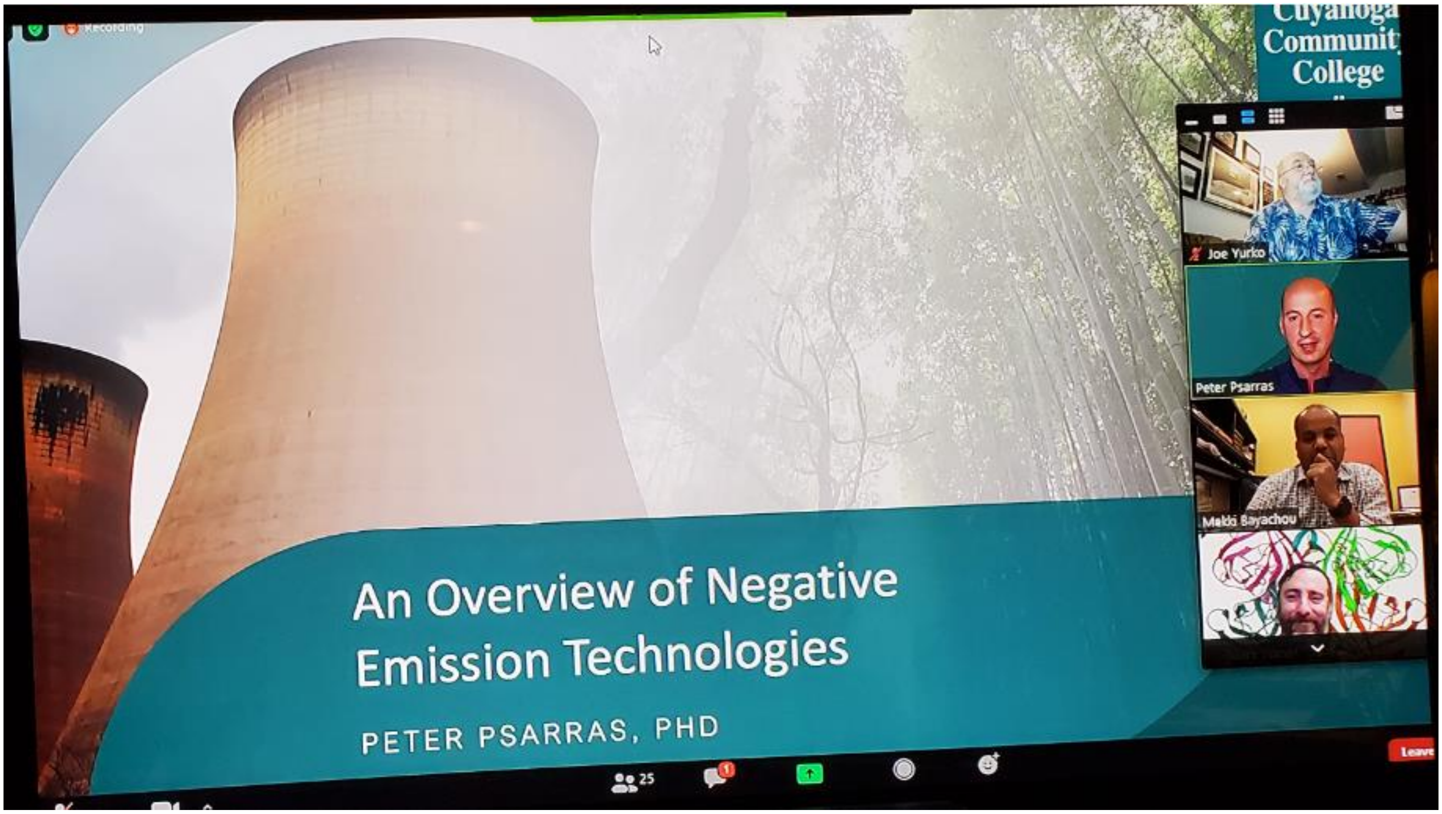
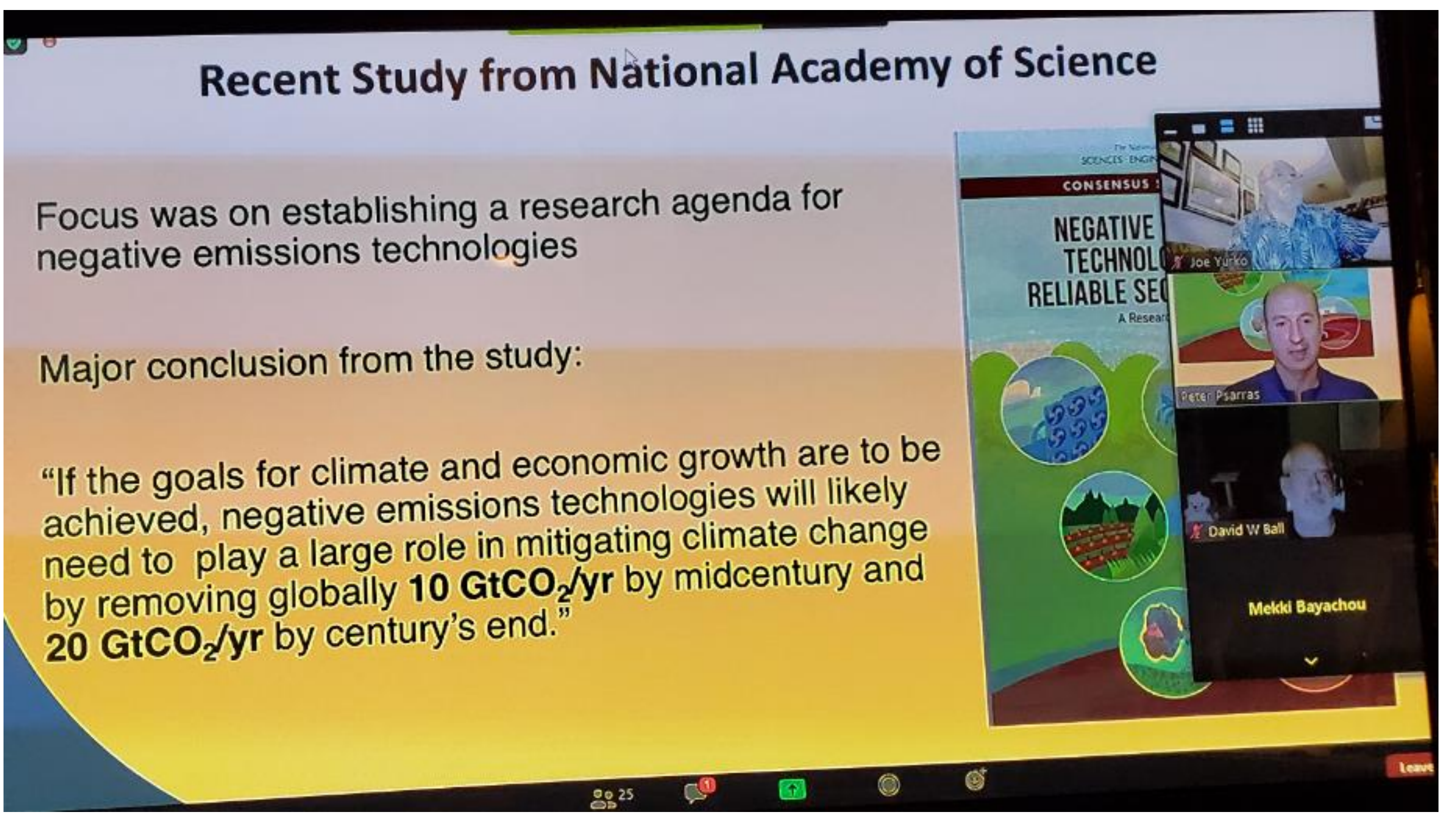
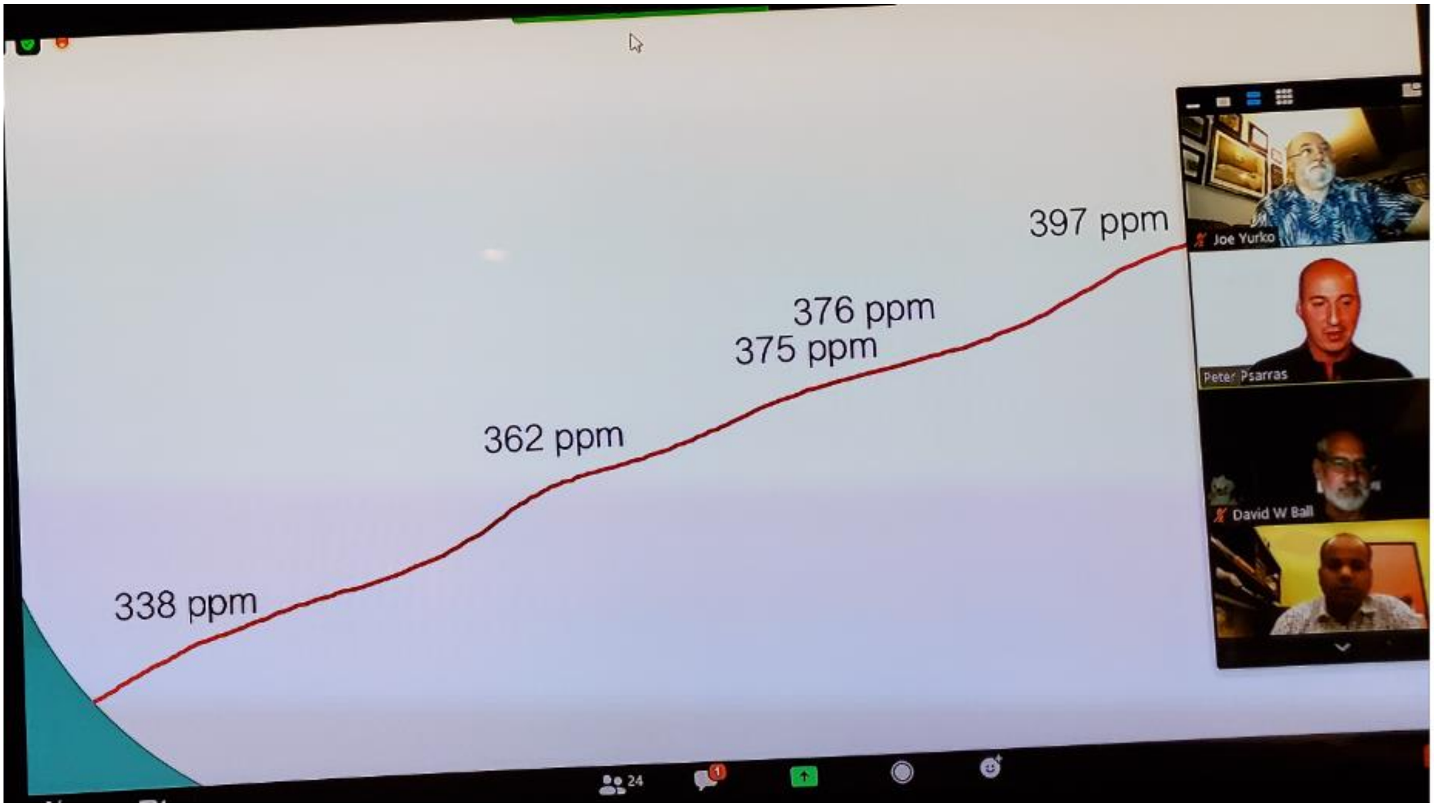
