OGREVANJE IN HLAJENJE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	OGREVANJE IN HLAJENJE
Course title:	HEATING AND COOLING
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo, tretja stopnja, doktorski	Energetske, procesne in okoljske inženirske znanosti (smer)	1. letnik, 2. letnik	Celoletni	izbirni

Univerzitetna koda predmeta/University course code:	0033450
Koda učne enote na članici/UL Member course code:	7205

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
90					160	10

Nosilec predmeta/Lecturer:	Andrej Kitanovski
Izvajalci predavanj:	Ciril Arkar, Andrej Kitanovski, Uroš Stritih
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni predmet /Elective course

Jeziki/Languages:	Predavanja/Lectures:	Angleščina, Slovenščina
	Vaje/Tutorial:	Angleščina, Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Veljajo splošni pogoji za doktorski študij.	General prerequisites for the third level studies.

Vsebina:	**Content (Syllabus outline):**
Pomen ogrevanja in hlajenja za človeško zdravje in delazmožnost v stavbah. Termodinamična analiza grelnih, hladilnih in klimatskih procesov. Raba primarne energije za ogrevanje in hlajenje. Eksergijska analiza procesov. Načini in ukrepi za izvedbo nizko exergijskih grelnih in hladilnih procesov. Zmanjšanje vplivov na okolje z alternativnimi viri energije. Statično in dinamično modeliranje procesov pretvorbe in rabe energije. Simulacija delovanja grelnih, hladilnih in klimatskih naprav. Optimizacija ogrevalnih, hladilnih in klimatskih sistemov glede na tehnično primernost in ekonomsko učinkovitost. Kombinirani sistemi z izkoriščanjem obnovljivih virov energije. Klasični in sorpcijski hladilniki gnani s toplotnimi kompresorji. Obrnljive toplotne črpalke gnane z električno energijo ali z odvečno toploto iz industrijskih procesov. Povezani grelno hladilni sistemi z izrabo odvečne toplote kondenzatorjev za sočasno hlajenje in ogrevanje objektov. Ekonomska analiza obratovalnih režimov ter optimizacija delovanja glede na minimalne letne stroške. Sodobni sistemi oskrbe objektov z grelno in hladilno energijo. Kogeneracija in trigeneracija. Daljinski energetski	Importance of heating and cooling for health of human being and working capability in buildings. Thermodynamic analysis of heating, cooling and air-conditioning processes. Usage of primary energy for heating, cooling and air-conditioning. Energy and exergy process analysis. Methods and measures for low-energy achievement of heating and cooling processes. Environment reduction influence with alternative sources of energy. Static and dynamic modeling of transformation processes and energy usage. Simulation of heating, cooling and air-conditioning systems operating due to the technical suitability and economical effectiveness. Combined systems with renewable energy sources exploitations. Classical and sorption’s refrigerators impelled by thermal compressors. Reversible heat pumps impelled by electrical energy or by waste heat from industrial processes. Fasten together heating cooling systems with condensers redundant heat for contemporary cooling and heating of buildings. Economic analysis of operating regimes and optimal operating due to the minimal annual costs. Advanced systems for heating and cooling energy supply. Cogeneration and

sistemi. Daljinsko ogrevanje in daljinsko hlajenje. Napredne ogrevalne, hladilne in klimatske naprave in sistemi. Ocena stroškov inštalacij ogrevanja, hlajenja in klimatizacije v življenjskem krogu (LCCA). LCC management, metode in orodja. Energijska študija posameznih sistemov, primerjava in vplivi na okolje. Delovanje stavbe in management. Industrijske aplikacije. Komisisoning. Energijsko povezane aplikacije (geotermalna, uporaba sončne energije, toplotni hranilniki, ...). Hibridni sistemi z uporabo fazno spremenljivih snovi (PCM).	tri-generation. District energy systems. District heating and district cooling. Advanced heating, cooling and air-conditioning device and systems. Costs evaluation of heating, cooling and air-conditioning installations in life cycle cost assessment (LCCA). Life cycle cost management, methods and tools. Energy study of individual systems, relationship and environment impact. Building operating and management. Commissioning. Industrial applications. Energy related applications (geothermal, solar energy usage, thermal storage ...). Hybrid systems using phase change materials (PCM).

