King Saud University
Deanship of Graduate Studies

Master of Science in Renewable Energy

(M.Sc. by Courses & Thesis)

Joint M.Sc. Program, College of Science and College of Engineering
Departments: Electrical Engineering, Mechanical Engineering, Chemical Engineering, Physics & Astronomy and Chemistry

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Table of Contents

Introduction

The kingdom has witnessed major research and developments at all levels and sectors over the last few decades particularly in the educational, industrial, water resources, energy and service sectors. A number of industrial organizations have established their own research and development activities, which emphasis the important role of scientific research as viewed by these organizations toward developing a knowledge-based industry and solving effectively and efficiently the encountered problems that face the industrial revolution of the country.
King Saud University (KSU) has already identified itself as a strategic partner of the industry and a major contributor in the establishment of the knowledge-based society. Consequently, KSU has given major importance to graduate studies to develop a generation of distinguished researchers that can be an important asset toward fulfilling KSU vision. The master program in Renewable Energy comes in full compliance with KSU directives of working heavily to improve considerably the output of scientific research both quantitatively and qualitatively in order to complement the role of KSU in providing highly qualified human resources and distinguished researchers and innovators and in strongly contributing in finding solutions of the technical problems to the industrial society.
The main objective of this master program in Renewable Energy is to offer excellent education in renewable energy science and technologies, and to strengthen future research in the utilization of renewable energies.
The master program is a joint program between five departments: Chemical Engineering, Chemistry, Electrical Engineering, Mechanical Engineering and Physics and Astronomy departments.

Degree Name

Master of Science in Renewable Energy

Degree Requirements

1. Successful completion of 25 credit hours of graduate courses distributed as follows:
   i. 13 credit hours: core courses.
   ii. 12 credit hours: three courses (9 credit hours) are selected from specialization track and one course (3 credit hours) is selected from any of the specialization tracks or from elective courses. Selection is under the supervision of the program academic supervisor.
2. Completing a successful thesis in the specialization track.

Program Tracks

The program includes the following three specialization tracks:

1- Solar Energy Technology
2- Wind Energy Technology
3- Hydrogen Energy Technology

Program Structure:

25 credit hours and a thesis are required; their distribution is as follows:

Type of Courses	Credit Hours
Basic core courses	13
Elective Course	12
Thesis	6
Total	31

Courses of the M.Sc. Program in Renewable Energy

1. Core Courses:

Course Code	Course Title	Credit Hours
REEN 501	Renewable Energy 1: Solar Energy	3
REEN 502	Renewable Energy 2: Wind, hydrogen and other Energies	3
REEN 503	Energy Conversion and Storage	3
REEN 504	Heat Transfer and Thermodynamics	3
REEN 505	Seminar	1

2. *Specialization Tracks*

2.1. Solar Energy Technology Specialization Track

Course Code	Course Title	Credit Hours
REEN 511	Solar Thermal Technology	3
REEN 512	Solar Cooling	3
REEN 513	Solar Active Heating Systems	3
REEN 521	Solar Cell and Module Technology	3
REEN 522	Advanced Solar Cell Designs	3
REEN 523	Photovoltaic Systems Technology	3
EE 612	Design and Technology of Solar Cells	3
EE 534	Power Semiconductor Converters	3
EE 613	Design and Applications of Photovoltaic Systems	3

2.2. Wind Energy Technology Specialization Track

Course Code	Course Title	Credit Hours
REEN 531	Wind Turbine Aerodynamics	3
REEN 532	Design and Control of Wind Turbines	3
REEN 533	Wind Farm Technology	3
REEN 534	Technologies for Wind Generation	3
EE 534	Power Semiconductor Converters	3
REEN 541	Hydrogen Production	3
REEN 542	Hydrogen Storage	3
REEN 543	Fuel Cells	3
REEN 544	Selected Topics in Hydrogen Technology	3
REEN 545	Materials characterization	3

3. Elective Courses:

REEN 551	Energy Economics and Policy
PHYS 572	Physics and Technology of Semiconductors (Dept. Physics & Astronomy)
PHYS 574	Materials Science (Dept. Physics & Astronomy)
PHYS 575	Solar Energy Conversion (Dept. Physics & Astronomy)
MATH 505	Numerical linear Algebra (Dept. of Math)
EE 502	Stochastic Modelling of Engineering Systems
GE 501	Computer Simulation of Engineering Systems
OR 543	Modelling & Simulation (Dept. of Statistics)

Program Schedule:

First Semester

Course Codes	Course Title	Credit Hours
REEN 501	Renewable Energy 1: Solar Energy	3
REEN 502	Renewable Energy 2: Wind, Hydrogen and other	3
REEN 504	Energies	3
REEN 505	Heat Transfer and Thermodynamics Seminar	1
Total		10

