DOE Bioenergy Technologies Office (BETO)
2021 Project Peer Review

3.5.2.202 HYPOWERS:
Hydrothermal Processing of Wastewater Solids

March 25, 2021
Session: Systems Development and Integration

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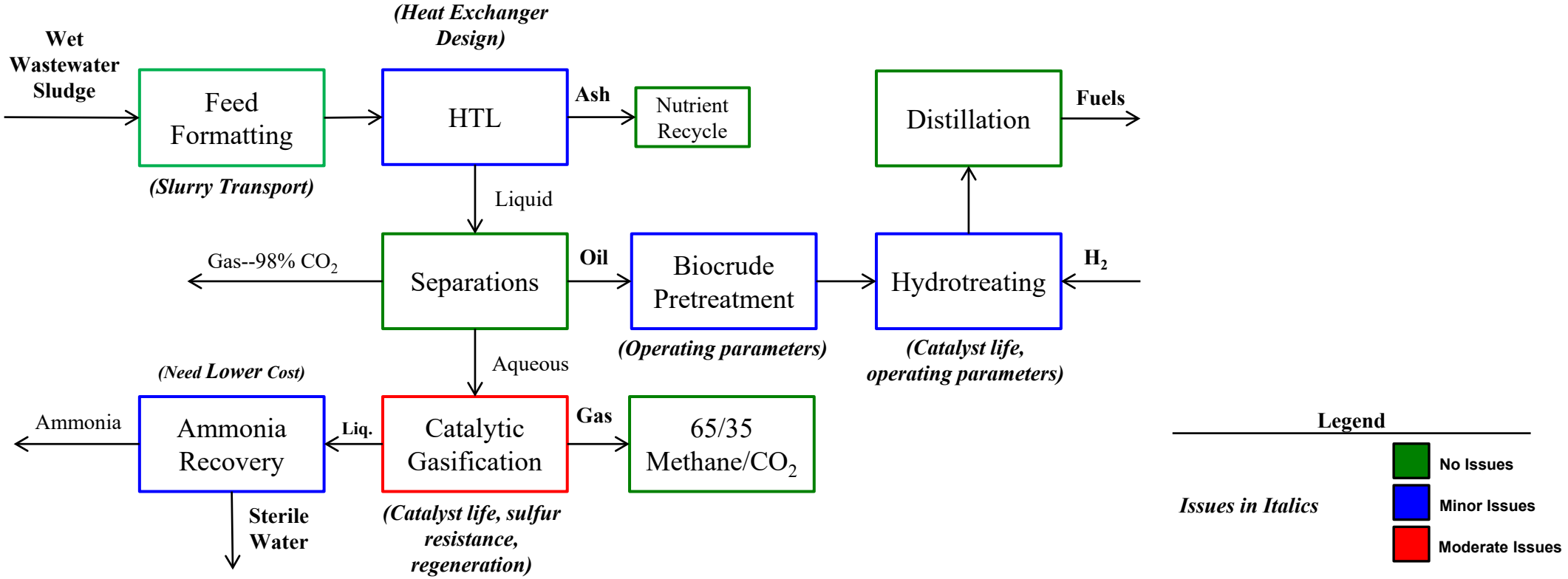
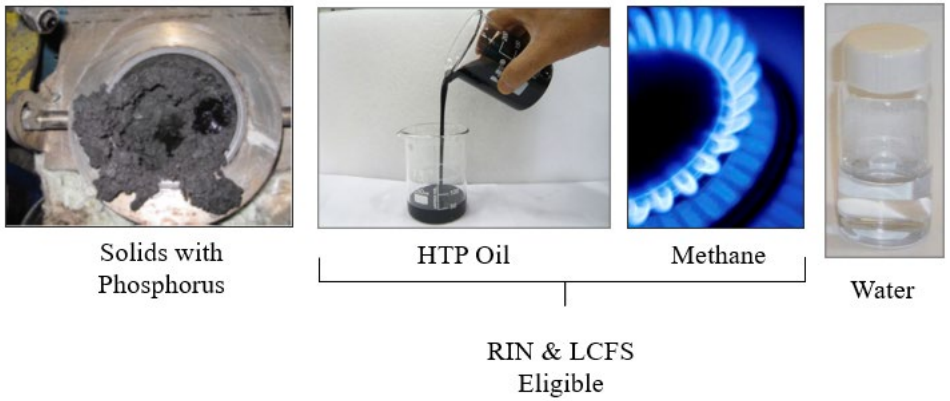
Goal Statement

