AFRY

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Simplified LCA study on biofuels

Decarbonizing heavy industries in Ontario

A&WMA Ontario Decarbonization Workshop

SEPTEMBER 2023

Agenda

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ABOUT AFRY

AFRY is a global engineering, design, and advisory company with 19,000 experts serving clients in more than 100 countries across the globe

AFRY AT A GLANCE

EMPLOYEES GLOBALLY

~ 19,000

(at the end of 2022)

NET SALES

€ 2.1 bn

(in 2022)

NUMBER OF COUNTRIES WITH OFFICES

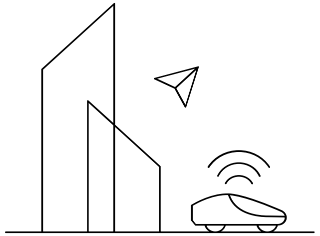
> 50

NUMBER OF COUNTRIES WITH PROJECTS

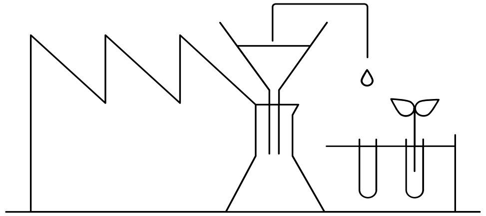
> 100

AFRY CORE EXPERTISE

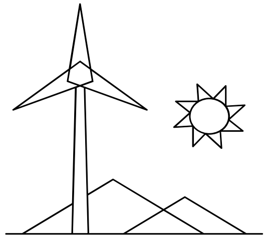
AFRY GROWTH DRIVERS



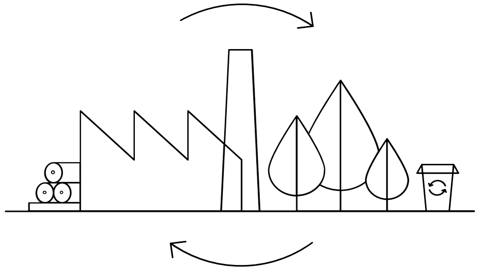
Infrastructure



Food & Life Science



Clean Energy



Bioindustry

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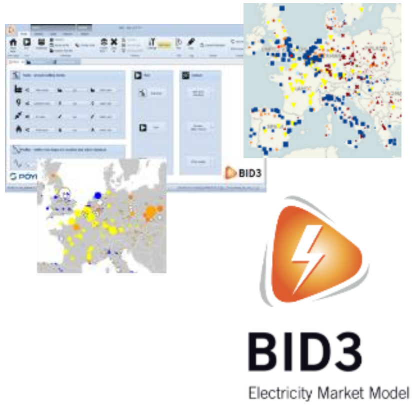
Our expertise is robust and makes use of AFRY’s cutting-edge know-how and practical experience



Energy Market Analysis & Modelling

Team access to AFRY modelling suite with electricity, gas, oil, carbon, hydrogen and other market prices

HYBRIT
FOSSIL-FREE STEEL
SSAB
LKAB
VATTENFALL

Engineering & Consulting

AFRY team members and experts have conducted pre-feasibility study, engineering and consulting work for new green steel plants in the Nordics

Senior Steel, Energy & Hydrogen Experts

Senior market experts from steel industry and AFRY experts are actively supporting our team

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AFRY offers a one-stop-shop for clients operating within the mining, minerals and metals industry

STRATEGIC ADVICE

- Corporate strategies and transformation, implementation plans and implementation support
- Evaluation of technology maturity
- Conceptual design and modelling
- Pre-feasibility studies and Feasibility studies (FEL 1,2)
- Bankable business plans
- Circular economy strategies, roadmaps and action plans
- Risk management strategies
- Policies and regulations and their future impacts
- Stakeholder engagement strategies and activities
- Partner search

OE AND TRANSFORMATION

- Technical benchmarking
- Non-technical benchmarking
- Operational Efficiency Diagnostics
- Operational Efficiency Implementation
- Post-merger integration

M&A SUPPORT

- Commercial and technical due diligence (DD)
- Environmental, Health and Safety & Eenvironmental, Social and Governance (ESG) DDs
- ESG assessment for lenders, banks and financing institutions (Equator Principles, IFC Performance Standards)

SUSTAINABILITY CONSULTING

- Defining strategic sustainability path (e.g. SDGs analysis, policies and plans)
- Defining sustainability governance models/ policies
- Carbon footprint calculations and LCAs, Environmental Product Declarations (EPDs)
- Socio-economic and environmental impact analysis (EIAs/ ESIAs)
- Climate and Biodiversity strategies and implementation
- Decarbonization roadmaps, strategic climate target setting (e.g. SBTi), climate KPIs
- Preparation of sustainability, climate, biodiversity and integrated reports, a voluntary basis (CDP, TCFD, TNFD) or e.g. in compliance with NFR Directive

ENGINEERING AND TECHNICAL ADVISORY

- Technical feasibility studies with various CAPEX and OPEX accuracies (FEL 2,3)
- Reserve estimates
- Field studies and surveys
- Geotechnical engineering
- Mine and process design, multi disciplinary engineering services
- Mine closure and mitigation plans
- EPCM (engineering, procurement, and construction management) services
- Project management services
- Tailings and water management
  - Waste reduction, recycling and elimination, and repurposing waste streams into new products
  - Process/ wastewater handling and reuse
- Independent engineer/ Bank’s/ Lender’s supervision
- EHS permitting support

