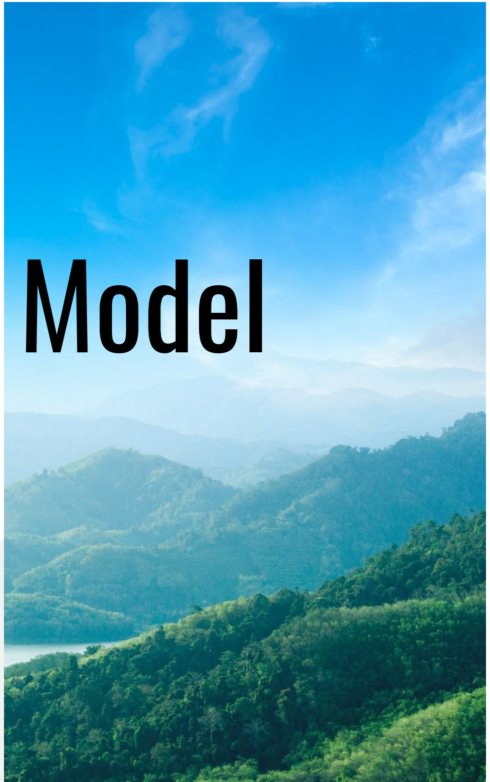
DEXMAT

GALVORN

CO_2 Impact Model

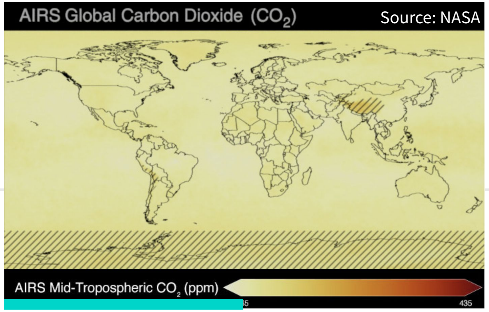


Life Cycle Analysis of high-performance Galvorn carbon nanomaterial.

About DexMat

Our "why"

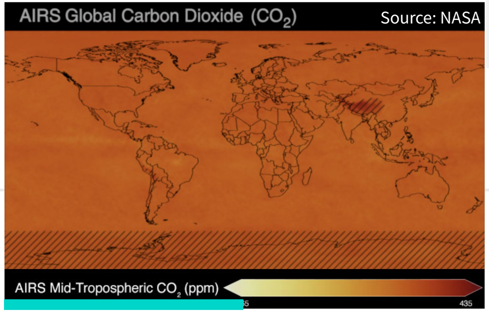
2002



Human activities have a tremendous impact on the carbon cycle

As a result, the amount of carbon dioxide in the atmosphere is rapidly rising; **it is already greater than at any time in the last 3.6 million years.**

2022



Steel, aluminum, and copper make up 8% of global emissions

They also make up 12% of global energy use, obliterate the environment, and are limited by single-purpose properties.

?

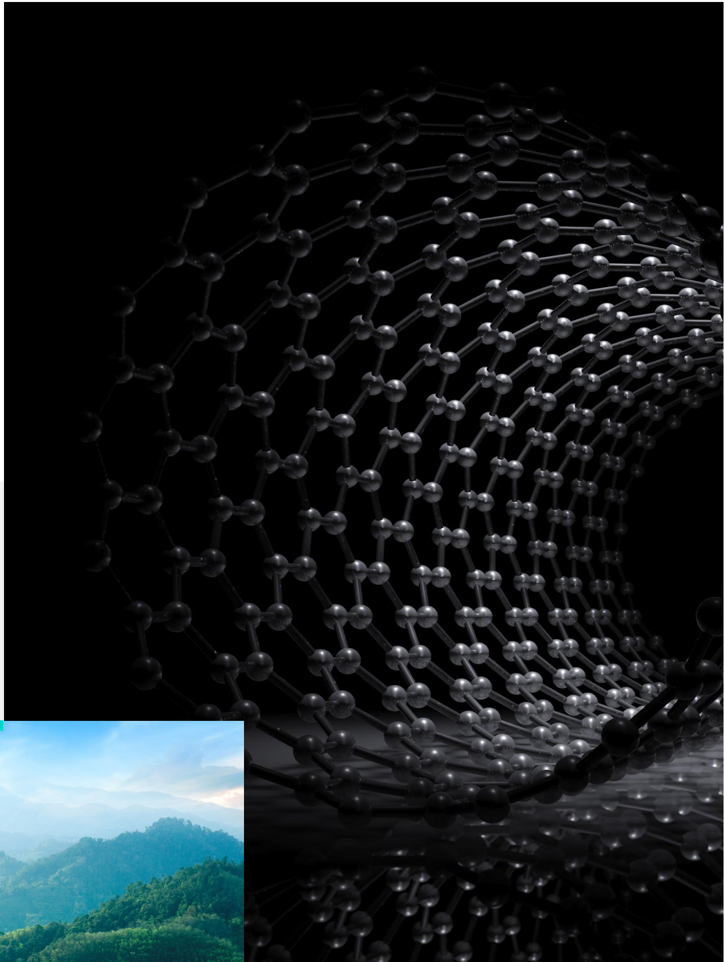
About DexMat

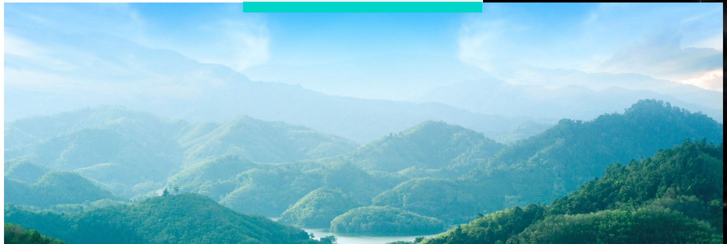
Our mission: drive the next materials revolution by making dirty metals and materials obsolete.

