Carbon Hub Webinar - Call for Proposals Fall 2021

Carbon Hub

Topic 3: Demonstrate the value of a Carbon nanotube [CNT] fiber-based power cable prototype.

Carbon Hub Webinar - Agenda

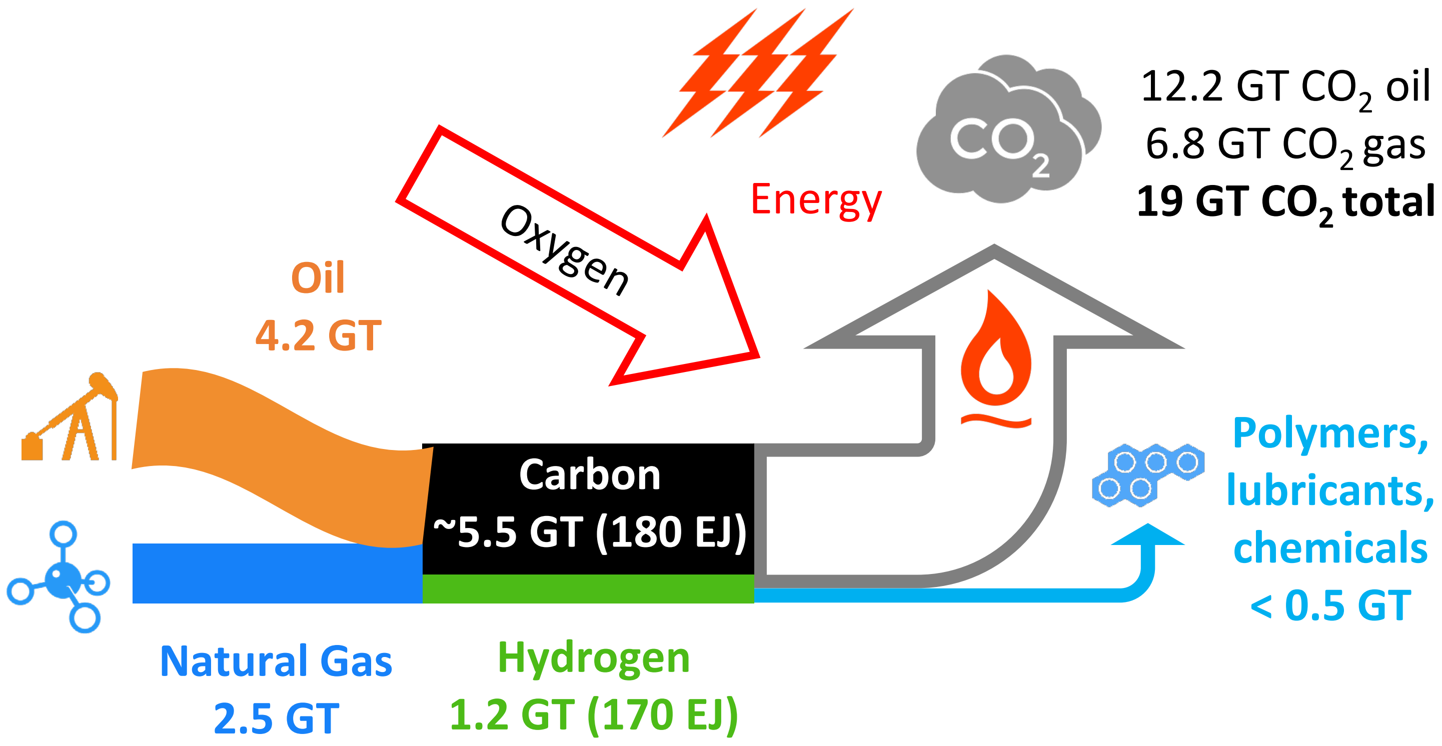
Carbon Hub

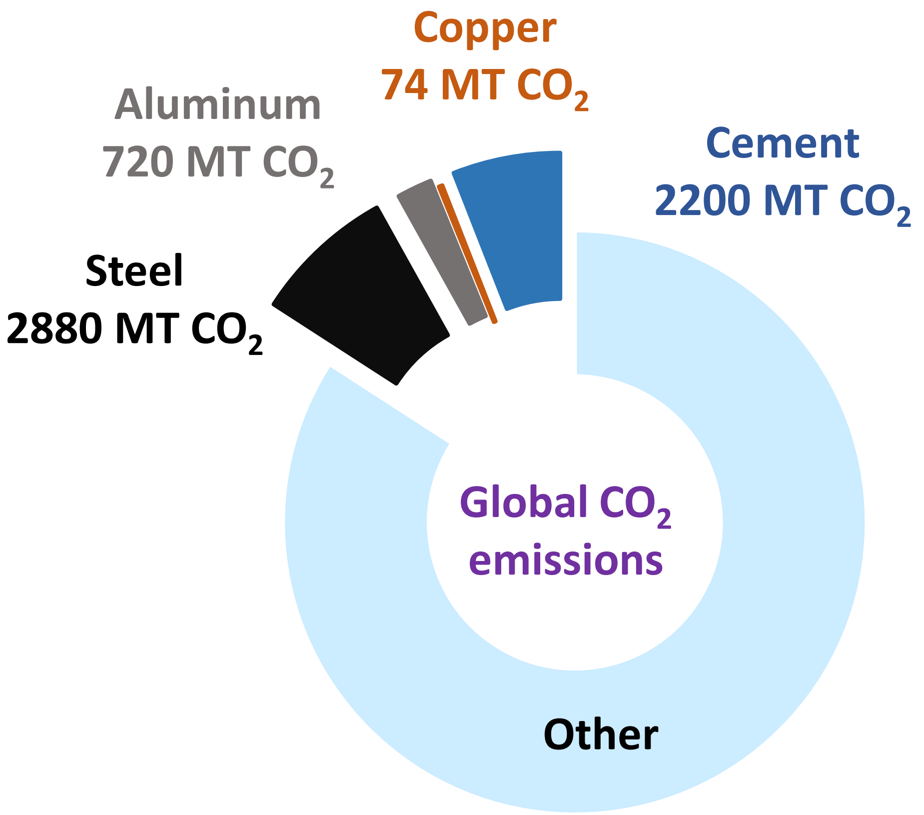
General	❑ Introduction Carbon Hub ❑ Mission and Vision	10 min
What are we trying to solve?	❑ Topic Introduction ❑ Expert deeper dive ❑ Key deliverables ❑ What is out of scope – What are we NOT looking for ❑ Budget and timeline	30 min
Q&A	❑ Please ask us questions	15 min
Next Steps	❑ In summary – How to submit your proposal ❑ Call for Proposal Process and timeline - Some Terms & Conditions	5 min