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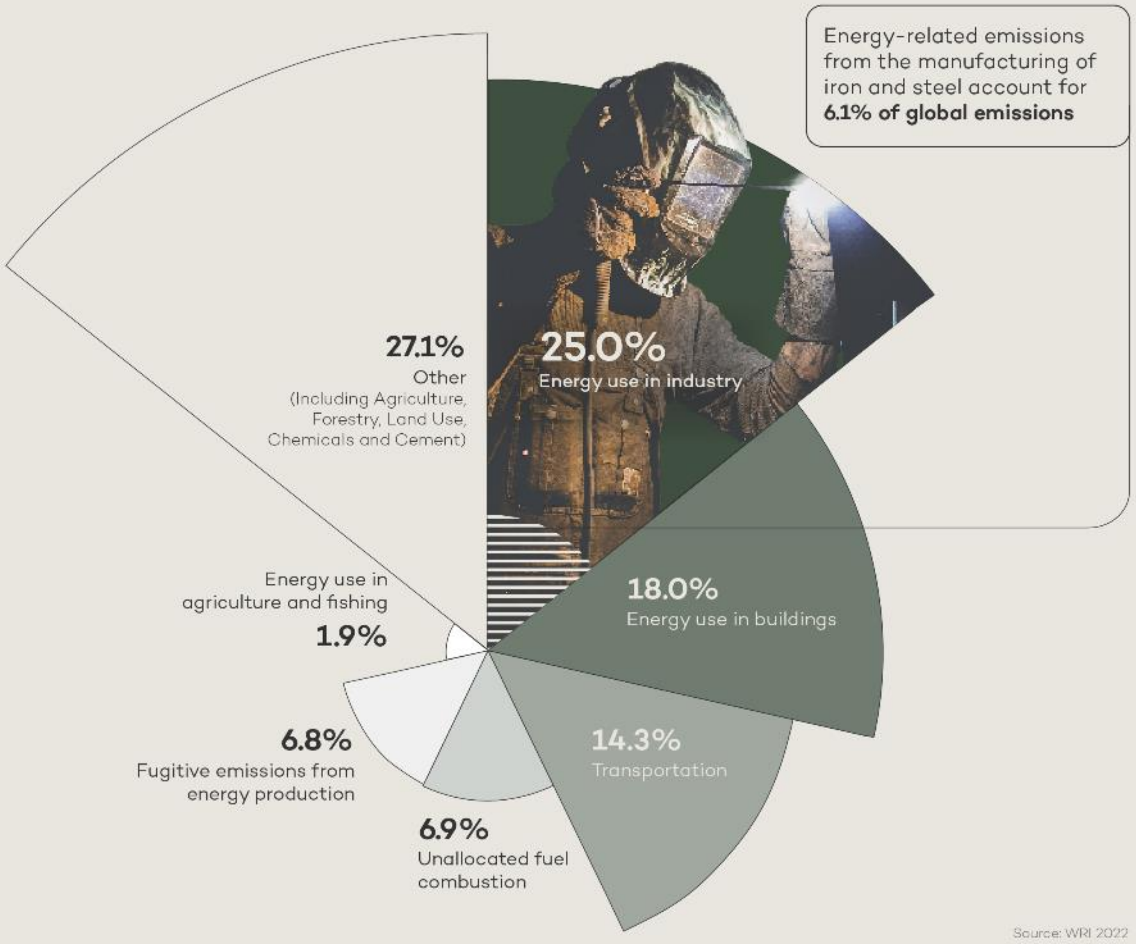
Global emissions

- Energy use in industry is responsible for 25% of global emissions
- Iron and steel production makes up a significant portion (6.1%) of industrial emissions
- Decarbonizing the steel sector is important step in achieving global reduction in carbon dioxide



Source: Climate Watch, based on raw data from IEA (2021), GHG Emissions from Fuel Combustion, www.ie

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Two main steel production routes with different decarbonization levers

<table>
<tr><th rowspan="2"></th><th rowspan="2">Steel quality and use</th><th colspan="2">Key inputs</th></tr>
<tr><th>Traditional</th><th>Green</th></tr>
<tr><td rowspan="3">BF Route</td><td rowspan="3">– High qualities with precise control of metallurgical characteristics
– Continuous material and refining innovations
– Advanced, high-added-value applications, e.g. automotive, packaging
– H_2 needed for decarbonization (limited availability)</td><td colspan="2">Iron ore</td></tr>
<tr><td>Coal[1]</td><td>Biomass[1]
Hydrogen[1]</td></tr>
<tr><td>Limestone</td><td>Green electricity[2]</td></tr>
<tr><td rowspan="2">EAF Route</td><td rowspan="2">– Basic quality with variations in alloy metal shares from varying scrap qualities
– Low degree of innovation
– Basic applications, e.g. construction steel
– Increasing importance of recycling in Europe
– Easier de-carbonization by using green electricity</td><td colspan="2">Scrap metal</td></tr>
<tr><td>Grey electricity[3]</td><td>Green electricity[3]</td></tr>
</table>

1) For heating and as reductant 2) For refining in electric arc furnace 3) For heating and refining BF: Blast Furnace EAF: Electric Arc Furnace

