Towards a Sustainable Technological World

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Preface

This book is about global limitations and local solutions found by local societies.

A Sustainable Technological World is defined in balance with the other great mass and energy streams in the geosphere and biosphere and in balance within the position of mankind in the biosphere.

The local societies are characterized in terms of population size and cultural dimensions and these interlinked properties give rise to sociodiversity. Sociodiversity and in its wake different appreciation of artifacts are a prerequisite for finding the pathway to sustainable development on a global scale,

This book is written top-down and in line with this kind of thinking I would like to thank all the people who took a warm interest in this journey of 7 years which resulted in this booklet. My special thanks goes to M.T.D. Kleizen MSc for the enchanting discussions and to S. Robinson for improving the language.

The work is not finished yet and I do hope that the local solutions will be found in the smallest society: my family.

H.H.Kleizen
Maassluis, August 2007

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1 Introduction

In the first chapter the subject is introduced, the central hypothesis and problem are defined and the scope of the thesis is outlined.

1.1 Preamble

The human world faces problems. Technological activities are nowadays threatening life on planet Earth on a global scale. Accessibility to the products of these technological activities differs from world region to world region. Old polluting technological fruits are sold to the poor enabling the rich to develop better ones and exporting thereby their contribution to the world's problems.

The threatening of life is not just physical. The rate of technological change makes life-long jobs impossible. Individuals are forced to live in larger communities than the standard two-generation family. Mass migration to the cities of the world will increasingly reveal the societal pressure to equity.

It is told how it started. It started in a way [1] with forbidden fruit hanging on a tree giving wisdom and immortality. The snake was doomed to use his three senses of sight, smell and taste [2] only one at a time. Mankind was denied immortality and had to live with [3] the concept of time. Human generations are one of the consequences of mortality, enabling the human wisdom to develop beyond the duration of each generation.

In 1987 the World Commission on Environment and Development issued a report globalizing traditional human feelings. It coined the phrase sustainable development [4]: "Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The new aspect is the coupling of two old ideas: the distribution of – in particular essential -needs (cultural, Marx) among the people and the limited capacity (Nature, Club of Rome) to supply them through social and technological structures.

The report, being rather vague in prescribing how to achieve this and offering a dialogue, did place sustainable development at the focal point. It stimulated a lot of research into feeding nature (biodegradable products), helping nature (Industrial Ecology, looking at the Earth and its activities as a somewhat peculiar reactor [5]), mimicing nature (Green Chemistry [6]), improving structures (social, technological) and reorienting sciences and technologies.

Chemical Technology at Delft University of Technology gave birth to Sustainable Chemical Technology [7], addressing questions in the design, use, updating, and recycling of factories, processes and products. Equipped with hints, principles (Precaution Principle [8]) and selection rules (auditing, closing material cycles) impact on society and environment can be taken into account. New instruments (LCA = Life Cycle Assessment) assess the environmental trace left behind by mortal products.

The problems started bottom-up. All aforementioned research activities are bottom-up solutions and are doomed to fail: they are part of the problem not of the solution. A top-down approach is to be preferred and consequently that is the path that has been followed in this thesis.

1.2 Hypothesis

The hypothesis is that there is a maximum to the mass technological products and energy needed for activities related to the manufacture and use of artifacts. This is called the Sustainable Technological World (STW). It is believed – once the STW is defined and its properties established - that all technological elements and activities can be qualified as sustainable or not. The new element is that an upper limit is set to industrial metabolism and societal technological activities.

The primary research problem is:

The problem is to determine the macroscopic properties of the Sustainable Technological World (STW), its relationship with the environment, its basic structure preferable down to the level of factories and products.

The secondary research problem is:

The problem is how these global limitations are related to the sum of individual needs

In this thesis the primary research problem is addressed fully and an opening is given to the secondary.

1.3 Thesis

Chapter 2 is basically a cast back to wondering why sustainable development went wrong as commonly believed within the timeframe mankind likes to define to judge development as right or wrong. It reviews the evolution of the Earth up to the present and its major surroundings the geosphere, biosphere and current Technological World, estimating their mass and energy.

Chapter 3 describes the basic properties of a STW on Earth assigning quantitative figures to mass, primary energy consumption, air and water consumption and maximizing activities within the period of one human generation. Rules for replacement are given as well as quantitative emissions and what stakeholders are in these activities.

Chapter 4 opens with a classification of design sizes and shows in 3 conceptual design examples (salinity power, integral biomass polymer processing and air & water filtration) how the concept of a STW interacts with the design. Apparently state of the art process designs lack any notion of functionality.

Chapter 5 treats a STW as a collection of artifacts. The global collection is split into that of subsocieties. The lifespan of artifacts is discussed and a novel lifespan is introduced and applied to the case of refrigerators 2000-2006. The innovation curve is interpreted and this novel view opens a new path to the mechanisms of autocatalytic reactions.

Chapter 6 opens with a novel population structure model allowing the description of the world population and other societies (companies, employees, parliaments). This 5 parameter model is used to compare societies differing only in population and it is calculated that major subsocieties are not healthy. In general the population model helps in comparing global and local developments in sustainability. Societies in the literature are described with up to 5 cultural dimensions. This cultural description is simplified and linked to the population 5 parameter model giving an opening to forecast conditions for change.

In Chapter 7 the major conclusions are summarised and recommendations are given for sustainable research.

1.4 Literature

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2 Back Casting World Spheres

Planet Earth is reviewed in order to find clues for a Sustainable Technological World. The Earth is almost a closed system with respect to mass but an open system with respect to solar energy. The outskirts of Earth are the playground of 3 major spheres: the geosphere, biosphere and current Technological World. The biosphere and Technological World are dispersed in the geosphere and concentrated at the interface of the 3 subspheres of the geosphere: atmosphere, hydrosphere and lithosphere.

The atmosphere exchanges water with the hydrosphere and carbon dioxide with the biosphere. The Technological World merely puts carbon dioxide in the atmosphere and is therefore not sustainable. These streams are in fact the energy streams coupled to evaporation, carbon fixation and carbon burning. The energy streams are calculated. But estimation of masses is difficult. The hydrosphere mass is known, the declining mass of the biosphere is hard to estimate and the growing mass of the Technological World is so hard to estimate that it is more an exercise of a would-be Technological World.

Much attention is paid to development of communication in time. Ultimately it is believed that planet Earth becomes more intelligent through a - more communicative - Sustainable Technological World

2.1 Introduction

The Earth currently encompasses very different spheres, which are related through great cycles of mass which are related to energy streams. The problem to be solved is, after defining them, in general to determine their mass and the great mass flows between them.

Of special importance is how these spheres evolved in geological time, since the goal of this Chapter is find clues for the concept of a STW treated in the next chapter.

2.2 Earth

The Earth is the home of mankind. Its past, present and future is sketched and its current mass and incoming solar radiation is given.

Past

About 11 to 18 billion years ago, a very tiny egg with a mass of 1 kg burst open at a temperature of 10^{30} K creating space and time. Nowadays it is a not yet full-grown universe with a temperature of 1 K and a mass of 10^{50} ton [1].

The egg was very busy in its earlier stages. Within a second, neutrons decayed into electrons, protons and neutrons were born. After three minutes neutrons and protons formed the nuclei of the three lightest chemical elements -hydrogen, helium and lithium.

After these hectic minutes it calmed, and cooled down until it was 300,000 years old. Electrons were attracted by the bare nuclei, forming atoms of hydrogen, helium and a smattering of lithium. This freed the path for the photons and the universe became transparent. In this visible universe atoms clustered forming embryonic galaxies. Stars started to manufacture elements by nuclear fusion creating all elements up to most stable one: iron. If a star has the right mass it retires as a neutron star, blasting away its top mantles. In this *demasqué* or supernova the heavier elements are formed and blasted away with the lighter ones in the surrounding [1,2].

