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Energy and recycling forecasting. Part I. Energy, recycling and emission models

Introduction

In 2012, the total energy consumption per unit of GDP (energy intensity) continued its fast 2011 decreasing trend (-1.6%) after a three-year stagnation during the economic crisis (Tab. 1–4) [*Global Energy Statistical Yearbook, 2012*]. Energy intensities levels and trends differ a lot across world regions, reflecting differences in economic structure and energy efficiency achievements. The largest decrease in energy intensity in 2012 was in North America (-4.1%). However its energy intensity remained above the European Union's as it is the region with the lowest energy intensity in the world. The decrease was also fast in the CIS (-2.6%/year), but the energy intensity remains there three times higher than in European countries. Chinese consumption per unit of GDP remained 37% above the world average, but China succeeded in cutting it by 65% between 1990 and 2012 (-3.8% in 2012). The energy intensity of India, which fell by 38% between 1990 and 2012 (but drop by only -0.5% in 2012), is now in line with the world average. The high energy intensity in the CIS, the Middle East, China and other Asian developing countries is mainly explained by the predominance of energy-intensive industries and low energy prices which do not favor energy efficiency.

For the survival, we need to diminish the system plastic, fibres and biomaterial waste level and the use of our natural resources.

The purpose of the work is the answer to the question: is the permanent energy and recycling development the basic requirements for future forecasting a goods and high processes effectiveness?

Starting from these survival conditions, the work presents an energy forecast model of a semi self-sustained social system with production and recycling (Tab. 1, 2).

Tab. 1. Ranking list of Electricity production(A) in the World* and Electricity domestic consumption(B) in the World*[*Global Energy Statistical Yearbook, 2012*]

A. Electricity production		B. Electricity domestic consumption	
Year: 2012	Unit: Mtoe	Year: 2012	Unit: Mtoe
China	2,459	China	2,713
United States	1,826	United States	2,152
Russia	1,325	India	774
Saudi Arabia	650	Russia	725
India	548	Japan	457
Canada	417	Germany	314
Indonesia	415	Brazil	281
Iran	323	South Korea	264
Australia	320	Canada	256
Nigeria	263	France	251
*Total: 13.000 Mtoe (million ton of oil equivalent)		*Total: 12.500 Mtoe (million ton of oil equivalent)	

The forecast model is formulated on the level of energy, waste and an equivalent energy (money) description. Some initial conclusions concerning the type of control and subsystem relation are drawn. However, the problem needs further investigation on the level of system description, formulation and analysis.

Generally, it is the demand not to destroy our biosphere any more, and for human beings and every users to live in harmony with the biosphere. Being more specific, it also means exploiting our resources less, and producing less waste. Most of us would like to live at the current level of social and technical evolution. But, in order to live, we need to *produce* our life support means, and as we know already, we must use *renewable* (Tab. 4), *recycling* and *re-use technology* at every possible level of system organization.

Tab. 2. Ranking list of share of renewable in electricity production (A) in the World* and in primary consumption (B) in the World* [*Global Energy Statistical Yearbook, 2012*]

A. Share of renewables in electricity production		B. Share of renewables in primary consumption	
Year: 2012	Unit:%	Year: 2012	Unit:%
Norway	98.0	Nigeria	80.5
Brazil	82.8	Norway	43.1
Colombia	80.6	Brazil	42.8
New Zealand	71.6	Sweden	40.0
Venezuela	63.6	Finland	30.6
Canada	63.2	Indonesia	26.2
Sweden	57.1	India	24.3
Portugal	44.6	Colombia	23.5
Finland	39.6	Chile	22.7
Chile	37.6	Portugal	22.5
*24% Share of renewables in electricity production in the EU (incl. hydro)		*12% Share of renewables in primary consumption in the EU (incl. hydro)	

