# MODELS AND INFORMATION TECHNOLOGY OF ENERGY-EFFICIENT DEVELOPMENT OF THE REGION

The report was written within the framework of the state task of the Ministry of Education and Science of the Russian Federation No. 26.4131.2017/ PCh, the project "Development of methods and information technologies for macroeconomic modeling and strategic planning of the energy-efficient development of the fuel and energy complex of the subject of the Russian Federation".

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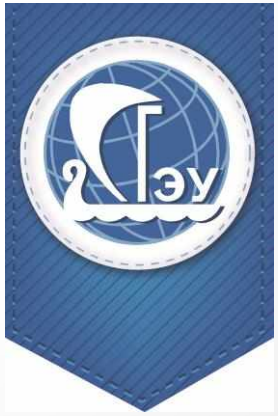


**Economic development must be energy-efficient.**

**Energy efficiency and the "energy efficiency first" principle are at the heart of the Energy Union strategy**

**The European Energy Commission has defined the content and objectives of the energy-efficient development of the EU for 2020 and 2030.**

**It is planned to increase energy efficiency at all stages of the energy chain, from generation to final consumption.**

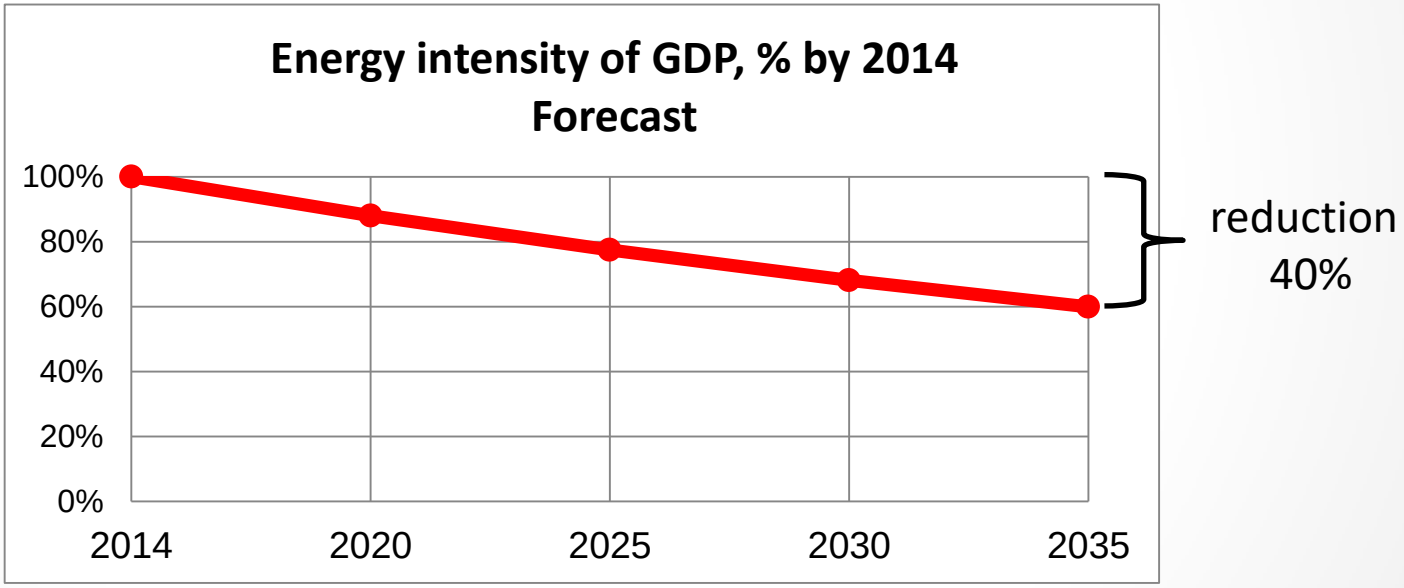
**At the same time, the benefits of energy efficiency should outweigh costs.**

"A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy", COM(2015) 80 final, 25 February 2015.

**According to the Energy Strategy of Russia, the energy-efficient development of the region means:**

- **reduction of unit costs for fuel and energy resources (FER) production;**
- **increase in production of basic energy resources;**
- **increase in primary energy exports;**
- **reduction of greenhouse gas emissions;**
- **decrease in energy intensity of gross domestic product (GDP);**
- **other**

**According to the Energy Strategy of Russia –**
**energy intensity of GDP is the most important indicator**
**of energy efficient regional development**



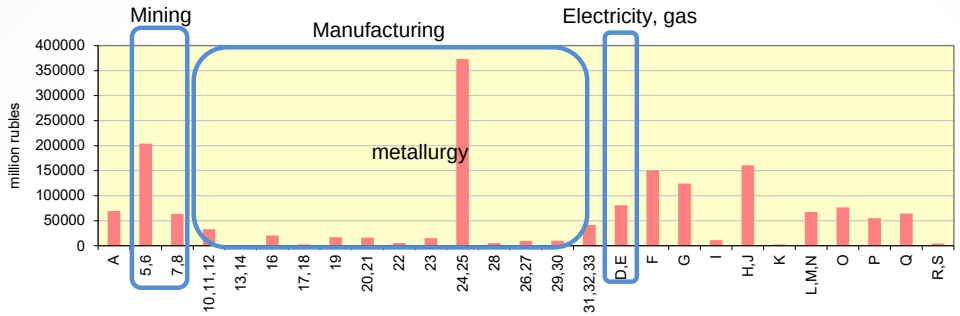

Source: Проект энергостратегии Российской Федерации на период до 2035 года (редакция от 01.02.2017). URL: http://minenergo.gov.ru/node/1920

**It is worth noting that the requirement to reduce energy intensity of GDP may contradict the decision to develop energy-intensive industries**

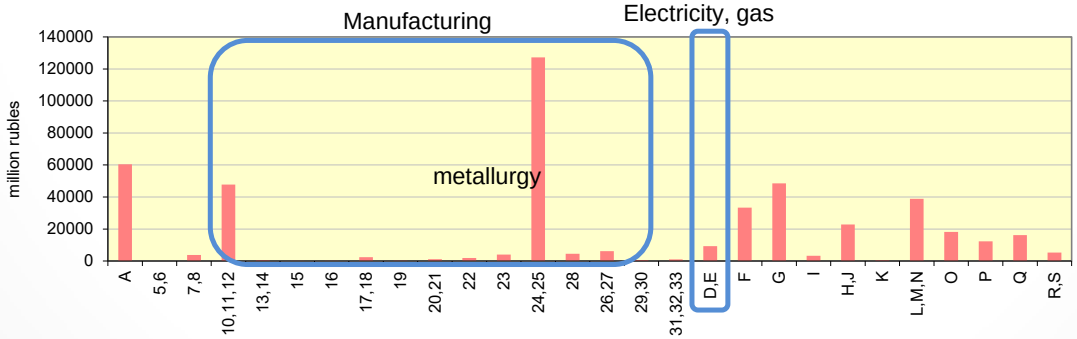
**This fully applies to resource-producing and energy-producing regions of Russia, such as, for example, Krasnoyarsk region, Lipetsk region, etc.**

**In fact, the best energy-efficient indicators are achieving in the transition from energy-intensive industries to services, which is impossible for many Russian regions because of the existing structure of the Russian fuel and energy complex.**

## GDP of Krasnoyarsk region




## GDP of Lipetsk region



**Energy efficiency indicators are also heavily influenced by changes in energy prices, and these changes can be both effective for the regional economy as a whole and ineffective.**

**Therefore, the objectives for the energy-efficient development of the subject of the Russian Federation should be balanced with the objectives of the regional social and economic development.**

**That is, the efficiency of energy solutions must be linked to the overall economic efficiency of regional development**

# The formal statement of the problem

The authors denote the general system of indicators of the regional development:

$$E = [E_{econ}, E_{ener}]^T, \quad (1)$$

where $E_{econ}$ - the vector of indicators that characterizes the socio-economic development of the region, namely: the level of human welfare and the potential of the regional economy;

$E_{ener}$ - the vector of energy indicators, characterizing the development of the regional economy in terms of energy efficiency.

The authors denote:

$$E^0(t) = [E^0_{econ}(t), E^0_{ener}(t)]^T \text{ - } \quad (2)$$

the vector of target values set for development indicators on the horizon of strategic planning $[0, t_T]$ at points $t = t_1, t_2, ...t_T$, and, the vector of target values for energy indicators $E^0(t)$ is the task plan for the energy-efficient development.

Formally, the task of the energy-efficient development of the region (the subject of the Russian Federation) can be reduced to the following task of multi-criteria optimization:

$$\left\| E(U,t) - E^0(t) \right\| \to \min_{U(t) \subset D_U} ; \quad (3)$$

$$E(U,t) = M_O(R,U,t); \quad (4)$$

$$dR(t)/dt = M_R(R,U,t); \quad (5)$$

$$R(t) \subset D_R(U,t); \quad (6)$$

$$t = t_1, t_2, ...t_T$$

In this case:

$U(t)$ - the vector of parameters for the development of the regional economy;

(4) - is the observation model that allows calculating estimates of the values of indicators for the scenario for the economic development of the regional economy and the fuel and energy complex (FEC):

(5) - the model of the region;

$R = [r_1, r_2, ..., r_m]^T$ - the vector of regional resources;

$D_R(U,t)$ - resource constraints.

