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Assessment of the Potential of Energy Conservation in Industry—a Method

The paper underlines from the beginning obvious reasons requiring a reduction in the growth rate of energy demand at the national and the world level.

It is emphasized within this framework the part detained by energy conservation and the economics of energy conservation. It is shown further that the equations of energy balance sheet help computing efficiency indicators in energy use in various industrial processes.

The method described in the paper offers thus a way for assessing the potential of energy conservation in industry.

1. THE CONTRIBUTION OF ENERGY CONSERVATION TO THE WORLD ENERGY EQUILIBRIUM. AN INSIGHT INTO THE PRESENT AND THE FUTURE

Assuming slower economic growth, forecasts indicate for the end of this century a world energy consumption twice to twice and a half bigger than in 1975. The same forecasts show for the year 2020 a figure four and a half times higher than in 1975. This continuous rise in world energy consumption raises a series of issues which concern ways of balancing supply and demand, in the present and in the years to come. These issues can be seen as follows:

— what are the depletion periods of old energy resources, particularly oil and natural gas;

— what are the prospects for alternative resources — coal, nuclear energy and the new sources of energy;

— there can be taken into account other possibilities besides those aforementioned.

In order to evaluate the running-out periods of energy reserves one needs to know their volume. But this is hard to ascertain. Therefore, prudence is required when utilising such data and judgements should not be made on too a large cover or be definite, even for the sake of strategic economic policy.

The difficulties met in the process of evaluating energy reservers are brought about by [1]:

— data cover different periods;

— there is no clear set of criteria or a unique methodology for making assessments;

— strategic or commercial secrets interfere often;

— reserves have their own dynamics; discoveries in science and technology make it possible to bring into economic sphere unutilised resources enlarging the existing stock;

— in many developing countries exploration and mining are not carried out systematically;

— higher costs constitute barriers for an overall investigation of the earthly crust, thus impeding a realistic assessment of energy reserves.

Despite the uncertainties involved, depletion periods T_e [2] of energy reserves can be computed:

$$T_e = \frac{R_k}{C_k}$$

where R_k is proved reserves at a certain moment and C_k the yearly consumption production at that moment. T_e which is called fictitious time T_f does not take into account changes in consumption $C(t)_k$ and reserves $R(t)_k$. Depletion periods should not overlook these changes. Hence the relationship becomes:

$$T_e = \frac{R(t)_k}{C(t)_k}$$

The use of this formula is hardly at our grasp since evolution of reserves can not be determined. Because of this a "minimum" T_e is resorted to that presumes no discoveries of nonrenewable reserves and no variation in annual consumption. To determine T_e one can use the equation:

$$T_e = \frac{\lg\left[\left(1 - \frac{R_{k0}}{C_{k0}}(q-1)\right)\right]}{\lg q} - 1$$

where R_{k0} is proved reserves in the initial year; C_{k0} represents initial consumption of those reserves and q, the steady growth rate of consumption.

In order to qualify the relationship between proved reserves of nonrenewable resources and possibilities for a rational use of them, it has been proposed the introduction of T_a as the secured period of those reserves. Between T_f and T_a there is the connexion:

$$T_f = \frac{q^{T_a - 1}}{q - 1}$$

where q shows the steady rate of use of reserves so that these should run out within the period T_a.

It is important then to know the depletion periods for oil and natural gas indicated in the field literature*. World proved reserves for oil at January the first, 1978, were 88, 351 million tons. The production level for 1977 of 2,976 million tons gives a depletion period of 29.7 years. As concerns natural gas, data for similar moments give a depletion period of 46.84 years, proved reserves of 71,388 billion m^3 and a world production of 1,524. 9 billion m^3.

Uncertainties and disagreements are conspicuous regarding possible discoveries of new oil and natural gas fields. A reassessment of oil reserves made in 1977 shows a quantity of 172 billion tons still to be discovered [3]. The similar figure for natural gas was 216—236 billion m^3.

Since energy alternatives can not meet a significant share of our needs during the years of transition, a slower growth rate of energy demand becomes imperative in order to produce the necessary adjustments.

Studies do confirm that a remarkable contribution in this respect can be made by energy conservation. This can be stricto sensu defined as follows: "actions and policies designed to enhance efficiency of energy utilisation" [4].

The potential for energy conservation is very high. It is to be related with various domains:

— heating and weathering of buildings;
— heating and cooling of water;
— industrial heat;
— electricity convertion.

In the table 1.1. the high potential in some industries is illustrated by energy consumption per unit of production (in GJ).