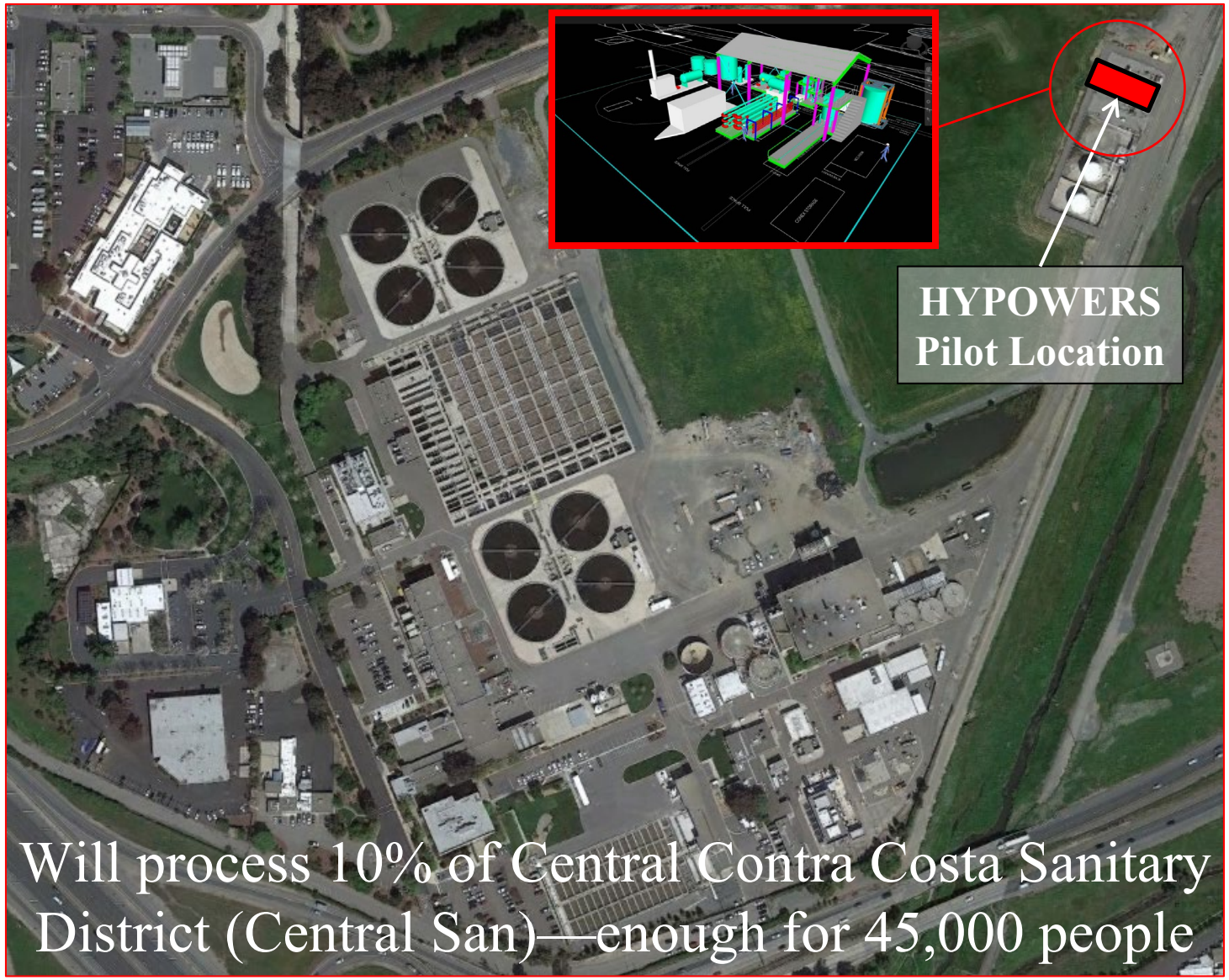
The goal of the HYPOWERS Project is to demonstrate scale-up of a Hydrothermal Processing (HTP) System to convert wastewater solids into renewable biofuel and methane at an operating wastewater treatment plant.



Project Overview

- Project will be located in Contra Costa County, California
- HTP pilot will process 3 dry metric tons/day of primary and secondary sludge
- HTP pilot will produce renewable fuels (biocrude and methane) and waste solids and water that can be used for fertilizer





Project Overview

- **Phase 1 validated HTP process data and completed system design**
  - $2.4 million with 50% cost share
  - All deliverables submitted on schedule and on budget

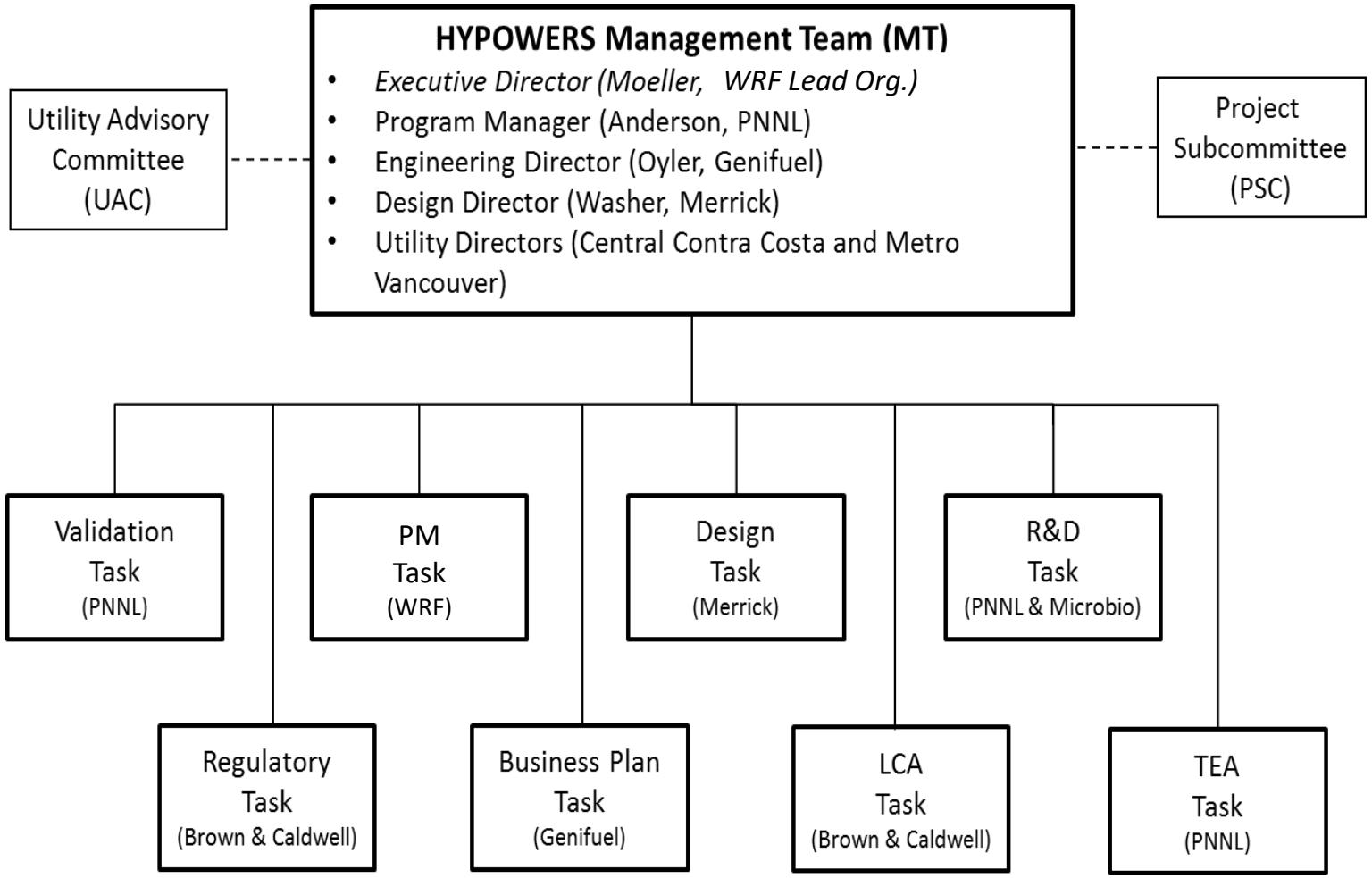
- **Phase 2 will build and operate the HTP pilot plant**
  - $18-20 million including 50% cost share, with additional 25% for contingency

