# Master of Science in Environmental, Process and Energy Engineering

## Program Description

The Department of Chemical and Energy Engineering (C&EE) at PAF-IAST is offering Master of Science (MS) program in the “Environmental, Process and Energy Engineering” w.e.f. Fall 2021. This master program blends the knowledge of three fields into a single curriculum to train graduates to cope challenges in modern day process industry. The department is already offering a bachelor’s degree program in Chemical Engineering. All our programs are approved by statutory bodies (HEC and PEC).

Process engineers help in transforming raw materials into valuable products. They design, implement, control, and optimize the industrial processes and machinery in manufacturing industry. An energy engineer designs, develops, or evaluates energy-related projects or programs to reduce energy costs or improve energy efficiency while environmental engineer helps in saving environment from hazardous wastes produced by process industries. Design of an efficient, economical, and environmentally friendly process requires the knowledge of all these fields. Environmental, Process and Energy Engineering master’s program brings these interdependent fields under one discipline. Graduates of this program will not only optimize processes to increase the production capacity but also help in managing consumption of energy and treating industrial wastes. Being an interdisciplinary program, students are taught courses which enable them to identify potential for energy and cost savings early on and adapt processes accordingly. They also learn about environmental regulations and how to minimize, treat and manage the wastes produced by industrial processes.

The Institute has signed MoUs with nearby Hattar Industrial State which has several process industries ranging from small scale production units to heavy manufacturing industry. Students and faculty members will be constantly engaged with these industries to improve the production performance and minimize the waste discharge. Students will be trained on environmental and energy audits and they will give recommendations to industries of Hattar Industrial State, how to cut their energy costs and save the environment from pollution without compromising on production. MoUs are not limited to Hattar Industrial State only but will be expanded to country-wide industries gradually.

Besides studying the core subjects, students also receive the opportunity to improve on their management, leadership, innovation and entrepreneurial skills. Science-based and industrial projects provide them with further skills and knowledge. Graduates will thus be enabled to solve industrial problems and to safeguard a livable future.

## Associated Careers

The students graduating from this discipline will find employment opportunities in water and power development sectors, oil and gas development corporations, environmental protection agencies and other process industries. Economic zones are being developed around the country under the CPEC project. These economic zones will have several process industries that will require expertise in designing cost-effective and green processes. Skilled graduate produced by the program will take full advantage of the opportunity. They will not only secure a bright career but also contribute to the economy of Pakistan. Apart from the job placements in conventional chemical and process industries, graduates will also find opportunities in research and development in fields of energy, power production and environmental sciences and engineering.

# Semester-wise Course Break-up and Detailed Course Outlines

**Duration to obtain a degree of *Master of Science in Environmental, Process and Energy Engineering* is 2 years (4 semesters). Students have to register and pass 5 compulsory courses (15 CHs), 3 elective courses (9 CHs) and Research Thesis (6 CHs) all equals to 30 CHs. Academic Writing and Research Methodology and Weekly Seminars are non-credit compulsory courses.**

**Semester-wise Course Break-up**

| ***1st Semester*** | | |
|---|---|---|
| **Course Code** | **Course title** | **Credit Hours** |
| CHE-821 | Process Technology | 3 |
| CHE-822 | Heat and Mass Transfer | 3 |
| XXX-### | Elective 01 | 3 |

| ***2nd Semester*** | | |
|---|---|---|
| **Course Code** | **Course Title** | **Credit Hours** |
| CHE-825 | Advanced Reaction Engineering | 3 |
| CHE-824 | Process Simulation and Integration | 3 |
| XXX-### | Elective 02 | 3 |

| ***3rd Semester*** | | |
|---|---|---|
| **Course Code** | **Course Title** | **Credit Hours** |
| SS-821 | Research Methodology* | 2 |
| XXX-### | Elective 03 | 3 |
| XXX-### | Elective 04 | 3 |

*******This course is non-credit compulsory course.*

| *4th Semester* | | |
|---|---|---|
| **Course Code** | **Course Title** | **Credit Hours** |
| CHE-899 | Master Thesis | 6 |

| **Total Credit Hours:** | **30** |
|---|---|

| **Electives** | | | |
|---|---|---|---|
| **S.No** | **Course Code** | **Course Title** | **Credit hour** |
| **1** | CHE-823 | Process and Plantwide Control | 3 |
| **2** | CH-813 | Polymer and Advanced Industrial Chemistry | 3 |
| **3** | CHE-862 | Chemical Product Design and Industrial Scale-up | 3 |
| **4** | CHE-861 | Plant Automation | 3 |
| **5** | CHE-843 | Waste Engineering and Noise Control | 3 |
| **6** | CHE-841 | Life cycle Assessment | 3 |
| **7** | CHE-844 | Advanced Water Treatment | 3 |
| **8** | CHE-845 | Flow and Transport in Environmental Engineering | 3 |
| **9** | CHE-846 | Energy Storage and Conversion Technologies | 3 |
| **10** | CHE-842 | Heating and Cooling Technologies | 3 |

