Moomaw William, Tuser Martin: RESHAPING ARBORICULTURE IN TIMES OF CLIMATE CHANGE.
Conference presentation, The ISA Annual Conference 2023. https://www.treeib.com/isa-abq

RESHAPING ARBORICULTURE IN TIMES OF CLIMATE CHANGE

William Moomaw

Martin Tušer

ISA 2023 Annual Conference

Albuquerque, 16 August 2023

WHO WE ARE

William (Bill) Moomaw

Tufts University and Woodwell Climate Research Center Massachusetts United States

Scientist working on climate mitigation by technology and Natural Climate Solutions involving forests and wetlands

A lead author of 5 Intergovernmental Panel on Climate Change Reports and multiple research reports and papers

Martin Tušer

LEDASCO: Owner, entrepreneur, Chief Researcher and Business Development Director TREEIB®

Urban Tree Offset Initiative: the NGO President

I connect scientists, policymakers, and local implementers to bring the latest scientific knowledge into daily practice.

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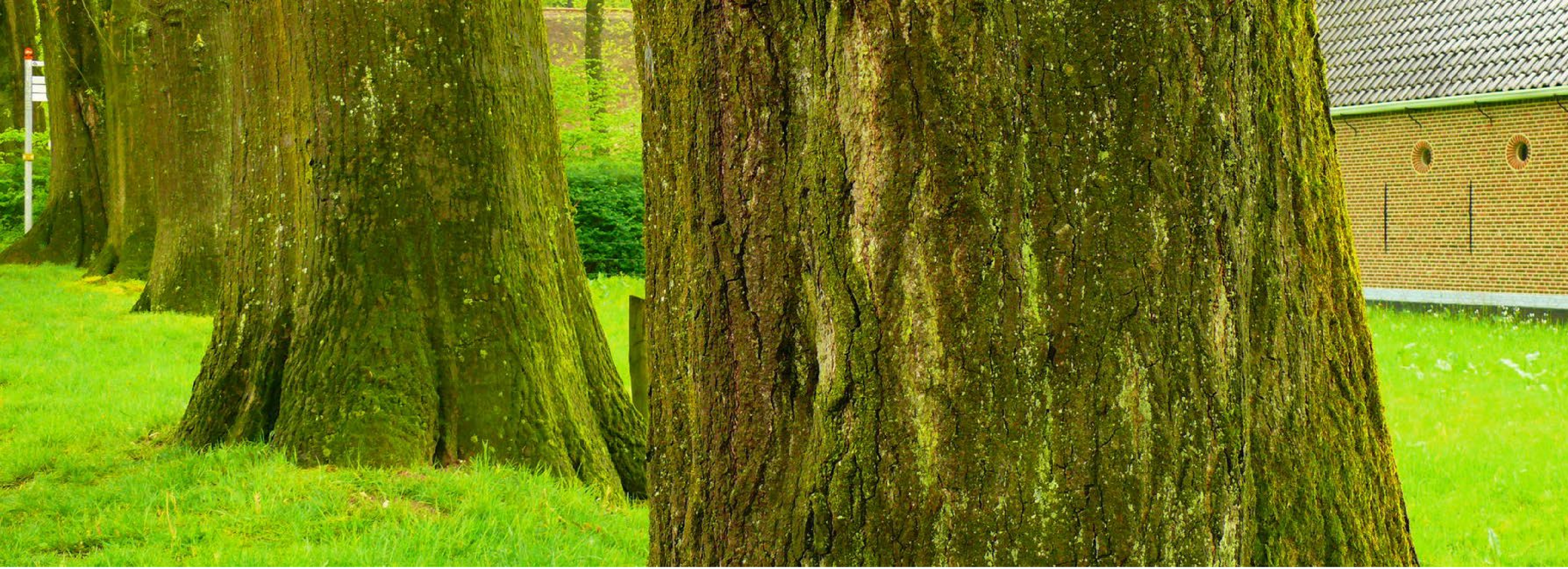


MAKE YOUR GUESS

HOW MANY TREES DO WE HAVE TO PLANT TO REPLACE ONE LARGE TREE?

Moomaw William, Tuser Martin: RESHAPING ARBORICULTURE IN TIMES OF CLIMATE CHANGE. Conference presentation, The ISA Annual Conference 2023. https://www.treeib.com/isa-abq

The message for today

But it is just beginning...

WE ARE PROPOSING

TO SHIFT THE MINDSET OF URBAN FORESTRY TO MEET CURRENT AND FUTURE NEEDS

- A LARGE TREE IS AN IRREPLACEABLE ASSET
- WE CAN IMPROVE PERFORMANCE OF URBAN FORESTS
- THE LARGER THE TREE - THE MORE SERVICES IT PROVIDES
- **WE NEED YOU!**

Definitions of Urban Forestry

DEFINITION:

"Urban and peri-urban forestry is the practice of managing urban forests to ensure their optimal contributions to the physiological, sociological, and economic well-being of urban societies."

FAO. 2016. Guidelines on urban and peri-urban forestry, by F. Salbitano, S. Borelli, M. Conigliaro and Y. Chen. FAO Forestry Paper, No.¬178. Rome, Food and Agriculture Organization of the United Nations.

DEFINITION:

"Arboriculture as the science and practice of the cultivation, establishment and management of amenity trees for the benefit of society…
… Ultimately the meaning is that arboriculture is tree care."

The Arboricultural Association (UK)

TODAY, it is not enough.

This is an INSUFFICIENT DEFINITION in this time of climate emergency.

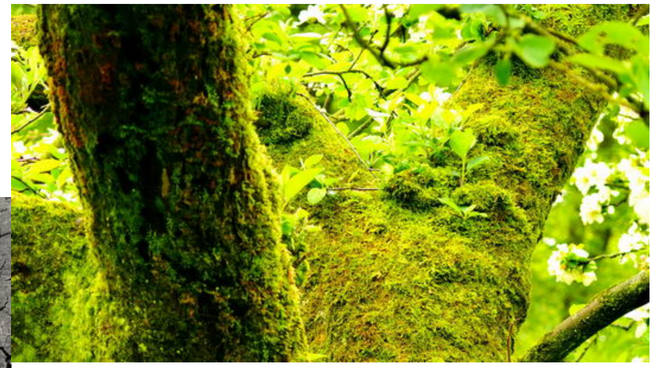
1. **Need to adapt urban and peri-urban forestry to provide additional services and increase resilience as climate changes**

2. **This requires a much longer time horizon than is currently considered**

SERVICES PROVIDED BY TREES

CARBON STORAGE

Carbon Reservoir
How much Carbon is in the above and below ground biomass of the tree.