The authors denote the vector of parameters for the development of the regional economy as two scenarios:

$$U(t) = \begin{bmatrix} U_{econ}(t) \\ U_{FEC}(t) \end{bmatrix}, \quad U(t) \subset D_U , \tag{7}$$

where $U_{econ}(t)$ - the vector of parameters for the development of the regional economy without FEC (the scenario for the economic development);

$U_{FEC}(t)$ - the vector of parameters for the development of the FEC (the scenario for the development of the FEC);

$D_U$ - scenario constraints (the space of managerial decisions)

# Private tasks

**To solve this problem, the following private subtasks were solved:**

**1. The development of the system of target indicators for the energy-efficient development of the region:**

$$E = [E_{econ}, E_{ener}]^T$$

$E_{econ}$ **- indicators of the growth of human welfare and the potential of the economy;**

$E_{ener}$ **- energy indicators characterizing the efficiency of production processes, conversion, distribution and final consumption of all types of fuel and energy resources**

**2. The development of information technology that ensures the formation of the reporting regional fuel and energy balance (TEB)**

**3. The development of the model for the regional fuel and energy sector as a dynamic multi-sectoral model in the composition model of the economy of the Russian Federation subject**

**4. The development of information technology that ensures iterative coordination of scenario forecasts of energy consumption and production of energy resources in the region by main types of fuel and energy**

**5. The development of tools to find scenarios for the development of fuel and energy and the economy of the region, in which the maximum approximation to the goals characterizing the development of the regional economy as energy efficient is achieved**

# 1. The proposed system of indicators

$$E=[E_{econ}, E_{ener}]$$

**The system of economic indicators $E_{econ}$ is formed on the basis of modern ideas about the essence of the category of "welfare", set out in the materials of the report of the Stiglitz-Sen-Fitoussi' commission*.**

**The proposed system of economic indicators contains 2 groups of indicators characterizing human welfare and the potential of the regional economy**

*Stiglitz, J.E., Sen, A. and J. Fitoussi. 2009. "Report by the Commission on the Measurement of Economic Performance and Social Progress," CMEPSP available at: http://ec.europa.eu/environment/beyond_gdp/download/CMEPSP-final-report.pdf

# Indicators of economic development

| Direction | Indicators |
|---|---|
| **1. Human welfare** | 1. The growth of real cash income of the population per capita,% to the base year.<br>2. The replacement ratio for pension income,%.<br>2. The proportion of the population with incomes below poverty line,%.<br>4. The decile coefficient of income differentiation.<br>5. The total area of residential units per resident, sq. m.<br>6. The total fertility rate, people.<br>7. The infant mortality rate, per mil.<br>8. Life expectancy at birth, years.<br>9. Provision of preschool educational institutions, places for 1000 children of preschool age.<br>10. The number of recorded crimes per 100 thousand people.<br>11. Expenditure on education, in % relative to regional GRP. |
| **2. Reproductive potential of the region's economy** | 12. The share of employed in the economy from the number of labor resources, %.<br>12. The unemployment rate (according to ILO methodology), %.<br>14. The degree of depreciation of fixed assets at the end of the year, %.<br>15. The share of intermediate consumption in output of goods and services, %.<br>16. The share of high-tech and science-intensive products in GRP, %.<br>17. The growth of exports (including FER) relative to the base year, %.<br>18. The share of own revenues in the structure of the regional budget, %<br>19. The regional budget deficit, %.<br>20. The public debt of the region, in % relative to GRP. |

**The energy indicators $E_{ener}$ used in this research are considered in terms of production and consumption of fuel and energy resources (FER).**

**The producer of fuel and energy is the regional fuel and energy complex (FEC).**

**Consumers of FER are represented by the following subjects of the regional economy:**

**- The real sector of the economy (without FEC);**

**- The non-market services sector;**

**- Households.**

# The system of energy indicators

| Subjects | Energy intensity | Energy saving | Energy security |
|---|---|---|---|
| **1. Regional Fuel and Energy Complex** | 1. Energy intensity of the FEC, % of the base year.<br><br>2. Specific fuel consumption for electricity supply, kgoe / kW-h.<br><br>2. Specific fuel consumption for heat output , kgoe / Gcal | 1. Specific losses of the fuel and energy complex, % of FER.<br><br>2. Electricity losses in electric grids from the total volume of electricity supply, %.<br><br>2. Losses in heat networks, % of heat production. | 1. Increase in the production of basic energy resources (%of the base year):<br>- primary energy:<br>hydro energy,<br>oil, gas,<br>- resources produced:<br>mineral oils;<br>electricity;<br>thermal energy.<br>2. Capacity utilization of fuel and energy enterprises,%<br>3. Depreciation of fixed capital in the FEC,%.<br>4. The rate of fixed capital formation in the FEC<br>5. Share of renewable energy sources in TER production,%.<br>6. The ratio of exports of energy products to the production of fuel and energy resources in the region, %. |
| **2. The real sector of the economy (without FEC)** | 1. Energy intensity of the real sector of the economy, % of the base year.<br>2. Energy intensity of the main types of economic activity, % of the base year:<br>- Agriculture<br>- Mining and quarrying<br>- Manufacturing<br>…… | 1. Energy savings in the real sector of the economy, in % of its consumption in the base year.<br>2. Heat energy saving in the real sector of the economy, in % of its consumption in the base year. | 1. Emissions of pollutants into the atmospheric air, % of the base year |

# The system of energy indicators(continuation)

| | Energy intensity | Energy saving | Energy security |
|---|---|---|---|
| **2. Non-market services sector** | 1. Energy intensity of non-market services sector, % of the base year | 1. Energy savings in the non-market services sector, in % of its consumption in the base year.<br>2. Heat energy saving in the non-market services sector, in % of its consumption in the base year. | 1. The budget expenses for consumption of fuel and energy resources, % of expenses of the regional budget. |
| **4. Household** | 1. The consumption of energy resources per capita, in % to base year<br>2. Electricity consumption per capita, % of the base year.<br>2. Specific energy consumption for heating of residential buildings (Gcal./ m2), % of base year | 1. Share of household expenditures for fuel and energy resources total expenditure, %<br>2. Energy savings in households, in % of its consumption in the base year.<br>2. Saving of heat energy in households, in % of its consumption in the base year. | 1. The ratio of household expenditures on fuel and energy to the subsistence minimum,%.<br>2. Share of dilapidated, obsolete, worn out residential buildings,%. |
| **5. Region in general** | 1. Energy intensity of GRP, % of the base year.<br>2. Electrical capacity of GRP, % of the base year.<br>2. The specific heat of GRP, % of the base year.<br>4. The integral coefficient of energy efficiency (the proportion of useful energy). | 1. The ratio of fuel and energy saving to the cost of energy-saving measures,%.<br>2. Energy savings in the region, in % of its consumption in the base year.<br>2. Saving of heat energy in the region, in % of its consumption in the base year | 1. Provision of the regional economy with its own energy resources,%.<br>2. Share of dominant fuel in gross consumption of fuel and energy resources, %.<br>2. The ratio of the volume of import of energy products to the total volume of energy resources consumption in the region, %. |

# 2. Economic and energy models

# The sectors and types of economic activity of the FEC

The energy model is presented by the model of the fuel and energy complex uniting branches of economy, producing and distributing fuel and energy resources according NACE

| The sectors of the FEC | Type of economic activity by NACE codes |
|---|---|
| **Sector: Extraction and production of fuel** | B.05 - Mining of coal and lignite<br>B.06 - Extraction of crude petroleum and natural gas<br>B.09 - Mining support service activities.<br>C.19 - Manufacture of coke and refined petroleum products<br>D.35.2 - Manufacture of gas; distribution of gaseous fuels through mains. |
| **Sector: Production of electricity and heat** | D.35.1 - Electric power generation, transmission and distribution.<br>D.35.3 - Steam and air conditioning supply |
| **Sector: Pipeline transport** | H.49.50 - Transport via pipeline |

# The fuel and energy complex of the Samara region

**Sector: Extraction and production of fuel**

**Extracting enterprise**

ЛиндеГазРус, ООО
Лукойл Волга
Лукойл Бурение
Самара-Нафта
СамараНефтеГаз

**Processing plant**

Сызранский НПЗ - Первичная переработка нефти и конденсата
Куйбышевский НПЗ - Первичная переработка нефти и конденсата
Новокуйбышевский НПЗ - Первичная переработка нефти и конденсата
Нефтегорский ГПЗ
Отрадненский ГПЗ

**Sector: Production of electricity and heat**

**Power plants, thermoelectric power station and boilers**

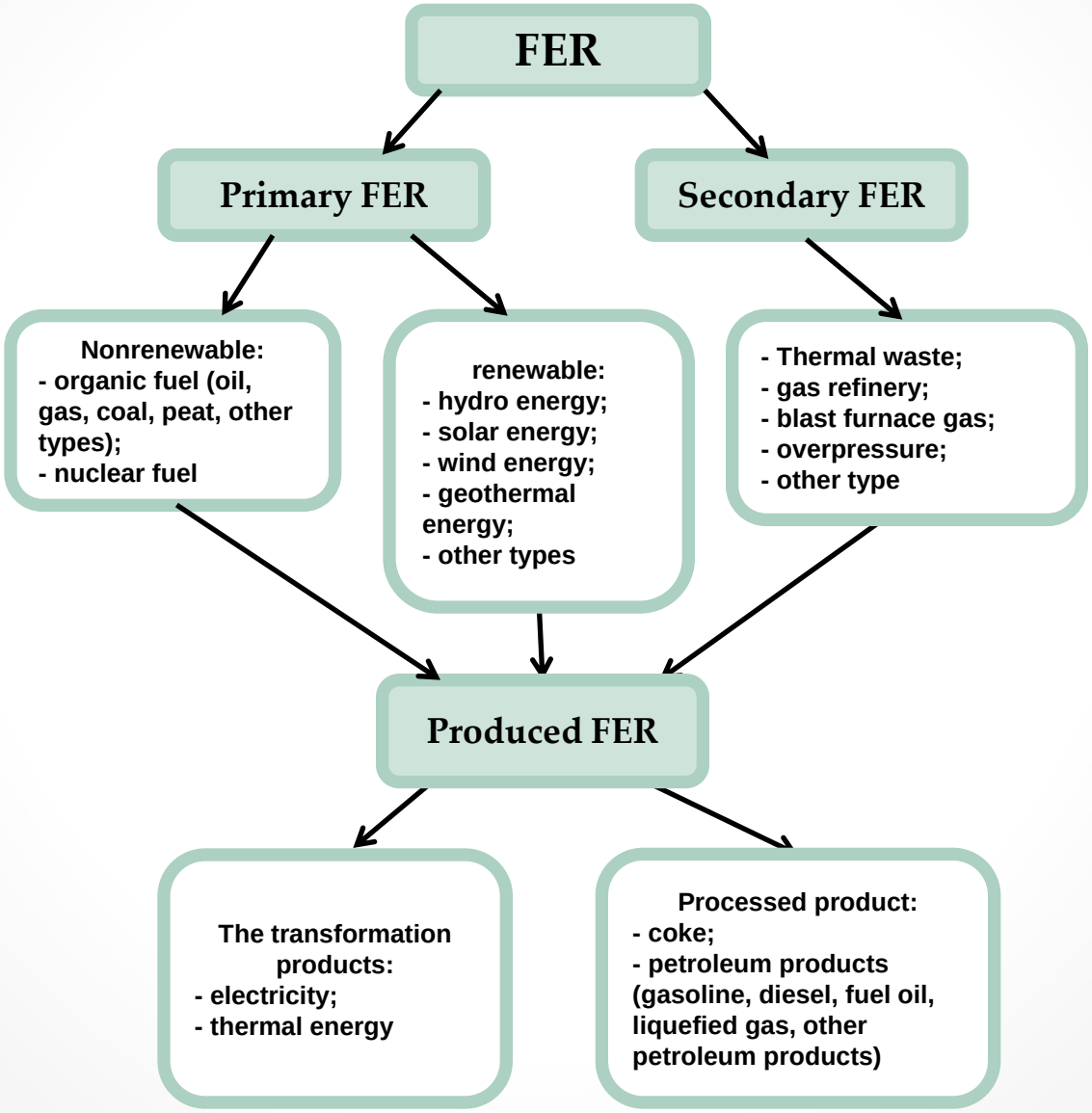
Жигулевская ГЭС
ТЭЦ ВАЗа в эксплуатации
Тольяттинская ТЭЦ
Новокуйбышевская ТЭЦ-1
Новокуйбышевская ТЭЦ-2
Самарская ТЭЦ
Сызранская ТЭЦ
Безымянская ТЭЦ
Самарская ГРЭС
ТЭЦ ОАО "Куйбышевский НПЗ"
Сызранская ГЭС
Тольяттинская ТЭЦ
Муниципальные котельные

