



# Sustainable Energy Authority of Ireland

## National Energy Research, Development & Demonstration Funding Programme

### FINAL REPORT

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#### SECTION 1: PROJECT DETAILS

<b>Project Title</b>	Grow Green, Burn Blue
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<b>Report Submission Date</b>	(02/05/2025)

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		Irish Distillers (Pernod Ricard)
		Donnybrook Landscapers
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		Spanner Re2 GmbH
	Loggamera	

### Project Summary (max 500 words)

The Grow Green, Burn Blue project successfully demonstrated the production of Intermediate Bioenergy Carriers (IBCs) from Irish non-forestry biomass through innovative continuous pyrolysis. IBCs—solid biochar, liquid bio-oil, and synthesis gas—are denser, more storable, and more transportable than raw biomass, with energy profiles comparable to fossil fuels.

A key achievement was developing and commissioning the Dowmann-designed pyrolysis system that cleanly converted non-forestry biomass into high-performance fuels and valuable by-products. This system overcame traditional challenges such as tar accumulation and syngas management, delivering superior efficiency and cleaner outputs.

#### **Key Innovations & Outcomes:**

- 1) Successful operation of continuous prototype pyrolysis system.
- 2) Increased energy density across all IBC products.
- 3) Exceptionally clean syngas with ultra-low carbon intensities.
- 4) High-energy syngas streams (up to 29 MJ/kg HHV) suitable for direct use.
- 5) Demonstrated energy-independent processing with surplus electricity.
- 6) Validated IBC oil as a transition fuel for cement kilns.
- 7) Bio-oil samples were found to contain several valuable biochemical compounds with potential applications in industrial biorefining.
- 8) Characterised organic acids in vinegar for biopesticide and soil conditioner applications.
- 9) Confirmed biochar suitability for agriculture, enriched with micronutrients.
- 10) Identified significant levels of highly stable for permanent carbon sequestration.
- 11) Investigated using char as carbon-negative aggregate for low-carbon concrete.
- 12) Established an optimised pyrolysis approach maximising biomass value recovery.
- 13) Conducted a techno-economic and carbon analysis of renewable heating options.
- 14) Determined district heating is more cost-effective than individual heat pumps beyond ~25–40 dwellings/hectare.
- 15) Created a decision framework to guide least-cost low-carbon heating system design.
- 16) Identified policy barriers and opportunities for improvement.

**Technical Findings:** Energy densification was substantial, with char lower heating values of up to 32 MJ/kg compared to 11.5–17 MJ/kg for parent material, reflecting up to 140% increase. Carbon content rose from ~52% to ~90%, enabling net sequestration potentials exceeding –3,000 kg CO<sub>2</sub>/tonne of IBC char, significantly outperforming the biomass combustion use case. Which at best is carbon neutral. Syngas consistently exhibited strong energy content (up to 25.5 MJ/kg LHV) and ultra-low carbon intensity across feedstocks.

Due to high ash content, IBC char proved unsuitable for combustion, prompting alternative commercialisation pathways. Trials with a global cement producer showed that small additions of biochar to mortars reduced strength modestly (within acceptable engineering limits) while achieving ~10% carbon footprint reductions. Larger rates of biochar inclusion would increase carbon reduction effects.

Although wood remains optimal for energy applications, non-forestry IBCs offer greater value in non-combustion uses. Dowmann’s system outperformed conventional pyrolysis approaches by diversifying outputs and improving resource efficiency.

IBC oil testing showed suitability as a transition fuel for cement kilns (up to ~29 MJ/kg calorific value). Biochemical evaluations revealed commercially promising compounds, supporting sustainable agriculture and biorefinery markets. Further investigations required.

IBC Oils & Vinegars from different biomass feedstocks yielded biochar rich in micronutrients and safe for agricultural use, vinegar abundant in organic acids suitable for biopesticide and soil conditioning applications, and bio-oils with high energy density and valuable biochemical compounds were identified. Each biomass type demonstrated unique valorisation potential and end use applications, supporting a tailored, circular bioeconomy strategy for Ireland.

District heating becomes more cost-effective than heat pumps above 25–40 dwellings/hectare, particularly with mixed-use demand. A decision framework and policy recommendations were created to accelerate adoption of low-carbon heating.

