Mathematical Model of the Ecosystem

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Nomenclature

$H_{ypf} = n_{ybp}/n_{ybf}$=mole density ratio of compound y on boundary b between entities p and f. Quantities H_{ypf} are thermostatic properties which can be measured for each boundary and compound.

n_{yp}= density of compound y of entity p (mole/m^3)

n_{yf}= density of compound y of entity f (mole/m^3)

$\dot{N}_{ypf} = A_{pf}\dot{N}''_{ypf}$ = flow of compound y from entity p to entity f per area (mole^{+1}s^{-1}m^{-2})

$\frac{dN_{yf}}{dt}$= increasing rate of compound y of entity f (mole^{+1}s^{-1})

$\dot{N}_{ypf} = -\dot{N}_{yfp}$ = flow of compound y from entity p to entity f (mole^{+1}s^{-1})

N_{ae}=number of element a of the ecosystem

N_{ap}= number element a of entity p

N_{yp}=number of compounds y in entity p

N_{Ce} = number of carbon atoms of the ecosystem.

$N'''_{CO2,I}$= mole density of CO_2 in the atmosphere (mole^{+1}m^{-3})

$N''_{Y,B}$= mole density of photosynthetic biomass in photosynthetic biomass entity B (mole/m^2)

$\dot{R}_{rf}$ =rate of reaction r of entity f

N_c= number of compounds

β_{ay}=number of element a of compound y

ν_{yr}=coefficient of compound y (mole/reaction) in reaction r

Abstract

In this paper standard procedures of thermodynamics have been applied for mathematical modeling of the ecosystem. The ecosystem was divided into 9 parts (hence forward entities) and compound and element balances were written for the entities. The atmosphere and waters of the globe (hence forward the watersphere) are continuous entities which are in contact with discrete entities of the atmosphere and the watersphere and with each other. Mathematically the model leads to a group of $N_e \cdot N_c$ differential equations (N_e=number of entities, N_c=number of compounds) which must be solved numerically with conservation equations of elements as bounding conditions. In the simplest physically relevant case ecosystem model contains 9 entities 12 compounds and 5 elements corresponding to 108 differential equations and 5 bounding conditions. Fortunately, without significant error can be assumed that compounds of the entities are in thermodynamic equilibrium whereupon the ecosystem model simplifies to $N_e - 2$ balance equations of solvent compounds of

discrete entities which must be solved with conservation of elements as bounding conditions, solubility equations of boundaries of discrete entities and the atmosphere and the water sphere and conservation equations of the elements. Calculations prove that 1) all fossil fuels can be used without increasing CO_2 concentration in the atmosphere whereupon IPCC's claim that use of fossil fuels increases CO_2 concentration in the atmosphere is wrong. 2) Returning fossil carbon to the cycle of nature increases remarkably photosynthesis of the ecosystem and thus sustainable use of biomass and production of food.

Introduction

Dogma of IPCC is that 1) using fossil fuels increases CO_2-concentration in the atmosphere which 2) causes disastrous global warming. Reference (1) shows that claim 2) is wrong whereupon mankind's challenge is not CO_2-concentration in the atmosphere but sustainable supply of food and energy when fossil fuels within the few next decades deplete.

Mankind changes CO_2-concentration in the atmosphere mainly by use of fossil fuels and biomass. Oxidation of fossil fuels causes CO_2 flow to the atmosphere but CO_2-concentration in the atmosphere increases only if CO_2 to the atmosphere is larger than from the atmosphere whereupon Dogma is per se wrong. This paper proves that carbon of all presently known fossil fuel reserves can be returned to the carbon cycle of nature without increasing CO_2-concentration in the atmosphere whereupon also claim 1) of Dogma is wrong.

Dogma has caused enormous damage among others

1. by causing demolishing of energy technically necessary fossil power plants which increase photosynthesis of the ecosystem
2. by replacing them by billions of euros energy technically invalid and ecologically useless wind turbines
3. by distorting by legislation and political guidance competition between energies and technologies
4. by guiding R&D to economically and ecologically invalid projects
5. by distorting liberty of scientific research by funding which is reserved only for the Dogma supporting research
6. by emissions trade which can be parallelized with indulgence trade and by gigantic "carbon footprint" business which has no influence on climate
7. by causing worldwide angst of ignorant children and young people like Greta Thunberg who categorically believe in IPCC.