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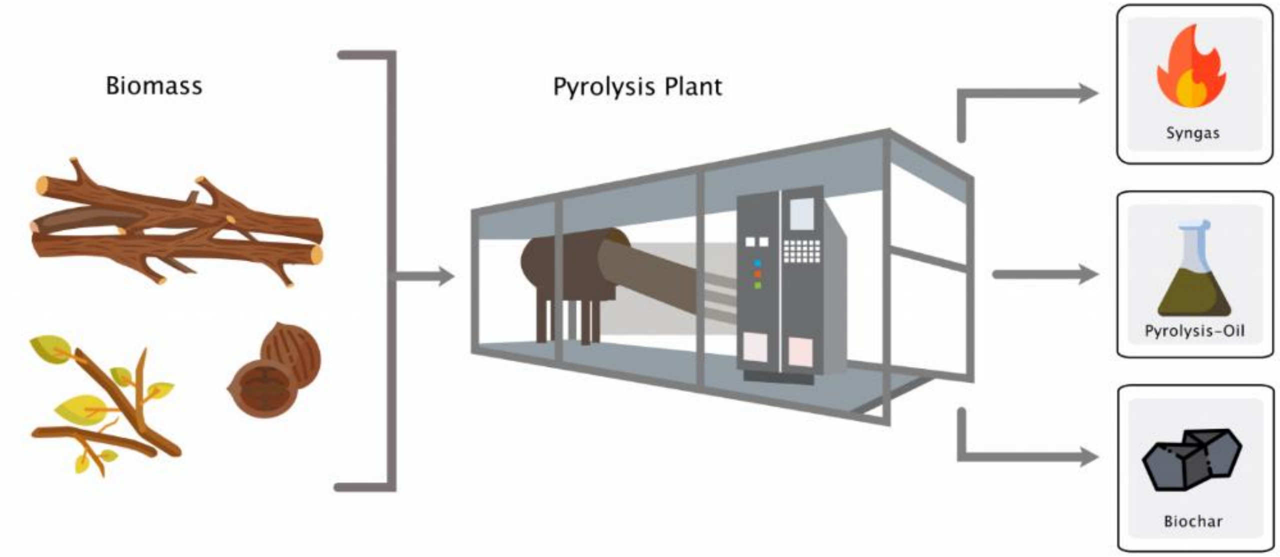
Biochar's use in steelmaking is an emerging application for decarbonization

BIOCHAR USAGE IN STEEL PRODUCTION

- Recent academic research into biochar's direct use in steelmaking show that biochar derived from wood and woody biomass can meet the requirements for coal and coke substitution
- Most significant application would be in the Blast Furnace production route as experimental studies show biochar can replace pulverized coal injection (PCI) in both mini and large blast furnaces
- Biochar usage instead of PCI brings about smaller slag amount since it contains lower impurity and ash in comparison
- Deploying biochar to completely substitute PCI could result in about 20-25% CO_2 reduction in the steel plant



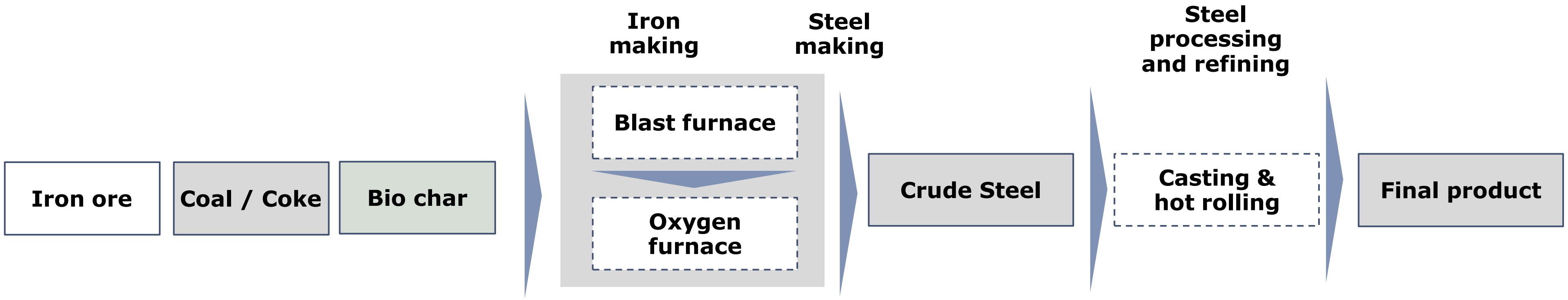


Image Source: The European Biochar Industry Consortium

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OBJECTIVE

Developing a forest-based biocarbon supply chain for heavy industry in Ontario

Sustainably sourced forest biomass could be used to decarbonize heavy industry in Ontario.

A high-level life cycle analysis (LCA) of select logistics scenarios, from the point of loading to unloading, and carbon intensity assessment was conducted to understand the viability of utilizing forest biomass as a means for decarbonizing heavy industry in Ontario

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The study compares three life cycle phases and various sources of emissions

Fuel production
- Fossil emissions
- Biogenic emissions
- Land transformation emissions

