INL/EXT-16-38319

Tire Pyrolysis Feasibility Study Approach

Submitted to: ***Dr. Richard Littlebear, President, Chief Dull Knife College***

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INTRODUCTION AND BACKGROUND

Chief Dull Knife College, in collaboration with the Northern Cheyenne Tribe, recently contacted Idaho National Laboratory (INL)'s Technology Based Economic Development team, inquiring about the technical assistance program (TAP). Chief Dull Knife College indicated the need to gain a more detailed understanding of available tire pyrolysis technology and requested INL's support to produce a feasibility study approach, outline, and estimate to complete.

Scrap tires are a serious threat to human health and the environment since they promote infestations of pest and insects and pose a high risk of fires. Tire fires can be difficult to extinguish and cause a significant environmental impact due to the emissions of potentially harmful compounds into the air, soil, and groundwater [1]. Options for treating or recycling scrap tires include use as a fuel in cement kilns and power plants, co-incineration with other wastes, material recovery, re-treading, and use of the tires in civil engineering applications such as road and rail foundations and embankments. There is a growing interest in alternative treatment paths such as pyrolysis to produce valuable oil, char and gas products in addition to the recovery of the steel [2]. Pyrolysis is the thermal decomposition of the organic compounds in waste tires in the absence of oxygen and under high temperature (300-900 °C) [3].

Pyrolysis oil may be used directly as a fuel, added to petroleum refinery stocks, upgraded using catalysts to a premium grade fuel, or used as a chemical feedstock. The gases from tire pyrolysis are typically composed of C_1–C_4 hydrocarbons and hydrogen with a high calorific value and sufficient energy content to act as fuel to provide the heat for the pyrolysis process. The solid char consists of the carbon black filler and also char produced during the pyrolysis of the rubber. It may be used as a solid fuel, as carbon black, or upgraded to produce an activated carbon [2].

The focus of the proposed study will be to assess the feasibility of using the pyrolysis of scrap tires to create valuable byproducts like kerosene, diesel fuel, gas, char and activated carbon. The feasibility study approach will include a review of the entire value chain from harvesting of the tires from the dump, transporting to the location to go through the pyrolysis process, and selling of the byproducts. Understanding the financial modeling, economics of markets for byproducts, logistics costs associated with shipping, and evaluation of existing technologies based upon published information and strengths, weaknesses, opportunities, and threats (SWOT) type analysis are additional areas the Chief Dull Knife College and the Northern Cheyenne Tribe would like included in the feasibility study. They also request the approach to be thoughtful of the pristine air status of the Tribal lands and seek a flexible solution that would allow future growth of the plant to increase capacity if the tire supply grows.

RECOMMENDED FEASIBILITY STUDY APPROACH

This document describes a systematic approach to gain an understanding of current tire pyrolysis technologies and assess the feasibility of using this technology to construct an economically and environmentally viable pyrolysis plant that will meet the needs of the Chief Dull Knife College and the Northern Cheyenne Tribe. It is assumed that the study will be performed at INL or another DOE laboratory.

Scope and Approach

The study approach follows a proven systems engineering process to assess the feasibility of a tire pyrolysis plant by understanding the whole problem, defining the problem in terms of measurable requirements, examining feasible alternatives and their life cycle costs, and selecting a preferred alternative. Figure 1 illustrates the study approach tasks, divided into three phases, as described below.

