# UČNI NAČRT PREDMETA/COURSE SYLLABUS

| | |
|---|---|
| **Predmet:** | Solarne tehnologije |
| **Course title:** | SOLAR UTILITY TECHNOLOGIES |
| **Članica nosilka/UL Member:** | UL FS |

| **Študijski programi in stopnja** | **Študijska smer** | **Letnik** | **Semestri** |
|---|---|---|---|
| Strojništvo - Razvojno raziskovalni program, druga stopnja, magistrski | Procesno strojništvo (smer) | 1. letnik | 1. semester |

| | |
|---|---|
| **Univerzitetna koda predmeta/University course code:** | 0566915 |
| **Koda učne enote na članici/UL Member course code:** | 6016-M |

| **Predavanja** | **Seminar** | **Vaje** | **Klinične vaje** | **Druge oblike študija** | **Samostojno delo** | **ECTS** |
|---|---|---|---|---|---|---|
| 30 | | 30 | | | 65 | 5 |

| | |
|---|---|
| **Nosilec predmeta/Lecturer:** | Ciril Arkar, Sašo Medved |

| | |
|---|---|
| **Vrsta predmeta/Course type:** | Obvezni strokovni predmet na smeri Procesno strojništvo, ki je izbirni strokovni predmet na ostalih smereh./Compulsory specialised course in the study of Process Engineering, which is an elective specialised course in other fields of study. |

| | | |
|---|---|---|
| **Jeziki/Languages:** | Predavanja/Lectures: | Slovenščina |
| | Vaje/Tutorial: | Slovenščina |

| **Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** | **Prerequisites:** |
|---|---|
| Izpolnjevanje pogojev za vpis v Magistrski študijski program II. stopnje Strojništvo - Razvojno raziskovalni program. | Meeting the enrollment conditions for the Master's study programme of Mechanical Engineering - Research and Development program. |

| **Vsebina:** | **Content (Syllabus outline):** |
|---|---|
| 1. Obnovljivi viri energije v perspektivi 2030 in 2050:<br>- Nastanek obnovljivih virov energije;<br>- Vloga OVE v preteklosti in prihodnosti;<br>- Vloga OVE v mednarodnih in nacionalni energetsko-okoljski politiki; | 1. Renewable energy sources (RES) in perspective 2030 and 2050<br>- Origin of renewable energy sources; |

