4.154 *Option Studio Spring 2022*

CARBON*FJORD* : CENTER FOR BIOGEOCHEMISTRY IN THE ANTHROPOCENE (CBA)

Re-thinking Materials + Modes of Habitation for a Despoiled Planet: Friluftsliv + Dugnad

Prof ***Mark Goulthorpe*** (he, him, his) + *TA* SMArchS Comp ***Dimitrious Chatzinikolis*** (he, him, his)

The Center for BioGeoChemistry in the Anthropocene (*CBA*) will be located in **Lotofen** in the north west of Norway

Studio Focus

Carbon Cycle , Bio Systems, Dwelling, Hydrogen, Composite Production, Energy/Climate Policy/Principle, Carbon Nanotube, Carbon Foam, Numeric Command Machining, Finite Element Analysis, Life Cycle Analysis, Parametric Modeling, Automated Production, Integrated Services, Anti-Tectonics, More from Less

Carbon*House* is an on-going research initiative funded by *ARPA-e* (the *Advanced Research Projects Agency* of the US *Dept of Energy*) that involves MIT and 9 groups of international scientists, researchers, composite fabricators, all focused on emerging forms of **Carbon** for their holistic use in benign, high-performance buildings. The lead MIT architecture team is tasked with inventing a new material/production potential as a means to supplement hydrogen production at vast scale: only the building sector is held to be able to absorb carbon at the scale of C21 projected global energy production, with renewables seen as falling well short of global demand.

In *Towards a New Architecture*, le Corbusier gave vision to steel and concrete buildings, evidenced in elegant pioneering prototypes (*Villa Savoie, Phillips Pavilion*, etc). The studio will be tasked with imagining a now-carbon material paradigm, similarly learning from boats and planes, but deploying the brilliant 6th element for its full architect potential, uniquely polyvalent and vividly polyfunctional.

The site will be the arctic coastline of Norway's stunning but desolate *Lotofen* archipelago, recently subject to a government moratorium on exploratory drilling for oil owing to the environmental activism of young Norwegian activists, yet poised atop the vast oil and gas reserves that have supplemented the enviable lifestyle of the small Scandinavian populace. The history of the region is animated by successive commercial exploitation of natural resources, from fish to timber to whales and now to hydrocarbons, each time facing economic hardship as reserves have been depleted, often being forced to *innovate* to remain competitive. *Here we seek innovation well in advance of depletion* in response to the looming environmental threat posed by hydrocarbons: we seek to build-with rather than *burn* the precious organic legacy.

You will devise a research institute, akin to the *Aspen Institute* (humanitarian issues), the *Rocky Mountain Institute* (Energy/CO_2 Policy) or the *Salk Institute* (Biomedical Research) – all serene research retreats that have exerted profound influence on their respective fields. But this will be a *Center For Biogeochemistry In The Anthropocene (CBA),* looking to instantiate a carbon architecture as a means to lock carbon in solid form to help restore the magisterial but increasingly fragile carbon cycle described by the Norwegian biologist, Dag Olav Hessen, who heads the *CBA Center*. It is poignantly sited in an evidently fragile and despoiled ecosystem.

The Carbon Cycle

Carbon*Portal* Poly-functionality of Carbon in Exhibition Prototype for *ARPA-e* Carbon>Building Research, *MIT*

The prime driver of the studio will be to devise radically-benign forms of habitation that deploy **carbon** materials via digital methods (the **organic** *contra* the **inorganic** legacy), and to conceptually map out the total life cycle of such carbon architecture and lifestyle. You will be aided in this by expert energy/environmental engineer **Mike Lepech** at *Stanford* and the pioneering energy/climate group, ***Transsolar*** NY. Using Carbon for virtually every aspect of building – structure, data, power, but also integrated details and aesthetic finishes - offers a compelling intellectual challenge, relentlessly thinking-through its CAD>FEA>CAM design-to-build potency.