- **Project is working on meeting Go/No-Go requirements for transitioning to Phase 2 (e.g., continuance application with cost share, contingency, and SOPO)**

Project Overview

Largest previous system now operating—
HYPOWERS will be 10x larger

1 – Management (Phase 1)



Two key success factors: (1) Management by WRF (PI) and Co-PI's PNNL and Genifuel; and (2) Clear definitions and reporting of tasks and deliverables for each team member.

1 – Management

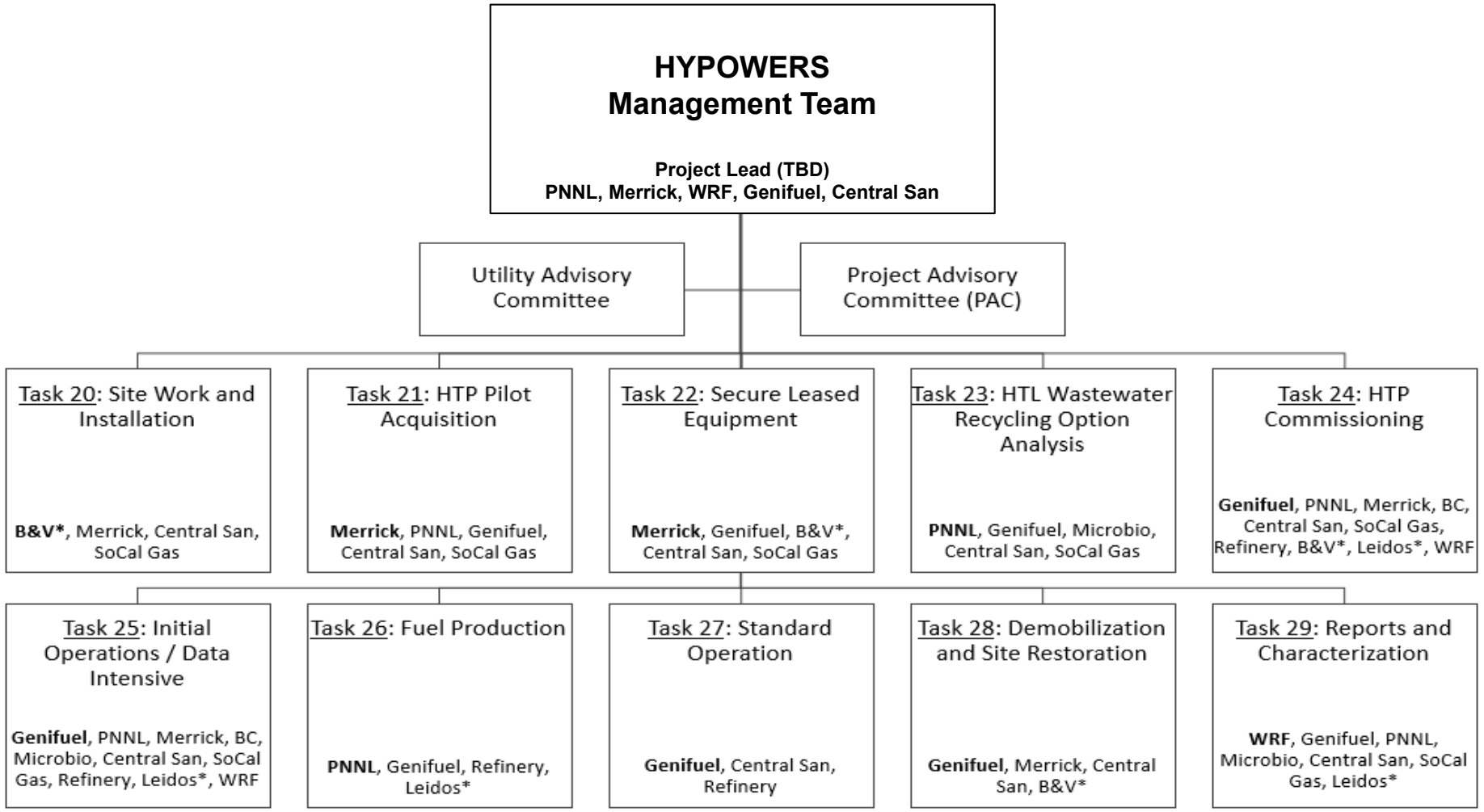
- **Detailed WBS with Experienced Task Leads**
  - Well defined scope/deliverables
  - Funding authorizations
- **Monthly Project Team Meetings**
  - Review progress, schedule and budget
  - Discuss issues and integration
- **Defined Milestones and Deliverables**
  - Monthly Reports
- **Regular Meetings with BETO**
- **Coordination and Integration with Utility Partners and Advisory Committee**
- **Management and Integration of Supporting Projects and Partners**
- **Management of Transition Activities to Phase 2 Go/No-Go**

