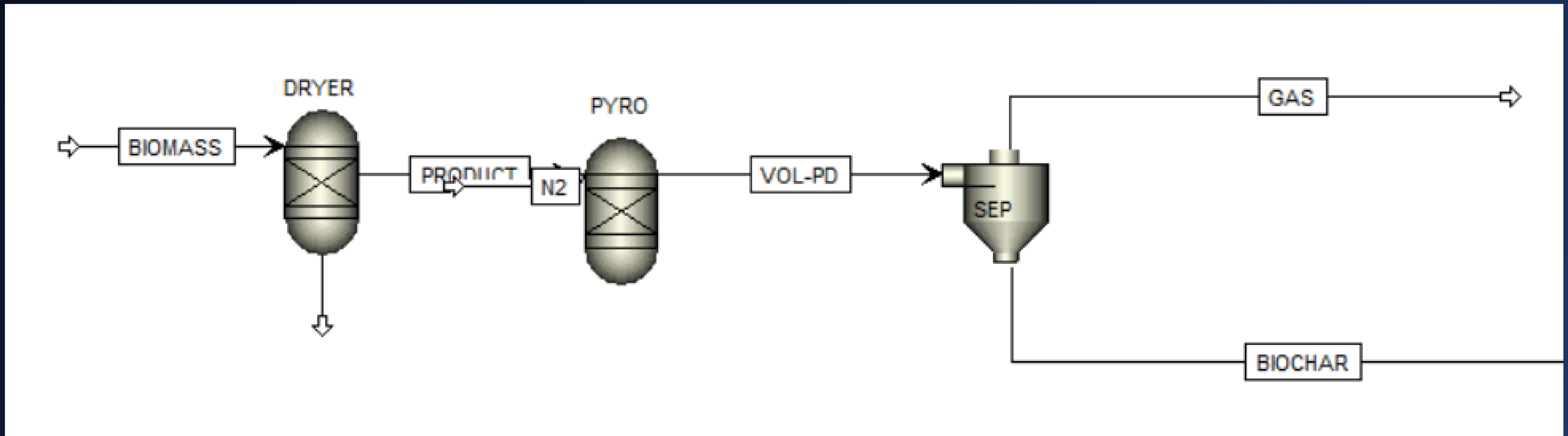
- **Purpose:** Removes moisture from biomass before pyrolysis.
- **Model Type: RYield reactor → converts moisture to vapor.**
- **Process:** Biomass is heated (100–150 °C) → water evaporates → dried biomass obtained.
- **Outputs:**
- **PRODUCT:** Dried biomass to pyrolysis unit
- **Vapor:** Moisture outlet
- **Reason:** Ensures better heat transfer and efficient decomposition during pyrolysis.

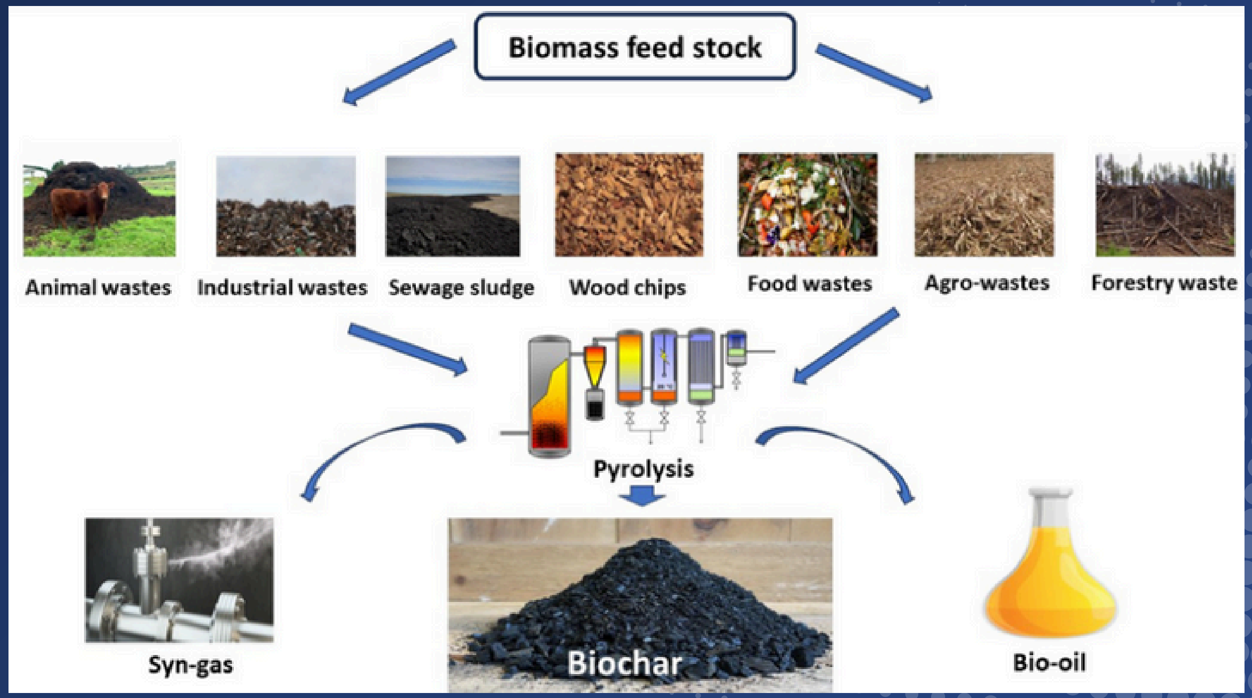
PYROLYSIS
Block: PYROL (RGIBBS)

