Non-Catalytic Pyrolysis of Associated Gas to Zero CO_2 Hydrogen and High value Carbon Black

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U.S. Department of Energy

National Energy Technology Laboratory

Resource Sustainability Project Review Meeting

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UNIVERSITY OF NORTH DAKOTA

COLLEGE OF ENGINEERING & MINES

Project Overview

Funding

- Federal: $500,000 (No cost share)
- UND - $274,992
- H Quest Vanguard, Inc. $225,008

Period of Performance

- Duration: Two years
- Start: 05/01/2023
- Stop: 04/30/2025

Overall Project Objectives

Develop a pre- Front End Engineering Design study for the conversion of Bakken Shale flare gas using H-Quest Vanguard's ***Microwave Plasma Pyrolysis*** (MPP) process

Project Team

UNIVERSITY OF NORTH DAKOTA
COLLEGE OF ENGINEERING & MINES

- College of Engineering and Mines Research Institute (CEMRI)
- Home to seven research centers - project under the Process engineering group

Junior Nasah, PI
Assoc. Director

Abdelmalek Bellal
Research Engineer II

Chinaecherem Okwuono
Graduate Student

HQuest

Developing microwave plasma processes since 2014

America's SEED FUND SBIR.STTR

U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY

Strong IP position

12 granted patents in US and Canada

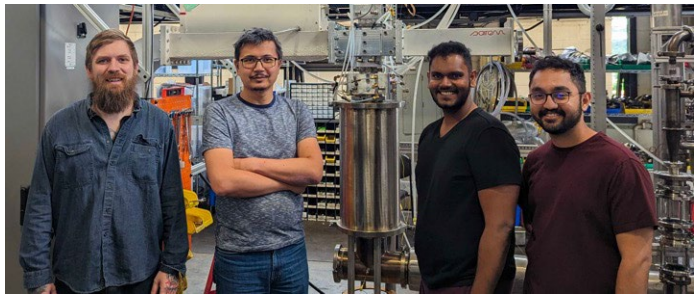
Customer pipeline

Paid pilots in 2023 and early 2024

Extensive validation

$3.6M in R&D project revenues from DOE and NSF

George Skoptsov
President & Inventor



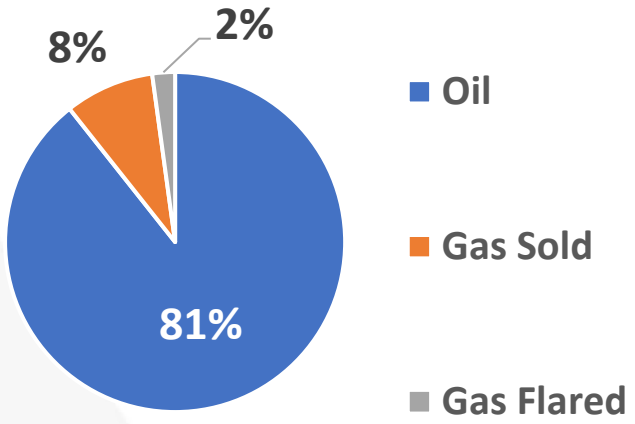
H-Quest Team

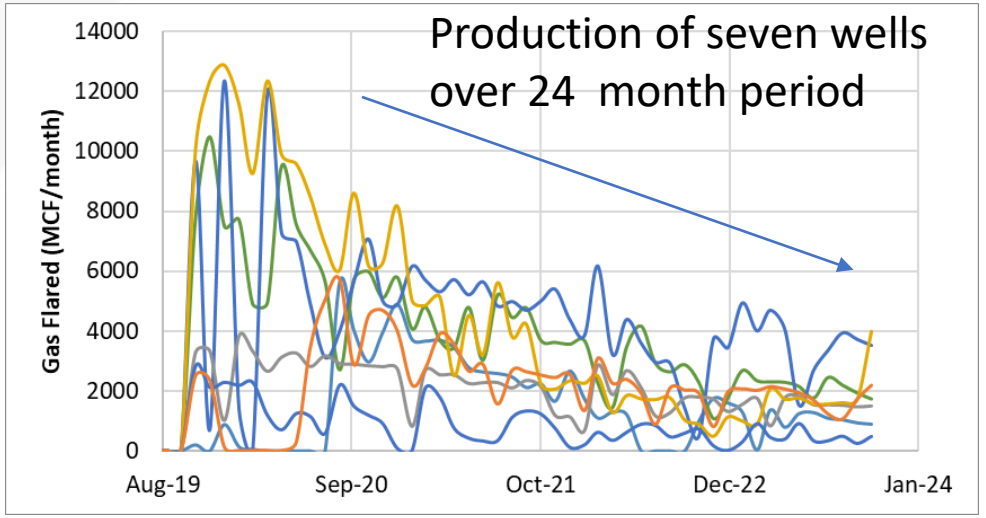
Example Case: Bakken O&G Producer A

Public data for Bakken producer with over 1,600 active wells

24 Month period of Nov. 2021 to Oct. 2023

- **98%*** of potential revenue from wells realized
- **2%** of unrealized revenue equals **~$120 million***, but…
- On a per well per month basis, average revenue only **~$3,000**
- Flared volumes **decrease** significantly over time