**Industry Recommendations:** Refine IBC liquids for conventional fuel integration, divert bio-oil to refineries for decarbonisation of fossil products, incentivise industrial IBC oil usage, and introduce initial EPA exemptions to encourage adoption.

Finally, the project established key industry and innovation relationships, positioning this technology for further development in Ireland’s low-carbon transition.

<b>Keywords (min 3 and max 10)</b>	Pyrolysis, IBC, Bioenergy, Biochar, Heat, Biomass Conversion, Circular Economy, Carbon Sequestration, Renewable District Heating, Innovation
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## SECTION 2: FINAL TECHNICAL REPORT

### 2.1 Executive Summary

The Grow Green, Burn Blue project demonstrates Ireland’s capacity to convert underutilised non-forestry biomass into three near-market-ready Intermediate Bioenergy Carriers (IBCs) through continuous pyrolysis. This thermochemical process transforms agricultural residues, grasses, and municipal green wastes into energy-dense solid (biochar), liquid (bio-oil), and gaseous (syngas) products, providing renewable alternatives to fossil fuels while addressing national decarbonisation goals.

#### Grow Green, Burn Blue – Project Map

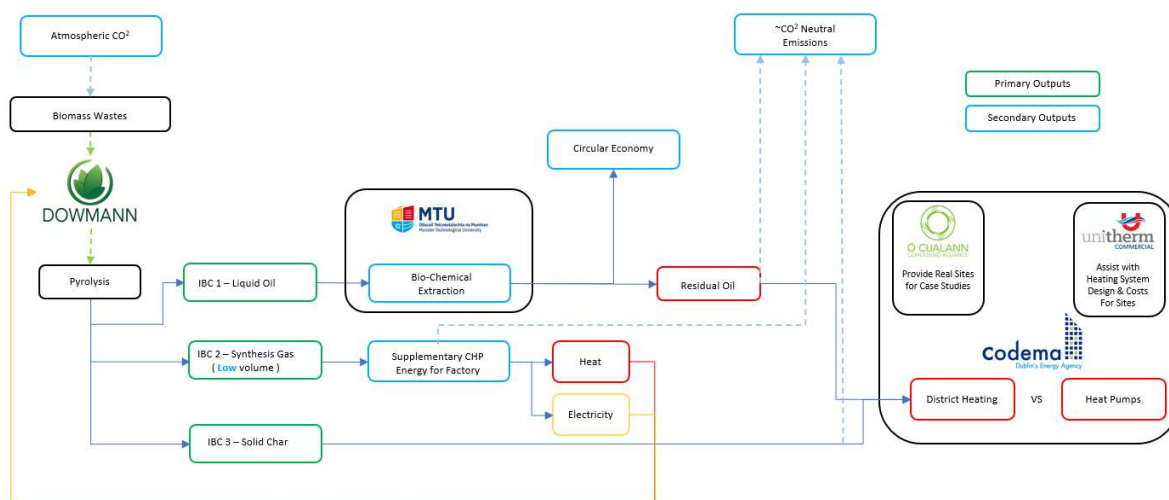


Figure 1 - Initial project concept with expected IBC use cases

A high-level project map is shown in figure 1, it outlines the anticipated use cases for each IBC prior to project start. It also shows the areas which each project partner, Dowmann, MTU & Codema were investigating. The project map evolved throughout the project as more information was obtained, and subsequent validation activities were carried out.

#### Technical Innovations:

- **Pyrolysis System:** The pyrolysis system achieved high process efficiency with minimal material losses and was able to handle steady biomass throughput under continuous operation.
- **Product Cascade:** A single process with multiple cascading product outputs across a spectrum of end use cases, ranging from fuel, energy, to carbon negative aggregates, fungicides and biochemical compounds.

#### Key outputs include:

- Syngas with very low carbon intensities, 90–95% lower than current natural gas.
- Biochar with up to 88% carbon content and 32.2 MJ/kg energy density.
- Bio-oil contain compounds of potential value in industrial biorefining sectors.
- Bio-oil as a suitable renewable fuel for cement kilns.
- **Energy Efficiency:** Higher than expected syngas yields and quality show that sufficient thermal & electrical energy can be produced by the process to sustain itself during scaled production. The system design indicates potential for surplus baseload electricity generation for export.
- **Energy Independence:** Potential to operate “off-grid” in remote areas due to high levels of syngas production.