1 – Management
Transition Activities to Phase 2 Go/No-Go

- **Assembling Funding for Cost Share**
  - Various Project Financing Options
  - California Energy Commission (CEC) Grant
  - Team Cash and In-Kind
  - New Capitalization Partner
- **Assembling Funding for Contingency**
  - New Capitalization Partner
- **Novation of DOE Contract**
- **Option for Reducing Phase 2 Budget**
  - Reducing capital costs; scale down pilot plant from 3 to 2 dry metric tons/day
  - Reduce operating costs: reduce project operation schedule

Phase 1 Management Team Continues to Lead and Manage Transition Activities to Move HYPOWERS into Phase 2

1 – Management (Phase 2)



*Indicates new team member in Phase 2; Bold indicates task lead

Completed Detailed Risk Management Plan (RMP) for Project and Task Level Risks

1 – Risk Management (Phase 2)

- **Clear definitions of tasks for each team member and clear plan from Phase 1**
- **Core team consisting of P.I., engineering lead, and Central San utility meet weekly to provide close management**
- **Full team meetings monthly with all participants to coordinate overall effort, plus monthly reports to DOE for invoicing and cost control**
- **Quarterly reports to utility advisory committee to maintain communication with the wastewater industry**
- **Annual meetings to review major milestones and coordinate next year plans**
- **Regular data analysis and coordination with regulatory requirements to ensure process and products are performing as expected**
- **Testing of revised catalyst from PNNL for gasification section**
- **Completed a risk management plan (RMP) including risk registry, HAZOP, etc.**
- **Will add fabrication partner with prior success building hydrothermal systems**

2 – Approach (Phase 1)

- **Developed Front-End Loaded CD-3 Design Package**
  - Basis of Design Report, HAZOP Report, Fabrication Specifications, P&IDs, PFD and MEB, TRA Report, QAPP, Site Layout & Drawings, Equipment List, etc.
  - Technical approach required engineering to define cost to -5%/+15% accuracy
- **Conducted R&D To Support Design, Process Integration with WWTP**
  - HTL Testing with Actual Feedstock
  - HTL Aqueous Waste Recycling Experiments to determine WWTP Impacts
  - CHG Catalyst Sulfur Poisoning Mitigation
- **Completed Techno-economic Assessment and Life Cycle Analysis, and addressed all regulatory issues sufficient to ensure project can proceed**
- **Produced Business Plan to provide clear pathway to commercial success both technically and financially**
- **Developed Plan for Fuel Production/Refinery Integration**
- **Developed detailed PMP for Phase 2**

2 – Approach (Transition to Phase 2)

- **Meet Go/No-Go metrics for transitioning to Phase 2**
  - Continuance Application with Phase 2 PMP/SOPO
  - 50% cost share and 25% contingency funding
  - CD-3 Design Package and all Phase 1 Deliverables
  - Sign Off by DOE Independent Engineer (IE)
- **Approach is focused on an integrated strategy**
  - Add new capitalization partner
  - Secure remainder of 50% cost share and contingency
  - Novation of the project contract from WRF to a new lead for Phase 2
  - Finalize Phase 2 Project Budget (Capital and Operating Cost)
  - Update CD-3 Design Package and Phase 2 PMP
  - Submit Phase 2 Continuance Application for IE Sign Off
  - Approval of the Phase 2 Continuance Application by DOE

2 – Approach (Phase 2)

- Phase 2 has two budget periods (BP3 and BP4) with a Go-No Go
  - BP3 focuses on fabrication of HTP pilot plant, site construction/installation, completing operational readiness review
  - BP4 focuses on operation of the pilot plant, data collection and fuel production
- Project will be complete with final report & demobilization of pilot plant
- Primary Go-No Go before proceeding to plant operation:

24.6	Go/No Go Readiness for Pilot Plant Demonstration (BP4)	GN14.6 Readiness for Pilot Plant Operation (BP3)	24G	Operational Readiness Review Completed	Operational Readiness Review approved by the HYPOWERS Review Team and DOE Independent Engineer

3 - Impact

- **HYPOWERS addresses the #1 problem in the wastewater industry, solids management (including disposal) by converting solids to oil and gas**
- **Sewage sludge provides an assured source of wet waste feedstock to meet BETO goals for renewable fuel production**
- **Full implementation of HTP in the wastewater industry will save $2.2 billion in cost and produce 41 million barrels of oil per year**
- **HYPOWERS will enable critical next steps to commercialization by demonstrating scale-up and continuous operations in an industrial setting**

3 – Impact

- **Project is directly relevant to BETO goals**
  - Proven ability to produce high-quality transportation biofuel
  - Feedstock always available with negative (avoided) cost
  - TEA shows HTP fuels can be competitive with fossil fuels
- **Project directly supports BETO's SDI Strategic Goal "to develop commercially viable biomass utilization technologies through public-private partnerships that build and validate pilot-, demo-, and pioneer-scale integrated biorefineries"**
  - The HYPOWERS pilot system will be the first HTP system in a US wastewater treatment plant and will serve as a model for US and worldwide wastewater treatment

3 – Impact

- **Utilities have high interest in HTP and HYPOWERS**
  - 16 utilities participating in project, including several of the largest wastewater utilities in the US and world
  - HTP is the most followed water technology in LIFT Link, WRF's online innovation platform
  - In a recent WRF survey, 50% of utilities indicated interest in implementing HTP; 10% in the next 10 years.
- **Successful demonstration would resolve two key issues for wastewater utilities:**
  - Reduce cost of solids management, currently 60% of total OpEx
  - Solve new problems such as PFAS destruction