**Sector: Pipeline transport**

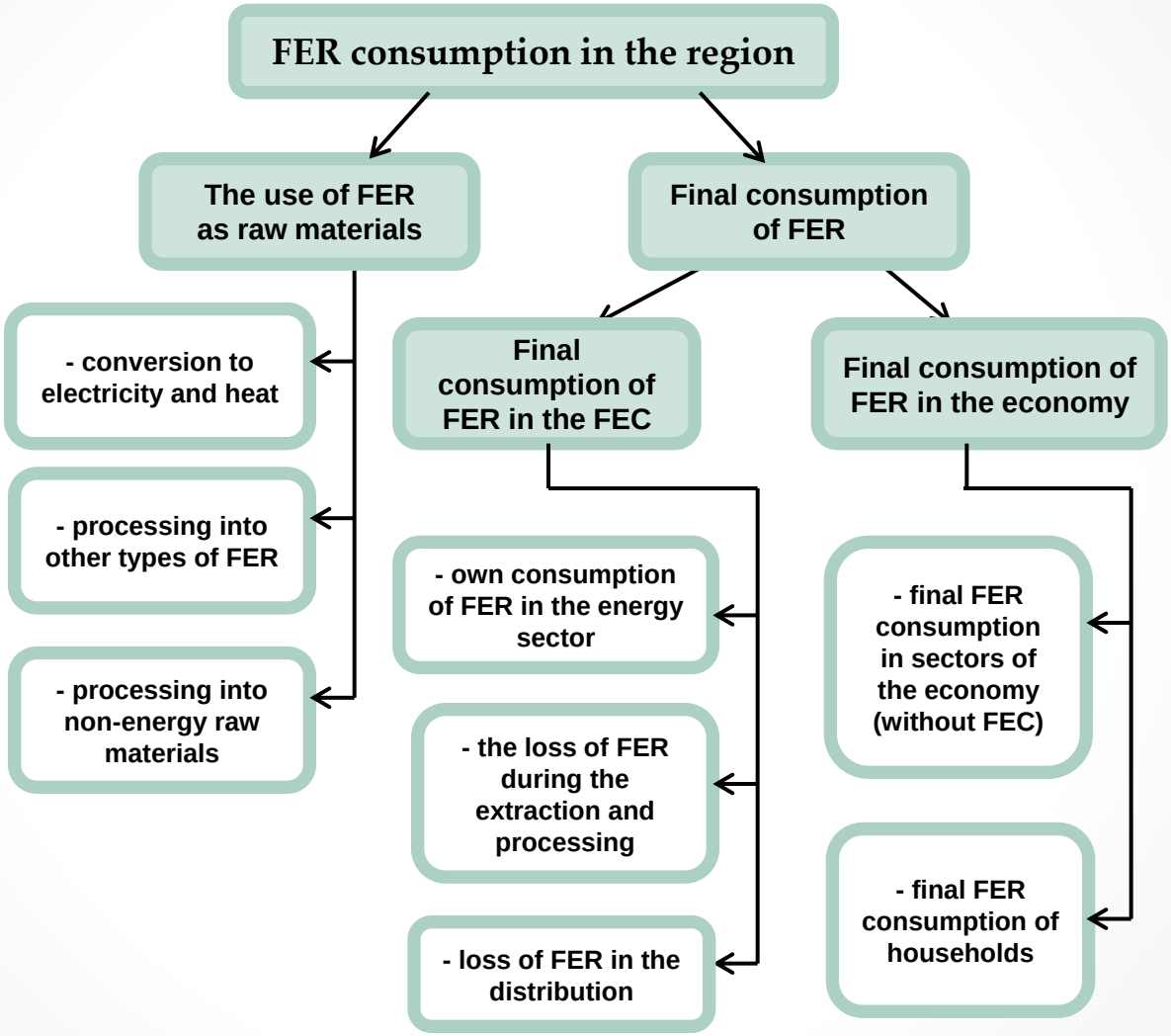
**Pipelines**

Магистральные нефтепроводы "Дружба", АО
Приволжский нефтепровод
Транснефть
Транснефть-Приволга, АО
Самаратрансгаз, ООО (ОАО «Газпром»)
Газпром энергохолдинг, ООО

# Classification of fuel and energy resources (FER)



# Use of fuel and energy resources (FER)



**Since the FEC is closely connected with other sectors of the economy, the FEC model is developed as a part of the General model of socio-economic activity of the region.**

**The model of social and economic activity of the region is developed *in the class of CGE models*.**

**In this model, the regional economy is divided into a set of economic agents along the boundaries of sections and major classes of economic activity of NACE codes adding such agents as:**

**"households",**

**"government authorities ",**

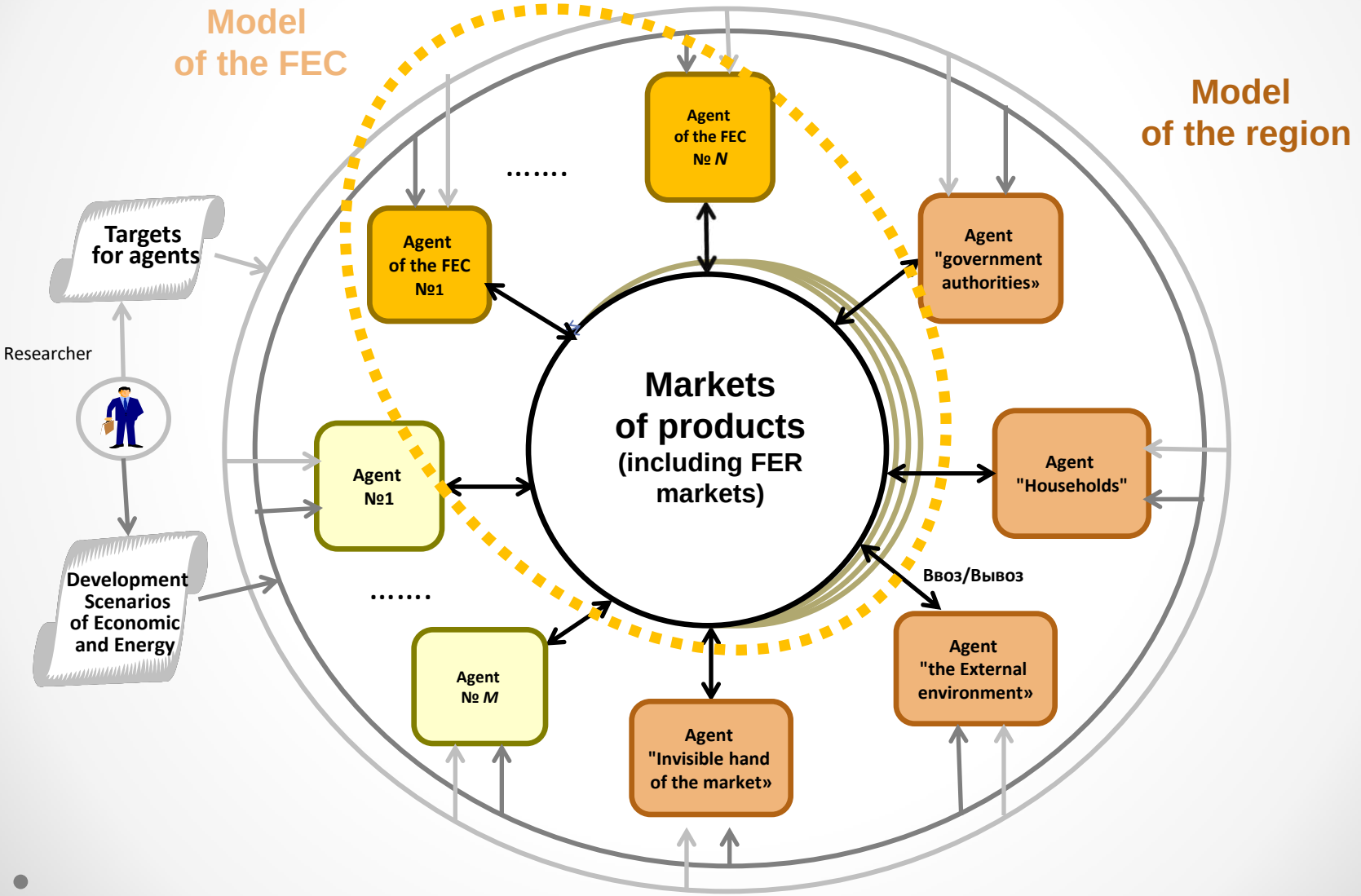
**"external environment», and the agent**

**"invisible hand of the market", responsible for the equilibrium of supply and demand in product markets.**

**Agents produce one or more products from the basic set that are sold within the region or exported.**

**At the same time, agents acquire necessary intermediate products (including necessary energy resources) and production factors both within the region and import, taking into account resource and budgetary constraints.**

# Fuel and energy complex (FEC) model as part of the region model



# Basic set of conditional products

**The following basic set of conditional products is used in the regional model:**

**1 - intermediate goods and services**
- raw materials
- fuel and energy products
- financial intermediation services

**2 - investment goods and services**

**3 - consumer goods and services**
- food products
- nonfood goods
- fuel and energy products for the population
- paid service