| | |
|---|---|
| - Modeliranje potenciala OVE, potencial v SLO.<br>2. Sončno sevanje in obsevanje:<br>- Metode oblikovanja podatkovnih baz;<br>- Podatkovne baze v SLO;<br>- Modeliranje ekstraterističnega in terističnega sončnega sevanja;<br>- Optične lastnosti ozračja;<br>- Modeliranje svetlosti neba.<br>3. Teristično sončno sevanje na poljubno orientirane ploskve:<br>- Komponente sončnega sevanja;<br>- Optimiranje namestitve nepremičnih ter 2D in 3D premičnih površin za zajem sončnega sevanja.<br>4. Selektivne sprejemne in oddajne površine:<br>- Prenos toplote s kratko in dolgovalovnim sevanjem na sprejemnih površinah;<br>- Modeliranje selektivnih optičnih lastnosti;<br>- Aplikacije za učinkovitejše pretvarjanje sončne energije.<br>5. Solarni toplotni sistemi I:<br>- Pasivni sistemi v stavbah;<br>- Pasivno in adaptivno senčenje sprejemnih površin;<br>- Shranjevanje toplote v pasivnih elementih;<br>- Modeliranje toplotnega odziva gradnikov pasivnih elementov (zasteklitev, solarni zid, Trombov zid).<br>6. Solarni toplotni sistemi II:<br>- Sprejemniki sončne energije in koncentratorji sončnega sevanja;<br>- Vodni, toplozračni in TPV sprejemniki sončne energije;<br>- Modeliranje energetske bilance;<br>- Določitev in navajanje učinkovitosti, preizkušanje sprejemnikov sončne energije;<br>- Sodobne tehnologije in materiali za srednje in visokotemperaturne aplikacije.<br>7. Solarni toplotni sistemi III:<br>- Aktivni solarni ogrevalni sistemi in njihovi gradniki;<br>- Vodni in toplozračni sistemi;<br>- Modeliranje energijskih tokov v gradnikih;<br>- Učinkovitost komponent in sistemov;<br>- Načrtovanje in modeliranje termosifonskih, črpalčnih in daljinskih solarnih ogrevalnih sistemov, študije primerov.<br>8. Solarne tehnologije v agronomiji:<br>- Model rasti;<br>- Modeliranje rastlinjakov;<br>- Drugi obnovljivi viri toplote.<br>9. Solarni toplotni sistemi za proizvodnjo električne energije:<br>- Solarni dimniki, solarna jezera, solarne toplotne elektrarne;<br>- Modeliranje energijskih tokov;<br>- Okoljski in stroškovni vidiki solarnih toplotnih elektrarn. | - The role of RES in the past and in the future;<br>- The role of RES in national and international energy and environmental policy;<br>- Modelling of RES potential and RES potential in Slovenia.<br>2. Solar irradiation and radiation<br>- Database design methods;<br>- Database for Slovenia region;<br>- Modelling of extraterrestrial and terrestrial solar irradiation;<br>- Optical properties of atmosphere;<br>- Modelling of sky illuminance.<br>3. Terrestrial solar irradiation on tilted surfaces<br>- Components of solar irradiation;<br>- Design and optimization of stationary and 2D and 3D tracking surface to capture solar irradiation.<br>4 .Selective absorption and emission surfaces:<br>- short and long wavelength radiative heat transfer on receiving/emitting surfaces;<br>- modelling of selective radiative properties of receiving/emitting surfaces;<br>- applications of selective surfaces for utilization of solar energy.<br>5. Solar thermal systems I:<br>- Passive solar heating of buildings;<br>- Passive and adaptive shading;<br>- Heat storage in building structures;<br>- Modelling of thermal response of passive systems (e.g. glazing, solar wall, Trombe wall).<br>6. Solar thermal systems II:<br>- Solar collectors and solar concentrators;<br>- Hydronic, air and TPV solar collectors;<br>- Modelling of solar collectors energy balance;<br>- Evaluation and indication of efficiency of solar collectors;<br>- Advance materials and solutions for mid and high temperature applications.<br>7. Solar thermal systems III:<br>- Active solar heating systems and building blocks;<br>- Hydronic and air systems;<br>- Modelling of energy balance in blocks of active solar thermal systems;<br>- Design and modelling of thermosiphon, pumped and district solar thermal systems and case studies.<br>8. Solar energy utilization in agriculture:<br>- Modeling plants growth;<br>- Modelling of energy balance of greenhouse;<br>- Backup renewable heat sources.<br>9. Solar thermal systems for electricity production (STPP):<br>- Solar chimney; solar pond; soalr thermal power plants;<br>- Modelling of energy balance of STPP;<br>- Environmental and cost assessment of STPP. |

| | |
|---|---|
| 10. Solarne tehnologije za industrijske aplikacije:<br>- Aplikacije za sušenje;<br>- Razsoljevanje;<br>- Solarna kemija, razgradnja odpadkov.<br>11. Solarni hladilni sistemi:<br>- Tehnologije;<br>- Modeliranje energijski bilanc;<br>- Povezava modelov sprejemnikov sončne energije ter modela toplotnega odziva stavb;<br>- Analize primerov.<br>12. Računalniška orodja za modeliranje solarnih ogrevalnih in hladilnih sistemov:<br>- Mesečne in urne metode;<br>- RETSCREEN;<br>- Dinamično modeliranje.<br>13. Solarni sistemi za proizvodnjo električne energije I:<br>- Elektrotehnične osnove PV in razširjenost;<br>- Parametrični modeli učinkovitosti;<br>- Zrcala, sledilniki in načrtovanje.<br>14. Solarni sistemi za proizvodnjo električne energije II:<br>- PV sistemi z otočnim in omrežnim delovanjem;<br>- Zasnova in gradnja;<br>- Tehnične zahteve;<br>- Shranjevanje električne energije on-site;<br>- LCA in LCC analize PV sistemov.<br>15. Računalnišča orodja za modeliranje PV sistemov:<br>- Optimiranje sončnega obsevanja;<br>- Analiza senčenja, mesečna in urna metoda;<br>- Priključitev v omrežje;<br>- Net-metering in zagotovljen odkup. | 10. Solar utilization technologies for industrial applications:<br>- Solar drying;<br>- Desalination;<br>- Solar chemistry, thermal waste treatment.<br>11. Solar cooling:<br>- Solar cooling heat driven processes;<br>- Modelling of energy balance;<br>- Coupling thermal response model of the solar heating system and thermal response model of the building;<br>- Case studies.<br>12. Computer modelling of solar heating and cooling systems:<br>- Monthly and hourly methods;<br>- RETSCREEN tool demonstration;<br>- Dynamic modelling.<br>13. Photovoltaic (PV) systems I:<br>- Electrotechnical basics of PV and PV system utilization status;<br>- Parametric models of PV cell and PV module efficiency;<br>- Design of solar concentrators and tracking device for PV modules.<br>14. Photovoltaic (PV) systems II:<br>- Off-grid and grid connected systems;<br>- Design and construction;<br>- Technical requirements for safe operation;<br>- On-site electricity storage;<br>- LCA and LCC assessment of PV systems.<br>15. Computer tools for modelling of PV systems:<br>- Optimization of solar radiation potential;<br>- Shading assessment, monthly and hourly methods;<br>- Grid connection;<br>- Net-metering and feed-in tariff schemes. |