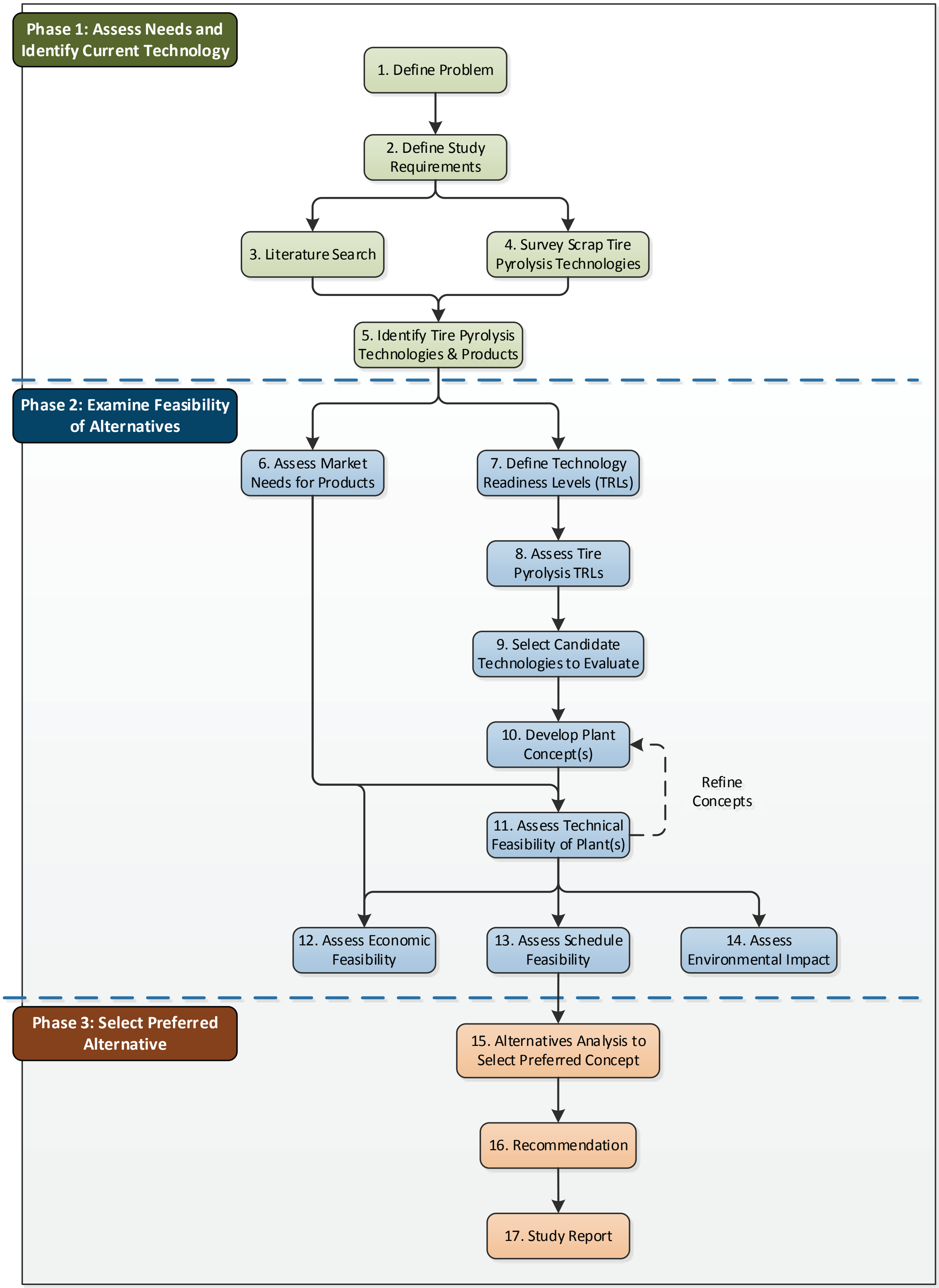


Figure 1 Tire Pyrolysis Feasibility Study Approach

Phase 1: Assess Needs and Identify Current Technologies

Phase 1 baselines the needs and objectives for the study and identifies applicable, current tire pyrolysis technologies that may meet the needs for a tire pyrolysis plant and as such should be considered for evaluation. Understanding the context to a problem and the associated requirements are essential for identifying and analyzing alternative technologies.

Task 1. Meet with representatives of Chief Dull Knife College and the Northern Cheyenne Tribe to fully understand their needs, objectives, and timeline for a tire pyrolysis plant and document them in a needs statement. This will provide a clear, mutual understanding and agreement on the problem and challenge being addressed and a foundation for identifying the right technology to assess. System boundaries, interfaces, outcomes, and affected stakeholders associated with the technology opportunities are relevant and must be established.

Task 2. Define the requirements and constraints (e.g., plant location restrictions) that the tire pyrolysis technology must meet. This includes examining environmental regulations, laws, codes, standards, contracts, and other procedural and policy documents. Identified requirements are then documented and tracked to verify that resulting solutions meet expectations. This task will also involve estimating the current and projected tire supply to establish a potential range for the operating capacity of the plant.

Task 3. Conduct a literature search to identify the current state of the art in tire pyrolysis technologies, including previous feasibility studies, pyrolysis products and uses, operating experiences, economic viability, performance, emissions, waste streams, barriers, and issues. An initial search has been conducted and numerous journal articles have been received, revealing a wide range of pyrolysis technologies, capacities, and differing levels of technology maturity that will need to be examined in the study. The remaining literature search will focus on drilling deeper into the processes that are more mature and potentially applicable to the needs and objectives identified in Tasks 1 and 2. Examples of identified tire pyrolysis systems and their capacities are shown in the following table [2].

