Załącznik nr 1 do uchwały nr 67/2023
Senatu Politechniki Rzeszowskiej im. Ignacego Łukasiewicza
z dnia 29 czerwca 2023 roku.

Study programme

Clean Energy

second degree study

The profile of studing: general academic

PRK VII

1. Basic information about the course

The name of the field of study	**Clean Energy**
The level of study	**second degree study**
The profile of studing	**general academic**

The name of the core discipline, in which more than half of the learning outcomes are obtained together with the percentage share of the number of ECTS credits for the core discipline in the total number of ECTS credits required to complete studies in the course of study.

The name of the core discipline	Share
mechanical engineering	**70 %**

Names of other disciplines together with the percentage share of the number of ECTS credits for other disciplines in the total number of ECTS credits required to complete a course of study. PRS7

	Share
environmental engineering, mining and energy	**20 %**
automation, electronics, electrical engineering and space technologies	**10 %**

Number of semesters	full time study: **3**
Number of ECTS credit points required to complete the studies	**90**
Total number of class hours	full time study: **975**
Recruitment requirements	Requirements annually determined by the Senate of Rzeszów University of Technology
After graduation, the graduate obtains a professional title	Master of science
Graduate's profile, employment opportunities	Education in this branch of study provides the knowledge necessary to solve problems concerning the utilization and transformation of various types of energy. Student understands the processes of energy conversion in biosphere and has a knowledge of acquiring various forms of energy from environment and their conversion to the effective types of energy. As far as Clean Energy field of study is concerned, particular attention was paid on following issues: acquire and conversion of renewable energy sources, highly effective and environmentally friendly energy technologies, energy conservation and rationalization of its use, as well as methods of short- and long-term energy storage. Also particular emphasis was put on hydrogen as an universal energy carrier and storage. In addition, the abilities of calculation which allow the description of conversion and transport of mechanical and thermal energy, are developed, as well as the knowledge and skills related to organization and implementation of transport processes, which include renewable energy sources. The knowledge of methods of conservation and effective conversion of energy is supplied with fundamental aspects of building energy audit and energy facilities. Student obtains knowledge and skills which enable the design and contracting of systems using conventional and renewable energy sources in multi-source and multi-receiver heat energy production and distribution systems, including multi-generation systems. Also, the knowledge of application of algorithms and systems optimizing the operation of small energy systems, are provided. Based on knowledge of processes of conversion and absorption of renewable energy sources, student acquires knowledge in the field of modelling phenomena, which occur in energy devices. Moreover, the knowledge of energy acquiring and conversion is supplemented with the issues of environmental and social costs of their implementation and methods of their minimization. Student is conversant with the organization of the energy market and the ability of utilization of local energy resources and raising funds for this purpose. Graduates obtain skills necessary to work in corporations designing and installing small and medium-sized energy systems and in companies utilizing energy systems. For this reason, particular emphasis is placed on including the specific properties of renewable energy sources and their cooperation with conventional energy sources. Design skills include the integration of energy installations and allow for solving more advanced problems in the field of energy devices. Graduates also gain knowledge essential to deal with energy issues in local government units. The curriculum covers the topics of using local energy resources, exploiting the energy infrastructure of a local government unit and planning local energy development and raising funds for this purpose. The knowledge acquired during the studies will allow the participation in the Polish and EU programs concerning transformation and development of the energy sector.

2. Learning outcomes

Symbol	Contents	References

		to PRK
K_W01	Knows and understands the structure and principles of operation of the power grid, its interaction with sources and receivers of various characteristics, particularly sources and receivers involving the "Clean Energy" technology; knows and understands the importance of distributed generation, smart grids and other specific concepts related to the operation and impact on the grid of renewable energy technologies.	**P7S_WG**
K_W02	Has structured knowledge in the field of nuclear energy, including the construction of nuclear reactors, mechanisms of fision reaction, safety of nuclear power plants and the impact of ionizing radiation on the environment.	**P7S_WG**
K_W03	Has advanced knowledge in the field of phenomenological and mathematical description of momentum, energy and mass transfer processes, notably the basic laws of thermodynamics, heat transfer and fluid mechanics, description of heat transfer through conduction, convection and radiation and mass flow, knows the basic mathematical methods of solving these problems.	**P7S_WG**
K_W04	Has knowledge of development trends and the latest new achievements in the field of energy conversion technologies, particularly in the field of clean energy technologies and the related quandaries resulting from their importance for society and impact on the natural and social environment.	**P7S_WG** **P7S_WK**
K_W05	He has advanced knowledge in the field of processing technology and the use of renewable energy in a way to meet the demands for mechanical and thermal energy in the industrial and household sector.	**P7S_WG**
K_W06	Has advanced knowledge of the principles of operation, construction and operation of systems and devices used in energy transport and processing, as well as fundamental knowledge of the manufacturing technology of their components.	**P7S_WG** **P7S_WK**
K_W07	Has structured and extensive theoretical knowledge of the meaning and qualitative description of energy conversion processes, knows the methods of implementing this knowledge to the analysis of energy conversion processes and systems and energy transport, and understands the importance of energy conversion efficiency for the development of modern civilization.	**P7S_WG**
K_W08	Knows and understands the natural and technical transformations of primary energy to direct energy and has structured knowledge about the chain of production, conversion, storage and use of primary and secondary energy carriers.	**P7S_WG**
K_W09	Has an organized knowledge of the principle of operation of objects and devices which are receivers of various types and energy carriers, in particular in the field of "Clean Energy", and understands the impact of their properties on the manner and efficiency of their use.	**P7S_WG**
K_W10	Has structured knowledge of the implementation of tasks based on design thinking and understands the importance of the creation process and analysis of the interdependencies between the stages and effects of the project.	**P7S_WK**
K_W11	Knows and understands the basic concepts and principles of the IP protection and copyright and the necessity to manage intellectual property resources.	**P7S_WK**
K_W12	Knows and understands the fundamental quandaries occurring in society and technology resulting from the growing energy demand and limited natural resources and technical possibilities.	**P7S_WK**
K_W13	Has the knowledge required to understand the political, social, economic, legal, ethical and other non-technical aspects of engineering activities, especially in the field of energy conversion and issues related to energy needs of the society and including them in engineering practice.	**P7S_WK**
K_W14	Knows the general principles of creating and developing forms of entrepreneurship with the use of knowledge in the field of science and scientific disciplines relevant to clean energy.	**P7S_WK**
K_U01	Communicates in a foreign language on technical topics using various techniques in an occupational environment and in other environments, both in simple and specialized language; is able to participate in a discussion in a foreign language, conduct a debate and present the results of work with the use of specialized terminology applied in the fields of science and technology related to energy conversion.	**P7S_UK**
K_U02	Can obtain information from literature, database and other properly selected sources in English language in the field of energy, particularly renewable energy and related fields of technology; is able to select and integrate them, as well as to interpret and critically evaluate them, noreover, can draw conclusions and formulate and justify opinions.	**P7S_UW**
K_U03	Can apply or adapt the existing methods and, if necessary, develop new methods or tools in order to prepare and implement an experiment, design or analytical assignments, and to formulate and discuss obtained results.	**P7S_UW**
K_U04	Based on the given knowledge, can formulate hypotheses regarding engineering or simple research problems, can plan and carry out measurements and simulations, can interpret obtained results and draw conclusions using knowledge in order to critically analyze the proceeding of various energy conversion processes.	**P7S_UW** **P7S_UU**
K_U05	Can formulate and solve complex and abnormal engineering problems, integrate knowledge in the field of science and scientific disciplines relevant to renewable energy and can use an innovative approach to solve problems occurring in the field of "clean energy".	**P7S_UW**
K_U06	Is able to select and apply methods and tools appropriate to the issue and forecasted results, including computer simulation and can interpret the results and draw conclusions also with respect to own scientific research.	**P7S_UW**
K_U07	Can properly define priorities for the implementation of a specific task and based on this can plan and organize a coherent and feasible sequence of activities of himself and others, can think and act in a creative and entrepreneurial manner.	**P7S_UU**
K_U08	Is able to cooperate and work in a group and can undertake a leadership role, depending on the current needs and possibilities, accepting the related scopes of rights and duties.	**P7S_UO**
K_U09	Can define the directions of further study; define the schedule and scope and implement the self-education process, as well as direct others in this area.	**P7S_UU**
K_K01	Is aware of the social role of a university graduate and understands the need to formulate and transfer information and opinions to the society based on a critical evaluation of reality and the achievements of science and technology.	**P7S_KK** **P7S_KO**
K_K02	Is aware of the importance and understands the non-technical aspects and effects of engineering activities, including its impact on the environment and society, and the related responsibility for decisions made.	**P7S_KR**
K_K03	Recognizes knowledge as the basis for the development of society and is ready to expand it through and develop his professional achievements throughout his life, as well as inspire and organize this process in others.	**P7S_KK** **P7S_KO** **P7S_KR**
K_K04	Correctly identifies and resolves quandaries related to the profession, understands the necessity to uphold and comply with legal and ethical principles within the professional activity and outside it.	**P7S_KR**
K_K05	Is ready to take initiatives and actions inspired by specialist knowledge and critical thinking for the benefit of the natural and social environment in the pursuit of the public interest.	**P7S_KK** **P7S_KO**