Second Semester

Course Codes	Course Title	Credit Hours
REEN 503	Energy Conversion and Storage	3
REEN 5xx	Course from specialized track courses	3
REEN 5xx	Course from specialized track courses	3
Total		9

Third Semester

Course Codes	Course Title	Credit Hours
REEN xxx	Course from specialized track courses	3
REEN xxx	Elective Courses	3
Total		6

Fourth Semester

Course Codes	Course Title	Credit Hours
REEN 600	Thesis	6

Courses Description

REEN 501 Renewable Energy 1: Solar Energy 3(3+0) (core course)

Solar radiation spectrum, Global distribution, seasonal variation, Effect of tilt angle, Resource estimation

Introduction to Solar Thermal: Applied heat transfer, flat plate collection and systems, Passive solar design, Concentrators, Solar thermal power stations.

Introduction to Photovoltaics: PV Cell Characteristics, Modules, Arrays.

Photovoltaic Systems: System types, System Components, System sizing, System Performance, Applications, Economics

REEN 502 Renewable Energy 2: *Wind, hydrogen and other energies 3(3+0) (core course)*

Wind energy distribution, Wind power, Wind turbines, Wind farms and energy generation, Hydrogen: Energy generation, Hydrogen energy transfer, Hydrogen: Fuel cells, Types of fuel cells, Hydropower, Ocean thermal energy conversion, Biomass: Energy feedstock, Biomass: Municipal solid waste, Biomass: Liquid and gaseous fuels, Geothermal energy, Tidal energy, Wave energy, Renewable energy contribution and energy balance, Typical projects: Renewable energy and the environmental issues.

REEN 503 Energy Conversion and Storage 3(3+0) (core course)

Analysis of thermo-mechanical, thermo-chemical, electrochemical, and photoelectric processes and technologies of renewable energy conversion and storage systems; on-shore and off-shore energy conversion; innovative energy storage devices; energy carriers, synthesized fuels, and fuel reforming. Emphasis is on advanced energy technologies, energy efficiency, systems performance, innovative grid connections, and minimizing environmental impacts

REEN 504 Heat Transfer and Thermodynamics 3(3+0) (core course)

Introduction to thermodynamics; Properties of pure substances; Energy transfer by heat, work, and mass; Energy and mass conservation; Entropy and the second law; Gas and vapor power cycles. Heat transfer by conduction, convection and radiation. Numerical analysis of steady and unsteady conductions. Natural and forced convection. Heat exchangers. Third law of thermodynamics and programmed applications.

REEN 505 Seminar 1(1+0) (core course)

Course objective: this course is to broaden and deepen students understanding of the different types of researches in the field of educational administration. Another aim is to help students develop skills of analysis and criticism through training them in order to evaluate researches and design research plans.

REEN 511 Solar Thermal Technology 3(3+0) (elective course)

Solar energy: radiation fundamentals, measurement and data processing required to predict solar irradiance with respect to time, location and orientation. The characteristics of various components in solar thermal systems: flat plate and concentrating collectors, heat exchangers

and thermal storage. System performance, Systems design, Predicted energy savings and economics. Low temperature applications for solar hot water, space heating and water distillation. Concentrating solar energy, Solar towers, solar thermo-chemical processes to produce hydrogen and solar power systems.

REEN 512 SOLAR Cooling 3(3+0) (elective course)

General cooling theory, Thermodynamics of vapor compression refrigeration systems, solar powered vapor compression systems, absorption cooling, binary mixtures and processes, Aqua-ammonia absorption systems, Lithium bromide-water absorption systems, evaporative cooling, desiccant cooling, vapor-jet cooling systems, thermoelectric cooling, applications of solar air-conditioning systems, miscellaneous solar cooling applications, passive and hybrid cooling systems. Economical consideration of solar cooling.

REEN 513 SOLAR ACTIVE HEATING SYSTEMS 3(3+0) (elective course)

Solar heating systems, flat-plate solar collectors, heating loads, simulations in solar heating systems, Long term performance of solar heating systems, Design of active systems by f-chart: the f-chart for liquid systems, the f-chart for air systems, Design of active systems by utilizability methods: hourly utilizeability, daily utilizeability, The (p-f chart methods, Solar heating economics

REEN 521 Solar Cell and Module Technology 3(3+0) (elective course)

Semiconductor Materials: Conduction theory, E-k curves, energy bandgaps, effective mass, direct and indirect transitions. Carrier statistics, intrinsic and extrinsic behavior, mobility, diffusion, scattering. Equilibrium and non-equilibrium behaviour, recombination, Optical and thermal properties.

Semiconductor Devices: p-n junctions, depletion region, derivation of I-V characteristics in the dark. Ideal diode under illumination, Loss mechanisms for real diodes, series and shunt resistances, interface states. Heterojunctions, Anderson model, current transport models, window layers. Introduction to multijunction concepts.

