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ПРИДНІПРОВСЬКОЇ ДЕРЖАВНОЇ АКАДЕМІЇ БУДІВНИЦТВА ТА АРХІТЕКТУРИ

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В ЭТОМ НОМЕРЕ

НАУЧНЫЕ ИССЛЕДОВАНИЯ

АРХИТЕКТУРА

IN THIS ISSUE

SCIENTIFIC RESEARCH

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SCIENTIFIC RESEARCH

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STUDY OF SHELL FOR ENERGY EFFICIENT OF SUSTAINABLE LOW-RISE BUILDING

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Abstract. The article presents the results of study the shell for energy-efficient environmental low-rise residential building, corresponding to the criteria of sustainable development in construction. ***Purpose***. The purpose of the presented research is providing a study of parameters for shell of energy-efficient environmental low-rise buildings. ***Methodology***. Research is carried out on the basis of an improved method for calculating the thermal characteristics of the external walling, as well as physical heat transfer simulation. ***Conclusion*.**The ratio between the thickness of external walling and the proportion of heat loss through them was determined, and also the heat loss through thermal "bridges" was studied. ***Originality.*** The limits for the optimum thickness of the external walling of ecological materials was analyzed, and it was offered solution for minimization of heat loss through the nodes of shell. ***Practical value.***Recommendations are worked out on constructing of thermal shell at planning of energy-efficient low-rise residential buildings.

Keywords: *energy efficiency in construction; sustainable development; sustainable building; thermal shell of the building; reduced resistance to heat transfer*

ВИВЧЕННЯ ОБОЛОНКИ ЕНЕРГОЕФЕКТИВНОЇ ЕКОЛОГІЧНОЇ МАЛОПОВЕРХОВОЇ БУДІВЛІ

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Анотація. У статті представлені результати дослідження оболонки енергоефективного екологічного малоповерхового житлового будинку, відповідає критеріям сталого розвитку в будівництві. ***Мета.*** вивчення необхідних параметрів оболонки енергоефективного екологічного малоповерхового будівлі. ***Методика.***

Дослідження виконані на основі на основі вдосконаленого методу розрахунку теплотехнічних характеристик зовнішніх огороджувальних конструкцій, а також фізичного моделювання теплопередачі. ***Результати.*** Визначено співвідношення між товщиною зовнішніх огороджувальних конструкцій і часткою теплових втрат через них, а також втрати тепла через термічні «мости». ***Наукова новизна***. Встановлена межа оптимальної товщини зовнішніх огороджувальних конструкцій з екологічних матеріалів, запропоновано оптимальні конструктивні рішення вузлів сполучення конструкцій будівлі з теплової оболонкою. ***Практична значимість***. Розроблено рекомендації щодо конструювання теплової оболонки при проектуванні енергоефективних малоповерхових житлових будинків.

Ключові слова: *енергоефективність в будівництві; сталий розвиток; екологічна будівля; теплова оболонка будівлі; приведений опір теплопередачі*

ИЗУЧЕНИЕ ОБОЛОЧКИ ЭНЕРГОЭФФЕКТИВНОГО ЭКОЛОГИЧЕСКОГО МАЛОЭТАЖНОГО ЗДАНИЯ

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Аннотация. В статье представлены результаты исследования оболочки энергоэффективного экологического малоэтажного жилого здания, соответствующего критериям устойчивого развития в строительстве. ***Цель.*** Изучение необходимых параметров оболочки энергоэффективного экологического малоэтажного здания. ***Методика.*** Исследования выполнены на основе усовершенствованного метода расчета теплотехнических характеристик внешних ограждающих конструкций, а также физического моделирования теплопередачи. ***Результаты***. Определены соотношение между толщиной внешних ограждающих конструкций и долей тепловых потерь через них, а также потери тепла через термические «мосты». ***Научная новизна***. Установлен предел оптимальной толщины внешних ограждающих конструкций из экологических материалов, предложены оптимальные конструктивные решения узлов сопряжения конструкций здания с тепловой оболочкой. ***Практическая значимость.*** Разработаны рекомендации по конструированию тепловой оболочки при проектировании энергоэффективных малоэтажных жилых зданий.

Ключевые слова: *энергоэффективность в строительстве; устойчивое развитие; экологическое здание; тепловая оболочка здания; приведенное сопротивление теплопередачи*

Introduction. In recent years, the issues of energy saving and energy efficiency policies have acquired special urgency in Europe and are directly linked not only with global environmental problems, but also with energy security.

Scientists and experts in numerous seminars and conferences, both national and international levels, are actively discussing various aspects of the energy-efficiency problem. The latest among these activities was the Climate Conference in Paris in 2015 (COP21), the results of which have been adopted by a number of solutions to reduce greenhouse gas emissions (GHE), the main cause of which is the production of oil and gas - the most common source of energy.

Buildings and communal services is one of the most energy-intensive sectors of the economy. In Ukraine and the countries of the European Union from 30 to 40% of total energy, consumption is spending in the operation of the building complex. However, the structure of these costs is fundamentally different in our country. In developed countries, a significant part of the energy is spending on ensuring the comfort of human life - a sub-holding of the normal temperature, both in winter and in the warmer months, to work appliances. In our country, the vast majority of energy is spending only for space heating at a low level to ensure comfortable heat and humidity parameters.

The economic crisis, increasing energy prices, irreversible environmental degradation of the planet make people to create new construction projects that would be economically viable in their construction, operation, utilization, and create a comfortable environment for human habitation, and were established in accordance with the concept of sustainable development.

There is a high cost of engineering equipment for the use of renewable energy sources on the market of Ukraine.Moreover,by the results of previous studies it has quite a long payback period.[1]That`s why for the wider dissemination of energy-efficient building at the national level, it is necessary to examine the best possible optimization of the thermal performance for the building shell. Itmay permit to achieve a high level of energy efficiency only through the efficient solutions of exterior building`s walling. In addition, the use of local organic materials from renewable resources is an opportunity to reduce costs and expenses of energy at the stage of construction of the building and its recycling.

Research purpose. The aim of the presented research is providing a study of parameters for shell of energy-efficient environmental low-rise building.

In accordance with this aim the following specific objectives were formulated:

- providing the analysis of possible optimization the thickness of the shell for energy-efficient environmental low-rise building;
- evacuation of modeling study of the heat loss through thermal "bridges" to minimize their effect to the energy-efficiency of the building shell;
- propose the recommendations for constructing of thermal shell at planning of energy-efficient low-rise residential building.

Methodology. The main arguments in the article are developed by applying an improved method for calculating the thermal characteristics of the external walling, as well as physical heat transfer simulation.

Conclusion. Energy-efficient building includes a set of architectural planning, design and engineering solutions that meet the goals to ensure a comfortable microclimate and minimal energy consumption in the building premises.

The architectural and planning solution includes: correct orientation of the building, compactness of the building, lack of jetties, zoning of the internal spaces, presence of elements of the summer sun protection as an independent structure, well-isolated thermal shell of the building, use of the terrain and vegetation.

The design solution includes the creation of a continuous shell of a building with high thermal insulation, with thermal "bridge" which are absent or reduced to a minimum.

For energy-efficient buildings is preferable to frame technology unit wall using environmentally friendly natural materials such as wood, soil-concrete. Eco-friendly, energy-efficient thermal shell is formed by filling the space between the uprights with environmental organic insolation material - cereal straw, hemp or flax fire, cane chaff and others.

The tightness of the thermal shell is provided: inside –by device protective layers of vapor barrier, thermal capacitance designs of soil-concrete blocks or bricks and plaster; outside –by device protective layers of wind-protection and facade decoration.

The engineering solutions include different systems such as heat pumps, solar and geothermal collectors, solar panels, wind turbines, etc.

Study of shell thickness for energy-efficient sustainable building. Designing of the heat-insulating shell for building on thermotechnical parameters of its elements includes a number of conditions [2]:

$$R_{\Sigma пр} \geq R_{q\min}, \qquad (1)$$

where $R_{\Sigma пр}$ – reduced R-value, m^{2}K/W;

$R_{q\min}$ – the minimum acceptable value of resistance of heat transfer.

From the point of view of energy efficiency, the rational design of heat-insulating building envelope requires that all non-transparent fence to have the same resistance to heat transfer, which is achieved by appropriate selection of the thickness of the insulation. We assume that the heat transfer resistance of the attic and basement floors equal to the resistance to heat transfer of walls, which in turn is determined by the formula (2).

Fig. 1 shows the dependence of the reduced thermal resistance $R_{\Sigma пр}$ of the thickness of insulation δ_2.

The relationship is nonlinear: with an increase δ_2 in the growth rate $R_{\Sigma пр}$ decreases significantly. This is due to the heat of the cost through a translucent fencing. The dimensionless fraction of heat loss through the opaque $\overline{q}_{нп}$ and translucent $\overline{q}_{сп}$ building shell are:

$$\overline{q}_{нп} = \frac{F_{нп}}{R_{нп}}\left(\frac{F_{нп}}{R_{нп}} + \frac{F_{сп}}{R_{сп}}\right)^{-1}, \quad \overline{q}_{сп} = \frac{F_{сп}}{R_{сп}}\left(\frac{F_{нп}}{R_{нп}} + \frac{F_{сп}}{R_{сп}}\right)^{-1}.$$

Fig. 2 shows the dependence $\overline{q}_{нп}$, $\overline{q}_{сп}$ of the insulation thickness δ_2.

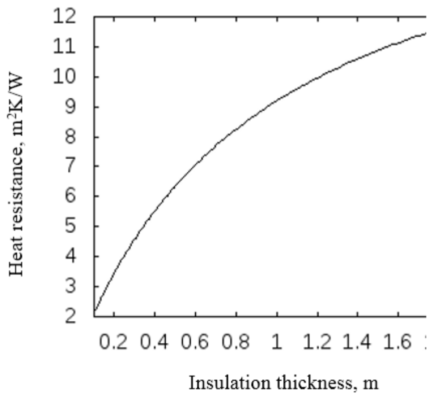


Fig. 1. The normalized thermal resistance

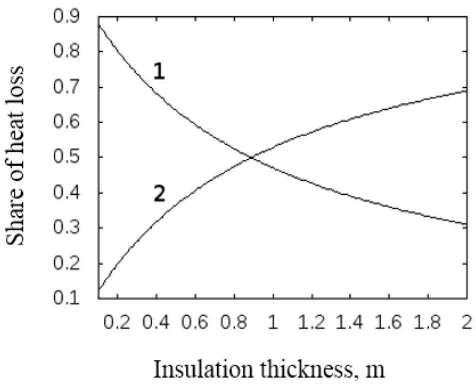


Fig. 2. Rates of the heat flow throw opaque (1) and translucent (2) fences

Analysis of the results shows that a relatively small thickness of the insulation (0.3-0.4m) when given thermal resistance $R_{\Sigma пр}$ close to the minimum value $R_{q\min}$, the vast majority of the costs of heat occurs through the opaque part of the outer fence. In this case, increasing the thickness of the insulation can significantly enhance $R_{\Sigma пр}$ and improve the energy efficiency of the house. When the insulation thickness is greater than 1m, the bulk of spending is on heat translucent enclosures and therefore an increase in the thickness of insulation does not result in a significant increase $R_{\Sigma пр}$. In this case, to improve energy efficiency of building, you must first increase the thermal resistance of translucent enclosures.

Studies of heat loss through the nodes for environmental building shell. Calculations of heat loss through the shell of building were carried out according to the procedure laid down in the normative document [3].Study of structural coupling nodes, where the formation of cold bridge is possible was realized using Elcut software package. [4] Analysis was provided for the building with the following design solution.

The design concept of the house - a wooden frame. Exterior walls are three-dimensional frame structure prefabricated, which consists of wooden pillars of the "ladder" shape in increments of 500 mm, filled with insulating material of hemp. The thickness of the wall fence - 500 mm. Interior and exterior walls - brick 120 mm.

Overlap the floor, overlapping the attic floor and the truss is wooden trusses 500 mm with fastening elements to the wall frame on metal toothed plates. Thermal insulation and sound insulation design provides cross-farm filling space in the same insulating material as the house walls. The height of the truss ceiling - 600 mm, roof trusses - 500 mm. On the outer and inner sides protecting load-bearing structures are sheathed film for hydro and wind protection and sheathed OSB plate 20 mm thick.Coverage of the roof - slabs of reeds.

Windows and doors - made of metal or wood with glass. Glazing - triple with low-emissivity coated glass and filled with an inert gas. Thermal resistance of glass Rpr = 0.85 m2 · K / W [5].

Figure 3 shows the general construction-planning solution of energy-efficient low-rise building. We investigated the window to the wall interface assembly (node) - determined the optimal location of the windows on the width of the wall (Fig.4)

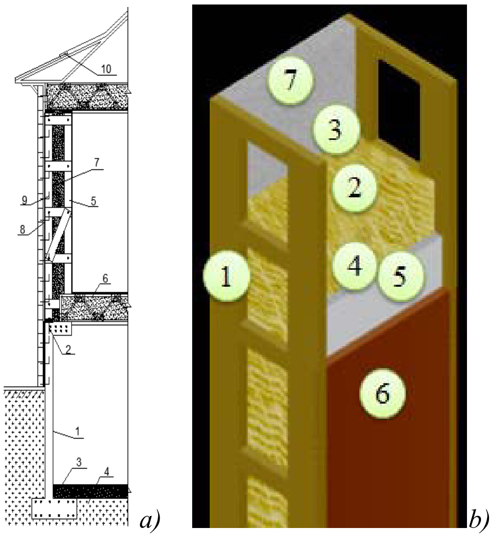


Рис. 4. Construction of low-storey building:
a) a vertical section through the outer wall:
1 - foundation; 2 anchor for fastening the frame to the foundation; 3 - technical underground floor;
4 - waterproofing and protection antiradon barrier;
5 - wooden frame "ladder" type;
6 - farm overlap; 7 - thermal insulation;
8, 9 - frame elementss; 10 - roofing;
b) Wall construction:
1 - Front wooden frame 2 - thermal insulation, vapor barrier 3 and 4 - windscreen;
5 – base net, 6 - clay plaster, 7 - internal finishing

For determination the location of the window frame of rational thickness of the outer wall of heat engineering calculations were made for the following options:

1. Scheme 0 (standart): framing the window opening - cement - sand mortar, the location of the window frame - in the middle.
2. Scheme 1 (-200_utepl): insulation thickness of 40 mm from the negative temperature, insulation thickness of 20 mm from the zero temperature, the window frame is shifted by 200 mm from the central position in the direction of the minus temperature.
3. Scheme 2 (-150_utepl): thickness of insulation is identical, the window frame is shifted by 150 mm from the central position in the direction of the minus temperature.
4. Scheme 3 (centr_utepl): thickness of insulation is identical, the location of the window frame - in the middle.
5. Scheme 4 (+ 150_utepl): thickness of insulation is identical, the window frame is shifted by 150 mm from the central position towards the positive temperature.
6. Scheme 5 (+ 200_utepl): thickness of insulation is identical, the window frame is shifted by 200 mm from the central position towards the positive temperature.

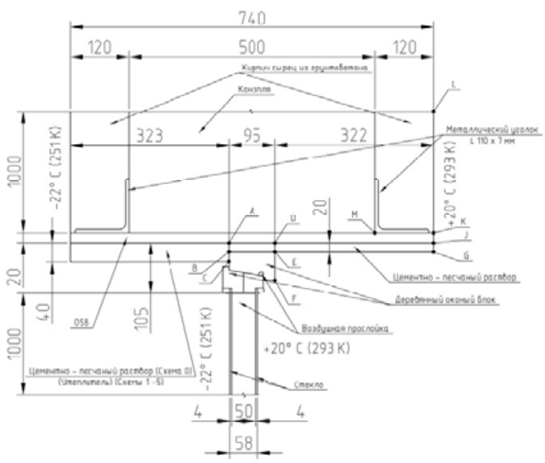


Рис.4. Structural decision of node interface of window with a wall

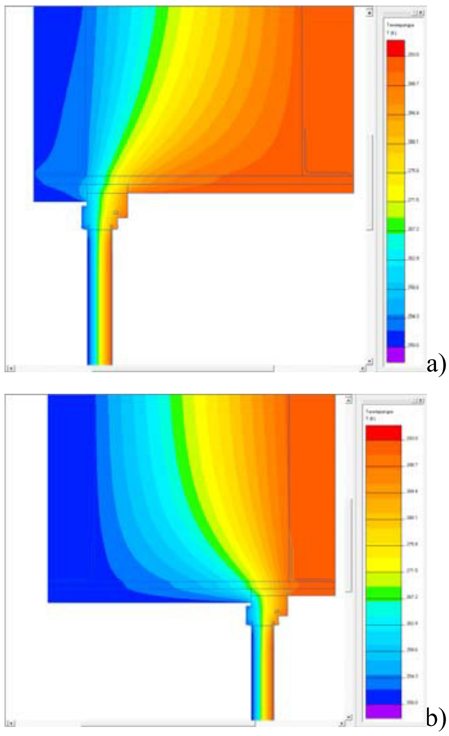


Fig. 5. Temperature field for variants:
a) Schema 1 (-200_utepl); б) Schema 5 (+200_utepl)

The criterion for evaluating the rational arrangement of the window frame were the heat flux passing through the segment and LG teperatury value at characteristic points: A, B, C, D, E, F, G, J, K, L and M.

The calculation results are shown in Fig. 5 and Table.1.

The calculation results indicate that the optimal location of the window at this constructive solution is the central location of the window on the wall thickness (Figure 1), since the total heat flow through the interface "wall-box" unit is minimal - 5.7 W (Table 1.).

Table 1

Thermal characteristics of the host interface options "window-wall"

№ Schema	The temperature in the characteristic points of the structure, °C			The heat flow through the segment EGJKL, W
	E	G	L	
0	15,27	19,85	19,46	7,50
1	13,48	19,99	19,47	5,70
2	14,08	19,99	19,47	6,06
3	14,55	19,98	19,46	6,41
4	15,10	19,95	19,45	6,17
5	15,76	19,93	19,45	6,80

In order to select a rational constructive solution for low-rise residential buildings we considered two options of nodal connection with the foundation of the building and outer wall. The node "wall-foundation" is the most vulnerable point in the thermal shell of the building, since it is possible the formation of "bridges". *Option one* - heat insulation of the basement of the building from the outside; *second option* - the outer wall of the building is insulated from the inside from the base (floor) insulation foam glass.

For the considered node interface options "foundation-wall" it was obtained values of heat flux passing through the connection node, the temperature differential across the inner surface of the coupling assembly designs and linear heat-transfer coefficient.

Constructive unit solution pairing options "wall-foundation" and the results of the calculations are presented in Table. 2.

Analysis of the results of the calculation shows that the option 2 is more efficient in terms of thermal performance.It`s linear coefficient of heat transfer is in 37.5% lower compared with the option 1. Moreover,the value of the temperature drop at the inner surface of the node option 1 does not satisfy the requirements of [6].

Originality and Practical value. The study analysed the problem constructive elements of shell to make rational design of energy-efficient environmental low-rise building.

The limits for the optimum thickness of the external walling of ecological materials was provided, and it was offered solution for interface design of building structures with a thermal jacket.

Recommendations are worked out on constructing of thermal shell at planning of energy-efficient low-rise buildings and outlined in the conclusions.

Conclusions.

1. For the wider dissemination of energy-efficient building at the national level, it is necessary to examine the best possible optimization of the thermal performance for the building shell. It may permit to achieve a high level of energy efficiency only through the efficient solutions of exterior building`s walling without expensive engineering equipment.

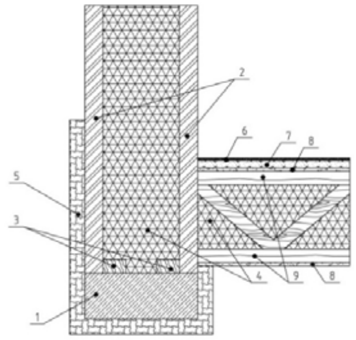
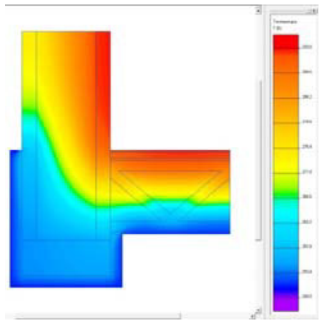
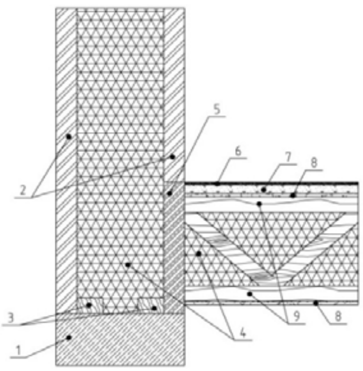
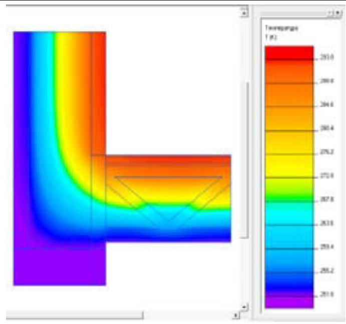
2. When the thickness of the insulation exceeds 1m, the bulk of the heat loss falls on translucent enclosures and therefore increasing the thickness of insulation does not result in significant growth. In this case, for energy efficiency the heat resistance of translucent enclosures should be increased.

3. The calculation results indicate that the optimal location of the window at this constructive solution is the central location of the window on the wall thickness.

4. Analysis of the results of the calculation shows that the option when outer wall of the building is insulated from the inside with foam glass is more efficient in terms of thermal performance. It`s linear coefficient of heat transfer is in 37.5% lower compared with the option when heat insulation of the basement of the building is realized from the outside with mineral wool.

Table 2

The Structural decision and heating engineering descriptions of variants knot of interface "wall-foundation"

Constructive decision of node "wall - foundation"	Description of constructive element	Thermal performance of node "wall - foundation"
Option 1 - building foundation insulation from the outside		
	1.concrete foundation 2.soil-concrete 3.wooden bar 4.insulation - hemp 5.Insulation - mineral wool 6 Ceramic tiles 7 Fibrous concrete 8 OSB plate 9 Wood Farm	 Linear heat transfer coefficient : k= 0.08 W/mK. The temperature drop across the inner surface of the structure: $\Delta t_{cr} = 3K$.
Option 2 - thermal insulation on the inside of the glass foam insulation		
	1.concrete foundation 2.soil-concrete 3.wooden bar 4.insulation - hemp 5.Insulation – foam glass 6 Ceramic tiles 7 Fibrous concrete 8 OSB plate 9 Wood Farm	 Linear heat transfer coefficient : k= 0.05 W/mK. The temperature drop across the inner surface of the structure : $\Delta t_{cr} = 2K$.

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3D-PRINTING OF BUILD OBJECTS

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Summary. ***Raising of problem.*** Today, in all spheres of our life we can constate the permanent search for new, modern methods and technologies that meet the principles of sustainable development. New approaches need to be, on the one hand more effective in terms of conservation of exhaustible resources of our planet, have minimal impact on the environment and on the other hand to ensure a higher quality of the final product. Construction is not exception. One of the new promising technology is the technology of 3D -printing of individual structures and buildings in general. 3D-printing - is the process of real object recreating on the model of 3D. Unlike conventional printer which prints information on a sheet of paper, 3D-printer allows you to display three-dimensional information, i.e. creates certain physical objects. Currently, 3D-printer finds its application in many areas of production: machine building elements, a variety of layouts, interior elements, various items. But due to the fact that this technology is fairly new, it requires the creation of detailed and accurate technologies, efficient equipment and materials, and development of common vocabulary and regulatory framework in this field. ***Research Aim***. The analysis of existing methods of creating physical objects using 3D-printing and the improvement of technology and equipment for the printing of buildings and structures. ***Conclusion***. 3D-printers building is a new generation of equipment for the construction of buildings, structures, and structural elements. A variety of building printing technics opens up wide range of opportunities in the construction industry. At this stage, printers design allows to create low-rise buildings of different configurations with different mortars. ***The scientific novelty*** of this work is to develop proposals to improve the thermal insulation properties of constructed 3D-printing objects and technological equipment. The list of key terms and notions of construction by 3D-printing and 3D-modeling. ***Practical value.*** Developed in this work equipment and materials allows in the nearest future to move from theory to practice and implement such effective method of construction as the technology 3D-printing.

