HYDRO POWER AND ENERGY PLANNING PROJECT (HPEP)

ENERGY PLANNING FINAL REPORT

TRAINING OF THE ANALYTICAL DEPARTMENT OF THE MINISTRY OF ENERGY OF GEORGIA AND UPDATE OF MARKAL GEORGIA PLANNING MODEL

Monday, August 25, 2014

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1.0 LIST OF TERMS AND ACRONYMS

AD	Analytical Department of the Ministry of Energy
AF	Plant seasonal availability factor
AYPEG	Association of Young Professionals of Energy in Georgia
CBA	Cost Benefit Analysis
CCGT	Combined Cycle Generation Turbine
CNG	Compressed Natural Gas
DCOP	Deloitte Overseas Consulting Project
DWG	Decision Ware Group
EC LEDS	Enhancing Capacity for Low Emissions Development Strategy
EFF	Efficiency
ESCO	Energy System Commercial Operator
GEOSTAT	National Statistics Office of Georgia
GDP	Gross Domestic Product
GNERC	Georgian National Energy Regulatory Commission
GIG	Georgian Industrial Group
GOG	Government of Georgia
GOGC	Georgian Oil and Gas Corporation
GSE	Georgian State Electrosystem
EE	Energy Efficiency
HPEP	Hydro Power and Energy Planning project
HPP	Hydro Power Plant
LPG	Liquid Petroleum Gas
MARKAL	Market Allocation energy planning model
MoE	Ministry of Energy
MoESD	Ministry of Economy and Sustainable Development
O&M	Operation and Maintenance costs
PMUM	Turkish electricity trading spot market
PP	Power Plants
PV	Photovoltaic
RE	Renewable Energy
RSDSOL	Solar energy in Residential sector
Shtech	Share of technologies in MARKAL that mean the share of a certain technology in a group of technologies fueled by the same energy carrier
STATA	Data analysis and statistical software
TPP	Thermal Power Plant
Urban Central	Dwelling type in MARKAL terminology that means urban private house with central heating system (boiler)
Urban Local	Dwelling type in MARKAL terminology that means urban private house with local heating (stove)
VBE	Veda Back End software
WPP	Wind power plant

2.0 TRAINING OF THE ANALYTICAL DEPARTMENT

2.1 TRAINING SESSIONS

The staff from the Ministry of Energy's Analytical Department and the representative of the Ministry of Environment were trained in planning based on MARKAL Georgia model. The group was divided into two MARKAL model operators, who had access to the model on their computers, and the group of analysts, who were mostly preoccupied with data collection, data preparation for input and interpretation of model outputs; they also recommended changes to inputs as well as details of future energy sector scenarios as needed.

In total 18 training sessions were conducted in the Ministry of Energy by Murman Margvelashvili, Natalia Shatirishvili, Giorgi Mukhigulishvili and Nino Maghradze. The training sessions were divided into two parts: a more theoretical presentation/lecture providing insight into various aspects of long term energy planning, and a practical modeling/planning part, where the technicalities of operating the MARKAL Georgia model, data preparation and input, interpretation of results and preparation of information for decision makers were taught. The staff of the Analytical Department was given various tasks at the end of each lecture to allow them to use the acquired theoretical knowledge in practice. These tasks were reviewed and revised as needed by the WEG staff upon completion.

The theoretical portion of the training covered the main energy issues such as demand projection methodologies, renewable energy, energy efficiency, energy security, electricity markets, integrated resource planning, and other similar topics. Best international experiences and an overview of the energy market in Georgia and its specifics were presented. The practical part of the training covered MARKAL Georgia model results' analysis, specific scenarios and preparation of a policy brief by AD members. It helped the AD in developing analytical skills to better understand MARKAL Georgia operation, correctly interpret the program results and improved their networking with energy companies through active participation in data collection and processing.

Theoretical training topics stated in initial Training Syllabus were slightly adjusted to devote more time to the issues that were considered to be most important and appropriate in relation to the knowledge of AD members. In-room trainings covered the following topics (summary of each training session can be found in Appendix I):

- Energy Policies, energy strategies and energy plans - main principles
- Organization of planning activities and the role of different parties
- Economic and financial basis of energy planning
- Energy demand projections/forecasting
- Energy Balance, its structure and data organization based on IEA standards

- Genesis, production and characteristics of fossil fuels
- Thermal power generation
- Integrated Resource Planning
- Methodology of cost benefit analysis of infrastructure projects including energy projects
- Energy efficiency
- Energy and climate change and overview of climate change issues in Georgia (by Ministry of Environment)
- Overview of electricity system of neighboring countries (Azerbaijan, Armenia, Russia and Turkey) conducted by representatives of AD
- Energy Economics
- Hydro Power
- Renewable energy with a focus on solar energy technologies
- Renewable energy with a focus on wind, geothermal and biomass energy technologies

The presentations are appended in Appendix II of this report.
In addition to trainings, the AD staff was invited to participate in a series of seminars on Energy Policy and Sustainability organized by WEG. The following seminars were attended by AD members: Georgia's Association with European Union in Energy Sector, Georgia's Households Energy Consumption and Wood Management Problems, Energy Demand Projection in Georgia and Georgia's Energy Security. All seminars were attended by high level professionals who also made presentations. The AD staff participated in professional debates and obtained information on the current challenges of Georgia's energy sector.

In the practical part of the training devoted to MARKAL Georgia model, the AD staff was trained in running different simple scenarios, analyzing their results, performing sensitivity analyses of selected parameters, conducting data processing and input preparation, working with analytics workbooks and preparing Policy Briefs (sample Policy Brief prepared by AD MoE is included in Appendix III).

In the course of trainings, WEG organized a visit to GSE's Dispatch Center where the AD staff learned the functions and principles of operation of the Dispatch Center as well as operation of power system. For the AD staff members, it was their first visit to the Dispatch Center. This trip established the initial contacts and improved their knowledge of the Georgian electricity system.

WEG also arranged a working meeting with Georgian Oil and Gas Corporation (GOGC) to discuss the issues of the natural gas sector. The meeting helped to establish the working contacts between the AD staff and the staff of GOGC. The details of future

natural gas availability from different sources and relevant prices were discussed for inputting relevant data into the MARKAL Georgia model.

Improved data collection and processing skills of the AD staff resulted in preparation of the energy balance that was primarily developed for MARKAL Georgia, however, can be also used for other internal analyses, until official energy balance is developed. With improved analytical skills, the AD staff prepared a Policy Brief with analysis of the preliminary Reference Scenario. In general, the AD staff acquired valuable skills that contributed to their professional development and capacity building of the Ministry as a whole.

2.2 SCENARIO ANALYSES

As a part of training sessions, with the participation of AD staff, WEG developed and analyzed several scenarios using the MARKAL Georgia model.

1. Scenario with Georgia 2020 Socio-Economic Strategy white paper parameters

The Ministry of Economy and Sustainable Development published the Country Social-Economic Development Strategy – Georgia 2020, where aggressive GDP growth as well as aggressive electricity production growth parameters were assumed. WEG together with the AD staff analyzed the scenario with “Georgia 2020” growth projections and namely examined the projections for power sector.

2. Energy Efficiency Scenarios

Several Energy Efficiency (EE) scenarios were conducted and analyzed to compare the effects of different methods for setting EE targets as well as change in EE technology penetration rates.

- Energy efficiency scenario with penetration ratios for different advanced technologies (UC 99 template)[1] modified by the AD staff and EE target with 9% gradual decrease in final consumption in comparison to Reference Scenario.
- Energy efficiency scenario with penetration ratios for different advanced technologies (UC 99 template) modified by the AD staff and EE target with 9% decrease in final energy consumption with respect to the average of 2012-2015.
- EE scenario with no changes to efficient technology penetration (UC 99) template and 9% gradual EE increase target with respect to the average 2012-2015 final energy consumption.

The goal of this exercise was to test the sensitivity to technology penetration assumptions and to demonstrate different methodologies of setting Energy Efficiency targets – based on the base year and based on Reference Scenario.

3. RE Scenarios

[1] User Constraint (UC) 99 template is a technical part of MARKAL where restrictions are written

A set of Renewable Energy (RE) scenarios with different RE targets were run to understand better the potential realistic targets for Georgia and to examine the effects of different methods of RE target setting. The cases with 55% and 70% target of RES were examined. List of new available technologies and their parameters was analyzed and modified by the AD staff. The goal of running these scenarios was also to demonstrate how the Renewable Scenario may be more complex and go beyond just setting renewable target.

4. Scenario with coal power plant excluding Khudoni from the energy system

This was an alternative scenario where the coal powered thermal power plant was included as must run, based on the existing agreement with GIG, the owner of the local coal mines and developer of coal-fired power plants. Khudoni was completely excluded from consideration.

5. Enguri disconnection Scenario

A test was conducted to determine whether the system is able to satisfy the demand if Enguri HPP is not available for an extended period of time, and what are the associated costs.

Enguri was disengaged from the system for two consecutive three-year periods 2015 and 2018 (i.e. for six years) and was allowed to reconnect to the system later. In view of the possibility of running Enguri in later periods the model chose not to build any considerable additional number of generation plants, but compensated the absence of Enguri through cutting off exports, increased import and increased thermal generation. The cross border transmission capacity allowed for such compensation, deferring the issue to sufficient contractual arrangements for such a scenario.

6. Sensitivity run with increased CNG in transport

The penetration of CNG in transport sector increased compared to conservative numbers in reference case. The effects on natural gas availability, CO_2 emissions, external dependence and system costs were examined together with other traditional parameters.

All of the above scenarios were based on the Reference Scenario available in May-June 2014. The results are stored in corresponding Analytics Workbook excel files. However, the numerical results aren't presented in this report because the Reference Scenario has been changed several times since then. The appended policy brief (see Appendex III) with reference case results also has mostly illustrative values to show the work of the AD staff on data for presentation and analysis of results to policy makers.

The main goal of developing the policy brief was to train the AD staff in conducting analysis and interpreting the results for policy makers in an easy and understandable manner. The reference scenario has been further improved through energy data verification and Households' survey data input as described below in this report.

3.0 MARKAL GEORGIA MODEL

In parallel to training sessions, WEG continued developing the MARKAL Georgia model. The development process involved refining the input data, identifying the illogical results and correcting the causes of the illogical results. On the data improvement side, the Household survey results were inputted into the MARKAL Gorgia model, and energy sector data improvement and verification with relevant sector experts was conducted. WEG worked in collaboration with DWG from the EC-LEDS project to achieve comprehensive model development by improving the modeling structures and considering both energy and environmental aspects. The model will be used as a tool by the Ministry of Energy for long term planning and its results will be also used by Ministry of Environment and Natural Resources Protection for development and analysis of Low Emissions Development Strategy.

Using the STATA software that is designed for large data set processing, WEG processed the Household Energy Use Survey results and inputted energy related data in the model. About 60 different parameters were analyzed and inputted. The list of all data inputted and processes together with main assumptions are presented in Appendix IV.

The data obtained through Households' survey helped improve the residential sector related inputs in the MARKAL Georgia model. Energy consumption by fuel type and by energy service demand (heating, water heating, cooling, etc.) were estimated and inputted as well as citizens' allocation by dwelling types and its projected evolution considering urbanization tendency and willingness of households to arrange central heating systems. The Households' survey also contained data on residential technologies, and their technical and economic characteristics. This information was used to make an estimation of average efficiencies and shares of people using certain technologies. The mentioned data was also considered in defining the penetration ratios and their projections for major residential technologies.

The Households' survey also provided the data on transport and some data on energy efficiency. Transport data was processed by WEG and was input into the model by the EC-LEDS' modeler. The energy efficiency portion of the survey was not included in the Reference Scenario; however, the information can be useful while conducting the Energy Efficiency scenario.

Along with the new input data, the largest role in MARKAL Georgia model improvements was data verification. The first phase of data input was carried out during the first cycle of training for the AD staff of MoE under regional EC-LEDS program. However, the main efforts were directed to training the AD staff and there was little quality control of data input. Starting from the second cycle of training under HPEP, WEG started data verification and correction. The major issues that were reviewed and verified were:

- Hourly electricity load data had to be corrected to include the Abkhazia load and, therefore, the peak load in the model differed from the real peak in 2012 by about 200 MW. WEG corrected the energy load information representing hourly load for the whole country including Abkhazia region and calibrated the load data.[2]
- Corrections were introduced to capacities in aggregated technologies including "Other regulating HPPs" and "Run of River HPPs" since they didn't correspond to their real capacity. Some run-of-river plants were counted as other regulating (reservoir HPPs) plants, which means that some run-of-river plants were given characteristics (with relatively high AFs) of regulating HPPs that exaggerates AF of existing HPP capacity. Corrected parameters were input into the model.[3]
- Since the plants were regrouped under existing plant categories, relevant seasonal and annual Availability Factors (AFs) were recalculated and inputted. Variable and fixed O&M costs were recalculated and inputted. Electricity generated in the base year was recalculated and inputted according to plant categories.
- The data on seasonal peak AFs of existing plants was verified with GSE's Dispatch Center and corrected values were inputted into the model. Previously Enguri and Vardnili HPP and Other regulated HPPs had 100% AF in peak in any season which doesn't correspond to reality.[4]
- AF of existing thermal power plants for future years was corrected to be 95%. Previously it was equal to base year AF, which meant that they had no opportunities to generate more than in the base year.
- Export/import seasonal constraint for electricity trade with Armenia and Azerbaijan were updated based on information obtained from the Dispatch Center.[5]
- To account for construction and financial risks, the upper limit of new small HPPs (more and less than 15 MW) was multiplied by 0.7 per each

[2] *GSE hourly load data for Georgia*
[3] ESCO*, Electricity Balance of Georgia 2012.* <http://www.esco.ge/files/energobalans_2012_eng.pdf>.
[4] Letter from *GSE, May 30, 2014*
[5] Interview with *GSE* - Archil Kokhtashvili Head of department, Ucha Uchaneishvili-member of management board May 15, 2014.

constraint. This is equivalent to assumption that only 70 of currently acknowledged hydropower potential can be commissioned before 2036.

- To account for delay risks and financial barriers for big HPPs, their initial commissioning year was shifted by one period later (except for Khobi 2 and Dariali, whose commissioning years were confirmed by MoE.
- The upper constraint on geothermal energy use in Residential and Commercial sectors was made more realistic by correcting the upper bound in the Agriculture sector. Use of geothermal energy should be restricted in the model, since it is available only in certain regions and its increased consumption is associated with investments in the infrastructure expansion, which has not been considered in the model. Possible growth of geothermal energy use was restricted to 200% over the planning horizon.[6] WEG recalculated the volumes and corrected the base energy balance and corresponding sector templates. The estimation on investment costs of new technologies for geothermal use expansion were adjusted based on USAID assessments of 1998, USAID/WEG reports of 2008 and experts inquiries. The data was inputted in the model. A new geothermal energy supply technology was added to the model based on concrete agriculture complex project with estimated investment cost more in line with similar cost in residential sector.[7]
- The investment costs of technologies using fuel wood in agriculture had zero investment cost. Such technologies were switched off. In the future, once data on wood consumption in Agriculture is available, these technologies can be switched on. However, according to 2012 year obtained data there is no wood consumption in the Agriculture sector.
- WEG reduced the projection of wood fuel price growth from initially assumed 50% growth in 2015 down to annual (real) 1% growth projection. This eliminated a sharp drop in wood consumption in the model.
- Investment cost of efficient wood stoves was corrected. WEG changed investment cost for efficient (70%) stoves, thus allowing more efficient technologies to penetrate the market.[8]
- A request was made for modeling the natural gas storage facility for seasonal balancing of gas supply. After initial attempts, the natural gas storage is not modeled yet. Therefore, for the time being the potential for natural gas storage cannot be included in the model as an option. The

[6] Interview with a Geothermal expert G. Vardigoreli, 6 June, 2014.
[7] *Renewable Energy Potential in Georgia and Policy Options for Its Utilization*, <http://weg.ge/wp-content/uploads/2012/12/renewable_energy1.pdf>.
[8] USAID, WEG, Winrock International, *Technology Needs Assessment for Georgia,* February 2008. <http://weg.ge/wp-content/uploads/2012/11/technology-needs-assessment-and-technology-action-plans-for-climate-change-mitigation.pdf>.

effect of storage can be analyzed outside the model and will be inputted as an external limitation in the relevant scenario.

After all of the above changes, the model was run and tested in the Reference Scenario and no illogical results were found. The time before end of August will be devoted to further verification of inputs and scrutiny of assumptions and restrictions in the model. Although the model should be subject to continuous revision and improvement, the current state of the MARKAL Georgia model is in an adequate condition for further scenario analysis and can be used in decision making for Georgia's energy strategy by coordinating the input parameters, assumptions and constraints with the working group of the strategy.

4.0 APPENDIX I

TRAINING SESSION SUMMARIES AND TASKS

This appendix contains the summaries prepared after each training session.

The training sessions mainly consisted of the following activities:

1. A theoretical presentation/lecture on specific topic related to long term planning,
2. Discussion of the tasks (homework) performed by analytical department
3. Practical training in modeling/planning with MARKAL
4. New task assignments for next training sessions.

Below is a training summary for each day, which describes the activities at the training session as well as tasks given to the analytical department and undertaken by WEG for the next training session.

March 12, Training Summary

1. The formal opening of training was conducted in the presence of Deloitte and USAID mission representatives
2. M. Margvelashvili made a presentation on the organization of planning activities and the role of different parties
3. *Discussion of tasks performed by AD*

Following the observations from previous session, WEG corrected biomass (wood) consumption in residential sector and restricted construction rates of Minor HPPs (less than 15 MW and more than 15 MW).

a. Biomass consumption was excessive in residential sector due to the assumption that on average a rural family consumes 10 m^3 of fuel wood per heating season. This assumption was changed and average consumption was reduced to 5 m^3 of annual fuel wood consumption for an average rural family. The assumption was verified with the AD team and inputted in the model by WEG.
b. The number of small HPPs representing hydro potential and some active projects with signed MOUs are represented in the model in aggregate technology “Minor HPP More than 15MW” and “Minor HPP less than 15MW”. These technologies are assigned average cost/performance characteristics of HPPs from the ministry list and are considered as two separate technologies. In reference case the model builds maximum capacity (3 GW) in 2015-2018, which is unrealistic. The AD team was asked to develop yearly constraint of new HPP construction consistent with current HPP construction trends, to smooth construction rate of

new HPPs. WEG team imposed the constraints in the model and analyzed the results with the AD team.

4. *Georgia 2020 case and analysis of results*

WEG conducted the runs with economic development Georgia 2020 parameters (GDP growth and electricity generation projections) and presented the results for analysis with AD team. The methodology of creation of Georgia 2020 case was explained to AD team. The main observations are: Coal consumption grows too fast, substituting wood consumption to some extent. This was considered as less likely and was resolved through restricting urban residential consumption of coal.

GDP growth projection from Georgia 2020 was imposed on Reference case but there were no significant changes neither in consumption patterns nor in generation, since Reference case GDP growth does not differ much from the one proposed by Georgia 2020.

On the other hand, achieving the 18 TWh generation level as envisaged in the strategy did not turn out to be straightforward. The amount of export envisaged by Georgia 2020 was difficult to achieve realistically.

Electricity generation, import/export and new power plants were discussed during the session concluding that with available generation options it is unlikely to have 18 TWh generation by 2021 as proposed in Georgia 2020 considering available generation options.

5. *Tasks for the next session:*

The following tasks were given to the AD

- Update data on coal extraction amount for 2012-2013
- Send to WEG team technology development newsletter prepared by AD
- Finalize analysis of analytics workbook with Georgia 2020 parameters

WEG will conduct the following activities

- Input in the model coal extraction cap and find the reason of high coal consumption in residential sector and correct it
- Prepare for energy efficiency run; prepare Analytics workbook with energy efficiency case.

March 19, Training Summary

1. M. Margvelashvili presented on Economic and Financial Basis of Energy Planning
2. *Discussion of tasks performed by AD*

Following the observations from previous session WEG corrected coal consumption in residential sector.

c. AD team provided data on coal extraction for 2012 and 2013 years. Since coal mining amount does not differ much in recent years it was decided to impose mining cap with gradual growth from 7.06 PJ in 2012 to 8 PJ in 2027 and the following years. Two heating technologies of coal combustion in urban residential sector were removed from possible options list, since such technologies are unlikely to appear. Gas and coal residential consumption was restored to more realistic levels.

3. *Reference case with corrected coal, energy efficiency case and analysis of results*

WEG conducted the runs with corrected coal consumption and compared the results to the Reference scenario. Together with AD team WEG analyzed the results.

Ways of making the energy efficiency scenario more comprehensive through energy efficient technologies market analysis and reflecting it in penetration ratio of efficient technologies were shown to AD as well as the ways of switching off/on different energy efficient appliances.

AD modelers performed Energy efficiency run with an imposed higher energy efficiency target.

4. *Tasks for the next session:*

The following tasks were given to the AD:

- Calculate leveled energy costs of different generation technologies provided by WEG in excel spreadsheet
- Consult with GEDF on current and potential wind power projects and their technical and economic characteristics
- Survey average world price of PV electricity generation systems
- Examine the Reference and EE scenario results and report findings.

WEG will conduct the following activities:

- Review renewable energy technologies and PP data

- Review elasticity for sector and sub sectors
- Conduct Renewable energy run, prepare Analytics workbook

March 26, Training Summary

1. G. Mukhigulishvili made a presentation on Energy Demand Projections/Forecasting and discussed different projection techniques as well as the role economic projections play in MARKAL. He also discussed concept of demand drivers and elasticity and showed corresponding values from MARKAL.
2. *Discussion of tasks performed by AD*

Leveled costs of several generation technologies including solar, hydro, thermal, nuclear power were calculated by AD. The results were reviewed and discussed.

3. *Renewable energy target case and analysis of results*

Current level of renewable energy development and existing barriers were briefly discussed.

WEG conducted the renewable energy target run. For this scenario, 4 wind power options were added to the model of potential wind power projects as well as one potential solar 110 MW PV plant option (inspired by previous Korean investor proposal). Additionally, new renewable energy demand technologies were added, like solar water heaters, solar/electricity heat pumps, geothermal heat pumps, etc. Having in mind that in Reference scenario the renewable energy share in total energy system is about 40%, it was decided to set a target of 55% of renewable share by 2027 for RE case.

Analytic workbook was updated with Reference and Renewable energy target cases. The key results were discussed as well as more detailed results from VBE software including new generation plants, their capacities and commissioning years, renewable technologies chosen, etc. Comparative analysis was conducted.

Ways of “enrichment” of renewable energy case were discussed.

Tasks for the next session:

The following tasks were given to the AD

- Conduct electricity projections using different techniques presented by WEG
- Conduct Renewable energy target case with imposed higher target of 70% by 2027.
- Update analytics workbook with higher target scenario

- Compare Reference, Renewable case with 55% target and Renewable case with 70% target and report findings on next session
- Obtain technical-economic data of coal plant to add such option to the model

WEG will conduct the following activities

- Review load curve data and availability factor of generation plants
- Conduct several runs with added/removed different generation options
- Prepare analytic workbook for discussion of results

April 2, Training Summary

1. Murman Margvelashvili presented on Load projections and system reserve planning. He presented basics of load curve analysis and projections, calculation of system reliability and discussed importance of reserve margin. Load curves of Georgian power system of 2012 were demonstrated as an example.
2. *Discussion of tasks performed by AD*

AD conducted Renewable energy target scenario with 70% target. The results were briefly discussed using analytics workbook.

3. *Load Calibration template and electricity generation options* – led by Natalia Shatirishvili

Load curves in MARKAL as well as load data were demonstrated and discussed. Process of setting reserve margin, calibration of load data, development of average and aggregated load curves were demonstrated and reviewed. The following load curves were reviewed: seasonal load curves, sector load curves, subsector load curves, overall and annual load curves.

The ways of how new generation option can be added to the model were demonstrated as well as the way how energy generation option can be excluded from the model. The list of existing generation options and their technical parameters was reviewed.

Tasks for the next session:

The following tasks were given to the AD

- Assess and classify available reserve margin in Georgia in summer and winter – consult with Energy Department
- Calculate the system reliability at night, shoulder and peak in lecture example
- Investigate Annual peak of December 19th, 2012
- Run the case with coal plant and excluded Khudoni HPP
- Update the analytics workbook and discuss the results

WEG will conduct the following activities

- Review energy balance in the model
- Conduct the run with aggressive GDP growth
- Conduct the run without Enguri and conduct sensitivity analysis
- Prepare the analytics for discussion
- Visit to the Dispatch Center will be arranged in the week of April 14.

April 10, Training Summary

1. Giorgi Mukhigulishvili made a presentation on Energy Balance, its structure and data organization based on IEA standards. Georgia's energy balance for 2012 was also reviewed and analyzed from the energy security perspectives.
2. *Discussion of tasks performed by AD*

AD conducted Renewable energy target scenario with 70% target and scenario with coal power plant and without Khudoni HPP in energy system. Discussion of the main findings was shifted to the next training session.

3. *Aggressive GDP growth scenario and Energy Security scenario–* led by Natalia Shatirishvili

WEG conducted run with aggressive GDP growth rate, which is on average 1-2% higher than in Reference case. The sensitivity analysis was conducted showing that small increase in GDP growth rate does not cause substantial changes in energy consumption patterns. The results were discussed during training session.

WEG also conducted a scenario where main HPP Enguri was shut down in 2015-2018 years to check whether Georgian energy system is able to satisfy domestic demand without Enguri in case of such force Majeure. The results were briefly discussed.

Methods of creating similar scenarios in MARKAL (from technical point of view) was demonstrated and explained to AD staff responsible for MARKAL software operation.

Tasks for the next session:

The following tasks were given to the AD

- Fill in tables with key parameters of the scenarios conducted by AD (Renewable energy target scenario with 70% target and scenario with coal power plant and without Khudoni HPP in energy system)
- Finalize analysis of Analytics workbook with Aggressive growth and Energy Security scenarios, conducted by WEG, fill tables with key parameters, add graphs and key messages for policy makers

- Look closer at the Reference case results and report on any anomalous results.
- Prepare new upper constraints for minor HPP (less than 15 MW) and minor HPP (more than 15 MW) in accordance with Ministry of Energy's favorable scenario of evolution of electricity sector.
- Fill in the IEA balance builder for Georgia (year 2012)
- Think and create indicators to analyze energy balance of Georgia for year 2012

WEG will conduct the following activities:

- Organize a visit to the Dispatch Center
- Conduct sensitivity run to understand the effect of uncertainties in the transport sector on the whole system
- Analysis of results, identification of data/assumptions limitations
- Work with any anomalous results of the Reference case
- Implement new upper constraints on minor HPPs (less than 15 MW) and minor HPPs (more than 15 MW)

April 16, Training Summary

1. Murman Margvelashvili made a presentation on genesis production and characteristics of fossil fuels to be considered in MARKAL model. He also described different types of fossil fuel deposits and showed a video on shale gas extraction process.
2. *Discussion of tasks performed by AD*

AD conducted Renewable energy target scenario with 70% target and scenario with coal power plant and without Khudoni HPP in the energy system. AD filled tables with key parameters of conducted scenarios for an easier representation of main findings. The main findings were briefly discussed.

The need for closer engagement of the whole AD was revealed and it was recommended that other AD members, except those responsible for running the model be actively involved in scenario analysis and preparation of the main findings for policy makers. Discussion meetings can be arranged at the end of the day each Monday to discuss within the group the main findings and anomalous results and prepare grounds for future policy briefs.

3. *Visit to Dispatch center*

WEG organized a visit to Dispatch center. Representative of Dispatch center made an overview of center's operation, its responsibilities and functions of Georgian electricity system in general. AD staff found the visit very useful and expressed their interest through number of questions to the center's representatives.

Tasks for the next session:

The following tasks were given to the AD

- Finish the task on load curves stated in the presentation of April 2.
- Finalize analysis of Analytics workbook with Renewable energy target and Coal plant scenarios conducted by AD.
- Look closer at the Reference case results and report on any anomalous results.
- Conduct a sensitivity run with increased CNG consumption in transport.

WEG will conduct the following activities:

- Implement new upper constraints for minor HPPs (less than 15 MW) and minor HPPs (more than 15 MW) in accordance with Ministry of Energy's favorable scenario of evolution of electricity sector.
- Analysis of results, identification of data/assumptions limitations.
- Work with any anomalous results of the Reference case.

April 23, Training Summary

1. Murman Margvelashvili made a presentation on thermal power generation. He discussed the principles of power generation and different types of thermal power plants including condensing cycle, gas turbine, cogeneration and combined cycle, efficiencies and prices.
2. *Discussion of tasks performed by AD*

AD conducted sensitivity test in transport sector to examine the effect of its energy consumption on other sectors. CNG consumption in transport was increased and the results of the run were compared by costs and consumption patterns. The main conclusion was that change of CNG consumption in transport didn't reflect in any other sector, neither in fuel consumption nor in expenditures.
AD conducted Renewable energy target scenario with 70% target and scenario with coal power plant, without Khudoni HPP in the energy system. The responsibilities of AD staff were divided between modeling team and analytical team. Modeling team prepared preliminary analysis and filled the tables with key parameters while analytical team together with WEG analyzed the model outcomes and looked for anomalous results. The main results' tables were discussed and some anomalous results were identified for a deeper analysis and clarification.

Tasks for the next session:

The following tasks were given to the AD:

- Calculate heat rate of Georgian TPPs in GJ/GW and BTU/kWh
- Through desk research compare typical efficiencies and heat rates of
    - Gas turbine plant
    - Combined cycle
    - Subcritical and supercritical coal PPs
- Calculate the cost per kW of Balance of Plant at 230MW CCGT using the Gas Turbine prices from the presentation and known total cost of the plant
- For analytical team: finalize analysis and prepare list of anomalous results. Present the list at the next training session.
- For modeling team: work with the list prepared by analytical team, investigate reasons of anomalous results and correct them. Present the outcome at the next training session.

WEG will conduct the following activities:

- Analyze export/import amounts, generation patterns, evolution of marginal costs
- Analysis of results, identification of data/assumptions limitations
- Work with any anomalous results of the Reference case

May 7, Training Summary

1. Giorgi Mukhigulishvili made a presentation on Energy Economics. He discussed types of energy markets and briefly discussed the situation in Georgian coal, oil, gas and electricity sectors.
2. *Discussion of tasks performed by AD*

AD calculated heat rate of Georgian TPPs in GJ/GW and BTU/kWh and presented their outcomes. They have also presented comparison of typical efficiencies and heat rates of Gas turbine plant, combined cycle and subcritical and supercritical coal PPs.

AD presented analysis of load curves of a typical winter and typical summer day and discussed day, night and peak patterns.

AD faced difficulties while preparing analysis of anomalous results of the completed runs and didn't manage to prepare the list of illogical results and formulize corresponding task for the modeling team. WEG made additional clarifications and asked analytical team to redo the task.

Under the instruction of WEG AD wrote a letter to Dispatch center requesting information concerning seasonal electricity export/import constraints.

Tasks for the next session:

The following tasks were given to the AD:

- Write one paragraph on characteristics of Georgian oil, coal, gas and power markets following instructions presented in the presentation.
- Investigate the main characteristics of gas storages in other countries (Europe etc.).
- For analytical team: finalize analysis and prepare list of anomalous results. Present the list at the next training session.
- For modeling team: work with the list prepared by analytical team, investigate reasons of anomalous results and correct them. Present the outcome at the next training session.

WEG will conduct the following activities

- Analysis of results, identification of data/assumptions limitations
- Work with any anomalous results of the Reference case
- Analyze barriers of renewable energy development in Georgia and discuss the ways of reflecting them in the model
- Conduct Renewable energy scenario

The next training will be conducted on Thursday June 15th to allow more time for preparation of tasks by AD.

May 15, Training Summary

1. Nino Maghradze made a presentation on Hydro Power. She discussed different types of hydro power plants and their main technical and economic characteristics, environmental and social impacts, as well as operational advantages and limitations of hydro power.

2. *Discussion of tasks performed by AD*

AD prepared an analysis of “anomalous” results noticed in current model run and made a list of illogical issues of the completed runs. The list was discussed in detail with analysis of reasons for such behavior of the model and at the end of practical part of the training, WEG together with two representatives of AD visited GSE and its dispatch center to discuss data concerning electricity sector, namely, realistic seasonal contribution to system peak by hydro power plants, export and import seasonal constraints by neighboring countries. The hydrology regime of the base 2012 year and its relevance for future planning was also discussed.

According to A. Kokhashvili and U. Uchaneishvili the 2012 actual hydrology was a very good representation of average year and is fully appropriate for the use as typical hydrology regime. It was agreed that AD will prepare a letter to Dispatch center with the current MARKAL inputs for seasonal export/import constraints and contribution to peak of hydro plants for further review and comment/corrections by Dispatch center's representatives.

Tasks for the next session:

The following tasks were given to the AD:

- Compare new HPP data with electricity sector Excel projection prepared by AD separately.
- Check an amount of CO_2 emission savings with HPP power generation in comparison to coal plant, oil plant and thermal power plant.
- For analytical team: finalize analysis of the list of anomalous results, think of possible reasons for them.
- For modeling team: WEG will send some illogical issues that weren't observed by AD analytical team. Modeling team should prepare analysis, find and correct reasons for illogical output of the model.

WEG will conduct the following activities:

- Analysis of results, identification of data/assumptions limitations.
- Correct reasons for illogical results in the Reference scenario.
- Work with Dispatch center on improving of electricity sector data.

May 21, Training Summary

1. Nino Maghradze made a presentation on Renewable energy focusing on solar energy technologies. She discussed types of solar panels, their technical and economic characteristics as well as principles of electricity generation and using heat from solar energy.

2. *Discussion of tasks performed by AD*

AD continued an analysis and improvement of the unexpected results noticed in previous model runs and made a list of the issues addressed. The discussion of improvements in detail with analysis of reasons for initial unexpected behavior of the model started during previous training session was continued on 21.05 training. The group was actively involved in the discussion and showed increased understanding of the model mechanics and the nature of technology specific constraints. Modeling team

will finalize analysis of those illogical issues and will try to correct the reasons in the model.

UC_99 template of user defined constraints for efficient and advanced technologies was with the explanation of tasks for analytical team for the next training session.

Tasks for the next session:

The following tasks were given to the AD:

- Compare new HPP data with electricity sector Excel projection prepared by AD separately.
- Check the model prices of PV systems and compare them to current world prices for similar technology.
- For analytical team: go through UC_99 template and think of new upper/lower constraints for efficient and advanced technologies. Prepare the template for Energy Efficiency scenario.
- For modeling team: Modeling team should finalize the analysis, find and correct reasons for illogical output of the model from the list that WEG sent them.

WEG will conduct the following activities:

- Continue with analysis of results, identification of data/assumptions limitations
- Collaborate with Dispatch center on hydrology data improvement and electricity import-export limitations
- Prepare for advancing Energy Efficiency scenario. Think of energy efficiency targets by sectors.

May 28, Training Summary

1. Nino Maghradze made a presentation on Renewable energy focusing on wind, geothermal and biomass energy technologies. She discussed types of wind turbines, types of geothermal and biomass technologies their technical and economic characteristics.

2. *Discussion of tasks performed by AD*

AD team examined UC_99 template of user defined constraints for efficient and advanced technologies and set new penetration rates for certain advanced technologies. The template was discussed and integrated into the energy efficiency scenario together with gradual target reaching 9% reduction of final energy consumption in the end of planning period. The ways of setting targets were discussed. 3 energy

efficiency scenarios were ran and analyzed: energy efficiency case with UC 99 template prepared by AD and 9% gradual target with respect to the corresponding Reference case final consumption, energy efficiency case with UC 99 template prepared by AD and 9% gradual target with respect to the average 2012-2015 final energy consumption and energy efficiency case with UC 99 template without any changes and 9% gradual target with respect to the average 2012-2015 final energy consumption.

Analytic workbook was updated and main observations were discussed.

HPP data with electricity sector Excel projection prepared by AD separately was compared to model HPP data and corresponding changes were made to model input.

Tasks for the next session:

The following tasks were given to the AD:

- For analytical team: Finalize analysis of conducted energy efficiency scenarios and write several pages describing main findings and key messages for policy-maker.
- For modeling team: try to correct reasons for illogical output of the scenarios from the list that WEG sent them.

WEG will conduct the following activities:

- Continue with analysis of results, identification of data/assumptions limitations
- Collaborate with Dispatch center on hydrology data improvement and electricity import-export limitations
- Prepare for renewable energy scenario, renewable energy target

June 4, Training Summary

1. Giorgi Mukhigulishvili made a presentation on Integrated Resource Planning. He spoke about evolution and importance of IRP and world practice in balancing supply and demand side measures in assuring the continuous and reliable supply to consumers. Various demand side management policies and measures were discussed in detail; a parallel was made to the status of Georgian energy sector.

2. *Discussion of tasks performed by AD*

AD team prepared the analysis of the main observations of conducted Energy Efficiency cases and documented their findings with explanations of their views. These finding will

be used during preparation of Policy Briefs. Findings were discussed during the training session.

AD presented world average prices of PV systems and their evolution that can be used as an alternative generation option in Renewable case scenario.

The way of setting renewable target in the model was discussed. Examples of different countries' targets were discussed. AD team will think of the target for Renewable case.

The ways how Renewable case may become more complex were discussed: namely list of all energy demand-side technologies, their role in the model and renewable technologies that they contain, list of generation options and ways of adding new renewable generation options to the model for Renewable case, sensitivity analysis of renewable target (setting different targets and choosing the most optimal one).

Tasks for the next session:

The following tasks were given to the AD:

- For analytical team: Think of renewable energy target for Renewable case, analyze the list of new demand technologies paying special attention to renewable demand technologies. Search for technical and economic parameters for PV systems for Renewable case.
- For modeling team: input data obtained by AD and implement Renewable target.
- Identify issues in power sector of Georgia which are relevant to IRP rules (Example – electrification)
- Identify energy efficiency measures in Georgia's power sector
- Compare prices of peak and base-load energy in the Georgian power system

WEG will conduct the following activities:

- Continue with the analysis of results, identification of data/assumptions' limitations
- Conduct several Renewable cases with different targets to prepare sensitivity analysis of the target
- Input the data obtained from Dispatch center

June 11, Training Summary

1. Giorgi Mukhigulishvili made a presentation on methodology of cost benefit analysis of infrastructure projects including the energy projects. He presented the basics of cost benefit analysis approaches and the key factors that should be considered.

2. *Discussion of tasks performed by AD*

AD team suggested using 35% renewable energy target. However, since under Reference case there is 40% share of renewables in energy mix, such target was not effective and didn't stimulate model to increase usage of renewables. AD team has also reviewed the list of available new technologies in the model and "switched on" some new renewable technologies in different demand sectors. This file was included in Renewable case run and analyzed at the training session.

The following scenarios were performed: renewable case with 35% target and new demand technologies, 55% target and 55% target with new demand technologies. The analytics workbook was updated and main observations were discussed. Comparative analysis of conducted case was performed.

Electricity sector data obtained from the Dispatch center was showed and discussed with AD.

The data on average peak contribution of existing plants will be inputted by WEG; however, the transmission line capacity constraints obtained from Dispatch center were decided not to be inputted at this stage, since they represent theoretical physical constraint of the line and not realistic amounts that can be imported / exported.

WEG observed that load data doesn't contain hourly load data of Abkhazia region and, therefore, peak in the model doesn't equal to real peak (difference is more than 200MW). Hourly load data for the whole country, including Abkhazia (TED sector in the model) will be inputted by WEG.

WEG observed that total capacity of existing plants does not correspond to real distribution of capacity by plant type. There were too many regulated plants while there were very few run-of-river HPPs, which means that some non-regulated plants had parameters of regulated ones, since model sees this group as one technology with certain technical and economical parameters. This data will be corrected by WEG.

The prices and volumes of geothermal energy supply were discussed and partly recalculated based on previous studies and applicable conversion factors. WEG corrected the conversion formula. The input data still looks too high and needs additional verification.

Tasks for the next session:

The following tasks were given to the AD:

- For analytical team: finalize comparative analysis of conducted scenarios. Write main observations and key messages supported by corresponding graphs if needed.
- Identify discount rates of different infrastructure projects in Georgia.
- Present brief summary of CBA of one energy project at the next training session.

WEG will conduct the following activities:

- Continue with the analysis of results, identification of data/assumptions' limitations
- Input the correct electricity load data and reallocate existing HPP capacities by plant type
- Geothermal data and conversion factors will be corrected and additional inquiries will be conducted to arrive at more realistic values
- Work on Reference scenario improvement will continue

June 18, Training Summary

1. Nino Maghradze made a presentation on energy efficiency. She discussed the measures of country's energy efficiency level and made international comparisons, energy efficient lighting technologies and energy efficient buildings were discussed in more detail.

2. *Discussion of tasks performed by AD*

AD performed an analysis of conducted Renewable energy target cases and presented their main observations. These main findings were discussed with WEG.

An issue of electricity export and import prices in the model was raised by WEG. Currently these prices are based on ESCO's balancing electricity prices instead of export/import agreements or PMUM price and previous actual prices. AD was asked to develop estimates of electricity export/import prices based on available information.

WEG conducted a number of changes in the model that were presented and discussed at the training session. The list of main changes introduced by WEG is as follows:

1. Hourly load data didn't contain data for Abkhazia. WEG inputted new load data that represents hourly load for the whole country including the Abkhazia region.
2. According to the latest data obtained from MoE, the price for geothermal water in residential sector is 2 GEL per m^3. The price in the model was corrected accordingly.

3. Amounts of geothermal consumption were calculated using the wrong coefficients. WEG recalculated the volumes and inputted in base energy balance and in corresponding sector templates.
4. Some estimation on investment costs of new technologies for geothermal usage expansion was made based on WEG's report[9] and expert inquiries. The data was inputted in the model. There was no new technology for geothermal use in the commercial sector. WEG has added such technology with estimated investment cost similar to the one in residential.
5. WEG restricted possible growth of geothermal energy use to 200% of current consumption over the planning horizon.
6. The installed capacities of aggregated technologies "Other regulating HPPs" and "run-of-river" didn't match to their real capacity. Some run-of-river plants were counted as regulating plants, which means that some run-of-river plants were given relatively high AFs of regulating HPPs. Corrected parameters were inputted in the model.
7. Corrections were made to other HPP grouping under existing plants categories. Seasonal and annual AFs were recalculated and inputted. O&M variable and fixed costs were recalculated and inputted. Electricity generated in the base year was recalculated and inputted.
8. The values of seasonal peak AFs of existing plants verified with Dispatch center were inputted into the model.
9. There was no data on export/import seasonal constraint for electricity trade with Armenia and Azerbaijan. Data obtained from Dispatch center was converted and inputted into the model.

Tasks for the next session:

The following tasks were given to the AD:

- Conduct an analysis of the updated Reference case. Write a summary with description of the main observations.
- Obtain/estimate export/import prices of electricity. Present the brief overviews of neighboring countries' electricity sectors at the next training session.

WEG will conduct the following activities:

- Continue with the analysis of results, identification of data/assumptions' limitations
- Analysis of results of household survey conducted by AYPEG
- Input the results of household survey conducted by AYPEG
- The work on Reference case improvement will continue

[9] *Renewable Energy Potential in Georgia and Policy Options for Its Utilization*, <http://weg.ge/wp-content/uploads/2012/12/renewable_energy1.pdf>.

June 25, Training Summary

1. Nestan Gaprindashvili, Senior Specialist of AD made a presentation on energy efficiency and renewable energy issues from training seminars she participated in Japan. She discussed the measures the country implements to assist development of energy efficient and renewable energy technologies as well as successful practice of implementation of energy efficient technologies in Industry and commercial entities.
2. *MARKAL - Discussion of tasks performed by AD*

AD conducted analysis of Reference case and presented the findings. The results and emerging issues were discussed in detail during the training session.

Structure of Policy Brief was presented by WEG using an old Policy Brief as an example. The key performance indicators of energy sector to be included were discussed in an interactive session. AD will review the suggested structure and present their suggestions on Policy Brief template at the next session.

Tasks for the next session:

The following tasks were given to the AD:

- Review Policy Brief prepared by WEG in 2012
- Suggest template for Policy Brief: what tables and graphs should be there, which are priority sectors, etc.

WEG will conduct the following activities:

- Continue with the analysis of results, identification of data/assumptions' limitations
- Analysis of results of household energy end-use survey conducted by AYPEG
- Input the results of household energy end-use survey conducted by AYPEG
- The work on Reference case improvement will continue

July 2, Training Summary

1. Murman Margvelashvili made a presentation on energy and climate change. He discussed sources and types of emissions and effect of climate change on the energy system. In the second presentation he also explained the relation between energy policy and energy strategy, the role of energy statistics and long term energy planning for strategy development. Giorgi Machavariani, representative of Ministry of Environment, made an overview of climate change issues in Georgia

and Ministry of Environment activities in this direction. He also discussed current priorities in climate change adaptation and mitigation in Georgia.

2. *MARKAL - Discussion of tasks performed by AD*

AD reviewed the Policy Brief document that was prepared by WEG in 2012. AD presented their suggestions concerning content of the new Policy Brief. The part of the Policy Brief devoted to Reference scenario was discussed in detail. AD staff was divided into three groups and each group is responsible for specific sections of policy brief.

Although Reference case is still subject to change and improvement, the main goal of the training is to help AD with MARKAL results' analysis and preparation of a Policy Brief. Therefore, the AD will continue practicing in Policy Brief preparation and once scenarios are ready they will be able to develop the policy brief on their own.

Tasks for the next session:

The following tasks were given to the AD:

- Fill in the Policy Brief tables with Reference case results and provide the comments
- Insert graphs and present their analysis

WEG will conduct the following activities:

- Continue with the analysis of results, identification of data/assumptions' limitations
- Discuss with the ministry staff possible new scenarios that are of particular interest for Ministry of Energy
- Analyze and prepare for input the results of household survey conducted by AYPEG
- Continue the work on Reference case improvement

July 9, Training Summary

1. Akaki Kharaishvili made a presentation on Azerbaijan electricity system. He discussed the main generation sources, electricity prices and infrastructure of Azerbaijan.
2. Ronnie Kvachadze made a presentation on Armenian electricity system. He discussed the main generation sources, electricity prices and infrastructure of Armenia.

3. Nestan Gaprindashvili made a presentation on Russian electricity and gas sectors. She discussed prices, the main generation sources and infrastructure capacities.
4. Avtandil Todua made a presentation on Turkish electricity sector. He discussed the main generation sources, infrastructure and electricity prices as well as generation volumes.
5. *MARKAL - Discussion of tasks performed by AD*

AD conducted analysis of the Reference case and filled corresponding part of Policy Brief. They presented graphs and tables that they considered interesting for Policy makers and made primary analysis of presented graphs. Each group presented their parts of Policy Brief and key messages were discussed.

Since this was the last training session within HPEP project, WEG will continue training in informal way (e.g. mail, telephone conversations, etc.). WEG will assist AD in development of Policy Brief to demonstrate their analytical skills and abilities of MARKAL results analysis.

Tasks for the next session:

The following tasks were given to the AD:

- Correct Policy Brief with comments given at training session. Send corrected PB to WEG
- Once WEG reviews PB it will send it back with additional comments and corrections for further improvement.

WEG will conduct the following activities:

- Continue with the analysis of results, identification of data/assumptions' limitations
- Discuss with the ministry staff the possible new scenarios that are of particular interest for Ministry of Energy
- Input results of household survey conducted by AYPEG
- Continue the work on Reference scenario improvement

5.0 APPENDIX II

Presentations

(Appended as a separate PDF file)

6.0 APPENDIX III

GEORGIA POLICY BRIEF

Prepared by Analytical Department of the
Ministry of Energy of Georgia
As part of training in MARKAL Georgia use

A. INTRODUCTION

This Policy Brief focuses on assessing the energy sector costs and benefits for the entire energy system of meeting energy demand throughout 2036. It also considers how meeting the targets impacts key issues facing energy sector decision-makers – namely, how to foster energy security and diversification, and ensure competitiveness and affordability, while taking into consideration climate mitigation and other environmental issues, as part of promoting cost-effectiveness in energy planning.

The following supply and demand analysis has therefore been undertaken:

- Reference (or Business-as-Usual (BAU)) Development: The likely supply and investment requirements to support the evolution of the national energy system in the absence of policies and programs aimed at altering current trends. The Reference scenario is fully discussed in Section B.

For convenience provided below is the energy unit and volume conversion table

Table 1

	PJ	GCal	kToe	Mbtu	kWh
PJ	1	238800	24	948000	2778E05
GCal	4.19E-06	1	0.0001	3.968	1163
kToe	0.042	10000	1	39500	116.3E05
Mbtu	1.0551E-06	0.252	0.252E-04	1	295
kWh	3.6E-09	0.00086	0.086E-06	3.4E-06	1
$1m^3$ =35.3cf= 6.29 bbl					

B. GEORGIA BUSINESS-AS-USUAL ENERGY PATHWAY

To assess the impact of different policies and programs on the evolution of the energy system in Georgia, a Reference scenario was developed, taking into account specific characteristics of the national energy system, such as existing technology stock, domestic resource availability and import options, and near-term policy interventions. The Reference scenario is aligned with the government plans of developing Georgia's abundant hydropower potential based on the Renewable Energy 2008 Program as well as the strategy of positioning Georgia as electricity hub in the region.

A key assumption underpinning the Reference scenario is that taking into consideration the trends in recent years, the rate of economic development will be about 5% annually that is considered as conservative; Natural gas will be available at today's prices (corrected only for inflation) over the period until 2025 with subsequent transition to regional prices.

Under the Reference scenario, primary energy as well as final energy are projected to increase significantly (by more than 85% and about 100%, respectively) by 2036, mostly driven by tripled amount of Gross Domestic Product (GDP) in the forecasted future. According to past trends in population growth, future growth rate of the population is not assumed to be significant (on average, 0.28%). These factors result to almost doubling energy intensity in terms of per capita consumption from 0.75 toe to 1.40 toe. Approximately 4.62% projected growth rate of GDP will require expanding the electricity generation system from 3,3 GW to 5,8 GW and higher import levels, as well as growth in CO2 emissions. Besides, export potential of produced electricity in the country is also taken into consideration. By almost doubling the power plant capacity, Georgia will have in total more than six times higher export than the current level. As the GDP growth rate is assumed to be more than final energy growth rate, final energy intensity in terms of total consumed energy per GDP is going to be lower than the current level (compare 0.27 toe/€000 GDP in 2012 to 0.18 toe/€000 GDP in 2036). All above mentioned key indicators from the Reference scenario are shown in Table 2 and summarized subsequently.