A win-win for the ages

DexMat is on a mission to displace GHG-intense metals and materials with Galvorn. This conductive high-performance material is efficient to produce and embodies carbon into a multi-purpose material that has a clean energy byproduct—hydrogen.

This study analyzes Galvorn's CO_2 impact today and considers the gigaton climate-positive opportunity.





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LCA

Key Highlights

Net Impact

0

Production emits no CO_2 in best case.

by 2029 / year 7

Net Impact

-1.1

ton net CO_2e impact per ton Galvorn

by 2030 / year 8

Net Impact

-50

ton net CO_2e impact per ton Galvorn

by 2048 / year 25

Biggest Drivers

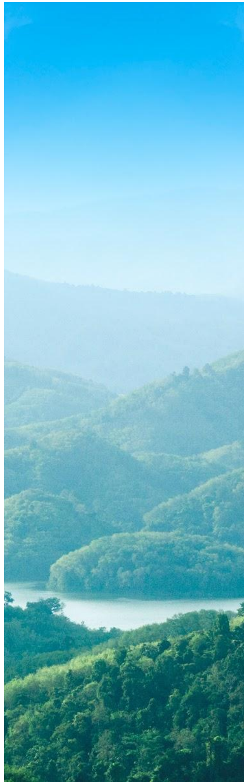
Displacing dirty incumbent materials is the biggest driver of impact—abating emissions and embodying them into advanced carbon materials.

Potential net impact of displacing steel, aluminum, and copper.

-2.7

Gigatons CO_2e per year

by 2048 / year 25



About

About this study

Gratitude

This CO_2 life cycle analysis was done in collaboration with Shell and the Grantham Foundation to evaluate the carbon-reduction opportunity that Galvorn represents.

We thank them for their continued support and guidance.

1. **Galvorn production**

   A fundamentally efficient process with the potential to be carbon negative.

2. **Gigaton impact via displacement**

   Galvorn can do the same work of incumbents with far fewer emissions.

3. **Bigger Outcomes with RNG**

   Galvorn can be fully sustainable with renewable natural gas as feedstock

4. **LCA Assumptions**

   The assumptions explained. Contact us if you still have questions.

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Impact

Galvorn's CO_2e impact has five components

Each component influences Galvorn's CO_2e impact to varying degrees.

This study considers each component across best, medium, and worst-case scenarios.

GALVORN **PRODUCTION**

Methane Feedstock

Today multiple sources offer the methane feedstock which undergoes pyrolysis. In the future, Galvorn could be made from captured CO_2e.

- CO_2e from NG
- CO_2e from RNG
- NG/RNG Mix %

CNT Synthesis

Carbon nanotubes (CNTs) can be made from hydrocarbons, capturing the carbon (abating CO_2e) and co-producing clean hydrogen.

- CO_2e from Electricity
- Synthesis Efficiency

Galvorn Fiber Spinning

DexMat processes raw (and recycled) carbon nanotubes to produce high-performance carbon nanotube fibers (CNTF). Electricity powers the machinery.

- CO_2e from spinning

GALVORN **UTILIZATION**

Displacement of Incumbent Materials

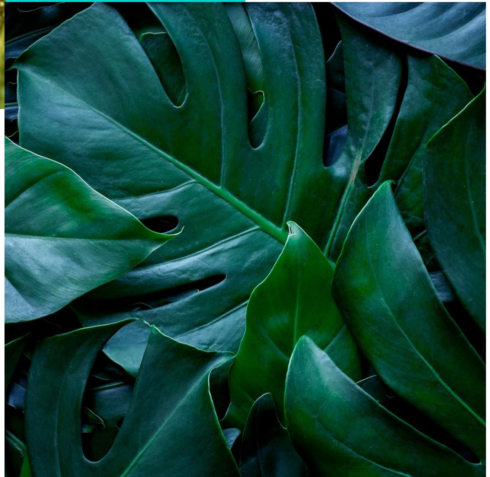
While Galvorn can be sustainably produced, its gigaton impact is achieved by displacing dirty incumbent materials. The biggest emitters are:

- Steel
- Aluminum
- Copper

Lightweighting Transportation

When Galvorn displaces many times its mass in dirty incumbent materials, the applications also benefit from lightweighting and more efficient use of fuel/energy.

- CO_2e reduction from lower fuel consumption



Carbon-Neutral Production

Offering a pathway to gigaton CO_2-negative impact

Galvorn has significant efficiency advantages

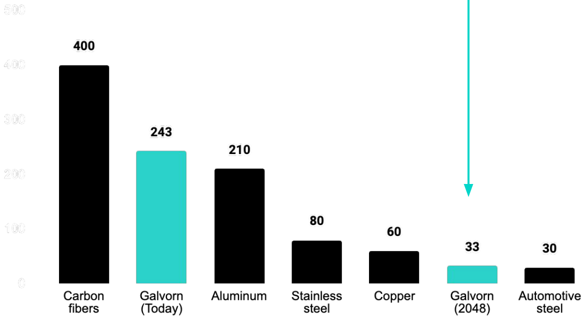
- **Near 1:1 feedstock-to-product conversion**
- **Production process is fundamentally less energy intense**
- **Clean energy byproduct**

Incumbent materials production involves massive physical footprints, and significant mass loss.

