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ENERGY EFFICIENCY AND PERFORMANCE INDICATORS SYSTEM FOR HEATING AND HOT WATER BOILERS

Запропоновано принципи побудови системи енергетичних індикаторів, гармонізованої до вимог Європейського Союзу. Систематизовано існуючу традиційну систему параметрів енергетичної ефективності функціонування котельного обладнання для опалення та гарячого водопостачання. Наведено приклади використання розробленої системи енергетичних індикаторів.

General Definitions: (1) Efficiency is the ratio of the useful work (production, resources or energy) output to the work (production, resources or energy) input; it is a terminal result of certain reasons, forces, resources, and actions that is a result with minimum waste and efforts. (2) Performance is an act, process, or manner of performing or functioning, execution of a duty. (3) Conventional system of parameters is a scalar system that does not change in time & space. (4) Indicator system of parameters is a vector system that changes in space and time.

Basic principles of energy efficiency and performance indicators system construction are: (a) comparability: indicators should enable a comparison and show changes in the performance and efficiency of boilers, (b) balance: between problematic (bad) and prospective (good) areas, (c) continuity: indicators should be based on the same criteria and should be taken over comparable time, sections or units, (d) timeliness: indicators should be updated frequently enough to allow action to be taken, (e) clarity: indicators should be clear, unambiguous, and understandable. Indicators should give an accurate appraisal of the organization's performance, allow for year on year comparison, comparison with sector, national or regional benchmarks, regulatory requirements [1, 2].

Construction of energy efficiency and performance indicators system hierarchy: sectorial intensities (GJ/capita); structure subsectorial intensities (area/capita, heat/area/degree-days); attributes: utilization, quality, etc. (hours heated, indoor temperature); process efficiencies (conversion efficiency, thermal integrity, etc.) [3].

Categories of energy efficiency and performance indicators system are: (1) Operational indicators: These concentrates on the aspects associated with equipment operations including activities, products or services and can cover such topics as emissions, product and raw material using, fuel diversification and consumption, and efficiency of energy usage. Operational indicators can be subdivided into input indicators, physical facilities and equipment indicators and output indicators. By integrating cost aspects into them, they furthermore represent a basis for energy and en-

vironmental cost management. (2) Institutional Indicators: These concentrates on the efforts of management to provide the infrastructure for energy and environmental management to succeed and can, among others, cover energy and environmental programs, objectives and targets, training, incentive schemes, audit frequency, sites inspections, authorities, community, and individuals relations. (3) Condition Indicators: These give information on the setting out priorities of community and individuals on the energy, equipment, and environment surrounding. The healthy and environmental problems that arise from operating equipment depend often on a variety of influences. Examples are emissions from different types of heating systems. Data about the condition of environmental media are usually measured and recorded by governmental institutions. These data are used to derive specific environmental indicator systems for the main environmental problems. In connection with energy and environmental policy goals, public energy and environmental indicators can be used by organizations as an orientation for setting priorities in determining their own indicators and objectives.

Structure elements of these 3 categories are shown at the Table 1.

Acceptability of energy efficiency and performance indicators system. The three categories of indicators should be accepted both equipment's suppliers and services consumers, and should be usually considered by them in combination of these indicators in order to be able to demonstrate, that: they understand the energy and environmental impacts associated with their activities, products and services; they are taking appropriate measures to ensure the management of energy and environmental aspects associated with the impacts; and the results of the management of energy and environmental aspects is improved efficiency and performance of equipment operation.

Compliance with state and local policy priorities. The selected indicators should comply with state and local policy priorities showing: how does the equipment operating affect the state, local or regional situation in relation to important state, local or

regional policy issues in the selected area of business, what problems dominate the current political and social discussions, what external requirements, for example from interested parties, affect the product (services)?