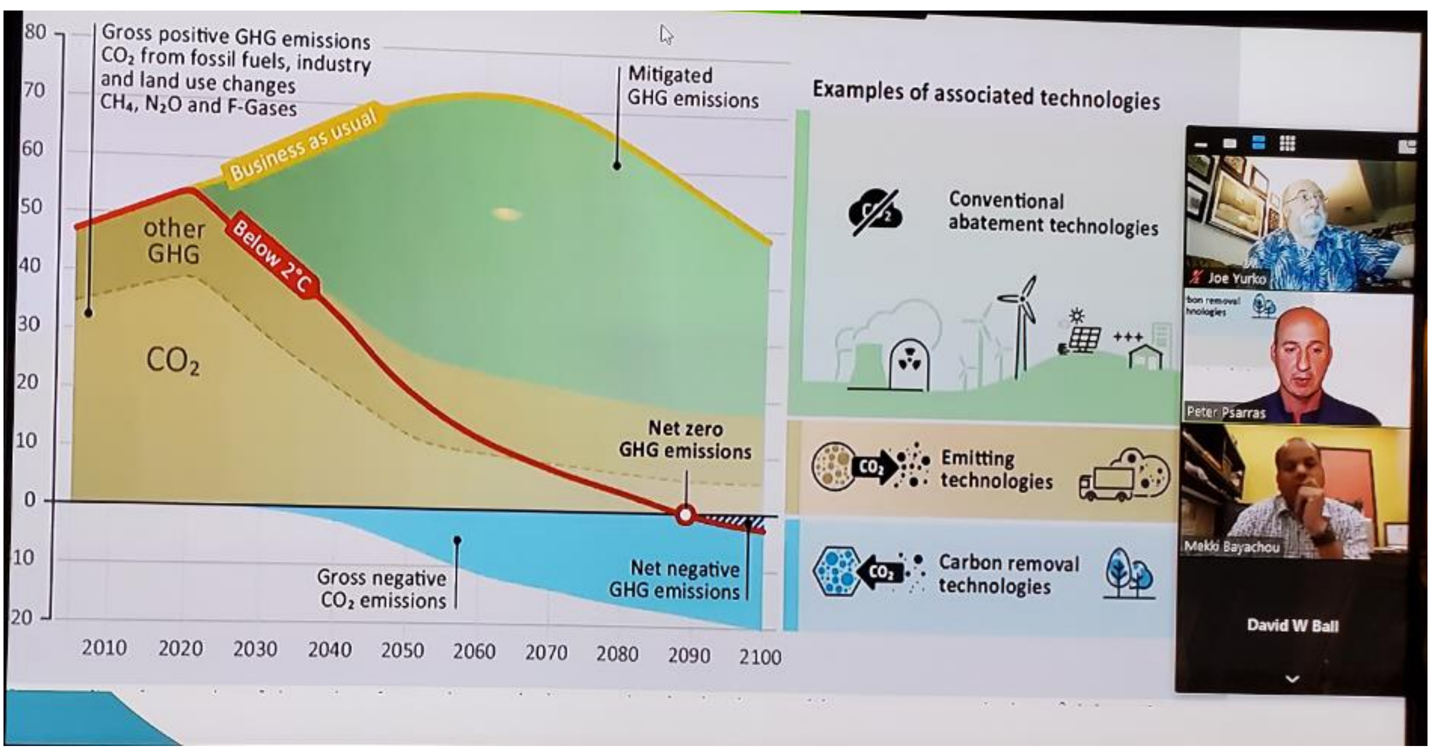
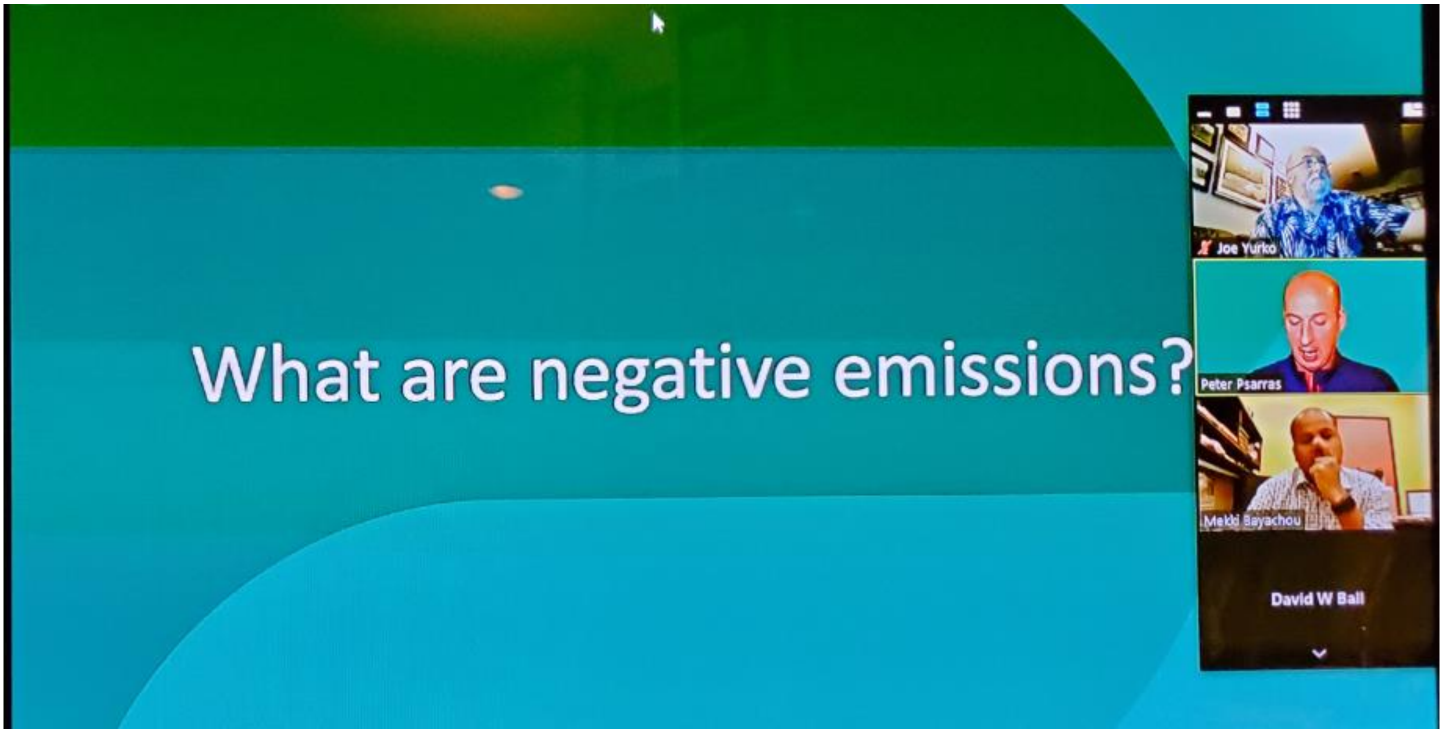
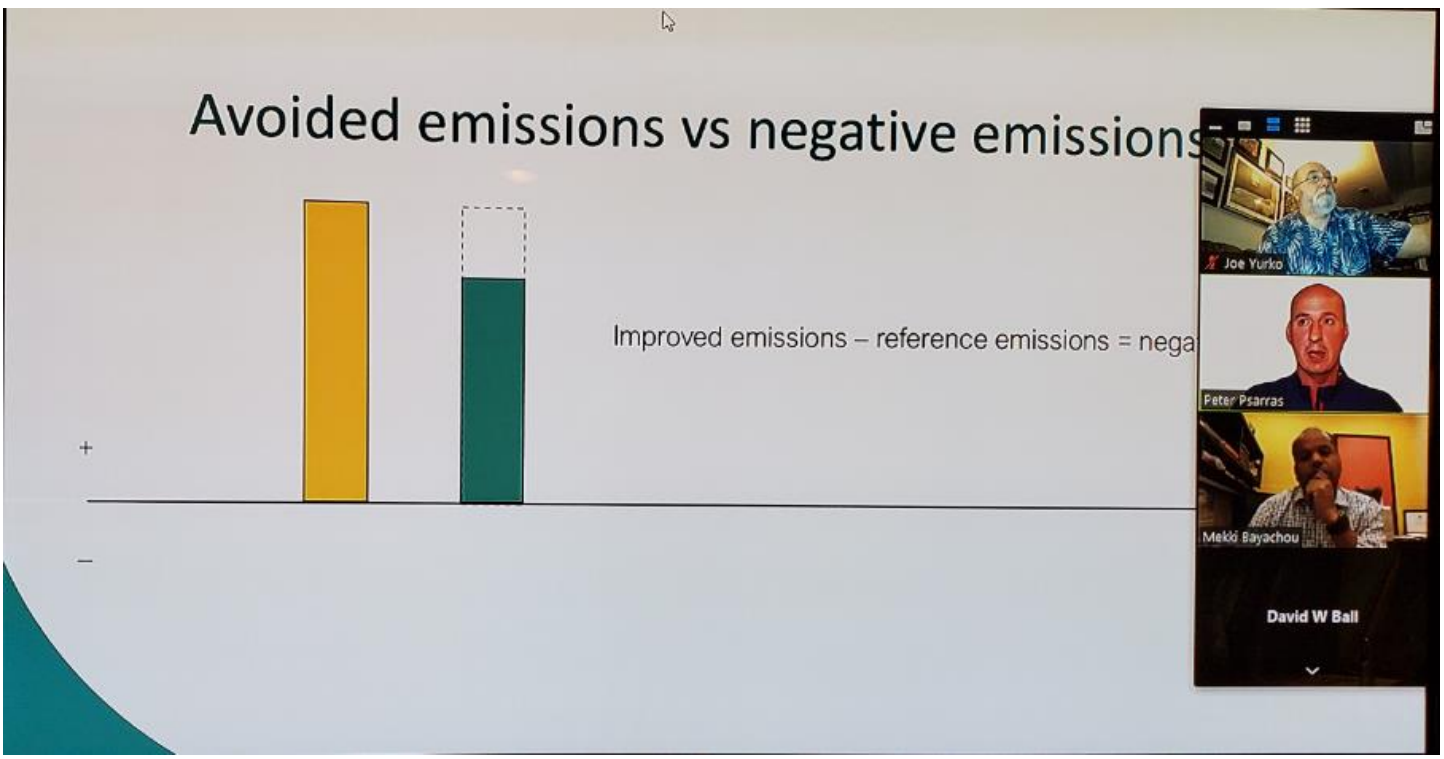