Governments compete with declarations on earliest dates of "carbon neutrality" of their country. Long term influences of these aims on the ecosystem can be known only by thermodynamically correct ecosystem models like the one of this paper. Even though the ecosystem model of this paper is approximate it shows that the aim to minimize amount of carbon in the carbon cycle of nature and CO_2 in the atmosphere is disastrous for mankind because it minimizes diversity of nature, photosynthesis of the ecosystem, and sustainable use of biomass for production of food and energy.

Theory

Mole balance of compound c of entity e (part of the ecosystem) is

$$\frac{dN''_{ce}}{dt} = \sum_{r=1}^{N_r} \nu_{cr} \dot{R}''_{re} - \dot{N}''_{eu} \qquad (1)$$

$\frac{dN''_{ce}}{dt}$= increasing rate of amount of moles of entity e (mole^{+1}s^{-1} m^{-2})

$\dot{R}''_{re}$ = rate of reaction r of entity e (mole^{+1}s^{-1}m^{-2})

$\dot{N}''_{eu}$ =use of entity e (mole^{+1}s^{-1}m^{-2})

Without significant error can be assumed that thermodynamic equilibrium prevails in all entities of the ecosystem and that compound density gradients of the entities are small whereupon

$$\frac{n_{cpb}}{n_{cfb}} = H_{cpf} = \frac{n_{cp}}{n_{cf}} \qquad (2)$$

Number of compounds c of entity p N_{cp} is bound by the number of elements of the ecosystem N_{ae} , which is constant of nature. Conservation of element a can be expressed mathematically by equation (3):

$$N_{ce} = \sum_{i=1}^{N_e} \sum_{j=1}^{N_c} \beta_{ej}\, N_{ci} \qquad (3)$$

N_{ce}=number of elements e of the ecosystem

N_{ci}=number of compounds c in entity i

β_{ej}=number of elements e of compound j

Each discrete entity is assumed to consists of one solvent compound and several soluble compounds. Without significant error can be assumed that mole density of solvent compound is independent of mole densities of soluble compounds of the entity. So, when number of moles of solvent compounds of discrete entities are calculated by equations (1) mole densities of soluble compounds of the entity are determined by mole densities of the watersphere and the atmosphere via equations (2). Amounts of compounds of the atmosphere are determined by equations (3) and compound density ratio of the watersphere and the atmosphere by equilibrium condition $\frac{n_{cw}}{n_{ca}} = H_{cwa}$. When initial mole densities of solvent compounds of discrete entities are known, equations (1) … (3) form a mathematically closed problem of $N_a$differential equations which must be solved with N_a conservation equations of elements as bounding conditions.

Applied calculations

Entities, compounds, and reactions

Table 1: Entities of the ecosystem: Alive biomass, Dead biomass, Alive plankton, Dead plankton, Natural gas, Oil, Coal, the watersphere (oceans, seas, lakes, rivers), the atmosphere.

Entity	**Alive Pl**	**Dead Pl**	**Alive Bm**	**Dead Bm**	**Nat.gas**	**Oil**	**Coal**	**Watersphere**	**Atmosphere**
m2	3.48E+14	3.48E+14	1.64E+14	1.64E+14	5.11E+14	5.11E+14	5.11E+14	3.48E+14	5.11E+14
kg/m2	10	4	10	4	0.249	0.349	1.217	3.94E+06	11190
kg	3.48E+15	1.39E+15	1.64E+15	6.54E+14	1.27E+14	1.79E+14	6.22E+14	1.37E+21	5.72E+18

Contact surfaces between the entities

Table 3 Contact surfaces between entities (10^{14} m^2)3

	Alive plankton	Dead pl	Alive biomass	Dead biomass	Natural gas	Oil	Coal	Water	Atmosphere
Entity	1	2	3	4	5	6	7	8	9
1	0	0	0	0	0	0	0	3.48	0

2	0	0	0	0	0	0	0	3.48	0
3	0	0	0	0	0	0	0	0	1.64
4	0	0	0	0	0	0	0	0	1.64
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	3.48	3.48	0	0	0	0	0	0	3.48
9	0	0	1.64	1.64	0	0	0	3.48	0

Compound flows through bottom surface of entity 8 and upper surface of entity 9 are assumed to be zero.