COOLING

Trees reduce urban and regional temperatures by evapotranspiration of water, and prevent warming of surfaces by shading

ADDING CARBON

Carbon Sink
How much Carbon will be added into the mass of the tree in certain time
Dynamic quantity

Many other benefits

Storm water management, increased property value, noise reduction, biodiversity

LIFE EXPECTANCY OF TREES IN CITIES IS 7-28 YEARS

THE ANNUAL MORTALITY RATE

of trees in cites is estimated to be as high as 9%

NEWLY PLANTED TREES

provide relatively few services and have the highest mortality rate

https://www.wakeforestnc.gov/public-works/urban-forestry/street-tree-replacement
https://www.researchgate.net/publication/238003598_Street_tree_survival_rates

A newly planted city tree IS CARBON NEUTRAL AFTER 26-33 YEARS

IT TAKES THIS LONG

for the planted tree to accumulate and store the amount of Carbon dioxide that as released in growing, transporting, planting the tree and caring for it.

https://meridian.allenpress.com/jeh/article/34/4/101/80299/How-Green-Are-Trees-Using-Life-Cycle-Assessment

NEWLY PLANTED TREES

provide relatively few services and have the highest mortality rate

https://www.wakeforestnc.gov/public-works/urban-forestry/street-tree-replacement
https://www.researchgate.net/publication/238003598_Street_tree_survival_rates

PLANTING NOT A GOOD SOLUTION

LARGE TREES
PROVIDE SIGNIFICANTLY MORE ECOSYSTEM SERVICES AND AMENITIES THAN SMALL TREES
(INCLUDING CARBON ACCUMULATION AND STORAGE)

https://extension.usu.edu/forestry/trees-cities-towns/tree-selection/small-trees-street-trees

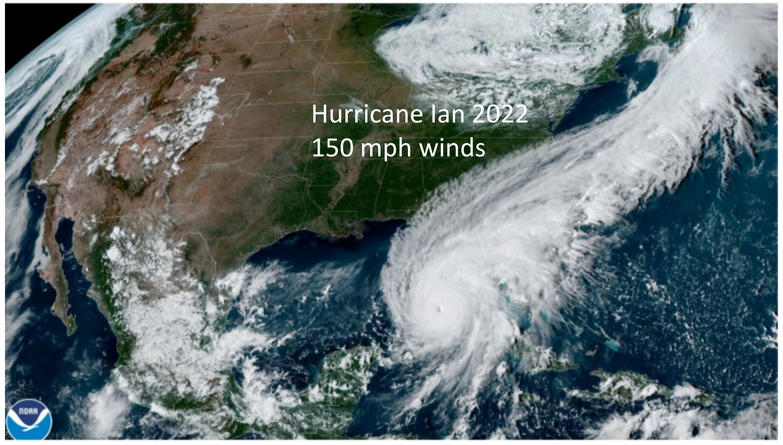
THE CLIMATE HAS CHANGED!