Energy conservation is a very intricate process since both ways to enhance it or constraints are different among energy consuming sectors or countries.

Table 1.1

Necessary energy to manufacture 1 ton of product (1 GJ)

	Alumi-nium	Steel	Cement	Oil	Paper
Present consumption	211.00	28.49	9.50	4.75	42.20
Possible consumption using available technologies	179.36	17.94	4.00	3.69	26.38
Minimum theoretical consumption	26.37	6.33	0.74	0.42	0.21

Source: Fortune, mars, 1974

*) Such depletion periods were put into evidence by the world energy conferences held in Detroit and Istambul (1977). Experts all over the world do not agree in defining resources and energy reserves, The World Conference for Energy of 1974, (Detroit) qualified resources as total available quantity underground, liable to successfull exploitation in a foresesable future. Reserves are resources that can be exploited locally under provailing economic and technological conditions.

Implementation of energy conservation takes longer or smaller time. For instance it takes ten years to change an automobile fleet, 20 to 30 years to change industrial equipment and 100 and even more to change the entire buildings stock of a nation.

Energy conservation in a certain field can be carried out gradually.

Modern enterprises that use up-to-date techniques have a smaller potential for energy conservation as compared to older units that use traditional technologies.

Implementation of energy conservation can be achieved on a centralised or a decentralised basis. It requires quick decisions, consistent collective or singular efforts on the part of governments, industries, individual consumers. The phasing in of new rules and standards, the appointment of energy conservation experts in many companies, are steps aiming at this end and and being considered all over the world.

It should be emphasised that energy conservation is a global requirement and must be dealt with as such.

Beside the effect of protecting energy reserves by extending their lives, energy conservation brings in other advantages [5], [6]:

— it reduces the emission of polluting agents thereby dwindling social costs entailed by the increase of pollution;

— it allows a speedier reduction in energy imports than that caused by an increase in domestic energy production;

— it exerts a downward pressure on energy prices, keeping thus a hold on the general level of prices and enhancing competitiveness in foreign trade;

— achievement of energy conservation is not a costly process.

The high rise in oil prices has led to a wide implementation of energy conservation as a means to substantially improve economic efficiency. Hence the conclusion to be drawn is that higher energy prices make more profitable carrying out energy conservation. From another perspective, artificially kept low prices for energy (under the world level) are not conducive to good results in the field of energy conservation.

The economics of energy conservation is then to be seen as that "branch of scientific inquiry which deals through a systemic approach with energy conservation under circumstances of national and international constraints aiming at securing further increases in GDP (gross domestic product), the general living standard and amenities for individuals".

2. ENERGY BALANCE SHEET: A BASIC TOOL FOR ENERGY CONSERVATION

Both quantitatively determined and qualitatively (exergetic) defined energy balance sheets have the purpose of calculating energy consumption, highlighting its useful components and leakages as well as indicating ways for reducing it. Hence it becomes clear the importance of such balance sheets for energy conservation.

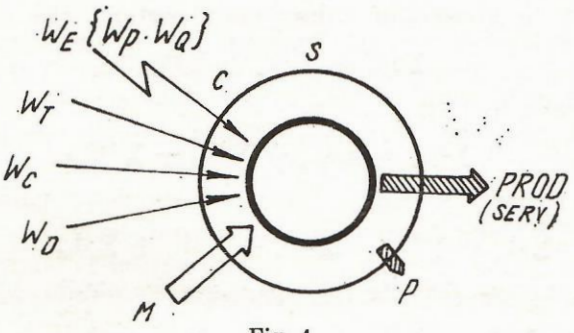

Fig. 1

In fig. 1 where S represents the system and C the outline that delineates it from other economic units. The inner circle refers to various energy consumers. The system has the following inputs which are significant for the energy balance sheet:

— electromagnetic energy W_E (including the active component W_P and the reactive one W_Q);

— thermal energy W_T;

— the energy (conventional) of the fuels consumed by the system, W_C;

— various other types of energy (for instance the energy of the fluid that is the compressed air delivered from without) W_D;

— raw materials and other materials, M, like rolled metals, welding electrodes, implements, industrial water, chemicals, all supplied from without;

— the production (service) carried out and delivered by the system, PROD (SERV) the only output and which is expressed in physical/value units or different services performed for other systems; besides, as "leaked" outputs can be considered various losses of energy and fuels, the refuse and recoverable wastes.

The fig. 1 can be interpreted similarly for a service system where the resulted production becomes the output of services. Obviously M has another meaning.