K_K06	Is ready to critically evaluate his knowledge and perceived content, as well as to recognize the importance of knowledge in solving cognitive and practical problems, and to consult experts in case of difficulties in solving the problem on his own.	**P7S_KK**

The description of learning outcomes includes learning outcomes referred to in the Act of 22 December 2015 on the Integrated Qualification System and takes into account universal characteristics of the first degree cycle specified in this Act and the characteristics of the second degree cycle specified in the regulations issued on the basis of Article 7, section 3 of this Act..

Detailed information about:

1. the relationship between learning outcomes and modular learning outcomes;
2. key learning outcomes in terms of knowledge, skills and social competences, demonstrating their relation to the discipline / disciplines to which the course is assigned;
3. the development of learning outcomes at the level of classes or group of classes, in particular related to the scientific activity conducted at the university;
4. learning outcomes in terms of knowledge, skills and social competences leading to the acquisition of engineering competences, in the case of study programmes on completion of which the student is awarded a professional title of engineer / Master of Engineering;

can be found in the Module Activity Sheets, available on the website of the faculty. Module Activity Sheets are integral part of the study programme.

3. List of classes, parameters of the study program, methods of verification of learning outcomes and program content

3.1 Common subjects for the field of study, independent of the students' choice

Semester	Org.Unit	name of the subject	Lecture	Class	Laboratory	Project/ Seminar	Sum of hours	ECTS	Exam	Mand.
1	ZH	Ethical and legal issues of professional and scientific activity	15	0	0	10	25	1	N	
1	MD	Energy efficiency	30	0	0	20	50	4	N	
1	ML	Fluid mechanics	30	10	10	0	50	4	N	
1	EE	Fundamentals of electrical power and grid	30	15	20	0	65	5	T	
1	ZE	Energy policy and legislation and social aspects of energy conversion and using	25	0	0	0	25	2	N	
1	MG	Project management	15	0	0	10	25	2	N	
1	MD	Thermodynamics and heat transfer	30	30	30	0	90	6	T	
1	MD	Energy devices	30	10	15	0	55	4	T	
1	MD	Energy sources and environmental aspects of energy conversion and using	30	0	0	0	30	2	N	
2	MD	Biomass energy	15	0	10	0	25	2	N	
2	ML	Wind and hydro energy	40	10	15	15	80	6	T	
2	MD	Modeling of energy transfer and systems	15	0	25	0	40	3	N	
2	MD	Basics of nuclear energy	20	0	0	0	20	1	N	
3	MD	Energy storage	20	10	10	10	50	3	N	

Note that not being granted credits from the modules marked with a red flag makes it impossible to make an entry for the next semester (even if the total number of ECTS credits is lower than the permissible debt), these are modules continued in the next semester or modules in which failure to achieve all assumed learning outcomes does not allow one to continue studies in the modules included in the next semester's study programme

3.2 List of thematic blocks

- Hydrogen biofuels and clean transportation
- Solar energy and heat pumps

3.2.1. Thematic block: Hydrogen biofuels and clean transportation

Subjects implemented after the selection of the thematic block

Semester	Org.Unit	name of the subject	Lecture	Class	Laboratory	Project/ Seminar	Sum of hours	ECTS	Exam	Mand.
2	ME	Liquid and gaseous biofuels	15	0	15	10	40	3	N	
2	ME	Energy efficiency in transportation	15	10	15	10	50	4	T	
2	ML	Fuel cells fundamentals and portable technologies	15	0	15	10	40	3	N	
2	FF	Hydrogen production, storage and distribution	30	10	10	0	50	3	N	
2	ML	Hydrogen burners and combustion systems	25	10	15	10	60	5	T	
3	ME	Clean vehicle power drives modelling and testing	15	0	15	20	50	3	T	
3	MD	Master Diploma thesis	0	0	0	0	0	20	N	
3	ME	Master Diploma seminar HB&CT	0	0	0	15	15	1	N	
3	ML	Hydrogen and hybrid aircraft propulsion systems	15	0	15	10	40	3	N	

Parameters of the study program

The total number of ECTS credits that a student must obtain in the course of classes conducted with direct participation of academic teachers or other persons conducting classes.	45 ECTS
The total number of ECTS credits allocated to classes related to scientific activity conducted at the university in a given discipline or disciplines to which the course of study is assigned.	86 ECTS
The total number of ECTS credits required to be obtained by a student in the humanities or social sciences for the courses of study assigned to disciplines within the fields of study other than the humanities or social sciences respectively.	5 ECTS
The total number of ECTS credits allocated to elective courses.	45 ECTS
The total number of ECTS points that a student must obtain as part of a foreign language course.	90 ECTS
Number of hours of physical education classes.	--

Verification methods of learning outcomes

Detailed rules and methods for the verification and assessment of learning outcomes that allow all learning outcomes to be verified and assessed are described in the Module Activity Sheets. Within the framework of a programme, verification of learning outcomes is carried out in particular by means of the following methods: written, exam part practical, exam part oral, written pass, pass a part practical, oral pass, essay, colloquium, written test, observation of performance, portfolio, project presentation, written report, oral report, project report, written test. Detailed information about the verification of learning outcomes achieved by students can be found in the Module Activity Sheets on the website of the faculty. Parameters of selected methods of verification of learning outcomes are presented in the table below.