July 2023 was highest global temperature month since 1750

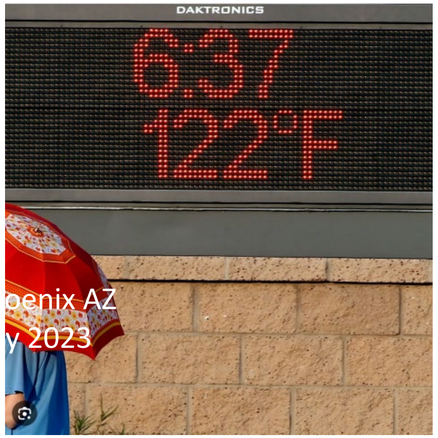

California Fires 2021

Death Valley CA 2020


Germany
2021


Hurricane Ian 2022
150 mph winds


Pakistan 115° F
April 2023

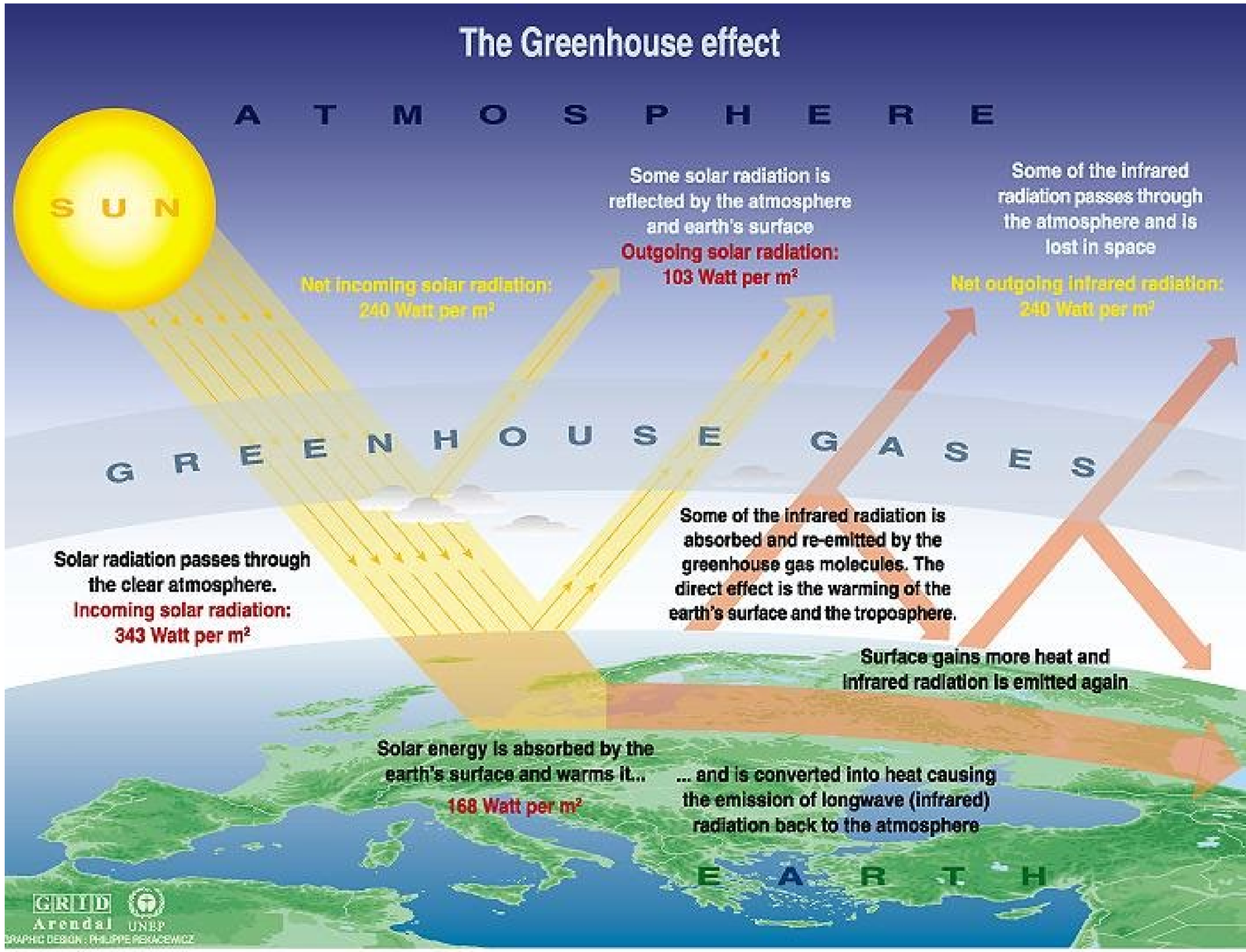


oenix AZ
y 2023

HUMAN CAUSED GLOBAL WARMING

- The greenhouse effect is trapping earth's radiant heat by carbon dioxide and other gases by analogy to the glass buildings in which plants are grown

- Today it would be called the "Hot Car Effect"
  - Outside air temperature is 80°F
  - **In one hour car interior is 125°F**



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

CARBON
C

CARBON DIOXIDE
CO_2

Which technology

IS CAPABLE OF PREVENTING ATMOSPHERIC CO2 FROM INCREASING BY NEARLY **30% PER YEAR**?

- SOLAR PANELS?
- WIND TURBINES?
- ELECTRIC VEHICLES?
- **NONE OF THE ABOVE!**

IT IS FORESTS!

TREES, FORESTS AND CLIMATE

To reduce global warming that is changing the climate,
we need to reduce the amount of heat trapping carbon dioxide added to the atmosphere

Growing trees move carbon from the atmosphere into the wood in trees

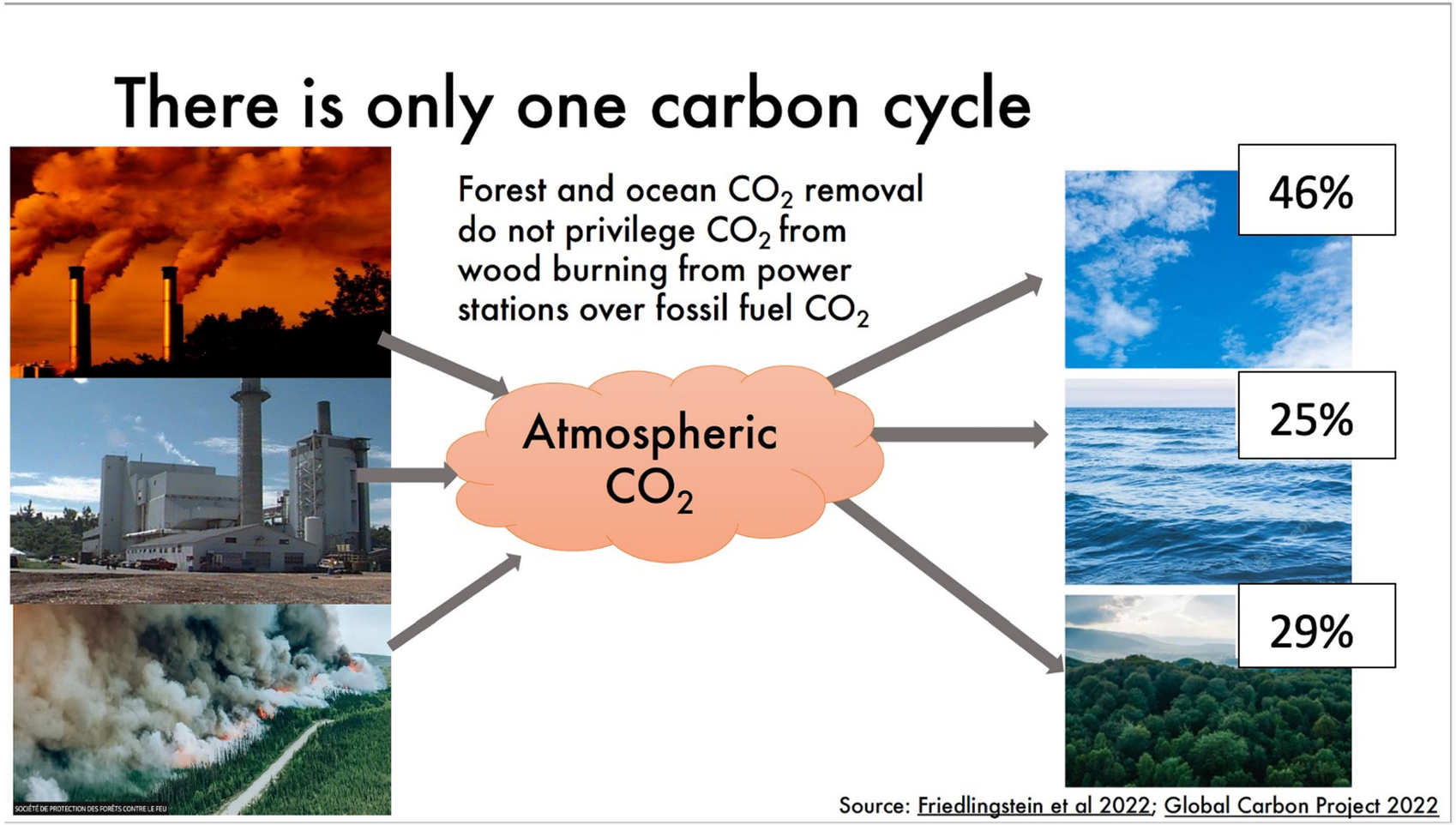
Dry wood in trees is approximately half carbon by weight

Which trees remove the most carbon dioxide and store the most carbon?