Table 2. Key Indicators for the Reference Scenario

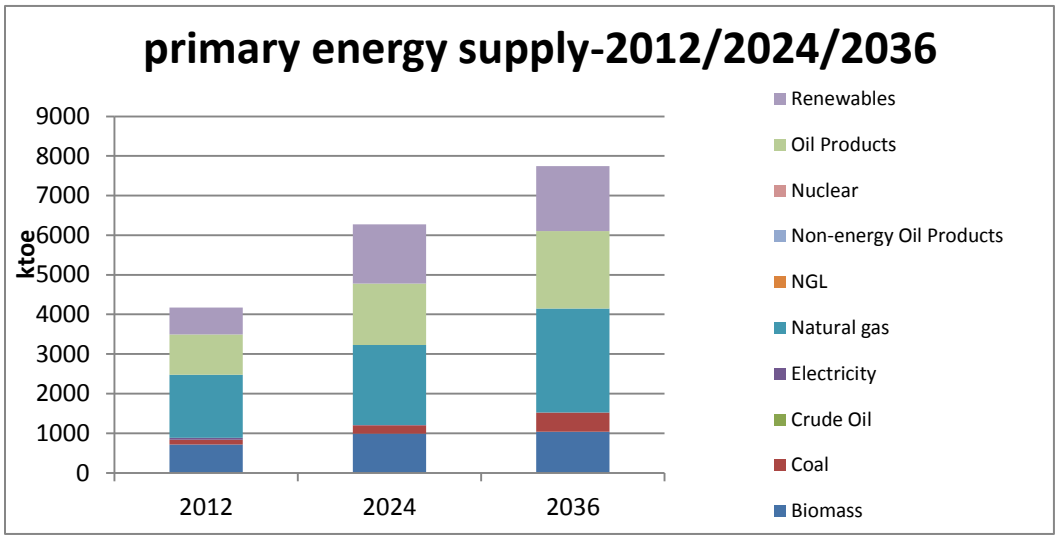
Indicator	2012	2036	Annual Growth Rate (%)	Overall Growth (%)
Primary Energy (Ktoe)	4,143	7,678	2.60%	85.31%
Final Energy (Ktoe)	3,386	6,727	2.90%	98.68%
Power plant capacity (MW)	3,300	5,780	2.36%	75.15%
Imports (Ktoe)	2,657	4,943	2.62%	86.07%
Exports (Ktoe)	(45.41)	(339.63)	8.75%	647.87%
CO_2 emissions (Kt)	6,370	12,533	2.86%	96.75%

GDP (ˆMill.)	12,323	36,447	4.62%	195.77%
Population (000s)	4,498	4,814	0.28%	7.03%
Final Energy intensity (toe/ˆ000 GDP)	0.27	0.18	-1.64%	-32.83%
Final Energy intensity (toe/Capita)	0.75	1.40	2.61%	85.62%

Primary energy consumption in 2036 is projected to be 7,678 ktoe, increasing from 2012 levels by 85%. While growing GDP and increasing household energy intensity are driving up energy demand, it is also important to note that energy intensity per unit of economic output is much lower than observed in 2012 – estimated to be 0.18 toe/€1000 GDP a reduction of around 33%. This is a result of the continuation of current structural changes in the Georgian economy and natural technological progress underway throughout the world.

Observed growth in primary energy does not lead to significant changes in supply mix. As shown in Figure 1, primary energy supply more than doubles with imported natural gas accounting for 38% of total supply. The growth in transport demand is reflected in the increase in oil products (imported), although the share in primary energy is similar. The contribution of renewable energy sources (excluding biomass) to total primary energy increases from 15% to 20% over the years 2012-2036. The biomass share drops from 17% to 14% in total primary energy while it increases in absolute volume.

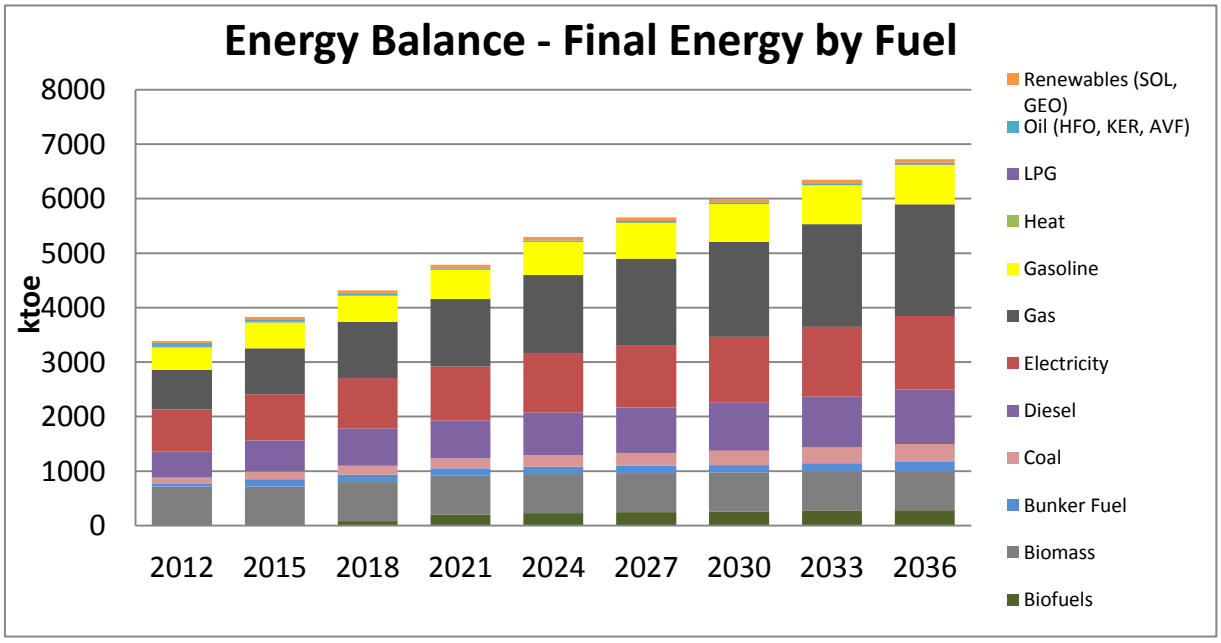
Figure 1. Primary Energy Supply



Total final energy consumption grows by over 99% over the planning horizon, as

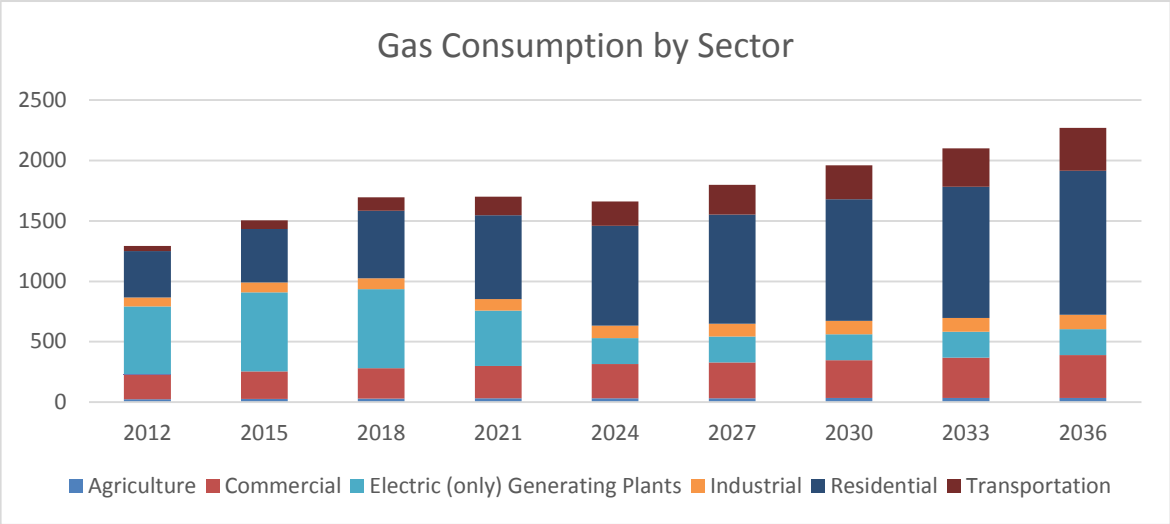
shown in Figure 2, remaining proportionally similar with the exception of the increasing role for gas and coal and introduction of biofuels. The share of gas, electricity and biomass is very high in final energy consumption. It must be noted that gas consumption in the period of 2012-2036 is increasing by 14% compared to previous year. In 2036 compared to 2012 it is predicted that gas consumption will be 2054 ktoe, i.e. 182% higher than in 2012. The mentioned fact will partially cause the share of gas consumption in residential sector to grow from 30% up to 53%, the increase is also deducted in other sectors. According to the fact that gas is an imported fuel, the dependence of fuel import in the country will also increase together with the increase of gas consumption.

Figure 2. Final Energy Consumption by Energy Type



Gas Consumption: A more detailed view of gas consumption by sector is shown in Figure below (Figure 3). It shows that because of gasification the majority of gas is used in the residential sector. Electric (only) generating plants and commercial sector also use large amounts of gas, but over the years Electric Generating plants' gas consumption is decreasing, because it is planned to build more HPPs and some gas fired power plants are going to be closed. In residential sector gas is used primarily for space/water heating and cooking. Gas price is lower than other fuel prices and it's the reason of gas consumption increase in transportation sector (many people use gas for transportation). Use of Gas in transportation reduces CO2 emissions relative to use of oil products in transportation sector.

Figure 3. Gas Consumption by Sector and Power Plant Type



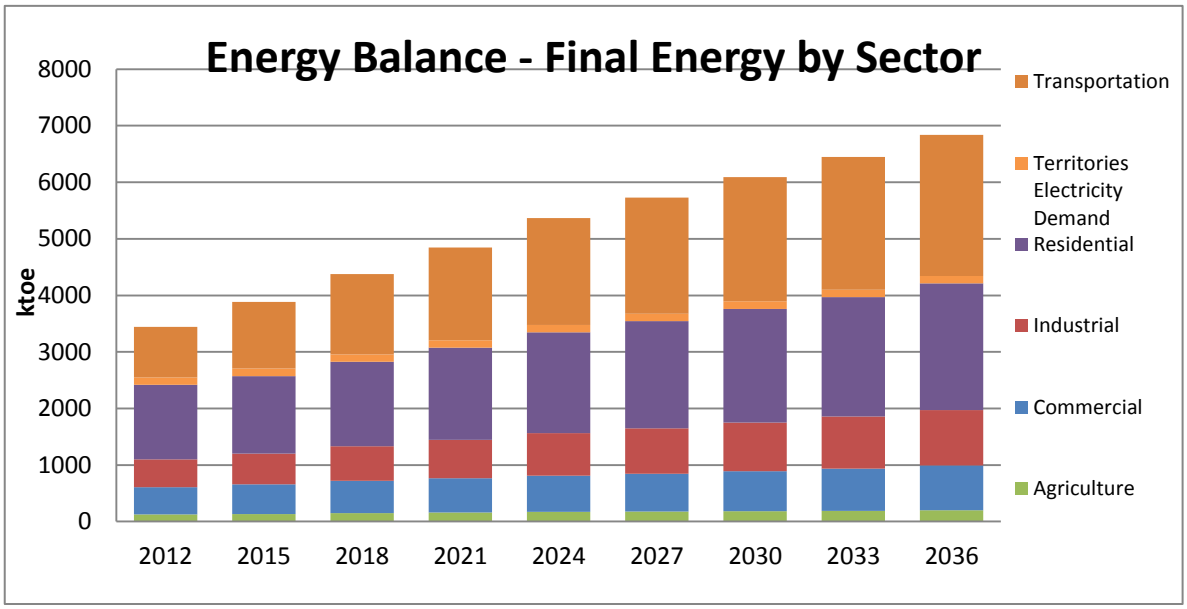
On the next table there is shown gas consumption growth by sector.

Table 3 gas consumption growth by sector

	Gas Consumption by Sector - Growth Rate							
	2015	2018	2021	2024	2027	2030	2033	2036
Agriculture	7%	11%	4%	4%	1%	1%	1%	1%
Commercial	12%	10%	7%	5%	4%	7%	6%	7%
Electric (only) Generating Plants	17%	0%	-30%	-53%	0%	0%	0%	0%
Industrial	9%	9%	9%	8%	4%	4%	3%	3%
Residential	15%	27%	24%	19%	9%	11%	8%	10%
Transportation	68%	51%	37%	32%	23%	14%	13%	12%
Total	17%	13%	0%	-2%	8%	9%	7%	8%

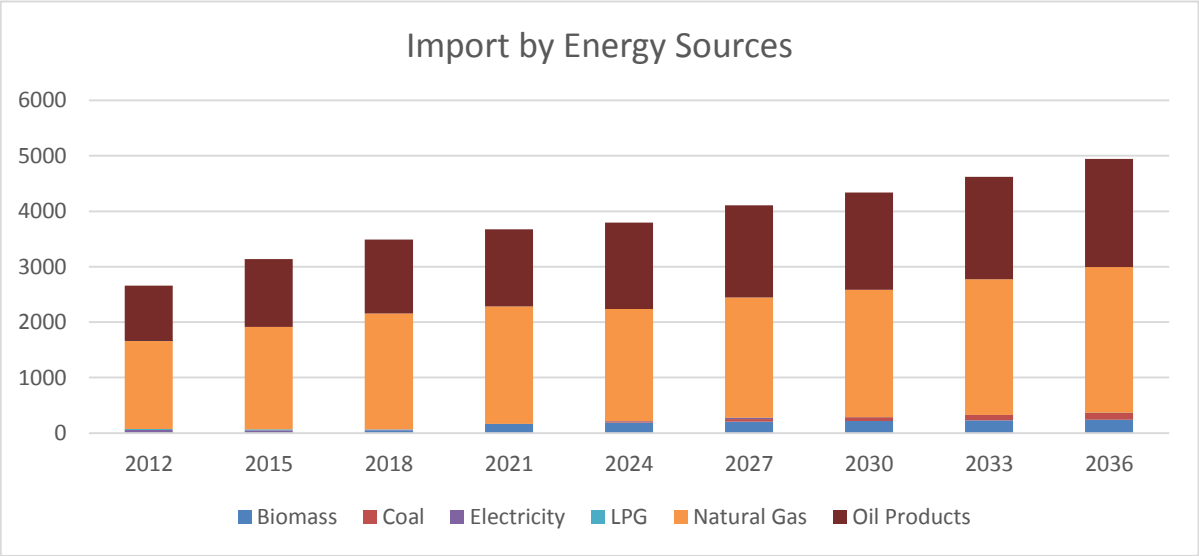
Energy consumption by sector is shown in Figure 4. It shows that majority of the Final Energy is used in the residential and transportation sectors. The contribution of transportation sector in energy sources during this period increases from 26%-36% during 2012-2036 years and final energy consumption in 2036 is projected to be 2,492 ktoe, increasing from 2012 levels by 178%. The above-mentioned increase is caused by the transport sector due to the high demand of fuel. The amount of fuel consumption is also high in residential sector, although, its contribution drops from 38% to 33% during 2012-2036 years. It is predicted that the increase of fuel by 100% will also be in the industry sector. This fact is caused by activation of the role of the industrial sector in the economy of the country, which will increase the demand on fuel.

Figure 4. Final energy by sector



Import: The majority of Georgia's fossil fuels are imported. Demand for natural gas and oil products increases import dependency, resulting in an almost doubling of imports by 2036 (relative to 2012 levels). The high consumption of gas in the end-use sectors reflects the critical need for energy diversification and shows the vulnerability of economic and social development to external factors, and thus is an important issue for sensitivity analysis. It is shown that biomass import also increases and it means that renewable energy sources substitute traditional fossil fuels and it closes country's energy structure to EU targets.

Figure 5. Imports by Type of Energy



New power generation capacity additions in each three year are shown in table 3, with the corresponding costs shown in Figure 5. Continued expansion of hydro power is the most prevalent trend with a cumulative additional capacity of 2,570 MW by 2036. A number of ongoing construction projects are taken into account as must build plants. This includes several hydro plants and a gas-fired power plant, which come online in 2017. At 2030 coal-fired power plant is introduced with 160 MW capacity. Wind also makes some contribution by the end of the planning horizon adding 90 MW to the country's electricity capacity at 2036. Capacity additions and the retirement of old power plants results in 5,780 MW of total installed generation capacity in place in 2036. These results are based on the available data, which needs to be specified, especially import - export prices and Investment Costs of New Power Plants (more detailed information is given in the Annex 1).

Table 4. Additional Power Plant Capacity by Fuel Type (MW)

Plant Type	Total Installed 2015	2018	2021	2024	2027	2030	2033	2036	Total Additional Capacity
Coal-fired						160			160
Gas-fired	680	230							230
Hydroelectric	3,464	547	1,185	464		62	128	19	2,570
Renewable and Other								90	90
Total New Capacity	4,144	777	1,185	464	0	222	128	109	3,050
% of Installed Capacity	4%	16%	19%	7%	0%	3%	2%	2%	43%

Total electric generation at 2036 reaches 15 604 MWh. Generation from the point of view of fuel is given in Table 4. The highest rate has hydropower generation, but gas has significant role in electricity generation: decreasing from 2 472 MWh to 2 160 MWh in 2021 and beginning from 2024 keeps constant level of 1 272 MWh. From 2030 the 692 MWh coal-fired power plant is introduced. It is notable, that at the end of the reporting period the wind power adds the additional 196 MWh to the total generation.

Table 5. Electric generation by fuel type (MWh)

Plant Type	2012	2015	2018	2021	2024	2027	2030	2033	2036
Coal-fired	0	0	0	0	0	0	692	692	692
Gas-fired	2477	2472	2472	2160	1272	1272	1272	1272	1272
Hydroelectric	7220	7881	10384	14327	15908	16134	16523	17144	17394
Renewable and Other	0	0	0	0	0	0	0	0	196

Total	9783	10550	11348	12068	12914	13639	14249	14986	15604
Electricity exports	-528	-405	-1594	-4418	-4330	-4073	-4238	-4123	-3950
Electricity imports	615	601	87	0	63	306	0	0	0

Despite of the new generation capacities, the country electric system still needs imported electricity and its amount varies from 615 MWh (in 2012) to 306 MWh (2027). From 2027 until the end of the reporting period there is no need to import, because of the additional capacity from the coal-fired and wind power plants.

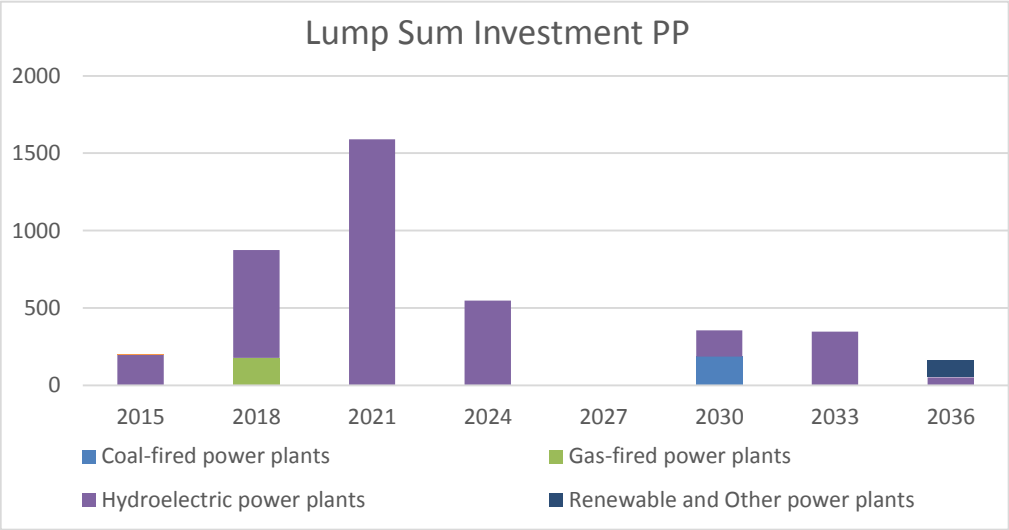
Electricity export

As for the export (Table 5.) the major exporter country is Turkey, with constantly increased export capacity reaching 2244 GWh at 2036 that is about 57% of the total export. Russia could be considered as the other notable exporter, where the highest level of export is reached in 2024 and decreases to 1025 GWh at the end of the period. Armenia and Azerbaijan could be seen as an equal potential, varying in rank 97 - 718 GWh. The total export capacity increases to 4418 GWh in 2021 and from this peak point goes down to 3950 GWh in 2036.

Table 6. Export (GWh)

Country	2012	2015	2018	2021	2024	2027	2030	2033	2036
Armenia		-97	-170	-499	-402	-487	-438	-353	-341
Azerbaijan		-97	-170	-718	-475	-475	-353	-380	-341
Russia	-528	-210	-349	-1333	-1466	-1343	-1208	-1319	-1025
Turkey			-904	-1868	-1988	-1769	-2239	-2071	-2244
Total	-528	-405	-1594	-4418	-4330	-4073	-4238	-4123	-3950

Figure 6. Total Investment Cost of New Power Plants



Growth in the energy system will require significant levels of new investment, for both the power sector and demand devices, and increased payments for fuel. Most of the investment goes to Hydroelectric Power plants (Country uses its own energy sources, which strengthens energy security and independence of the country, also it helps Georgia to get closer to EU targets).

	Annual Energy System Expenditure (M€)								
	2012	2015	2018	2021	2024	2027	2030	2033	2036
Fuel Supply Costs	1171	1390	1681	1729	1955	2197	2368	2563	2780
Delivery Costs (All Sectors)	406	480	561	619	696	776	854	933	1018
O&M Costs (Demand)	362	409	477	545	626	706	763	824	890
O&M Costs (Power)	313	337	373	397	415	440	468	495	520
Annualized Investment (Demand)	0	630	1373	2123	2942	3559	3852	4174	4527
Annualized Investment (Power)	0	15	81	201	242	242	269	295	308
Total	2252	3261	4547	5615	6875	7921	8574	9285	10043

Table 7. Annual Energy System Expenditure (M€)

There is a growth in energy system expenditures. Table below shows the growth in expenditure for fuel (extraction, import, and sector differential charges), operating and maintenance (O&M) costs (fixed and variables), investments in new power plants, and the purchase of new end-use devices. The investment expenditures for new power plants and devices are incurred as demand rises and existing power plants and devices reach the end of their operational lifetimes.

Under the Reference scenario assumptions, 3,050 MW of new generation capacity is needed by 2036, requiring a total investment of 4,277€ million, which translates to average annual payments on the order of 508€ million by 2036. Fuel supply costs will also increase significantly, driven by growing demand and increasing prices, from 1171€ million per year today to 2,780€ million in 2036. This will have a significant impact on country's foreign trade balance.

Annex 1 - Additional Power Plant Capacity by Fuel Type (MW)

Plant Type		2015	2018	2021	2024	2030	2033	2036	Total
Coal-fired	Lignite Coal Power Plant, improved, centralized					160			160
	Total					160			160
Gas-fired	Gardabani TPP (natural Gas Combined Cycle Power Plant		230						230
	Total		230						230
Hydroelectric	Dariali		108						108
	KHobi1			46.5					47
	Khobi2			39.5					40
	Minor HPP (less than 15 MW)		21	35	355.6				412
	Minor HPP (more than 15 MW)		287	1,064	108.5				1,460
	Mtkvari		46						46
	Nenskra					62.3	128.4	19.3	210
	New HPP (in operation since 2013)	164							164
	Pharavani		85						85
	Total	164	547	1,185	464.1	62.3	128.4	19.3	2,570
Renewable and Other	Power plant, wind large farms.06.centralised - Cho							90	90
	Total							90	90
Total		164	777	1,185	464.1	222.3	128.4	109.3	3,050

7.0 APPENDIX IV

CORRECTIONS AND INPUTS MADE TO MARKAL MODEL USING THE HOUSEHOLD ENERGY END-USE SURVEY DATA

The following data inputs were corrected based on the household survey information provided by HPEP project:

ENERGY

1. The number of households (previously model contained old data from 2006);
2. Distribution of households by dwelling types;
3. Number of persons per household was adjusted to a new value of 3.8 to match the number of population in 2012 according to GEOSTAT;
4. Shares of households with cooling per dwelling type were inputted;
5. Evolution of household shares per dwelling type was adjusted based on historical trends from GEOSTAT (urbanization);
6. Availability factor of Paravani WPP was changed according to data from MoE;
7. Reworked the number of households owning washing machines. Calculated and inputted electricity consumption by appliances (bottom up approach);
8. Calculated and inputted number of households with dish washing machines (1.65%) and corresponding consumption of electricity;
9. Calculated and inputted number of drying machines (0.55%) and corresponding electricity consumption;
10. Number of households using electricity for cooking and corresponding electricity consumption were calculated and inputted;
11. Number of households with refrigerators and corresponding electricity consumption were calculated and inputted;
12. Number of households with lighting technologies and corresponding electricity consumption were calculated and inputted. These numbers were verified using average number of bulbs, average hours used, etc. as per consumer answers;
13. Calculated the share of households prepared to implement energy efficiency measures: energy efficient bulbs, high energy efficiency devices, house insulation, PVC windows, solar heaters, central heating;
14. Shares of households planning to arrange central heating were considered in dwelling allocation evolution (transfer from urban single house with local heating to central heating);
15. Number of households using cooling appliances were calculated and inputted as well as corresponding electricity consumption for cooling (different types of technologies with corresponding shares were considered);

16. The numbers of households using cooling per dwelling types and corresponding electricity consumption were calculated and inputted;
17. Average heat content factor for wood was calculated and inputted considering types of wood fuel used, density, water content, etc. Based on the survey data and wood expert Koba Chiburtanidze;
18. Calculated and inputted the number of households using electricity for water heating and the corresponding electricity consumption;
19. Calculated and inputted the shares by dwelling types that use electricity for water heating;
20. Calculated and inputted number of households that use electricity for space heating and corresponding electricity consumption;
21. Calculated and inputted shares by dwelling types that use electricity for space heating;
22. A share of households per dwelling type planning to implement thermal insulation of house was inputted to user constraint template;
23. Share of households planning to use high energy class appliances was considered in user constraint template;
24. The statistical difference between total electricity consumption and the sum of electricity consumption by useful energy types, was added to other electricity use;
25. Calculated the share of households planning to use energy efficient lighting technologies;
26. Inputted penetration rates (calculated form AYPEG data) in Demand Projections file for refrigerators, washing machines and cooling;
27. Reduced penetration of dish washing machines and dryers;
28. Inputted penetration ratio for cooling per dwelling type (based on calculations from STATA);
29. Estimated average consumption of wood for heating, water heating and cooking (from STATA);
30. Calculated the number of households, using wood for heating (STATA), estimated wood consumption for heating and inputted into the model;
31. Calculated and inputted the shares of dwellings using wood for heating (STATA). Share of dwellings with central heating was very small and was added to “Urban Local”, since in the model bio technology does not exist in dwelling with central heating;
32. Calculated the number of households, using wood for water heating (STATA), estimated the wood use for water heating and inputted into the model;
33. Calculated the number of households using wood for cooking (STATA), estimated and inputted wood consumption for cooking;
34. Calculated the number of households using gas for space heating (STATA), estimated and inputted their gas consumption;

35. Calculated shares of dwellings that use gas for space heating (STATA) and inputted it;
36. Calculated the number of households that use gas for water heating (STATA) estimated and inputted its corresponding consumption;
37. Calculated and inputted the shares of dwellings that use gas for water heating (STATA);
38. Calculated the number of households that use gas for cooking (STATA), estimated and inputted their gas consumption;
39. Calculated the average consumption of LPG in cooking separately and cooking and water heating together (STATA). Estimated the amount of energy that goes to solely water heating (difference in averages);
40. Calculated the number of households that use LPG for cooking (STATA), estimated and inputted consumption of LPG for cooking;
41. Calculated and inputted the number of households that use LPG for water heating (STATA), estimated consumption of LPG for water heating;
42. Calculated and inputted the share by dwellings of those who use LPG for water heating;
43. Corrected purpose of RSDSOL that now goes to solely water heating (the most common technology that uses solar);
44. Estimated number of households that use solar water heater by dwelling types and inputted it;
45. Estimated solar energy consumed in residential and inputted it.

TECHNOLOGIES (DEVICES)

46. Calculated the shares of households that use inefficient wood stoves (28% average efficiency) more efficient (Svanetian) wood stoves with average 47%, and the most efficient (80%) stoves. Derived and inputted the average efficiency for wood stoves in 2012. (estimation based on prices of technologies: inefficient cost <100 GEL, Efficient >100GEL and the most efficient >300 GEL);
47. Removed the technologies fueled by wood from “House Urban central”, since such dwellings use the wood only in fireplaces;
48. Corrected other technologies that are not used in the common types of dwellings (LPG heating stove, Electricity furnace H+W, solar water heaters for “Urban Local” and “Urban Central”, central cooling systems, etc.);
49. Calculated the number of households per dwelling that use cooling technologies and split systems and inputted corresponding “shtech” shares per each type of dwelling;
50. Added Solar water heater to the list of technologies for Apartments;
51. Added LED lighting technology to set of lighting technologies for base year;

52. Inputted “shtech” shares for heating with wood for all types of dwellings;
53. Inputted “shtech” shares for heating with electricity and corresponding efficiency for technologies for all types of dwellings;
54. Inputted “shtech” shares for heating with gas and corresponding efficiency for technologies (based on shares of technologies used and their technical parameters) for all types of dwellings;
55. Inputted the total surface area and load factor for all types of dwellings. Data calculated using STATA;
56. Added central heating technology fueled by gas to rural house, since according to the survey results approximately 9% use this technology;
57. Estimated efficiency of cooking technologies and inputted;
58. Inputted “shtech” shares for lighting technologies. There was no question on halogen lighting in the questionnaire and the share of halogen lighting was assumed to be 5%;
59. Inputted “shtech” shares for refrigerators and freezers;
60. Inputted “shtech” shares for all water heating technologies and dwelling types; Inputted efficiency of water heating technologies, considering the types of technologies used and their shares.

TRANSPORT SECTOR

61. Calculated from STATA the number of vehicles by vehicles types and by fuel types;
62. Calculated average consumption of fuel per 100 km (from STATA) by vehicle types and by fuel;
63. Calculated (from STATA) the consumption of fuel per month by fuel and vehicle type;
64. Estimated kilometers travelled by vehicle types using the information above;
65. Calculated (from STATA) vehicle load factor (passengers and load) per vehicle type;
66. Calculated the shares of vehicles converted to CNG by vehicle type;
67. Calculated the number of vehicles (per vehicle type) with the age of above 20 years, 15-20 years, 10-15 years and less than 10 years. This data can be used while setting lifetime of vehicles and estimating the shares of those to be replaced.

8.0 REFERENCES

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Strategic Planning for Energy

Why does not Georgia have robust energy strategy yet?

Murman Margvelashvili

WEG

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content

- Description of data collection analysis and planning system for planning
- Description of functions of the participants and their interactions.

***Note**: The suggested scheme describes the functions that can be allocated as needed*

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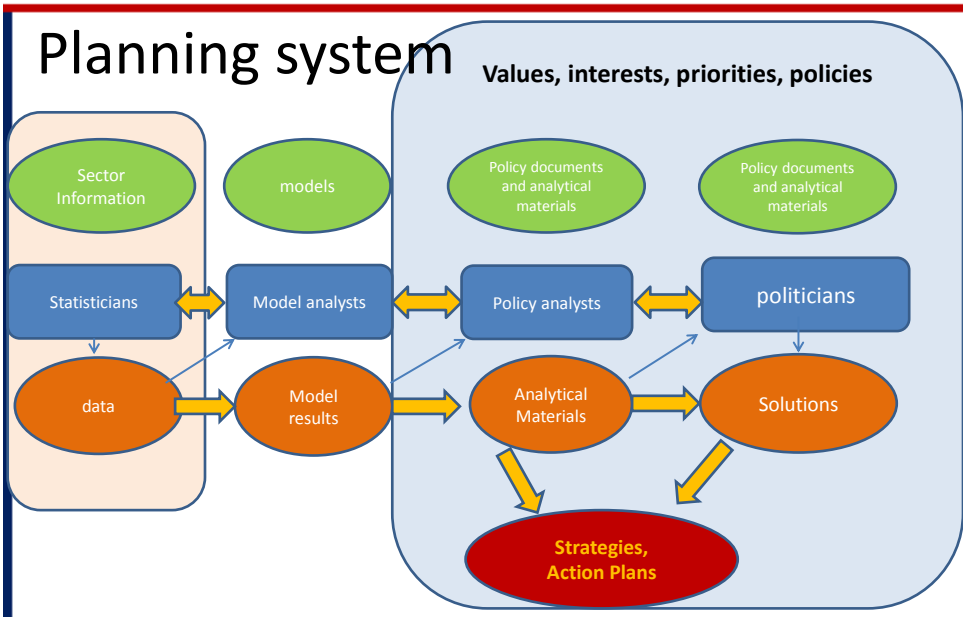
Planning system



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„ Statisticians“

- Data collection from various agencies
  - Energy Information, consumption
  - Economic Information
  - Data validation and statistical analysis in accordance with the model input data
- Further details of the data for periodic updates and improvements

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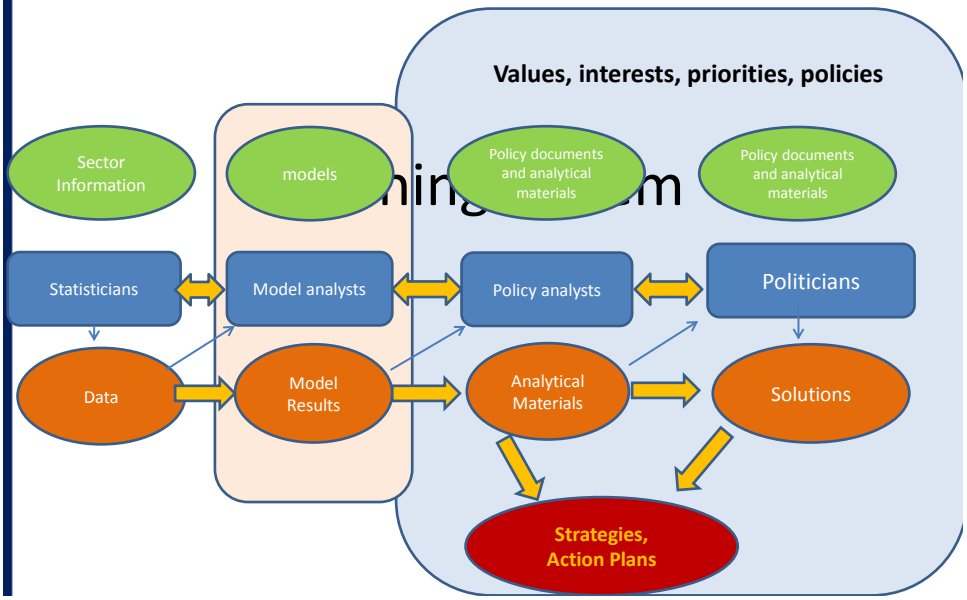

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Model analysts are responsible for

- Data collection, interpretation and translation into model inputs
- Data Quality Control and Improvement
- Upgrading the model and updating the input data.
  - Modern technology parameters
  - System changes
  - New data and statistics
- New concepts for modeling
- Quality control of the results
- Preparation of technical reports

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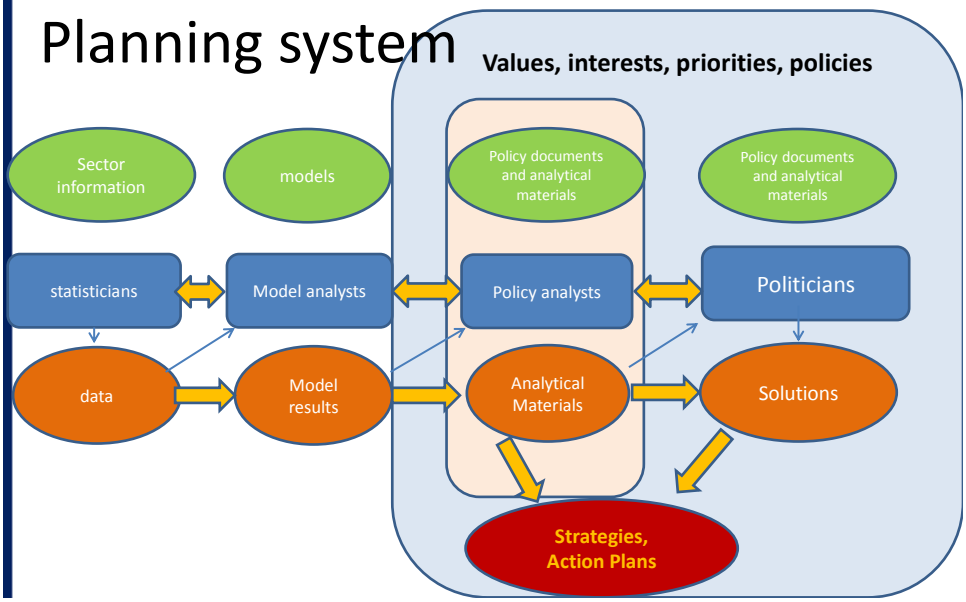
Planning system



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Responsibilities of Policy Analysts

- Quality control of model and it`s results
- interpretation of existing policies, priorities and constraints for the model.
- preparation of scenarios and questions for the model
- Interpretation of the model results and preparation of improvement proposals
- Preparation of policy documents based on model results.
- Working with existing policy documents and reports.
- Keeping track of Energy and technology trends
- Communication and cooperation with other partner agencies and colleagues

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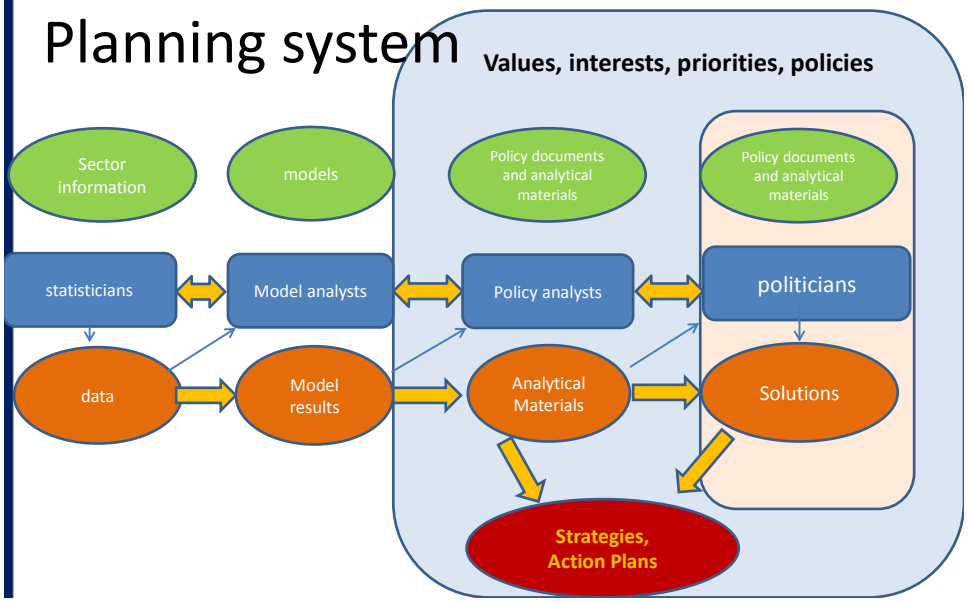
Planning system



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Politicians' functions

- Organizing the analysis and planning system
- Setting priorities and the boundary conditions (time horizon, political restrictions, etc.).
- Defining the key decision parameters (KPIs) and their priorities.
- Giving tasks and questions to analysts
- Reviewing the recommendations, properly interpreting and taking them into consideration.
- Decision-making on the basis of policy analysis and other policy documents (no decision is also a decision!)

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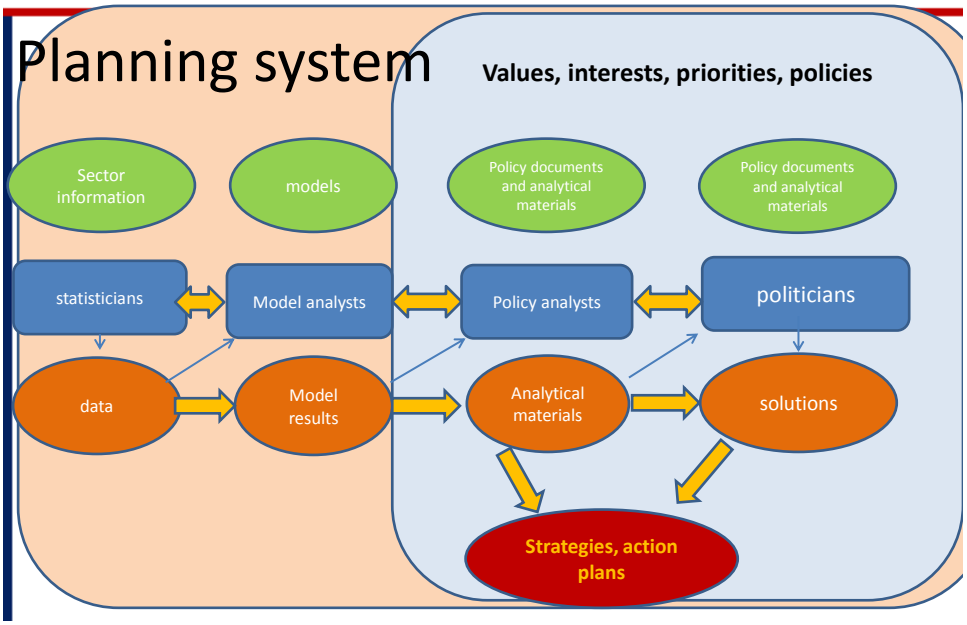
Planning system



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Analysis and Planning System

- Planning is an iterative process, different options are being verified and specified before and after preparing the final version of the strategy.
- United interdependent system
  - If any group or a link is not functioning properly, the system and its components can not be developed
  - all participants and connections must be developed together.
  - Setting up and maintenance of each function and procedure is needed.

Only under such conditions the comprehensive energy strategy can be formulated

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What the Model Is Not

(Keep in mind)

- Oracle and forecaster
- Decision provider
- Final product
  - At each stage the model reflects current information and views
  - There is always room for refinement, improvements are stmulated by new questions and cases

Model only provides better systemic view of reality

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What the Model Is

- Basis for planning functionality development
- Analytic instrument in continuous refinement
- Repository of current knowledge and data
- Reference and communication means between analysts and policy makers
- Means for consensus building

At each stage the model should reflect current best knowledge and information

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From Model to Planning

Economic benefit is not the only criterion

- Energy security – security risks
- Environmental considerations
- Political visions and priorities
- Regional development
- Social considerations (e.g. gasification & fuel wood)
- etc
- Externalities should be incorporated in decision making

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From Model to Planning

- Scenarios
  - Asking policy questions
  - Agreement on boundary conditions, constraints and main assumptions
- From Scenarios to Decisions
  - Agreement on decision criteria
  - Comparison of different scenarios through multiple criteria
  - Final decision that may differ from scenarios
  - New scenario runs
- From decision to plan
  - Planning for policies
  - Financial planning
  - Organizational planning

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Economic and financial basics of energy planning

What does MARKAL optimize?

WEDNESDAY, 19 MACH, 2014

Murman Margvelashvili

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Content

- Time value of money, discounted cash flow, annuity, NPV, IRR
- MARKAL objective function and its compounds
- Levelized cost – comparing prices of different technologies

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The Time Value of Money

How to compare $1 million now to $1 million 10 years from now?

People much prefer the money now!

There is an inherent monetary value attached to time.

A dollar received today is worth more than a dollar received tomorrow

- This is because a dollar received today can be invested to earn interest
- There is also a perceived risk of not getting the same money in future

Time value of money quantifies the value of a dollar through time

3

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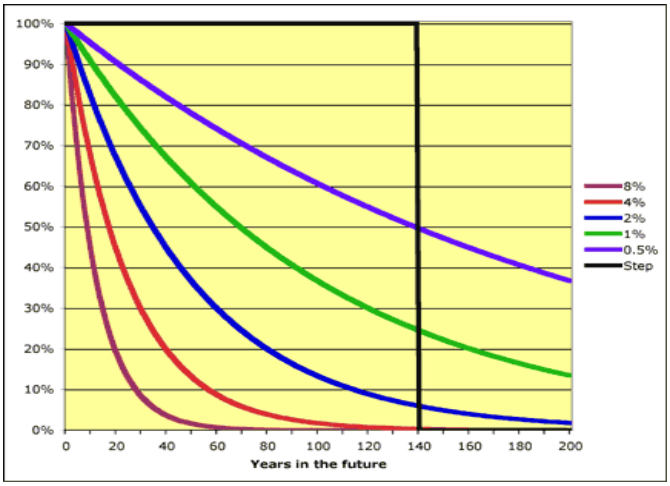
Interest rate



– Compound interest

C X (1+r) , **C X (1+r) X (1+r),** **C X (1+r) X (1+r) X (1+r)**

$$FV_t = C \times (1+r)^t$$

– Present value of a lump sum:

$$PV = C_t / (1+r)^t \quad \textit{OR} \quad PV = FV_t / (1+r)^t$$

– Present value of a cash flow stream:

$$PV = \sum_{t=0}^{n} [CF_t / (1+r)^t]$$

Where:
- **r** = interest rate or rate of return
- **t** = time period
- **n** = number of time periods
- **CF** = Cash flow
- **PV** = present value
- **FV** = future value

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Present Value and Future Value

- Present value calculations determine what the value of a cash flow received in the future would be worth today (time 0)
- Process of finding a present value - - “discounting”
- The interest rate used to discount cash flows - discount rate
- Future value determines the amount that a sum of money invested today will grow to in a given period of time
- “compounding” adding interest to base value and interest

Present Value of a Cash Flow Stream

- The PV of the cash flow stream is equal to the sum of the present values of each of the individual cash flows in the stream.
- The PV of a cash flow stream can also be found by taking the FV of the cash flow stream and discounting the lump sum at the appropriate discount rate for the appropriate number of periods.

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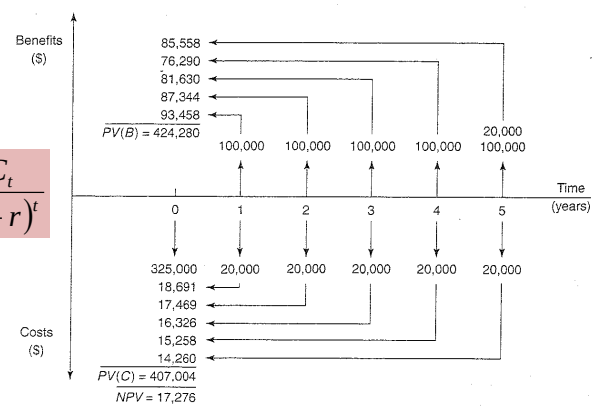
Annuities

- An annuity is a cash flow stream in which the cash flows are all equal and occur at regular intervals.
- Note that annuities can be a fixed amount, an amount that grows at a constant rate over time, or an amount that grows at various rates of growth over time. We will focus on fixed amounts.

Net Present Value (NPV)

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$$



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NPV – Decision

- *NPV depends on the required rate of return*
- *If the NPV is positive, accept the project*
- A positive NPV means that the project is expected to add value
- NPV is a measure of how well this project will meet this goal.

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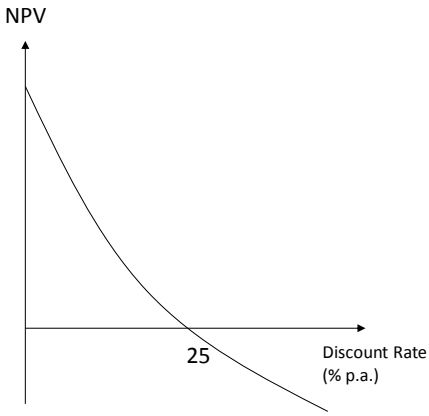
Internal rate of return (IRR)

- Definition: IRR is the return that makes the NPV = 0
- Decision Rule: ***Accept the project if the IRR is greater than the required return***

	YEAR				
	0	**1**	**2**	**NPV**	Discount rate
Cash flows	-12.0	5.0	10.0		
	-12.0	4.5	9.1	1.6	10%
	-12.0	4.3	8.7	1.0	15%
	-12.0	**4.0**	**8.0**	**0.0**	**25%**
	-12.0	2.5	5.0	-4.5	100%
	-12.0	1.0	2.0	-9.0	400%



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MARKAL objective function: total system cost

The MARKAL objective is to minimize the total cost of the system, discounted over the planning horizon. Each year, the total cost includes the following elements:

- *Annualized investments* in technologies
- Fixed and variable annual *Operation and Maintenance (O&M)* costs of technologies;
- Cost of energy and material *imports* and domestic resource *production* (e.g., mining);
- Revenue from energy and material *exports;*
- Fuel and material *delivery* costs;
- *Taxes and subsidies associated with energy sources, technologies, and emissions.*

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Levelized cost

Levelized Energy Cost – the price at which electricity must be generated from a specific source to break even over the project lifetime.

Cost of the energy-generating system including: initial investment, operations and maintenance, cost of fuel, cost of capital.

$$LEC = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

where

- LEC – levelized energy cost
- I_t - Investment expenditures in the year *t*
- M_t Operations and maintenance expenditures in the year *t*
- F_t - Fuel expenditures in the year *t*
- E_t - Electricity generation in the year *t*
- r - Discount rate
- n - Life of the system

Useful in calculating the costs of generation from different sources

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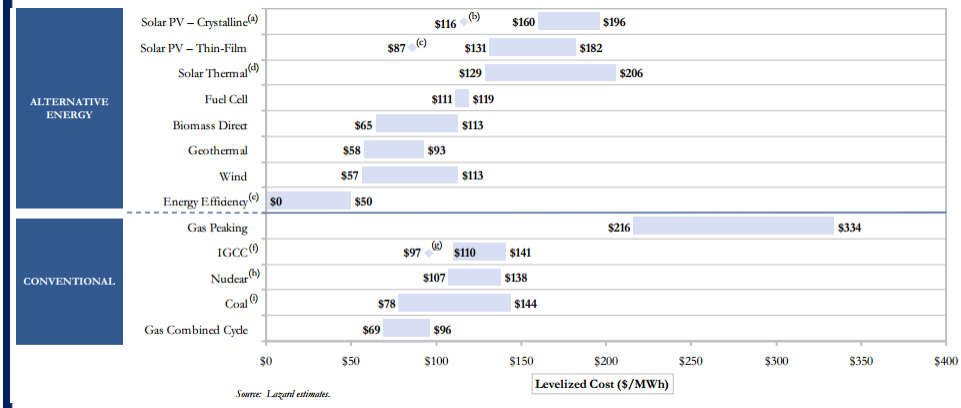
Levelized cost of Energy



B & V 2009

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MARKAL Objective function

$$NPV = \sum_{r=1}^{R} \sum_{t=1}^{t=NPER} (1+d)^{NYRS \bullet (1-t)} \bullet ANNCOST(r,t) \bullet \left(1 + (1+d)^{-1} + (1+d)^{-2} + \cdots + (1+d)^{1-NYRS}\right)$$

where:

NPV is the net present value of the total cost for all regions (the MARKAL objective function)

ANNCOST(r,t) is the annual cost in region *r* for period *t*, discussed below

d is the general discount rate

NPER is the number of periods in the planning horizon

NYRS is the number of years in each period *t*

R is the number or regions

In each period, the investment costs are annualized, before being added to other (annual) costs to obtain the full annual cost in each period. MARKAL then computes a net present value of all annual costs, discounted to a user selected reference year. This quantity is minimized by the model to compute the equilibrium.