*$2/MCF estimate: https://www.dmr.nd.gov/oilgas/stats/statisticsvw.asp; $82.5/bbl. average for time period https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=F002038__3&f=M

Example Case: Bakken O&G Producer

Bakken gas composition*

	Mole %
C1	58%
C2	20%
C3	11%
C4	4.9%
C5	1.6%
CO2	1%
Other	3%
Total	100%

Estimated revenue based on gas sales, electricity production or products

	Gas Sales	Electricity	Products (C & H_2)
Assumptions	$2/MCF	$0.05/kWH. 32% conversion eff. 1500 Btu/CF.	$1/kg Carbon $0/MCF H_2 80% conversion eff.
Revenue per MCF	$2	$7.04	**$18.32**
Multiplier	1	~3.5	**~9**
Challenges / Requirements	**Higher capacity** on gathering pipeline required	**Intermittent;** not compatible with demand/response grid. **Storage** required for grid application	**Small footprint** (~1000m^2) **Modular** (volume flared declines with age) **Utilize** H_2 (~2X flare gas vol.)

*EERC (2020) *Assessment of Bakken Petroleum System Produced Gas Compositions*, Final Report, 2020-EERC-09-04

Solution: Microwave Plasma Pyrolysis (MPP)

Rapid, direct energy input

Microwave energy coupling directly into the gas stream
10,000 deg/sec heating rates: high throughputs in compact vessels

Non-catalytic hydrocarbon conversion

Simple single-stage process.
Pyrolysis to carbon products and hydrogen in a small package.
Carbon black captured from gas stream and transported off-site.

Carbon product control and flexibility

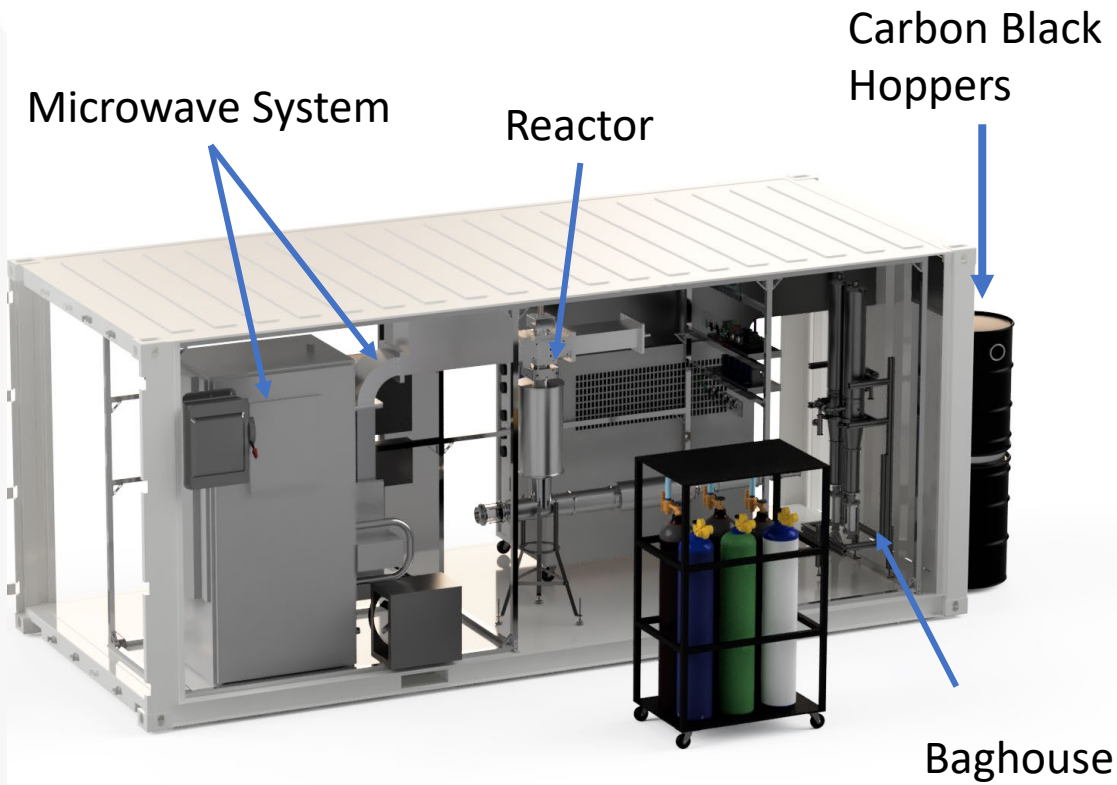
Demonstrated selectivity control and production of
carbon black, graphene, acetylene, and graphite precursors.