The Carbon and Material Challenge

85% of world energy comes from carbon combustion

12% of world energy is used for production of steel , aluminum and copper



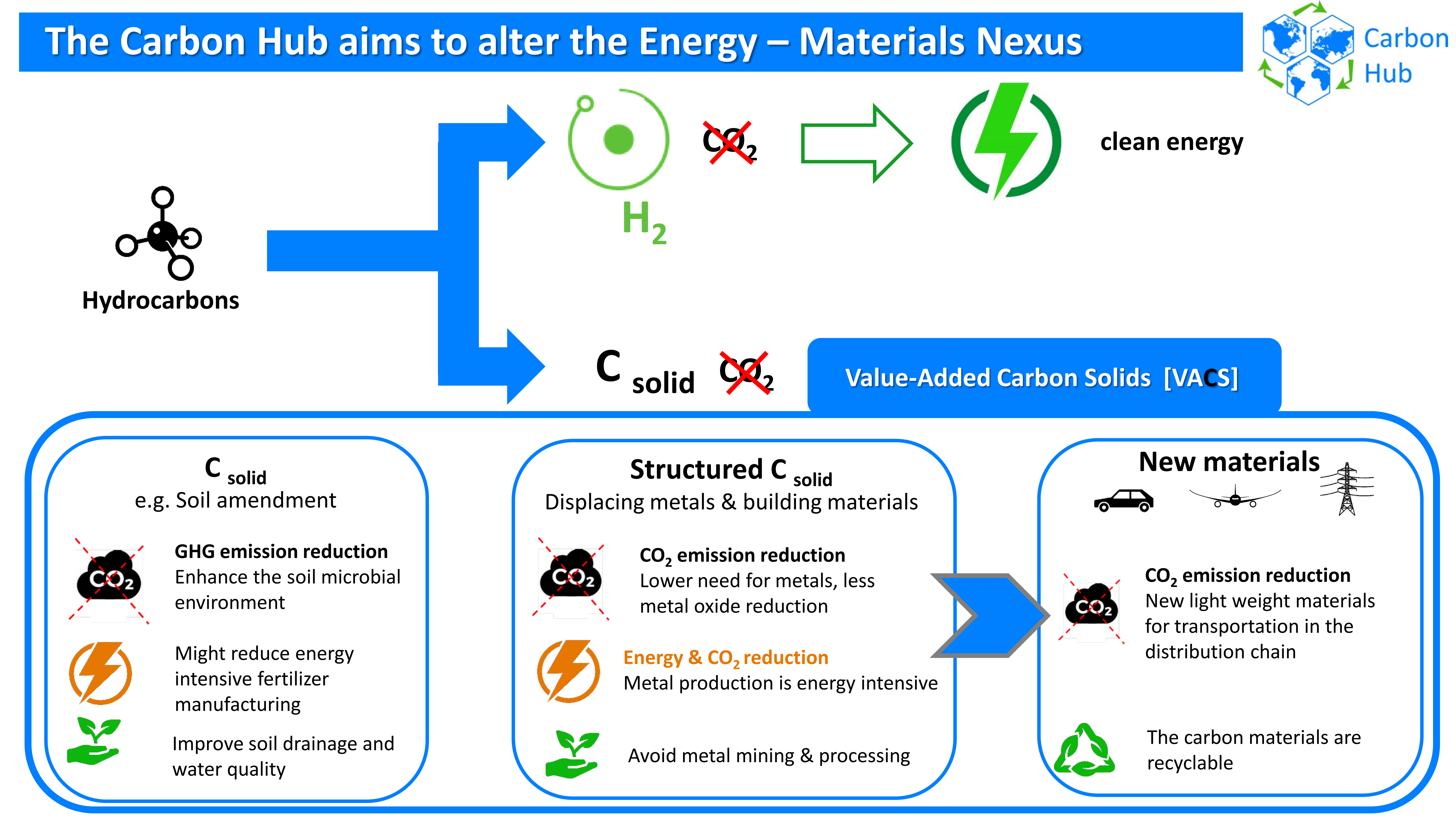


19 GT CO_2 / yr

“indicative numbers” 2017 data

5.9 GT CO_2 / yr

“indicative numbers”


The Carbon Hub aims to alter the Energy – Materials Nexus
Carbon Hub
Hydrocarbons
H2
CO2
clean energy
C solid
CO2
Value-Added Carbon Solids [VACS]
C solid
e.g. Soil amendment
GHG emission reduction
Enhance the soil microbial environment
Might reduce energy intensive fertilizer manufacturing
Improve soil drainage and water quality
Structured C solid
Displacing metals & building materials
CO2 emission reduction
Lower need for metals, less metal oxide reduction
Energy & CO2 reduction
Metal production is energy intensive
Avoid metal mining & processing
New materials
CO2 emission reduction
New light weight materials for transportation in the distribution chain
The carbon materials are recyclable

Value-Added Carbon Solids – Our definition

Carbon Hub

NG
Natural Gas
Light HC

→

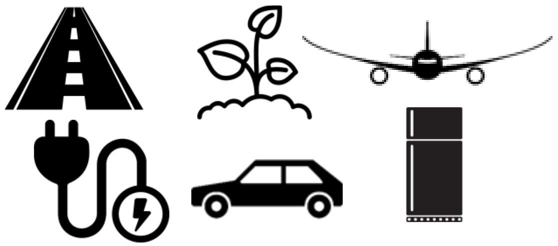
H_2 ~~CO_2~~

C solid

→

Application in end-products

scale value



VACS

A solid carbon material produced by splitting efficiently (e.g., by pyrolysis) methane and light hydrocarbons with concurrent production of hydrogen and no carbon dioxide emissions.

Being used pervasively (>1 MM Tons/year)

Displacing metals, traditional construction ceramics, fertilizers and other materials with high CO_2 footprints.

excluded

- Carbon black, amorphous carbons, graphite
- Polymers
- Solid carbon whose only value is a CO_2 emission avoidance or that will be oxidized in other processes (e.g., metallurgical coke)

included

- Carbon materials that have macroscale structural integrity and properties that overlap with widespread materials
- Carbon powders that have potential use as additives in very large-scale systems, e.g., in soil or concrete

Examples of Value-Added Carbon Solids – Carbon Nanotubes (CNTs)

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Opportunities

- ❑ CNTs can be synthesized in one process step from methane or light hydrocarbons
- ❑ CNTs can be converted into macroscopic materials;
- ❑ based on properties, a subclass of CNT macro-materials could replace metals or other construction material

Challenges

- ❑ CNT synthesis is still an early-stage, **low-volume** endeavor;
- ❑ synthesis **efficiency is low** and must be increased by orders of magnitude to attain competitiveness with incumbent materials;
- ❑ the **knowledge base** for increasing the efficiency and scale of CNT synthesis must be developed

VACS

Application in end-products

scale value

Examples of Value-Added Carbon Solids – Soil Amendment

Opportunities

- forms of carbon (e.g., biochar) may improve the fertility and viability of soils while simultaneously reducing fertilizer usage and the agricultural carbon footprint.

Challenges

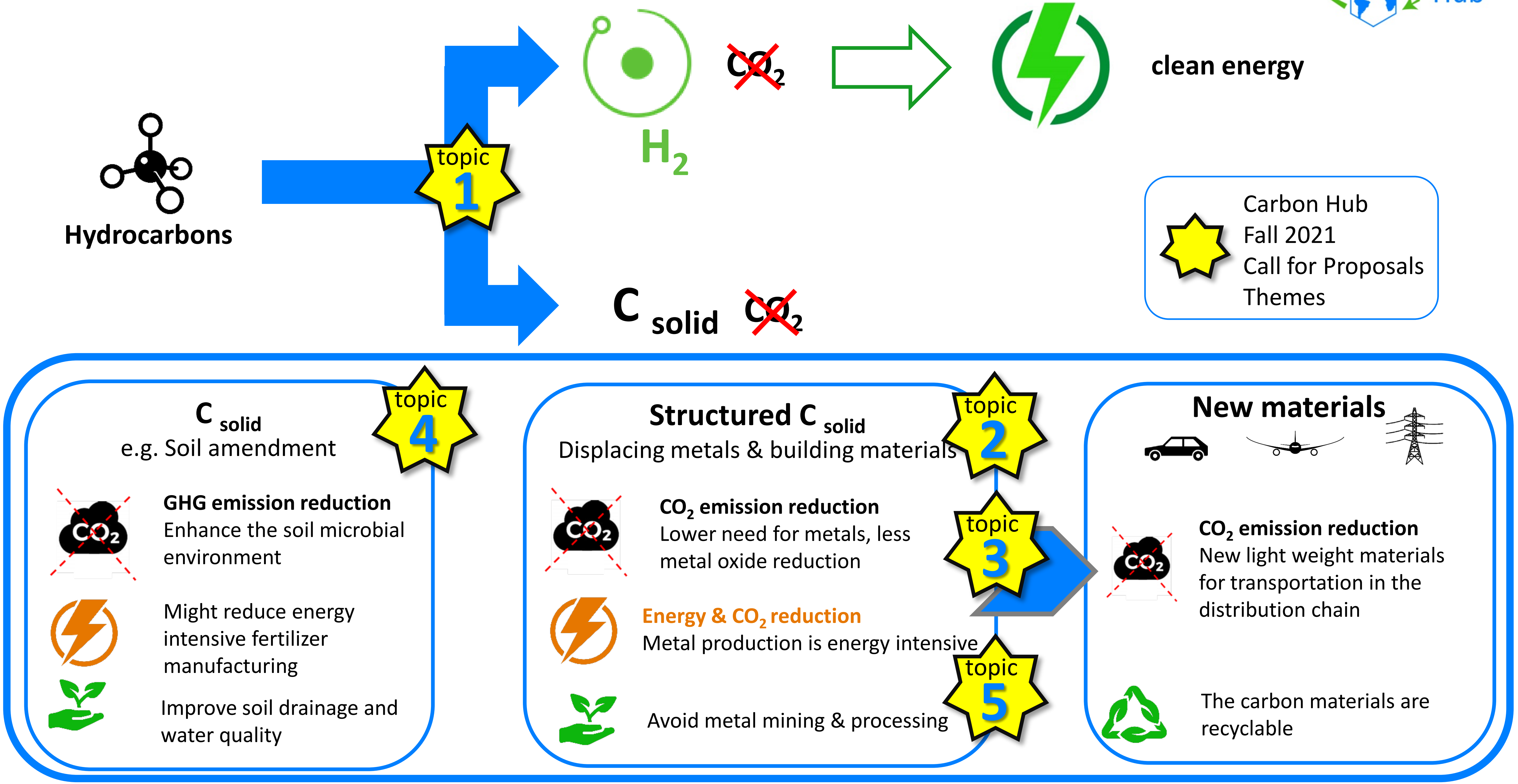
- current carbon soil additives are **too expensive** for large-scale deployment
- and are **not made from methane** and light hydrocarbons;
- the **knowledge base** for efficiently synthesizing soil additives from methane and light hydrocarbons must be developed