# Detailed Course Outlines

## CHE-821 Process Technology

Chemical process engineering:
- Introduction to the basic physicochemical principles of the description of reaction engineering processes with a focus on chemical equilibrium and reaction kinetics
- Basic types and operating modes of reactors
- Evaluation criteria for reactors
- Calculation of conversion, yield, and selectivity in complex reactions
- Introduction to kinetics
- Kinetics of homogeneous reactions
- Principles of heterogeneous catalysis
- Analysis of reaction kinetics data
- Residence time distribution in ideal reactors

Thermal process engineering:
- Phase equilibrium
- Vaporization (p-x diagram)
- Distillation (t-x diagram/McCabe-Thiele)
- Rectification
- Absorption
- Extraction

Mechanical process engineering:
- Characterization of particles and particle systems in mechanical process engineering
- Particle measurement technology
- Basic principles of separation, classification, and sorting processes
- Gas-particle separation processes
- Solid-liquid separation processes
- Mixing processes
- Agitation

## CHE-822 Heat and Mass Transfer

- Advanced thermal separation processes (unit operations) and calculation of devices employed (H, NTU, HTU, HETP, and HDU)

- Rectification of mixtures of materials, reactive rectification

- Design and calculation of mass transfer columns for absorption, gas scrubbing

- Mass transport in adsorption, interpretation of sorption isotherms, design of devices

- Drying stages, Mollier diagrams of drying processes

- Calculation and design of single and multi-stage extraction systems for (counter-current and cross-current) solvent extraction

- Membrane techniques, micro-, nano-, and ultrafiltration, reverse osmosis, gas permeability

Theoretical foundations of mass and energy transfer:
- Conservation equations
- Transfer equations

Numerical solution of selected problems:
- Transfer phenomena related to sorption and chemical reactions or the degradation of individual components
- Models of free flow and flow in porous media
- Basic troubleshooting of one-dimensional cases and step-by-step approaches to advanced troubleshooting of multi-dimensional problem cases

**CHE-825 Advanced Reaction Engineering**

Kinetics of heat and mass transfer processes, Kinetics of complex reactions (reaction networks), Molecular transfer processes, Knowledge of reaction mechanisms, Elements of optimum design for various reactor types, multiple reactions, and temperature effects. Yield and selectivity optimization with emphasis on small-scale pharmaceutical production. Introduction to non-ideal reactor design. Study of various models for catalytic and non-catalytic solid-fluid reactions.

**CHE-824 Process Simulation and Integration**

-Physicochemical property calculations in (bio)chemical process engineering

- Modeling and simulation of complete process plant systems

- Energy integration and optimization across plants and larger plant sections

- Pinch analysis of plants in process engineering
- Optimization of energy concepts
- Design of heat-exchanger concepts
- Detailed planning of heat exchangers

3D-modelling of apparatus and machines in plant design
- Detailed design of piping systems
- Detailed planning of plants (incl. constructive considerations)

- Fundamentals of plant engineering and construction

- Design, construction, implementation, and operation of technical systems

- Selected examples of apparatus and component construction

Numerical Simulations

Basic concepts of fluid flows
- Conservation equations (Navier-Stokes)
- Spatial and temporal discretization: finite volume method, lattice types, convergence
- Boundary conditions
- Methods of stationary and non-stationary flow
- Numerical solution methods for equation systems
- Turbulent flows and modeling
- Boundary conditions
- Boundary layers and idealized solutions
- Thermal problems
- Further simulation models (Lattice Boltzmann methods, particle simulation)
- Development of solution strategies

-Data types, vectors, and matrices in MATLAB
- Vector and matrix operations
- Loops and branches
- Scripts and functions
- Data importing and exporting, communication with other common software
- Graphical user interface
- Numerical analysis by MATLAB

**SS-821 Research Methodology**

Basics of technical writing process, Technical writing techniques and applications, Definition and basics of research, research purpose, Design of research methods, Identification of research problem, literature review, Selection of data collection techniques, selection of representative sample, writing of research proposals, Data collection and analysis techniques, Limitations and significance of research techniques, Quantitative and qualitative research procedures, Writing of research reports, Presentation skills, oral presentations, **,** Assessment as a peer reviewer**,** Elaboration and submission of a short proposal**,** Elaboration of the basic structure**,** Advice for colleagues**,** Elaboration of the paper**,** Peer review**,** Compilation