Easy, lost-cost deployment

COTS generators and proprietary reactor trains fit in ISO containers
Required utilities: electricity and natural gas.
“Island-mode” capable; can run on own power.

Advancement toward commercialization

36 kW system piloted in the field.
100 kW system under test in the lab.



Project Status

- Pilot demonstration ongoing (separate funding)
  - TRL 6-7 for core process with pipeline gas
- Current project focus on auxiliary systems for well site remote deployment – initial high level
- Preliminary heat mass balance initiated
- Preliminary technology gaps assessed
- Initial discussions with O&G host site

Deliverable Title	Due Date
Project Management Plan	5/31/23
Initial Technology Maturation Plan (TMP)	7/28/2023
Quarterly Report	Quarterly
Design Basis Report and Technology Gap Assessment Report	7/1/2024
Performance Results Report and Environmental Information Volume	7/1/2024
Cost Results Report	3/31/2025
Final Technology Maturation Plan (TMP)	3/28/2025
Commercialization Plan	4/15/2025
Final Technical Scientific Report	7/28/2025

Pilot system at Peoples Gas, Pittsburgh


Installation of Unit


Captured carbon in sight glass & drum


Inside Unit


Natural gas supply

Control room


Installed Unit

Example Case of MPP Pilot System Deployed at Well Site

H Quest MPP system

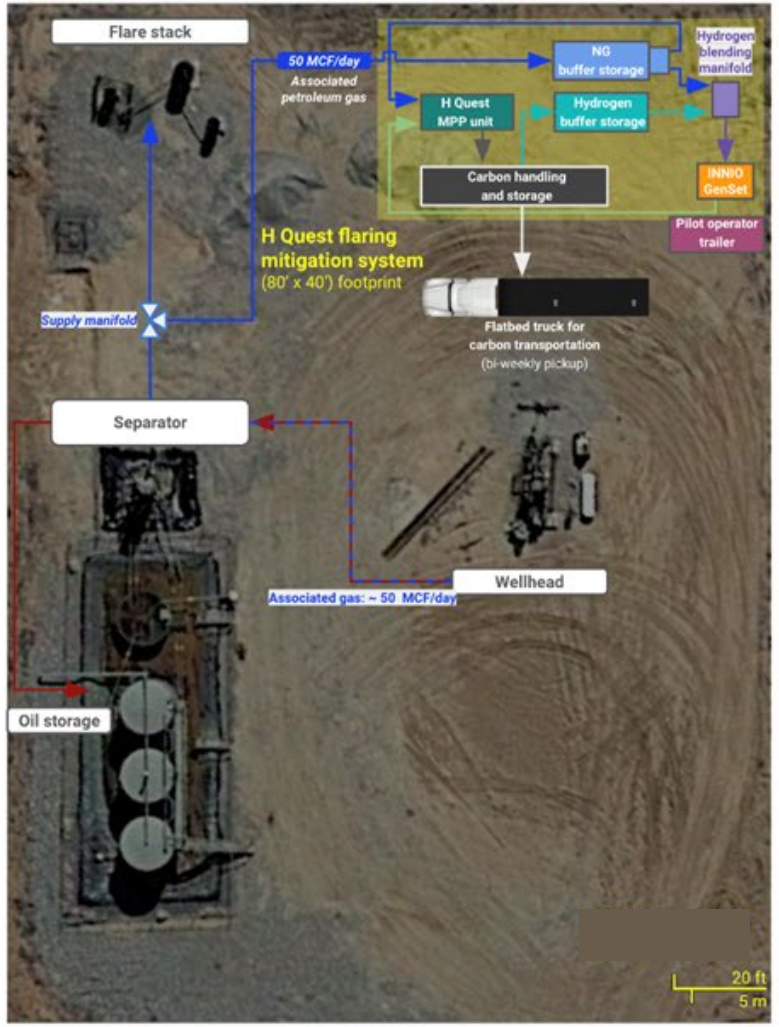
The microwave generator, reaction vessels, and heat exchanges are housed in a standard 20' ISO container (no additional construction required for installation)

Natural gas buffer storage

CNG buffer storage vessels will be used as an interface to smooth the gas supply to the MPP system

Operator center

An operator trailer (for pilot operation only) will also support remote data transmission to H Quest's network operating center



Hydrogen buffer storage

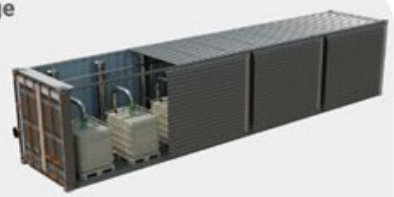
Hydrogen (>90% purity) from the MPP system will be compressed and stored in tube trailers for powering generation using the GenSet

