Energy Networks Innovation Process

Project Close Down Form

Notes on Completion: Please refer to the NIA Governance Document to assist in the completion of this form.
Do not use tables

Step 1 - Initial Project Details

Project Title

Active Creosote Extraction (ACE)

Project Reference

WPD_NIA_061

Project Contact(s)

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Project Start Date

11/21

Project End Date

03/24

Scope (15000 Characters max)

Across all four license areas, NGED currently has approximately 1,377,000 creosote treated wood poles. Annually 27,000 of these poles are replaced and are either left with landowners at the place they came down or returned to a local depot site. Traditionally, poles that are returned to depot account for approximately 10%, but the most recent data suggests that this number has risen to 37%. Due to their creosote content, all returned poles must be disposed of as hazardous waste and do so through an incineration facility in South Yorkshire. In 2016/17 NGED spent £253,320 on the disposal of returned poles at the South Yorkshire facility, and the most current disposal figures, between November 2019 and October 2020, show 840 tonnes of treated poles were sent for incineration at a cost of £185k. NGED is reliant on the continued operation of the South Yorkshire site to accept and dispose of all treated waste poles.

In order to achieve the NGED Net Zero ambition whilst also aiding with the wider UK goal to reach Net Zero by 2050, an alternative disposal methodology must be created in order to effectively reduce our carbon emissions around the disposal of wood poles. Current figures show that the emissions generated from the wood poles that have been disposed of since 2017 equal that of a modern day van driving 34 million kilometers, equivalent to 5960 tonnes of CO_2 being released into the atmosphere. This number is only exacerbated when you take into account other DNOs and wider industries such as the rail and telecoms sector.

To address this, project ACE established a new solution to dispose of wood poles and thus created an environmentally friendly alternative. The project scoped, designed, built and trialed a methodology that is able to extract creosote from wood poles to levels that can deem the wood as non-hazardous waste. Tests carried out to determine the most efficient extraction procedure and its scalability from a 2.5m pole to a 5.0m pole.

ACE demonstrated a robust, proven concept that can efficiency extract creosote from wood to levels where they are deemed as non-hazardous waste. Further work is now being made to identify funding strategies to make this a commercially viable product.

Objective (15000 Characters max)

- Develop an extraction method that can extract creosote from wood poles at a length of 2.5m.
- To determine the best type of extraction method that can be used for creosote extraction.
- To develop an extraction method that can extract creosote from wood poles at a length of 5.0m
- To determine the best type of extraction method that can be used for creosote extraction.
- To develop the extraction method further to enable a carbon recovery unit within the extraction loop.
- To create a disposal method where wood poles can be deemed as non-hazardous waste.
- To assess the commercial validity of the extraction method.

Success Criteria (15000 Characters max)

The success criteria are outlined below;

- Extraction tests carried out for a 2.5m pole.
- Identification of best extraction method.
- Extraction tests carried out for a 5.0m pole.
- An assessment carried out on the commercial validity of the system.
- Creating a method that can deem poles that have had creosote extracted from them as non-hazardous waste.

Step 2 - Performance Outcomes

Performance Compared to Original Project Aims

Details of how the Project is investigating/solving the issue described in the NIA Project Registration Pro-forma. Details of how the Project is performing/performed relative to its aims, objectives and success criteria. (15000 Characters max)

The following sections outline the overall performance compared to the project's aims and original objectives with detailed commentary surrounding some of the key areas that have generated learning and relevant outputs for the project.

System Design
The system design was the most significant undertaking part of the project overall. This phase of work concerned the initial design, construction, procurement and overall safety sign off in order to utilise the extraction system. This is the area which resulted in the request for a project extension due to delays and changes in the design and impediments in the safety sign off process. All goals and objectives that were originally set, were achieved with a functional extraction system that was able to operate on creosote impregnated poles.

Baseline Analysis
Whilst the design element was being carried out, it was key that a baseline level of creosote concentration could be established to understand;
a. the amount of creosote levels throughout redundant poles
b. the consistency, if any, of creosote levels between poles, and
c. how far away are the existing wood poles from non-hazardous waste classification.