- **Purpose:** Converts dried biomass into gases, vapors, and solid char.
- **Process**: At 500–700 °C under inert N_2, biomass decomposes thermochemically.
- Outputs:
- **VOL-PD:** Volatile gases, vapors, and biochar
- **Unreacted N_2:** Recycled or vented

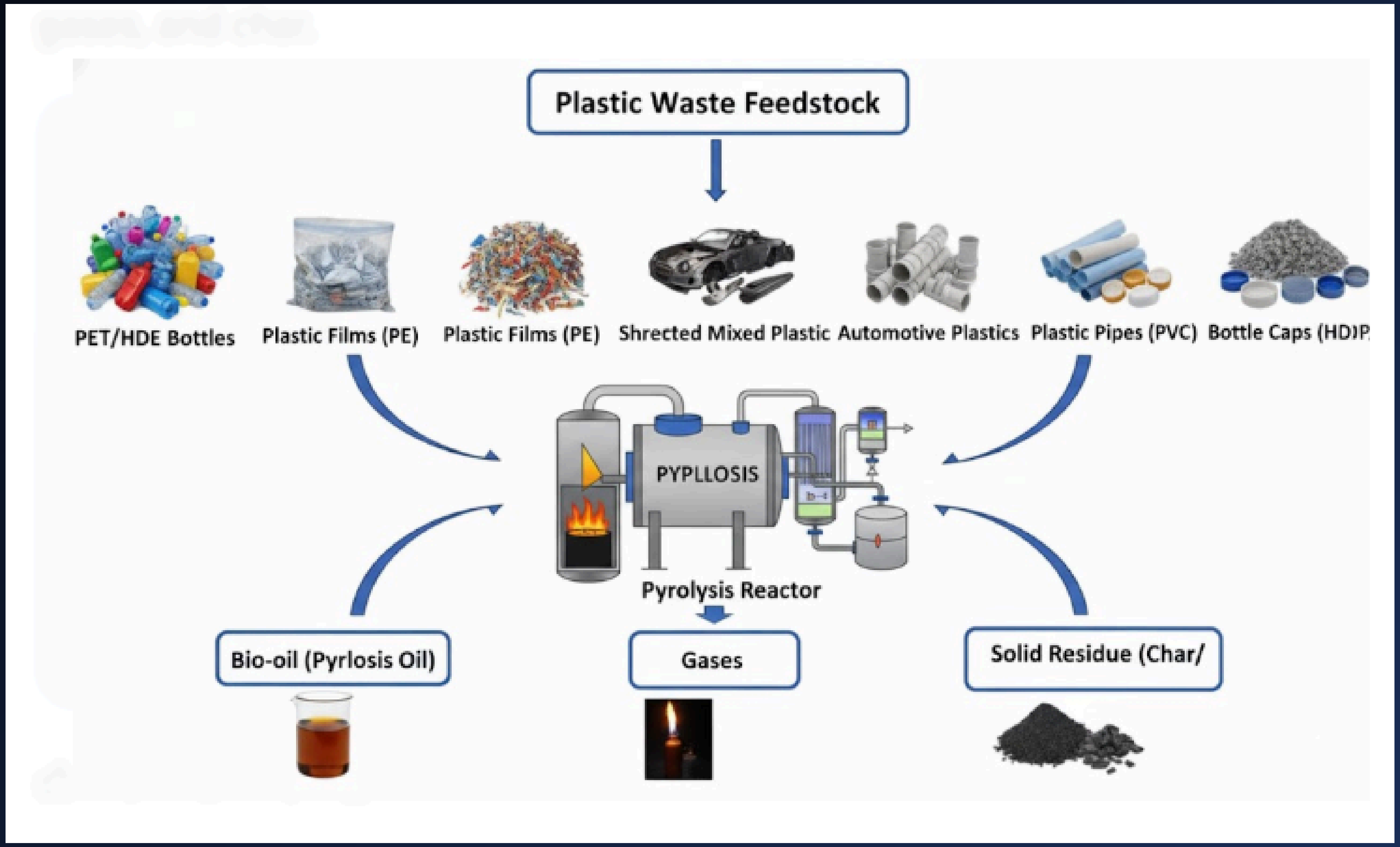
PRODUCT SECTION
Block Used: SEPRATOR

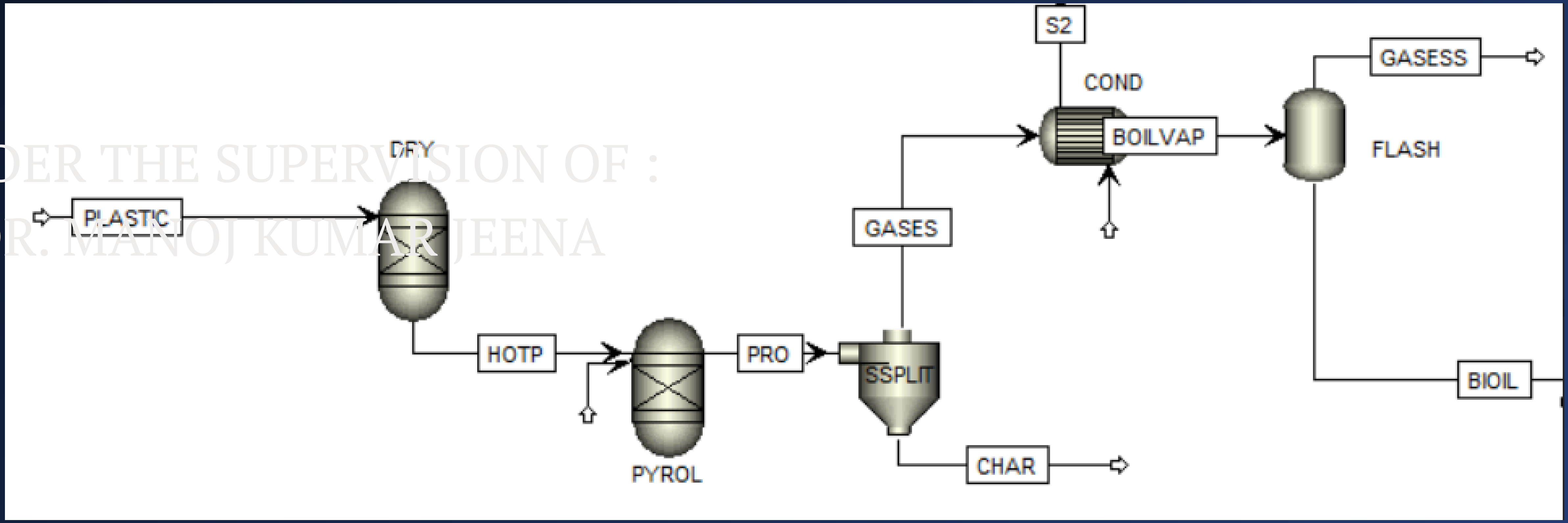
- **Purpose:** Separates solid biochar from volatile gases and vapors.
- **Process**: Based on phase/density difference – solids settle, vapors exit as gas stream.
- **Outputs:**
- **BIOCHAR:** Solid residue (carbon + ash)
- **GAS:** Light gases and condensable vapors





ASPEN PLUS SIMULATION FLOWSHEET PLASTIC WASTE TO BIO-OIL





UNDER THE SUPERVISION OF :
DR. MANOJ KUMAR JEENA

MY APPROACH

ASPEN PLUS SIMULATION FLOWSHEETBIOMASS TO BIO-CHAR

DRYING
Block: RYILED

- **Feed: Shredded plastic waste (PE, PP, PS, etc.)**
- **Block: DRY (RYIELD)**
- **Function: Removes moisture or surface water from plastic waste.**