Generator set

Waukesha VHP gensets built for efficiency, durability and longevity and rated at 315--600 kWe are ideal for remote power generation applications

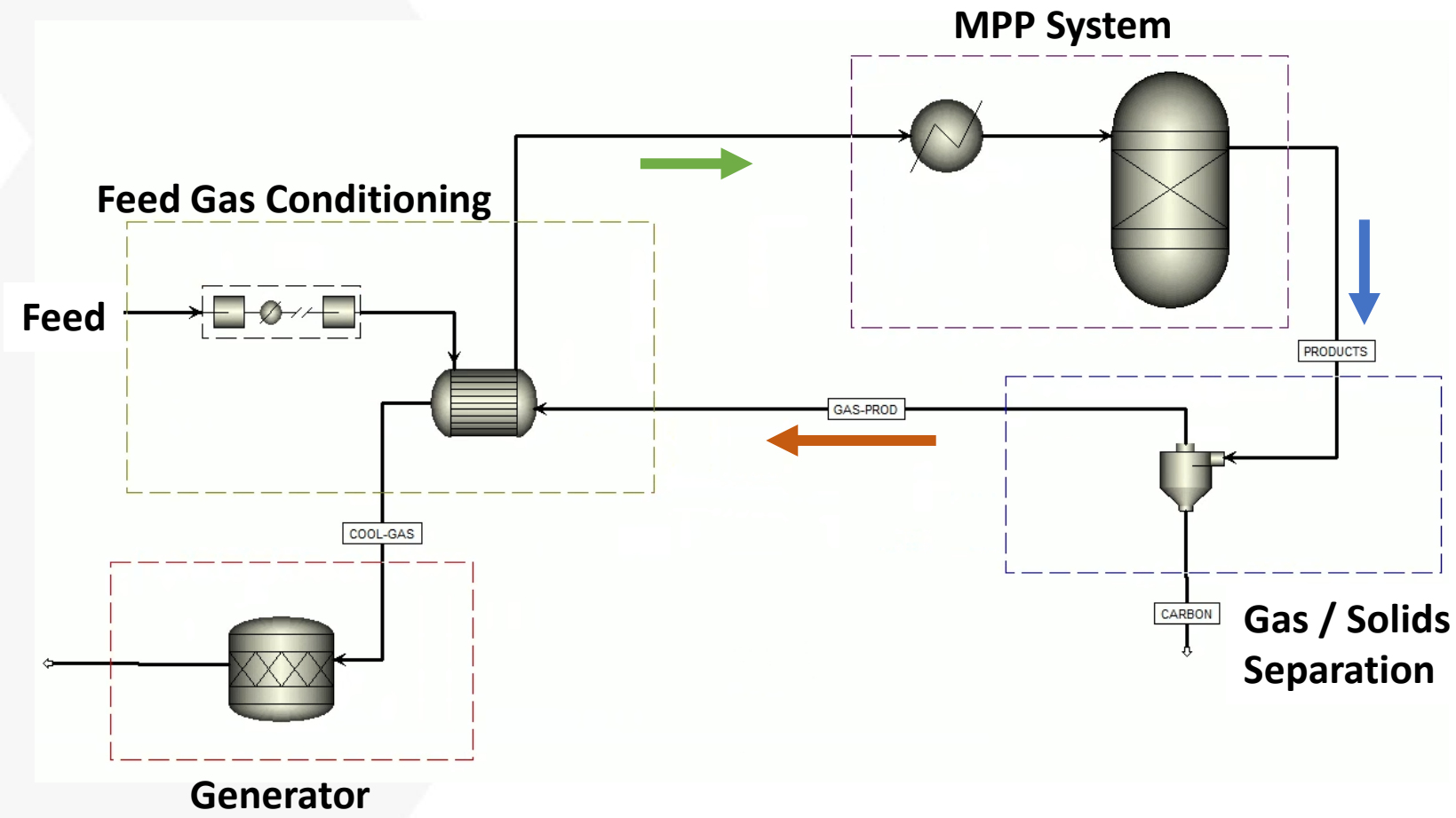
Carbon handling and storage

The carbon separation and storage system is housed in a 40 ft container composed of 8 individually addressable baghouse units each of which empties into an IBC tote



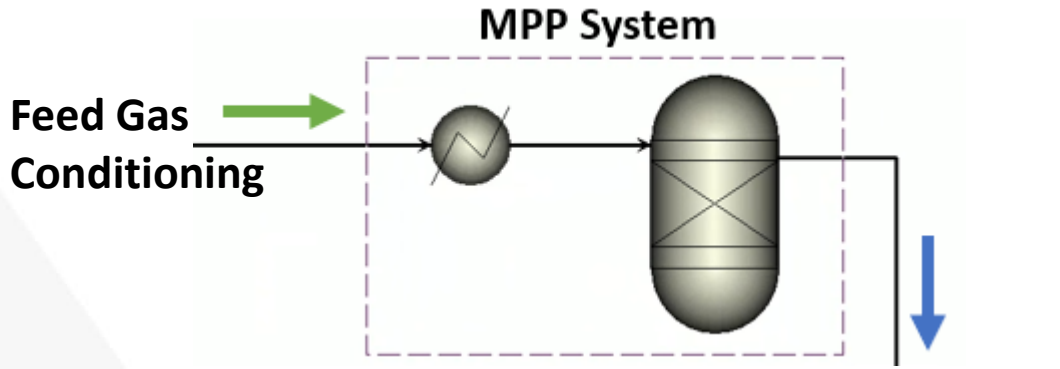
Preliminary Heat Mass Balance (HMB)