1 ton ore yields
3 kg Copper

1 ton bauxite yields
300 kg Aluminum

1 ton iron ore yields
625 kg steel



Energy Intensity of Materials (MJ/kg)

Galvorn's energy intensity is higher today because of its small scale (typical of materials production). At scale process efficiencies improve and significantly reduce the energy required to produce it. Contact us to learn more about our techno-economic analysis.

Production

Galvorn production has low energy intensity with a clean energy byproduct, hydrogen.

GALVORN

CH_4
Methane
1 kg
55.6 MJ

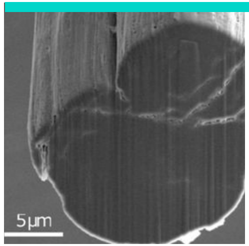
H_2
Hydrogen
0.25 kg
35.5 MJ

CNT
Carbon nanotubes
0.75 kg

1:1

GALVORN
High-performance carbon nanotube fibers
0.75 kg

Recyclable!

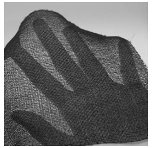


Fiber & Yarn

Conductive wire, power lines, motor windings

Film

EMI shielding, batteries, antennas



Fabric

Composite panels, electrodes, garments

3 — **Chemical Processes**

Splitting of the hydrocarbon, purification*, catalyst removal*.

*May not be necessary.

10

2 — **Phase Changes**

Dissolution of CNT in solvent; coagulation of CNTs into fibers.

4

2 — **Mechanical Processes**

Fiber spinning and winding.

4

Compared to PAN-Based Carbon Fiber at 400MJ/kg and 18 steps.

Production

Galvorn's CO_2e impact starts with its production

Methane Feedstock	CNT Synthesis	Galvorn Fiber Spinning	
-3.98 ton CO2e	+0 ton CO2e	+0.01 ton CO2e	=
-1.74 ton CO2e	+0.11 ton CO2e	+0.20 ton CO2e	=
+0.64 ton CO2e	+1.58 ton CO2e	+2.77 ton CO2e	=

BEST

-3.97

- 100% Renewable Gas
- 100% Renewable Electricity

Reaching -1.43 by 2030 (year 8)

ton CO_2e per ton Galvorn produced by 2048 / year 25

MEDIUM

-1.43

- 9% RNG for feedstock
- Texas renewables mix for CNT synthesis electricity
- Modest efficiency improvements in fiber spinning during scaleup

Reaching +4.04 by 2030 (year 8)

ton CO2e per ton Galvorn produced by 2048 / year 25

WORST

+4.99

- 100% fossil gas
- Low renewables grid uptake

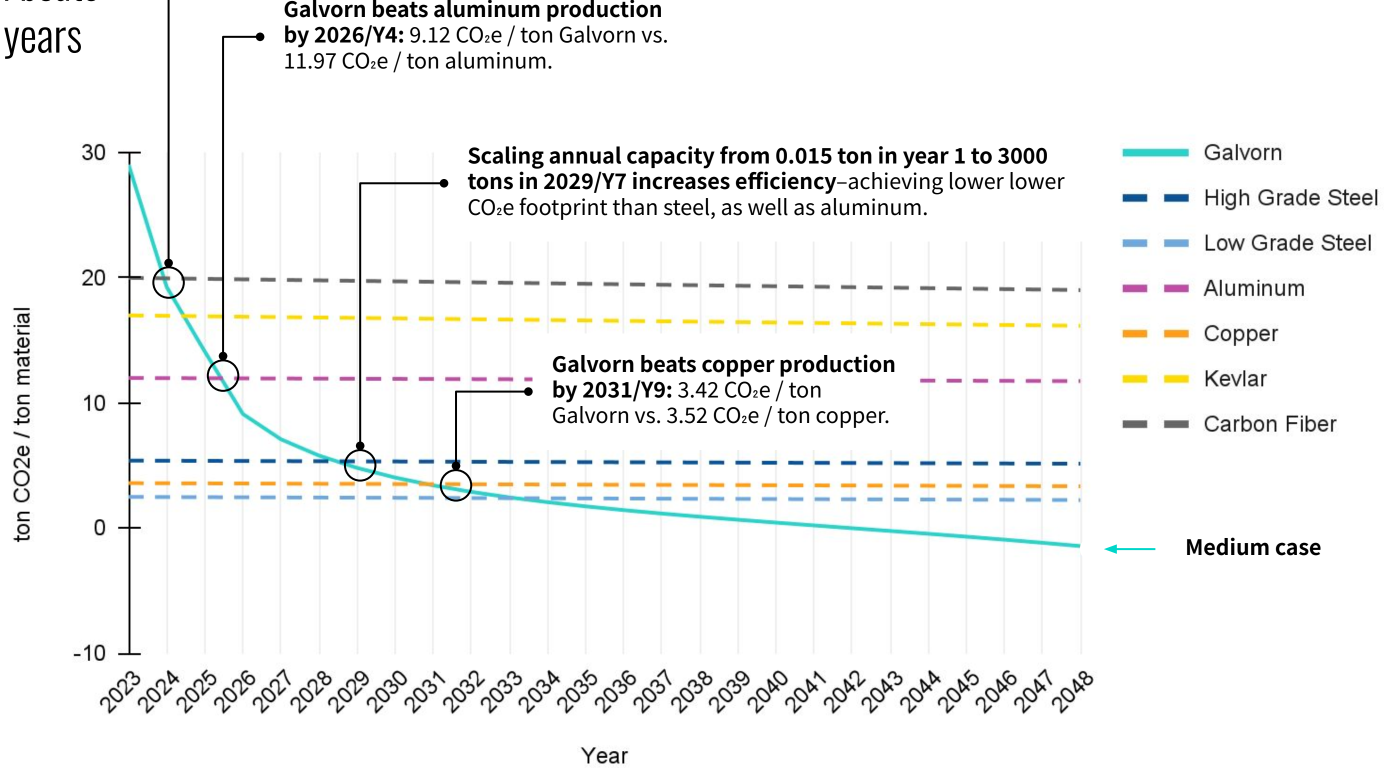
Reaching +8.39 by 2030 (year 8)