At another scale, we will spend time looking at the *planetary* carbon cycle, understanding the critical re-balancing of oxygen and carbon dioxide by bio-systems through Earth's history. As forests and oceanic algae become depleted, and carbon sequestered by ancient bio-systems is released through burning, there is a critical tipping point where diminished bio-systems will likely be unable to mitigate such CO_2 swamping. We will consider this from past and future viewpoints, weighing *The Many Lives of Carbon* and *The World at a Tipping Point* (Dag Olav Hessen) with *The Collapse of Western Civilization* (Erik Conway, Naomi Oreskes), but by mapping the macro mechanisms of atmospheric and oceanic change poignantly. This aims to give salience to our projects through the startling clarity each account offers, equipping the studio with environmental acuity.

The prospect of a CNC-enabled all-carbon architecture holds promise in its unitary-material poly-functionality, where computational analysis and computational production become seamlessly linked. A new level of fully-integrated and highly-finessed digital production offers prospect of a holistic and formally/functionally-enhanced architecture that *remains to be defined*: every light switch, door handle, window frame can be shaped and fastidiously milled, offering greater finesse than any prior material paradigm. *Towards a Carbon Ontology* offers counterpoint to *Towards a New Architecture* that ushered in steel and concrete as Modernism took hold early C20th; but with carbon we ***do more with less***, deploying nano-scale fibers or foams to build-up *property* just as needed, be it structural, thermal, electrical, aesthetic…

Expert input will be given by:

Prof **Laia Mogas**	Bio-Inspired Architect
Prof **Dag Olav Hessen**	Biologist (the Carbon Cycle)
Dr **Mia Siochi**	*NASA* Composite Research
Dr **Erik Olsen**	Engineer (Energy/Climate)
Dr **Dave Gailus**	Chemist (CNT production)
Prof **Matteo Pasquali**	Rice University (CNT research)
Radek Michalik	Engineer (Composites/FEA)
Prof **Mike Lepech**	Engineer (Environmental/LCA)
Prof **Betti Marenko**	Theorist + Textile Architect

Carbon in Ra[illegible]ail Additive Manufacturing

Carbon vs Mineral/Metal : Wasteland vs Wilderness

The northern Fjords, gouge-out by repeated glaciation, epitomize the fragility of ecosystems under Anthropocenic change

The prime site will be in *Lotofen,* a dramatic archipelago on the desolate and eerily beautiful *artic coatline* of Norway. Issues of state revenue, oil/gas resources, natural beauty, cultural heritage, resource extraction, etc exert competing claims and wrenching ethical dilemmas, as they always have here. There is abundant wind but very limited solar energy given the latitude, a vibrant tourist industry attesting to the landscape and marine wildlife especially. The Norwegian government claims exemplary environmental policy, largely owing to 95% of electricity being hydro, yet oil/gas extraction from the North and Barent Sea provides massive export revenue, with Norway one of the top 5 oil/gas producers globally. Yet concepts such as Friluftsliv (healthy living in nature) resonate deeply, evidently sustained only by ignoring the impact of such extraction "elsewhere". But the *University of Oslo* is especially active in environmental research, well-funded to identify the deep effects of anthropocenic extraction and use, the *CBA Center* a newly-funded initiative.

