1. GENERAL INFORMATION				
1.1. Course teacher	Associate Professor Domagoj Vulin, PhD		1.6. Year of the study	II.
1.2. Name of the course	Underground storage of gas and energy		1.7. ECTS credits	5
1.3. Associate teachers	-		1.8. Type of instruction (number of hours L + E + S + e-learning)	18L+15E+15S+12e-learning
1.4. Study programme (undergraduate, graduate, integrated)	graduate		1.9. Expected enrolment in the course	15
1.5. Status of the course	☐ mandatory	☒ elective	1.10. Level of application of e-learning (level 1, 2, 3), percentage of online instruction (max. 20%)	level 3, 20% online
2. COUSE DESCRIPTION				
2.1. Course objectives	Upon completing the course, the student will be able to explain the mechanisms of gas dissolution in oil and water; assess the storage capacities of underground storage facilities for natural gas, carbon dioxide, thermal energy, hydrogen and compressed air; discuss the problem of permeability of isolating rocks and design simulation models of injecting gases and energy into the storage geosystem.			
2.2. Enrolment requirements and/or entry competences required for the course	-			
2.3. Learning outcomes at the level of the programme to which the course contributes	Predict reservoir behaviour and the behaviour of hydrocarbon and geothermal water production system; Plan the methods and procedures for avoiding or minimizing environmental impact of petroleum engineering and geoenergy engineering activities.			
2.4. Expected learning outcomes at the level of the course (3 to 10 learning outcomes)	Predict the behaviour of the reservoir and the production system during the gas injection and withdrawal cycle; Develop a simulation of natural gas injection model into the reservoir, and simulation of CO_2 storage model into depleted reservoirs and into aquifers; Determine the possibilities of wind energy storage in underground energy storage facilities; Determine the possibilities of storing hydrogen underground; Optimize the underground storage system by the ratio of injection and withdrawal speed and water cut; Determine safety of the assessments based on technical, economic and geological parameters.			

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<table>
<tr><td>2.5. Course content (syllabus)</td><td colspan="10">Types of fluids that can be stored underground; Activities related to individual methods of energy storage, conversions of energy units, efficiency / effectiveness / cost-effectiveness of each method; Underground gas storage - divisions of underground gas storage (aquifers, depleted gas reservoirs, depleted oil reservoirs); Gas dissolution in oil and water - problems of gas injection into the aquifer zone; Ternary systems H_2O-NaCl-CO_2 - special types of phase diagrams of non-hydrocarbon mixtures;
Gas storage - calculation of the well pressure drop, pressure drop depending on the injection and the pressure profile in the near-wellbore zone; Calculation of the influence of reservoir properties and present fluids (hydrocarbons, aquifer) on gas injection and prediction of reservoir and production system behavior during frequent gas withdrawal and injection; Estimates of changes in the mobility of injected or withdrawn gas; Estimates of energy expended on gas injection; Volumetric estimates of storage capacity in old hydrocarbon reservoirs; Analytical calculation of natural gas injection into an depleted gas reservoir; Simulation assessment of natural gas storage in deep saline aquifer and comparison with storage in depleted hydrocarbon (gas) reservoir; Determining the working volume, deliverability and injectivity of underground gas storage (UGS) site; Determining the function of cyclic withdrawal or injection of media (natural gas, compressed air, hydrogen);
Project / seminar assignments: assessment of storage potential of (1) thermal energy storage, (2) CO_2 storage, (3) hydrogen and compressed gas storage, (4) natural gas storage, simulation example of gas injection into a reservoir (comparison with analytical prediction).</td></tr>
<tr><td>2.6. Format of instruction:</td><td colspan="4">☒ lectures
☒ seminars and workshops
☒ exercises
☐ online in entirety
☒ partial e-learning
☐ field work</td><td colspan="4">☒ independent assignments
☒ multimedia and the internet
☐ laboratory
☒ work with mentor
☐ (other)</td><td colspan="2">2.7. Comments:
-</td></tr>
<tr><td>2.8. Student responsibilities</td><td colspan="10">The student should submit project in the prescribed seminar format, making clear the difference between individual work and teamwork.</td></tr>
<tr><td rowspan="6">2.9. Monitoring student work</td><td>Class attendance</td><td>YES</td><td></td><td>Research</td><td></td><td>NO</td><td>Oral exam</td><td>YES</td><td></td></tr>
<tr><td>Experimental work</td><td></td><td>NO</td><td>Report</td><td></td><td>NO</td><td></td><td></td><td></td></tr>
<tr><td>Essay</td><td></td><td>NO</td><td>Seminar paper</td><td>YES</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Preliminary exam</td><td></td><td>NO</td><td>Practical work</td><td>YES</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Project</td><td>YES</td><td></td><td>Written exam</td><td></td><td>NO</td><td>ECTS credits (total)</td><td colspan="2">5</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td>2.10. Required literature (available in the library and/or via other media)</td><td colspan="7">Title</td><td>Number of copies in the library</td><td>Availability via other media</td></tr>
</table>

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	Zakirov, I., Asti, A., Zakirov, E., & Schweng, K. (1998, January): *History matching for Lauchstaedt underground gas storage*, In SPE Gas Technology Symposium. Society of Petroleum Engineers.	NO	YES
	Clemens, T., de Kok, J., & Yanze, Y. (2009.) Rejuvenation of a mature oil field: Underground Gas Storage and Enhanced Oil Recovery, *30th Annual Workshop & Symposium IEA Collaborative Project on Enhanced Oil Recovery,* Schönkirchen Tief Field, Austria.	NO	YES
	Amid, A., Mignard, D., & Wilkinson, M. (2016.). *Seasonal storage of hydrogen in a depleted natural gas reservoir*, International journal of hydrogen energy, 41(12), 5549-5558.	NO	YES
	Patel, M. J., May, E. F., & Johns, M. L. (2016.): *High-fidelity reservoir simulations of enhanced gas recovery with supercritical CO_2*, Energy, 111, 548-559.	NO	YES
2.11. Optional literature	-		
2.12. Other (as the proposer wishes to add)	-		

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