In addition, equipment's suppliers and services consumers should select indicators, which enhance their co-operation. Indicators, which do not contribute to the co-operation of the organizations and individuals will ultimately not be incorporated in day-to-day management and hence will have little effect in improving efficiency and performance. In short, only those indicators, which enable the equipment's suppliers and services consumers to perform their tasks, better are the ones, which are most appropriate. It is important that the equipment's suppliers and services consumers can have a correct assessment of its energy and environmental performance. The indicators should represent performance as accurately as possible, providing a balanced il-

lustration of energy and environmental aspects and impacts.

In addition to absolute values of energy efficiency and performance impacts, measurement units may also address the efficiency and performance impact per unit of product or service, per turnover, gross sales or gross value added (energy- and ecology) or the energy (environmental) impact per employee.

Structure elements of the input, facilities & equipment, and output indicators of the operational category are shown, accordingly at the Tables 2-4.

Structure elements of the conformance and involvement indicators of the institutional category are shown at the Tables 5-6, accordingly.

Structure elements of the condition indicators of the institutional category are shown at the Table 7.

As an example of case study, a conventional system of parameters for heating and hot water boilers is shown at the Table 8.

Table 1. Structure elements of operational, institutional, and condition categories.

Operational Indicators			Institutional Indicators		Condition Indicators
Input Indicators	Facilities & Equipment Indicators	Output Indicators	Conformance Indicators	Involvement Indicators	Surrounding medium
Materials	Marketing	Products provided	Legislation	State & Local Authorities	Operation & maintenance costs
Energy resources	Design	Services provided	Norms & Standards	Community	Prices
Services supporting the operation	Installation	Losses	Technical specification	Counterparts	Services availability
Products supporting the operation	Operation	Emissions	Community	ESCOs	Safety
Efficiency	Maintenance	Effluents and Waste	Individuals	Funds	Health

Table 2. Operational category input indicators structure elements.

Operational performance and efficiency: Input indicators		
Indicator subcategory	Examples of indicators	Examples of measurement units
Materials	Operating and auxiliary raw materials, water, etc.	- kg per year - kg per unit (unit of volume) of product per year - liters per year - liters per unit (unit of volume) of product
Energy resources	Natural gas, electricity, fuel oil, renewables, etc.	- liters per year - liters per unit of product - k W*hours per year - k W*hours per unit of product
Services supporting the operation	Maintenance, cleaning, repair, waste disposal, training, financial services, etc.	- warranty period, months - costs for services per year, US\$ - number of services per year
Products supporting the operation	Preliminary and auxiliary products, heat carrier, lubricating oil, etc.	- kg per year - liters per year
Efficiency	Useful work (product, resources or energy) output	- relative number - kg (calories, liters)/ operating costs (cost for services, etc.) per year

Table 3. Operational category facilities & equipment indicators structure elements

Operational performance and efficiency: Facilities and equipment indicators		
Indicator subcategory	Examples of indicators	Examples of measurement units
Marketing	Products, materials, and equipment, volume of sales, etc.	- number of products (materials, equipment) to be sales per year
Design	Buildings, products, materials, and equipment, etc.	- heat loss of buildings in kW per square meters and degrees centigrade - installed power of equipment, kW, Gcal per hour
Installation	Buildings, products, materials, and equipment, etc.	- % of energy efficient labeled equipment - % or number of equipment with eco-labels
Operation	Buildings, products, materials, and equipment, etc.	- hours per year equipment is in operation - kg of substances, materials or products per year used for operation - fuel consumption in kg per year
Maintenance	Buildings, products, materials, and equipment, etc.	- hours per year specific unit or equipment needs maintenance - kg of substances, materials or products per year used for maintenance

Table 4. Operational category output indicators structure elements

Operational performance and efficiency: Output indicators		
Indicator subcategory	Examples of indicators	Examples of measurement units
Products produced	Work, energy, substances in products, packaging form, etc.	- GJ (Gcal) per year - kW*hours per year (per unit of product) - kg of packaging material per year
Services provided	Heating, hot water, repair, waste disposal, training, etc.	- fuel (energy) consumption per service unit and year - number and percentage of services with eco-labels (per year)
Efficiency	Useful work (product, resources or energy, services) output	- relative number - kg (calories, liters)/ operating costs (cost for services, etc.) per year
Emissions	Greenhouse gases, volatile organic compounds, fine and ultrafine particles, etc.	- kg per year - kg per kg of product - liters per year - liters per kilograms of product
Effluents & Waste	Discharge of specific hazardous substances, process water or cooling water, hazardous wastes, heat noise, etc.	- kg of substances per cubic meter of waste - percentage of waste (per year) - kJ per kg of product - decibels