Number of classes where the exam is required	7
Number of classes where a written exam is required	7
Number of classes where an oral exam is required	0
Number of hours devoted to the written exam	12
Number of hours devoted to oral exam	0
Estimated number of hours students should spend preparing for exams and credits	324
Number of classes which result in a pass without an exam	16
Number of hours to be completed in writing	12
Oral number of hours to complete	3
Estimated number of hours that students should spend on preparing for credits during semesters during classes (no final credits)	27
Number of classes in which the verification of the achieved learning outcomes is carried out on the basis of observation of performance (laboratories)	15
Number of laboratories where the achieved learning outcomes are checked on the basis of tests during the semester	8
Estimated number of hours students should spend in preparing for laboratory tests	40
Number of project classes in which the learning outcomes achieved are checked on the basis of a project presentation, a written report, a written report, an oral report or a project report	12
Estimated number of hours students should spend on design / documentation / report preparation and preparation for presentation	146
Number of lecture classes that require separate credit in writing or orally, regardless of the requirements of other forms of classes in this module	9
Estimated number of hours students should spend in preparing for lecture tests	53

3.2.2. Thematic block: Solar energy and heat pumps

Subjects implemented after the selection of the thematic block

Semester	Org.Unit	name of the subject	Lecture	Class	Laboratory	Project/ Seminar	Sum of hours	ECTS	Exam	Mand.
2	MD	Solar radiation fundamentals and thermal solar systems	40	15	15	15	85	6	T	
2	EE	Photovoltaics	30	0	10	10	50	4	N	
2	BB	Pasive solar systems	15	10	0	15	40	3	N	
2	BD	Heat networks and building internal systems	30	0	15	20	65	5	T	
3	MD	Heat pumps and geothermal energy	45	15	15	15	90	6	T	
3	MD	Master Diploma thesis	0	0	0	0	0	20	N	
3	MD	Master Diploma seminar SE&HP	0	0	0	15	15	1	N	

Parameters of the study program

The total number of ECTS credits that a student must obtain in the course of classes conducted with direct participation of academic teachers or other persons conducting classes.	46 ECTS
The total number of ECTS credits allocated to classes related to scientific activity conducted at the university in a given discipline or disciplines to which the course of study is assigned.	86 ECTS
The total number of ECTS credits required to be obtained by a student in the humanities or social sciences for the courses of study assigned to disciplines within the fields of study other than the humanities or social sciences respectively.	5 ECTS
The total number of ECTS credits allocated to elective courses.	45 ECTS
The total number of ECTS points that a student must obtain as part of a foreign language course.	90 ECTS
Number of hours of physical education classes.	--

Verification methods of learning outcomes

Detailed rules and methods for the verification and assessment of learning outcomes that allow all learning outcomes to be verified and assessed are described in the Module Activity Sheets. Within the framework of a programme, verification of learning outcomes is carried out in particular by means of the following methods: written, exam part practical, exam part oral, written pass, pass a part practical, oral pass, essay, colloquium, written test, observation of performance, portfolio, project presentation, written report, oral report, project report, written test. Detailed information about the verification of learning outcomes achieved by students can be found in the Module Activity Sheets on the website of the faculty. Parameters of selected methods of verification of learning outcomes are presented in the table below.

Number of classes where the exam is required	7
Number of classes where a written exam is required	6
Number of classes where an oral exam is required	2
Number of hours devoted to the written exam	13
Number of hours devoted to oral exam	2
Estimated number of hours students should spend preparing for exams and credits	323
Number of classes which result in a pass without an exam	14
Number of hours to be completed in writing	11
Oral number of hours to complete	4
Estimated number of hours that students should spend on preparing for credits during semesters during classes (no final credits)	32
Number of classes in which the verification of the achieved learning outcomes is carried out on the basis of observation of performance (laboratories)	12
Number of laboratories where the achieved learning outcomes are checked on the basis of tests during the semester	5
Estimated number of hours students should spend in preparing for laboratory tests	26
Number of project classes in which the learning outcomes achieved are checked on the basis of a project presentation, a written report, a written report, an oral report or a project report	11
Estimated number of hours students should spend on design / documentation / report preparation and preparation for presentation	181
Number of lecture classes that require separate credit in writing or orally, regardless of the requirements of other forms of classes in this module	11
Estimated number of hours students should spend in preparing for lecture tests	69

3.3 Programme content

Programme content (educational content) is consistent with the learning outcomes and takes into account, in particular, the current state of knowledge and research methodology in the discipline or disciplines to which the course of study is assigned, as well as the results of scientific activity in this discipline or disciplines. A detailed description of the program content is available in the Module Activity Sheets on the website of the faculty.