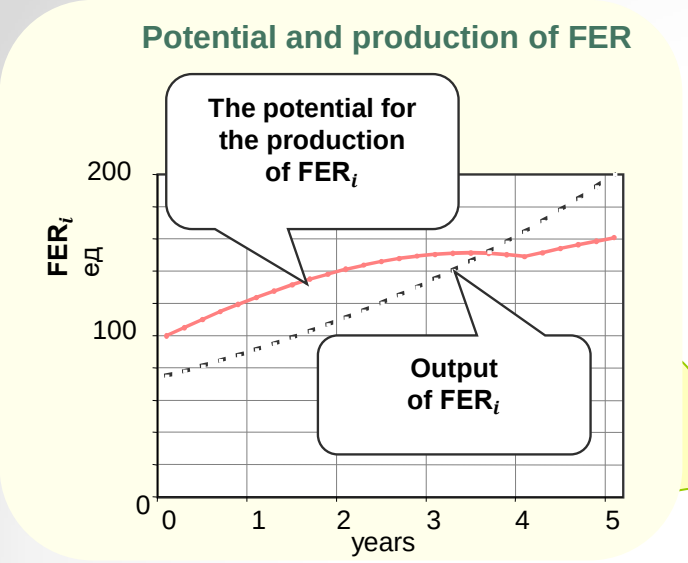
**4 - infrastructure services**

**5 - public services**

**6 - labor services**

# Model of an agent that is part of the FEC

(production of primary FER)




Cost elasticity of all types of fuel and energy resources for production and tariffs

Primary FER

FER market

FER for their own needs

non-energy products

The production function of the industry

Primary FER

FER market

Input of fixed capital

Investment products market

Fixed capital

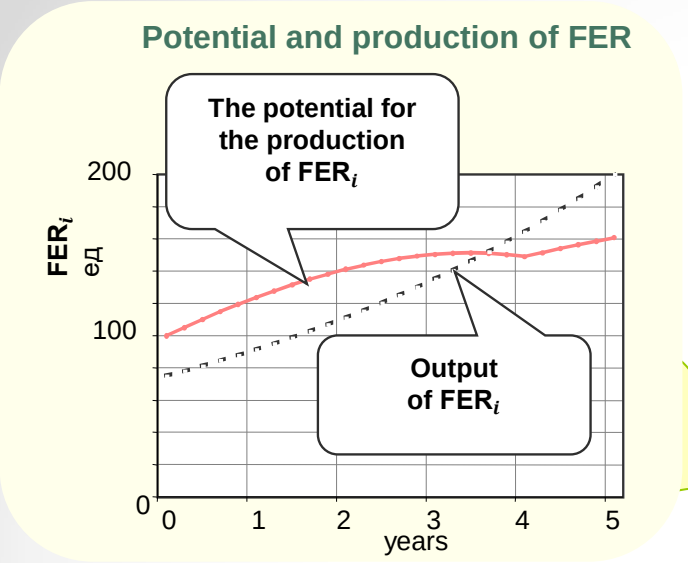
Labor

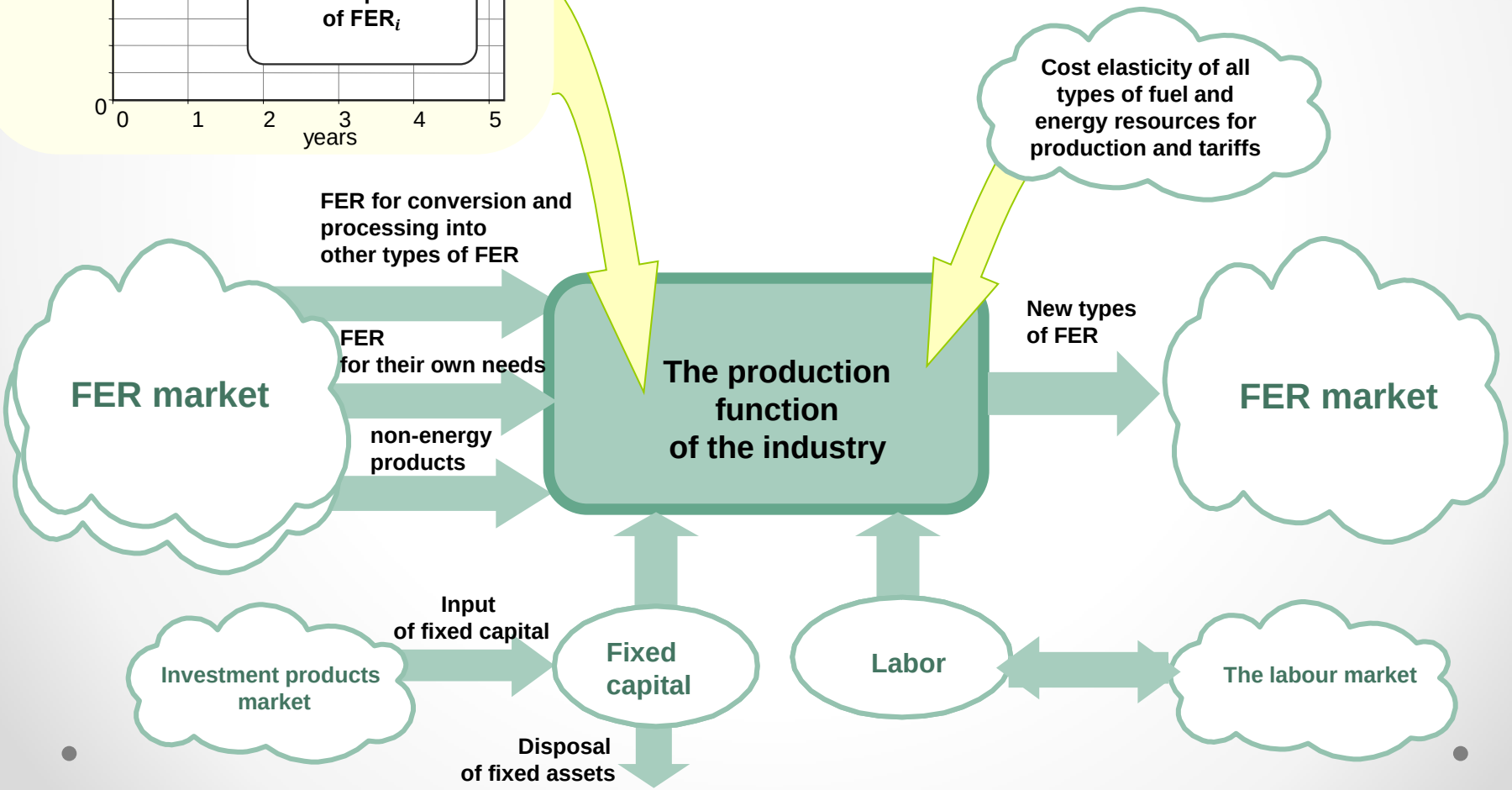
The labour market

Disposal of fixed assets

# Model of an agent that is part of the FEC

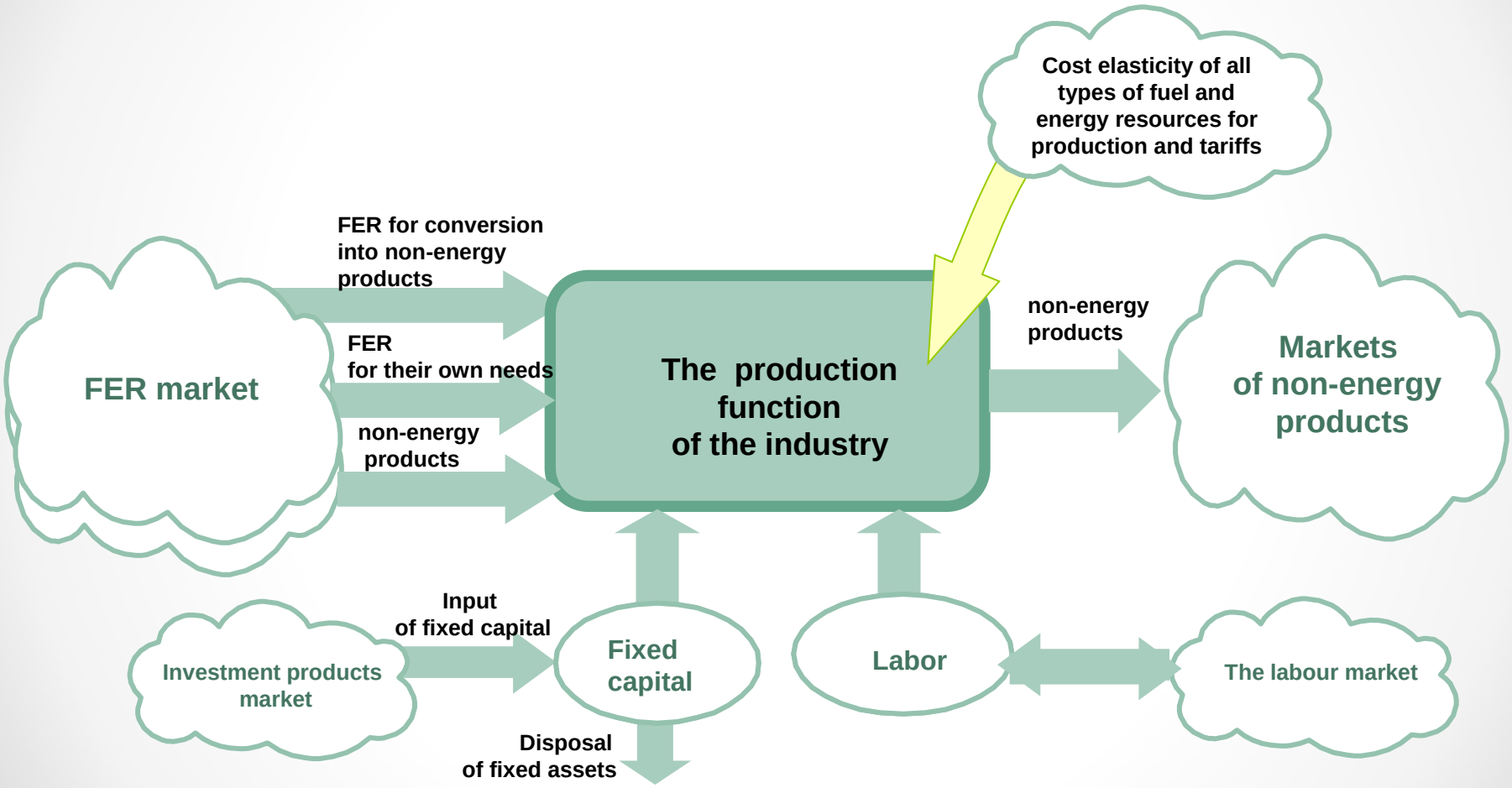
(convert fuel to electricity and heat, processing fuel into other fuels)