- **Reason: Prevents steam generation and side reactions during pyrolysis; prepares a dry, clean feed for better decomposition efficiency.**
- **Output:**
- **HOTPT: Water vapor outlet**
- **Dried plastic: Sent to the pyrolysis reactor**

PYROLYSIS
Block: PYROL (RGIBBS)

- **Function:** Thermally decomposes dried plastic into smaller molecules (gas, vapor, and solid).
- **Reason**: Converts complex polymer chains into simpler hydrocarbons through thermal cracking; this is the main conversion step of the process.
- **Operating Range:** 400–800°C under inert N_2 atmosphere
- **Output Stream:** PRO → Mixed pyrolysis products

PRIMARY SECTION
Block Used: SSPLIT

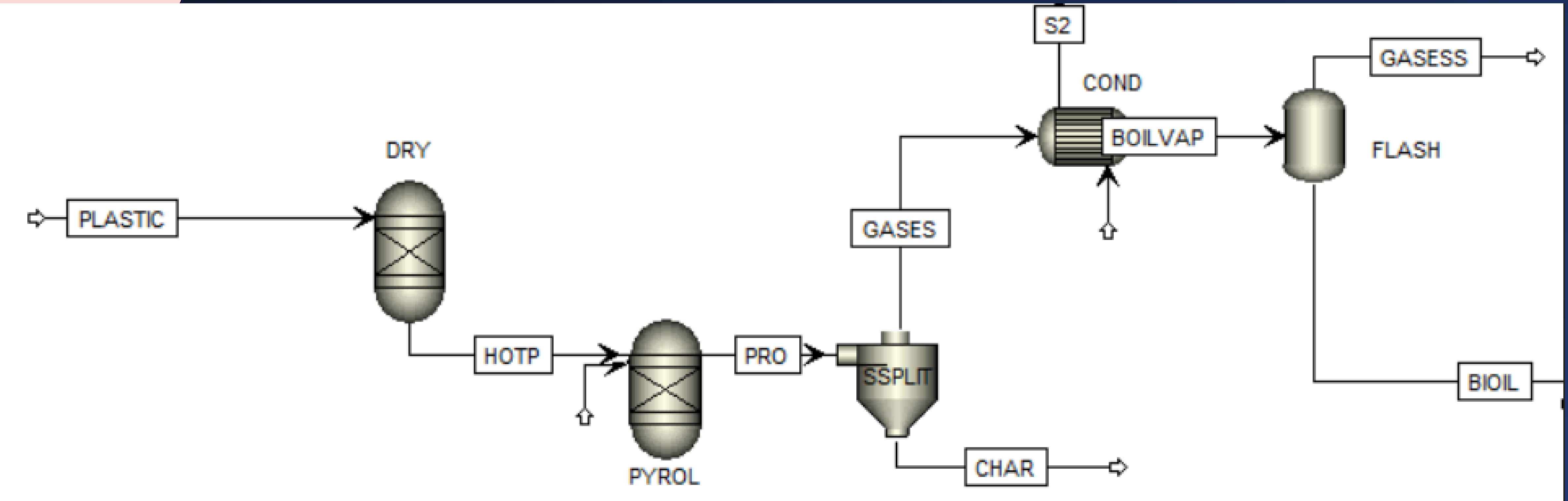
- **Function:** Splits product stream based on phase (gas, liquid, solid).
- **Reason:** Enables initial classification of outputs – separating solid char from volatile gas and vapor fractions for downstream purification.
- **Outputs:**
- **GASES:** Volatile components (H_2, CH_4, C_2H_4, etc.)
- **CHAR:** Solid carbon residue

