SPIRIT

SPIRIT Summer school

Industrial high-temperature heat pumps for decarbonization of industrial process heating

General information

Dates: June 1st – June 12th (last class will end at 15:00 on the 12th)

Location: Technical University of Denmark, Copenhagen (Lyngby)

Scope & Form: The class is taught all week days from 8-17. The Teaching will be a combination of lectures, Q&A sessions and supervised project work. During the course a project description of an industry case study will be developed. The project will be cried out after the conclusion of the course.

Evaluation: The final assessment is based on a submission consisting of one abstract and one poster on the industrial case study (submission date 1/9-2026)

Workload: 5 ECTS

Program at-a-glance

Week 1: Fundamentals of HTHP and heat pump integration				
Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Decarbonization of Industrial Process Heat	Pinch Analysis & Heat Pump Integration	HTHP Technology 1 Working fluids & Cycles	HTHP Technology 2 Compressors	HTHP Technology 3 Heat Exchangers

Week 2: HTHP integration in practice				
Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Excursion to Danish Technological Institute (DTI) Århus	Sector collaboration & Thermal storage	Assessment, modelling and simulation tools	HTHP Demonstrator experience	Business models & Regulatory Framework

Social events

Sunday May 31st	**Welcome reception and get-together**
Saturday June 6th	**Tour of Copenhagen with boat tour on the canals**
Thursday June 11th	**Dinner in Copenhagen**

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Confirmed speakers (additional speakers are pending confirmation)

Adriano Sciacovelli	Technical University of Denmark
Benjamin Zühlsdorf	Danish Technological Institute
Florian Scholsser	University of Paderborn
Gabriele Fregonese	SINLOC
Jasper Walden	Technical University of Denmark
Jonas Kjær Jensen	Technical University of Denmark
Jonas Lundsted Poulsen	Danish Technological Institute
Jozefien Vanbecelae	European Heat Pump Association
Laura Alonso Ojanguren	Technalia
Martin Stage Pihl Andersen	Danish Technological Institute
Manuel Gräber	TLK Energy
Miguel Ramirez	TNO

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Agenda and curriculum

Day 1: Decarbonization of Industrial Process Heat	
Monday June 1st	**Speakers:** • Martin Pihl Stage Andersen - Danish Technological Institute • Jonas Kjær Jensen – Technical University of Denmark **Location:** • To be confirmed
	09:00-10:00 - Welcome and course introduction
	10:00 – 12:00 Session 1: **Introduction to industrial process heat & decarbonization** • Overview of current process heat technologies in different industrial sectors (Food & Beverage, Paper & Pulp, Chemical, Pharmaceutical) • Economic and environment impact of industrial process heat • Decarbonization strategies: indirect electrification, direct electrification, integration of renewable energy • Cost savings and emissions reduction potential for decarbonization of industrial process heat • Technical, non-technical and economic barriers for decarbonizing industrial process heat
	12:00 – 13:00 Lunch
	13:00 – 15:00 Session 2: **Introduction to industrial heat pumps** • Heat pump working principles, work driven and heat driven cycles • Heat pump performance measures • Thermodynamic limits for infinite & finite Reservoirs • Second Law and exergy-based performance measures
	14:30 – 15:00 Coffee and afternoon snack
	15:00 – 16:30 Session 3: **Student case introduction** • Presentation of industrial cases • Peer discussion session, case selection & group formation • Project work

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Day 2: Process integration and techno-economic analysis of HTHP	
Tuesday June 2nd	**Speakers:** • Jasper Walden – Technical University of Denmark **Location:** • To be confirmed
	09:00 – 12:00 Session 1: **Process Integration and Pinch Analysis** • Introduction to Process Integration and Pinch Analysis: • Composite curves and Grand Composit Curves • Heat Exchanger Networks • Energy Savings Potential via pinch analysis and energy demand management
	12:00 – 13:00 Lunch
	13:00 – 15:00 Session 2: **Heat Pump Integration in industry** • Emerging trends and methods in Process Integration and Pinch Analysis • Minimum work targets • Pinch Analysis under variable heat demands • Partial electrification and hybridization • Utility level and process level integration • Integration of multiple heat pumps
	15:00 – 15:30 Coffee and afternoon snack
	15:30 – 16:30 Project work and supervision