Balance sheets can be worked-out for installations, sectors, technological processes or whole plants. They can be actual, optimal or projected. The mathematical model of quantitative energy balance sheets expreses the first law of thermodynamics, namely the principle of energy conservation. Exergetic balance sheets express both the first and the second laws of termodynamics, namely the principle of energy conservation and that of energy degradation by irreversible transformations.

The general equation for quantitative balance sheets observes the first law [7]':

$$\Sigma W_i' = \Sigma W_e'$$

where $\Sigma W_i'$ is the sum of the quantities of energy of all kind brought to a common denominator and which enter the blance sheet from without; $\Sigma W_e'$ is the sum of the quantities of energy of all kind brought to a common denominator and which leave the balance sheet.

In its turn $\Sigma W_i'$ is divided into three main parts:

$$\Sigma W_i' = \Sigma W_i + \Sigma W_g$$

and $\Sigma W_e'$ is made up of:

$$\Sigma W_e' = \Sigma W_u + \Sigma W_1 + \Sigma W_p$$

One may write then:

$$\Sigma W_i + \Sigma W_g = \Sigma W_u + \Sigma W_1 + \Sigma W_p$$

By splitting useful components from leakages we obtain:

$$\Sigma W_p = \Sigma W_i + \Sigma W_g - \Sigma W_u - \Sigma W_1$$

$$\Sigma W_u = \Sigma W_i + \Sigma W_g - \Sigma W_1 - \Sigma W_p$$

$$\Sigma W_1 = \Sigma W_i + \Sigma W_g - \Sigma W_u - \Sigma W_p$$

where:

ΣW_i — the sum of all quantities of energy of any kind, which enter effectively the balance sheet from without;

ΣW_g — the sum of all quantities of heat generated within the framework of the balance sheet through exothermal chemical reactions; exception is made for the heat resulted from the exothermal chemical reactions of fossil fuels which enter the outline from without and are included in ΣW_i;

ΣW_1 — the sum of all quantities of energy contained in secondary energy resources of any kind and which after leaving the outline are entering others;

ΣW_u — the sum of the quantities of energy of any kind which enter usefully the outline from without;

W_p — the sum of all leakages (irrespective of the kind).

The general equation of exergetic balance sheets fits entirely that made use of for quantitative balance sheets. There is still one small change: W_k components are split into energy E_k and energy A_k.

$$W_k = E_k + A_k$$

where E_k is that portion of W_k which exceeds the reference temperature of the environment (taken as 25°C or 398°K) and A_k, the portion under the respective temperature and that cannot be turned into mechanical drive.

3. ENERGY EFFICIENCY INDICATORS USED FOR ANALYSIS OF THE POTENTIAL OF ENERGY CONSERVATIONS IN INDUSTRY

Analysis of the potential for energy conservation is made with the help of a set of indicators that measure energy efficieny and specific energy consumptions.

Indicators for measuring energy efficiency are classified with regard to the nature or processes they define, energy transformation and final consumtion.

Processes (installations) of energy transformation signify turning one form or a carrier of energy into another form and, respectively, another carrier of energy; they are called energy producing processes. They could also signify changes in the parameters of a kind or a carrier of energy.

Processes (installations) of final consumption aim at turning out a non-energetic product. These processes may result in secondary energy resources.

The following indicators are used for processes of energy transformation: η_b (gross energy efficiency), η_n (net energy efficiency), $C_{bx/y}$* (gross specific consumption of energy of the kind x for producing the desired type of energy y) and $C_{nx/y}$* (net specific consumption of energy x for producing energy y).

$$\eta_b = \frac{\Sigma W_1 + \Sigma W_{s.a}}{\Sigma W_i + \Sigma W_{s.a}}$$

$$\eta_n = \frac{\Sigma W_1}{\Sigma W_i}$$

$$C_{bx/y} = \frac{\Sigma W_{xi}}{\Sigma W_{yi} + \Sigma W_{ys.a}}$$

$$C_{nx/y} = \frac{\Sigma W_{xi}}{\Sigma W_{yi}}$$

where:

ΣW_1 — the sum of all desired useful energy (usually a single kind of energy) delivered outside the process;

$\Sigma W_{s.a}$ — the sum of all desired energy consumed by the ancillary services of the installation of transformation;

ΣW_i — the sum of energy of various kind entered into the process;

ΣW_{xi} — the sum of energy x entered into the process;

ΣW_{yi} — the sum of energy y delivered outside the process;

$\Sigma W_{ys.a}$ — the sum of energy y consumed by the ancillary services of the transformation installation.