4 – Progress and Outcomes

All Phase 1 Deliverables Complete

DELIVERABLE OR REQUIREMENT		STATUS
CD-3 or FEL-3 Design Package with Cost Estimate		CD-3 design with -5%/+15% accuracy complete and included in Deliverables Package
Project Management Plan (PMP) and Risk Management Plan (RMP)		The Phase 2 PMP and RMP are combined in a single document
Summary of Regulatory Approvals		Included in the combined PMP/RMP in the Deliverables Package and in the Business Plan
Life Cycle Analysis (LCA)		Included in the LCA in the Deliverables Package
Business Plan	Intellectual Property	Included in the Business Plan
	Project Site and Permitting	Written commitment from Central San has been obtained
	Project Team Experience	Included in the PMP/RMP in the Deliverables Package
	Project Team Financial / Management Capabilities	Included in the PMP/RMP in the Deliverables Package
	Scale-Up Analysis	Complete and described in Business Plan
	Feedstock Supply	Included in PMP/RMP in the Deliverables Package
	Utility Verification	Documented in the Merrick Engineering Package
	Offtake Agreements	Agreements in place except oil offtake, which still has several process options to be determined before final offtake agreement
	Market Analysis	Complete and included in Business Plan
	Technoeconomic Analysis	Complete TEA document included in the Deliverables Package
	Validation Sheet	Full Validation Report and Validation Worksheet are included in the Deliverables Package
	Cost Share and Contingency Funding	Financial model complete with Cost Share and Contingency and included in Business Plan

4 – Progress and Outcomes Phase 1

- **Engineering design reviewed internally and by DOE IEs; HAZOP completed and reviewed for safety; cost estimates reviewed for accuracy; business plan completed for commercial viability; environmental and regulatory processes on track.**
- **TEA/LCA show fuels eligible for D3 RINS and LCFS**
- **Process results validated with multiple sludge sources**
- **Effluent streams tested for ability to return to headworks of utility; testing showed no toxicity or inhibition to existing process at Phase 2 scale**
- **Phase 2 plan has been improved by close coordination with proposed fabrication partner and continuing technical work with proposed refinery partner—both key steps to minimize risk and control cost**

4 – Progress and Outcomes: (Phase 1 to Phase 2 transition)

- **Phase 1 successfully completed except for optional design modifications**
- **Assembling cost share & contingency funding for Phase 2**
  - Successfully won $3 million in additional funding from the CEC
  - CRADA with SoCalGas ($500K)
  - In-kind cost share from team partners (approximately $1.4 million)
  - Remaining cost share and contingency will be provided by new capitalization partner
- **Adding valuable new offtake partner (Kern Oil)**
- **Adding experienced new fabrication partner**
- **Catalyst investigations still ongoing at PNNL with funding from SoCal Gas (will be completed in time for Phase 2 demonstration)**
- **Continued regular team meetings in interim period (weekly, monthly, quarterly), at no cost to DOE**

4 – Progress and Outcomes: Future Work

- **Phase 2 work will address several key objectives**
  - Validate cost and performance at larger scale
  - Demonstrate industrial reliability and operability
  - Identify gasification catalyst with good cost and function
  - Optimize pathway for upgrading and finishing fuels
  - Reduce CapEx through Phase 2 experience and manufacturing improvements
- **Key Phase 2 milestone is completion of fabrication and commissioning system ready for production**
- **Project will support technology transfer**
  - Demonstration at relevant scale and duration at major utility
  - 16 utility partners actively involved

Summary

- **Overview:** Plans are complete to design and build an HTP system to process 3 dry metric tons/day of wastewater sludge—enough to serve 45,000 people
- **Management:** Will follow similar management approach that was successful in Phase 1, with a new capitalization partner and some adjustments to team for refining and fabrication
- **Approach:** Build and integrate with existing wastewater treatment plant to meet all regulations and performance requirements
- **Impact:** Solves critical problem of sludge disposal in wastewater industries
- **Progress/Outcomes:** All tests support production of high-quality fuels at competitive price in support of BETO
- **Future Work:** Build system as planned, produce fuels in Phase 2, and qualify for D3 RINs and LCFS credits

Acknowledgements

- **Liz Moore, DOE BETO**
- **Remy Biron, Allegheny Science & Technology**
- **Carol Babb and John Lukas, ICF**
- **HYPOWERS Project Team**
  - The Water Research Foundation
  - Genifuel Corporation
  - PNNL
  - Merrick & Company
  - Central San
  - Marathon Corporation
  - Southern California Gas Company (SoCal Gas)
  - MicroBio Engineering
  - Metro Vancouver
  - Brown and Caldwell (BC)
  - 14 Wastewater Utilities

Thank You!

Quad Chart Overview

Timeline (Phase 1)

- Project Start: January 15, 2017
- Project End: June 1, 2020
- Phase 2: 34 months from start of work (pending)

Phase 1	FY20 Costed	Total Award (Contract)
DOE Funding	$0	$1,228,633
Project Cost Share	$0	$1,228,666

Notes:

- Phase 1 DOE Funding Remaining: $90,644
- Phase 1 Cost Share Obligations Achieved
- Phase 2 DOE Funding (pending): up to $11M
- Phase 2 Cost Share Required (pending): up to $11M

Project Goal

To demonstrate scale-up of a Hydrothermal Processing (HTP) System to convert wastewater solids into renewable biofuel and methane at an operating wastewater treatment plant.

End of Project Milestone (for Phase 2)

The Phase 2 end of project technical milestone is to demonstrate extended operations of greater than 500 hours runtime. The project will also produce final reports showing laboratory tests of all products, final TEA & LCA, and a final overall project report.