VACS

Application in end-products

scale value

The Carbon Hub aims to alter the Energy – Materials Nexus



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Overview Fall 2021 - Call for Proposal Topics

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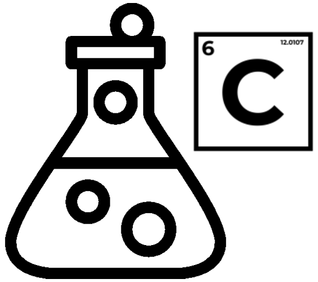
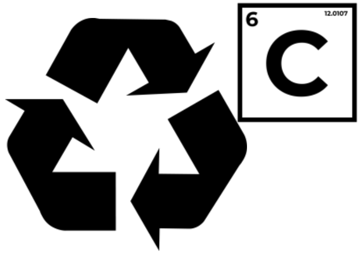
1

Improve understanding of the catalysis and reaction mechanism in (thermocatalytic) pyrolysis to efficiently convert methane to VACS.



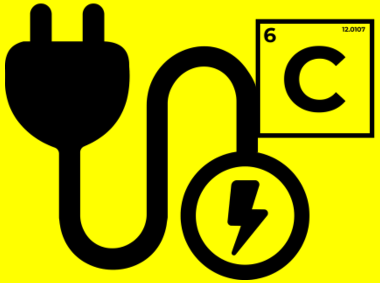
2

Improve Carbon nanotube [CNT] material standardization and environmental impact understanding.



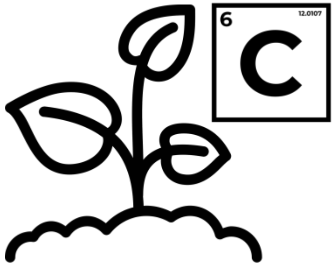
3

Demonstrate the value of a Carbon nanotube [CNT] fiber-based power cable prototype.



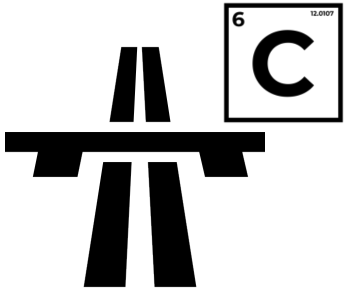
4

Demonstrate and explain efficacy of a VACS as a soil amendment.



5

Demonstrate the value of CNT or other VACS, in structural applications, including non-critical ones.



Q&A – Please ask us any questions you might have

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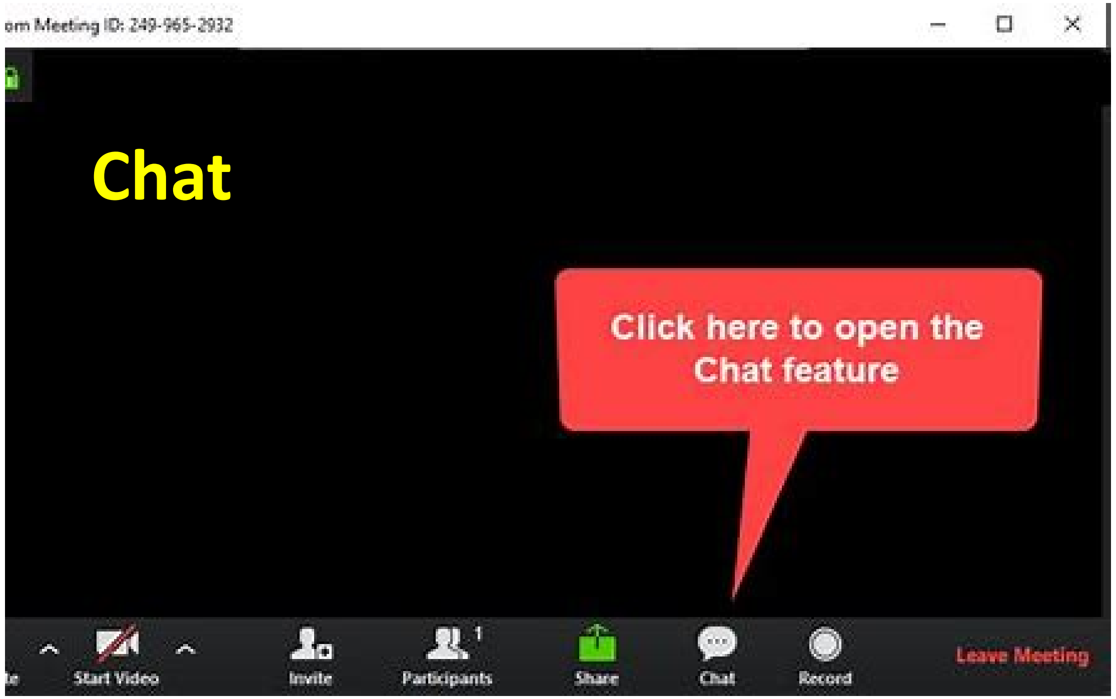
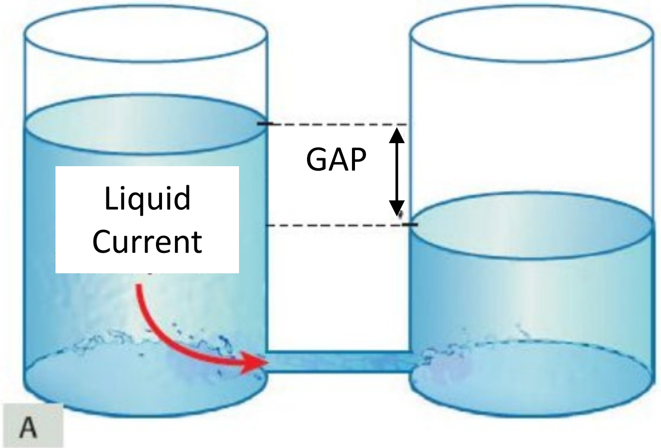


Cables' Basics

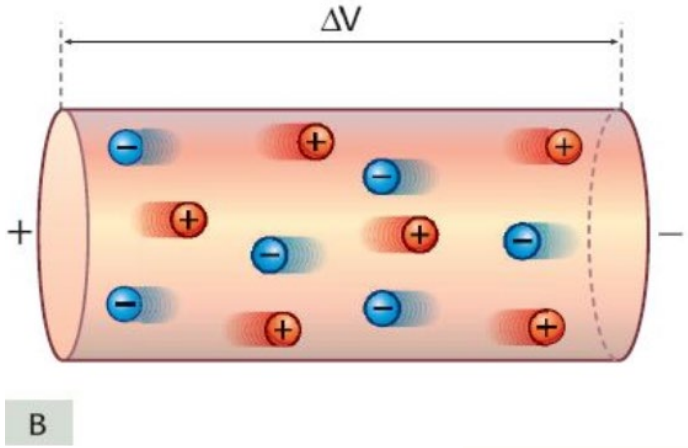
- Transports energy or data
- Passive element
- Connects supply to user