- ASPEN Plus for HMB
- 50 MCFD feed capacity
- ~100 – 300 metric ton/yr. C.
- Technology gaps (challenge level):
  - Gas conditioning (low)
  - Heat management (medium)
  - Sorbent handling (high)



Preliminary Heat Mass Balance (HMB)

- Modelling of carbon requires correct data
- Thermodynamic properties for graphene, diamond will not work
- Currently using Coronene ($C_{24}H_{12}$) as a surrogate
- For provided carbon, will measure:
  - Heat capacity (DSC)
  - Enthalpy of formation (TG-DSC, GC)



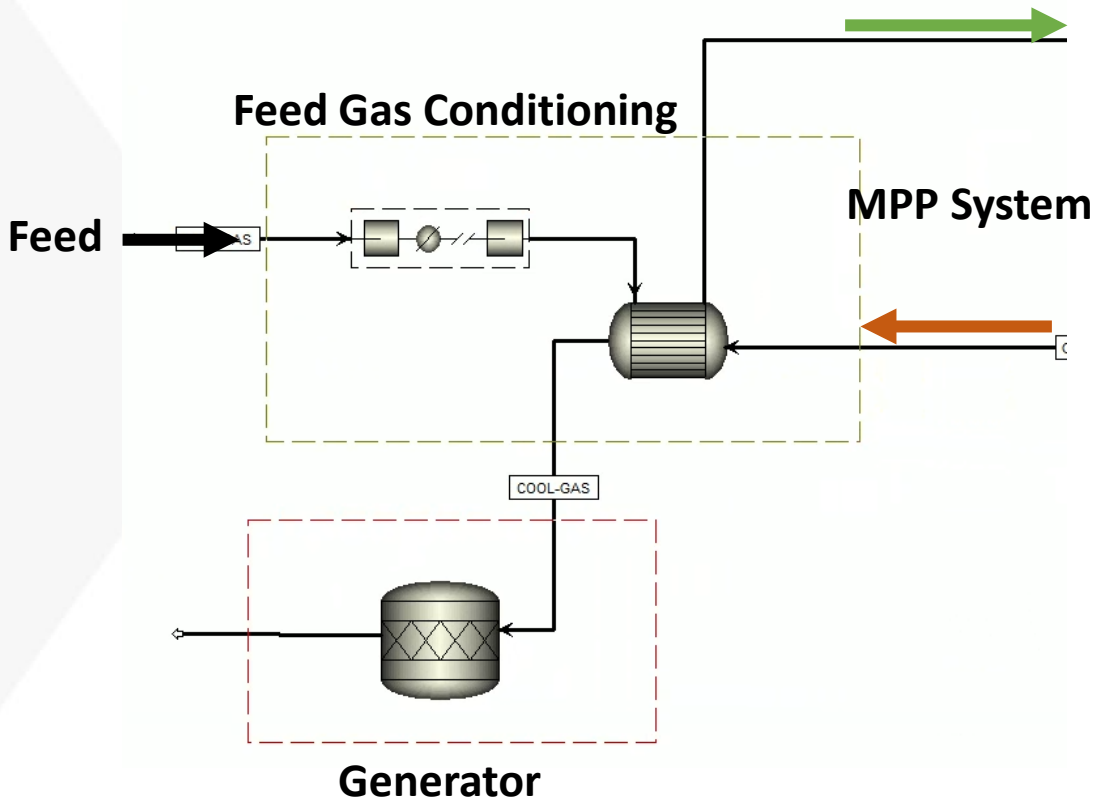
Carbon sample from pilot system

Themys TG-DSC system

Preliminary Technology Gap Assessment

Conditioning system:

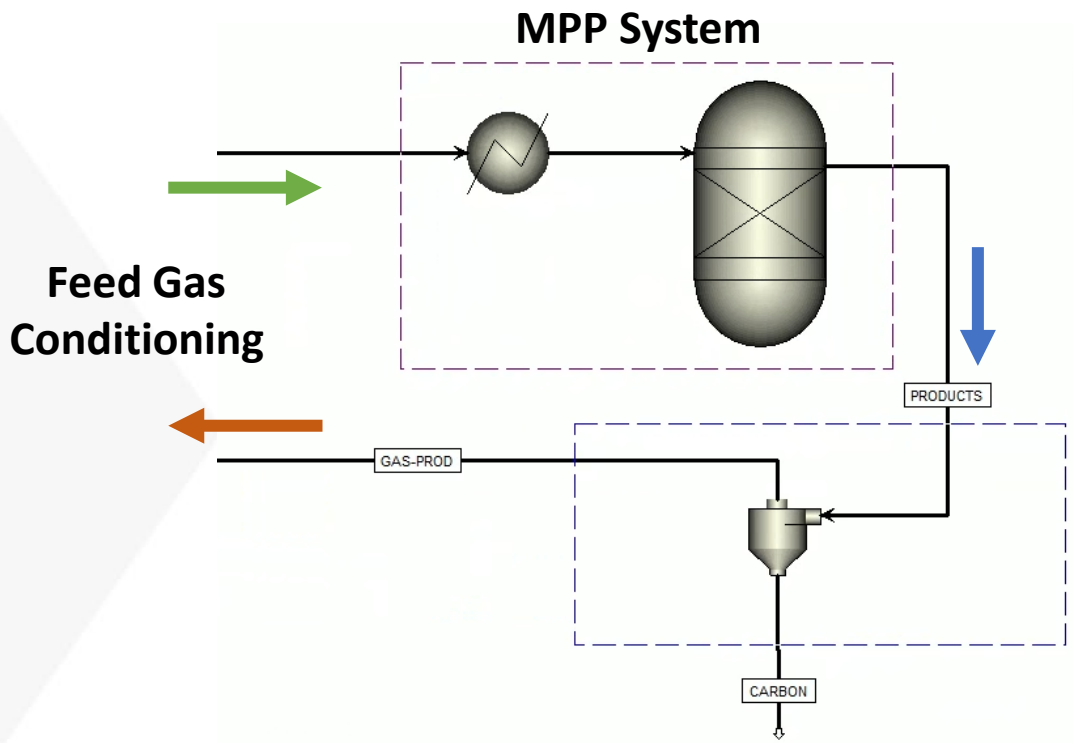
- **Objective**: 1) Minimize start/stop of system, 2) manage variability in gas flow to flare, and 3) Vapor phase NGL recovery
- **Design targets**: minimum steady state runtime, always available fuel for genset
- **Approach**:
  - Evaluate flaring frequency data (minutes)
  - Develop compression + storage + recycle + NGL knockout



Preliminary Technology Gap Assessment

Heat management

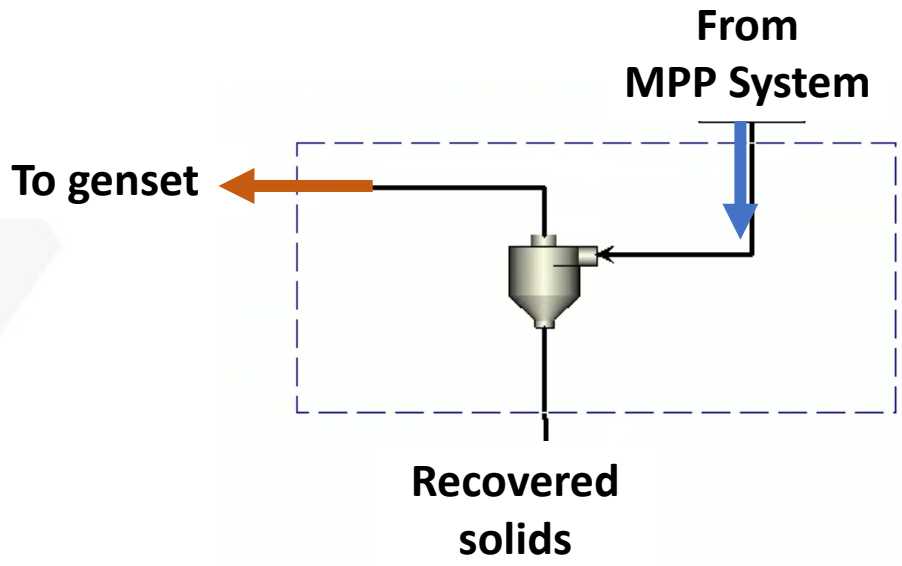
- **Objective**: condition product for recovery (solid carbon) and genset fuel (gaseous hydrogen)
- **Design Targets**: 1) Cool solids below auto-ignition, 2) Cool gases for inlet specifications of genset
  - Evaluate auto-ignition for products
  - Determine solids heat capacity
  - Direct cooling (quench) vs indirect (heat exchanger) vs heat loss contribution



Preliminary Technology Gap Assessment

Solids Handling

- **Objective**: Fully automate solids recovery system
- Primary challenge is remote location of well systems
  - Is additional solids cooling required?
  - How is gas isolation achieved? Failure to fully isolate gases could lead to Division 1 classification