Energy, recycling and emission models

Consider a part of users that can organize itself as a sustainable (sub-)users, or let us say a *forecasting model.* In order to live, such a system must produce goods and wastes, distribute and use them, and recycle the waste from every subsystem. As is known, our energy and recycling ability or efficiency is <100%, and there are many reasons for this. Hence, our energy, recycling and emissions system and, therefore, the corresponding model must also have some self-regulating mechanisms for reacting to the intensity of local plastic, fibres [*Buell, 1975*] and biomaterial waste. The next question we must answer is the level of abstraction and the language of description and analysis of our energy, recycling and emissions system. One of the best approaches is to use energy as such a language, and the equivalent product, waste and processes energy as the most general quantity enabling us to make such an analysis. In such a case one can use the concept of the energy processor (EP), developed earlier [*Cempel and Natke, 1996*].

The environment-system elements and relations itself are shown in fig. 1. It consists of four subsystems: production, distribution/ use, recycling and societal feedback on plastic, fibres and biomaterial waste. This feedback depends on the level of plastic, fibres and biomaterial waste, *P,* which, if it acts, decreases production and increases recycling to the volume of the designed capacity of production and recycling. The production and recycling subsystem, in essence, may itself possess internal damage and ageing feedbacks. But we already know how it operates and how it influences the life of subsystems. Hence, we can assume for the sake of simplicity that the internal breakdown time of

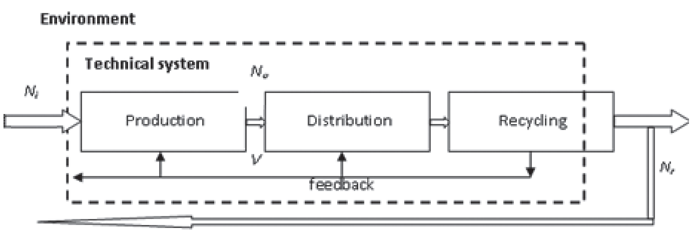

Fig.1. Energy technical system and energy sources, production, distribution and recycling environment

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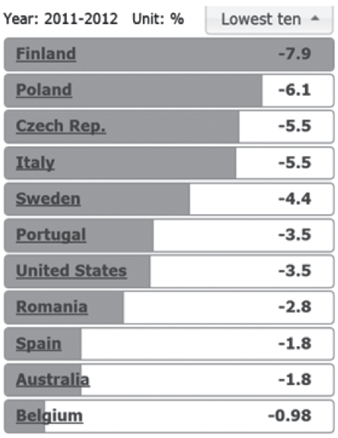
these subsystems is much bigger than the life time of the *Eco Energy Processor* (EEP), which is try to investigate [e.g.: *Cempel and Natke, 1996; Cempel, 1997; Cempel and Natke, 1998; 2002; Cempel, 2011*]

The phase-out of systems followed by recycling are the last working phases within the time dimension of systems engineering. Sustainable environmental protection requires recycling in order to rely on natural resources, to reduce waste products and to regain material or energy from them. The various steps of recycling, from planning up to material recycling are a reverse production process which needs a mathematical model based on reverse logistics for its design, development, process simulation and evaluation. Part of it is: reverse distribution; reuse; and recycling.

Of course, collection, sorting, disassembling, etc. are also parts of this process. Model assumptions including a typical network superstructure, the input and output information, will finally lead to a multicriteria optimization problem with respect to the various costs and subject to various constraints, e.g. with respect to logical variable requirements and capacity constraints. However, optimization of the recycling process is not only a hard task to perform, but also it is outside the scope of this work.

The aim here is to develop a methodology for the model-building of users with production, use, emissions (Tab. 3) and recycling in principle, which is based on an energy approach. In a broader sense, costs are also a type of equivalent energy.