THE LARGEST TREES!

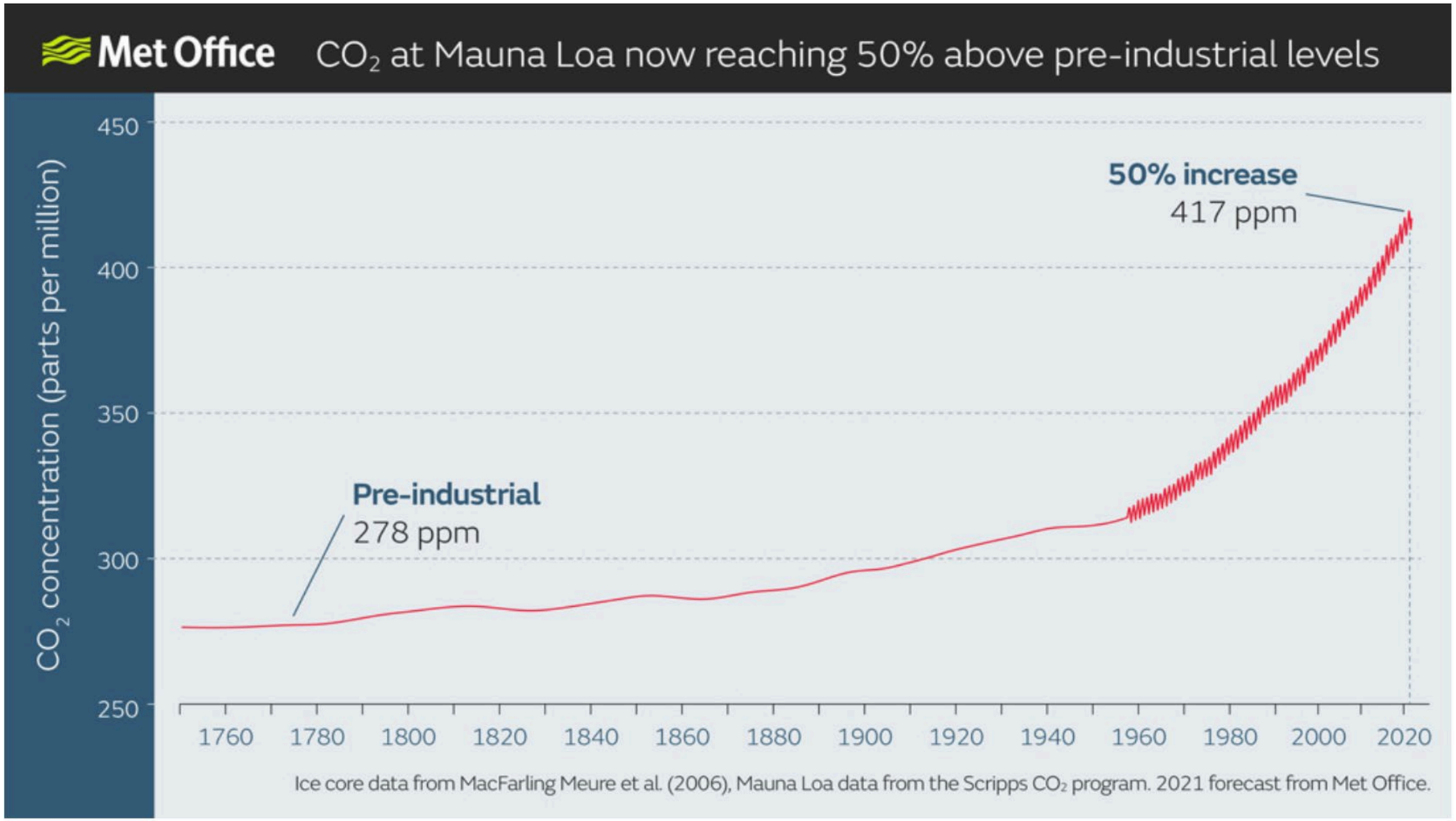
Fossil fuel burned for energy
Wood burned for energy
Forest fires all emit to atmosphere

AFTER ONE YEAR
46% remains in atmosphere
25% is removed by oceans
29% is removed by forests