SECONDARY SEPARATION
Block: CONDENSOR

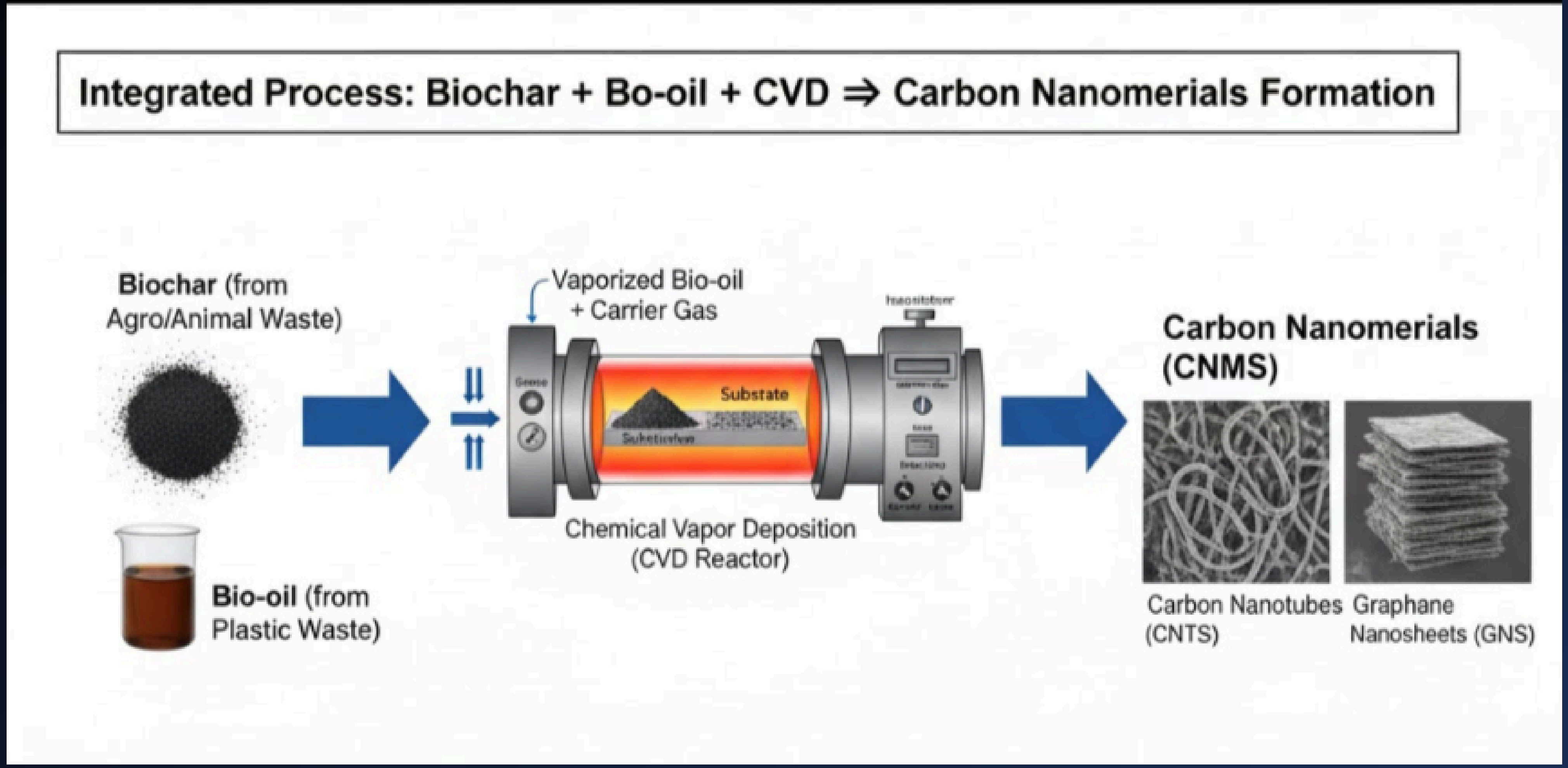
- **Function:** Cools gas–vapor mixture to condense heavier hydrocarbons.
- **Reason:** Separates bio-oil/wax (liquid) from non-condensable gases, improving product purity.
- **Outputs:**
- **COND:** Non-condensable gases
- **S2:** Cooling medium
-