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Economic Optimum vs Reality

- Optimum depends on assumptions
- Sensitivity tests – assess the cost of deviations
- Not all decision factors can be easily monetized
  - Energy security
  - Political visions and priorities
  - Environmental and social considerations
- Externalities to be incorporated in decision making

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Energy Demand Projection/Forecasting

WEDNESDAY, 26 MACH, 2014

Giorgi Mukhigulishvili

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Content

- Demand projection/forecasting models and techniques
- Demand forecasting based on econometric models
- Demand drivers by sector and their relative importance
- Demand elasticity for sectors and subsectors
- Review of elasticity in MARKAL

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Projection vs. Forecasting

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Why do we need energy demand projection/forecast?

It allows:

- Sellers to plan and develop the appropriate capacity
- Buyers to pick the appropriate mix of appliances to minimize costs
- Government to make policy plans
- Financial institutions to pick the projects to back and those to reject

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Demand Projection/Forecasting Techniques

- Historical trends
- Univariate time series
- Multivariate time series
- Econometric models
- Optimization

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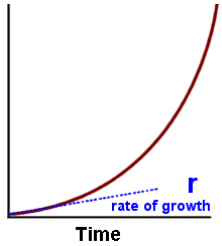
Historical trends

- Constant growth rate - Exponential growth rate

$$O_t = (1+r)O_{t-1} \longrightarrow O_t = e^{rt}O_0$$

- Simplest and longest-used tools for forecasting
- Effective in the short run with a business-as-usual scenario



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Univariate time series

- More sophisticated technique of historical extrapolation
- Current value of an energy variable is a function of past values
- Good for shot-term forecasts
- Does not allow policy analysis

$$X_t = \sum_{i=1}^{n} a_i X_{t-i} + \varepsilon_t$$

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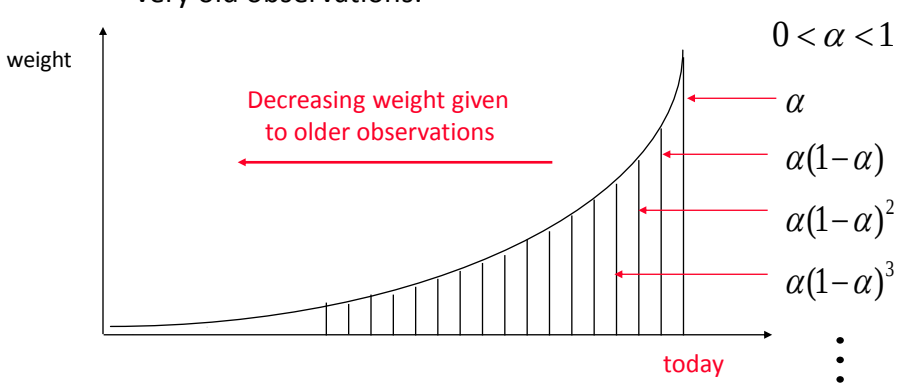
Univariate time series - Exponential Smoothing

- Include all past observations
- Weight recent observations much more heavily than very old observations:



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Univariate time series - Exponential Smoothing

$$F_t = aD_t + a(1-a)D_{t-1} + a(1-a)^2 D_{t-2} + \cdots$$
$$F_t = aD_t + (1-a)F_{t-1}$$

- Thus, new forecast is weighted sum of old forecast and actual demand
- Notes:
  - Only 2 values (D_t and F_{t-1}) are required, compared with *n* for moving average
  - Parameter a determined empirically (whatever works best)
  - Rule of thumb: $\alpha < 0.5$
  - Typically, $\alpha = 0.2$ or $\alpha = 0.3$ work well

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Multivariate time series

$$Q_d = a_1 + a_2 P + a_3 P_d + a_4 Y + a_5 Y_{t-1} + \varepsilon$$

Q_d - quantity purchased
P – Price of gasoline
Y_{t-1} - income lagged
P_d - Price of diesel

Need lot of data over a consistent time period

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Econometric Models

- More attention is paid to the model and variables
- In case of short time series – use cross-section time series
- Good for forecasting turning points and for policy analysis
- Require forecast of exogenous variables

Examples of the econometric models

$$\ln G_{jt} = \beta_o + \beta_1 \ln P_{jt} + \beta_2 \ln Y_{jt} + \beta_3 \ln P_{jt} \ln Y_{jt} + \varepsilon_j + \varepsilon_{jt}$$

$$Y_{it} = \alpha + \beta_1 X_{it} + \beta_2 X^2_{it} + \Psi P_{it} + \phi\, ln(Z_{it}) + \mu_{it}$$

$$Y_{it} = \alpha + \beta\, ln(X_{it}) + \Psi\, ln(P_{it}) + \phi\, ln(Z_{it}) + \mu_{it}$$

$$ln(Y_{it}) = \alpha + \beta\, ln(X_{it}) + \Psi\, ln(P_{it}) + \phi\, ln(Z_{it}) + \mu_{it}$$

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Optimization Models

- MARKAL, TIMES, MESSAGE, MAED, WASP
- Identify the socio-economic activities that “drive” the consumption of energy.
- Organize structure of energy consumption into a hierarchical “tree”.
  Example: Sectors, Subsectors, End-Uses, Fuels/Device
- Typically, specify overall activity levels at top of tree.
  Example: total number of households, industrial value added, etc.
- Disaggregate total activities down to lower levels of the tree. (e.g. 30% of households are urban, and of these 45% have refrigerators).
- At lowest levels in tree, specify the fuels consumed by each device and assign an annual energy intensity (e.g. 10 GJ/household for cooking with LPG stoves).

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Energy demand drivers

- GDP structure and its growth rate;
- Population growth rate, households;
- GDP/capita;
- Energy Prices;
- Technology change/development;
- Country energy, environmental and economic policy;
- others…

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Demand Elasticity

- Elasticity is a **ratio** of the percentage change in one variable to the percentage change in another variable, when the latter variable has a **causal** influence on the former.

$$\mathbf{E} = \frac{\%\Delta\mathbf{Q}}{\%\Delta\mathbf{P}}$$

- Elasticity vs. intensity

$$\mathbf{I} = \frac{\mathbf{Energy\ (kWh)}}{\mathbf{GDP\ (USD)}}$$

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Energy Demand Projections in MARKAL

Elasticity of energy demand in 5 economic sectors: Industry, Agriculture, Commercial, Transport, Residential with respect to their own demand drivers.

Driver / years	2012	2015	2018	2021	2024	2027	2030	2033	2036
GDP (2012EURM)	12,323	14,263	16,987	19,665	22,765	25,607	28,805	32,401	36,447
GDP growth rate		5.00%	6.00%	5.00%	5.00%	4.00%	4.00%	4.00%	4.00%
Population (1000)	4,498	4,467	4,534	4,602	4,672	4,707	4,742	4,778	4,814
Population growth		0.50%	0.50%	0.50%	0.50%	0.25%	0.25%	0.25%	0.25%
GDP/pop		4.47%	5.47%	4.48%	4.48%	3.74%	3.74%	3.74%	3.74%
Number of persons per household	3.75	3.69	3.63	3.58	3.53	3.47	3.42	3.37	3.32

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Review of elasticity in MARKAL

	2012	2015	2018	2021	2024	2027	2030	2033	2036
Agriculture	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Commercial large and small cooling		1	1	0.8	0.7	0.6	0.5	0.5	0.5
Commercial cooking	0.5	0.8	1.0	0.9	0.7	0.4	0.4	0.3	0.3
Commercial large water heating	0.4	0.4	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Commercial small water heating	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Commercial large space heating	0.6	0.6	0.6	0.5	0.4	0.4	0.4	0.4	0.4
Commercial small space heating	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5
Commercial Lightning	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Commercial Other Electricity		0.8	0.8	0.7	0.6	0.5	0.5	0.5	0.5
Commercial Public Lighting		0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.3
Commercial Fridges and Freezers		1.0	1.0	1.0	0.7	0.5	0.4	0.3	0.3
Industry all subsectors	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

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Review of elasticity in MARKAL

	2015	2018	2021	2024	2027	2030	2033	2036
Residential Apartments heating– Urban(elasticity with GDP/POP)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Residential Single House - Urban – Central heating elasticity with GDP/POP)	0	0	0	0	0	0	0	0
Residential Single House - Urban – Local heating elasticity with GDP/POP)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Residential Single House - Rural - Localheating elasticity with GDP/POP)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Residential water heating Apartments – Urban	1.0	1.0	1.0	0.8	0.6	0.4	0.2	0.1
Residential water heating Single House - Urban – Central	1.0	1.0	1.0	0.8	0.6	0.4	0.2	0.1
Residential space cooling Apartments – Urban	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Residential cooking	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Residential Cloth Drying	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residential Dish Washing	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Residential Lightning	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Residential Fridges and Freezers	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Residential Cloth Washing	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

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The End

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Electricity Load Projection and System Planning

MURMAN MARGVELASHVILI

WEDNESDAY 2 APRIL 2014

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- Balance between demand and generation – Generation equals net demand **at all times**
- Variability of demand should be followed by variability of supply (generation+import-export)
- Factors
  - Regular consumption patterns
  - Unplanned variations of demand (Football case)
  - Variability of renewable sources
  - Generation outages

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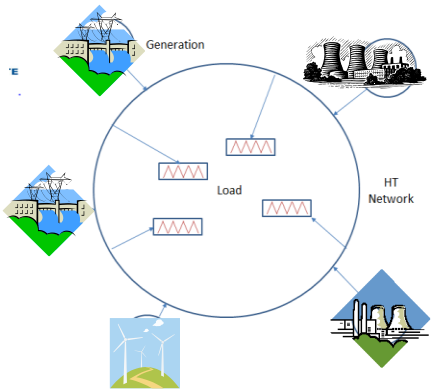
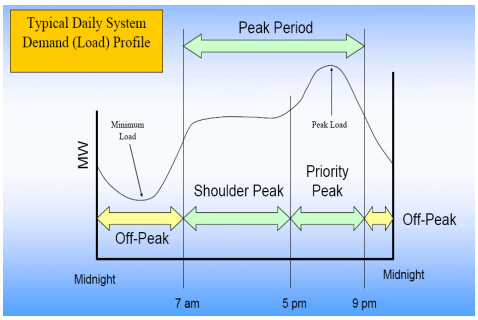
Power System Dispatch
Base Load vs.Peaking Load





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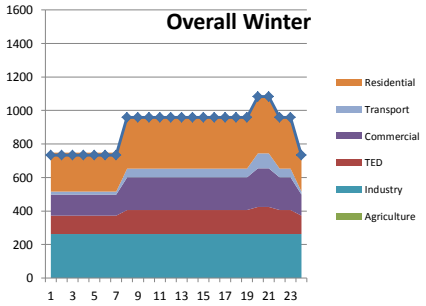
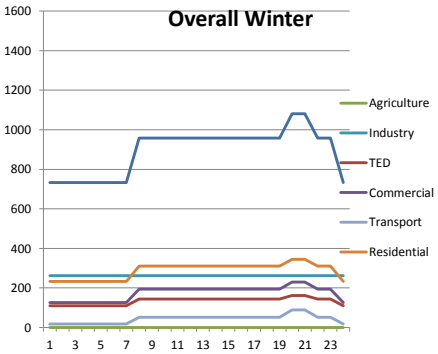
System Load Curve in MARKAL





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Simple load projection approach

$$\mathbf{LC} = LC_r x G_r + LC_i x G_r + LC_a x G_a + LC_c x G_c + LC_{ted} x G_t + LC_{tr} x G_{tr}$$

$LC_{i,r,c,a,t,tr}$ - load curves for various sectors

$G_{i,r,c,a,t,tr}$ - growth factors of corresponding sectors

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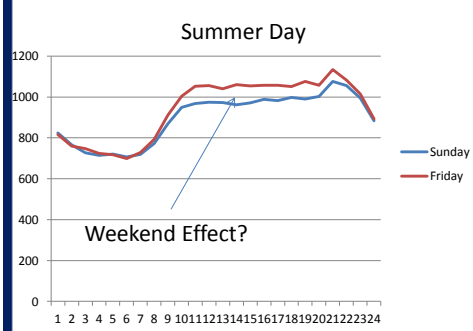
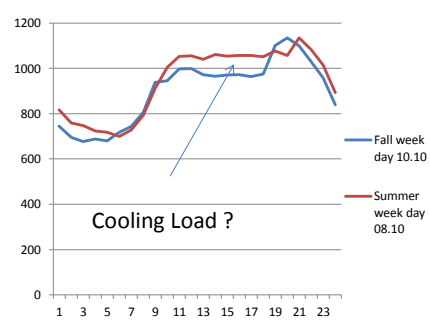
Analyzing Load Curves





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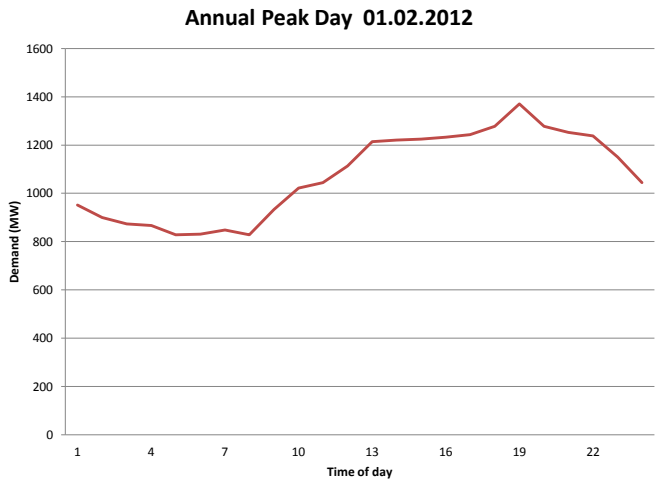

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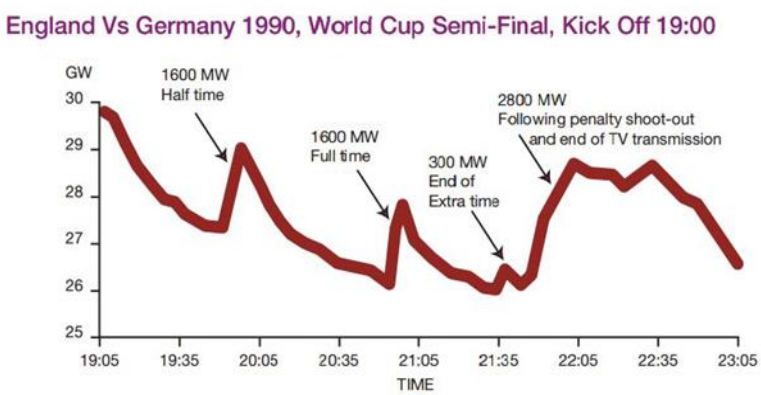
Actual Load is Hard to Predict



Source: John Swinscoe INOGATE presentation

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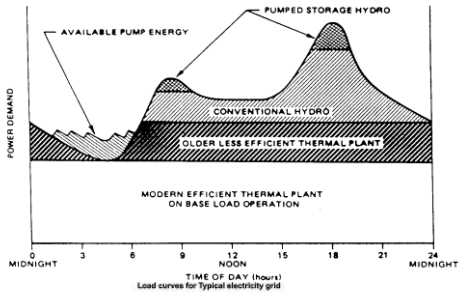
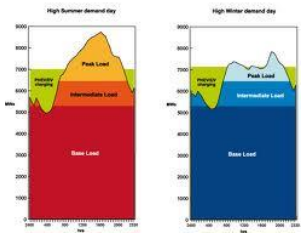


Load curves for Typical electricity grid



- Nuclear PP
- Coal PP - base
- Thermal Condensing cycle- base
- Thermal Combined cycle - base
- Thermal gas turbine - peaking
- HPP – Base/peaking
- Wind - intermittent

http://www.world-nuclear.org/

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System Reserve

- System reliability 99%? 99,9%, 99,99%
- Generation reserve – transmission reserve

- Factors of risk
  - Outages of units and lines
  - Deviations of demand
  - Hydrology deviations

- Spinning reserve
- Cold reserve

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Reliability of Power Units

- Forced and Planned outages
- Forced outage rate (FOR)

FOR = FOH/(FOH+SH)x100 %

- FOH = forced outage hours - იძულებითი გამორთვის საათები
- SH = service hours (planned outages subtracted) მუშაობის საათები (სარემონტო საათების გამოკლებით)

Equivalent forced outage rate (EFOR)

$$EFOR = \frac{FOH + EFDH}{FOH + SH + EFDH} \times 100\ \%$$

- EFDH = equivalent forced derated hours= output reductions **x** forced reduction hours

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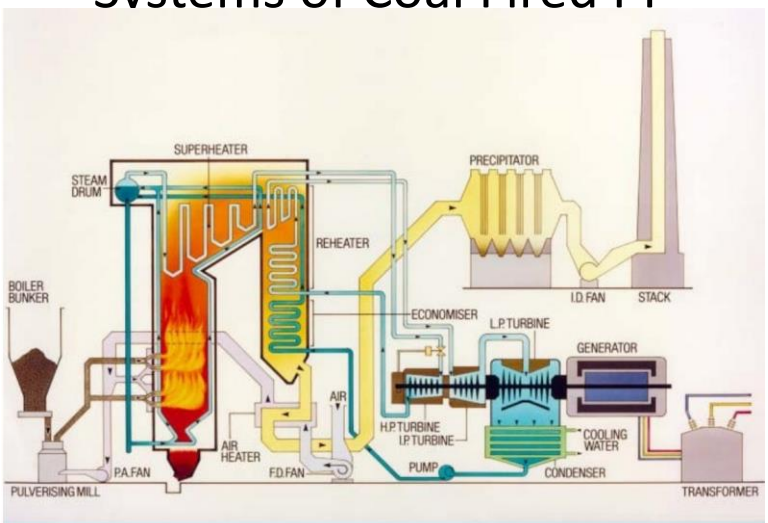
Systems of Coal Fired PP



Layout of a Pulverized Fuel Power Plant

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Probability that exactly m of n units are in operation

$$P(M=m \mid n, R) = \frac{n!}{m!\,(n-m)!} R^m (1-R)^{n-m}$$

n = number of units in the system

n! = 1 x 2 x 3 x …x n

m = number of units in operation

m!= 1 x 2 x 3 x … x m

R = reliability of an <u>unit</u>

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Probability that at least m of n units are in operation

$$P(M=m \mid n, R) = \sum \frac{n!}{m!\,(n-m)!} R^m (1-R)^{n-m}$$

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SYSTEM RELIABILITY R_s @ R_u = 95 %

Number of units n	3	4	5	10	20	100
Units in operation						
n	0.8574	0.8145	0.7738	0.5987	0.3585	0.0059
n-1	0.9928	0.9859	0.9774	0.9139	0.7358	0.0371
n-2	0.9999	0.9995	0.9988	0.9885	0.9245	0.1183
n-3		0.9999	0.9999	0.9989	0.9841	0.2578
n-4				0.9999	0.9974	0.4360
n-5					0.9997	0.6160
n-6					0.9999	0.7660
n-7						0.8720
n-13						0.9995
n-15						0.9999

http://www.optimalpowersystems.com/

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Reserve Margin

$$RM = \frac{\text{Capacity-Peak load}}{\text{Peak load}} = \frac{1-R}{R}$$

R= System Reliability

System Reserve need 99,9%

3 x 100 %	200 %
4 x 50 %	100 %
5 x 33 %	67 %
13 x 10 %	30 %
25 x 5 %	25 %
113 x 1 %	13 %

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- Reserve requirements with one large and several small units

$RR = \sum((1-R) \times P_i) + P_{max}$

RR = reserve requirement

P_{max} = largest unit in the system

R = reliability of the other units

P_i = output of unit I

N-1 criterion

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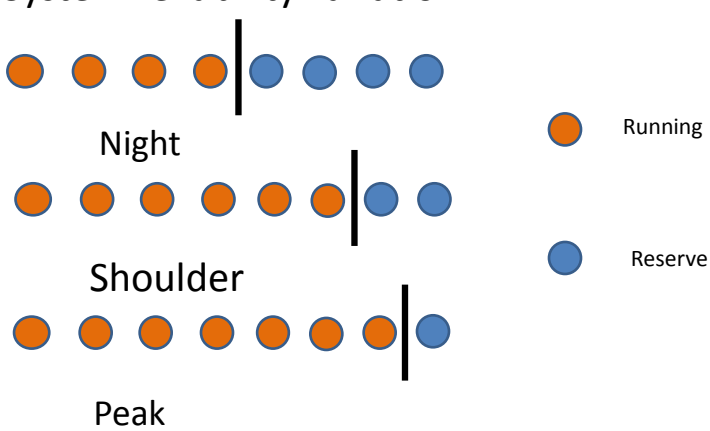
- System reliability variation



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- Power system needs less reserves, if the number of units (n) will grow and the reliability of units (R) increases
- System with 100 units needs 10 – 20 % reserves when the reliability of units varies from 92 to 97 %
- Reserve needs become lower by planning systems with smaller and more reliable units
- Largest unit determines the need of reserve capacity, if the unit sizes are unevenly distributed
- The modern electronic age requires higher system reliability figures because everything depends on computers

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Tasks:

- Analyze one actual winter and one summer day
- Assess and classify available reserve margin in Georgia in summer and winter
- Calculate the system reliability at night, shoulder and peak in previous example
- Visit Dispatch Center
- Investigate Annual peak of 01.Feb.2012
- Startup times of Various generators

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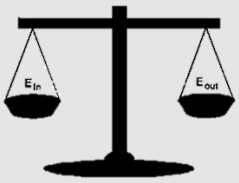
Energy Balance



THURSDAY, 10 APRIL, 2014

Giorgi Mukhigulishvili

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Content

- Composition of energy balance, structure, data organization
- Overview of Georgia's energy balance – from MARKAL/Georgia model
- Analysis of Georgia's energy balance – Energy security, renewables' share, losses etc.

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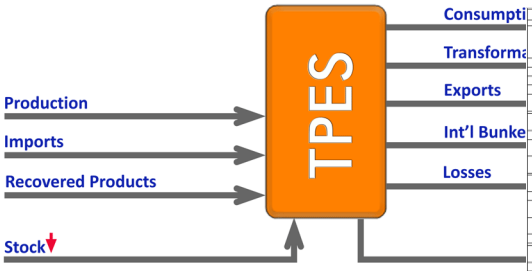
What is Energy Balance?

Energy supply = Energy consumption



Model Energy Balance of Georgia (kilotons of oil equivalent KTOE)

#		Coal	Crude Oil	Oil Products	Natural Gas	Hydroel & Energy	Renewa ble	Firewood and waste	Electricit y	Thermal Energy	Total
10	Production	4	64		17	574	14	385			1058
11	Import	3		792	1462				23		2280
12	Export		-53	-3					-32		-88
13	Stock Build Up	-1	2	4	-3						2
15	Primary Production 15=10+11-12±13	6	13	793	1476	574	14	385	-9	21	0	3252
20	Electricity plants, Boilers			-6	-401	-574			708	32	-241
21	Oil refineries		-13	12							-1
22	Other transformations and losses			-14	-346				-91		-451
30	Energy Supply 30=15+20+21-22	6	0	785	677		14	385	600	32	2499
40	Industrial Sector 40=41+42+43+44	2	0	92	167	0	0	0	116	12	389
41	Metallurgy			3	5				43	3	54
42	Chemical production & Petrochemistry			17	27				36	3	83
43	Nonmetallic materials			15	18				13	2	48
44	Other production	2		57	117				24	4	204
50	Transportation 50=51+52+53	3		512	24				52	0	591
51	Aviation, marine			24	4				4		32
52	Railway and automobile transport	3		448	14				36		501
53	Unspecified transport			40	6				12		58
60	Other sectors 60=61+62+63+64	1		181	293		14	385	432	20	1326
61	Agriculture			64	58		0	20	14	4	160
62	Services	1		16	28		6	24	16	16	107
63	Households			75	201		8	329	396	0	1009
64	Unspecified			26	6		0	12	6	0	50
70	Non-energy consumption			0	193			0			193

Table 4.4. Model 2007 Energy Balance of Georgia

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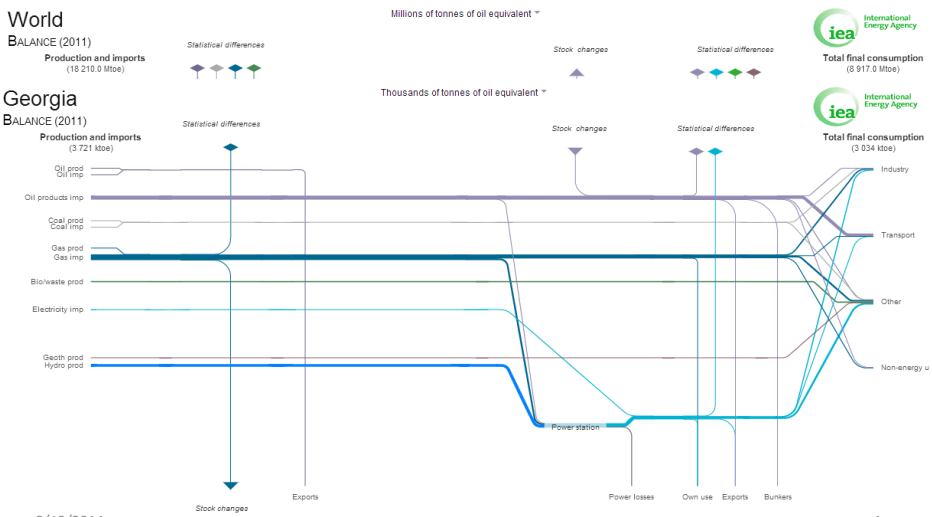
Energy Balance - IEA



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Why calculate an energy balance?

To compare

- Energy sources in the energy supply of a country
- Sectors of economic activity
- Countries

To analyze and monitor

- Energy efficiency
- Dependence on energy imports or exports
- Data quality

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What units?

MBtu

kilowatt-hours

Mtoe

Mtce

terajoules

IEA opted for Mtoe

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Net vs. Gross Calorific Values?

Difference between NCV and GCV is the latent heat of vaporization of the water produced during combustion

5%

5%

10%

IEA uses Net Calorific Values

Bomb Calorimeter

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Conversion to energy units (1)

COAL

Physical units (tonnes) are converted to energy units using NCV [kJ/kg], reported in the questionnaires (varies over time)

Specific NCV for Production, Imports, Exports, Inputs to Power Plants and Industry

Average NCV for all other flows

CRUDE OIL AND OIL PRODUCTS

Using NCV [kJ/kg]

Primary oil - Specific NCV for Production, Imports and Exports, reported in the questionnaires (varies over time)

Oil products - region specific default values

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Conversion to energy units (2)

NATURAL GAS

Figures collected in Mm^3 and gross TJ (energy unit). They are converted to net TJ (0.9·gross TJ) and then to Mtoe (1 PJ = 0.02388 Mtoe)

OTHER GASES

Data collected in gross TJ, then converted to net TJ (0.9·gross TJ) and then to Mtoe (1 PJ = 0.02388 Mtoe)

ELECTRICITY

Figures collected in TWh, then electricity production is converted to Mtoe (1 TWh = 0.086 Mtoe)

Gross electricity production is shown and the own use and losses are shown separately

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Choice of primary energy form

First energy form downstream for which multiple energy uses are practical

Heat

- nuclear heat and electricity production
- geothermal heat and electricity production
- solar heat production

Electricity

- hydro
- wind
- wave/ocean
- photovoltaic solar electricity production

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Energy balance layout: compact source of information

Supply

Transformation and energy industries own use

Final consumption

Industry

Transport

Other final consumption

Non-energy use

Electricity and heat output

Comparable information for all products

Comparable energy units (Mtoe)

Global picture of energy situation in a country

Totals

SUPPLY AND CONSUMPTION	Coal & peat	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geotherm. solar etc.	Biofuels & waste	Electricity	Heat	Total
	Million tonnes of oil equivalent										
Production	0.21	-	-	-	13.60	5.66	0.22	10.38	-	0.27	30.35
Imports	1.54	19.59	7.37	1.10	-	-	-	-	1.18	-	30.79
Exports	-0.19	-0.38	-13.68	-	-	-	-	-	-0.78	-	-15.03
Intl. marine bunkers	-	-	-2.09	-	-	-	-	-	-	-	-2.09
Intl. aviation bunkers	-	-	-0.71	-	-	-	-	-	-	-	-0.71
Stock changes	-1.16	0.32	-0.18							-	0.15
TPES									0.40	0.27	45.41
Transfers										-	0.09
Statistical differences	-0.06	-0.14	-0.02	-0.19						-	0.33
Electricity plants							-0.01	10.38		-	-9.10
CHP plants	-0.66							-3.76	1.37	2.81	-0.97
Heat plants	-0.05							-1.18	-0.14	1.39	-0.07
Blast furnaces	-0.22									-	-0.41
Gas works	0.02	-	-0.01	-0.00	-	-	-	-	-	-	0.00
Coke/pat. fuel/BKB plants	-0.29	-	-0.01	-	-	-	-	-	-	-	-0.29
Oil refineries										-	-0.39
Petrochemical plants										-	-
Liquefaction plants										-	-
Other transformation										-	-
Energy industry own use	-0.09		-0.26	-0.10					-0.55	-	-1.48
Losses	-0.04								-0.85	-0.21	-1.13
TFC	0.47						0.01	5.45	10.61	4.26	31.98
INDUSTRY	0.44	-	1.06	0.45	-	-	-	4.03	4.42	0.38	10.74
Iron and steel	0.17	-	0.21	0.03	-	-	-	-	0.31	-	0.73
Chemical and petrochem.	0.01	-	0.06	0.18	-	-	-	0.01	0.38	-	0.64
Non-ferrous metals	0.04	-	0.03	0.01	-	-	-	-	0.20	-	0.27
Non-metallic minerals	0.15	-	0.11	0.04	-	-	-	-	0.08	-	0.38
Transport equipment	0.01	-	0.02	0.01	-	-	-	-	0.15	-	0.19
Machinery	-	-	0.05	0.01	-	-	-	-	0.18	-	0.24
Mining and quarrying	0.06	-	0.06	-	-	-	-	-	0.21	-	0.33
Food and tobacco	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	-	0.41
Paper, pulp and print	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	-	5.92
Wood and wood prod.	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	-	0.54
Construction	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	0.09	-	0.09
Textile and leather	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	0.01	-	0.03
Non-specified	0.00	-	[illegible]	[illegible]	-	-	-	-	0.52	-	0.98
TRANSPORT	-	-	-	-	-	-	-	-	0.21	-	7.67
Domestic aviation										-	0.18
Road										-	7.18
Rail	-	-	0.00	-	-	-	-	-	0.21	-	0.21
Pipeline transport	-	-	-	-	-	-	-	-	-	-	-
Domestic navigation	-	-	0.13	-	-	-	-	-	-	-	0.13
Non-specified	-	-	-	-	-	-	-	-	-	-	-
OTHER	0.01	-	0.84	0.14	-	-	0.01	1.05	5.98	3.88	11.91
Residential	0.01	-	0.08	0.07	-	-	0.01	0.68	3.52	2.58	6.95
Comm. and public services	0.01	-	0.55	0.05	-	-	-	0.05	2.30	1.29	4.23
Agriculture/forestry	-	-	0.18	0.02	-	-	-	0.32	0.16	0.01	0.68
Fishing	-	-	0.03	-	-	-	-	-	-	-	0.03
Non-specified	-	-	0.01	-	-	-	-	-	-	-	0.01
NON-ENERGY USE	0.01	-	1.64	-	-	-	-	-	-	-	1.65
in industry/transf./energy	0.01	-	1.59	-	-	-	-	-	-	-	1.60
of which: feedstocks	-	-	1.08	-	-	-	-	-	-	-	1.08
in transport	-	-	0.06	-	-	-	-	-	-	-	0.06
in other	-	-	-	-	-	-	-	-	-	-	-
Electricity and Heat Output											
Elec. generated - TWh	1.60	-	0.73	1.55	52.17	65.85	2.49	12.20	-	-	136.59
Electricity plants	-	-	0.16	-	52.17	65.85	2.49	-	-	-	120.68
CHP plants	1.60	-	0.57	1.55	-	-	-	12.20	-	-	15.91
Heat generated - PJ	17.20	-	6.12	16.18	-	-	-	####	0.63	19.52	187.15
CHP plants	16.17	-	2.55	15.94	-	-	-	83.05	0.29	5.44	123.44
Heat plants	1.73	-	3.57	0.44	-	-	-	43.55	0.34	14.09	63.71

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What flows are collected?

Production
Import
Export
International Marine Bunkers
Stock Changes
Domestic Supply

Transfers
Statistical Differences

Transformation Sector *(18 sub-sectors)*
Energy Sector *(16 sub-sectors)*
Distribution Losses

Final Consumption
Industry Sector *(13 sub-sectors)*
Transport *(7 sub-sectors)*
Other Sectors *(4 sub-sectors)*
Non Energy Uses

Electricity and Heat Outputs

TOTAL: 95 FLOWS

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What products are collected?

- Coal (17 products/categories)
- Natural gas
- Crude Oil and Petroleum products (25 products)
- Nuclear Energy
- Hydro Energy
- Renewable Energy (19 products/categories)
- Waste Energy (3 products/categories)
- Electricity
- Heat (7 categories)
- TOTAL: over 75 products/categories

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Energy balance

Supply

Refined products and electricity are secondary energy: production = 0

Coal-to-coal transformation

Value represents transformation losses; further detail available in BIGBAL

SUPPLY AND CONSUMPTION	Coal & peat	Crude oil	Oil products				m. etc.	Combust. renew. & waste	Electricity	Heat	Total
Production	7371					823	48	806	-	-	9922
Imports	945					-	-	1	763	-	7440
Exports	-57					-	-	-4	-757	-	-1056
Intl. marine bunkers	-					-	-	-	-	-	-
Intl. aviation bunkers	-					-	-	-	-	-	-48
Stock changes	-136					-	-	1	-	-	-227
TPES	**8122**					**823**	**48**	**804**	**6**	**-**	**16032**
Transfers	-	51	-47	-	-	-	-	-	-	-	4
Statistical differences	303	59	-48	-	-	-	-	-	5	10	329
Electricity plants	-6785	-	-17	-17	-	-823	-	-	3127	-	-4515
CHP plants	-	-	-33	-99	-	-	-	-	36	39	-58
Heat plants	-104	-	-349	-389	-	-	-42	-1	-	778	-106
Blast furnaces	-247	-	-	-				-	-	-	-247
Gas works	-	-	-	-				-	-	-	-
Coke/pat.fuel/BKB plants	-99	-	-	-				-	-	-	-99
Oil refineries	-	-3457	3160	-				-	-	-	-297
Petrochemical plants	-	99	-103	-				-	-	-	-4
Liquefaction plants	-	-	-	-				-	-	-	-
Other transformation	-	-	-	-				-	-	-	-
Energy industry own use	-	-	-	-45				-	-322	-20	-387
Losses	-76	-	-	-31				-	-508	-81	-696
TFC	**1115**	**-**	**3541**	**1420**				**804**	**2344**	**727**	**9956**
INDUSTRY	**582**	**-**	**498**	**1002**				**22**	**608**	**296**	**3007**
TRANSPORT	**1**	**-**	**2178**	**4**				**-**	**23**	**-**	**2206**
OTHER	**511**	**-**	**176**	**281**	**-**	**-**	**6**	**781**	**1714**	**431**	**3901**
NON-ENERGY USE	**21**	**-**	**689**	**132**	**-**	**-**	**-**	**-**	**-**	**-**	**842**

Transformation

- Negative value represents an input, positive value represents an output

- Transformation **losses** appear in the **Total** column as negative figures

- **There are constant changes in the energy sector**
  - **New products**
    - Orimulsion
    - Oil shale, tar sands
    - LNG
    - Ethanol
  - **New forms of energy**
    - Wind
    - Photovoltaic
    - Hydrogen
  - **New players**
    - Liberalisation
    - Development of trade (oil, coal, gas, electricity)
  - **New Needs**
    - Kyoto protocol
    - Energy efficiency

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Importance of Energy Balance

- Saving energy in all sectors:
  - Residential
  - Transports
  - Industry
  - Services
  - Electricity generation
- Increasing exports - reducing imports
- Increasing domestic (and global) energy security
- Strengthening R&D
- Creating jobs
- Reducing greenhouse gas (mainly CO_2) emissions

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Using the energy balance with economic indicators

Using:

- Population
- GDP (using 2000 exchange rates to US dollars)
- GDP-PPP (using 2000 PPPs to US dollars)

- Energy Production/TPES
- Net Oil Imports/GDP
- TPES/GDP
- TPES/Population
- Oil Supply/GDP
- Oil Supply/Population
- Electricity Consumption/GDP
- Electricity Consumption/Population

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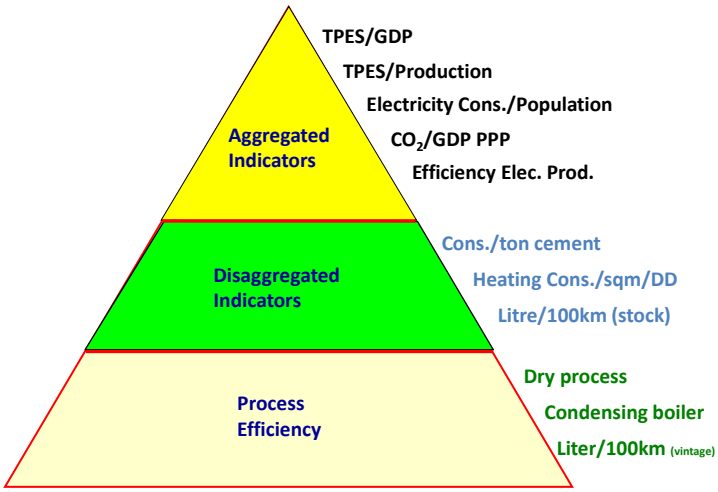
What data for what indicators



The Indicator Pyramid

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Energy Statistics of Georgia

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Energy governance

Responsible institution on energy statistics:

National Statistics Office of Georgia - GEOSTAT

Institutions involved in energy statistics:

- Ministry of Energy of Georgia

LEGAL BASIS:

- The Law of Georgia on Official Statistics
- The Law on electricity and Natural Gas
- The Law on the Electricity Market Rules
- Annual state program of statistical works

No legal regulation on energy statistics, publications and energy balance
Monitoring of the energy statistics data is regulated by the Ministry of Energy

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Georgia – Energy Balance 2012 (MARKAL)

Primary energy supply	BIOWOO	COABRO	ELC	GASNAT	OILDST	OILGSL	OILLPG	OILAVF	GEOTH	Total
Production	30	7		0.2	0.0	0.0	0.0		1	**38**
Import	0	2	2	72	21	18	0	3		**118**
Export + Stock change	0	2	2	-3		0		0		**1**
Total energy supply	**30**	**7**	**0**	**76**	**21**	**18**	**0**	**3**	**1**	**156**
Final energy demand										
Industry	0.0	6.65	11.78	3.86	0.84				0.00	**23**
Transport	0.0		1.02	2.06	15.87	18.39		2.66	0.00	**40**
Households	27.0	0.40	7.82	19.92	1.03		0.01		0.01	**56**
Commercial&Services	3.0	0.09	6.20	10.57	0.010				0.63	**21**
Agriculture	0.0	0.01	0.13	1.32	3.13		0.00		0.02	**5**
Non energy consumption				10.00						**10**
TED (Abkhazia)			5.52							**6**
Total	**30.00**	**7.14**	**32.48**	**47.74**	**20.88**	**18.39**	**0.01**	**2.66**	**0.66**	**160**

Unit: PJ

Georgia Energy Balance 2012

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Analysis of Georgia's energy balance

- Energy security
  - Net import/Total final consumption=74%
- Renewables shares
  - Fuel wood/TPES=19%
- Losses
  - Electricity losses – 16% (dist.), 1.8% (trans.)
  - Natural gas losses (transmission) – 1.8%

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Energy Balance of Georgia 2006 (kilotons of oil equivalent—KTOE)

#		Coal	Crude Oil	Oil Prod-ucts	Natural Gas	Hyd-raulic Energy	Renew-able	Fire-wood and waste	Elec-tricity	Thermal Energy	Total
10	Production	4	64		17	457	14	385			941
11	Import	3		792	1517				65		2377
12	Export		-53	-3					-12		-68
13	Stock Build Up	-1	2	4	-3						2
15	Primary Production 15=10+11-12±13	6	13	793	1531	457	14	385	53	0	3252
20	Electricity plants, Boilers			-6	-508	-457			638	32	-301
21	Oil refineries		-13	12							-1
22	Other transfor-mations and losses			-14	-346				-91		-451
30	Energy Supply 30=15±20±21-22	6	0	785	677		14	385	600	32	2499
40	Industrial Sector 40=41+42+43+44	2	0	92	167	0	0	0	116	12	389
41	Metallurgy			3	5				43	3	54
42	Chemical production & Petrochemistry			17	27				36	3	83
43	Nonmetallic materials			15	18				13	2	48
44	Other production	2		57	117				24	4	204
50	Transportation 50=51+52+53	3		512	24				52	0	591
51	Aviation, marine			24	4				4		32
52	Railway and automobile transport	3		448	14				36		501
53	Unspecified transport			40	6				12		58
60	Other sectors 60=61+62+63+64	1		181	293		14	385	432	20	1326
61	Agriculture			64	58		0	20	14	4	160
62	Services	1		16	28		6	24	16	16	107
63	Households			75	201		8	329	396	0	1009
64	Unspecified			26	6		0	12	6	0	50
70	Non-energy consumption			0	193			0			193

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Tasks:

- Fill in the IEA balance builder for Georgia (2012 year) IEA balance builder
- Think and create indicators to analyze energy balance of Georgia for 2012 year

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The End

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Fossil Fuels
Production and Characteristics

M.Margvelashvili

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Fossil Fuels

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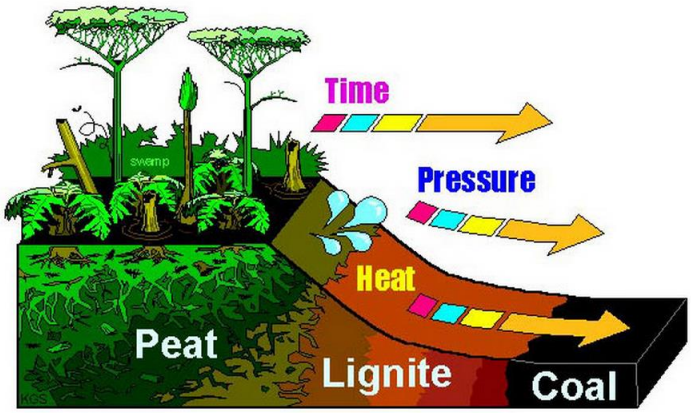

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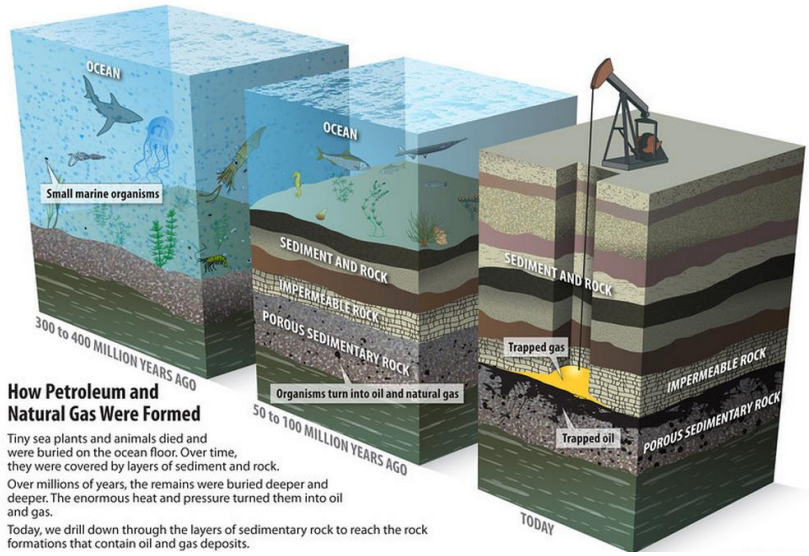

How Petroleum and Natural Gas Were Formed

Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sediment and rock.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through the layers of sedimentary rock to reach the rock formations that contain oil and gas deposits.

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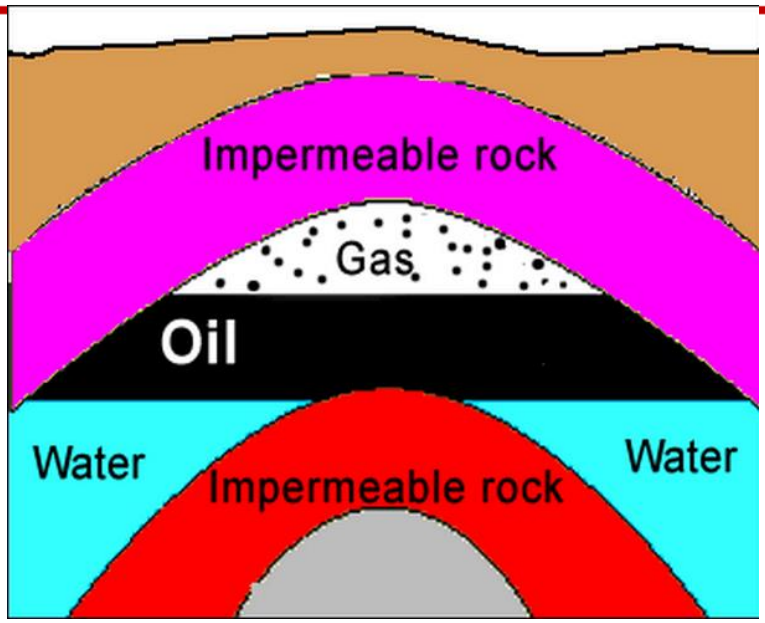
Oil and Gas Deposits



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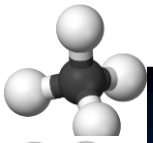
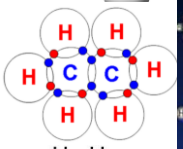
Hydrocarbons – C_nH_{2n+2}

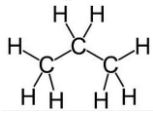
Methane



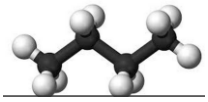
Ethane

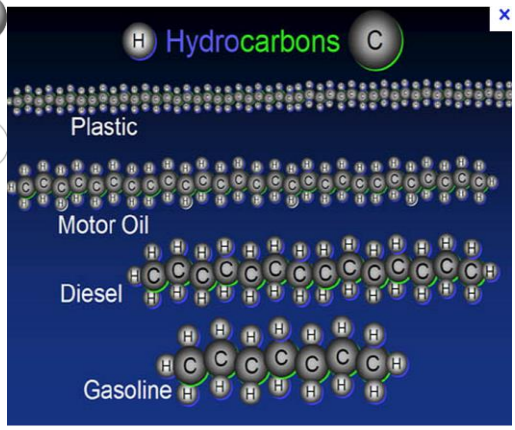


Propane



Butane





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Combustion

- $C_nH_{2n+2}+O_2=nCO_2+H_2O$??
- High Heating Value
- Low Heating Value

http://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html

- CO_2 –emissions

http://www.engineeringtoolbox.com/co2-emission-fuels-d_1085.html

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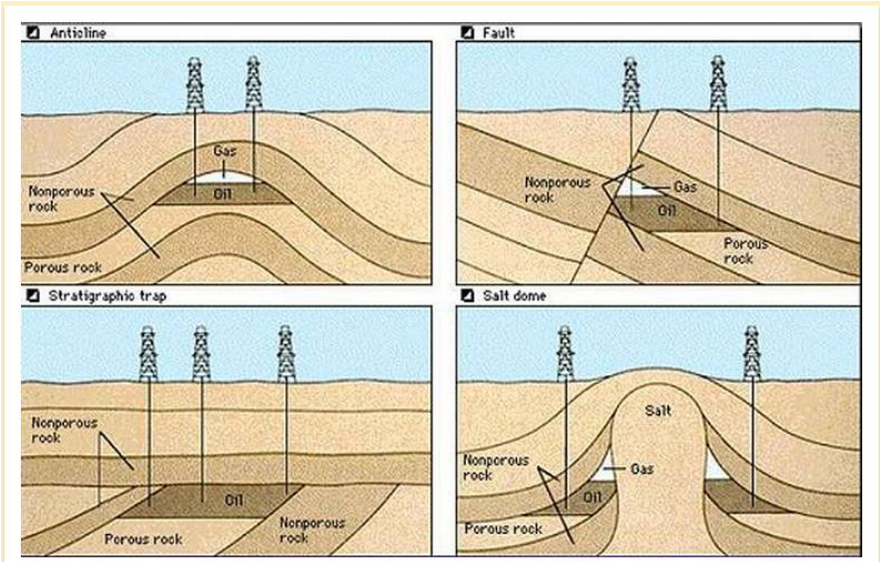
Oil & Gas Reservoirs



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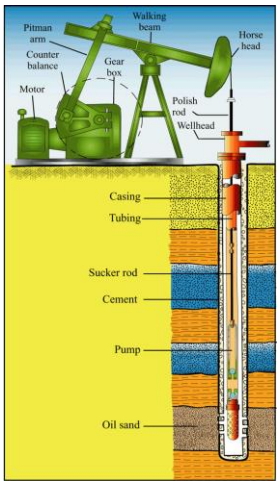
Fossil Fuel Production



http://www.conservation.ca.gov/dog/picture_a_well/Pages/qh_well.aspx

Gas Well

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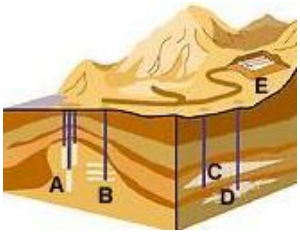
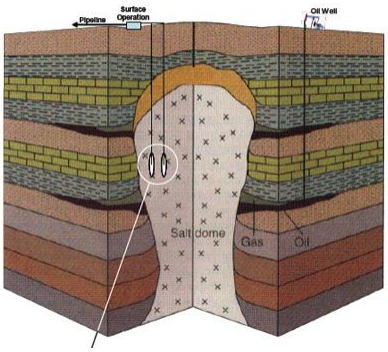
Gas Storage

Depleted Reservoirs



Not to Scale



Salt Dome Caverns

http://www.geostockus.com/what-we-do/natural-gas-storage-primer

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Tight Gas and Oil

Coal bed Methane

Shale Gas, Shale Oil

- Conventional hydrocarbon reservoirs are made up of porous rock such as sandstone or limestone which allows hydrocarbons to flow.
- Shale rocks are of low porosity and permeability and need to be fractured to produce the hydrocarbons they contain.