Basics of nuclear energy	K_W02, K_W04, K_U01, K_K01, K_K03, K_K06
• Nuclear energy: a standard model, structure of the atomic nucleus, mass excess, radioactive decay, radioactive material, fissile materials, the impact of the neutron to the nucleus, fertile materials, physics of fission reaction, the Ogle reactor, nuclear fusion. • Nuclear reactors - operation: controlled fission reaction, delayed neutrons, multiplication factor, control of the reactor power, xenon poisoning and other operational issues, types and use of reactors, thermal reactors - moderators and coolants, fast reactors - coolants, breeder reactors - fuel production; structure of a nuclear power plant, reactor block, loops of coolants, safety and auxiliary systems. • Nuclear reactors - the types and design: nuclear reactors I and II generation - the genesis and development; Third-generation nuclear reactors, light water reactors PWR, light water reactors BWR, heavy water reactors CANDU, sodium reactors, gas reactors AGR; IV generation reactors, thermal reactors inherently safe, liquid metal reactors, hgh temperature gas reactors HTR , the Rubbi's reactor, heating reactors. • Fuel cycle: open and closed cycle, fissile and fertile materials - types and resources, the production of nuclear fuel, fuel enrichment and production of fuel elements, in the core fuel economy, transportation and processing of spent fuel, low and high-level waste - protection and storage. • Nuclear power vs environment, siting of power stations, failures of nuclear power plants, the effect of ionizing radiation on living organisms, the phenomenon of radiophobia, LNT hypothesis vs hormesis, the safety of nuclear energy, nuclear energy safety systems and procedures. • Nuclear energy: the current state and development plans in the world, the share of nuclear energy in electricity production, the development of nuclear technology in world regions, possible applications and development prospects. • Nuclear energy in Poland: the history of nuclear power in Poland, the plans and their implementation, the locations of the components of nuclear power. Prospects for the development of nuclear energy in Poland	
Biomass energy	K_W04, K_W05, K_W08, K_U01, K_U03, K_U04, K_U05, K_U06, K_U08
• Fundamentals of thermodynamics of combustion. Combustion of solid, liquid and gaseous fuels. Sources of biomass for energetic use. Thermophysical properties of biomass. Biomass combustion heat and calorific value. Theoretical bases of biomass combustion processes. Fundamentals of kinetics of the combustion process. Gasification of biomass. Technologies of the gasification. Energetic properties of the gaseous fuel - syngas - from biomass gasification. Biomass fermentation and biogas production. Properties and energetic use of the biogas. Possibilities of the applications of syngas and biogas in energy devices. Bimass from wood in energy devices. Methods of treatment of exhaust gas from biomass combustion. • The determination of the moisture content of energy plants. The determination of the calorific value of various types of biomass: The determination of the calorimeter constant The measurement of the calorific value of selected biomass with the use of standard bomb calorimeter. The measurement of the calorific value of selected biomass with the use of semi-automatic bomb calorimeter.	
Clean vehicle power drives modelling and testing	K_W04, K_W06, K_W08, K_W09, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06, K_U08, K_U09
• Basic concepts. Modern vehicle propulsion systems. Methods of modeling vehicles, propulsion systems. Methodology of vehicle testing for the WLTP procedure. Technologies of clean sources for powering vehicles. The current state for clean vehicle propulsion technologies. Analysis of development trends in the topics discussed. • Introduction to the lab. Getting acquainted with the software. Analysis of selected vehicle drives in the software. Clean drives used in transportation. Characteristics of selected vehicle powertrains. Electric, hybrid and internal combustion drives - characteristics and modeling. • Introduction to project activities. Project topic selection and discussion. Analysis of the realized project topic for clean vehicle propulsion. Work in the program. Modeling of drives and their testing.	
Energy devices	K_W01, K_W03, K_W04, K_W06, K_W08, K_U01, K_U03, K_U04, K_U05, K_U06, K_U08, K_U09

• Kinds and forms of energy, conversion of primary energy into secondary energy and energy units. Energy resources in the world and in Poland. The structure of consumption of primary energy sources. Fuels: Combustion of fuels. Energy fuels: coal, oil, natural gas and methane from coal beds and municipal landfills; LPG fuels. Biomass. General information about machines and thermal devices; division according to types and functions. Basic energy transformations that are important in practice. Modern thermal power plant, classification of power plants. Energy cell. Comparative Clausius-Rankine cycle modeling a condensing power plant as well as machines and devices in a simple condensing power plant. Instantaneous circulation efficiency. Enthalpy and entropy analysis of the steam power plant cycle. Characteristic parameters of the power plant. Technological modules of a steam condensing power plant. Water used in power plant. Raw water classification, pollution. Water quality indicators. Brief and complete water analysis. Boilers: Energy balance, boiler efficiency and heat losses. Markings of boilers. Characteristic sizes of boilers. Classification of steam boilers. Types of furnace and grate: Influence of the fuel combustion process in the furnace on the environment. Dust boilers. Boilers with supercritical parameters. Fluidized bed boilers in prospective energy technologies. Coal mills and their division. Mill installations. Construction and operation of a reciprocating steam engine. Advantages and disadvantages of steam engines. Compressors and fans. Centrifugal and axial fans. Ventilation ducts. Pumps, characteristics, types of pump. Turbines: steam and water turbines with auxiliary devices. The principle of operation of the action and reaction stages of the turbine. Simple installation of the gas turbine. Turbine energetic efficiency. Machines and devices used in the gas turbine system; compressor, gas turbine, combustion system, gears and fuel, cooling, starting, control and oil systems. Examples of turbine design solutions. Schemes of gas-steam systems. The use of gas turbines in other fields. Wind energies. Windmill, theoretical basis; power utilization factor; Betz's criterion. High-speed distinguishing feature. Properties and division of internal combustion engines. Construction and operation of internal combustion piston engines. Elements of thermal systems. Heat exchangers: types, methods of thermal and hydraulic calculations. Ways of lowering the wall temperature and improving the uniformity of the flow of media. Regenerators: advantages and disadvantages, examples of applications, methods of thermal calculations. Heat accumulators: construction, calculation, application examples. Dehydrators: types, installation diagrams. Chimneys: principle of operation, ecological limitations. Industrial water coolers. Cooling towers and fans. Refrigeration equipment. Refrigeration compressors: types, exemplary design solutions, principle of operation, examples of applications, advantages and disadvantages. Absorption refrigeration equipment: principle of operation, used refrigerants. Heating pumps: compressor, sorption and thermoelectric. Working factors of steam heating pumps. The use of heating pumps. Heat pipes and their application. Solar panels. Construction. Application. Generation of distributed electricity and heat. Technologies for the production of combined electricity and heat as well as technologies using renewable energy sources. • 1. Introductory information. Health and Safety. Discussion of the subject of laboratory exercises carried out as part of the subject and the methodology of measurements. 