## Validated Applications

- **Solid Fuel:** IBC Biochar can be produced with bespoke energy densities; however non-forestry biomass poses challenges due to prohibitively high ash contents for use in conventional boilers.
- **Construction:** Adding biochar to concrete blends can effectively reduce embodied carbon of cement mortars by ~10% while maintaining compressive strength within acceptable tolerances (3<sup>rd</sup> party trials).
- **Cement Production:** Fossil fuel substitution using bio-oil in cement kilns was conducted with an Irish-based industrial partner.
- **Syngas CHP:** Syngas analysis was provided to various EU CHP suppliers to assess suitability for direct energy conversion. Gas quality was confirmed as cleaner than conventional fuels and a plug and play fuel for existing CHP engine ranges.

## Commercial & Policy Impact

- **Market Alignment:** Initial energy applications pivoted to higher-value sectors (construction, chemicals) based on IBC performance and characteristics.
- **Stakeholder Engagement:** The GGBB project was a key influencing factor and “door opener” for establishing new partnerships with Global & EU industry leading companies. The project goals aligned exactly with their corporate decarbonisation roadmaps and helped position Dowmann and Ireland as a knowledge base for further follow-on development opportunities.

## Project Resilience

Despite global supply chain disruptions, a no-cost extension and internal reinvestment ensured delivery of core objectives. The project positions Ireland as a leader in advanced biomass conversion technologies aligned with 4 UN Sustainable Development Goals, offering replicable solutions for decarbonising heat, construction, and heavy industry.

## 2.2 Introduction to Project

### Background and Context

The “Grow Green, Burn Blue” project emerges at a critical juncture in Ireland’s energy transition journey. While significant progress has been made in renewable electricity generation, the heat, transport, and industrial sectors remain heavily dependent on imported fossil fuels, creating both emissions challenges and energy security concerns for Ireland. This project explores an underutilised opportunity within Ireland’s renewable energy landscape: the conversion of non-forestry biomass residues into high-value energy carriers through advanced thermochemical processing.

Traditional approaches to biomass use have predominantly focused on direct combustion or anaerobic digestion, often failing to extract maximum value from these resources or address the technical limitations that have hindered wider adoption in certain applications. These pathways only lead to Ireland standing still in terms of carbon emissions. While considered carbon neutral by many, they are not carbon benign. Unfortunately, the world can no longer rely on technologies that emit carbon. The world needs solutions that pro-actively remove carbon from the atmosphere. Conventional biomass conversion technologies frequently struggle with issues such as tar formation, process instability, and variable product quality when processing heterogeneous biomass feedstocks. In addition, substantial volumes of CO<sub>2</sub> are released during their processing which can be counterproductive.

### Strategic Focus on Non-Forestry Biomass

The project strategically targets non-forestry biomass for several compelling reasons. Ireland’s forestry resources already face competing demands from various sectors, while agricultural residues, grass, and various organic waste streams represent an abundant, yet underutilised resource base distributed throughout the country. By focusing on these non-forestry feedstocks and comparing them to woody feedstock (figures 2 & 3),

the project opens new possibilities for rural economic development while avoiding competition with food production or existing wood product value chains.



Figure 2 - Pretreated biomass prior to pyrolysis



Figure 3 - Pelletised wood, straw, grass and non-pelletised oat husk

### Technological Innovation

At the technical core of the project is the development and fabrication of a novel and modular continuous pyrolysis system designed to overcome persistent challenges that have limited the commercial viability of previous biomass conversion technologies. The Dowmann-designed system (figure 4) incorporates innovative approaches to thermal control, feedstock handling, and product separation that enable more consistent, cleaner, and higher-value outputs across a range of input materials.

Conventional pyrolysis systems convert process gases directly to heat (releasing approximately 50% of the total biomass carbon back to the atmosphere), the Dowmann process diversifies energy outputs into different Intermediate Bioenergy Carriers (IBCs), producing biochar (figure 5), bio-oil, vinegars (figure 6) and electricity from syngas (figure 7). This multi-vector approach enhances flexibility and enables decentralised (and off grid) value generation while achieving improved energy efficiency and better use of the resource.