Table 5. Institutional category conformance indicators structure elements

Institutional performance and efficiency: Conformance indicators		
Indicator subcategory	Examples of indicators	Examples of measurement units
Legislation	Conformance with state and local legislative practices in particular area, energy and environment	- % of objectives and targets reached per year
Norms and Standards	Conformance with state and local normative and standards in particular area, energy and environment	- % of units/workplaces with energy efficiency and environ, requirements (per year) - % of units/workplaces audited per year number of units/workplaces brought to conformity per year
Technical Specification	Qualitative and quantitative conformance with equipment operation	- % of units/workplaces audited per year - % of units/workplaces integrated into energy and environmental systems (per year)
Community	Conformance with community strategic plans, behavior's rules and norms	- % of units/sites audited per year - number/(%) of suggestions implemented per employee and year
Individuals	Conformance with individuals habits and temper, ability to pay	- % of units audited per year - number/(%) of suggestions implemented per employee (year)

Table 6. Institutional category involvement indicators structure elements

Institutional performance and efficiency: Involvement indicators		
Indicator subcategory	Examples of indicators	Examples of measurement units
State & Local Authorities	Strategic planning, contracting, guarantees, budget funding, etc.	– number of policy developments (per year) – number/amount of contracts made (per year)
Communities	Meetings, collective and individual contracting, etc.	– number/amount of contracts made (per year) – number of meetings (their participants) per year – number of condominiums created – total value in US\$ of equipment sold
Counterparts	Performance contracting, demand side management, etc.	– number/amount of contracts made (per year) – total energy savings and amount (percentage) of capital investments per year
ESCOs	Turnkey projects implementation, investments, etc.	– number/amount of contracts and projects made (per year) – total value in US\$ of products sold – total energy savings and amount (percentage) of capital investments per year
Funds	Contracting, guarantees, funding, investments, etc.	– number/amount of contracts made (per year) – total amount in US\$ or percentage of capital investments per year

Table 7. Structure elements of operational, institutional, and condition categories

Conditional performance and efficiency: Surrounding medium indicators		
Indicator subcategory	Examples of indicators	Examples of measurement units
Prices	Equipment, materials, products, services and ability to pay	– prices for equipment & products, tariffs for services per country, per companies – householders income per year, ability to pay in US\$
Operation and maintenance costs	Equipment, materials, products, services	– time and costs of repair – cost of substances, materials or products per year used for operation – costs of energy & fuel consumption per year
Services availability	Services centers, storehouses, personnel	– number of local services centers (storehouses) per country – time of materials or products delivery
Health and safety	Accidents, illnesses, indoor air quality, water quality, noise, etc.	– number of accidents per year – concentration of harmful substances in milligram per liter or parts per million – level of noise in decibels