**Temeljna literatura in viri/Readings:**


1. Medved, S., Arkar, C. Renewable energy sources : 2. stopnja Strojništvo, Študijsko gradivo. Fakulteta za strojništvo, Ljubljana, 2019.
2. Duffie, J. A., Beckman, W. A. Solar engineering of thermal processes. 2nd Edition. John Wiley & Sons, Inc., New York, 1991.
3. Tiwari, G. N., Tiwari, A., Shyam. Handbook of Solar Energy : Theory, Analysis and Applications. Springer Singapore, 2016.
4. Malamatenios, C., Giakoumelos, L., Mavrou, E. Handbook for the Renewable Energy Sources Course. Centre for Renewable Energy Sources and Saving, Athens, 2016.A


| **Cilji in kompetence:** | **Objectives and competences:** |
|---|---|
| Cilji: | Education goals: |

| | |
|---|---|
| 1. Spoznati pomen OVE s poudarkom na procesih in tehnologijah pretvarjanja sončne energije v toploto, hlad in električno energijo ter aplikacije v agronomiji in solarni kemiji.<br>2. Pridobiti znanje na področju modeliranja energijske učinkovitosti, okoljske primernosti in stroškovne učinkovitosti solarnih tehnologij.<br>Kompetence:<br>1. S1-MAG, P1-MAG: Razvijanje novih znanj in razumevanja s področja varovanja okolja in tehnologij za pretvarjanje sončne energije. Sposobnost za nadgrajevanje znanj s področja energetike.<br>2. S10-MAG, P7-MAG: Sposobnost uporabe sodobnih raziskovalnih postopkov in orodij za numerično modeliranje procesov in tehnologij za pretvarjanje sončne energije. Sposobnost iskanja optimalnih rešitev energetske oskrbe stavb in mest s sončno energijo. | 1. Learn about renewable energy source with emphases on the solar energy utilization for supply of heat, cold and electricity as well as applications for agriculture and solar chemistry.<br>2. Learn about methods and techniques of modelling of energy efficiency, environmental advantages and cost optimization of solar utilization technologies.<br>Competence:<br>1. S1-MAG, P1-MAG The ability to define and understand fundamental scientific problems in field of solar energy utilization to creatively deal with professional challenges and the ability to upgrade and use the fundamental mechanical engineering knowledge, including the developmental-technical implementation.<br>2. The ability to use modern research methods and procedures for modelling solar utilization processes, systems and devices and gain capacity to transfer the knowledge into the practice in form of optimal solutions based on analysis and synthesis. |

| **Predvideni študijski rezultati:** | **Intended learning outcomes:** |
|---|---|
| Znanja:<br>Z2: Poglobljeno teoretično, metodološko in analitično znanje z elementi raziskovanja, ki so osnova za zelo zahtevno stokovno delo na področju vrednotenja in uvajanja solarnih tehnologij.<br>Spretnosti:<br>S2.1: Obvladovanje zelo zahtevnih energetskih procesov z uporabo numeričnih orodij na področju pretvarjanja sončne energije. | Knowledge:<br>Z2: Thorough theoretical, methodological, analytical knowledge with elements of research work that form a basis for very demanding professional work in field of design and assessment of solar utility technologies.<br>Skills:<br>S2.1: Mastering very demanding and complex work processes and methodological tools in specialised professional fields of design and evaluating of solar utility technologies. |

| **Metode poučevanja in učenja:** | **Learning and teaching methods:** |
|---|---|
| Klasične oblike poučevanja:<br>P1: Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov.<br>P3: Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri.<br>P4: Laboratorijske vaje z namenskimi didaktičnimi pripomočki z dostopom na daljavo. | Conventional teaching methods:<br>P1: Auditorial lectures with solving selected field-specific theoretical and applied use cases.<br>P3: Auditorial exercises, in which theoretical content from lectures is supported with practical examples.<br>P4: Laboratory work with dedicated computer tools and test equipment with remote access.<br>Contemporary and flexible teaching methods: |

| | |
|---|---|
| Moderne oblike poučevanja:<br>P6: Interaktivna predavanja.<br>P8: Izdelava in predstavitev aplikativnih seminarskih nalog.<br>P15: Uporaba video vsebin kot priprava na predavanja in vaje. | P6: Interactive lectures.<br>P8: Making and presenting applied seminar exercises.<br>P15: Application of multimedia presentations for preparation to the lectures and exercises. |

| **Načini ocenjevanja:** | **Delež/Weight** | **Assessment:** |
|---|---|---|
| Teoretične vsebine (predavanja). | 50,00 % | Theory (lectures). |
| Samostojno delo na vajah. | 25,00 % | Tutorials. |
| Seminar. | 25,00 % | Seminar. |

