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Dynamic programming in optimization of comprehensive housing stock modernization

Динамическое программирование в оптимизации комплексной модернизации жилищного фонда

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Ключевые слова: жилищный фонд; комплексная модернизация; экономическая эффективность; срок окупаемости; энергосберегающие технологии; оптимизация; динамическое программирование

Abstract. Research in the area of dynamic programming in optimization of comprehensive housing stock modernization has shown that there are a number of important issues that require effective and rapid solutions. The purpose of research is the organization of repair and construction works by modeling the organizational and technological solutions to the use of energy-saving technologies for the comprehensive modernization of the housing stock. The proposed method of an integrated approach to the modernization of the housing stock and, accordingly, the implementation of energy saving measures will reduce the cost of homeowners to pay for housing and communal services by improving the thermal performance of buildings. Formulated and discussed the theoretical aspects of dynamic programming for solving problems of optimal allocation of allocated funds having minimal losses, which allows calculating the conditions for the implementation of energy-modernization. The mathematical model of optimization of process of energy-modernization. Is executed economic assessment of energy saving decisions in the course of complex energy-modernization, are given results of calculations of distribution of the allocated funds and payback periods on of holding actions for increase in indicators of energy saving.

Аннотация. Исследования в области динамического программирования в оптимизации комплексной модернизации жилищного фонда показали, что имеется ряд важных проблем, требующих эффективного и быстрого решения. Целью исследования является организация ремонтно-строительных работ путем моделирования организационно-технологических решений с использованием энергосберегающих технологий при комплексной модернизации жилищного фонда. Предложенная методика комплексного подхода к модернизации жилищного фонда и, соответственно, реализации энергосберегающих мероприятий позволит снизить расходы собственников жилья на оплату жилищно-коммунальных услуг за счет улучшения теплотехнических характеристик зданий. Сформулированы и рассмотрены теоретические аспекты динамического программирования для решения задач оптимального распределения выделяемых денежных средств, имеющего минимальные потери, которая позволяет рассчитать условия реализации энергетической модернизации. Построена математическая модель оптимизации процесса энергетической модернизации. Выполнена экономическая оценка энергосберегающих решений в процессе комплексной энергетической модернизации, приведены результаты расчетов распределения выделенных средств и сроков окупаемости проведения мероприятий по повышению показателей энергосбережения.

Introduction

One of the most important tasks of the state level and the level of regional public authorities is the development and implementation of effective programs to upgrade the housing stock in order to solve major social problems connected with availability and comfort of housing [1]. The housing sector should

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be regarded as a complex system, the development of which depends on the final number of factors. Identification of the most significant factors affecting the dynamics of the housing stock is of fundamental importance. A clear definition of the relationship within the system in question leads to a correct or adequate accounting and forecasting the state of the housing stock.

At the present stage, it is possible to allocate the following main problems of the housing sphere in general:

- Shortage of housing;
- A high percentage of the moral and physical deterioration of buildings;
- Low quality of housing and communal services and maintenance of residential buildings;
- Rising prices for housing and communal services;
- Low and very low class's energy-efficiency housing [1, 2].

It should be noted the need to develop a comprehensive approach for the organization of an integrated mechanism for the modernization of the housing stock, taking into account energy- and resource-saving in the first place, using a variety of innovative technologies that improve the level of development of the city and the territory [1]. For the organization of the control method it is appropriate to use elements of computer mathematical modeling, numerical methods, which allows a certain accuracy to optimize the process of modernization. This process cannot be comprehended within static representations, as its sense is always connected with the future, with forecasting [3]. Therefore, task of complex modernization can be considered as a problem of dynamic optimization, the analysis tool that is a dynamic programming [3].

The need to systematization and maximize the cost-effectiveness of energy retrofit as part of a comprehensive modernization of housing stock led to the choice of the theme of scientific work.

Research problems in the housing and communal services, energy issues and resource conservation, the development of methods to solve them were engaged in domestic and foreign scientists: V.Ya. Mishchenko, V.S. Bogolyubov, S.G. Sheina, P.G. Hornbeam, L.B. Zelencov, O.N. Popova, T. L. Simankina, N.G. Selyutina, E.B. Smirnov, A.K. Schreiber, V.V. Klimenko, A.N. Dmitriev, V.G. Gagarin, A.S. Bolotin, I.A. Bashmakova, L.N. Chernyshov, G. Arman, A. Thumann, C.M. Carol, T. Goven, J.M. Clapp, G. Payne, A.D. Russell, A. Shtub, S. Selinger, J.F. Bard, B. Cheong-Hoon, J.M. Clapp, S. Globerson, K. Davar, M. Kataoka, H. Kim et al. [1, 4-9, 24].

Methodological issues of dynamic optimization of multistage processes, which include the possibility of different processes and a fundamental principle of optimality system control, have been proposed and investigated further by R. Bellman, R. Kalaba, I. Glicksberg, O.A. Gross, S.E. Dreyfus, R. Aris, G.L. Nemhauser, D. Wilde [10–13].

Foreign and domestic scientists S.V. Chukanov, O.A. Shcherbina, M.V. Lewis, D. Coen, K.D. Kuhn, A. Flint, C. Mei, D. Murray, Z.C. Lin, Y. Zhao, W.T. Ziemba, J. Doucette and others analyzed the possibility of using the dynamic programming method to solve the economic problems and modeling of economic systems [14–19].

The cycle of articles is earlier published by us was devoted to development of techniques of the description of a problem of complex updating of housing stock with application of methods of linear and dynamic programming [1, 14, 20, 21]. On the basis of these researches, and also the idea of the integrated application of methods of mathematical and information modeling in management of processes of the organization of construction, repair construction works and in general housing stock we offer the scheme of optimization of processes of complex modernization of housing stock.

Methods

Updating of conceptual structure of the theory of reproduction of the real estate.

Housing sector includes a number of methods of reproduction, depending on the degree of comfort under consideration specific property [2]. For the most complete review and study, the issue of housing modernization is necessary to update the conceptual structure theory. Any abstract theory is considered on some set of elements. A set is called set of elements, distinguishable among themselves and imaginable as a unit. In the theory of reproduction is explored the set of buildings, constructions and accompanying them the engineering infrastructure. We will call a set of residential buildings the city or country the housing stock.

On a set of residential objects, we will set various functional representation, which transform the given object in object with the minimum level physical and obsolescence. For any object of a given set is determined the number of parameters that can be divided into certain groups according to the degree of similarity. Let us allocate the main functional displays:

- new construction;
- reconstruction;
- modernization;
- Overhaul;
- current repair;
- sanitation;
- restoration;
- Renovation.

Analysis of the above types reproduction of objects of housing facilities was given in the works of V.Ya. Mishchenko, E.P. Gorbaneva, A.P. Prokopshina, V.V. Buzyrev, V.I. Tavina, E.B. Smirnov, A.I. Deeva and other scientists. In the studies of E.P. Gorbaneva an overview of these concepts and their definitions was given. Based on the results of the studies and an attempt to further formalize these terms, we proposed their understanding of both functional mappings; the concept of complex modernization of the housing stock has also been introduced.

New construction - function, domain of definition of which is housing stock, through which happens the compensation of physical and moral deterioration of old and obsolete assets, and increases the main index fund - the total area. This display is an old dilapidated facility assigns a new building with a completely new qualitative and quantitative indicators, it remains only invariant construction site with a number of fixed parameters.

Reconstruction - the display object with the old qualitative and quantitative indicators in themselves, but updated. Here, the update is meant reorganization, a change in the basic technical and economic indices of the building: the total area, the number of apartments, the area of apartments, capacity, bandwidth, construction volume (outbuilding, superstructure, remodeling), the provisions of a functional purpose in whole or in part (in this case, this area will not be included in the set under consideration). As the differences between the new building reconstruction of a partial refund of wear and tear can be distinguished [2, 22].