Gas and dust from stars and supernovae concentrated in a corner of the Milky Way galaxy 4.6 billion years ago. The gas collapsed in the centre forming the sun and in the disc surrounding the nascent star the dust concentrated in planetesimals. The larger ones grew at the expense of the smaller ones. The skies became cleaned that way and planet Earth emerged among others. A fierce collision with a Mars-size planetisimal 4.5 billion years ago, produced the Moon-Earth system as it is today [2].

The Earth, at that time a hot magma ball, increased its mass with incoming meteorites and icy objects such as comets. But it cooled down as the fieriness and frequency of these collisions decreased. The metallic iron sunk to the core and the mantle of the lighter elements solidified, forming a solid crust: the lithosphere. The solidified rock allowed the volatiles to leave, but the Earth could not retain the hydrogen. 4.4 to 4 billion years ago, the temperature had dropped enough that the water from the skies rained down, creating the hydrosphere and leaving an atmosphere of mainly carbon dioxide and nitrogen [2].

Present

Nowadays the Earth is almost a closed system with respect to mass. Its current mass of 6.0E+12 Gton [3] is nearly constant, considering the input of meteorites (50 kton/yr [4]) and the output of hydrogen by photolysis of water in the upper atmosphere (less than 2 Mton/yr, calculated from data in [2,3]).

Table 2.1: Mass, incoming solar radiation and specific power consumption Planet Earth. Data solar radiation: see Table 2.6 and 2.7.

Planet	Gton	GW	W/kg
Earth	6.0E+12	2.0E+08	3.3E-08

With respect to energy the Earth it is an open system. The incoming radiation is reflected for 31% and the remaining 69% is given to the Universe as long wave radiation (see Table 2.6 and 2.7).

Future

The far future will be less peaceful. The Sun is middle-aged and in another 4.5 billion years it will become a red giant flooding the Earth, before ending as a white dwarf.

In terms of human generations that means still about 180 million generations. For a stable world population of about 6 billion it takes 32 generations (about 1 millennium) to have the whole world population as family. See further [5].

Any now living human being on Earth has a chance to find its genes back minimally 6 million times before the Sun engulfs the Earth. This high frequency of brings in the aspect of long range gene communication between living in different millennia.

2.2 Geosphere

The geosphere is defined here as the outer third shell of the Earth encompassing the solid lithosphere (crust), the liquid/solid water hydrosphere (fresh and salt water and ice) and gaseous atmosphere. Its mass is confined in a shell of about 1 percent of the radius of the Earth (6378 km [3]).

The past and future of the geosphere is that of the Earth, disregarding details such as continental drift (earthquakes and Earth expansion) and crust renewal.

The geosphere interacts through these processes with the mantle, but this mass and energy exchange can luckily be neglected. So like the Earth it is a closed system with respect to mass and an open system with respect to energy.

Table 2.2: Mass, solar energy cycle and specific power consumption of the geosphere. Data mass: see Table 2.4, solar radiation: see Table 2.7 and 2.8.

Sphere	Gton	GW	W/kg
Geosphere	2.53E+10	2.0E+08	7.8E-06

Having only 0.4% of the mass of the Earth it is of course much more sensitive to change than the complete Earth.

The geosphere is just the place in space where life is concentrated. The actual players are its three subspheres. So most attention is paid to its subspheres which provide human beings with the resources they need. In particular the mass and energy exchange between these three subspheres and which of the three is most sensitive to change.

Table 2.3: Mass contributions of the first 26 elements to the atmosphere (data calculated from [3] and [6]), the hydrosphere [3], the lithosphere [3] and the geosphere.

Element			Mass Gton				Moles Gmol				Bruto Molecular Composition Per Oxygen Atom			
Protons	Symbol	Mol Mass g/mol	Atmosphere	Hydrosphere	Lithosphere	Geosphere	Atmosphere	Hydrosphere	Lithosphere	Geosphere	Atmosphere	Hydrosphere	Lithosphere	Geosphere
1	H	1.01	1.21E+00	1.80E+08	3.31E+07	2.13E+08	1.21E+06	1.78E+14	3.29E+13	2.11E+14	1.62E-05	2.00E+00	4.82E-02	2.74E-01
2	He	4.00	3.54E+00	1.16E-02	1.89E+02	1.93E+02	8.85E+05	2.91E+03	4.73E+07	4.82E+07	1.19E-05	3.27E-11	6.94E-08	6.25E-08
3	Li	6.94		3.00E+02	4.73E+05	4.74E+05		4.32E+07	6.82E+10	6.82E+10		4.84E-07	1.00E-04	8.85E-05
4	Be	9.01		9.32E-03	6.63E+04	6.63E+04		1.03E+03	7.35E+09	7.35E+09		1.16E-11	1.08E-05	9.54E-06
5	B	10.81		7.39E+03	2.37E+05	2.44E+05		6.83E+08	2.19E+10	2.26E+10		7.67E-06	3.21E-05	2.93E-05
6	C	12.01	7.38E+02	4.66E+04	4.73E+06	4.78E+06	6.14E+07	3.88E+09	3.94E+11	3.98E+11	8.24E-04	4.35E-05	5.78E-04	5.16E-04
7	N	14.01	3.87E+06	8.32E+02	4.50E+05	4.32E+06	2.76E+11	5.94E+07	3.21E+10	3.09E+11	3.71E+00	6.66E-07	4.71E-05	4.00E-04
8	O	16.00	1.19E+06	1.43E+09	1.09E+10	1.23E+10	7.45E+10	8.91E+13	6.82E+14	7.71E+14	1.00E+00	1.00E+00	1.00E+00	1.00E+00
9	F	19.00	6.06E-03	2.16E+03	1.38E+07	1.38E+07	3.19E+02	1.14E+08	7.29E+11	7.29E+11	4.28E-09	1.28E-06	1.07E-03	9.45E-04
10	Ne	20.18	2.86E+01	2.00E-01	1.18E+02	1.47E+02	1.42E+06	9.90E+03	5.86E+06	7.29E+06	1.90E-05	1.11E-10	8.60E-09	9.46E-09
11	Na	22.99		1.80E+07	5.59E+08	5.77E+08		7.82E+11	2.43E+13	2.51E+13		8.77E-03	3.56E-02	3.25E-02
12	Mg	24.31		2.15E+06	5.52E+08	5.54E+08		8.83E+10	2.27E+13	2.28E+13		9.91E-04	3.33E-02	2.95E-02
13	Al	26.98		3.33E+00	1.95E+09	1.95E+09		1.23E+05	7.22E+13	7.22E+13		1.38E-09	1.06E-01	9.36E-02
14	Si	28.09		3.66E+03	6.67E+09	6.67E+09		1.30E+08	2.38E+14	2.38E+14		1.46E-06	3.48E-01	3.08E-01
15	P	30.97		9.98E+01	2.49E+07	2.49E+07		3.22E+06	8.02E+11	8.02E+11		3.62E-08	1.18E-03	1.04E-03
16	S	32.07		1.51E+06	8.28E+06	9.79E+06		4.70E+10	2.58E+11	3.05E+11		5.27E-04	3.79E-04	3.96E-04
17	Cl	35.45		3.23E+07	3.43E+06	3.57E+07		9.11E+11	9.68E+10	1.01E+12		1.02E-02	1.42E-04	1.31E-03
18	Ar	39.95	7.08E+04	7.49E+02	8.28E+04	1.54E+05	1.77E+09	1.87E+07	2.07E+09	3.86E+09	2.38E-02	2.10E-07	3.04E-06	5.01E-06
19	K	39.10		6.64E+05	4.95E+08	4.95E+08		1.70E+10	1.27E+13	1.27E+13		1.91E-04	1.86E-02	1.64E-02
20	Ca	40.08		6.86E+05	9.82E+08	9.83E+08		1.71E+10	2.45E+13	2.45E+13		1.92E-04	3.59E-02	3.18E-02
21	Sc	44.96		9.98E-04	5.21E+05	5.21E+05		2.22E+01	1.16E+10	1.16E+10		2.49E-13	1.70E-05	1.50E-05
22	V	47.88		4.16E+00	2.84E+06	2.84E+06		8.69E+04	5.93E+10	5.93E+10		9.75E-10	8.70E-05	7.69E-05
23	Ti	50.94		1.66E+00	1.34E+08	1.34E+08		3.27E+04	2.63E+12	2.63E+12		3.66E-10	3.85E-03	3.40E-03
24	Cr	52.00		4.99E-01	2.41E+06	2.41E+06		9.60E+03	4.64E+10	4.64E+10		1.08E-10	6.81E-05	6.02E-05
25	Mn	54.93		3.33E-01	2.25E+07	2.25E+07		6.06E+03	4.09E+11	4.09E+11		6.80E-11	6.00E-04	5.31E-04
26	Fe	55.85		3.33E+00	1.33E+09	1.33E+09		5.96E+04	2.39E+13	2.39E+13		6.69E-10	3.50E-02	3.09E-02
sum			5.14E+06	1.66E+09	2.37E+10	2.54E+10	3.53E+11	2.69E+14	1.14E+15	1.41E+15	4.73E+00	3.02E+00	1.67E+00	1.83E+00