https://essd.copernicus.org/articles/14/4811/2022/

50% CO_2 increase in the atmosphere since 1750

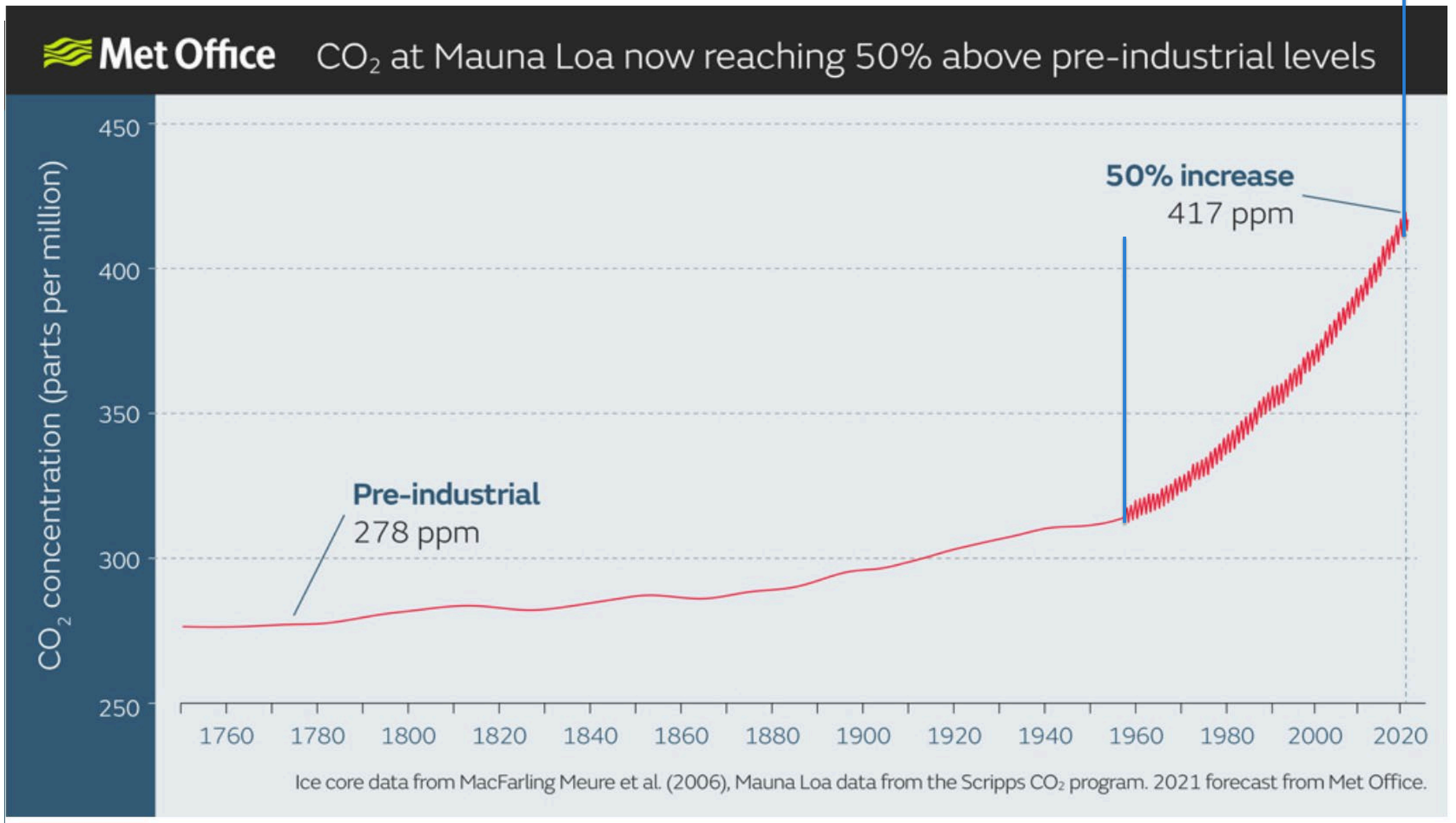


One-third
of this added CO_2
is from
deforestation
and
Soils degradation

Global atmospheric CO2 concentrations from 1700 to 2021. Credit: Met Office.

https://www.carbonbrief.org/met-office-atmospheric-co2-now-hitting-50-higher-than-pre-industrial-levels/

WHAT WOULD HAPPEN



542 ppm X

IF forests did not remove from the atmosphere **29% of annual emissions** from all **Sources?**

Global atmospheric CO2 concentrations from 1700 to 2021. Credit: Met Office.

https://www.carbonbrief.org/met-office-atmospheric-co2-now-hitting-50-higher-than-pre-industrial-levels/

RECENT DISCOVERIES

Forests are capable of storing twice as much carbon if not harvested

2x

Erb et al. 2018
https://www.nature.com/articles/nature25138

RECENT DISCOVERIES

Half the carbon in multi-aged mature forests is in largest 1% of trees

1% = 50%

Lutz et al 2018

https://onlinelibrary.wiley.com/doi/abs/10.1111/geb.12747

RECENT DISCOVERIES

Just 3% of the trees in Oregon National Forests were greater than 21” in diameter but held 42% of the carbon

3% = 42%

Mildrexler et al. 2020
https://onlinelibrary.wiley.com/doi/abs/10.1111/geb.12747

RECENT DISCOVERIES

Allowing trees to continue growing accumulates the most carbon out of the atmosphere much more rapidly than planting new trees

PROFORESTATION

Moomaw et al. 2019
https://www.frontiersin.org/articles/10.3389/ffgc.2019.00027/full

HOW DO WE GET BIG TREES?

LET MORE OF THEM GROW!

Proforestation Management
managing forests without harvest
to reach their potential for biodiversity and carbon accumulation in trees and soils

Larger trees in older and growing forests accumulate the most atmospheric carbon over time, and store it in the wood of their trunk and limbs and in soils

Intergovernmental Panel on Climate Change 2022

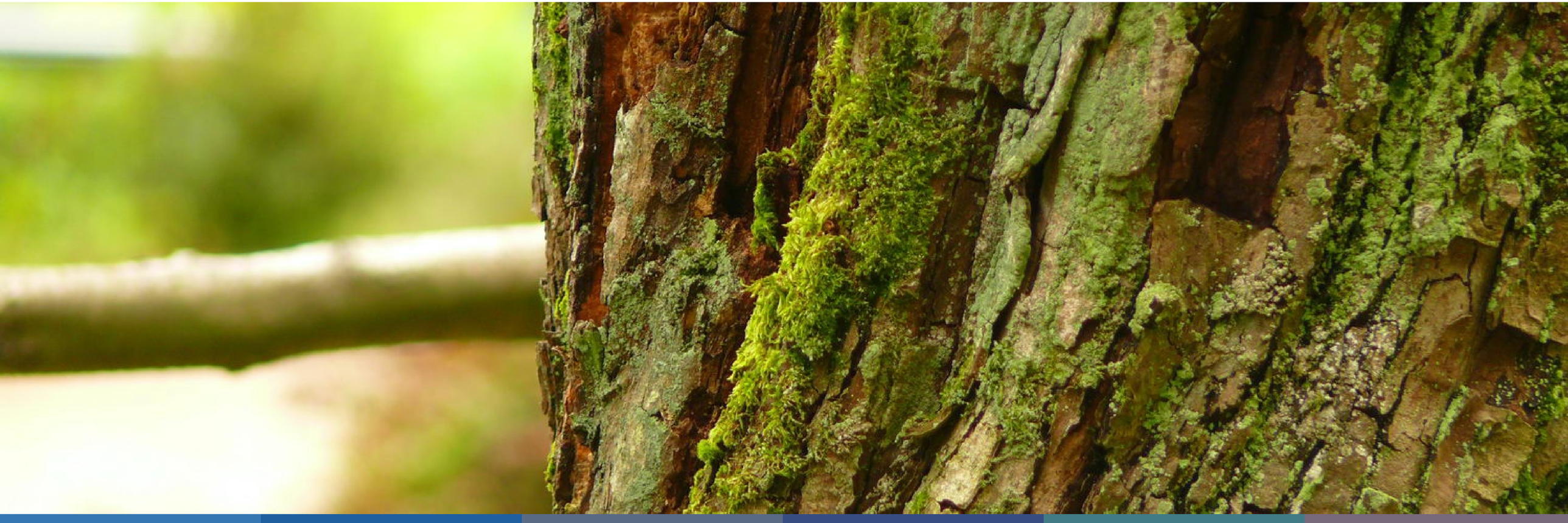
It is also the case that protection of existing natural forest ecosystems is the highest priority for reducing GHG emissions (Moomaw et al., 2019) and restoration may not always be practical (see Section 2.6.5.10).