This process was carried in both house and externally using a range of techniques. In doing so, we have now founded a steady baseline for the amount of creosote we can expect with redundant poles and numerous processes to investigate these levels during the trial.

Testing Methodology
The idea for the tests was to trial a range of techniques and methods to establish the most effective, efficient and reliable technique to remove creosote from wood poles. A methodology report has been produced, outlining the procedures that will take place to determine the feasibility of the use of supercritical CO_2 for the reduction in concentration of creosote in end-of-life wood poles. This methodology provided a solid basis as to what was to be carried out during the test window.

Testing
Once sign off had been agreed upon with the external processing engineers, the project team was able to undertake commissioning, pressure testing and pole testing with the extraction system in place. The commissioning process tied together the pressure testing and establishing the most efficient procedure to reach the operating pressure and temperature conditions. Once this was achieved, the testing methodologies could be tested with the wood poles as subjects. The tests were found to be effective with efficiencies of up to 89% reduction reached. Test durations ranged from 60 to 240 minutes.

Carbon recovery Testing

The final stages of the project aimed to procure a carbon recovery unit as the medium for the extraction of creosote was supercritical carbon dioxide. This aimed to make the process as environmentally friendly as possible. The carbon recovery unit itself, had the ability to carry out its own extraction with two cylindrical vessels accompanying the recovery system. The advantage of these vessels over the original 2.5m vessel was it could withstand greater temperatures and operating pressures. The new operating conditions were over 4000 psi and over 60˚C. This resulted in an increased efficiency of extraction paired with a new theory of extracting chipped wood due to the increased surface area the supercritical carbon dioxide could target. This new method resulted in a major breakthrough, managing to extract over 1kg of creosote per 10kg sample of wood. In other tests, the creosote concentration reductions were seen to go from 9000mg/kg down to 300mg/kg. These tests were consistent in being achieved in 45-60 minutes.

Performance against objectives.

- **Develop an extraction method that can extract creosote from wood poles at a length of 2.5m. – *Complete***

  Outputs from ACE have developed an extraction methodology that enables creosote to be extracted from end-of-life poles. Four such methods have been developed with their effectiveness captured throughout the life cycle of the project

- **To determine the best type of extraction method that can be used for creosote extraction. – *Complete***

  Four methods have been tested. SFE, Pulsed, Methanol and Acetone. The most effective from the four initial methods was the pulsed extraction technique.

- **To develop an extraction method that can extract creosote from wood poles at a length of 5.0m – *Incomplete***

  This work package was re scoped as it was determined through the initial testing phases that scaling up to 5.0m proved to be inefficient due to the labour-intensive process of loading and unloading poles pre and post treatment in addition to the large range of creosote concentrations over the length of a pole (shorter poles will have less spread in creosote concentrations than longer poles sections).

- **To develop the extraction method further to enable a carbon recovery unit within the extraction loop. *Complete***

  The additional inclusion of a carbon recovery unit further increases the efficiency and effectiveness of the testing methodology. Furthermore, the carbon emissions were significantly reduced to enable a clean method and creosote extraction and pole disposal.

- **To create a disposal method where wood poles can be deemed as non-hazardous waste. – *Partially Complete***

  The tests that included the carbon recovery system, resulted in a successful test, in that the concentration levels of the samples tested were below the classification post extraction. Further work is needed with the environmental regulator to determine the exact process for determining the post treated wood as non-hazardous waste as no current methodology for determining exists.

- **To assess the commercial validity of the extraction method. – *Complete***

  The project has developed and produced a detailed cost benefit analysis to indicate the scalability of the proposed test system.

Performance against success criteria

- **Extraction tests carried out for a 2.5m pole. – *Complete***
  Four different extraction methodologies were carried out on several test poles of 2.5m in length.

- **Identification of best extraction method. – *Complete***
  All four methodologies were subjected to testing and the data recorded indicated their effectiveness for creosote removal. The most effective methodology was deemed to be Pulsed SFE, with a maximum creosote reduction of 89%.
- **Extraction tests carried out for a 5.0m pole. – *Incomplete***
  As aforementioned, the scope moved away from testing on extended lengths of poles due to the wider spread in creosote concentrations, thus reducing testing effectiveness due to increased inefficiencies in addition to increased labour regarding loading and unloading the poles before and after a test respectively.
- **An assessment carried out on the commercial validity of the system. – *Complete***
  The project has developed and produced a detailed cost benefit analysis to indicate the scalability of the proposed test system.