Keywords: *3D-printing, printer, printing head, extruder, energy-efficient materials, building*

3D-ПЕЧАТЬ СТРОИТЕЛЬНЫХ ОБЪЕКТОВ

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Аннотация. ***Постановка проблемы.*** На сегодняшний день во всех сферах нашей жизни идет перманентный поиск новых, более современных методов и технологий, отвечающих принципам устойчивого развития. Новые подходы должны быть с одной стороны более эффективными с точки зрения сохранения небезграничных ресурсов нашей планеты, иметь минимальное влияние на окружающую среду, а с другой стороны обеспечивать более высокое финальное качество продукции. Строительство не является исключением. Одной из новых перспективных технологий является технология 3D–печати как отдельных конструкций, так и зданий и сооружений в целом. 3D-печать – это процесс воссоздания реального объекта по образцу 3D-модели. В отличие от обычного принтера, который выводит информацию на лист бумаги, 3D-принтер позволяет выводить трёхмерную информацию, т.е. создавать определённые физические объекты. На данный момент 3D-принтер находит свое применение во многих сферах производства: элементы машиностроения, разнообразные макеты, элементы интерьера, различные детали. Но в связи с тем, что эта технология достаточно новая, она требует создания точных и детально проработанных технологий, эффективного оборудования и материалов, а также разработки общепринятой лексики и нормативной базы данной сферы. ***Цель.*** Анализ существующих методов создания физических объектов 3D-печатанием и усовершенствование технологии и оборудования для печати зданий и сооружений. ***Вывод.*** Строительные 3D-принтеры – это оборудование нового поколения для возведения зданий и сооружений, а также элементов конструкций. Разнообразие строительной печатной техники открывает широкие возможности в строительной индустрии. На данном этапе конструкции принтеров позволяют создавать малоэтажные постройки различных конфигураций с применением разных строительных смесей. ***Научная новизна*** данной работы состоит в разработке предложения по повышению теплоизоляционных свойств возводимых 3D-печатанием объектов и усовершенствованию технологического оборудования. Предложен перечень основных терминов и понятий строительной 3D-печати и 3D-моделирования. ***Практическая значимость***. Разработанное в рамках данной работы оборудование и материалы позволят уже в ближайшем будущем перейти от теории к практике и внедрить такой эффективный метод строительства, как технология 3D –печати.

Ключевые слова: *3D-печать, принтер, печатная головка, экструдер, энергоэффективные материалы, здание*

3D-ДРУК БУДІВЕЛЬНИХ ОБ'ЄКТІВ

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Анотація. ***Постановка проблеми.*** На сьогоднішній день у всіх сферах нашого життя йде перманентний пошук нових, більш сучасних методів і технологій, що відповідають принципам сталого розвитку. Нові підходи повинні бути з одного боку більш ефективними з точки зору збереження небезмежних ресурсів нашої планети, мати мінімальний вплив на навколишнє середовище, а з іншого боку забезпечувати вищу кінцеву якість продукції. Будівництво не є винятком. Однією з нових перспективних технологій є технологія 3D-друку як окремих конструкцій, так і будівель і споруд в цілому. 3D-друк - це процес відтворення реального об'єкта за зразком 3D-моделі. На відміну від звичайного принтера, який виводить інформацію на аркуш паперу, 3D-принтер дозволяє виводити тривимірну інформацію, тобто створювати певні фізичні об'єкти. На даний момент 3D-принтер знаходить своє застосування в багатьох сферах виробництва: елементи машинобудування, різноманітні макети, елементи інтер'єру, різні деталі. Але в зв'язку з тим, що ця технологія досить нова, вона вимагає створення точних та детально опрацьованих технологій, ефективного обладнання і матеріалів, а також розробки загальноприйнятої лексики і нормативної бази даної сфери. ***Мета.*** Аналіз існуючих методів створення фізичних об'єктів 3D-друкуванням та удосконалення технології та обладнання для друку будівель і споруд. ***Висновок.*** Будівельні 3D-принтери - це обладнання нового покоління для зведення будівель і споруд, а також елементів конструкцій. Різноманітність будівельної друкарської техніки відкриває широкі можливості в будівельній індустрії. На даному етапі конструкції принтерів дозволяють створювати малоповерхові будівлі різних конфігурацій із застосуванням різних будівельних сумішей. ***Наукова новизна*** даної роботи полягає в розробці пропозиції щодо підвищення теплоізоляційних властивостей зводяться 3D-друком об'єктів і вдосконалення технологічного обладнання. Запропоновано перелік основних термінів і понять будівельного 3D-друку і 3D-моделювання. ***Практична значимість***. Розроблене в рамках даної роботи обладнання і матеріали дозволять вже в найближчому майбутньому перейти від теорії до практики і запровадити такий ефективний метод будівництва, як технологія 3D-друк.

Ключові слова: *3D-друкування, принтер, головка для друкування, екструдер, енергоефективні матеріали, будівля*

Introduction. Today, in all spheres of our life we can constate the permanent search for new, moderner methods and technologies that meet the principles of sustainable development. New approaches need to be, on the one hand more effective in terms of conservation of exhaustible resources of our planet, have minimal impact on the environment and on the other hand to ensure a higher quality of the final product. Construction is not exception. One of the new promising technology is the technology of 3D -printing of individual structures and buildings in general. 3D-printing - is the process of real object recreating on the model of 3D. Unlike conventional printer which prints information on a sheet of paper, 3D-printer allows you to display three-dimensional information, i.e. creates certain physical objects. Currently, 3D-printer finds its application in many areas of production: machine building elements, a variety of layouts, interior elements, various items. But due to the fact that this technology is fairly new, it requires the creation of detailed and accurate technologies, efficient equipment and materials, and development of common vocabulary and regulatory framework in this field. These objectives and the focus of this work.

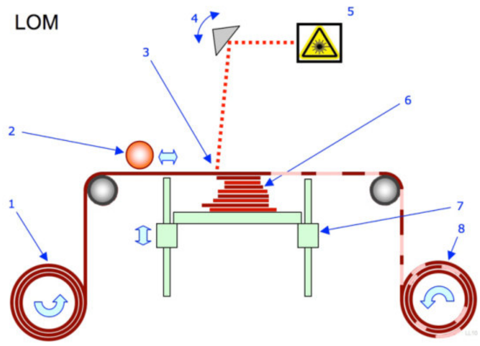
Findings. Key technologies of 3D-printing are [1-3]:

- *Layer Object Manufacturing, LOM.* The main idea is to cut the sheet of various materials with a laser beam (paper, laminates, metal foil, ceramic), and then heated rollers glue the layers between each other (Fig. 1a). The disadvantages are: a rough surface products, the possibility of bundling and mistaking if sheet is not completely cuted (damaged layers are needed to be removed, and done again);

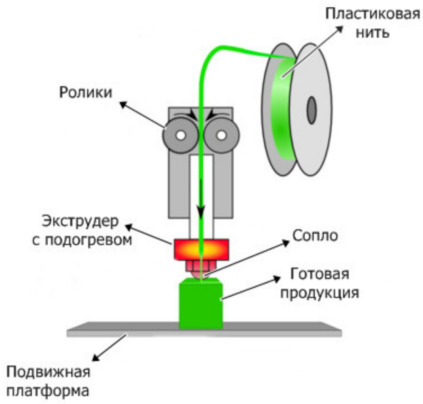
- *Fused Deposition Modeling, FDM* — This is three-dimensional printing technology, in which the object is created of the melting the plastic thread it fed through the extruder on a work surface and is hardened there later. After the first layer, the working platform is lowered and the process continues again (Fig. 1b). It is the only technology of «cultivation» 3D-objects using industrial thermoplastics which can withstand high temperatures and mechanical loads. Layering allows to receive parts of complex geometry. The method has such disadvantages: plastic melts and spreads in all directions, so the models have pronounced relief surface, so the object precision is lost;

- *laser stereolithography, SLA* - this is three-dimensional printing technique in which liquid photopolymer under the action of laser light changes its physical properties and solidifies. The three-dimensional object is grown layer by layer, the thickness of layer in an average is 0.1 mm, which ensures high print quality. The disadvantages of the technology is high cost of equipment and low printing speed (a few millimeters per hour);

- *selective laser sintering, SLS,* is like the previous technology, but the basic material is powdered thermoplastic, sintering with laser beam.



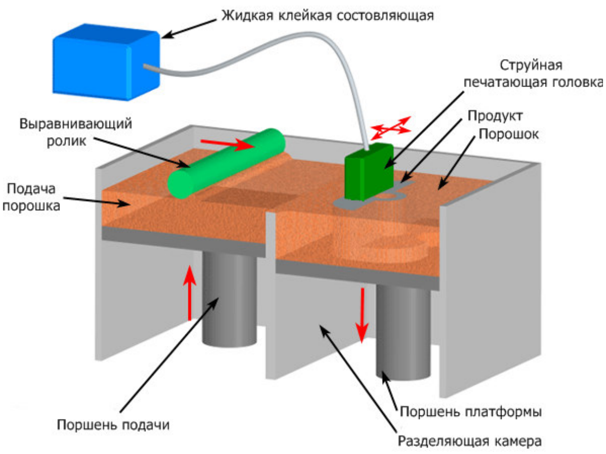
a



б

Fig. 1. 3D-printers with print technology [3]:
a – production of object by layers: 1 – foil; 2 – heated roller; 3 – laser beam; 4 – scanning prism; 5 – laser device; 6 – layers; 7 – mobile platform; 8 – remains;
б – modeling by melting method

The powder in the chamber is heated till the nearly melting point temperature, than it is leveled and the laser beam draws the required contour on it. At the point of contact of the beam and powder the particles melt and sinter with each another and with the previous layer. Then the platform is lowered a new layer of the powder is poured in the chamber, it is leveled, and the process is repeated. The technology is characterized by high speedy printing (up to 35 mm / hour), but it requires a lot of time to prepare to heat the powder and stabilize the temperature while resulting models have rough and porous structure.



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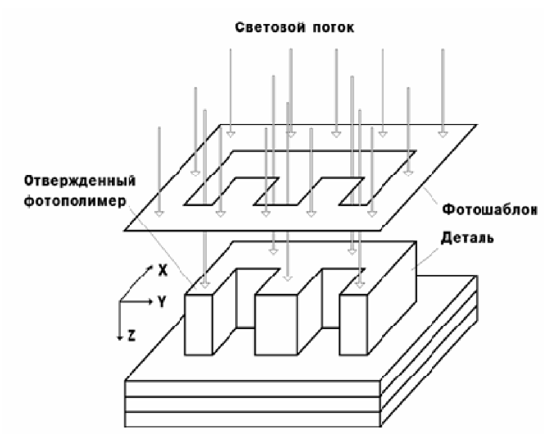

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Fig. 2. 3D-printers with print technology [3]:
a – stereoscopic printing; б – photopolymer sintering

- *Three-Dimensional Printing, 3DP,* is based on inkjet technology. This kind of printers is provided with two ingredients powdered mass and liquid binder. The working chamber of each printer consists of two parts (Figure 2, a.): The first part is a powder feed chamber (model material is loaded), and the second part is the construction chamber where necessary 3D-model is grown. Initially, the material is distributed uniformly on the entire surface of chamber construction. Then, on the first thin layer special binder is applied that glues all the particles of the material together. After the platform is displaced. The supply chamber platform is lifted up, and the construction field platform is lowered down. Dislocation must be made on the same height. After this, immediately the offset printing head again begins to move, building up the model.

- *Solid Ground Curing, SGC,* is based on the fact that the special tonic creates the specific model template on a glass plate (Fig. 2b). Formed photomask is located over a thin layer of photopolymer situated on the desktop, further it should be exhibited by UV lamp. The layer corresponding photopolymer pattern hardens, and all liquid stocks are removed. In the next step all inside cavities must be filled with molten wax, solidifying enough quickly. Then the process is repeated again, but the template for the next section is already used. The advantage of the technology is that the process can be paused at any time and then be restarted from the same moment (this is important when you need to remove the defective layers or contamination). The printer creates the model with a moving component parts. A lot of noise, large weight and the constant presence of the operator are disadvantages of this type of printing.

Constructions 3D-printing is a new technology of building, which allows to build a house on an individual project using different materials in a short terms. Building 3D-printer uses extrusion technology, where each new layer of building material is squeezed out of the printer on the previous one. Construction printers are divided into two groups, printers, printing the entire building (Figure 3, b.), and printers, printing separate elements (Figure 3 in.). An example can serve models of buildings from the real building materials, elements of landscape design, etc.

Application of printers producing separate structural elements eliminates the seasonality of the construction, i.e., it is possible to print the buildings parts, to cure them in the warehouses till concrete sets necessary strength and then to assemble them into a building on the construction site (Fig. 3d).

Before start building mixture must be prepared in accordance with the requirements of the equipment. Accept the place for 3D-printer, it is also required to provide land for: mixture preparation, its supply to the printer printing head, pre-drying station, warehouses and loading site. To install the manufacturing equipment, the area or equipment room should have connection points to service lines (power, water supply).

а

б

в

г

Fig. 3. 3D-printing of constructions [11]:
а, б – building; в – printing of construction;
г – assembly of printed building structures

In the process of creating a ready-made objects at least two people are involved : the operator (directly controls the printer) and a worker (prepares a mixture, reinforces the products in the process of printing, prepares equipment for use at the beginning and the end of shift). The number of workers is up tothe equipment size and the complexity of the process, depending on design solutions manufactured object.

Printers for 3D-printing are of different dimensions and weight, for example, a printer format of 12 x 12 meters for printing elements of buildings, landscape items up to 3 meters high, is a large-size 120-ton structure (Figure 4a.). To print individual structures in the enclosed space we can use small-format printers with the capacity of the head storage device 18 ... 32 liters, dimensions of 4 x 6 meters and weight of 620 kg (Fig. 4b). At this stage, the design of printers allows to create low-rise buildings of different configurations using different construction mixtures.

It is reasonable to simulate the shape of the construction and verify the printing process of the object (3D-modeling) before the construction using technology of 3D-printing. This can be made by small format equipement using real building mixes, allowing to check the adopted architectural design and solutions. To print the building model plaster mixes are used, while cement mixture are used to create products designed for outdoor use. The process of horizontal and vertical reinforcement, installation of reinforcing skeletons inside wall cavities, laying of communications is worked out on models. An important aspect is that printed patterns are convenient for carrying out laboratory tests on various parameters.

Advantages of 3D-printing are:

the ability to create objects of any shape and complexity;

speed of building;

the use of different materials, including environmentally friendly materials;

wasteless production;

the simplicity of the process;

reduction of the human factor, and thus quality improvement and construction accuracy.

The disadvantages of this construction technology are:

lack of common terminology;

constructed facilities do not have an effective thermal insulation and have a high energy consumption;

tooling elements require further improvement.

а

б

Fig. 4. Building printers [11]:
а – format 12 x 12 metres; б – format 4 x 6 metres

Research purpose. is to analyze the existing methods of creating physical objects by 3D-printing and the improvement of technology and equipment for the printing of buildings and structures.

Results of the study. Based on the analysis of publications and research, authors suggest, the following key terms and notions in the field of 3D-printing building.

3D-printing – the process of real object recreating based on the 3D-model.

Technology of 3D- printing – is based on the principle of layered growing (creation) of solid model.

3D-modelling – the process of construction object physical model creating.

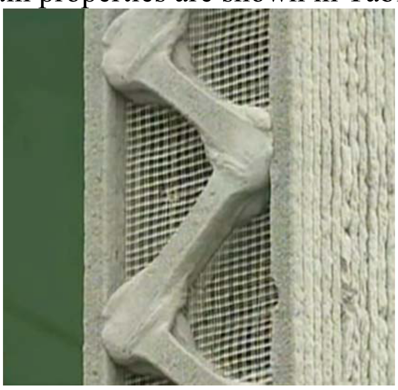
3D-printer - device to recreate real object per sample of 3D-model.

Printing head – a component of the printer, delivering the mixture to the object of construction.

Extruder – part of the printing head, forming a thick layer of extruded mortar.

Extrusion – technological process, when each new layer of building material is extruded from the printer over the previous.

During the construction of the building by any known at present method it is necessary to ensure high energy efficiency of building envelopes as well as the whole building. Alternative building wall structure created by 3D-printing, makes it necessary to search for alternative methods of energy efficiency. In this paper, we propose to increase the thermal insulation properties of objects created by 3D-printing, and reduce the overall energy losses of the building by laying energy-efficient thermal insulation of ecological materials in empty wall structures (Fig. 5) (on the basis of cut reed, pressed straw, hemp shives, adobe, lightweight adobe, lightweight concrete on the base of boon of hemp). All these materials have been created in our laboratory [9, 10] and passed preliminary tests. Their main properties are shown in Table 1.



а

б

Fig. 5. Building hollow structure [11]:
а – reinforced with fiber;б – reinforced by partitions

As for the technology, the printing process by different mortars basically differs by thickness of the printed layer and the total height of the product. The thickness of the extruded layer formes extruder. During the printing we can adjust the geometry of the extruded layer, change the speed of printing to obtain high-quality products.

Table 1

Characteristics of thermal insulation materials [10]

Material	Volume weight, kg/m^3	Thermal conductivity coefficient, Watt/(m*K)
Chop of jonk	400	0,12
	300	0,09
	260	0.078
	220	0,06
Pressed straw	150-250	0,09
	90-110	0.045
	73-85	0.04-0.05
	100	0.054-0.065
Boon of hemp	70-90	0.048-0.06
Adobe	1500	0,5
Lightweight adobe	1000	0.13
	900	0.114
	580	0.073
	420	0.071
Lightweight concrete on the base of boon of hemp	260	0,075
	360	0,079
	400	0,084

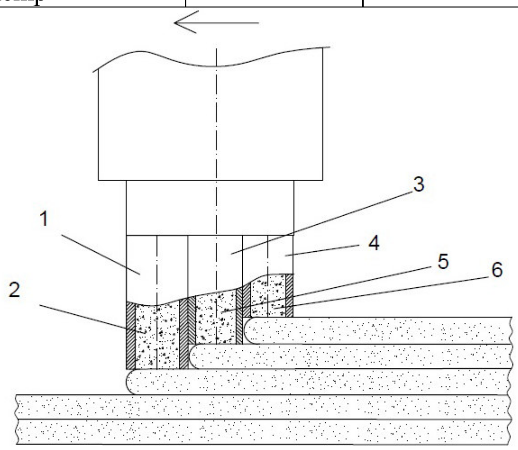


Fig. 6. Printing head with multiple extruders:
1, 3, 4 – extruders; 2, 5, 6 – cavity of mixture feed

To increase the efficiency of printing it is proposed to use printing head with several extruders set at different levels one after the another (Fig. 6).

Taking into account the properties of a stacked mixture the distance between extruders 1, 3 and 4 can regulated extending the possibilities of printing technology and capacity of construction projects.

Originality and Practical value. Developed in this work equipment and materials allows in the nearest future to move from theory to practice and implement such effective method of construction as the technology of 3D-printing and make the process of building fast, efficient and modern.

Conclusions.

1. Building 3D printers is a new generation of equipment for the construction of buildings structures, and structural elements. A variety of building printing technologies opens up wide range of opportunities in the construction industry. At this stage, printer design allows to create low-rise buildings of different configurations with different mortars.
2. The proposals for improvement of the thermal insulation properties of constructed 3D-printing objects and improvement of technological equipment are developed.
3. The list of key terms and notions of construction by 3D-printing and 3D-modeling technology are proposed.

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INFLUENCE OF REBOUND EFFECTS ON THE ACHIEVEMENT OF ENERGY SAVING TARGETS AFTER AN INCREASE IN ENERGY EFFICIENCY ON NON-RESIDENTAL BUILDINGS

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Abstract. ***Purpose.*** This article draws attention to rebound effects, which are responsible for missing the planned energy savings after an increase in efficiency. For residential buildings already exist wide scientific studies to rebound effects after a thermal retrofit. This article present first findings to rebound effects in non-residential buildings. ***Methodology***. It is presents a methodology for the determination of rebound effects and their causes in non-residential buildings. In addition to the mathematical calculation of the rebound effects semi-structured-interviews to identify the causes were describe. Conclusion***s.*** This article focuses on four office and administrative buildings with regard to their actual and calculated building heat pre- and post-thermal-retrofit and comes to the conclusion that even in non-residential buildings rebound effects are to be expected. However, the causes differ significantly compared to residential buildings. ***Originality.*** For the first time a methodology for the determination of rebound effects and its causes has been developed for non-residential buildings and tested on case study objects. In addition, the obtained results compared with literature review for non-residential buildings and residential buildings. ***Practical value.*** These article gives information on whether rebound-effects exists after a thermal retrofit and in the case these effect exist it renames possible reasons of this effect.

Keywords*:* *rebound effect, direct rebound effect, non-residential buildings, thermal retrofits*

ВПЛИВ ЗВОРОТНИХ ЕФЕКТІВ НА ДОСЯГНЕННЯ ЦІЛЕЙ ЕНЕРГОЗБЕРЕЖЕННЯ ПІСЛЯ ЗБІЛЬШЕННЯ ЕНЕРГОЕНЕРГОЕФЕКТИВНОСТІ НЕЖИТЛОВИХ БУДІВЕЛЬ

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Анотація. ***Мета.*** Ця стаття звертає увагу на зворотні ефекти, які пов’язані з відсутністю запланованих дій щодо економії енергії, але впливають на досягнення енергозберігаючих цілей. Для житлових будинків вже існують широкі наукові дослідження щодо зворотних ефектів після теплової модернізації. Ця стаття представить перші висновки щодо зворотних ефектів у нежитлових будинках. ***Методика.*** Стаття представляє методологію для визначення зворотних ефектів і їх причин в нежитлових будинках. У доповнення до математичних розрахунків щодо зворотних наслідків для виявлення причин було використано полуструктуроване інтерв’ю. ***Результати.*** Ця стаття зосереджена на чотирьох офісних та адміністративних будівлях, демонструє фактичні і розрахункові показники споживання будівлею тепла до і після теплової модернізації, приходить до висновку, що навіть у нежитлових будівлях можна очікувати зворотні ефекти. Тим не менш, їх причини істотно відрізняються у порівнянні з житловими будинками. ***Наукова новизна.*** Вперше була розроблена методика для визначення зворотних ефектів для нежитлових будівель, з’ясовано їх причини, застосоване соціологічне дослідження. Крім того, отримані результати порівнюються з наведеними у літературі матеріалами для нежитлових будівель та житлових будинків. ***Практична значимість.*** У статті наводяться відомості про те, чи існує зворотний ефект після термічної модифікації та з’ясовані можливі причини цього ефекту.

Ключові слова: *зворотний ефект, пряма дія зворотного ефекту, нежитлові будівлі, теплове переобладнання*

ВЛИЯНИЕ ОБРАТНЫХ ЭФФЕКТОВ НА ДОСТИЖЕНИЕ ЦЕЛЕЙ ЭНЕРГОСБЕРЕЖЕНИЯ ПОСЛЕ УВЕЛИЧЕНИЯ ЭНЕРГОЭФФЕКТИВНОСТИ НЕЖИЛЫХ ЗДАНИЙ

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Аннотация. ***Цель.*** Данная статья обращает внимание на обратные эффекты, которые связаны с отсутствием запланированных действий относительно экономии энергии, однако влияют на достижение энергосберегающих целей. Для жилых зданий уже существуют широкие научные исследования по обратным эффектам после тепловой модернизации. Эта статья представит первые выводы по обратным эффектам в нежилых зданиях. ***Методика.*** Статья представляет методологию для определения обратных эффектов и их причин в нежилых зданиях. В дополнение к математическим расчетам по обратным следствиям для выявления причин было применено полуструктурированные интервью. ***Результаты.*** Эта статья сосредоточена на четырех офисных и административных зданиях, демонстрирует фактические и расчетные показатели потребления зданиями тепла до и после тепловой модернизации, приходит к выводу, что даже в нежилых зданиях можно ожидать обратные эффекты. Тем не менее, их причины существенно отличаются по сравнению с жилых домов. ***Научная новизна.*** Впервые была разработана методика для определения обратных эффектов для нежилых зданий, выяснены их причины, использованы социологические исследования. Кроме того, полученные результаты сравниваются с приведенными в литературе материалами для нежилых зданий и жилых домов. ***Практическая значимость.*** В статье приводятся сведения о том, существуют ли обратные эффекты после термической модификации и выяснены возможные причины этого эффекта.

Ключевые слова: *обратный эффект, прямое действие обратного эффекта, нежилые здания, тепловое переоборудование*

Introduction. The production of thermal energy accounted 58% of total final energy consumption in the year 2013 in Germany [1]. The largest proportion (approximately 35% of total final energy consumption) accounted for the production of heat in buildings for space heating and hot water (building heat) [1]. This leads to a high proportion of the building heat on the carbon dioxide emissions (CO_2). Around 24% of carbon dioxide emissions of Germany caused by the building heat, approximately 17% accounted for residential buildings and 7% for non-residential buildings [2].

