Forests, Carbon, and Solar PV Projects

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The author declares no conflict of interest.

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Recent estimates of carbon sequestration in temperate forests

	(Luyssaert, 2008)	(Richardson, 2013)	(Curtis, 2018)
old growth forest	**0.97**	(na)	**1.8**[1]
young growth forest	(na)	**0.23**	**1.2**[1]

Estimates of carbon sequestration in 1000s of kg C ("tonnes") per acre per year measured and reported from various regions.

[1] Mean calculated from Figure 3(a) of (Curtis, 2018).

Estimates of forest carbon sequestration converted to MWh per annum per acre in New England

New England (EPA)	fossil fuels only	all fuels
old growth forest, Luyssaert	**8.7** MWh/acre/year	**15** MWh/acre/year
old growth forest, Curtis	**16** MWh/acre/year	**28** MWh/acre/year
young growth forest, Richardson	**2.0** MWh/acre/year	**3.5** MWh/acre/year

MWh equivalents from estimates of sequestration of carbon from grid electricity per acre per year from two mixes, fossil fuels only, and all mixes on grid, New England, per recent EPA figures.

Years of generation from Shuttleworth Field project per acre needed to offset carbon sequestration per acre

Shuttleworth Field is estimated to produce 215.8 MWh/acre/year.

New England (EPA)	fossil fuels only	all fuels[2]
old growth forest, Luyssaert	**0.04** years	**0.07** years
old growth forest, Curtis	**0.07** years	**0.13** years
young growth forest, Richardson	**0.009** years	**0.02** years

Rationale: Convert forest stand sequestration rate into MWh using carbon pollution rates of two kinds of grid electricity, per year per acre. Then divide that by generation after capacity factors expected from Shuttleworth Field project per year per acre.

[2] This is a bit problematic because it includes renewables in the mix.

Days of generation from Shuttleworth Field project per acre needed to offset carbon sequestration per acre

Shuttleworth Field is estimated to produce 215.8 MWh/acre/year.

New England (EPA)	fossil fuels only	all fuels[3]
old growth forest, Luyssaert	**15** days	**26** days
old growth forest, Curtis	**26** days	**47** days
young growth forest, Richardson	**3** days	**7** days

Rationale: Convert forest stand sequestration rate into MWh using carbon pollution rates of two kinds of grid electricity, per year per acre. Then divide that by generation after capacity factors expected from Shuttleworth Field project per year per acre. Then divide by 365.25 days per year.

[3] This is a bit problematic because it includes renewables in the mix.

An independent calculation . . .
(Durrenberger, 2015)

- Durrenberger has calculated comparisons of solar generation with trees *even on personal properties* and concluded that the environmental benefit of felling trees to boost PV generation outweighs keeping the trees.
- His 8 kW PV system produces 8.7 MWh per year, which, he calculates is the equivalent of 50 trees worth of avoided emissions..
- Durrenberger recommends planting compensatory trees elsewhere, perhaps trees which are more suitable for the local ecosystem.
- ***I*** would also suggest rehabilitating *badly abused* wetlands, since wetlands in New England sequester *more* carbon than trees per acre, and they are abused, particularly in Westwood. Runoff from pesticide treated properties is a specific concern.

A little history about forests and carbon sequestration ...

- Much work before 2000 was based upon the pioneering work of **(Odum, 1969)**, based upon the knowledge of the time.
- His arguments were that young growth forests captured carbon rapidly, sequestering it in woodstock, and that as stands aged, they sequestered less over time until a limit was approached.
- In the late 1980s sensors and systems became available *to actually measure* CO_2 intake and emissions from forests. Experiments were constructed for long term monitoring, including knowing what kinds and ages of trees were nearby. **FLUXNET**.
- These experiments took 30 years to develop series indicative of forest CO_2 processes (and many other aspects), showing old growth forests really did not reach a limit of sequestration, and young growth forests, depending upon the nature of the disturbance that created them, could actually be *net carbon sources*.