Initial Discussions with O&G

Oil & Gas (O&G) Well Site Description

- **Two** flare systems – well head (high pressure) and oil tanks (low pressure)
- Significant flared gas **variability**
- Buffer storage could cause **NGLs** to be knocked out
- **Winterizing** of all equipment critical
- Vessels need to follow **ASME certifications** (pressure)
- Equipment needs to be **Class 1, Division 2**.
- Additional review H_2 of handling and storage

Other Opportunities

- Relieve oil production artificial constraints; Some wells are “shut in” due to lack of gas transport capacity
- Monetize ethane glut in Bakken, no current market options
- Relieve congestion in gathering pipeline stations

Future Activities

Current Project

- Complete engineering design activities
  - Waiting for host site data from O&G partner
  - Measure thermodynamic properties of carbon
  - Operate pilot MPP with simulated Bakken gas
- Work on process deliverables:
  - Technology Gap Assessment (ongoing)
  - Technology Maturation Plan
  - Commercialization Plan (Business strategy, Impact on carbon market, FOAK vs NOAK)
  - Environmental Information Volume (Emissions assessment, review of applicable regulations)

Beyond Project

- HQV seeking opportunities to exit “startup” phase
- Discussions with new partners that could build and deploy system
- Had initial discussions with some O&G operators in the Bakken
  - Focus areas for methane mitigation?
  - Interest in technology deployment?
- Developing technology for other applications – opportunity in de-carbonizing natural gas fired processes.

Summary Slide

- Developing a pre-FEED system of the Microwave Plasma Pyrolysis process
- Preliminary process model developed
- Technology and data gaps identified for process model
- Feed and product gas conditioning are important to support remote/automated operation
- Initial discussions with O&G partner on host site challenges.
- Specifications for host site submitted to O&G partner