Company	Location	Reactor Type	Capacity (tonnes/day)
Splainex Ltd	Hague, Netherlands	Rotary kiln	~20
Xinxiang Doing Renewable Energy Equipment Co., Ltd	Xinxiang, China	Rotary kiln	6-10
RESEM	Shangqui, China	Rotary kiln	8-20
Kouei Industries	Vancouver, Canada	Fixed bed/Batch	16
DG Engineering	Gummersbach, Germany	Rotary kiln	~10
FAB India	Amedabad, India	Rotary kiln	5-12
Octagon Consolidated	Selangor, Malaysia	Rotary kiln	2.4-120
No-Waste Technology	Reinach, Germany	Fixed bed/Batch	4
PYReco	Teeside, UK	Rotary kiln	200
Pyrocrat Systems	Navi Mumbai, India	Rotary kiln	2-10

Task 4. Survey companies identified in the literature search to gather as much data as possible on their technologies, including a description of the process, commercial status, capacity, products and composition, inputs required (e.g., water, energy), waste streams, emissions, capital and operating costs, and operating experience.

Task 5. Examine the results of the literature search and company surveys and summarize the information gathered on each of the tire pyrolysis technologies and manufacturers. It is very important to identify the composition and quality of the pyrolysis products as the quality may dictate the need for further processing or upgrading to produce a saleable product. For example, researchers have reported that the main barriers to the direct implementation of scrap tire pyrolysis oil are high sulfur content, high content of aromatics, and high proportion of heavy molecules [4].

Phase 2: Examine the Feasibility of Alternatives

Phase 2 assesses the market demand for pyrolysis products and screens the technologies identified in Phase 1 to select the most promising options to evaluate in depth for feasibility. Based on the selected technologies, Phase 2 will also develop plant concepts in sufficient detail to compare concepts and conduct a technical, economic, and environmental feasibility assessment of the plants.

Task 6. Assess the market demand for the pyrolysis products produced by the technologies identified in Phase 1, including defining the product composition and quality requirements to meet industry needs.

Task 7,8. Evaluate the technologies identified in Task 5 to determine their maturity for use in a commercial pyrolysis plant, which is a major factor in determining technical feasibility. Maturity will be assessed using Technology Readiness Levels (TRLs) based on industry best practices and INL's experience on DOE and U.S. Department of Defense programs. Figure 2 illustrates typical TRL levels corresponding to the maturity of the technology, from a basic principle up to a first of a kind (FOAK) plant and finally a fully operational plant. The risk levels and design phase associated with the TRLs are also shown.