By upgrading is meant a functional image of the subject in itself, in which there is a qualitative improvement in the housing using the latest technologies and innovative materials, improving its comfort, partial or total compensation of moral and physical wear and tear. From the reconstruction is characterized in that the total value of the volume and area of a building, the appointment object remain unchanged.

Overhaul – a display object, the functional value of which is to reduce the percentage of physical deterioration by replacing or restoring the structures of the building or its parts, engineering equipment. The level of comfort of the building, however, the overhaul does not provide a change of its volume, the total area of rooms and spaces. [7]

As many authors have studied the literature, include the process of overhaul and redesign of the building, which leads to a decrease in the degree of identification of the concepts of modernization and overhaul. This is a significant disadvantage in the design of computer mathematical process model [2, 11–12].

Object Maintenance work is a map in which there is a restoration of working capacity of structural elements and systems engineering equipment facility. Maintenance work includes a partial reduction for deterioration by keeping the operational performance of the building. Allocate by type of construction work scheduled (planned on the implementation of the time, volume and value) and unscheduled maintenance overhaul (identified in the operation and made a matter of urgency, is random) [18].

Remediation – a functional image of the subject, providing for the rehabilitation of the technical condition of the building, improvement of hygiene and living conditions, improvement of intra territories. Decompression development and improvement of intra-area can be carried out by demolition of inefficient buildings for different purposes and using them to build underground, surface parking lots, recreation areas and a variety of modern sports and cultural complexes. That is, in the application of the reporting function display must be considered multi-criteria indicator of the quality of intra territories.

Restoration – is a functional image of the subject in itself, and its functional significance – it recreated the ancient appearance of the building. When the restoration is carried out a complex range of repair and construction works aimed at restoring the cultural heritage. It consists of the following operations:

- Reconstruction of the object by removing later distorting its parts;
- Recovery of lost items;
- Elimination of physical deterioration.

Renovation of housing – functional display, including a general, a sequence of transformations: new construction, capital repairs, modernization, restoration, reconstruction, demolition of buildings, sanitation. Thus, a housing renovation is understood one of the above functional maps for a particular object of the housing stock.

We introduce the concept of a comprehensive modernization of housing. Comprehensive modernization of housing – a functional domain that serves a variety of functions (reconstruction, modernization, repair, maintenance, restoration, rehabilitation, renovation), thus reverses the physical and moral property of wear, that is, improvement of qualitative and quantitative indicators. Here it is obligatory to carry out energy modernization of housing stock and taking into account the funds allocated for this purpose. Under the modernization of energy, we mean an element of a comprehensive modernization of the housing stock, which is carried out in the course of repair and construction work using energy-saving technologies, leading to an increase in comfort and property owners a significant reduction of costs for housing and communal services [1].

Effective management of the modernization process in the public financial support would solve the problem of ensuring the proper use, maintenance and repair, reconstruction of the facility; preservation in the required state of the technical and operational characteristics of the property; creation of comfortable living conditions for the citizens; resource; a phased increase in energy systems engineering; reduce the size of obligatory payments.

The economic situation in the country is usually characterized by local instability. Examining the growth and development of the housing stock in general, we concluded that it was necessary to develop methods for strategic planning of all spheres with a view to more effective management. There have sharp differences in growth, while at the same time, there are no clear long-term development prospects. If we introduce the assumption that the more distant future will be stable, that is stationary or quasi-stationary, it can be divided into a model for the current period and the period of "steady-state" of the future. For the model of "steady-state" of the future ask Bellman function, which has developed in non-stationary model of the current phase [3]. This will allow responding to emerging changes in the housing sector. The method will be to address the dynamic functional Bellman equation [10]. Next, we consider an element of a comprehensive modernization of housing – the modernization of energy, in which the following energy-saving technologies have been introduced:

- Installation of curtains from PVC film into space windows (ET 1);
- Automation of lighting in the common areas (ET 2);
- Organization of the automated thermal points (ET 3);
- The use of automatic door closers on the doors (ET 4);
- The use of automatic sensor faucets (ET 5);
- Improving the thermal insulation properties of the building envelope (walls) (ET 6);
- Improving the thermal insulation properties of the roof (ET 7);
- Insulation of external doors (ET 8);
- The use of motion sensors (ET 9);
- Installation of heat-reflective designs for radiators (ET 10) [7,20].

Application of methods of dynamic programming in solving this problem is conditioned by the fact that it allows controlling both energy-saving efficiency and implemented energy-saving technologies. This methodology has a complex character and allows us to investigate the economic effect of the implementation of ET in the renovation of the housing stock as a whole, rather than individual objects.

The composition and structure of the so-called energy modernization can be changed depending on the types of buildings and their technical properties.

When carrying out repair and construction works that have a complex nature, the main criterion for their implementation or non-performance is the restriction in financial resources. Proceeding from this, in our article it is offered in parallel with carrying out of various repair-building works to realize energy-saving measures with the optimum distribution of means leading accordingly to the maximum economic effect.

Statement of research problem

Let the volume investments (*C*) it is allocated for carrying out for energy action the modernization of housing stock. As the input data is set the volume of funds allocated for holding *n* energy-saving measures.

Consider the generalized scheduling problem for an energy modernization using two types of energy saving measures I and II for a period of *m* years.

The quantity of means *x*, enclosed in an action of *I* yields revenue in one year

$$f(x) = A \cdot x \tag{1}$$

and at the expense of it decreases to

$$\varphi(x) = A' \cdot x. \tag{2}$$

The quantity of means *y*, enclosed in an action of *II* yields revenue in one year

$$g(y) = B \cdot y \tag{3}$$

and decreases to

$$\psi(y) = B' \cdot y. \tag{4}$$

It is required distribution is of resources Z_0 between the carrying out of action I and II for each year of the planned period. Income is understood here as an economic effect from the introduction of energy-saving technologies in the process of modernization of housing stock.

Decision. Conditional optimal control x_m^* in the last step (quantity of the funds allocated in action of I) is defined as value x_m at which the income reaches maximum on the last step:

$$W_m^*(Z_{m-1}) = \max_{0 \le x_m \le Z_{m-1}} \{w_m(Z_{m-1}, x_m)\},$$

where

$$w_m(Z_{m-1}, x_m) = A \cdot x_m + B \cdot (Z_{m-1} - x_m) = (A - B) \cdot x_m + B \cdot Z_{m-1}, \quad A \ne B \text{ [15].} \tag{5}$$

The graph of the function $w_m = w_m(Z_{m-1}, x_m)$, depending on the argument x_m for a given Z_{m-1}, will be a straight line. The maximum value can be reached only at the boundaries of the gap $(0, Z_{m-1})$. To define on what border, let's substitute in formula (5) $x_m = 0$ and $x_m = Z_{m-1}$. Proceeding from the submitted schedules, obvious that in case of the decreasing function the maximum value $w_m = B \cdot Z_{m-1}$ at $x_m = 0$. In the second case at $x_m = Z_{m-1}$, is reached the maximum value of function w_m, equal to the value $A \cdot Z_{m-1}$ [23].

Consequently, the maximum income for the last step is independent of Z_{m-1} and its value depends on the values *A* and *B*, and it means that at the beginning of the final year, all available investment must be invested in action of I, if *B*<*A* or in II, if *B*>*A*. It is natural as the income from the chosen action is more, and expenses of means does not interest us any more (last stage).

At this optimum control of final year will bring us income $w_m = B \cdot Z_{m-1}$ or $w_m = A \cdot Z_{m-1}$.