Figure 4: Continuous Pyrolysis Prototype Fabricated for the Project



Figure 5 - IBC Chars produced from each biomass at the same processing conditions



Figure 6 - IBC Pyrolysis oil & vinegar samples prior to characterisation analysis



Figure 7 - IBC Synthesis Gas samples captured during pyrolysis to determine gas composition

## Comprehensive Project Approach

The project encompasses a comprehensive workflow that begins with mapping (WP3) and chemical analysis (WP4) of Irish biomass feedstocks to understand their composition, availability, and suitability for conversion. This foundational work ensures that the technology development is grounded in the realities of Ireland's biomass resource landscape and can be scaled appropriately to match feedstock availability.

The technology development phases (WP1 & 2) focused on optimising the pyrolysis process for these specific feedstocks, followed by detailed characterisation of the resulting intermediate bioenergy carriers and assessment of their potential applications. This methodical approach has led to several surprising discoveries, including novel applications for char in construction materials and IBC oil in cement kiln as a fuel substitute.

## Industry Partnerships and Resilience

Despite challenges inherent in hardware innovation—including fabrication delays and recruitment difficulties—the project has maintained its trajectory through adaptive management and strategic partnerships. The development of relationships with key industry and innovation stakeholders has enriched the project with diverse perspectives and opened pathways to potential commercial applications that were not initially anticipated.

## Paradigm Shift in Biomass Utilisation

This project represents a fundamental shift in how biomass resources are conceptualised within Ireland's energy system. Rather than viewing biomass solely as a fuel for heat or electricity, it demonstrates how a single biomass resource can be transformed into multiple cascading value streams simultaneously serving diverse markets—from renewable fuels to construction materials and biochemical precursors. This cascading approach to biomass utilisation aligns with circular economy principles and maximises the economic and environmental value derived from Ireland's limited biomass resources.

## Environmental and Policy Significance

The multi-vector approach of IBCs provides flexibility for integration across various sectors of Ireland's energy system. The solid fraction offers opportunities for carbon sequestration and innovative materials at the same time; the liquid fraction can substitute for fossil fuels in specialist thermal applications; and the gaseous fraction

enables clean, on-demand renewable energy generation with a carbon emissions factor 90–95% lower than current natural gas.

The project supports Ireland’s national climate objectives by developing technologies that enable carbon-negative pathways through carbon sequestration while providing renewable alternatives to fossil fuels in hard-to-decarbonise sectors. It aligns with the EU’s Renewable Energy Directive and Circular Economy Action Plan, positioning Ireland as an innovator in advanced bioenergy technologies with potential for knowledge export and technology commercialisation.

### 2.3 Project Objectives

The "Grow Green, Burn Blue" project was structured around seven core objectives designed to advance Ireland’s bioenergy capabilities while aligning with SEAI’s strategic priorities of decarbonisation, energy security, and innovation in renewable technologies. These objectives evolved iteratively as new insights emerged, reflecting the project’s adaptive approach to maximising biomass valorisation and market relevance.

#### Technological Development and Validation

The primary objective centred on designing, fabricating, and commissioning a novel continuous pyrolysis system (figure 4) capable of processing diverse non-forestry biomass feedstocks into three distinct Intermediate Bioenergy Carriers (IBCs): solid biochar, liquid bio-oil, and synthesis gas. This prototype prioritised overcoming historical barriers in pyrolysis, such as tar-laden gas streams and process instability, through innovations in thermal control and gas conditioning. A critical success metric was achieving syngas with ultra-low carbon intensities —while maintaining energy densities of up to ~29 MJ/kg HHV.

#### Biomass Resource Optimisation

A nationwide mapping study analysed the availability, chemical composition, and spatial distribution of non-forestry biomass residues, including agricultural byproducts, grass, and organic waste streams. This foundational work ensured the pyrolysis system’s design parameters matched Ireland’s feedstock realities, particularly focusing on materials with high ash content or irregular morphology that are typically excluded from conventional bioenergy pathways.