ton CO2e per ton Galvorn produced by 2048 / year 25

Production

Galvorn production beats metals within 3-6 years

Even in the worst-case scenario Galvorn can still have gigaton impact by displacing dirty incumbent materials.



Future

DexMat has future pathways to improve Galvorn production LCA, including:

Utilizing captured CO_2 instead of methane as a feedstock

But, conservatively, these pathways have **not** been included in this CO_2e impact modeling.

Co-producing H_2 during CNT synthesis

Utilizing recycled Galvorn instead of new CNTs

Sensitivity

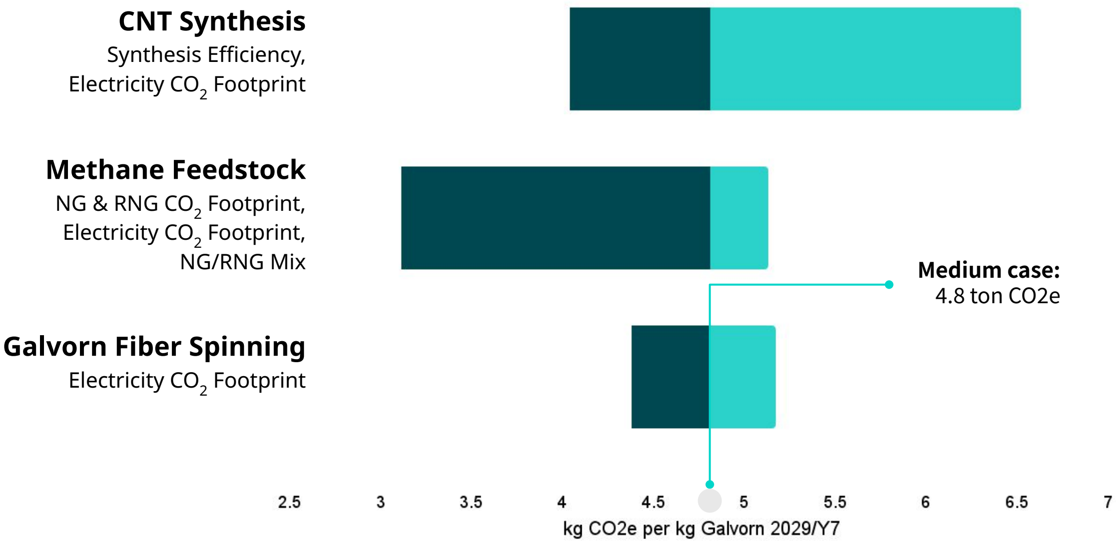
CO_2e of Galvorn production is most sensitive to CNT synthesis

About CNT Synthesis

The process for making carbon nanotubes (CNTs), which are the feedstock for Galvorn, is pyrolysis. Electricity is used to split methane (CH_4) into hydrogen (H_2) and carbon (C).

Most of the energy required to produce Galvorn today goes into CNT synthesis. Spinning the CNTs into fiber does not require as much energy.

Galvorn production as a whole is thermodynamically efficient in terms of its chemical reactions. Powered by electricity, it can also have the benefit of being produced with renewable energy.



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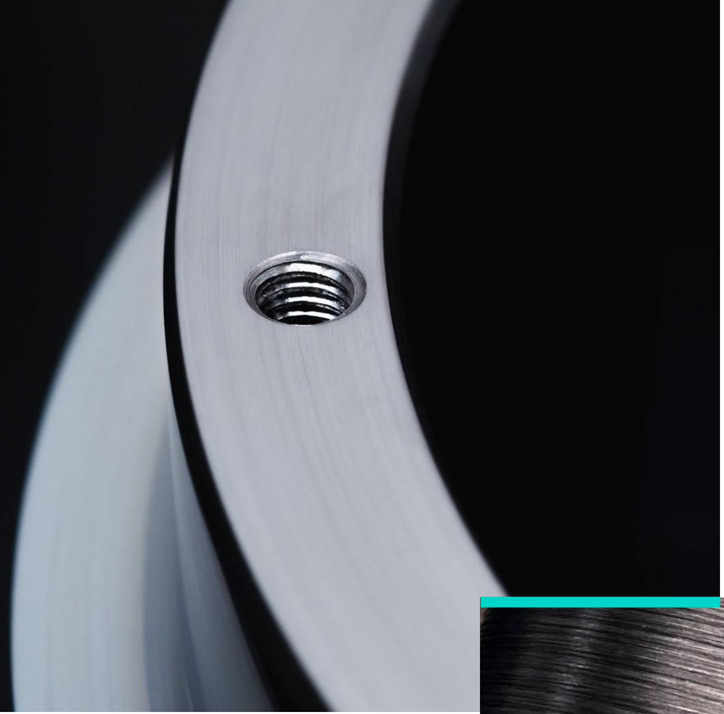