2. Evaluation of a pipe heat exchanger. 3. Energy balance of a plate heat exchanger. 4. Energy balance of a gas tankless water heater. 5. Efficiency evaluation of a CHP (Combined Heat and Power) unit. 6. Determination of the overall heat transfer coefficient of a finned tube. 7. Thermodynamic analysis of a steam power plant with a computer program. 8. Pass a laboratory • 1. Gas compressors. 2. Combustion of fuels. 3. Comparative cycles of steam and gas power plants. 4. The cycle of the engine room with inter-stage steam superheating. 5. The cycle of the regenerative gym. Real circuits of gas power plants. 6. Circuits of piston engines. 7. Co-current and counter-current heat exchangers. 8. Pass a tutorials	
Energy efficiency	K_W01, K_W03, K_W04, K_W05, K_W06, K_W07, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06
• Energy auditing - basic terms: definition of auditing, full and extended auditing. Methods of approach during the implementation of auditing. The purpose of auditing, preparation and collection of information, measurements, compilation of the energy balance • Expenditures and effects in projects to improve energy use. Characteristics of the effects caused by the implementation of projects. Ways of indicating financial resources for modernization. Reduce your energy costs. Calculation of the total effects of modernization • Economic profitability analysis of industrial installation modernization projects. Calculation of profitability indicators. Cash flows for specific income and expenses. Discount rate and discount factor. Actual interest rate. Financial flows financed from own resources. Cash flow when financing with a bank loan • Project profitability analysis. Discount methods. Simple methods of assessing profitability. Net present value. Internal rate of return. Payback period. The cost of producing a unit of energy. • Cost sensitivity analysis. Uncertainty due to capital expenditure. Methods of taking into account the risk - one-parameter sensitivity analysis. Profitability Assessment Examples - Calculating Net Present Value with known cash flows. Application of the payback period • Energy saving potential. Characteristics of buildings: flat roofs, roofs, external walls, doors, heating and ventilation systems. Reasons for heat loss. • Purpose and scope of auditing. Methodology. Assessment criteria. Basic technical data. Description of the building structure. Heating and ventilation installations - inventory. Assessment of the current technical condition. Determination of heating power demand and seasonal heat demand for heating. Determination of energy demand for domestic hot water. Heating and DHW charges. Proposed projects to improve the use of energy. Determining investment outlays. Profitability analysis results • Assessment of the technical condition of the building. Description of the structure. Building heating system • Calculation of heating power demand and heating costs. • Building ventilation system - determination of ventilation air demand • Energy balance of the selected facility. Proposed projects to improve the use of energy • Project profitability analysis. Investment expenditure	
Energy efficiency in transportation	K_W04, K_W07, K_W09, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06, K_U09
• Introduction - discussion of the course charter. Transport efficiency indicators. Energy sources in transportation. Energy efficiency in different branches of transport. Analysis of energy consumption in transport in terms of sustainable development. Energy consumption and pollution emission. Approval tests of the means of road transport. Energy demand by means of transport. Energy losses. Analysis of energy intensity of means of transport. Ways to reduce energy intensity in transport. Development trends in improving energy efficiency in transportation. • Introduction. Resistance of transport means to motion. Energy consumption of traffic. Energy demand of the means of land transport including the parameters of the driving cycle. Analysis of energy demand and energy consumption by selected modes of transportation, taking into account different types of propulsion: combustion, hybrid, electric. Credit. • Transportation energy efficiency analysis for selected sustainable transportation projects. Evaluation of environmental impact by means of transportation, taking into account the source of energy. Presentation of projects. Credit. • ntroduction, health and safety regulations. Road vehicles traffic resistance tests considering driving speed, load and tyre pressure. Energy efficiency tests on a chassis dynamometer Braking tests of the efficiency of the vehicle powertrain. Credit.	
Energy policy and legislation and social aspects of energy conversion and using	K_W07, K_W08, K_W12, K_W13, K_U01, K_K01, K_K02, K_K05
• Characteristics of the energy policy • Dimensions of energy security • Global trends in the energy policy • The aims of the EU energy and climate policy • Regulatory environment of the EU energy policy • The EU common energy market • EU energy transition • Geopolitics of energy transition - hydrogen • Opportunities and threats - the common EU hydrogen market • Barriers to the development of the hydrogen economy • Lobbying in the EU energy sector	
Energy sources and environmental aspects of energy conversion and using	K_W04, K_W05, K_W07, K_W08, K_W12, K_W13, K_U01, K_K01, K_K02, K_K05, K_K06
• Basic concepts: primary energy - energy carriers - direct energy - usable energy; primary and secondary energy sources; primary energy sources - primary energy - sources of primary energy- energy carrier; energy - anergy - exergy. • Promieniowanie słoneczne - generacja i właściwości. • The interaction of solar radiation with the atmosphere - direct and diffuse radiation. • Earth's energy balance - the energy balance of the surface - atmosphere - space, global and local energy balance, the global atmospheric circulation, the global ocean circulation. • The global atmospheric circulation: three-cell model, troposphere structure, global Hadley cell - transformations of energy, wind - generation mechanism, atmospheric dynamics of polar latitudes. • The water cycle and global oceanic circulation: small and large water cycle, ocean thermal structure, waves - formation, tides, surface circulation - causes and structure, thermohaline circulation. • Photosynthesis. Processes of sedimentation and storage of biomass. Geological processes of biomass transformation. Geological carbon deposits. Hydrocarbons formation processes and forms. • Rational energy managment: the concept and its evolution, energy management system components and their characteristics. • The concept of sustainable development: the concept of quality of	