The German housing stock consists of more than 18 million residential and 2.5 million non-residential buildings [3, 4]. About 70% of the residential buildings were erected before the first legal regulations for the thermal quality of buildings were adopted in 1979 [4]. Starting with that year, minimum requirements for energy efficiency of buildings became obligatory. Among the majority of these older buildings only for a small amount a thermal retrofit on the building envelope has been carried out. This majority of existing buildings do not fulfill any minimum energy standards and, therefore, they have very high energy consumption.

The German government has decided reduction of primary energy demand in existing buildings by 80% until the year 2050 (based on 2008) by the Energy Concept in the year 2010 [5]. Already by 2020 reduction target for building heat says 20% based on 2008 [5]. To achieve these goals a significant reduction of energy consumption for space heating in residential and non-residential buildings is necessary. A reduction of building heat be achieved by retrofit to improve the thermal quality of the building envelope (e.g. insulation of the façade and/ or the upper and lower building closure or a replacement of windows and doors) or replacement the heat generator or the heat source.

For residential buildings was observed that the amount of the calculated consumption and the actual consumption are different in several scientific studies. The calculated consumption is determined by approach of standard condition of use (e.g. temperature of rooms, the consumption of warm water, the ventilation durations). In Germany, the standard conditions of use are specified in the “Energieeinparverordnung” [5]. In contrast of the calculated consumption the actual consumption reflects the real consumption of energy (e.g. listed on the invoice of companies for energy supply). After a thermal retrofit the amount of the actual consumption is higher than the amount of the calculated consumption. Before the thermal retrofit it was the other way around, the calculated consumption is higher. One explanation can be offered by the rebound effect. Rebound effects occur after there was an increase in the energy efficiency of products or services and the costs for these products or services are reduced, and, as the result, they are consumed more than previously [8]. The consumers change their behavior and consume more energy than previously. Thus, the expected energy savings and energy reduction goals will not be achieved. A direct rebound effect is present when an increase in energy efficiency leads to increased consumption of this product or service. For example, as a result of purchasing a new car with lower fuel consumption per kilometer driven, the cost per kilometer declines and, as a consequence of the lower costs, more total kilometers are driven with the new car, compared to the older one. The planned energy savings were reduced by additional trips. An indirect rebound effect occurs when an increase in energy efficiency leads to increased consumption of other product or service. For example, as a result of buying a new car with lower fuel consumption per kilometer driven, the cost per kilometer declines and, as a consequence of lower costs, money will be accumulated. With this money an additional electrical device (e.g. a TV) is bought. This article considers only the direct rebound effect, therefore in the following just called rebound effect.

Identification of an unsolved problem. Residential buildings are already well studied for the presence of the rebound effect after a thermal retrofit. But for non-residential buildings only a few results are available. However, the known results of residential buildings cannot be transferred to non-residential buildings really, because on the one hand the buildings are used differently and on the other hand the occupants of the non-residential buildings aren´t pay for the cost of building heat usually [6]. In residential buildings, the residents pay the costs for the building heat itself usually. However, it seems the level of costs for energy consumption is an important motivation for the user behavior. Therefore, it is interesting to determine if there is a change in user behaviors by occupants of non-residential buildings after a thermal retrofit.

Analysis of the recent research. The mathematical derivation of the rebound effect has been described several times in detail, compare [6, 7, 8]. At this point, the adopted definition is reproduced [6]:

$$R(S) = \frac{\ln\left(\frac{E_2 * C_1}{C_2 * E_1}\right)}{\ln\left(\frac{C_1}{C_2}\right)}$$

R(S) elasticity rebound-effect of energy services consumption (S);

E_1 / E_2 actual consumption pre / post-retrofit;

C_1 / C_2 calculated consumption pre / post-retrofit.

The mathematical model is based on the actual and the calculated consumption pre / post-retrofit. This makes it possible to analyze if the user behavior has changed as a result of the thermal retrofit.

The rebound effect is understood as elasticity rebound effect. The elasticity is a term from the economics that expresses the development of demand to prices changes. In the context of rebound effects was found that the elasticity approach fits very well [6, 8, 12].

Only if the rebound effect is zero, there are no change in user behavior. For residential buildings the rebound effect lies between 16% (study in Belgium with 964 buildings [9]), 48% (studies in UK with 52 buildings [8]) and 50% (study in France with 913 buildings [10]).

Identification of unsolved part of the general problem. The attention of rebound effects has been established in science for wide range of applications. However for the general public, rebound effects and their causes and consequences are mostly unknown. But this can result in overestimation of energy saving, compare Fig. 1. For residential buildings in Germany it had been founded that residents, which are living in old and inefficient buildings, limit their user comfort. Thus, the actual energy consumption for space heating is lower than the calculated consumption.

After the thermal retrofit the user behavior has change, the residents know that the building is now more efficiency and consume more energy for space heating mostly unconsciously. For example the room temperature raised, more rooms heated or room are heated for a longer time.

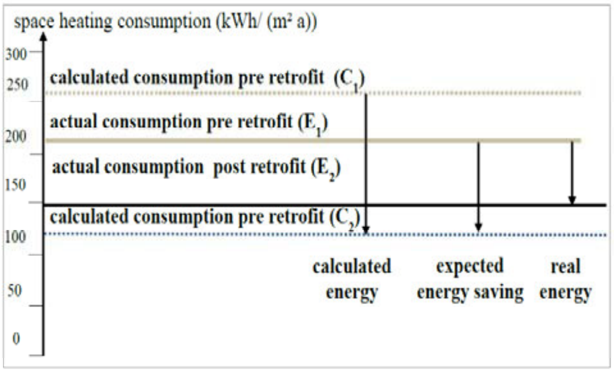

Fig. 1. Schematic diagram for residential buildings (Source: compiled by the authors)

Thereby the actual energy consumption is above the calculated energy consumption after thermal retrofit. As a consequence of Rebound-Effects the real energy saving is less than the expected and calculated saving. This can lead to failure: a) the climate protection goals and b) the individual expectations of the economics for the thermal retrofit of homeowners.

Purpose. The purpose of the research is the development and testing a method to estimate if Rebound-Effects exist by non-residential-buildings. And should this be the case, the causes and the amount have been determined.

Methodology. After a definition of terms and mathematical definition of evaluation parameters, a methodology was developed [6]. The methodology was tested on four selected case study objects. Selection criteria for the case study objects were [6]: a) building should be office or administration buildings, which were used as constant as possible throughout the year and for several years; b) comprehensive thermal retrofit was carried out; c) thermal retrofit completed already three years ago; d) the amounts of the actual and calculated consumption pre- and post-retrofit are available; e) buildings should have undergone no extensive floor space change the last years.

The calculated consumption was removed from energy-concept of each building. These energy concepts were developed based on the requirements of the German "Energieeinsparverordnung" by engineering offices. The state pre- and post-retrofit were calculated separately. The actual consumption pre and post-retrofit were removed from invoice values of energy supply companies and divided by the heated area. For the actual consumption different numbers of observed periods are available (2-5 years). Each observed period was corrected of the weather by the correction factors of the German Weather Service for the respective postcode area. The available values were averaged arithmetically.

By the case study objects semi-structured interviews have been carried out with technical staff like caretaker, technicians, facility and property managers. Content of the interviews were [6]: a) a comparison between the structural condition of the building, the thermal retrofit with the adoptions of the energy concept of the buildings and b) checked the reactions of the occupants with regard to the condition of the building pre- and post-retrofit. In addition in each case study object have been carried out semi-structured interviews with the occupants (approximately five persons in each object). Content of the interviews were [6]: a) the ventilation and heating behavior of a typical office day, b) type of ventilation (opening the whole window, shock-ventilation in German „Stoßlüften" or tilting the window in German „Kipplüftung"), c) type of use the space heating, d) expectations for the retrofit; e) changes caused by the retrofit; f) private ventilation and heating behaviors. The digitally recorded interviews were transcribed and the transcript analyzed.

Another point was the calculation of rebound effects for case study objects and interpretation of the results with literature data and the findings from the interviews.

Findings. As case studies objects four buildings in Germany were selected: two customs building, one police office and a College building for Music. Semi-structured-interviews were conducted with 32 persons (21 occupants and 12 persons of the technical staff) [6].

First, the results of the analysis of user behavior will be presented. Over 90% of occupants had an office in an old and inefficient building before the thermal retrofit, either in the case study object or in another building. Therefore, it can be assumed, that the occupants could reflect the expectations and impact of the thermal retrofit very well. More than a half of the occupants can use their office most of the time alone. Some of the users (10 of the interviewed people), which are housed in shared offices, reported that they have a different temperature sensitivity as the colleague/s in the office. They said that they adapted to each other via the clothing style, individual operation of the “own” radiator or ventilation of the overheated office when the colleague is not in the office. Nearly all occupants ventilated their office in the beginning of a working day. The type of ventilation varied: the half of the interviewed persons opening the whole window, a quarter of them tilting the window and a quarter combined both types. Reasons for tilting instead of whole opening are the fear against flying paper on the desk and flowers that stand in the way, or temperature-sensitive technology. The duration and the type of ventilation are greatly influenced by subjective user behavior but also by external factors. It was observed that the occupations, which have an office near a multi-lane road, said that they quickly close the window because the traffic noise had a negative impact on the working environment.

In analyzing the type of use the space heating the occupants indicated that they turned up the heating much higher before retrofit and the rooms cooled down more quickly. In addition, the heating control before the retrofit was bad, so they turned on the heating to the maximum level and then ventilated the warm air away.

During the ventilation only a small part of the user turns the heating off or down. For many respondents it is only important that the office would be warm. After the retrofit, many users find it pleasant that the heating can be controlled better and the rooms remained warm longer.

The occupants said that the common areas become problematic after the retrofit in terms of ventilation and heating. These rooms must be ventilated after retrofit and nobody felt responsible for it. The heating position has been changed in the common areas often and remaining after the use at this level. Thus, the common areas for the next users were either overheated or cooled too much.

More than half of the respondents said that they pay more attention to efficient behavior in the private sector for themselves and other persons in the household. The heating turned off while ventilation and when leaving the house / apartment significantly more. Also during ventilation in the private sector there is more attention to energy efficiency, thus two thirds of the persons which tilt and tilt / shock ventilation in the office said that they ventilate only shock. Also seeming barriers, like flowers in front of the window are removed willingly.

The calculation of rebound effects for non-residential buildings showed negative or very small positive rebound effects in three of the four case study objects, see Table 1.

Table 1

Calculated and actual space heating consumption and the rebound effects of the case study objects (non-residential buildings) [7]

	Calculated consumption C (kWh/ (m² a))		Actual consumption E (kWh/ (m² a))		Rebound-Effect (%)
	Pre-retrofit	Post-retrofit	Pre-retrofit	Post-retrofit	
Police office	123	61	106	52	-1,6
Customs office 1	244	136	204	117	4,9
Customs office 2	215	96	206	88	-5,5
College building for Music	140	83	143	47	-113

A negative rebound effect suggests a positive change in user behaviors after retrofit. These findings are in contrast with the results of rebound effects in residential buildings. Therefore, the results of case studies objects must be interpreted: a) on the one hand the number of examined objects with four buildings is very low. From literature studies a rebound effect in non-residential buildings be detected, but this is also a wide spread of 17% - 73% (in 30-93 buildings [8]). b) Another reason for a small rebound effect of the case study objects lies in the fact that in contrast to residential buildings the actual and calculated consumption pre-retrofit demand closer together. That means, users of non-residential buildings consume careless energy as in residential buildings before retrofit, it also indicate the results of the users interviews. c) It would also be conceivable that the calculation rule (Energieeinsparverordnung) for the amount of the calculated consumption is too high for non-residential buildings.

The case studies object for the College building for Music is a special case, because inside installed sound insulation of the practice rooms works like an additional interior insulation. This additional interior insulation was not considered in the energy concept and so the amount for the calculated consumption is probably too high.

Originality and Practical value. For the first time a methodology for the determination of rebound effects and its causes has been developed for non-residential buildings and tested on case study objects. In addition, the obtained results compared with literature review for non-residential buildings and residential buildings.

These article gives information on whether rebound-effects exists after a thermal retrofit and in the case these effect exist it renames possible reasons of this effect.

Conclusions. Although the case studies objects have negative or very low rebound effects, but it can be concluded from the analysis of the literature that rebound effects exist for non-residential buildings too. However, the number of examined buildings is still relatively low, comparisons [8]. The aim should therefore be that comparison data sets for actual and calculated consumption for non-residential building pre- and post-retrofit will create. It is important to know the basis of the amounts. It is notable that occupants in non-residential buildings use carefree energy markedly as in private homes. Here it seems to missing incentive to save energy through energy efficiency behavior. Rebound effects should be given more attention not only in residential buildings but also in non-residential buildings. It is important to know Rebound-Effects and their causes, because they have an impact on the achievement of savings goals for the government and private house-owners.

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METHODS FOR ACHIEVMENT OF ENERGY EFFICIENCY TARGETS: ANALYSIS OF EXPERIENCE IN THE EU

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Abstract. ***Purpose.*** The purpose of the presented research is to discuss the key directions for the reformation of energy management in support of sustainable development policy implementation under conditions of transitional economy. In accordance with this aim the following objectives were formulated: 1) to analyse the experience of the EU and European countries, which have implemented the energy efficiency concept; 2) to identify the main methods for the implementation of energy efficiency concept in a transitional economy; 3) to suggest conceptual approaches for balancing targets of energy saving and economic growth in Ukraine. ***Methodology***. The main arguments in the article are developed by analysing scientific papers on the issue of energy efficiency in the context of sustainable development, through comparative analysis of statistics in the area of energy consumption, energy efficiency and economic growth in various regions and countries, and by analysing experience of different countries in this field, Germany in particular. ***Conclusions.*** This article analyses the relationship between energy intensity and GDP growth, reviews the contemporary model for energy efficiency in the EU and studies differences between energy policies in various regions and the EU. The system approach allows to identify the main methods and measures that ensure the effectiveness of energy policy in Germany, which can be considered as useful for Ukraine. ***Originality.*** The study reviewed and analysed the main methods and measures that ensure the effectiveness of energy policy in Germany, including the domains of regulatory policy, funding, market instruments. ***Practical value.*** The proposed system of methods and measures may be useful for the planning of actions towards strengthening the capacity of energy efficiency in the conditions of the transition economy.

Keywords*: energy efficiency management; energy saving; sustainable development; New European Energy Policy; energy trilemma; energy efficiency indicators*

МЕТОДИ ДОСЯГНЕННЯ ЦІЛЕЙ ЕНЕРГОЕФЕКТИВНОСТІ: АНАЛІЗ ДОСВІТУ ЄС

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Анотація. ***Мета.*** Мета дослідження полягає у визначенні ключових напрямків реформування енергетичного менеджменту в підтримку здійснення політики сталого розвитку в умовах перехідної економіки. У відповідністю з цією метою, були сформульовані наступні дослідницькі завдання: 1) проаналізувати досвід ЄС і європейських країн, які пройшли шлях імплементації концепції енергоефективності; 2) визначити основні способи реалізації концепції енергоефективності в умовах перехідної економіки; 3) запропонувати концептуальні підходи до збалансування цілей зниження споживання енергії та економічного зростання в Україні. ***Методика.*** Основні аргументи у статті розроблені на основі аналізу наукових праць з проблем енергоефективності в контексті сталого розвитку, порівняння статистики в області енергоспоживання, енергоефективності та економічного зростання в різних регіонах і країнах, аналізу досвіду різних країн, особливо в Німеччині. ***Результати***. У статті аналізується взаємозв'язок між енергоємністю і зростанням ВВП, розглядає сучасну модель ЄС у галузі енергоефективності, вивчає відмінності енергетичної політики в різних регіонах та ЄС. Системний підхід дозволяє виявити основні методи і заходи, що забезпечують ефективність енергетичної політики в Німеччині, що корисні для України. ***Наукова новизна.*** У дослідженні проаналізовано основні методи і заходи, що забезпечують ефективність енергетичної політики в Німеччині, у тому числі таких областях, як регуляторна політика, фінансування, ринкові інструменти. ***Практична значимість.*** Запропонована система методів і заходів можуть бути корисними для планування дій, спрямованих на зміцнення потенціалу енергоефективності в умовах перехідної економіки.

Ключові слова: *управління енергоефективністю; енергозбереження; сталий розвиток; Нова Європейська Енергетична Політика; енергетична трілемма; показники енергоефективності*

МЕТОДЫ ДОСТИЖЕНИЯ ЦЕЛЕЙ ЭНЕРГОЭФФЕКТИВНОСТИ: АНАЛИЗ ОПЫТА ЕС

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Аннотация. ***Цель.*** Цель исследования состоит в определении ключевых направлений реформирования энергетического менеджмента в поддержку осуществления политики устойчивого развития в условиях переходной экономики. В соответствие с этой целью, были сформулированы следующие исследовательские задачи: 1) проанализировать опыт ЕС и европейских стран, которые прошли путь имплементации концепции энергоэффективности; 2) определить основные способы реализации концепции энергоэффективности в условиях переходной экономики; 3) предложить концептуальные подходы для сбалансирования целей снижения потребления энергии и экономического роста в Украине. ***Методика.*** Основные аргументы в статье разработаны на основе анализа научных работ по проблемам энергоэффективности в контексте устойчивого развития, сравнения статистики в области энергопотребления, энергоэффективности и экономического роста в различных регионах и странах, анализа опыта различных стран, особенно в Германии. ***Результаты.*** В статье анализируется взаимосвязь между энергоемкостью и ростом ВВП, рассматривается современная модель ЕС в области энергоэффективности, изучаются различия энергетической политики в различных регионах и ЕС. Системный подход позволяет выявить основные методы и меры, обеспечивающие эффективность энергетической политики в Германии, которые полезны для Украины. ***Научная новизна.*** В исследовании проанализированы основные методы и меры, обеспечивающие эффективность энергетической политики в Германии, в том числе таких областях, как регуляторная политика, финансирование, рыночные инструменты. ***Практическая значимость.*** Предложенная система методов и мер может быть полезна для планирования действий, направленных на укрепление потенциала энергоэффективности в условиях переходной экономики.

Ключевые слова: *управление энергоэффективностью; энергосбережение; устойчивое развитие; Новая Европейская Энергетическая Политика; энергетическая трилемма; показатели энергоэффективности*

Introduction. In Europe and the world the issues of energy supply and energy efficiency are extremely urgent on the agenda. The demand for mineral hydrocarbon-based fuel – coal, oil and gas – is growing steadily. According to the International Energy Agency, the global primary energy demand will increase by 37 per cent during the period of 2013-2040. The growth of energy consumption affects the overall level of environmental pollution and accelerates the process of climate change: the energy-related CO_2 emissions are projected to be 16 per cent higher by 2040 [1]. At the same time, it is proven that the growth and continuing increase in energy consumption does not always correspond to rates of economic growth, both in the short and the long run [2]. In recent studies it is well documented that governments of various countries could pursue the energy conservation policies aimed at reduction of energy use for purposes of environmentally friendly development without causing significant negative effects on the economic growth [3-4].

This is why back in April 2010 the Secretary-General's Advisory Group on Energy and Climate Change (AGECC) called for the adoption of two related targets: 1) to achieve universal access to modern energy services by 2030; 2) and for a 40 per cent reduction in global energy intensity also by 2030 [5]. They were later included as targets 1 and 3, respectively, to goal 7 from the recently adopted list of UN's Sustainable Development Goals (SDGs).

The aim of providing universal access to energy should create favourable conditions for the economic take-off. Access to modern energy services must be reliable, affordable and sustainable, as well as, where possible, based on sources with a low greenhouse gas emission potential.

According to Ban Ki-moon, improving energy efficiency is paramount if we are to stop the growth of energy consumption and to reduce greenhouse gas emissions [5, p. 2]. Measures for improving energy efficiency are aimed at the reduction of energy intensity through reducing energy consumption, while maintaining the same level of productivity, and through transformation of energy sources. Since 2000, the global energy intensity has been decreasing at a rate of about one per cent per year due to both of these approaches [11]. At the same time, it should be noted that the European Union makes a decisive contribution to the global energy policy through its missions, activities and authoritative interaction with countries, peoples and organisations throughout the world.

The European Union member states have committed to the 20/20/20 goals, cutting greenhouse gas emissions by 20 per cent, increasing the use of renewable energy by 20 per cent, and cutting energy consumption through improved energy efficiency by 20 per cent. A number of reviews and scientific publications have shown the fundamental achievements of the European countries (e.g. Germany, Denmark, the Netherlands and others), which in the course of the past decades continuously promoted the energy efficiency mechanisms at national level [17-19].

It should be emphasised that energy efficiency is produced domestically, supporting national energy security [17]. So in 2014, the International Energy Agency countries are estimated to have avoided primary energy imports of natural gas, oil and coal, totalling at least 190 Mtoe, and saving USD 80 billion in import bills. Germany achieved the greatest reductions in imports overall, and is estimated to have saved USD 30 billion as a result of energy efficiency gains that reduced consumption of imported oil, gas and coal.

However, while noting the progress made in developed countries, the special reports confirm that in countries with transitional economies, such as Ukraine, energy management remains limited to an outdated concept of energy consumption. The existing policies, strategies, as well as the practice of coordination of economy- and energy-related issues, are inadequate and insufficient to avert a further deepening of the crisis. In these countries energy policy is still an emerging sphere of activity where little progress has still been made.

Research Purpose. The aim of the presented research is to discuss the key directions for the reformation of energy management in support of sustainable development policy implementation under conditions of transitional economy.

In accordance with this aim the following specific objectives were formulated: 1) to analyse the experience of the EU and European countries, which have implemented the energy efficiency concept; 2) to identify the main methods for the implementation of energy efficiency concept in a transitional economy; 3) to suggest conceptual approaches for balancing targets of energy saving and economic growth in Ukraine.

Methodology. The main arguments in the article are developed by analysing scientific papers on the issue of energy efficiency in the context of sustainable development, through comparative analysis of statistics in the area of energy consumption, energy efficiency and economic growth in various regions and countries, and by analysing experience of different countries in this field, Germany in particular.

Findings. Today, the EU has a common energy policy in the overall context of sustainable development concept. However, it should be noted that the basic objectives and approaches of energy efficiency policy have been developed in the EU in the course of many years.

Following a long consultation process with all EU member states, in January 2007, the European Commission published the decision to develop a common energy policy – “Energy for a Changing World: The New European Energy Policy”, which has been approved at a meeting of the European Council on 8-9 March 2007 [8]. As the point of departure the new European Energy Policy declared the progress in re-directing energy management towards achieving the objectives of sustainable, competitive and secure energy supply.

This fundamental goal anticipates that energy policy will lead to a ‘post-industrial revolution’, and to a low-carbon economy in the European Union, as well as it will increase competition in the energy markets and improve security of energy supply and employment prospects [8].

The EU’s common energy policy includes the following key provisions: 1) integration of networks and energy capacity in the EU; 2) diversification of energy sources for strengthening the energy security; 3) assisting EU countries to increase independence from energy imports; 4) making the EU a world leader in renewable energy and in the fight against global warming.

The EU model for achieving the energy efficiency is set out in the series of directives of the European Parliament and the Council, such as: Directive 2006/32/EU on energy end-use efficiency and energy services; Directive 2010/31/EU on the energy performance of buildings (recast); Directive 2010/30/EU on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products; Directive 2012/27/EU on energy efficiency. These directives established a unified framework for all member states determining the principles of energy efficiency and coordinating their actions.

Under this main line, the European Union wants to achieve a positive effects by 2020 compared to the 1990 levels, also known as '20-20-20', including a 20 per cent cut in greenhouse gas emissions, a 20 per cent reduction in energy use through energy efficiency improvements and a 20 per cent increase in renewables. In addition, all EU member states must also achieve at least 10 per cent share of renewable energy in their transport sector [8].

But some countries make even more ambitious commitments. For example, Germany aims to cut its greenhouse gas emissions by 40 per cent by 2020 and up to 95 per cent in 2050. Germany's climate targets were put on paper in 2007 and have been held up by all governments since (Germany's climate targets were confirmed in the 2014 progress report and are subject to an annual monitoring process. The latest monitoring report was published in November 2015.) [9]. The new energy policy of the UK is designed to achieve steady economic development while reducing greenhouse gas emissions by 60 per cent by 2050 [10].