An Overview of Negative Emission Technologies
PETER PSARRAS, PHD
Cuyahoga Community College
Joe Yurko
Peter Psarras
Mekki Bayachou
Leave

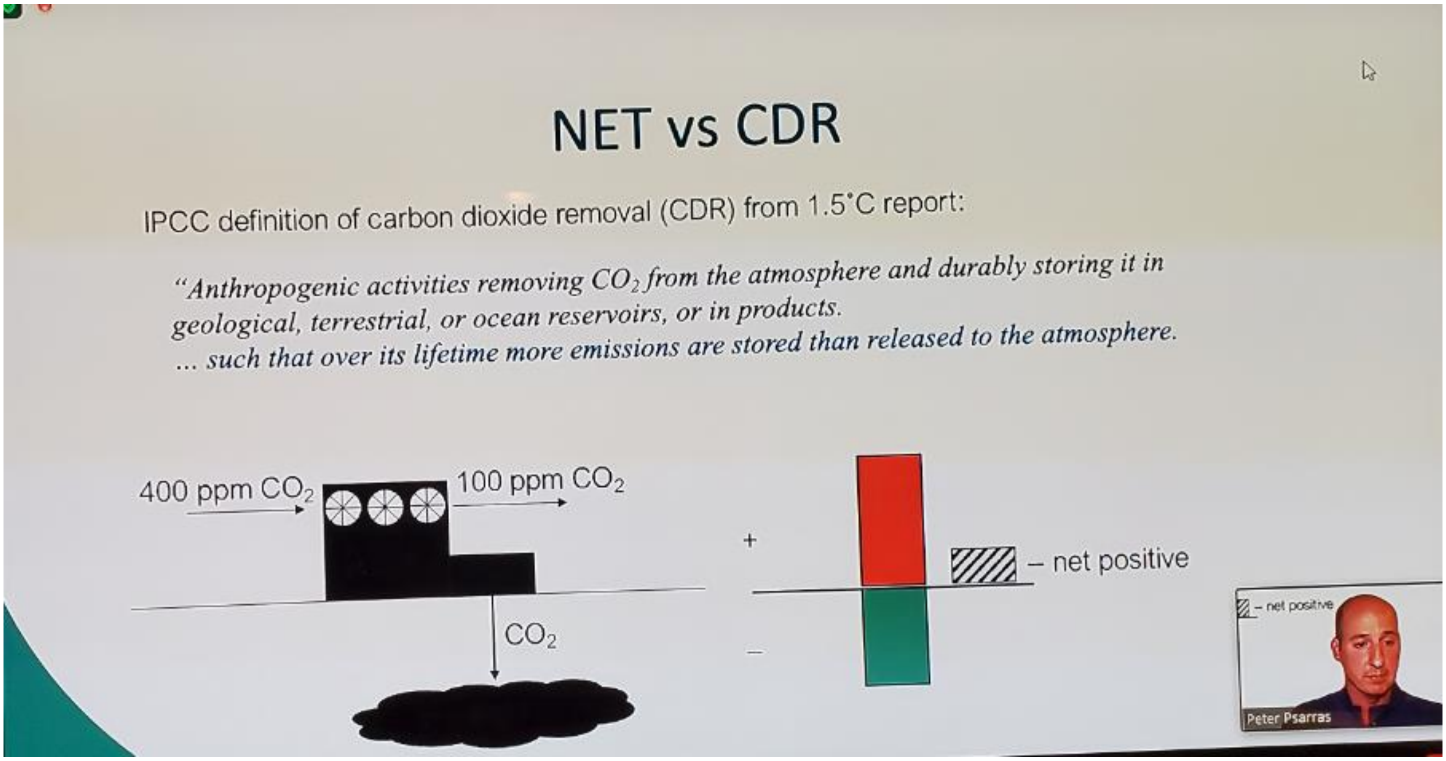

Recent Study from National Academy of Science
Focus was on establishing a research agenda for negative emissions technologies
Major conclusion from the study:
"If the goals for climate and economic growth are to be achieved, negative emissions technologies will likely need to play a large role in mitigating climate change by removing globally 10 GtCO2/yr by midcentury and 20 GtCO2/yr by century's end."
CONSENSUS
NEGATIVE
TECHNOL
RELIABLE SE
Joe Yurko
Peter Psarras
David W Ball
Mekki Bayachou
Leave

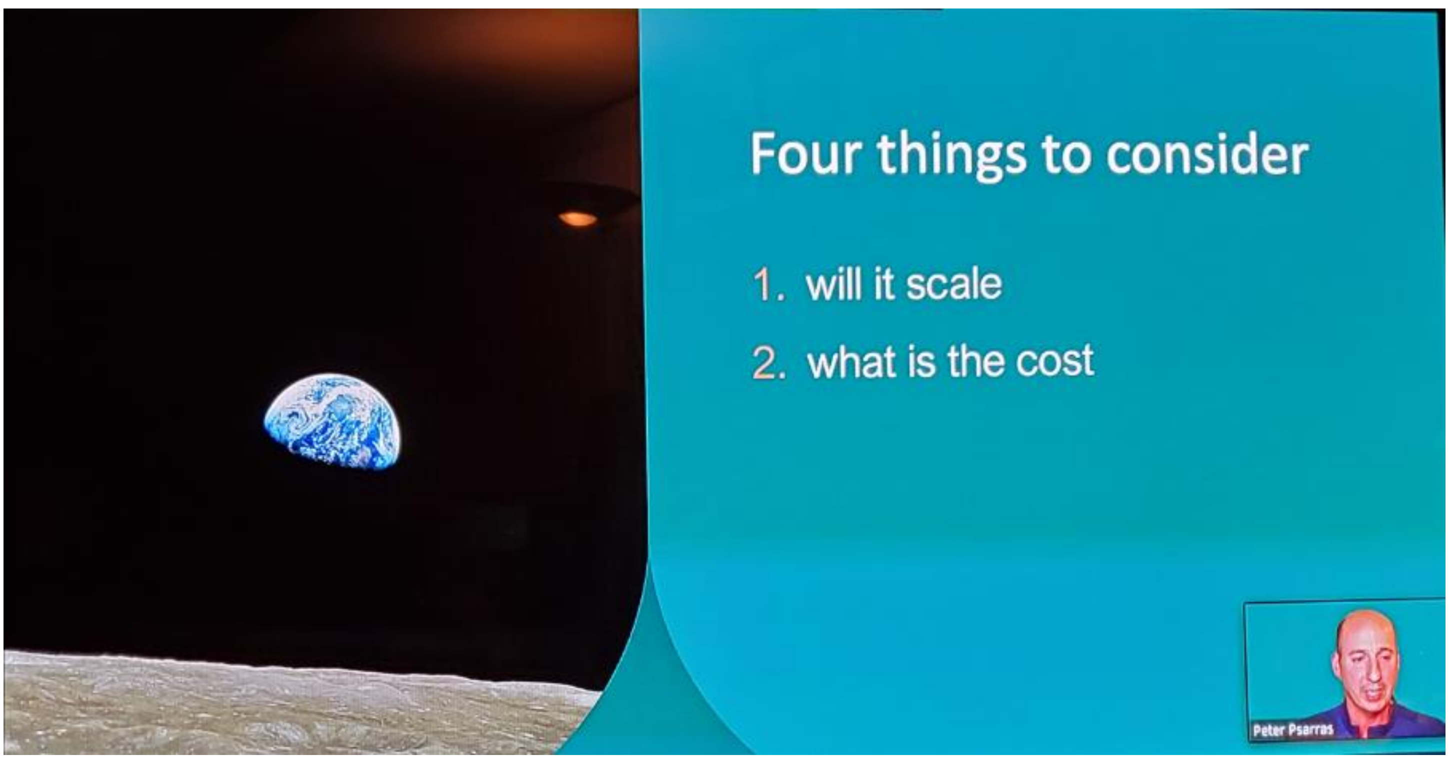

338 ppm
362 ppm
375 ppm
376 ppm
397 ppm
Joe Yurko
Peter Psarras
David W Ball

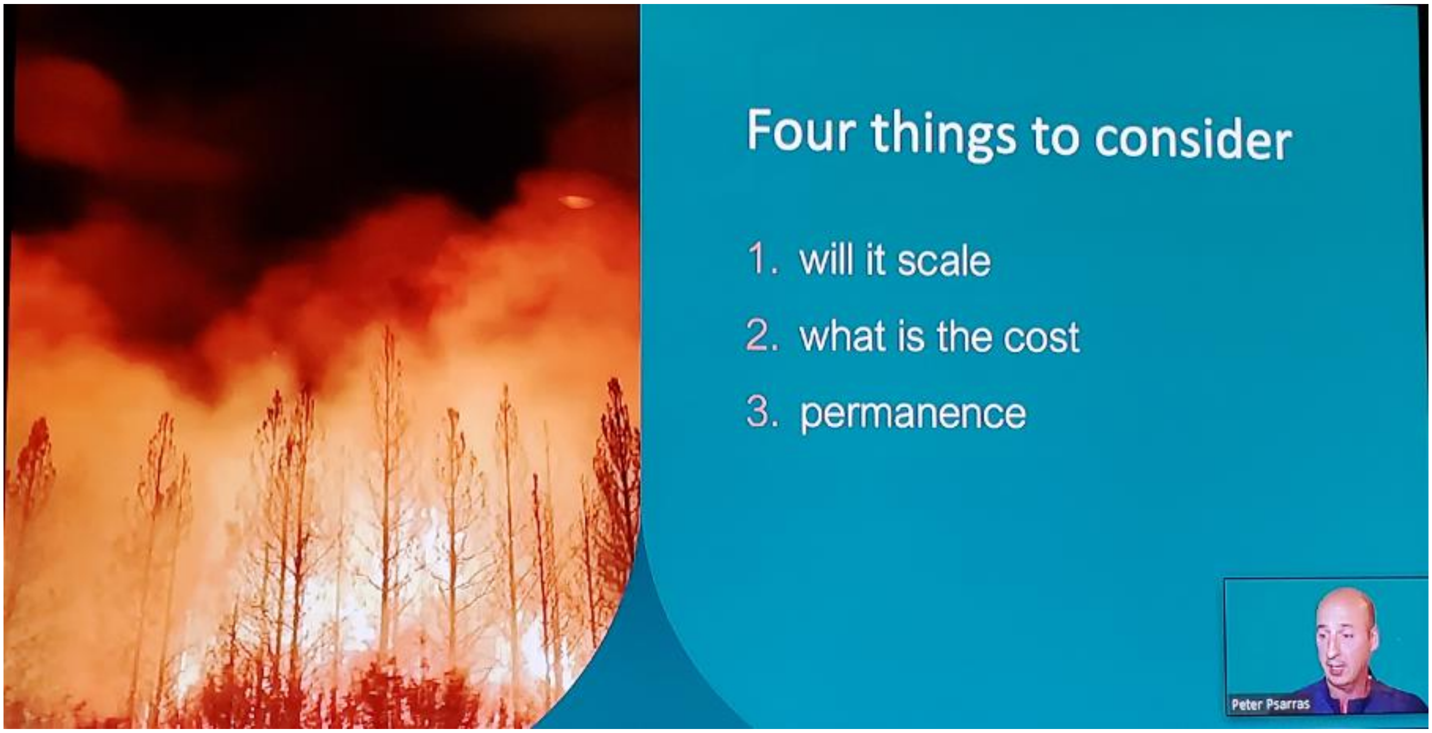

Gross positive GHG emissions
CO2 from fossil fuels, industry and land use changes
CH4, N2O and F-Gases
Mitigated GHG emissions
Business as usual
Below 2°C
other GHG
CO2
Net zero GHG emissions
Gross negative CO2 emissions
Net negative GHG emissions
80
70
60
50
40
30
20
10
0
10
20
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Examples of associated technologies
Conventional abatement technologies
Emitting technologies
Carbon removal technologies
Joe Yurko
Peter Psarras
Mekki Bayachou
David W Ball