life, components and their origin. The model of sustainable development: economic resources, human resources, demography, human vs environment. Sustainable development in the EU and Poland: historical picture, local conditions, EU legislation in the field of sustainability, legitimacy in the Polish legislation. • Energy conversion vs sustainable development: the energy needs of society, depletion of resources, Renewable energy sources and sustainable development. Energy efficiency: energy intensity of the economy, cumulative energy consumption account. • Energy balance: global and national energy demand, global and national reserves and resources of primary energy. • Characteristics of energy sources and carriers in Poland: the national energy system, the characteristics of producers and consumers, solid fuels subsystem, subsystem of liquid fuels, subsystem of gas fuels, electricity subsystem, heating subsystem, RES - hopes and realities, nuclear power - facts and myths. • Impact of energy on the environment - impacts and ways of influence. Impact of renewable sources of energy on the environment. Technical measures limiting the effects of the impact of energy on the environment. • Ecological cost. Life cycle analysis in energy technologies. Test	
Energy storage	K_W01, K_W03, K_W04, K_W05, K_W06, K_W08, K_U01, K_U03, K_U04, K_U05, K_U06, K_U08
• Storage in the fuel distribution system; Periodic storage; Load loveling; The mechanical equivalent of heat; Enthalpy, entropy, irreversible and reversible storage modes; the Carnot limitation, energy quality. • Thermal energy storage, Sensible and latent heat, Phase change materials; inorganic and organic PCM, quasi-latent heat; Reversible chemical reactions, thermal effects related to chemical reactions; Energy storage in organic fuels, hard biomass, synthetic fuels. • Mechanical energy storage, potential energy storage, energy storage in pressurized gas, potential energy storage using gravity, pump-hydro storage, kinetic energy in moving water, kinetic energy in mechanical systems. • Electromagnetic energy storage, energy storage in capacitors, electrochemical charge storage mechanisms, energy storage in magnetic systems; Hydrogen storage, hydrogen as a energy carier; the question of safety; Electrochemical energy storage, major reactions, the charge capasity, self discharge. • Calculation of mass and volume for different energy storage technologies; Ground heat storage system, Heat losses from thermal energy storage unit, Calculations of PCM storage units, Calculations of mechanical energy storage unit. • Design of a heat accumulator using phase change materials. • Measurements of phase change material properties, Measurement of storage capacity for different energy storage, Investigation of PCM energy storage unit.	
Ethical and legal issues of professional and scientific activity	K_W11, K_W14, K_U01, K_U07, K_U08, K_K01, K_K02, K_K04
• The notions of ethics and law, CSR in the activity of the scientific system and in the professional activity • Genesis and the determinants of the scientific system and professional activity • Sources of law and ethics • Contemporary forms of economic activity and ethics • New forms of activity of the scientific system on selected examples • Basic notions and genesis in the field of intellectual property protection • Industrial property and copyright - similarities and differences • Passing test	
Fluid mechanics	K_W03, K_U01, K_U03, K_U04, K_U05, K_U06, K_U08
• Basic equations of fluid Mechanicss and their simplified forms. • Potential Fluid Flow: two and three dimensional. • Vortical motion of fluids: Biot-Savart Law. Finite aspect ratio wings: various vortex methods approach: Prandtl-Glauert-Lenchester lifiting line, Vortex-Lattice Method. • Bounadary Layer: laminar and turbulent. Laminar-turbulent transition: natural or forced. Laminar bubble. Separation of boundary layer. Influence of boundary layer on characteristics of body. • Viscous flow tin the pipeline.. • Flows in the poen channels: sub and overcritical flows. • Flow of the compressible miedium. Isentropic gas flow in the channel with varying cross-section, Hydraulic hammmer phenomenon.	
Fuel cells fundamentals and portable technologies	K_W04, K_W06, K_W07, K_W09, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06, K_U08
• Physical basics and thermodynamics of electrochemical energy conversion and fuel cells. Kinetics of fuel cell reaction and charge transport. Operation characteristics and efficiency of fuel cells and factors influencing them. Modeling of fuel cells, polarization curves and measurement techniques of fuel cells. Hydrogen as a fuel and its characteristics, storage and use as well as safety aspects. Fuel cell systems and applications in transport. • Measurements of the performance characteristics of hydrogen fuel cells and drive units using hydrogen fuel cells. • Computational analyzes of the operation of hydrogen fuel cells and drive units using hydrogen fuel cells.	
Fundamentals of electrical power and grid	K_W01, K_W04, K_W06, K_U01, K_U03, K_U04, K_U05, K_U06, K_U08, K_U09
• Characteristics and basic concepts in power networks • The operation of the National Power System in Poland • AC and DC voltage transmission systems • System modeling - generators, transformers, transmission lines and loads • Calculations of flows of currents and power in the power grid • Distributed generation - phenomena occurring in power grids cooperating with sources in the field of "Clean Energy" technology • Integration of renewable energy and energy storage with smart grid • Electric car as a storage tank for prosumer energy • Impact on the supply network of renewable energy sources, assessment of the quality of electricity in networks with renewable energy sources • Energy efficiency and consumption of electricity from renewable sources • Modular FACTS (M-FACTS) solutions • The final test	
Heat networks and building internal systems	K_W06, K_W08, K_W09, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06, K_U08
• Thermal comfort requirements. The microclimate of the room - the parameters. Designed temperatures inside and outside • The rules of calculating heat transfer coefficients • Heat losses by infiltration and ventilation. Heat load calculations • Classification, characteristics and criteria for the selection of radiators. • Classification and characteristics of heating systems. • Graphic imaging of central heating installation • Hydraulic calculations of central heating installation • Classification and characterization of heat sources. Overview of types of boilers and thermal substations. • Safety of central heating installations of open and closed systems. • Introduction to district heating. Classification and characteristics of thermal substations. • Characteristic of technology and fittings used in heating and district heating systems. • Clasification and characteristic of technology district heating network. • Pre-insulated networks designing. • Computer-aided designing of heating and district heating systems. • Testing and commissioning of heating systems, thermal substations and heat networks. • The project of heating installation according to individual data for building. • Design of a dual-function thermal substation. • Analysis and testing of heating installations and devices. Study of temperature distribution in heating systems. Testing the hydraulic characteristics of water heating systems and elements of the pre-insulated network.	
Heat pumps and geothermal energy	K_W01, K_W03, K_W04, K_W05, K_W09, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06, K_U08, K_U09
• Quality of energy, Energy - anergy - exergy, the concept and types of exergy, substance source exergy and heat source exergy, exergy balance, Gouy-Stodola's law, exergy analysis and principles resulting from it. • Classification and characteristics of heat pumps, the principle of operation of compressor heat pumps, elements of compressor heat pumps, the basic Linde cycle, theoretical and real thermodynamic cycle, operating factors of compressor heat pumps - selection of operating factors and operating parameters, selection of design parameters, databases of working media properties - content and usage, modeling of the heat pump cycle. . • Renewable low energy sources for heat pumps - coherence and other properties. Ground, surface and ground water, air, solar collectors/ponds etc. as LSHP: properties, types of collectors, installation and operation requirements. Waste energy as low energy sources for heat pumps: municipal, industrial, etc.: properties, collection systems. • High energy sources for heat pumps: characteristics of heat receivers, HWS-CH microsystems, heating systems, building, municipal, industrial and other installations. • Characteristics of heat pumps. Control and regulation of heat pumps. Alternative, parallel systems. Bivalent points. Cascade systems. • Systems of installations with heat pumps. GHP and trigeneration systems, Mono and bivalent systems, multi-source and multi-receiver systems. Two and multi-tube systems. Errors made when designing installations with compressor heat pumps. • Absorption heat pumps: thermodynamic cycle, sorption systems; properties, fields of application, COP, cycle with regeneration, drive sources, elements of sorption heat pumps: boilers, absorbers, throttle valves, regenerative exchangers.. Thermo-economic characteristics of heat pumps. • Sub-cooling and superheating of the working medium of heat pumps, regenerative exchangers, multi-stage and cascade heat pump cycles,	