Mass and Composition

Supernovae do occur, but not all stars have the power or mass to die in that spectacular way. So it is to be expected, that the geosphere contains not much of the elements with more than 26 protons. In Table 2.3 the contributions of these 26 chemical elements are given. And indeed Earth's geosphere is very well described by a composition based on these 26 elements. Together they fill up the contents of the subspheres of the geosphere, and consequently the geosphere itself, comparing the data collected in Table 2.3 and Table 2.4. It can be seen that the atmosphere is by far the lightest of the three subspheres, and thus the most sensitive to changes in composition.

Nowadays the atmosphere is a mixture of three gases: N_2, O_2 and Ar with mass fractions x_m = 0.754, 0.232 and 0.014. The hydrosphere is more homogeneous on this level of accuracy: H_2O with 1% dissolved NaCl.

Table 2.4: Characteristic data of the geosphere and its three subspheres (calculated from [3] and Table 2.2 extracts).

Sphere	Mass	Relative Mass %			Bruto Chemical Conposition Xn											
	Gton	Earth	Geosphere	Z =1 to 26	O	H	N	Si	Al	Fe	Ca	Mg	Na	K	sum	n
Atmosphere	5.14E+06	8.59E-05	2.03E-02	1.00E+02	1		3.71								4.71	4.73
Hydrosphere	1.66E+09	2.78E-02	6.57E+00	1.00E+02	1	2									3	3.02
Lithosphere	2.37E+10	3.96E-01	9.34E+01	9.98E+01	1	0.05		0.35	0.11	0.035	0.036	0.033	0.036	0.019	1.669	1.67
Geosphere	2.53E+10	4.24E-01	1.00E+02	9.99E+01	1	0.27		0.31	0.09	0.031	0.032	0.03	0.033	0.016	1.812	1.83

More complex is the lithosphere. It has a complex composition resembling those of clay minerals. In these clay minerals oxygen anions form layer structures, where the small quadrivalent silicon ions seek shelter in the tetrahedral interstices. Some Si (overall 30%) is displaced by trivalent cations (Al,Fe) and other similar sized cations (Mg), resulting in negative charged oxygen sheets: $[(Si,Al,Fe,Mg)_{1.05}O_2]^{0.11}$. The sodium and calcium ions and oxygen-sized potassium ions are too large to occupy even the largest hole formed by oxygen ions: the octahedral ones [7]. So they bridge the negative charged oxygen sheets forming - on average - incomplete layers with the overall structural composition: $\{[Ca,Na,K]_{0.09}[(Si,Al,Fe,Mg)_{1.05}O_2]\}^{0.05}$. The remaining 50% of the path to charge neutrality is achieved by hydrogen ions (protons). These very tiny protons have two structural ways to do so: either by combining with oxygen anions in the sheets forming hydroxyl ions, or by forming water molecules joining the large cations between the oxygen sheets. After which hydrogen bonding between the sheets plays the game of “who is the molecule and who is the ion”.

Internal cycles

The second problem is the internal energy and mass exchange between the subspheres of the geosphere. Both occur, so the subspheres are open systems with respect to energy and mass. See Figure 2.1.

As far as mass exchange is concerned there are formally three cyclic processes. However mass exchange between lithosphere and atmosphere is of no importance and its impacts only becomes clear when volcano’s become active. Mass exchange between lithosphere and hydrosphere is slow and limited to rock formation by sedimentation and rock dissolution by sedimentation.

The most important mass exchange process is that between the atmosphere and the hydrosphere. This is not due to the sublimation of water and deposition of water between the ice of the hydrosphere and the water vapour of the atmosphere, which is also not important. It is the vaporisation of liquid water from the hydrosphere and the closing of the cycle by the condensation of fresh liquid or solid water from the atmosphere back to the hydrosphere.

What is valid for mass exchange is also valid for energy exchange. Thus that is also the energy exchange associated with the vaporisation of water.

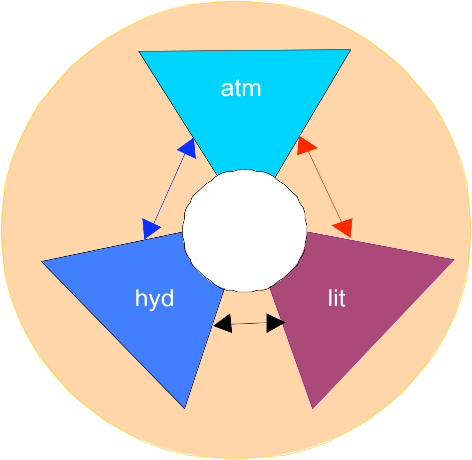

Figure 2.1: Exchange of mass and energy between the three subspheres of the geosphere: atmosphere, hydrosphere and lithosphere.

Atmosphere / Hydrosphere exchange

The cyclic process of water vaporisation and condensation is shown in Figure 2.2.

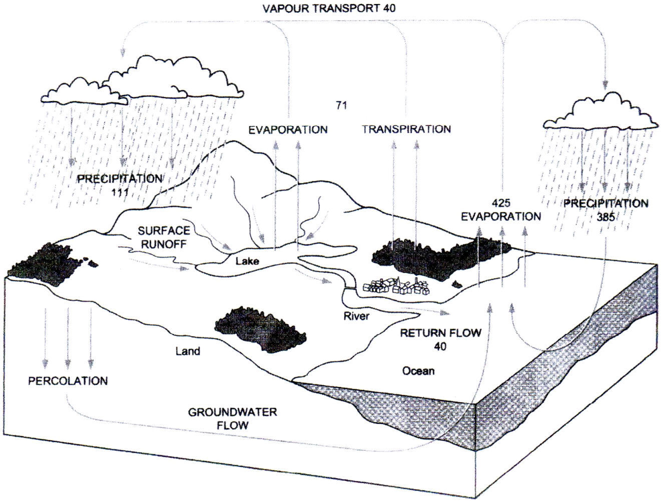

Figure 2.2: Global fresh water cycle in thousand Gton/yr ([8,9]).

Similar data can be found in [10] In Table 2.5 the extreme data on the water exchange flow are compared.

Table 2.5: Comparing the lowest and highest water flow between hydrosphere and the atmosphere on an annually basis. Data in thousand Gton/yr. Data given in Figure 2.2 and in [11].

evaporation			precipitation		
	min	max		min	max
oceans	425	510	oceans	385	460
land	71	70	land	111	120
cycle	496	580	cycle	496	580

Table 2.5 shows that the annual water flow between atmosphere and hydrosphere is 496 up 580 thousand Gton/yr. On the land the annual precipitation is larger than evaporation. The return flow to the seas and oceans is thus 40 to 50 thousand Gton/yr. Of this return flow (“runnoff”) one-third is stable runoff [11,12] the rest flows to the seas as floods. Two-third flows through inhabited areas, so the available amount of fresh water reduces to 10 thousand Gton/yr [11], or only 1.7% of the annual water circulating between hydrosphere and atmosphere.