Annual analytical reviews of the World Energy Council reconfirm that the EU is serious about advancing the path toward a low-carbon future. Today, the EU's GDP has grown by more than 44 per cent, and at the same time, it has decreased its emissions 19 per cent below 1990 levels; per capita emissions have likewise fallen [11]. Countries such as Germany set a benchmark for other countries to follow by putting forward its contribution. In contrast, in many countries with transition economies (e.g. Ukraine), one of the main economic differences is high energy consumption leading to increased energy intensity (see *Table 1*).

Table 1

Dynamic of energy intensity and GDP growth

(Source: compiled by the authors according to [11-12])

	2000	2014	2000 - 2014, %/year	2000	2014
	Energy intensity of industry*			**GDP(billion US$)**	
World	**0.13**	**0.12**	**-1.0**	-	-
European Union	**0.11**	**0.08**	**-2.0**	-	-
CIS**	**0.36**	**0,20**	**-4.0**	-	-
Ukraine	0.59	0.27	-5.4	31.3	131.8
Russia	0.35	0.23	-2.9	259.7	1 860.6
Kazakhstan	0.25	0.20	-1.6	18.3	217.9
South Africa	0.18	0.18	0,2	136.4	350.1
China	0.23	0,18	-1.9	1 205.3	10 354.9
Sweden	0.19	0,14	-2.4	259.8	571.1
Canada	0.18	0.14	-1.9	739.5	1 785.4
Australia	0.18	0.12	-2.6	415.0	1 454.7
South Korea	0.16	0.12	-2.0	561.6	1 410.4
India	0.13	0.11	-0.7	476.6	2 048.5
United States	0.13	0.09	-2.6	10 284.8	17 419.0
Japan	0.11	0.09	-1.2	4 731.2	4 601.5
France	0.11	0.08	-1.9	1 368.4	2 829.2
Germany	0.08	0.07	-1.1	1 949.9	3 868.3
United Kingdom	0.09	0.06	-2.0	1 554.8	2 988.9

*The energy intensity of industry is defined as the ratio between the final energy consumption of industry and the value added measured in constant purchasing power parities

**CIS – New Independent States, the former Soviet Union

A World Bank study indicates that countries with underperforming energy systems may lose up to 1-2 per cent of growth potential annually as a result of inefficient use of scarce energy resources, over-investment and energy subsidies, energy supply outages, and direct energy losses [12].

As for the understanding of efficiency energy systems, it should be noted that it is viewed through the lens of the energy trilemma: energy security, energy equity and energy-related environmental sustainability.

According to the interpretation of the World Energy Council [13], achievement of energy security requires the effective management of primary energy supply, the reliability of energy infrastructure, and the responsibility of energy companies operation to meet current and future demand. Energy equity provides the accessibility and affordability of energy supply across the population. Environmental sustainability is supported by the achievement of provision / consumption efficiencies, and by the development of energy supply from renewable and other low-carbon sources.

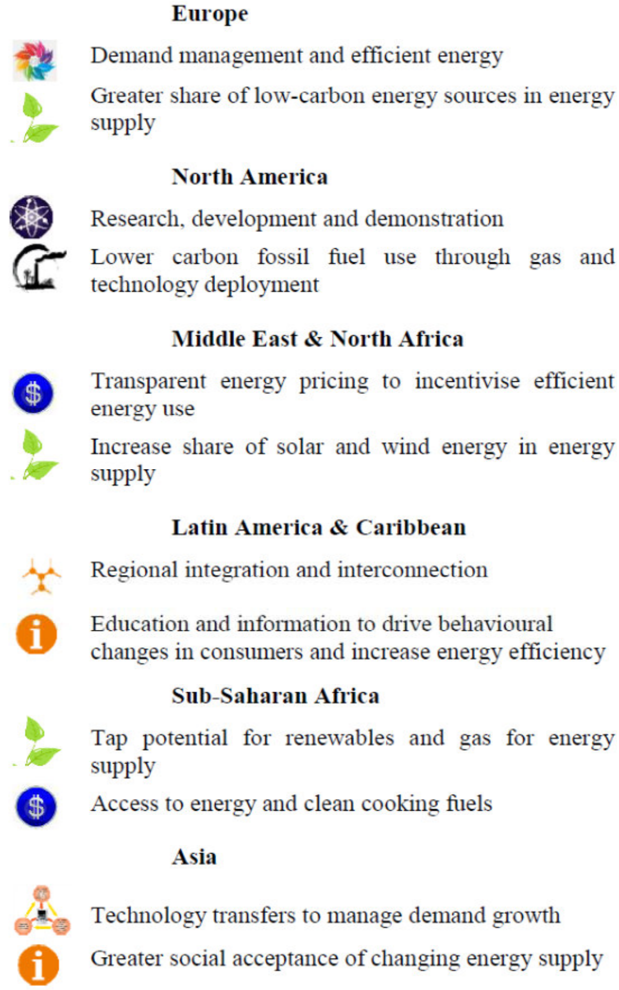


Fig. 1: Regional differences and priorities in measures for developing the energy efficiency (Source: [16])

In this regard, Ukraine's obligation to EU is to create news models of energy management based on nature conservation and reduction of fossil fuel consumption while minimising additional environmental impacts caused by emissions of greenhouse gasses into the atmosphere [14-15].

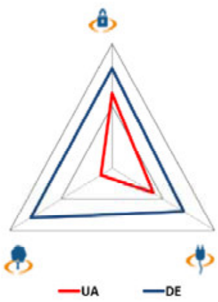
The results of this study show that specific measures for developing the energy efficiency vary greatly between regions and, in addition, present great diversity among them (*see Fig. 1*).

Country reports also reveal that the speed and willingness to act varied greatly between countries. The challenges have varied with each country but often included limited financial resources, insufficient experience or training in leadership of authorities, as well as the lack of experience in the developing and submitting competitive proposals on energy services.

German experience is particularly valuable for Ukraine, because both countries do not have sufficient reserves of their own natural energy resources. However, Germany's ranking reached the thirteenth position in the Energy Trilemma Index (calculated by the World Energy Council among 129 countries, 2015). Germany also constantly improves its position to balance the three sides of the energy trilemma, with additional focus on social and economic indicators, see Fig. 2 [13].

Ukraine (UA): Rank 110
Germany (DE): Rank 13

ENERGY TRILEMMA BALANCE



ENERGY TRILEMMA INDEX RANKINGS

		2012	2014	2015
Energy performance	UA	92	89	105
	DE	8	14	19
Energy security	UA	60	54	88
	DE	24	27	25
Energy equity	UA	73	74	65
	DE	13	42	46
Environmental sustainability	UA	114	116	121
	DE	31	27	44
Contextual performance	UA	104	110	112
	DE	13	12	13
Political strength	UA	100	96	107
	DE	16	16	15
Societal strength	UA	88	83	88
	DE	18	11	14
Economic strength	UA	109	113	110
	DE	26	14	16
Overall Rank	UA	99	94	110
	DE	8	11	13

Fig. 2. 2015 Energy Index Rankings
(Source: compiled by the authors according to [13])

Germany has made progress in the implementation of energy efficiency targets owing mainly to technology innovations and new emerging energy service models, as well as due to priorities set towards clean energy sources and energy management systems. A large variety of services is offered by a plenitude of stakeholders that differ significantly in size and specification and that actively compete with each other [6].

Consultation for private consumers is most common in the following subjects: buildings, saving electricity and saving fuel. The German market-oriented energy efficiency approach is characterised by a variety of instruments and measures that can be structured in the fields of regulatory policy, funding and market instruments.

The regulatory policy includes legal requirements regarding quality of buildings and energy consumption of new and refurbished buildings (EnEV), legal requirements for energy services (EDL-G), and legal requirements for energy consumption of products (EVPG).

Examples of financial instruments include: programme BAFA 'Local consultations to save energy', providing, among others, grants for consultations with home owners by qualified engineers; KfW programmes for energy-efficient construction and refurbishment, providing public authorities with four to five euros in revenue for every euro that went into the promotion of energy-efficient construction and refurbishment (as of 2010); market incentives programme for the use of highly efficient cross-sectional technologies, etc.

Examples of marketing instruments include: energy performance certification, pilot projects, information and motivation, training and qualification of technical specialists.

Originality and Practical value. The study reviewed and analysed the main methods and measures that ensure the effectiveness of energy policy in Germany, including the domains of regulatory policy, funding, market instruments. The proposed system of methods and measures may be useful for the planning of actions towards strengthening the capacity of energy efficiency in the conditions of the transition economy.

Conclusions

1. The government can pursue the energy conservation policies aimed at reduction of energy use for purposes of environmentally friendly development while supporting economic growth.

2. UN included a goal to ensure access to affordable, reliable, sustainable and modern energy for everybody to its list of Sustainable Development Goals (SDGs) based, among others, on two related targets: 1) to achieve universal access to modern energy services; 2) to reduce the global energy intensity.

3. The EU's energy policy includes the following key lines of action: 1) integration of networks and energy capacity of the EU; 2) diversification of energy sources for strengthening the energy security in the EU; 3) development of renewable energy.

4. The measures for developing the energy efficiency vary greatly between regions and, in addition, present great diversity among them.

5. Energy management in the EU includes two main sets of actions: 1) demand management and efficient energy; 2) greater share of low-carbon energy sources in energy supply.

6. The German market-oriented instruments and measures can be structured in the domains of regulatory policy, funding and market instruments. All of these methods can be recommended to Ukraine.

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COMPETITIVE ADVANTAGES THROUGH THE IMPLEMENTATION OF INTERNATIONAL ENERGY MANAGEMENT STANDARDS

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Abstract. ***Purpose.*** The purpose of the presented research is to explore the potential of international energy management standards to increase competitiveness of industrial enterprises under conditions of Ukrainian transitional economy. The study had the following objectives: to trace the evolution of fundamental energy efficiency standards; to discuss experience in their use in various countries; to identify factors that are key to achieving competitive advantage under the implementation ISO 50001. ***Methodology***. This article presents a historical overview of the standardisation of principles and approaches for the purpose of the energy-efficient management. The research was carried out by studying the international documents, voluntary standards and national practices in the field of energy efficiency. ***Conclusions.*** The study examines the experiences of different countries in the field of energy management systems. The authors conducted a comparative analysis of the ISO 50001 with the other basic standards for the organisation of management. The system approach enables to identify the main factors and their impact on capacity to achieve competitive advantages, which are possible to obtain after certification to ISO 50001. ***Originality.*** The study reviewed and analysed the energy management penetration within its dynamics at time and country level. After analysing the statistical data and the results of the interviews, the authors identified 20 key factors affecting the competitiveness of enterprises that are certified to ISO 50001. All of these factors were divided into four groups, two groups represent external environment – opportunities and threats, and two groups – internal capacity – strengths and weaknesses of enterprises. ***Practical value.*** The proposed system of factors may be useful for the planning of actions towards strengthening the capacity of energy management systems in the context of the formation competitive advantages on the industrial markets.

Keywords: *energy efficiency management; sustainable development; voluntary standards for efficient energy management; energy efficiency indicators related to competitiveness*

ОТРИМАННЯ КОНКУРЕНТНИХ ПЕРЕВАГ ЗА ДОПОМОГОЮ ВПРОВАДЖЕННЯ МІЖНАРОДНИХ СТАНДАРТІВ УПРАВЛІННЯ ЕНЕРГОЕФЕКТИВНІСТЮ

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Анотація. ***Мета.*** Метою запропонованого дослідження є вивчення потенціалу міжнародних стандартів з енергетичного менеджменту для підвищення конкурентоспроможності промислових підприємств в умовах української перехідної економіки. Дослідження має наступні завдання: простежити еволюцію основних стандартів енергоефективності; обговорити досвід їх використання в різних країнах; виявити фактори, які є ключовими для досягнення конкурентних переваг в рамках реалізації ISO 50001. ***Методика.*** Стаття являє собою історичний огляд принципів і підходів до організації систем енергоефективного менеджменту. Дослідження проводилося шляхом вивчення міжнародних документів і національних практик в області досягнення енергоефективності. ***Результати.*** У дослідженні розглядається досвід різних країн в області систем енергетичного менеджменту. Автори провели порівняльний аналіз ISO 50001: 2011 з іншими базовими стандартами щодо організації менеджменту. Системний підхід дозволив виявити основні фактори та їх вплив на здатність досягти конкурентних переваг, які можливо отримати після сертифікації на ISO 50001. ***Наукова новизна.*** У дослідженні розглядається і аналізується проникнення енергетичного менеджменту в динаміці у часі та на рівні країн. Після аналізу статистичних даних та результатів опитувань, автори визначили 20 ключових факторів, що впливають на конкурентоспроможність підприємств, сертифікованих на ISO 50001. Всі ці фактори були розділені на чотири групи, дві групи представляють зовнішнє середовище – можливості і загрози, і дві групи – внутрішній потенціал – сильні і слабкі сторони підприємства. ***Практична значимість.*** Запропонована система факторів може бути корисна для планування дій у напрямку зміцнення потенціалу систем енергетичного менеджменту в контексті формування конкурентних переваг на промислових ринках.

Ключові слова: *управління енергоефективністю; сталий розвиток; добровільні стандарти управління енергоефективністю; показники енергоефективності для виміру конкурентоспроможності*

ПОЛУЧЕНИЕ КОНКУРЕНТНЫХ ПРЕИМУЩЕСТВ ПОСРЕДСТВОМ ВНЕДРЕНИЯ МЕЖДУНАРОДНЫХ СТАНДАРТОВ УПРАВЛЕНИЯ ЭНЕРГОЭФФЕКТИВНОСТЬЮ

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Аннотация. ***Цель***. Целью представленного исследования является изучение потенциала международных стандартов по энергетическому менеджменту для повышения конкурентоспособности промышленных предприятий в условиях украинской переходной экономики. Исследование имеет следующие задачи: проследить эволюцию основных стандартов энергоэффективности; обсудить опыт их использования в различных странах; выявить факторы, которые являются ключевыми для достижения конкурентного преимущества в рамках реализации ISO 50001. ***Методика.*** Статья представляет собой исторический обзор принципов и подходов к организации систем энергоэффективного менеджмента. Исследование проводилось путем изучения международных документов и национальных практик в области достижения энергоэффективности. ***Результаты.*** В исследовании рассматривается опыт разных стран в области систем энергетического менеджмента. Авторы провели сравнительный анализ ISO 50001: 2011 с другими базовыми стандартами по организации менеджмента. Системный подход позволяет выявить основные факторы и их влияние на способность достигнуть конкурентных преимуществ, которые возможно получить после сертификации на ISO 50001. ***Научная новизна.*** В исследовании рассматривается и анализируется проникновение энергетического менеджмента в динамике во времени и на страновом уровне. После анализа статистических данных и результатов опросов, авторы определили 20 ключевых факторов, влияющих на конкурентоспособность предприятий, сертифицированных на ISO 50001. Все эти факторы были разделены на четыре группы, две группы представляют внешнюю среду – возможности и угрозы, и две группы – внутренние емкости - сильные и слабые стороны предприятия. ***Практическая значимость.*** Предложенная система факторов может быть полезна для планирования действий в направлении укрепления потенциала систем энергетического менеджмента в контексте формирования конкурентных преимуществ на промышленных рынках.

Ключевые слова: *управление энергоэффективностью; устойчивое развитие; добровольные стандарты управления энергоэффективностью; конкурентоспособность; показатели энергоэффективности для измерения конкурентоспособности*

Introduction. Today, the need to improve energy efficiency of industrial enterprises with an outlook of attracting investments and increasing competitiveness of the industrial sector of Ukraine through the implementation of advanced international practices in this field can be clearly recognised. Energy efficiency management enables enterprises to lower savings in consumer spending, improve the product quality and increase their profitability, while reducing the need for additional investments in development.

However, the ultimate goal of an energy-efficient approach is not only to raise the overall performance levels, but also to achieve significant competitive characteristics that will enhance access to certain markets, to integrate into efficient and inclusive industry value chains, and ultimately to maintain the sustained economic growth.

For many years Ukraine firmly occupies a leading position in the world ranking of energy intensity of the industrial sector[1]. In 2014, for Ukraine this indicator was 0.27, while for China – 0.18, for United States – 0.09, for Germany – 0.07 [1]. The unit consumption of steel industry[2] in Ukraine is 0.59, while in China this indicator is 0.48, Germany – 0.31, United States – 0.25 [2].

Global energy crisis has created a significant stress in Ukrainian metallurgy, which is the basis of its national economy. Rising energy

[1]The energy intensity of industry is defined as the ratio between the final energy consumption of industry and the value added measured in constant purchasing power parities [3].

[2]The unit consumption of steel industry is calculated as the ratio between the final energy consumption of steel industry and steel output measured in tons [3].

costs and conditions of an ongoing energy deficit accelerated the requirements to reform the production policy in support of the progressive principles of energy management.

The sustainable and responsible development of the production companies must be carried out in an adequate framework, where energy efficiency and safety are essential elements. At the same time, such framework must provide the necessary guarantees to all stakeholders that the company is committed to complying with the high standards of energy efficiently and contributes to this requirement's implementation along the entire production chain.

Taking into account these considerations, the international scientific community offers universal voluntary energy efficiency standards, which were designed to ensure building systemic capacity for industrial energy efficiency as tool to promote sustainable production, markets and market relations.

For the Ukrainian enterprises obtaining competitive advantages through the application of energy efficiency standards is still a new phenomenon, so the potential for reducing energy consumption by the industry in Ukraine remains enormous.

It is worthwhile to note that scientific debates on energy management in the industrial sector have recently increased. Ukrainian scientists investigate the role of energy management and government control of energy-savings in industry (e.g. Y. O. Kostenok [3]), the need for energy efficiency and problems of implementation of energy management system (e.g. K. O. Bratkovska [4]), approaches for the improvement of energy efficiency (e.g. N. V. Parhomenko and O. A. Polozova, [5]), and others.

In context of this research, of particular interest are the last monographic publications in this field, including those on the fundamental principles and systematic processes of maintaining and improving energy efficiency by Craig B. Smith & Kelly E. Parmenter [6], energy efficiency management for the process industries by Alan P. Rossiter & Beth P. Jones [7], interdisciplinary approach to the various barriers with energy efficiency by Patrik Thollander & Jenny Palm [8]. Nonetheless, the capacity of voluntary energy efficiency standards for the formation of competitive advantages in the industrial markets remain relatively uncharted.

Purpose. The purpose of the presented research is to explore the potential of international energy management standards to increase competitiveness of industrial enterprises under conditions of Ukrainian transitional economy. The study had the following objectives: to trace the evolution of fundamental energy efficiency standards; to discuss experience in their use in various countries; to inquire the problem of implementing the ISO 50001 standard in Ukraine; to analyse functions of voluntary energy efficiency standards in the context of formation of competitive advantages.

Methodology. This article presents a historical overview of the standardisation of principles and approaches for the purpose of the energy-efficient management organisation. The research was carried out by studying the international documents, voluntary standards national practices in the field of energy efficiency. The system approach enables to analyse the properties and functions of voluntary energy efficiency standards and to identify their capacity to achieve competitive advantages by Ukrainian industrialists.

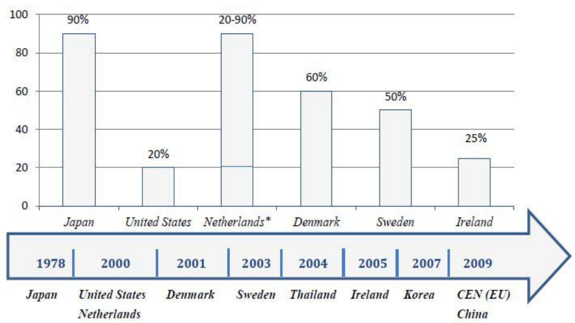
Findings. Progress in achieving industrial energy efficiency is one of the most important components of the sustainable development concept, which is directly aimed at realisation of its objectives – a balanced economic growth and social development based on inexhaustible and equitable use of primary natural resources. This approach became the basis for the EU development strategy, which includes not only reduction in global energy intensity but the transition to clean energy and green economy, formation of a new type of markets and value chains, based on the support of energy-efficient tools and techniques.

In Ukraine since independence until recent years the energy sector remained the most vulnerable and the most disturbing element in the pursuit of competitive economy. The fundamental challenges for industrialists are how to decouple the consumption of energy resources from economic growth. In this regard, energy efficiency programmes for enterprises and regions are primarily concentrated on achieving energy saving – reducing or even partially operating without an energy service to save energy[3]. Thus, 'energy efficiency gain' is defined as providing the same level of production while reducing the use of energy, or obtaining higher economic benefits from the same energy input [6-8].

At the same time it is important to understand that the objectives of energy efficiency and sustainable development are closely linked. In this regard, the World Energy Council (WEC) framed the energy efficiency concept as the Energy Trilemma, which involves three objectives of a balanced (sustainable) development: energy security, energy equity and environmental sustainability [10]. Such interpretation is steadily gaining weight in international initiatives for energy efficiency management, of which the energy efficiency standards can be highlighted. Today's energy standards may be designed as industry standards (for specific industries)[4] or universal /cross-sectoral standards (for all industries)[5]; both types of energy standards can come in two formats: required (mandatory) and recommended (voluntary) standards.

It should be noted that voluntary application of international standards, such as ISOs and sector specific voluntary standards, is a new phenomenon for post-Soviet states linked to a transition economy. As part of measures on joining the EU space, Ukraine implemented reforms to reduce the abundance of technical regulations in production, management and trade through harmonisation of certification procedures with provisions of EU Directives [14]. Moreover, starting with January 2016 the technical standards in Ukraine cease to exist as mandatory (i.e. compulsory) standards – the private sector / business will start implementing western standards [15]. Under these conditions it is important to understand the peculiarities of voluntary standards of energy management and the benefits for industrial enterprises.

Studying the best world practices on the enhancement of energy management showed that countries had different approaches to understanding and solving the problem of energy efficiency. For example, Japan has the Energy Conservation Act (1978), which includes multi-sectoral requirements for energy efficiency. Energy management was introduced in the Netherlands within the Voluntary Agreement (VA) programme, not a standard; the programme was established in the late 80's of the previous century as a policy instrument to increase energy efficiency in Netherlands' industry. In some countries, the introduction of ISO 50001 is mandatory for large companies (e.g. in Thailand). The penetration rate of energy management in industrial sector is also very different (see Fig. 1).



**Companies representing 20% of energy use have LTAs and must use the Energy Management System. The most energy intensive companies, representing 70% of the energy use, have a separate, more stringent, bench marking covenant and are typically ISO 14000 certified, but are not required to use the EM System.*

Fig. 1. The dynamics of penetration of the energy systems in time and country (Source: [16] as updated by the authors)

Almost all the national standards rests upon several identical fundamentals – in particular, the concept of continuous improvement (Plan-Do-Check-Act Cycle), the existence of energy baseline date, the procedure for developing energy efficiency indicators, etc.

Today, the leading role in the development of international standards belongs to the International energy agency (IEA) and International

[3]For example, in Ukraine the project of the German Society for International Cooperation (GIZ) "Energy efficiency in municipalities" focuses mainly on the implementation of energy-saving technologies in the housing and communal services to reduce total energy consumption in municipalities [9].

[4]For example, the Electric Efficiency Institute (Washington, USA) has developed the integrated codes and standards for energy efficiency management in electric power sphere (2011) [11]. The International Energy Agency (IEA) proposed requirements for certain building codes relating to the new construction (2009) [12].

[5]These include ISO standards – documents that provide requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose [13].

Organization for Standardization (ISO). At the G-8 meeting in 2008 these organisations submitted a joint Memorandum ISO/IEA to develop ISO 50001:2011 Standard, Energy management systems – Requirements with guidance for use. The new basic standard is intended for creating and certification of energy management systems (EnMS). The ISO 50001:2011 standard has taken into account the experience of the U.S. standard ANSI/MSE 2000:2005, Korean standard KS A 4000:2007, and other national standards on energy management (see Table 1).

Table 1

National standards for energy management*

Country	Reference	Title of the standard
USA	ANSI/MSE 2000:2008	Management System for Energy
Denmark	DS 2403:2001	Energy Management – Specification
Sweden	SS 627750:2003	
Ireland	IS 393:2005	Energy Management Systems – Specification with Guidance for Use
Spain	UNE 216301:2007	Energy Management System – Requirements
EU	EN 16001:2009	Energy Management Systems
France	BPX30-120:2006	Le Pré diagnostic énergétique dans l'industrie (engl. Diagnosis of energy consumption in the industry)
Spain	UNE 216501:2009	Auditorías energéticas. Requisitos (engl. Energy audits. Requirements)
Italy	UNI CEI 11339	Gestione dell'energia - Esperti in gestione dell'energia - Requisiti generali per la qualificazione (engl. Requirements for experts in the field of energy management)
South Korea	KS A 4000:2007	Energy Management System
China	GB/T 23331:2009	Management System for Energy – Requirements
South Africa	SANS 879:2009	Energy Management – Specifications

**Source: compiled by the authors according to [16-17]*

It must be stressed that focus on the implementation of the energy management systems has significantly increased after the publication of European energy management standard – EN 16001 in July 2009. In accordance with the rules of the European Union standardisation, the standard was to be adopted as national standards in the EU member states.