Sandstone

Shale

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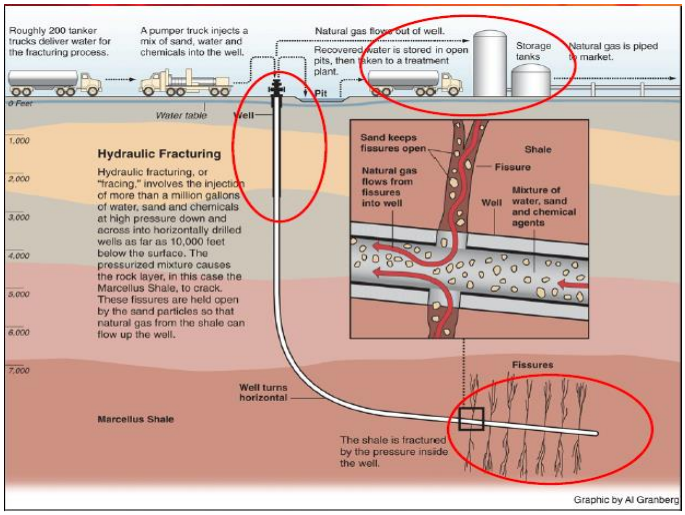
Shale gas - process



- http://www.youtube.com/watch?v=CM8Lh7SAm6A

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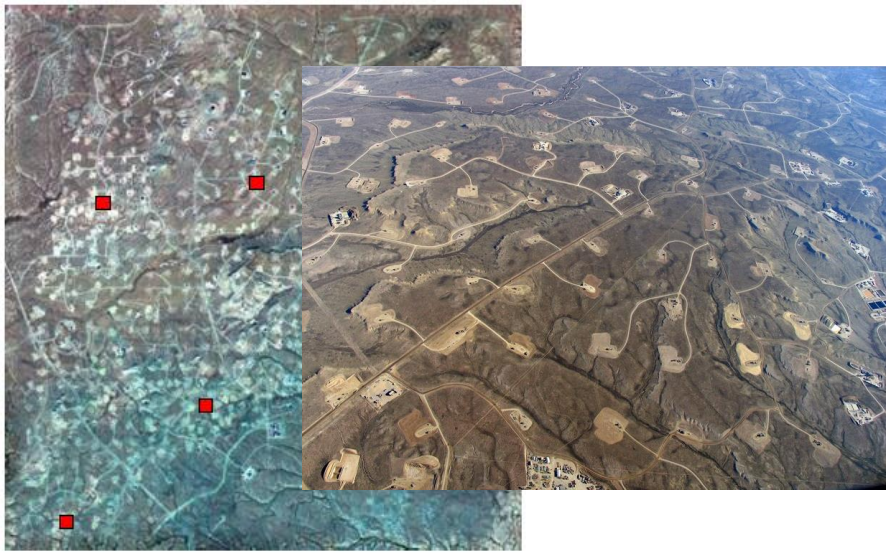

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Shale Gas Production

- *8 well pad*
- *92 stages pumped in 6 days*
- *15,000 tonnes of sand (850 trucks)*
- *150,000 m³ of water (5,000 trucks)*
- *30 pumps(80,000 HHP)*

2011

A huge task for industry and regulators

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Tasks

- Types and characteristics of coal
- Types and characteristics of oil products

- Table of low and high heat values of
- Fuel oil
- Natural gas
- Other emissions

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Thermal Power Generation

MURMAN MARGVELASHVILI

WEDNESDAY 23 APRIL 2014

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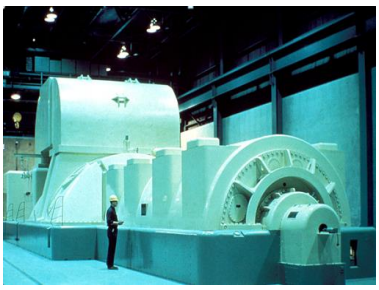
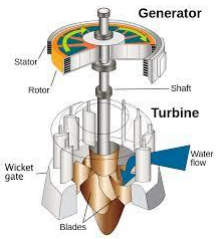
– http://www.youtube.com/watch?v=ATFqX2Cl3-w
AC power generation





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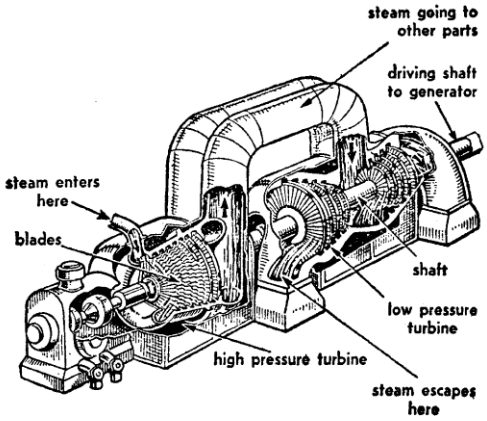
- Steam Turbines



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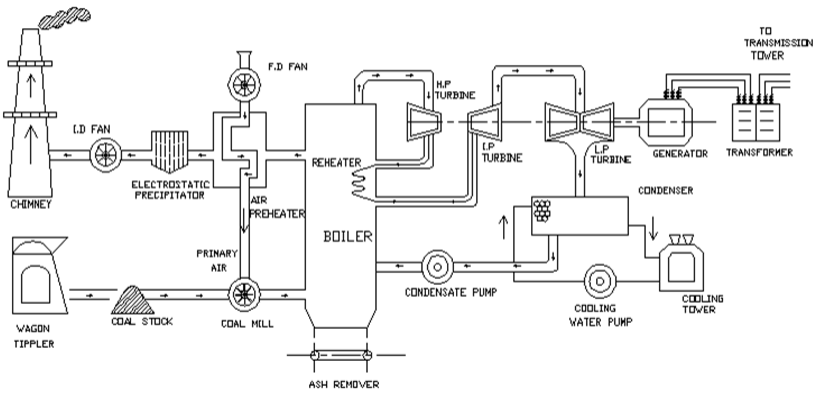
Condensing cycle

SCHEMATIC DIAGRAM



www.enggroom.com/Code/**thermal-power**-plant.**ppt**

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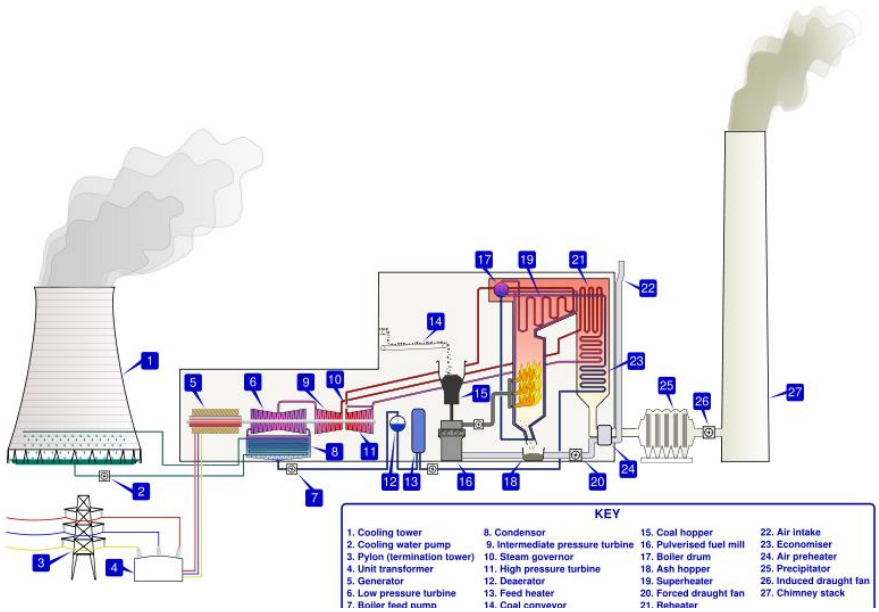

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TPP Boiler

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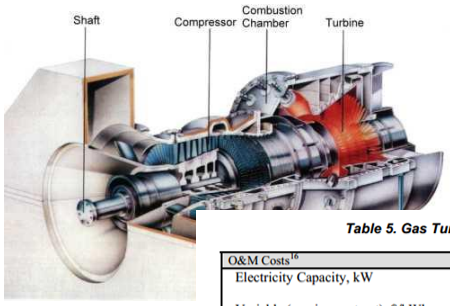
Gas Trubines



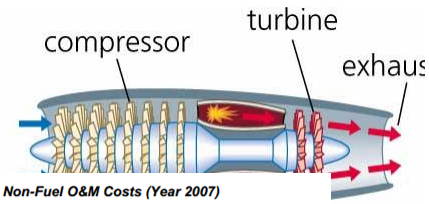
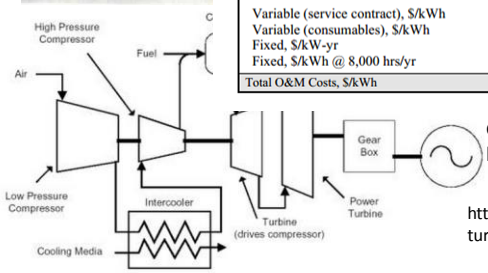


Table 5. Gas Turbine Non-Fuel O&M Costs (Year 2007)

O&M Costs[16]	System 1	System 2	System 3	System 4	System 5
Electricity Capacity, kW	1,000	5,000	10,000	25,000	40,000
Variable (service contract), $/kWh	0.0060	0.0060	0.0060	0.0040	0.0035
Variable (consumables), $/kWh	0.0001	0.0001	0.0001	0.0001	0.0001
Fixed, $/kW-yr	40	10	7.5	6	5
Fixed, $/kWh @ 8,000 hrs/yr	0.0050	0.0013	0.0009	0.0008	0.0006
Total O&M Costs, $/kWh	0.0111	0.0074	0.0070	0.0049	0.0042

Precision Graph



Gas Trubine Prices
http://www.gas-turbines.com/trader/kwprice.htm

http://www.epa.gov/chp/documents/catalog_chptech_gas_turbines.pdf

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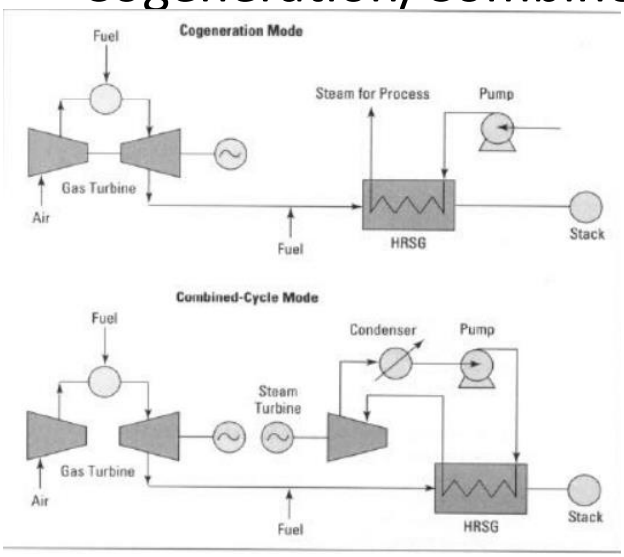
Cogeneration/Combined Cycle



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Plant efficiency = useful output/input energy

$\eta = E_o/E_i$ (%)

Heat Rate = input energy (GJ)/output power (GWh)

J=W*sec kWh=3600*kW*sec=3600kJ

MJ=0,278kWh, GJ=1/3600*GWh

HR=1/η*3600

η=30% => HR=12000 GJ/GWh

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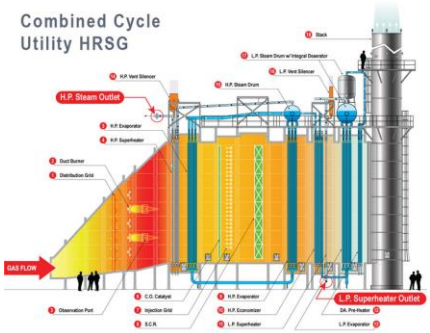
Heat recovery Steam Generator



http://www.victoryenergy.com/heat-recovery-steam-generator/

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Coal Characteristics

Coal Grade	Heating Value	
	(Btu/lb)	(kJ/kg)
Anthracite	12910	30080
Semi-Anthracite	13770	32084
Low-volatile bituminous	14340	33412
Medium-volatile bituminous	13840	32247
High-volatile bituminous A	13090	30499
High-volatile bituminous B	12130	28262
High-volatile bituminous C	10750	25047
Subbituminous B	9150	21319
Subbituminous C	8940	20830
Lignite	6900	16077

- Coal content
  - Carbon 60% in lignites to 97% antracit
  - Sulfur content
  - Ash content

Emissions
- Local - SO_2, No_x, Particulate matter, trace elements (mercury)
- GHG – CO_2, CO

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Coal PP costs

- Subcritical cost per kW $600-1900/kW
- Supercritical cost per kW $700-2300/kW

- Supercritical 20% higher costs
- 38% thermal efficiency

- Critical point of water 22.1Mpa, 374^{0}C

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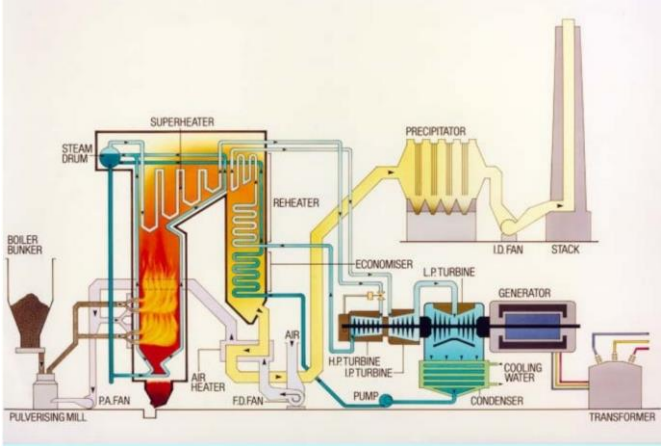
Pulverised Coal Combustion



Layout of a Pulverized Fuel Power Plant

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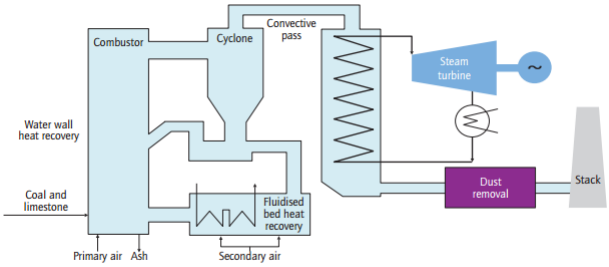
Circulatign Fluidized Bed Combustion



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	CO_2 intensity factor (Efficiency [LHV, net])	Coal consumption[1]
A-USC (700°C[2]) IGCC (1 500°C[3])	670-740 g CO_2/kWh (45-50%)	290-320 g/kWh
Ultra-supercritical	740-800 g CO_2/kWh (up to 45%)	320-340 g/kWh
Supercritical	800-880 g CO_2/kWh (up to 42%)	340-380 g/kWh
Subcritical	≥880 g CO_2/kWh (up to 38%)	≥380 g/kWh

[1] For coal with heating value 25 MJ/kg; [2] Steam temperature; [3] Turbine inlet temperature.

Source IEA Technology Roadmap – HELE coal power generation

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- Tasks
  - Energy Unit Conversions - BTU, GJ, KWh,
  - Calculate heat rate of Georgian TPPs in GJ/GW and BTU/kWh
  - Compare efficiencies and heat rates of
    - Gas turbine plant
    - Combined cycle
    - Coal PPs from the slide above
  - Calculate the cost per kW of Balance of Plant at 230MW CCGT using the Gas Turbine prices (link above)

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Energy Economics

WEDNESDAY, 7 MAY, 2014

Giorgi Mukhigulishvili

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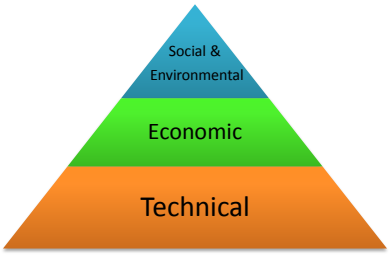
What is Energy Economics about?

- Economics – a science that studies how decisions are made by users that compete for scarce resources;
- Energy as a product (non/renewable, unique-electricity, supply-demand continuity);
- Resource constraints of energy;
- Energy supply & demand
- Energy Markets
- Regulation
- Price formation
- Externalities
- Interests of energy importing, exporting and transiting countries



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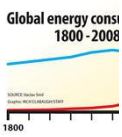
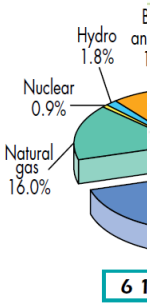
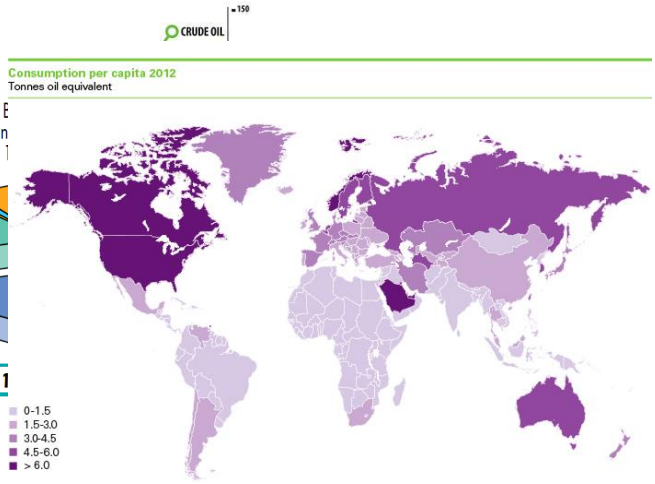
Global Energy Consumption



Source: IEA



Source: IEA



Source: BP

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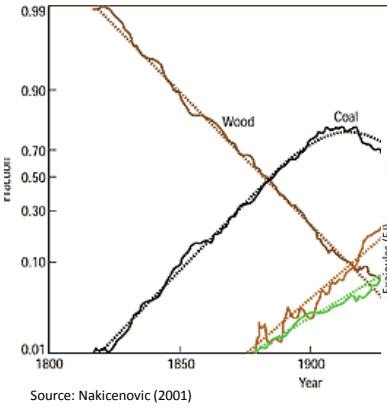
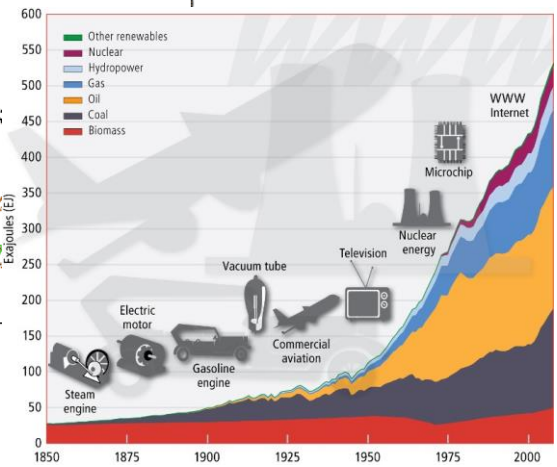
Energy Product Substitutions



Source: Nakicenovic (2001)



Source: Grubler A et al. (2012)

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Energy Demand Elasticity

- Elasticity is a **ratio** of the percentage change in one variable to the percentage change in another variable, when the latter variable has a **causal** influence on the former.

$$\mathbf{E} = \frac{\%\Delta\mathbf{Q}}{\%\Delta\mathbf{P}}$$

- Energy demand elasticity w.r.t its price (purchased oil – oil prices)
- Energy demand elasticity w.r.t the price of substitutes (purchased gasoline – diesel price)
- Energy demand elasticity w.r.t price of complements (fuel wood – price of the stove)
- More examples???

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Energy demand drivers

- GDP structure and its growth rate;
- Population growth rate, households;
- GDP/capita;
- Energy Prices;
- Technology change/development;
- Country energy, environmental and economic policy;
- others…

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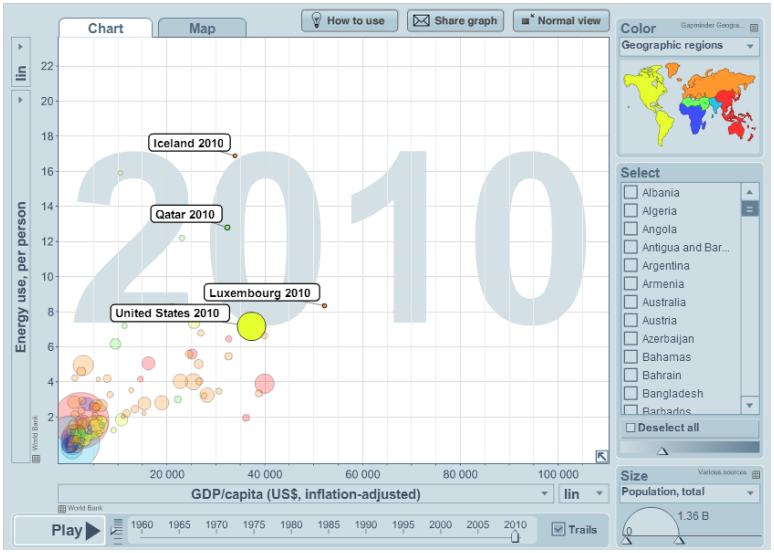

8/14/2014

www.gapminder.org

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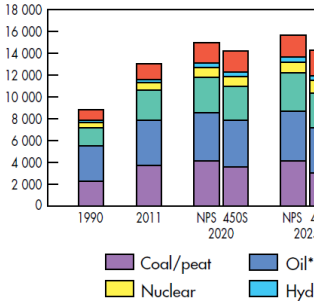
Energy Outlook 2013

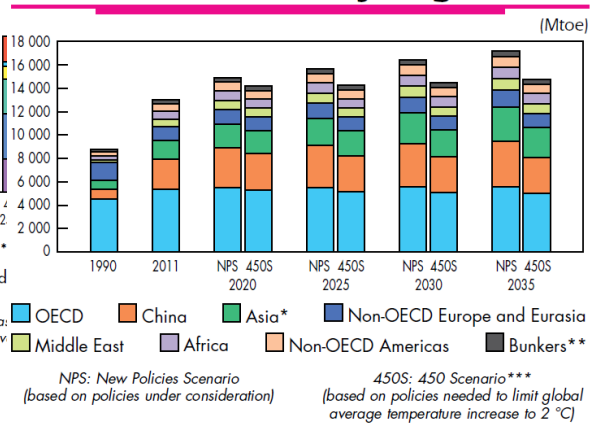
TPES Outlook by Fuel



NPS: New Policies Scenario (based on policies under consideration)

Source: IEA (2013)

TPES Outlook by Region



NPS: New Policies Scenario (based on policies under consideration)

*450S: 450 Scenario*** (based on policies needed to limit global average temperature increase to 2 °C)*

8/14/2014

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Energy Markets

- **Perfect competition** – a market structure in which the following five criteria are met:
  1. All firms sell an identical product;
  2. All firms are price takers - they cannot control the market price of their product;
  3. All firms have a relatively small market share;
  4. Buyers have complete information about the product being sold and the prices charged by each firm; and
  5. The industry is characterized by freedom of entry and exit.
- **Monopoly** – A situation in which a single company or group owns all or nearly all of the market for a given type of product or service. High prices, inferior products, deadweight loss.
- **Natural Monopoly** - A type of monopoly that exists as a result of the high fixed or start-up costs of operating a business in a particular industry. It's economically sensible to have certain natural monopolies, governments often regulate those in operation, ensuring that consumers get a fair deal.
- **Monopsony** - A market similar to a monopoly except that a large buyer not seller controls a large proportion of the market and drives the prices down. Sometimes referred to as the buyer's monopoly.

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Herfindahl–Hirschman Index - HHI

measure of the size of firms in relation to the industry and an indicator of the amount of competition among them.

S_i – share in Industry
H≈0 Competition
H≈1 Monopoly

$$H = \sum_{i=1}^{N} s_i^2$$

Georgian power market

2012 – Enguri 33%; Mtkvari 11,8%; Tbilsresi 11,7%; HHI=0.1365

2013 – Enguri 36%; Mtkvari 8,8%; Vartsikhe 8,4%; HHI=0.1445

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Oil

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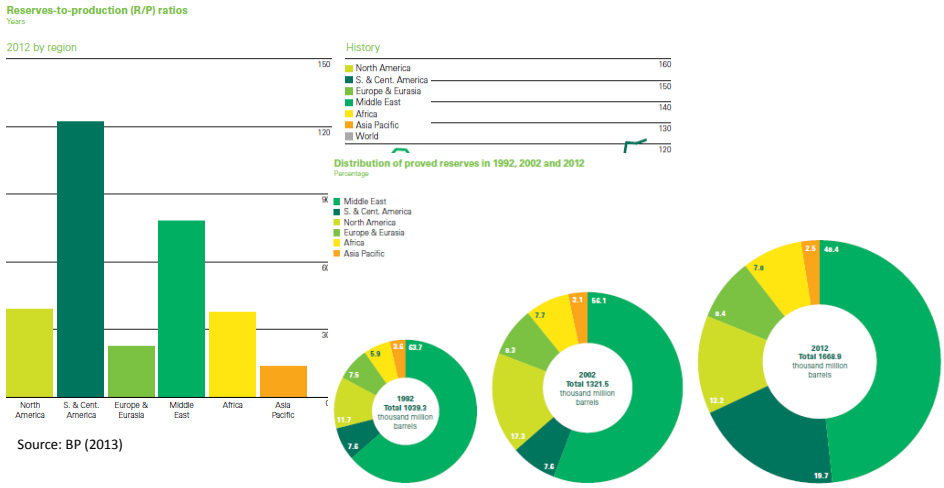
Oil Reserve-to-production (R/P) ratios



Source: BP (2013)

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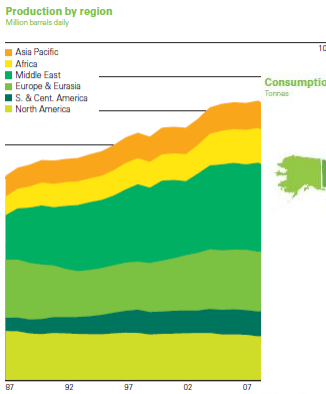
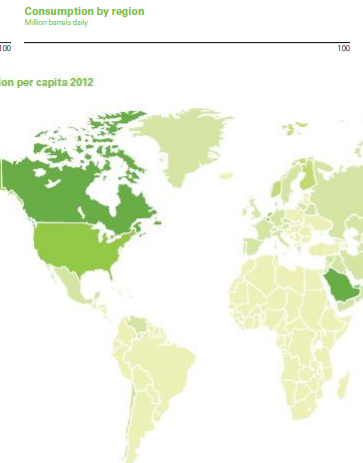
Oil Production and Consumption





Source: BP (2013)

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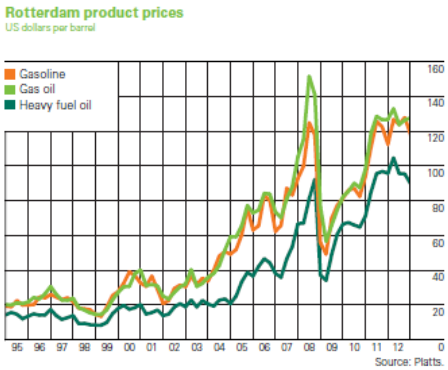
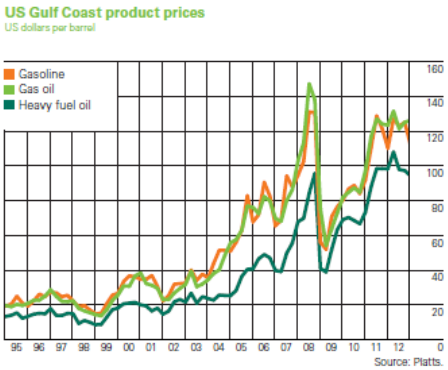
Oil Prices





Source: BP (2013)

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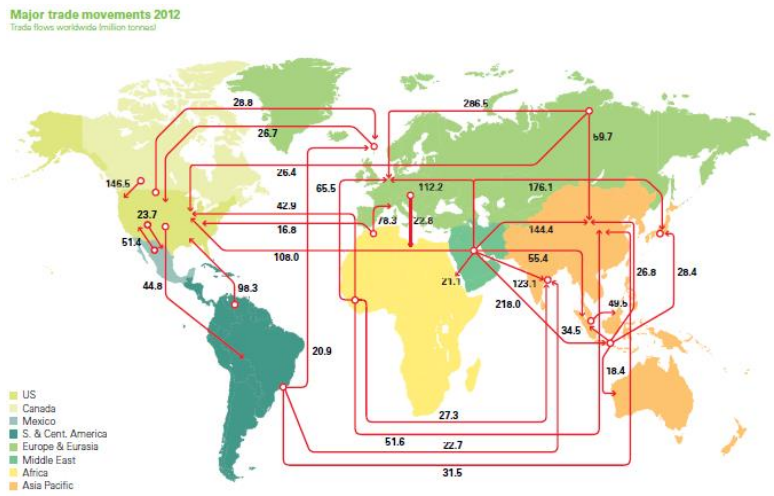
Oil Trade Movements



Source: BP (2013)

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Oil Market Development

- Market power on the global oil market – "Standard Oil"
- Innovative technologies, high capital costs and low operating costs, economies of scale led to large firms with an incentive to collude.
- Produce less than is socially optimal and charge a higher price – deadweight loss
- National oil companies are privatizing (Canada, UK, Argentina)
- OPEC - 11 members behave as dominant firm

- Discussion – Georgian oil market? (Producers, Suppliers, distribution, prices…)

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Natural Gas

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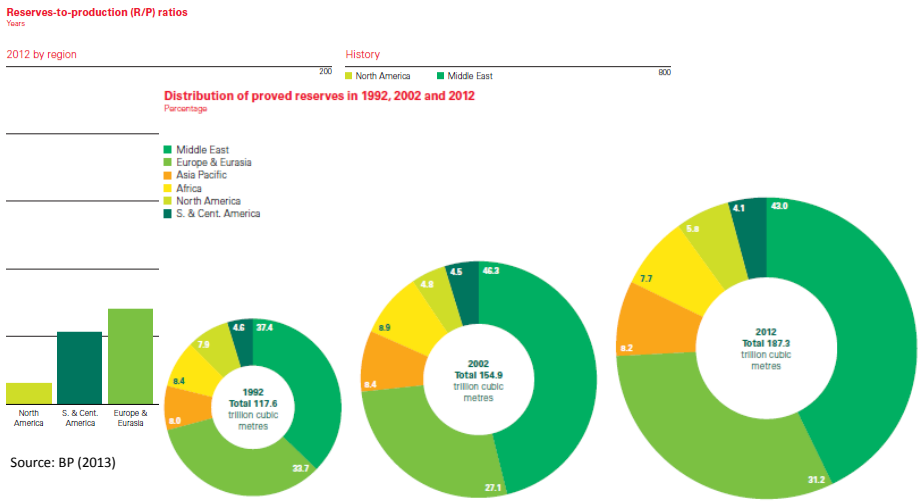
NG Reserve-to-production (R/P) ratios



Source: BP (2013)

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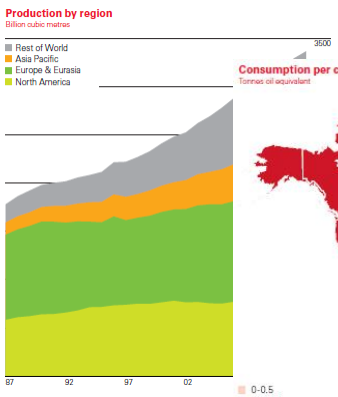
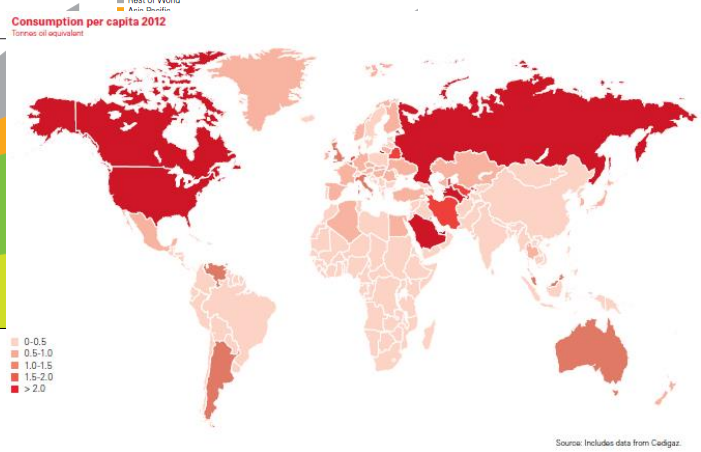
NG Production and Consumption





Source: BP (2013)

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NG Prices

Source: BP (2013)

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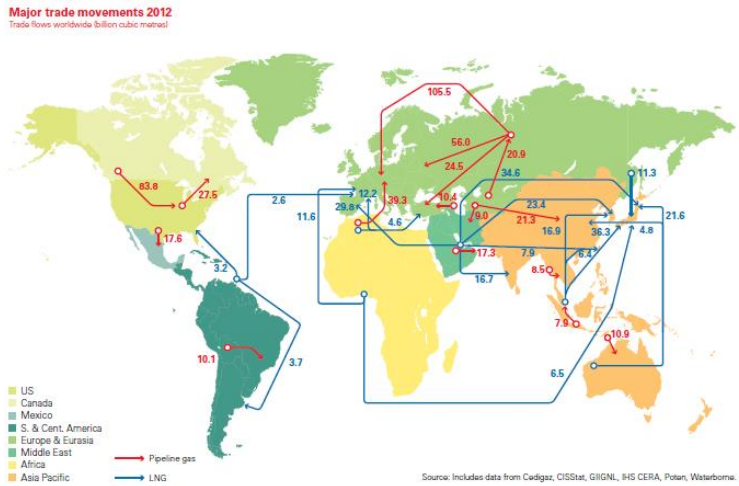
NG trade movements



Source: BP (2013)

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NG Market

- With high transportation cost natural gas tend to be more regionally oriented in North America, South America, Western Europe, LNG in Asia-Pacific.
- Upstream (exploration, production) – competition
- Midstream (transportation) – natural monopoly, TPA
- Downstream (refining) – competition

- What about Georgian gas market?
- Transit projects?

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Coal

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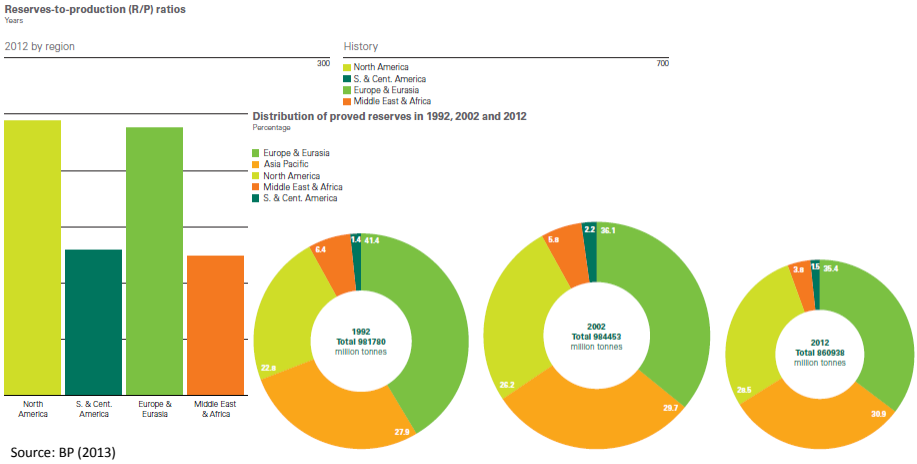
Coal Reserve-to-Production (R/P) ratio



Source: BP (2013)

Source: Survey of Energy Resources 2010, World Energy Council.

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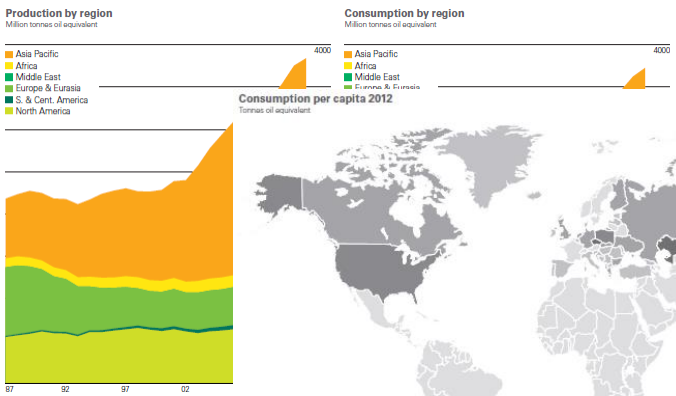
Coal Production and Consumption



Source: BP (2013)

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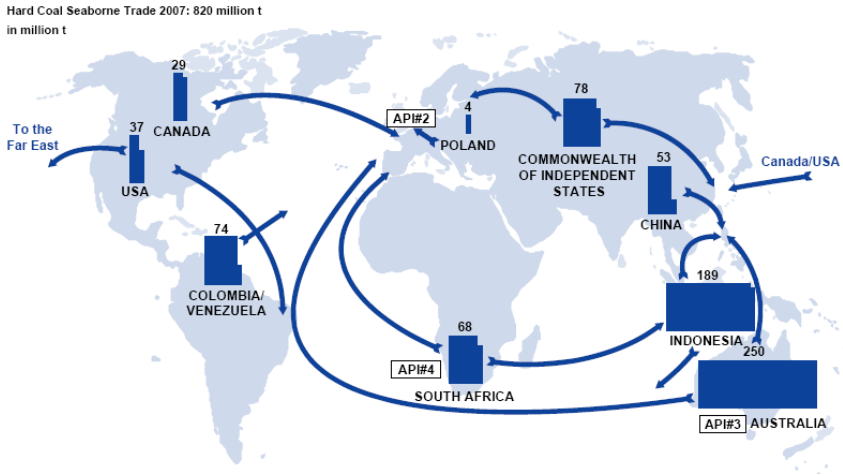
Coal trade routs



Source: Verein der Kohlenimporteure

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Coal Market

- Coal is the world's most abundant and widely distributed
- Negative externalities - emissions
- Elasticity
- Competitive market

- What about Georgian coal market?
- Producers, import sources, demand, prices, main consumers – MARKAL

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Electricity

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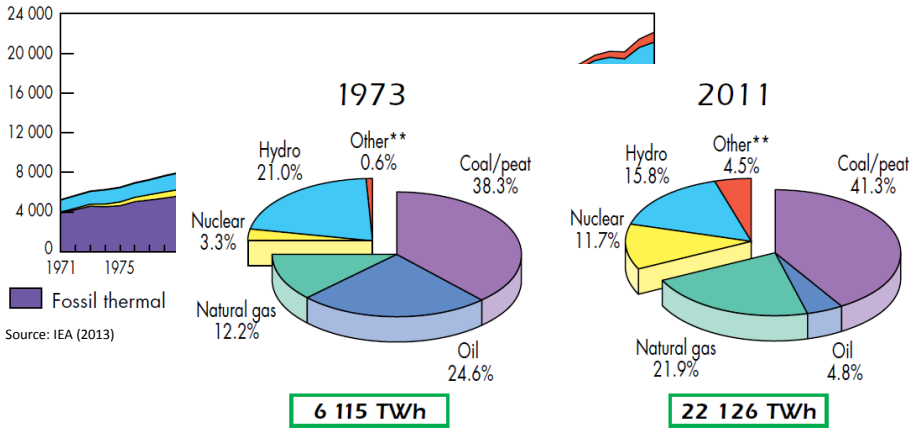
Electricity generation by fuel

World electricity generation* from 1971 to 2011 by fuel (TWh)



Source: IEA (2013)

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Electricity Generation by country

Coal/peat	TWh
People's Rep. of China	3 723
United States	1 875
India	715
Japan	281
Germany	272
South Africa	243
Korea	225
Australia	173
Russian Federation	164
Poland	141
Rest of the world	1 332
World	**9 144**

2011 data

Oil	TWh
Japan	153
Saudi Arabia	142
Islamic Rep. of Iran	67
Mexico	48
Indonesia	42
United States	40
Kuwait	36
Pakistan	34
Russian Federation	27
Egypt	25
Rest of the world	444
World	**1 058**

2011 data

Natural gas	TWh
United States	1 045
Russian Federation	519
Japan	374
Islamic Rep. of Iran	160
Mexico	156
United Kingdom	147
Italy	145
Egypt	117
Korea	116
India	109
Rest of the world	1 964
World	**4 852**

2011 data

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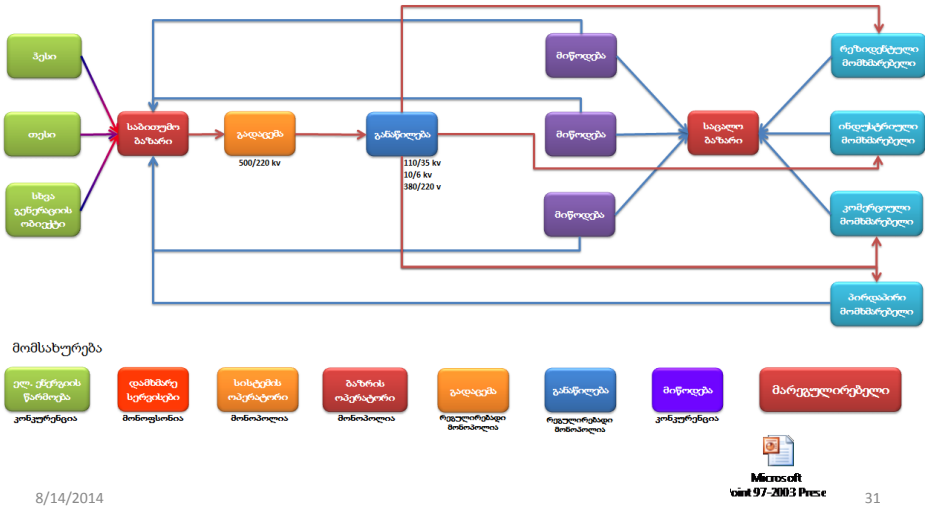
Markets in Power sector



Microsoft Point 97-2003 Prese

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Components of end-user price of energy

- **Wholesale electricity generation cost**
  - Capital cost of power plants
  - Fuel cost
  - CO_2 cost
  - Operation and maintenance cost
- **System operation cost**
  - Balancing cost
  - Adequacy cost
- **Transmission and distribution cost**
  - Capital cost of network infrastructure
  - Operation and maintenance cost
  - Cost of network losses
- **Supply cost**
  - Metering
  - Billing and payment recovery
  - Other commercial costs
- **Taxes and subsidies**
  - Value-added taxes
  - Renewables subsidies
  - Other taxes and subsidies

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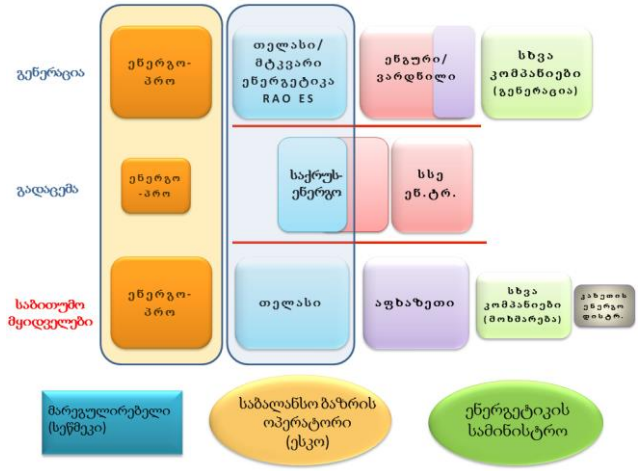
Georgia's Power Market



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Interests of energy exporting, importing and transiting countries

- Energy exporting countries:
  - Diversify markets
  - Diversify transit routs
  - Higher prices
- Energy Importing countries:
  - Diversify supply sources
  - Diversify transit routs
  - Lower prices
- Energy transiting countries:
  - Increasing transit capacity
  - High profit tax, TPA tariff, in-kind fee…

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Task

Identify Georgian energy market characteristics

Oil market:
Producers
Import sources
Export
Prices

Gas market:
Producers
Import sources
Export
Transit
Prices

Coal market:
Producers
Import sources
Export
Prices

Power market:
Generation
Import sources
Export

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The End

g.mukhigulishvili@weg.ge

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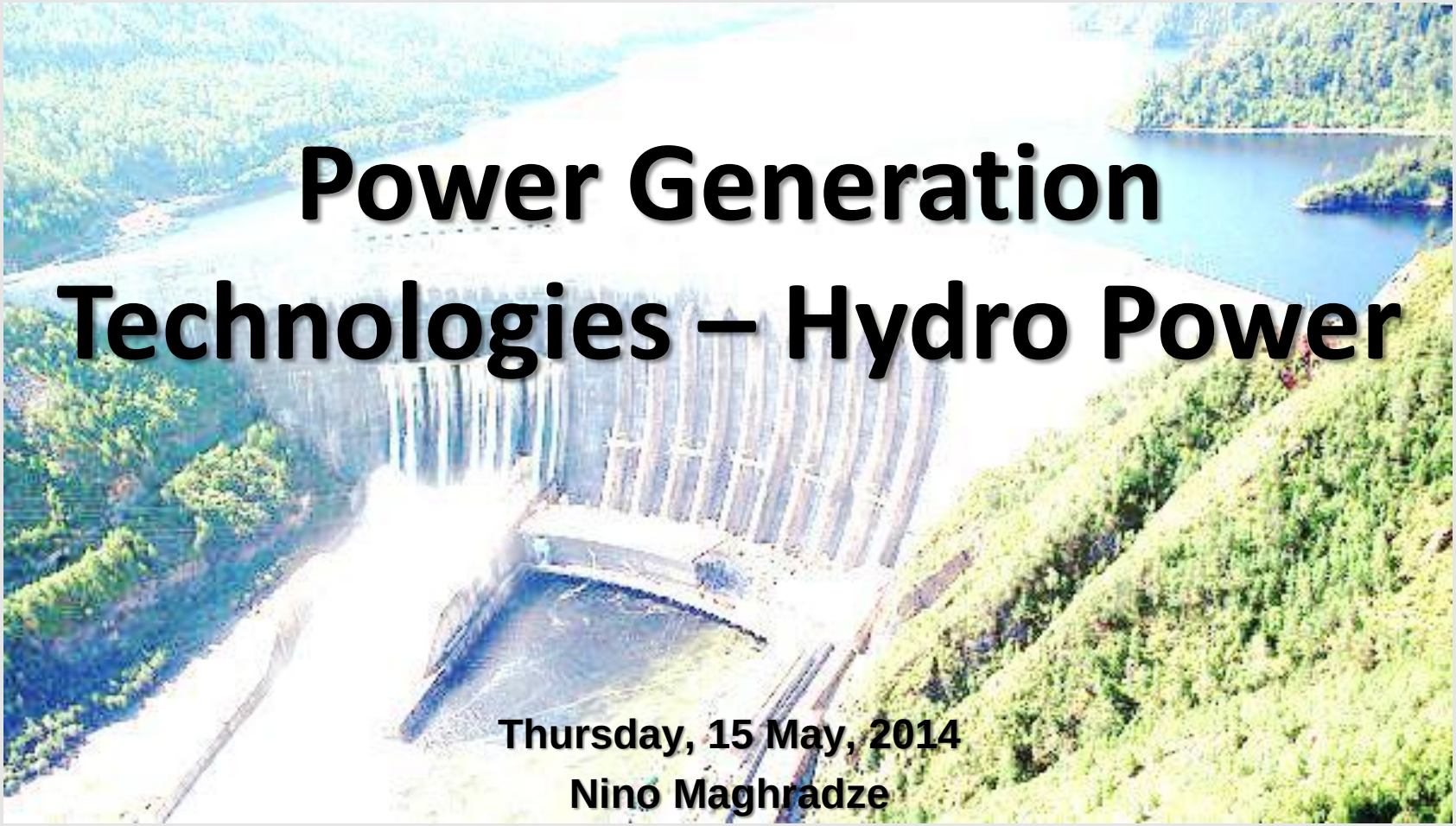


Power Generation Technologies – Hydro Power

Thursday, 15 May, 2014

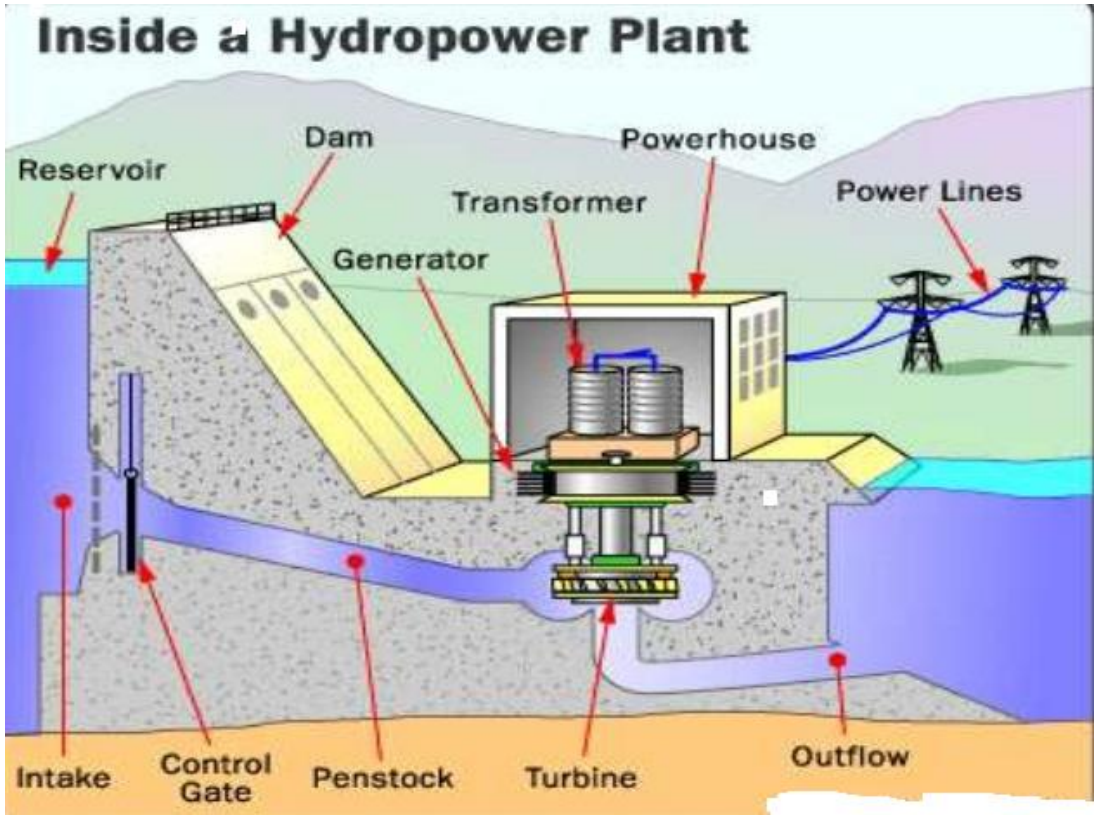
Nino Maghradze

Significance

- Hydropower stands as the most significant renewable energy source. It uses the single but very powerful energy force of moving water. By some comparison competes with the energy produced by fossil fuels and nuclear power, but is considered much cleaner and more simplistic. Hydropower remains popular even in third-world countries, which do not have the resources to build expensive nuclear generating stations. Hydropower does not pollute the atmosphere or environment.