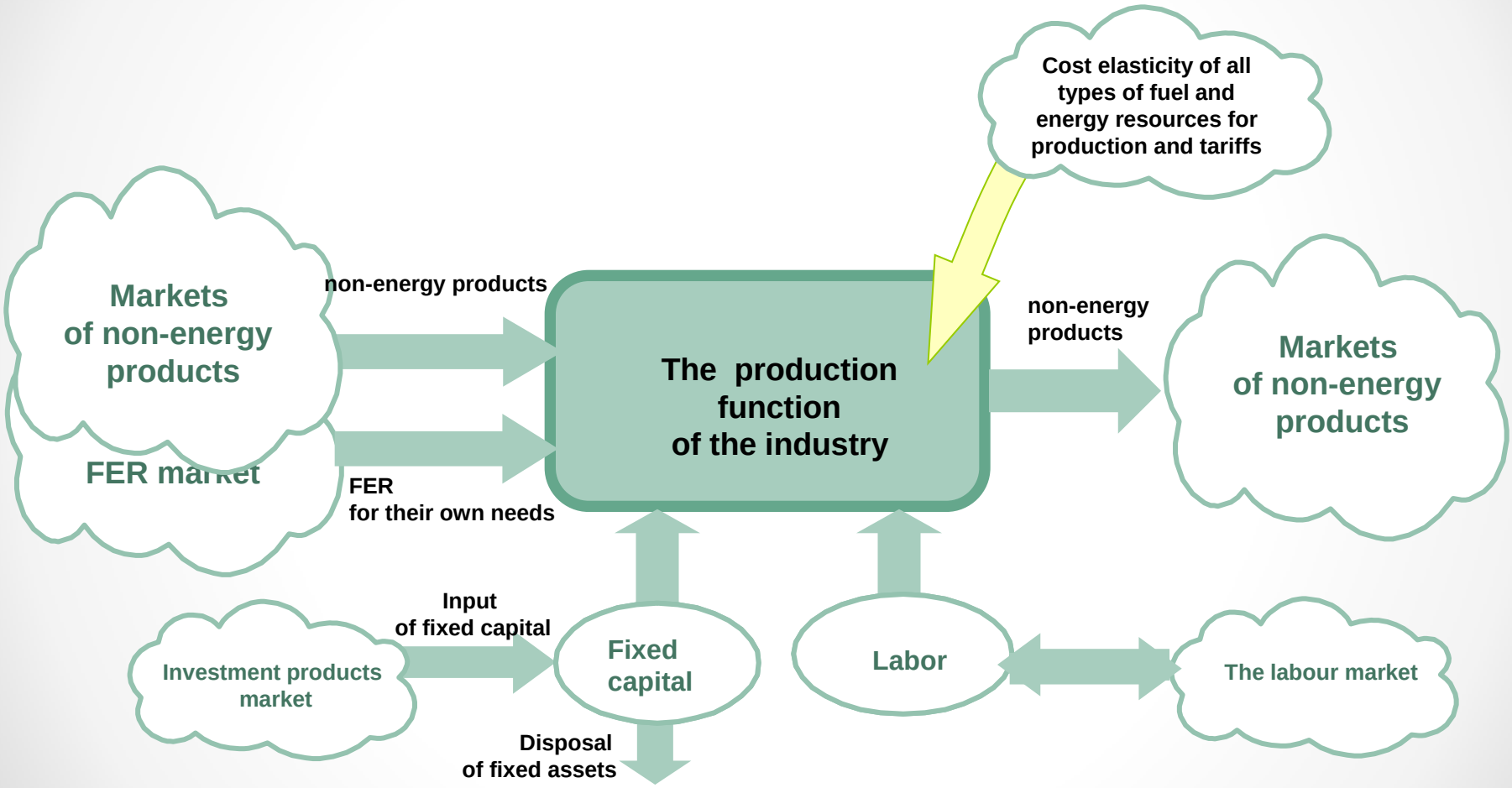
# Model of an agent that is not part of the FEC

(FER conversion into non-energy products)

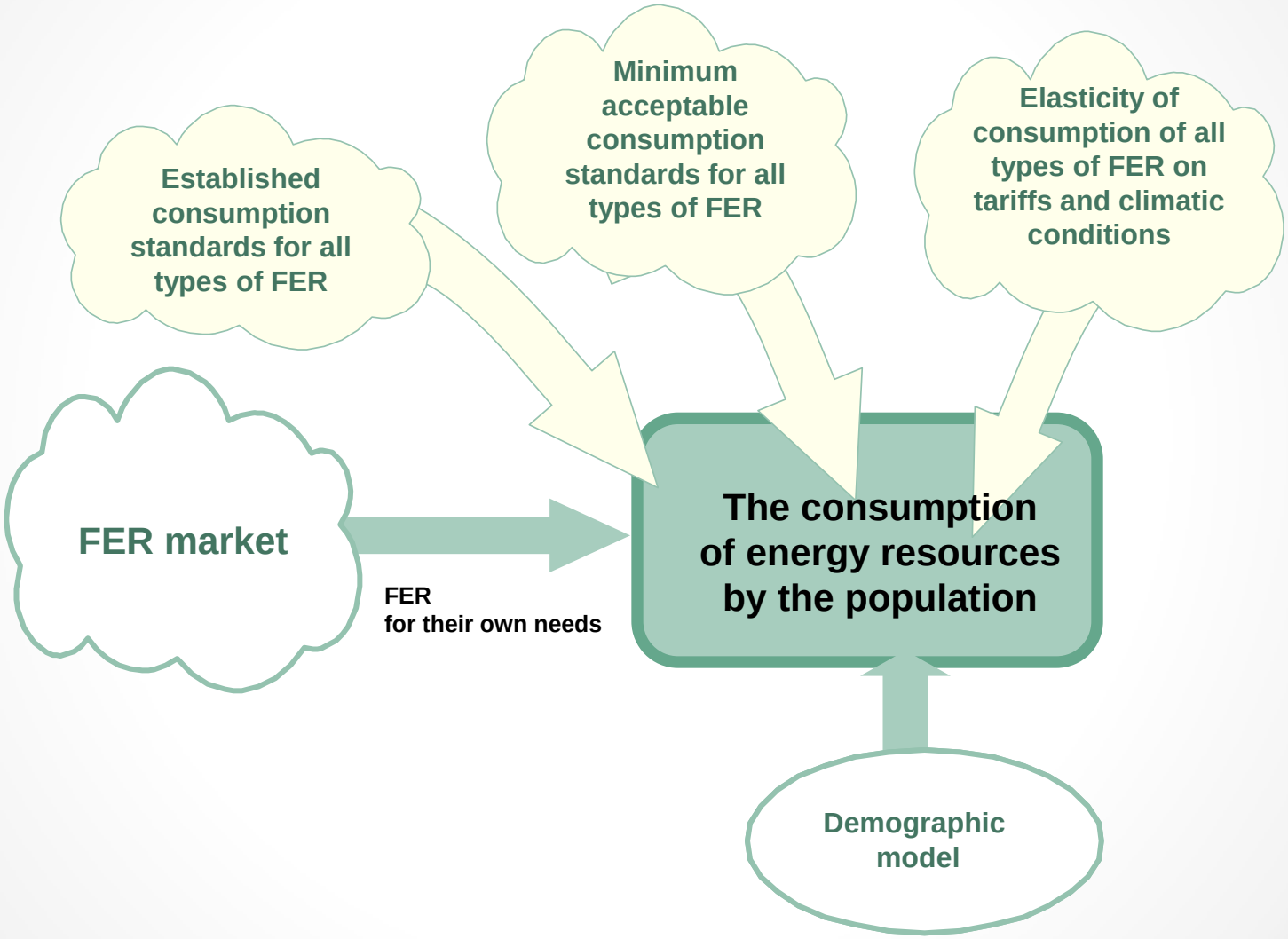


# Model of an agent that is not part of the FEC

(non-energy types of economic activities)



# Model of energy resources consumption by the population



# 3. Information technology of forming fuel and energy balance of the subject of the Russian Federation

# Methodological basis of TEB construction

**1 – methodological developments and terminology of Rosstat**

**Об утверждении официальной статистической методологии составления топливно-энергетического баланса Российской Федерации»** ФЕДЕРАЛЬНАЯ СЛУЖБА ГОСУДАРСТВЕННОЙ СТАТИСТИКИ. ПРИКАЗ от 4 апреля 2014 года N 229

**2 - methodological developments of the Ministry of energy**

**Приказ Министерства энергетики РФ от 14 декабря 2011 г. N 600**
**"Об утверждении Порядка составления топливно-энергетических балансов субъектов Российской Федерации, муниципальных образований» . С изменениями и дополнениями от 19 ноября 2015 г.**

**3 – approaches to TEB construction used in the European Commission for energy**

**4 - methodological recommendations of Eurostat and the International Energy Agency (IEA)**

**5 - approaches to balance sheet preparation used at the Institute of Energy research of the Russian Academy of Sciences**

**6 – experience of Samara region and Krasnoyarsk region**

# One-product balance

| № | Balance sheet item |
|---|---|
| 1 | **1. Gross supply of FER** |
| 2 | Production (extraction) of FER |
| 3 | Stock change |
| 4 | Import |
| 5 | Export |
| | |
| 6 | **2. The total consumption of FER in the region** |
| 7 | 2.1. Conversion and processing |
| 8 | 2.1.1. Convert fuel to electricity and heat |
| | *among them:* |
| 9 | In thermoelectric power station |
| 10 | In boiler plant |
| 11 | 2.1.2. Conversion fuel to other fuels |
| 12 | 2.1.3. Use of FER as raw materials and for non-fuel needs |
| 13 | 2.2. Final consumption of FER in the region |
| 14 | 2.2.1.Final consumption of the FER at the FEC |
| 15 | Own consumption |
| | *among them:* |
| 16 | electroenergetics |
| 17 | fuel industry |
| 18 | pipeline transport |
| 19 | Extraction and production losses |
| 20 | Distribution losses |
| 21 | 2.2.2.Final consumption (without FEC), |
| | *among them:* |
| 22 | agriculture |
| 23 | mining and quarrying (except FER) |
| 24 | manufacturing (except FER) |
| 25 | water supply |
| 26 | construction |
| 27 | transport (without pipeline) |
| 28 | other |
| 29 | household |