Soil flora and fungi are key

- Modern work reveals that microbial flora in soils and especially mycorrhizal fungal communities control initiation of forest stages in succession, and are key to millennial scale storage of carbon in soils.
- These communities take time to develop, and are incompatible with rough-and-tumble young growth forests.
- Young growth forests can be carbon sources if the old growth forest that preceded them was deeply disturbed (e.g., for agriculture) so the previously stored soil carbon leaked out and was re-oxidized to CO_2.
- New appreciation for carbon sinks, especially in New England: wetlands. To serve, these need to remain *undisturbed* by novel inflows or bank perturbations.

Agrivoltaics

- "Under solar panels, crops thrive", 2018
- "Doubling up crops with solar farms could increase land-use efficiency by as much as 60%", 2017
- "Renewable Energy: Smart greenhouses generate solar power and grow crops at the same time", 2017
- "Farms that grow crops and solar power together", 2017

Summary

- 70% of U.S. Eastern forests are aged between 50 and 100 years old (Pan, 2011). Also about 70% of New England forests are privately owned.
- Different features of forests move people to want to preserve them. It's important to *know* what they really are and aren't. And it's important to *know* what solar PV is and isn't.
- Climate disruption and *landscape change due to human development* are the two biggest threats to forests, ecosystems, diversity, and life.
- Nearly *all* of our landscape is *unnatural*, having been destroyed by the massive deforestation which happened after colonization 3 centuries ago.
- Local landscapes are *still* emitting CO_2 from decomposition of those ancient old growth forest soils. Local streams and rivers have banks and bottoms filled with silt from colonial farms.
- It is *really late* to start taking action on climate changing emissions. We need to change ***fast***. Solar PV is the cheapest and easiest way. And it brings many collateral benefits, including cheaper energy, more jobs, better health.
- We have the *luxury* of electricity, and that comes at the expense of people who live near *unhealthy*, *dirty*, and *ugly* fossil fuel electric plants, tanks, pipelines, and drilling sites. Fair is fair.

(Supporting Slides)

Life cycle emissions for various energy sources
(Dones, 2004)

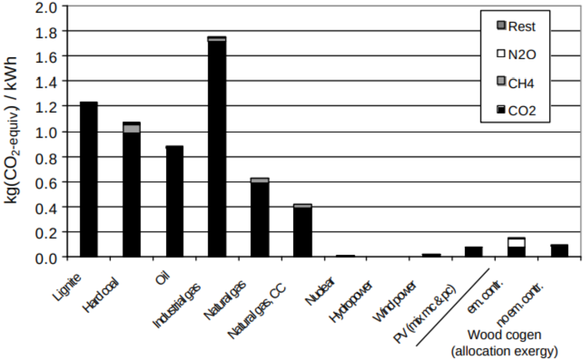


Fig. 6: Overview of full chain GHG emissions for different electricity generation systems [1]. Lignite, hard coal, oil, industrial gas, natural gas, and nuclear refer to energy systems associated with average UCTE power plants for the year 2000. Natural gas CC refers to combined-cycle power plants utilising the current best technology, and with gas supplied by the European high-pressure grid. The renewables — hydropower, wind power, photovoltaic, wood — refer to data pertinent to Switzerland.

Forest and wildlife densities in New England during the last 400 years (Foster, 2002)