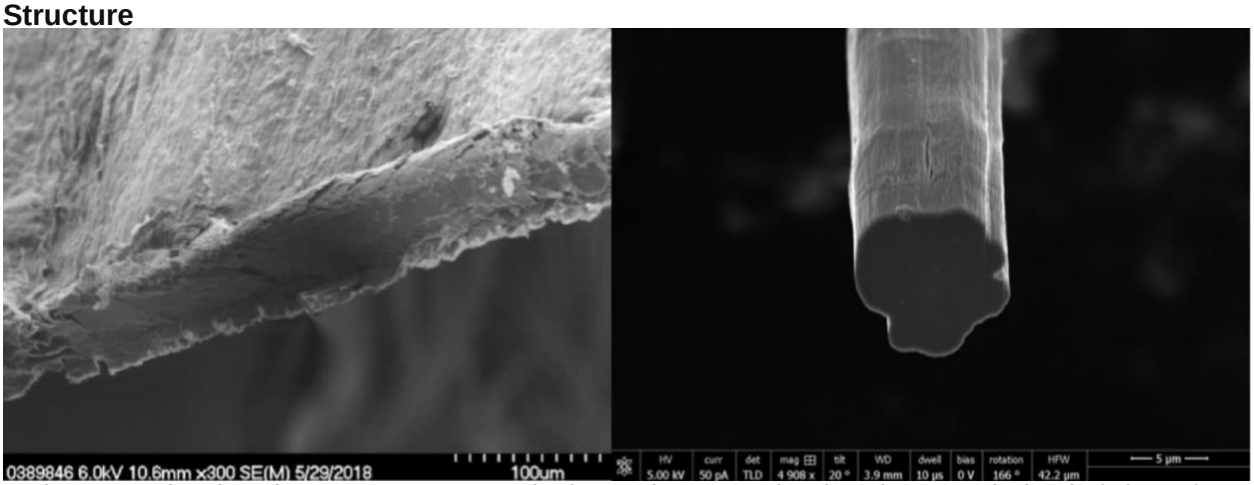
Students will develop independent responses to these complex issues, hopefully offering a range of viewpoints that generate a diversity of original and different visions. If elegant and principled habitation and land-use can be attained in such a stringent context, the *CBA Center* will offer a poignant *alternative* to rethink current practices and especially the use of hydrocarbon resources. *Equinor*, the state oil/gas company, is already providing research funding into alternative uses for hydrocarbons, carbon>building a prime goal.

Together with pioneering carbon/composite industry groups (*DexMat, Composite Design Studio, NanoComp*) and leading energy/life-cycle engineers (*Transsolar, Stanford Environmental Engineering*), we will learn from the brilliant success of the composites sector. Here, thin-skin, lightweight, fiber-based structural monocoques have displaced mineral/metal assemblies, utterly outperforming them (racing yachts, military aircraft, *NASA* satellites, etc), offering vivid economy (commercial aircraft, transport vehicles, wind turbine blades, etc), but demanding a profound re-think of *tectonics* and *manufacture*. In considering composites for buildings, we will look at emerging forms of carbon – *carbon nanotube* and *carbon foam* especially – that offer bizarre yet remarkable nano-scale poly-functionality: structural, electrical, thermal, acoustic, fire-retardant capabilities. These forms of carbon hold promise for unitary-material, lightweight, energy-efficient, thin-skin buildings, and *MIT* techno-economic analyses suggest that as a complement to **hydrogen** production (as a clean fuel), CNT/*CFoam* mass production would undercut even the per lb price of steel and cement, while offering radically enhanced performance. Each week these specialist groups will present to us, offering insight to an emerging material and manufacturing paradigm – a real privilege given their technical caliber.

In this, we will follow on from *ARPA-e* funded research done by the ***Carbon>Building*** group here at *MIT Architecture*, benefitting from 8 external groups who are pioneering various aspects of carbon material-production in support of hydrogen, which is *DOE's* prime interest. Since buildings consume approx 40% of global energy production, with some 10% embodied energy, so the re-orientation of the hydrocarbon legacy to produce clean energy and ultra-benign buildings at macro scale, is seen as a critical endeavor. The studio projects will augment this research effort by helping to envisage new carbon architectures, both housing and research buildings - *ie* your projects will build the case "for carbon" to hopefully influence *Equinor*, the *Norwegian Government, ARPA-e and DOE*, etc. Students can choose the scale of their projects, from event spaces or research labs or manufacturing hubs to housing and community spaces – these all offer challenges in formal, detail, manufacturing, environmental, etc terms.