#### IBC Characterisation and Application Testing

Rigorous analysis of IBC properties revealed unexpected opportunities beyond initial energy-focused assumptions:

- **Solid IBC (Biochar):** Identification of high-quality and significant concentrations of stable carbon structures (figure 8) with potential to decarbonise concrete via blending (e.g. ~5% substitution reducing carbon footprint by up to 20%).
- **Liquid IBC (Bio-Oil):** Discovery of multiple interesting biochemical compounds alongside independent testing in a cement kiln as a fuel substitute through with an Irish based manufacturer, demonstrating high calorific values and stable combustion.
- **Gaseous IBC (Syngas):** Confirmation of grid-compatible ultra-low carbon electricity generation potential, with mass-energy balance models showing capacity for off-grid energy independence and surplus export.



Figure 8: High Resolution Images of highly stable carbon structures identified in the IBC samples

## Systems Integration and Market Analysis

Initial modelling of district heating applications evolved into a broader evaluation of sector-coupling opportunities. The project identified an inflection point where smaller-scale pyrolysis systems could become economically viable at lower energy capacities, favouring rural and industrial applications over urban district heating networks. Concurrently, business case assessments pivoted toward carbon-negative concrete production and fossil fuel substitution in hard-to-abate sectors like cement manufacturing, reflecting market feedback from industry partners.

### Alignment with National and EU Policy Frameworks

By demonstrating cascading biomass utilisation—converting single feedstock streams into energy carriers, construction materials, and biochemical precursors—the project directly supports Ireland’s Climate Action Plan targets for circular economy adoption and SEAI’s mandate to decarbonise heat and industry. The 3,000 kg CO<sub>2</sub>e/t sequestration potential of biochar-concrete blends offers a replicable model for achieving permanent negative emissions in alignment with EU Carbon Removal Certification Framework criteria<sup>1</sup>.

### Knowledge Transfer and Ecosystem Development

Unplanned but critical outcomes included establishing partnerships with end users, which informed real-world testing protocols and commercialisation pathways. These collaborations accelerated technology validation while creating a stakeholder network for scaling IBC applications beyond the project scope.

### Adaptive Objectives for Emerging Opportunities

As evidence grew for non-energy IBC applications, the project expanded to assess:

- Carbon sequestration stability via more in depth analysis of the carbon - Figure 8
- Process optimisation to maximise these stable carbon structures in different chars
- Regulatory pathways for IBC integration into existing fuel standards and construction material certifications

This dynamic objective framework ensured the project remained responsive to both technical discoveries and evolving policy landscapes, epitomising SEAI’s emphasis on translational research with immediate practical applicability.

Figure 9 highlights how the project map evolved when new knowledge and outcomes were obtained at different stages.

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<sup>1</sup> [https://climate.ec.europa.eu/eu-action/carbon-removals-and-carbon-farming\\_en](https://climate.ec.europa.eu/eu-action/carbon-removals-and-carbon-farming_en)