Solar radiation and water exchange

The key players in the solar energy balance are the hydrosphere (the oceans covering 70.8% of Earth’s surface [3]) and the atmosphere. Table 2.6 and Table 2.7 show this in greater detail.

Table 2.6. Solar radiation balance of the atmosphere. Created from relative [10] and absolute data on Earth surface incoming solar energy after correcting for reflected solar radiation [9.13,14]. See also Table 2.1.

in			out		
	%	GW		%	GW
Earth surface radiation	102	1.85E+08	Back radiation to Earth surface	95	1.73E+08
Incoming solar radiation	100	1.82E+08	Solar radiation to Earth surface	58	1.05E+08
Latent heat water vapour	23	4.18E+07	Radiation to Outer Space	57	1.04E+08
Thermals	7	1.27E+07	Reflected solar radiation	22	4.00E+07
total	232	4.21E+08	total	232	4.21E+08

Table 2.7: Solar radiation energy balance of the Earth surface. Created from relative [10] and absolute data on Earth surface incoming solar energy after correcting for reflected solar radiation [9,13,14]. See also Table 2.1.

in			out		
	%	GW		%	GW
Back radiation from atmosphere	95	1.73E+08	Earth surface radiation	114	2.07E+08
Incoming solar radiation	58	1.05E+08	Latent heat water vapour	23	4.18E+07
			Reflected solar radiation	9	1.63E+07
			Thermals	7	1.27E+07
total	153	2.78E+08	total	153	2.78E+08

The net energy exchange between the atmosphere and the Earth's surface has three components: radiation (102%), latent heat water vapour and thermal convection amounting together to 132% of the incoming solar radiation. The total cyclic energy is 2.4E+8 GW. In this exchange process clouds are all important, facilitating back radiation and therefore directly and indirectly water vaporisation between hydrosphere and atmosphere must be seen as the motor behind the temperature control.

Water vaporisation itself exchanges 23 % of the solar energy (4.18E+7 GW), corresponding to about 540 thousand Gton/yr of water. (Putting its enthalpy of vaporisation to 44 kJ/mol [3].) A value halfway between the extremes of 496 and 580 thousand Gton/yr mentioned earlier.

Fresh water resources

As the Sun supplies the energy the fresh water resources are important as other resources. The renewable rate is about 1.7% of the water cycle corresponding to 10 thousand Gton/yr.

Due to the melting of icecaps and glaciers the world fresh water reserves have decreased the last 17 thousand years by 38 million Gton and nowadays the loss is about 640 Gton annually [15]. Estimates of the current fresh water resources are found in [11] and [12] varying from 85 [11] to 41 million [12] Gton. The major sources are groundwater (60 [11] and 13 [12] million Gton) and ice (24 [11] and 27 [12] million Gton). Lakes, reservoirs and rivers contain 0.1 Gton and the atmosphere carries 0.014 Gton [11].

The groundwater and ice resources should be maintained and mankind should rely on the 10 thousand Gton/yr stable runnoff.

Atmosphere and Hydrosphere

Summing up it can be concluded that the atmosphere is the most sensitive subsphere of the geosphere. It is open to mass and energy exchanging water with the hydrosphere. The hydrosphere main data are presented in Table 2.8.

Table 2.8. Mass, power, specific power, exchange molecule, annual flow and specific energy of the hydrosphere.

Sphere	Gton	GW	W/kg		Gton/yr	MJ/kg
Hydrosphere	1.66E+09	4.18E+07	2.52E-05	H_20	5.40E+05	2.44E+00

The mass exchange flow is coupled via the enthalpy of vaporisation (2.44 MJ/kg) to the energy exchange flow. Only 1.7% of this amount (10 thousand Gton/yr.) is annually available as stable runnoff water.

The amount of liquid fresh water on Earth is stored in the hydrosphere chiefly in the form of ice and groundwater. The total reserves are an order of magnitude larger than the mass of the atmosphere, but the ice declines steadily. So the most sensitive areas in the geosphere are the atmosphere and the fresh water resources.

2.3 Biosphere

Contrary to other definitions including the view that the biosphere is merely occupying a portion of the volume of the Earth [16], the biosphere is here defined as the sum of mass of all living creatures on Earth. It includes all the living biomass used for food of humans, pets and other creatures tasting or eating it. But it excludes (growth of) biomass for other purposes, energy farming, material farming etc. So the biosphere is a collection of living organisms dispersed in the geosphere, without technological activities and intentions.

First the history of the biosphere is reviewed, its current behaviour in terms of mass and energy exchange is revealed and its relation to the atmosphere is treated. Finally the position of mankind is quantified.

<u>8 transitions</u>

Soon after the first rain fell 4 to 4.4 billion years ago, the Earth facilitated life. The oldest species found in nature are bacteria, found in sedimentary rocks dating back to 3.86 billion years ago [17]. So in a relatively short time, the Earth witnessed the transformation of simple molecules into living cells, called prokaryotes meaning without a nucleus. Not much is known about this process, but there is consensus about the major stages [17,18,19,20]. See Table 2.9. The zero stage is the making of simple organic molecules by lighting or UV. Next comes the making of self-replicating molecules by a process known in chemistry as autocatalysis. These molecules found perhaps shelter in minerals such as those making montmorillonite, a clay mineral. In these closed environments they were forced to co-operate rather than to compete. As a result their mutual relations became more sophisticated and eventually they were able to create their cell wall and barrier to the environment and were free. Initially they were powered by producing hydrogen from hydrogen sulfide. But as their environment changed they left their waters and moved towards other, less reducing, conditions.

To do so they had to change their energy source. More than 3 billion years ago, cyanobacteria found one by converting carbon dioxide into sugars, producing oxygen gas as waste. They kept on doing so for about 1.5 billion decreasing the greenhouse gas carbon dioxide steadily and building an atmosphere protected by an ozone shield to keep the once so useful UV-radiation out. That opened the way for new species living in an protected oxidic environment.

A major biological transition occurred about 1.4 billion years ago [17] with the birth of cells with a nucleus (eukaryotes). An eukaryote has typically the volume of 10 thousand prokaryotes and is much more complex. It is hypothesised [18] that softening of the cell wall started this transition. This made possible internal structural changes. Inner membranes were formed by pushing in the cell wall and allowed the formation of internal structures: most notably the cell nucleus and its chromosomes but also the formation of organelles (cell organs). By similar processes large structures could be eaten and excreted. Finally complete bacteria could be engulfed and given a specific function by symbiosis [20]. (The mitochondria, the power plants in a cell are trapped bacteria.) Cyanobacteria now living in and outside single cells stayed busy increasing the oxygen concentration in the atmosphere.

Table 2.9: Major transitions in the biosphere according to [18].

Transition	From	To
1	Replicating molecules	Populations of molecules in protocells
2	Independent replication	Chromosomes
3	RNA as gene and enzyme	DNA genes, protein enzymes
4	Bacterial cells (prokaryotes)	Cells with nuclei and organelles (eukaryotes)
5	Asexual clones	Sexual populations
6	Single-celled organisms	Animal, plants and fungi
7	Solitary individuals	Colonies with non-reproductive castes (ants, bees and termites)
8	Primate societies	Human societies (language)

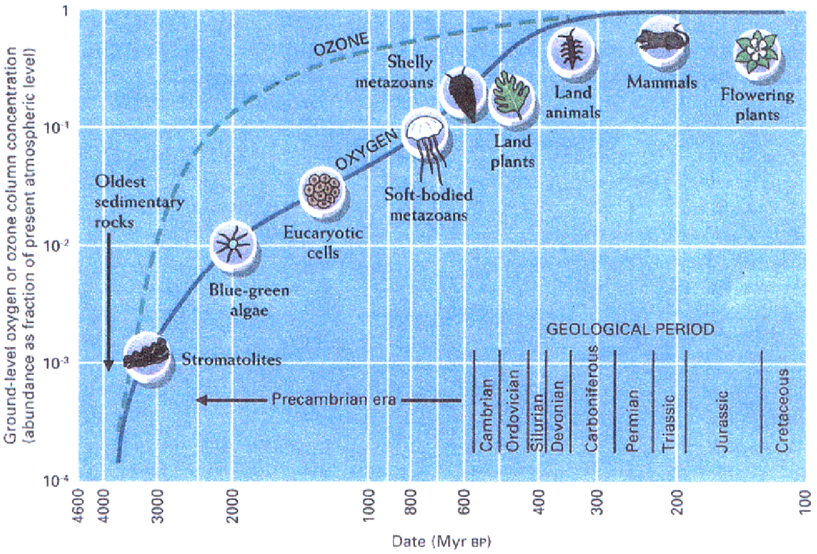

Figure 2.3: Atmospheric and biological changes throughout time [10].