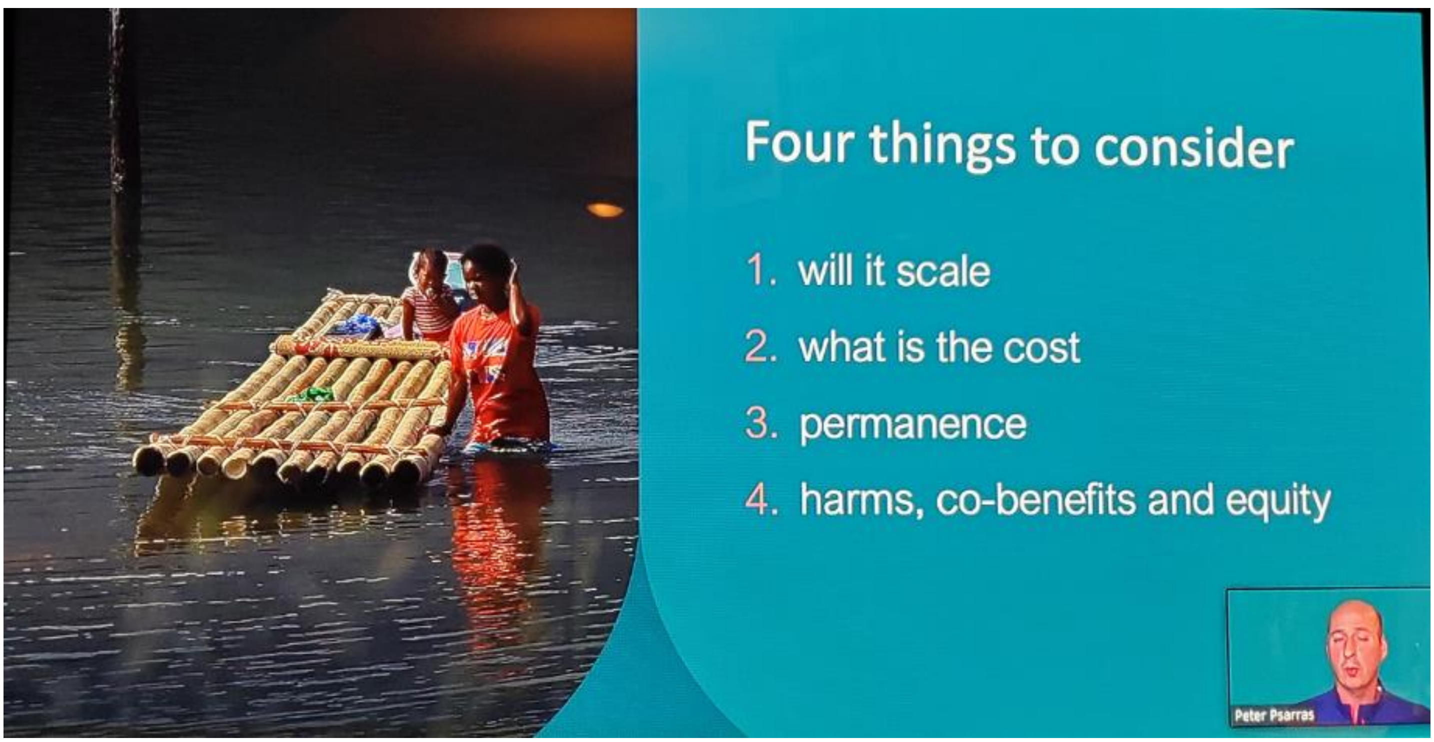

What are negative emissions?
Joe Yurko
Peter Psarras
Mekki Bayachou
David W Ball

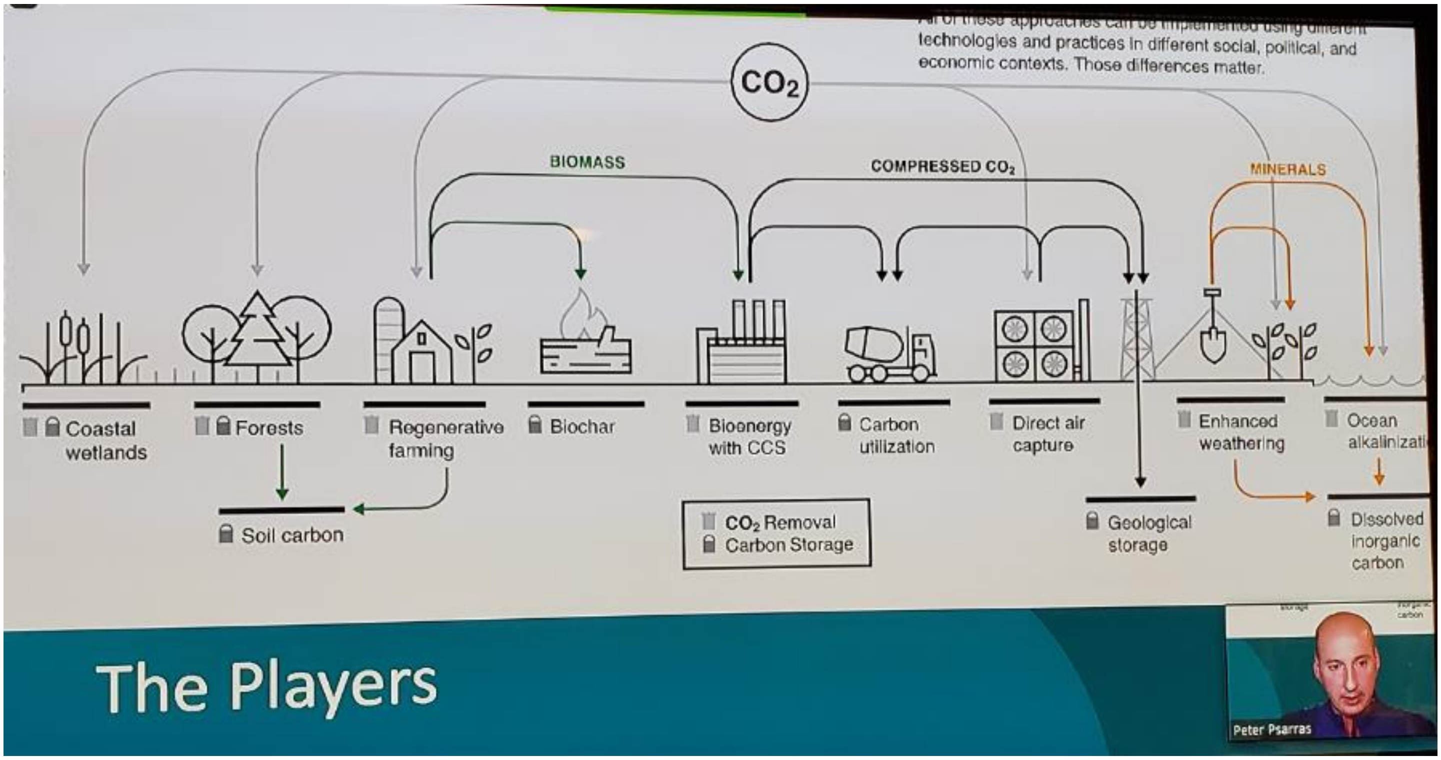

Avoided emissions vs negative emissions
Improved emissions – reference emissions = nega
+
–
Joe Yurko
Peter Psarras
Mekki Bayachou
David W Ball

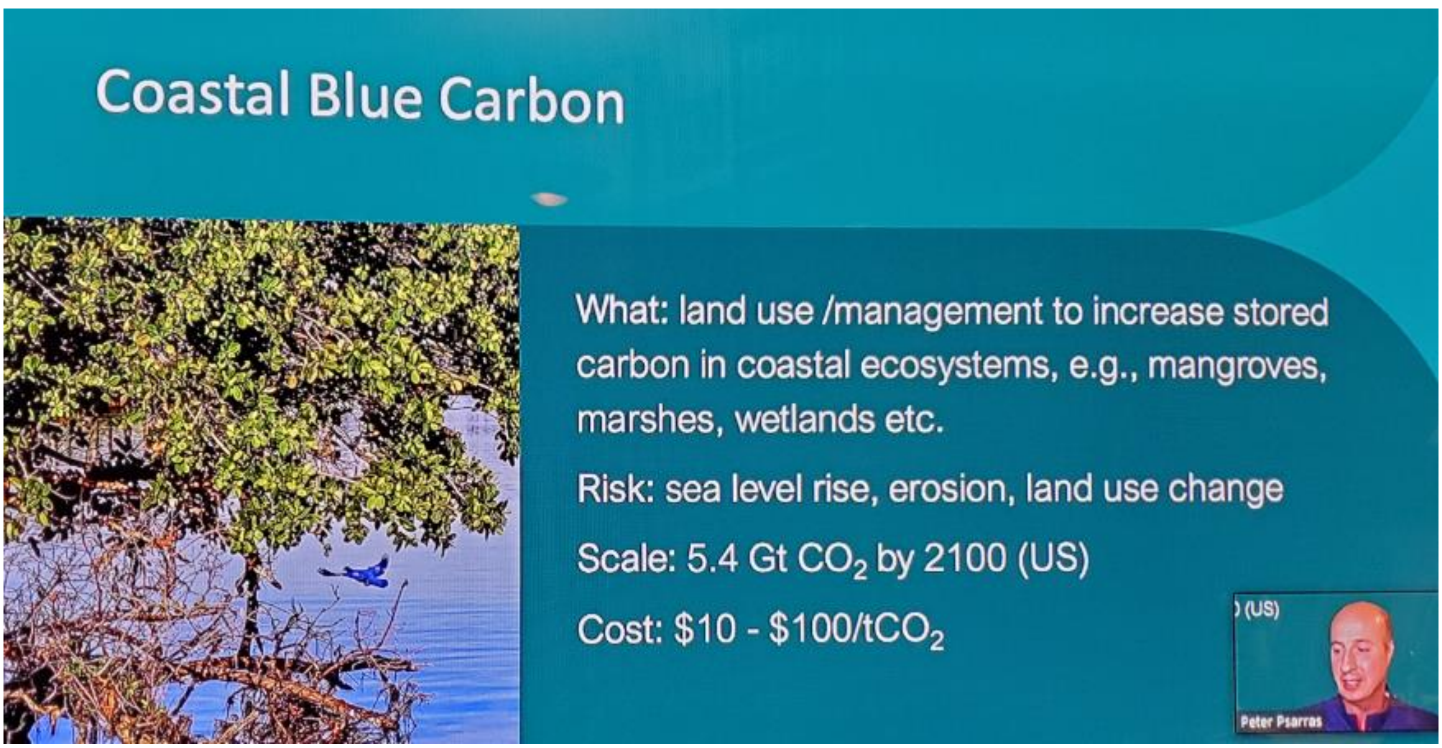

NET vs CDR
IPCC definition of carbon dioxide removal (CDR) from 1.5˚C report:
"Anthropogenic activities removing CO2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products.
... such that over its lifetime more emissions are stored than released to the atmosphere.
400 ppm CO2
100 ppm CO2
CO2
+
–
– net positive
Peter Psarras