Temeljna literatura in viri/Readings:

[1] Kotas, T.J.: The Exergy methods of thermal plant analyses.- London: Butterworths, 1985. [COBISS.SI-ID – 1166085]
[2] Stoecker, W.F.: Design of thermal systems.- 3rd ed.- New York /etc.): McGraw-Hill, 1989. [COBISS.SI-ID – 939269]
[3] Gosney, W.B.: Principles of refrigeration.- Cambridge /etc./: Cambridge University Press, 1982. [COBISS.SI-ID – 743707]
[4] ASHRAE Handbook: HVAC Systems and Equipment, Atlanta, 2008, izbrana poglavja. [COBISS.SI-ID – 15736603]
[5] ASHRAE Handbook: HVAC Application, Atlanta, 2007, izbrana poglavja. [COBISS.SI-ID – 1196827]
[6] Wrixon, G.T.: Renewable energy – 2000, Berlin, 1993. [COBISS.SI-ID – 14643717]
[7] Sorensen,B.: Renewable energy conversion, transmission and storage, Amsterdam, 2007. [COBISS.SI-ID – 29233925]

Cilji in kompetence:	**Objectives and competences:**
Cilji: Študentu prikazati vlogo in pomen ogrevanja in hlajenja z namenom zagotavljanja in vzdrževanja ustreznih bivalnih in delovnih pogojev. Predstaviti vse možne načine in principe za zmanjšanje rabe energije pri ogrevanju, hlajenju in klimatizaciji prostorov v stavbah ter industrijskem hlajenju. Podati možne načine za učinkovito integracijo sistemov ogrevanja, hlajenja in klimatizacije v procesne sisteme.	**Goals:** To show the role and importance of heating and cooling with the aim of providing and maintaining adequate living and working conditions. Present all possible ways and principles for the reduction of energy use for heating, cooling and air-conditioning in the building and industrial cooling. To show all possible ways and principles for lowering the energy use for heating, cooling, air conditioning systems in

Pokazati nove napredne sisteme ogrevanja, hlajenja in klimatizacije za zagotavljanje varčevanja z energijo in višje stopnje ugodja v bivalnem in delovnem okolju. Usposobiti študenta za samostojno raziskovalno delo. **Kompetence:** Študent osvoji nova znanja in nadgradi že pridobljena znanja za izračun in modeliranje toplotnih izgub in dobitkov stavb. Nadalje študent na konkretnih primerih pridobi znanje in praktične izkušnje za obvladovanje računalniških orodij za simulacijo tokovnih in temperaturnih razmer v prostoru ter delovanja sistemov ogrevanja in hlajenja. Študent si z eksperimentalnim delom na laboratorijskih modelih sistemov ogrevanja, hlajenja in klimatizacije pridobi praktične izkušnje in rezultate za preverjanje rezultatov simulacij. Študent bo kompetenten za samostojno razumevanje, ocenjevanje in ovrednotenje ogrevalnih, hladilnih in klimatskih sistemov.	buildings and industrial cooling. Give possible ways for the effective integration of the heating, cooling and air conditioning systems in the process systems. To demonstrate a new advanced systems for heating, cooling and air conditioning to provide energy savings and a higher level of comfort in living and working environment. Qualify students for independent research. **Competences:** The student acquires basic skills and upgrades the already acquired knowledge for the calculation and modeling of thermal losses and gains of buildings. Furthermore, a student on concrete examples acquired the knowledge and practical experience for the control of computer tools for the simulation of flow and temperature conditions in the room and the operation of the heating, cooling and air conditioning systems. Student with the help of the experimental work on laboratory models of the heating, cooling and air conditioning acquire practical experience and results, which are verified with the results of simulations. The student will be competent for a self-dependent understanding, assessment and evaluation of heating, cooling and air-conditioning systems.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Študent osvoji nova znanja in nadgradi že pridobljena znanja za izračun in modeliranje toplotnih izgub in dobitkov stavb. Nadalje študent na konkretnih primerih pridobi znanje in praktične izkušnje za obvladovanje računalniških orodij za simulacijo tokovnih in temperaturnih razmer v prostoru ter delovanja sistemov ogrevanja in hlajenja. Študent si z eksperimentalnim delom na laboratorijskih modelih sistemov ogrevanja, hlajenja in klimatizacije pridobi praktične izkušnje in rezultate za preverjanje rezultatov	The student acquires basic skills and upgrades the already acquired knowledge for the calculation and modeling of thermal losses and gains of buildings. Furthermore, a student on concrete examples acquired the knowledge and practical experience for the control of computer tools for the simulation of flow and temperature conditions in the room and the operation of the heating, cooling and air conditioning systems. Student with the help of the experimental work on laboratory models of the heating,