Climate Change 2022: Impacts, Adaptation and Vulnerability

The Working Group II contribution to the IPCC Sixth Assessment Report assesses the impacts of climate change, looking at ecosystems, biodiversity, and human communities at global and regional levels. It also reviews vulnerabilities and the capacities and limits of the natural world and human societies to adapt to climate change.

URBAN FORESTS

In the changing climate urban forests must provide climate mitigation, adaptation and resilience.



Climate consequences for urban trees

Warmer temperatures and increased **droughts REDUCE GROWTH** and **VIABILITY**

DROUGHT

AIR POLLUTION

DISEASE and **INSECTS**

UPROOTING BY WIND INTENSITY

CURRENT SPECIES MAY NO LONGER BE SUITABLE

Urban Trees Provide Resilience in a Changing Climate

1. As **TREES GROW** they **REMOVE** atmospheric carbon dioxide and STORE the carbon out of the atmosphere reducing the amount of global warming

2. Trees help keep cities **COOLER** Reducing Heat Island Effect
   - **SHADE** reduces heating of pavement and buildings
   - **EVAPORATIVE COOLING** by evapotranspiration

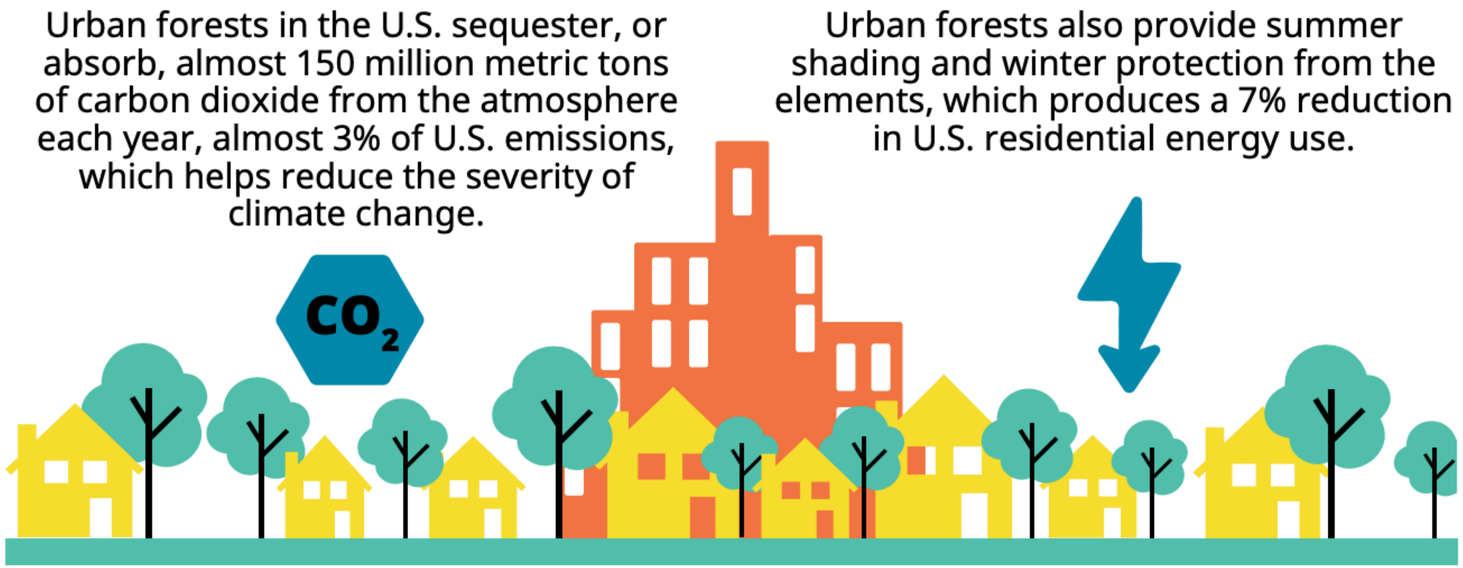
3. Trees **REDUCE FLOODING** by evaporating water from increased frequency and intensity of precipitation and storms

URBAN TREES ACCUMULATE AND STORE CARBON

As trees grow they remove atmospheric carbon dioxide and store the carbon out of the atmosphere

US Urban forests store 700 million tons of C and remove 80 million tons C/year

https://www.fs.usda.gov/research/treesearch/15521



https://www.fs.usda.gov/nrs/pubs/gtr/gtr_nrs203.pdf

Large elm tree in a residential neighbourhood in Québec City. The planting and protection of large species should be strongly encouraged. (Alison Munson), Fourni par l'auteur

THE ANNUAL NET BENEFIT

IS GREATEST FOR LARGE TREES

One study reports
the annual net benefit of

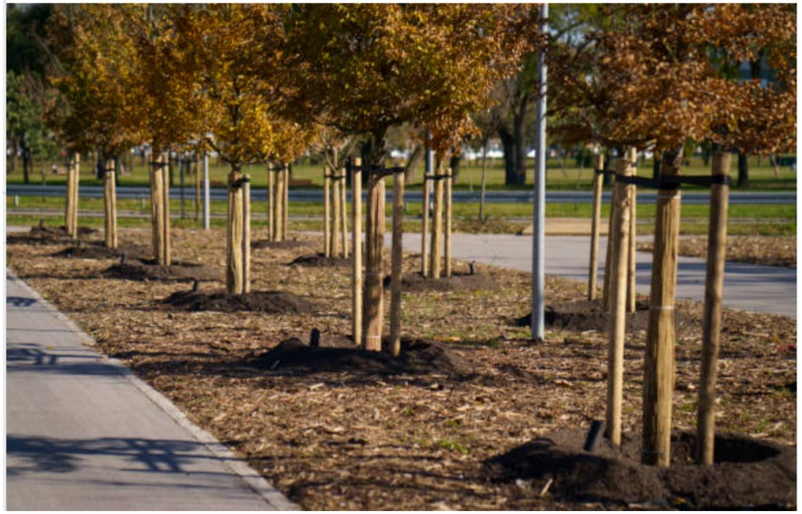
PLANTING LARGE TREE SPECIES is

44% higher than that of a **medium** sized tree species and
92% higher than a **small species** .