Hydro power plant consists:

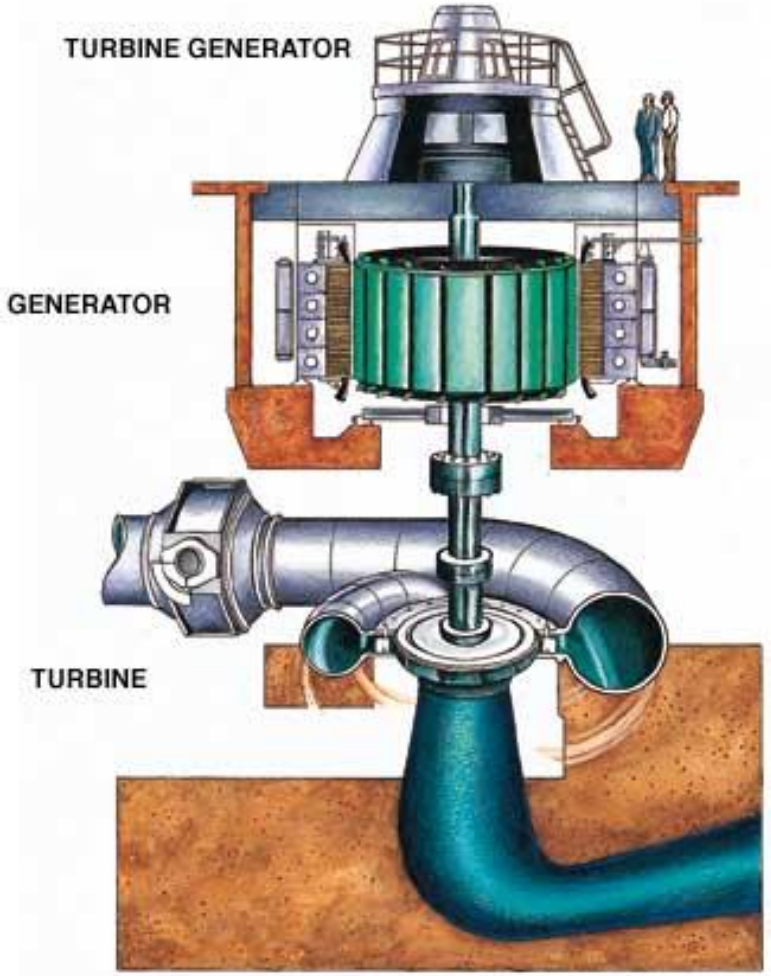
- Turbine
- Generator
- Automatic and protection equipment
- Transformer
- Buiding of the plant
- Hydro building



How a Hydroelectric Power System Works

- Flowing water is directed at a turbine. The flowing water causes the turbine to rotate, converting the water's kinetic energy into mechanical energy.
- The mechanical energy produced by the turbine is converted into **electric energy** using a turbine generator. Inside the generator, the shaft of the turbine spins a magnet inside coils of copper wire. It is a fact of nature that moving a magnet near a conductor causes an electric current.

video



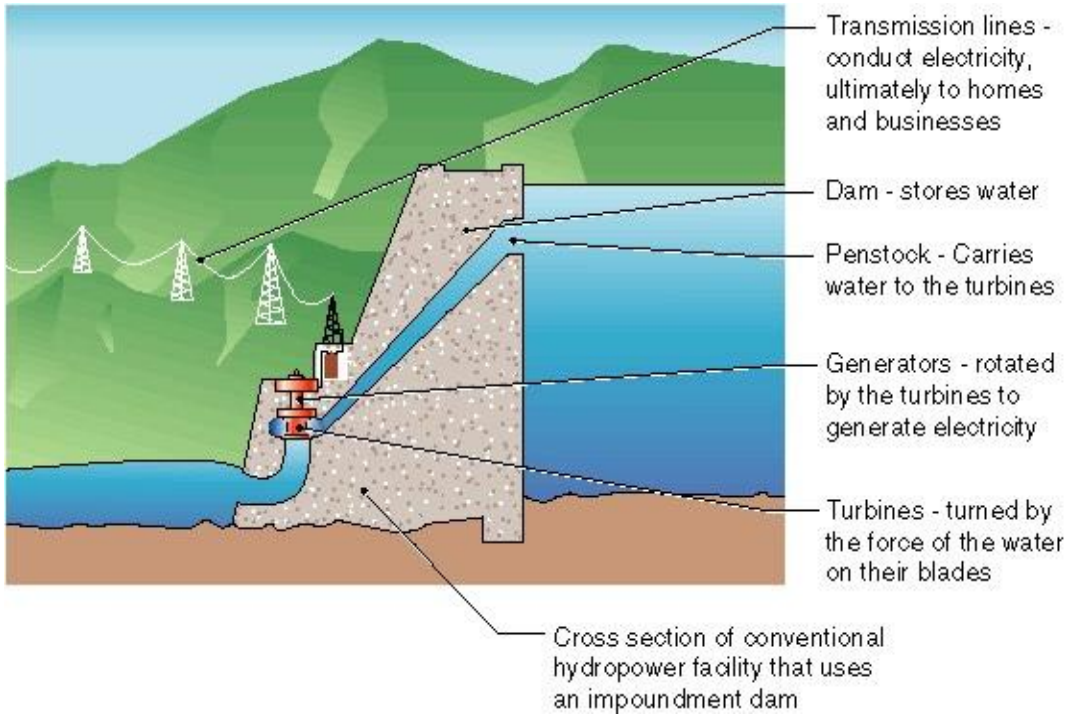
Types of Hydropower

- **Impoundment** – An impoundment facility, typically a large hydropower system, uses a dam to store river water in a reservoir. The water may be released either to meet changing electricity needs or to maintain a constant reservoir level;
- **Diversion** – Also called run-off-the-river, facility channels a portion of a river through a canal or penstock. It may require the use of a dam.
- **Pumped Storage** – When the demand for electricity is low, a pumped storage facility stores energy by pumping water from a lower reservoir to an upper reservoir. During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity

Impoundment System

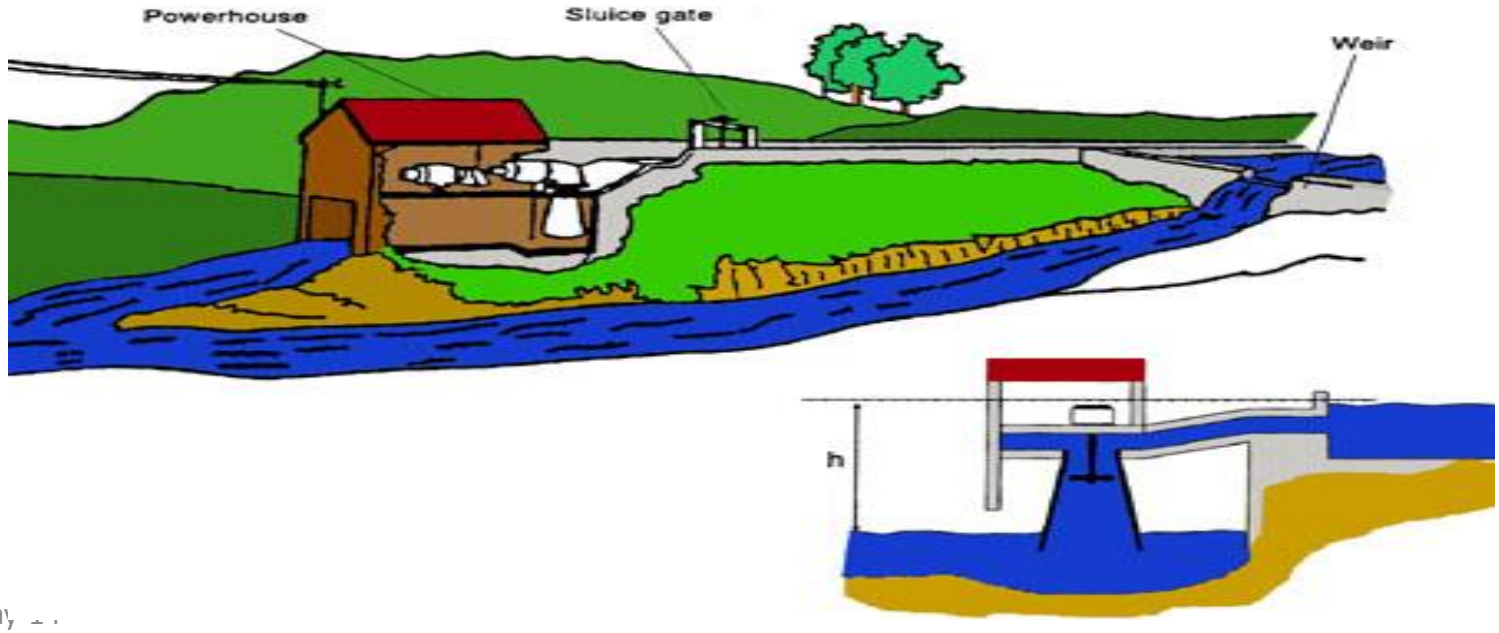
- An impoundment is simply a dam that holds water in a reservoir. The water is released when needed through a penstock, to drive the turbine.

- This illustration shows the parts of a standard hydroelectric dam. Most large, high-head hydropower facilities use impoundments.



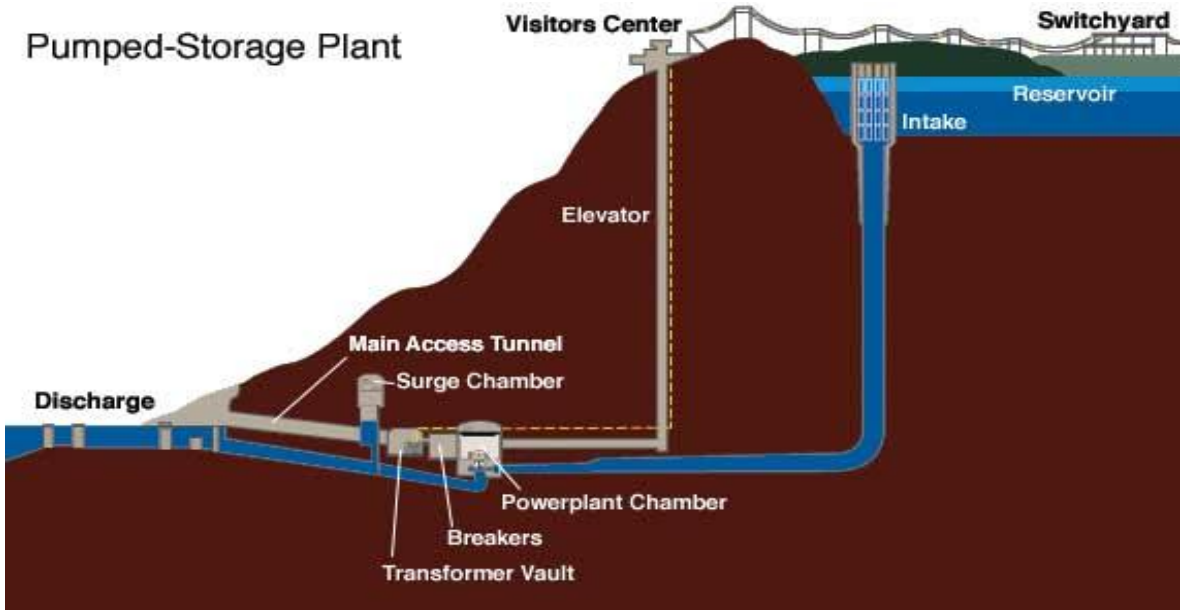
Run-of-the-River Hydropower System

A **run-of-the-river** system uses the river's natural flow and requires little or no impoundment. It may involve a diversion of a portion of the stream through a canal or penstock, or it may involve placement of a turbine right in the stream channel. Run-of-the-river systems are often low-head.



Pumped Storage

- Pumped-storage hydroelectricity is used for load balancing. The method stores energy in the form of gravitational potential energy of water, pumped from a lower elevation reservoir to a higher elevation.



Power Generation

- The amount of electricity that can be generated by a hydropower plant depends on two factors:
- **flow rate** - the quantity of water flowing in a given time; and
- **head** - the height from which the water falls.
- The greater the flow and head, the more electricity produced
- **Flow Rate = the quantity of water flowing**
- **Head = the height from which water falls**

Prognosis of hydro power plant capacity

Capacity of hydro power plant

$$P = 9{,}81 \cdot H \cdot Q \cdot \eta$$

where P –capacity of hydro power plant (kW)

H – pressure (m)

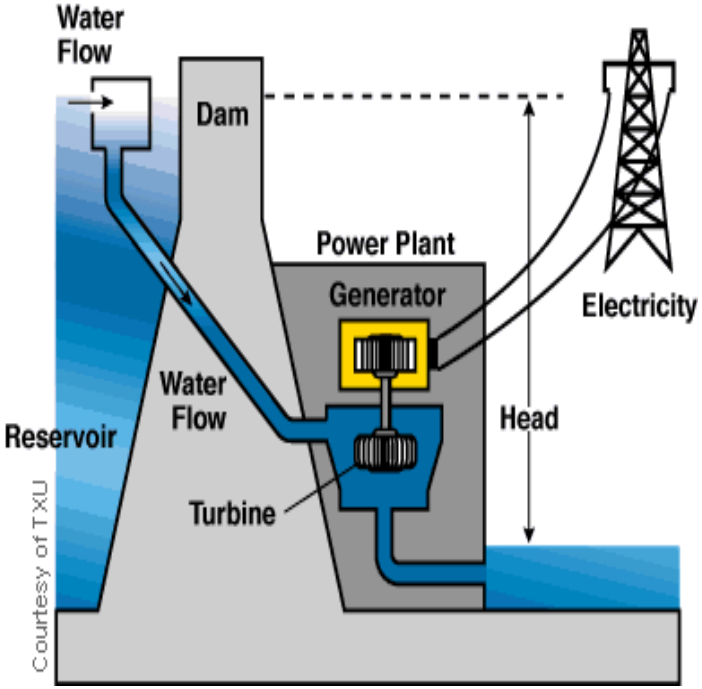
Q – rate of water flow (m^3/s)

η - efficiency

η – contain losses in turbines, transmissions and generators – 0,6-0,8

- It is important to note that when determining head, hydrologists take into account the pressure behind the water. Water behind the dam puts pressure on the falling water.
- Tall dams are sometimes referred to as **"high-head"** hydropower systems. That is, the height from which water falls is relatively high.

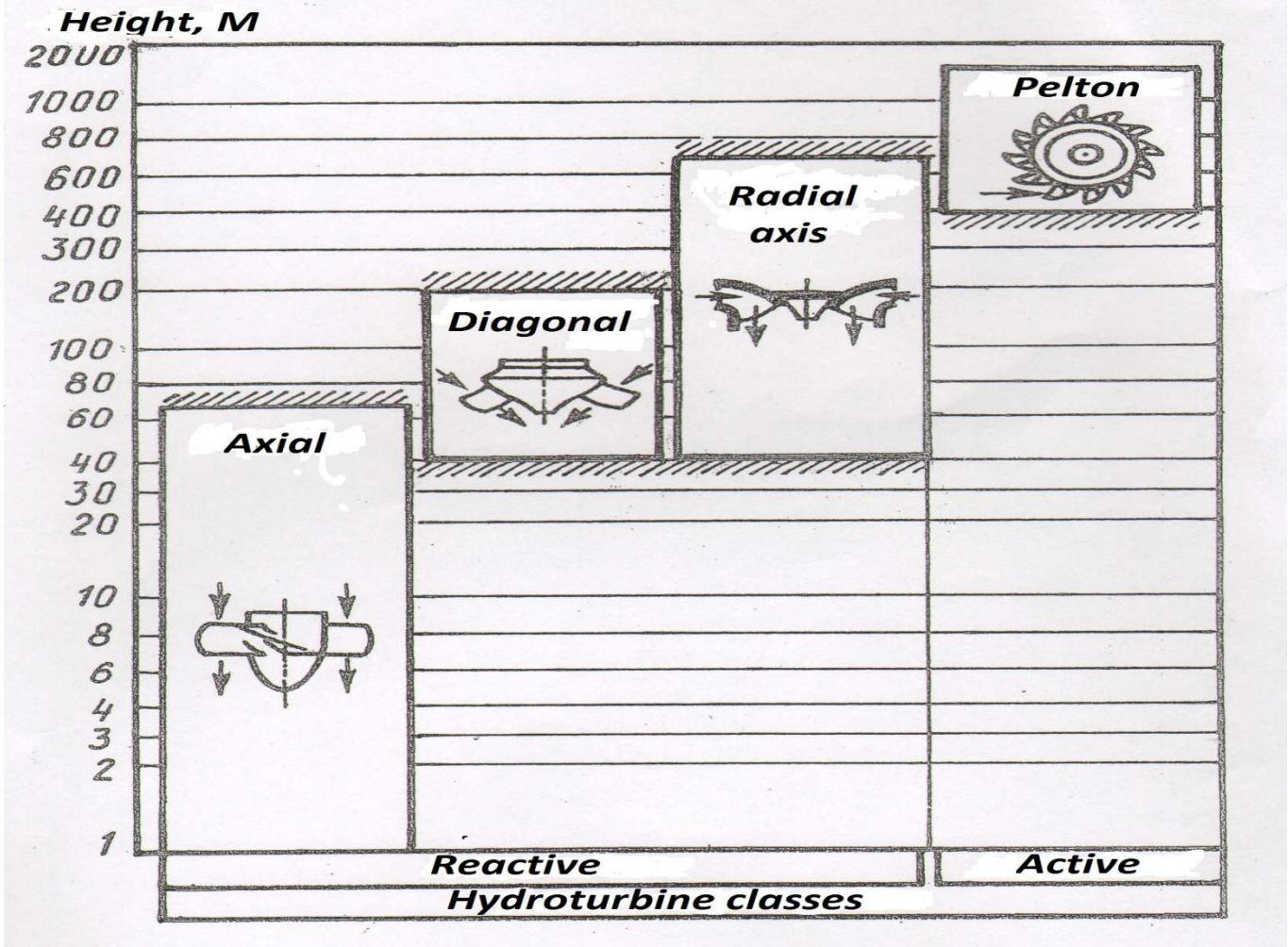
Many smaller hydropower systems are considered **"low-head"** because the height from which the water falls is fairly low. **Low-head** hydropower systems are generally less than 6 meters high.



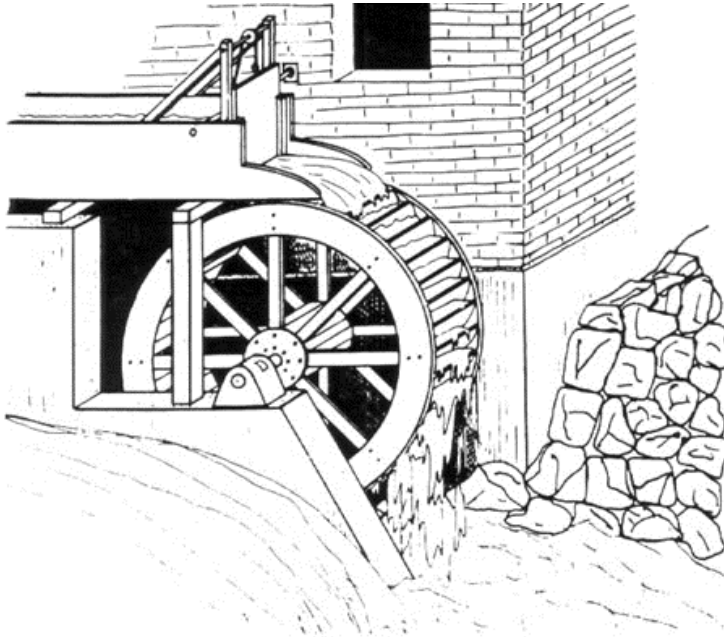
Sizes of Hydropower Plants

- Definitions may vary.
- Large plants : capacity >30 MW
- Small Plants : capacity b/w 100 kW to 30 MW (In Georgia <13 MW)
- Micro Plants : capacity up to 100 kW

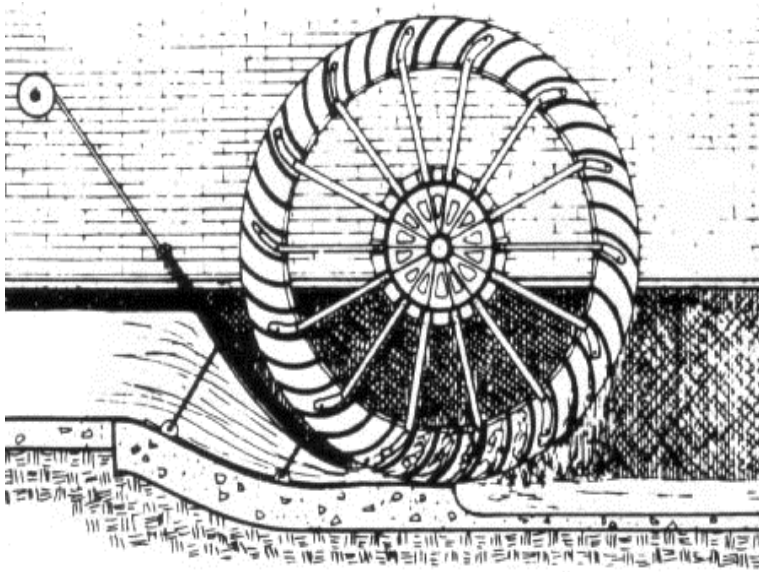
Turbine and their usage



Overflow water wheel

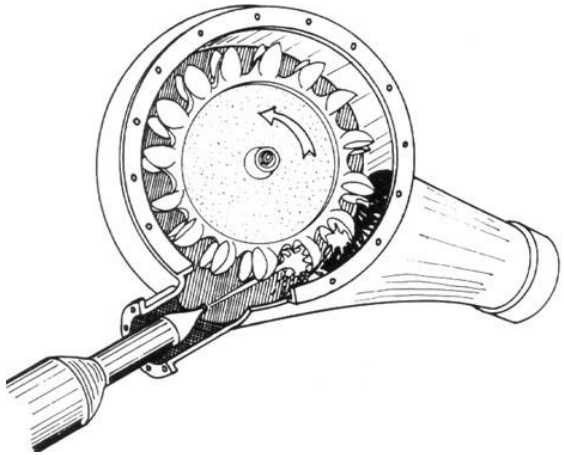


Underflow water wheel - Poncelot



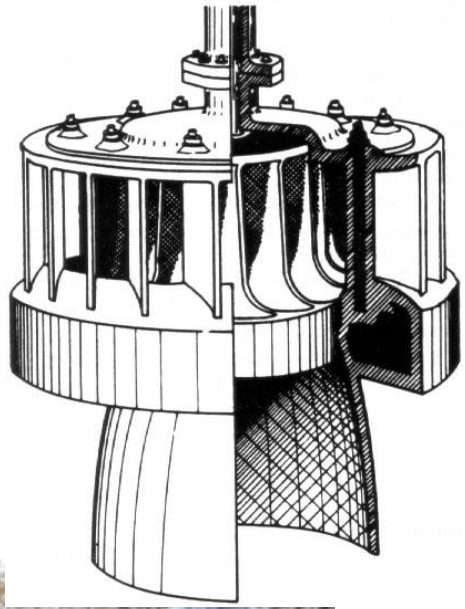
Pelton turbine

- Nozzles direct forceful streams of water against a series of spoon-shaped buckets mounted around the edge of a wheel.
- Each bucket reverses the flow Of water and this impulse spins the turbine.



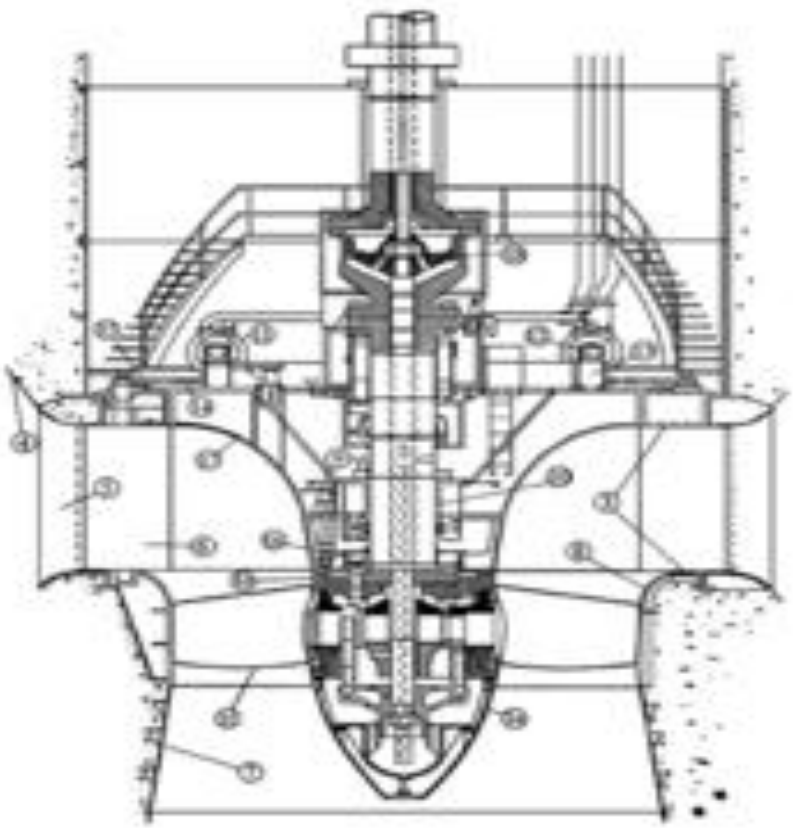
Francis Turbine (Radial-axis)

- The inlet is spiral shaped.
- Guide vanes direct the water tangentially to the runner.
- This radial flow acts on the runner vanes, causing the runner to spin.
- The guide vanes (or wicket gate) may be adjustable to allow efficient turbine operation for a range of water flow conditions.
- Best suited for sites with high flows and low to medium head.
- Efficiency of 90%.
- Expensive to design, manufacture and install, but operate for decades



Kaplan Turbine (Diagonal)

- The inlet is a scroll-shaped tube that wraps around the turbine's wicket gate.
- Water is directed tangentially, through the wicket gate, and spirals on to a propeller shaped runner, causing it to spin.
- The outlet is a specially shaped draft tube that helps decelerate the water and recover kinetic energy.



VERTICAL KAPLAN TURBINE

Others:

- Crossflow turbine:Water flows through the blades twice;
- Straflo: The generator is attached directly to the perimeter of the turbine;
- Tube Turbine: The penstock bends just before or after the runner, allowing a straight line connection to the generator;
- Bulb Turbine: The turbine and generator are a sealed unit placed directly in the water stream.

Reaction Turbine

- Combined action of pressure and moving water.
- Runner placed directly in the water stream flowing over the blades rather than striking each individually.
- lower head and higher flows than compared with the impulse turbines.

Generators

- **Types**

1. Squirrel cage generators and motors
2. Synchronous generators

- **Principles of working**

1. Parallel with network
2. Autonomously

Requirements to operation systems

- Protect equipment to overload
- Switch off power plant (disconnect from network) in case of disappearing voltage in network
- Not switch power plant to network in case of lacking voltage in network
- Close immediately inflow when disappeared voltage in network
- By starting plant, open water inlet
- Measure active and reactive power
- Compensate reactive power

Hydro Power Economics

Local Hydropower Economics

- Cost of HP is affected by oil prices; when oil prices are low, the demand for HP is low.
- More plants built, greater demand for HP
- Reduces dependency on other countries for conventional fuels

Local Hydropower Economics

- Development, operating, and maintenance costs, and electricity generation
- First check if site is developed or not.
- If a dam does not exist, several things to consider are: land/land rights, structures and improvements, equipment, reservoirs, dams, waterways, roads, railroads, and bridges.
- Development costs include recreation, preserving historical and archeological sites, maintaining water quality, protecting fish and wildlife.

Construction Costs

- Hydro costs are highly site specific
- Dams are very expensive
- Civil works form two-thirds of total cost
  - Varies 25 to 80%
- Developing nations: $ 800 to $ 2000/kW
- Compare with CCGT: $ 600 to $800/kW

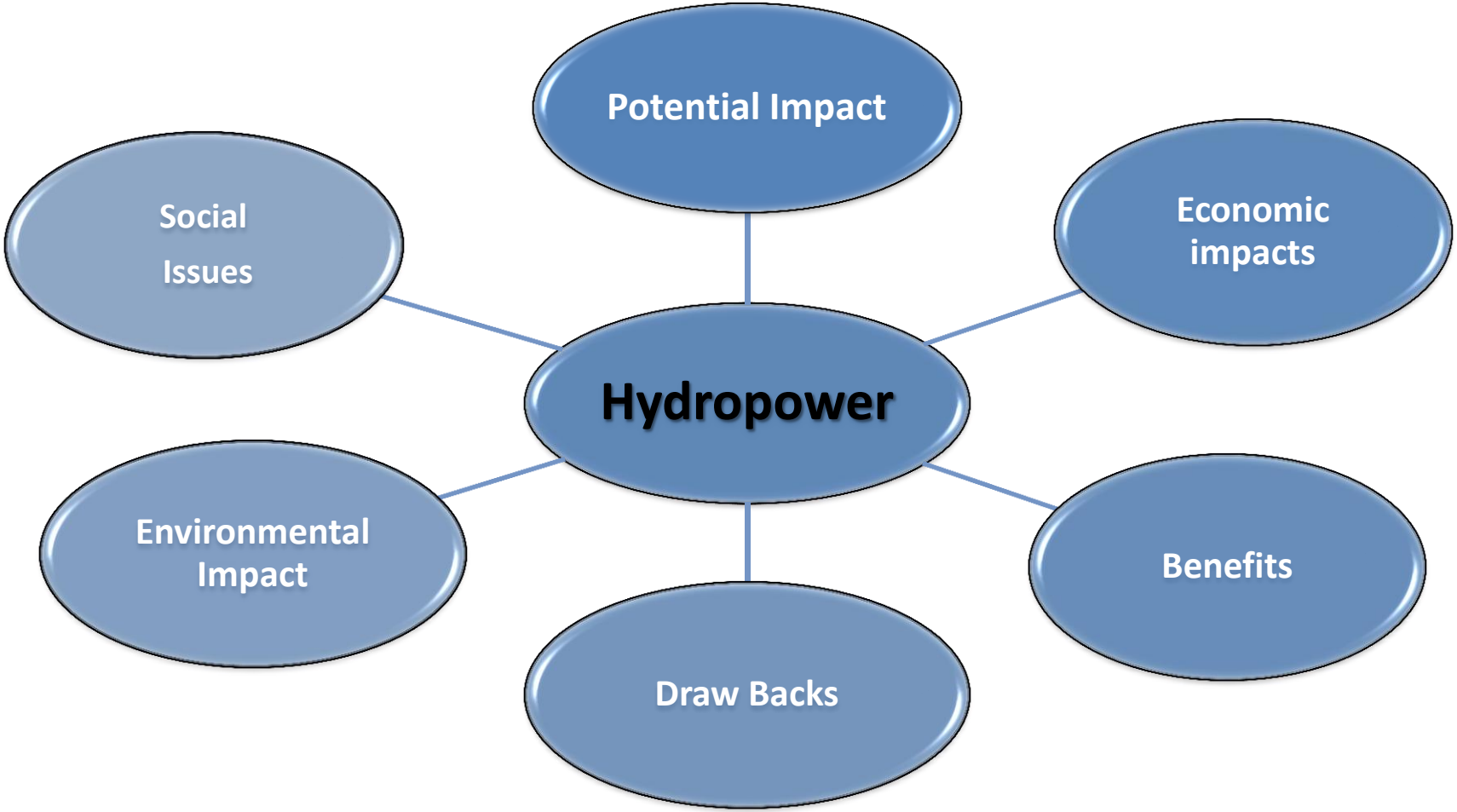
Production Costs

- Compared with fossil-fuelled plant
  - No fuel costs
  - Low O&M cost
  - Long lifetime

Typical costs of 100 KW plant

	Low head	High head
	$1000s	$1000s
Machinery	50-150	25-100
Civil works	16-67	31-67
Electrical works	16-33	16-33
External (no grid connection)	13-25	13-25
Total:	95-275	85-225

Impacts of Hydropower



- **Social Issues** - Relocating people from reservoir area leads to significant concerns regarding local culture, religious beliefs and effects associated with inundating burial sites. While there can never be a 100% satisfactory solution to involuntary resettlement, enormous progress has been made in the way the problem is handled;
- **Environmental Impacts** – Hydroelectric power includes both massive hydroelectric dams and small run-if-the-river plants. There are environmental impacts at both types of plants.

  - Environmental Benefits - No operational greenhouse gas emissions.

  Savings (kg of CO_2 per MWh of electricity): Coal 1000 kg, Oil 800 kg, Gas 400 kg, No SO_2 or NOX.

  - Non-Environmental Benefits – Flood control, irrigation, transportation, fisheries and tourism.
- **Economic Impacts** – The larger a hydro project is, the larger its construction cost overrun in percentage terms.

Interference with sediment transport

- Rivers carry a lot of sediments.
- Creation of a dam results in the deposition of sediments on the bottom of the reservoir.
- Land erosion on the edges of the reservoir due to deforestation also leads to deposition of sediments.
- Capture of sediment decreases the fertility downstream as a long term effect.
- It also leads to deprivation of sand to beaches in coastal areas.
- If the water is diverted out of the basin, there might be salt water intrusion into the inland from the ocean, as the previous balance between this salt water and upstream fresh water in altered.
- It may lead to changes in the ecology of the estuary area and lead to decrease in agricultural productivity.

Climatic and Seismic effects

- It is believed that large reservoirs induce have the potential to induce earthquakes.

- In tropics, existence of man-made lakes decreases the convective activity and reduces cloud cover. In temperate regions, fog forms over the lake and along the shores when the temperature falls to zero and thus increases humidity in the nearby area.

Other problems

- Many fishes require flowing water for reproduction and cannot adapt to stagnant resulting in the reduction in its population.
- Heating of the reservoirs may lead to decrease in the dissolved oxygen levels.
- The point of confluence of fresh water with salt water is a breeding ground for several aquatic life forms. The reduction in run-off to the sea results in reduction in their life forms.
- Other water-borne diseases like malaria, river-blindness become prevalent.

Advantages

- Hydropower is a fueled by water, so it's a clean fuel source.
- Hydropower relies on the water cycle, which is driven by the sun, thus it is a renewable power source.
- Hydropower doesn't pollute the air like power plants that burn fossil fuel, such as coal or natural gas.
- Hydropower is a domestic source of energy, produced in the Country.
- Hydropower is generally available as needed; engineers can control the flow of water through the turbines to produce electricity on demand.
- Hydropower plants provide benefits in addition to clean electricity. Impoundment hydropower creates reservoirs that offer a variety of recreational opportunities, notably fishing, swimming, and boating. Most hydropower installations are required to provide some public access to the reservoir to allow the public to take advantage of these opportunities.
- Other benefits may include water supply and flood control.

Disadvantages

- Fish populations can be impacted if fish cannot migrate upstream past impoundment dams to spawning grounds or if they cannot migrate downstream. Upstream fish passage can be aided using fish ladders or elevators, or by trapping and hauling the fish upstream by truck. Downstream fish passage is aided by diverting fish from turbine intakes using screens or racks or even underwater lights and sounds, and by maintaining a minimum spill flow past the turbine.
- Hydropower can impact water quality and flow. Hydropower plants can cause low dissolved oxygen levels in the water, a problem that is harmful to riverbank habitats and is addressed using various aeration techniques, which oxygenate the water. Main taining minimum flows of water downstream of a hydropower installation is also critical for the survival of riparian habitats.
- Methane emissions from reservoir.
- Hydropower plants can be impacted by drought. When water is not available, the hydropower plants can not produce electricity.
- New hydropower facilities impact the local environment and may compete with other uses for the land. Those alternative uses may be more highly valued than electricity generation. Humans, flora, and fauna may lose their natural habitat. Local cultures and historical sites may be impinged upon.
- Some older hydropower facilities may have historic value, so renovations of these facilities must also be sensitive to such preservation concerns and to impacts on plant and animal life.

Thank you!

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განახლებადი ენერგო რესურსები და სხვა სუფთა ენერგო ტექნოლოგიები

21, 28 მაისი, 2014

მ. მარგველაშვილი
ნ. მაღრაძე

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განახლებადი ენერგიის წყაროების გამოყენების აუცილებლობა

- მილიონობით წლების განმავლობაში დაგროვილი მარაგები მნიშვნელოვნად შემცირდა და წარმოიშვა ბევრი თანამდევი პრობლემა, მათ შორის უმთავრესია:
  - სათბობის ამოწურვა და მისი თანამდევი ენერგეტიკული კრიზისი;
  - გლობალური დათბობა და ა შ.
- აუცილებელია რადიკალურად შეიცვალოს ენერგეტიკის განვითარების მიმართულება და კაცობრიობა თანდათანობით დაუბრუნდეს ენერგიის ისეთ წყაროებს, რომელთა ბუნება განისაზღვრება პროცესებით მზეზე და დედამიწის სიღრმეში, გრავიტაციული ურთიერთქმედებით მზეს, დედამიწასა და მთვარეს შორის. აღსანიშნავია, რომ წყაროების რესურსი განახლებადია და შესაბამისად ამოუწურავი, მისი პოტენციალი მნიშვნელოვნად აღემატება საზოგადოების მოთხოვნილებას ენერგიაზე და პრაქტიკულად არ აბინძურებს გარემოს.
- ენერგიების დღევანდელი გამოყენების დონე მიუთითებს იმაზე რომ გლობალური დათბობა გაგრძელდება 21 საუკუნის განმავლობაშიც და მას შემდეგაც, ვინაიდან დედამიწის სისტემის ნაწილები მოგვიანებით რეაგირებენ სათბური გაზების გამოყოფის დონესთან. შესაბამისად მოხდება ტემპერატურის გაზრდა, რაც თავის მხრივ ოკეანეების დათბობით გამოიწვევს გობალური ზღვის დონის ზრდას
- თანამედროვე ტექნოლოგიური დონის გათვალისწინებით სავსებით რეალური და აუცილებელია, რომ უახლოეს მომავლში ენერგიის განახლებადმა წყაროებმა მნიშვნელოვანი როლი შეასრულონ მსოფლიო ენერგოუზრუნველყოფაში.
- განახლებადი ენერგიის წყაროების გამოყენების საჭირო დონეზე გაზრდისათვის აუცილებელია მკვეთრად შეიცვალოს საზოგადოების ცნობიერება და მომზადდეს შესაბამისი დარგის სპეციალისტები, რომლებიც არა მარტო დააპროექტებენ მოწყობილობებს, არამედ სწორადაც გამოიყენებენ მათ.

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განახლებადი ენერგიის წყაროების გამოყენების საფუძვლები

ენერგიის განახლებადი წყაროები ესაა ბუნებაში მუდმივად არსებული ან პერიოდულად შევსებადი ენერგიის ნაკადებზე დაფუძნებული ენერგიის წყაროები. აღნიშნული წყაროები არ წარმოადგენენ ადამიანის მიზანმიმართული მოქმედების შედეგს და შეიძლება დავყოთ სამ ჯგუფად:

1. მზის გამოსხივების ენერგია;
2. მზის, მთვარისა და დედამიწის მოძრაობის და მიზიდულობის ენერგია;
3. დედამიწის ბირთვის თბური ენერგია და დედამიწის ქერქში მიმდინარე ქიმიური რექციის და დაშლის ენერგია.

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ენერგიის წყაროები

- **მზის გამოსხივების ენერგია:**

ა) თბური გამოსხივების ენერგია;
ბ) თბური ენერგია გარდაქმნილი წყლის ნაკადის ენერგიად;
გ) ქარისა და ზღვის ტალღების ენერგია;
დ) ბიომასის ენერგია.

- **მზის, მთვარის და დედამიწის მოძრაობის და მიზიდულობის ენერგია:**

ა) ზღვების მოქცევის ენერგია;
ბ) ოკეანეების მოქცევის ენერგია.

- **დედამიწის ბირთვის თბური ენერგია და დედამიწის ქერქში მიმდინარე ქიმიური რექციის და დაშლის ენერგია.**

ა) გეოთერმული ენერგია

შენიშვნა: ენერგიის განახლებად წყაროებს არ მიეკუთვნება გამყარებული - ორგანული ნაერთებიდან მიღებული სათბობი და ცხელი სამთო ქანების ენერგია.

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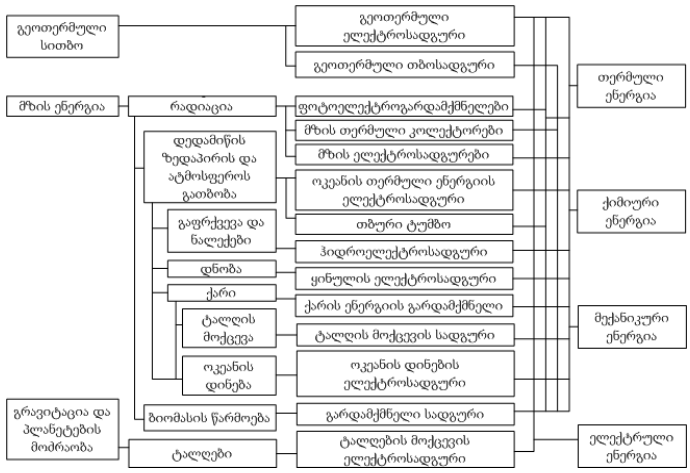
განახლებადი ენერგიების გამოყენება სასარგებლო ენერგიის უზრუნველსაყოფად



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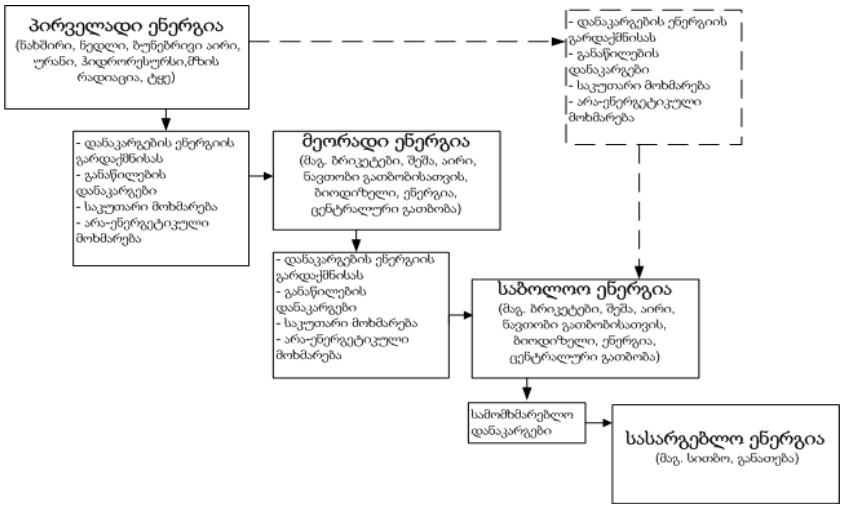
ენერგიის გარდაქმნა



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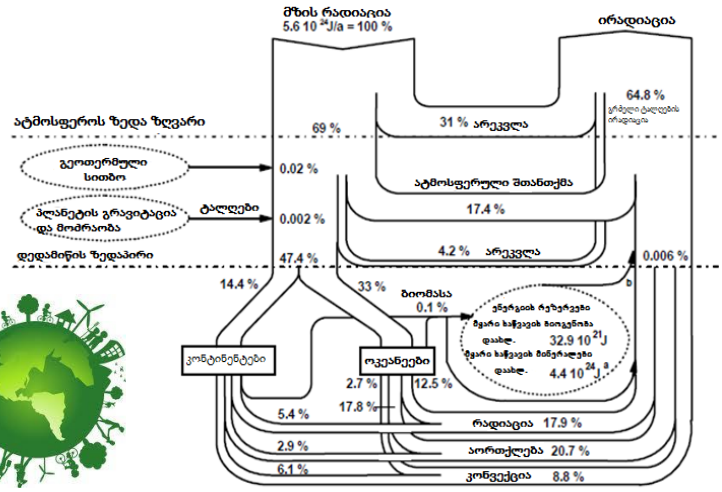
დედამიწის ენერგეტიკული ბალანსი



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ძირითადი განახლებადი ენერგო რესურსები

- ჰიდროენერგეტიკა
- გეოთერმული ენერგია
- ქარის ენერგია
- მზის ენერგია
- ბიოგაზი
- ბიოსაწვავი

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ენერგიის განახლებადი წყაროების ძირითადი მახასიათებლები

ენერგოსისტემის მახასიათებლები	ენერგიის განახლებადი წყაროები	ენერგიის ამოწურვადი წყაროები
წყარო	მზე, ქარი, მოქცევა	ნავთობი, ქვანახშირი, ბუნებრივი გაზი
განთავსების ადგილი	გარემომცველი სივრცე	ცალკეული შეყურსული საბადოები
არსებობის ფორმები	ენერგიის ნაკადები	პოტენციალური ბმული ენერგია
საწყისი ინტენსიობა	დაბალი გაბნეული ინტენსიობა საშუალოდ 0,3 კვტ/მ^2 სიმკვრივით	მაღალი ინტესიობა 100 კვტ/მ^2 და უფრო მაღალი
ამოწურვის ვადა	უსასრულო	სასრული, შეზღუდული
გამოყენებული ენერგიის ფასი	უფასო	თანდათანობით იზრდება 0,02 დოლარი/კვტსთ-ზე და მეტი
მოწყობილობის ფასი	მაღალი, საშუალოდ 2000 დოლარი/კვტ დადგმულ სიმძლავრეზე	საშუალო, დაახლოებით 500 დოლარი/კვტ დადგმულ სიმძლავრეზე
სტაბილურობა და მართვადობა	დაბალი სტაბილურობა, მართვა დატვირთვის რეგულირების პირდაპირი კავშირით	მაღალი სტაბილურობა, მართვა-ხარჯის რეგულირების უკუკავშირით
შეზღუდვები გამოყენებაში	ადგილობრივი პირობები	არ არის
მეცნიერული საფუძვლები	მეცნიერების სხვადსხვა დარგების ფართო დიაპაზონი, მათ შორის ბიოტექნოლოგია და აგრარული დარგებიც	ძირითადი ემქანიკა, თბოტექნიკა და ელექტროტექნიკა
ექსპლუატაციის უსაფრთხოება	აქვს საშიში ზონები, ძირითადად უსაფრთხოა	სპეციალური ღონისძიებების გარეშე საფრთხე მაღალია
ავტონომიურობა	უზრუნველყოფილია ენერგიით	დამოკიდებულია სათბობის მიწოდებაზე
გარემოზე ზემოქმედება	პრაქტიკულად არ მოქმედებს გარემოზე	აბინძურებს გარემოს, ძირითადად ჰაერს და წყალს

9

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ენერგიის განახლებადი წყაროების პერიოდულობა და ინტენსიობა

წყარო	პერიოდულობა	განმსაზღვრელი პარამეტრები	ენერგეტიკული თანაფარდობა	შენიშვნები
მზის პირდაპირი გამოსხივება	24 საათი, 1 წელიწადი	დასხივებულობა (ვტ/მ^2), სხივის დაცემის კუთხე	$P \sim G_{სრ} \cos\theta_z$, მაქსიმუმ 1კვტ/მ^2-ზე	მხოლოდ დღის განმავლობაში
მზის გაბნეული გამოსხივება	24 საათი, 1 წელიწადი	ღრუბლიანობა	$P<300$ვტ/მ^2-ზე	მხოლოდ დღის განმავლობაში
ბიოსათბობი	1 წელიწადი	ნიადაგის ხარისხი, დასხივება, წყალი, სათბობის სპეციფიკა	ბმული ენერგია ≈10მჯ/კგ-ზე	სათბობის მრავალი სახეობა, ტყე, სოფლის მეურნეობა და სხვა
ქარი	დაუზუსტებელი, 1 წელიწადი	ქარის სიჩქარე, მიწის ზედაპირიდან სიმაღლე	$P \sim v^3$, $v_z/v_0=(z/h)^b$	მაღალი ფლუქტაცია $b \approx 0,15$
ჰიდრო ენერგია	1 წელიწადი	წყლის მოცულობითი ხარჯი და დაწნევის სიმაღლე	$P \sim Q*H$	წყლის ხელოვნურად დაგროვება
ტალღები	დაუზუსტებელი, 1 წელიწადი	ტალღის ამპლიტუდა და პერიოდი	$P \sim H_s*T$	მაღალი ხვედრითი ენერგია
მოქცევა	12 საათი და 25 წუთი	მოქცევის სიმაღლე, აუზის ფართობი	$P \sim R^2 *A$	
ოკეანის და ზღვის თბური ენერგია	მუდმივი პარამეტრები	ტემპერატურათა სხვაობა ზედაპირსა და სიღრმეს შორის	$P \sim (T_{ზედ} - T_{სიღ})^2$	ტროპიკული საიონები

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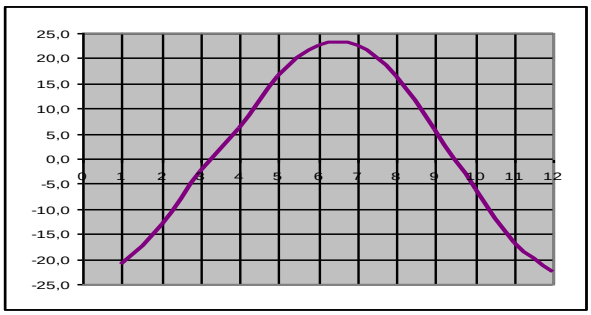
მზის გამოსხივება

- ენერგიის იმ რაოდენობას,რომელიც დედამიწის ატმოსფეროს საზღვარზე მზის პირდაპირი გამოსხივებისადმი მართებულად განლაგებულ ერთეულოვან ფართზე დროის ერთეულში მოდის ,,მზის მუდმივა" (I_0) ეწოდება. **I_0 =1353 ვტ/მ²**

მზის დახრილობის მნიშვნელობის ცვლილება თვეების მიხედვით



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ფოტოელექტრული ელემენტი

ფოტოელექტრული ელემენტი (ფე) ყველაზე ახლოსაა მზის ენერგიის გარდამქმნელ იდეალურ სისტემასთან. იგი იყენებს ჩვენს პლანეტაზე ყველაზე ხელმისაწვდომ ენერგიის წყაროს – მზის სხივის ენერგიას. მისი უპირატესობებია:

- ეკოლოგიურად გაცილებით უფრო სუფთაა, ვიდრე წიაღისეულ და ბირთვულ ენერგიაზე მომუშავე დანადგარები;
- თითქმის მთლიანად მზადდება სილიციუმისგან, რომელიც ფართოდაა გავრცელებული დედამიწაზე;
- არ აქვს მოძრავი ნაწილები, რაც უზრუნველყოფს მის ექსპლუატაციას ხანგრძლივი პერიოდის განმავლობაში დაზიანების გარეშე;
- გამოიმუშავებს ელექტროენერგიას, ყველაზე მოხერხებულს ენერგიის ფორმებს შორის.
- ფოტოელექტრული ეფექტი ცნობილია აგრეთვე ფოტოვოლტაიკის სახელწოდებით.