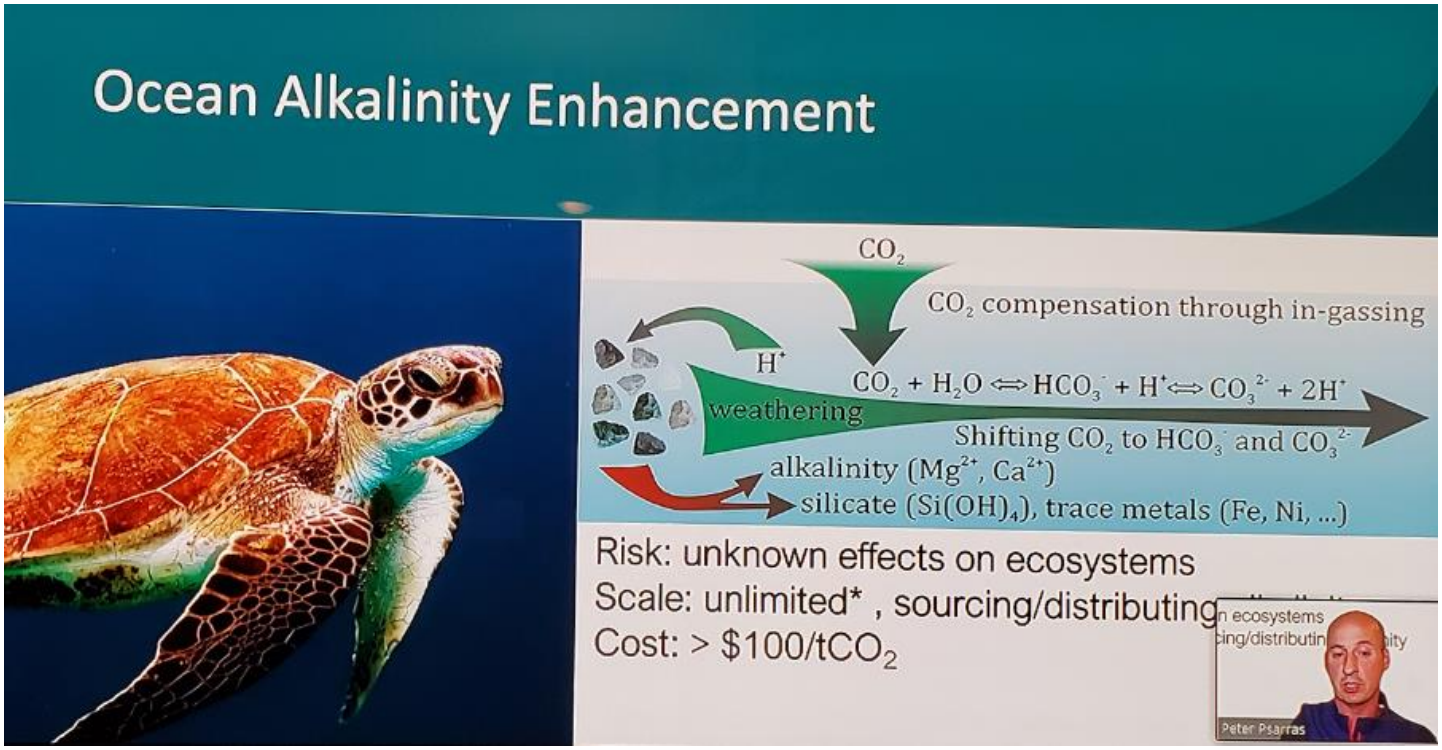

Four things to consider
1. will it scale
2. what is the cost
Peter Psarras

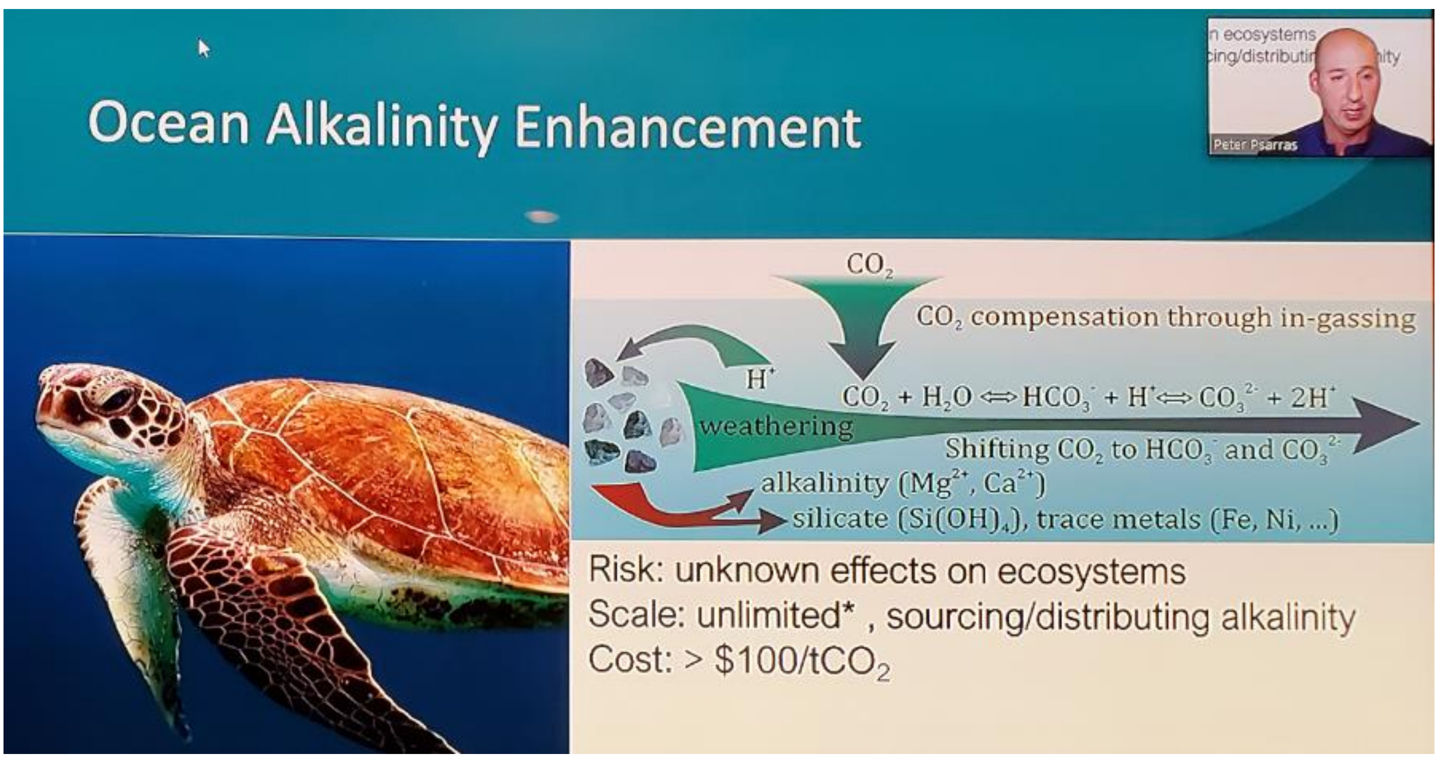

Four things to consider
1. will it scale
2. what is the cost
3. permanence
Peter Psarras


Four things to consider
1. will it scale
2. what is the cost
3. permanence
4. harms, co-benefits and equity
Peter Psarras


technologies and practices in different social, political, and economic contexts. Those differences matter.
CO_2
BIOMASS
COMPRESSED CO_2
MINERALS
Coastal wetlands
Forests
Regenerative farming
Biochar
Bioenergy with CCS
Carbon utilization
Direct air capture
Enhanced weathering
Ocean alkalinizati
Soil carbon
CO_2 Removal
Carbon Storage
Geological storage
Dissolved inorganic carbon
The Players
Peter Psarras


Coastal Blue Carbon
What: land use /management to increase stored carbon in coastal ecosystems, e.g., mangroves, marshes, wetlands etc.
Risk: sea level rise, erosion, land use change
Scale: 5.4 Gt CO_2 by 2100 (US)
Cost: \$10 - \$100/tCO_2
Peter Psarras


Ocean Alkalinity Enhancement
CO2
CO2 compensation through in-gassing
H+
CO2 + H2O ⇔ HCO3- + H+ ⇔ CO3 2- + 2H+
weathering
Shifting CO2 to HCO3- and CO3 2-
alkalinity (Mg2+, Ca2+)
silicate (Si(OH)4), trace metals (Fe, Ni, ...)
Risk: unknown effects on ecosystems
Scale: unlimited* , sourcing/distributing
Cost: > $100/tCO2
Peter Psarras