Questions & Contact

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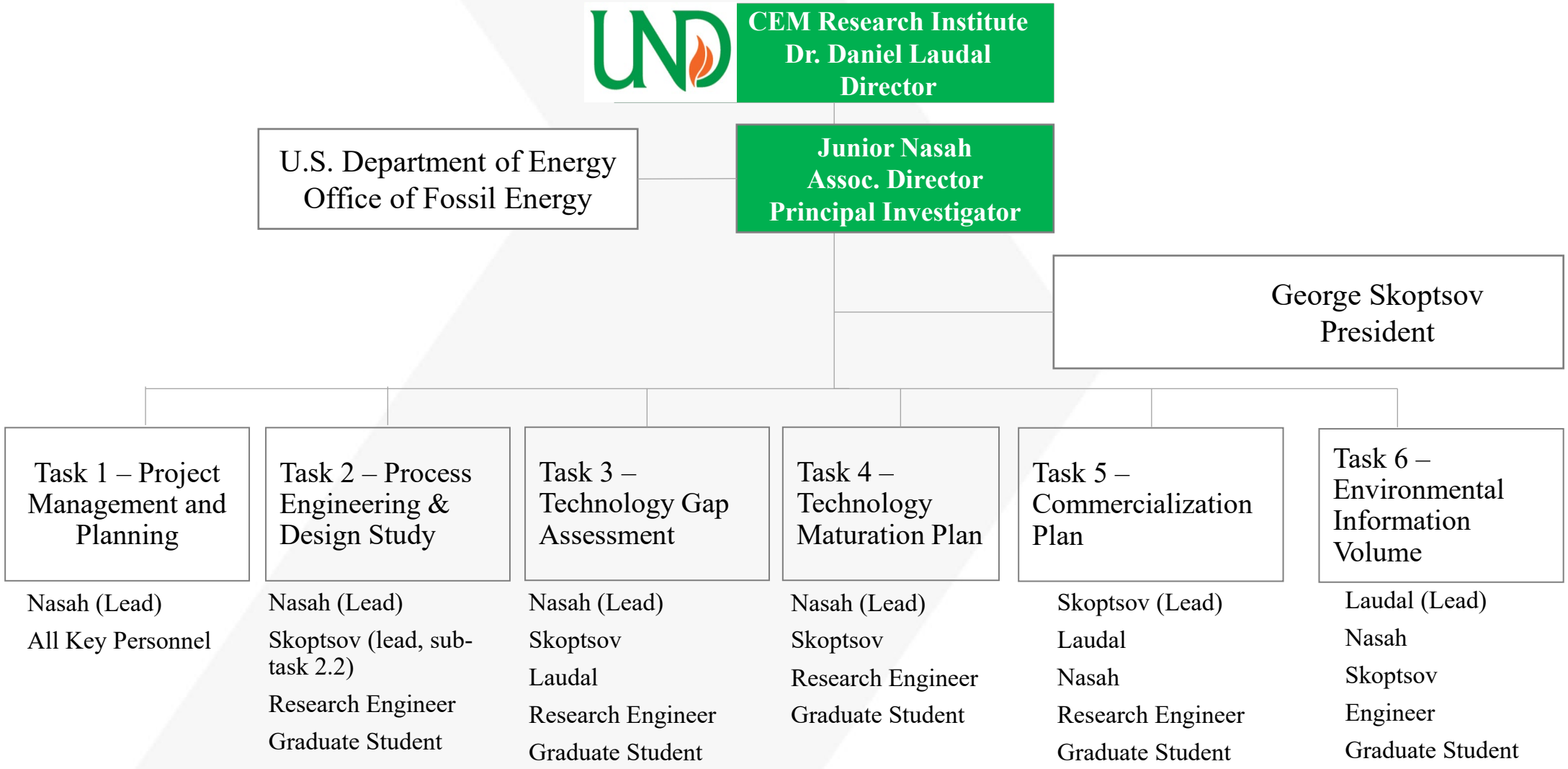
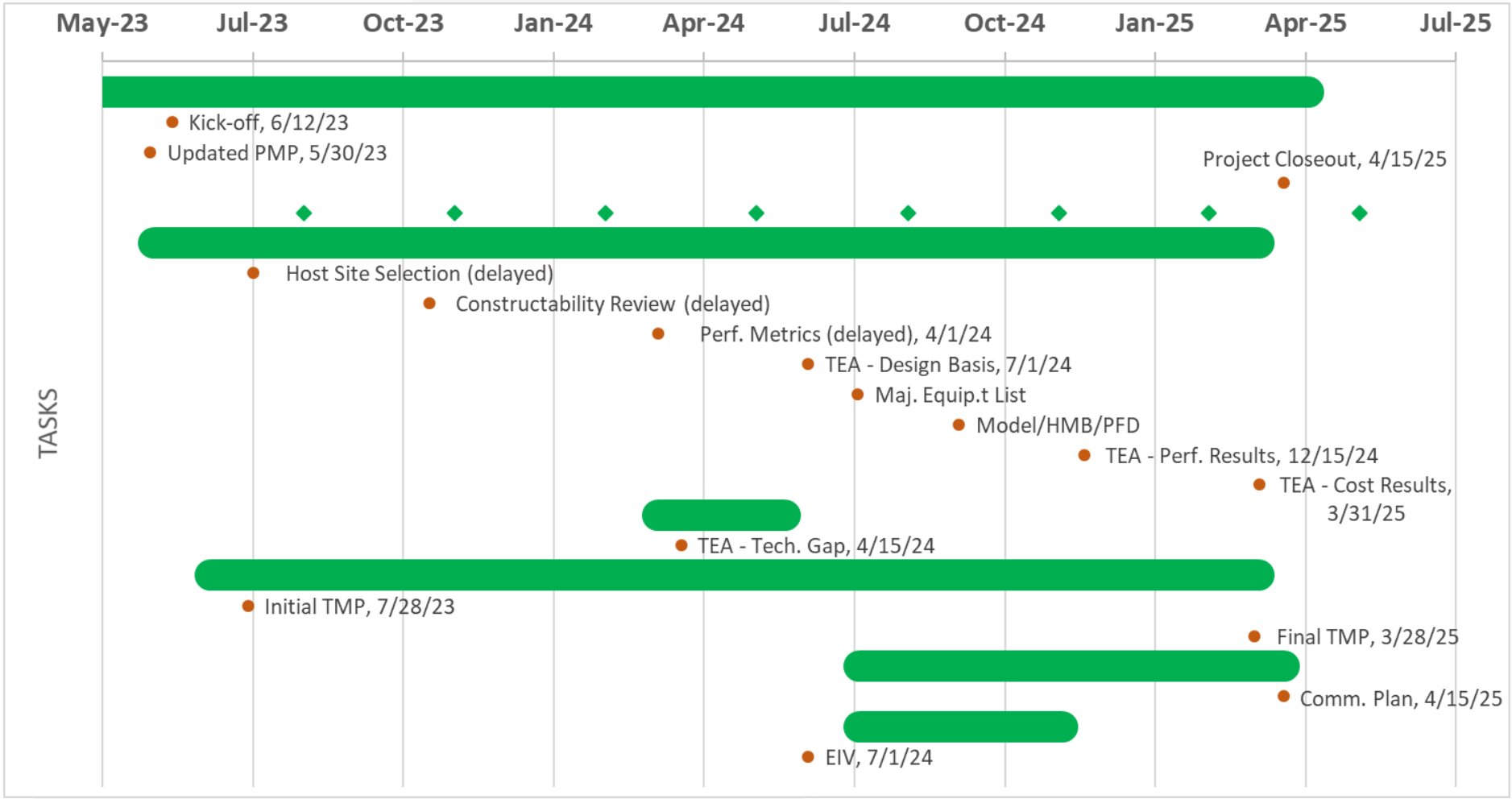
Team Organization



Schedule with Deliverables and Milestones



Acknowledgement and Disclaimer

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