ECO-ENERGY LIFE CYCLE ANALYSIS OF DOMESTIC REFRIGERATORS

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Introduction. The technological progress in the refrigeration industry, as well as in other industries, is focused on energy saving. In addition, last decades the refrigeration industry has been developed within framework of the Kyoto Protocol (GHG emission reduction). But keeping the terms of the Kyoto Protocol is rather difficult.

The manufactures have used different ways to reduce the energy consumption of household refrigerating appliances. But such improvement often leads to the increasing in energy and material expenditures on household refrigerating appliance manufactured. Therefore, the manufacturing indirect contribution in total GHG emission also increases. Taking into account this fact it can be concluded that low electricity consumption household refrigerating appliances are not always environmental friendly.

The main purpose of this study is analysis of three domestic refrigerators using the traditional energy efficiency index and alternative eco-energy efficiency indicator that consider refrigerator life cycle.

Method of eco-energy analysis of household refrigerating appliance.

Currently, the basic energy characteristic of household refrigerating appliance is daily electricity consumption. This value is used to calculate the Energy Efficient Index – EEI of household refrigerating appliance [1] – eq. (1). The energy efficient class is estimated by value of the EEI.

$$EEI = 100 \cdot AE_c / SAE_c \qquad (1)$$

where SAE_c is annual energy consumption of the household refrigerating appliance, kW h; SAE_c is standard annual energy consumption of the household refrigerating appliance, it should be evaluated by [1], kW h.

The EEI tale into account only the equipment energy consumption at its operation. At the same time the environmental impact at manufactured and utilization of the equipment do not considered.

For estimating the eco-energy efficiency of the household refrigerating appliance with different both storage volume of compartments and lifetime the new indicator is proposed [3]

$$EEEI = TEGHGE / V_{eq} \cdot \tau \qquad (2)$$

were $TEGHGE$ is the total equivalent emission of GHG of household refrigerating appliance life cycle, kg CO_2-eq; V_{eq} is the equivalent volume of household refrigerators [1], l; τ is the lifetime of the household refrigerators, years.

For household refrigerating appliance analyzing the equation for *TEGHGE* [3] can be presented as

$$TEGHGE_{HR} = \sum em_i \cdot m_i^{comp} + \sum em_{UTIL\,i} \cdot m_i^{comp} + em^{h\,l} \cdot T^{h\,l} + \beta \cdot E_{annual} \cdot \tau + m_R \cdot GWP_R \cdot L_{annual} \cdot \tau + m_R \cdot GWP_R \cdot \gamma_{R\,UTIL}, \qquad (3)$$

were em_i and $em_{UTIL\,i}$ are manufacturing and utilization GHG emission for i-th material used at creating of the equipment on that the producing artificial cold, kg CO_2-eq (kg of material)$^{-1}$; m_i^{comp} is the mass of the i-th material, kg; τ is average lifetime of the equipment, years; $em^{h\,l}$ is equivalent of GHG emission for

human labor, kg CO_2-eq (man-hour)$^{-1}$; is labor expenditures for manufactured the equipment, man-h; β is an average indirect emission factor for a certain region (country), kgCO_2-eq (kW h); E_{annual} is the annual electricity consumption of household refrigerator, kW h; m_R is refrigerant charge, kg; GWP_R is the global warming potential of refrigerant, kg CO_2-eq (kg of refrigerant)$^{-1}$; L_{annual} is annual refrigerant leakage (part of the refrigerant charge); $\gamma_{R\,UTIL}$ is end of life refrigerant leakage (part of the refrigerant charge).

The proposed indicator can be used for justified advisability of the modernization of the household refrigerators for the purpose of the enhancement theirs eco-energy characteristics.

Analysis of the Results.

The analyzed refrigerators have approximately equal characteristics: total storage volume of compartments, temperatures of freezing and cooling compartments – minus 18 °C and 4 °C, correspondently, the same manufacturer. The main characteristics of the analyzed household refrigerating appliances are presented in Table 1. The input data for analysis are presented in table 2. Another input data was consumed equal: τ=12 years, refrigerant R600, GWP_R=20 kg CO_2-eq (kg of refrigerant)$^{-1}$, β=0.697 kg CO_2-eq (kW h)$^{-1}$, $em^{h\,i}$ = 0.46 CO_2-eq (man-hours)$^{-1}$, m_R =90 g, $\gamma_{R\,UTIL}$=0, L_{annual} =0.05 part from mass charge per year.