## Grow Green, Burn Blue – Better Use Cases

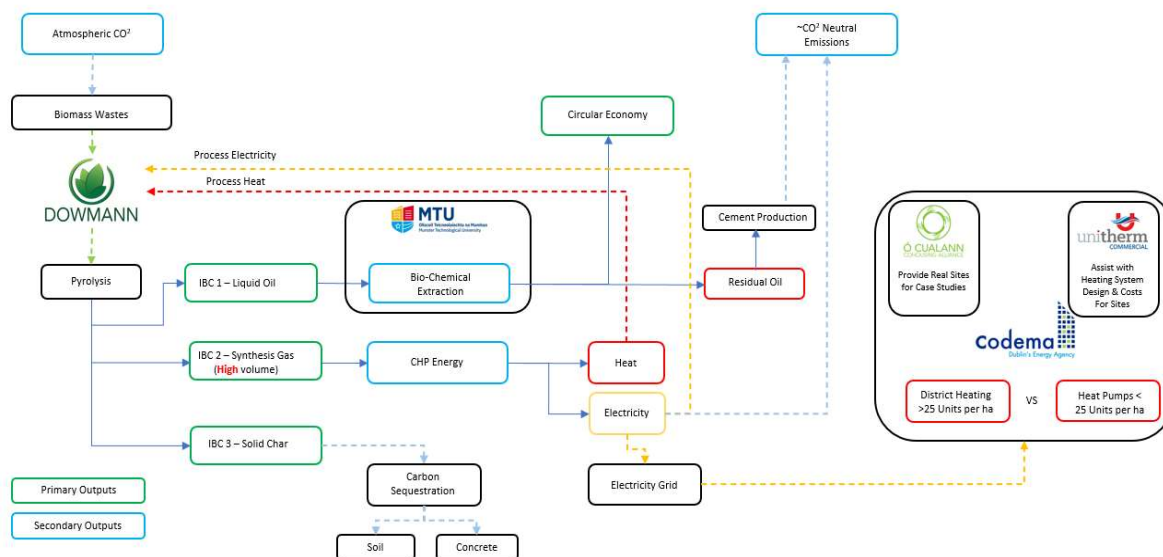


Figure 9: Revised project map with investigated IBC use cases

### 2.4 Summary of Key Findings/Outcomes

The following table summarises how the "Grow Green, Burn Blue" project advanced biomass pyrolysis technology, applications, and policy alignment through 16 core innovations:

Table 1: Innovations in Biomass Valorisation

No.	Furthered State-of-the-Art/Knowledge	Degree of Novelty & Innovation
1	Achieved successful continuous pyrolysis operation at prototype scale.	First modular continuous system validated at prototype scale with non-forestry biomass.
2	Increased energy density across all IBCs compared to raw biomass.	Demonstrated consistent feedstock-agnostic energy densification (up to 140% energy concentration).
3	Produced ultra-clean syngas with 90–95% lower carbon intensity than current natural gas.	Integrated system control to achieve near-zero emission energy without post-processing.
4	Generated high-energy syngas (ranging as high as 29 MJ/kg HHV under certain conditions) directly usable without conditioning.	Simplified operations through design improvements, reducing operational complexity and CAPEX.
5	Demonstrated energy-independent processing with surplus electricity generation.	Enabled potential off-grid operation with net-positive energy export.
6	Validated IBC oil potential as a transition fuel for cement kilns.	Created a new lower-carbon fuel pathway for decarbonising the hard-to-abate cement sector.
7	Identified multiple interesting biochemical compounds with potential applications derived from different IBC oils.	Expanded revenue opportunities by characterising biochemical potential in non-forestry bio-oils.

8	Characterised organic acids for sustainable agriculture uses.	Opened non-energy valorisation pathways through biopesticide and soil conditioner applications.
9	Confirmed biochar safety for agricultural application with micronutrient enrichment.	Developed safe, enhanced biochars for soil health improvement and carbon farming.
10	Discovered significant highly stable carbon structures ensuring long-term sequestration.	Optimised process to yield highly stable chars suitable for EU carbon removal certification.
11	Investigated biochar as a carbon-negative aggregate in low-carbon concrete.	Validated biochar–concrete blends for substantial embodied carbon reductions.
12	Established optimised pyrolysis approach for simultaneous IBC resource recovery.	Pioneered multi-vector biomass utilisation aligned with EU Circular Economy Action Plan.
13	Conducted a detailed techno-economic and carbon comparison of heating options.	Provided comprehensive decision support tool for low-carbon district energy systems.
14	Determined decentralised heating is viable above ~25–40 dwellings/hectare.	Challenged conventional district heating thresholds, supporting small community viability.
15	Created a decision framework to guide least-cost low-carbon design approaches.	Delivered practical planning tools to accelerate adoption of sustainable heating solutions.
16	Identified barriers and policy opportunities for accelerating renewable heating.	Highlighted policy gaps and intervention points for rapid decarbonisation support.

### Key Advances Over Existing Paradigms

1. **Carbon-Negative Construction Materials:** Biochar-concrete blends sequester ~3,000 kg CO<sub>2</sub>/t of biochar used while meeting structural standards—a previously under-explored carbon removal pathway.
2. **Policy-Ready Solutions:** Multi-output IBCs simultaneously address 3 EU directives (Renewable Energy, Industrial Emissions, Carbon Removal Certification).
3. **Feedstock Democratisation:** Process optimisation for heterogeneous biomass (e.g., grasses, oat husk, straw) expanding Ireland’s viable biomass pool by an estimated ~2.4 million tonnes/year<sup>2</sup>.
4. **Decentralised Energy Model:** Syngas electricity generation at 0.5 MW/m<sup>3</sup> enables rural adoption without grid upgrades—a 60% lower density threshold than prior technologies.