Ocean Alkalinity Enhancement
Peter Psarras
CO2
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CO2 + H2O ⇔ HCO3- + H+ ⇔ CO3 2- + 2H+
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Shifting CO2 to HCO3- and CO3 2-
alkalinity (Mg2+, Ca2+)
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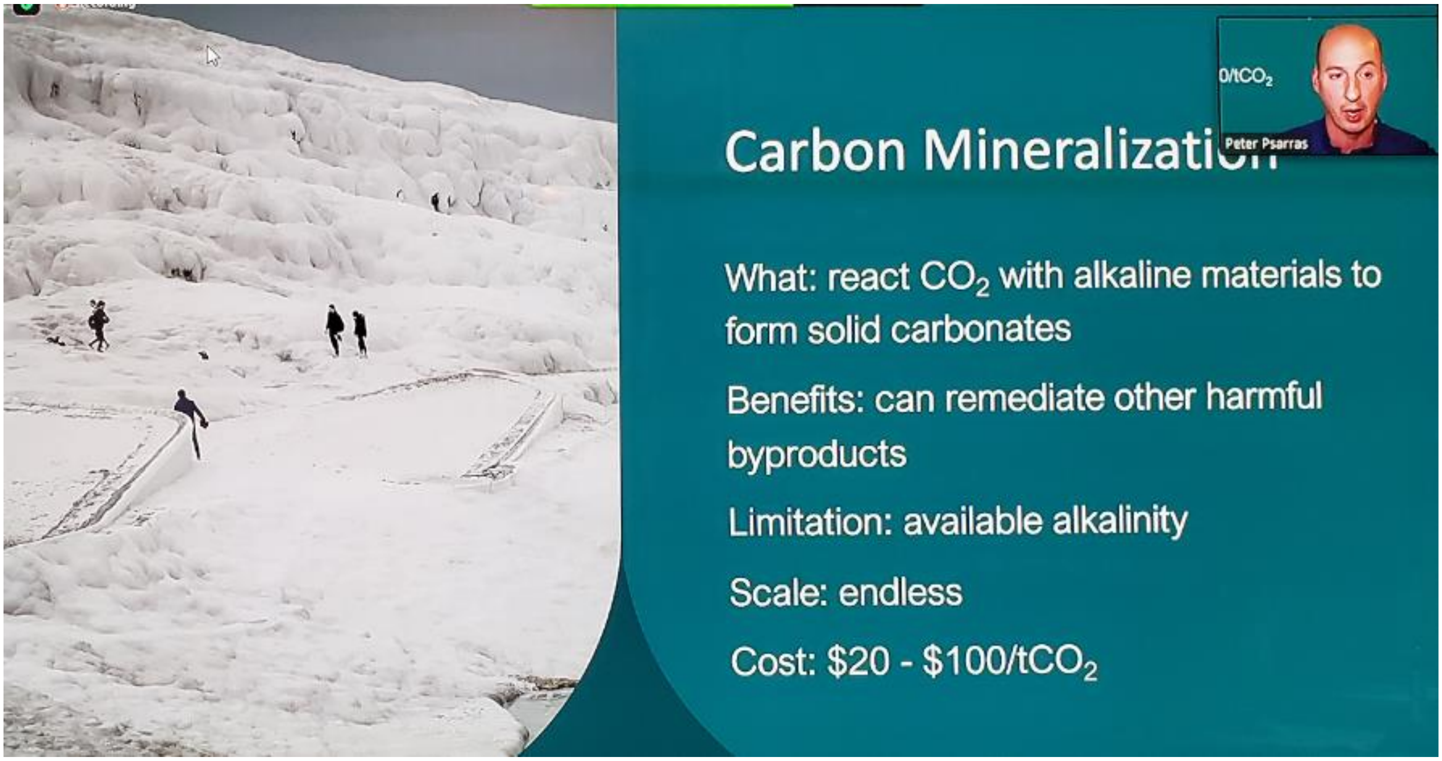
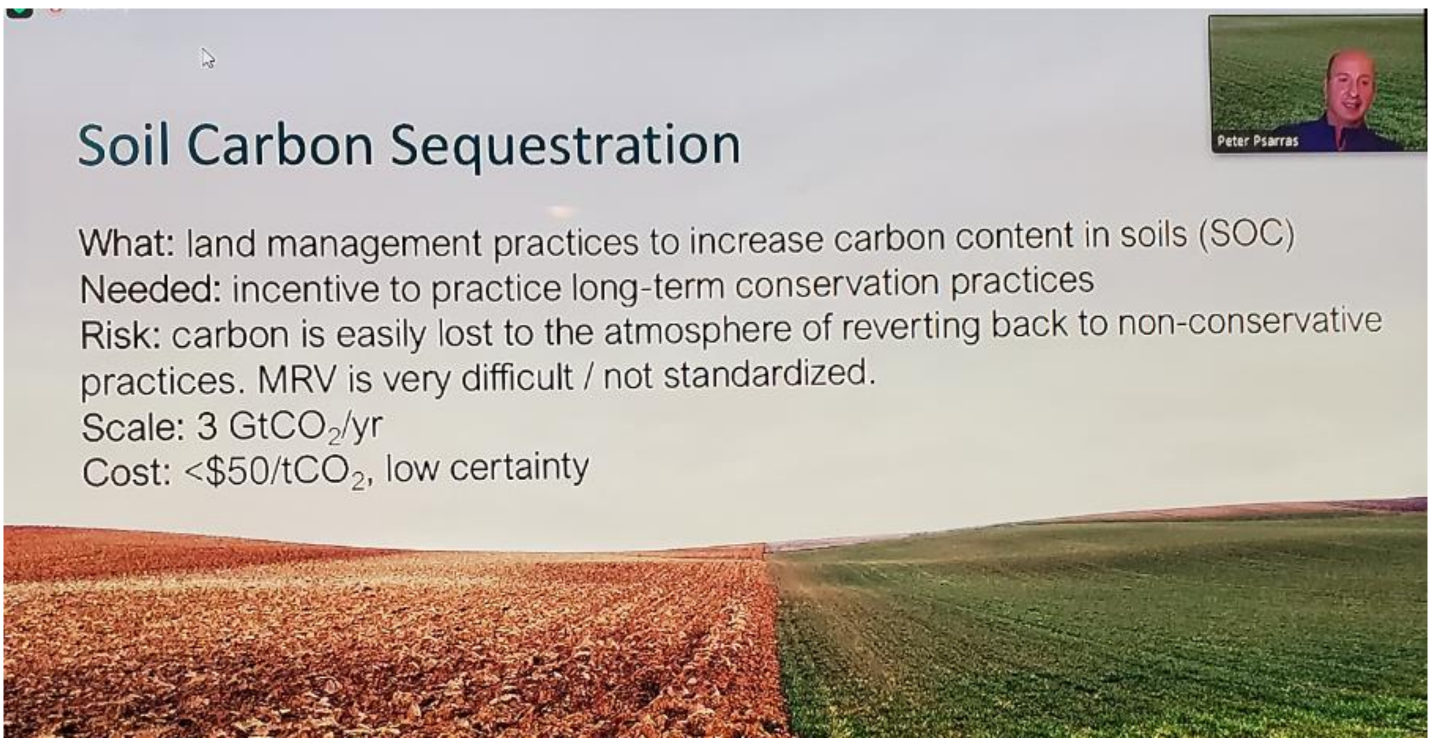
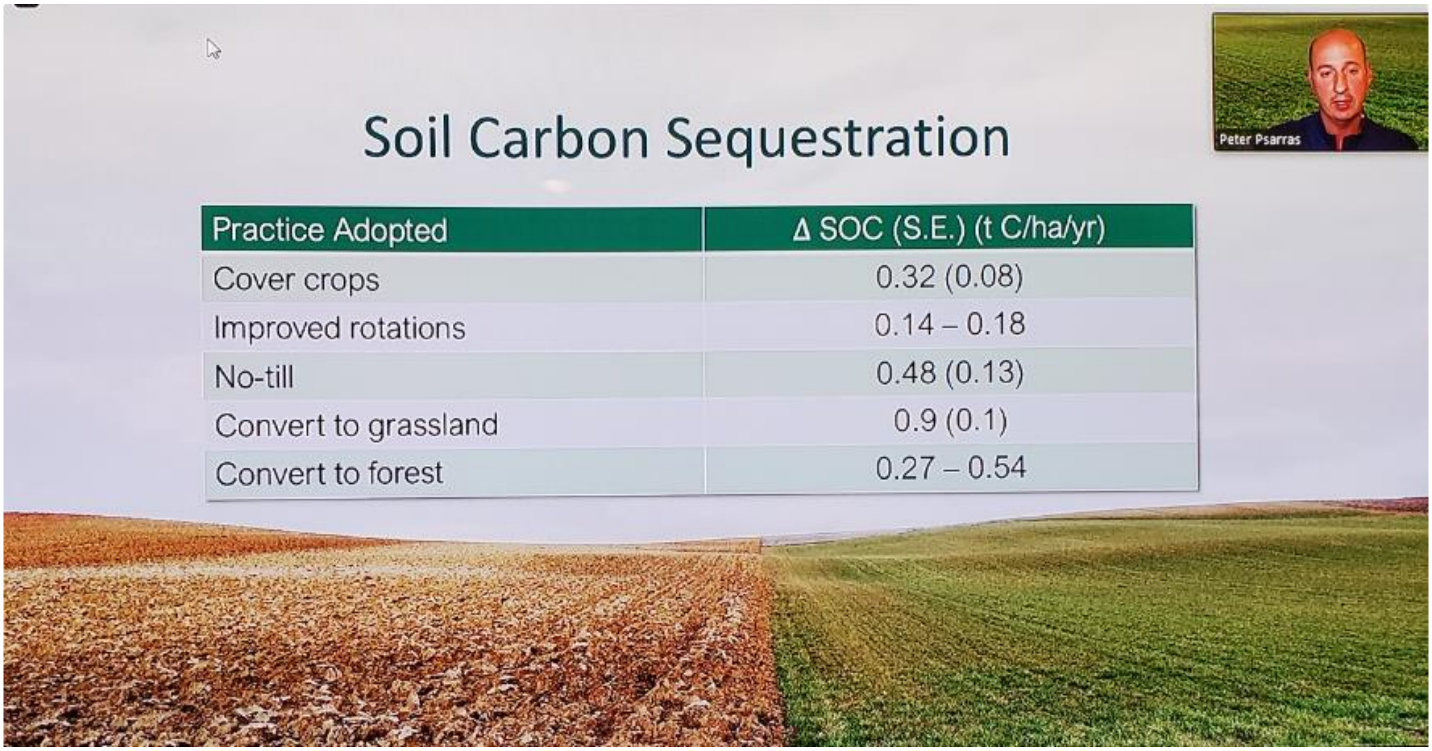
Risk: unknown effects on ecosystems
Scale: unlimited* , sourcing/distributing alkalinity
Cost: > $100/tCO2

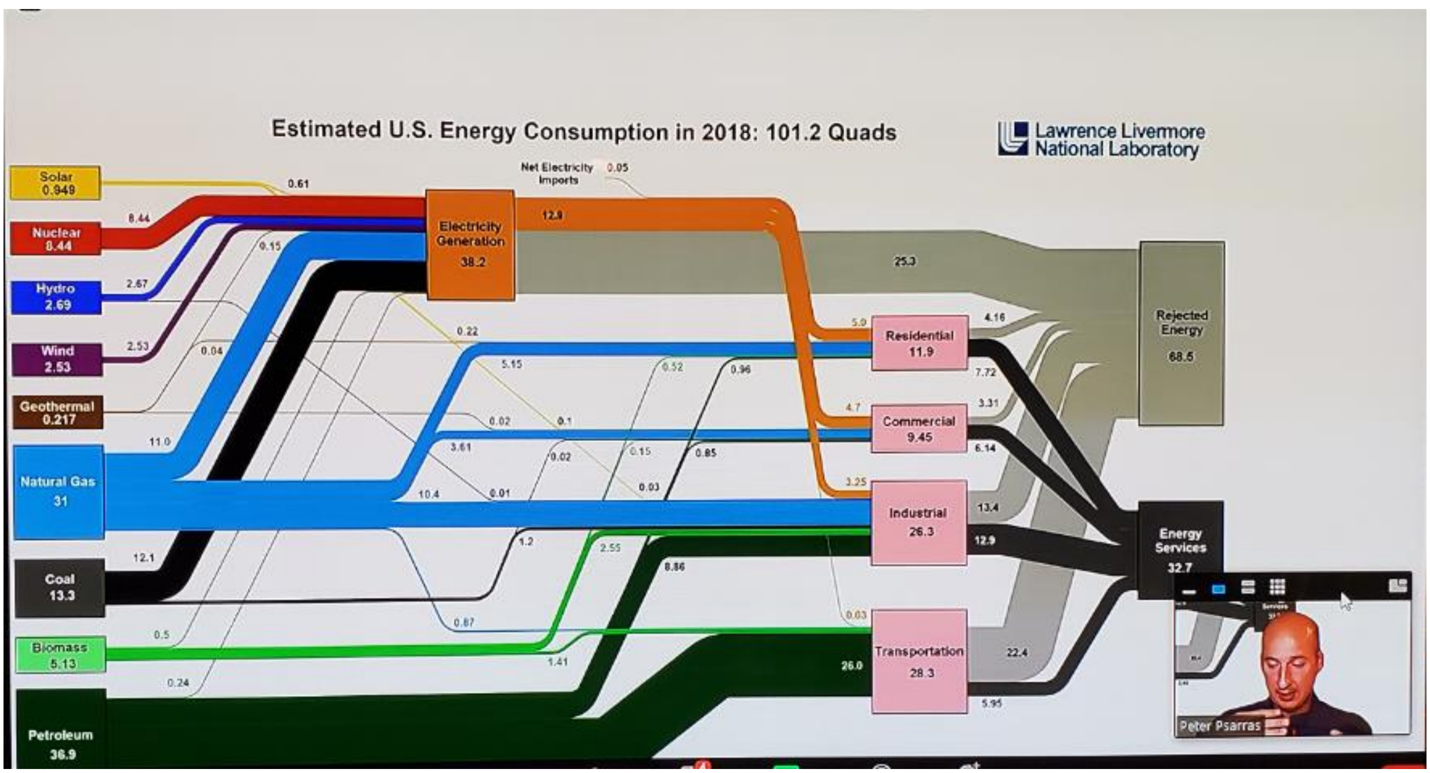

0/tCO$_2$
Peter Psarras
Carbon Mineralizati
What: react CO_2 with alkaline materials to form solid carbonates
Benefits: can remediate other harmful byproducts
Limitation: available alkalinity
Scale: endless
Cost: \$20 - \$100/tCO_2


Peter Psarras
Soil Carbon Sequestration
What: land management practices to increase carbon content in soils (SOC)
Needed: incentive to practice long-term conservation practices
Risk: carbon is easily lost to the atmosphere of reverting back to non-conservative practices. MRV is very difficult / not standardized.
Scale: 3 GtCO_2/yr
Cost: <\$50/tCO_2, low certainty