The increase of the oxygen content of the atmosphere ended, when the rate of use of oxygen (respiration, oxidation of dead biomass minus burial of biomass) balanced its production (growth new biomass). At that time it reached its present value (see Figure 2.3), the transition to multicellular organism (animals, fungi and plants) was almost complete.

100 thousand years ago modern man came to birth, judging them on brain capacity. But apparently they waited some 50 thousand years before producing something to be remembered by. Cave paintings, tools of antler, bone and stone are younger than 50 thousand years old.

It is argued in [18], that like the preceding 7 major transitions, information was the driver. The difference in the last transition is the use of language. Language makes it possible to exchange cultural knowledge between contemporaries and the generations to come.

Agriculture

5000 years ago mankind changed its surrounding by settling down. At that time it is estimated [21] that the continental living plants (phytomass) had a mass of 1100 Gton Carbon. (This is also approximately the mass of the biosphere as sea life and animal life put little extra weight in.)

A mature forest can store 100 to 250 ton Carbon/ha [9,21], grassland a factor of ten less and cropland generally a factor of twenty less [21]. Trees may live for centuries, but agricultural products only for months. So agricultural activities reduce the living biomass and shortens it average lifespan.

It has been estimated that in the period from 1700 to 1850 the amount agricultural land doubled from 0.26 to 0.54 Gha [21]. As that occurred by deforestation, it can be calculated that the continental phytomass had decreased in that period by about 70 Gton Carbon, or about 6% of the amount in the biosphere in the time of the pharaohs.

After that, another 150 Gton Carbon got lost [21] so that in 1995 it could be concluded that the biosphere had lost 20% of its Egyptian weight due to changes in land use.

Changes in the landscape also affect the energy balance on Earth surface (see Table 2.7). Grass is lighter so its reflects more sunlight and absorbs less. Related phenomena are less cooling of land by vaporisation of water, lesser formation of lower clouds due to increasing air thermals, higher temperatures on land, more unstable weather, but more renewable wind energy blowing away top soil in dry seasons.

Mass and exchange properties biosphere

The biosphere is an open system with respect to mass and energy.

It started with mass zero, peaked about 3000 B.C. and has decreased ever since. The mass of the biosphere is nowadays still not well known. Current estimates vary from 360 Gton [3], via more than 550 Gton Carbon [21,22,23] up to the range 420 to 840 Gton Carbon and beyond [21]. The value adopted in Table 2.10 is simply the harmonic mean between the two extremes of 360 [3] and 1100 Gton Carbon in Egyptian times. (The question is not so much what it is but what it should be.) The mass exchange by photosynthesis varies from 62 [9] via 175 [21] up to 240 Gton C/yr. But the harmonic mean of 120 Gton C/yr will be taken, as again a balanced position is taken in time.

The biosphere with a mass of 630 Gton C and a mass exchange of 120 Gton C/yr are the cornerstone data of Table 2.10. To convert the mass to wet biomass the composition of sugar was assigned to the living mass with a water content of 50%. To calculate the reaction enthalpy the procedure in [24] was copied: carbon dioxide reacts with liquid water to form solid sugar and oxygen (see also legend Table 2.10).

Table 2.10: Wet mass, power, specific power, exchange molecule, annual flow and specific energy of the biosphere. Assumptions composition biosphere wet mass C6H12O6.10H2O, combustion enthalpy sugar 2808 kJ/mole [24].

Sphere	Gton	GW	W/kg		Gton/yr	MJ/kg
Biosphere	3.15E+03	1.51E+05	4.79E-02	CO_2	4.47E+02	1.06E+01

The biosphere is dispersed in the geosphere and keeps open relationships with the three subspheres as pictured in Figure 2.4. It has in particular a strong relationship with the top layers of the hydrosphere and the lithosphere. Plants need typically about a thousand water molecules to fix one carbon dioxide molecule and without a fertile soil they don’t assimilate [21].

Mankind

With about 6 billion people and an average mass of 50 kg the mass of mankind is 0.3 Gton or 0.01 % of that of the biosphere producing a carbon dioxide flow of 2.2 Gton /yr (calculated from [25,26]) or 0.4% of the biosphere.

The concern is not that mankind’s position in the biosphere may increase due to an increasing population either by higher birth rates or extended lifespan.

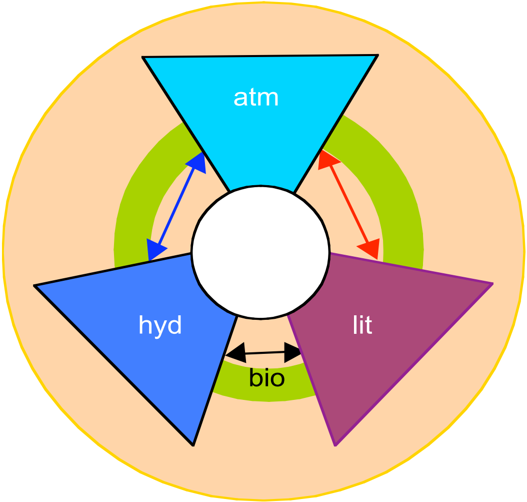

Figure 2.4: Exchange relationships of the biosphere with the three subspheres of the geosphere: atmosphere, hydrosphere and lithosphere.

The main point is that human generations reduce the mass of the biosphere by larger amounts each year. Current deforestation rates are estimated at 1.5 to 2 Gton/yr [9,21]. Burning grasslands by farmers and shepherds sends yearly a similar amount to the atmosphere. Half of that amount comes from the Sub-Saharan African. The best one can hope for that the grass grows as quickly as it is burnt, but again the lifespan of species is shortened.

Mankind reduces animal mass too. Human infrastructure makes the habitat for large animals too small. Domesticated animals for food production have such small quarters that they can not move around, eat the wrong food, have such a short lifespan that they never see the next generation and think they have millions of parents or children. They are mentally disturbed.

In short mankind shrinks the biosphere, reduces biodiversity, the lifespan of species and manipulates their evolution.

Concluding

The biosphere is an open system with respect to mass and energy. In terms of mass it is much lighter than the atmosphere and therefore much more sensitive to compositional change. Mankind decreases its mass and stresses its life.

2.4 Technological World

Just as the biosphere is defined as the collection of all living organisms the Technological World is defined as the collection of technological artifacts on Earth. The difference is it that includes the dead artifacts: they are nobody's property and decay in Nature, interacting with biosphere and geosphere and endangering future generations in an unknown way. This alone already makes the current Technological World a growing sphere.

The Technological World includes the products of energy farming and material farming: there is no reason why active carbon should be in the technological world and its predecessor biomass grown by industrial agriculture not. This is the difference between renewable biomass grown naturally and industrial grown renewable biomass for non-food applications. The former is related to the biosphere and limited in production, the latter not necessarily. So both biomasses compete, and should belong therefore to different spheres. A similar difference can be found between natural decaying isotopes in Nature (in the geosphere) and the synthetic production of them (in the Technological World).

A third reason for growth is driven by material equity, which is accelerated by the few who have more and persist in maintaining the difference.

In this Section the development of the Technological World is described in terms of diffusion of information, believed to be motor behind change, the main properties of the current Technological World are estimated and its ends with an essay about its current growth rate.

4 stages

The informational line of thinking preferred by the development of the Biosphere will be extended towards the development of the Technological World (TW).