Henry-coefficients boundaries between entities

Henry correlations for boundary between the atmosphere (entity 9) and the watersphere (entity 8) are presented in thermodynamic manuals. For boundaries of entities 1 … 4 Henry coefficients were set 1.0. Henry coefficients influence the results only via reaction rates of reactions 4 and 7. Because

Reactions

Table 2: Reactions 1,2,3 are oxidation reactions of Natural gas, Oil, and Coal. Reaction 4 is photosynthesis reaction of biomass, Reaction 5 death reaction of photosynthetic biomass, Reaction 6 is oxidation reaction of dead biomass, Reaction 7 is photosynthesis reaction of plankton, Reaction 8 death reaction of photosynthetic plankton, Reaction 9 is oxidation reaction of dead plankton.

Compound		Molemass (g)	Reaction 1	Reaction 2	Reaction 3	Reaction 4	Reaction 5	Reaction 6	Reaction 7	Reaction 8	Reaction 9
H2O	1	18.02	125	72.00	20.34	-33.0		+33.0	-33.0		-33.0
CO2	2	44.01	62.5	67.00	75.93	-46.0		+46.0	-46.0		-46.0
O2	3	32.00	-125	-105.5	-85.6	+51		-51.	+51.0		-51.0
N2	4	28.01			0.56	-0.50		+0.5	-0.50		+0.50
SO2	5	64.06			0.24						
Natural gas	6	1000	-1.00								
Oil	7	1000		-1.00							
Coal	8	1000			-1.00						
Alive biomass	9	1000				+1	-1				
Dead biomass	10	1000					+1	-1			
Alive plan	11	1000							+1	-1	

kton											
Dead plankton	12	1000								+1	-1

Balance equation of compound 9 (Alive biomass)

Compound 9 (Alive biomass) is created only by reaction 4 of entity 3 ($\nu_{9,4} = 1$). Compound 9 is decreased only by reaction 5 of entity 3 ($\nu_{9,5} = -1$). All other reactions r coefficients of compound 9 are zero whereupon balance equation of compound 9 simplifies to

$$\frac{dN''_{9,3}}{dt} = \dot{R}''_{3,4} - \dot{R}''_{3,5} - \dot{N}''_{3u}(t)$$

$\frac{dN''_{9,3}}{dt}$ = increasing rate of entity 3 (mole^{+1}s^{-1}m^{-2})

$\dot{R}''_{3,4} = 7.7 \cdot 10^{-8} \, |N''_3|^{0.881} \left|n_{CO2,3}\right|^{1.0}$ = growing rate of entity 3 (s^{-1}m^{-2})

$|N''_3|$ =absolute value of mole density of entity 3

$\left|n_{CO2,3}\right|$ = absolute value of mole density of CO_2 of entity 3

$\dot{R}''_{3,5} = 3.04 \cdot 10^{-9} |N''_3|^{1.33}$ = decreasing rate of entity 3 (s^{-1}m^{-2})

$\dot{N}''_{3u}(t)$ = = thermal oxidation rate of entity 3 (mole^{+1}s^{-1}m^{-2})

Balance equation of compound 10 (Dead biomass)

Compound 10 (Dead biomass) is created only by reaction 4 of entity 3 ($\nu_{10,5} = 1$) and decreased only by reaction 6 of entity 4 ($\nu_{10,6} = -1$). All other reactions r coefficients $\nu_{12,r} = 0$ whereupon balance equation of compound 12 simplifies to

$$\frac{dN''_{10,4}}{dt} = \dot{R}''_{3,5} - \dot{R}''_{4,6} - \dot{N}''_{4u}(t)$$

$\frac{dN''_{10,4}}{dt}$ = changing rate of entity 4 (mole^{+1}s^{-1}m^{-2})

$\dot{R}''_{4,6} = 0.05 |N''_3|^{1.0}$ = biological oxidation rate of entity 4 (s^{-1}m^{-2})

$\dot{N}''_{4u}(t)$ = thermal oxidation rate of entity 4 (mole^{+1}s^{-1}m^{-2})