Note: you're NOT expected to have carbon/composites/computation skill, but to bring open-mindedness to engage the material, formal, manufacturing, environmental opportunities offered by such materials/ methods. Given the newness of carbon as a prospective architecture, we will look to learning from carbon-skilled groups to offer technical, formal, manufacturable solutions, even if we are to a large degree *inventing* such forms.

Structure



Carbon Nanotube Sheet (0.1mm = 10,000 nanotubes) *Carbon Nanotube Thread: structural, electrical, thermal properties*

Input
Benefitting from the extended *ARPA-e* research team, the course will offer more technical input than usual, with cameo appearances from the extended Carbon>Building research group: from *Rice University* carbon nanotube research; the leading carbon nanotube production group, *NanoComp*; the pioneers of carbon foam, *Touchstone*; finite element structural engineers, *CDS*; the prescient climate/comfort engineers, *Transsolar*, advanced CNC composite fabrication, *TPI/MouldCam*; etc. These presentations will usually occur at the start of each Tuesday session.

Output
You will essentially produce **3 pieces of work**, asking for poetic invention but allowing enough tectonic maturity that the final *CBA Center* will be a technically accomplished as well as visionary portfolio project

- ***Exquisite Diagramming of the Carbon Cycle*** through Planetary History (from *The Many Lives of Carbon*) to offer striking graphic clarity to the macro forces shaping atmospheric and oceanic states…
- ***GeoMorph Form-ation*** land art intervention in the *fjord* landscape that looks to deploy rule-based generative techniques as an inventive para-morphism…
- ***CBA Center***: an all-carbon proposal to permit benign and dignified habitation to the many groups who might gravitate to this new research enclave: carbon research scientists, architects, engineers; park rangers, eco tourists, geological engineers, archaeologists, mining engineers, etc

The work will be structured in short periods with mid- and final-presentations, with a few desk crits in the final stages: but the onus is on the students to exhibit independence in defining the siting, form and even program of their own projects, albeit with an outline offered by Dag Olav Hessen. We hope the tenor of what is a quite experimental design studio is joyful but poignant in giving opportunity for inventiveness and discovery of salient issues. Working in groups is certainly possible (with amended scope of work agreed).

Pedagogy
The educational goals are diverse, but first is to absorb knowledge of emerging material science and to think through its potential deployment in beneficial ways for architecture. The understanding of composites and CAD>CAM production we hope also equips you with technical acumen whether or not you go on to build composite structures in practice: the aptitude will be useful as architecture embraces more and more new materials and digital methods. Finally, we hope you develop an independent critical stance as to the mounting stringency of environmental change, and understand the scale and science of the issue, especially the carbon cycle.

The diverse speakers will offer technical and theoretical framing to your design imagining, which we hope is helpful as you look towards your independent theses: we are in a sense looking for mini-theses by leaving the architectural response conceptually open. It is for each student to decide how best to intervene in the serene Norwegian landscape, and to offer a reasoned case as to the potential of your research center.

Reading List

If the celebrated Ray and Charles Eames' *Powers of Ten* film was an expression of architectural imagination in the 1970s, we here scale by **a billion** (in time and dimension), thinking back through eons of planetary history to understand carbon, and zooming into the exquisite nanoscale morphologies of such new forms of carbon fiber and foam… The properties in fact derive from the nanocscale "architecture," as you will learn…