single-factor and multi-factor systems, one-refrigerant and a condenser-evaporator systems - advantages and disadvantages. Components of compressor heat pumps: compressors, throttle valves, condensers, evaporators. • Computer aided design of heat pump installations. Graphical imaging of installations with heat pumps. Principles of developing documentation for the implementation of a heat pump installation project. Commissioning of installations with heat pumps. • Geothermal energy: generation mechanism, geothermal gradient, nature and types of geothermal sources, hydrothermal basins, possibilities of using geothermal heat, geothermal energy in the world, European and Polish geothermal resources, Polish geothermal installations. • Ways of extracying of geothermal energy, organization of heat reception, single and multi-hole installations, characteristics of the heat carrier, material requirements, geothermal exchangers, geothermal power plants and heating plants. • Geothermal heating plants - basic technological schemes, the influence of the parameters of the geothermal resource and the upper source, the use of absorption and compression heat pumps, examples of implementation. • Geothermal power plants - basic technological schemes, the influence of geothermal parameters, the basic Rankine cycle, open and closed systems, ORC cycles, production efficiency - the influence of thermodynamic parameters and the working medium. • Calculation of left and right running steam cycles. Energy and hydraulic calculations for installations with heat pumps. • 1. Overview of the multisource electroenergetic system based in the Solar and Environment Thermal Energy Lab. 2. Influence of the parameters of high-temperature and low-temperature sources on the coefficient of performance and efficiency of the heat pump. 3. Experimental analysis of the vapor-compression heat pump cycle. 4. Coefficient of performance and pollutants emissions of the vapor-compression heat pump over the period of one month of the heating season. 5. Measurement of the thermal properties of the ground. 6. Thermoelectric heat pump efficiency. • Design of a multi-source and multi-sink installation with a heat pump	
Hydrogen and hybrid aircraft propulsion systems	K_W04, K_W06, K_W08, K_W09, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06, K_U08
• Power units and fuels used in transport • Hydrogen as the fuel of the future • Hydrogen power units in transport • Direct hydrogen combustion engines • Hybrid power units • Hydrogen drive units in other modes of transport • Technologies and materials used in hydrogen engines • Research on hydrogen and hybrid aviation propulsion systems • Analysis of physical processes in hydrogen powered power units. Simulation analyzes of aircraft propulsion systems using hydrogen.	
Hydrogen burners and combustion systems	K_W04, K_W06, K_W08, K_W09, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06, K_U08, K_U09
• The student learns about the basic properties of hydrogen and its mixtures as fuel. • The student gets acquainted with the thermodynamic bases of using hydrogen as a fuel. • the student learns the construction of piston engines, their combustion chambers and injection systems cooperating with hydrogen fuels • The student learns the construction of turbine engines, turbine combustion chambers and fuel systems in these engines. • The student learns the construction of rocket engines, their combustion chambers and fuel systems. • The student becomes familiar with the issues of exhaust emissions and ecological aspects.	
Hydrogen production, storage and distribution	K_W01, K_W04, K_W06, K_W08, K_U01, K_U03, K_U04, K_U05, K_U06, K_U08
• Why hydrogen - basic facts of hydrogen • Common methods of hydrogen production: thermal processes, electrytic processes, solar-driven processes, biological processes • Hydrogen storage technologies: compressed gas, liquid hydrogen, solid-state storage and underground hydrogen storage. • Fuel cells - operation and performance. Consideration of technology status, costs and market development. • Hydrogen technologies integration into the existing conventional autonomous power system. • Hydrogen-based autonomous power system - barriers and benefits. • Fuel cell vehicles - hydrogen in the transport sector.	
Liquid and gaseous biofuels	K_W04, K_W05, K_W08, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06, K_U08
• Introductory information - classification of conventional, alternative and biofuels used in transportation vehicles. Basics of fuel combustion process. Creation of alternative fuels and biofuels. Characteristics and operation of liquid alternative fuels and biofuels used in positive-ignition engines. Characteristics and operation of liquid alternative fuels and biofuels used in compression ignition engines. Gaseous alternative fuels. Properties of conventional and alternative fuel blends. Research methods used to assess the properties of alternative fuels and biofuels. • Introduction to the class. Health and safety rules in the ME lab. Automatic measurement of heat of combustion of diesel fuel with biocomponent additive. Methodology of determining the auto-ignition properties of fuels using the CVCC method. Use of oscillating densimeter to study the effect of temperature on the density of alcohol fuel. Automatic measurement of the ignition temperature of biofuel in a Martens Pensky closed crucible. Test of volatility of alcohol fuel. Automatic measurement of kinematic viscosity of fuel. Passing the laboratory exercises. • Introduction to the class. Development of a preliminary design of a system for evaluating physicochemical parameters of liquid biofuel. Development of a preliminary design of a system for evaluation of physicochemical parameters of gaseous biofuel. Pass the project.	
Master Diploma seminar HB&CT	K_U01, K_U02, K_U08, K_U09, K_K03, K_K06
• Gathering materials on a given topic using available sources: books, textbooks, magazines, Internet. Analysis of the collected material - short literature reports. Critical analysis of the material and its report containing references to the used sources with the knowledge gained during the studies. Editing and presentation of the thesis. Discussion on other diploma thesis topics carried out in the group.	
Master Diploma seminar SE&HP	K_U01, K_U02, K_U08, K_U09, K_K03, K_K06
• Gathering materials on a given topic using available sources: books, textbooks, magazines, Internet. Analysis of the collected material - short literature reports. Critical analysis of the material and its report containing references to the used sources with the knowledge gained during the studies. Editing and presentation of the thesis. Discussion on other diploma thesis topics carried out in the group.	
Master Diploma thesis	K_W04, K_W05, K_W06, K_W07, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06, K_U07, K_U09, K_K03, K_K04, K_K06
• The preparation of the thesis plan. • Looking for and analysis of the literature related to the subject of thesis. • Drawing conclusions from the study / analysis / calculations. • Editing of thesis. • Defending of the thesis.	
Modeling of energy transfer and systems	K_W03, K_W04, K_W05, K_W06, K_W07, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06
• The principle of conservation of energy, heat flow in solids: Fourier's law, Kirchhoff-Fourier differential equation. Boundary conditions: I, II, III and IV types, contact resistances, initial conditions. Differential equations describing convective heat transfer: Kirchhoff-Fourier, momentum balance for an incompressible fluid, equation of stream continuity. • Using MBE to solve stationary two-dimensional problems. Nonlinear heat conduction problems: temperature dependent thermal properties, nonlinear boundary conditions • Selected methods of solving systems of equations: iterative point line, Gauss-Saidel, Liebmann extrapolation. Selected methods of solving systems of equations: iterative point line, Gauss-Saidel, Liebmann extrapolation. Solving extramural problems: Euler explicit, implicit, Crank-Nickolson diagram. Stability conditions for a numerical solution for MBE. • Finite element method –MES: mathematical formulation of the method in terms of variation and Galerkin. Shape functions. Flat element: triangular and rectangular. • Building a conductivity matrix and creating a global system of equations. Solving stationary two-dimensional problems. Solving non-stationary problems - stability criteria • Principles of modeling flow and energy phenomena in elements of thermal devices; modeling of thermal systems and installations based on model sets of energy devices; static and dynamic states in the operation of power devices. • Characteristics of the ADINA-T commercial code. Analysis of stationary heat transfer in a solid. Modeling of radiation heat transfer in two-dimensional problems. • Modeling of a fixed heat transfer. Analysis of the nonlinear problem (thermal properties depending on temperature, anisotropy, nonlinear boundary conditions, radiation). • Modeling of transient heat transfer taking into account phase changes in two-dimensional problems. • Solving the problems of transient heat transfer. Analysis of three-dimensional issues. Analysis of thermo-mechanically coupled problems (contact resistance, friction). • Characteristics of the ADINA-F program. Exercises in modeling	