Let us pass to distribution of funds for (*m*-1)-th year. Let we approached it with a stock of means Z_{m-2}. Let us define the conditional maximum income in the last two years:

$$W_{m-1,m}^*(Z_{m-2}) = \max_{0 \le x_{m-1} \le Z_{m-2}} \{A \cdot x_{m-1} + B \cdot (Z_{m-2} - x_{m-1}) + W_m^*(Z_{m-1})\}$$

But $Z_{m-1} = A' \cdot x_{m-1} + B' \cdot (Z_{m-2} - x_{m-1})$, consequently,

$$W_m^*(Z_{m-1}) = B \cdot (A' \cdot x_{m-1} + B' \cdot (Z_{m-2} - x_{m-1}))$$ or
$$W_m^*(Z_{m-1}) = A \cdot (A' \cdot x_{m-1} + B' \cdot (Z_{m-2} - x_{m-1})).$$

From here we will receive

$$W_{m-1,m}^*(Z_{m-2}) = \max_{0 \le x_{m-1} \le Z_{m-2}} \{A \cdot x_{m-1} + B \cdot (Z_{m-2} - x_{m-1}) + A \cdot (A' \cdot x_{m-1} + B' \cdot (Z_{m-2} - x_{m-1}))\}$$

or

$$W_{m-1,m}^*(Z_{m-2}) = \max_{0 \le x_{m-1} \le Z_{m-2}} \{A \cdot x_{m-1} + B \cdot (Z_{m-2} - x_{m-1}) + B \cdot (A' \cdot x_{m-1} + B' \cdot (Z_{m-2} - x_{m-1}))\}$$

[23–25].

Expression in braces represents a polynom of the first degree relatively x_{m-1}, and its schedule – a straight line, function, proceeding from the received parameters can be increasing or decreasing: $x_{m-1} = 0$ and $x_{m-1} = Z_{m-2}$.

In the first case (at $x_{m-1} = 0$) we receive $W_{m-1,m}^*(Z_{m-2}) = (B + A \cdot B') \cdot Z_{m-2}$ or $W_{m-1,m}^*(Z_{m-2}) = (1 + B') \cdot B \cdot Z_{m-2}$; in the second case (at $x_{m-1} = Z_{m-2}$) $W_{m-1,m}^*(Z_{m-2}) = (1 + A') \cdot A \cdot Z_{m-2}$ or $W_{m-1,m}^*(Z_{m-2}) = (A + A' \cdot B) \cdot Z_{m-2}$.

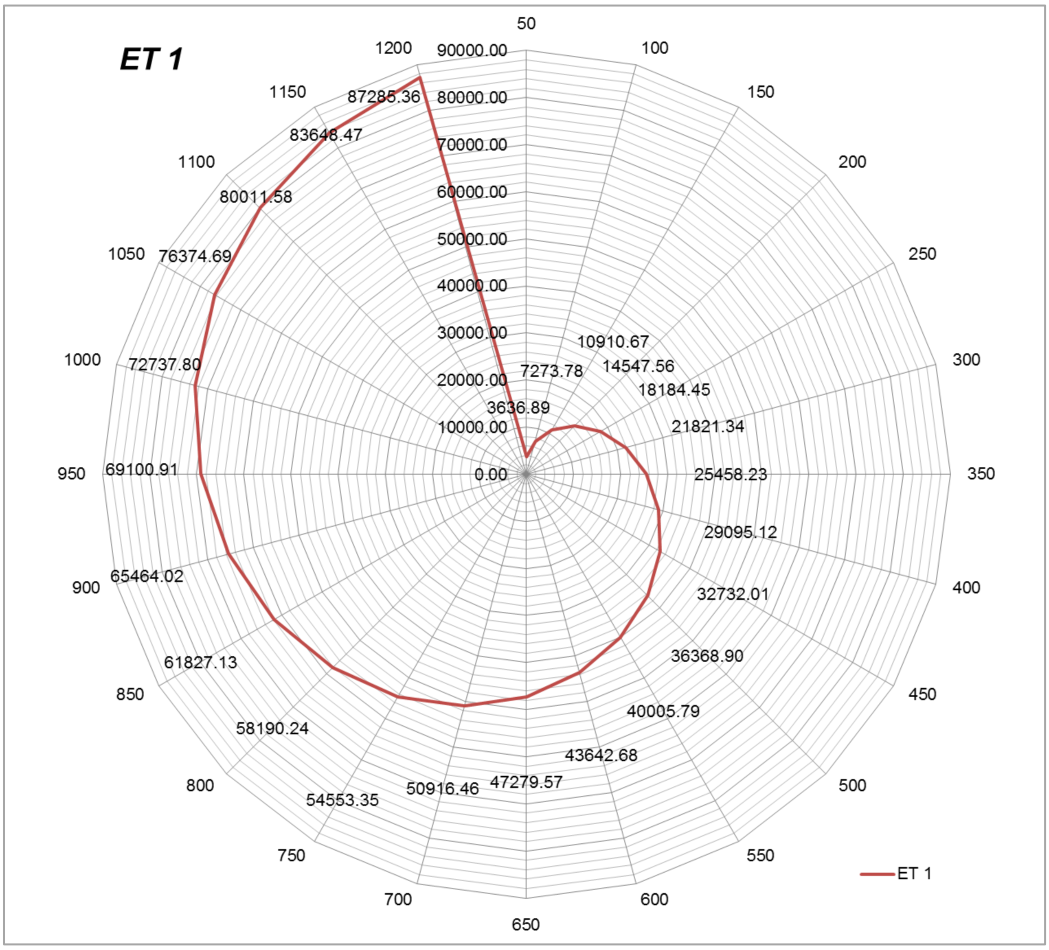
From the given expressions clearly that the maximum of the income depends on values: *A, B, A', B'.*

We turn to the (m - 2)-th step. Here it is necessary to maximize value of $W_{m-2,m-1,m}^*(Z_{m-3})$ on a similar principle [23].

Thus, the optimal control is found. Let us notice, that this solution will be obtained regardless of any number of steps, and any of the initial stock of assets Z_o.

Results and Discussion

The results calculations of economic efficiency (the economic efficiency from introduction of the energy saving technologies (ET) within one year), of considered energy saving actions are presented graphically in the form circulars charts in the figure 1. Values of the coefficients used in calculations were chosen from normative documents, statistical data on the Karachay-Cherkess Republic and other reliable data [26–31].


ET 1
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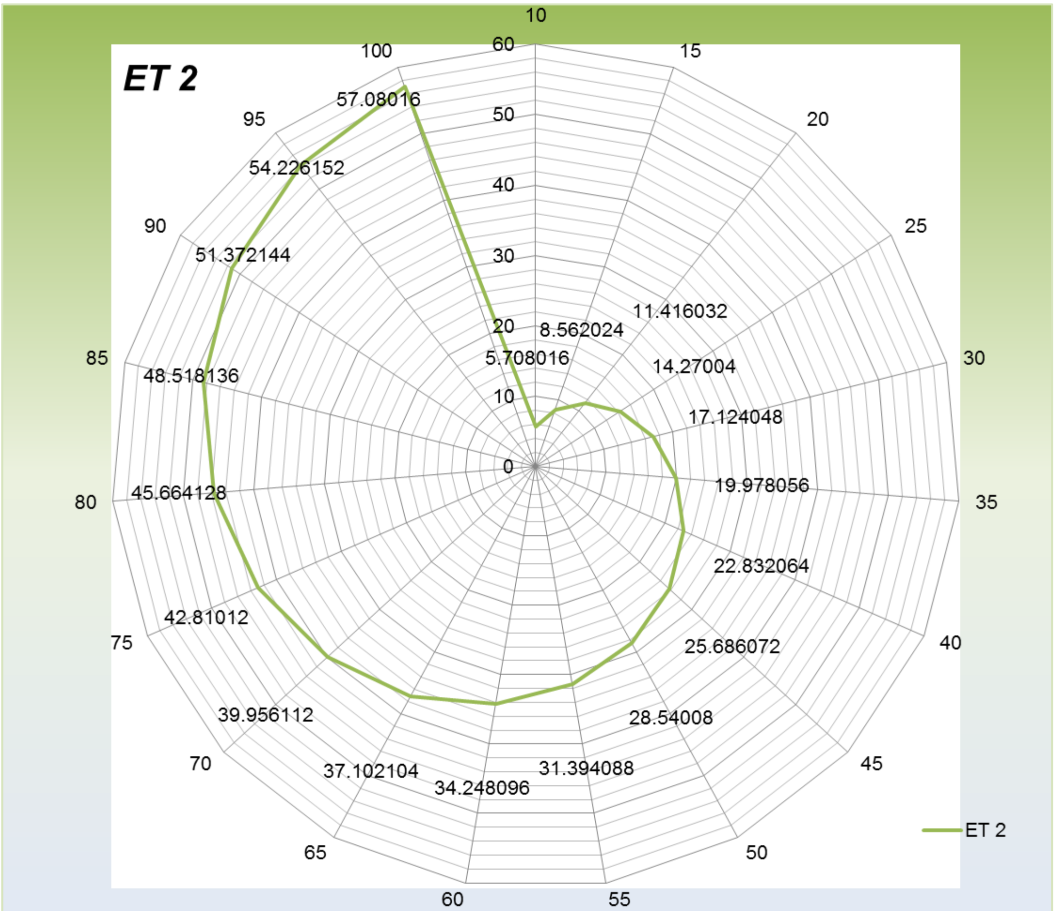
3636.89
7273.78
10910.67
14547.56
18184.45
21821.34
25458.23
29095.12
32732.01
36368.90
40005.79
43642.68
47279.57
50916.46
54553.35
58190.24
61827.13
65464.02
69100.91
72737.80
76374.69
80011.58
83648.47
87285.36
ET 1