**Reference nosilca/Lecturer's references:**

**Sašo Medved:**

1. ARKAR, Ciril, ŠUKLJE, Tomaž, VIDRIH, Boris, MEDVED, Sašo. Performance analysis of a solar air heating system with latent heat storage in a lightweight building. *Applied thermal engineering*. [Print ed.]. Feb. 2016, vol. 95, str. 281-287, ilustr. ISSN 1359-4311. DOI: 10.1016/j.applthermaleng.2015.11.031. [COBISS.SI-ID 14370075]
2. 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]
3. 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]
4. ARKAR, Ciril, MEDVED, Sašo. Building envelope element for decentralized ventilation with solar energy utilization. V: FRANKOVIĆ, Bernard (ur.), DALENBÄCK, Jan-Olof (ur.). *Eurosun 2012 : solar energy for a brighter future : book of proceedings*. Rijeka: Croatian solar energy association; Freiburg: International solar energy society, 2012. [8] str., ilustr. ISBN 978-953-6886-20-3, ISBN 978-3-9814659-2-1. [COBISS.SI-ID 12459547]
5. MEDVED, Sašo, ARKAR, Ciril, DOMJAN, Suzana, DOVRTEL, Klemen, LESKOVŠEK, Uroš. *SOLAIR : EIE/06/034/S12.446612 : podpora tržnemu uvajanju manjših in srednje velikih sistemov solarnega hlajenja v stanovanjskih in poslovnih stavbah : končno poročilo projekta*. Ljubljana: Fakulteta za strojništvo, 2008. 18 str. [COBISS.SI-ID 10428955]

**Ciril Arkar**

1. MEDVED, Sašo, DOMJAN, Suzana, **ARKAR, Ciril**. Passive and free cooling of buildings : chapter 15. V: SHARMA, Atul (ur.), SHUKLA, Amritanshu (ur.), SINGH, Renu (ur.). Low carbon energy supply technologies and systems. New York: CRC Press, 2020. Str. 237-270, ilustr. ISBN 978-0-367-37340-5. https://www.taylorfrancis.com/books/e/9780429353192/chapters/10.1201/9780429353192-15, DOI: 10.1201/9780429353192-15. [COBISS.SI-ID 21695235]
2. **ARKAR, Ciril**, ŽIŽAK, Tej, DOMJAN, Suzana, MEDVED, Sašo. Comparative analysis of free cooling of photovoltaics – phase change versus evaporative cooling. Journal of energy storage. [Print ed.]. May 2022, vol. 49, str. 1-13, ilustr. ISSN 2352-152X.

https://www.sciencedirect.com/science/article/pii/S2352152X22001967, DOI: 10.1016/j.est.2022.104162. [COBISS.SI-ID 97940227]
3. **ARKAR, Ciril**, ŽIŽAK, Tej, DOMJAN, Suzana, MEDVED, Sašo. Dynamic parametric models for the holistic evaluation of semi-transparent photovoltaic/thermal façade with latent storage inserts. Applied energy. Dec. 2020, vol. 280, str. 1-16, ilustr. ISSN 0306-2619. https://www.sciencedirect.com/science/article/abs/pii/S0306261920314392?via%3Dihub, DOI: 10.1016/j.apenergy.2020.115994. [COBISS.SI-ID 34825731]
4. **ARKAR, Ciril**, MEDVED, Sašo. Optimization of latent heat storage in solar air heating system with vacuum tube air solar collector. Solar energy. [Print ed.]. Jan. 2015, vol. 111, str. 10-20, ilustr. ISSN 0038-092X. DOI: 10.1016/j.solener.2014.10.013. [COBISS.SI-ID 13778971]
5. **ARKAR, Ciril**, ČERNE, Peter, DOMJAN, Suzana, DURINI, Petra, MEDVED, Sašo, ŠUKLJE, Tomaž. Algoritmi naprednega krmiljenja naravnega prezračevanja stavb z inteligentnimi gradniki. Ljubljana: Fakulteta za strojništvo, 2017. 34 f., graf. prikazi. [COBISS.SI-ID 16746267]