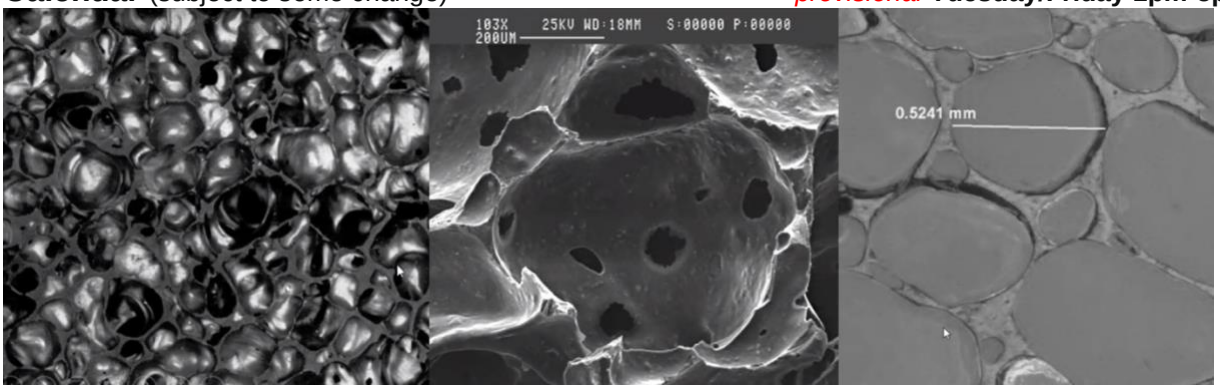
Low Footprint *Sub-Tropical Martime* (Mississippi Delta) all-Carbon Housing for *ARPA-e* Carbon>Building Research

We will reference the following texts (and others), especially those referenced in **bold**:
Utopia by *Sir* Thomas More
Ten Books on Architecture by Marcus Vitruvius Pollio
Towards a New Architecture by le Corbusier
Composite Architecture: Building and Design with Carbon Fiber and FRPs by Quang Truong
Composites, Surfaces and Software: High Performance Architecture by Greg Lynn, Mark Gage
The Many Lives of Carbon by Dag Olav Hessen
Tipping Points by Dag Olav Hessen
The Question Concerning Technology essay by Martin Heidegger
Labor, Work, Action (lecture) by Hannah Arendt
Heuretics, The Logic of Invention, Gregory Ulmer
Plato's Hystera (essay) and ***The Mechanics of Fluids*** (essay) by Luce Irigaray
UnDesign: Design from Problem-solving to Problem-finding by Betti Marenko
Sand Talk: How Indigenous Thinking Can Save the World by Tyson Yunkaporta
Cyclonopedia by Reza Negarestani
The Collapse of Western Civilization by Erik Conway, Naomi Oreskes
At the Edge of the Smoking Pool of Death by Timothy Morton
Nurse With Wound *Shipwreck Radio*

Grading / Policy / Protocols

Grading will be accomplished according to standard MIT/Dept criteria, and will include consideration of attendance, participation, and positive contribution to studio culture. Course instructors and participants are expected to adhere to all other relevant MIT policies, including those relating to Non-Discrimination, Harassment, and Non-Retaliation.

Calendar (subject to some change) *provisional* **Tuesday/Friday 1pm-5pm**



Carbon Foam Morphology: compression strength, non-combustibility, acoustical absorption, thermal, electrical properties

Feb 4 *Course Overview* + *Intro:* Exquisite Carbon Diagrams start **MG** / DC

Feb 8 *The Many Lives of Carbon* **Dag Olav Hessen** (biologist)

Feb 11 *Dr* **Dave Gailus** *NanoComp* Carbon Nanotube Scientist

Feb 15 **Laia Mogas Soldevila** + **Jorge Duro** (bio-inspired architects) *Mediated Matter*

Feb 18 *Exquisite Carbon Diagrams* **Final Review** + *Intro: TerraMorph* **Intro MG**

Feb 22 *No Studio (Presidents' Day)*

Feb 25 *Glaphyros House* + *One Main Paramorph* **MG**

Mar 1 *Prof* **Matteo Pasquali** *Rice University* + *DexMat* Carbon Nanotube Research Scientist

Mar 4 *TerraMorph* **Final Review** w/jury

Mar 8 *Intro: The Center for BioGeoChemistry in the Anthropocene* **Dag Olav Hessen** (*CBA*)

Mar 11 *Composite Structures/FEA* **Radek Michalik**, *CDS*

Mar 15 *Composite Fabrication* **Jaime Marina**, *MouldCam*

Mar 18 *CBA Center* **Pin-Up** MG/DC

Mar 22 *No Studio (mid term break)*

Mar 25 *No Studio (mid term break)*

Mar 29 *NASA Use of CNT/CFoam* **Mia Siochi**, *NASA*

April 1 *Energy/Climate/Comfort* **Erik Olsen/Francisco Gallardo/Lakshmi Venu Gopal**, *Transsolar*