Table 8. Conventional system of parameters for heating and hot water boilers

№	List of parameters	Unit	№	List of parameters	Unit
1	Brand (type) boiler		12	Output-input ratio of boiler	%
2	Nominal expense of fuel: – liquid – hard – gaseous	m ³ /hour kg/hour m ³ /hour	13	Range of adjusting of temperature of heat carrier in the system of heating	°C
3	Calorific value of fuel – m ³ liquid – kg hard – m ³ gaseous	kcal	14	Tariffs for heating and hot water for consumers categories: population, budgetary sphere, other	US\$/Gcal
4	Maximal / minimum pressure of gaseous fuel	kg-f/cm ²	15	Temperature of smoke gases after a boiler	°C
5	Maximal / minimum pressure of input water	kg-f/cm ²	16	Range of adjusting of temperature of water on the hot water-supply	°C
6	Nominal / minimum productivity of boiler for heating	Gcal/hour	17	Mean-time-between-failures	hour
7	Nominal / minimum productivity of boiler for hot water-supply	Gcal/hour	18	State of boiler automation	
8	Heat carrier before boiler	pressure temperature	19	Cost of fuel for unit: – m ³ liquid – kg hard – 1000 m ³ gaseous	US\$
	after boiler	pressure temperature			
9	Total expense of heat carrier through a boiler	m ³ /hour	20	Duration of heating season	hour/year
10	Contents CO ₂ in smoke gases	%	21	Duration of hot water using	hour/year
11	Content NO _x in smoke gases	%	22	Weight of boiler	kg

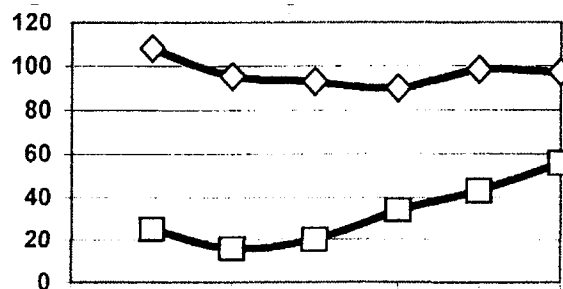
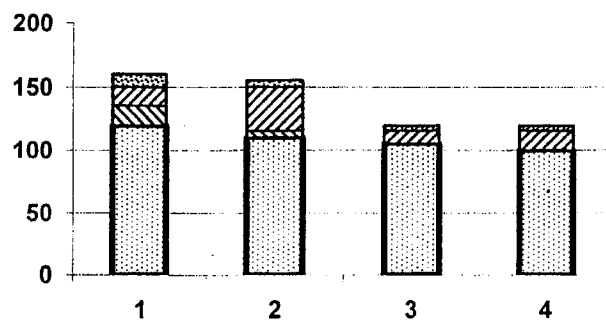


Figure 1. Trends in total production of heat energy (upper curve) and share of sold energy efficient boilers per years



(1 - district heating boiler; 2 - building block boiler; 3 - multifamily building boiler; 4 - individual (flat) boiler).

Figure 2. Indicators following energy loss comparison in different types of heating systems

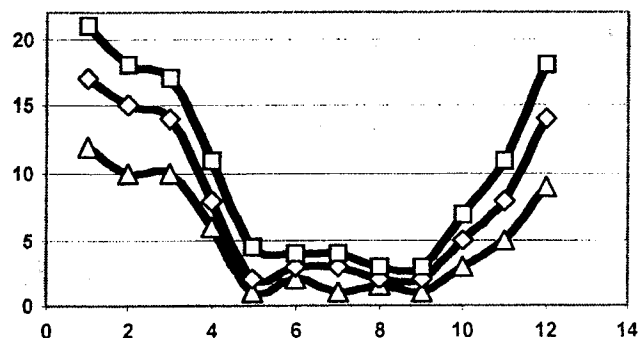


Figure 3. Indicators following fuel consumption per months for the three types of boilers

Using the conventional system of parameters, some of the typical energy efficiency and performance indicators' examples for heating and hot water boilers are presented at the Figures 1-3 below.

One more class of typical energy efficiency and performance indicators' examples are indicators following investment heating projects' financing and economy, as Life Cycle Cost indicators (Net Present Value, Savings-to-Investments Ratio, Internal Rate of Return, etc.

1. European Union Commission Recommendation of 10 July 2003 on Guidance for the Implementation of Regulation (EC) No761/2001// Official Journal of the European Union Commission. - 2003. - No.L 184. - P. 19-32.

2. Energy Indicators for Sustainable Development: Guidelines and Methodologies. - Vienna: IAEA, 2005. - 171 p.

3. Indicators for Sustainable Energy Development. - Vienna: IAEA, 2000. -20 p.