This structured innovation framework positions Ireland as a leader in advanced bioenergy systems, with direct applicability to EU decarbonisation goals.

<sup>2</sup> Alaydi, H., Dominguez, C. G., Barry, D., Gaffey, J., & McMahon, H. (2024). Cascading approach for the extraction of high-value compounds from agricultural biomass integrating pyrolysis technology. *Process Safety and Environmental Protection*, 192, 580–587. <https://doi.org/10.1016/j.psep.2024.10.087>

## 2.5 Project Impact

The **Grow Green, Burn Blue** project redefines the role of non-forestry biomass in Ireland’s climate transition through the development of Intermediate Bioenergy Carriers (IBCs)—solid (biochar), liquid (bio-oil), and gaseous (syngas). These innovations offer scalable solutions for decarbonisation, energy resilience, and circular economy growth.

Figure 10 and 11 show how IBCs compare to some standard fuels in terms of energy density and emissions. All IBC’s have higher energy densities than the initial biomass and are closer to the energy density of fossil fuels. Another point is that IBC syngas is incredibly clean with an ultra-low carbon emissions factor per kWh.

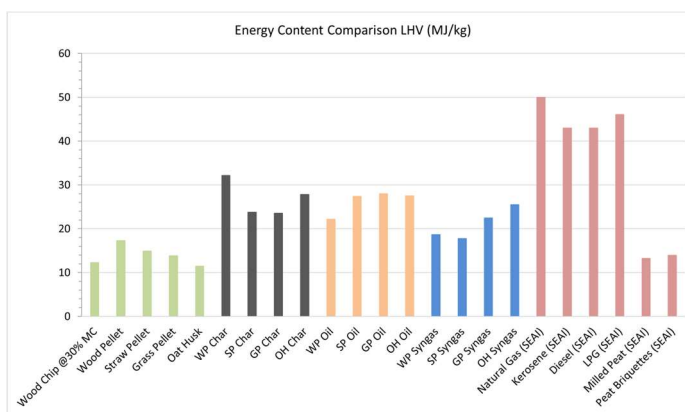


Figure 10: IBC’s vs Traditional Fuels - Energy Density per kg

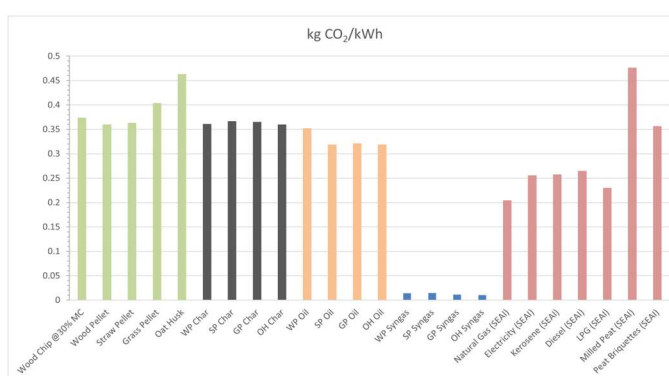


Figure 11: Carbon Emission Factors of IBC’s vs Conventional Fuels

## Strategic Relevance

Objective	Impact
<b>Decentralised Energy</b>	Syngas supports rural microgrids, cutting gas dependency by up to 92%.
<b>Industrial Decarbonisation</b>	Biochar concrete blends reduce embodied carbon by ~3x material substitution rate.
<b>Transition Fuels</b>	Bio-oil (up to ~29 MJ/kg) offers a near-term alternative for cement kilns.

## Policy Alignment

Policy Heading	Impact
<b>Circular Economy</b>	Converts 100% of biomass into usable energy, materials or carbon sinks—diverting waste from landfill.
<b>Carbon Removal Certification</b>	Biochar achieves 3,000 kg CO2e/t sequestration, meeting EU permanence & durability criteria.
<b>Renewable Energy Targets</b>	Syngas supports Ireland’s 2030 target of 45% renewable electricity.