Transportation
- Fossil emissions

Energy production (1 GJ)
- Fossil emissions
- Biogenic emissions

Biofuel Types: Wood chips, Biochar and Pyrolysis oil

Fossil Fuel Types: Heavy fuel oil and Bituminous coal

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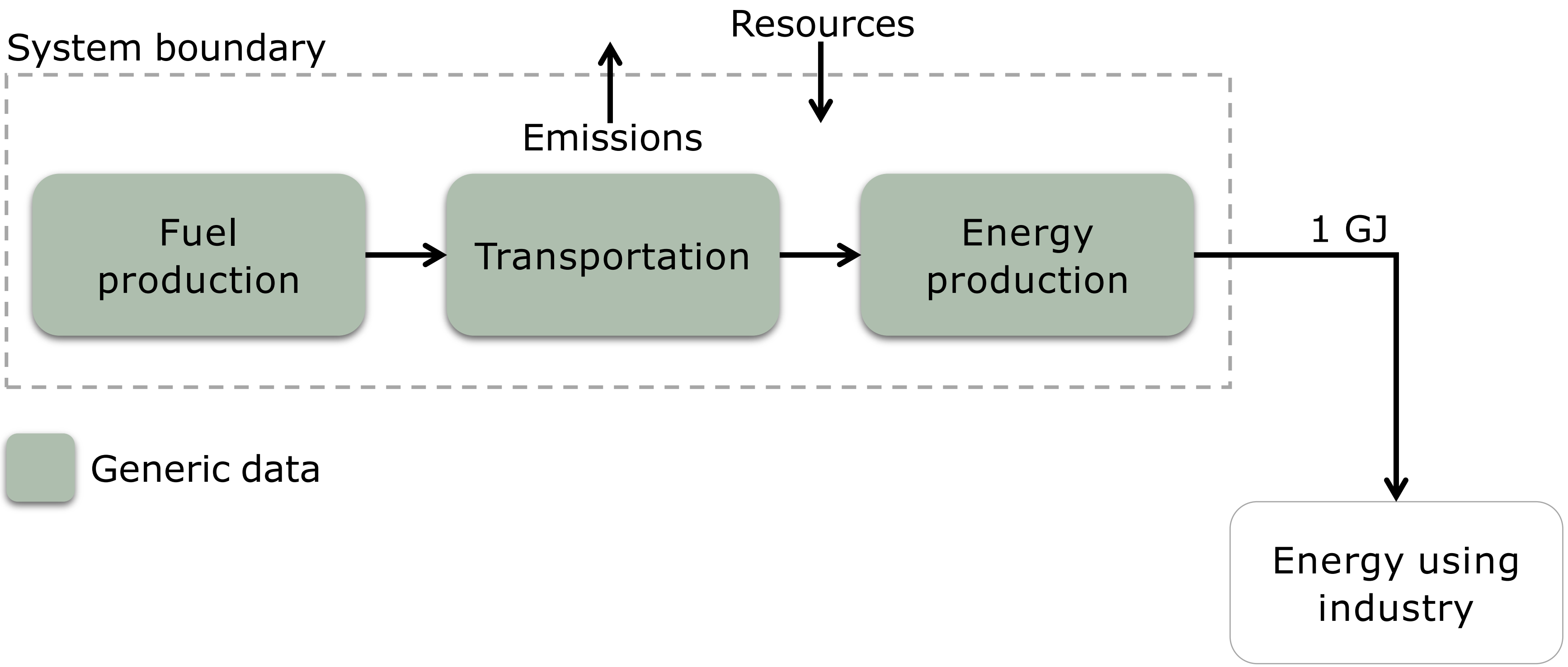
System boundaries are specified for energy production



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Logistics scenarios and benchmark fossil fuels are outlined below

Scenario A	Wood chips	Biochar	Pyrolysis oil
Thunder Bay to Hamilton	1) Marine: 1500 km 2) Rail: 1600 km 3) Road: 1450 km		
Sault Ste. Marie to Hamilton	1) Marine: 750 km 2) Rail: 800 km 3) Road: 750 km		

Scenario B	Wood chips	Biochar	Pyrolysis oil
Within Sault Ste. Marie	1) Road: 200 km		

Benchmark	Heavy fuel oil	Bituminous coal
Within Sault Ste. Marie	1) Pipeline + Road: 250 km	-
Knoxville, TN to Hamilton	-	1) Rail: 800 km + Marine: 350 km