a).


ET 2
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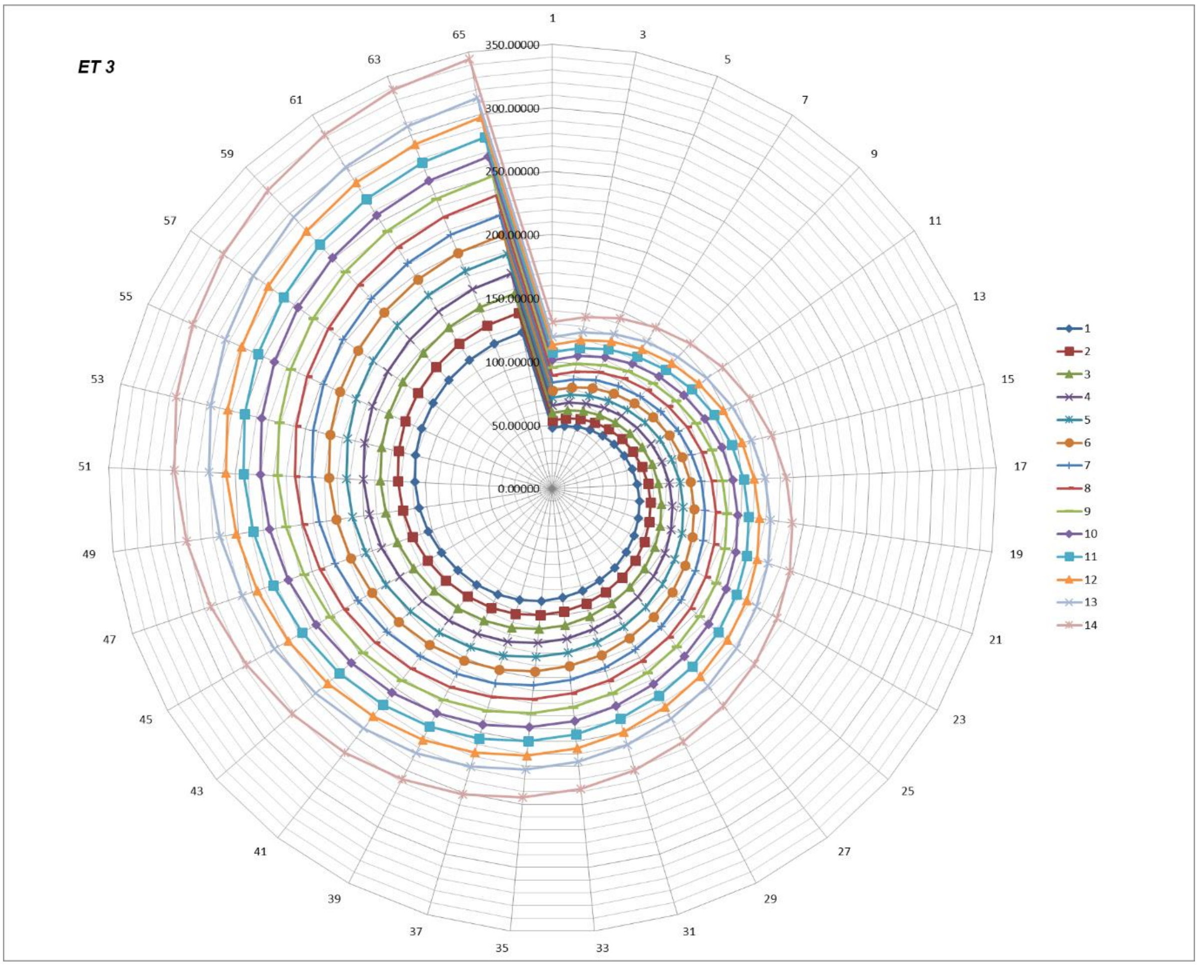
5.708016
8.562024
11.416032
14.27004
17.124048
19.978056
22.832064
25.686072
28.54008
31.394088
34.248096
37.102104
39.956112
42.81012
45.664128
48.518136
51.372144
54.226152
57.08016
ET 2

b).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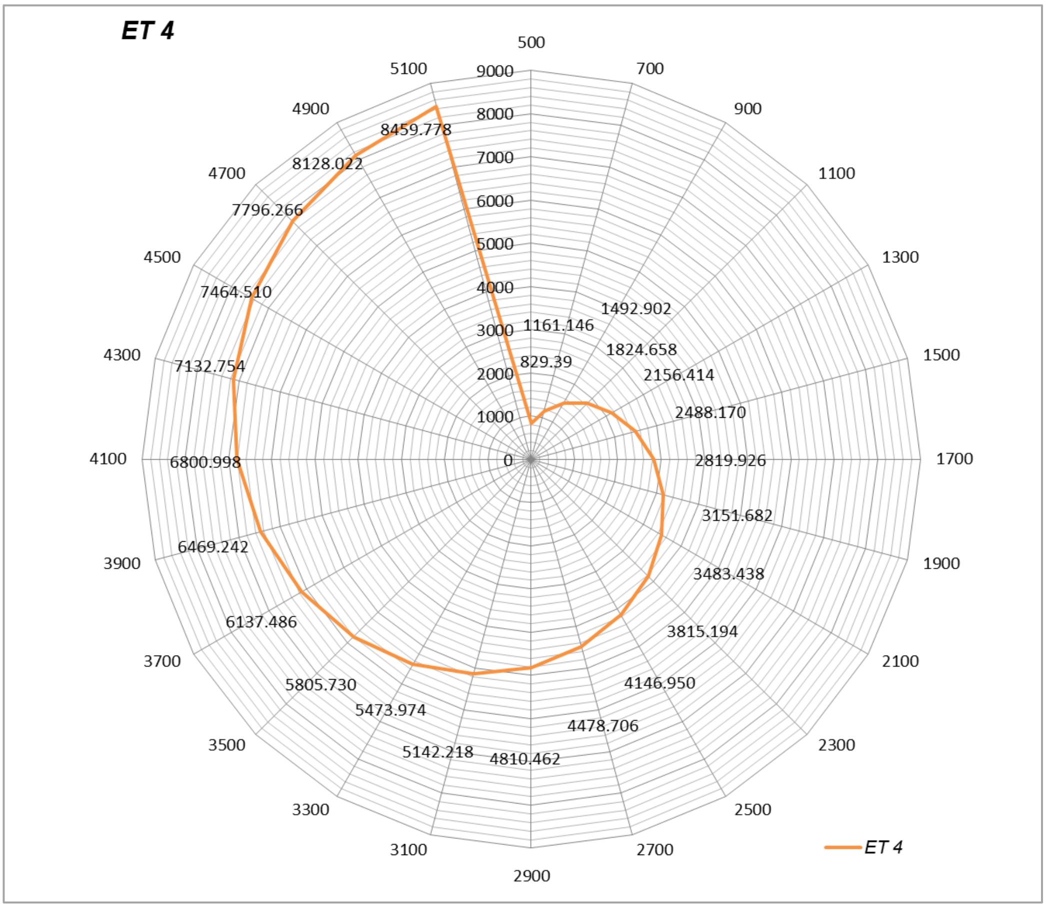
c).