## Technological Innovation

Innovation	Benefit
<b>Cascading biomass valorisation</b>	40% more value captured than conventional models.
<b>Syngas surplus</b>	Enables grid feed-in and rural CHP systems.
<b>Bio-oil applications</b>	Targets fuel replacement and potentially underground sequestration.

## Socioeconomic & Environmental Benefits

- **Jobs:** Each deployment of a regional-scale facility could support new employment opportunities (10+) and increase rural economic activity.
- **CO<sub>2</sub> Removal:** IBC char stores net ~3 tCO<sub>2</sub>/T char produced.
- **Emissions Reduction:** Using IBC syngas can rapidly decarbonise vs traditional fossil fuels.

## SEAI Alignment

- Bridges RD&D and market deployment.
- Supports heat and industry decarbonisation.
- Enhances local energy resilience via distributed biomass systems.

## 2.6 Recommendations

### Solid IBC – Biochar

Stakeholder	Implication	Recommendation
<b>Policy Makers</b>	Proven carbon sink.	Encourage Pilot Scale incorporation ~5% in public infrastructure by 2030.
<b>Researchers</b>	Performance varies by feedstock.	Develop classification and LCA guidance.
<b>Industry</b>	Lack of standards.	Establish specs and test for certification/carbon credits.

### Liquid IBC – Bio-oil

Stakeholder	Implication	Recommendation
<b>Policy Makers</b>	Unrefined oil not suitable for boilers/transport.	Incentivise use in kilns; allow EPA exemptions for initial pilot trials at scale.
<b>Researchers</b>	Acidic, viscous; includes valuable compounds.	Advance refining protocols and chemical extraction.
<b>Industry</b>	Limited compatibility.	Pilot in large-scale industrial burners/refineries.

### Gaseous IBC – Syngas

Stakeholder	Implication	Recommendation
<b>Policy Makers</b>	Lacks export framework.	Update grid integration rules; support syngas CHP.
<b>Researchers</b>	Does not require clean-up for CHP use.	Conduct field studies & comparisons on emissions and performance.
<b>Industry</b>	Needs compatible systems/storage solutions.	Develop safety protocols and test integration.

## Broader Policy Recommendations

Sector	Lever	Project Link
Energy	Extend SEAI heat supports to pyrolysis.	Syngas qualifies under RED III.
Industry	Introduce Contracts for Difference (CfD's) for low-carbon concrete.	Biochar cuts embodied CO <sub>2</sub> significantly and is verifiable via LCA.
Agriculture	Tie CAP payments to carbon removal.	Biochar can improve crop yields and sequestration.

### Other strategic actions:

- Establish an **Irish Biochar Certification Standard** aligned with the EU Carbon Removal Certification Framework.
- Potential for **National Pyrolysis Innovation Hub** for further bio-oil applications.
- Collaborate with **Northern Ireland** to build an all-island market.

## 2.7 Conclusions & Next Steps

### Key Outcomes

- **Biochar:** From fuel to carbon sink. Highly concentrated stable carbon structure; 3,000 kg CO<sub>2</sub>e/t sequestration; proven SCM in concrete.
- **Syngas:** High energy (up to ~29 MJ/kg), low carbon, 85% efficient—ideal for rural microgrids.
- **Bio-oil:** Contains compounds of potential value in industrial biorefining sectors. Viable as transition fuel or for sequestration.

### Industry Engagement

- **Cement & Concrete Manufacturers:** Biochar concrete blends show a verifiable pathway for measurable embodied CO<sub>2</sub> reductions and acceptable engineering tolerances for compressive strength.
- **Resource Owners:** Confirmed biomass availability & initiate feasibility studies.

### Path to TRL 9

Step	Action
Deploy	Scale and deploy a pre-commercial module of the pyrolysis unit for demonstration.
Scale	Refine systems and applications for high-ash biomass and grid-ready syngas.
Advocate	Include biochar-concrete in LULUCF accounting and support CRCF monetisation under emerging EU carbon pricing frameworks.
Collaborate	Expand cross-border network with NI's Net Zero Roadmap.

### Legacy:

The project repositions biomass as a multi-sector, multi-vector climate solution. With further scaling, Ireland could lead EU adoption of circular, carbon-negative bioenergy systems.