Tab. 3. Ranking list of 2011–2012 variation of CO_2 and emissions in 2012 Year from fuel combustion in the World* [*Global Energy Statistical Yearbook, 2012*]



Variation of CO_2 emissions from fuel combustion	
Year : 2012	Unit : in $MtCO_2$
China	7,673
United States	5,056
India	1,889
Russia	1,620
Japan	1,161
Germany	736
South Korea	572
Iran	533
Saudi Arabia	524
Canada	514

*Poland 297 $MtCO_2$, Europe: 8%

This is the most important environment-system in energy processor, delivering all the goods and services needed by users. As Fig. 1 and Fig. 2 indicate, it receives part of energy the (power) N_i, equivalent to materials, feeding, control, interaction with the environment, etc.

The second part of the total input, N_r, comes from the internal recycling subsystem. Part of this total input N_i + N_r to subsystem is upgraded as N_u, being the designed product (service) of this subsystem, and part is dissipated outside the subsystem as the power V. Also, a small part of the degraded energy accumulates inside the production subsystem, as well as in any subsystem of processor/technical system, but it is assumed here that the lifetime (more exactly, the internal breakdown time) of any subsystem is much larger than the anticipated breakdown time of technical system itself.

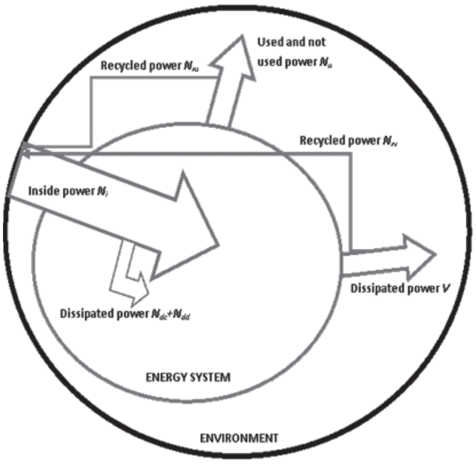


Fig. 2. Energy system model of inside, used and recycled (plastic, fibres and biomaterial wastes) power in environment

The upgraded part of the input energy N_u; with maximum production capacity N_{uc}, is controlled externally by the plastic, fibres and biomaterial waste level in the whole system, $P(\theta)$. The plastic, fibres and biomaterial waste P is the accumulated waste in the whole eco-system, and, of course, it depends on the system life-time θ. This quantity controls the societal feedback, reacting, to the plastic, fibres and biomaterial waste level P in the entire system and, when it acts, it decreases the production level (output) N_u, with negative feedback $(-\xi)$ (Fig. 1), and increases the recycling level (output) N_r with positive feedback (μ). The whole production subsystem is characterized by its loss coefficient $\eta = V/N_{uc}$, being the design coefficient of the production module.

Looking at Fig. 1, we can specify the following analytical description of the production subsystem (without subsystem ageing):

Power balance (according to studies, dissertations and books of *Cempel)*:

$$N_i + N_r = N_u + V \tag{1}$$

Plastic, fibres and biomaterial waste control law (there may be another form of dependency, but this seems to be the simplest one) [*Cempel and Natke, 1996; Cempel, 1997; Cempel and Natke, 1998; 2002; Cempel, 2011; Flizikowski, 2013; Bieliński and Flizikowski, 2013, Flizikowski and Bieliński, 2013; Flizikowski and Macko, 2013*]:

$$N_{ui} = N_{uc} \exp(\xi P) \Rightarrow P = -\frac{1}{\xi} \ln \frac{N_u}{N_{uc}} \tag{2}$$

This control law can be given in the differential form:

$$dN_u = -\xi N_{uc} \exp(-\xi P)\, dP = -\xi N_u dP \tag{3}$$

and also lineralized as

$$N_u \cong N_{uc}(1-\xi P)\, dN_u dP \tag{4}$$

The exponent ξ of the plastic, fibres and biomaterial waste control subsystem here determines the rate of decrease of production due to the increase in the plastic, fibres and biomaterial waste level. The higher it is, the greater the sensitivity of the production level change to a system plastic, fibres and biomaterial waste P. So, the exponent must be chosen carefully.

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