When human beings started talking with each other about cultural things 50 thousand years ago [18] knowledge could be transferred. So the Technological World is 50 thousand years old or, in geological and biological terms, young.

With the help of the literature [18,27] and some personal knowledge Table 2.11 was constructed. It recognises four stages in human communication.

Table 2.11: Major transitions in the diffusion of information requiring technology. BP = Before Present.

from	to	period years BP		travels	transport		
spoken language	written language	50,000	5,000	local			animal
written language	books	5,000	500	regional		boat	carriage
books	analogue apparatus	500	50	global	aircraft	vessel	car
analogue apparatus	digital apparatus	50		space	shuttle	hoovercraft	

1st Period

The 1st period starts with spoken language [18] and ends with the Sumerians, using clay tablets for their accounting [27]. In that period human beings left their caves and paintings, settled in villages around 13 thousand years ago [28] and domesticated different mammals and plants in different locations. The dog came around 12 thousand years ago to be followed in about 2 thousand years' intervals by the sheep, cow, horse and finally the camel [28]. Agricultural innovation started 10 thousand years ago and came to a standstill when people started to write. At that time they could have written about wheat, olive, rice, corn, sorghum, potato to name some of the plants mentioned in [28].

Accounting, camels and horses could very well imply trade. And indeed 5 thousand years ago, some technology had been known for millennia (pottery) and one of the most revolutionary innovation of all times, the wheel, was already 400 years old [28].

2nd Period

The 2nd period, from 5 thousand to 5 hundred years BP (Before Present), covers the era where civilisations rose and fell. Following the track of inventing book printing, one starts 37 hundred years ago in the region of Greece [28], arrives around 500 AD in China and finally in Europe a thousand years later [27], marking the end of the trip and the second period.

Books were used to transfer knowledge of religious, medicinal and technological nature. So a similar technological pilgrimage can be made in other areas of technology. Processing of food and alcoholic beverages (wine, beer), hydraulic engineering, textile and clothes, metallurgy (cast iron production in China rose to 125,000 ton/yr in 1078 [29]) etc.

Manufacture of paper was invented in China 100 AD [27,29]. Binding of books too (950 AD), in the very same year that bored Chinese concubines invented playing cards, but not long after (875 AD) visitors to China to their astonishment encountered the phenomenon of recycling: toilet paper [27].

A good and suitable example for a technological trip is to follow the Olysses trail of the paper manufacture, mentioned in [29]:

begin in China (100 AD), go to Tibet (650) and then in intervals of centuries: Samarquand (751), Cairo (850), Fez (1050), Jativa (1150) leave Spain to France near Ambert (1326) go quickly to Nuremberg in Germany (1390) and take some time, in Holland for instance, before ending in England (1490). So in pre-medieval times new technology took more than 50 generations to diffuse through the world.

3rd Period

The start of the 3rd period coincides with the West European notion that the window of Catholicism was the only view on the path seeing space and time converge in heaven [30].

Being able to print they thought once again “let’s do something different”. And planet Earth was discovered by the Portuguese, Spanish, Dutch and English sailors. Religion and Science broke up their marriage and their children developed different identities leading to an outbreak of different religions and sciences. In the tracks of these independent sciences, different technologies followed. A deterministic world developed, powered by machines that replaced human work force.

In the first 250 years of this period technical progress was induced by medieval knowledge collected and distributed through books. Mines, shipyards and iron melting became large-scale industrial activities powered by coal and cokes rather than by wood [31]. The first industrial Revolution (1750-1850] started in England and was driven by water and steam. New industrial activities included chemical treatment of textiles (washing (soda) and painting) as a result of progress in chemistry [31]. The second industrial Revolution (1850-1950) saw the rise of oil as the energy carrier. Science and technique founded technology, replacing batch by continuous production and stimulated innovation (oil refining). The scale of production rose and design of factories and operating them became different industrial activities. At the brink of World War II plastics started to conquer the world [32].

4th Period

The third period Christian quest or mission ended after the Second World War and the mission became a dialogue [30], marking the beginning of the 4th period. Information became available globally and instantaneously with telecommunication satellites. The modern sailors became astronauts starting to explore the universe. Societal structures broke up and groups became individuals, organised temporarily by age, look or item rather than culture. A spin-off of the voyage to the Moon was the personal computer, commercialised by IBM and nowadays connecting everybody with everybody else. Planet Earth became smaller: not only by internet, but also by miniaturisation: from tubes via transistors to chips. Chips float the information society and not oil, the fossil fuel of the third period.

Main properties

The main properties of the Technological World are collected in Table 2.12.

Table 2.12: Mass, power, specific power, exchange molecule, annual flow and specific energy of the Technological World. Combustion enthalpy methane: 890 kJ/mole [24].

Sphere	Gton	GW	W/kg		Gton/yr	MJ/kg
TW	1.69E+02	1.08E+05	6.41E-01	CO_2	2.27E+01	1.50E+02

The concept of the Technological World is new. Its mass, given in Table 2.12, is estimated in the next Section.

The average carbon dioxide flow to the atmosphere due to the combustion of fuels was 5.5 Gton/yr Carbon in the period 1980-9 [33]. A more recent estimate [23] arrives at the 6.2 Gton Carbon/yr. This flow, corresponding to 22.7 Gton CO_2/yr, is mentioned in Table 2.12. The energy consumption is calculated from the combustion of methane with oxygen to carbon dioxide and water. By this procedure one arrives theoretically at too high a value, but practically it allows for the inclusion of other minor contributions of renewable and non-renewable energy sources.

Mass

The concept of the Technological World is new, so its mass has to be determined by elaborate guessing. Two values are calculated. A maximum is calculated assuming that all people reach the material possession of the industrial world and a minimum range by looking at the current state of affairs. The average mass is then calculated and the errors in it are discussed.

Maximum Mass

In Table 2.13 an elaborated guess of a maximum of 243 Gton is given, based upon the living standard in the industrialised world.

Table 2.13. Estimates of the mass and surface load (area) of the Technological World and its product groups, assuming a living standard of the industrial world.

product group	mass		area		per capita		
	Gton	%	km2	%	ton	m2	% land area
residential buildings	186	76.7	1.47E+05	55.8	31.0	24.4	9.84E-02
other buildings	31.0	12.8	2.44E+04	9.29	5.17	4.07	1.64E-02
infrastructure	16.0	6.6	7.09E+04	27.0	2.66	11.8	4.76E-02
consumer products	8.22	3.39	1.80E+04	6.83	1.37	2.99	1.21E-02
other products	1.37	0.56	2.99E+03	1.14	0.228	0.499	2.01E-03
total	243	100	2.63E+05	100	40.4	43.8	1.76E-01

List of Assumptions:

General: Number of humans: 6 billion; Earth land surface: 1.49E8 km2 [3], hence available land per capita 2.48 ha (a square with an edge of 158 m).

Residential buildings (houses): per capita 100 m^3 internal space (a cube with an edge of 4.64 m); wall thickness 0.15 m; wall density 1.5 ton/m^3.

Consumer products: private transport + house interiors. Private transport: equivalent with 0.25 car per capita; car volume 2/27th of 100 m^3, car projected surface 1/3rd of internal floor space house. House interiors: porosity internal house volume (100 m3): 0.95. Consumer product density: 0.2 ton/m^3.

Infrastructure: infra-structural area per 4 capita: a footpath with a length equal to the edge of the land per capita (157.6 m) and a width of one foot (0.3 m); thickness and material density: see residential buildings.

Other Buildings and Other Products: 1/6th of human life-time is dedicated to out-of-house activities (in factories, shops, offices, schools, museums etc). Therefore is respectively put equal to 1/6th of Residential Buildings and Consumer Products.

Remark:

In the calculation of surface load of mobile goods only parking sites (porosity 0.4) are taken into account.

Minimum Mass

From maximum to a minimum mass is simple. Not all humans can live in the industrial world. It is stated in [34] that in 1995 22% of the world population lived in the industrial world, while in [35] it is foreseen that 80% will never reach the level of being employed according to western world standards. That sets the mass of the Technological World at a fixed minimum of 49 Gton.