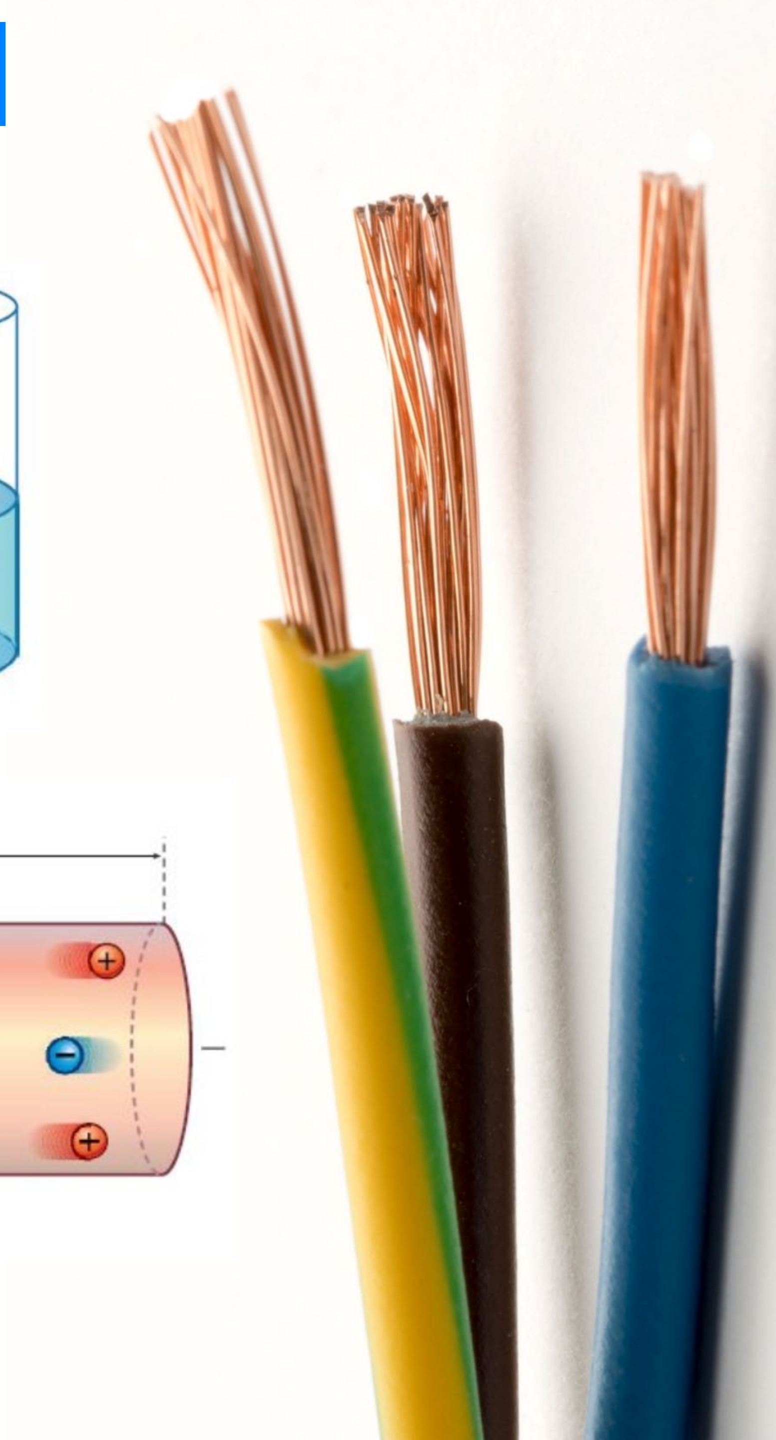
An energy cable is like a water pipe..

- Current = Water Flow
- Voltage = Pressure difference

A. Higher is the required flow, higher will be the cross-section of the pipe
B. Higher is the required current, higher will be the cross-section of the conductor



A. Higher is the pressure, higher will be the mechanical stress in the pipe
B. Higher is the voltage, higher will be the insulation thickness (or performance)



Applications - Overview

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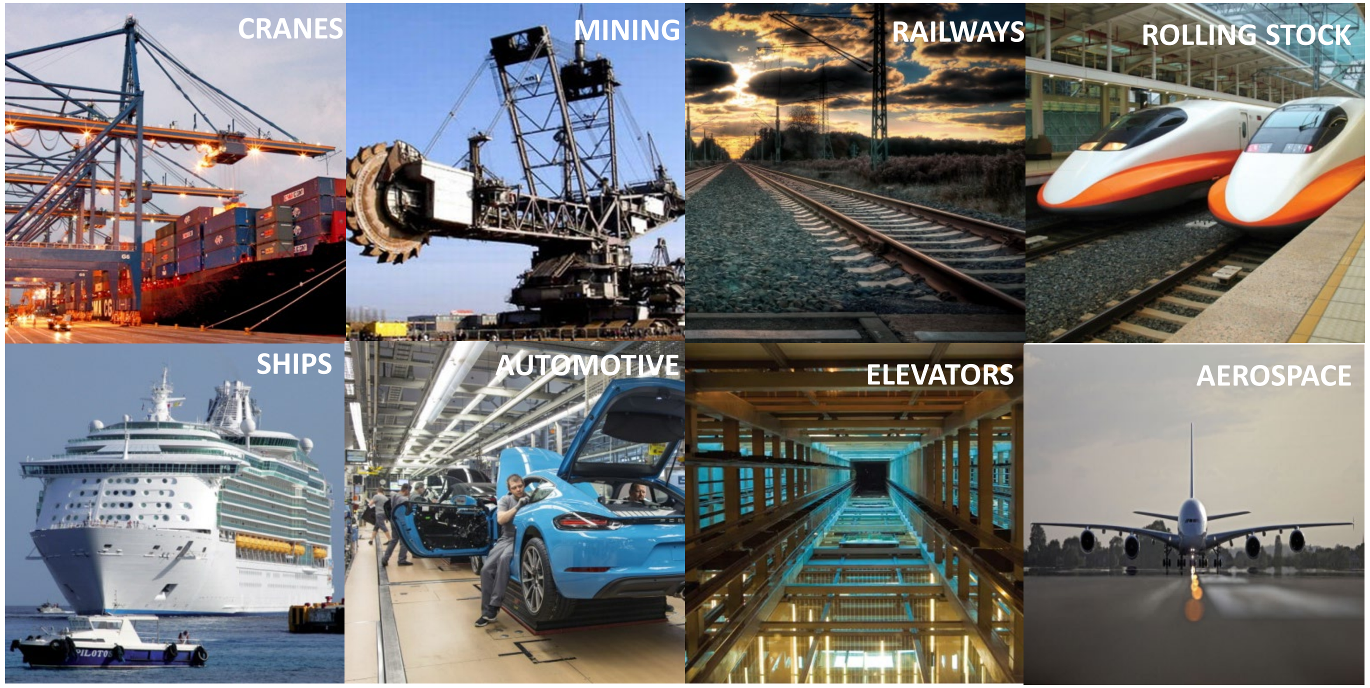
ENERGY & INFRASTRUCTURES

INDUSTRIAL - OEMs



OIL & GAS

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What Makes Cables Different?

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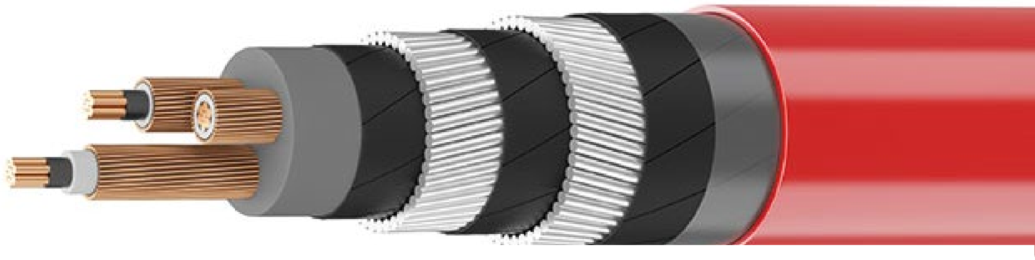
Application Needs / Environment Constraints

- Temperature
- Mechanical Stresses (Static - Dynamic)
    - Bending
    - Pulling
    - Torsion
    - …
- Chemical Inertia
- Fire performances
- EMC
- Electrical stresses
- …



Design and Materials Solutions

- Materials
- Design of elements and materials
    - Fine wires conductors
    - Lay length
    - Armoring
    - Insulation and Sheathing materials
- Sheathing materials
- Metallic protections
- Special materials
- Screens design
- Insulation materials and design
- …

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CNT Yarns properties in comparison with existing Conductor materials