Project Partners

- The Water Research Foundation
- Genifuel Corporation
- PNNL
- Merrick & Company
- Central San
- Marathon Corporation
- Southern California Gas Company
- MicroBio Engineering
- Metro Vancouver
- Brown and Caldwell
- 14 Wastewater Utilities

Funding Mechanism

- FOA # DE-FOA-0001232 (2016)
- "Project Development for Pilot and Demonstration Scale Manufacturing of Biofuels, Bioproducts, and Biopower"

Additional Slides

Acronyms

- **BC:** Brown and Caldwell
- **BETO:** Bioenergy Technologies Office
- **B&V:** Black & Veatch
- **CD-3:** Critical Decision - 3
- **CEC:** California Energy Commission
- **Central San:** Central Contra Costa Sanitary District
- **CHG:** Catalytic Hydrothermal Gasification
- **CRADA:** Cooperative Research and Development Agreement
- **HAZOP:** Hazard and Operability
- **HTL:** Hydrothermal Liquefaction
- **HTP:** Hydrothermal Processing
- **IE:** Independent Engineer
- **LCA:** Life Cycle Assessment
- **LCFS:** Low Carbon Fuel Standard
- **MEB:** Mass and Energy Balance
- **PAC:** Project Advisory Committee
- **PFD:** Process Flow Diagram
- **P&ID:** Piping and Instrumentation Diagram
- **PMP:** Project Management Plan
- **PSC:** Project Subcommittee
- **PNNL:** Pacific Northwest National Laboratory
- **QAPP:** Quality Assurance Project Plan
- **RIN:** Renewable Identification Number
- **RMP:** Risk Management Plan
- **SoCal Gas:** Southern California Gas Company
- **SOPO:** Statement of Project Objectives
- **TEA:** Techno-Economic Analysis
- **TRA:** Technology Readiness Assessment
- **UAC:** Utility Advisory Committee
- **WBS:** Work Breakdown Structure
- **WRF:** Water Research Foundation
- **WWTP:** Wastewater Treatment Plant

Summary Responses to Previous Reviewers' Comments

- **Process Economics: Process economics have been modeled extensively and are reported in both the Techno-Economic Analysis (TEA) and the Business Plan. Hydrothermal Processing (HTP) in the wastewater industry is one of the few biofuel processes which can be economically viable with or without government incentives**
- **CHG Catalyst and Final Fuel Conversion: Both the catalyst and the final fuel development are major focus areas. These investigations will continue from Phase 1 into Phase 2.**
- **Scalability: Scalability has been extensively tested, with this project being the 8th generation of successful scale-up.**
- **Capital Cost of Plant: It is clear that larger systems will be more economical both to build and to operate--this project is probably close to the minimum that would be economically viable.**
- **Life-Cycle Costs (without RINs and LCFS): If the output fuels are priced at market, the LCA shows that Hydrothermal Processing (HTP) is less expensive than available alternatives across the life cycle.**
- **Host Utility Participation: The host utility for this project (Central Contra Costa Sanitary District) has been intimately involved in all aspects of the work, and has been the principal focus for regulatory matters, plant integration, sludge supply under various conditions, and handling of all effluents from the project.**

Publications, Patents, Presentations, Awards, and Commercialization

- October 2018, 2019, and 2020 presented HYPOWERS project at annual WEFTEC conference with more than 20,000 attendees annually.
- Q3 and Q4, 2020 continuing collaboration to train Jacobs Engineering personnel on Hydrothermal Processing.
- 11/22/2020: Presented HYPOWERS project at Bay Area Air Quality Management District (BAAQMD) Climate Tech Marketplace.
- 4/2/2020: Presented Hydrothermal Processing at Central States Water Environment Association Conference on New Technologies for Wastewater Solids.
- 10/7/2019: Presented Hydrothermal Processing at tcBiomass conference sponsored by GTI.
- March 2019: Conducted briefing for AECOM engineers to familiarize them with Hydrothermal Processing.
- 3/6/19: BETO 2019 Project Peer Review. *HYPOWERS Project*.
- 11/28/18: SERDP-ESTCP Symposium. *Hydrothermal Processing of Wastewater Solids to Produce Renewable Fuels*
- 9/13/18: NJWEA Technology Transfer Seminar. *Hydrothermal Liquefaction: From Biosolids to Biocrude*
- 5/17/18: 2018 WEF Residuals and Biosolids Conference. Panel on Biofuels and Bioproducts from Wet and Gaseous Waste Feedstocks.
- 4/25/18: LIFT Biosolids-to-Energy Focus Group Meeting. *Update on HYPOWERS Project.*
- 3/20/18: 2018 LIFT Presentation Series - Biosolids-to-Energy. *Genifuel.*
- 12/7/17: *CHG Commercial Overview*, CHG Workshop, presentation at PNNL to US Army Corps of Engineers, University of Illinois, Technical University of Netherlands, PNNL, to discuss HTP technology.
- 11/14-15/17: *Hydrothermal Processing in Wastewater Treatment*, CASA/CWEA (California Association of Sanitation Agencies and California Water Environment Association,) 14 November in Northern California (Berkeley) and 15 November in Southern California (UC Irvine), presentation to all major utilities at annual CASA/CWEA biosolids meeting.
- 11/8/17: Isle Utilities Technical Advisory Group, London. *Hydrothermal Processing in Wastewater Applications.* Presentation of HTP technology to select international audience.
- 8/11/17: Intensification and Resource Recovery (IR^2) Forum. *Genifuel Technology* - The Genifuel presentation was made jointly with Metro Vancouver to discuss the status of Hydrothermal Processing for wastewater solids. The attendees were a select group of approximately 100 executives from utilities, engineering firms, consultants, and technology developers worldwide.
- Bioeconomy 2017- *Hydrothermal Processing Of WastewatER Solids (HYPOWERS) Project* - Overview of the project at DOE BETO's flagship event.
- 7/18/17: Mid-Atlantic Biosolids Association Annual Meeting. *Innovations in Thermochemical Conversion*.