Balance equation of compound 11 (Alive plankton)

Compound 11 (Alive plankton) is created only by reaction 7 of entity 1 ($\nu_{11,7} = 1$). Compound 11 is decreased only by reaction 8 of entity 1 ($\nu_{11,8} = -1$). All other reactions r coefficients of compound 11 are zero whereupon balance equation of compound 11 simplifies to

$$\frac{dN''_{11,1}}{dt} = \dot{R}''_{1,7} - \dot{R}''_{1,8} - \dot{N}''_{1u}(t)$$

$\dot{R}''_{1,7} = 4.85 \cdot 10^{-8} H_{CO2,1,9} |N''_1|^{0.9} \left|n_{CO2,1}\right|^{1.0} = 4.85 \cdot 10^{-8} |N''_1|^{0.9} \left|n_{CO2,9}\right|^{1.0}$ = growing rate of entity 1 (s^{-1}m^{-2})

$\left|n_{CO2,1}\right|$ = absolute value of mole density of CO_2 of entity 1

$|N''_1|$ =absolute value of mole density of entity 1

$\dot{R}''_{1,8} = 3.04 \cdot 10^{-9} |N''_3|^{1.33}$ = natural dying rate of entity 1 (s^{-1}m^{-2})

$\dot{N}''_{1u}(t)$ = thermal oxidation rate of entity 1 (mole^{+1}s^{-1}m^{-2})

Balance equation of compound 12 (Dead plankton)

Compound 12 (Dead plankton) is created only by reaction 8 of entity 1 ($\nu_{12,8} = 1$) and decreased only by reaction 9 of entity 2 ($\nu_{12,9} = -1$). All other reactions r coefficients $\nu_{12,r} = 0$ whereupon balance equation of compound 12 simplifies to

$$\frac{dN''_{12.2}}{dt} = \dot{R}''_{1,8} - \dot{R}''_{2,9} - \dot{N}''_{2u}(t) = \dot{R}''_{1,8} - \dot{R}''_{2,9} - \dot{N}''_{2u}(t)$$

$\frac{dN''_2}{dt}$ = increasing rate of entity 2 (mole^{+1}s^{-1}m^{-2})

$\dot{R}''_{2,9} = 0.1|N''_2|^{1.0}$ = biological oxidation rate of entity 2 (s^{-1}m^{-2})

$\dot{N}''_{2u}(t)$ = thermal oxidation rate of entity 2 (mole^{+1}s^{-1}m^{-2})

Balance equation of compound 6 (Natural gas)

The only reaction of compound 6 (natural gas) is reaction 1 (thermal oxidation) whereupon balance equation natural gas is

$$\frac{dN''_{6,5}}{dt} = -\dot{N}''_{5u}(t)$$

$\dot{N}''_{5u}(t)$ = thermal oxidation rate of entity 5 (mole^{+1}s^{-1}m^{-2})

Balance equation of compound 7 (Oil)

The only reaction of compound 7 (oil) is reaction 2 (thermal oxidation) whereupon balance equation natural gas is

$$\frac{dN''_{7,6}}{dt} = -\dot{N}''_{6u}(t)$$

$\dot{N}''_{6u}(t)$ =thermal oxidation rate of entity 6 (mole^{+1}s^{-1}m^{-2})

Balance equation of compound 8 (Coal)

The only reaction of compound 7 (oil) is reaction 2 (thermal oxidation) whereupon balance equation natural gas is

$$\frac{dN''_{8,7}}{dt} = -\dot{N}''_{7u}(t)$$

$\dot{N}''_{7u}(t)$ = thermal oxidation rate of entity 7 (mole^{+1}s^{-1}m^{-2})

Boundary equilibrium of entity 1 (Alive plankton) and entity 8 (the watersphere)

$\frac{n_{c1}}{n_{c8}} = H_{c,1,8}$, c=1 … N_c

When mole densities of compounds of watersphere are known all compound densities in the Alive plankton entity are determined by corresponding Henry coefficients.

Boundary equilibrium of entity 1 (Dead plankton) and entity 8 (the watersphere)

$\frac{n_{c2}}{n_{c8}} = H_{c,2,8}$, c=1 … N_c

When mole densities of compounds of watersphere are known all compound densities in the Dead plankton entity are determined by corresponding Henry coefficients.