Specifications of EN 16001:2009 and ISO 50001:2011 are very similar because both are formed on the basis of the widely used ISO 14001 standard. This not only facilitates the implementation of new basic standard, but determines its high compatibility with the programs of quality management (ISO 9001-2000), environmental management (ISO 14001), occupational health and safety management (OHSAS 18001), and allows you to organise an integrated management system of the enterprise. It is very important that the introduction of ISO 50001 has eliminated the inconsistency in relevant national standards and unified energy management in different countries [17].

The adoption of Energy Efficiency Directive 2012/27/EU greatly encouraged the certification of large enterprises in the EU. To reach the EU's 20% energy efficiency target by 2020, Directive requires energy audits should be mandatory and regular for large enterprises [18]. This energy audits can be applied through energy audit itself (EN 16247-1), energy management systems (EN ISO 50001) or undertaken in accordance with EMAS, because EMAS-certified companies often already meet all the requirements of an energy management system. Nevertheless, certification according to ISO 50001 by global region is very uneven. (see Fig. 2).

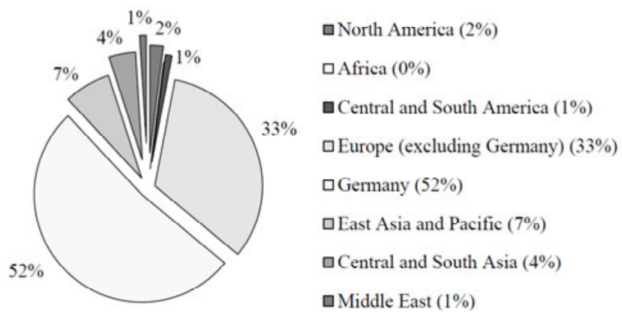


Fig. 2. Global distribution of certification according to ISO 50001 by region (%) as of January 2014 (Source: compiled by the authors according to [16-17])

Today, the leader in certification to ISO 50001 is Germany that occupies 52% of the market. That could be explained partially by the focus of national legislation on the issue of sustainable development and energy efficiency, as well as a higher awareness and recognition of the part that strong energy management plays in corporate social responsibility (CSR).

It shall be reminded that in Ukraine the certification to ISO 50001 is only just beginning to develop. In this direction, the Ministry of Economic Development and Trade approved the National Standard DSTU ISO 50001:2014 "Energy Saving. Energy Management Systems: Requirements and Application Guidelines (ISO 50001:2011, IDT)", which entered into force in January 2015. At the same time, many industrial companies have already gone on a way of certification on compliance with ISO 50001 (e.g. JSC Ingulets Ore Mining and Processing Plant, PJSC Energomashspetsstal, JSC Zaporizhstal, etc.). The study of the experience made it possible to highlight the preconditions for the expansion of the process, as well as the motivations, difficulties faced and the intended benefits of introducing an EnMS standard.

Economic theory and the best international practices have already proved that voluntary certification of the energy management systems is a tool of market activity. For the purpose of gaining in-depth knowledge about the factors that promote or inhibit the increase in the competitiveness of certified companies, we have interviewed 10 managers of 4 industrial enterprises. Interviews were conducted with the use of laddering method[6], including ten open questions. Respondents also had to identify the main factors of success and failure, to assess the strength of their impact and probability of occurrence.

Factors were selected by the assessing the efforts and achievements. The identified factors were divided into four groups, two groups represent external environment – opportunities and threats, and two groups – internal capacity – strengths and weaknesses of enterprises. Twenty of the most significant factors (five factors in each group) are represented in table 2.

We shall dwell on some of these factors. The analysis confirmed that in Ukraine the necessary political and legal environment is being formed. Firstly, under the Action Plan for Implementation of Ukraine-EU Association Agreement and the Ukraine's joining to the Energy Community Treaty, the Government carries out the harmonisation of domestic legal framework for energy to the *acquis communautaire*. These actions are supported by a program for implementation of EU Directives in the field, and the road map for compliance with the EU energy efficiency legislation [19].

Sustainable energy value chains perceive the high value for Ukrainian enterprises. However, all managers have noted as a strong threat the lack of measures to enhance energy management.

In this regard, the German market oriented approach is characterised by a variety of instruments and measures at federal, land and municipal level. Germany has the biggest and sophisticated markets of energy services – energy consulting and contracting; a huge variety of services is offered by a plenitude of stakeholders that differ significantly in size and specification and that actively compete with each other. Contracting is one of the most important energy services, its market turnover is estimated well over 2 Billion Euro per year [20].

By implementing the ISO 50001 management system, companies can achieve significant energy savings and gain a real competitive advantage [21].

Also, the strength of the Ukrainian industrialists is certainly the experience in basic standards of management DSTU ISO 9001, DSTU ISO 14001, DSTU OHSAS 18001. As of today, around two thousand certificates for quality management system and environmental management system operate in Ukraine. Such enterprises have already been creating the integrated system of corporate management [13]. Among the factors, that are important drivers for Ukrainian enterprises certified to ISO 50001, can be noted the increase of investment attractiveness due to the reduction of energy and environmental risks with energy supply, consumption limitations and other problems.

Another problem is poor Ukrainian public knowledge and awareness of energy management practices and successful experiences both in Ukraine and in other countries. In this regard it is important to take into account that objectives of energy efficiency and sustainable development cannot be achieved only by the efforts of individual companies, and even coun-

[6]The laddering method of interviewing is a technique that is particularly helpful in eliciting underlying values and goals, and therefore is useful for capturing qualitative research data with a small stock of empirical experience and a small sample.

tries or regions. The experience on energy efficiency should be available and distributed easily both in countries with advanced economies and in developing countries.

Table 2

Factors of influence on the competitive advantages in the implementation of ISO 50001 management*

№	Factors	Rating (-5 to +5)		
		Value	Chance	Overall Rating
External factors				
Opportunities				
1	Prospect for Ukraine-EU Association Agreement and the Ukraine's joining to the Energy Community Treaty	4	4	16
2	Initiatives to establish energy value chains	5	3	15
3	Market development of energy saving technologies	3	3	9
4	Establishing an energy audit scheme and energy baseline date for industries	2	4	8
5	Programs of bank loans on preferential terms	1	3	3
			In total	51
Threats				
6	The lack of government measures to stimulate the implementation of ISO 50001	-5	5	-25
7	Lack of information and exchange of experience	-4	5	-20
8	Lack of quality audit of the internal market	-3	2	-6
9	The lack of tax incentives for businesses that are certified	-2	1	-2
10	The absence of labelling practice of energy efficient products	-1	1	-1
			In total	-54
Internal factors				
Strengths				
11	Reduction of energy consumption and the level of costs	5	4	20
12	Experience of basic management standards (DSTU ISO 9001, DSTU ISO 14001, etc.)	4	5	20
13	Increasing investment attractiveness	3	2	6
14	Improving the environmental performance	2	2	4
15	Improving the image and prestige of the company	1	2	2
			In total	***52***
Weaknesses				
16	Senior managers do not really know the principles of energy management	-5	4	-20
17	The worn out equipment and low technology	-4	5	-20
18	Insufficient level of basic staff training	-3	2	-6
19	No integrated development programs	-2	3	-6
20	The absence of internal incentives	-1	1	1
			In total	-53

**Source: compiled by the authors*

To overcome these barriers the universities should assume the mission of guides of new ideas and achievements in this area. It is remarkable that such a position was manifested by of participating universities in the International Workshop "Energy supply and energy saving" (Baku, 21-27 September 2015), which discussed the problems of energy efficiency in Germany, Russia, Ukraine and Azerbaijan. At this forum, the universities have established the Neseff – the international network of universities for energy supply and energy efficiency.

Originality and Practical value. The study reviewed and analysed the energy management penetration within its dynamics at time and country level. After analysing the statistical data and the results of the interviews, the authors identified 20 key factors affecting the competitiveness of enterprises that are certified to ISO 50001: 2011. All of these factors were divided into four groups, two groups represent external environment – opportunities and threats, and two groups – internal capacity – strengths and weaknesses of enterprises.

The proposed system of factors may be useful for the planning of actions towards strengthening the capacity of energy management systems in the context of the formation competitive advantages on the industrial markets.

Conclusions

1. It is important to understand that the objectives of energy efficiency and sustainable development are closely linked. In this regard, the energy efficiency concept as the Energy Trilemma involves the following objectives: energy security, energy equity and environmental sustainability.

2. The best international practices confirmed that voluntary certification of the energy management systems is a tool of market activity.

3. The main factors of success or failure to achieving competitiveness can be divided into four groups, two groups represent external environment – opportunities and threats, and two groups – internal capacity – strengths and weaknesses of enterprises.

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FORMING OF THE SUSTAINABLE SUPPLY CHAINS BASED ON INCREASING OF THEIR INTEGRATED ENERGY EFFICIENCY

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Abstract. ***Purpose.*** Key challenges and barriers of mining machinery enterprises in the context of forming sustainable supply chains in the mining industry are specified. ***Methodology***. The algorithm of forming the industrial relations, which are carried out by the enterprises of mining machinery in order to increase the sustainable development of a mining industry, is offered. ***Conclusions..*** Modern supply chains are confronted with dynamic trends and developments that are hard to predict. In order to respond to these changes and remain competitive advantage, companies should be able to identify and understand new sustainability issues in their branches. It is established that in the conditions of globalization of the market and the general orientation of Ukraine's economy to the European principles of development, for mining machinery enterprises a proof of the commitment and observance of requirements of energy efficiency, i.e. energy saving, energy safety and social energy responsibility are very important. Supply channels should increase not only energy efficiency, economic and production stability of the company, but also strengthen the stability of all participants in the production chain, as well as other stakeholders (business partners, customers, investors, local communities, etc.). ***Originality.*** The interrelation of an indicator of energy efficiency in forming sustainable supply chain in a mining industry is established. ***Practical value.*** Using the principles of sustainable development in the forming of value chains will improve energy efficiency of industry in general; provide a competitive advantage to entry into the global production chains in terms of European integration of Ukraine.

Keywords: *sustainable development; energy efficiency; responsible production; mining engineering; supply and distribution channels; Ukrainian market of components*

ФОРМУВАННЯ СТІЙКИХ ВИРОБНИЧО-ЗБУТОВИХ ЛАНЦЮЖКІВ НА БАЗІ ПІДВИЩЕННЯ ЇХ ІНТЕГРАЛЬНОЇ ЕНЕРГОЕФЕКТИВНОСТІ

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Анотація. ***Мета.*** Уточнити ключові завдання і бар'єри підприємств гірничого машинобудування в контексті формування стійких ланцюгів постачань в гірничодобувному секторі. ***Методика.*** Запропонований алгоритм формування виробничих зв'язків, що здійснюються підприємствами гірничого машинобудування для цілей забезпечення і розподілу, з метою підвищення стійкості розвитку видобувної промисловості в цілому. **Результати.** Встановлено, що в умовах глобалізації ринку та спільної орієнтації економіки України на європейські принципи розвитку, для підприємств гірничого машинобудування стає важливим доказ своєї прихильності і дотримання вимог енергоефективності, тобто енергозбереження, енергобезпеки та соціальної енерго-відповідальності. Канали забезпечення та розподілу повинні підвищувати не тільки енергоефективність, економічну і виробничу стабільність підприємства, а й сприяти зміцненню стійкості розвитку всіх учасників виробничого ланцюга, а також інших зацікавлених сторін (бізнес-партнерів, покупців, інвесторів, територіальних громад, т. п.). ***Наукова новизна.*** Встановлено, що існує взаємозв'язок показника енергоефективності з формуванням стійкого виробничо-збутового ланцюжка у видобувній промисловості. ***Практична значимість.*** Використання принципів сталого розвитку при формуванні виробничо-збутових ланцюжків дозволить підвищити енергоефективність промисловості в цілому, забезпечить досягнення конкурентної переваги для входження в глобальні виробничі ланцюжки в умовах євроінтеграції України.

Ключові слова*:* *сталий розвиток, енергоефективність, відповідальне виробництво, гірниче машинобудування, канали забезпечення і розподілу, український ринок комплектуючих*

ФОРМИРОВАНИЕ УСТОЙЧИВЫХ ПРОИЗВОДСТВЕННО-СБЫТОВЫХ ЦЕПОЧЕК НА ОСНОВЕ ПОВЫШЕНИЯ ИХ ИНТЕГРАЛЬНОЙ ЭНЕРГОЭФФЕКТИВНОСТИ

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Аннотация. ***Цель***. Уточнить ключевые задачи и барьеры предприятий горного машиностроения в контексте формирования устойчивых цепей поставок в горнодобывающем секторе. ***Методика.*** Предложенный алгоритм формирования производственных связей, осуществляемых предприятиями горного машиностроения для целей обеспечения и распределения, с целью повышения устойчивости развития добывающей промышленности в целом. ***Результаты.*** Установлено, что в условиях глобализации рынка и общей ориентации экономики Украины на европейские принципы развития, для предприятий горного машиностроения становится важным доказательство своей приверженности и соблюдения требований энергоэффективности, т.е. энергосбережения, энергобезопасности и социальной энерго-ответственности. Каналы обеспечения и распределения должны повышать не только энергоэффективность, экономическую и производственную стабильность предприятия, но и способствовать укреплению устойчивости развития всех участников производственной цепи, а также других заинтересованных сторон (бизнес-партнеров, покупателей, инвесторов, территориальных общин, т. д.). ***Научная новизна.*** Установлена взаимосвязь показателя энергоэффективности и формирования устойчивой производственно-сбытовой цепочки в добывающей промышленности. ***Практическая значимость.*** Использование принципов устойчивого развития при формировании производственно-сбытовых цепочек позволит повысить энергоэффективность промышленности в целом, обеспечит конкурентное преимущества для вхождения в глобальные производственные цепочки в условиях евроинтеграции Украины.

Ключевые слова: *устойчивое развитие, энергоэффективность, ответственное производство, горное машиностроение, каналы обеспечения и распределения, украинский рынок комплектующих*

Introduction. Due to the ratification of economic part of the Ukraine–European Union Association Agreement, Ukraine has to provide implementation of the provisions fixed in the section V "Economic and sectorial cooperation". This section contains the basic provisions of the harmonization of Ukrainian legal system and EU legal system, the principles of cooperation between Ukraine and the EU, and also a number of liabilities for reforming establishments in the main fields of activity, including industry, energy, environment protection etc. The fastest implementation of basic provisions of this section will allow the ratification of the section IV «Trade and issues related to trade". It will promote full integration of Ukraine into EU internal market.

The industrial sector is one of the main in economy of Ukraine as it provides a third of Ukraine's GDP. During the last decade the share of the industry in GDP of Ukraine fluctuated from 36.7% in 2007 to 25% in 2014 (See Fig. 1). Therefore, priority Ukraine must reconsider their attitude to the principles of development of the industry, especially in terms of reducing energy consumption and increasing the sustainability of resource use, increase social transparency and accountability, the connection to the international initiatives aimed at creating a sustainable development in the industrial supply chain and distribution. [12]

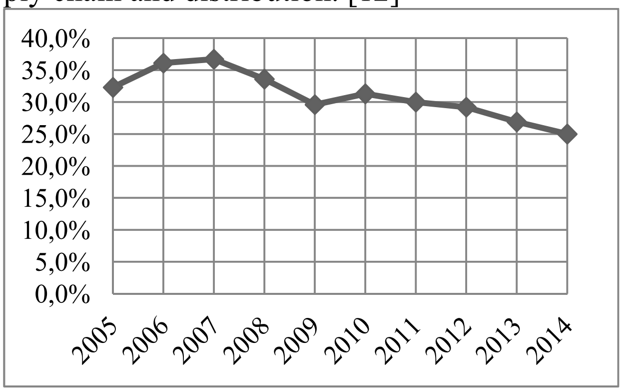

Fig. 1. Share of industry in GDP of Ukraine 2005 - 2014 (Source: calculated and compiled by the authors according to [11])

In order to harmonize national and European standards it is necessary to: 1) implement the European method of industry standards; 2) transit from compulsory to voluntary certification; 3) mutually recognize of certificates which will promote export-import operations; 4) carry out information campaigns.

Results. It should be noted that industrial enterprises in Ukraine, as in many other post-Soviet countries, take first place in the world in specific energy consumption and resource intensity of products. This is proved by GDP per unit of energy use (See Fig. 2).

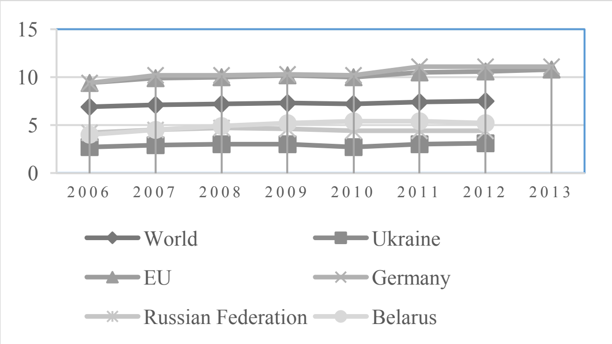

Fig. 2. GDP per unit of energy use (constant 2011 PPP $ per kg of oil equivalent) 2006 – 2013 (Source: calculated and compiled by the authors according to [16])

The reason for this situation in the post-Soviet Union space is the absence of well-founded state energy policy, which presupposes:

- established branch indicators of energy intensity;
- state structure responsible for compliance with the established rules;
- effective policy of taxation and financing of industrial enterprises;
- principles of responsible environmental management in society.

Today progressive tendencies of resource-saving, responsible mining, processing and using extend in the majority of industrialized countries, particularly in the EU. This is due to global trends of rising energy prices, growing public awareness of environmental protection and climate (reducing CO2 emissions). The EU plans to reduce primary energy consumption by 20% until 2020. According to the energy program of the EU it is expected annual increase in energy efficiency by 2.1% up to 2050. This will be achieved through the introduction of modern technologies. The EU at the political level supports wider use of energy efficient technologies through the relevant standards. According to researches which were conducted by the German organization Roland Berger Strategy Consultants, energy efficiency will be of importance in the future for companies developing technologies and technically complicated products. It will allow to realize competitive advantages. In European countries today, increasing energy efficiency is one of the consumer's important selection criteria. It is a central factor of differentiation (Unique Selling Proposition, USP) the company's offer to consumers. Also one of the main criteria for making management decisions is life cycle costing: in increasing frequency consumers take into account not only purchase price, but also all operating costs, including costs of energy consumption. Moreover, energy efficiency is considered as a significant long-term market entry barrier for new sellers.

In the conditions of increasing energy prices Ukrainian industrial products become more and more uncompetitive in comparison with technologically developed products such as Germany, Britain, etc., that is one of the main factors of decreasing the volume of national industrial production. For example, for the last three years in Ukraine sales of machine-building production decreased by 27,5%, and the number of cars produced for the mining industry (drilling and tunneling equipment) – decreased by 73,7% (see Table 1). Such dynamics was followed by increase in prime cost almost by 9 times. By 2013 the share of electric energy expenses in structure of costs of machine-building production increased from 30 to 55%.

Table 1

Dynamics of production of machine-building products in 2012-2014*

	2012	2013	2014	in % to 2012
Sales of machine-building products, mln. UAH	140539,3	113926,6	101924,7	72,5
Production of equipment for the mining industry (drilling, tunneling equipment), thousand pieces.	1,9	0,9	0,5	26,3

**In 2014 - excluding the occupied territories of Autonomous Republic of Crimea and regions of Donetsk and Lugansk. (Source: calculated and compiled by the authors according to [2])*

The most part of needs for means of production is satisfied on an extensive basis, which is due to accumulation of absolute volumes of mining of raw products. It leads to increase the weight of the mining and processing industries, as a result, considerable scales of environmental destruction. At the reached sizes and rates of miming, and primary processing of fuel, raw materials the existing mechanisms of relationship between industrial enterprises in supply and distribution channels, and also a measure for environmental protection don't allow to solve the arisen problems as are aimed only at eliminating the consequences, but not the reasons of the developed situation. The crisis state of machinery, including the mining industry, indicates weaknesses in the supply chain management and marketing, lack of orientation of the enterprise policy on sustainable development, imperfection of the current management system of energy resources and production costs. Low energy and resource efficiency of products increases its competitiveness, and, as a result, complicates entry of companies into profitable industry supply chain.

Analysis of recent researches and publications. The worsening of situation in machine-building branches of Ukraine intensified search of scientific decisions to optimize resource management and supply policy for the production purposes. A number of fundamental and applied academic researches is dedicated to this subject. In particular, the attention to problems of economic stability management of machine-building enterprise based on reduction of resource policy risks is increased (for example, Maslyuk O. [9], Zanora V. [3]). A number of researches are devoted to the method of strategy management of logistics procurement as a tool for adapting the machine building company to the changing market conditions (for example, Kopilets P. [5], Neurov I. [7]).

New directions of scientific research are connected with understanding of the concept of sustainable supply chains. In particular, there are researches on development of logistic integration into production chains from a position of level system approach (for example, Kuzmenko Yu. etc. [6], Kiryukov S., Krotov K. [4]). Issues of using the voluntary standards of a sustainable development for forming the stable horizontal and vertical production supply chains (for example, Palekhova L., Pivnyak G. G. [17]) became the important direction of researches. At the same time, these researches need to be deepened for individual industries, for which adaptation to globalization and integration is especially critical factor of competitiveness. The relevance and importance of solving this problem for the enterprises of mining machinery are caused by insufficiency of system development concerning ways of accumulation of the mining sustainability.

Purpose. This research aims to clarify key challenges and barriers of mining machinery enterprises in the context of forming sustainable supply chains in the mining.

The presentation of the main research material. The paradigm of supply chain management based on sustainable development initiatives has led to subsequent changes in business behavior concerning the interaction strategy between enterprises in supply chains. As a result, traditional theories (for example, resource approach of firm, the transaction theory) aren't able to provide a comprehensive explanation of management of a sustainable development in these chains. The modern management theory of supply chains, can't explain and predict the behavior observed concerning initial sources of sustainability [13].

It is known that economic actors in production chains (distribution and supply) enter into a specific interaction (or interrelation) during rather long time. Such interaction represents the certain combined process, including not only physical movement of goods, but also social, business, information exchange across the supply chain [12].

Entry into stable production chains reduces uncertainty in the conditions of supply of material resources and services for their own production, and also promotes stabilization of demand for the final products. In addition, each of the subjects included in the production chain, have different possibility of impact on stability development of other participants. Machine building enterprises, due to the specifics of their specialization and role in the technical development of production, can be a powerful generator of vertical stability of enterprises in a number of industries, allowing to meet modern requirements to save resources, energy efficiency, environmental sustainability and safety.

Enterprises of mining machinery are good examples of such opportunities. Activity of such enterprises and their products should consider tendencies of development and the increasing requirements (branch, regional, national, international) to the mining production and promote formation of its responsibility in Ukraine. Unfortunately, in Ukraine, as well as in other post-Soviet countries, mining production is in a critical condition and requires a profound transformation. In transition economy conflicts confrontation of mining sector becomes a serious barrier for forming the sustainability of the national industry.

Apparently, from Fig. 3, for the last four years production of a mining industry have a steady trend on increase in sales, while industrial production in Ukraine decreased. Substantially such increase is due to stressful condition of the Ukrainian energy market – the Russian-Ukrainian political conflict threatened direct supply of gas from the Russian Federation. Therefore, Ukraine is forced to look for other ways to solve the problem of energy supply, including building its own production of hydrocarbons and enhance energy independence. The increase in production of coal and lignite, crude oil and natural gas has to promote the solution of problems of energy safety of domestic production.

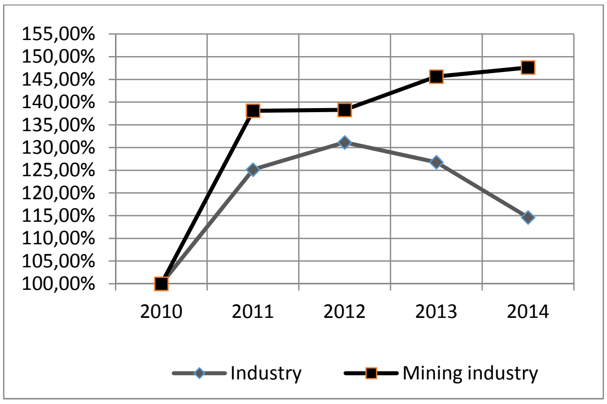

Fig. 3 The basic indicator of growth rate of industrial products sales in general and in mining industry for 2010-2014. (Source: calculated and compiled by the authors according to [10])

It should be emphasized that the crisis state of Ukraine's energy sector generates not only a challenge, but unique opportunities for transition of mining industry to absolutely new model of development which will bring them out from traditionally low-profitable, ecologically dangerous and socially unstable sector of economy.