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Day 3: HTHP Technologies – Cycles & Working Fluids	
Wednesday June 3rd	**Speaker:** • Jonas Kjær Jensen – Technical University of Denmark **Location:** • To be confirmed

	09:00 – 12:00 Session 1:
	Thermodynamic cycles and working fluids for HTHP
	• Overview of HTHP working fluids:
	  ○ Classification of working fluids synthetic vs. natural
	  ○ Environmental impact of working fluids
	  ○ Safety and technical constraints
	• Overview of HTHP cycles:
	  ○ Vapour Compression Cycles (Rankine),
	  ○ Gas Cycle (Brayton & Sterling)

	12:00 – 13:00 Lunch

	13:00 – 15:00 Session 2:
	Thermodynamic cycles and working fluids for HTHP
	• Advanced cycle layouts for HTHP
	  ○ Transcritical Cycles
	  ○ Zeotropic Mixture Cycles
	  ○ Two-stage cycles
	  ○ Cascade cycles
	  ○ Open-cycles and steam generating heat pumps

	15:00 – 15:30 Coffee and afternoon snack
	15:30 - 16:30 Session 3: **Industrial HTHP in practice** • Component design for high temperature heat pump • Safety and compliance

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Day 4: HTHP Technologies – Compressors for HTHP	
Thursday June 4th	**Speakers:** • Panagiotis Stathopoulos - DLR **(To be confirmed)** **Location:** • To be confirmed

	09:00 – 10:30 Session 1:
	Compressor technology overview
	• Working principles of HTHP compressors
	  ○ Volumetric compressors – reciprocating and screw
	  ○ Dynamic compressors – centrifugal and axial
	• Application range of the above HTHP compressors in terms of capacity, pressure and temperature

	10:30 – 12:00 Session 2: **Dynamic Compressors** • Design and optimization of axial and centrifugal compressors • Technical constraints of axial and centrifugal compressors • Operational and part-load performance of axial and centrifugal compressors
	12:00 – 13:00 Lunch
	13:00 – 14:45 Session 3: **Volumetric compressors** • Lubrication of compressors and HTHP lubricants • Design and optimization of reciprocating and screw compressors • Technical constraints of reciprocating and screw compressors • Operational and part-load performance of reciprocating and screw compressors
	14:45 – 15:00 Recap and final remarks
	15:00 – 15:30 Coffee and afternoon snack
	15:00 – 16:00 Session 4: **Lab tour - DTU Construct refrigeration and Heat Pump Lab**
	15:00 – 16:30 Session 4: **Project work and exercises.**

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Day 5: HTHP Technologies – Heat exchangers for HTHP	
Friday June 5th	**Speaker:** • Carlo De Servi - VITO **(To be confirmed)** • Nitish Anand **-** VITO **(To be confirmed)** **Location:** • To be confirmed

	09:00 – 12:00 Session 1:
	Heat exchanger technology overview
	• Working principles of HTHP heat exchangers
	  ○ Plate Heat Exchangers
	  ○ Shell and Tube Heat Exchangers
	  ○ Shell and Plate Heat Exchangers
	• Application range of the above HTHP heat exchangers in terms of capacity, pressure and temperature

	12:00 – 13:00 Lunch
	13:00 – 15:00 Session 2: **Dimensioning of single-phase and two-phase (condensers & evaporators) heat exchangers** • Fundamentals of heat exchanger design • Estimation of heat transfer coefficients • Estimation of friction factors and pressure loss • Advanced heat exchanger design methods
	15:00 – 15:30 Coffee and afternoon snack
	15:30 - 16:30 Session 5: **Project work and supervision**

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Day 6: Excursion to Danish Technological Institute (DTI) Århus	
Monday June 8th	**Speakers:** • Jonas Lundsted Poulsen - Danish Technological Institute • Benjamin Zühlsdorf - Danish Technological Institute **Location:** DTI in Århus
	The Bus will leave from DTU at 07:00 and will return to DTU and approx. 20:00. **Session 1: Insights from Annex 58:** • Overview of available HTHP technology and close to market technologies. • Integration concepts for HTHPs **Session 2: Guided tour at DTI heat pump test center**