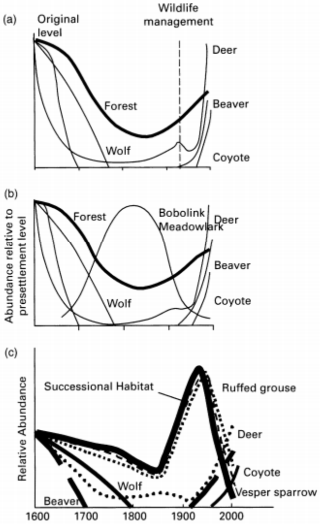
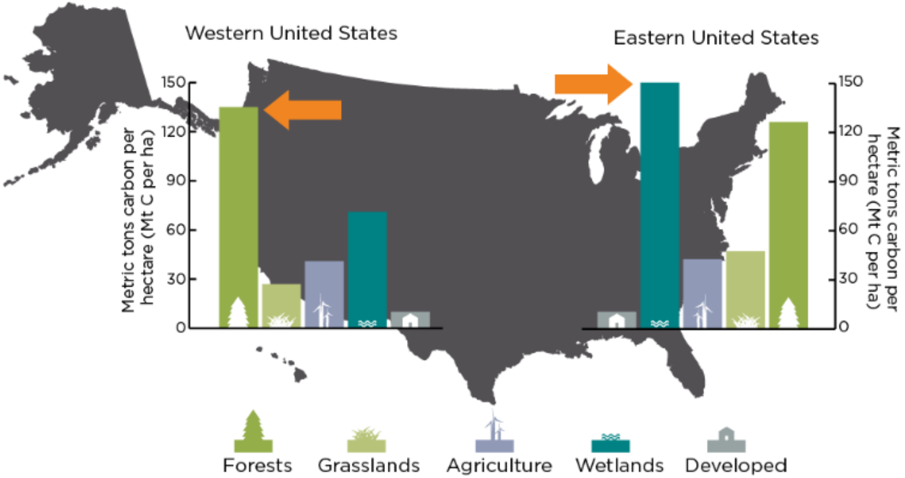
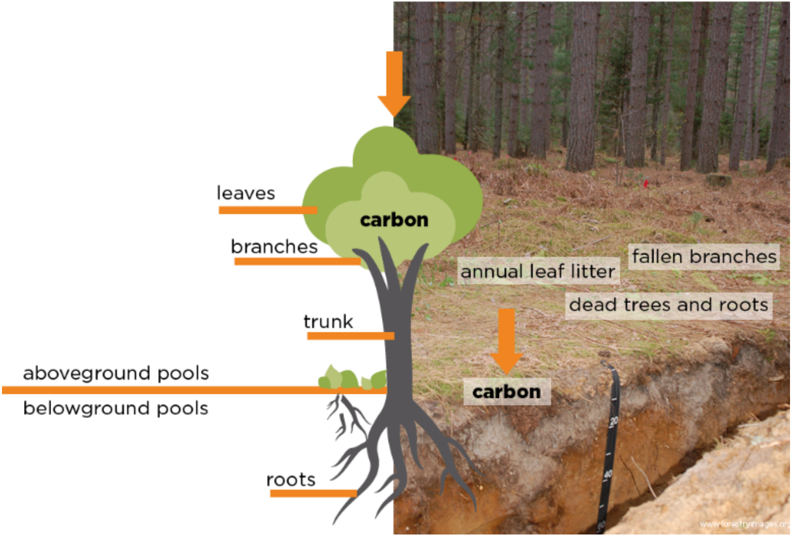


Figure 2 Three related but contrasting depictions of land cover and wildlife dynamics in New England that highlight the important role that historical research plays in the interpretation of modern conditions and the development of management approaches. The bottom figures (b, c)

Wetlands are big sinks in the East (MSU-FCPP, 2020)

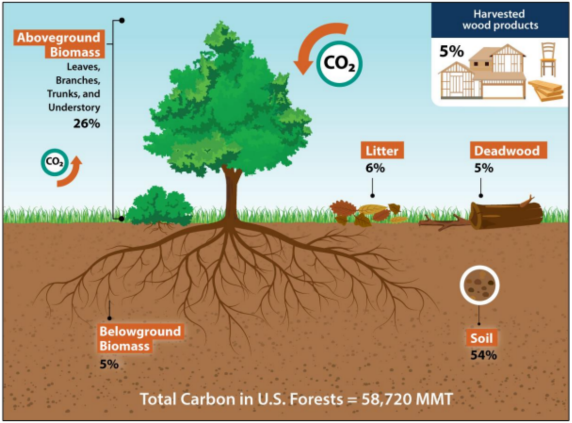


Places carbon can go in forests (MSU-FCPP, 2020)



How much carbon goes where (MSU-FCPP, 2020)