- **Creating a method that can deem poles that have had creosote extracted from them as non-hazardous waste. *Partially Complete***
  The tests that included the carbon recovery system, resulted in a successful test, in that the concentration levels of the samples tested were below the classification post extraction. Further work is needed with the environmental regulator to determine the exact process for determining the post treated wood as non-hazardous waste as no current methodology for determining exists.

Required Modifications to the Planned Project Approach

The Network Licensee should state any changes to its planned methodology and describe why the planned approach proved to be inappropriate. Please confirm if no changes were required. (15000 Characters max)

The project required a range of modifications and changes to the initial planned approach during the course of the project. The main changes are captured below with further specific commentary around the nature of the change and what action plans were taken forward to mitigate them.

The original plan was to deliver ACE in approximately 15 months. The original dates were November 2021 – March 2023. This was put in place in order to deliver a RIIO ED1 project within the RIIO ED1 settlement period. At the time of the project being scoped, there was uncertainty behind the allowance of RIIO ED1 projects being allowed to be delivered within the new RIIO ED2 settlement period. Nevertheless, the project was scoped to deliver all activity within the original timeframe.

Throughout the delivery of the first work package, numerous delays were incurred during the design, construction and commissioning phases of the work. It was noted that a bespoke quick release mechanism was needed to be developed in order to avoid, re-torqueing and pressure testing the vessel every time a pole was loaded. This resulted in a lead time of an extra three months prior to the extraction vessel being able to be delivered and commissioned.

In order for the vessel to be commissioned, a team of process engineers were engaged to assess the overall process, safety and operation of the vessel. This resulted in numerous additional procedures that needed to be put in place that included multiple levels of redundancy to avoid contaminating the CO2 storage tank with extracted creosote. This process took several months to be resolved.

An additional modification to the approach was needed to be made during the testing phase. It was determined that the approach to testing a 5.0m pole was an inefficient way of gaining an effective extraction. Due to the outputs from the baselining phase, it was found that there were huge variations between creosote concentrations across a pole. Some areas had high intensity concentration whereas other areas had much lower concentrations, some already below the non-hazardous waste classification threshold. Therefore, the focus changed to testing poles where the spread of creosote concentration was kept at a minimum. This increased efficiency and also reduced the labour intensive process of loading a 5.0m pole into a 5.0m vessel.

Overall, the project observed a one-year extension, concluding in March 2024.

Lessons Learnt for Future Projects

Describe how the project (methodology, stakeholder engagement etc.) changed, or provided opportunities, from your expectation at the start of the project and therefore could be useful for a future project. In addition, please discuss the effectiveness of the research development or demonstration undertaken. (15000 Characters max)

Below is a summary of the key learning that have been generated over the project.

Pre treatment

It is estimated that 50% of a redundant wood pole can be recovered through pre-treatment by selectively removing the outer layer for treatment. In essence, the majority of the inside of a pole can already be classified as non-hazardous. The full report can be viewed here.

Initial analytical results have shown that the highest levels of creosote (known as hot spots) concentration can be around 6500mg/kg. This is approximately 6.5 times greater than the classification levels for non-hazardous wood. As per the waste acceptance criteria, the level for non-hazardous waste classification is below 1000mg/kg. This has shown us the areas to target for future tests.

Initial data has shown gravitational effects play a part in the distribution of creosote hotspots. Towards the bottom end of the poles, the greatest concentration of creosote is observed. There are however, anomalies from time to time. This has opened up the scope of the anticipated scaled up system from a 2.5m vessel to a 5.0m vessel. It could prove more economical to have two separate vessels that focus on high and low creosote concentrated wood.
Fracturing in the wood significantly increases creosote penetration into the wood. It has also been observed that there have been higher creosote levels deeper into the poles compared to the outside. This will be due to the inner section being 'shielded' from the environment. Similar to the above, this opens up scope as to what we could do with multiple vessels being used in tandem. i.e. one vessel used for higher creosote concentrated wood and one with less.