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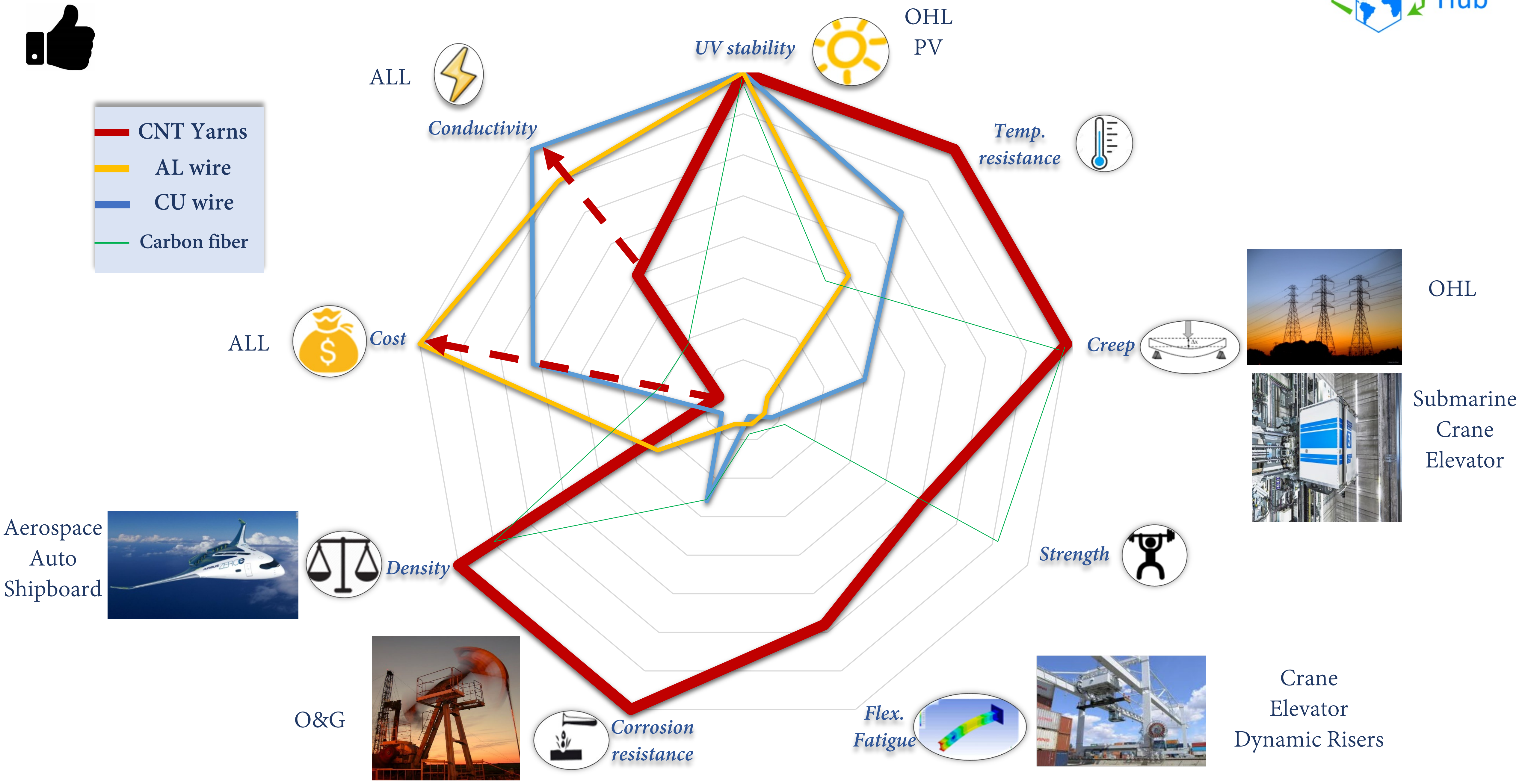

Low voltage DC and AC – Project Examples

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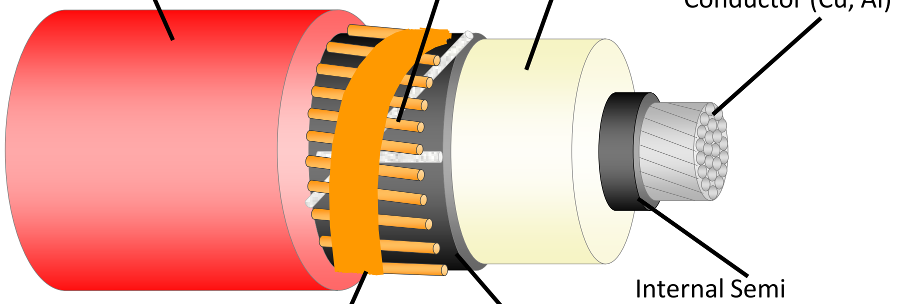
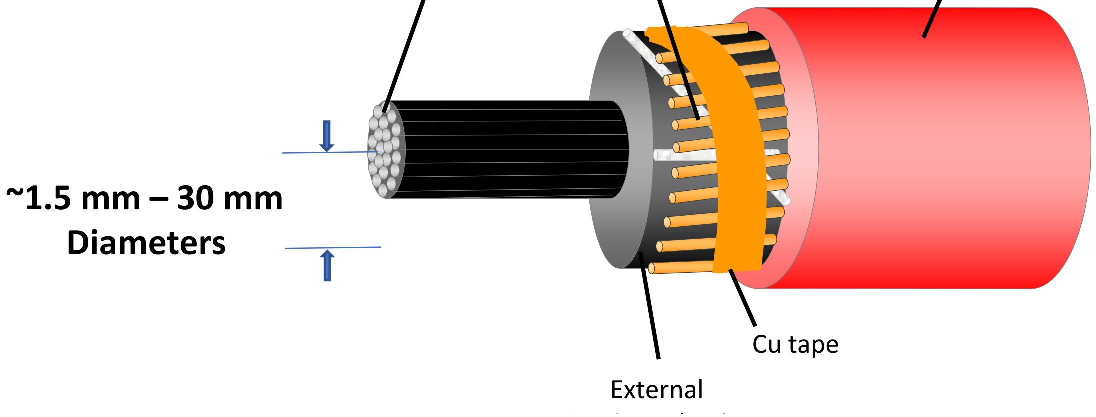
Traditional Power Cable Design





CNT Fiber Low Voltage Power Line – Prototype Studies

- Build CNT Fiber only wires of 1.5 mm – 30 mm
- We do not want a fully built wire (insulation etc) as a requirement in this prototype studies request
- Current vs. temperature studies (within limits of insulation, typically up to 90°C) - what is performance at temperatures from 50 – 90°C
- Testing and assessment of electrical and thermal transport in wires, comparing with single fiber to determine what are controlling factors
- Ampacity comparable to

an
oup

HV Distribution Network – OHL Project Examples

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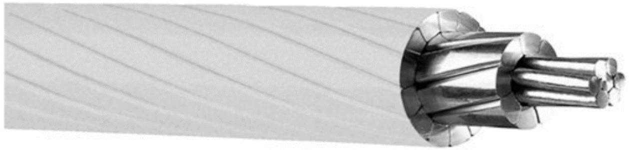
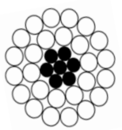
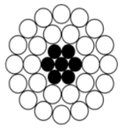
Standard Overhead Power Line Al-Steel Composite Structure



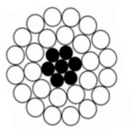
Higher Conductor Temp


ACSR

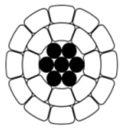
→ + 80% Capacity


ACSS

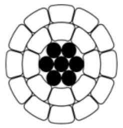
More Aluminum


ACSS

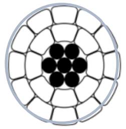
→ + 10% Capacity


ACSS/TW

High Emissivity Surface


ACSS TW

→ + 15% Capacity


ACSS TW/E3X

For Overhead Power Line Applications, to meet specific performance needs, composite Structures have been developed using Al or Cu as main conductor and Steel or carbon fibers for the tension (weight) control

CNT Fiber Overhead Power Line – Prototype Studies

- The potential to meet all of the needs of composite structures is possible with CNT Fibers, alone
- We do not want a fully built wire as a requirement in this prototype studies request
- Understanding how CNT wires perform in tests with dimensions consistent with the application are important at this stage of tech development :
  - Electrical – ampacity v. diameter & wire architecture
  - Thermal – rate of heat rejection, max loads compared to similar rated wires
  - Mechanical – creep, thermal expansion as function of load, vibration and time
  - Weight – evaluate kilograms/kilometer at same ampacity which can inform current carrying capacity, tension-temperature-sag characteristics design rules
- For OHL prototypes, bare conductors studied at several diameters (ampacities) to evaluate performance under different electrical loads, and max temperatures

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What is known and has been tried