**CHE-823 Process and Plantwide Control**

- Systems Analysis for process technology (with focus on process control)
- Conventional and specific control loops
- Design and optimization of control loops
- Plantwide control concepts
- Illustration of control technologies by piping and instrumentation diagrams

**CH-813 Polymer and Advanced Industrial Chemistry**

- Introduction: crystallinity, glass transition, polydispersity, tacticity, copolymers, thermodynamic, thermal, mechanical, and optical properties, rubber elasticity
  - Conventional polymers:
- polypropylene (structure, synthesis, properties)
  polyvinyl chloride (structure, synthesis, properties)
  - Biopolymers:
  cellulose (structure, synthesis, properties)
  starch (structure, synthesis, properties)
  chitin/chitosan (structure, synthesis, properties)
  lignin (structure, synthesis, properties)
  Biodegradable plastics:
  polyglycolic acid (structure, synthesis, properties)
  polylactic acid (structure, synthesis, properties)
  polycaprolactone (structure, synthesis, properties)
  polyhydroxyalkanoate (structure, synthesis, properties
- Material aspects
  Processes of resource processing
  Processes of basic chemical manufacturing
  Processes of secondary product and end product manufacturing
  Process development
  General boundary conditions of the chemical industry
  Economic aspects
  Technical and scientific aspects
- Fundamentals of Catalysis (Definitions, Historical Evolution, Mode of Action)
  Concepts of Heterogeneous Catalysis (Kinetic Mechanisms, Energetic, Steric and Electronic aspects)
  Catalyst Preparation (Active surface area, Catalyst supports, Preparation of supported

catalysts)

Catalytic Reactors (Static, Stirred, (Plug) Flow, Pulse reactors, TAP, SSITKA, In situ and Operando Characterization, Mass and heat transfer limitations)

Catalysis by Nanostructured Materials - Metal/Support Interaction - Catalysis by Gold - Methanol Steam Reforming

Catalysis by Cu-ZrO2 materials - Homogeneous Catalysis (Basics, Essential reactions, 16/18 rule, HSAB principle, industrial examples)

**CHE-862 Chemical Product Design and Industrial Scale-up**

- Introduction
- Needs-oriented product design
- Selection criteria
o Thermodynamic criteria
o Kinetic criterias
o Other criteria
- Manufacturing process
- Chemical products
o Primary chemicals: bulk chemicals
o Secondary chemicals: speciality chemicals
- Micro- and macrostructure
- Product design toolbox
- Process design vs. product design
- Methodology and application: needs, ideas, selection, manufacture
- Bench, pilot, demonstration, and commercial scale
- Problems of scale-up:
o kinetics and transport phenomena
o differences in facilities
o real processes, catalyst aging, etc.
- Scale-up of unit operations
- Reactor types
- Mathematical modeling
- Computer-aided modeling

**CHE-861 Plant Automation**

- Presentation of essential elements of digital plant automation and of process control engineering in particular
- Illustration of control logic and control logic components through professional piping and instrumentation diagrams
- Implementation and programming of control systems by means of professional process control engineering (Siemens, Honeywell, Allen Bradley, etc.)

**CHE-843 Waste Engineering and Noise Control**

- Mathematical and physical foundations of noise control
- Legal framework
- Methods of sound measurement
- Noise control measures
- Landfill
- Structure
- Environment
- Landfill leachate
- Landfill gas
- Legal aspects
- Practical examples
- Landfill mining/urban mining
- Soil remediation
- Remediation concepts
- Recultivation

**CHE-841 Life cycle Assessment**

- The concept of sustainable development
- Corporate sustainability management (integrated management systems; process and product standards)
- The history of LCA
- LCA models (e.g., MIPS, SPI, EPS, CED, etc.)
- LCA applications (in line with ISO 14040/14044)
- Carbon footprint; water footprint
- Project assignment: LCA methods in practice (e.g., practical use of the ecological scarcity method)

**CHE-844 Advanced Water Treatment**

- Basic principles of membrane processes
- Driving forces of membrane processes
- Production and characterization of membranes
- Membrane materials
- Functional principles of membrane filtration
- Performance-reducing effects of membrane processes
- Membrane plant design
- Sustainable water management
- Groundwater
- Introduction to hydrogeology
- Local and global groundwater resources
- Groundwater flow modelling
- Groundwater pollution