Utility Advisory Committee

- American Water (130 wastewater plants)
- Central Contra Costa Sanitary District
- City of Calgary
- City of Orlando
- Clean Water Services (Hillsboro, OR)
- Eastman Chemical Company
- Great Lakes Water Authority (Detroit)
- Louisville Metropolitan Sewer District
- Metro Vancouver
- Metro Wastewater Reclamation District (Denver)
- Metropolitan Sewer District of Greater Cincinnati
- Metropolitan Water Reclamation District of Greater Chicago (MWRDGC)
- New York City Department of Environmental Protection (NYC DEP)
- Silicon Valley Clean Water
- Toho Water Authority
- Unity Water

Risk Registry Table – Project Related Risks (1 of 5)

Subtask	Description	Likelihood	Impact	Strategy Approach (accept, avoid, transfer, or reduce)	Risk Response Strategy
Project	Scheduling Interdependencies	High	Medium	Reduce	Active communication could identify ways to avoid these inevitable issues from having cascading impacts on the project.
Project	Problems with novation of DOE contract	Low	High	Avoid	This would delay the project as WRF is unable to be the prime for Phase 2. Work proactively with DOE to plan and prepare all documentation for this activity.
20.3	Risk is dependent upon chosen contracting methodology	Medium	Medium	Transfer and Accept	Contracting methodology shall be chosen to manage and transfer risk. Contingency fund in place.
20.4	Anchor bolt layouts for the skids will need to be coordinated and verified to ease field assembly and installation.	Low	Medium	Transfer	Final designs will dictate these items and they will be included in the contract.
20.4	Pre-built piping spools may not line up perfectly with connection locations and may need to be field modified.	Medium	Medium	Reduce	Additional equipment piping will be shipped on site to accommodate siting issues.
20.4	The Canopy Structure will need to be erected after all the equipment and piping is set, as access to equipment may be limited once Canopy Structure is installed.	Low	Low	Reduce	Final design/layout should make a conscious effort to allow for access.
21.1	The Long lead time for certain pieces of equipment may affect/increase the duration of this task.	High	High	Reduce	Ordering of major equipment will be sequenced earlier in the project.
21.1	Timing the receipt of vendor data must be managed to progress fabrication design.	Medium	Medium	Reduce	Vendor data should be specified as part of the PO in anticipation of these questions.
21.1	Getting an accurate schedule from fabricator and managing against it.	Medium	Medium	Transfer	Contracting methodology should address fabrication scheduling.
21	Ease of accessibility of fabricator to engineer or inspector(s).	Medium	High	Reduce	Fabricator selection process should account for this in selection criteria.
21.2	Open communication between fabricator and engineer.	Medium	High	Reduce	Fabricator selection process should account for this in selection criteria.

Risk Registry Table – Project Related Risks (2 of 5)

Subtask	Description	Likelihood	Impact	Strategy Approach (accept, avoid, transfer, or reduce)	Risk Response Strategy
21.2	Schedule risks due to equipment delivery times and time required to design equipment integration into structural skids.	Medium	Medium	Reduce	Planning should identify long lead time equipment and materials and sequence earlier.
21.3	Scheduling of FAT testing with multiple parties' schedules.	Low	Medium	Reduce	Scheduling of event will be done well ahead of time.
21.3	Punchlist items delaying FAT test or causing re-tests that must be scheduled.	Medium	High	Accept	Factory re testing delays should save significant time/effort in the field.
21.3	Availability of space and/or utilities to perform FAT testing.	Low	High	Reduce	Fabricator selection process should account for this in selection criteria.
21.4	Damage due to shipping.	Medium	Medium	Transfer	Fabricator will be paid for shipping the skid to site and should be held liable.
21.4	Equipment or parts lost during shipping.	Low	High	Transfer	Fabricator will be paid for shipping the skid to site and should be held liable.
21.4	Poor weather affecting shipping or delivery times.	Low	High	Accept	Build in schedule buffer.
21.4	May need laydown area at Central San during construction to receive all skids, likely at once.	Low	High	Reduce	Communicate with Central San/B&V early about spacing requirements.
21.5	Extent of cost reduction engineering that is done during this task may affect scope and schedule.	Low	Medium	Reduce	Contingency fund in place to address unexpected events.
22	Leased systems have less flexibility than purchased system in terms of connections and configurations available to match what was reviewed in the HAZOP.	High	Medium	Reduce	Make an informed lease/buy decision, which accounts for this issue.
22	Cost of long-term lease may exceed the purchase cost of the equipment, such that in the long term it would be more cost effective to purchase the equipment.	High	Medium	Reduce	Make an informed lease/buy decision, which accounts for this issue.
22.2	Central San may look at providing a facility trailer as part of a longer-term plan to have one on site.	Medium	Low	Accept	This would reduce project costs, but would require increased coordination
23.1	Process evaluations for HTLww do not provide a solution that meets gas production and/or water treatment objectives for pilot operations	Low	High	Accept	This would result in a no-go for for CHG, and require an alternative approach for water treatment to enable return of HTLww to the WWTP.