ფოტოვოლტაიკების მუშაობის პრინციპი:
https://www.youtube.com/watch?v=1gta2lCarDw

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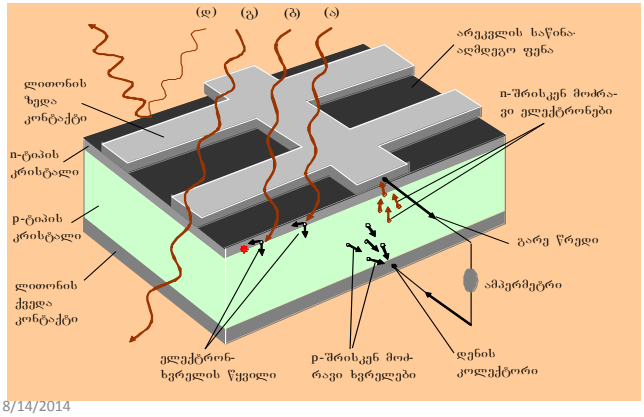
სილიციუმის ფოტოელექტრული ელემენტი

ა) აკრძალული ზონის სიგანის ტოლი ენერგიის მქონე ფოტონი წარმოქმნის ელექტრონ-ხვრელის წყვილს; ბ) აკრძალული ზონის სიგანეზე მეტი ენერგიის მქონე ფოტონის ენერგიის ნაწილი ხმარდება ელექტრონ-ხვრელის წყვილის წარმოქმნას, ნაწილი კი გარდაიქმნება სითბოდ;



გ) აკრძალული ზონის სიგანეზე ნაკლები ენერგიის მქონე ფოტონი ატომებთან ურთიერთქმედების გარეშე გამჭოლავს ფოტოელემენტს; დ) ფოტონების ნაწილი აირეკლება ფოტოელემენტის ზედაპირიდან.

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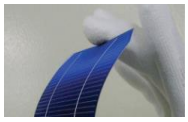
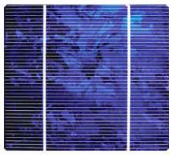
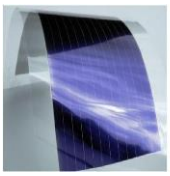
ფოტოვოლტაიკების ტიპები



1) პოლიკრისტალური (მულტიკრისტალური) სილიციუმი (poly-Si or mc-Si);



2) მონოკრისტალური სილიციუმი (mc-Si)
3) ამორფული სილიციუმი (a-Si);
4) კადმიუმ ტელურიდი (CdTe);
5) ჰიბრიდული (HIT);



6) სპილენძ ინდიუმი/ გალიუმის დისელენიდი (CISe, CIGS);
7) ორგანული.

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მზის სისტემები

- **ქსელზე მიერთებული:**
  1) ქსელზე მიერთებული ენერგიის შემნახველი წყაროების გარეშე (ბატარიის გარეშე)
  2) ქსელზე მიერთებული ბატარიით

კატეგორიები:

- მცირე - 1-10 კვტ.Ს (საყოფაცხოვრებო დონეზე)
- საშუალო - რამოდენიმე ასეული კვტ.Ს
- დიდი - 1 მვტ.ᲡᲖევით

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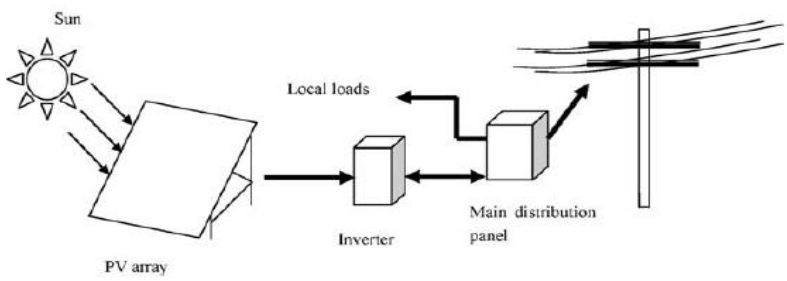
ქსელზე მიერთებული სისტემები



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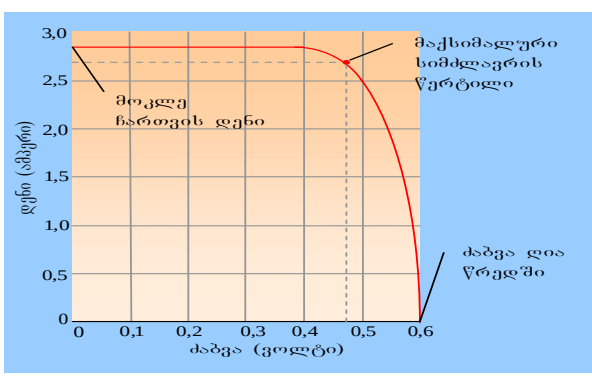
ფოტოელემენტის ვოლტამპერული მახასიათებლის მრუდი

როდესაც დატვირთვის წინაღობა იცვლება ნულსა და მაქსიმუმს შორის, მაშინ წრედში დენის ძალის და ელემენტის ბოლოებზე ძაბვის სიდიდე შეგვიძლია ვიპოვოთ ვოლტამპერული მახასიათებლის საშუალებით. ფოტოელემენტის გამოსასვლელი სიმძლავრე ნულის ტოლია გახსნილი წრედის შემთხვევაში (ვინაიდან დენი=0), და მოკლე ჩართვის დროს (ვინაიდან ძაბვა=0). ამ წერტილებს შორის სიმძლავრე ჯერ იზრდება, ხოლო შემდეგ მკვეთრად ეცემა;



მისი მაქსიმალური მნიშვნელობა ემთხვევა ვოლტამპერული მახასიათებლის მრუდის M წერტილს. მოცემული მრუდი შეესაბამება მზის გამოსხივების სტანდარტულ მნიშვნელობას - 1000 ვტ/მ2.
მზის გამოსხივების შემცირებისას, ვოლტამპერული მრუდის ფორმა შენარჩუნდება, მაგრამ მოკლე ჩართვის შესაბამისი დენის ძალა მცირდება მზის გამოსხივების ინტენსივობის პროპორციულად, მაშინ, როცა გახსნილი წრედის ბოლოებზე ძაბვა ეცემა ნაკლებად მკვეთრად.
გახსნილი წრედის ბოლოებზე ძაბვა და ელემენტის მაქსიმალური სიმძლავრე ტემპერატურის ზრდასთან ერთად ხაზოვნად ეცემა.

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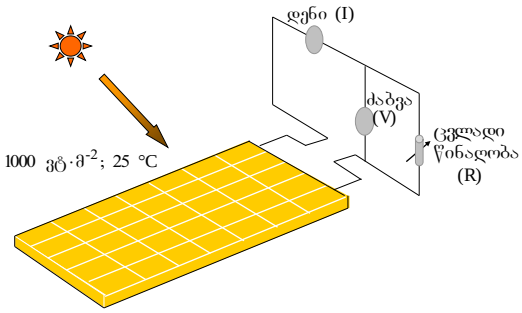
ფოტოელექტრული ელემენტის მახასიათებლების დასადგენი წრედის სქემა



უსასრულოდ დიდი წინაღობის შემთხვევაში (რაც ნიშნავს გახსნილ წრედს), დენი ნულის ტოლია, ძაბვა მაქსიმალური. როდესაც წინაღობის სიდიდე ნულის ტოლია, (რაც ნიშნავს მოკლე ჩართვას), დენის სიდიდე წრედში მაქსიმალურია, ძაბვა კი - ნულის ტოლი.

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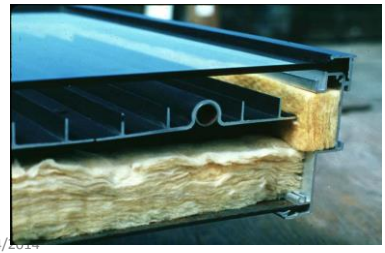
მზის ენერგიის მიმღები მოწყობილობა (კოლექტორი)

- მზის კოლექტორი წარმოადგენს ერთ-ერთ ძირითად ელემენტს დანადგარისა, რომელიც მზის გამოსხივების ენერგიას გარდაქმნის ჩვენთვის სასარგებლო სითბურ ენერგიად. კოლექტორის დანიშნულებაა მზის გამოსხივების ენერგიის მიღება შთანთქმა და გადაცემა მუშა სხეულისთვის (წყალი, ჰაერი და სხ.).
- კოლექტორებს, რომლებიც კონცენტრატორების გარეშე ფუნქციონირებენ ბრტყელ კოლექტორებს უწოდებენ. ბრტყელ კოლექტორებში მზის გამოსხივების მიმღები ზედაპირი ერთდროულად წარმოადგენს მის მშთანთქმელსაც. ისინი ძირითადად გამოიყენება თბომტარების (წყალი, ჰაერი და სხ.) გასაცხელებლად (მაქსიმუმ 100-1200C 0 მდე).



ბრტყელი კოლექტორების დადებით მხარეს წარმოადგენს ის გარემოება, რომ ისინი ღებულობენ როგორც პირდაპირ ისე გაბნეულ გამოსხივებას, არ არის აუცილებლობა ისინი აღჭურვილი იყვნენ მზეზე მიდევნების სისტემით და გამოირჩევიან კონსტრუქციული სიმარტივით.

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სხვა სახის კოლექტორები

- შავი რეზერვუარი მინის საფარის გარეშე
- ლითონის ფირფიტა-მილაკები ორმაგი მინის სახურავით
- შავი რეზერვუარი მინის სახურავიან კონტეინერში
- შავი რეზერვუარი სელექციური ზედაპირით
- ლითონის ფირფიტა-მილაკები მინის სახურავიან კონტეინერში
- ვაკუუმ-მილაკებიანი მიმღები

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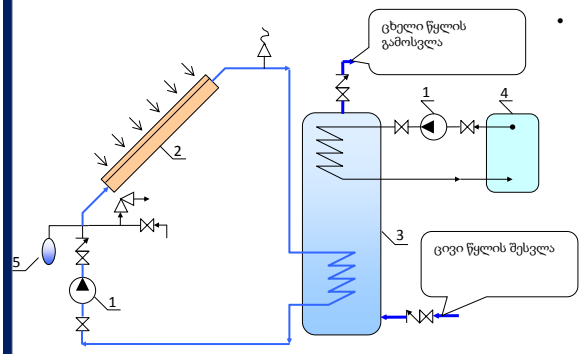
მზის ენერგიაზე მომუშავე გათბობა-ცხელწყალმომარაგების ტიპური ორკონტურიანი სისტემა

1-საცირკულაციო ტუმბო; 2-მზის კოლექტორი; 3-ცხელი წყლის ავზი; 4-წყალსათბობი ქვაბი; 5-საფართოებელი ავზი. პირველი კონტური, რომელშიც შედის მზის კოლექტორი (2) საცირკულაციო ტუმბო (1) და საფართოებელი ავზი (5) შევსებულია ყინვაგამძლე სითხით.



- კოლექტორში შემთბარი სითხე გაივლის რა ცხელი წყლის ავზს (3) გადასცემს სითბოს წყალს და ბრუნდება საცირკულაციო ტუმბოს საშუალებით კოლექტორში. მეორე კონტური შედგება ცხელი წყლის ავზისგან (3) და დამატებითი წყალსათბობი ქვაბისგან (4). წყალსათბობი ქვაბის დანიშნულებაა დამატებითი ენერგიის მიწოდება არამზიანი დღეების განმავლობაში და მომხმარებლის მოთხოვნილების უზრუნველყოფა.

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მზის კოლექტორი კონცენტრატორით

- მზის კოლექტორები კონცენტრატორებით ფართოდ გამოიყენება მზის ელექტრო - სადგურებში. თერმოდინამიკული ციკლით მომუშავე მზის ელექტროსადგურები.

1. პარაბოლური სარკეებიანი კონცენტრატორები აცხელებენ ფოკუსში მყოფ მილებში გამდინარე თბომტარს და მიიღება ორთქლი, რომელიც შემდგომ მიემართება ტურბინაში.

2. ბრტყელი სარკეების საშუალებით მზის სხივები ფოკუსირდება კოშკურაზე მყოფ ორთქლის ქვაბის მიმღებ ზედაპირზე, რომელშიც წარმოიქმნება თბომტარის ორთქლი და რომელიც შემდგომ მიემართება ტურბინაში.

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ქარის ენერგია

- ქარი წარმოადგენს ატმოსფერული ჰაერის მასების მოძრაობას, რომელიც წარმოიშვება მზიდან მოსული ენერგიის მიერ დედამიწის ზედაპირის და მასთან შეხებაში მყოფი ჰაერის (ატმოსფეროს) არათანაბარი გათბობით. არათანაბრად გამთბარ ჰაერში, სიმკვრივეთა სხვაობა (არქიმედის ძალების მოქმედება), იწვევს თბილი და ცივი ჰაერის მასების ურთიერთ-ჩანაცვლებას და შედეგად მოძრაობას.
- ქარის დახასიათება სიძლიერის მიხედვით ხდება "ბოფორტის" 12 ბალიანი სკალის მიხედვით.

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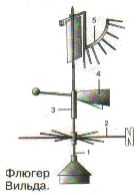
ქარის სიჩქარის ათვლა

- ქარის სიჩქარეების ათვლა ჩვეულებრივად წარმოებს მეტეოსადგურებზე , სადაც სხვა მონაცემებთან (ტემპერატურა, წნევა,მზის რადიაცია, ტენიანობა) ერთად იზომება ქარის სიჩქარე. ქარის სიჩქარის გამზომ ხელსაწყოს ანემომეტრი ეწოდება. ანემომერები განსხვავდებიან მოქმედების პრინციპით და კონსტრუქციით. მეტეოსადგურებში ფართოდ იყო გავრცელებული ფლუგერ-ანემომეტრები (1). შემდგომში, ტექნიკის განვითარებასთან ერთად დამუშავებულ იქნა შედარებით უფრო სრულყოფილი ფლუგერ-ანემომეტრები (2), რომლებშიც ქარის სიჩქარის და მიმართულების განსაზღვრა და ჩაწერა ხდება ავტომატურ რეჟიმში და უფრო მოგვიანებით გაჩნდა პორტატული ანემომეტრები (3).



1

2

3

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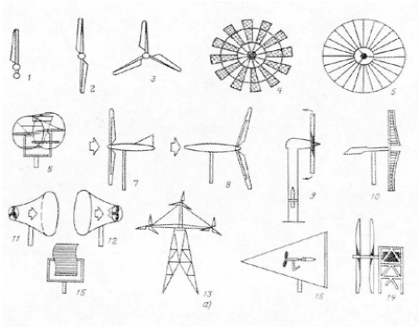
ქარის ძრავების კლასიფიკაცია

- ქარის ძრავები შეიძლება დაიყოს სამ ძირითად ჯგუფად:

1) ძრავები, რომელთა ქარის ბორბლის ბრუნვის სიბრტყე ქარის მოძრაობის პერპენდიკულარულია და შედეგად ქარის ბორბლის ღერძი ქარის ნაკადის მიმართულების პარალელურია. მათ ასევე უწოდებენ ჰორიზონტალურ ღერძიან ძრავებს.

1-ერთფრთიანი; 2-ორფრთიანი; 3-სამფრთიანი; 4-5-მრავალფრთიანი; 6-ნიჩბიანი წყლის ბორბლის მსგავსი; 7-ქარის საწინაარმდეგოდ მიმართული; 8-ზურგის ქარის; 9-ენფილდ ანდროს როტორით; 10-აფრიანი ფრთებით; 11-დიფუზორიანი; 12-კონცენტრატორიანი; 13-მრავალროტორიანი; 14-საწინააღმდეგოდ მბრუნავი ფრთებით; 15-სავონიუსის გვერდითი ქარის; 16-სამკუთხა ფრთის შეუზღუდავი გრიგალის.



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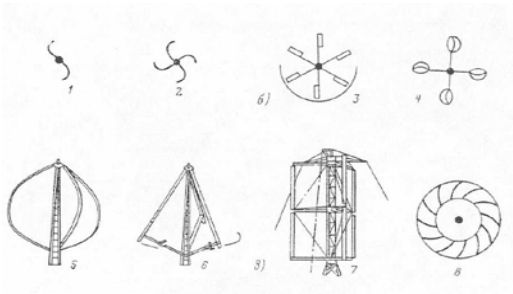
2) ძრავები, რომელთა ქარის ბორბლის ღერძი დედამიწის ვერტიკალურადაა განლაგებული. კონსტრუქციულად ისინი კიდევ იყოფიან ქვეჯგუფებად (ვერტიკალურ ღერძიანი):

ა) კარუსელური – მათი არამუშა ფრთები ან დაფარულია ეკრანით ან განლაგებულია წიბოთი ქარის მიმართ (1,2,3,4);

ბ) დარიუსის და სავონიუსის როტორული ძრავები (5,6,7,8).



1-2-ორი და ოთხ ფრთიანი; 3-ეკრანირებული ნიჩბებიანი; 4-ჯამებიანი; 5-6-7 დარიუსის ტურბინა; 8-”ბანკის” ტიპის ტურბინა

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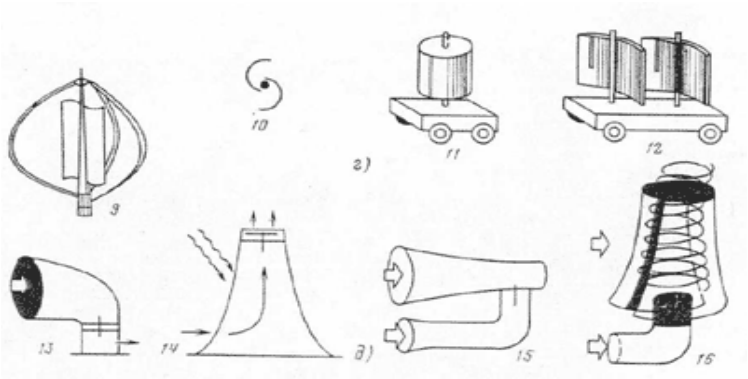
3) კომბინირებული ტიპის ძრავები, რომლებშიც გამოყენებულია სხვადასხვა ტიპის ძრავების მექანიზმები და პრინციპები.



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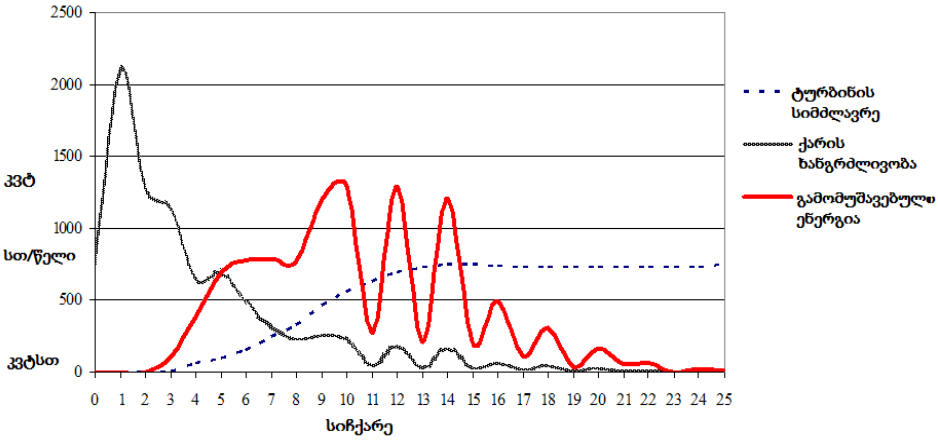
ქარის ტურბინის მიერ გამომუშავებული ენერგია



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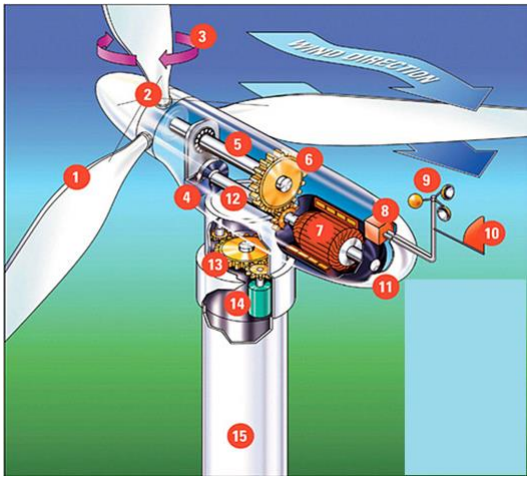
ქარის ტურბინის ძირითადი ელემენტები



1-ფრთა;
2-როტორი;
3-ფრთის ქარისადმი დახრილობის ცვლილება;
4-მუხრუჭი;
5-დაბალი სიჩქარის ღერძი;
6-რედუქტორის კბილანები;
7-ელექტროგენერატორი;
8-მართვის სისტემა;
9-10-ფლუგერ-ანემომეტრი;
11-კაბინა, რომელშიც მოთავსებულია ყველა ეს მოწყობილობა (გონდოლა);
12-მაღალი სიჩქარის ღერძი;
13-კაბინის მოტრიალების მოწყობილობა;
14-კაბინის მოტრიალების ძრავი;
15-კოშკი.

ქარის სადგურის მუშაობის პრინციპი
https://www.youtube.com/watch?v=LNXTm7aHvWc

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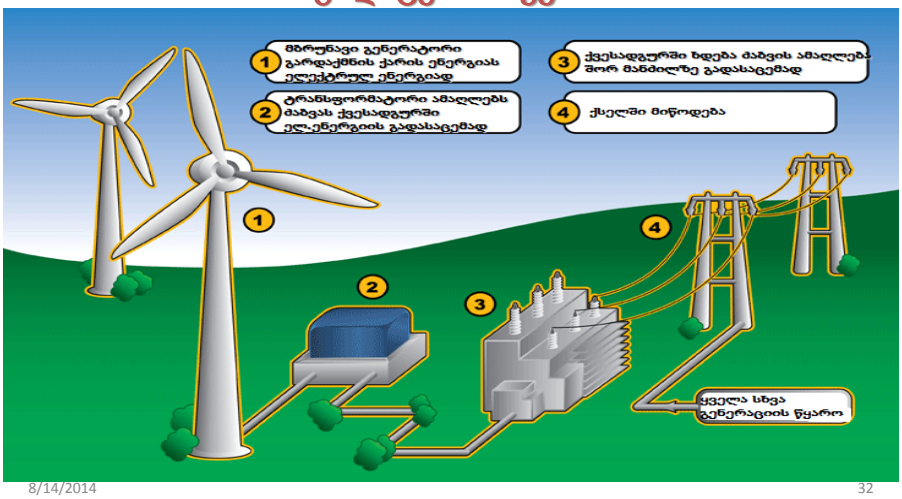
ქარის მიერ გამომუშავებული ელექტროენერგიის გადაცემის სქემა



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ქარის ენერგიის შენახვა

- ნიკელ-კადმიუმიანი (Nickel-cadmium) და ტყვია-მჟავიანი (lead-acid) აკუმულატორები
- მრავალჯერადი გამოყენების (დასატენი) აკუმულატორები
- მქნევარა თვალი (Flywheel)
- ჰიდრომააკუმულირებელი სადგური
- დაჭირხნულუ ჰაერის ენერგო შენახვა
- თბური კონდენსატორები
- წყალბადის ტექნოლოგია

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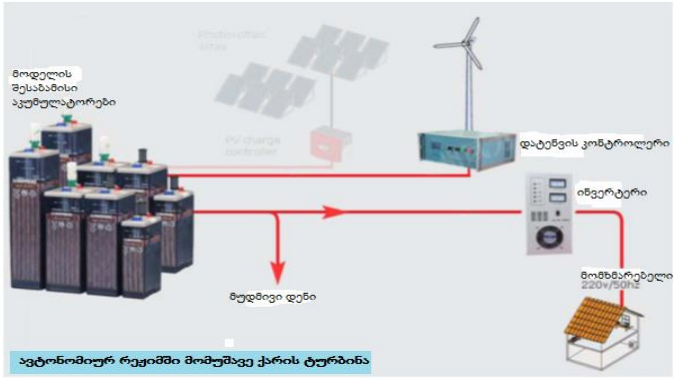
ქარის სადგურის მუშაობის რეჟიმები

- ქსელზე მიერთებული ქარის ტურბინა
- ავტონომიურ რეჟიმში მომუშვე ქარის ტურბინა
- ინტეგრირებული (მზის, ქარის, მცირე ჰიდროს სადგურთან და ა.შ)



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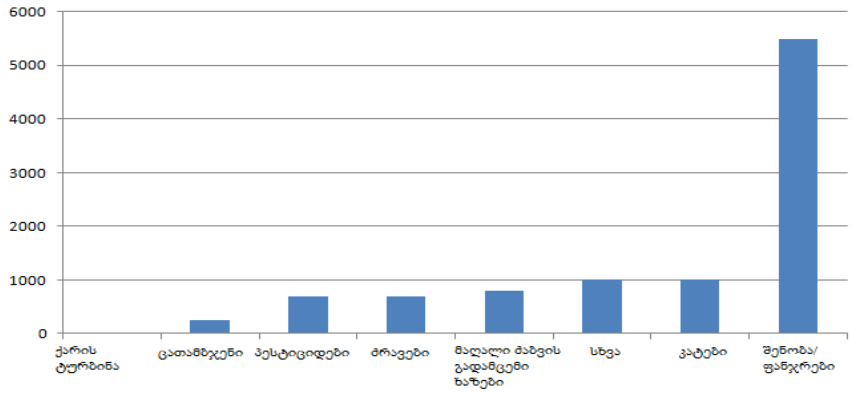
ფრინველების სიკვდილიანობა (რაოდენობა 10 000 გარდაცვლილ ფრინველზე)

წყარო: Ericson et al., 2002. Summary of Anthropogenic Causes of Bird Mortality



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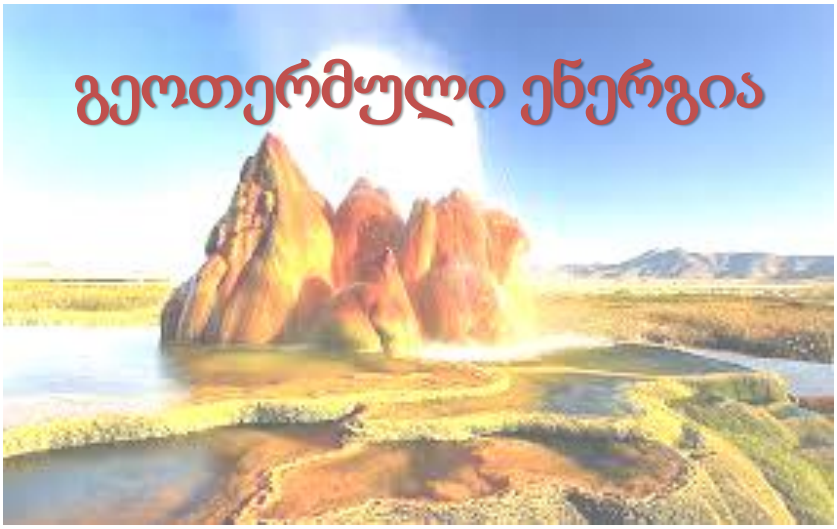

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გეოთერმული ენერგია

- გეოთერმული (გეო-დედამიწა, თერმა-სითბო) რესურსები წარმოადგენს სიღრმული სითბოს მარაგს, რომელიც წარმოიქმნება დედამიწის წიაღში მიმდინარე თერმოქიმიური და ფიზიკური პროცესების შედეგად, როგორიცაა დედამიწის ბირთვში მიმდინარე რადიოაქტიური დაშლის რეაქციები (ძირითადათ ურანისა და თორიუმის იზოტოპების დაშლა), ეგზოთერმული ქიმიური რეაქციები მანტიაში, ხახუნი ტექტონიკურ ფილებს შორის და სხვ. გეოთერმული სითბო დედამიწის გულიდან ზედაპირისაკენ ვრცელდება თბოგამტარობით მყარ ქანებში და კონვექციით ოკეანეებსა და გათხევადებულ მაგმაში.

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გეოთერმული რესურსების კლასიფიკაცია

გეოთერმული რესურსებუ სამ კატეგორიად კლასიფიცირდება:

- მაღალი ტემპერატურის რესურსები, რომლებიც ჩვეულებრივ მაგმატურ პროცესებთანაა დაკავშირებული. აღწევენ 200- 350°C ბურღვად სიღრმეებზე.
- საშუალო და დაბალი ტემპერატურის რესურსები, არამაგმატური წარმოშობის, ჩვეულებრივ დაკავშირებულია ღრმა რღვევებთან. ტემპერატურამ შესაძლოა მიაღწიოს 140°C.
- ძალიან დაბალი, ტემპერატურის რესურსები, რომლებიც ფართოდაა გავრცელებული.

გეოთერმული ენერგია შესაძლებელია გამოყენებული იქნას ელექტროენერგიის წარმოებაში, კომერციული, ინდუსტრიული და საცხოვრებელი სახლების გათბობის სისტემებისათვის და ასევე გეოთერმული სითბური ტუმბოების გამოყენებით შენობობის გათბობა-გაგრიელბისათვის.

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გეოთერმული სითბოს მოპოვების მეთოდები

გეოთერმული სითბოს მოპოვების სამი მეთოდი არსებობს:

1) **ბუნებრივი ჰიდროთერმული ცირკულაცია**, რომლის დროსაც, სითბური ენერგია მოიპოვება ცხელი წყლის ან ორთქლის სახით. ამისათვის ჰიდროთერმულ რეზერვუარებში (საბადოებში) აკეთებენ საექსპლუატაციო ჭაბურღულების, საიდანაც სხელი წყალი ამოდის თვითდინებით.
2) ე.წ. **ხელოვნური გადახურების მეთოდი** ითვალისწინებს ნახევრადთხევადი მაგმის გაცივებას, რომელიც დედამიწის ზედაპირზე ამოსულია ლავას სახით.
3) **მშრალი კლდოვანი ქანების გაცივების მეთოდი** ითვალისწინებს ღრმა ქანების (5-10 კმ. სიღრმეზე) გაცივებას მასში წყლის იძულებითი გატარებით.

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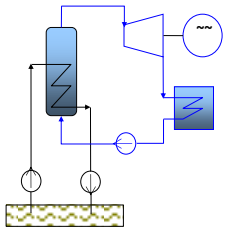
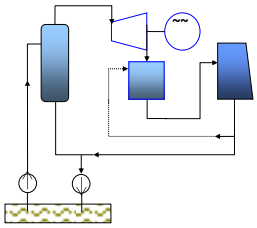
გეოთერმული სადგურები

- არსებობს ე. წ. მყისიერი აორთქლების და ბინარული ციკლის გეოთერმული ელექტროსადგუ-რები. მყისიერი აორთქლების ელექტროსადგურებში იყენებენ ცხელ წყალს, რომლის ტემპერატურაც აღემატება 170 C. ის მაღალი წნევით მიეწოდება საფართოებელ რეზერვუარში, სადაც ფართოვდება და გარდაიქმნება ორთქლად.
- ბინარული ციკლის ელექტროსადგურებში გამოიყენება 170C-ზე ნაკლები ტემპერატურის მქონე წყალი. მისი სითბო თბოგადამცემის გავლით გადაეცემა იოლად აორთქლებად სითხეს (მაგ., იზობუტანს ან იზოპენტანს), რომელიც ორთქლდება და მეორე კონტურის გავლით მიეწოდება ტურბინას. ასეთი ელექტროსადგურებით გეოთერმული ანომალიების რაიონებში შესაძლებელია 20-25 მგვტ/კმ2 - მდე სიმძლავრის მიღება.



ბინარული ციკლის გეოთერმული სადგურის პრინციპული სქემა



მყისიერი აორთქლების გეოთერმული სადგურის პრინციპული სქემა

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ბიომასა

- ბიომასის ზოგად ტერმინში იგულისხმება ყველაფერი ის რისგანაც შედგება დედამიწაზე არსებული მცენარეული საფარი და ცხოველების ორგანიზმი.
- ბიომასა პირობითად შეიძლება დაიყოს პირველად და მეორად ბიომასად. პირველად ბიომასას წარმოადგენს მცენარეები, ცხოველები და მიკროორგანიზმები, ხოლო მეორად ბიომასაში განიხილება პირველადი ბიომასის გადამუშავების და მოქმედების შედეგად მიღებულ ნარჩენები.
- ბიომასის საფუძველი არის ნახშირბადის ორგანული ნაერთები, რომლებიც ჟანგბადთან შეერთების დროს ან ბუნებრივი მეტაბოლიზმის დროს გამოყოფენ ენერგიას (სითბოს). გარდა იმისა, რომ ბიომასის ცალკეული სახეები შეიძლება პირდაპირ იქნას გამოყენებული ენერგიის მისაღებად, ის სხვადასხვა ქიმიური თუ ბიოლოგიური პროცესებით შეიძლება გარდაქმნილი იქნას სხვადასხვა ტიპის სათბობად (მეთანი, მეთანოლი, ხის ნახშირი და სხვა).

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ბიოსათბობის კლასიფიკაცია

- **მცენარეული ბიოსათბობის სახეებია:**
  - შეშა;
  - სატყეო მეურნეობის ექსპლოატაციის ნარჩენები;
  - ხე-ტყის ინდუსტრიის ნარჩენები;
  - სოფლის მეურნეობის მოსავლის ნარჩენები;
  - აგროგადამამუშავებელი ინდუსტრიის ნარჩენები;
- **ენერგეტიკული პლანტაციების მოსავალი.**
- **ცხოველური ბიომასის სახეებია:**
  - მეცხოველეობის და მეფრინველეობის ნარჩენები;
  - გამწმენდი მოწყობილობების ნარჩენები;
  - ქალაქების საყოფაცხოვრებო მყარი ნარჩენები.

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ბიომასიდან ბიოსათბობის წარმოება

- ბიომასიდან ბიოსათბობის წარმოებისთვის არსებობს სამი ძირითადი მეთოდი, რომლებიც თავის მხრივ იყოფიან კიდევ რამდენიმე განსხვავებულ პროცესებად.
- თერმოქიმიურ მეთოდში შედის:
  - <u>პირდაპირი წვა</u>, რომლის დროსაც ხორციელდება ჰაერში არსებული ჟანგბადის საშუალებით და გამოიყენება უშუალოდ სითბოს მისაღებად;
  - <u>პიროლიზი,</u> რომლის დროსაც ბიომასას აცხელებენ ან უჰაერო სივრცეში ან თვით ბიომასის გარკვეული ნაწილის წვით ჰაერის შეზღუდულ პირობებში.
  - <u>გაზიფიკაცია</u> წარმოადგენს პიროლიზის პროცესს იმ განსხვავებით, რომ ამ დროს პროცესის ძირითადი მიზანია საწვავი აირის მიღება.
  - <u>სხვა თერმოქიმიურ პროცესები.</u> შესაძლებელია ბიომასის ნედლეულის წინასწარი მომზადების და შემდეგ მისი ბიოსათბობად გარდაქმნის პროცესის წარმართვის სხვადასხვა ვარიანტები (ჰიდროგენიზაცია, ჰიდროლიზი და სხვა)
- ბიოქიმიური მეთოდები:
  - სპირტული დუღილი (აერობული ფერმენტაცია).
  - უჟანგბადო ხრწნა (ანაერობული ფერმენტაცია).
  - ბიოფოტოლიზი.

- აგროქიმიური მეთოდები:
  - სათბობის ექსტრაქცია. ზოგიერთ შემთხვევებში ცოცხალი ან ახლად მოჭრილი მცენარეებისგან შესაძლებელია სათბობის მიღება პრესის ქვეშ მათში არსებული წვენის გამოწურვით.

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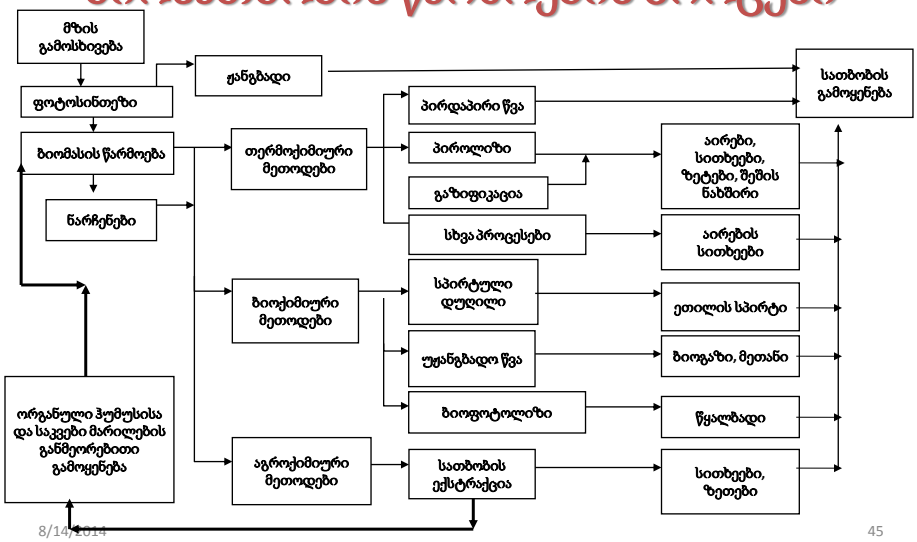
ბიოსათბობის წარმოების პროცესი



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ბიოგაზის წარმოება: მეცხოველოების და საკვების ნარჩენების მახასიათებლები

ნარჩენის სახეობა	ბიოგაზის გამოსავალი (m^3 /კგ)	გადამუშვების დრო (დღე)	მეთანის შემცველობა ბიოგაზში (%) მეთანის
საკვების ნარჩენები	0,5-0,6	10-20	70-80
მსხვილფეხა საქონლის ნაკელი	0,2-0,3	20-30	55-75
ქათმის ნარჩენი	0,35-0,6	30 და მეტი	60-80
ღორის ნარჩენი	0,25-0,50	20-40	70-80

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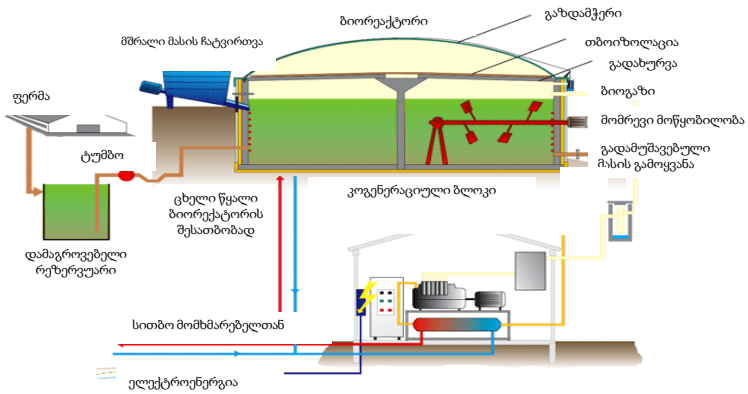
მეცხოველეობის ფერმის ნარჩენების გადამუშავება



ბიოგაზის წარმოება:
https://www.youtube.com/watch?v=3UafRz3QeO8

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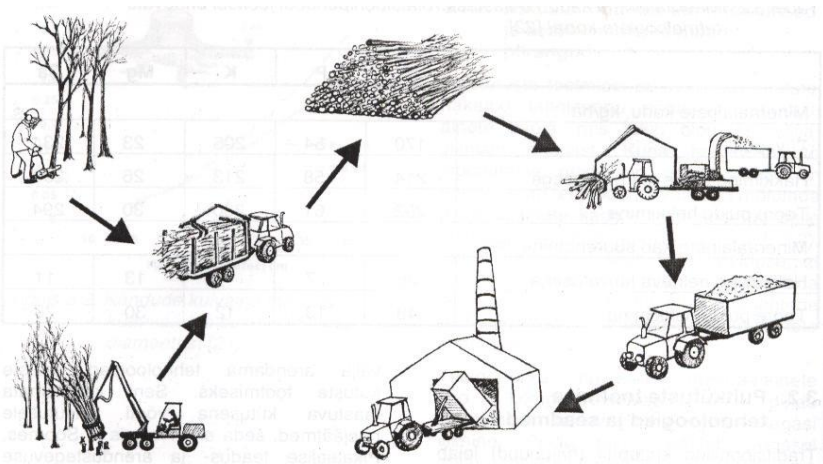
ხის საწვავად წარმოების ტექნოლოგია



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ბიომასის გამოყენების უპირატესობა

- ბიომასა წარმოადგენს განახლებადი ენერგიის წყაროს და აქედან გამომდინარ არ აბინძურებს გარემოს.
- ბიომასაში გოგირდის შემცველობა ძალიან მცირეა და აქედან გამომდინარე არ გამოყოფს გოგირდის ორჟანგს, რომელიც იწვევს მჟაურ წვიმებს.
- ბიომასის დაწვით წარმოიქმნება ნაკლები ნახშირი ვიდრე ქვანახშირის დაწვისას და შესაძლოა გამოყენებული იქნას სასუქად სასოფლო მეურნეობაში.
- ბიოსაწვავი ქვეყნის შიდა პროდუქტია და არაა დამოკიდებული მსოფლიო ფასებზე
- განვითარებად ქვეყნებშინ თხევადი ბიოსაწვავის გამოყენება, როგორიცაა ბიოდიზელი და ეთანოლი, ამცირებს ეკონომიკურ ზეწოლას იმპორტირებულ ნავთობ პროდუქტებზე.

ბიოსაწვავის გამოყენების უარყოფითი მხარე:

- ბუნებაში ბიოსაწვავს შედარებით დაბალი ენერგია შემცველობა აქვს და მისი ტრანსპორტირება ზრდის ხარჯებს.

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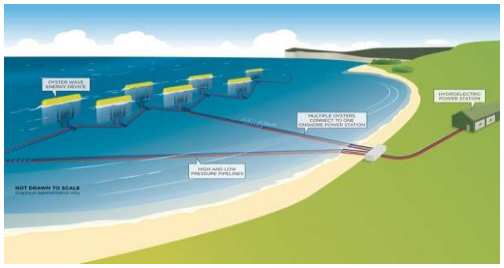
ზღვისა და ოკეანის მოქცევის და ტალღების ენერგია

- ტალღების მოქცევისაგან ელექტროენერგიის მიღება იმავე პრინციპს ემყარება რაც წყალსაცავიანი ჰიდროელექტროსადგურების შემთხვევაში. ზღვისა და ოკეანის მიქცევისა და მოქცევის ენერგია ამოძრავებს ტურბინებს, გენერატორებს და მიიღება ელექტროენერგია.
- **ზღვისა და ოკეანის მოქცევის ენერგიაზე მომუშავე სადგური**

https://www.youtube.com/watch?v=gcStpg3i5V8https://www.youtube.com/watch?v=gcStpg3i5V8

- **ტალღების დინებაზე მომუშავე სადგური**

https://www.youtube.com/watch?v=4Iq-h4ShZ8s



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სხვა ენერგიის წყაროები და შენახვის საშუალებები

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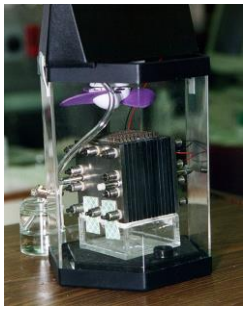
სათბობის ელემენტი (Fuel Cell)

- სათბობის ელემენტი წარმოადგენს მოწყობილობას, რომელიც საწვავის ქიმიურ ენერგიას გარდაქმნის ელექტრულ ენერგიად ჟანგბადის სხვა მჟანგავი აგენტის რეაქციის შედეგად. წყალბადი წარმოადგენს ყველაზე გავრცელებულ საწვავს, მაგრამ ასევე გამოიყენება ჰიდროკარბონები, როგორიცაა გაზი და მეთანოლი.

სათბობის ელემენტები განსხვავდება აკუმულატორებისაგან, იმიტთ რომ ისინი მოითხოვენ მუდმივი საწვავის წყაროს ჟანგბადს/ჰაერს რომ მოახდინოს ქიმიური რეაქცია, მაშინ როდესაც აკუმულატორებში ქიმიური ნაერთები რეაქციაში შედიან რომ აწარმოონ ელექტრომამოძრავებელი ძალა. სათობის ელემენტს შეუძლია ენერგიის წარმოება მანამ სანამ მას მიეწოდება ენერგიის წყარო.



სათბობის ელემენტის მუშაობის პრინციპი

https://www.youtube.com/watch?v=Tk_iIzOUjTU

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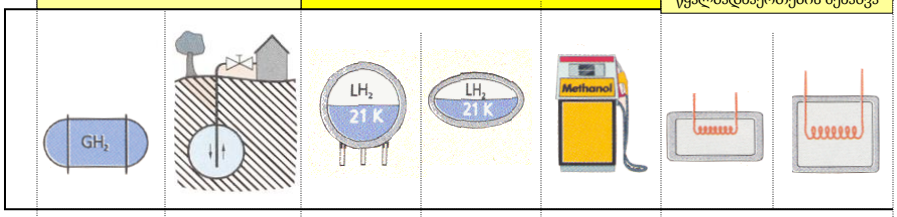
წყალბადის შენახვა

დაწნევა		სითხე		ქიმიური		
გაზ საცავი		კრეოგენურიი შენახვა		მეთანოლი	"მყარი აირი"	
					მეტალის წყალბადნაერთების შენახვა	



მობილური შენახვის ჭურჭელი 7 მპა–მდე წნევის	მიწისქვეშა სეზონური საცავი	დიდი ზომის სეზონური საცავი	თხევადი წყალბადის გადასატანი ტანკერი	მეთანოლის სადგური	უძრავი/მობილური/გ ადასატანი შესანახი	

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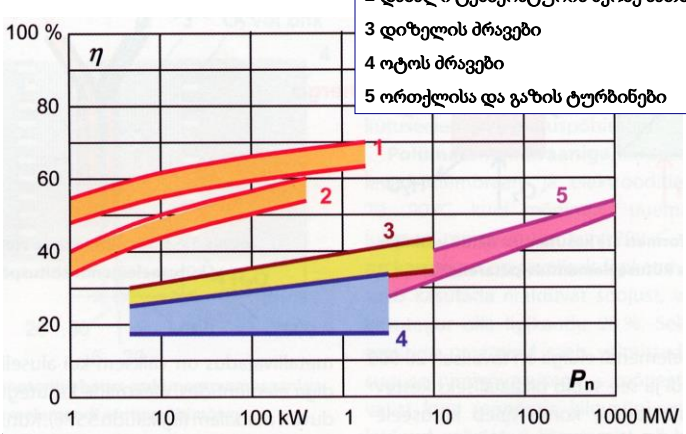
ენერგიის წყაროების ეფექტურობა

1 მაღალი ტემპერატურის მქონე სათბობის ელემენტი
2 დაბალი ტემპერატურის მქონე სათბობის ელემენტი
3 დიზელის ძრავები
4 ოტოს ძრავები
5 ორთქლისა და გაზის ტურბინები



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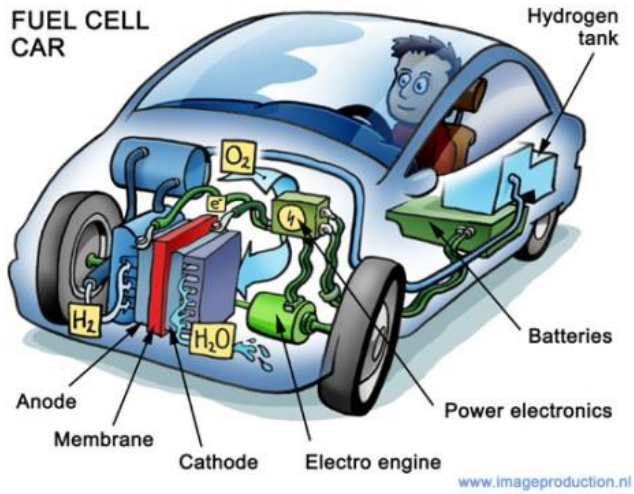
სათბობის ელემენტზე მომუშავე მანქანები



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ენერგიის შენახვა

- **აკუმულატორები:**

– ენერგია ინახება ელექტროქიმიური რეაქციის შედეგად
– სიცოცხლის ხანგრძლივობა 100....10000 ციკლამდე
– დატენვის დრო რამოდენიმე წუთიდან საათებამდე
– დაცლის დრო რამოდენიმე წუთიდან საათებამდე
– ენერგო ტევადობა 180 ვატი საათში კგ–ზე
– სიმძლავრის ტევადობა 0,4 ვატი საათში კგ–ზე

- **სუპერკონდენსატორები (super capacitors):**

– ენერგია ინახება ადსორბციის შედეგად (გაზის ან სითხის შთანთქმა მყარი ნივთიერების ზედაპირის მიერ)
– სიცოცხლის ხანგრძლივობა 1 000 000 ციკლამდე (ტითქმის ულიმიტო)
– დატენვის და დაცლის დრო არის რამოდენიმე წამი ან უფრო ცოტა
– ენერგო ტევადობა 5-10 ვატი საათში კგ–ზე
– სიმძლავრის ტევადობა 50 ვატი საათში კგ–ზე

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განახლებადი ენერგიების გამოყენების პოტენციალი საქართველოში

- **მზე:** მზის ნათების წლიური ხანგრძლიობა 250-დან 280 დღემდე; წლიური ჯამური რადიაცია 1250-1800 კვტ.სთ/მ2; მზის საშუალო რადიაცია 4,2 კვტ.სთ/მ2 დღეში. მზის ენერგიის სრული წლიური პოტენციალი 108 მვტ.
- **ქარი:** ქარის ენერგიის პოტენციალის საშუალო წლიური რაოდენობა 4 მლრდ კვტ.სთ. ქარის ენერგეტიკული ბუნებრივი პოტენციალის მიხედვით საქართველოს ტერიტორია დაყოფილია ოთხ ზონად.
- **გეოთერმული:** საქართველოში პროგნოზული მარაგი 250 მლნ. კუბ.მ-ს წელიწადში. დღეისათვის ცნობილია 250-ზე მეტი ბუნებრივი და ხელოვნურად გაბურღული გამოსავლები, რომლებშიც გეოთერმული წყლის ტემპერატურა მერყეობს 30-110 C-ის ფარგლებში, ხოლო მთლიანი დებიტი აღწევს 160 ათას კუბ.მ-ს დღე-ღამეში
- **ჰიდრო:** ტექნიკური პოტენციალის კადასტრის" მიხედვით, მცირე მდინარეების თეორიული ყოველწლიური ჰიდროენერგეტიკული პოტენციალი შეადგენს 40 მლრდ.კვტ.სთ-ს, ხოლო ტექნიკური ჰიდროენერგეტიკული პოტენციალი კი - 19,5 მლრდ.კვტ.სთ-ს.