ET 4
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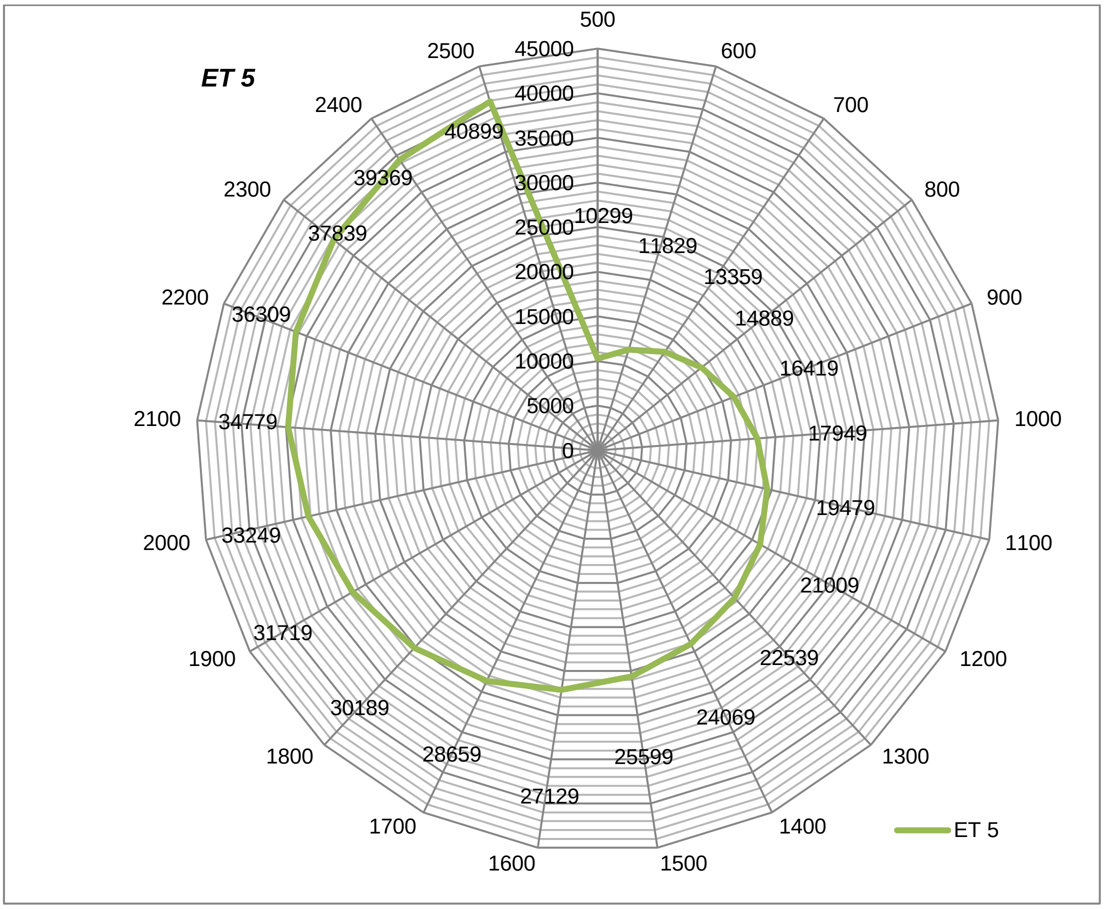
1161.146
1492.902
1824.658
2156.414
2488.170
2819.926
3151.682
3483.438
3815.194
4146.950
4478.706
4810.462
5142.218
5473.974
5805.730
6137.486
6469.242
6800.998
7132.754
7464.510
7796.266
8128.022
8459.778
ET 4

d).


ET 5
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11829
13359
14889
16419
17949
19479
21009
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34779
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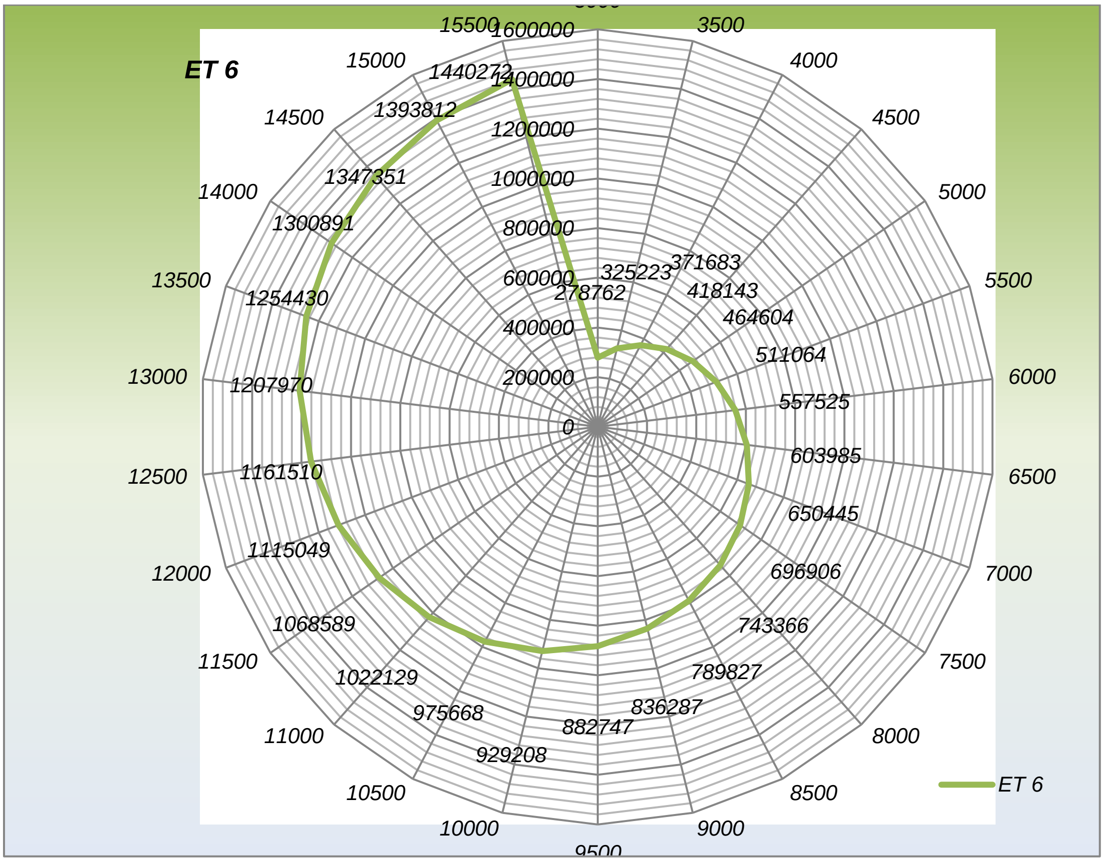
40899
ET 5

e).