simulacij. Študent bo kompetenten za samostojno razumevanje, ocenjevanje in ovrednotenje ogrevalnih, hladilnih in klimatskih sistemov.	cooling and air conditioning acquire practical experience and results, which are verified with the results of simulations. The student will be competent for a self-dependent understanding, assessment and evaluation of heating, cooling and air-conditioning systems.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, laboratorijske vaje, seminarsko delo, e-izobraževanje, konzultacije. Seminarsko delo v čim večji meri navezujoče se na področje doktorskega raziskovanja. Študij z uporabo priporočene literature.	Lectures, laboratory practice & seminar work, e-education, consulting. The seminar work is related, as much as possible, to the student's doctoral research field. Study on a recommended literature basis.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Ustni izpit, poročilo o seminarskem delu. Pogoj za opravljanje ustnega izpita je uspešno izdelano in pozitivno ocenjeno seminarsko delo: • seminarsko delo 60% • ustni izpit 40%		Oral exam, report on seminar work. The condition for admission to oral exam is successful completion of seminar work, rewarded with a passing grade: • Seminar assignment (60%) • Oral exam (40%)

Ocenjevalna lestvica:	**Grading system:**
5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10

Reference nosilca/Lecturer's references:

prof. dr. Andrej Kitanovski

LORBEK, Luka, KUHELJ, Anja, DULAR, Matevž, KITANOVSKI, Andrej. Two-phase flow patterns in adiabatic refrigerant flow through capillary tubes. *International journal of refrigeration*. [Print ed.]. 2020, vol. 115, str. 107-116, ilustr. ISSN 0140-7007. https://repozitorij.uni-lj.si/IzpisGradiva.php?id=124219, DOI: 10.1016/j.ijrefrig.2020.02.030. [COBISS.SI-ID 17060891], [JCR, SNIP, WoS do 23. 12. 2022: št. citatov (TC): 8, čistih citatov (CI): 7, čistih citatov na avtorja (CIAu): 1,75, Scopus do 28. 3. 2023: št. citatov (TC): 9, čistih citatov (CI): 8, čistih citatov na avtorja (CIAu): 2,00]

KLINAR, Katja, TOMC, Urban, JELENC, Blaž, NOSAN, Simon, KITANOVSKI,

Andrej. New frontiers in magnetic refrigeration with high oscillation energy-efficient electromagnets. Applied energy. Feb. 2019, vol. 236, str. 1062-1077, ilustr. ISSN 0306-2619. https://www.sciencedirect.com/science/article/pii/S0306261918318749, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=105929, DOI: 10.1016/j.apenergy.2018.12.055. [COBISS.SI-ID 16410139], [JCR, SNIP, WoS do 14. 4. 2023: št. citatov (TC): 24, čistih citatov (CI): 19, čistih citatov na avtorja (CIAu): 3,80, Scopus do 22. 4. 2023: št. citatov (TC): 30, čistih citatov (CI): 21, čistih citatov na avtorja (CIAu): 4,20]

PLAZNIK, Uroš, VRABELJ, Marko, KUTNJAK, Zdravko, MALIČ, Barbara, ROŽIČ, Brigita, POREDOŠ, Alojz, KITANOVSKI, Andrej. Numerical modelling and experimental validation of a regenerative electrocaloric cooler. International journal of refrigeration. [Print ed.]. Feb. 2019, vol. 98, str. 139-149, ilustr. ISSN 0140-7007. https://www.sciencedirect.com/science/article/pii/S0140700718304201?via%3Dihub, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=105768, DOI: 10.1016/j.ijrefrig.2018.10.029. [COBISS.SI-ID 31863079], [JCR, SNIP, WoS do 24. 1. 2023: št. citatov (TC): 29, čistih citatov (CI): 26, čistih citatov na avtorja (CIAu): 3,71, Scopus do 6. 4. 2023: št. citatov (TC): 32, čistih citatov (CI): 29, čistih citatov na avtorja (CIAu): 4,14]