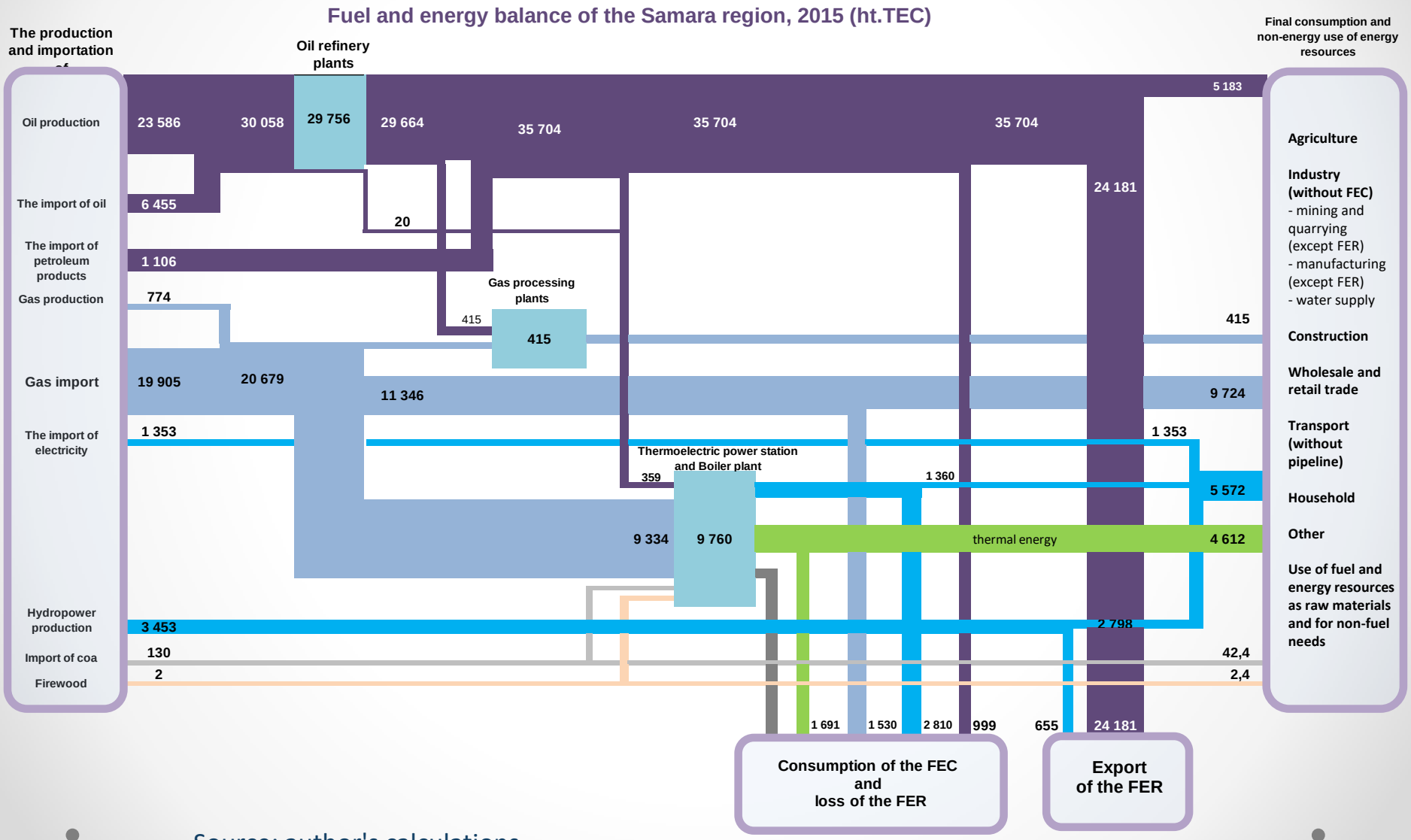
# Combined fuel and energy balance of the
## Samara region, 2015

**Consolidated fuel and energy balance of the region** — **2015 year**

| № | Balance sheet item | Solid fuel | | | | Oil | Natural gas | Petroleum gas | Hydro energy | Нефтепродукты | | | | | | | Electric energy | Thermal energy | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | total | в том числе: | | | | | | | total | в том числе: | | | | | | | | |
| | | | Coal | Coke | Firewood | | | | | | Gasolines | Diesel fuel | Masut | Petroleum gas | Liquefied gas | Other petroleum products | | | |
| | | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC | th. TEC |
| 1 | Production of primary energy resources | 2,0 | 0,0 | 0,0 | 2,0 | 23 586,0 | 774,0 | 1 025,7 | 3 452,9 | | | | | | | | | | |
| 2 | Import | 130,2 | 91,7 | 38,5 | 0,0 | 6 455,2 | 19 905,3 | 0,0 | | 1 106,4 | 514,4 | 234,1 | 249,5 | 0,0 | 108,4 | 0 | 1 352,9 | | |
| 3 | Export | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | -24 180,5 | -4 385,3 | -8 654,0 | -8 911,8 | 0,0 | 0,0 | -2 229,5 | -655,2 | | |
| 4 | Stock change | 1,4 | 0,5 | 0,4 | 0,5 | 16,9 | 0,0 | 0,0 | 0,0 | 98,3 | 27,9 | 14,6 | 60,8 | 0,0 | -5,0 | 0,0 | | | |
| 5 | ***Gross supply of energy resources*** | **133,5** | **92,2** | **38,9** | **2,5** | **30 058,2** | **20 679,3** | **1 025,7** | **3 452,9** | **-22 975,8** | **-3 843,0** | **-8 405,3** | **-8 601,4** | **0,0** | **103,4** | **-2 229,5** | **697,7** | **0,0** | **33 071,4** |
| 6 | Statistical discrepancy | -3,3 | -3,3 | 0,0 | 0,0 | 37,3 | 92,1 | | | -3,3 | 0,0 | -0,6 | 1,3 | 0,0 | -1,6 | -2,4 | 0,0 | 0,0 | 122,8 |
| | ***Transformation of primary resources*** | **-92,0** | **-73,2** | **-18,7** | **0,0** | **-29 876,1** | **-10 863,2** | **-1 025,7** | **0,0** | **28 010,7** | **4 927,4** | **9 020,5** | **9 157,7** | **1 193,0** | **759,9** | **2 952,3** | **1 421,6** | **4 611,65** | **-7 813,0** |
| 7 | Electricity production | -23,7 | -23,7 | 0,0 | 0,0 | 0,0 | -4 140,6 | 0,0 | 0,0 | -6,0 | -0,7 | -4,4 | -0,9 | 0,0 | 0,0 | 0,0 | 4 232,1 | | 61,9 |
| 8 | Heat production | -43,4 | -43,3 | 0,0 | 0,0 | -19,8 | -5 193,0 | -712,8 | 0,0 | -333,3 | 0,0 | 0,0 | -100,4 | -229,7 | -3,3 | 0,0 | | 5 872,9 | -429,4 |
| 8.1 | Thermoelectric power station | -21,3 | -21,3 | 0,0 | 0,0 | 0,0 | -2 577,2 | 0,0 | 0,0 | -0,9 | 0,0 | 0,0 | -0,9 | 0,0 | 0,0 | 0,0 | | 2 599,4 | 0,0 |
| 8.2 | Boiler plant | -22,1 | -22,0 | 0,0 | 0,0 | -19,8 | -2 615,8 | -712,8 | 0,0 | -332,4 | 0,0 | 0,0 | -99,5 | -229,7 | -3,3 | 0,0 | | 2 990,1 | -712,8 |
| 8.3 | Electric boiler and heat recovery units | | | | | | | | | | | | | | | | | | 0,0 |
| 9 | The conversion of fuel | -19 | 0 | -19 | 0 | -29 756 | 0 | 0 | 0 | 29 249 | 4 961 | 9 081 | 9 358 | 1 423 | 1 048 | 3 378 | | | -525,9 |
| 9.1 | Oil processing | | | | | -29 756 | | | | 29 664,2 | 4 960,8 | 9 080,9 | 9 358,1 | 1 422,6 | 1 463,9 | 3 378,0 | | | -91,7 |
| 9.2 | Gas processing | | | | | | | | | -415,4 | | | | | -415,4 | | | | -415,4 |
| 9.3 | Coal (coke) enrichment) | -19 | 0,0 | -19 | | | | | | | | | | | | | | | -18,7 |
| 10 | Own needs | -2,9 | -2,9 | 0,0 | 0,0 | -20,5 | -1 508,9 | 0,0 | 0,0 | -822,8 | -29,3 | -50,8 | -94,5 | 0,0 | -221,8 | -426,4 | -2 134,4 | -851,3 | -5 340,9 |
| 11 | Distribution losses | -3,3 | -3,3 | 0,0 | 0,0 | -79,8 | -20,7 | -312,9 | 0,0 | -75,9 | -3,3 | -5,3 | -4,5 | 0,0 | -63,4 | 0,7 | -676,1 | -409,9 | -1 578,6 |
| 12 | ***Final consumption of energy resources.*** | **44,8** | **22,3** | **20,1** | **2,4** | **144,7** | **9 724,0** | **0,0** | **0,0** | **5 038,2** | **1 084,4** | **615,8** | **554,9** | **1 193,0** | **864,9** | **725,2** | **5 572,2** | **4 611,65** | **25 135,6** |
| 13 | agriculture | 1,8 | 0,1 | 0,0 | 1,7 | 0,1 | 33,7 | 0,0 | 0,0 | 53,6 | 7,2 | 37,4 | 0,3 | 0,0 | 0,6 | 8,0 | 62,0 | 47,0 | 198,2 |
| 14 | industry (without FEC) | 24,8 | 4,5 | 20,1 | 0,2 | 1,4 | 926,7 | 0,0 | 0,0 | 1 849,6 | 46,5 | 72,5 | 463,3 | 1 193,0 | 14,0 | 60,3 | 2 051,0 | 2 357,5 | 7 211,0 |
| 14.1 | Mining and quarrying (except FER) | 1,6 | 1,6 | 0,0 | 0,0 | 0,0 | 231,4 | 0,0 | 0,0 | 25,8 | 3,3 | 12,1 | 1,4 | 0,0 | 0,0 | 9,1 | 8,7 | 9,0 | 276,6 |
| 14.2 | manufacturing (except FER) | 23,2 | 2,9 | 20,1 | 0,2 | 0,0 | 695,3 | 0,0 | 0,0 | 1 819,9 | 43,3 | 56,7 | 461,7 | 1 193,0 | 14,0 | 51,3 | 1 769,0 | 2 267,8 | 6 575,2 |
| 14.3 | water supply | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 3,8 | 0,0 | 3,6 | 0,2 | 0,0 | 0,0 | 0,0 | 273,3 | 80,6 | 357,8 |
| 15 | construction | 0,1 | 0,1 | 0,0 | 0,0 | 0,3 | 5,0 | 0,0 | 0,0 | 86,9 | 10,8 | 55,1 | 0,4 | 0,0 | 0,5 | 20,1 | 80,5 | 16,1 | 188,9 |
| 16 | wholesale and retail trade; | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 8,6 | 0,0 | 0,0 | 81,1 | 9,5 | 20,5 | 41,1 | 0,0 | 0,0 | 10,1 | 766,4 | 74,1 | 930,2 |
| 17 | transport (without pipeline) | 3,2 | 3,1 | 0,0 | 0,0 | 1,6 | 51,3 | 0,0 | 0,0 | 306,6 | 25,2 | 197,2 | 4,0 | 0,0 | 7,7 | 72,4 | 373,5 | 82,4 | 818,5 |
| 18 | household | 13,6 | 13,5 | 0,0 | 0,1 | 0,0 | 1 987,6 | 0,0 | 0,0 | 1 119,3 | 901,3 | 195,8 | 0,1 | 0,0 | 22,1 | 0,0 | 1 471,8 | 1 882,6 | 6 475,0 |
| 19 | other | 1,4 | 0,9 | 0,0 | 0,5 | 0,4 | 85,6 | 0,0 | 0,0 | 200,1 | 83,8 | 37,4 | 45,2 | 0,0 | 3,6 | 30,2 | 767,0 | 151,9 | 1 206,5 |
| 20 | Use of fuel and energy resources as raw materials and for non-fuel needs | 0,0 | 0,0 | | 0,0 | 140,9 | 6 625,5 | 0,0 | 0,0 | 1 341,0 | 0,0 | 0,0 | 0,5 | 0,0 | 816,4 | 524,1 | 0,0 | 0,0 | 8 107,4 |
| 21 | ***Final consumption of fuel and energy resources as fuel and energy*** | **51,1** | **28,5** | **20,1** | **2,4** | **104,2** | **4 628,1** | **312,9** | **0,0** | **4 595,9** | **1 117,1** | **671,9** | **653,5** | **1 193,0** | **333,7** | **626,8** | **8 382,7** | **5 872,85** | **23 947,8** |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |

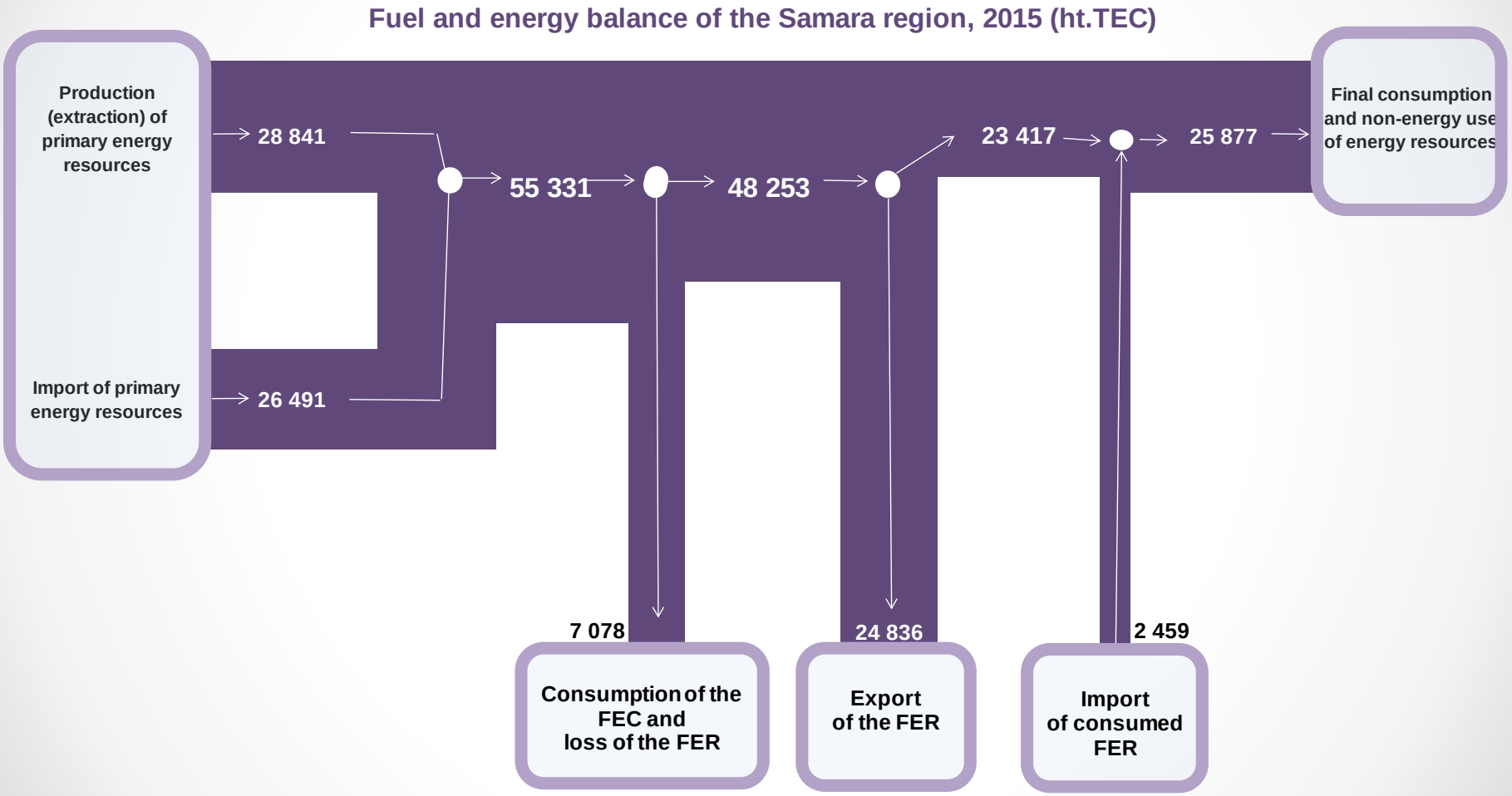
Source: author's calculations

# Production and conversion of energy resources
## Samara region, 2015



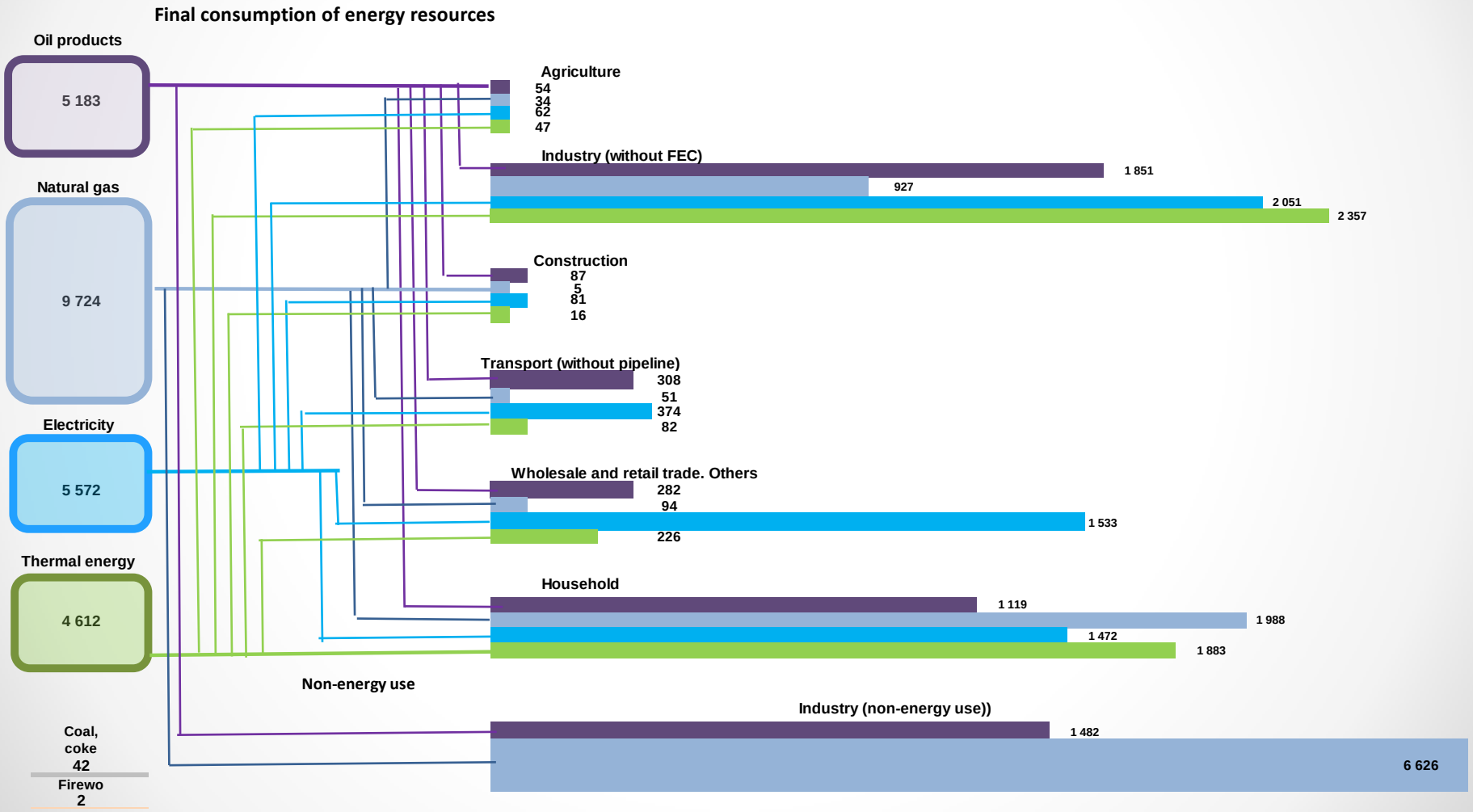

Source: author's calculations

# Production and conversion of energy resources
## Samara region, 2015




Source: author's calculations

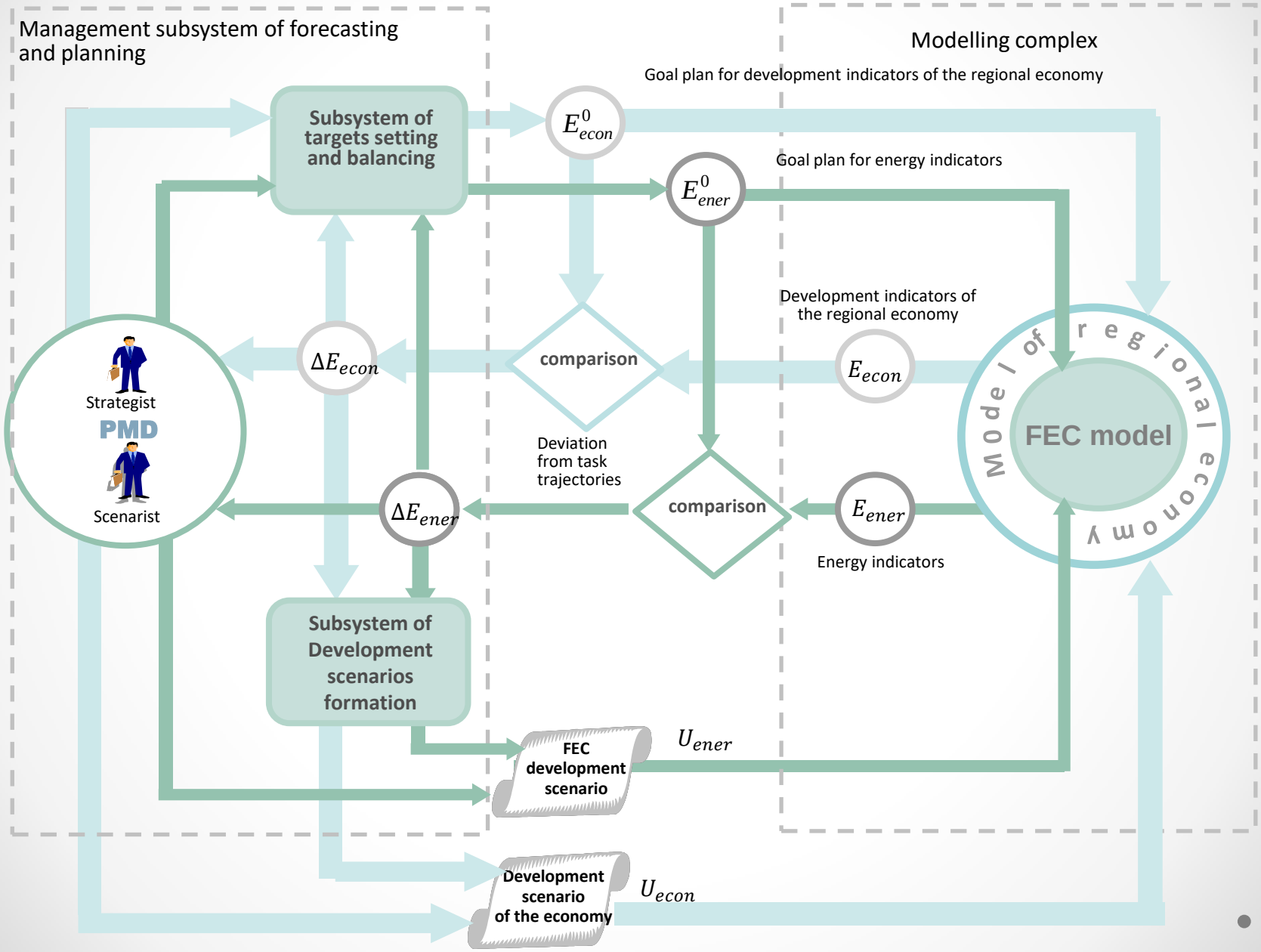
# Final consumption and non-energy use of fuel and energy resources
## (th.TEC)
## Samara region, 2015




Source: author's calculations

# 4. Information Technology for energy-efficient Development of the regional Economy

# Forecast-analytical Complex

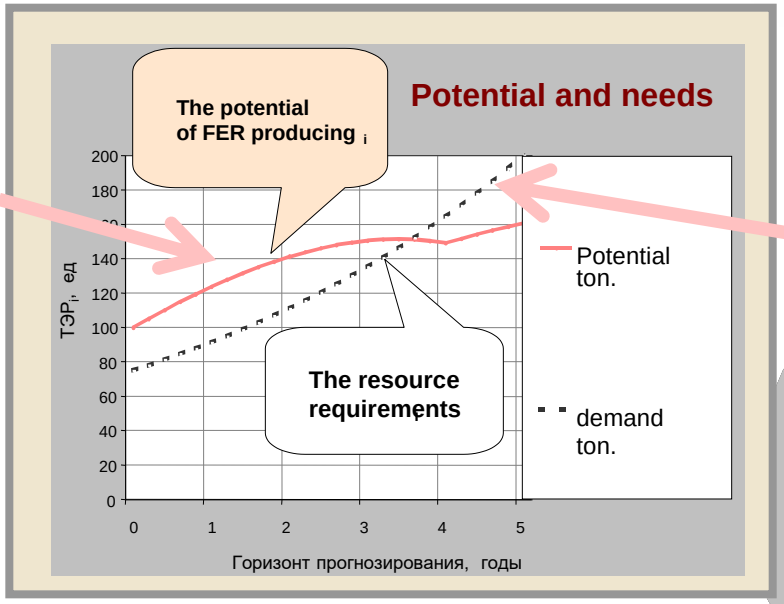


***Forecasting*** **is the construction of a future balanced by goals and resources, based on past statistics and expert vision of the future**

# Forecasting a balanced Development of Economy and Energy

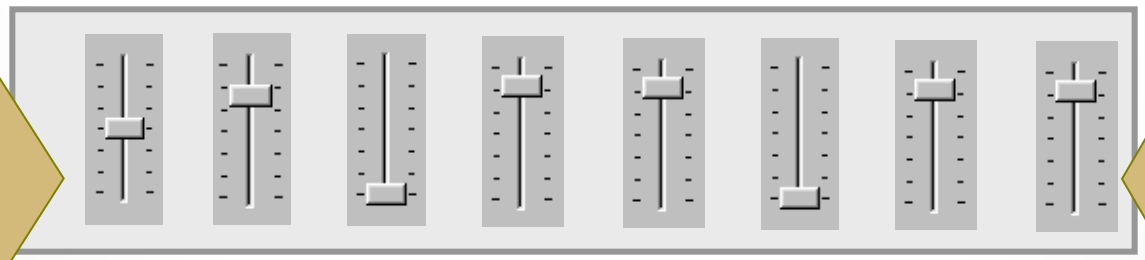
**Parameters of management of FEC**

- Investments in FEC
- Tariffs for FER
- Budget expenditures for FER
- The production efficiency of FER
- Loss of FER
- Export FER




**Parameters of management of the economy**

- Demographic parameters
- The production indices
- Indexes-deflators of prices
- Tax rate
- Parameters of investment and fiscal policy
- Energy saving options
- The import TER



**The scenario of development of the FEC**

$$U_{ener}(t)$$

**The scenario of economic development**

$$U_{econ}(t)$$

# The technology to find the best scenario for the energy-efficient development

Let us introduce a criterion $\Phi$, characterizing cumulative relative deviation of the vector of indicators

$$E(t) = [E_{econ}(t), E_{ener}(t)]^T = [e_1(t), e_2(t), ..., e_N(t)]^T$$

from the target trajectories

$$E^0(t) = [E^0_{econ}(t), E^0_{ener}(t)]^T = [e^0_1(t), e^0_2(t), ..., e^0_N(t)]^T$$

in measure points $t \in [t_1, t_2, ..., t_T]$:

$$\Phi(U,t) = \left\{ \sum_{i=1}^{N} \left\{ g_i \sum_{k=1}^{T} \left| \frac{e_i(U,t_k)}{e_i^0(t_k)} - 1 \right| \right\} \right\}$$

Where $N$ - the total number of indicators (economic and energy);

$g_i$ - the value (weight) of the *i*-th indicator

$T$ - the number of points in the interval of strategic planning.

Then the task to find the option of the energy-efficient development (3) - (6) will be reduced to the following optimization problem:

to find the acceptable scenario for the development of the regional economy and the fuel and energy sector U(t), which minimizes the general "dissatisfaction" with not achieving the objectives set for indicators at the points $t = t_1, t_2, \ldots, t_T$, on the horizon of strategic planning $[0, T]$.

$$\min_{U(t)\subset D_U} \Phi(U(t)) = \min_{U(t)\subset D_U} \left\{ \sum_{i=1}^{N} \left\{ g_i \sum_{k=1}^{T} \left| \frac{e_i(U(t_k))}{e_i^0(t_k)} - 1 \right| \right\} \right\}$$