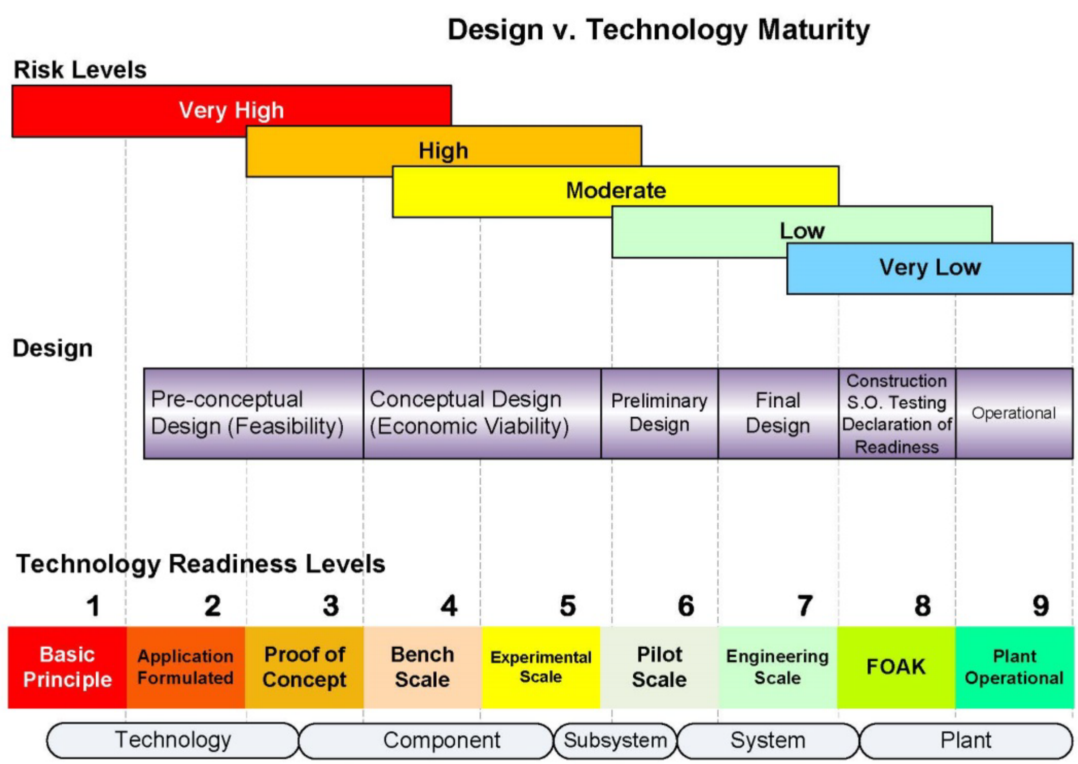


Figure 2 Technology Readiness Levels.

Task 9. Based on the results of the technology readiness assessments of Task 8, establish screening criteria and select the most promising technologies that can be matured and implemented within the desired timeline to construct an operational plant. In general, only technologies that are assessed at a TRL of 6 or greater will be considered for further evaluation.

Task 10. For each of the technologies selected in Task 9, develop a plant concept in sufficient detail to compare concepts, including system description, components list, plant size, operating concept/scenarios, performance, flowsheet analysis, etc.

Task 11. Assess the technical feasibility of each plant to meet requirements and market needs. The assessment will include parameters such as the products produced; their composition, quantity, and quality; plant capacity and efficiency; and the need for further processing or upgrading to produce a saleable product. Concepts will be refined, if possible, to better meet requirements and improve performance and then re-evaluated.

Task 12. Assess the economic feasibility of each concept, including life cycle cost estimates, revenue estimates, return on investment (ROI) and sensitivity to cost and revenue variations. Note that the cost estimates will include the costs associated with constructing and maintaining the pyrolysis plant, harvesting the tires from the dump, transporting the tires to the pyrolysis plant, processing the tires, and transporting the byproducts to market.

Task 13. Assess the time required to completely mature the technology, if any, and the time to construct an operational plant, including the time to obtain the necessary permits and regulatory approvals.

Task 14. Assess the environmental impacts of each concept, including air emissions and waste streams.

Phase 3: Select the Preferred Alternative

Phase 3 will compare the plant concepts that were found to be feasible in Phase 2 to select the preferred concept. A recommendation and path forward will be prepared and documented in a final report.

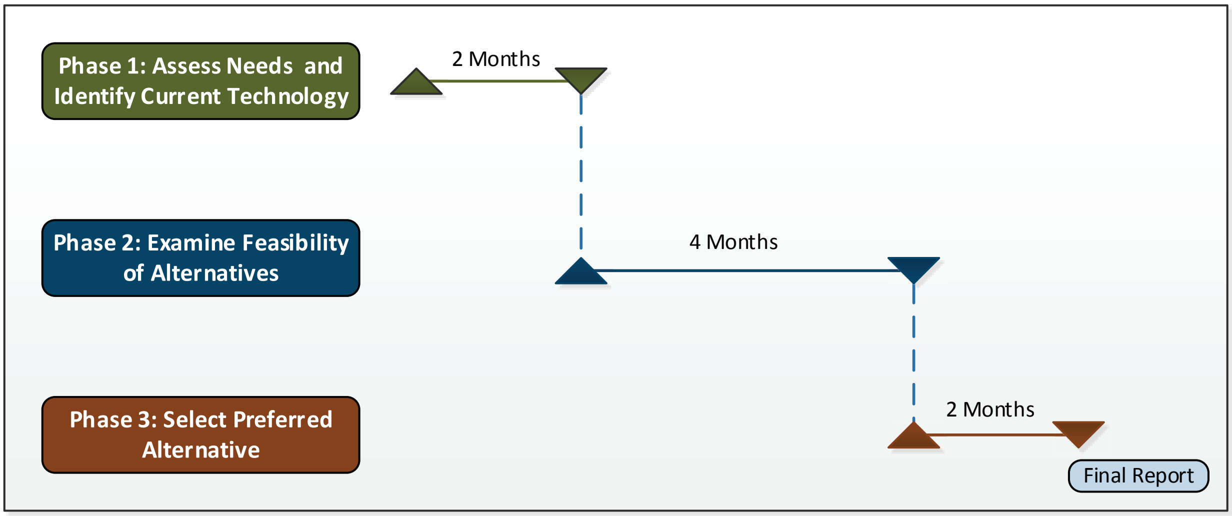
Task 15. Perform an alternatives analysis to compare data on each alternative and select the preferred plant concept using SWOT analysis and quantitative decision analysis tools.