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ენერგიის სხვადასხვა წყაროებიდან ელექტროენერგიის წარმოების ღირებულება აშშ დოლარი/მვტ.სთ-ზე

ენერგიის წყარო	ელექტროენერგიის წარმოების ღირებულება [ევრო/მვტსთ-ზე]
ატომური ენერგია	146 – 169
ქვანახშირი	142 – 146
ბუნებრივი აირი	144 – 161
ქარის ენერგია	67– 131
ქარის ენერგია (ნაპირიდან მოშორებული)	47 – 205
ჰიდროენერგია	47 – 172
ბიომასა	105 – 157
მზის ენერგია	388 – 534

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ენერგიის სხვადასხვა წყაროებზე მომუშავე სადგურების დაყვანილი ღირებულება [აშშ დოლარი/მვტსთ-ზე]

სადგურის ტიპი	გამოყენების კოეფ. [%]	კაპიტალური დაყვანილი ღირებულება	ფიქსირებული საოპერაციო ხარჯები	ცვალებადი საოპერაციო ხარჯები	გადაცემის ინვესტირება	მთლიანი სისტემის დაყვანილი ღირებულება
ქვანახშირზე მომუშავე	85	84.4	6.8	30.7	1.2	123.0
ატომური ელექტროსადგური	90	83.4	11.6	12.3	1.1	108.4
ბიომასა	83	53.2	14.3	42.3	1.2	111.0
გეოთერმული	92	76.2	12.0	0.0	1.4	89.6
ჰიდრო	52	78.1	4.1	6.1	2.0	90.3
ბუნებრივ აირზე მომუშვე	87	34.0	4.1	54.1	1.2	93.4
მზის ფოტოელექტრული	25	130.4	9.9	0.0	4.0	144.3
მზის თერმული	20	214.2	41.4	0.0	5.9	261.5
ქარი (ნაპირიდან მოშორებული)	37	193.4	22.4	0.0	5.7	221.5
ქარი	34	70.3	13.1	0.0	3.2	86.6

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After one looks at this planet any visitor from outer space would say „I want to see the manager”

- “Treat the earth well: it was not given to you by your parents, it was loaned to you by your children. We do not inherit the Earth from our ancestors, we borrow it from our children”
- ”The main hope of nation lies in the proper education of its youth”
- “You” must be the change you want to see in the world

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მადლობა ყურადღებისათვის!

n.maghradze@gmail.com

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Integrated resource planning

WEDNESDAY, 4 JUNE, 2014
GIORGI MUKHIGULISHVILI

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Background

- Vertically integrated state monopolies
- Distributed generation – decentralized power systems
- Direct connection of generator and consumer
- Traditional electricity planning has sought to expand supply resources to meet anticipated demand growth with very high reliability, and to minimize the economic cost of this expansion.

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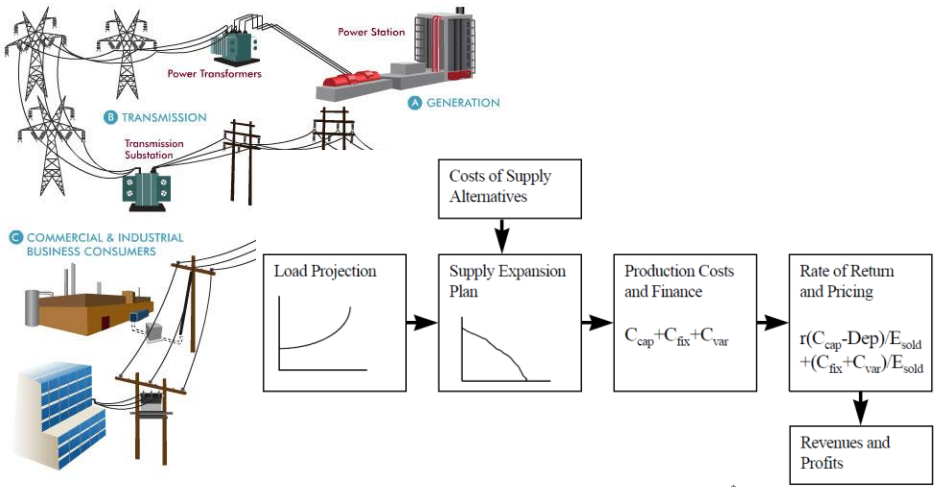
The traditional "least cost" electric planning model



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Towards Efficient Use of Energy

- Increasing supply costs (1973 oil crises) and environmental constraints have reduced or removed these incentives, and the concept of "least-cost" utility planning has begun to be completely redefined in some countries.
- From supply to system cost minimization - Investment exp. in EE is cheaper than in Supply to meet the demand!!!
- IRP can be and already are being applied in other areas such as natural gas, water supply, and even transportation and health services.

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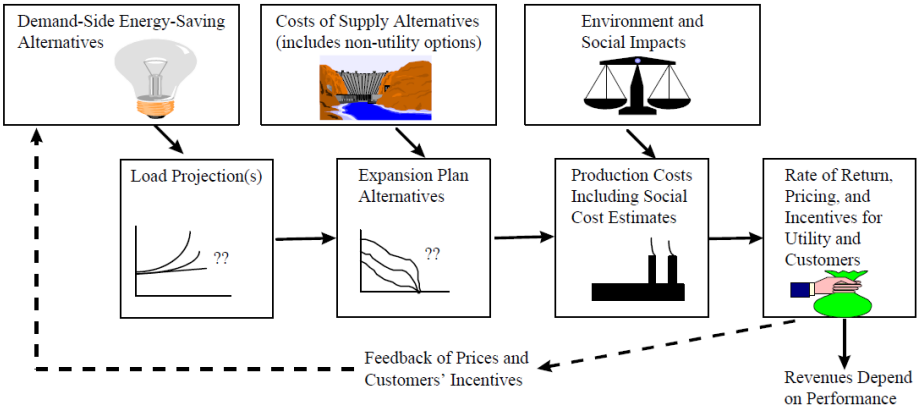
An integrated "least-cost" electric production cost and load model



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What is an Integrated Resource Planning (IRP)?

IRP is the combined development of electricity supplies and demand-side management (DSM) options to provide energy services at minimum cost, including environmental and social costs.

- IRP evaluates the full range of alternatives, including new generating capacity, power purchases, energy conservation and efficiency, alternative and renewable energy resources, to provide adequate and reliable service at the lowest system cost.
- Consistently integrates demand and supply resources.
- The concept of IRP developed from the North American context of private utility monopolies, regulated at the state or provincial level in late 1970s.

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Integrated Resource Planning Process

1. Collection of reliable data on electricity end-use demand patterns and technical alternatives for improving their energy-efficiency or load profiles,
2. Definition and projection of future energy-service demand scenarios,
3. Calculation of the costs and electric-load impacts of the demand-side alternatives,
4. Comparison of their costs with the economic costs and environmental impacts of conventional and alternative electricity supply options,
5. Design of an integrated supply and demand-side plan that satisfies the least-cost criteria in terms of economic costs and environmental impacts,
6. Implementation of the least-cost strategy.

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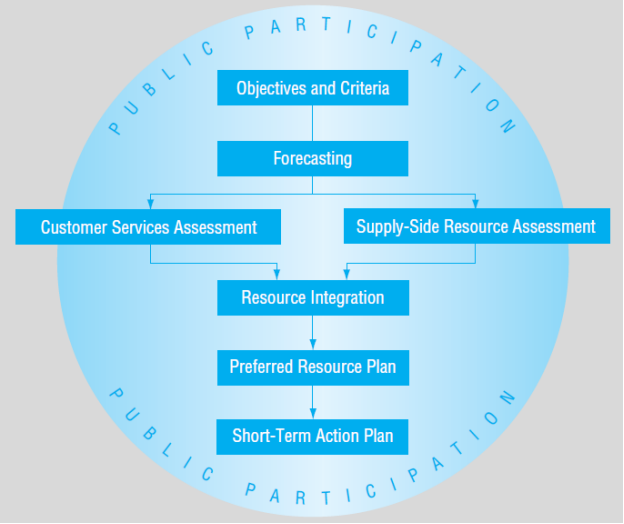
Integrated Resource Planning Process



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Discount rate in IRP

- The same discount rate used for making investments in supply-side and energy-efficiency
- However, the implicit discount rates applied by energy-users to energy-efficiency investments range from 20% to 200%, compared to utility discount rates of 6-10% (Ruderman et al 1987).

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Example of IRP

Northwest (US) Power Planning Council (NWPPC)

- Every 5 years, the Council produces 20-year demand forecasts and electricity-resource plans
- two important changes in the region's energy planning process
  - energy forecasts now explicitly consider the uncertainty of Demand
  - energy efficiency improvements are now treated as part of the electricity supply resource.
- Future energy-efficiency potential - EE sufficient to meet all the new demand in forecasts based on low and medium rates of economic growth (high growth requires additional generating resources)

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Trends in Power Sector development

Two trends

- The widespread adoption of DSM
- The deregulation in the electricity sector

environmental concerns are one of the primary factors motivating the application of IRP.

Competition increases innovation by rewarding more efficient performance.

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Who Carries Out the IRP Analysis?

- The utilities were pushed by their regulatory commissions to adopt IRP in order to identify and capture the potential for cost effective energy-efficiency improvements.
- Government agencies - policies and programs to implement energy-efficiency improvements
- The concepts of IRP are applicable at the national level as well as at the level of regional or municipal power systems.
- For small countries, the national level and the utility system may be the same, in which case national IRP makes good sense.
- In larger countries, IRP analysis can be conducted at the national level and/or the local level, but many measures are best delivered through relatively decentralized structures.

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Conclusion

- Public authorities can use IRP principles to design programs to encourage end-use efficiency and environmental protection through environmental charges and incentives, non-utility programs, and utility programs applied to the functions remaining in monopoly concessions such as the distribution wires.
- Again, the principles of IRP will continue to be relevant to environmental protection in deregulated power markets, even if the process of "traditional" IRP is dissolved.

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Tasks

- Identify issues in power sector of Georgia which are relevant to IRP rules (Example – electrification)
- Identify energy efficiency measures in Georgia's power sector
- Who can do IRP in Georgia – key institutions?
- Which is more expansive, peak or base-load energy in Georgian power system?

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Useful Videos

- Integrated Water Resources Management
- Integrated Resource Plan
- IRP Recommended Actions: Conserve More, Build & Reinvest
- IRP Recommended Actions: Prepare for Potentially Greater Demand

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The End

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Cost-Benefit analysis – CBA

WEDNESDAY, 11 JUNE, 2014
GIORGI MUKHIGULISHVILI

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Background

- The concept of CBA dates back to an 1848 article by **Jules Dupuit** and was formalized in subsequent works by **Alfred Marshall**.
- To improve decision-making and facilitate better policy outcomes, US Federal Navigation Act of 1936 effectively required cost–benefit analysis for proposed federal waterway infrastructure.
- The Flood Control Act of 1939 was instrumental in establishing CBA as federal policy.
- In 1960s the concept of option value was developed to represent the non-tangible value of preserving resources such as national parks.

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CBA

- **Cost Benefit Analysis** (CBA) - a systematic process for calculating and comparing benefits and costs of a project, decision or government policy. Benefits and costs are expressed in **monetary terms**, and **adjusted for** the **time value of money**

- CBA has two purposes:
  - To determine if it is a sound investment/decision,
  - To provide a basis for comparing projects.

- CBA attempts to measure the positive or negative consequences of a project, which may include:
  - Effects on users or participants
  - Effects on non-users or non-participants
  - Externality effects
  - Option value or other social benefits.

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Process of CBA

The following is a list of steps that comprise a generic CBA:

- List alternative projects/programs. (status quo)
- List stakeholders.
- Select measurement(s) and measure all cost/benefit elements.
- Predict outcome of cost and benefits over relevant time period.
- Convert all costs and benefits into a common currency.
- Apply discount rate.
- Calculate net present value of project options.
- Perform sensitivity analysis.
- Adopt recommended choice.

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Principles of CBA

- CBA Involves a Particular Study Area - city, region, state, nation or the world.
- Double Counting of Benefits or Costs Must be Avoided
- NPV differences between government CBA and private sector evaluation - Broad – Society VS. Narrow - Project
- **Surveys** (stated preference techniques) or **market behavior** (revealed preference techniques) are often used to estimate the compensation associated with a policy;
- Causes of inaccuracies in CBA include:
  - Overreliance on data from past projects
  - Use of subjective impressions by assessment team members
  - Inappropriate use of heuristics to derive money cost of the intangible elements
  - Confirmation bias among project supporters (looking for reasons to proceed).

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Specify Costs	Specify Benefits
1 …	1 …
2 …	2 …
3 …	3 …
4 …	4 …
Total	Total

Values are expressed in Lari. CBA determines the most cost-effective solution.

$$NPV = \sum_{t=0}^{N} \frac{(Benefits - Costs)_t}{(1+i)^t}$$

$$BC\ Ratio = \frac{PV \sum Benefits}{PV \sum Costs} \geq 1.0$$

Where:
N = Number of years
= discount rate
t = year

If Benefits > Costs ….
Implement Policy or Project

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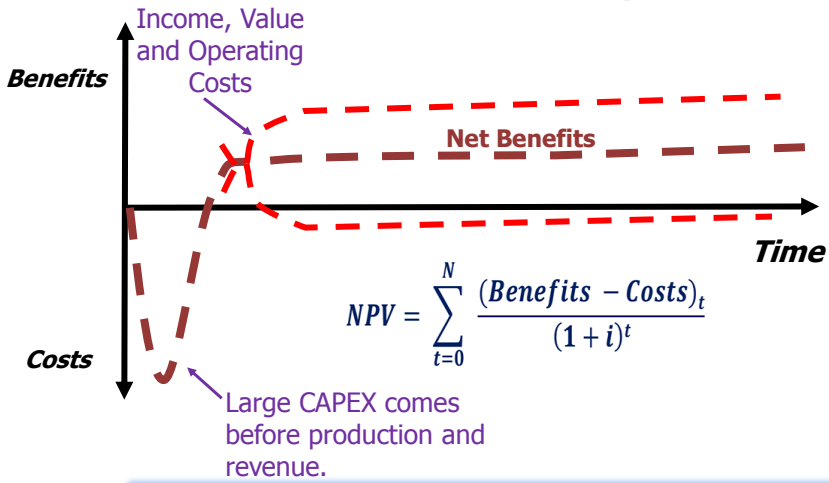
Cash Flow Timing



$$NPV = \sum_{t=0}^{N} \frac{(Benefits - Costs)_t}{(1+i)^t}$$

Private Sector Omits Externalities

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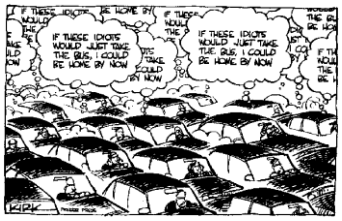
- **Externalities**: effects of a project that extend beyond the project itself, and consequently are not included in the financial analysis.
- In general an externality exists when the production or consumption of a good or service by one economic unit has a direct effect on the welfare of the producers or consumers in another unit without compensation.
- **Externalities may be positive or negative**.



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CBA Issues

1. **Units**: Use currency; "real prices" in constant values. Controversy converting *externalities* to currency.

2. **Time**: Establish the time lines for costs and benefits. Length of time – 20 years, 40 years, etc.

3. **Discount Rate**: to bring benefits & costs to the same time period, what discount rate should be used?.

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Discount Rate – World Experience

- **The World Bank** and, more recently, the EBRD have adopted a required economic rate of return of 10%. This is usually regarded as a quite high rate. Usually national governments set the social discount rate for public projects at a lower level than international institutions.
- **In the UK**, social time preference rate and private rate of return are set both at 6%. **In Italy**, the discount rate is currently set at 5%. **In Spain** different values of the social discount rate have been set depending on the sector involved: 6% in real terms for transport and 4% for water resource projects.
- **In France**, the discount rate set by the Commissariat Général du Plan is equal to 8% in real terms. This rate has not been updated since 1984.

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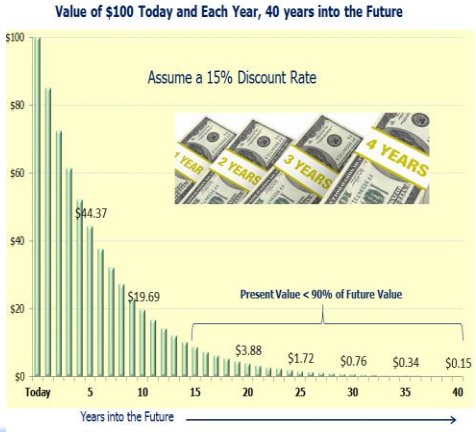

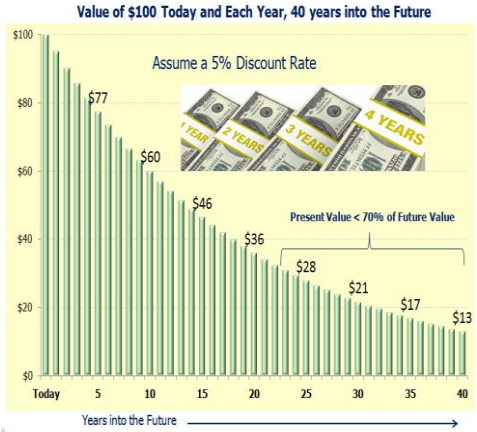

Key Point:

A **higher** discount rate implies that present values carry greater weight in the PV formula compared to a lower discount rate.

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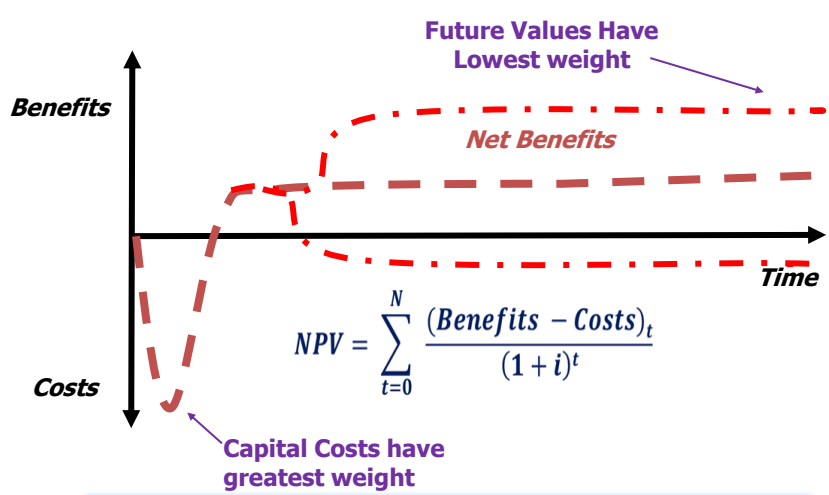

$$NPV = \sum_{t=0}^{N} \frac{(Benefits - Costs)_t}{(1+i)^t}$$

Private Sector Omits Externalities

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Benefit and Cost estimation

METHOD			COMMENT / EXAMPLE	REFERENCES
Market Valuation	Market Price		Mainly applicable to the "goods" (e.g. fish) but also some cultural (e.g. recreation) and regulating services (e.g. pollination).	Brown et al.1990; Kanazawa 1993
	Cost Based	Avoided Cost	The value of the flood control service can be derived from the estimated damage if flooding would occur.	Gunawardena & Rowan 2005; Ammour et al. 2000; Breaux et al. 1995; Gren 1993
		Replacement Cost	The value of groundwater recharge can be estimated from the costs of obtaining water from another source (substitute costs).	
		Mitigation / Restoration Costs	E.g. Cost of preventive expenditures in absence of wetland service (e.g. flood barriers) or relocation.	
	Production Function/Factor Income		How soil fertility improves crop yield and therefore the income of the farmers, and how water quality improvements increase commercial fisheries catch and thereby incomes of fishermen.	Pattanayak & Kramer 2001
Revealed Preferences	Travel Cost Method		E.g. part of the recreational value of a site is reflected in the amount of time and money that people spend while travelling to the site.	Whitten & Bennet 2002; Martin-Lopedz et al. 2009b
	Hedonic Pricing Method		For example: clean air, presence of water and aesthetic views will increase the price of surrounding real estate.	Bolitzer & Netusil 2000; Garrod & Willis 1991
Simulated Valuation	Contingent Valuation Method (CVM)		It is often the only way to estimate non-use values. For example, a survey questionnaire might ask respondents to express their willingness to increase the level of water quality in a stream, lake or river so that they might enjoy activities like swimming, boating, or fishing.	Wilson & Carpenter 2000; Martin-Lopez et al. 2007
	Choice Modelling		It can be applied through different methods, which include choice experiments, contingent ranking, contingent rating and pair comparison.	Hanley & Wright 1998; Lii et al. 2004; Philip & MacMillan 2005
	Group Valuation		It allows addressing shortcomings of revealed preference methods such as preference construction during the survey and lack of knowledge of respondents about what they are being asked to allocate values.	Wilson & Howarth 2002; Spash 2008

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Economic Valuation Studies Undertaken in Georgia and Used Approaches

- Georgian Forest Development Project:
  - *Legal, Institutional and Economic Background of Georgia's Forest Sector and Principles of Total Economic Valuation*. Report 1. URS Corporation Ltd (2003);
  - *Legal, Institutional and Economic Analysis, Forest Resource Evaluation Methodology, Resource Pricing Mechanisms and worked Example of Forest Resources Economic Valuation for Oni Forest District for Forest Management Planning and Valuation Purposes in Georgia.* Report 2. URS Corporation Ltd (2003).
- 2010: UNDP/GEF project Catalyzing the Financial Sustainability of Georgian Protected Areas System: *Economic Valuation of the Tusheti National Park and of the Network of Georgian Protected Areas.*

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Continuation…

- In 2000-2001 the WB conducted a study - valuation of the Contribution of Borjomi-Kharagauli and Mtirala National Parks Ecosystem Services to Economic Growth and Human Well-being. (WWF)
  - Total Economic Valuation (TEV) methodology was applied in estimating the costs and benefits associated with the establishment of the national park.
  - This approach accounts for all uses and services of ecosystems and biodiversity that humans derive from them.
  - The results of the cost-benefit analysis revealed that the establishment of the KNP under the current KPA Law would lead to significant net losses to the local communities. A socially and ecologically sustainable alternative was needed.

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Current need of CBA in Georgia

- Khudoni HPP
- Energy Community membership
- New highway
- ???

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The End

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ენერგოეფექტურობა

18 ივნისი, 2014

ნინო მაღრაძე

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რა არის ენერგოეფექტურობა

- ენერგოეფექტურობა - მაღალეფექტიანი ტექნოლოგიების და მოწყობილობების გამოყენებით, ნაკლები ენერგეტიკული დანახარჯებით, იგივე მოცულობის და ხარისხის ენერგეტიკული მომსახურების და პროდუქტის მიღება;
- ენერგოდაზოგვა - ნაკლები ენერგიის და ენერგეტიკული მომსახურების გამოყენება, რაც ძირითადად ადამიანურ ფაქტორთან არის დაკავშირებული და ენერგომოხმარების ჩვევებს და ოპერატიულ რეჟიმებს ასახავს;
  - ენერგოეფექტიანობა - აერთიანებს წინა ორ ცნებას და ნიშნავს ნაკლები ენერგიის გამოყენებას რომელიმე ამ ფაქტორის გამო.

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ენერგოდაზოგვის მნიშვნელობა

- ენერგოუსაფრთხოება
- სტაბილური ენერგოსისტემა
- შემცირებული ნახშირბადის ემისიესბი
- სარეზერვო სიმძავრეების აუცილებლობის მინიმუმამდე დაყვანა
- უკეთესი პირობები მოსახლეობისთვის

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ენერგოეფექტურობის მნიშვნელობა

ენერგოეფექტურობის და ენერგოდაზოგვის მნიშვნელობა განპირობებულია რამდენიმე ფაქტორით, რომელთა შორის განსაკუთრებით მნიშვნელოვანია:

- ენერგოშემცველების (ნახშირწყალბადების) მარაგების შემცირება;
- ენერგოშემცველებზე, თბურ და ელექტროენერგიებზე ფასების მკვეთრი და შეუქცევადი ზრდა;
- ენერგოშემცველებზე მოთხოვნილების ზრდა;
- თითქმის ყველა სახის ენერგიის წარმოებისა და გამოყენებისას გარემოზე მავნე ზემოქმედება;

ენერგოეფექტიანობის მაღალი დონე მიიღწევა, მხოლოდ საზოგადოების მაღალი ორგანიზებულობით და აქტივობით. საქართველოს აქვს ყველა ქინაპირობა იმისათვის, რომ დანერგოს და განავითაროს ენერგოდაზოგვის და ენერგოეფექტურობის ღონისძიებები.

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ენერგოეფექტურობის აქტუალობა

• კიოტოს პროტოკოლით დადგენილმა მიზნებმა უკანასკნელი ათწლეულების მანძილზე დიდი ბიძგი მისცა მსოფლიოში ენერგოეფექტურობის პოლიტიკის ამაღლებას და ამ კუთხით ღონისძიებების გატარებას.

- თითქმის ყველა OECD წევრ ქვეყანაში გამოიყენება ახალი ან/და განახლებული ინსტუმენტები, რომლებიც ადაპტირებულია თითოეული ქვეყნის ადგილობრივ სიტუაციასთან. ბაზრის ინსტრუმენტების გარდა ფართოდ გამოიყენება (ნებაყოფლობითი ხელშეკრულებები, იარლიყები, ინფორმაციის გავრცელება) რეგულატორის მიერ მიღებული ზომები. განვითარებად ქვეყნებში ენერგოეფექტურობა მნიშვნელოვანი საკითხია.
- განვითრებად ქვეყნებში ემისიების გაფრქვევის და ადგილობრივი დაბინძურები შემცირების ნაკლები პრიორიტეტია. მეტი მოხმარებლის იგივე ელექტროენერგიით მომარაგება წარმოადგენს ძირითად დაბრკოლებას აზიისა და აფრიკის ბევრ ქვეყანაში. ასევე ეს ძალიან მნიშვნელოვანია ისეთ ქვეყნებში სადაც ასევე სწრაფად იზრდება მოთხოვნა ენერგიაზე, როგორიცაა და ჩინეთი და სამხრეთ აჭმოსავლეთის აზიური ქვეყნები.

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ენერგოეფექტურობის პრობლემები საქართველოში

წარსულში:

- ქვეყანაში (მოსახლეობა, წარმოება და ა.შ.) ენერგოდაზოგვის დაბალი მოტივაცია;
- თვითღირებულებაზე დაბალ ფასად არსებული სათბობი რესურსები.

ამჟამად:

- ენერგოდაზოგვის გაზრდილი მოტივაცია ქვეყანაში;
- სათბობი რესურსები კონკურენტულ ფასად.

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- **ენერგოინტენსიურობა** წარმოადგენს ქვეყნის ენერგოეფექტურობის მთავარ საზომს და განისაზღვრება, როგორც ენერგიის მოხმარების წილი ქვეყნის მთლიან შიდა პროდუქტში (ტონა ნავთობის ექვივალენტურ ენერგიაზე).

- **მოსახლეობის ენერგომოხმარება** წარმოადგენს ასევე ქვეყნის ენერგოეფექტურობის ერთ-ერთ საზომს, რაც საქართველოსთვის საშუალოდ 40%-ს აღწევს. მაშინ როდესაც განვითარებული ქვეყნებისათვის ეს ნიშნული არ აღემატება 30%-ს.

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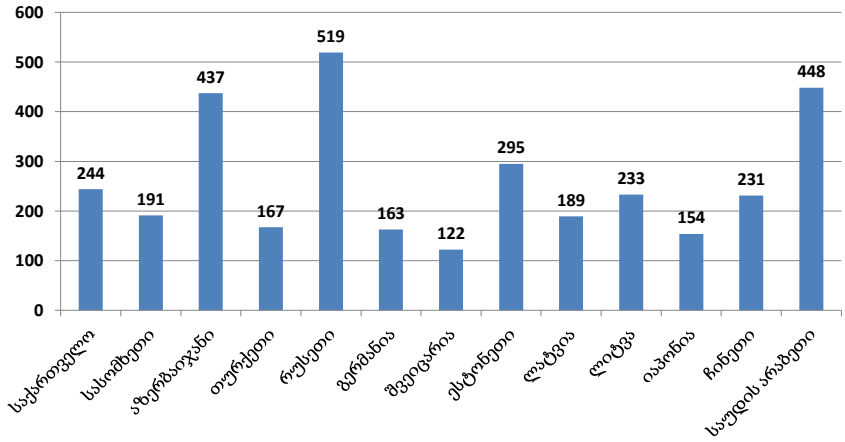
ენერგოინტენსიურობა ქვეყნების მიხედვით



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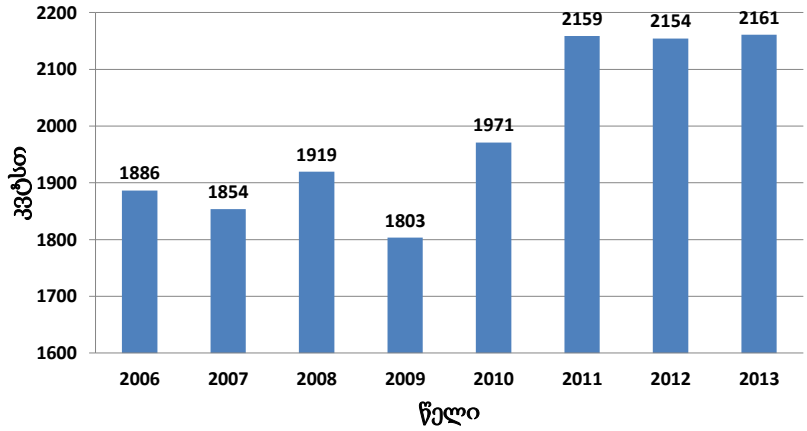
ელექტროენერგიის მოხმარება ერთ სულ მოსახლეზე საქართველოში (კვტსთ)



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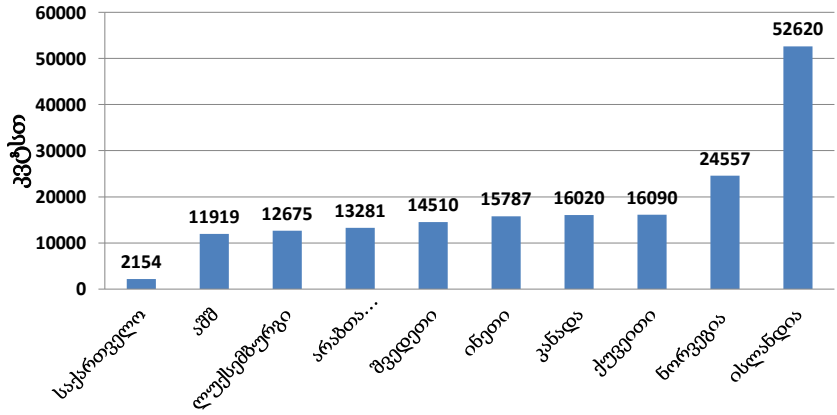
ელექტროენერგიის მოხმარება ერთ სულ მოსახლეზე 2012 წელს (კვტსთ)



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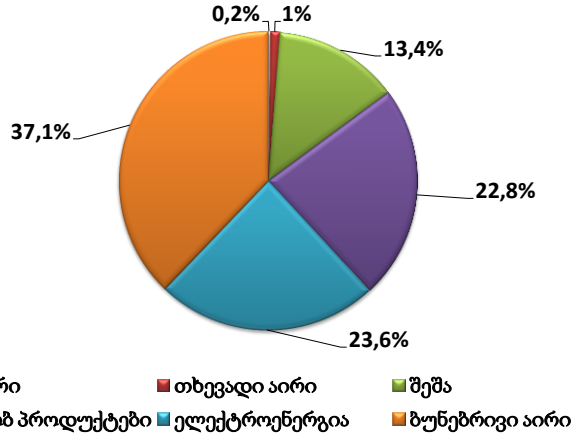
საქართველოს ენერგეტიკული რესურსების მოხმარების სტრუქტურა 2003-2013 წლებში



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საქართველოს ენერგობალანსი

- საქართველო წარმოადგენს ბუნებრივი აირის და ნავთობპროდუქტების იმპორტიორ ქვეყანას, რომლებიც ჰიდროენერგიასთან და ბიომასასთან ერად წარმოადგენენ საყოფაცხოვრებო სექტორში გათობიბის ძირითად ენერგო წყაროს.
- საქართველო ახორციელებს ბუნებრივ აირზე და ნავთობ პროდუქტებზე მისი ძირითადი ენერგო მოთხოვნილების 98%-ის იმპორტს, რომელიც ჯამურად შეადგენს მთლიანი ენერგო მოხმარების 2/3 ნაწილს.
- საქართველოშ არსებული ნავთობისა და ბუნებრივი აირის რესურსები მოკრძალებული. 15 ნავთობის საბადოს რეზერვი შეადგენს საშუალოდ 8,3 მილიონ ტონას, მაგრამ არსებობს ვარაუდი რომ არსებობს უფრო დიდი საბადოები.
- შავი ზღვის შელფის ნავთობის პოტენციალი დაახლოებით შეადგენს 70 მილიონიდან 1,3 მილიარდ ბარელამდე.
- მიუხედავად იმისა, რომს აქართველოს არ გააჩნია ნავთობისა და ბუნებრივი აირის მძლავრი მარაგები, მას შეუძლია შემოსავლის მიღება ამ პროდუქტების ტრანზიტის გზთ, ქვეყნის გეოპოლიტიკური სიტუაციიდან გამომდინარე.
- საქართველოს გააჩნია უამრავი, თითქმის ყველა ტიპის განახლებადი ენერგორესურსები: მზე, ქარი, გეოთერმული, ჰუდრო, ბიომასა. ამჟამად მხოლოდ ეკონომიკურად განხორციელებადი ჰიდრორესურსების 25%-ია ათვისებული.

USAID FROM THE AMERICAN PEOPLE | HYDRO POWER AND ENERGY PLANNING PROJECT (HPEP)

განათების ტექნოლოგიები

- ელექტროენერგიაზე გადასახედების შემცირების ერთ-ერთი გზა განათების სისტემაში ცვლილებების შეტანაა. საყოფაცხოვრებო სექტორში საშუალოდ ენერგო ბიუჯეტის 11% განათებას ხმარდება.
- განათების სისტემების ახალ ტექნოლოგიებს შეუძლიათ ელექტროენერგიის მოხმარება 50-75%-ით შეამციროს.
- საქართველოში ძირითადად 60-100-150ვტ-ის სიმძლავრის ვარვარა ნათურებს მოიხმარენ. მათი საექსპლუატაციო ვადა 800-1000 სთ-ია. ამ ნათურების ერთადერთი დადებითი მხარე მათი სიიაფეა.

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ეფექტური ნათურის ტიპები

1. **ჰალოგენური ნათურები** - ჩატუმბულია ინერტული აირები, რაც ვარვარა ნათურასთან შედარებით ზრდის მის ეფექტურობას 10-20%-ით და ექსპლუატაციის ვადას.
2. **მილისებრი ფლუორესცენტული ნათურა** – დღის ნათების ნათურა. ასეთი ნათურები მოიხმარენ 80%-ით ნაკლებ ენერგიას ვიდრე ვარვარა ნათურა, მაგრამ მისი ენერგომოხმარება დამოკიდებულია ბალასტის ტიპზე.
3. **კომპაქტური ფლუორესცენციული (ენერგოდამზოგი) ნათურები** - ისინი მოიხმარენ 75%-ით ნაკლებ ელექტროენერგიას ვიდრე ვარვარა ნათურები, მათი სიცოცხლისუნარიანობა 8 – 10 ჯერ უფრო მეტია. მათ იყენებენ ისეთ ადგილებში, სადაც ხანგრძლივი პერიოდის განმავლობაში სჭირდებათ სინათლე. გასათვალისწინებელია, რომ ვარვარა ნათურის ენერგოდამზოგი ნათურით ჩანაცვლება, უფრო მეტ ეკონომიას გვაძლევს იქ, სადაც მათი ყოველდღიური მოხმარება ხანგრძლივია. მაგალითად, სასტუმრო ოთახში, გარე განათებებში ან სამეცადინო/სამუშაო მაგიდასთან.

(1)

(2)

(3)

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ეფექტური განათების დანაზოგი

- თუ გავითვალისწინებთ, რომ 100 ვტ ვარვარა ნათურას აქვს 1600 ლუმენი ნათების სიმძლავრე რაც შეესაბამება 23-30 ვტ-იან ფლუორესცენციულ ნათურის ნათების სიმძლავრეს (1600 ლუმენი) შეიძლება დავითვალოთ, რომ 100 ვტ-იანი ვარვარა ნათურის 20 ვტ-იანი ფლუორესცენციული ნათურის შეცვლით მიღებული დაზოგვა: 100 ვტ ნათურა დღეში 6 სთ-ის განმავლობაში მოიხმარს 600 ვტ.სთ ელექტროენერგიას, ხოლო წელიწადში 219 000 კვტ.სთ ანუ 219 კვტ.სთ. 6 სთ-ს განმავლობაში ანთებული 20 ვტ-იანი ნათურა მოიხმარს 120 ვტ.სთ/დღეში ანუ წელიწადში 43 800 ვტ.სთ/წ=44 კვტ.სთ. ეს იმას ნიშნავს, რომ წელიწადში ფლუორესცენციული ნათურით ვარვარა ნათურის ჩანაცვლება დაგიზოგავთ 175 კვტ.სთ ანუ 32 ლარს (ტარიფი 1 კვტ.სთ=0,18 ლარი). ანუ ეფექტური ნათურა უფრო ნაკლებ ელექტროენერგიას მოიხმარს და ნათების იგივე სიმძლავრე აქვს, როგორც ვარვარა ნათურას, რომელიც მეტ ელექტროენერგიას მოიხმარს. ფლუორესცენციული ნათურის საექსპლუატაციო ვადა 8000 – 10000 საათია, ხოლო ვარვარა ნათურის 1000 საათი. ვარვარა ნათურის ერთ-ერთი უპირატესობა მისი ფასია- 0,5-0,6 ლარი. 20 ვტ-იანი ფლუორესცენციული ნათურის ფასი 5-დან 12 ლარამდე მერყეობს, მაგრამ თუ გავითვალისწინებთ იმას, რომ წელიწადში 32 ლარის ეკონომიას გავაკეთებთ ნათურის შესაძენად ფული ნამდვილად არ უნდა დაგვენანოს.

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ანალოგიური ნათების მქონე ვარვარა და ენერგოდამზოგი ნათურის სიმძლავრეები

ვარვარა ნათურა	ექვივალენტური ნათების ფლუროსცენციული ნათურები
25 ვტ	5-6 ვტ
40 ვტ	7-10 ვტ
60 ვტ	11-18 ვტ
100 ვტ	20-25 ვტ

განათების ტექნოლოგიების შედარება: https://www.youtube.com/watch?v=76SHiFQq4t0

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რჩევები ნათურების მოხმარებისას

- დაიცავით ნათურებისა და ბრების სისუფთავე, რადგანაც ჭუჭყიანი ნათურა და ბრა ნაკლებ ნათებას მოგცემს;
- შეძლებისდაგვარად გამოიყენეთ ბუნებრივი განათება;
- ოთახი შეღებეთ უფრო ნათელი ფერებით, ამით შესძლებთ ხელოვნური განათების შემცირებას;
- ნუ დატოვებთ ანთებულ ნათურებს იმ ოთახებში, სადაც არ იმყოფებით;
- შეცვალეთ ვარვარა ნათურები ეფექტური ნათურებით, ამით დაზოგავთ განათებაზე მოხმარებული ენერგიის 75%;
- მაგიდასთან მუშაობისას ჭერზე მდებარე ნათურის ნაცვლად გამოიყენეთ პირდაპირი ნათების მაგიდის სანათური, ამით გექნებათ უკეთესი ნათება და კომფორტი;
- გამოიყენეთ დღის ნათების ნათურები იქ, სადაც მეტი სინათლე გჭირდებათ;
- ავტოფარეხში, სადარბაზოში, ვესტიბიულში დაამონტაჟეთ მოძრაობის დეტექტორები, რათა სინათლე ავტომატურად აინთოს და ჩაქრეს;

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ენერგოდაზოგვის პოტენციალი

ენერგოდაზოგვის დიდი პოტენციალი:

- სკოლები
- საბავშვო ბაღები
- საავადმყოფოები
- ოფისები
- საცხოვრებელი სახლები
- და ა.შ.

- ენერგოდაზოგვა დაკავშირებულია პირველადი (ბუნებრივი აირი, ნავთობი, ქვანახშირი) და მეორადი (ელექტროენერგია, ორთქლი, ცხელი წყალი) ენერგორესურსების ნაკლები მოხმარების შედეგად გარემოს დაბინძურების შემცირებასთან, რაც ეკონომიკურთან ერთად ქმნის დადებით ეკოლოგიურ ეფექტს.

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შენობების ენერგომოხმარება

- შენობის ენერგაუდიტი გულისხმობს გამოკვლევას, არსებული სიტუაციის შეფასებას და ანალიზს, აგრეთვე ყველა იმ ღონისძიებას, რომლებიც უნდა განხორციელდეს ენერგიის მოხმარების შესამცირებლად და შენობაში მიკროკლიმატის გასაუმჯობესებლად.
- შენობებში ენერგოეფექტურობის პოტენციალის შესაფასებლად განსაზღვრავენ ენერგოეფექტურობის არსებულ პოტენციალს.
- შენობის ენერგოეფექტურობა იზომება კუთრი ენერგომოხმარებით (კვტსთ/მ2 წელიწადში).ა სევე გასათვალისწინებელია ისეთი აფქტორები როგორიცაა:

- შენობის ფუნქციური დანიშნულება (ადმინისტრაციული, საავადმყოფო, სკოლა და სხვა)
- კლიმატური პირობები;
- ტექნიკური მოწყობილობები;
- და ა.შ

ყველა ზემოთ ჩამოთვლილი ფაქტორები გავლენას ახდენს ჯამურ და კუთრ ენერგო მოხმარებაზე

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ენერგიის და სიმძლავრის მოხმარება

#	დასახელება	ენერგიის წყარო	წელიწადის დრო
1	გათბობა	ბუნებრივი აირი, ცენტრალური თბომომარაგება, ნავთობპროდუქტები, ქვანახშირი, ელექტროენერგია, მზის ენერგია	ზამთარი
2	ვენტილაცია (გათბობა)		მთელი წლის განმავლობაში
3	ცხელწყალმომარაგება		
4	ვენტილატორები/ ტუმბოები	ელექტროენერგია, ბუნებრივი აირი	ზაფხული
5	განათება		
6	სხვადასხვა დანადგარები		
7	გაციება		
8	გარე მოწყობილობები		

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ენერგოეფექტური სახლები

- **თბური დანაკარგები სახლში.** სახლში ენერგოდანაკარგების ძირითადი კვანძები:
  - კედლები,
  - ფანჯრები/კარები,
  - სახურავი/სხვენი,
  - იატაკი,
  - საკვამურები.
- **გათბობის სისტემები:**
  - შეშის ღუმელები,
  - ბუნებრივ აირზე მომუშავე გამათბობელი (სწორად შერჩეული ქვაბის სიმძლავრე და გასათბობი მოწყობილობა , თერმოსტატული ვენტილები.
- **ცხელწყალმომარაგება.**

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რჩევები სახლის ენერგოეფექტურობისათვის

- დღის განმავლობაში გადაწიეთ ფარდები და შემოუშვით ოთახებში მზის სითბო და სინათლე, საღამოს კი დახურეთ ფარდები, რათა შეინარჩუნოთ ოთახში არსებული სითბო.
- თუ შესაძლებლობა გაქვთ დაამონტაჟეთ დარაბები, ტენტები, რადგანაც ისინი ამცირებენ სითბოს დანაკარგებს ფანჯრებიდან და კარებიდან.
- შეაკეთეთ ფანჯრებისა და კარების დაზიანებული ჩარჩოები, ამით თქვენ მეტ ენერგიას დაზოგავთ.

ენერგოეფექტური სახლის დიზაინი https://www.youtube.com/watch?v=xSzu83fyQaQ

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საკანონმდებლო ბაზა

საქართველოში არ მოქმედებს ენერგოეფექტურობის შესახებ კანონი. სხვადასხვა დოკუმენტებში გაბნეული სახითვ წარმოდგენილია რეგულაციები ენერგო-ეფექტურობასთან დაკავშირებით, მაგრამ ეს არ არის საკმარისი. ასეთ დოკუმენტებს წარმოადგენს:

- სახელმწიფო პოლიტიკის ძირითადი მიმართულების შესახებ პრეზიდენტის ბრძანება;
- საქართველოს კანონი ენერგეტიკისა და ბუნებრივი გაზის შესახებ
- შესახებ;
- საქართველოს კანონი გარემოს დაცვის შესახებ.

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საქართველოში მიმდინარე პროექტები

მოსახლეობაში ცნობიერების ამაღლება ენერგოეფექტურობის შესახებ ენერგოეფექტური ტექნოლოგიების დანერგვისათვის:

- ბროშურები, სემინარები, ტრენინგები;
- წამახალისებელი - ენერგოკრედიტი.

ენერგოეფექტურობის გაზრდისაკენ მიმართულ აქტივობაში ჩართული ორგანიზაციები:

- დონორები: EU, BP, USAID, EBRD და სხვა;
- სამთავრობო და არასამთავრობო სექტორი;
- კერძო კომპანიები.

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გამოყენებული ლიტერატურა:

1.http://www.worldenergy.org/documents/energyefficiency_final_online.pdf

2. ენერგოეფექტიანობის პოტენციალი და საქართველოში მისი ათვისების ღონისძიებები. http://weg.ge/wp-content/uploads/2012/12/energy_efficiency_geo.pdf

3. საქართველოს სტატისტიკის ეროვნული სამსახური http://www.geostat.ge/

4. ელექტროენერგეტიკული ბაზრის ოპერატორი http://www.esco.ge/

5. Energy Efficiency policies around the world: review an evaluation/ World energy council 2012

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დიდი მადლობა ყურადღებისთვის!

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ენერგეტიკა და კლიმატის ცვლილება

ოთხშაბათი, 2 ივლისი, 2014
მურმან მარგველაშვილი

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კლიმატის ცვლილება

- გლობალური ტემპერატურის ზრდა
- მყინვარების დნობა
- წყლის დონის მატება
- მდინარეების ჩამონადენი
- ტყის საფარის შემცირება
- კატასტროფების ზრდა (წყალმოვარდნები)
- გაუდაბნოება
- ტემპერატურული უთანაბრობა
- ?

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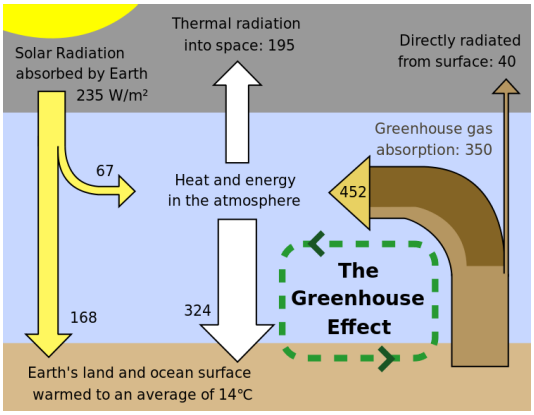
სათბურის აირები

გაზი	სიცოცხლის ხანგრძლივობა, წელი	100-წლიანი გდპ
CO_2	ცვლადი (50-200)	1
CH_4	12±3	21
N_2O	120	310
HFC		
HFC-23	264	11700
HFC-32	5,6	650
HFC-125	32,6	2800
HFC-134	10,6	1300
HFC-143	48,3	3800
HFC-152	1,5	140

- ნახშირორჟანგი (CO_2);
- მეთანი (CH_4);
- აზოტის ქვეჟანგი (N_2O);
- ჰიდროფტორნახშირბადები (HFC-ები);
- პერფტორნახშირბადები (PFC-ები);
- გოგირდის ჰექსაფტორიდი (SF_6).



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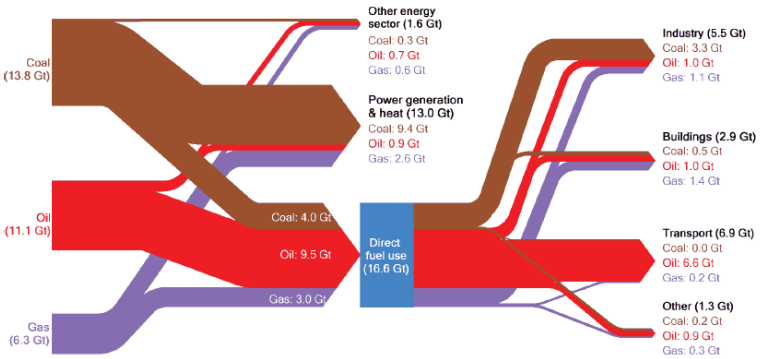
World energy-related CO_2 emissions by fuel and sector, 2011



Power and heat is the largest single source of CO_2 emissions with transport being the largest end-use sector source

© OECD/IEA 2013

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ენერგეტიკის წვლილი სათბურის აირების გაფრქვევებში

მსოფლიო

2011 წელი - 13 მლრდ. ტონა CO2 (ელ.ენერგია და სითბო)

საქართველოში

2011 წელი - 1.218 მლნ. ტონა CO2 (ელ.ენერგია და სითბო) = 0.01%

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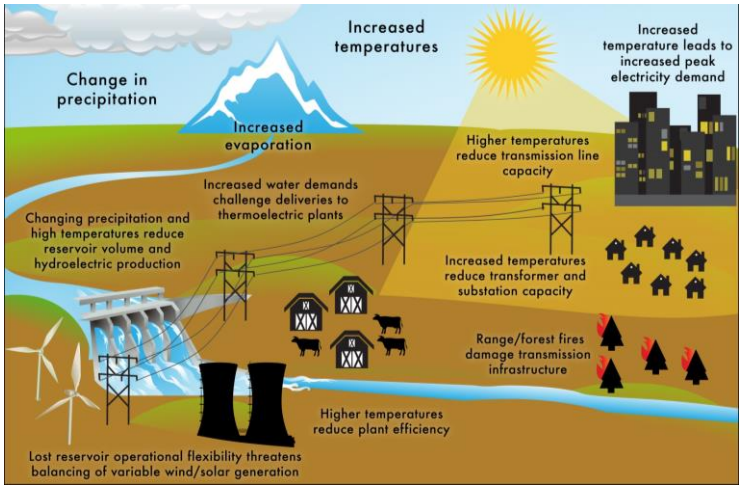
კლიმატის გავლენა ენერგეტიკულ სისტემაზე



http://ipfieldnotes.org/category/energy-and-climate/

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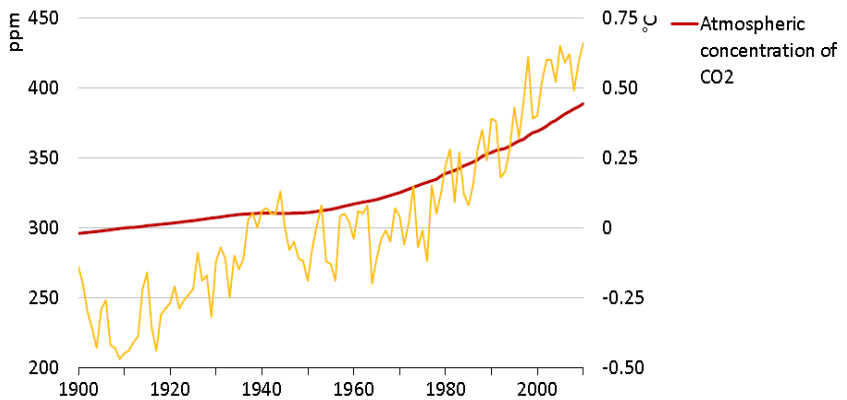
World atmospheric concentration of CO_2 and average global temperature change



Average global temperatures have already increased by 0.8 °C and are likely to increase a further 2.8 °C to 4.5 °C without additional action

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გლობალური დათბობის გავლენა ენერგიის მიწოდებასა და მოხმარებაზე

<u>ენერგიის მიწოდება:</u>

- მყინვარების დნობა - წყალდიდობა და წყალმცირობა;
- ჰესების გამომუშავების შემცირება;
- თესების ეფექტურობის შემცირება;
- გადამცემი ქსელის, ტრანსფორმატორებისა და ქვესადგურების ეფექტურობის შემცირება;

<u>ენერგიის მოხმარება:</u>

- გაგრილებაზე ენერგიის მოთხოვნის ზრდა;
- პიკური დატვირთვების ზრდა;

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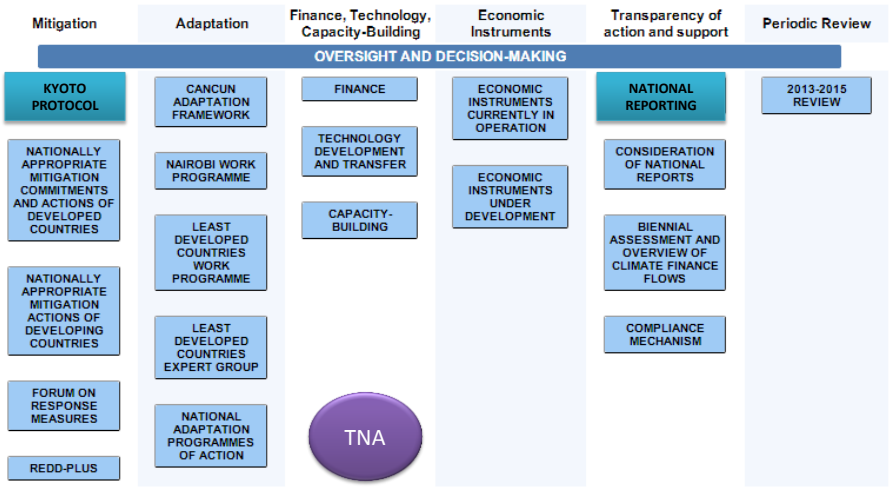
კონვენციის მექანიზმები



8/14/2014 Source: http://unfccc.int/focus/overview/items/7879.php 10

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შერბილება

Mitigation

According to the Fourth Assessment Report of the International Panel for Climate Change (IPCC AR4), global greenhouse gas (GHG) emissions have grown since pre-industrial times, with an increase of 70 per cent between 1970 and 2004. With current climate change mitigation policies and related sustainable development practices, these emissions will continue to grow over the next few decades. Continue

More on UNFCCC Mitigation work

Focus Mitigation main page	Action on mitigation: Reducing emissions and enhancing sinks
Reporting on national implementation and MRV	Resources

8/14/2014 11

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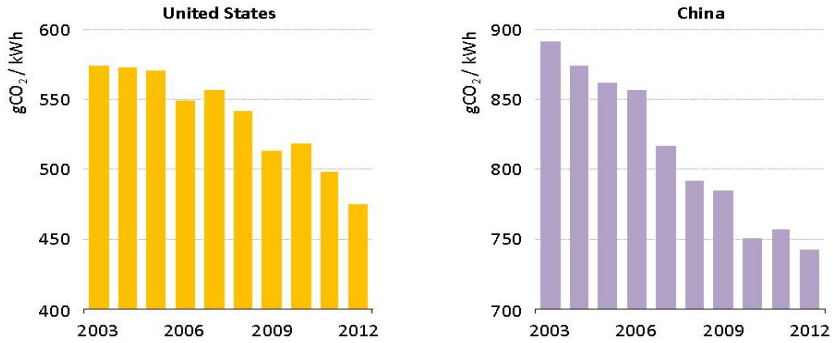
The two largest emitters make encouraging steps toward decarbonisation…

WORLD ENERGY OUTLOOK Special Report

CO_2 emissions per unit of electricity generation



In 2012, total CO_2 emissions in the US were back at the level of the mid-1990s, while total CO_2 emissions growth in China was one of the lowest in the last decade

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ფინანსური მექანიზმები

- NAMA
- CDM
- JI
- Golden standard
- LEDS

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ადაპტაცია

The adaptation process

Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.