Upper Limits Minimum Mass

An upper limit of this minimum can be obtained comparing scattered information about product groups. The global number of cars exceeds 500 million [36], so a factor three less than 1.5 billion cars guessed in Table 2.13, giving rise to a participation percentage of 33%.

Table 2.14: Mid-1990s road and rail networks in 9 selected countries in 9 different world demographic regions (Country area and population [34], length of roads and rails [36]).

World Region	**Country**	**Area**	**Population**		**Length**		**Per Capita**			**R&R/Edge**
		km2			km		ha	m		
				Road	Rail	R&R		Edge	R&R	
North America	USA	9.63E+06	2.73E+08	6.31E+06	1.70E+05	6.48E+06	3.53	188	23.8	0.126
Western Europe	France	5.47E+05	5.90E+07	8.93E+05	3.19E+04	9.24E+05	0.93	96	15.7	0.163
European FSU	Russia	1.71E+07	1.46E+08	5.71E+05	8.75E+04	6.58E+05	11.66	342	4.5	0.013
Pacific OECD	Japan	3.78E+05	1.26E+08	1.15E+06	2.01E+04	1.17E+06	0.30	55	9.3	0.170
Industrialized		**2.76E+07**	**6.04E+08**	**8.92E+06**	**3.10E+05**	**9.23E+06**	**4.57**	**214**	**15.3**	**0.071**
China &CPA	China	9.60E+06	1.25E+09	1.53E+06	5.46E+04	1.58E+06	0.77	88	1.3	0.014
Pacific Asia	Indonesia	1.92E+06	2.16E+08	3.43E+05		3.43E+05	0.89	94	1.6	0.017
South Asia	India	3.29E+06	1.00E+09	3.32E+06	6.27E+04	3.38E+06	0.33	57	3.4	0.059
Sub Saharian Africa	South Africa	1.22E+06	4.34E+07	3.31E+05	2.56E+04	3.57E+05	2.81	168	8.2	0.049
Latin America	Brazil	8.51E+06	1.72E+08	1.89E+06		1.89E+06	4.95	223	11.0	0.049
Developing		**2.45E+07**	**2.68E+09**	**7.41E+06**	**1.43E+05**	**7.55E+06**	**0.92**	**96**	**2.8**	**0.029**
Industr. & Develop.		**5.22E+07**	**3.28E+09**	**1.63E+07**	**4.53E+05**	**1.68E+07**	**1.59**	**126**	**5.1**	**0.041**

Comments:

The nine countries make up about 35 % of the land area of the Earth and about 55 % of the human population.

Lacking four world demographic regions: East Europe (belonging to the industrialised region), North Africa, Middle East and Central Asia (belonging to the developing region).

In Table 2.14 the road and rail networks in the industrialised and developing regions are characterised by a single number (R&R/edge), a ratio of two lengths. R&R stands for the sum of the length of the Rails and Roads pro capita in a country. Dividing the area by the population gives the available area per capita (in ha). Assuming that this area per capita has the shape of a square, allows the calculation of its edge the characteristic size of a country. In [30] all countries are classified in thirteen demographic world regions and two economic regions (industrial and developing). The nine countries fell in nine different world regions and are distributed neatly over the two economic regions. So an estimated value can be calculated for the two economic regions and the world. The industrial world has a characteristic length ratio of 0.71, while the global value is calculated to be 0.41. This implies that the current Technological World has a participation percentage of 57% and that this product group points to a mass of the current Technological World of 139 Gton.

Considering these two light product groups, the minimum mass of the Technological World is somewhere in the range between 49 and 139 Gton. The arithmetic average of 94 Gton is preferred, because it can be generally expected that the contribution of the developing region increases with decreasing complexity of the product and the more simple products are the most massive.

Average Mass

In Table 2.15 the upper and lower estimates are collected and the average mass is of the current Technological World is presented.

Table 2.15: Lower, higher and average estimates of the mass of the current Technological World.

	Gton		
	min	max	average
TW	94	243	169

Systematic errors in Average Mass

That leaves the problem of systematic errors in the average mass. Two kinds of errors can be expected. Errors made by systematically neglecting objects and systematic errors in the estimates and underlying assumptions.

About the systematic errors in masses nothing is known (thickness and density), except that in [11] is mentioned that an American household takes away 3 Gton, when moving to another house. That could be in agreement with the Table 2.13 estimate of 1 Gton house interiors per capita.

More information is available on surface loads, as given in Table 2.16.

Table 2.16: The impact of the heaviest product groups on surface loads (calculated from area and population data in [34] and product group information in [11]).

Industrialized			**area**	**population**	**per capita**						
World Region	Country	City	km2		ha		m2			land area	per
						res. build.	oth build.	infrastruct.	sum	%	res. build.
Western Europe	Netherlands		4.15E+04	1.58E+07	0.263	194	34.2	47.3	276	10.5	1.42
Pacific OECD	Japan		3.78E+05	1.26E+08	0.299	56.9	35.9	15.0	108	3.60	1.89
	Both		**4.19E+05**	**1.42E+08**	**0.295**	**72.2**	**35.7**	**18.6**	**127**	**4.28**	**1.75**
Western Europe	Austria	Vienna			0.0255					32.9	2.32
Pacific OECD	Japan	3 MA			0.0709					6.7	2.79

Comments:
3 MA stands for three Metropolitan Area's: Nagoya, Osaka and Tokyo. Residence Buildings in Vienna: including private gardens and parks. Other Buildings: Commerce, Industry, Office and Public Buildings [12]. No data available to [12] regarding Dutch Office and Public Buildings.

From Table 2.13 it follows that the ratio between the total of the products group and residential buildings is 1.79. This is in reasonable agreement with the average ratio for Japan and The Netherlands: 1.75 (Table 2.16). One difference is relative larger contribution in
of the product group "Other Buildings". Another absolute difference is the area necessary for "Residential Buildings". The major reason behind this fourfold difference is not cultural but definitional. In my experience not many Dutch live in such large houses. The same problem is encountered in the Vienna data. The "Residence Buildings" in Vienna include private gardens and parks. Correcting for the latter green contributions gives 25 m^2 per capita in Vienna and 50 m^2 for the three product groups together [11]. These values are in reasonable agreement with the 40 m^2 per capita, given in Table 2.13. Although it should be realised that Vienna is not an island: especially in the weekend the rich leave Vienna to go to their second house in the country-side, which has a positive effect on the 50 m^2 mentioned.

In can be concluded with [11] and Table 2.13 that less than 0.2% of the Earth land surface is occupied by the product of the Technological World. So their no evidence in the literature that there are systematic errors due to wrong estimates in the surface loads.

Systematic errors by neglecting objects which are present in the current Technological World as defined come twofold: stored objects and living objects.

Stored objects include dumps in the geosphere and biosphere of which those on the ocean floor and in the soil will have the largest contribution. Visible storage (dikes, beneath roads) is economically limited and molecular storage in atmosphere and biosphere poses physical limitations.

As remarked earlier material and energy farming is drawn into the Technological World. Since these activities are yet not very economical they contribute for the time being less than storage.

Summarising it can be concluded that there is a positive systematic error in the average mass of the current Technological World. It is mainly caused by not taking into account the artifacts of the Technological World dumped into Nature.

Relationships

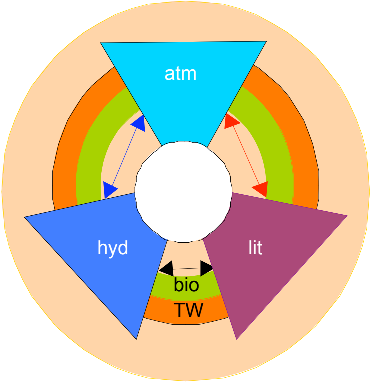

Figure 2.6: Relationships of current Technological World with biosphere and the three subspheres of the geosphere: atmosphere, hydrosphere and lithosphere.