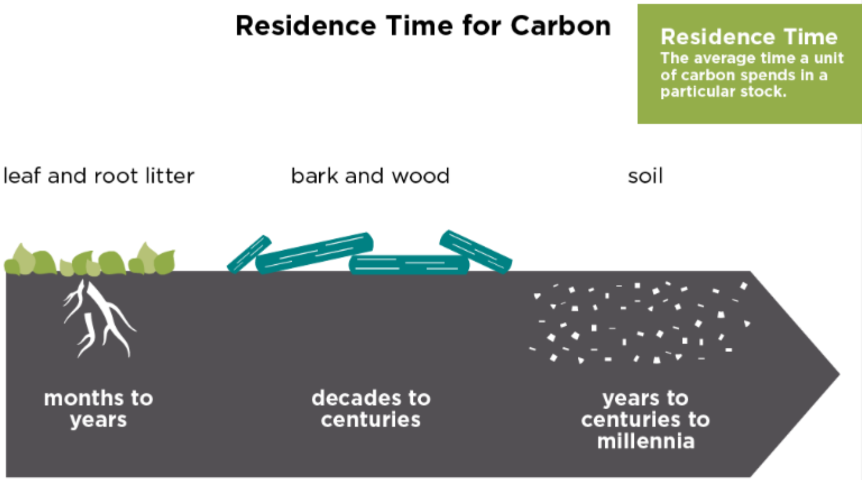
Figure 2. Forest Carbon Pools



Source: CRS, using data for 2019 from EPA, Table 6-12 in Chapter 6, "Land Use, Land-Use Change, and Forestry," in *U.S. National Greenhouse Gas Inventory*, EPA 430-R-20-002, April 13, 2020.

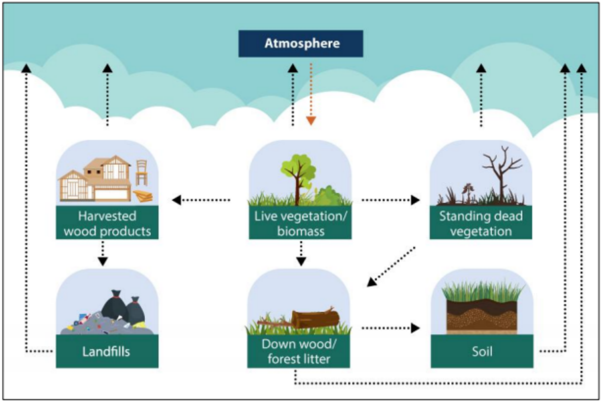
Notes: MMT = million metric tons. Percentages based on the total forest carbon stock estimate for 2019 (see **Table 3**).

. . . And how long it remains (MSU-FCPP, 2020)



Choices and flows (MSU-FCPP, 2020)

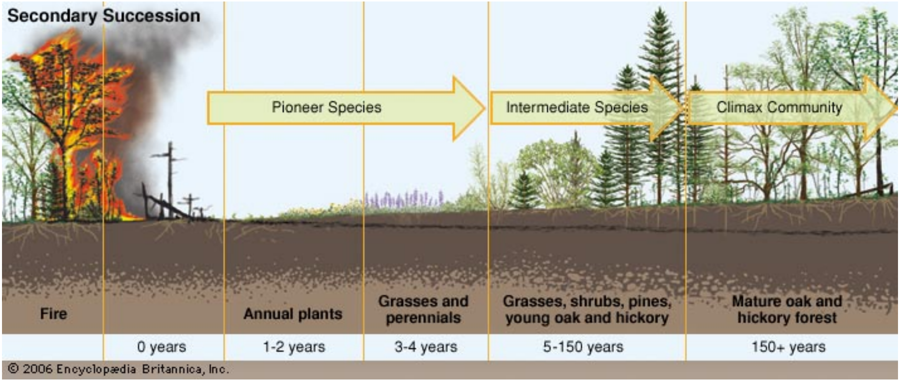
Figure 4. Forest Carbon Cycle



Source: CRS, adapted from Maria Janowiak et al., *Considering Forest and Grassland Carbon in Land Management*, USDA Forest Service, GTR-WO-95, June 2017, p. 4.