According to the modern vision of progress of the mining industry, management of mining company has to provide its responsibility of all supply chain. Forming the sustainable supply chains in terms of minimization of energy consumption or a share of the energy component in product cost will provide a sustainable competitive advantage.

It is planned that in 2016 the international standard "Initiative for Responsible Mining Assurance" – IRMA will come into force. It will be recommended for wide use by all mining companies in the world. It is supposed that this standard will become key part of global system of ensuring responsibility of mining sector, will help to form responsible branch chains of industrial productions, calculated on using of the extracted metals and minerals. IRMA forms multilateral agreement on the establishment of general values for all stakeholders, the use of responsible practices by all participants of the production chain. IRMA offers the guidelines for all life cycle of production – from investigation and an operational phase to closing of object and long-term monitoring of environment [15].

Besides, in September, 2009, Ukraine began the process of accession to the international standard EITI (Extractive Industries Transparency Initiative) – the standard of responsibility of the mining branches; and till 17.10.2015 the country has to publish its first EITI report. According to the accepted obligations Ukraine carries out necessary reforms in the organizations of subsurface use and the mining industry [10].

In these conditions, requirements to the enterprises of mining machinery change. Producers of the equipment for mining production have to join in carrying out reforms and promote strengthening of technical and technological progress in a mining complex [1].

The process of increasing the energy efficiency of the mining enterprise covers all elements of its value chain. At each stage of the value chain for energy efficiency management is necessary to determine the key factors affecting energy efficiency, identifying dependencies that determine the impact of energy consumption on the production component.

It is possible to allocate the following stages for increasing the energy efficiency:

1. analysis of the economic and environmental impact of the accepted changes;

2. determination at each stage of the supply chain problem energy-intensive places, which can be eliminated and ranking;

3. identification of the impact of changes on the entire value chain. Each change in any place of a chain influence the energy efficiency of its subsequent units. Therefore, it is necessary to take into account the integral effect of the events on the energy efficiency of individual units. So improving the quality of the output product of one of the links, even with an increase of the specific energy consumption for its production, may lead to a noticeable reduction in energy consumption during its further processing, i.e. integral effect can be positive, and with a slight increase - negative.

As one of the main difficulties for forming the sustainable chains of the mining enterprises is that these companies are the largest consumers of mining equipment, component parts, fuel and energy resources, some of which they receive from suppliers, and another part of them produce by itself. Due to the high-energy intensity of products, reduction of the share of energy component in the cost of production is a very complicated issue. It is obvious that the main sources of energy consumption reduction of mining companies consist in supply of the corresponding equipment and component parts to them. Mining companies establish precise and explicit criteria of quality to equipment and component parts before making the purchase. Thus, formation of sustainable interrelations occurs when products meet these criteria. These criteria are often quantitative: the percentage of energy consumption reduction, the percentage of increase in efficiency or productivity, etc.

Potentially, mining machinery enterprises have good market prospects of sales, because today in the Ukrainian mining companies replacement more than 40% of all park of drilling rigs is required. At the same time the drilling companies seek to receive the hi-tech installations that meet high production characteristics. They require carrying out the control of the installation of drilling rigs on a platform of the producer and carrying out their tests in the presence of the customer.

However more than 75% of the drilling equipment made in Ukraine are already obsolete, and its production doesn't meet the international requirements in terms of energy consumption, reliability, safety, level of equipment instrumentation, computerization, etc. New development has too long terms of implementation and becomes outdated even before their launch [8]. As a result it is difficult to domestic producer to compete with foreign corporations which seek to expand the sales markets and to create the stable production chains covering the Ukrainian consumers.

Analysis of export and import structure of trade flows allows confirming that in 2014 import of drilling rigs exceeds export that defines import focused structure of the market of component parts. Mining machinery companies, which specialize on the production of parts, components for machines, simple mechanisms, can focus on repairing of both domestic and imported equipment, as well as the production of component parts for them. This product is an integral part of the mining machine. They are the most high-loaded and responsible elements of drilling machine. Therefore, if the quality of components is higher, the easier it is to overcome the complexity of mining and geological conditions, allowing mining enterprise to implement the principles of sustainability of production. Decisive factors of efficiency of the components are operational stability, decrease in loss of time for installation, dismantling and also replacement of the worn-out tool and reliability of assemblies and mechanisms. Expenses on the boring tool for the entire period of equipment using exceed by several times cost of it as their life duration is less than the drilling rig, and the change is more frequent.

Since, as noted earlier, mining machinery is obsolete, the number of mining companies that use the upgraded mining machines does not exceed 20%, respectively, the entire value chain does not correspond to European standards of sustainable development, including energy efficiency. Germany and the United States take the leading place in production of high-tech mining equipment. Today, the majority of foreign producers of components for mining machinery focused on customers that have modern equipment and require a correspondingly high-quality tool. The Ukrainian producers of similar components deliver them mainly on companies with "worn" machine park, with the appropriate technical level of production. But also in this case the quality and durability of the components is important, because the reduction in the time of their installation and dismantling impact on energy efficiency of production (the less often it will be carried out, the production process will be more effective).

In the context of the modernization of the equipment (for example, "Ukrgazvydobuvannya" in 2016 plans to upgrade a half of the existing drilling rigs) it is advisable to develop a mechanism of interaction between all actors of supply chain.

It should be noted that the increase of the share of new equipment is not due to a gradual upgrade of capacities, but due to the creation of new industries. The peculiarity of the formation of technological and production chain is the high technical complexity of the task. Therefore, in this case the supplier should be flexible. Foreign producers of equipment and components more often do not create a network of regional offices and technical specialists who used to provide the necessary service to customers. It allows domestic producers of component to take place in supply and distribution chain of mining machinery.

Conclusions. One of approaches in the development of Ukrainian mining machinery can be stimulation of the creation of joint ventures such as technology parks with the participation of foreign companies. At the same time, it is necessary to consider that such approach will require from domestic producers to observe standards of sustainable production, which observe the parent companies. Today the western producers of the mining equipment are guided by the principles and standards of sustainable production, which provide energy efficiency and high technological efficiency, reliability of production and compliance to the best world samples. The use of reliable components will help to reduce operating costs up to 30%.

In the context of globalization and the pursuit of sustainable industrial relations, marketing of machine-building enterprises increasingly takes the form of deliveries in cooperation with the high interest of the parties. In this situation, for the purposes of strategic planning of markets, foreign practice widely uses a horizontal segmentation and situational analysis allowing to define entry points and a format of responsibility in the markets of mining equipment. Using results of situation analysis it is possible to choose the most effective supply channels. It will allow not only to predict volumes of ensuring production with resources (raw materials, etc.), but to standardize and harmonize the requirements in the supply chain, including their energy efficiency. To reduce the involvement extent of raw materials and energy resources in economic circulation it is necessary to reduce unit costs and increase re-use of material resources. Thus, an urgent need of modernization the reproduction model is dictated as political, economic, social, and ecological circumstances.

In recent years in Ukraine, there are high expectations on the formation of a global sustainable supply chains, which, according to domestic and foreign experts, are capable to solve fundamental socio-economic problems, including reproductive rebuild of the structure. However, to overcome gaps between desired result and existing will require a long time. For transition to their formation should be created corresponding starting conditions, including implementation of standards (IRMA, EITI), modernization of reproduction structure, a competent tax policy and other organizational and economic measures. Otherwise, the Ukrainian industrial enterprises cannot be participants in the global value chain.

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ALGORITHM OF DETERMINATION OF POWER AND ENERGY INDEXES OF SCREW INTENSIFIER ON THE BULLDOZER WORKING EQUIPMENT AT TRENCH REFILLINGS

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Summary. ***Problem statement.*** A bulldozer work at trench refilings is conducted by cyclic, machine shuttle motions that increases a right-of-way; increasing of time charges, fuel and labour by the side of the continuous refilling method. Besides the indicated defects gets worse also the quality of the trench refilling: the uneven soil output into a trench with large portions results the damages of pipes isolation and emptinesses formation, in consequence – settling and washing of soil. A bulldozer with the screw intensifier (SI), is deprived lacks of an odinary bulldozer – moving along a trench, it moves the loose soil that does not fall on a pipeline, but rolles on it. Thus the circuitous speed of a cutting edge of SI exceeds the speed of the base machine moving that provides the strong soil treatment (before dispersion) before output into a trench. ***Purpose.*** The algorithm development of the rotational moment determination on the SI driveshaft, the consumable energy, the energy intensity and the working process productivity of the reverse trench refillings depending on physical and mechanical properties of soil, geometrical parameters of SI and bulldozer optimal speed. ***Conclusion.*** The developed algorithm allows to define that at the fixed value of the rotational speed ω_0 the rotational moment $M_{кр}$ and indicated efficiency $N_{пр}$ of SI at the optimum speed increasing $\vartheta_м$ of the base machine change on a linear law; the optimum speed change of the base machine $\vartheta_м$ practically does not influence on the energy intensity E at the considered change of the rotational speed ω_0.

Keywords: *screw intensifier, rotational moment, rotational speed, energy, energy intensity, trench refillings*

АЛГОРИТМ ВИЗНАЧЕННЯ СИЛОВИХ ТА ЕНЕРГЕТИЧНИХ ПОКАЗНИКІВ ШНЕКОВОГО ІНТЕНСИФІКАТОРА НА РОБОЧОМУ ОБЛАДНАННІ БУЛЬДОЗЕРА ПРИ ЗАСИПЦІ ТРАНШЕЙ

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Анотація. ***Постановка проблеми.*** Робота бульдозера при засипці траншей, проводиться циклічними, човниковими рухами машини, що збільшує смугу відчуження; збільшуються витрати часу, палива і праці у порівнянні з безперервним способом засипки. Крім вказаних недоліків також погіршується якість засипки траншеї: нерівномірна подача ґрунту в траншею великими порціями призводить до пошкоджень ізоляції труб та утворення пустот, в наслідок чого – осідання та вимивання ґрунту. Бульдозер з шнековим інтенсифікатором (ШІ), позбавлений недоліків звичайного бульдозера – рухаючись вздовж траншеї, він переміщує в неї розпушений ґрунт, що не падає на трубопровід, а скочується по ньому. При цьому окружна швидкість ріжучої кромки ШІ перевищує швидкість переміщення базової машини, що забезпечує сильне подрібнення ґрунту (до розпилення) перед подачею в траншею. ***Мета статті.*** Розробка алгоритму визначення крутного моменту на валу ШІ, споживаної потужності, енергоємності та продуктивності робочого процесу зворотної засипки траншей в залежності від фізико–механічних властивостей ґрунту, геометричних параметрів ШІ та швидкості руху бульдозера. ***Висновки.*** Розроблений алгоритм дозволив визначити, що при фіксованому значенні кутової швидкості ω_0 крутний момент $M_{кр}$ та потужність приводу $N_{пр}$ ШІ при зростанні швидкості $\vartheta_м$ руху базової машини змінюється по лінійному закону; зміна швидкості руху базової машини $\vartheta_м$ практично не впливає на енергоємність E при розглянутій зміні кутової швидкості ω_0.

Ключові слова: *шнековий інтенсифікатор, крутний момент, кутова швидкість, потужність, енергоємність, засипка траншей*

АЛГОРИТМ ОПРЕДЕЛЕНИЯ СИЛОВЫХ И ЭНЕРГЕТИЧЕСКИХ ПОКАЗАТЕЛЕЙ ШНЕКОВОГО ИНТЕНСИФИКАТОРА НА РАБОЧЕМ ОБОРУДОВАНИИ БУЛЬДОЗЕРА ПРИ ЗАСЫПКЕ ТРАНШЕЙ

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Аннотация. ***Постановка проблемы.*** Работа бульдозера при засыпке траншей, проводится циклическими, челночными движениями машины, которая увеличивает полосу отчуждения; увеличиваются расходы времени, топлива и труда в сравнении с непрерывным способом засыпки. Кроме указанных недостатков также ухудшается качество засыпки траншеи: неравномерная подача грунта в траншею большими порциями приводит к повреждениям изоляции труб и образования пустот, вследствие чего – оседание и вымывание грунта. Бульдозер с шнековым интенсификатором (ШИ), лишен недостатков обычного бульдозера – двигаясь вдоль траншеи, он перемещает у нее разрыхленный грунт, который не падает на трубопровод, а скатывается по нему. При этом окружная скорость режущей кромки ШИ превышает скорость перемещения базовой машины, которая обеспечивает сильное измельчение грунта (до распыления) перед подачей в траншею. ***Цель статьи.*** Разработка алгоритма определения крутящего момента на валу ШИ, потребляемой мощности, энергоемкости и производительности рабочего процесса обратной засыпки траншей в зависимости от физико–механических свойств грунта, геометрических параметров ШИ и скорости движения бульдозера. ***Выводы.*** Разработанный алгоритм позволил определить, что при фиксированном значении угловой скорости ω_0 крутящий момент $M_{кр}$ и мощность повода $N_{пр}$ ШИ при росте скорости $\vartheta_м$ движения базовой машины изменяется по линейному закону; изменение скорости движения базовой машины $\vartheta_м$ практически не влияет на энергоемкость E при рассмотренном изменении угловой скорости ω_0.

Ключевые слова: *шнековый интенсификатор, крутящий момент, угловая скорость, мощность, энергоемкость, засыпка траншей*

The problem topicality. The geographical position of Ukraine contributes to the transportation of oil and gas through its territory to Europe, for what are used the pipelines. The features of trench refilling works (heavy workloads, a length of the pipeline, a great distance from construction objects to the mechanization base complex, the frequent machinery relocation from object to object, a wide variety of technology operations) define specific requirements for machines used in these works.

Problem statement. A bulldozer work at trench refilings is conducted by cyclic, a machine shuttle motion that increases a right-of-way; increasing of time charges, fuel and labour by the side of the continuous refilling method. Besides the indicated defects gets worse also the quality of the trench refilling: the uneven soil output into a trench with large portions results the damages of pipes isolation and emptinesses formation, in consequence – settling and washing of soil. A bulldozer with the screw intensifier (SI), is deprived lacks of an odinary bulldozer – moving along a trench, it moves the loose soil that does not fall on a pipeline, but rolles on it. Thus the circuitous speed of a cutting edge of SI exceeds the speed of the base machine moving that provides the strong soil treatment (before dispersion) before output into a trench.

Analysis of publications. In the technical literature, informating the definition of power and energy indexes of screw intensifier on the bulldozer working equipment at trench refillings is in a limited number. The most complete information is reflected in the works of Sevast'yanov K.M. [1], Zenkov R.L. [2], Grigoriev A.M. [3], Balovnev V.I, Shkryl V.M [4], Spivakovsky A.O. [5, 6], Ivanchenko F.K. [7], Sukhorukov V.S. [8].

The purpose of the article. The algorithm development of the rotational moment determination on the SI drivashaft, the consumable energy, the energy intensity and the working process productivity of the reverse trench refillings depending on physical and mechanical properties of soil, geometrical parameters of SI and bulldozer optimal speed.

The material presentation is based on the method of determining of the rotational speed [9], the rotational moment on the SI drivashaft, the consumable energy, the energy intensity and the working process productivity of the reverse trench refillings [10] is developed an algorithm for their determination, which is presented in the form of a block diagrams (Fig. 1).

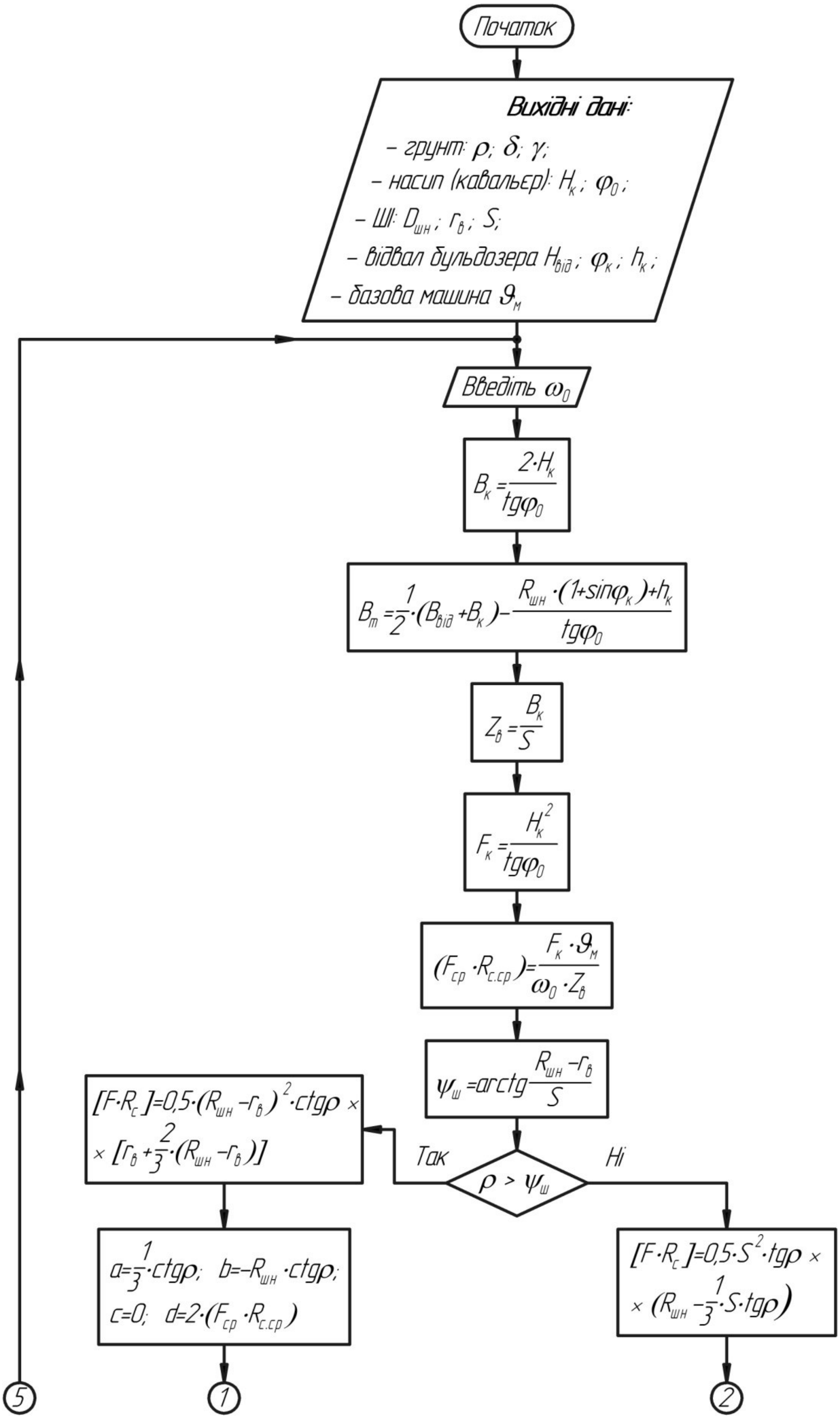

Fig. 1. The block diagram of determining of the rotational moment on the SI driveshaft, the consumable energy, the energy intensity and the working process productivity of the reverse trench refillings (continued on the page).

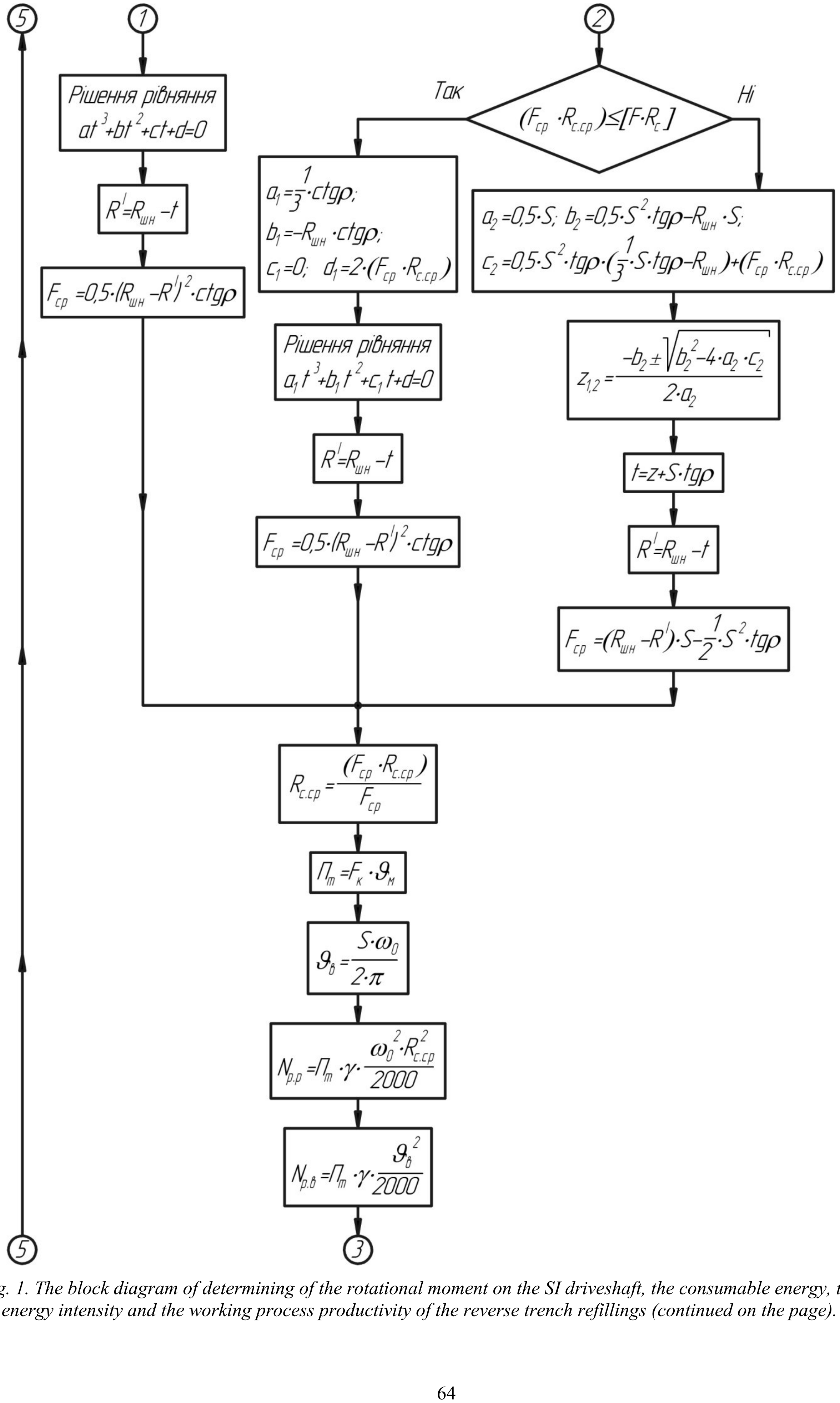

Fig. 1. The block diagram of determining of the rotational moment on the SI driveshaft, the consumable energy, the energy intensity and the working process productivity of the reverse trench refillings (continued on the page).