Risk Registry Table – Project Related Risks (3 of 5)

Subtask	Description	Likelihood	Impact	Strategy Approach (accept, avoid, transfer, or reduce)	Risk Response Strategy
23.2	HTLww will only be available from PNNL derived from their ongoing DOE R&D programs until the HTP pilot plan begins operations	High	Low	Accept	PNNL will provide HTLww from multiple sources that can used for water treatment testing by MicroBio to select an appropriate treatment system. Scheduling dependencies are a reality of complex projects.
23	Design changes and needed upgrades to mobile CHG system require significant costs and schedule to complete.	Medium	High	Accept	Operation of the CHG unit presents a host of benefits. Increase costs will have to be accounted for to validate CHG at a pilot-scale.
23.3/25.3	Mobile CHG may not be an appropriate process system for testing the selected process option. (If this is the case, PNNL will work with SoCal Gas to determine an alternative approach to demonstrate the gasification technology as part of the HYPOWERS project).	Low	High	Accept	Must work with stakeholders to determine the viability of proceeding with alternative gasification technology.
24.1	Unforeseen operating scenarios or processes requiring additional dedicated operating procedures.	Low	Medium	Accept	Safety is paramount and cannot be compromised. Build ample time in schedule for development of SOPs.
24.2	Fabrication and installation delays can delay the start date for this Task.	High	Low	Reduce	Build slack into schedules to account for this inevitability
24.2	Equipment failures and design issues may require additional resources, rework of contracts, and result in schedule delays.	Medium	High	Reduce	Build slack into schedules, apply rigor at the FAT and Redundancy of critical equipment and spares and materials where possible.
24.2	If long delays are encountered, key staff could be reassigned.	Medium	Medium	Reduce	Plan for staff redundancy and obtain staffing commitments at a high level with the organizations' management.
24.2	Piping leaks, especially at joints subject to thermal cycling, are most likely to be discovered during this phase of the project.	High	Low	Accept	Ad-hoc repairs are anticipated in the schedule.
24.2	Control loop tuning can take significant time to refine during this period, to stabilize the operation of the system.	Medium	Low	Accept	Schedule slack allocated to this process.

Risk Registry Table – Project Related Risks (4 of 5)

Subtask	Description	Likelihood	Impact	Strategy Approach (accept, avoid, transfer, or reduce)	Risk Response Strategy
24.3	Sufficient operators with required skills are unavailable or cost significantly more than anticipated.	Medium	High	Reduce	Start search early and have ample backups.
24.4	Delay of a critical permit	Medium	High	Reduce	Defining permitting landscape was high priority in Phase1; high level of attention to be maintained.
24.4	An assessment of what would be required for gas upgrading is needed to inform the LCA/GHG analysis of CHG.	Medium	Low	Reduce	Open a line of communication with critical regulatory stakeholders.
24.5	Establishing an off-take agreement with a refinery partner or a hydrotreating supplier willing to handle this volume/type of fuel.	High	High	Reduce	Consider other options for off-take with smaller biorefinery, toll processing and waste oil disposal.
24.5	A byproduct stream must be treated as hazardous waste.	Medium	Low	Reduce	Develop a plan "B" for filter solids.
24.5	The offtake for CHG is minimal unless extended runs are planned or there is opportunity to add CHG capacity once a workable catalyst solution is found—although the definition and cost of a pipeline interconnect should be developed in cooperation with SoCalGas.	Low	Low	Accept	The success of CHG piloting would pay enormous dividends for the commercialization of this technology. Gas can be flared, once air permits are met.
24.6	Findings from ORR result in significant rework, resulting in unplanned cost and schedule delays.	Medium	High	Reduce	Closely coordinate ORR Plan with Shakedown testing.
25.1	Thickening and feeding operations fail to deliver 20 wt% sludge feed.	Medium	Medium	Accept	Fix to the extent possible, but may have to proceed at low concentration.
25.1	Initial sludge processing could reveal process vulnerabilities that require further modification prior to proceeding with HTP test campaigns.	Low	High	Accept	Having done extensive research, we will have to react to these situations as they arise.
25.1	Confidence/support from a key stakeholder (e.g., permitting authority) is lost).	Low	High	Reduce	Proactive engagement with stakeholder to be pursued.
25.2	Equipment/process fails to meet expectations.	Low	High	Accept	Robust FAT testing to be conducted. We will have to react to these situations as they arise.
25.2	Aqueous byproduct adversely affects CCCSD operations.	Low	High	Reduce	Characterization continuing and options to be investigated and implemented.

Risk Registry Table – Project Related Risks (5 of 5)

Subtask	Description	Likelihood	Impact	Strategy Approach (accept, avoid, transfer, or reduce)	Risk Response Strategy
25.3	CHG testing may not proceed if PNNL current efforts to develop new catalysts and/or catalyst regeneration methods are not successful.	High	High	Reduce	Significant work is underway at PNNL.
25.4	Refinery partner does not participate/support biocrude and HT product evaluation.	Medium	Medium	Accept	PNNL has capability to perform this activity.
25.4	Operation of AOP is required for return of HTLww to Central San headworks.	High	High	Accept	We are budgeting for an AOP unit that will ensure compliance with all Central San discharge policies.
25.4	Subtask may get tabled based on availability of CHGww for ammonia (N) recovery.	Medium	Low	Accept	Task may be limited to ensuring exclusion from 503 regulations. This is of lower priority to the other barriers to commercialization.
25.5	Application may not be able to be submitted until final fuel products from the HYPOWERS project have been produced. This would delay the submissions by at least 18 months.	High	Medium	Accept	Having already begun discussion with the regulatory agencies we must keep the lines of communication open and await the data.
26	Discussions are ongoing with several potential refinery partners. These agreement(s) must be negotiated and finalized during BP3.	High	High	Reduce	Numerous conversations are ongoing, with the intention of finding a willing partner who sees the potential value.
27	Failure to secure an offtake agreement for biocrude.	Medium	High	Reduce	Develop back up strategy for biocrude use.
28	Low scope definition for site restoration at this moment.	Medium	Low	Accept	This risk is likely to only reduce the requirements, e.g., leaving the concrete pad.
29	Loss of key staff between data intensive testing and extended operations.	Medium	Medium	Reduce	Prepare draft report after data intensive testing.
29	Final report loses impact because of planned issuance date.	Medium	Medium	Reduce	Consider issuing a summary report after completing Task 25.