PRODUCT SECTION
Block Used: FLASH

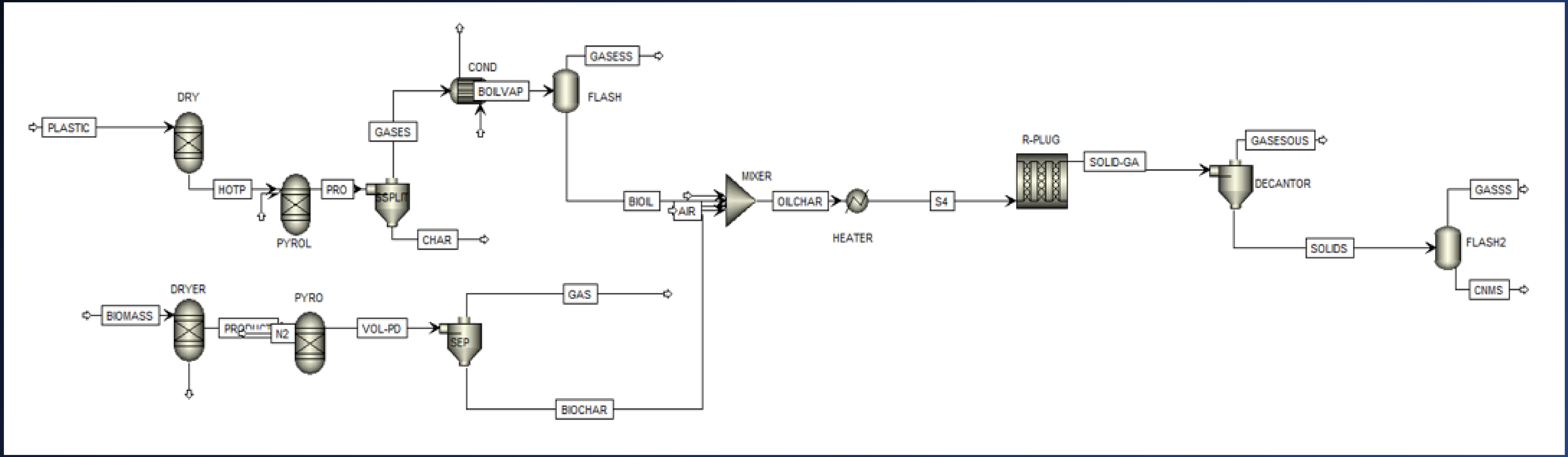
- **Function:** Final vapor–liquid separation under controlled temperature and pressure.
- **Reason:** Ensures complete phase split between fuel gas (GASESS) and bio-oil (BIOIL), refining product recovery.
- **Outputs:**
- **GASESS:** Final gas (H_2, CH_4, C_2H_4, CO)
- **BIOIL:** Liquid fuel/wax product



INTEGRATED COMPLETE FLOWSHEET



MY APPROACH



INTEGRATING THE WHOLE PROCESS

MIXER

- **What:**
  Homogenizes bio-oil + biochar + air into one feed (S4).
- **Why:**
- Ensures uniform composition and proper contact for downstream reaction.

HEATER

- **What:**
  Preheats mixed feed to reaction temperature (650–800 °C) in N_2.
- **Why:**
  Activates biochar surface and cracks volatiles into reactive gases.

R-PLUG

- **What:**
- Catalytic decomposition of hydrocarbons; carbon deposits on biochar → CNMs.
- **Why:**
- Main synthesis zone – converts gas-phase hydrocarbons into nanocarbon structures.

DECANTER

- **What**
- Cools and separates solid CNM_laden material from gases.
- **Why:**
- Recovers solid product for purification and removes bulk vapors.

B9 Cyclone

- **What**
- Gas-solid separation by centrifugal force; solids collected, gases exit
- **Why:**
- Efficiently isolates CNMs from off-gas for final recovery and gas recycling.

OUTPUTS (VERY SHORT):
CNM_SOLID: BIOCHAR + DEPOSITED NANOCARBON → SENT FOR PURIFICATION.
CNM_GAS / GASESQU: H_2/CO/CO_2/CH_4 – RECYCLED OR USED FOR ENERGY.

KEY RESULTS

1. Successful Dual Waste Conversion

Integrated plastic waste (20-30% bio-oil) + biomass waste (20-35% biochar)

Addresses 3.5 million tonnes plastic + 500 million tonnes agro waste (India)

2. High CNM Production Performance

Methane conversion: 40-70%

Carbon deposition: 9.4-15.6 $mg \cdot h^{-1} \cdot g^{-1}$catalyst

CNM yield: 20-25% of reactor output

3. Valuable Co-Products Generated

H_2-rich syngas (75-80%) - energy/fuel use

Upgraded bio-oil - reduced PAHs

All products commercially viable

4. Cost-Effective Catalyst

Biochar replaces expensive metal catalysts (Ni, Co, Fe)

Enhanced stability from crystalline carbon growth

Surface area: 100-500 m^2/g

5. Optimized Process Conditions

Temperature: 650-800°C optimal

Energy self-sufficient (autothermal)

Validated Aspen Plus V14 simulation

Key Performance Results

Methane Conversion

40-70%

Varies with temperature & residence time

Carbon Deposition

9.4-15.6

$mg \cdot h^{-1} \cdot g^{-1}$ catalyst

Product Distribution

CNM Reactor Output:

- Solids (CNMs): **20-25%**
- H_2-rich gas: **75-80%**

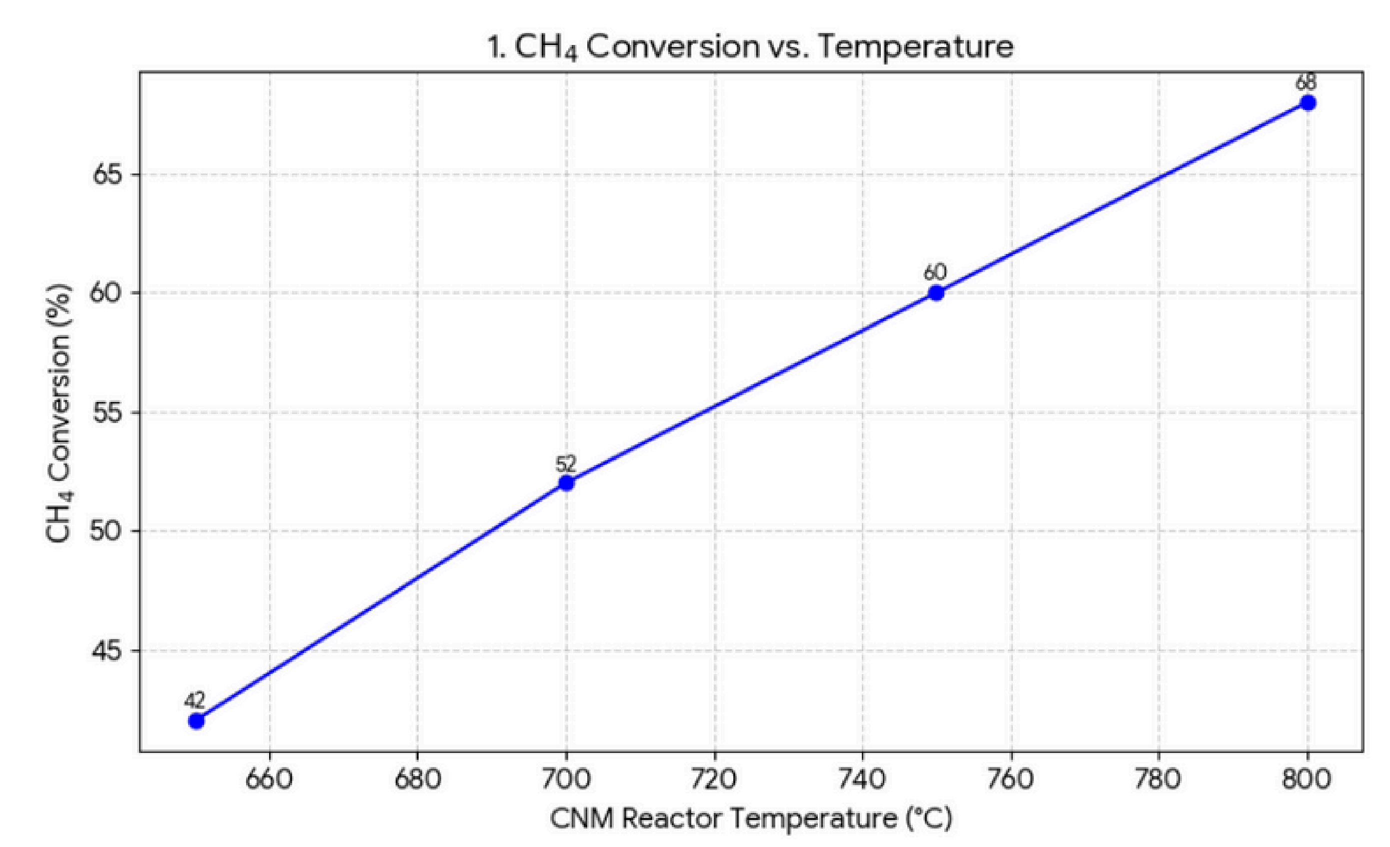
Additional Products:

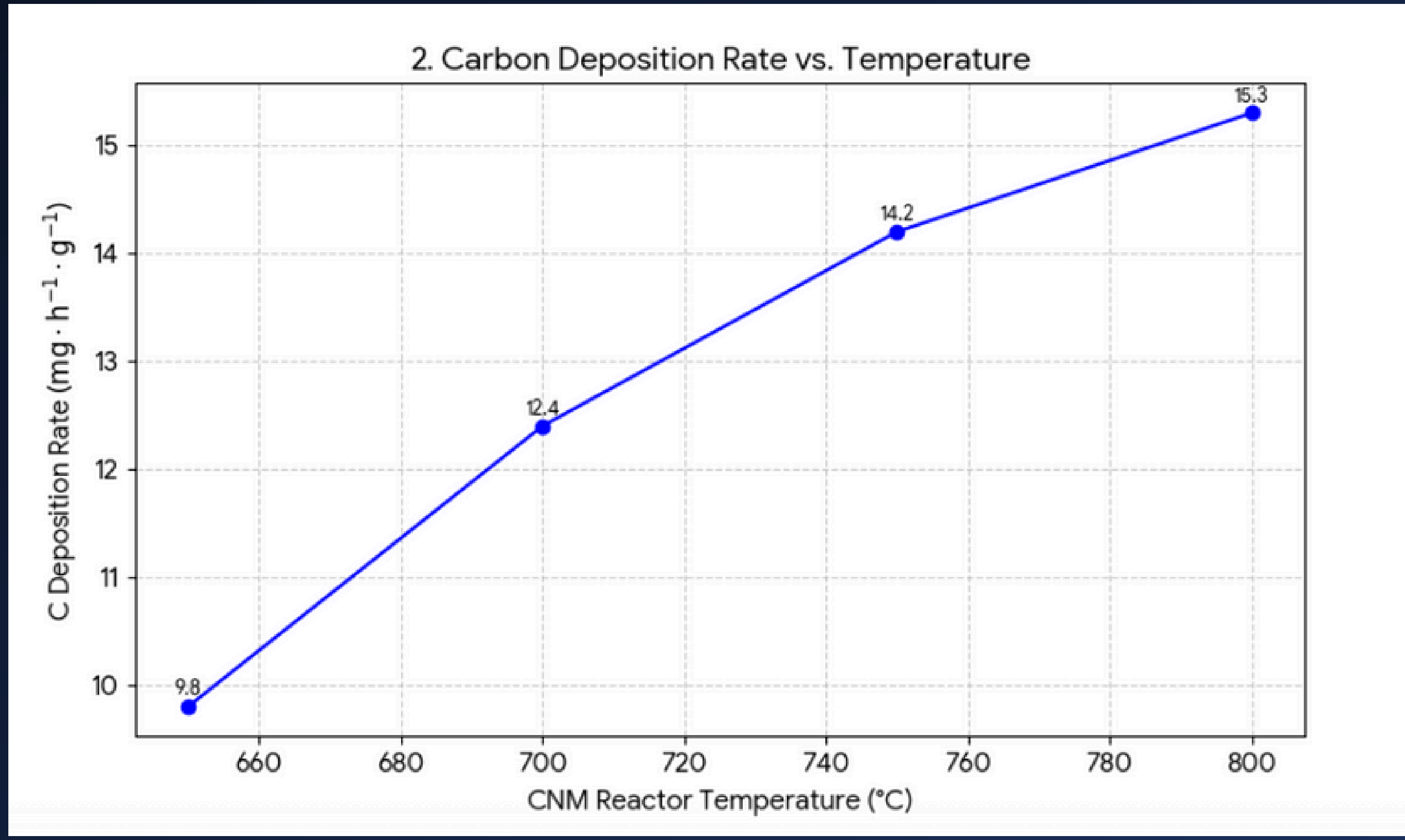
- Improved bio-oil (lower PAHs)
- Syngas for energy recovery