    - Geochemistry
    - Hydraulic engineering in environmental engineering
    - Water wells
    - Drinking water purification
    - Distribution systems
    - Irrigation
    - Sewage plants
    - Reuse
- Water reuse
- Recycling

**CHE-845 Flow and Transport in Environmental Engineering**

- Fundamentals of the dispersion of substances in soil, water, and air
- Dispersion calculations of air pollutants in the lower troposphere
- Legal regulations
- Groundwater flow models
- Fundamentals of soil mechanics

**CHE-846 Energy Storage and Conversion Technologies**

- Structure, properties, and characterization of energy raw materials, Fundamentals of thermal, chemical, and biological conversion of energy sources, Trends and innovations of energy conversion methods, Phenomenology and kinetics of thermochemical conversion (combustion and gasification), Synthetic biofuels, Fischer-Tropsch process, substitute natural gas, mixed alcohol, methanol/dimethyl ether synthesis, Development and respective potential analyses of Thermal energy storage (for sorption sensible heat, latent heat, reversible chemical reactions), Mechanical energy storage (compressed air energy, flywheel energy, potential energy), Types of Batteries like Daniell cell, voltaic cell, concentration cell, metal-air batteries, lead-acid batteries, metal hydride batteries, lithium-ion batteries, Basic Principle for electrolysis, hydrogen technology, fuel cell, Power2Gas

**CHE-842 Heating and Cooling Technologies**

Advanced knowledge of conventional heating, ventilation, and air conditioning technologies, Current state of technology and research in the use of geothermal, solar thermal energy energy for the operation of heat pumps, Building technology, thermal insulation, energy consumption standards, Intelligent solutions for the combination of renewable systems and conventional heating and air conditioning systems

- Technical calculations of conventional combined application of heating, air conditioning and renewable technology, Calculations of the potential of new

technologies, Considerations of the overall ecological and economic use of different renewable systems and respective combinations.

## CHE-892 Weekly Seminar

***Semester 1:***

**Literature Seminar:**

Students reach an understanding of how scientific findings are obtained, appropriately documented, and published. They are expected to research, analyze, and discuss current journal articles. They are encouraged to place a particular focus on the specific methodologies applied in original articles while identifying general relations on the basis of recent reviews from relevant journals.

**Legal Aspects of Engineering:**

- Overview and general considerations
- Permit application project case example
- International tendering case example
- Basic considerations and standards regarding the elaboration of expert reports

**Ethics:**

- Introduction and basic concepts
o Logical reasoning
o Inferences
o Fallacies
o Definition of ethics
o Definition of science
- Types of ethics
o Theological ethics and ethics of sentimentalism
o (Moderate) deontology
o Social contract theory
o Utilitarianism
o Consensus theory

***Semester 2:***

**Regulations and Standards in Process Engineering**

- Phase model for the implementation of a plant project
- Basic evaluation and project preparation

**Design of Experiments**

- Screening designs
o Full factorial design
o Fractional factorial design

- Design optimization
o Box-Behnken design
o Central composite design
- Mixture design
o Simplex centroid design
o Simplex lattice design
o Limitations of DOE
- Practical application of DOE
o Literature and software

**Semester 3:**

**Business Economics:**

- Companies and their environment
- Marketing (marketing mix; consumer goods marketing vs. B2B marketing)
- Legal forms
- Cost accounting (e.g. depreciation of operating assets, preparation of balance sheets and profit and loss statements, fundamentals of cash flow, calculation and analysis of selected performance indicators, implementation of quarterly income statements, calculation of operating income, analysis of annual profit and loss)
- Organization, human resources and management
- Investment and financing
- Selected aspects of strategic management (e.g. market-related decision making, strategic considerations of the production portfolio)
- Operational management of production plants
- Procurement and sales strategies:
o Basic types of analysis (ABC and XYZ) and key performance indicators (KPI) in employment
o Assessment, development and rating in supplier management
o Strategic partnerships with purchasers, cost planning, cost analysis, procurement methods from a strategic viewpoint
o Peculiarities of technical marketing
o Capital goods marketing
o Phases of organizational procurement
o Information behavior and asymmetry
o Working capital management
- Product costing and break-even analysis

# Research Areas

Product and Process Design, Modeling and Simulation, CFD, Membrane Separations, Nano Fabrication, Synthesis & Characterization of Catalysts, Adsorption, Gases Adsorption, CO2 Reduction, Photocatalysis Catalysis, Sustainable Development, Green Production, Climate Change, Adaptation and Mitigation, Water Quality Monitoring, Remediation And Treatment, Solid Waste/Hazardous Waste, Biomass, Renewable Energy, Energy Efficiency, Energy Audit