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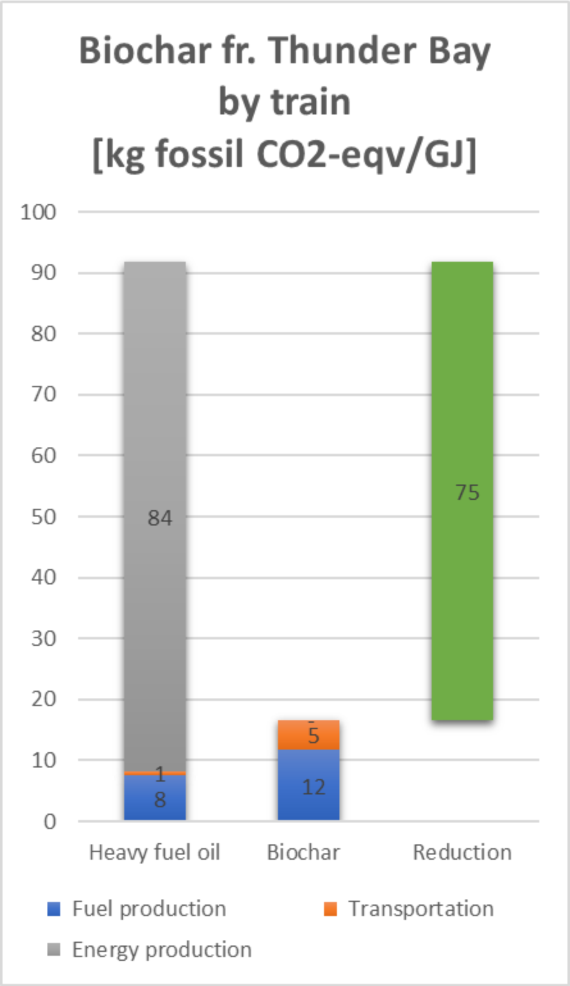
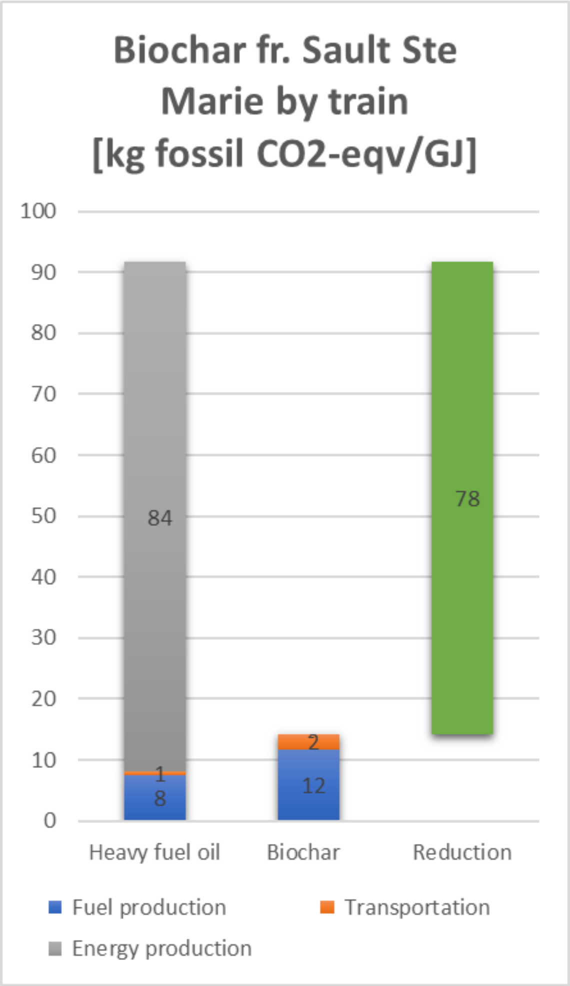
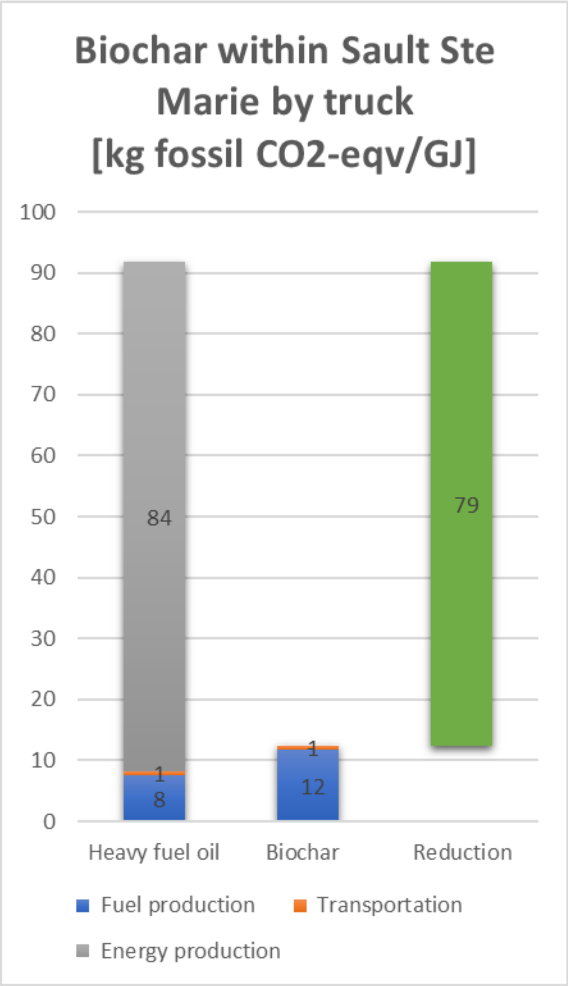
Benchmark: **biochar** vs. **heavy fuel oil**



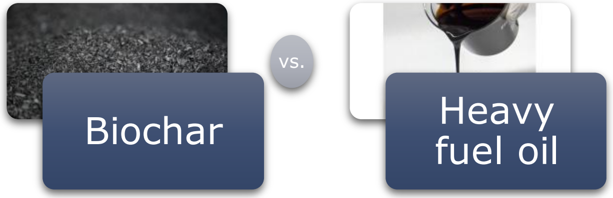
Scenario A



Scenario A



Scenario B



Replacing **heavy fuel oil** with **biochar** can reduce fossil GHG emissions with 82-87%, or by 75-79 kg fossil CO2-eqv/GJ.

The reduction increases with reduced transportation distances.

All transportation means for biofuels result in similar GHG emissions. In these graphs, the worst case is used: train, except for transports within Sault Ste Marie, where truck is the only option.