Boundary equilibrium of entity 3 (Alive biomass) and entity 9 (the atmosphere)

$\frac{n_{c3}}{n_{c9}} = H_{c,3,9}$, c=1 … N_c

When mole densities of compounds of the atmosphere are known all compound densities in the Alive biomass entity are determined by corresponding Henry coefficients.

Boundary equilibrium of entity 4 (Dead biomass) and entity 9 (the atmosphere)

$\frac{n_{c4}}{n_{c9}} = H_{c,4,9}$, c=1 … N_c

When mole densities of compounds of the atmosphere are known all compound densities in the Dead biomass entity are determined by corresponding Henry coefficients.

Boundary equilibrium of entity 8 (the watersphere) and entity 9 (the atmosphere)

$\frac{n_{c8}}{n_{c9}} = H_{c,8,9}$, c=1 … N_c

When mole densities of compounds of the atmosphere are known all compound densities in the Dead biomass entity are determined by corresponding Henry coefficients.

Carbon balance of the ecosystem

$N_c = \sum_{i=1}^{N_e} \sum_{j=1}^{N_c} \beta_{cj} N_{ji}$

Hydrogen balance of the ecosystem

$N_H = \sum_{i=1}^{N_e} \sum_{j=1}^{N_c} \beta_{Hj} N_{ji}$

Nitrogen balance of the ecosystem

$N_N = \sum_{i=1}^{N_e} \sum_{j=1}^{N_c} \beta_{Nj} N_{ji}$

Oxygen balance of the ecosystem

$N_O = \sum_{i=1}^{N_e} \sum_{j=1}^{N_c} \beta_{Oj} N_{ji}$

Sulphur balance of the ecosystem

$N_S = \sum_{i=1}^{N_e} \sum_{j=1}^{N_c} \beta_{Sj} N_{ji}$

Results

All fossil fuels can be used without increasing CO_2-concentration in the atmosphere

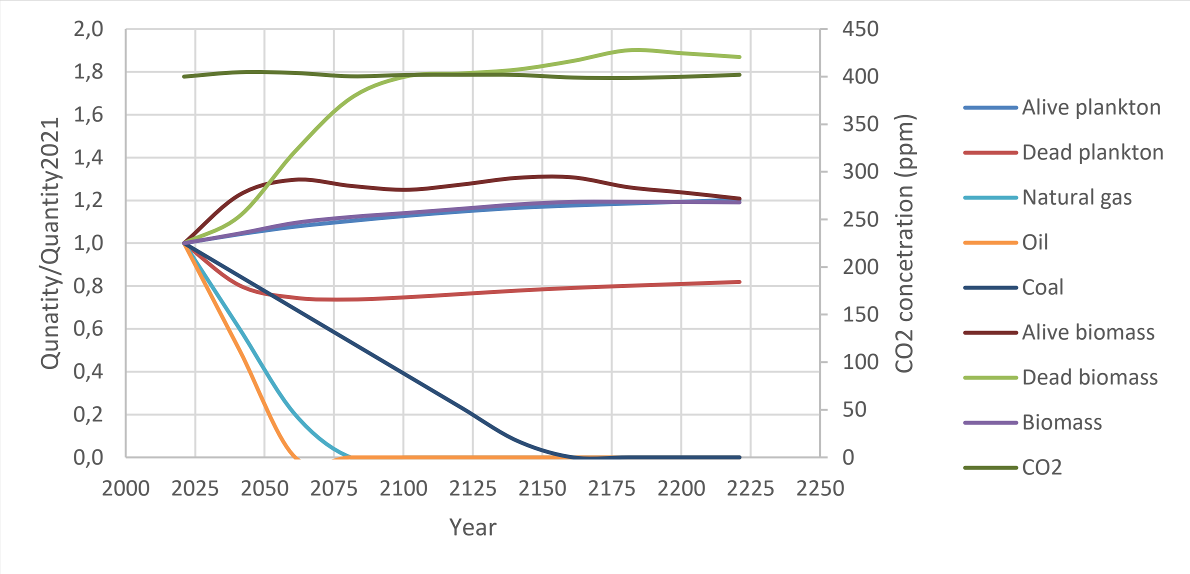

Figure 1. In the calculations of figure 1 present use of fossil fuels was continued until they deplete and use of photosynthetic biomass was adjusted so that CO_2-concentration in the atmosphere did not change. Calculations prove that all carbon of presently known fossil fuels reserves can be returned to the cycle of nature during the next 160 years without increasing CO_2-concentration in the atmosphere. This demands that biomass of the ecosystem is increased about 19 % during the next 160 years.