PLAZNIK, Uroš, VRABELJ, Marko, KUTNJAK, Zdravko, MALIČ, Barbara, POREDOŠ, Alojz, KITANOVSKI, Andrej. Electrocaloric cooling : the importance of electric-energy recovery and heat regeneration. Europhysics letters : EPL. 2015, vol. 111, nr. 5, str. 57009-1-57009-6, ilustr. ISSN 0295-5075. https://repozitorij.uni-lj.si/IzpisGradiva.php?id=126396, DOI: 10.1209/0295-5075/111/57009. [COBISS.SI-ID 14221083], [JCR, SNIP, WoS do 24. 9. 2022: št. citatov (TC): 28, čistih citatov (CI): 18, čistih citatov na avtorja (CIAu): 3,00, Scopus do 22. 12. 2022: št. citatov (TC): 29, čistih citatov (CI): 19, čistih citatov na avtorja (CIAu): 3,17]

izr. prof. dr. Ciril Arkar

MEDVED, Sašo, BABNIK, Miha, VIDRIH, Boris, ARKAR, Ciril. Parametric study on the advantages of weather-predicted control algorithm of free cooling ventilation system. *Energy*. Aug. 2014, vol. 73, str. 80-87, ilustr. ISSN 0360-5442. DOI: 10.1016/j.energy.2014.05.080. [COBISS.SI-ID 13562907]

VENKO, Samo, PAVLOVIČ, Erik, VIDRIH, Boris, ARKAR, Ciril, MEDVED, Sašo. An experimental study of mixed convection over various thermal activation lengths of vertical TABS. *Energy and buildings*. [Print ed.]. 2015, vol. 98, str. 151-160, ilustr. ISSN 0378-7788. DOI: 10.1016/j.enbuild.2014.08.036. [COBISS.SI-ID 13757467]

MEDVED, Sašo, BEGELJ, Žiga, DOMJAN, Suzana, ŠUKLJE, Tomaž, ČERNE, Boštjan, ARKAR, Ciril. The dynamic thermal response model and energy performance of multi-layer glass and BIPV facade structures. *Energy and buildings*. [Print ed.]. Apr. 2019, vol. 188/189, str. 239-251, ilustr. ISSN 0378-7788. https://www.sciencedirect.com/science/article/pii/S0378778818332997?via%3Dihub, DOI: 10.1016/j.enbuild.2019.02.017. [COBISS.SI-ID 16497179]

DOMJAN, Suzana, ARKAR, Ciril, BEGELJ, Žiga, MEDVED, Sašo. Evolution of all-glass nearly zero energy buildings with respect to the local climate and free-cooling

techniques. *Building and environment*. [Print ed.]. 2019, vol. 160, str. 1-15, ilustr. ISSN 0360-1323. https://www.sciencedirect.com/science/article/pii/S0360132319303932?via%3Dihub, DOI: 10.1016/j.buildenv.2019.106183. [COBISS.SI-ID 16653339]

izr. prof. dr. Uroš Stritih

Zavrl, Eva ; El Mankibi, Mohamed ; Dovjak, Mateja ; Stritih, Uroš: Experimental investigation of air-based active-passive system for cooling application in buildings. Leto: 2022, Vir: Sustainable cities and society [Elektronski vir]. - ISSN 2210-6715. - Vol. 85, str. 1-13, COBISS.SI-ID 117204483

Mlakar, Urška ; Stropnik, Rok ; Koželj, Rok ; Medved, Sašo ; Stritih, Uroš Experimental and numerical analysis of seasonal solar-energy storage in buildings. Leto: 2019, Vir: International journal of energy research. - ISSN 0363-907X. - Vol. 43, iss. 12, str. 6409-6418, COBISS.SI-ID 16558619

Krese, Gorazd ; Koželj, Rok ; Butala, Vincenc ; Stritih, Uroš: Thermochemical seasonal solar energy storage for heating and cooling of buildings. Leto: 2018, Vir: Energy and buildings. - ISSN 0378-7788. - Vol. 164, str. 239-253 COBISS.SI-ID 15839515

Stropnik, Rok ; Stritih, Uroš: Increasing the efficiency of PV panel with the use of PCM. Leto: 2016, Vir: Renewable energy, - ISSN 0960-1481. – Vol. 97, str. 671-679 COBISS.SI-ID 14692891

Osterman, Eneja ; Hagel, K. ; Rathgeber, C. ; Butala, Vincenc ; Stritih, Uroš: Parametrical analysis of latent heat and cold storage for heating and cooling of rooms. Leto: 2015, Vir: Applied thermal engineering. - ISSN 1359-4311. - Vol. 84, str. 138-149, COBISS.SI-ID 13978139

Osterman, Eneja ; Butala, Vincenc ; Stritih, Uroš: PCM thermal storage system for free heating and cooling of buildings. Leto: 2015, Vir: Energy and buildings. - ISSN 0378-7788. - Vol. 106, str. 125-133 COBISS.SI-ID 14117659