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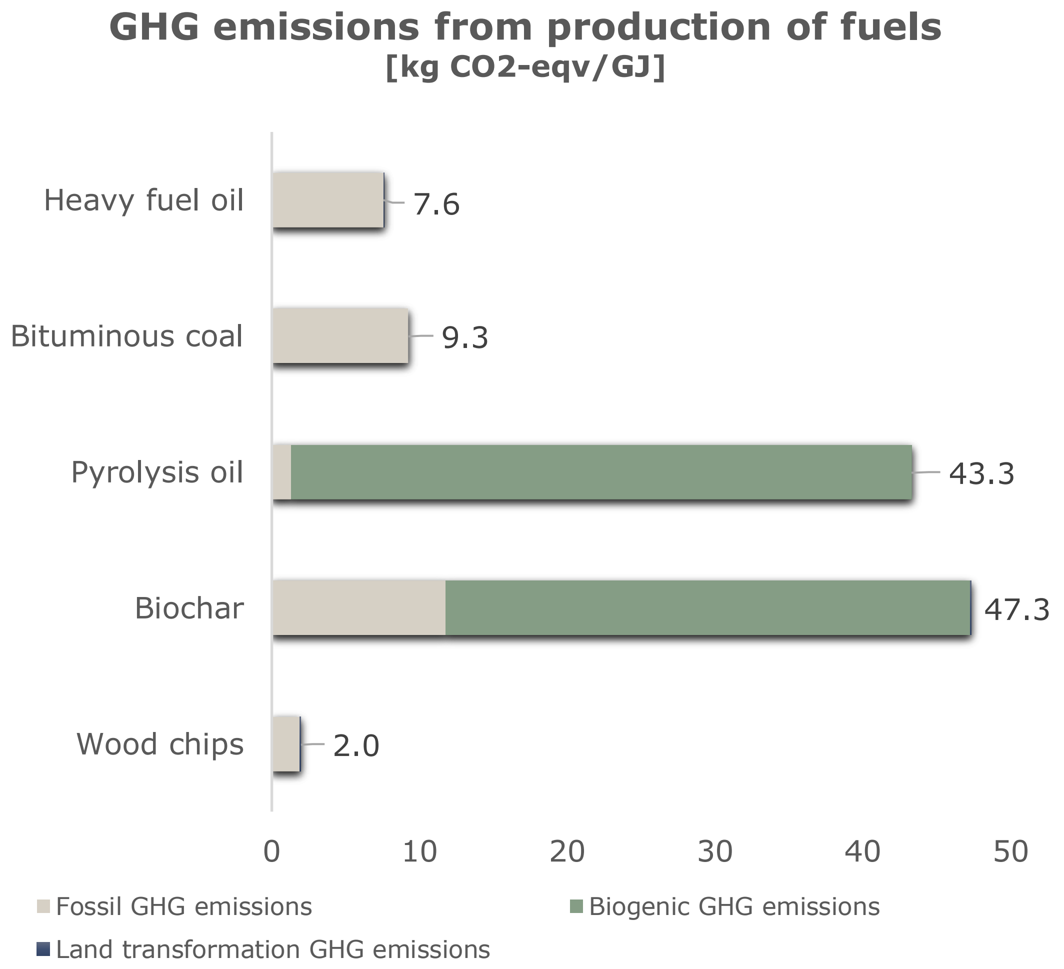
GHG emissions from the **fuel production** phase*



The GHG emissions from fuel production:

- Fossil GHG emissions from e.g. fossil fuels used in the processing of the fuel
- Biogenic GHG emissions from e.g. biofuels used in the processing of the fuel
- Land transformation GHG emissions from land use changes

Large fossil CO_2 emissions from producing biochar are mainly due to the large wood volume requirements: 2.5 kg wood/kg biochar incl. harvesting etc.

*Expressed as carbon intensity

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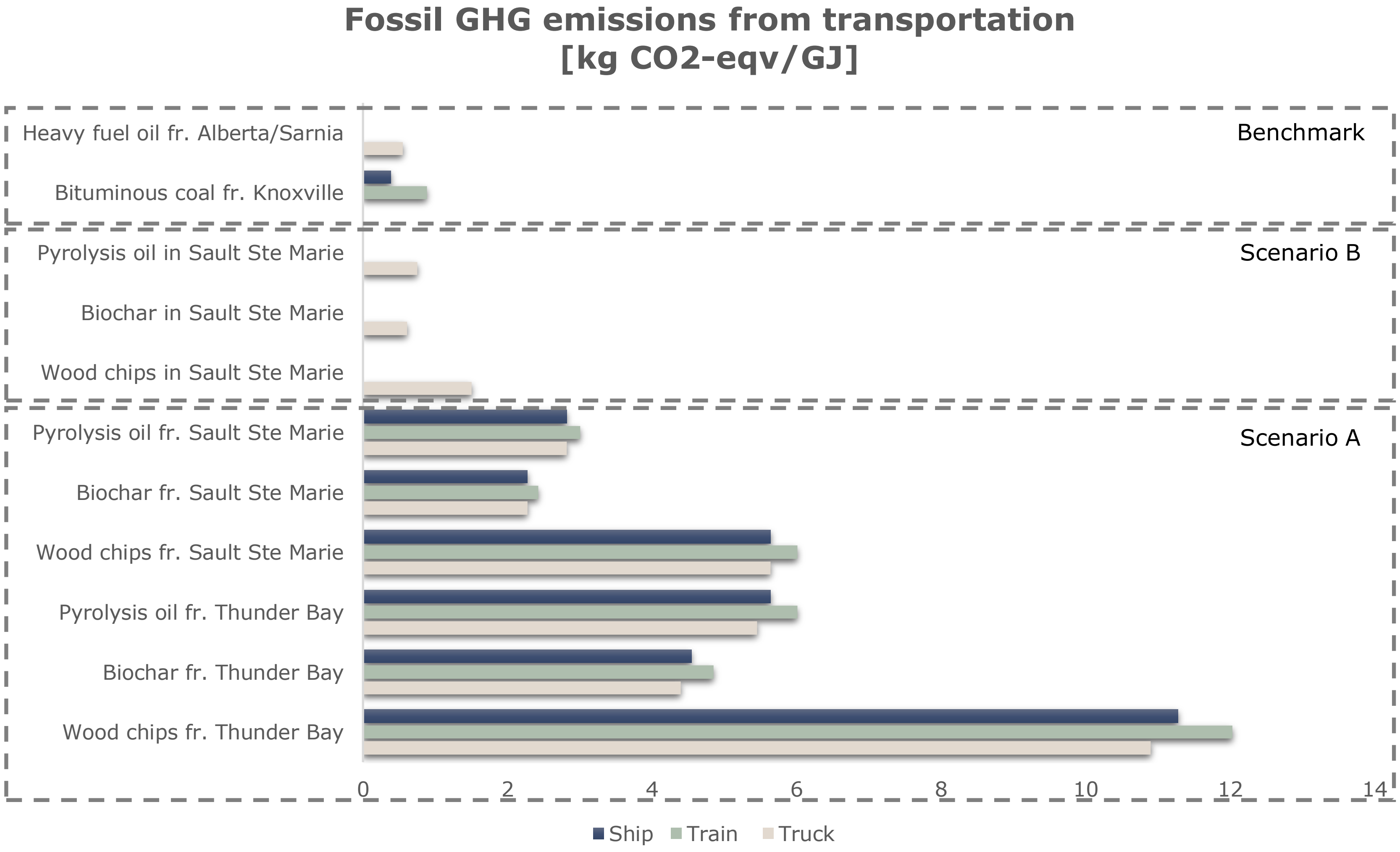
Fossil GHG emissions from **transportation** phase