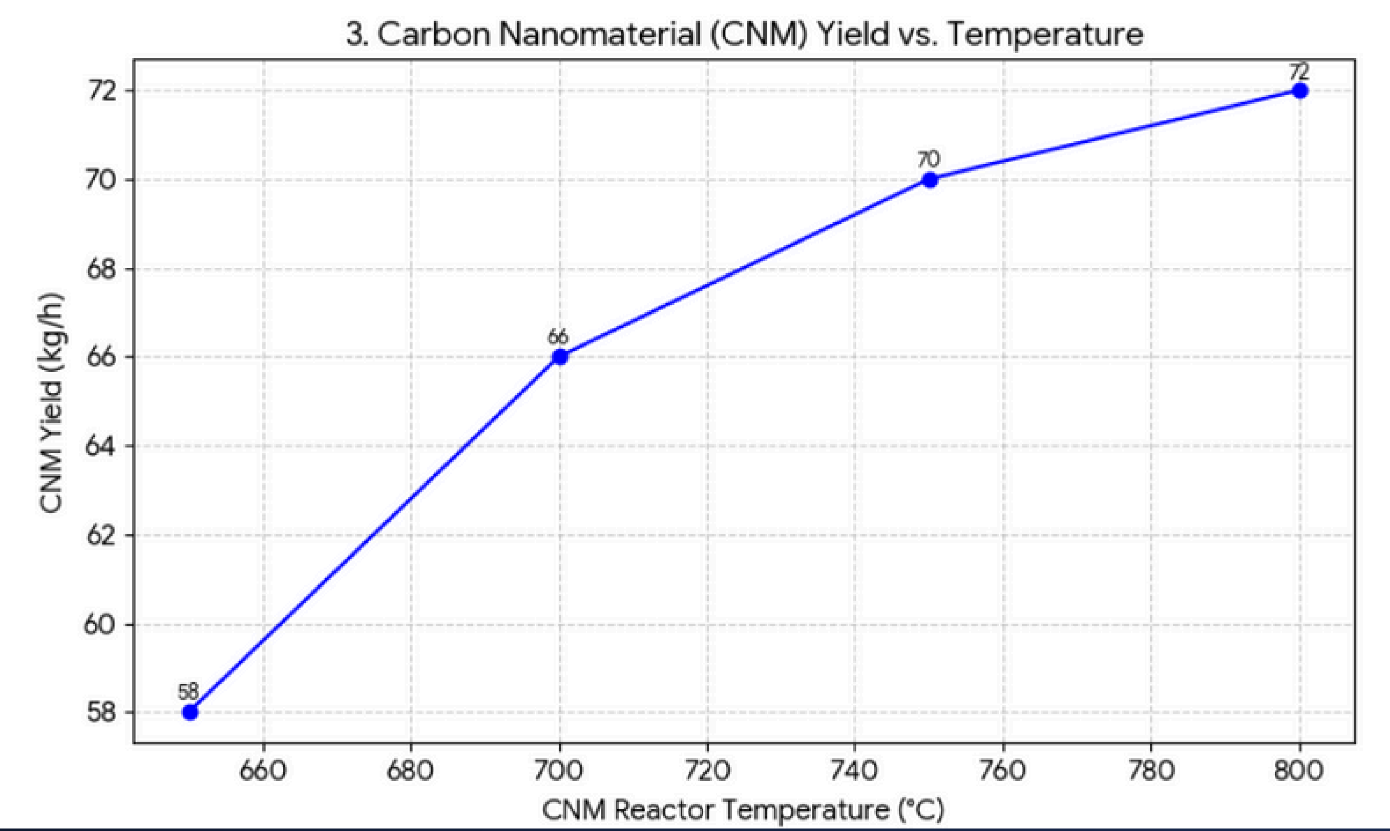
⚡ Biochar catalyst shows enhanced stability with crystalline carbon deposits