ET 6
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278762
325223
371683
418143
464604
511064
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603985
650445
696906
743366
789827
836287
882747
929208
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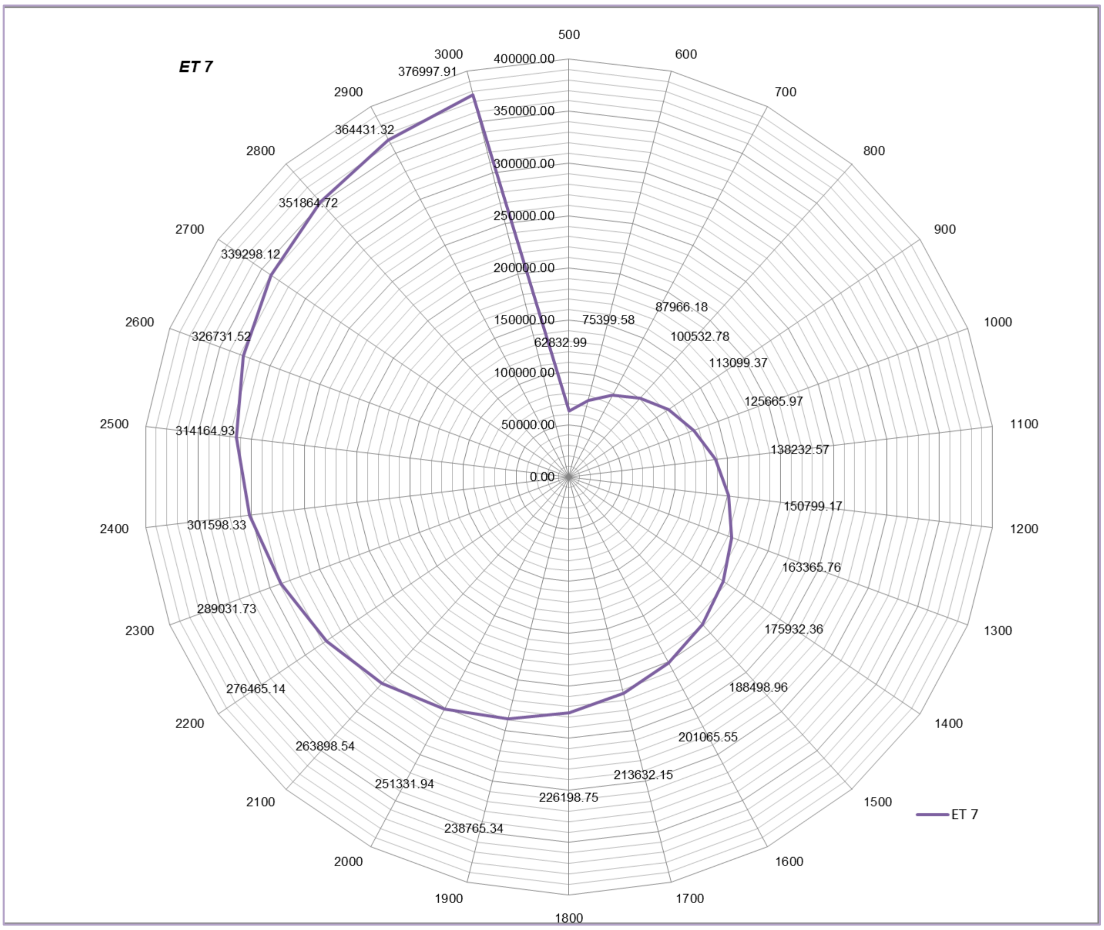
ET 6

f).


ET 7
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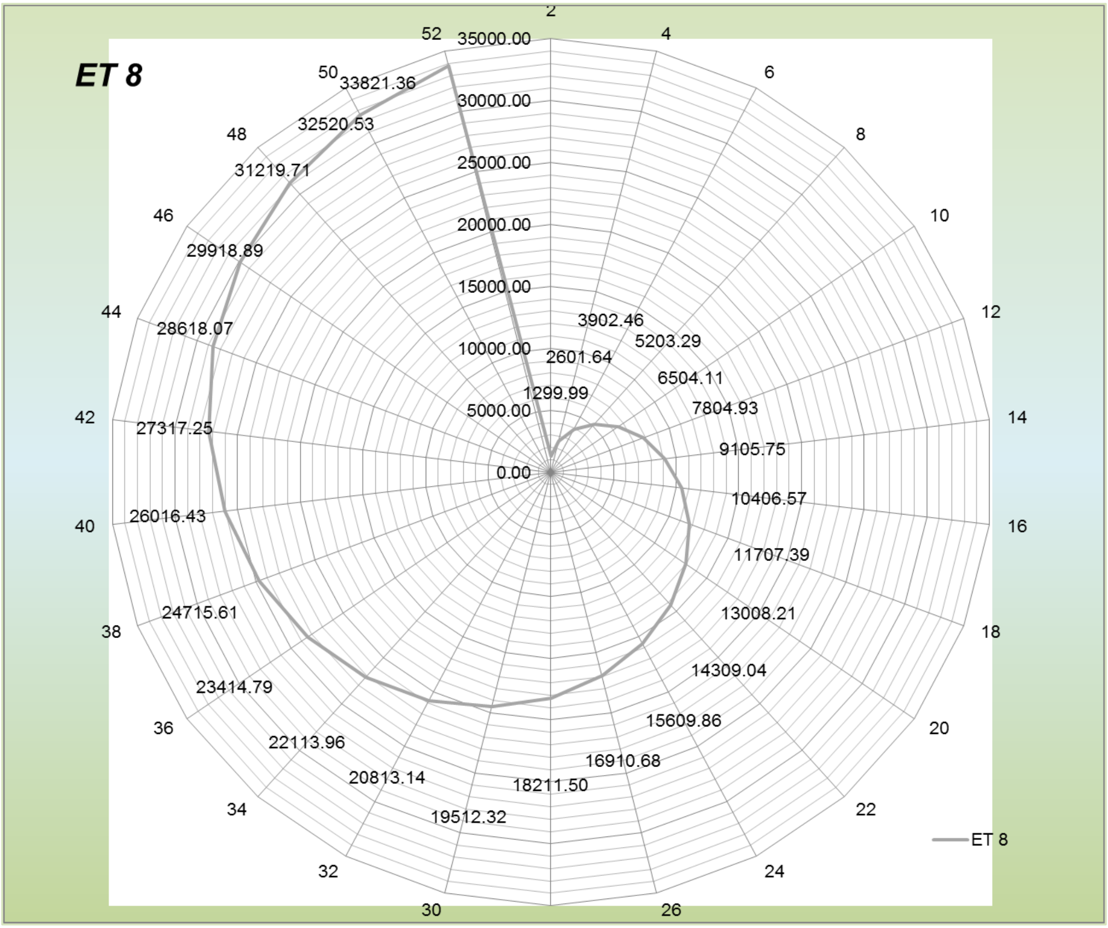
400000.00
350000.00
300000.00
250000.00
200000.00
150000.00
100000.00
50000.00
0.00
62832.99
75399.58
87966.18
100532.78
113099.37
125665.97
138232.57
150799.17
163365.76
175932.36
188498.96
201065.55
213632.15
226198.75
238765.34
251331.94
263898.54
276465.14
289031.73
301598.33
314164.93
326731.52
339298.12
351864.72
364431.32
376997.91
ET 7

g).