Where the indicators $e_1(U(t)), e_2(U(t)), \ldots, e_N(U(t)),$ are calculated on the model of the region when solving the direct problem of scenario forecasting (4) - (6) for the development scenario U(t) belonging to the space of management decisions $D_U$, given in the form of admissible intervals to regulate the scenario parameters:

$$U^{\min}(t) \le U(t) \le U^{\max}(t)$$

# Approach to decision

Let us submit the general scenario $U(t)$ in the form of the control matrix $\mathrm{U}$ with the dimension $L \times T$, where $L = m + n$ - dimension of a united vector of scenario parameters of the regional economy development $U_{econ} = [u_{econ,1}, u_{econ,2}, ..., u_{econ,m}]^T$ and scenario parameters of FEC development $U_{ener} = [u_{ener,1}, u_{ener,2}, ..., u_{ener,n}]^T$, and $T$ is a number of points at the strategizing interval:

$$\mathrm{U} = \begin{bmatrix} u_{1,1}, & u_{1,2}, & ..., u_{1,T} \\ u_{2,1}, & u_{2,2}, & ..., u_{2,T} \\ ..... & ..... & ..... \\ u_{L,1}, & u_{L,2}, & ..., u_{L,T} \end{bmatrix}.$$

Let us denote $\mathrm{U}^{(0)}$ as initial approximation of the control matrix $\mathrm{U}$ (basic scenario) and submit it in the following form:

$$\mathrm{U} = \mathrm{U}^{(0)} \otimes K,$$

where $K = \left\| k_{i,j} \right\|_{L \times T}$ - a correcting matrix with the dimension $L \times T$;

$\otimes$ - a symbol of the elementwise matrix multiplication.

The record

$$\mathrm{U}(t) = \mathrm{U}^{(0)} \otimes K\,(t)$$

allows reducing the task to the search of the efficient correcting matrix $K^{opt}$. The authors developed an effective method for finding the optimal matrix $K^{opt}$. It allows solving this task for many tens of the purposes $N$ and hundreds of control variables $L$ for acceptable time.

The universal solver, developed on the basis of the matrix method, automatically forms development scenarios:

$$\mathrm{U}^{\mathrm{opt}} = \mathrm{U}^{(0)} \otimes K^{opt} \rightarrow \begin{bmatrix} U^{opt}_{econ}(t) \\ U^{opt}_{ener}(t) \end{bmatrix},$$

where values of energy indicators $E_E$ approach to the established purposes $E_E^0$ as close as possible with due account for the importance of these indicators (scales $g_i$) and resource restrictions for the operating influences.

# Modelling and strategic planning outlines

**The task of strategic management**

**The outline of strategic management**
solution of problems of attainability of strategic goals

**The tasks of targeted behavior of economic agents**

**The outline of endogenous management**
(modeling of purposeful activity of economic agents)

**The outline of management of equilibrium in the markets:**

The invisible hand of the market

**The task of ensuring balance in the markets in natural form**

**The task of ensuring the balance in the markets in value terms**

**Universal solver**