What is known

✓ **MECHANICAL STRENGTH:**

- A single-wall nanotube is the most resistant organic material.
- An ideal nanotube is much stronger than traditional carbon fibers (they are **100 times stronger than steel, 2 times lighter than aluminum**)

✓ **ELECTRIC FIELD SENSITIVITY:**

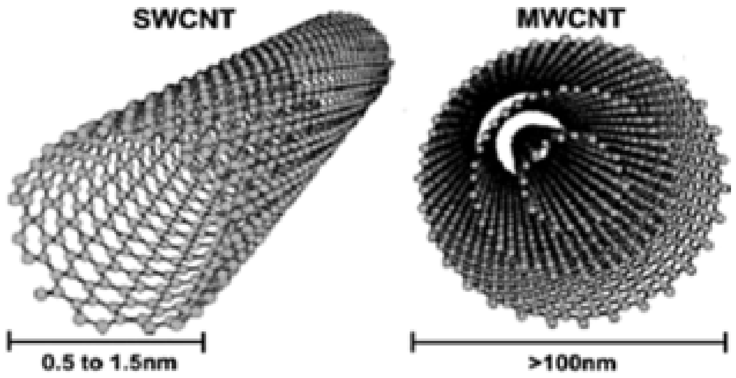
- Nanotubes are extremely sensitive to the presence of high intensity electric fields.
- They react to such fields by bending up to 90° to resume their original shape as soon as the electric field is interrupted.

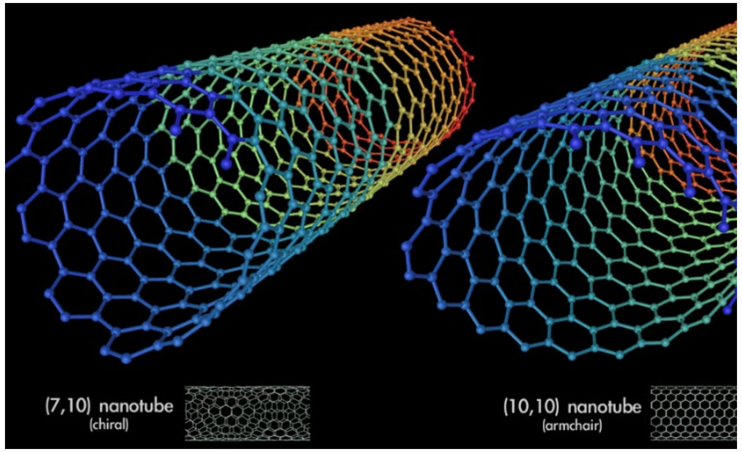
✓ **CONDUCTIVITY:**

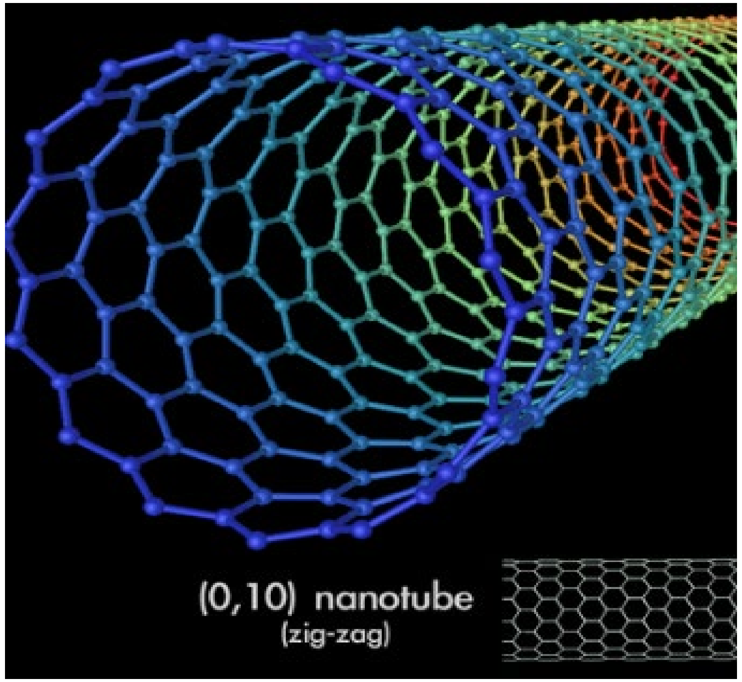
- The electronic structure of nanotubes is very similar to graphite.
- They have highly conductive properties that change according to their geometry.

What has been tried

- CHIRALITY (Armchair vs zig-zag)
- SW vs MW
- Length of single CNT (aspect ratio)
- Defects free structure
- Purity (no contaminants, catalyst, etc.)
- CNT Alignment
- Density/Compaction
- Doping