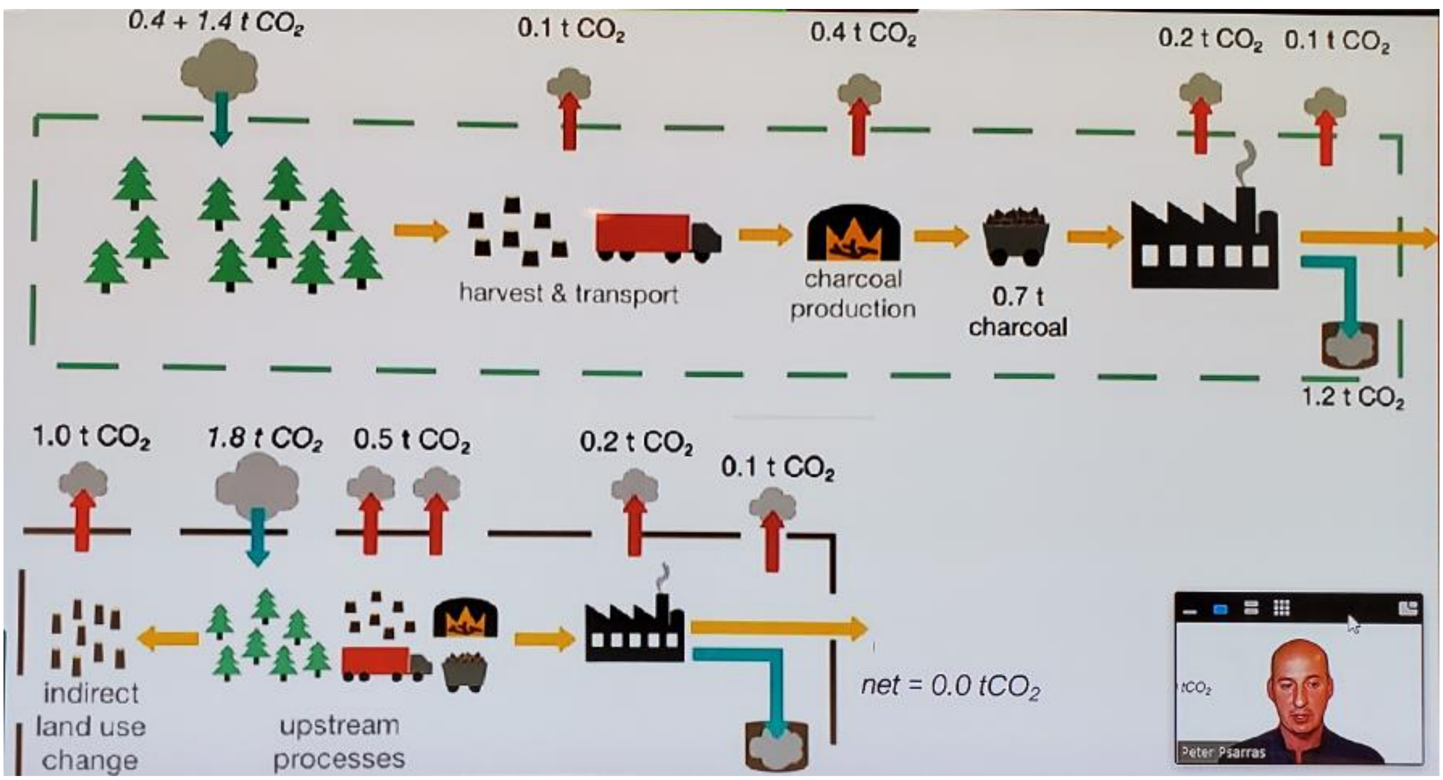

Soil Carbon Sequestration
Peter Psarras
Practice Adopted
Δ SOC (S.E.) (t C/ha/yr)
Cover crops
0.32 (0.08)
Improved rotations
0.14 – 0.18
No-till
0.48 (0.13)
Convert to grassland
0.9 (0.1)
Convert to forest
0.27 – 0.54


Indirect land use change
ILUC
the cultivation of crops for BECCS displaces traditional
production of crops for food and feed purposes
Peter Psarras


JUST PLANT SOME TREES!
Peter Psarras


Estimated U.S. Energy Consumption in 2018: 101.2 Quads
Lawrence Livermore National Laboratory
Solar 0.949
Nuclear 8.44
Hydro 2.69
Wind 2.53
Geothermal 0.217
Natural Gas 31
Coal 13.3
Biomass 5.13
Petroleum 36.9
Net Electricity Imports 0.05
Electricity Generation 38.2
Residential 11.9
Commercial 9.45
Industrial 26.3
Transportation 28.3
Rejected Energy 68.5
Energy Services 32.7
Peter Psarras

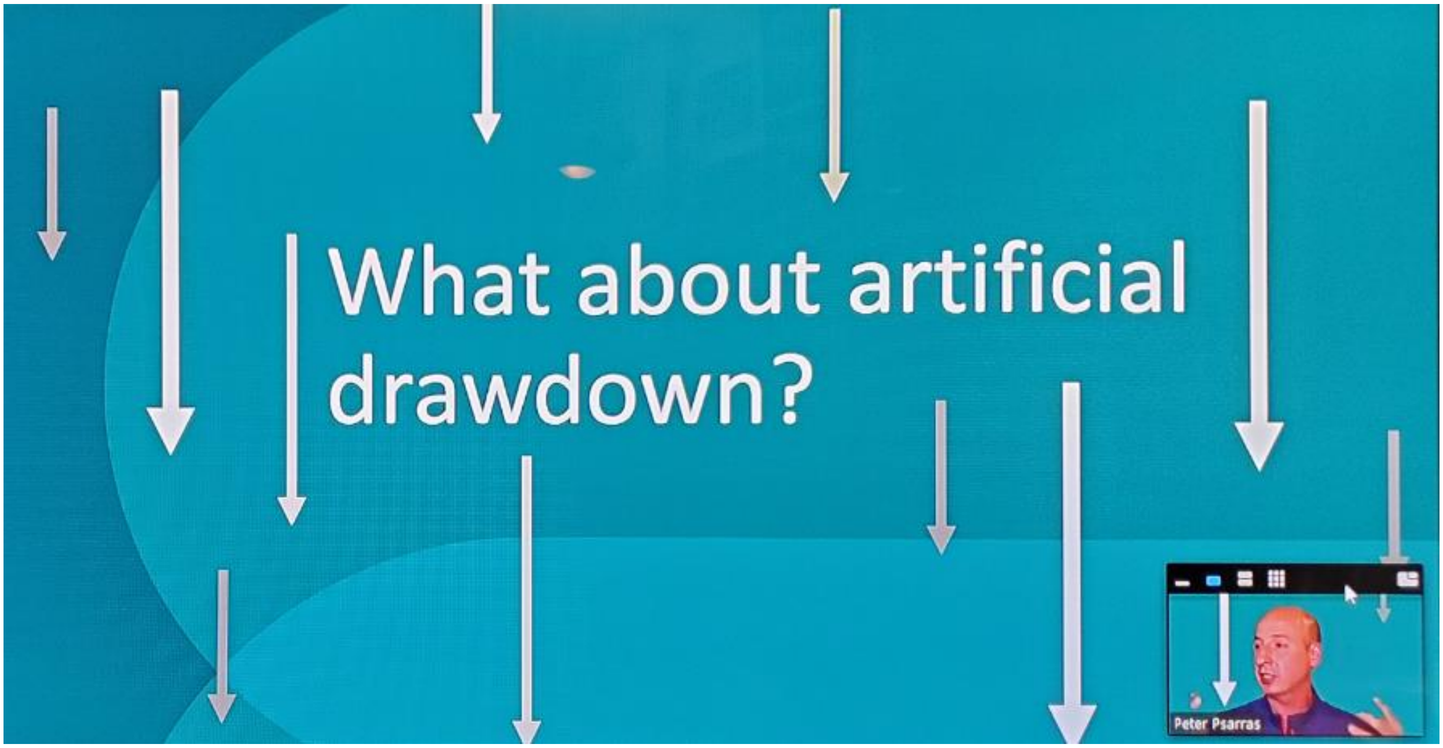

Plant some trees
aka
Afforestation/Reforestation
*Forest-based CDR approaches can take decades, often 100+ years to have substantiative effects
Peter Psarras


0.4 + 1.4 t CO2
0.1 t CO2
0.4 t CO2
0.2 t CO2
0.1 t CO2
harvest & transport
charcoal production
0.7 t charcoal
1.2 t CO2
1.0 t CO2
1.8 t CO2
0.5 t CO2
0.2 t CO2
0.1 t CO2
indirect land use change
upstream processes
net = 0.0 tCO2
Peter Psarras


Avoided Conversion
protects native forest from being cleared for crops or grassland
Peter Psarras

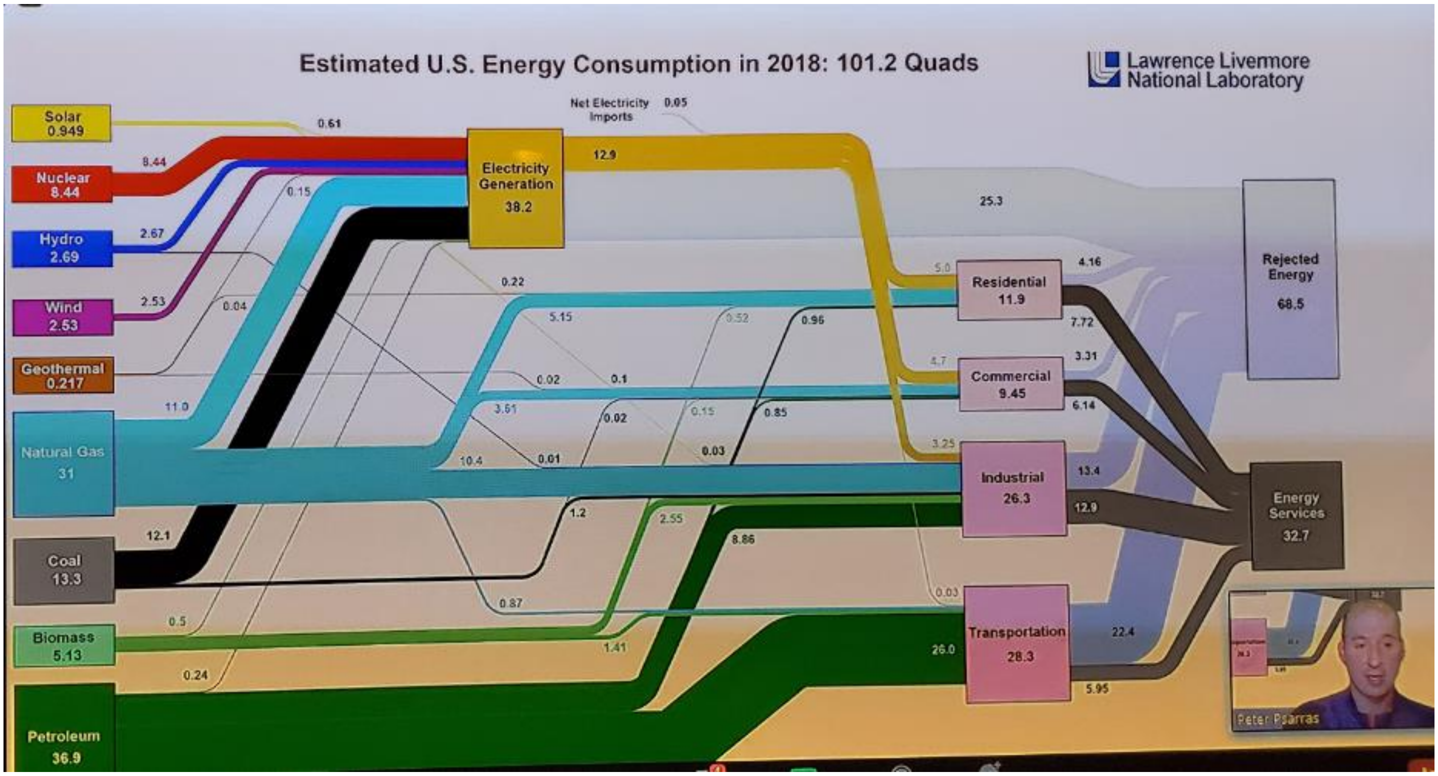

Improved Forest Management
IFM currently owns a 70-90% share of all CO_2 offset programs.
What: active modification of foresty practices to promote higher forest biomass and carbon storage
How: longer harvest intervals, improved fire management, improved tree plantation management
Peter Psarras


TALK ABOUT CURRENT CHALLENGES!
• Forestry methods face competition for land
• Limitation due to albedo effects
• Long maturation periods
• Permanence risks
Peter Psarras