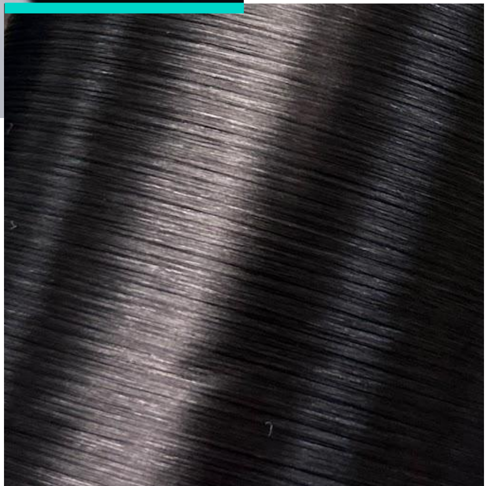

Gigaton Impact

Through Displacement

Galvorn’s unique combination of high-performance properties enable it to do the same work of incumbent materials—without the emissions impact.

Our material world can be sustainable.

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Impact

Galvorn can achieve net negative CO_2e impact in 2029 when utilization is included

-1.1 ton net CO_2e impact / ton Galvorn by 2029 / year 7

Methane Feedstock	CNT Synthesis	Galvorn Fiber Spinning	Displacement of Incumbent Materials	Lightweighting Transportation
+0.5 ton CO2e	+2.8 ton CO2e	+1.5 ton CO2e	-5.8 ton CO2e	-0.07 ton CO2e

+4.8 ton CO2e per ton of Galvorn produced

+

-5.94 ton CO2e avoided per ton of Galvorn used

Medium case

Impact

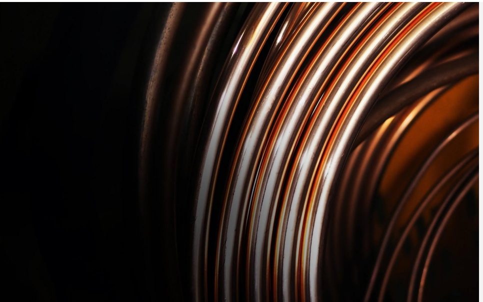
Galvorn's displacement of dirty incumbent materials drives its CO_2e impact

ANALYSIS

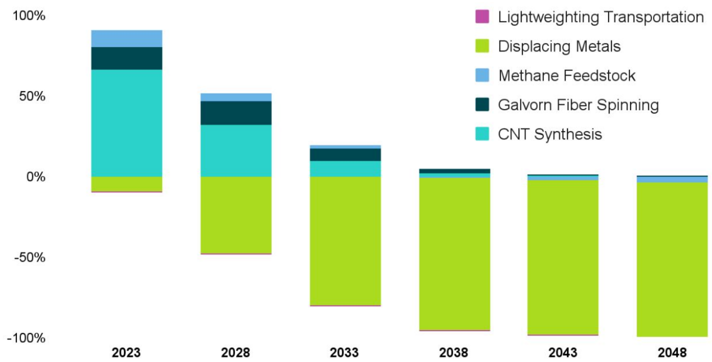
Galvorn's total CO2e impact is most sensitive to:

Rate of metal displacement from improving Galvorn properties

Greening of Steel, Al, and Cu

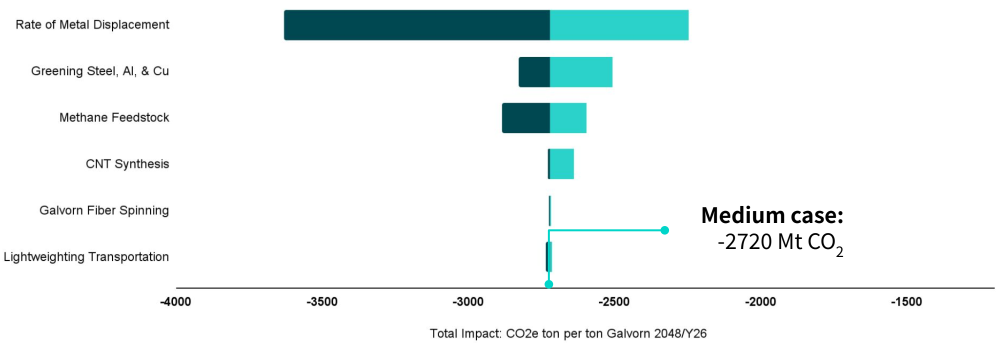


Segmentation of CO_2 Impact (%)