Sample selection and preparation is fundamentally important and equally important is accurately quantifying the creosote concentration in the samples. Because it is impracticable to analyse the whole of the pole, samples prepared for analysis must be a random, representative of the whole, and homogeneous. This is done by grinding the wood into a powder. This ensures that each sample was not only well ground, but also well mixed to ensure a true representation was produced, limiting any sample bias.

Logistics

The activity of procuring poles has proven to be quite a challenge at times. Local depots can be reluctant to retrieve poles from their pole skips which results in that they can only be collected before this is done. This leaves a narrow pickup window as local depots also dispose wood poles after a short time period too. This has shown us that, regular cooperation is needed with local depots in order to efficiently pick up poles that have been left for the project team.

System Learning

Initially the liquid CO_2 storage tank must be set to the conditions of -17 ˚C and a pressure of 280 psi in order for the pumps to work efficiently. Heat exchangers are subsequently needed to get the supercritical conditions within the vessel of 1070 psi and 32˚C. Further details can be found in the extraction system overview report on the National Grid website. (nationalgrid.co.uk/downloads-view-reciteme/637791).

Due to heat exchangers being needed, trace heating has been applied to the design as liquid CO_2 cools under expansion from the transfer of the stored CO_2 conditions of -17 ˚C to the working conditions of 32 ˚C. Further details can be found in the extraction system overview report on the National Grid website (nationalgrid.co.uk/downloads-view-reciteme/637791).

In order to ensure safety venting lines and integrated safety relief valves have been attached to ensure safe release of gaseous CO_2 in a case of a failed case of the refrigeration system. These safety relief valves are set to release the pressure before the pressure rating of the fittings, and the extraction vessel, are reached the spring loaded valve is opened and the pressure released. This has assured a safety route, if testing elements were to go wrong. Further details can be found in the extraction system overview report on the National Grid website (nationalgrid.co.uk/downloads-view-reciteme/637791).

Procuring a CO_2 storage tank compared to traditional bottles has increased complexity of the system with regards to the required redundancy measures to be put in place. This is due to the risk of creosote entering the CO_2 tank once returned which carries severe consequences. Although the complexity has been increased with this change, it can be seen as an investment into what a scaled-up system would potentially look like. Rather than dispensing numerous CO_2 bottles, a single tank is able to be used. For this to be BaU, it would be highly unlikely that the source CO_2 delivery would be through bottles. In that regard, this addition will only contribute to the commercial potential and success of this project.

Testing

Due to the design being completely bespoke, establishing a methodology into the quickest and most effective way to achieving operating pressurisation took more time than anticipated.

Incremental pressure testing is required to achieve the desired operational pressure to solve leaking. Leaking occurs due to fittings not being tight enough and higher pressures causes further leaks, hence the need to incremental testing to address these. Due to the temperature deltas being used (range of 50 degrees C difference), compression / expansion is observed.

A chiller unit has had to be procured due to CO2 warming and state change during the introduction to the pump head. This resulted in cavitation and some CO2 leakage. By introducing the chiller unit, the CO2 can continuously be pumped in a liquid state.

5.0m pole sized needed to be re scoped due to the labour-intensive process of loading a 5.0m pole into a 5.0m pressure vessel. This process was deemed inefficient due to the size issue and also the variability of creosote concentration with a 5.0m poles. i.e. parts of the pole are non-hazardous during the test compared to other areas. This highly reduces space efficiency.

It was decided to design and build a skid to initially load the poles into the vessel in an easier way but to also introduce a barrier between the wood and the extracted creosote that was still left in the vessel. This would reduce surface contact and yield more creosote out of the wood.

Pulsed SFE – this method of extraction seemed to be more consistent than the standard Supercritical Fluid Extraction (SFE) and indicates extraction during the additional depressurisation periods.

Methanol modified SFE. – Methanol as an additive to the Supercritical Fluid Carbon Dioxide (SFCO2), seems to have an effect, with the possibility for the requirement for additional to be added, but once again the physical condition of the poles seems potentially to be a contributing effect on the extraction efficiency.

Acetone modified SFE – the addition of acetone seemed to have no additional effect on the extraction efficiency, and so can be discounted as an influencing factor.