What about artificial drawdown?
Peter Psarras


Direct Air Capture (DAC)
Peter Psarras


World's first commercial DAC plant: Climeworks
Peter Psarras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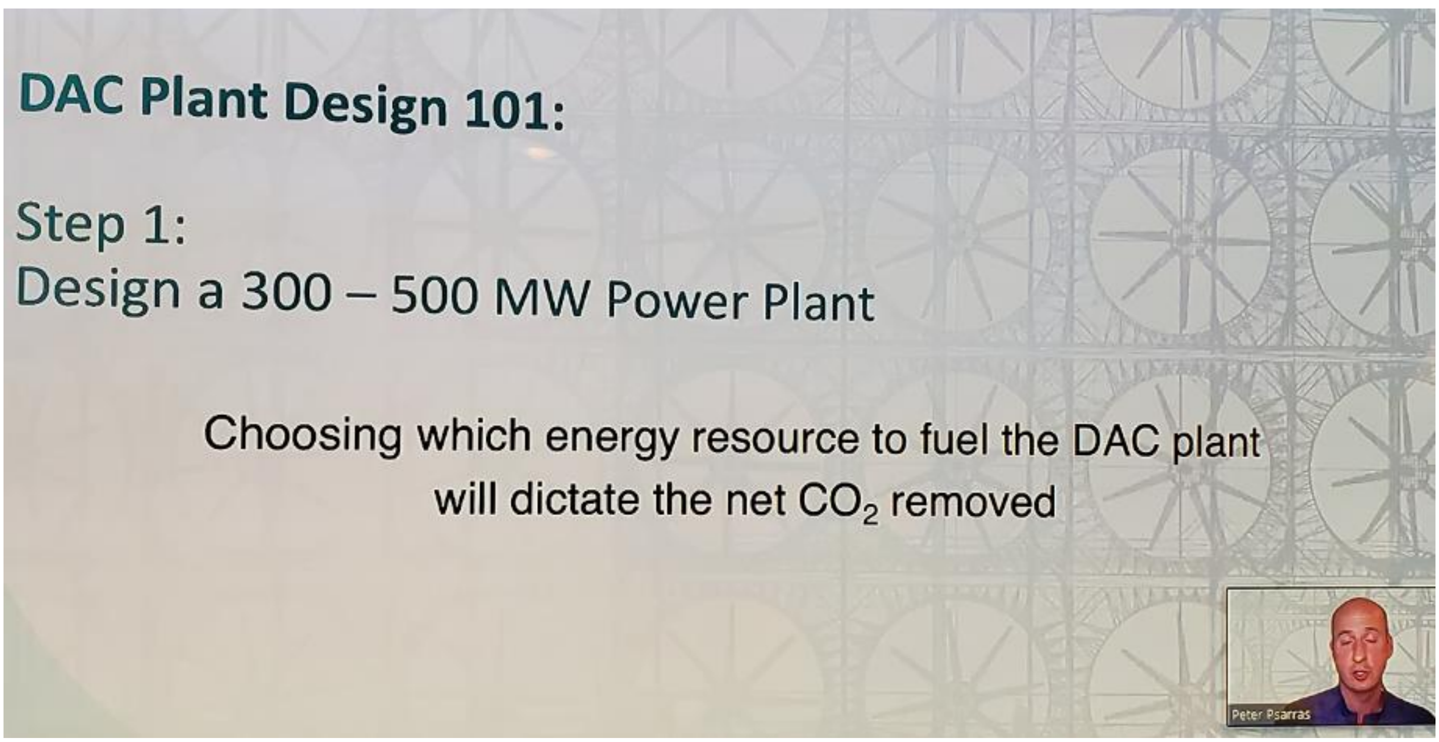
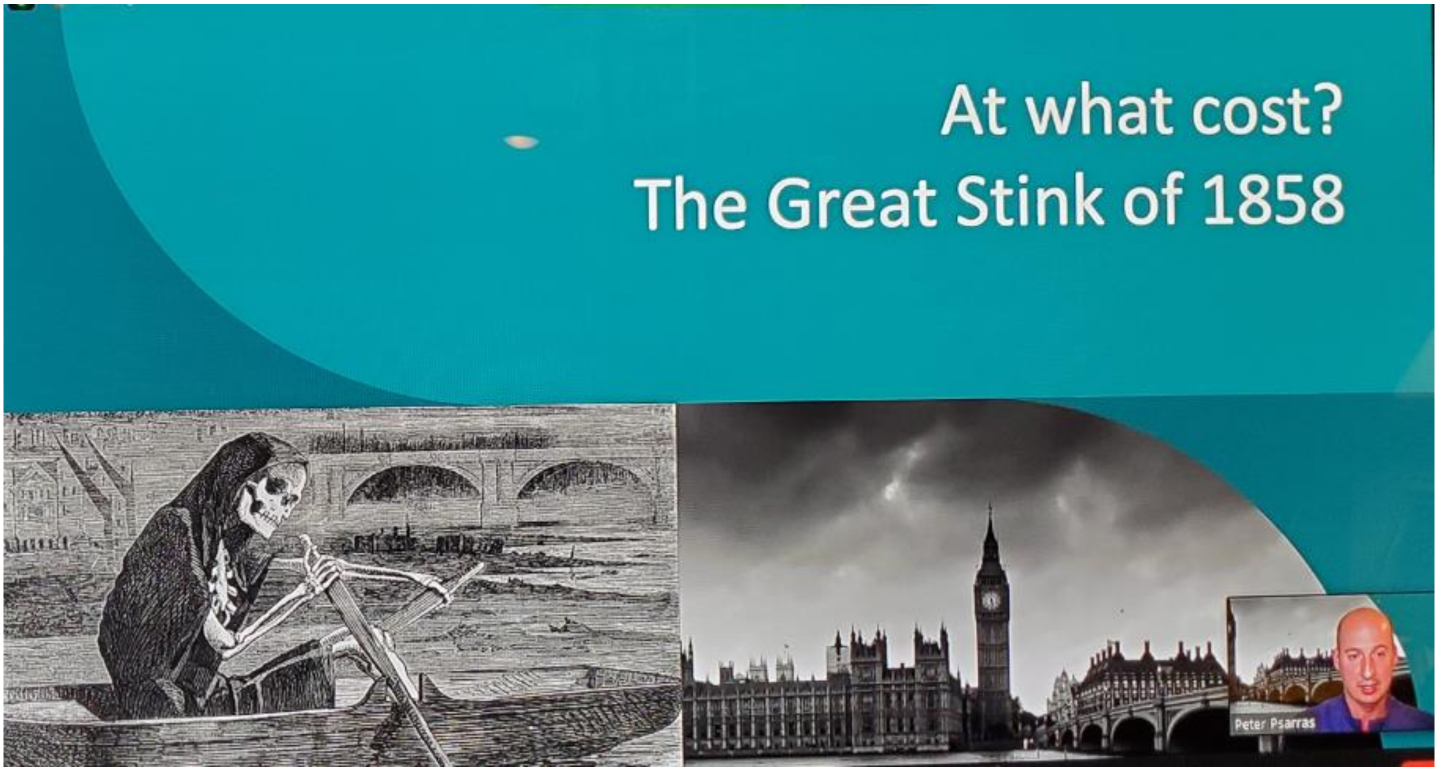

DAC Plant Design 101:
Step 1:
Design a 300 – 500 MW Power Plant
Choosing which energy resource to fuel the DAC plant will dictate the net CO_2 removed
Peter Psarras


Land: a comparison
To remove 1 Gt CO_2 / yr
DAC
if powered by natural gas with CCS
185 sq mi.
Peter Psarras


Land: a comparison
To remove 1 Gt CO_2 / yr
What about forests?
if tropical forests
70,000 sq mi.
if boreal forests
263,000 sq mi.
Peter Psarras

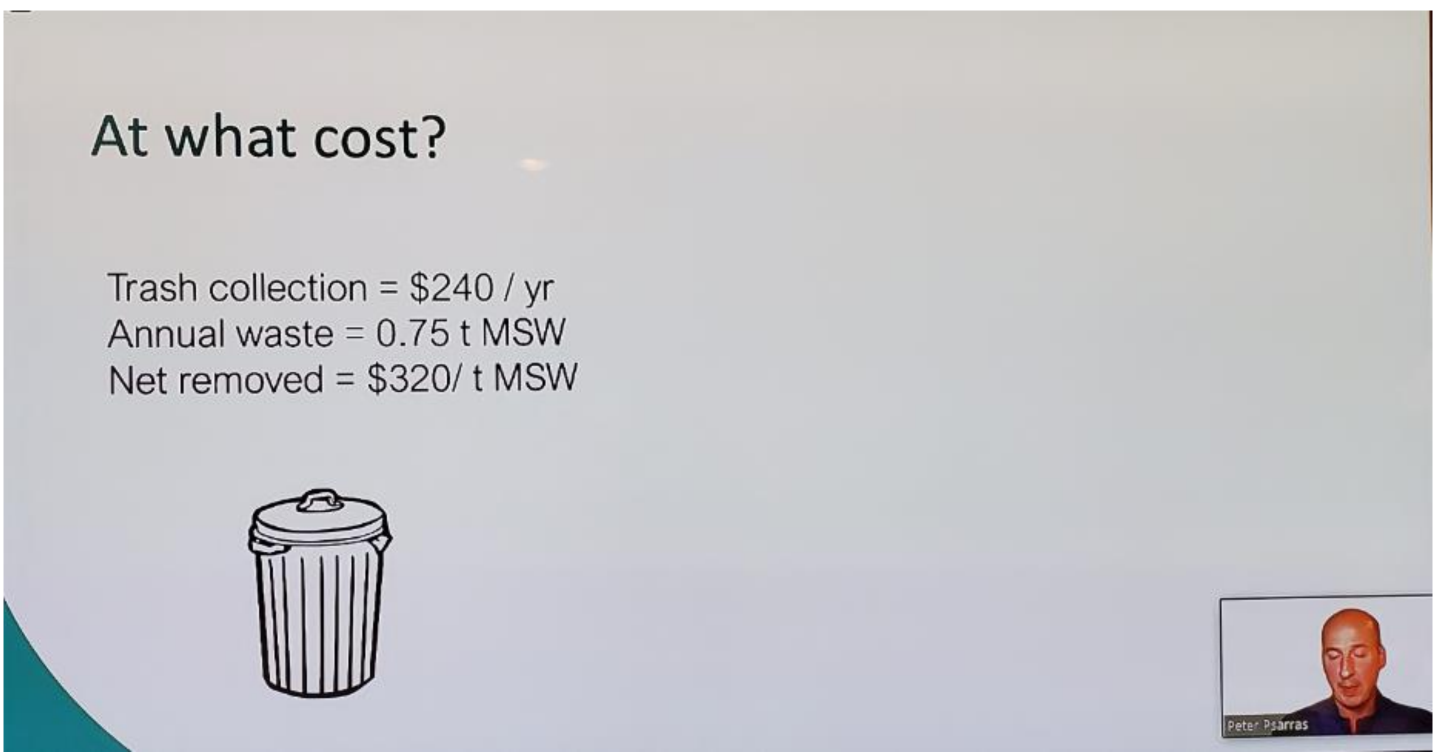

Land: a comparison
To remove 1 Gt CO_2 / yr
DAC
if powered by natural gas with CCS
185 sq mi.
if powered by solar and H_2
62,000 sq mi.
Peter Psarras


At what cost?
Trash collection = $240 / yr
Annual waste = 0.75 t MSW
Net removed = $320/ t MSW
Peter Psarras


At what cost?
The Great Stink of 1858
Peter Psarras


At what cost?
Peter Psarras


At what cost?
Peter Psarras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Peter Psarras


THANK
YOU!
David W Ball