Year	Total Annual CO_2 Impact (Mt)
2023/Y1	0
2028/Y6	-0.0018
2033/Y11	-0.3628
2038/Y16	-70
2043/Y21	-956
2048/Y26	-2720

Sensitivity Analysis



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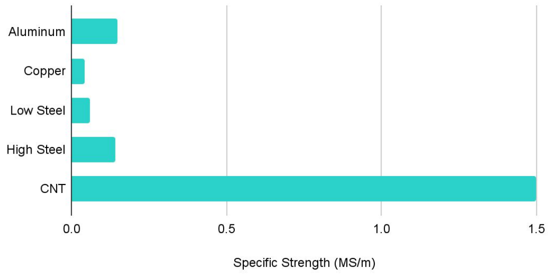
Opportunity

Galvorn can do the work of incumbent materials with far lower emissions

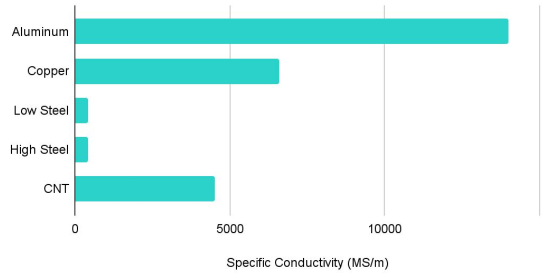
It’s time to re-think how materials get the job done. For example, though Galvorn has a lower specific conductivity than copper or aluminum, their displacement leads to lower emissions—even if you need more Galvorn to conduct the same amount of electricity.

This is accounted for in the analysis.

Specific Strength

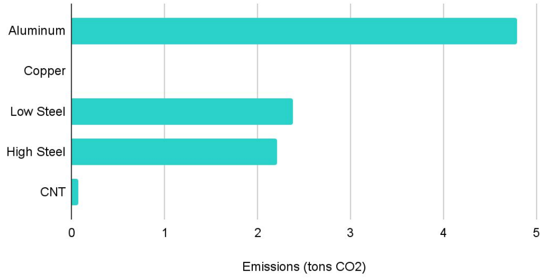


Specific Conductivity



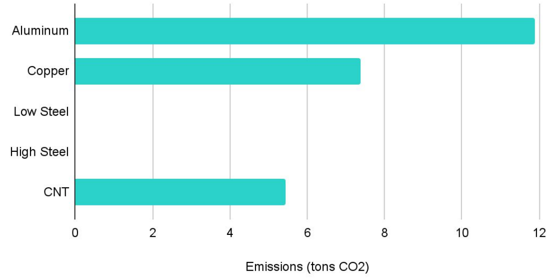
Emissions to Support Same Weight

As 1 ton of low-grade steel



Emissions to Conduct Same Amount of Electricity

As 1 ton of aluminum



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Impact

Galvorn's net negative impact increases with greater utilization

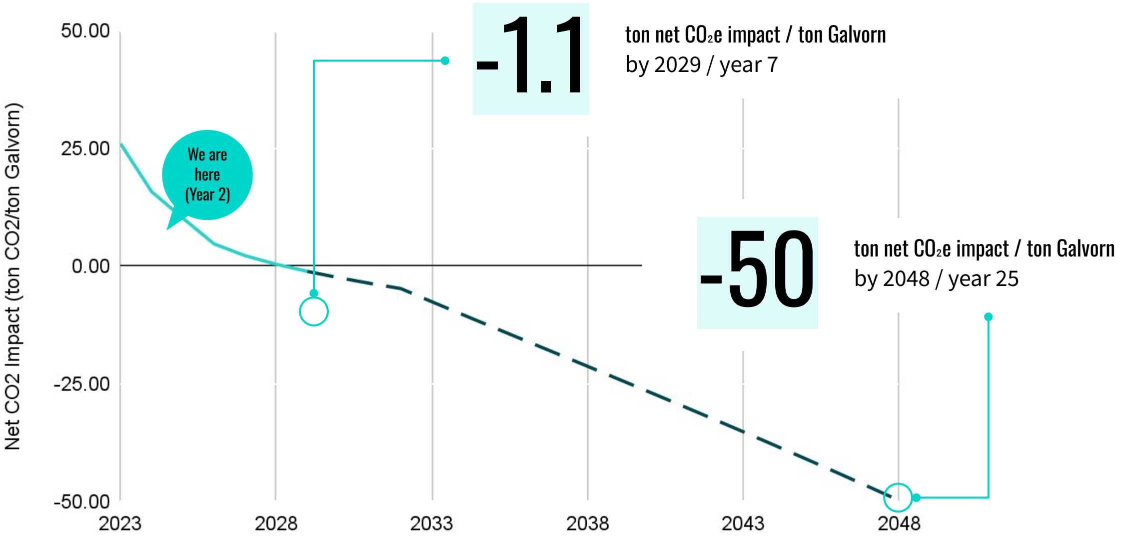
ANALYSIS

Galvorn's Net CO_2e Impact by Year 7

Assumes we are:

- Using 9% RNG for CNT synthesis
- Using 1 ton of Galvorn to displace any one of the following (on a performance levelized basis):
  - 7.7 ton high-grade steel
  - **...or** 1.6 ton aluminum
  - **...or** 0.8 ton copper

Impact varies based on which metal is being displaced. Regardless, Galvorn will reach price parity with high-grade steel by year four, in which case displacement makes sense economically–as well as environmentally.