Notes: This figure reflects a stylized diagram of the multiple pathways through which forest carbon flows, but it does not reflect the amount or time frame of the carbon exchange. Standing dead vegetation and down wood/forest litter are represented separately to illustrate the different pathways through which the carbon in aboveground biomass flows upon death.

Forest successions



References, 1

(Luyssaert, 2008)
S.Luyssaert, E.D.Schulze, A.Borner, A.Knohl, D.Hessenmoller B.E.Law, P.Ciais, J.Grace, "Old-growth forests as global carbon sinks" (2008), *Nature* **455**: 213–215.

(Holl, 2020)
K.D.Holl, P.H.S.Brancalion, "Tree planting is not a simple solution", *Science* (8 May 2020), **368**(6491), 580-581.

(Hoover, 2020)
K. Hoover, A. A. Riddle, "Forest carbon primer", *Congressional Research Service*, **R46312** (5 May 2020), `www.crs.gov`.

(Curtis, 2018)
P.S.Curtis, C.M.Gough, "Forest aging, disturbance and the carbon cycle", *New Phytologist* (2018), **doi:** 10.1111/nph.15227.

(Odum, 1969)
E. P. Odum, "Strategy of ecosystem development", *Science* (1969), **164**: 262-270.

References, 2

(Clemmensen, 2015)
K.E.Clemmensen, R.D.Finlay, A.Dahlberg, J.Stenlid, D.A.Wardle, B.D.Lindahl, "Carbon sequestration is related to mycorrhizal fungal community shifts during long-term succession in boreal forests", *New Phytologist* (2015), **205**: 1525-1536, **doi**: 10.1111/nph.13208.

(Friend, 2014)
A.D.Friend, *et al*, "Carbon residence time dominates uncertainty in terrestrial vegetation responses to future climate and atmospheric CO_2", *Proceeds of the National Academy of Sciences* (4 March 2014), **111**(9), 3280-3285.

(Lu, 2017)
Y. Lu, *et al*, "Transient dynamics of terrestrial carbon storage: mathematical foundation and its applications" (2017), Biogeosciences **14**, 145–161.

References, 3

(Zhou, 2015)

T. Zhou, *et al*, "Age-dependent forest carbon sink: Estimation via inverse modeling" (2015), *Journal of Geophysical Research: Biogeoscieces* **120**, 2473-2492, **doi**:10.1002/2015JG002943.

(McGarvey, 2015)

J.C.McGarvey, J.R.Thompson, H.E.Eptstein, H.H.Shugart, Jr, "Carbon storage in old-growth forests of the Mid-Atlantic: toward better understanding the eastern forest carbon sink" (2015), *Ecology* **96**(2), 311-317.

(Richardson, 2013)

M.Richardson, M.Stolt, "Measuring soil organic carbon sequestration in aggrading temperate forests", *Soil Science of America Journal* (2013), **77**:2164-2172. **doi**:10.2136/sssaj2012.0411.

(MSU–FCCP, 2020)

Forest Carbon and Climate Program, Michigan State University, Open Resource Library, and other sources (2020).

References, 4

(Dones, 2004)

R.Dones, T.Heck, S.Hirschberg, "Age-dependent forest carbon sink: Estimation via inverse modeling" (2015), *Journal of Geophysical Research: Biogeoscieces* **120**, 2473-2492, **doi**:10.1002/2015JG002943.

(Pan, 2011)

Y.Pan, J.M.Chen, R.Birdsey, K.McCullough, L.He, F.Deng, "Age structure and disturbance legacy of North American forests" (2011), *Biogeosciences* **8**:715-732.

(Durrenberger, 2015)

M. Durrenberger, “Tree Math 2: Solar vs. Trees, What’s the Carbon Trade-off?”, *The Energy Miser*, 24 September 2015, blog post.

(Foster, 2002)

D.R.Foster, G.Motzkin, D.Bernardos, J.Cardoza, "Wildlife dynamics in the dhanging New England landscape", *Journal of Biogeography* (October-November, 2002), **29**(10/11), 1337-1357.