ენერგეტიკას სჭირდება ადაპტაცია
- ჰიდროლოგიის ცვლილება
- თბოსადგურების დაბალი ეფექტურობა მაღალ ტემპერატურებზე
- წყალსაცავიანი სადგურები
- მტკიცე ნაგებობები
- გაზრდილი რეზერვები

Elements of adaptation

Adaptation activities span five general components: observation; assessment of climate impacts and vulnerability; planning; implementation; and monitoring and evaluation of adaptation actions.

Observation	Assessment	Planning
Implementation	Monitoring & Evaluation	

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ენერგეტიკული პოლიტიკა და სტრატეგია დაგეგმვიდან განხორციელებამდე

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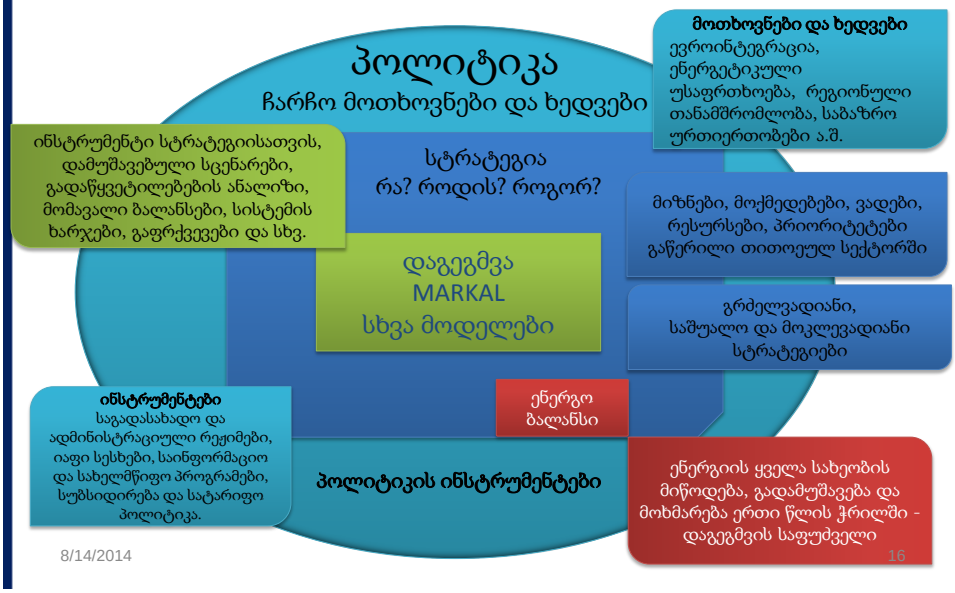

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ენერგეტიკული პოლიტიკა და სტრატეგია

ენერგეტიკული პოლიტიკა:

- სექტორის განვითარების ხედვა
- სექტორში სახელმწიფოს როლი და ფუნქციები
- სექტორის უსაფრთხო, ეფექტური და მდგრადი ფუნქციონირების პრინციპები
- პოლიტიკის ძირითადი მიმართულებები / გრძელვადიანი პრიორიტეტები
- ჩარჩო სტრატეგიის განხორციელებისათვის
- კანონმდებლობა
- საერთ. ხელშეკრულებები და თანამშრომლობა

ენერგეტიკული სტრატეგია:

- სტრატეგიული მიზნები
- სამოქმედო გეგმა
- ფინანსირების მექანიზმები
- შეფასებისა და მონიტორინგის სისტემა
- მის განხორციელებაზე პასუხისმგებელი უწყებები

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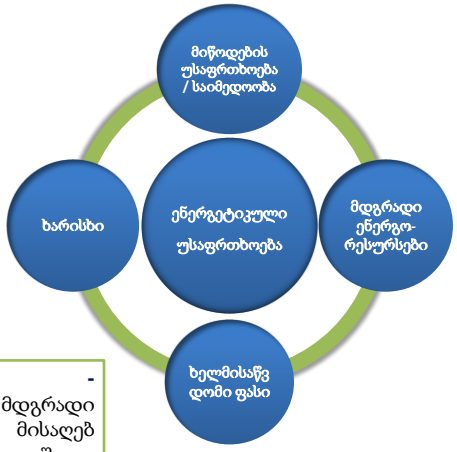
პოლიტიკის ხედვა და სტრატეგიული მიზნები

- ენერგეტიკული უსაფრთხოება
- სექტორის მდგრადი განვითარება
- სისტემის ეფექტიანი მართვა
- ფასების სტაბილურობა
- ენერგოდამოუკიდებლობა
- კონკურენტუნარიანობა
- ინოვაციური განვითარება და სხვა.



ენერგეტიკული უსაფრთხოება - ენერგორესურსების საიმედო და მდგრადი მიწოდება ხელმისაწვდომ ფასად და მისაღებ ხარისხად საშუალო და გრძელვადიან პერიოდში.

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ენერგეტიკული პოლიტიკის & სტრატეგიის ძირითადი საკითხები

- ენერგეტიკული პოლიტიკა, ხედვა, მიზნები, ამოცანები
- არსებული ენერგეტიკული და ეკონომიკური მდგომარეობის მიმოხილვა
- ენერგეტიკული სექტორის SWOT ანალიზი
- მომავალი ენერგო მოთხოვნა სექტორების მიხედვით
- ენერგეტიკული უსაფრთხოების გამოწვევები
- ენერგოეფექტურობა
- ენერგიის განახლებადი წყაროები
- კონკურენტული ბაზარი
- ინფრასტრუქტურა
- მიწოდების სექტორები (ელ.ენერგია, გაზი, ნავთობპროდუქტები, ქვანახშირი...)
- მოხმარების სექტორები (ინდუსტრია, ტრანსპორტი, შენობები...)
- ინოვაციები და კვლევა&დანერგვა, კადრების მომზადება
- გარემოსდაცვის საკითხები
- სამოქმედო გეგმა
- სტრატეგიის განხორციელების მექანიზმები
- სტრატეგიის მონიტორინგი და შეფასება
- სტრატეგიის განხორციელების პასუხისმგებელი ორგანოები

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წინაპირობები

- სამინისტროს ძირითადი ფუნქცია - ენერგეტიკის დარგში. . . **სახელმწიფო პოლიტიკის ძირითადი მიმართულებების შემუშავება,**). განვითარების **მოკლე-, საშუალო- და გრძელვადიანი სტრატეგიისა და პრიორიტეტების, ენერგეტიკული სექტორის პროგრამების შემუშავება და განხორციელების კოორდინაცია**
- მიმდინარე სამუშაო - ბალანსები, სტრატეგიის მონახაზი, MARKAL მოდელით დაგეგმვა, GEMM-2015, DCFTA, AA, EC წევრობა, კანონმდებლობის რეფორმები, განახლებადების კანონი, სხვ.

<u>საჭიროა ერთიან ჩარჩოში გაერთიანება და გეზის მიცემა</u>

ამავე დროს:

- მაღალი საზოგადოებრივი ინტერესი და აქტივობა
- ადგილობრივი ექსპერტების ჩართულობა
- დონორების წინასწარი მზაობა
- წინა გამოცდილების და ცოდნის ნაკლებობა, კადრების სიმწირე
- სამინისტროს მუშაობის ფორმალიზების საჭიროება
- სხვა უწყებებთან კავშირების აწყობის საჭიროება
- მოსალოდნელი ენერგეტიკული პრობლემები და გამოწვევები

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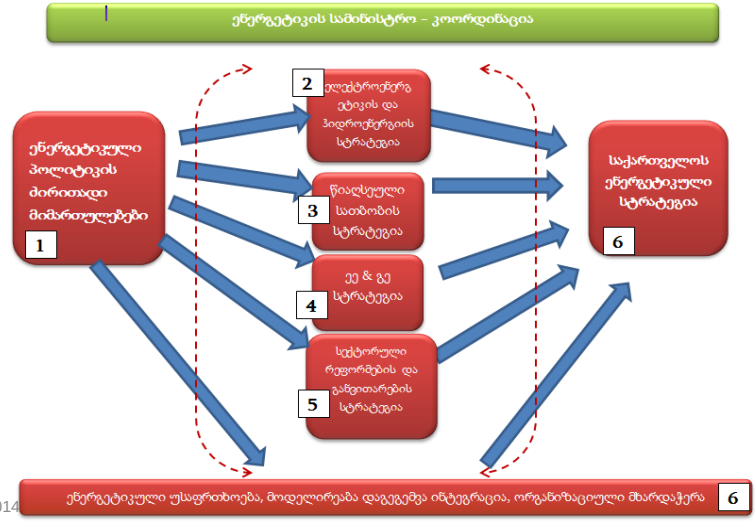
სამუშაო პროცესი



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ენერგეტიკული პოლიტიკის ძირითადი მიმართულებები MDEP

- ენერგეტიკული პოლიტიკის ძირითადი განმსაზღველი დოკუმენტი - საერთაშორისო და საშინაო გამოყენებისთვის - აჩვენებს ქვეყნის მისწრაფებებს, პრიორიტეტებს და ხედვებს ენერგეტიკის სექტორში;
- სტრატეგიის ძირითადი მიმართულებების განსაზღვრა (პრიორიტეტები, პერიოდები სხვ.);
- ენერგეტიკის სექტორის აღწერილობის მომზადება, მისი სუსტი და ძლიერი მხარეების, შესაძლებლობების და საფრთხეების სრულფასოვანი ანალიზი (SWOT);
- სტრატეგიის შესაქმნელად სამუშაო პროცესის ჩამოყალიბება.
- დაინტერესებული მხარეების ჩართვა, ცნობიერების და პროფესიული დონის ამაღლება.

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2-5. დარგობრივი სტრატეგიები

- ქვესექტორის სრულაფასოვანი აღწერა და SWOT
- დაგეგმვის მონაცემების მომზადება, სამუშაო პროცესების აწყობა

- **ელექტრობა და ჰიდროენერგიის სტრატეგია**
  - ჰიდროპოტენციალის ათვისების სახელმწიფო სტრატეგია
  - ეკონომიკური მომგებიანობის ანალიზი და პროგნოზები
  - გარემოზე ზემოქმედების გათვალისწინების მეთოდიკა, არასამთავრობოებთან რაციონალური ურთიერთობის ჩამოყალიბება
- **წიაღისეული და ტრანზიტი**
  - ადგილობრივი რესურსების განვითარების სტრატეგია
  - გაზის სექტორის სტრატეგია
  - საერთაშორისო ტრანზიტის სტრატეგია
- **ენერგოეფექტურობა და განახლებადები**
  - კანონმდებლობის ძირითადი პრინციპების განსაზღვრა
  - შესაძლებლობების ინვენტარიზაცია
- **რეფორმა და განვითარება**
  - ევროპული დირექტივების დანერგვის სამოქმედო გეგმა
  - ინოვაცია, კვლევა და დანერგვა, განათლება
  - სამინისტროს განვითარების გეგმა

- **გაერთიანდება ერთიან სტრატეგიაში**

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6. ენერგეტიკული სტრატეგია

- დაგეგმვის მოდელის MARKAL-გამართვა ახალი მონაცემებით
- ქვესექტორული სტრატეგიების გაერთიანება, ოპტიმიზაცია
- სცენარების განხილვა და გადაწყვეტილებების მიღება
- ერთიანი სტრატეგიის „მწვანე წიგნი“
- საჯარო განხილვა
- მთავრობის მიერ მიღება

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საბოლოო დოკუმენტები

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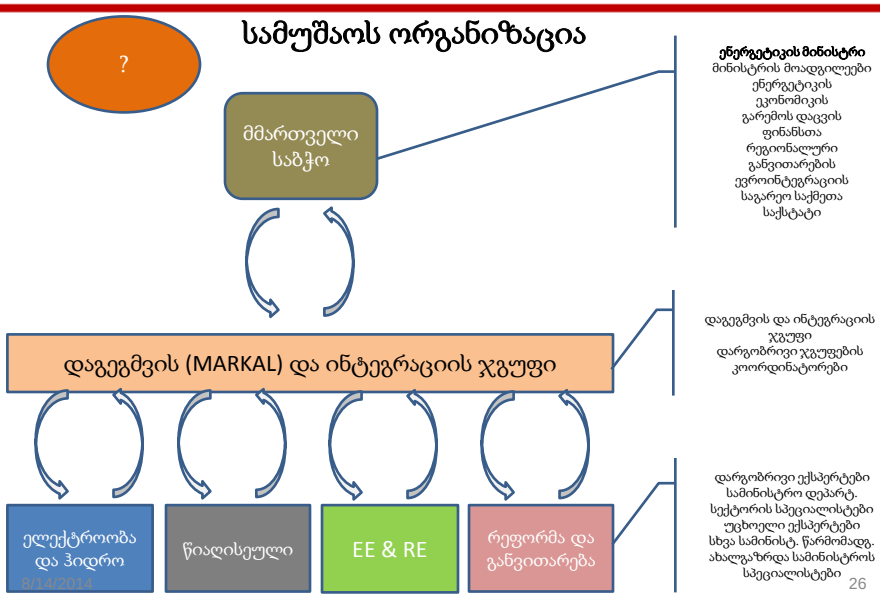
სამუშაოს ორგანიზაცია



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Emissions of Carbon Dioxide by fuel type

Fuel	Specific Carbon Content	Specific Energy Content	Specific CO2 Emission	Specific CO2 Emission
	(kgC/kgfuel)	*(kWh/kgfuel)*	(kgCO2 /kgfuel)	(kgCO2/kWh)
Coal (bituminous/anthracite)	0.75	7.5	2.3	0.37
Gasoline	0.9	12.5	3.3	0.27
Light Oil	0.7	11.7	2.6	0.26
Diesel	0.86	11.8	3.2	0.24
LPG - Liquid Petroleum Gas	0.82	12.3	3	0.24
Natural Gas, Methane	0.75	12	2.8	0.23
Crude Oil				0.26
Kerosene				0.26
Wood				0.39
Peat				0.38
Lignite				0.36
Bio energy				0

Source: http://www.engineeringtoolbox.com/co2-emission-fuels-d_1085.html

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დასასრული

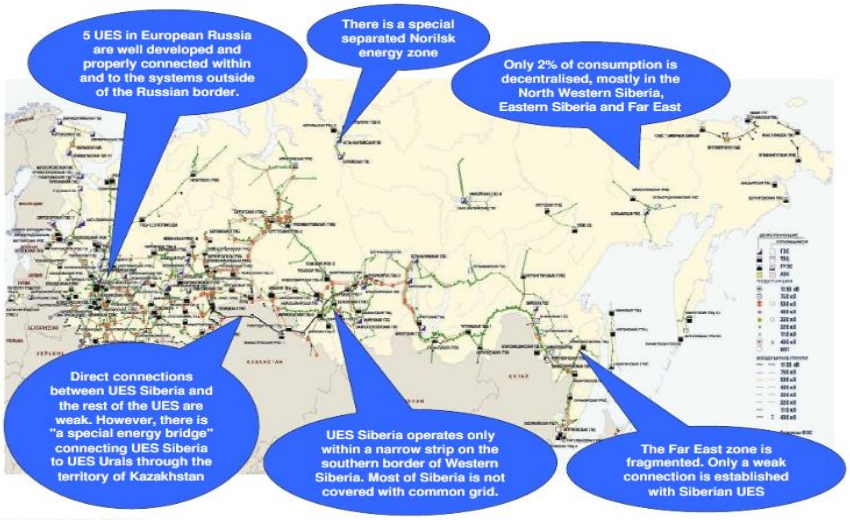
RUSSIA

ENERGY SECTOR REVIEW

Electricity Markets in Russia

There are 7 territorial divisions (united energy systems; UES) in Russia : Northwest, Central, South, Middle Volga, Urals (incl. Tyumen and Khanty-Mansiisk), Siberia, and Far East

Electricity Markets in Russia

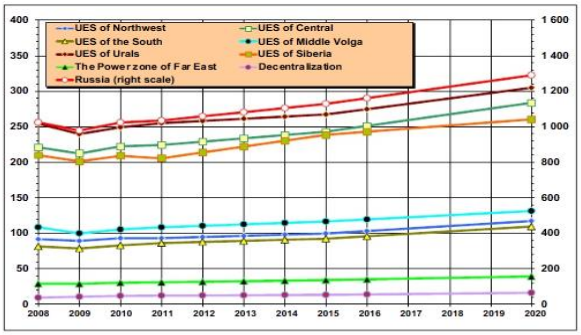


Source: RAO UES of Russia

Electricity Markets in Russia

Electricity output in Russia (bn kWh)

The greatest gain of the electricity output till 2015 is expected in UES of Central and Siberian UES, and greatest rate of growth is in UES of the South and The Power Zone of the East.

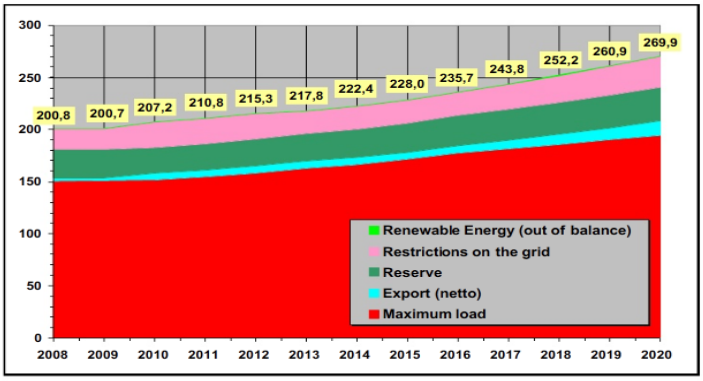


Source: Agency on forecasting balances in electric power industry (APBE)

Electricity Markets in Russia

Capacity balance in Russia (GW)

It is assumed that by 2020 demand for capacity will increase by 34%

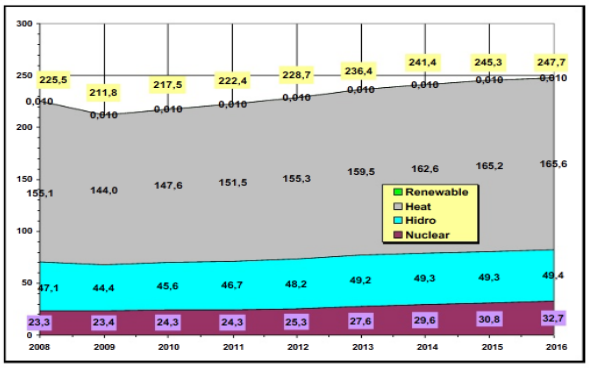


Source: APBE

Electricity Markets in Russia

Structure of the capacity in Russia (GW)

Until 2016, the structure of the capacity in Russia will not change. Renewable energy (solar, wind, tidal, geothermal etc.) does not play a significant role in a power balance of Russia so far.



Source: APBE

Electricity Markets in Russia

Capacity structure by UES and types of inputs

Electricity generation in Russia is dominated by thermal plants (more than 65% in 2008). The absolute leader are co-generation plants (35%), which dominate in UES of Northwest, Central, Middle Volga and The Far East (with Hydro plants).
The UES of the South and Urals are dominated by condensation thermal plants, and Siberia – by Hydro plants.

Capacity type	UES							Russia
	Northwest	Central	Middle Volga	South	Urals	Siberia	FarEast	
Nuclear	24,40	23,50	20,45	6,13	1,14	0,00	0,35	10,34
Hydro & Pumped Storage	21,55	9,80	28,50	21,99	5,70	48,21	35,44	22,43
Diesel	1,66	0,00	0,01	0,02	3,46	0,53	5,72	1,45
Thermal (Condensation)	16,97	24,61	1,28	54,02	57,62	18,73	23,65	30,32
Renewables	0,03	0,00	0,00	0,12	0,21	0,00	0,58	0,10
Thermal (Co-generation)	35,40	42,08	49,76	17,72	31,87	32,53	34,26	35,35
All (GW)	23,61	50,36	19,56	16,30	52,66	48,34	13,85	224,68 / 100%

Source: RosStat

Electricity Markets in Russia

Fuel consumption by UES and types of inputs

The fuel in UES of Northwest, Central, Middle Volga, South and Urals is mainly gas, and in UES of Siberia and the Far East – coal. Thus in the Power Zone of Far East the share of gas (from Sakhalin deposits) has increased over the last few years.

Fuel type	UES							Russia
	Northwest	Central	Middle Volga	South	Urals	Siberia	FarEast	
Gas	73,16	91,35	96,64	81,11	83,16	12,08	21,57	69,31
Coal	10,01	4,56	0,26	16,91	12,91	82,82	69,20	25,42
Diesel	0,61	0,01	0,01	0,35	0,26	0,21	2,76	0,32
Black oil	9,16	0,67	2,84	1,45	0,84	0,58	6,23	1,82
Other	7,06	3,41	0,24	0,19	2,84	4,31	0,24	3,12
All[1]	25,99	69,58	21,28	20,10	114,62	58,98	13,89	324,44 / 100%

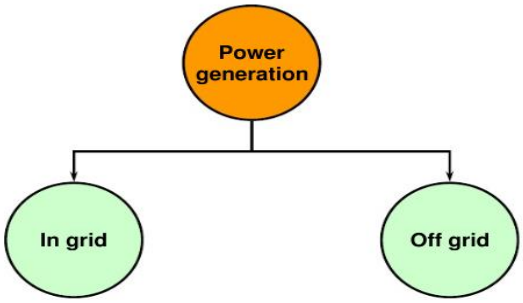
Source: RosStat
Notes:
[1] Tons of conditional fuel (recalculation on equivalent quantity standard coal)

8

Electricity Markets in Russia

Generations business in Russia is possible in two fundamentally different schemes

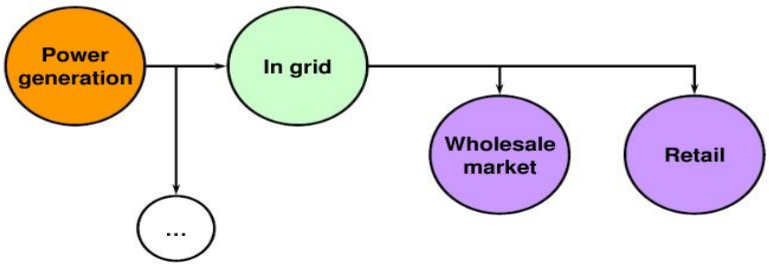
- ✓with the issue of energy produced in the grid
- ✓within the framework of an autonomous energy source (off grid)



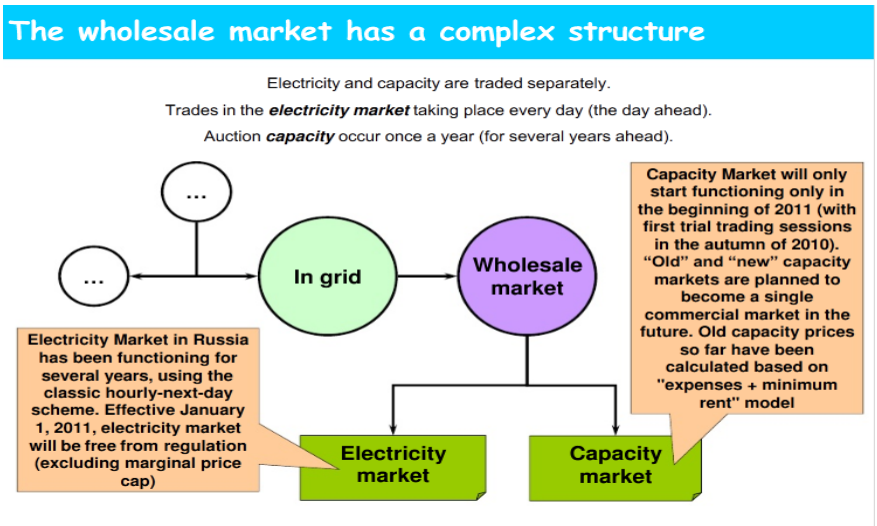
Electricity Markets in Russia

Issuance of electricity to the grid

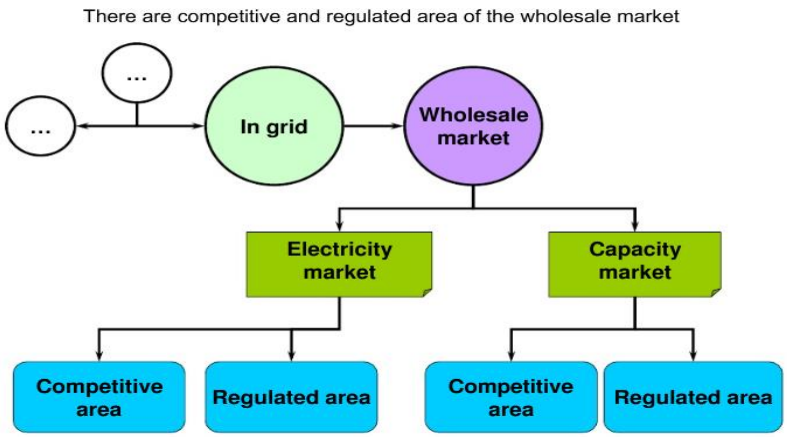
A plant can participate in the wholesale (25 MW and above) or retail markets.



Electricity Markets in Russia



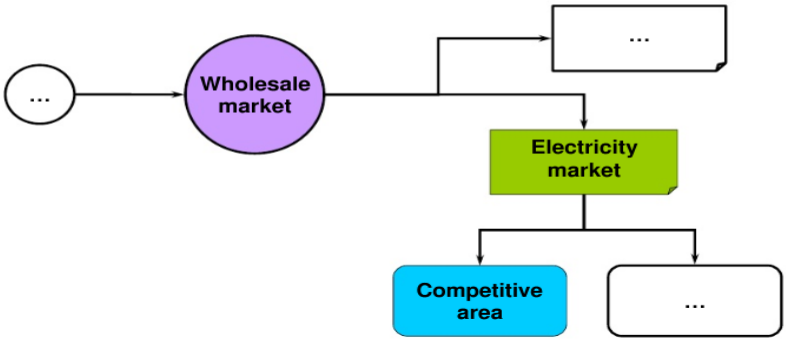
Electricity Markets in Russia



Electricity Markets in Russia

Electricity market

Most consumers of European Russia and Siberia to buy electricity at prices determined by the market



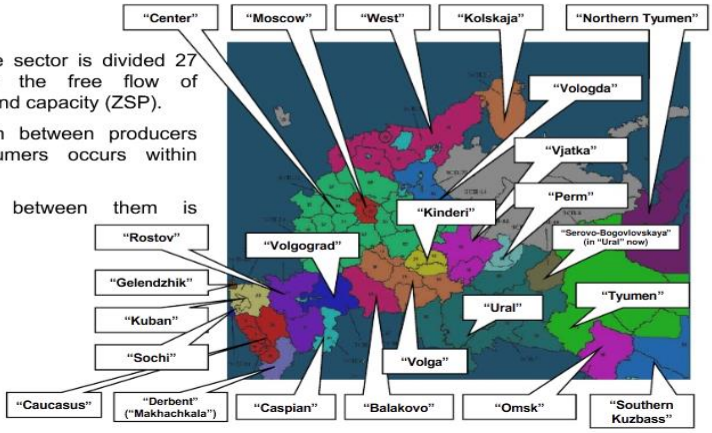
Electricity Markets in Russia

Electricity market: 27 bands compete

Competitive sector is divided 27 bands for the free flow of electricity and capacity (ZSP).

Competition between producers and consumers occurs within each ZSP.

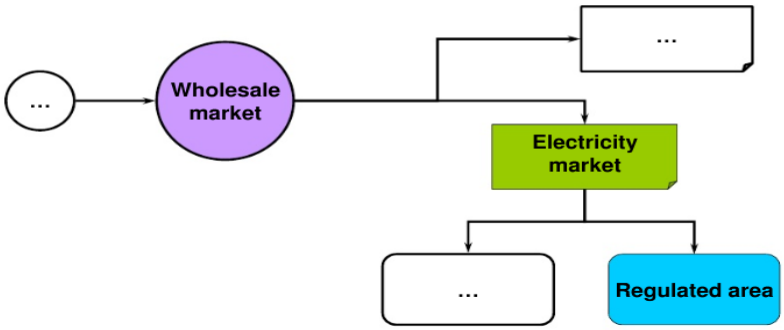
Exchange between them is limited.



Electricity Markets in Russia

Electricity market

Regulation of electricity prices implemented in the Arkhangelsk and Kaliningrad regions, Komi Republic, Norilsk power district and throughout the Far East, including the Amur Region and Yakutia



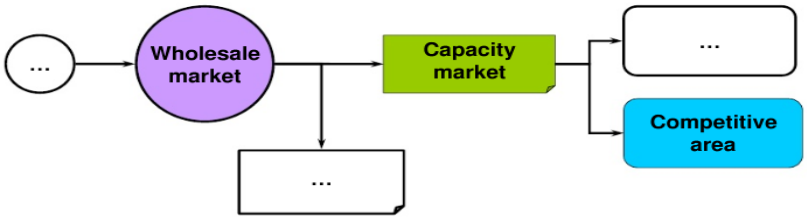
Electricity Markets in Russia

Capacity market

Capacity market has long-term, investment character: the plants receive reimbursement to establish and maintain working capacity

Capacity market in the foreseeable future will remain almost wholly controlled because the FAS found the competition of capacity suppliers is possible in 3 of 27 ZSP only:

- ✓**in Krasnoyarsk Krai, Irkutsk and much of the Kemerovo area;**
- ✓**in the part of the Urals (mostly in the South);**
- ✓**virtually throughout UES of Centre (without Vologda and Moscow regions).**

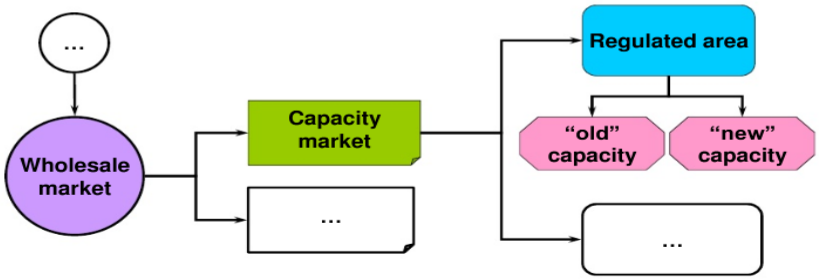


Electricity Markets in Russia

Regulated segment of capacity market is divided into the markets of the "old" and "new" capacity in turn

Such division is due to the dominance in Russia the plants with fully depreciated assets: the cost of their capacity is significantly lower than in newly plants due to lack investment component.

(A competitive market sector is currently very limited and the price from the top.)



Electricity Markets in Russia

"New" capacity market

Regulation of prices for the "new" capacity carried out within the framework of the system of Contracts for the supply of capacity (CSC). These define the mechanism of capacity pricing for newly plants (their number is very limited), ensured the return of investments in their creation.

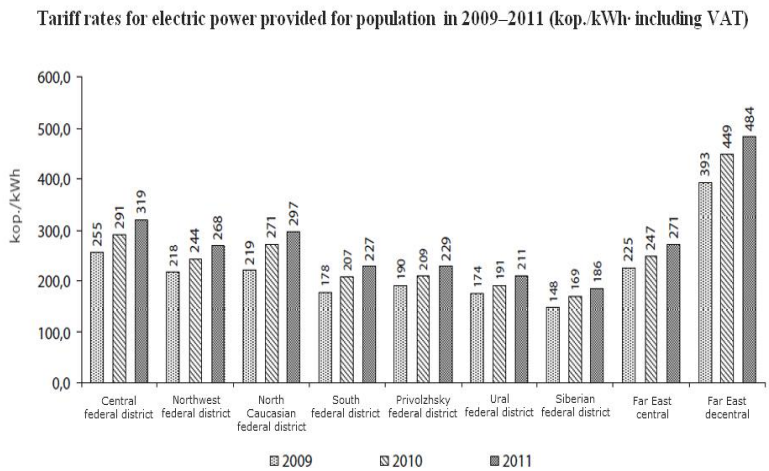
Excess the CSC-prices over the market prices is paid by all participants of the market (European part and Siberia).

Convener of CSC assigned to the System Operator of the United Power System (SO UPS).

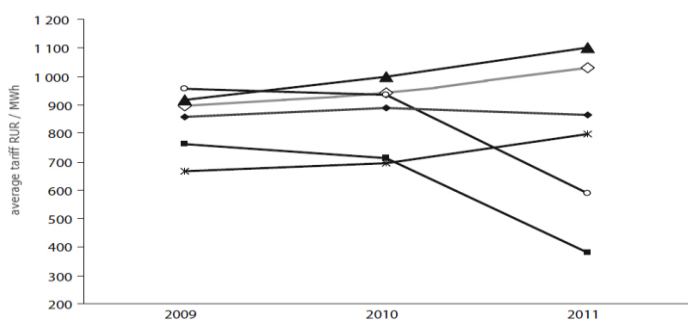
Previously it was projected that the dividing into "old" and "new" capacity will be cancelled by 2020 by raising the maximum prices for the "old" followed by the opening of the capacity market to free competition, but recent findings of FAS that thern't competition in most ZSP are likely to make significant amendments to these plans.

http://www.academia.edu/2204254/Electricity_Markets_in_Russia_english_updated_

Analytics from Federal Tariff Service of Russia

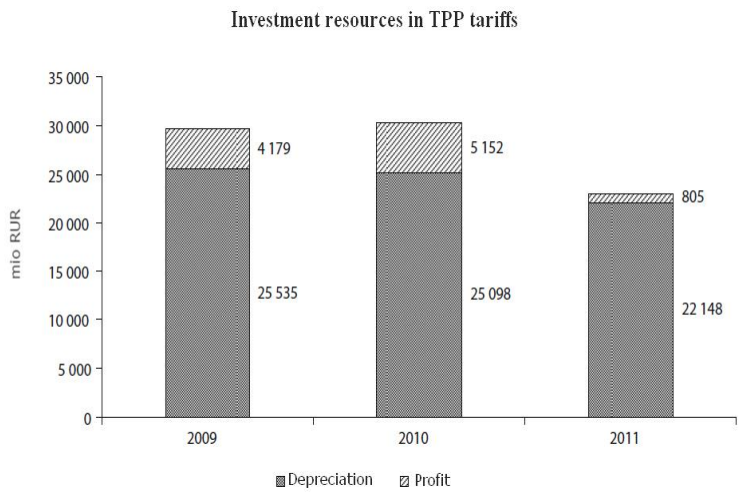


Analytics from Federal Tariff Service of Russia

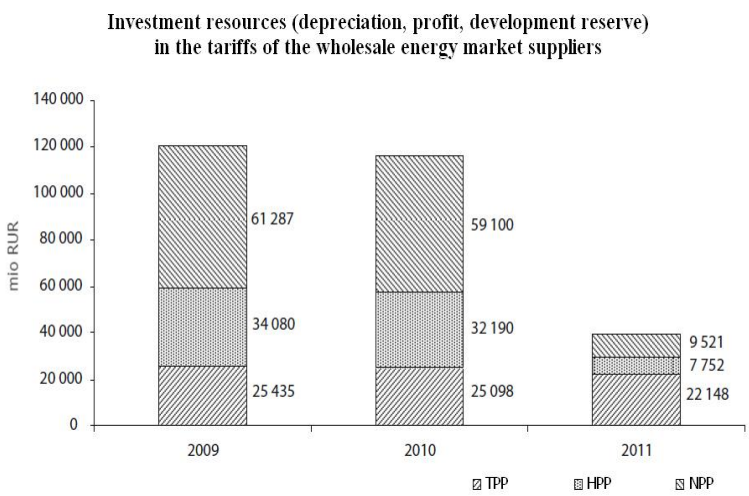


	2009	2010	2011
OGK	896,88	941,7	1 029,71
RusGidro	760,46	710,96	379,81
TGK	916,95	999,77	1 099,83
NPP	956,80	935,96	590,23
Others	668,01	694,45	798,42
Average	857,19	888,52	864,68

Analytics from Federal Tariff Service of Russia



Analytics from Federal Tariff Service of Russia



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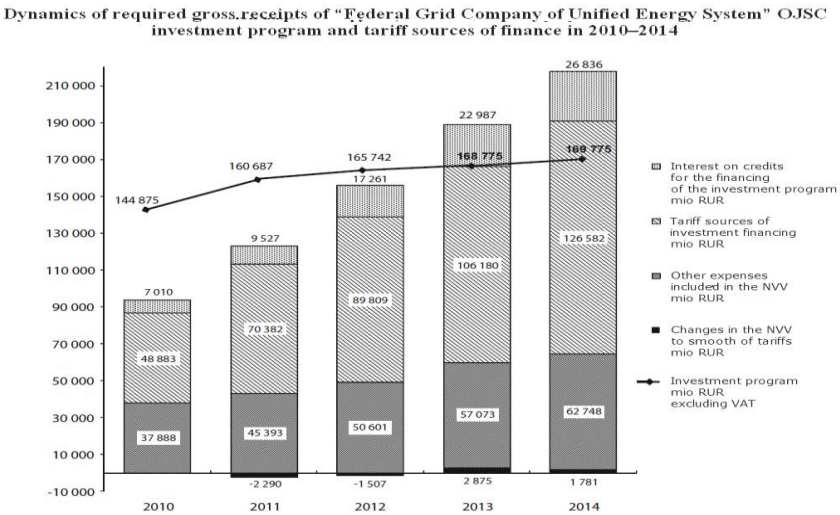

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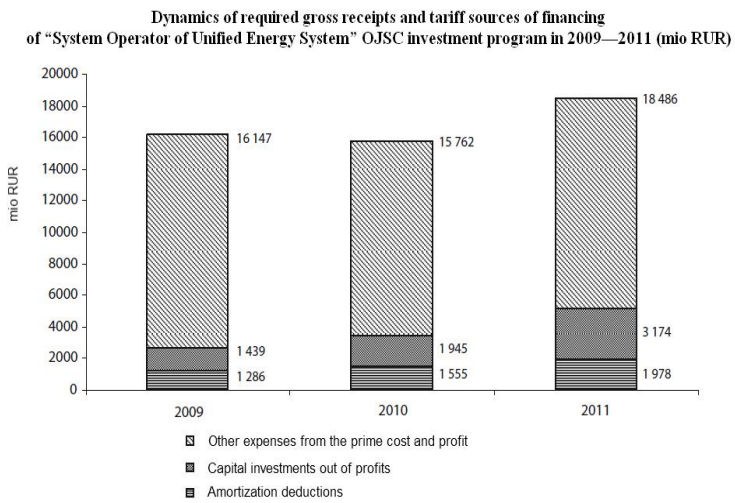

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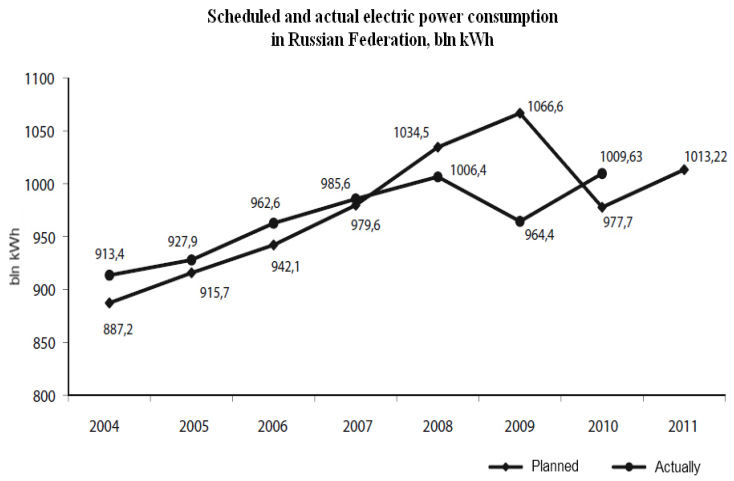

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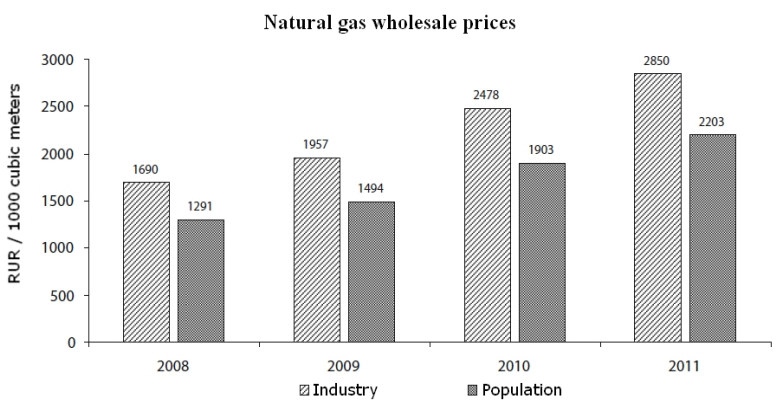

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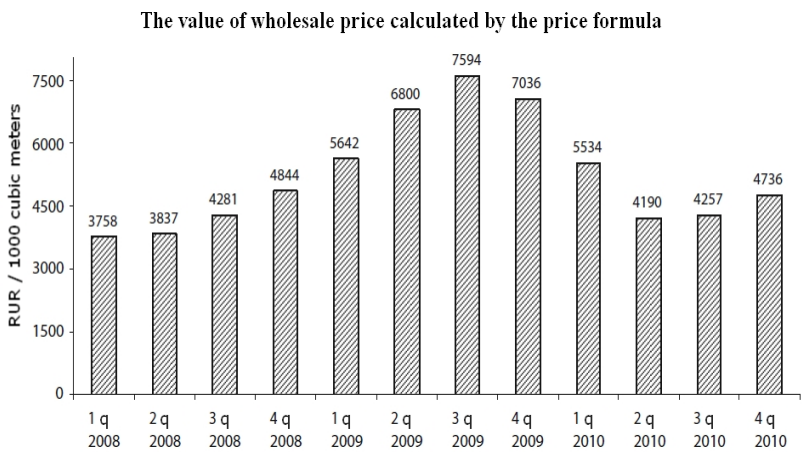

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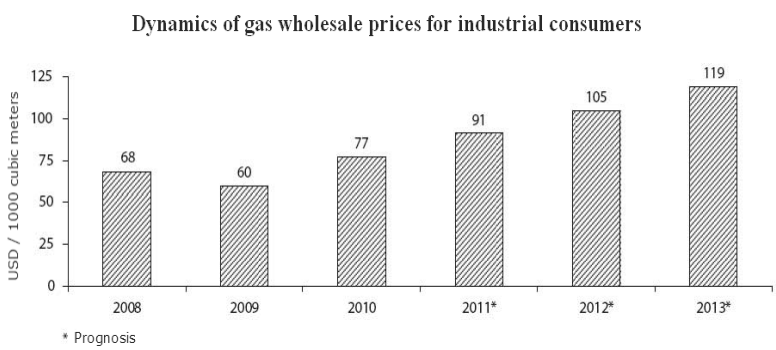

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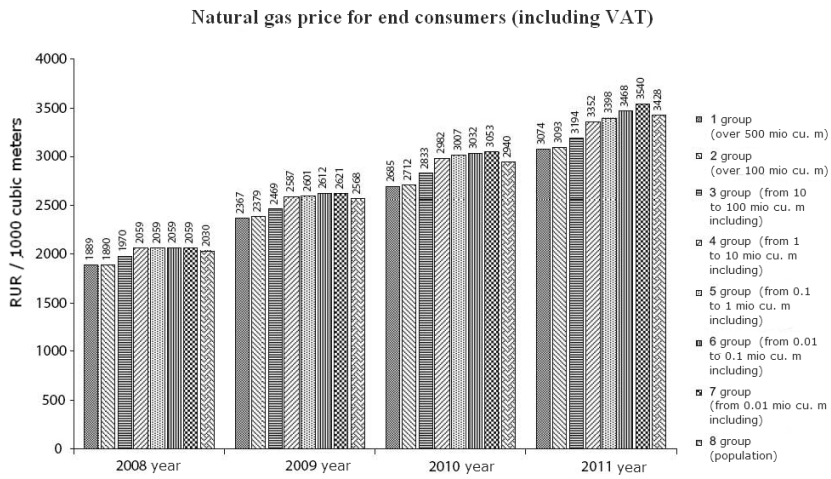

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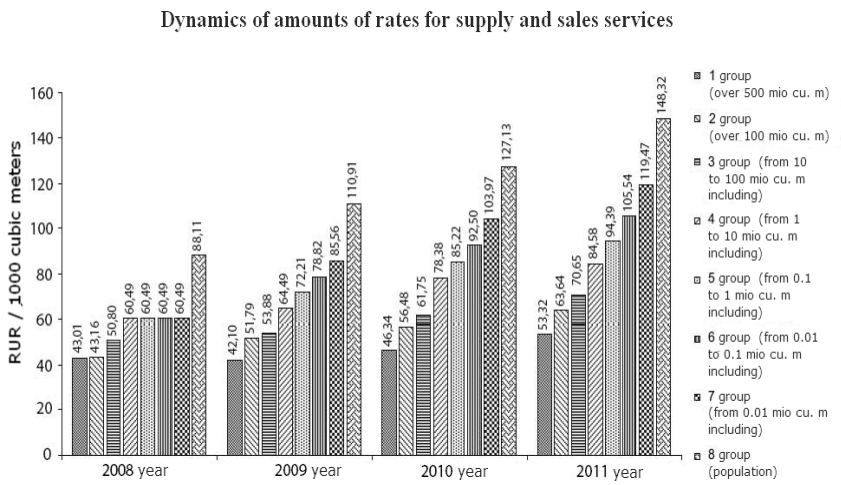

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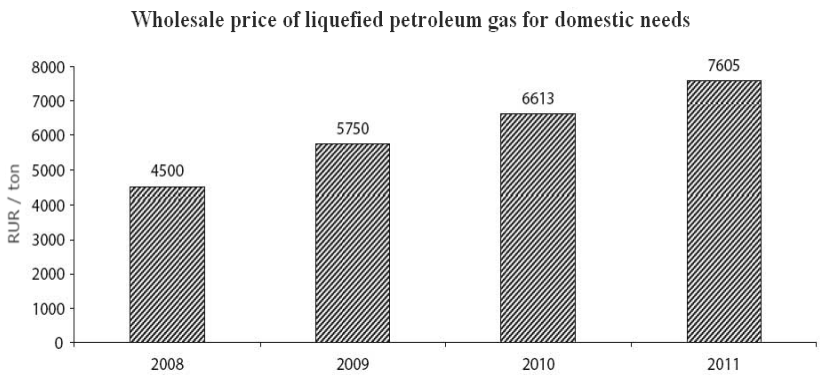

Analytics from Federal Tariff Service of Russia

Average level of tariffs for "Gazprom" OJSC services for independent organizations for gas transportation through gas main pipelines

Valid-from date	For domestic market and Customs Union member countries (RUR/1000 cu m for 100 km)	Beyond Customs Union member countries (RUR/1000 cu m for 100 km)
- from January 1, 2008.	36,13	40,02
- from January 1, 2009	37,86	41,94
- from April 1, 2009	40,44	44,79
- from July 1, 2009	43,19	47,84
- from October 1, 2009	45,74	50,66
- from January 1, 2010	51,37	56,90
- from January 1, 2011	56,15	62,19

Analytics from Federal Tariff Service of Russia

Average increase in final natural gas prices in 2011 classified by the consumer groups against December, 2010

group 1 (over 500 mio cu m)	group 2 (over 100 mio cu m)	group 3 (from 10 to 100 mio cu m inclusive)	group 4 (from 1 to 10 mio cu m inclusive)	group 5 (from 0,1 to 1 mio cu m inclusive)	group 6 (from 0,01 to 0,1 mio cu m inclusive)	group 7 (from 0,01 mio cu m inclusive)	group 8 (population)
114,51 %	114,05 %	112,76 %	112,38 %	112,99 %	114,39 %	115,97 %	116,61 %