- Due to differences in the heating values of the fuels, the fossil GHG emissions for transportation will differ even with the same distance and transportation mode.
- All 3 transportation modes result in similar levels of fossil GHG emissions when transporting the same weight and distance.
- Longer transportation distances will result in more fossil GHG emissions.
- For wood chips significant share of fossil GHG emissions in the transportation phase, especially for larger distances.
- Fossil CO_2 emission of low bulk density fuel such as wood chips is 2-3 times more that biochar and pyrolysis oil.

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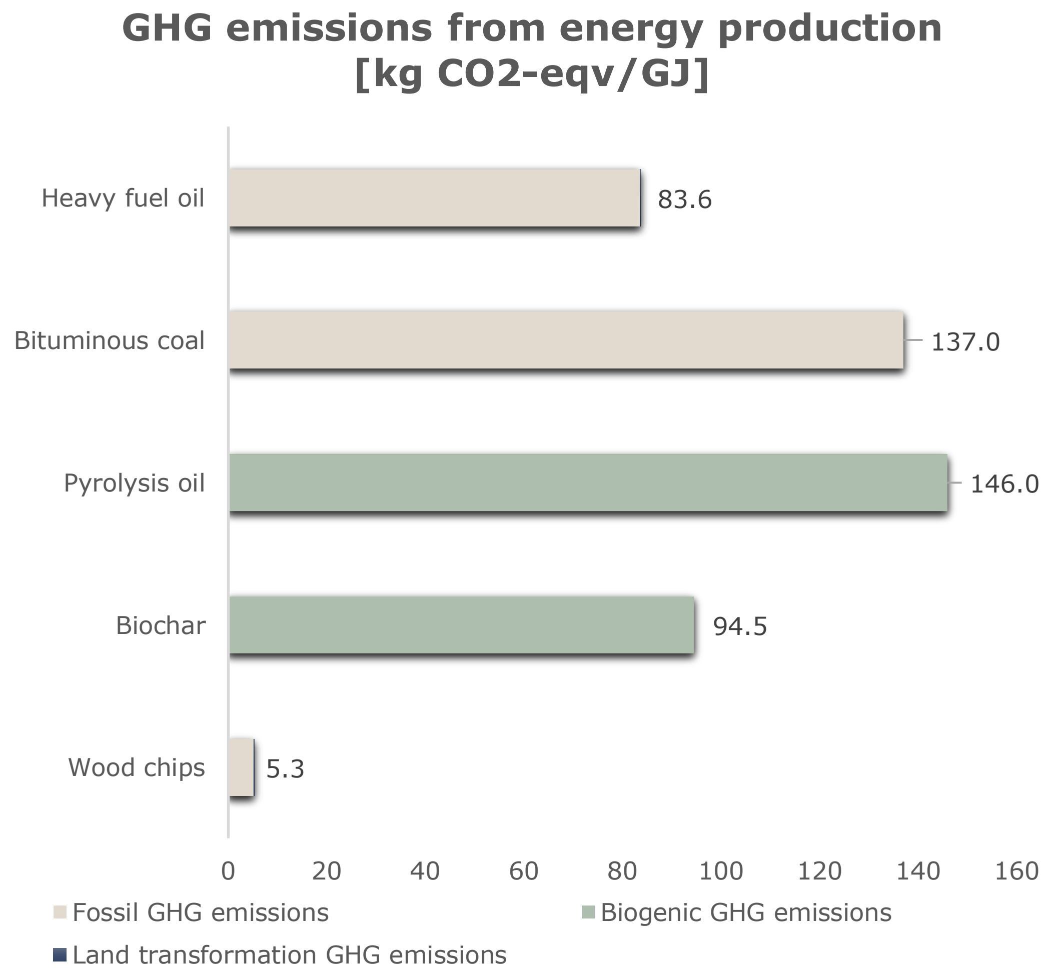
GHG emissions from **energy production** phase



The fossil CO_2 emission from wood chips is due to the release of nitrous oxide (N_2O) during combustion.