Looking at the poles as a whole it can be seen that the core, which contributes between 40 and 70% of the total mass, are devoid of creosote and so do not require processing, and generally can be reused. Removal of this core would seem an obvious next step, along with the "mulching" of the remaining wood which would make it more uniform and also result in a much greater surface area for extraction, both of which would improve extraction.

The highest extraction efficiency was seen at 89% for a pulsed SFE test reducing the concentration from 17,206 mg / kg to 1816 mg / kg.

The best way for creosote removal is through the use of chipped wood due to the increased surface area available for the carbon dioxide to target.

The inclusion of the carbon recovery unit significantly improved the extraction effectiveness with the ability to operate at higher pressures and temperatures. One test resulted in an extraction from 9000 mg / kg to 300 mg / kg.

Outcomes of the Project

When available, comprehensive details of the Project's outcomes are to be reported. Where quantitative data is available to describe these outcomes it should be included in the report. Wherever possible, the performance improvement attributable to the Project should be described. If the TRL of the Method has changed as a result of the Project this should be reported. The Network Licensee should highlight any opportunities for future Projects to develop learning further. (15000 Characters max)

Throughout the project, there have been a number of outcomes that have been reported. These are as follows:

- Servicing, Calibration and Installation of Analytical Equipment – this report documented the process that will be undertaken in analysing the results that come through with the extraction tests. An overview of the extraction process has been highlighted and the role of each piece of equipment is detailed.
- Extraction System Report – this report summaries each key stage of the extraction process and the role each piece of equipment represents.
- Baseline analysis – this deliverable documented the expected 'baseline' levels of creosote present within a pair of poles prior to being treated with the extraction vessel.
- Extraction methodology – this document outlined the testing methodology that will be carried out throughout the whole testing period.

All project outputs can be found on the National Grid Website: National Grid - Active Creosote Extraction (ACE)

Step 3 - Outputs And Implementation

Data Access Level

A description of how any network or consumption data (anonymised where necessary) gathered in the course of the Project can be requested by interested parties. Please include a link to the publicly available data policy. (15000 Characters max)

All reports and supporting work are published on the National Grid – ACE project page. Additional data can be requested by contacting us directly.
NGED data can be requested via the National Grid Connected Data Portal (https://connecteddata.nationalgrid.co.uk/).
http://www.nationalgrid.co.uk/innovation/contact-us-and-more

Foreground IPR

A description of any foreground IPR that have been developed by the project and how this will be owned. (15000 Characters max)

The foreground IPR that has been generated from the project can be seen below.

- Work Package reports.
- Extraction system design and implementation.
- Techniques used to extract creosote from end of life wood poles.

New foreground IPR has been created in the project reports. These are published and freely available on the National Grid - Active Creosote Extraction (ACE) website.

Planned Implementation

Please describe the next steps to implement this innovation project. What policies and standards need to be updated or created as part of this implementation. (15000 Characters max)

The ACE project has successfully demonstrated the technical ability to extract creosote from end of life utility poles to such levels, that the test subject has concentration quantities that are below the non-hazardous threshold level. For this to be rolled out into a Business as Usual (BaU) environment, there are two points that have to be satisfied:

- Commercial viability of the ACE methodology
- Capital Investment for vessels at scale

The project assessed, through the use of a singular modular extraction vessel, paired with a carbon recovery unit the possibility of removing creosote from wooden poles to such levels they could be deemed as non-hazardous waste. This required significant financial investment, through the RIIO ED1 NIA funding mechanism in order to design, procure, build and test the system. Now this has been achieved, the overarching challenge is the upfront investment needed to procure sufficient extraction systems that can meet to throughput of poles that are disposed of by NGED, other DNOs and potentially wider industry users such as the rail and telecoms industry. The scale of this role out will be tremendous and the next steps are to convince potential investors in investing in the ACE system so that the full financial and environmental benefits can be realised. Further funding opportunities are currently being looked at for this to be delivered

Other Comments

N/A

Standards Documents

Identify any industry standards that may require updating due to the outcomes or understanding developed from this innovation project. If no standards will need to be updated, please state - not applicable

Not applicable