Use of fossil fuels increases sustainable use biomass and production of food

Dogma is per se wrong because at each amount of carbon in the cycle of nature CO_2-concentration in the atmosphere depends on amount of biomass of the ecosystem.

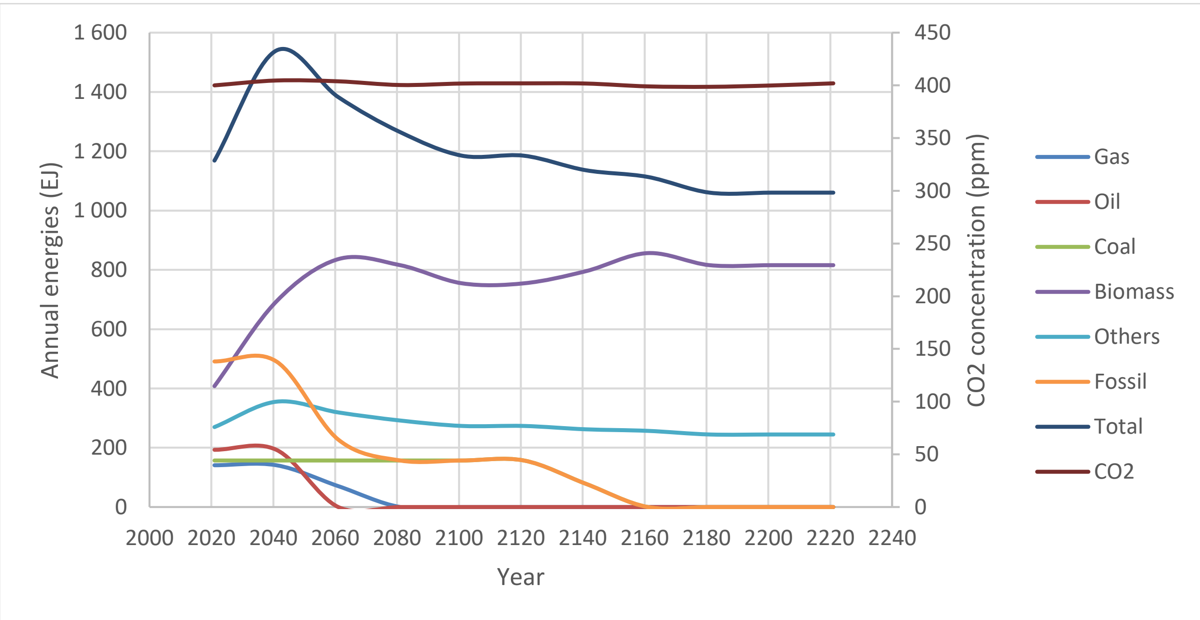

Figure 2. Annual energies (EJ=10^{18}J) of natural gas, oil, coal, biomass, other energy sources, fossil energy, total energy, and CO_2-concentration in the atmosphere as functions of time.

In 2020 about 83% from global energy consumption was produced by fossil fuels (2). Fossil fuels are nonrenewable but when carbon of presently known fossil fuels reserves has been returned to the cycle of nature it increases photosynthesis of the ecosystem so that sustainable use of bioenergy increases to about 820 EJ/a which is about 1.66-times the energy of in 2020 used fossil fuels. Mankind cannot afford rejecting the enormous natural resource of fossil fuels. Aim to stop use of fossil fuels by 2050 is unrealistic, senseless, and destructive for mankind. Particularly because all fossil fuels can be used without increasing CO_2 concentration in the atmosphere.

References

(1) https://asiakas.kotisivukone.com/files/pertti.sarkomaa.ota.fi/climate/three_entity_climate_model.pdf

(2) BP Statistical Review of World Energy, 2019