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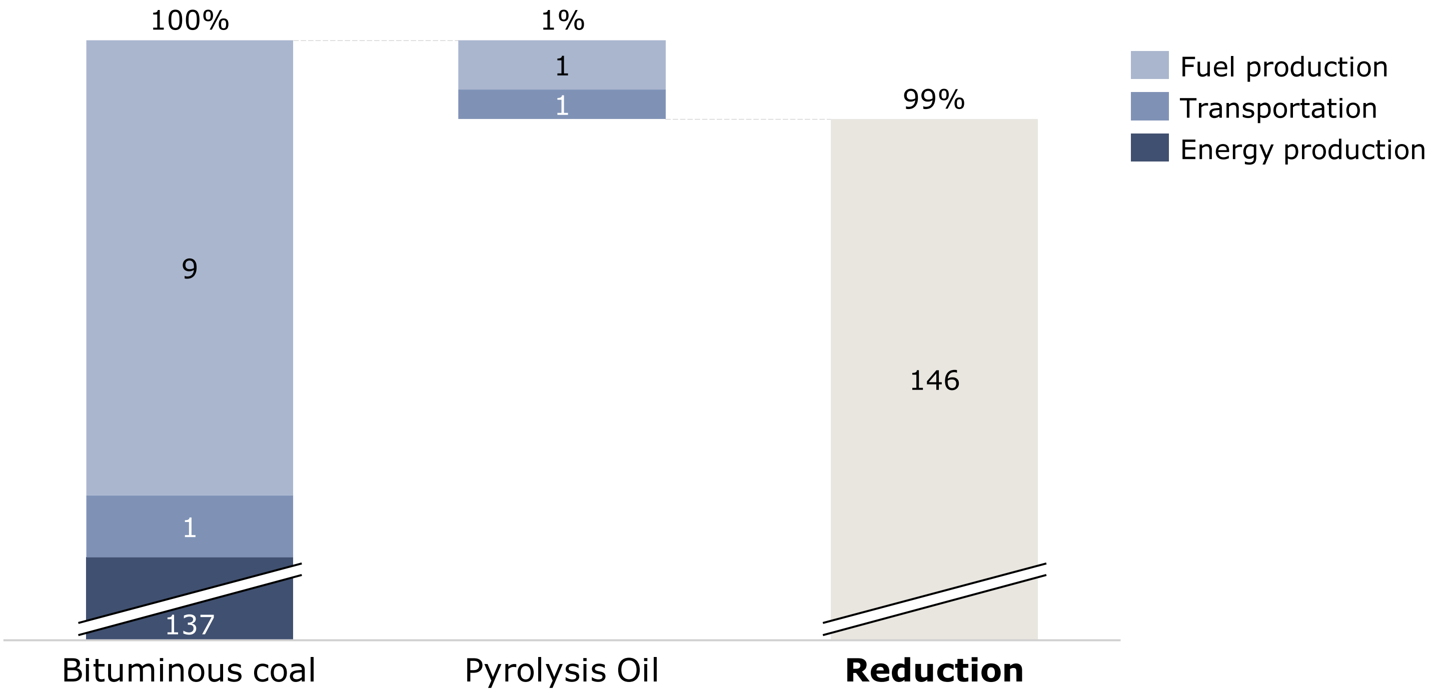
CRIBE, SIMPLIFIED LCA OF BIOFUELS

Pyrolysis oil has the greatest potential for reducing GHG intensities when replacing heavy fuel oil and coal

BITUMINOUS COAL VS. PYROLYSIS OIL WITHIN SAULT STE. MARIE (KG FOSSIL CO2-EQ/ GJ)



The study finds that shifting from fossil fuels to biofuels can reduce the GHG emissions radically, by up to 99%

For a more complete assessment, specific data should be considered that includes all types of GHG emissions.

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Conclusions

Production Phase

While production of biofuels can generate more GHG emissions than fossil fuels, these are largely biogenic.

When considering the fossil GHG emissions only, biochar has the highest fossil GHG emissions.

Energy Content

Increasing the energy density of the biofuel will lead to reductions in carbon intensity and GHG emissions.

Pyrolysis oil, which has the highest energy density, is preferred.

Transport Phase

Transportation distances are for obvious reasons important.

The choice of transportation modes (truck, train and ship) results in similar GHG emissions within the same distance.

Energy Production Phase

Biofuels can cause fossil GHG emissions during the energy production phase due to the production of nitrous oxide (N_2O) and other greenhouse gases released during combustion. Standard flue gas treatments can substantially reduce these emissions.

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Recommendations

- The focus for benchmarking should be on fossil GHG emissions.
- Further sustainability aspects, such as biodiversity, should be assessed by considering how the choice of fuel impacts the Sustainable Development Goals.
- Review the current and forthcoming relevant regulations to further understand how emissions from biofuels should be accounted for.
- Source low bulk density fuels such as wood chips close to client sites to reduce transport-related GHG emissions.

The results from this simplified LCA are not verified and cannot be used for communication with 3rd party.

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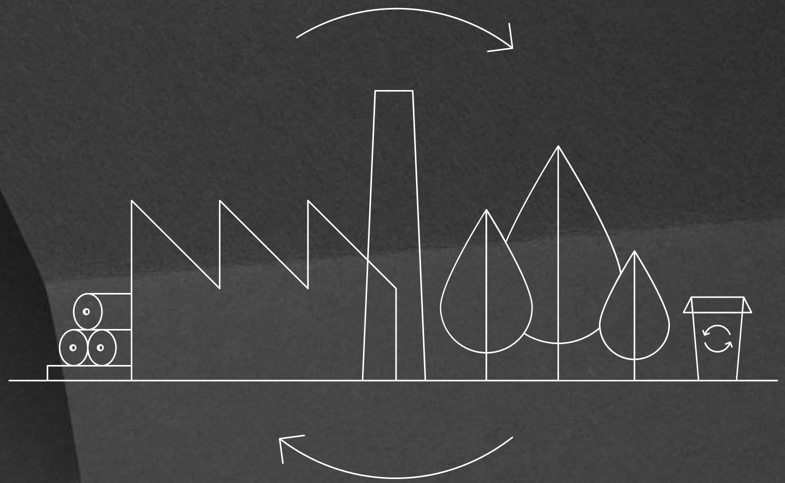
CONTACT INFORMATION

Thank you!



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