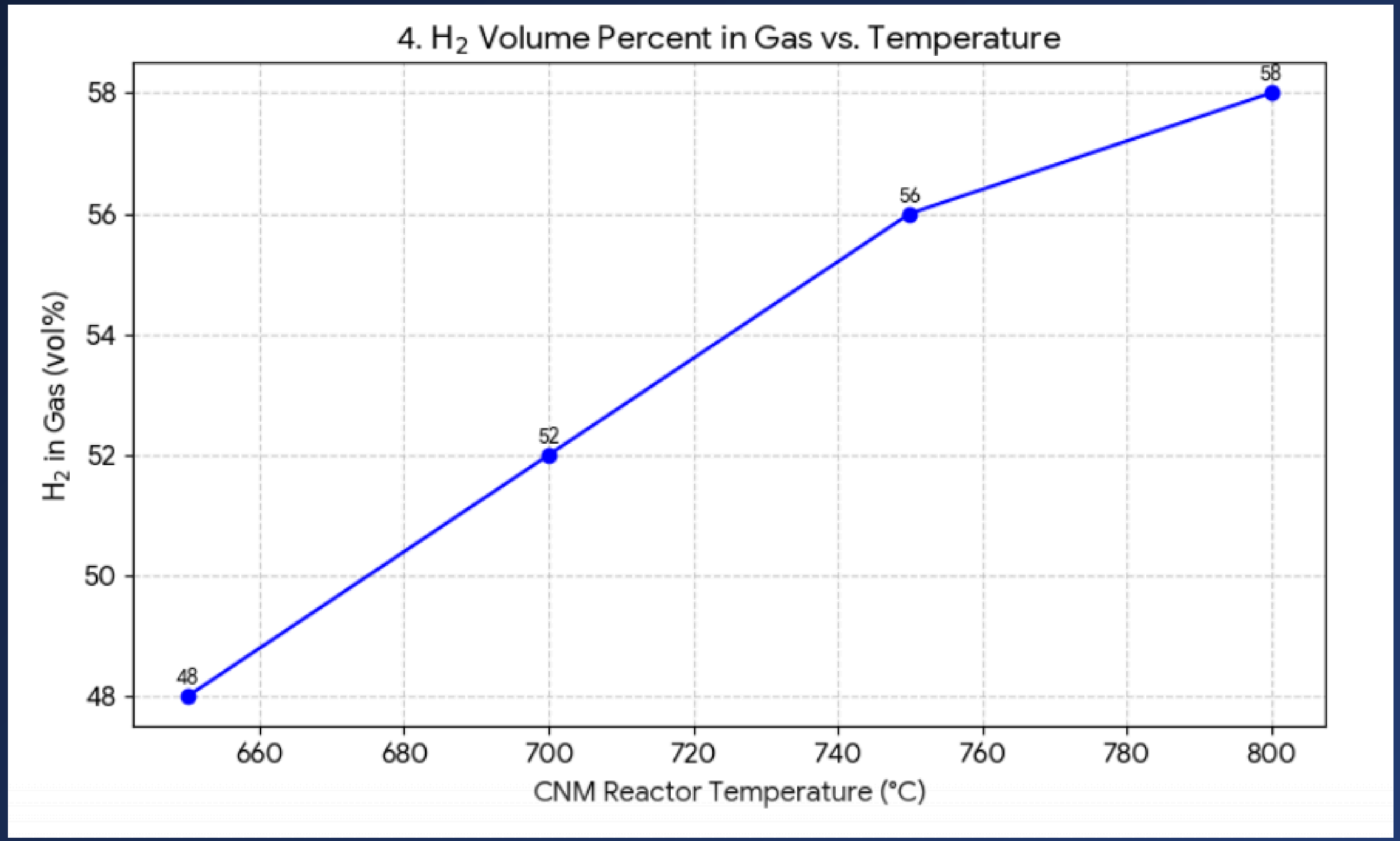
Temperature (°C)	CH_4 Conversion (%)	C Deposition Rate ($mg \cdot h^{-1} \cdot g^{-1}$)	CNM Yield (kg/h)	H_2 in Gas (vol%)
650	42	9.8	58	48
700	52	12.4	66	52
750	60	14.2	70	56
800	68	15.3	72	58

ALL PLOTS USE THE CNM REACTOR TEMPERATURE C AS THE X-AXIS.









1. ch4 Conversion vs. Temperature

This graph shows the percentage of methane converted as the reactor temperature increases.

2. Carbon Deposition Rate vs. Temperature

This graph illustrates the rate at which carbon nanomaterials are formed on the catalyst surface.

3. Carbon Nanomaterial (CNM) Yield vs. Temperature

This graph shows the total hourly production of carbon nanomaterials.

4. H2 Volume Percent in Gas vs. Temperature

This graph displays the volume percentage of the valuable hydrogen co-product in the off-gas.

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CONCLUSION

This project demonstrates that waste is not waste—it's a resource. By intelligently integrating plastic and biomass waste streams through thermochemical conversion, we can simultaneously solve environmental problems while producing high-value nanomaterials and clean hydrogen energy, creating a truly circular and sustainable economy."

Waste → Resource → High-Value CNMs.

A scalable, green pathway that turns plastic and biomass waste into marketable carbon nanomaterials — closing the loop on circular materials.

<u>Future Work</u>

- **The Aspen Plus steady-state model captures pyrolysis, biochar integration, and CNM formation with encouraging yields and >90% product purity .**
- **Key strengths: feedstock flexibility, integration of biochar as support, and tunable reactor conditions for tuning CNM morphology.**
- **Next steps: pilot plant trials, catalyst optimization, life-cycle & techno-economic assessment, and exploring application-specific CNM functionalization.**

- **Final note: This work provides a robust technical foundation and a clear roadmap from lab model to pilot demonstration — bridging waste management and advanced materials commercialization.**

Thank you!