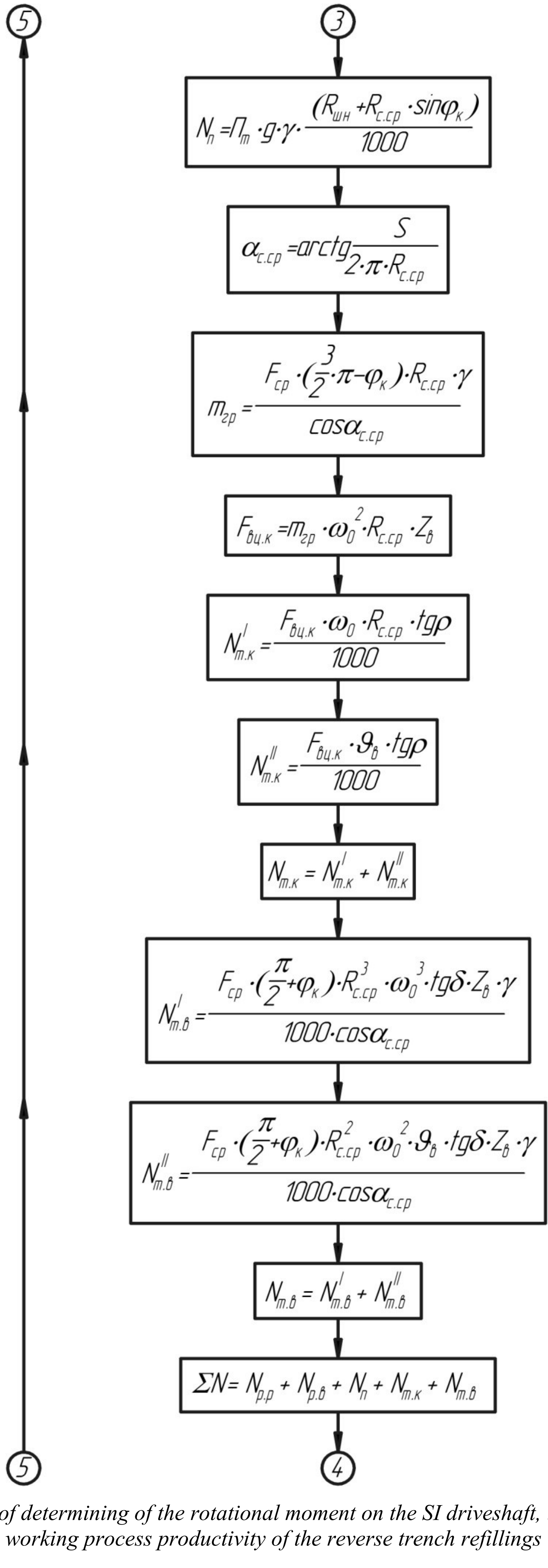

Fig. 1. The block diagram of determining of the rotational moment on the SI driveshaft, the consumable energy, the energy intensity and the working process productivity of the reverse trench refillings (continued on the page).

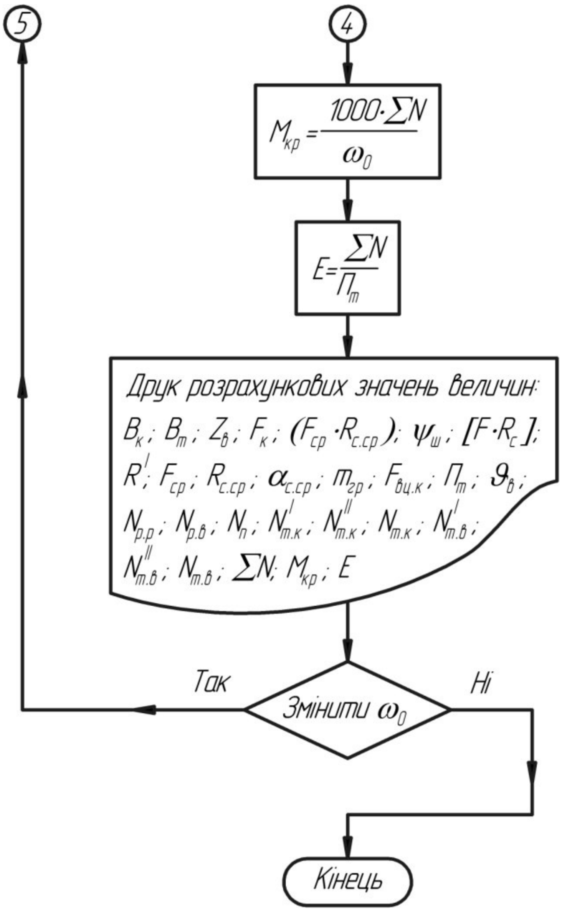

Fig. 1. The block diagram of determining of the rotational moment on the SI driveshaft, the consumable energy, the energy intensity and the working process productivity of the reverse trench refillings (the end).

On the basis of the algorithm is developed computer program in Qbasic language and were received dependencies of the rotational moment $M_{кр}$ on the SI driveshaft on the rotational speed ω_0 (Fig. 2), the indicated efficiency $N_{пр}$ of SI drive on the rotational speed ω_0 (Fig. 3), the energy intensity E of the SI working process on the rotational speed ω_0 (Fig. 4).

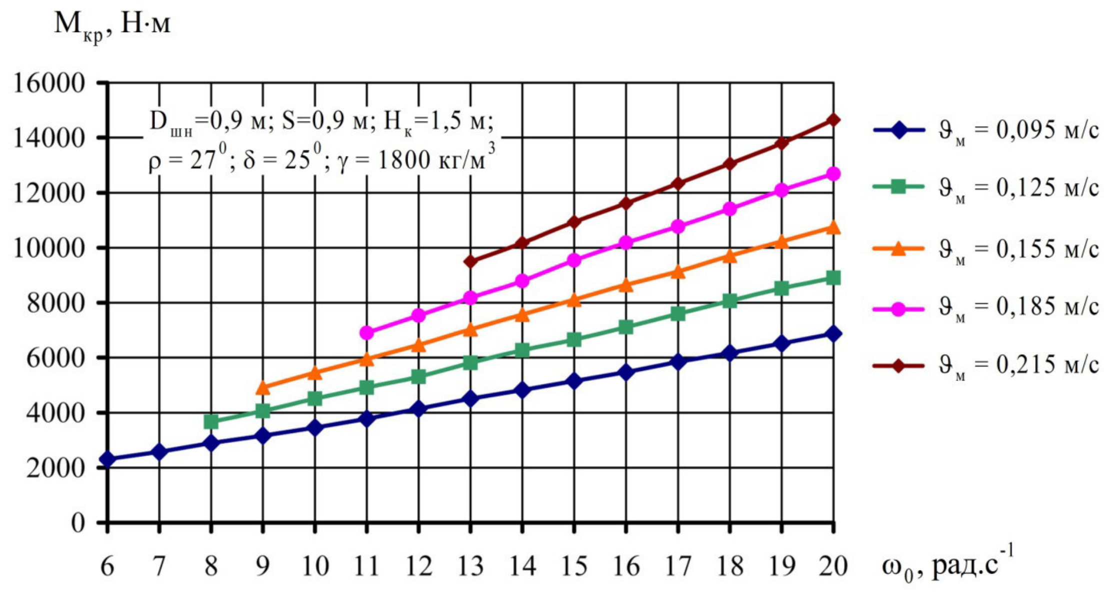

Fig. 2. The dependence of the rotational moment $M_{кр}$ on the SI driveshaft from the rotational speed ω_0

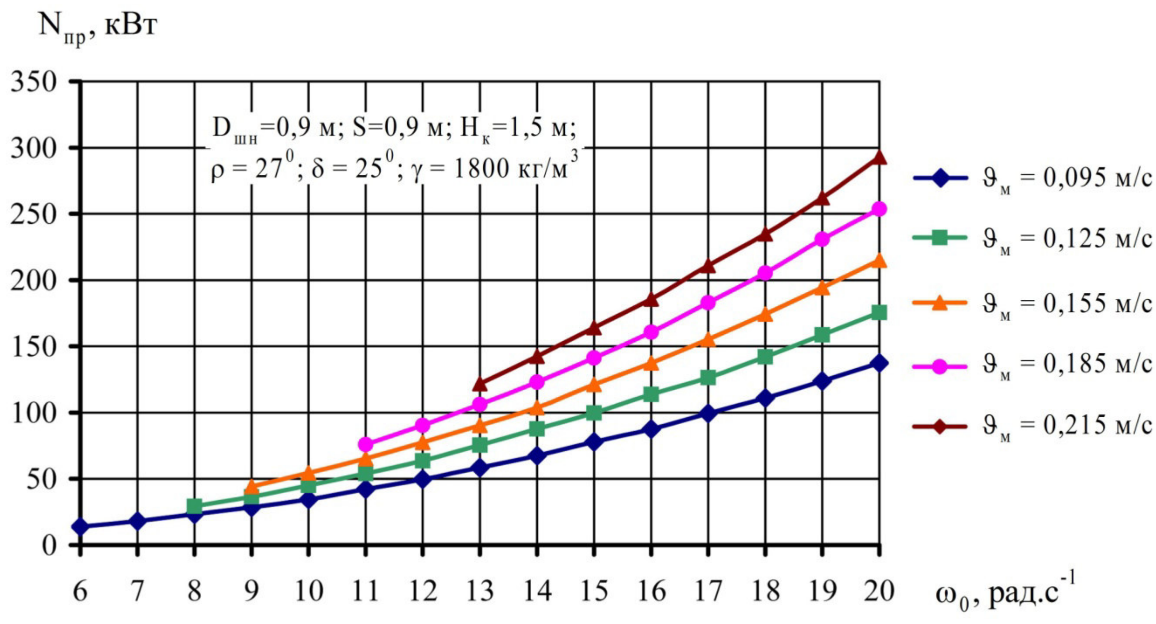

Fig. 3. The dependence of the SI indicated efficiency N_{np} on the rotational speed ω_0

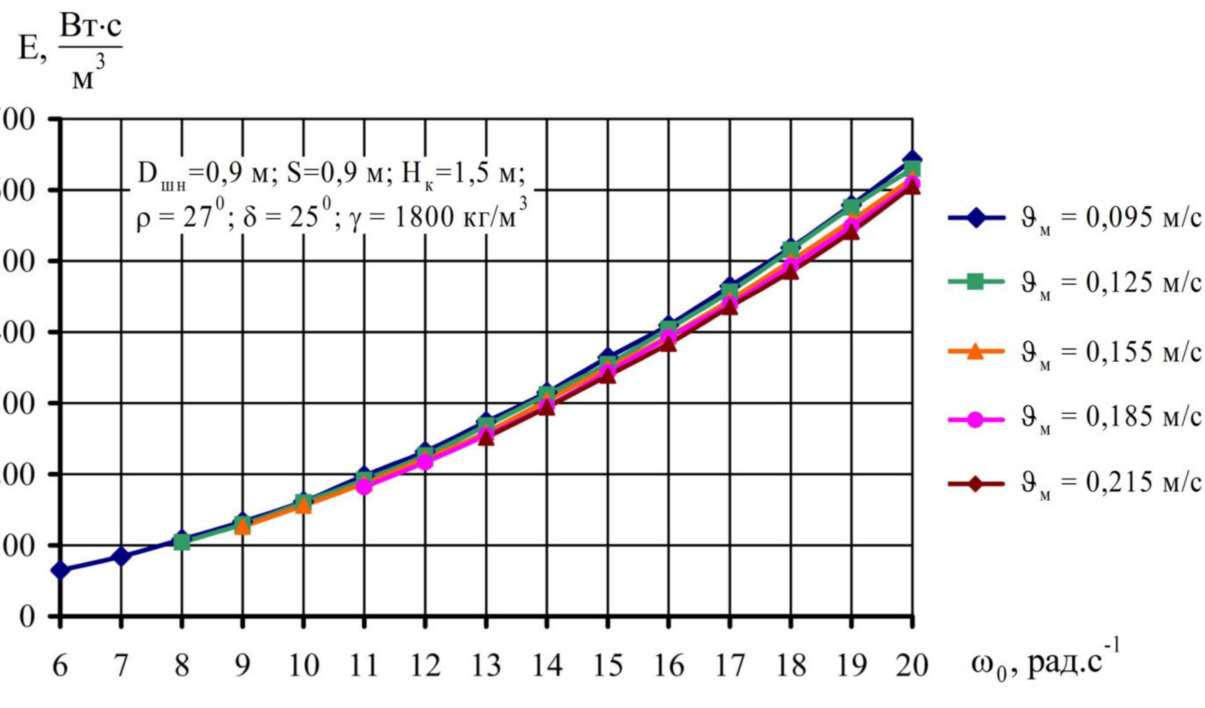

Рис. 4. The dependence of energy intensity E on the SI working process on the rotational speed ω_0

Conclusion. The developed algorithm allows to define that at the fixed value of the rotational speed ω_0 the rotational moment $M_{кр}$ and indicated efficiency N_{np} of SI at the optimum speed increasing $\vartheta_м$ of the base machine change on a linear law; the optimum speed change of the base machine $\vartheta_м$ practically does not influence on the energy intensity E at the considered change of the rotational speed ω_0.

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ARCHITECTURE

CONSTRUCTION TECHNOLOGY OF UKRAINIAN NATIONAL HOUSING (PRYDNIPROVSK REGION IS AS AN EXAMPLE)

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Abstract. ***Problem statement***. Nowadays it is difficult to see a typical, old peasant house, or different types of national confident buildings. It will take a little time and some monuments of national architecture will be difficult to find. Meanwhile, rural housing was the most massive object of traditional construction. It embodies the best achievements and experience of national architects; it is of great value for the history of Ukrainian culture, history of Ukrainian art, architecture and ethnography, sustainable construction. National art of peasant house construction of Prydniprovsk region of Ukraine, is multidimensional space and time in an array of hand-made Ukrainian art is a national architecture, its decoration, clothing filling of the interior of the house and estate, as well as plastic and spatial formation, determining loci ritual of family life of Ukrainian village since the ancient times to the present. ***Analysis of publications.*** The first publications about the Ukrainian national housing, was made in the late nineteenth - early twentieth century. These were the works of ethnographers and historians M.Sumtsova [17] and D. Bagaliya [1-4], G.Lukomskogo a little [12]. B. Kharuzin's work is interesting in the context of our study .[19]. The interesting materials were found by us in the series of publications that have appeared in the end of XIX and beginning of XX centures and are associated with vital trend to build fire-resistant housing, and ukrainian peasant house was such kind of housing. "Nowadays such kind of peasant houses and storages are put because they cheap, strong and good and the most important is to be resistant to fire. Houses with brick and stone trying to be built by reach people, and houses with the clay and saman are built by poor people,they are elegant, strong, cheap long-existed and non-flammable " that is stated in the foreword to a small edition by I. Ulashivsky "Saman building" [18]. A small booklet" Valkovi Building (with 20 figures into text). F.S. Dudko also describes in detail tehnology of ukrainian peasant houses construction as the safetiest and the cleanest houses of present. In the 70th of the XX century, works began to appear devoted to the study of nation architecture in Ukraine. The features of construction of one or another region, the types of peasant houses, their interior; construction of farm buildings, equipping of the yard were considered in this work. Among them A. Danyluk "Closed yards in Polesie" [6-7], A. Danyluk and M. Shpak "Traditional and new in boikivskyi housing construction" [8], M. Strunka "Ukrainian national housing of Mykolaivshchina" [16], M. Manurevich "Gagauz nation housing…"[14], Z. Petrova "Rural houses in the Carpathians" [15] and others [11; 13]. The purpose and the main directions of our research is to study the complex technology of the walls construction of the Ukrainians'national housing of Middle and Lower Naddniprianshchyny of Ukraine (of Prydniprovsk region) of the end of XIX and middle of the XX century, as the Dnipropetrovsk region belongs to this historical and geographical, industrial and economic region.

Keywords: *saman, rolls, pise-walled house, clay-moulded house*

ТЕХНОЛОГІЇ ВИВЕДЕННЯ СТІН УКРАЇНСЬКОГО НАРОДНОГО ЖИТЛА (НА ПРИКЛАДІ ПРИДНІПРОВСЬКОГО РЕГІОНУ)

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Анотація. ***Постановка проблеми***. Уже сьогодні по всій території України не часто можна зустріти типову, стару хату, той чи інший тип народних господарчих споруд. Мине небагато часу і окремі пам'ятки народної архітектури важко буде знайти. Між тим, сільське житло було найбільш масовим об'єктом народного будівництва. У ньому втілені кращі надбання і досвід народних зодчих, воно становить велику цінність для історії культури українського народу, історії українського мистецтва, архітектури та етнографії, екобудівництва. Народне мистецтво хатобудування Наддніпрянської України − багатовимірний у просторі й часі масив українського рукотворного мистецтва − являє собою народну архітектуру, її оздоби, речове наповнення інтер'єру дому та садиби, а також пластично-просторові утворення, що визначають ритуальні локуси родинно життя українського села від найдавніших часів до сьогодення. ***Аналіз публікацій***. Перші фундаментальні спроби дослідити народну архітектуру, зокрема українське народне житло, були зроблені в кінці XIX – на початку XX століття. Це були праці етнографів та істориків М.Сумцова [17] та Д. Багалія [14−4], у певній мірі –Г.Лукомського [12]. У розрізі нашого дослідження цікавою є робота В. Харузина [19]. Цікаві матеріали знаходимо в серії публікацій, які з'явилися в кінці XIX на поч.. XX століття і пов'язані з життєво необхідною тенденцією будувати вогнестійке житло, яким власне була українська хата. «Скрізь тепер намагаються ставити такі хати та комори, щоб і дешеві були, й міцні, і ловкі, а саме головне – щоб не піддавалися так «червоному півневі». Заохочуються ставити – хто заможнішій – будівлі з цегли та каменю, а хто убогіший, той до глиняних, саманних береться, – вони чепурні, міцні, дешеві, довговічні й негорючі», – зазначається в передмові до невеликого видання І. Улашівського «Саманні будівлі» [18]. Невеличка брошура «Вальковия постройки (съ 20 рисунками въ текстъ)» Ф. С. Дудко також детально описує технологію будування української хати як найбезпечнішого та найчистішого (*в значенні екологічного Г. Є.)* житла цього часу [10].

У 70-ті роки XX ст. почали з'являтися праці, присвячені вивченню народного будівництва в Україні. Це роботи, в яких розглядалися особливості забудови того чи іншого регіону, типи хат, їх інтер'єр; будівництво господарчих споруд, облаштування двору. Серед них А. Данилюк «Замкнені двори на Поліссі» [6−7], А. Данилюк та М. Шпак «Традиційне і нове в бойківському житловому будівництві» [8], М. Струнка «Українське народне житло Миколаївщини» [16], М. Мануревич «Народное жилище гагаузов…» [14], З. Петрова Сельские жилые дома в Карпатах [15] та інші [11; 13]. Мета й основні напрямки нашого дослідження полягає у комплексному вивченні технології виведення стін народного житла українців Середньої та Нижньої Наддніпрянщини України (Придніпровського регіону) кінця XIX - середини XX ст., оскільки Дніпропетровщина належить саме до цього історико-географічного та промислово-економічного регіону.

Ключові слова: *саман, вальки, глинобитна хата, глинолита хата*

ТЕХНОЛОГИИ ВЫВЕДЕНИЯ СТЕН УКРАИНСКОГО НАРОДНОГО ЖИЛЬЯ (НА ПРИМЕРЕ ПРИДНЕПРОВСКОГО РЕГИОНА)

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Аннотация. ***Постановка проблемы***. Уже сегодня по всей территории Украины не часто можно встретить типичную, старую хату, тот или другой тип народных хозяйственных сооружений. Минует немного время и отдельные достопримечательности народной архитектуры трудно будет найти. Между тем, сельское жилье было наиболее массовым объектом народного строительства. В нем воплощены лучшие приобретения и опыт народных зодчих, оно представляет большую ценность для истории культуры украинского народа, истории украинского искусства, архитектуры и этнографии, экостроительства. Народное архитектурное искусство Украины Надднепрянщины многомерный в пространстве и времени массив украинского рукотворного искусства; являет собой народную архитектуру, ее убранства, вещественное наполнение интерьера дома и усадьбы, а также пластично-пространственные образования, которые определяют ритуальные локусы семейной жизни украинского села от самых давних времен до нынешнего времени. ***Анализ публикаций***. Первые публикации об украинском народном жилье, были сделаны в конце XIX - в начале XX века. Это были труды этнографов и историков М. Сумцова [17] и Д. Багалія [1−4], в определенной мере - Г. Лукомського [12]. В разрезе нашего исследования интересной является робота В. Харузина [19]. Интересные материалы находим в серии публикаций, которые появились в конце XIX начале. XX века и связаны с жизненно необходимой тенденцией строить огнестойкое жилье, которым собственно была украинская хата. "Везде теперь пытаются ставить такие хаты и кладовые, чтобы и дешевые были, и крепкие, и хорошие, а главное - чтобы не поддавались "красному петуху". Поощряются ставить - кто более состоятельный - здания из кирпича и камня, а кто более убог, тот к глиняным, самановым берется, - они нарядны, крепки, дешевы, долговечны и негорючи", - отмечается в предисловии к небольшому изданию І. Улашивского "Самановые здания" [18]. Небольшая брошюра "Вальковия постройки (съ 20 рисунками въ текстъ)" Ф. С. Дудко также детально описывает технологію. В 70-ые годы XX ст. начали появляться труды, посвященные изучению народного строительства в Украине. Это работы, в которых рассматривались особенности застройки того или другого региона, типы хат, их интерьер; строительство хозяйственных сооружений, обустройства двора. Среди них А. Данилюк "Замкнутые дворы на Полесье" [6−7], А. Данилюк и М. Шпак "Традиционное и новое в бойковском жилищном строительстве" [8], М. Струнка "Украинское народное жилье Николаевщины" [16], М. Мануревич "Народное жилище гагаузов". [14], З. Петрова «Сельские жилые дома в Карпатах» [15] и другие [11; 13]. Цель и основные направления нашего исследования заключается в комплексном изучении технологии возведения стен народного жилья украинцев Средней и Нижней Надднепрянщины Украины (Приднепровского региона) конца XIX - середины XX ст., поскольку Днепропетровщина принадлежит именно к этому историко-географическому и промышленно-экономическому региону.

Ключевые слова: *саман, вальки, глинобитная хата, глинолитая хата*

Problem statement. Nowadays it is difficult to see a typical, old peasant house, or different types of national confident buildings. It will take a little time and some monuments of national architecture will be difficult to find. Meanwhile, rural housing was the most massive object of traditional construction. It embodies the best achievements and experience of national architects; it is of great value for the history of Ukrainian culture, history of Ukrainian art, architecture and ethnography, sustainable construction. National art of peasant house construction of Prydniprovsk region of Ukraine, is multidimensional space and time in an array of hand-made Ukrainian art is a national architecture, its decoration, clothing filling of the interior of the house and estate, as well as plastic and spatial formation, determining loci ritual of family life of Ukrainian village since the ancient times to the present.

Analysis of publications.

Presenting main material. In the Prydniprovsk region a tradition of different housing technologies became traditional during the centuries, but among the large variety, distinguished which required for its implementation the smallest quantity of timber. This was crucial to the treeless or little wooded rural Ukraine territories and Dnipropetrovsk region territory belongs to them. territory of the Dnipropetrovsk region. On the territory of the region the construction of housing was given with the following technologies:

Saman peasant house. Saman production technology. **Saman** is a small block of clay and straw mass. As a construction material it is widely used in national housing of southern areas and western part of the forest-steppe zone of Ukraine. The main advantage of saman wall over other construction with clay is that they quickly dries out and give a relatively small subsidence. Ease of this design is that preform of saman can be done gradually, pre-dry it. A major drawback of clay walls, including with saman, is that under the influence of atmospheric moisture they become humid, thus they get very significant deformation. As noted by some studies [114] to avoid this, in the southern walls of saman after their subsidence, it is veneered often with brick, sometimes it is only the lower part of the wall (to the level of windows), and sometimes it is the whole wall. Typically, houses with sush walls have been warmer and stronger, but also more expensive because they were built mostly by wealthy farmers.

For production of saman with clay the greasy, sticky, plastic clay are taken (plasticity and determine the fat content, see Part 3) because the clay dries crack, it added straw. Specifically breeze straw (threshing or chopped straw) of different lengths from 10 sm to 20-25 sm. This straw strengthens (binding) clay solution, especially for broken efforts. If the straw uses from 2 sm to 5 sm (chaff) so, the solution loses its binding properties.

Straw may be wheat, barley, rye, and even flax or hemp. If in the economy there was not thrashing straw, it crushed on special equipment, it is straw-mill. (Fig. 4.5).

Fig. 4.5.Straw-mill (Drawn by Oksana Yakovenko, master of architecture).

Adding straw to clay reduces the thermal conductivity of clay mud wall that for housing is paramount. However, a large amount of straw lead to an increase subsidence of wall, makes the walls loose, accessible to rodents that are too dangerous for rural areas. Value of clay and straw clearly no one defines as the ratio depends on the quality of clay and straw, and it is in every village and even in yard is own. But generalizing heard and seen, in our opinion, the straw can be up to 25% of the volume of clay, or 16 -20 kg per 1m3 of clay.

There are several successive operations in the production of saman:

1) preparing of clay solution;
2) mixing of clay solution;
3) production (formation) of saman;
4) drying of saman.