the established convective heat transfer under the conditions of free and forced convection. • Exercises in modeling flow and energy phenomena in elements of thermal devices and modeling of thermal systems and installations based on model sets of energy devices.	
Pasive solar systems	K_W04, K_W05, K_W08, K_W09, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06
• Types of energy sources, development strategy of solar systems. • Characteristics of individual solar radiation gains, characteristics of passive solar systems • Hybrid solar systems, prospects for the use of energy sources. • Practical importance of passive solar systems in construction. • The use of individual passive solar solutions in various building facilities, dimensioning of energy systems used in construction. • Issues concerning the present and future use of passive solar systems in construction.	
Photovoltaics	K_W01, K_W04, K_W05, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06, K_U08
• Solar radiation. Introduction to photovoltaic systems. Theoretical analysis and experimental study of PV system. • PV system components and configurations. Methods to improve the performance of solar PV panels using different cooling systems. Review of experimental and numerical studies. • Cells, modules and arrays, batteries, PV energy storage • Charge controllers for PV systems • Solar Inverters • System sizing. Electrical integration	
Project management	K_W10, K_W14, K_U01, K_U02, K_U07, K_U08, K_U09, K_K04
• Project definition. Examples of projects. Project features. Project management. Features of project management. Project types. Project evaluation parameters. • Organization of project teams: composition and competences of the project team, consultants and contractors, creating an organizational structure, building a project team, matrix organizational structure. Conditions for effective project management. Project management and changes. Threats to the proper implementation of the project. Project life cycle. • Defining and organizing the project. Problem identification. Determining the conditions. Desired target situation. Objectives of the projects. Initial project outline. • Risk and project change analysis. Risk analysis methods. Feasibility study. Project evaluation: technical, financial, operational, geographic, time, resource and legal feasibility. • Create a project plan. Planning. Basic elements of a project plan. Project plan limitations. Basic principles of planning the results and work. Detailed planning and time schedule. • Gantt charts. Project organization and control system. Common project management problems. Possibility to use standard software to supervise the implementation of projects. • Project tracking and supervision. Principles of project management. Project organization and control system. Project cost management. Closing the project. Final report. • Development of assumptions for the project: company model, justification of the topic, goals and scope of the project, expectations of interested parties, deadlines, assumptions and design constraints. • Development of the structure of project tasks • Development of the project's organizational structure and responsibility matrix • Assessment of the feasibility of the project, possible variants of the project implementation and assessment of the project's resistance to disruptions • Development of the project cost estimate • Development of the project implementation schedule. The use of Microsoft Project for project planning and supervision. • Presentation and defense of projects • Final test	
Solar radiation fundamentals and thermal solar systems	K_W03, K_W04, K_W05, K_W08, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06, K_U08, K_U09
• Electromagnetic radiation: types of electromagnetic radiation, radiation laws, interaction of electromagnetic radiation with a body. Solar radiation: emission spectrum of the Sun - the generation, emission spectrum of the Sun - a black body, solar constant. • Earth's orbital motion parameters - influence on the properties of solar radiation. • The interaction of solar radiation with the atmosphere: direct and diffuse radiation, the Bouguera- Lambert law, air mass, transparency of the atmosphere, strong absorption in heterogeneous medium, the spectrum of the scattered radiation, direct radiation spectrum - the influence of optical mass. • Solar energy - properties: equation of time, the way of the sun in the sky, the geometry of the Sun - absorber scheme, insolation and sunshine duration, the measurement of solar radiation, parameters and components of solar radiation. • Solar energy resources: solar resources in the world and in Europe, optimization of solar collector setup, technical resources of solar energy. • Low-temperature photothermal conversion: methods of using solar energy, photothermal conversion - operating principle, types and construction of low-temperature collectors. • Liquid solar collectors: energy balance of the collector, collector efficiency, research the collectors. • Systems of solar liquid collectors: the basic elements of the system, the types of collectors,hot water systems, integrated hot water/central heating systems, integrated multi-source and multiple receiver systems, cooperation of solar collectors with heat pumps and other heat sources. • Aerial collectors: types and principle of operation, low-cost solar - application and construction, rigid collectors , types and properties of absorbers, installation of aerial collectors. • High temperature photothermal conversion: types of concentrators, types of systems, Stirling engines, heliothermal energy - current status and prospects. • Solar ponds: types, structure and principle of operation, applications. Solar chimneys: construction and operation, use and properties, existing and planned installations. • Simplified analysis of installation shading and calculations of insolation based on the solar position graph and insolation tables, presentation of project results. • Simplyfied project of heating system in residential or public building for hot water and centaral heating based on solar collectors and supplementary source of high temperature heat. • Introductory classes. Measurement error analysis. • Influence of the orientation of a flat surface on the absorbed solar radiation. • Effects of setup of the flat surface on the power of absorbed solar radiation • Determination of the insolation and the sunshine duration values from the experimental database. • Determination of the characteristics of low temperature flat liquid collector. • Forecasting of the energy yield of a flat-plate solar collector with software simulation tools. • Determination of the atmospheric aerosol optical thickness from the skyradiometer measurements. • Solar energy properties calculations. • Insolation and sunshine duration, parameters and components of solar radiation. • Energy balance of the collector: transmission of energy in the system environment- transparent coatings-absorber, transmission-absorption ratio for direct and scattered radiation, coefficient of heat dissipation, thermal losses of the collector, the collector efficiency, the impact of parameter of the collector on efficiency.	
Thermodynamics and heat transfer	K_W03, K_W07, K_U01, K_U03, K_U04, K_U05, K_U06, K_U08, K_U09
• 1. Heat conduction - Fourier's law. Transient heat transfer equation with internal heat sources in single and multiple spatial dimensions in different coordinate systems and special cases. Thermal conductivity of materials. 2. Heat convection. Critical diameter of insulation. 3. Two-dimensional heat cnduction. Form factors. 4. Heat transfer by fins. 5. Transient heat conduction - lumped system with accumulation. Transient heat transfer - Heisler's and Grober's plots.. 6. Forced convection - Newton's law, Bernoulli's equation for the inviscid flow and the energy equation for compressible flow. Thermal and hydraulic boundary layer. 7. The theory of similarity Criterion numbers. 8. Forced convection in channels. 9. Natural convection. Grashof number, solution for the Nusselt number, examples of empirical correlations. 10. Heat radiation: physical mechanism, properties of bodies, Stefan-Boltzman law, Kirchhoff's identity, Planck's law, Wien's law, grey bodies. Form factors in radiation. 11. Heat exchangers: types, design problems. 12. Mass transfer. • 1. Steady heat conduction in flat and cylindrical walls. 2. Steady heat transfer in flat and cylindrical walls. 3. Steady heat transfer with fins. 4. Transient heat transfer in lumped system and half-space. 5. Forced convection without phase-change. 6. Free convection without phase-change. 7. Thermal radiation. • Introduction to measurement uncertainty The determination of the dependency between boiling point of water and pressure The determination of the enthalpy of evaporation (condensation) of water The indication of a piston compressor. The analysis of indicator diagrams The study of the dependence of rheological properties of liquids on temperature The determination of the calorific value of gaseous and liquid fuels The measurement of thermal conductivity of solids by means od plate and tubular apparatus The measurement of heat transfer coefficient in free convection on pipe The determination of thermal diffusivity with the ordered state method The experimental determination of heat transfer coefficient under transient heat transfer condition in a solid body The measurement of heat losses through building partitions using an auxiliary wall type meter	
Wind and hydro energy	K_W01, K_W04, K_W05, K_W08, K_U01, K_U02, K_U03, K_U04, K_U05, K_U06, K_U08, K_U09

• Conservation principles for fluid flow machinery. • Euler's equation for rotary machinery. • impulse model for open-rotor axial wind or water turbine. Betz's Limit.: Power curve for controlled and non-controlled rotors. • Axial turbine in yawed flow. Influence of wind yaw wind profile and interference with tower on turbine performance. • and water turbines with energy concentators: partially-static turbines. • Vertical axis wind and water turbines: VAWT. • Peculiar designs of the energy harvesting devices, employing the wind and water energy • Design schemes of wind turbines • Genarators applied in wind power plants • Generators appied in water turbines • Turbines suited for dam employing electric power stations • Water turbines: design schemes, Flow in the linear and circular cascades of hydrofoils. • Hydraulic devices of water turbines:: inlets, guiding vanes, spiraql chambers, suction diffusers. • Design setups of water electric power stations: flow type, with pipe or channel derivation, tdamm type or with pumped storage,