(A) **Design processes and manufacture process equipment and systems**

Design processes and manufacture process equipment and systems. Development and support of heterogeneous information systems for monitoring processes as well as systems for measuring physico-chemical properties.

(B) **Modeling, Design and Optimization of Complex Process Systems**

Modelling complex static and dynamic process systems to predict process behaviour under nominal operating conditions. The models include properties' distribution in multiple dimensions (time, space and structure). Development and investigation of technological and mathematical methods for process model reduction to enable their use in real-time applications (control, optimization). Applications of advanced optimization techniques and their modifications to meet specific applications needs in energy processes.

(C) **Design and Development of Advanced Automatic Control Systems Operation and Monitoring Process**

Develop methods and techniques of automatic control systems in process, mechanical and electrical systems. Use process models to design optimal control systems. Systematically design control systems to achieve the desired dynamic behavior. Analyze and study the effects of interaction of design variables to quality control achieved. Develop integrated control systems for autonomous systems producing energy and chemicals. Implement embedded control systems.

(D) **Operation and maintenance support of pilot plants and associated infrastructure**

Instrument calibration, maintenance of analytical equipment, maintenance of information systems and automated systems.

(E) **Development and management of quality systems**

Develop and coordinate quality management systems (ISO 9001) and laboratory accreditation systems, test and calibration (ISO 17025). Conduct internal audits and staff training.

(F) **Advanced Electrochemical Methods in Complex Processes**

Explore practical applications of Electrochemical Promotion with emphasis on optimizing the operation of monolithic reactors MEPR to develop air pollutants' process units as well as useful chemicals and fuels production processes. Exploitation of natural gas through via methane (main component) upgrading to larger hydrocarbons or synthesis gas. Production of primary chemicals such as ammonia, methanol, silicon carbide etc. using electrochemical catalysts. Study the aforementioned chemical reactions using solid electrolytes, oxygen ion conductors (O-2) and pipelines protons (H+).

(G)**Integrated energy systems**

Polymer Membrane (PEM) and solid oxide (SOFC) fuel cells
Develop catalyst-electrodes for use as anodes in PEM and SOFC fuel cells and optimize their performance by exploiting the three-way operation phenomenon. Develop materials and optimize systems for regenerative fuel cells.

Electricity production from methanol
The pilot plant unit EL.UN.D.A. is based on the use of hydrogen as a promising alternative fuel. The main objective of EL.UN.D.A. is the total power generation of 10kWel, by autothermal reforming of methanol and using the produced hydrogen in fuel cells. The plant is an excellent example of the integrated systems design and development to which the laboratory aims.

Electricity production from renewable energy sources and its long-term storage as hydrogen

The HYRES unit is based on power generation using renewable energy sources. Solar panels and wind-generators utilize solar and wind energy to meet the desired electrical load. Excess energy is stored in the form of hydrogen produced via water electrolysis. Similarly, the energy deficit is covered by using the stored hydrogen in fuel cell. Lead-acid battery is used for energy flow levelling which is observed due to fluctuations weather data.

(H) **Development of Hydrogen Production Systems from Hydrogen**

The aqueous phase of the biomass pyrolysis liquid product or biooil is a particularly complex mixture of organic compounds, the treatment of which gives high yields of coke. The main premise of this research work is to design a suitable reactor which will employ optimal catalyst materials leading to the successful development of a process which can be implemented in industrial scale. All experimental work takes place in a pilot scale SYNGAS unit, targeting at the most realistic conditions possible.