ET 8
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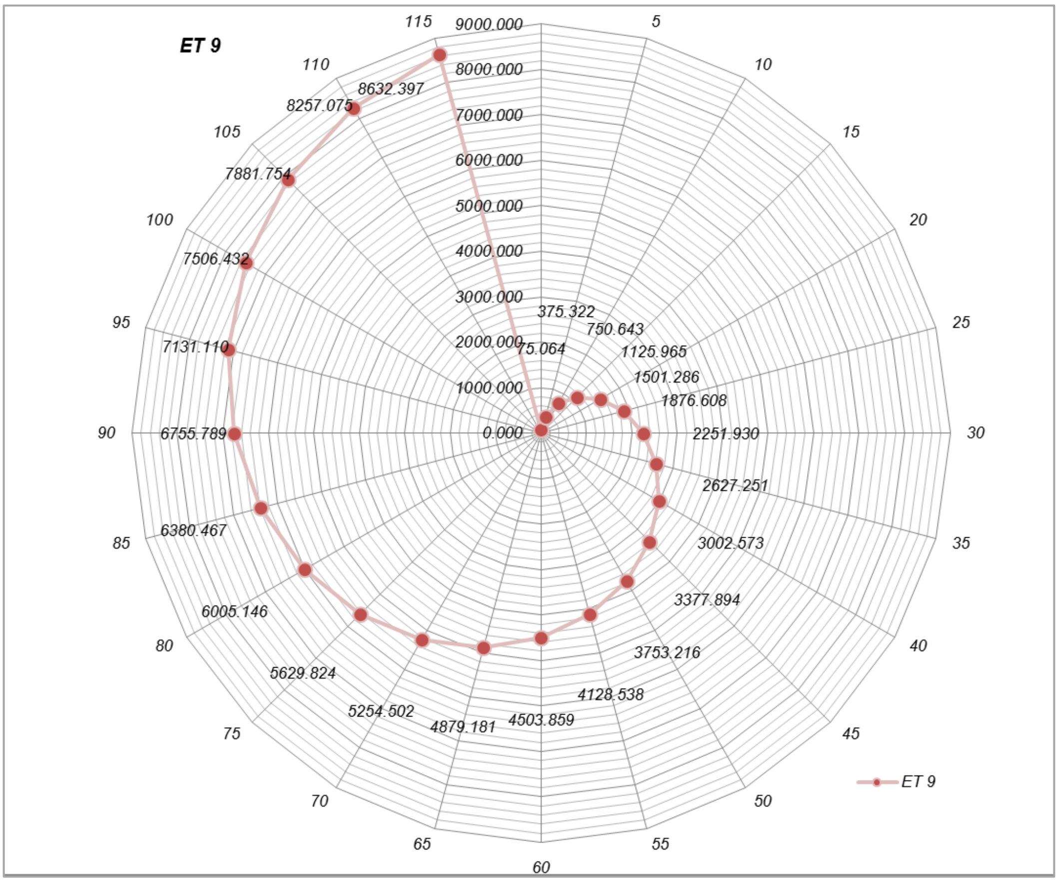
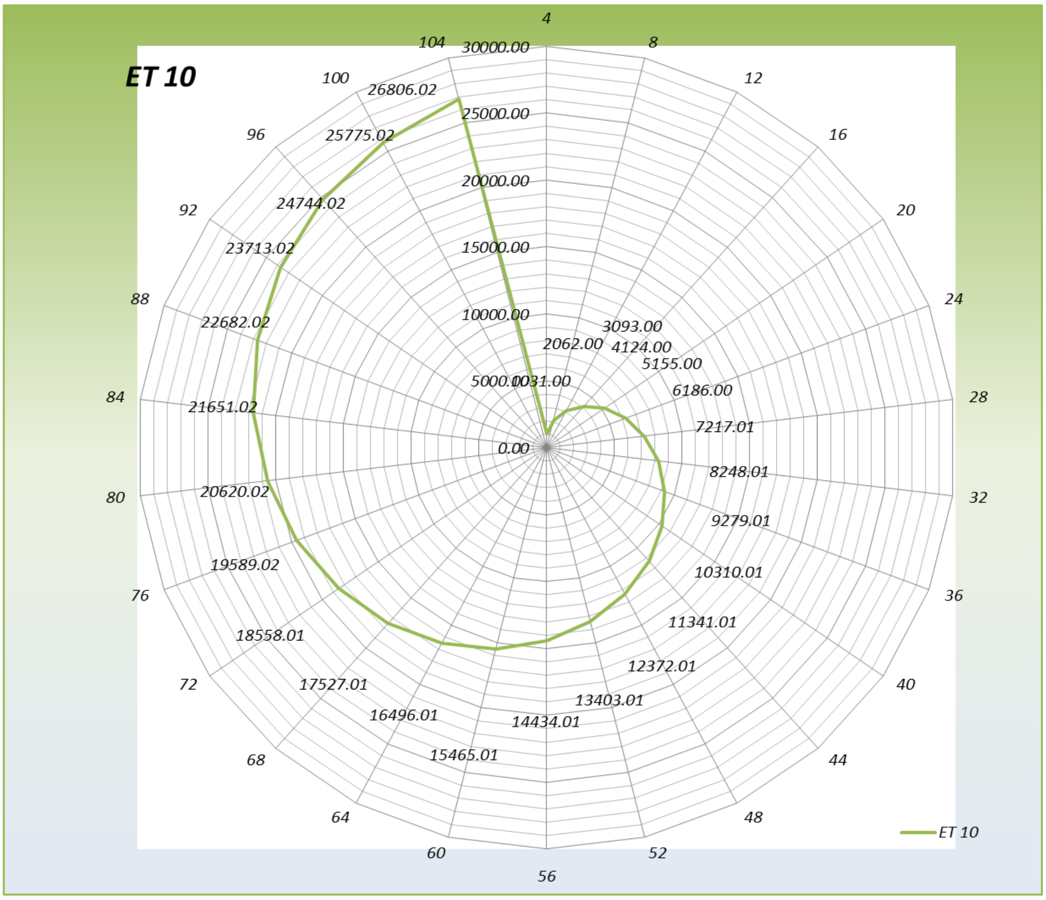
5000.00
0.00
1299.99
2601.64
3902.46
5203.29
6504.11
7804.93
9105.75
10406.57
11707.39
13008.21
14309.04
15609.86
16910.68
18211.50
19512.32
20813.14
22113.96
23414.79
24715.61
26016.43
27317.25
28618.07
29918.89
31219.71
32520.53
33821.36
ET 8

h).



i).



j).

Figure 1. The cost-effectiveness of the introduction of ET

a. ET 1 (depending on an indicator of the area of a glazing), rub.

b. ET 2 (depending on the number of glow lamps in places with temporary stay of people), thousand rubles.

c. ET 3 (depending on the number of completely heated days in the heating period and an indicator of annual consumption of thermal energy on heating of the building), thousand rubles.

d. ET 4 (depending on the volume of the thermal energy consumed during the heating period in the base year), rub.

e. ET 5 (depending on volumes of consumption of hot and cold water), rub.

f. ET 6 (depending on the surface area of walls), rub.

g. ET 7 (depending on the area of a roof), rub.

h. ET 8 (depending on the total area of surfaces of external doors), rub.

i. ET 9 (depending on the electric power of lamps), rub.

j. ET 10 (depending on the total area of projections of heating devices on of wall), rub.

On basis of the received results, it is visible that energy-saving actions not only increase technical comfort of a residential facility, but also make it possible to optimize parameters of internal temperature background. So ET 3 assumes to maintain the required temperature schedule in the heating system installation of regulators for heating with sensors for external and internal air. Under the appropriate program, the regulator can reduce the temperature of the air in the rooms. Automated control of the heating load allows you to save in the autumn-spring period. Figure 1, c) shows the graphs of financial savings, depending on the number of heated days in the heating season, with different annual heat loads for the heating system of the building.

Introduction of energy saving technologies of economy increases of thermal and electric energy. So at change of heat-shielding properties of a roof the percent of economy of thermal energy increases by 8–12%, 6–15% – due to increase in a heat-shielding of windows and external doors; 15–20% – at the expense of the device of the automated knot of management of system of heating and installation of thermostats on the heating devices; 10–25% (electric energy) – due to application of energy saving lamps and motion sensors. The received values will be applied for realization of a problem of optimum distribution of investments in processes of complex modernization housing stock.

The given pie charts are the input material for modeling the system based on the methods of dynamic programming. The task is to carry out repair work in such a way to the results of their performance lead to a significant increase in the savings that have been spent on them taking into account the introduction of energy-saving technologies.

The task to distribute the specified amount of money between n actions so that in general the maximum effect of economy of money was gained is set. The solution of this problem must be divided into several stages. Generally we considered a problem of scheduling of carrying out energy-modernization with use of two types of energy saving actions for m of years, it can be generalized also prior to a final set of actions. But since the state programs for renovation (for example, the program "Capital repairs of common property in apartment buildings in the territory of Karachay-Cherkess Republic for 2014-2044 years") is carried out over a certain object at a time, we consider m = 1 year, And the criterion for splitting into stages is not a time factor, and the solution of the problem of allocation of funds at the 1st stage – between 2 measures, in the second stage it is necessary to optimally distribute between activities 1 + 2 and 3, etc.