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Day 7: Sector Collaboration and Thermal Storage	
Tuesday June 9th	**Speakers:** • Florian Schlosser – University of Paderborn • Adriano Sciacovelli - Technical University of Denmark **Location:** • To be confirmed
	09:00 – 12:00 Session 1: **Sector Collaboration:** •
	12:00 – 13:00 Lunch
	13:00 – 14:00 Session 1 continues
	14:00 – 15:00 Session 2: **Heat storages for high temperature process heat** • Heat storage methods and mechanisms • Heat storage modelling approaches • HTHP and heat storage integration
	15:00 – 15:30 – Coffee and afternoon snacks
	15:30 – 16:30 **Session 2 continues**

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Day 8: Modelling, Simulations and Assessment Tools	
Wednesday June 10th	**Speakers:** • Manuel Gräber – TLK Energy **Location:** • To be confirmed
	09:00 – 10:00 Session 1: **Introduction to Modelling and Simulation** • Overview of modelling and simulation software and languages • Overview of EoS-resources • Steady-State and dynamic modelling • Recommendations and state-of-the-art
	10:00 – 12:00 Session 1: **TLK Pinch Tool & Heat Pump Selection Tool** • Introduction to TLK Pinch Tool • Step-by-step guide on conducting Pinch Analysis including examples from industry • Energy Savings Potential via pinch analysis and energy demand management • Introduction and Step-by-Step Guide to TLK Pinch Analysis Tool
	12:00 – 13:00 Lunch
	13:00 – 15:00 Session 2: **Dynamic Modelling and Simulation** • Software for dynamic modelling • Numerical methods for solving differential-algebraic systems • Modelling control and regulation
	15:00 – 15:30 – Coffee and afternoon snacks
	15:30 – 16:30 **Project work and supervision**

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Day 9: HTHP Demonstrator experience	
Thursday June 11th	**Speakers:** • Laura Alonso Ojanguren - Technalia • Maximilian Kriese **(To be confirmed)** • Miguel Ramirez - TNO **Location:** To be confirmed

	09:00 – 12:00 Session 1:
	Experience from HTHP Demonstration projects
	• SPIRIT demonstration cases
	  ○ Paper & pulp
	  ○ Food industry – shrimp processing
	• Push2Heat demonstration cases
	  ○ Chemical industry
	  ○ Paper & pulp

	12:00 – 13:00 Lunch

	13:00 – 14:00 Session 1 (continued):
	Experience from HTHP Demonstration projects
	• EEETHOS demonstration cases
	  ○ Paper & Pulp
	  ○ Roof tiles

	14:00 – 17:00 Session 2: **Industrial site visit - District Heating Heat Pump: Tårnby Forsyning**

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Day 10: Business modes & regulatory frameworks	
Friday June 12th	**Speakers:** • Gabriele Fregonese - SINLOC • Jozefien Vanbecelae - EHPA **Location:** To be confirmed
	09:00 – 10:00 Session 1: **Project proposal pitch presentation**

	10:00 – 12:00 Session 2:
	Business models for HTHPs
	• Introduction to business models
	  ○ Definition and importance
	  ○ The business model canvas
	  ○ Detail of the components of the BM canvas
	• Risk and uncertainty in economic analysis
	  ○ Definitions and types of risks
	  ○ Measuring, managing and hedging risks
	  ○ Decision-making under uncertainty
	  ○ The cost/price of risks
	• Business models in the energy sector and servitization
	  ○ "Traditional" manufacturing and sale
	  ○ Leasing
	  ○ Energy-as-a-Service and Heat-as-a-Service

	12:00 – 13:00 Lunch

	13:00 – 15:00 Session 3:
	EU regulations for heat pumps and HTHP integration
	• Regulatory framework for industrial electrification
	  ○ EU's legislation on industrial decarbonisation
	  ○ Current policies such as RED, CID
	• Financial incentives for adoption
	  ○ Overview of the existing financial barriers
	  ○ Proposed mechanism to overcome those barriers
	• Waste heat recovery
	• Regulatory framework for waste heat recovery

	Farewell

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