Impact

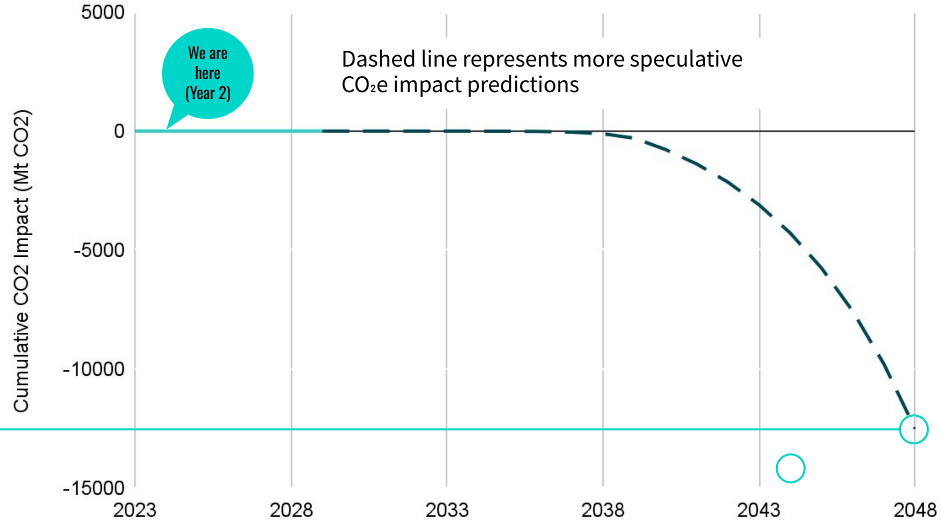
Galvorn's cumulative net CO_2e impact can reach gigaton scale in less than 20 years

ANALYSIS

Cumulative CO_2e Impact in Megatons

-12.5

Gt CO_2e
Cumulative Impact
@ -2.7 Gt / year in 25 years



Impact

Galvorn has a massive, growing CO_2e advantage over equivalent amounts of dirty incumbent materials

ANALYSIS

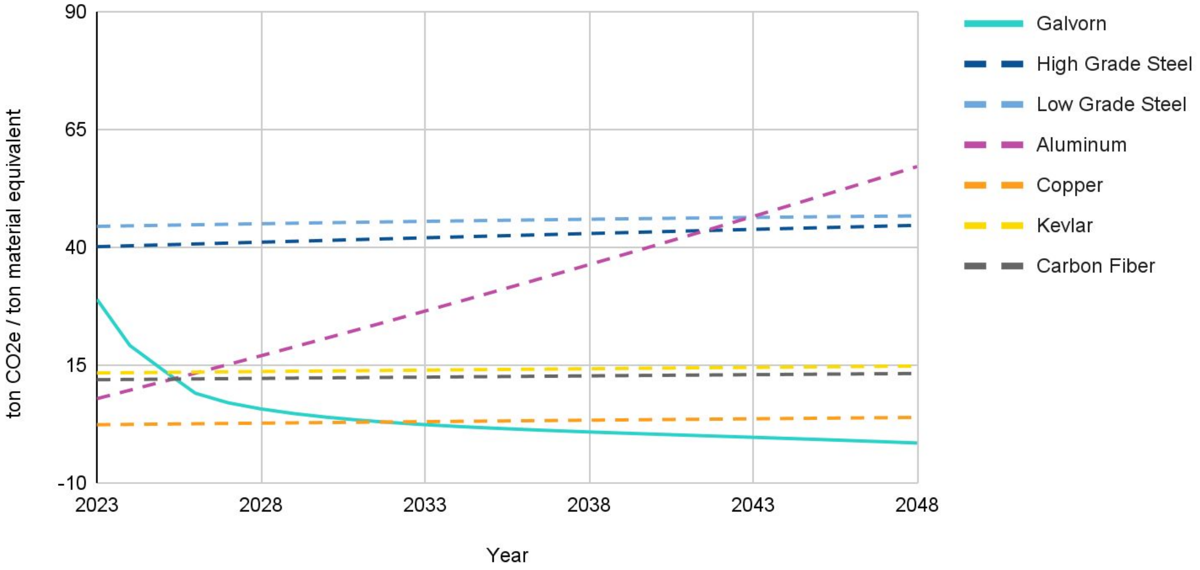
Assumptions

CO_2e for Galvorn and metals all assumed to decrease over time.

Amount of metals that can be displaced per ton of Galvorn assumed to increase over time.

With improving Galvorn properties, 2048/Y26, 1 ton of Galvorn can displace:

- 8.7 ton high grade steel
- **OR** 21 ton low grade steel
- **OR** 4.9 ton aluminum
- **OR** 3.4 ton copper



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Renewable Natural Gas

A pathway to Galvorn’s negative carbon footprint.

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RNG

Renewable natural gas (RNG) provides a pathway to Galvorn's negative carbon footprint

-2.3 kg CO_2 emissions per kg RNG

GREET ascribes -2.3 kg CO_2 emissions per kg renewable natural gas (RNG) when produced from landfill gas.