If modernization works are planned in a residential building, they can be profitably combined with energy-saving measures. Additional costs for energy-saving investments are often a smaller amount. So, when updating the facade, the framework of the woods has to be established anyway. Then the surcharge for thermal insulation becomes comparatively less. In the future, this same event can cost much more expensive only because you will again need to install the framework of the woods. Saving energy pays off: additional investment will pay off due to lower energy costs.

A number of measures of the program "Capital repairs of common property in apartment buildings in the territory of the Karachay-Cherkess Republic for 2014–2044 years" can be combined with appropriate energy-saving actions, so repair of in-house engineering systems of electricity, heat, gas, water supply, water disposal – with ET2 , ET3, ET4, ET5, ET9, ЭТ10; repair of the roof, including the conversion of an unventilated roof to a ventilated roof, the device of exits to the roof – with ET7; repair of the facade with ET1, ET6, ET8. Financing of complex modernization is made by the saved-up funds of implementation of the state and regional programs of updating of housing stock of updating of housing stock of the housing stock and additional funds for energy modernization, collected own means of tenants, or taken on credit.

Using the results of the energy survey, numerical experiment and scientific research in the chosen direction, it is possible to estimate the investment potential of introducing energy-saving technologies with relatively consolidated indicators.

Using results of a numerical experiment and scientific research on the chosen direction, it is possible to estimate the investment potential of introduction of energy saving technologies with relatively enlarged parameters.

Let for carrying of actions energy modernization housing stock is allocated volume of money of C = 100 000 rub. Let us allocate 4 types of energy saving technologies with relatively enlarged indicators (n = 4). Types of energy saving technologies, which are established systemically, will be considered as a uniform measure. Actions, which can be interchangeable, are considered separately. Basic value has Selection of the major limiting factors. To them concern Amounts of works, financing restriction, the accounting of system of a variation of cost indexes of materials of works. As the most important information for development of model and its decision, we will choose a number of properties: types of actions, specific costs of their carrying out, tariffs for payment of utilities, energy saving and economic efficiency. In addition, we will plan creation of fund of reserve means, which will be used, on carrying out the repair construction works, which are not providing energy-savings, such as finishing works and works on updating of the territory around the considered objects and other works. Accumulation of means will go to the created fund as percent of means from economic effect of energy modernization of housing stock. And additionally, if the result involves the partial implementation of energy-saving measures, then the funds for their implementation are collected in this special fund.

Results of calculations are given in a type of schedules in the Figure 2.

	1	2	3	4
The economic effect	70654.6	25758	21192	4566
Deposits	100000	50000	40000	10000

Figure 2. Distribution of funds between with 4 ET

From these tables and graphs it is clear that any process of the energy modernization consisting of different quantity and quality of energy-saving measures can be based on indicators of the amount of investments by optimizing the allocation of funds that provide the maximum economic effect.

To carry out or not to hold these or those events solves the given management algorithm (figure 2), in the conditions of shortage of funds and relatively low efficiency, an event cannot be conducted. The use of methods of dynamic programming makes it possible to identify those measures that most effectively reduce the cost of housing and utilities and at the same time regulate the available funds for their joint implementation. Calculations were carried out on the basis of a survey of the technical condition of residential buildings in the city of Cherkessk (Table 1) and their energy-saving potential.

Table 1. The main characteristics of survey objects

№	Address	Year of commissioning Property	Type of wall material (House type)	Class of energy efficiency
1	Dovatora street, house number 72	1977	Brick	D
2	Dovatora street, house number 74	1974	Brick	E
3	Dovatora street, house number 76	1979	Claydite concrete panels	D
4	Dovatora street, house number 78	1974	Brick	E
5	Dovatora street, house number 80	1973	Brick	E
6	Dovatora street, house number 82	1980	Brick	D
7	Lobodina street, house number 57	1976	Claydite concrete panels	E
8	Lobodina street, house number 59	1975	Claydite concrete panels	E
9	Lobodina street, house number 59a	1986	Brick	D
10	Lobodina street, house number 61	1981	Claydite concrete panels	D

The Figure 3 given the calculated indicators of payback periods of energy saving measures.

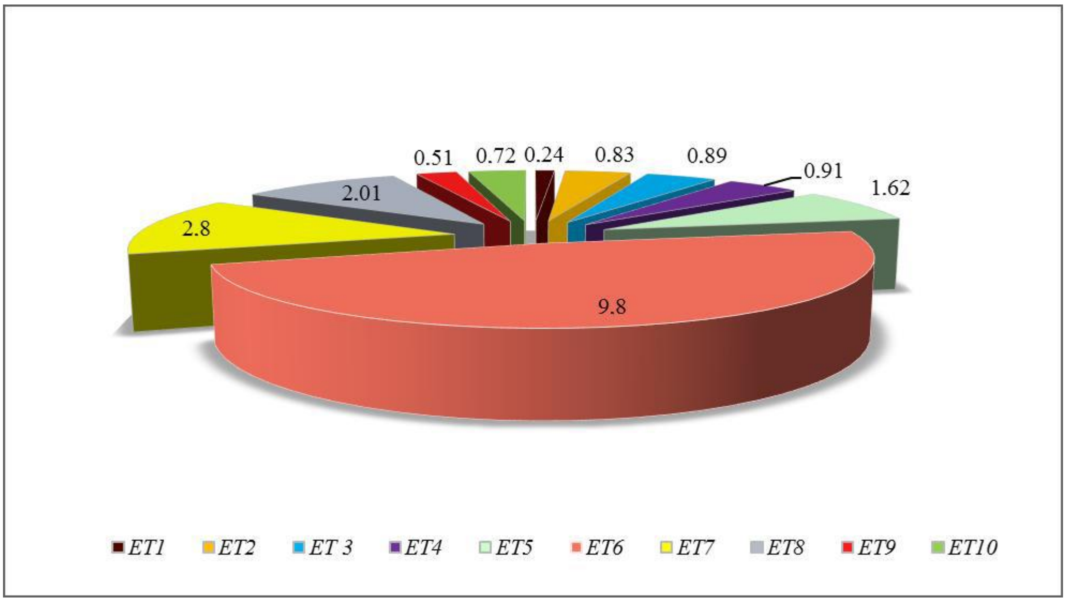


Figure 3. The payback period of energy-saving measures, year

The figure shows that the greatest payback period has kind of a comprehensive modernization housing – warming of external walls. For other technologies, we introduce a reserve fund in charge for the subsequent control, further updating and carrying out other construction works.

The above method of calculation is adequate, and at the expense of computer, technology has the property of efficiency. Dynamic programming techniques allow a certain error to calculate the maximum version of the "income" of the implemented technology.

Conclusions

1. The offered technique of assessment of efficiency of energy saving actions allows to increase quality of decision-making on restoration of housing stock, increase in its energy efficiency; application of

methods of mathematical modeling allows to realize the project of distribution of financial means in such a way that implementation of organizational-technology solutions of consecutive performance of actions will result to maximum possible positive socio-economic effect.

2. Executed economic evaluation of energy saving solutions in the process of a comprehensive energy-modernization, are given results of calculations of distribution of the allocated funds and deadlines of recoupment of holding actions for increase in indicators of energy saving which make 1–3 years for ET1–5, ET 7–10, for ET 6 up to 10 years.

3. Is offered the mathematical model allowing to maximize the number of quality housing due to realization of energy saving and other actions at complex modernization of housing stock.

4. Formulated and considered the theoretical aspects of dynamic programming for solving problems of optimal allocation of allocated funds with minimal loss, which allows calculating the conditions for the implementation of energy-modernization.

5. Is offered the multi-step procedure evaluating the economic efficiency of resource allocation when implementing of energy saving technologies in the process of updating the housing stock. The integrated use of information technology and mathematical descriptions of the processes allows obtaining complex information about the property at different stages of their life cycle, their actual condition and the necessity of modernization and reconstruction. Their joint use during the entire life cycle of buildings will lead to the optimal management of objects, maximizing an economic benefit and, respectively, to social effect.

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