Tom Armour, Mark Job and Rory Canavan of Arup
The benefits of large species trees in urban landscapes: a costing, design and management guide
https://www.brebookshop.com/samples/326911.pdf

LITTLE TREES: TOO LITTLE TOO LATE

For a newly planted tree to remove as much carbon as was emitted in producing, transporting and planting, requires **28-36 years or longer**



MAKE YOUR GUESS

HOW MANY TREES DO WE HAVE TO PLANT TO REPLACE ONE LARGE TREE?

TO REPLACE biomass stored in ONE OAK (Quercus Rubra)

DBH: 4.5 ft
HEIGHT: 100 ft

you need to plant:

But we don't have space and other resources, right?

DBH: 12″ Height: 50 ft Age: 30	DBH: 6″ Height: 40′ Age: 16	DBH: 4″ Height: 25′ Age: 10	DBH: 2″ Height: 10′ Age: 7	DBH: 1″ Height: 4.5′ Age: 3
OAKS NEEDED	OAKS NEEDED	OAKS NEEDED	OAKS NEEDED	OAKS NEEDED
35	151	472	3,068	48,061

Source: Robert Leverett, Martin Tušer, FIA COLE model, 2021, published at www.treeib.com

If the wood from the tree is burned, the numbers has to be doubled.

Carbon accumulation in growing trees

The Size and The Growth are BOTH crucial

A tree, which does not grow, does not remove carbon from the atmosphere. But even if a small young tree grows very fast and a large tree grows very slowly, the performance of the young tree will be far lower.

AGE 100 y

DBH: 4.46 ft **Carbon storage**
Height: 100 ft **15,340 lbs**

	Carbon added annually lbs	Annual DBH gain in	Annual height gain ft
POOR	61	0.04	0.1
	235	0.2	0.3
BEST	438	0.2	1.3

AGE 30 y

DBH: 12 inch **Carbon storage**
Height: 50 ft **436 lbs**

Carbon added annually lbs	Annual DBH gain in	Annual height gain ft
8	0.04	0.3
54	0.3	1.0
250	0.5	2.0

AGE 7 y

DBH: 2 inch **Carbon storage**
Height: 10 ft **5 lbs**

Carbon added annually lbs	Annual DBH gain in	Annual height gain ft
0.3	0.04	0.1
1.3	0.2	0.3
4.4	0.3	3.3

Source: Martin Tuser, simulation on Robert Leverett FIA COLE model, 2021

PROPOSED ADDITIONAL GOALS

FOR URBAN TREES IN A CHANGING CLIMATE

MAXIMIZE CLIMATE MITIGATION AND ADAPTATION SERVICES

by keeping more large trees and promote their growth

PROPOSED ADDITIONAL GOALS

FOR URBAN TREES IN A CHANGING CLIMATE

MAXIMIZE CLIMATE MITIGATION AND ADAPTATION SERVICES

by keeping more large trees and promote their growth

ADDITIONAL COOLING as temperatures rise

REDUCE FLOODING from increased number of intensified rainfalls

REMOVE HEAT TRAPPING CARBON DIOXIDE from the atmosphere and stores the carbon in trees and soils

VAST VOLUME OF CO-BENEFITS

Worcester case

Removal **of 30,000** trees in Worcester MA to eliminate Asian Long Horned Beetle led to an increase of **15% in electricity use for summer cooling**. https://digital.wpi.edu/pdfviewer/zg64tm55j

Other tree depleted areas of the city have 9°F higher air temperature than tree-lined streets https://www.telegram.com/story/news/2022/07/29/heat-island-effect-worcester-weather-hot-temperatures-urban-massachusetts-wpi/10120853002/

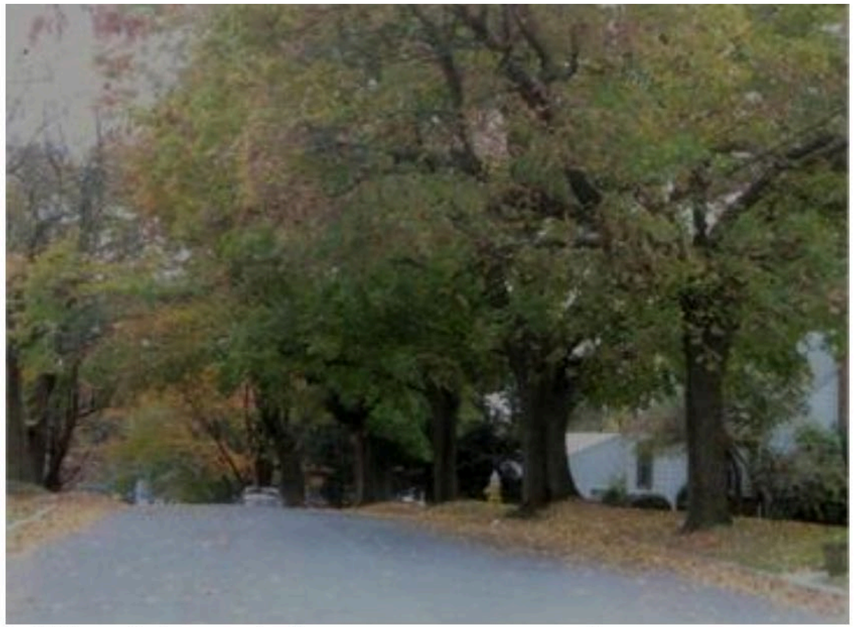


Figure 1: Hillcroft Avenue before trees were removed

Figure 2: Same location on Hillcroft Ave. after removal

Cooling function

Making cities livable

CRUCIAL

- SIZE
- GROW
- SPECIES
- WATER

CRUCIAL

SIZE

GROW

SPECIES

WATER

ONE OAK

(Quercus Rubra)

DBH: 4.5 ft

HEIGHT: 100 ft

Per year

Potential evapotranspiration

5,268 ft^3

Potential cooling

101,694 kWh

Source: Martin Tuser, simulation on i-Tree ECO and own calculations based on M Pavelka data, CzechGlobe, 2023

Vast amount of heat energy removed by a single large oak

Potential water evaporated by a single large oak in one year

40,000 gal of water

This is the amount of electricity to air condition 12 average US homes for one year