Figure 2.6 shows a sketch of the position of the current Technological World with respect to biosphere and the three geosphere subspheres.

The current Technological World is an open system with respect to mass and energy. It has no regenerative power: it converts feedstock (mass, fuel) from biosphere and dumps the products (technological artifacts, fuel residues) somewhere in Nature (geosphere, biosphere). In itself this is acceptable if both feedstock and product belong to a natural cycle. Because this is not a criterion for current human actions, the Technological World depends on adaptive changes in biosphere and geosphere. Since the only thing that is within adaptive control is that part of the biosphere called mankind, it follows that mankind has to change: this train of thoughts leads then to the concept of a Sustainable Technological World treated in Chapter 3.

Here the discussion will be limited to a qualitative treatment of the current relationship between Technological World and Nature.

The Technological World retrieves its feedstock from the lithosphere and dumps it in the atmosphere by burning (exothermic reactions) and dissociation (endothermic reactions). The carrying capacity of the atmosphere is limited and the products (particles, molecules) return to the surface Earth, cover living species or penetrate them or are eventually drowned in the seas or buried in the soil. In general this gives rise to problems: the cycle is unknown in time and space and everything changes.

Since the carrying capacity of the atmosphere is not zero, an increase in carbon dioxide is measurable and its increase with time is linked with human activities: decrease of the biosphere by deforestation, increase of the Technological World, burning of fossil fuel and decomposition of calcium carbonates.

Human activities change the reflective properties of the Earth's surface by technological artifacts and farming for the TW and together with the changing composition of the atmosphere its seems that the radiation equilibrium is changing causing temperatures changes.

The steadily increasing concentration of humans in small areas called cities, makes local flows to the atmosphere more important and have an increasing but unknown contribution to changing conditions (Gulf Stream, weather).

Future developments

The artifacts of the Technological World are in their infancy comparing them with species in the biosphere. The most advanced artifacts have nowadays in some respect the brain of the simplest one in the biosphere, that of a dragon fly. A larva of the dragonfly brain can only do one thing; stop the hunt if it does not catch the prey within 40 seconds [37]. It is a kind of energy saver, found also in laptops and other energy intensive apparatus.

Animals do move around and intelligent artifacts will do the same in time. Animals consume a lot of energy and therefore it is reasonable to expect that the mass of a single artifact decreases and that their energy demand increases. For the Technological World this means a larger number of artifacts for a given mass and a higher specific energy demand.

A frequently debated question is whether or not modern communication technologies make personal mobility redundant. This did not occur in France before 1985 and Internet. In Figure 2.6 the growth of transport (bicycles, cars, rails) and messages (fax, letters, telephone calls) are compared. So there is no evidence that communication technologies substitute for personal mobility.

It is more likely that they enlarge mobility enabling contact when on the move, explaining the success of mobile phones which conquered the Technological World within one-third of a human generation as compared with the 50 generations paper manufacture needed.

With no new frontiers to explore on Earth it seems that mankind can only change its local surroundings, demanding increasing numbers of new light artifacts with short lifetimes and high energy input

The complexity of the Technological World will increase, inviting a service industry taking care for the communication with consumers. The central message being to relate to a yesterday's product for today is too short for tomorrow's new product.

Extrapolating this the difference between energy and mass vanishes: energy is a throwaway kind of product and mass will get this qualification more and more in time to come.

With no regenerative power it is to be expected that mass and energy of the Technological World will both increase sharply, independent of increasing population figures and equity issues.

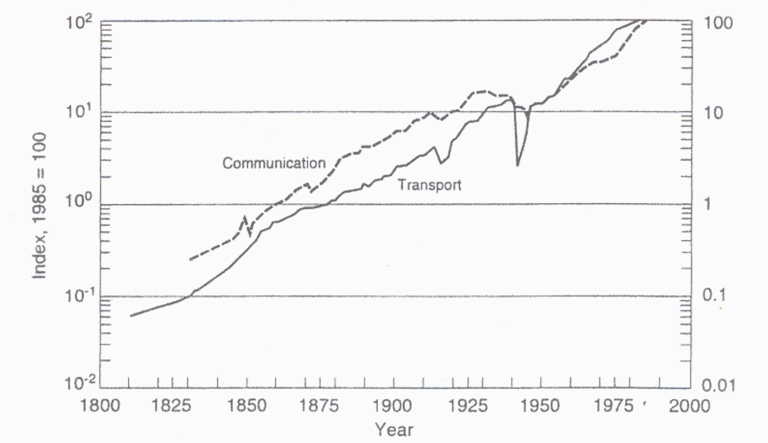

Fig.2.7. Relative growth of transport and communication in France [11].

Concluding

The current Technological World is an open system with respect to mass and energy. It has no regenerative power and depends on adaptive changes in biosphere and geosphere. It is expected that its mass and energy will increase sharply as a consequence of more intelligent technological artifacts with shorter lifespans and increasing demands of communications (between artifacts, artifacts and mankind and within mankind).

2.5 Discussion

The three great World Spheres are described separately in this Chapter and the present discussion is focussed on their collective interdependence.

Their separate dependence increases going from large to small or old to young. The geosphere is closed to mass and open to energy. The biosphere is open to mass and energy, making it dependent on the geosphere. The Technological World is also open to mass and energy, but also lacks any power to regenerate. That makes it completely dependent on adaptive changes in geosphere and biosphere.

The lightest subsphere of the geosphere is the atmosphere. That makes it the most vulnerable to compositional changes. The biosphere has changed its composition in the past and now it seems the Technological World is doing it. Thus a first conclusion is that the three world spheres have a common interest and are interdependent.

The atmosphere has to deal with water, carbon dioxide and oxygen. It exchanges water with the hydrosphere, carbon dioxide and oxygen with the biosphere and is related to all three molecules with the Technological World

Again this suggests interdependency.

The Technological World is expanding and the mass of the biosphere shrinks. The adaptive power of the biosphere therefore reduces. Hence the balance between biosphere and Technological World is still not found. Considering the fact that fossil fuel burning is still going on the balance goes back to the time where mankind could not live on Earth.

Knowledge of systems starts with mass, followed by volume and descends further to surfaces and lengths and ends with the never complete comprehension of shape.

To describe the great world spheres quantitatively in terms of such simple properties as mass and mass/energy exchange surprisingly is a problem. There are no reliable data on the mass of Biosphere mass and Technological World. (The TW-concept is new but all the same countries may know what they possess, rather than what they process and for whom and some NGO can add them up.)

So there are large uncertainties in the masses of the biosphere and Technological World. The mass of the Technological World can move freely between 150 and 50% making discussions about its mass growth rate somewhat academic.

Rather better known are the mass flows to and from the atmosphere. A typical error is at least 20%. Other flows to and from world spheres and subspheres are either much smaller, occur occasionally or are simply unknown. (Volatile Organic Compounds are not only emitted by cars but also by trees.)

Links are present with the development in communication technology between objects turning - in due evolutionary time - into subjects. It has every thing to do with closed shelters followed by communication and leaving these shelters for larger ones. That is the story behind evolution repeated through each human generation, but becomes a thread once generations can not communicate any more. That thread is already the case for chicken, cows and pigs it becomes increasingly the case for artifacts and the laws of scale also are on the doorsteps of the houses still occupied by more than one human generation.

This red communication line will be picked up again in the last chapter discussing the future.

2.6 Conclusions

1. The characteristics with respect to the atmosphere of the hydrosphere, biosphere and Technological World are:

Sphere	Gton	GW	W/kg		Gton/yr	MJ/kg
Hydrosphere	1.66E+09	4.18E+07	2.52E-05	H_20	5.40E+05	2.44E+00
Biosphere	3.15E+03	1.51E+05	4.79E-02	CO_2	4.47E+02	1.06E+01
TW	1.69E+02	1.08E+05	6.41E-01	CO_2	2.27E+01	1.50E+02

2. The Technological World grows at the expense of the biosphere polluting also the geosphere in all it subspheres: atmosphere, hydrosphere and lithosphere.

3. The direction of change is towards increasing communication.

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