April 5 CBA Center **Mid Review** (with invited jury)

April 8 *Glaphyros House* **MG**

April 12 *Probabilistic Life Cycle Analysis Prof* **Mike Lepech**/**Tess Heggarty**, *Stanford Dept Env Engineering*

April 15 *Desk Crits* MG/DC *Paramorph Miran Galerie* + *One Main* **MG**

April 19 No Studio *(Patriots Day)*

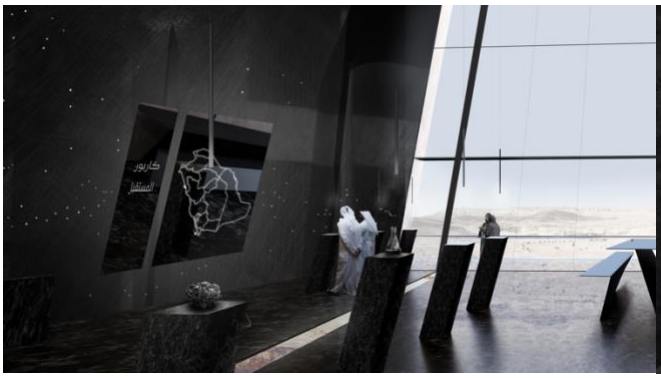
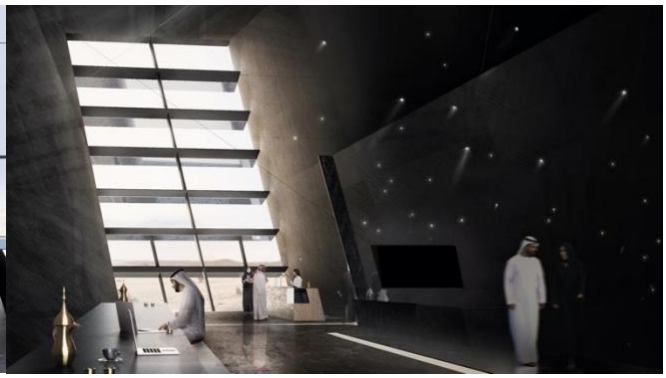
April 22 **Pin Up** Carbon Building Element (window/door/stair/basin…)

April 26 **Carbon***House,* **Carbon***Condo* MG

April 29 **Desk Crits** MG/DC

May 3 **Desk Crits** MG/DC

May 6 CBA Center **Final Review** (with invited jury)

Ithra **Carbon***Pavilion* as a celebration of Carbon>Building

CNC Endmills for Composite Fabrication

ACMA Competition Opportunity

There is an *AIA*-supported competition run by *OSU Prof* **Justin Diles** for *the American Composites Manufacturing Association* (*ACMA*) on the topic of housing:

Composites in Architecture Design Challenge:
FUTURE HOUSING—Rethinking Domestic Materiality

2021 Composites Challenge IV Schedule (deferred by CV-19, likely until Fall 2022)

- Classes begin students receive Composites Challenge brief, FRP reference material, and have initial discussions with industry partners
- Composites material kits delivered to universities.
- Conversations between industry partners and student teams.
- Final Submission Due. Digital submission including images of prototypes and experiments uploaded to Dropbox site by end of day.
- Jury Review Period
- **Winning entries announced**
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MG advised *ACMA* on this competition theme, and while I think we will go beyond its quite straightforward mandate for composite housing, student projects should be well aligned with its ambitions. Your projects should be absolutely aligned with its ambitions so I would absolutely encourage students to enter, and hope that with the expert input from the *ARPA-e* team, you *should* be able to win some of the awards!

Carbon*Condo* as part of the *ARPA-e* Carbon>Building research (*MIT* Design, 2021)