The negative footprint of RNG in the model is a sum of 3 factors:

1. Carbon in landfill gas is from biogenic sources (i.e., food)
2. Biogenic carbon emissions are carbon neutral
3. Capturing LFG and preventing its emission is a net negative change from status quo

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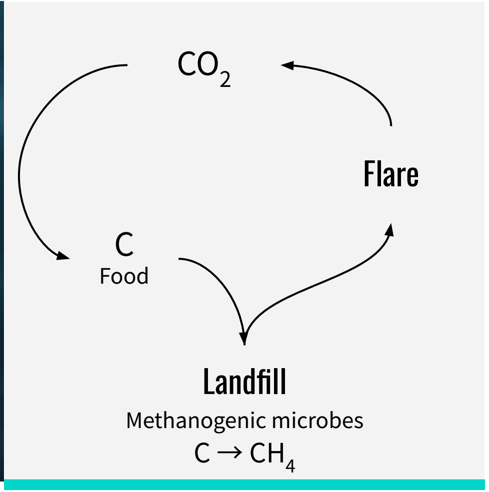

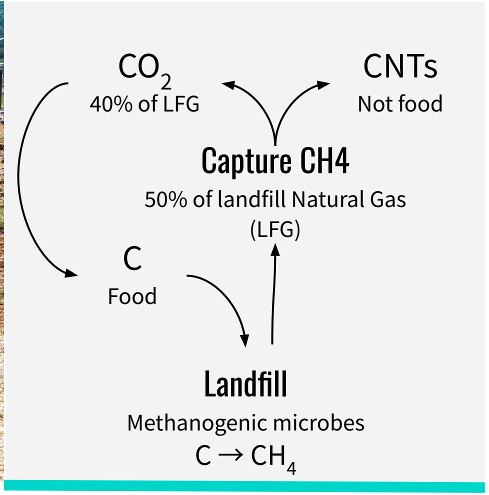

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Biogenic CO_2 emissions are carbon neutral

Landfill Gas (LFG) is usually emitted or flared. The gas does not stay in the landfill.

02

...so capturing CH_4 is carbon negative

Using LFG prevents CO_2 (if flared, or CH_4 if not) from entering the atmosphere.

<1% other stuff

LFG Composition:

RNG

Forms of RNG and their footprints (GREET)

RNG Type	CO_2	CO_2 biogenic*
Animal Waste Anaerobic Digestion	2.6182	-0.0073
Food Waste	0.6297	1.5099
Landfill Gas (LFG)	-2.3748	2.7044
Wastewater Sludge	-6.2727	43.0332

*** Biogenic CO_2 emissions are neutral** because the carbon came from the atmosphere initially

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LCA

Assumptions

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Assumptions

Assumptions for CO_2e from Galvorn production

	Initial	Low Case	Medium Case	High Case
Renewable NG Mix (% RNG)	5%	0% always	+10% per yr	100% always
CO_2e Footprint Electricity (kg CO_2e / kW-h)	0.39	-1% per yr	-10% per yr	-20% per yr
Galvorn Fiber Spinning (kg CO_2e / kg Galvorn)	4.4	-0.25 kg CO_2e/yr	-0.4 kg CO_2e/yr	-0.8 kg CO_2e/yr
CO_2e Footprint RNG (kg CO_2e/ kg RNG)	-2.2	-0.01 kg CO_2e/yr	-0.05 kg CO_2e/yr	-0.08 kg CO_2e/yr
CO_2e Footprint NG (kg CO_2e / kg RNG)	0.9	-0.01 kg CO_2e/yr	-0.02 kg CO_2e/yr	-0.03 kg CO_2e/yr
CNT Synthesis Efficiency (% Efficiency)	0.8%	0.5% per yr	1% per yr	2% per yr

Assumptions

Sensitivity analysis assumptions for total CO_2e impact

	Units	Initial	Low Case	Medium Case	High Case
Rate of Metal Displacement	(kg CO_2e / kg metal)	Steel: 8.0, Al: 1.0, Cu: 0.3	-0.05 kg metal/yr	-0.1 kg metal/yr	-0.15 kg metal/yr
Greening Steel, Al, & Cu	(kg CO_2e / kg metal)	Steel: 3.4, Al: 12.0, Cu: 3.7	-0.02 kg CO_2e/yr	-0.01 kg CO_2e/yr	-0.005 kg CO_2e/yr
Renewable NG Mix	(% RNG)	5%	0% always	+2% per yr	100% always after 5 years
CO2 Footprint Electricity	(kg CO_2e / kW-h)	0.39	-1% per yr	-10% per yr	-20% per yr
Galvorn Fiber Spinning	(kg CO_2e / kg Galvorn)	4.4	-0.25 kg CO_2e/yr	-0.4 kg CO_2e/yr	-0.8 kg CO_2e/yr
CO2 Footprint RNG	(kg CO_2e / kg RNG)	-2.2	-0.01 kg CO_2e/yr	-0.05 kg CO_2e/yr	-0.08 kg CO_2e/yr
CO2 Footprint NG	(kg CO_2e / kg NG)	0.9	-0.01 kg CO_2e/yr	-0.02 kg CO_2e/yr	-0.03 kg CO_2e/yr
CNT Synthesis Efficiency	(% Efficiency)	0.8%	0.5% per yr	1% per yr	2% per yr
Lightweight Transportation	(kg CO_2e / kg Galvorn)	-0.01	-0.005 kg CO_2e/yr	-0.01 kg CO_2e/yr	-0.02 kg CO_2e/yr

Thank you

Questions?

Our team is available to answer your questions.

Contact us at **dexmat.com**

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