Table 1 – The main characteristics of the analyzed household refrigerating appliances manufactured by Atlant (according to the manufacturer catalog 2019).

Model	XM-4625	XM-6323	XM-6221
Total storage volume of compartments, l	378	371	373
Storage volume of cooling compartments, l	206	256	252
Storage volume of freezing compartments, l	172	115	121
Refrigerator mass, kg	76	81	84
Daily electricity consumption, (kW h) day^{-1}	0.88	0.81	0.84

Table 2 – Household refrigerators main materials percentage composition and GHG emissions at manufacturing and recycling of some materials

Material	Materials percentage composition	em_i, (kg CO_2-eq) kg^{-1}	$em_{UTIL\,i}$, (kg CO_2-eq) kg^{-1}
Steel	65 4 %	1.43	0.54
Aluminum	0.6 %	4.50	0.63
Copper	29.0 %	2.78	2.46
Plastics	5.09 %	2.61	0.12

The results of calculation of the energy efficiency index *EEI* (a) and eco-energy efficiency indicator *EEEI* (b) for analyzed household refrigerating appliances are presented on Fig. 1.

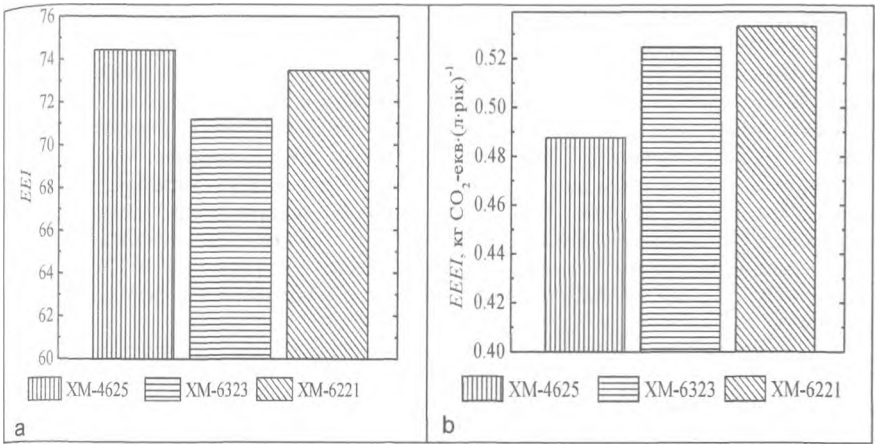

Fig. 1 – The comparison of the energy efficiency index *EEI* (a) and eco-energy efficiency indicator *EEEI* (b) for analyzed household refrigerators

As we can see from Fig. 1 the performed analysis of energy efficiency indexes *EEI* and eco-energy efficiency indicators *EEEI* allow us to make qualitatively opposite conclusion about efficiency of analyzed household refrigerators. Therefore, the energy efficiency index is not an objective criterion for assessing the environmental performance of household refrigeration equipment.

REFERENCES

1. Commission delegated regulation (EU) No 1060/2010 of 28 September 2010 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of household refrigerating appliances // Official Journal of the European Union.

2. Chen G., Zhelezny V., Khliyeva O., Shestopalov K., Ierin V. Ecological and energy efficiency analysis of ejector and vapor compression air conditioner // International Journal of Refrigeration. 2017. Vol. 74. P. 127-135.

ОЦІНКА РОЛІ ЯКОСТІ ВОДИ В ЖИТТІ НАСЕЛЕННЯ УРБОСИСТЕМИ

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На сьогодні до найбільш дефіцитних ресурсів планети можна віднести прісну воду, а забезпечення її якості є однією з глобальних проблем суспільства. Якість води – це характеристика складу і властивостей води, що визначає її придатність для конкретних видів водокористування. Оцінка якості води проводиться на основі систем показників таких як: фізичні,