Task 16. Prepare recommendations regarding the findings of the feasibility study and a path forward to implement the recommendations.

Task 17. Prepare a final feasibility study report using the draft outline provided in Appendix A.

Preliminary Schedule

The estimated schedule for each phase of the study is shown below.



Milestones and Deliverables

The deliverables for the study are a final feasibility study report and a progress report and/or presentation at the end of Phases 1 and 2.

Cost Estimate

The estimated total cost for all phases of the study, including both labor and several trips to meet with representatives of the Chief Dull Knife College and the Northern Cheyenne Tribe are shown below.

Description	Cost ($K)
Phases 1-3:	
Labor	$ 482K
Travel	$10K
Grand Total	**$ 492K**

REFERENCES

1. J. Daniel Martinez, R. Murillo, T. Garcia, A. Veses, Demonstration of the waste tire pyrolysis process on pilot scale in a continuous auger reactor. *Journal of Hazardous Materials* 261, 637-645 (2013).
2. P. T. Williams, Pyrolysis of waste tyres: A review. *Waste Management* 33, 1714-1728 (2013).
3. N. Jantaraksa, P. Prasassarakich, P. Reubroycharoen, N. Hinchiranan, Cleaner alternative liquid fuels derived from the hydrodesulfurization of waste tire pyrolysis oil. *Energy Conversion and Management* 95, 424-434 (2015).
4. I. Hita *et al.*, Opportunities and barriers for producing high quality fuels from the pyrolysis of scrap tires. *Renewable & Sustainable Energy Reviews* 56, 745-759 (2016).

APPENDIX A FEASIBILITY STUDY REPORT OUTLINE

Executive Summary
Acronyms
1. Introduction
   1.1 Purpose
   1.2 Study Background
   1.3 Approach
2. Requirements
   2.1 Objectives
   2.2 Requirements
      2.2.1 Current and Projected Tire Supply
      2.2.2 Tire Characteristics (Size, Composition, etc.)
      2.2.3 Environmental Regulations and Policies
      2.2.4 Need Date
   2.3 Assumptions, Issues and Constraints
3. Review of Tire Pyrolysis Technologies and Products
4. Survey of Existing Tire Pyrolysis Technologies and Facilities
5. Market Analysis of Tire Pyrolysis Products
   5.1 End Products and Composition
   5.2 Quality Requirements
   5.3 Market Demand
6. Tire Pyrolysis Technology Readiness Assessment
   6.1 Definition of Technology Readiness Levels (TRLs)
   6.2 Assessment of Tire Pyrolysis Technologies/Plants
7. Candidate Tire Pyrolysis Technologies/Plants
   7.1 Selection Criteria
   7.2 Selection of Technologies/Plants for Further Evaluation
8. Plant Alternatives
   8.1 Description of Plants
   8.2 Sizing Plants to Match Supply
   8.3 Operating Concept
9. Plant Alternatives Technical Feasibility Analysis
   9.1 Products Produced
   9.2 Inputs Required
   9.3 Performance (Output Quantity and Quality)
   9.4 Flowsheet Analysis
   9.5 Energy Balance
   9.6 Evaluation Against Market Needs and Requirements
   9.7 Risks and Issues
10. Environmental Impact of Plant Alternatives
   10.1 Air Emissions
   10.2 Waste Streams
11. Economic Analysis of Plant Alternatives

11.1 Life Cycle Cost Estimate
11.2 Revenue Estimate
11.3 Return on Investment (ROI) Analysis
11.4 Sensitivity Analysis to Cost and Revenue Variations
12. Schedule Analysis
12.1 Time Estimate to Build Plant
13. Alternatives Analysis
13.1 SWOT
13.2 Quantitative Analysis
13.2.1 Evaluation Criteria
13.2.2 Comparison of Alternatives
13.2.3 Preferred Alternative
14. Recommendations
References
Glossary
Appendix A: Survey Questionnaire
Appendix B: Description of Pyrolysis Technologies and Plants Identified from Literature Search and Survey
Appendix C: Life Cycle Cost Analyses