The first stage begins in the spring. Preformed clay in the autumn (see part 3) of early spring start to soak. This is done either in current or in holes (Fig. 4. 6). On threshing-floor the clay is put by layer of 25 - 35 sm of thick with rollers on the edges to resist water. Then pour water on the clay at the rate of 0.75 bucket of water in a bucket of clay by breaking down large lumps of clay. At the threshing-floor mostly clay soaked with a small amount of work: construction of barn, cellar, chicken coop and etc.. With a significant amount of work, such as building houses, barns, stables, etc., soaking the clay did in the pits. Soaking pit for clay was made by depth of 60 to 80 sm with a radius of 3 m to 4 m (it depended on the amount of work). Pit was dug round, because this is the best way to mix clay in pit by all sides, in addition to the round pit there is more space for backfilling clay. It is easier to take ready solution from round pit. The edges or walls of such pits were entrenched with boards, to avoid slipping of these walls. Clay is put with layers into a pit: a layer of clay

By thickness of 20 - 25 sm, layer of straw, filling with water. Having filled the pit, water is poured to cover the clay, the top covered with a thick layer of straw and left for 3-6 days. The pit with of soaked clay and straw called Gras. It is important to remember that soaked the clay never stirred during soaking. Because of it clay loses its quality, because clay lumps during mixing slip and then are out of further slaking.

The second stage is mixing clay. Mixing clay is one of the most important operations of clay preparation solution, thus as clay is mixed, the quality of the solution, its homogeneity depends on it, and the strength and purity of saman.

When the amount of clay solution is small, it is kneaded with your hands or feet. This work is done by women. The skills of women of dough kneading are useful in the kneading of clay. Only women's hands or feet are able to qualitatively knead clay. With a large amount of construction work a clay solution then is mixed by using animals, usually horses. Wrought iron horse well stirred clay. In the old days used traction force oxen. When is kneaded clay by animals and also they are under control by, their riding. This work was performed with great pleasure by teenagers who rides well even without bareback.

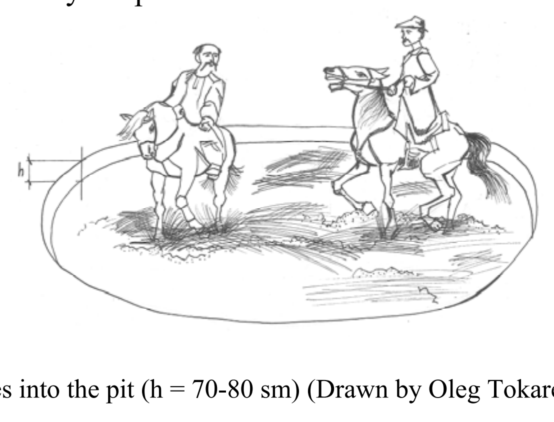

Fig. 4.6. Kneading of clay by horses into the pit (h = 70-80 sm) (Drawn by Oleg Tokarev, architect student).

Regardless of the method of kneading clay, clay is kneaded until it becomes completely homogeneous and soft dough. Kneading technology is that the first clay is kneaded then straw is added to it. Readiness of solution is determined with help of visual inspection: ready mixture does not stick to hands and feet during stirring. Or quality kneaded of clay can be set as follows: clod of clay is taken and cut with a knife or spade, and if a cut across the surface has the same color, moisture, viscosity and the same allocation of straw, so clay and straw solution is ready. Ready to use solution covered with matting, and straw so clay do not dry up.

The third stage of production of saman.

Three ways of making saman has been forming for the long centuries among Ukrainian, that is hand, heel and machining methods. Workplace to form saman is near the pit. Formation conducted at the level of planned and sprinkled with straw place (estrus) When hand-made saman "moulder" (the same woman who kneads clay) separates from clay and straw mass of a piece of clay straw mixture, plunges it into the water, and with the force throws soaked in water form, which is placed on a thin layer of straw. The form for making of saman made as a box without a bottom from 19 mm planks on one or two samans (Fig. 4.7.).

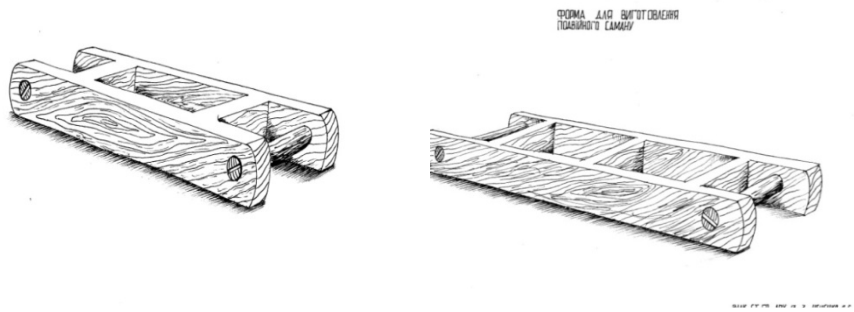

Fig. 4.7. Forms for production of saman (for one and two samans)

Then clay and straw solution is rammed down with fists in the form so as to fill completely the whole form. Then it is smoothed on surface by both hands (Fig. 4.8.), clearing the surplus of top of wooden rolling pin or by hand. Then carefully the form is removed with the cuttings and on the chute is put the formed saman. Next form rearrange to another place, and the process begins all over again.

Photo 4.8. Formation of saman blocks.

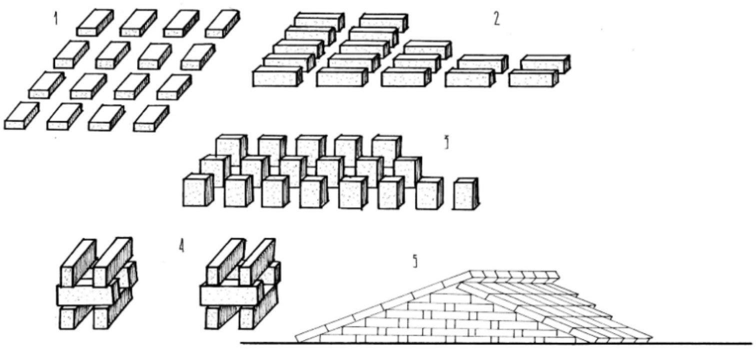

Fig.4.9. The procedure for drying of saman: 1) by flat; 2) on the edge; 3) on a threshing - floor; 4) in the cell; 5) in the stack (Drawn by M. Ershov, student).

Production of saman of heel method, clay and straw solution is trampled down with feet, and placing the dampened shape on a thin layer of straw. As in the hand and heel methods, distances between the ready saman should be 10 - 20 cm in the transverse direction and 4.10 cm in longitudinal direction. One "moulder" with help of assistant can be formed during daylight hours from 400 to 600 pieces of saman.

Some farmers said that the mass post-war reconstruction of villages (50-60 years of the twentieth century.) there were machines for the formation of saman. Production of saman with them is called machine-way. Description of the drawings the machine described in the literature [114, p.17; 57 p.14]. The advantage of machine production is that during the day "moulder" with an assistant can be molded from 900 to 1000 pieces of saman. Making saman in any manner described above, it is necessary to remember that the form must be filled with a mixture in a single step, as another part of mixture and for further drying easily fallen off and it will reduce the quality of saman.

Fig. 10.4. Drying of saman (by stacks and by expanded).

The fourth stage is drying saman. In hot and windy weather adobe covered with straw matting, etc., avoiding rapid drying or over drying. After 2-3 days saman dries and then it is turned over on a long edge, and then after a while is put on the short edge (Figure 4. 9); When saman well dries and hardens, it is made up in the box, and then in stacks, leaving gaps between saman. Stack is covered from getting wet in the rain, or it is put under cover. As such, saman finally dried 10-15 days (Fig. 4.10). In hot weather saman is drying faster and ready within 7 - 10 days. In some villages there was a tradition of smoking saman. For this stack with saman lay round with straw and scorch. There was a belief that the peasant house built with smoking saman is"cleaner" (more ecological, it lacks the unhealthy energy, G.Ye.).The owner ensures that the dried saman had right surfaces and edges, and in the hacking is the same color. The absolutely dried saman, can be stored for several years, becoming stronger. Saman of the best quality meet the following requirements:

While broking down on the ground from a height of 1.5 - 1.7 m (human growth) saman should not break;

While hitting with an ax handleon saman surface should remain bright, shallow dent;

Qualityof saman canbe hacked and hewed with an ax, while saman is not cracking

Saman which was put in water should not lose saman rectangular form for 2 hours and should not disintegrate earlier than 8 hours;

Saman should not fall apart into pieces when the nail is hit in it with length of 150-180 mm.

Saman should be light in weight.

Thickness of saman wall determined by the purpose and size of the buildings. People practice, based on climatic conditions of Prydniprovsk region of Ukraine confirms the need for residential buildings (houses)of 50 cm is for external walls and 35 sm is for interior walls and for little load wall. According to this the most common saman size is 33 × 16 × 12 sm, but there are other dimensions. The best size is where length is ¼ larger than the width and thickness equal to half of the width. This size is advantageous when walling up. Saman peasant house is walled up in the basement (see. Section 4.1.).

Construction technology of clay walls of peasant house. For the construction of peasant houses with clay walls need wood material for scaffolding. For medium-sized peasant houses of 10 × 6 meters with one capitalpartition need: rod of 22 pairs, of each length of about 6 meters and a thickness of 13 - 15 sm; props for foundations to 18 pairs, the length is about 4 m; 6 m boards are 14 pieces. The size of the boards should be approximately as follows: 4-6 sm thick and 22 sm wide. Boards preferably should be cleaned with gamble (plane). This purification greatly affects on the improvement work on construction of the walls, and then the board can be used for its intended purpose.

Picking up the wood for work, the owner starts to prepare a solution. In the production of a clay solution for pouring the walls, in front of the building, two round pits for a clay solution are dug out. Clay is filled with layers had been freezing in fall, then is poured with water in the spring. The solution was stirred in the same manner as for saman (i.e., feet or horses) only without straw. The clay is kneaded sparsely, "as the thick cream." According to this the clay solution is good: rye or wheat straw is taken with length of the elbow or two hands, put it down to the solution, and if the straw immediately leans over and lay down on the surface of the solution, so the solution is liquid and heterogeneous, if it stands without swaying, so the solution is thick and when the straw slopes on the side, but does not fall, it is a good solution"; "A good solution when the bucket is colored with it and does not flow from the bucket walls or clumps stick to the walls." Quality of solution for the strength of the building is of great importance. For example, "when the solution is liquid, so during trampling of the straw in troughs, the solution will flow down and then the straw is not enough saturated and conversely, when the clay solution is thick, in the troughs the layer of clay and straw will lie, and in both cases the strength of the walls will be small and will be a good shelter for mice". To make sure, whether the solution is made in right way you should, look at the wall, when the shape is lifted and you will not see the individual layers of straw or clay, then touch with hand and, when the whole mass will be the same, it shows that the solution is made correctly.

After the solution is prepared the walls will begin to be poured. Pour the wall as follows: "at first soft straw is put, an even layer of about 8-10 sm of thickness over the entire wall in ready forms then clay solution is filled with and immediately is trampled down with feet until the top of straw does not act bubbles clay solution. In, to be equal and sharp, in the corners of the sides it is necessary not to trample with feet, and a stake or a special tamper (Figure 4.11). Having trampled a good one layer of straw, the second layer is put, fill it and trample over again until the entire form is filled to edge of shields. To give greater strength to walls and solidity, better each time over filling out forms just across the wall make it with a wooden club (rammer Figure 4.11), and after that lift up the molding board".

Molding boards must be lifted carefully and the job is done by entrusted experienced master, who generally directs the entire work, in addition, several workers who tramping walls during lifting molding boards should remain on the surface of the wall, thereby not to give the opportunity to rise the top of layer of straw, that may be particularly at the edges and corners of the walls.

Forming boards lifted with lever, on a stand with notches. Molding boards is lifted as follows: enclose one end of the lever (stick or board) under molding board substitute board with cutouts, and click on the other end down. Molding board lift evenly around the walls to the same height, so they covered with lower edges one third of the width of the stuffed layer walls, or in other words the board is lifted up in the high of two-thirds of the entire width of molding boards, having lifted the molding boards, every time soil is checked with weight, so the wall should be equal".

First they poured the first layer of height of 30 - 40 sm, sometimes up to 100 sm. After its drying it shields raised to the height of the first layer and poured next. Artificial of each next wall layer after drying the previous, and so to the required height. Wooden frame inside of clay form strengthened clay wall mass, forming a solid structure of the building.

With this technology the thickness of the walls was different. At the bottom they could reach one meter and rising to be narrowed. Thickness of the lower and upper levels of the walls had a 2: 1 ratio. The interior walls of the building retained the right angle, and external were under slight slope. This design provided wall facades trapezoid shape.

Poured walls every day without a break, but after bringing to the half of wall they were been given to dry for 1-2 days and then has again continued to work through. Walls were not poured during inclement weather (rain, etc.). In this case, when the rain was great, the walls were covered with top boards or other material not to be wet especially when the forms are not filled to overflowing mass. Spout wall to the desired height, they made it possible to dry well, then just continued other work (ceiling, roof, windows, doors, etc.).

Soil and clay technology of walls. The peasant houses or farm buildings with such walls are built with soil or clay of moisture which it usually has on the depth of 15-20 sm. Suitability of soil (any clay) determined simply, if the soil does not fall while digging pit, so soil is suitable for soil technology. Clay or soil are loosened. There is any other special preparation is required. Earth and clay are used freshly dug, old materials are not used. The material for the walls is ready. Technology of soil and clay wall are the same. Lathing is fixed of boards on foundation (as in clay walls). In lathing, earth (clay) is put by men with buckets, litter, There deploying with thin layer is10-15 sm. The thinner the layer, the better is trampled. Trample with rammer (Fig. 4.11), made of solid and dry wood. Sometimes base of rammer is sheathed with iron.

Soil is trampled too much, so until while hitting by rammer earth or clay will give a clear sound, like the sound of hitting a tree and put layer is reduced by half. Thus construct all of the walls, the building is crammed simultaneously around the perimeter, leaving openings for windows and doors. The earth and clay buildings warm and dry, cheap.

They construct without water, so don't raw. Such buildings dries quickly after reconstruction, so quickly livable. This house owners can "trample" by their own, and therefore should not pay to masters.

The disadvantage of this technology is that the building needs to be perfect with trampling across the wall. If "to trample with unequal force, the walls will be thick in some places, while others will give porous cracks, and it is dangerous for strength of building". In place of porous plaster is put not well , eventually porous places can crumble, it can cause the destruction of the building. Therefore, accurate and thorough without printing the entire building will be strong. That is why the technology of soil and clay is built with small rooms (chicken coops, barns). So clay houses have some flaws, but the advantages of this forgotten technology are too much. Firstly it is, cheap. Secondly, the material is available and on its strength does not inferior either brick or concrete. Thirdly, such kind of building "breathes". So creating a comfortable environment for living and health: it is proved that the clay acts as a filter for absorbing pollutants indoors. In other words cleans the air. So in clay peasant houses feel good even those who are prone to allergies.

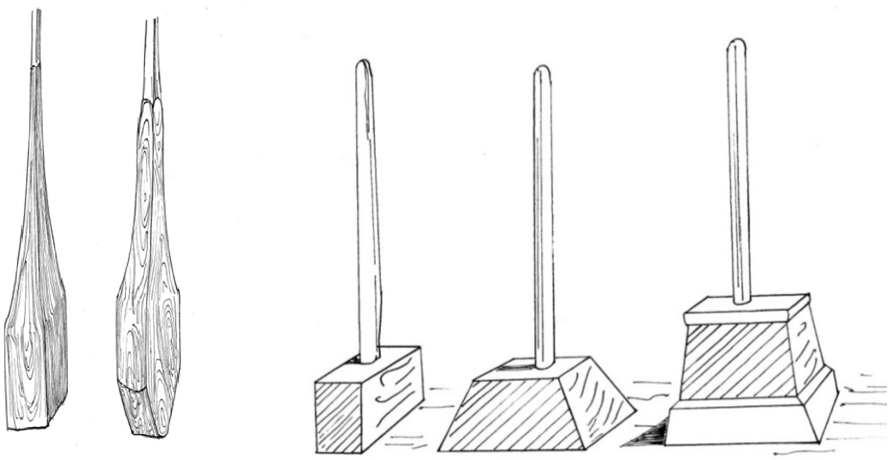

Fig. 4. 11. Wooden rammers and with metal base

Soft saman (valkovi) walls. For soft saman walls, solution is prepared as well as for saman (sometimes is called raw saman). Soft saman is made by women kneading clay and straw solution like dough. Even clay and straw consistency similar to dough mixture. For soft saman, straw was taken long, but the mint unlike saman. Production of it was as follows: "straw was spread out on the threshing - floor and trampled on it with help of horses until the straw would be soft" or straw - mill used (Fig. 4.5). The straw are put in sheaves around dug pit with straw and clay mixture.Women who made soft saman, stay on knee around du pit with straw and clay mixture.the ground they put straw. Taking clay and straw mixture from pit women put it on the straw and begin to knead. Soft straw is kneading until it will be plastic. The prepared soft saman men put into the prepared lathing (fig.4.12). One woman for one hour can produce 10 to 15, putting them near them. Clay soft saman walls had two design solutions that are: simple clay and soft saman and clay and soft saman “in herring bone “. In the first case used a fairly large soft saman of clay and straw mass that concluded across the walls in rows, close to each other. For the construction of walls out of soft saman"in herring bone" used soft saman of smaller size.Every layer of soft saman stacked on wall not horizontally but at an angle of 45 °, though two adjacent layers have tilt in different directions. This design of clay wall appeared in the national construction at the beginning of the XX century. and widespread from 20 - 30 years up to 50-60 years of the twentieth century. within the reconstruction of the Ukrainian village in the postwar years.

Soft saman walls of houses construct over one day, laying house ceiling beam. Traditional house measuring of 10 × 6 construct team of women who makes soft saman about 10 - 15 people, and men and adolescent boys. Home built from soft saman is warm, economical, does not require large expenditures but sometimes used instead of clay soil, so these houses were built often.

Sometimes, instead of soft saman used soft saman with adding of excrements (lympachi) The difference between soft saman with adding of excrements and soft saman was that the mixture from which made lampachi besides straw, clay (or soil) and water added organic impurities, including animal manure (dung). Often used horse dung because the horse was considered "clean" animals. In the steppe region , sheep dung is used. Technology of soft saman with adding of excrements peasant house was like a soft saman peasant house but soft saman with adding of excrements is used raw. Sometimes soft saman with adding of excrements was dried, then technology of such peasant house was like a saman house technology.

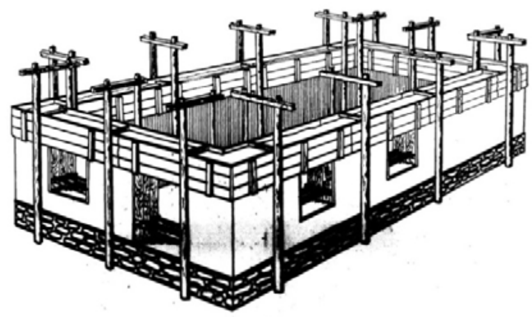

Fig. 4. 12. Lathing for clay and soft saman peasant house (Drawn by Oksana Yakovenko, master of architecture).

All clay and soil structures, which have been described above, characterized as construction almost without wood in it. It is used at these constructions not for windows and doors, only for ceilings and rafters.

In the Prydniprovsk region it were popular peasant houses on wooden frame (as a rule from waste of wood) (turluchni khaty) among peasants or peasant houses with wooden support in the corner (as a rule from good sort of tree) (khaty na sohah) so that is framed building. This was associated with the natural and geographical conditions which housed the village. Unlike the above described technologies in peasant houses on wooden frame, wood play a great role because it is the main part of building the house, it‘s a frame of future peasant house. The technology of building this peasant house was in correct previous planning , choosing a place and trampling to soil of 4 wooden support at the corners of peasant house,(it were very thick pillar) and from quite hard sort of tree (for the Prydniprovsk region , it were: oak, acacia, pine). At the top of the wooden support there was connection between them with two rows of horizontal bars or beams Bars or beams are sharpened at the end with lock and on the board (the upper layer of tree) put the center balk, and put above ceiling the wooden overlap in "A" form for the roof. Then between wooden support are trampled wooden stakes or put transverse wooden sticks (wooden stick .Fig. 4. 13).

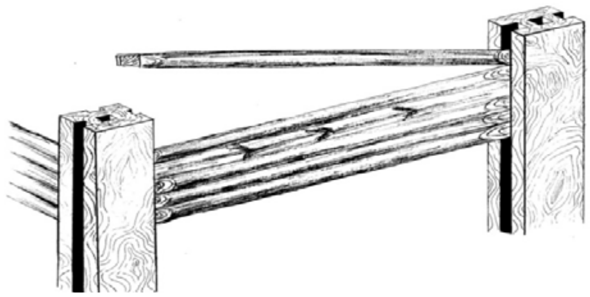

Fig. 4. 13. Inserting of wooden sticks

Further shell of the peasant house is joined to wooden stick. The shell has its own variants depending on local conditions. There are houses that often are covered with clay and straw solution. In such houses along the walls, between wooden support vertically and fairly close to each other in soil is trampled wooden stakes (often used with willow), putting in the upper end of the stakes on the board (the upper layer of tree) of peasant house. Then the stakes thin are braided with thin vine or wheat straw or reeds (fig.4.14). In the Prydniprovsk region there are peasant houses with braided walls with one, two and three rows of netting (fig. 4.14 and fig.4.15). Sometimes two - and three-row of braiding covered with soil. Then such braided frame coated with clay plaster.

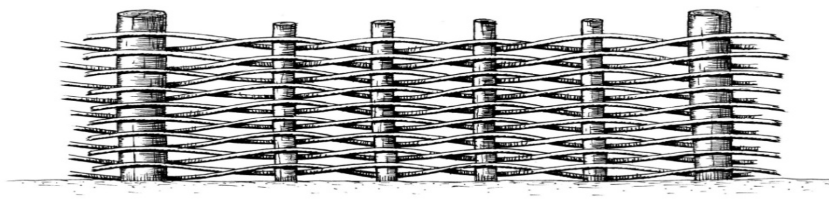

Fig. 4.14. Braided frame of peasant house

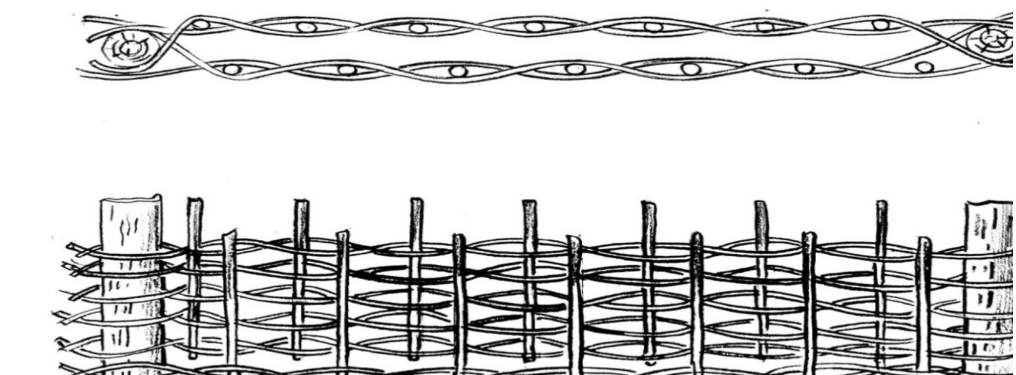

Fig. 4. 15. Two raw braiding of peasant house frame

Plaster (thick doughy solution) whirs with fists (Fig.D1.24), then tight, like smearing with less dense of solution. Then allow to dry and then whitewashed. These peasant houses are called mazanka. Peasant house – mazanka for centuries has been the traditional dwelling of central and eastern Ukraine. Mazanka is a very warm peasant house all of peasant houses which are built with clay. In the construction of mazanka was used local building materials. Mazanka is a structure that combines both comfort and genuine housing, and strength, and resistance to moisture and cold. The thickness of the walls of mazanka are from 26 to 30 sm, that equate as 120 sm of brick masonry. Advantage of mazanka is also because it dries much faster than conventional clay peasant house, it consumes less clay, that makes the construction easier and specialist should not be there while constructing .Mazanka could be built by family own.

In villages which are located along rivers and streams, especially in the southern part of the region, the peasant house with the same frame are put with the reed or cane. Reed is bind in bundles and thin tie, both inside and outside to the wooden sticks, inserted between wooden support. Make it so that there were no gaps between the sheaves. Having tied of peasant house of two sides, it is thrown with clay and straw solution, making solution by hands (fists), then trowel. After drying whitewashed. Reed peasant house not as strong as saman or clay pouring peasant house, but cheap because have a large number of reed and ease while making aframe, they are made quickly and work is not hard.

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