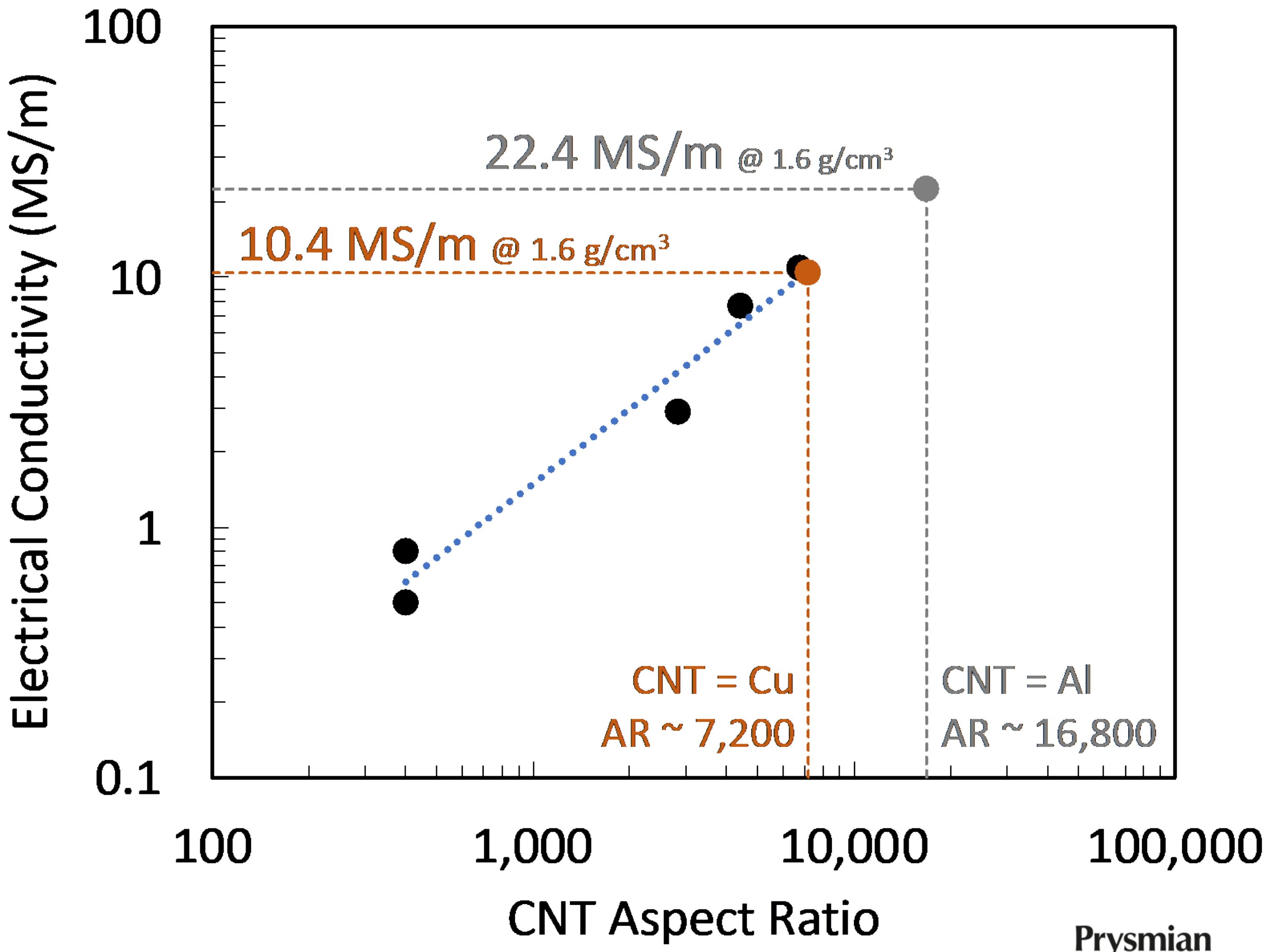




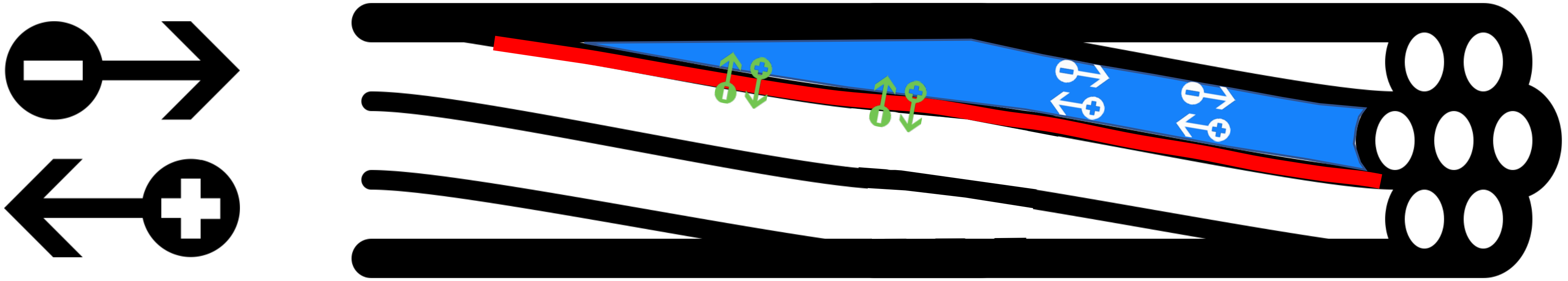


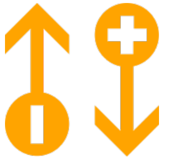
• Electrical Conductivity – Aspect Ratio Effect

Material	Conductivity (MS/m)	Density (g/cm³)	Specific Conductivity (kS·cm²/g)
Aluminum (=61,5% IACS)	37.7	2.7	140
Copper (=100% IACS)	58	8.9	65
CNT Yarn	**7.0**	1.3	54
CNTF SoA	**10.9**	**1.9**	**57**



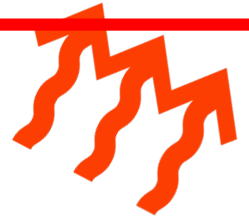
Fundamental questions on transport in CNT macrostructures: Project Ideas





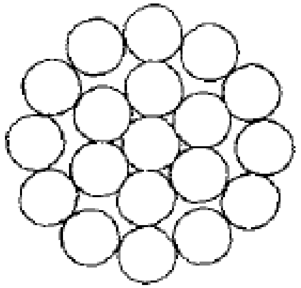
- Electrical conductivity of a single CNT fiber (10 to 100 um typical diameter)
  - Resistance within each CNT
  - Resistance across CNTs (interfaces)
  - For both: dependence on
    - CNT type (SWNT, DWNT, semiconducting, metallic etc.)
    - CNT diameter, length
    - Doping
    - Temperature

Similar questions for thermal conductivity

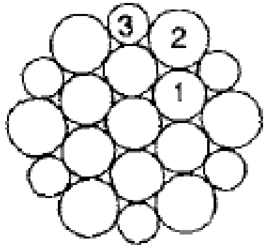


- **Axial** vs **Radial** conductivity of single CNT fiber
- Electrical conductivity of arrays
  - Packing (all same diameter vs. two or three sizes?)
  - Axial vs. radial conductivity

Uniform Diameter Distribution



Mixed Diameter Distribution: Improved Packing



Topic Introduction – More about the Challenge

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- **To reach a level or specific conductivity at least comparable to Cu or Al wires, which makes CNT fibers attractive for cable application;**
- Understand and demonstrate how to improve electrical (specific) and/or thermal conductivities to enable higher power line ampacity per weight.

- To find a solution for this challenge might open the door to completely new horizon for energy transportation and cables.
- Their use won't be limited to one sector. CNT's overall range of features makes it an unique material suitable for many application.

WHAT IS THE CHALLENGE WE NEED TO SOLVE?

WHY IS THIS A CHALLENGE?

WHY IS IT IMPORTANT TO ADDRESS THIS CHALLENGE?

- After many years of research on this field we are still far away from the target;
- Recent trend of improvement are not promising enough;
- Carbon nanotubes play an important role in innovative technologies. A deeper understanding of conduction mechanisms is key to target an achievable level of improvement.

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What deliverables are we looking for and What is OUT OF SCOPE

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AREA OF INTEREST INCLUDE

- Low-voltage power lines, DC and AC;
- Medium to high voltage power transmission lines;
- Cables for Industrial and Special applications, where not only electrical conductivity is relevant, but also mechanical, thermal, physical and chemical properties (or a combination of them) are relevant;
- Fundamental understanding of transport in CNT fibers and fiber assemblies;
- Understanding the key parameters to improve conductivity in CNT fibers;
- Reliable measurement technique to assess to key parameter.
- Is there differences in Axial vs. Radial conductivity in single fiber up to small bundles e.g. 37 fibers

AREA OF INTEREST EXCLUDE

- Prototype studies based on instrumentation, control, data cables;
- Studies that seek to improve CNT fiber properties empirically, without relating properties to the application performance, or without understanding the dependence of properties on fundamental CNT parameters;
- Screening effectiveness for high frequency application;
- Connecting techniques;
- Metal plated CNT.

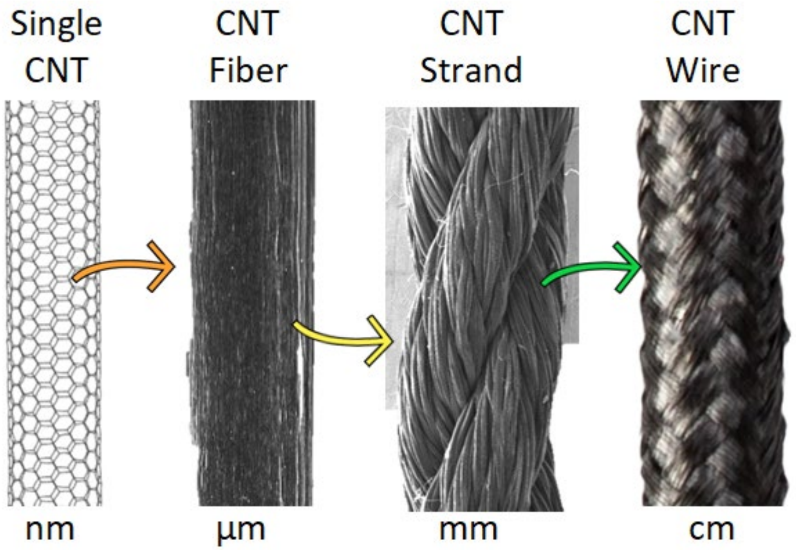
First Project Awarded in Topic #3 – 2020 Cycle

- ***Multiscale optimization of electrical and thermal transport in carbon nanotube conductors for power cable applications***

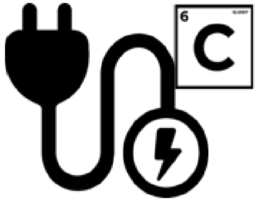
Dr. Geoff Wehmeyer
Assistant Professor in Mechanical Engineering

Carbon Hub 2020 CFP Cycle Awardee in Topic #3

Rice's Geoffrey Wehmeyer, Junichiro Kono and Matthew Foster will lay the groundwork for replacing metal power transmission cables with carbon nanotube fibers. To allow side-by-side comparisons, they will investigate fundamental electrical and thermal conductivity at scales ranging from individual nanotubes to bundles of tubes, fibers of bundles and yarns of fibers



TOPIC #3: **Demonstrate the value of a CNT fiber-based power cable prototype.**



We seek fundamental and applied advances towards the development and testing of a prototype CNT fiber-based power cable meeting commercial AC or DC power transmission requirements.