Provide el;ectricity to ten avrage U.S. h0omes for one year

Heat energy removed by evaporation

102,000 kWh

This amount of energy can drive an electric car 400,000 miles

Source: Martin Tuser, simulation on i-Tree ECO, Bill Moomaw calculations 2023

Shade also cools by preventing streets and buildings from absorbing heat

Tulsa Oklahoma
https://www.strongtowns.org/journal/2016/6/26/the-magic-of-tree-lined-streets-1

Cooling function

Making cities livable

TO REPLACE cooling effect of ONE OAK (Quercus Rubra)

DBH: 4.5 ft
HEIGHT: 100 ft

DBH: 12″ Height: 50 ft Age: 30	DBH: 6″ Height: 40′ Age: 16	DBH: 4″ Height: 25′ Age: 10	DBH: 2″ Height: 10′ Age: 7	DBH: 1″ Height: 4.5′ Age: 3
OAKS NEEDED	OAKS NEEDED	OAKS NEEDED	OAKS NEEDED	OAKS NEEDED
4	13	33	152	415

Source: Martin Tuser, simulation on i-Tree ECO, 2023

Limitations of cooling by urban trees

WE CANNOT EXPECT
huge cooling effect
from LARGE TREE when

WATER IS NOT AVAILABLE.

WE CANNOT EXPECT
huge cooling effect
from

SMALL CROWN TREE.

WE CANNOT EXPECT
huge cooling effect
from

DROUGHT RESISTANT TREE.

Meanwhile in The IDEAL CITY

Value of urban forest

Replacement based on carbon stored in removed tree. One planted tree replaces 1,3 lb of caron

Proactive acting policies in place, 200 large trees were saved from removal, ongoing efforts for sequestering additional carbon

Time: 5 years

Sample: 30 000 trees with DBH ≥ 10 inch / 25 cm

Urban forest 3000 trees	Value
Carbon stored	$ 32 976 000
Carbon added naturally (5 years)	$ 2 198 400
Carbon added additionally (5 years)	$ 3 051 746
Total	**$ 38 226 146**

Saving 200 trees / 5 years	Value
Saved carbon stored	$ 146 560
Saved sequestration potential (5 years)	$ 15 022
Planting costs savings	$ 9 272 727
Land costs savings / 500 ft^2 / tree	$ 283 333 333
Saved emissions from plating	$ 2 448 000
Total	**$ 295 215 643**

Value of urban forest

Per 5 years

Urban forest (30,000 trees), DBH 10 inch+	Volume / metric ton	Price per metric ton CO2	CO2 / tons	Value
Carbon stored	90.000	$ 100	329 760	$ 32 976 000
Carbon added naturally	6.000	$ 100	21 984	$ 2 198 400
Carbon added addtionally	8.329	$ 100	30 517	$ 3 051 746
Total				**$ 38 226 146**

Value of urban forest

In 5 years

Saving 200 large trees	Volume / metric ton	Price per metric ton CO2	CO2 / tons	Value
Carbon stored	400	$ 100	1 466	$ 146 560
Carbon added (in 5 years)	41	$ 100	150	$ 15 022

Other savings	units	price per unit	Value
Replacement 200 trees (68 per 1 tree)	13.600	$ 682	$ 9 272 727
Saved emissions (1,8 tons CO2 per 1 tree)	24.480	$ 100	$ 2 448 000
Saved land costs (500 ft^2 per tree)	680.000	$ 417	$ 283 333 333
Total			**$ 295 215 643**

WORLD CARBON MARKET

TO FINANCE ADDITIONALITY

SIZE	Mandatory m. $760 Bn., Voluntary m. $2 Bn.
GROWTH	From $2 to $1600 per ton. From $2 Bn. to $50 Bn.
QUALITY	Not enough high quality compensations.
PILOT	Raised more than $900 for a single tree

IT MAKES ECONOMICAL AND ENVIRONMENTAL SENSE

to use trees we already have

to mitigate climate change and use the current infrastructure to adapt to climate change.

ADAPTING THE PRACTICE OF URBAN FORESTRY AS THE CLIMATE CHANGES

time urgency

Need to recognize time urgency of maintaining urban trees as climate changes

all factors

Need to consider all factors that influence the health of trees

differentiate

Need to differentiate between services provided by small and large trees

cost of replacement trees

Production and transportation cost of replacement trees is often greater than maintenance of existing trees

proactive care

The default needs to be proactive care rather than tree removal

care of current trees

Prioritize care of current trees over planting new ones

altering the infrastructure of concern

Address safety considerations by altering the infrastructure of concern rather than replacing large older trees with younger smaller trees

Fewer large trees provide far more services and benefits than many more smaller trees

CAN THIS TREE BE SAVED

SHOULD IT BE SAVED?

YES

YES

YES!

This one was not saved

"It might have been rotten and fall on the house!"

IT WAS NOT ROTTEN!

CALL FOR RESULTS REPLICATION

REGROW ON STRESSED TREES

Regrowth of foliage on conifers was observed on a testing site in two cases in 2019 and 2023.

If the results can be replicated, extended to deciduous trees, and the cause confirmed, it would greatly contribute to removing carbon from the atmosphere.

New growth responded to a significant watering dose.


SEPTEMBER 6, 2019
Picea Abies, 35 years

July 31, 6, 2023

Pinus Nigra 40 years

LET US ADAPT

THE PURPOSE OF URBAN FORESTRY TOGETHER

TO MEET THE CLIMATE CHALLENGE

We call on all scientists, companies and governments to search and implement all possible ways to maximize ecosystem services of the trees we have!

Join the international movement to Protect Large Trees in Urban Settings (PLTUS)

Declaration to Protect Large Trees in Urban Settings

- Large trees provide much greater services and amenities in Urban settings than do smaller trees
- They are especially important in providing mitigation, adaptation and resilience in a changing climate
- The high mortality rate of urban trees has lead to urban settings that have relatively few large trees to provide these essential services
- It is more carbon intensive and costly to continuously replace urban trees that do not survive in current urban settings

THEREFORE BE IT RESOLVED

- It is essential to recognize **time urgency to** Protect Large Trees in Urban Settings to accumulate and store more carbon out of the atmosphere as climate changes
- The default needs to be **proactive care** rather than tree removal
- Prioritize **care of current trees in appropriate urban settings** over planting new ones
- Address **safety considerations** by **altering the infrastructure of concern** rather than replacing large older trees with younger smaller trees

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SUGGEST