As for processes (installations) of final consumption the efficiency indicators are: η_g (overall/energy efficiency), $\eta_{g.int}$ (overall internal energy efficiency), η_e (economic efficiency), $\eta_{ec.int}$ (overall internal economic efficiency), $C_{x/z}$ (specific consumption of energy x for turning out one unit of

*) $C_{bx/y}$, is a consumption indicator for installations of transformation and $C_{nx/y}$ an indicator for processes of transformation.

product z) and $C_{complex\ tot/z}$ (total complex specific consumption of energy for turning out one unit of product z). Their formula are:

$$\eta_g = \frac{\Sigma W'_u}{\Sigma W'_i}$$

$$\eta_{g.int} = \frac{\Sigma W_u}{\Sigma W'_i}$$

$$\eta_{ec} = \frac{\Sigma W'_u}{\Sigma W_i}$$

$$\eta_{ec.int} = \frac{\Sigma W_u}{\Sigma W_i}$$

$$C_z = \frac{\Sigma W_x}{V_z}$$

$$C_{complex\ total/z} = \frac{\Sigma W_i}{V_z}$$

$$W_i = B + \frac{1}{7 \cdot 10^6}(E_{t.ext.} + 860\ E_{e.ext})$$

$$C_{complex\ total/z} = \frac{B + \frac{1}{7 \cdot 10^6}(E_{t.ext} + 860\ E_{e.ext})}{V_z}$$

where:

W_x — the sum of energy x entered into the process from without or generated in the process;

V_z — the volume of output z

ΣW_i — the sum of electrical energy, thermal energy and fuels entered into the process from without;

B — the sum of quantities of conventional fuel and heated gas entered into the process from without (in tons of conventional fuel);

$Q_{et.ext}$ — thermal energy entered into the process from without, in kcal;

$Q_{ec.ext}$ — electrical energy entered into the process from without, in kWh.

Indicators for exergetic efficiency can be obtained from those for energetic efficiency by taking into account optimal quantities of energy.

Energy consumption is to be related with the loading degrees (productivity) of a process or a system of production as well as with other endogenous or exogenous factors. It is necessary then to draw up energy balances for more figures covering possible variantion of the loading level and other factors; particularly when variations influence to a considerable extent energy consumptions.

Curves relating variation of energy consumptions — simple or complex — ΣW_i to productivity A can be drawn:

$$W_i = f(A)$$

$$\eta = \varphi(A)$$

$$c = \psi(A)$$

When a series of other parameters $p_1, p_2, \ldots$ enters the framework, curves can be drawn in function of their particular values $p_{1j}, p_{2j} \ldots$:

$$W_i = f(A, p_{1j}, p_{2j}, \ldots)$$

$$\eta = \varphi(A, p_{1j}, p_{2j}, \ldots)$$

$$C = \psi(A, p_{1j}, p_{2j}, \ldots)$$

The curves for processes of energy transformation and the curves c for processes of final consumption allow us to determine the optimal running of installations. They provide covering loading size and other factors that are conducive to highest efficiency and lowest specific consumption.

Other factors that exert influence on energy efficiency [8] are: volume and range of production, quality of raw materials, technologies used, temperature of the environment, features of energy consumed.

By analogy, useful exergetic characteristics can be obtained by replacing energy with exergy.

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UNE METHODE POUR L'EVALUTION DU POTENȚIEL DE CONSERVATION DE L'ENERGIE DANS L'INDUSTRIE

Les auteurs précisent la nécessité objective de la réduction de la tranche de la demande d'énergie tant sur le plan national que sur le plan mondial. Dans ce contexte, on définit le rôle de la conservation de l'énergie et respectivement de l'économie de la conservation de l'énergie. Les auteurs présentent aussi les équations du bilan énergétique sur la base desquelles on peut calculer les indicateurs d'efficacité dans l'utilisation de l'énergie dans différents processus industriels. On peut évaluer ainsi sur la base de cette méthode le potentiel de la conservation de l'énergie dans l'industrie.

МЕТОД ОЦЕНКИ ПОТЕНЦИАЛА КОНСЕРВАЦИИ ЭНЕРГИИ В ПРОМЫШЛЕННОСТИ

Сообщение начинается с уточнения обьективной необходимости понижения темпов роста спроса на энергию в мировом и национальном планах. Затем, в этой связи, определяется роль консервации энергии и, соответственно, экономики консервации энергии. При этом излагаются также аспекты менеджемента при осуществлении консервации энергии. В продолжение, приводятся уравнения энергетического баланса, на основе которых можно рассчитать показатели эффективности использования энергии в различных промышленных процессах. На основе этого метода можно таким образом установить потенциал консервации энергии в промышленности.

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