Key research questions to consider:

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QUESTIONS

01 **Can we establish a correlation between CNT composition/microstructure and electrical conductivity?**

02 **How CNTs conduct electricity? How to optimize the production process based on this?**

03 **How can we measure electrical conductivity on a macro scale CNT conductor sample in a reliable way?**

04 **How the CNT conductor design may affect the overall electrical cable performance? Architecture of fibers to wire**

05 **How do we design/manufacture the correct conductor (yarns/bundles/wires diameter, composition, etc.) to maximize ampacity?**

06 **Which is the application where the mix of CNT features becomes competitive with respect to traditional conductors materials?**

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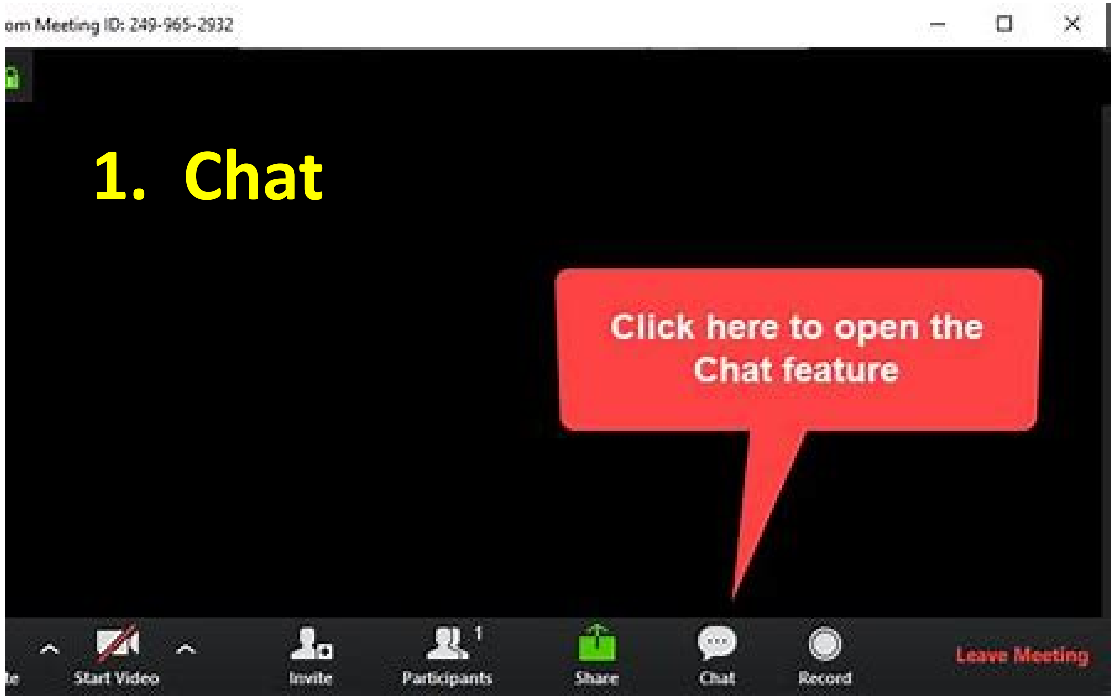

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Next Steps – How to submit

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carbonhub.rice.edu/CFPCollaborators

RICE UNIVERSITY
Carbon Hub
Accelerating the Energy Transition Through Green Hydrocarbons

Menu

Carbon Hub - Call For Proposals 2021

On this page, you will find the Call for Proposals details that are restricted to our Collaborators only.

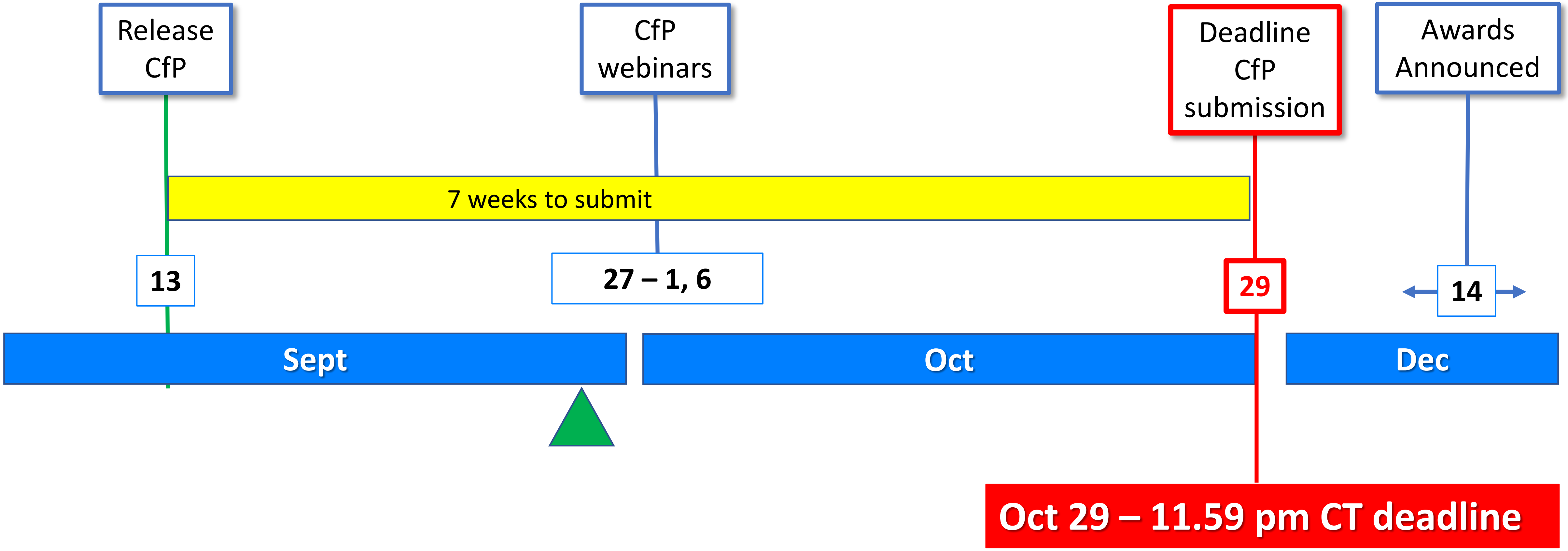
You may download the full Call for Proposals guidelines and instructions document in PDF form here.

**UPDATE: The Budget guidelines are attached here and the referenced spreadsheet can also be found here.

Please note, all Rice Collaborators should contact us directly at carbonhub@rice.edu to obtain the internal Budget template. That template cannot be shared with external Collaborators.

Oct 29 – 11.59 pm CT deadline

Call for Proposal Timeline



A Summary of the aspects we'd like you to address in your proposal (1/2)

Carbon Hub

CURRENT PROPOSAL SECTION	SECTION CONTENTS	PAGE LIMITATIONS
Executive Summary	Research Team a) Name of Principal Investigator(s) b) Affiliation – institute c) Address, city, country Contact details: email and phone Topic # and Proposal Title Abstract	1
Innovation, Impact, and Linkage to Carbon Hub Vision	How are you addressing the Topic Challenge? Provide a concise description of why the proposed research will further the Carbon Hub Vision.	1
Proposed Work	What techniques & knowledge will you use? Provide a concise description of the equipment, technology and knowledge you will be using. Why is this an effective way to address the challenge? Provide a concise description why your approach is an effective and innovative way to create new insights and value. What are the key deliverables?	4

A Summary of the aspects we'd like you to address in your proposal (2/2)

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Team Organization and Capabilities	What is the team to address this challenge? Concise description of research team actively working on proposed effort: names, project roles. Why should we fund your team? What is the team's expertise and capabilities? Concise description of key expertise and capabilities as related to the project approach.	1
Budget	Breakdown by categories, including any cost share. (budget template will be provided by September 30, 2020)	1
References cited	Includes both literature references and references to earlier work by the proposing team.	2
Personnel Qualifications Summaries	NSF-style preferred	2 pages per person
Risks and Other Insights	What are the key risks in your approach? How are you managing the risks? What else might be important?	1

Some of the Terms & Conditions

- ❑ **The primary Principal Investigator (PI) must be a Carbon Hub Academic Collaborator** (https://carbonhub.rice.edu/collaborators) to be eligible to submit a proposal
- ❑ If you are not currently a Collaborator, please inquire at **carbonhub@rice.edu**

- ❑ **Fall 2021 : $1.5+ million budgeted for new and continuing awards**
- ❑ Anticipate~~s~~ granting 4 - 7 awards across the 5 Topic areas
- ❑ **Individual awards may vary between $50,000 and $250,000**
- ❑ For PIs who are not at Rice University, funding will start upon successful negotiation of a subcontract between Rice University and their home institution
- ❑ Funding agreements are expected to launch in Feb 2022, or once negotiations are complete

Results can be published – THEY ARE <u>NOT</u> CONFIDENTIAL
Results will be shared with Carbon Hub members

Further details on the Carbon Hub website and in the Call for Proposal documents

Carbon Hub Webinar - Call for Proposals Fall 2021

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