Material Fabrication Technologies: Purification of silicon, zone refining and gettering, segregation coefficient. Growth of crystalline silicon, Bridgmann, Czochralski and floating zone methods. Epitaxial growth methods, MBE, MOCVD, LPE, VPE. Thin film deposition methods, evaporation, sputtering, wet chemical, spray pyrolisis, screen printing.

Device Fabrication: Doping, alloying, diffusion and implantation. Device processing methods. Deposition of anti-reflection coatings. Photolithography. Dry and wet etching. Surface texturing and passivation techniques.

REEN 522 Advanced Solar Cell Designs 3(3+0) (elective course)

Cell and Module Concepts: Flat plate and concentrator cells and modules. Multi-junction concepts, Overview of cell types and technology status.

Advanced Devices: High efficiency crystalline silicon designs. Passivation, light trapping and contact structures. Cost reduction strategies. III-V devices, high concentration, quantum wells devices, multi-junction structures, thermos-photovoltaic devices. Thin film solar cells, structures and fabrication, novel device designs.

Characterization Methods: Cell measurement, solar simulation, conversion efficiency and spectral response. I-V-T and C-V-f measurements. Measurement and performance standards.

REEN 523 Photovoltaic Systems Technology 3(3+0) (elective course)

Basic system design: PV arrays, electrical connections and wiring issues BOS components Overview of standalone and grid connected systems, System sizing

Stand Alone systems: Applications, Performance assessment , Standards and regulations Grid connected systems: Inverter systems, electrical supply issues, Grid connection regulations, Harmonic content, reactive power, wiring issues, Design of large scale systems Building integrated systems: System design and sizing, Energy in buildings, building components, Installation and operation.

Concentrator systems: Design of concentrator systems, Operation and maintenance Monitoring and performance: Monitoring specifications, Yield and performance ratio, MTBF Operational issues and maintenance, Standards for construction and operation, Regulations governing system design and operation, Health and safety issues,

Space systems: Array configurations, Quality control and assessment, Design of systems.

REEN 531 Wind Turbine Aerodynamics 3(3+0) (elective course)

Advanced methods, Aerodynamic stall, Unsteady aerodynamics, Vortex wake structure, Advanced wake models, Optimum design of wind turbine blades.

Static and Dynamic Loading of Wind Turbines: Aerodynamic and gravity loading, Inertial and structural loads, Aero-elastic modeling, Fatigue of wind turbine blades

REEN 532 Design and Control of Wind Turbines 3(3+0) (elective course)

Design of Wind Turbines: Important factors, Design options, Design parameters, Design of components, System designs, Megawatt scale design.

Performance Testing and Modeling: Measurements under controlled conditions, Field testing instrumentation.

Wind Turbines Control: Aerodynamic power, Electromagnetic torque control, Control -dynamic analysis and stability, Control strategies.

REEN 533 Wind Farm Technology 3(3+0) (elective course)

Wind Data and Statistics: Gusts and gust probability distributions, Effects of topography. Wind exploitation in wind farm, Energy predictions and optimization, Balance of plant, Wind farm electrical design.

Electrical Integration: Weak grids, Power quality, Network costs and benefits.

REEN 534 Technologies for Wind Generation 3(3+0) (elective course)

Analysis of doubly-fed induction generators, analysis of permanent magnet generators, vector control of generators, operation and control of wind farms, economic optimization of wind generators within a power system, AC-DC transmission links for offshore wind farms.

REEN 541: Hydrogen Production 3(3+0) 3(3+0) (elective course)

Chemical Production of hydrogen, Partial Oxidation, Steam Reforming, Thermal Decomposition, Syngas, Shift reaction, Methanation, Hydrogen Purification, Desulfurization, CO_2 Removal, Electrolytic Hydrogen, Liquid Electrolyte Electrolyzers, Solid Polymer Electrolyte Electrolyzer, Ceramic Electrolyte Electrolyzer, Photolytic Hydrogen, Solar Photolysis.

REEN 542: Hydrogen Storage 3(3+0) (elective course)

Compressed Gas, Cryogenic Hydrogen, Storage of Hydrogen by Adsorption, Storage of Hydrogen in Chemical Compound, Metal Hydrides, Hydrogen Storage Materials, Graphite Nanofibres, Sponge Iron, Glass Microspheres, Carbon nanotubes, Aerogels.

REEN 543: Fuel cells 3(3+0) (elective course)

Introduction to fuel cells, difference between fuel cells and other electrochemical cells. Characteristics of fuel cells (energy efficiency, environmental issues, operating performance, and so on). Fuel cells basics: thermodynamics and kinetics of electrochemical reactions, types of over-potentials, electrodes reactions in fuel cells, gas diffusion electrode, electro-catalysis, fuel cell efficiency). Components of fuel cells, Fuel cell design and components. stack components, Fuel Cell systems: Phosphoric Acid Fuel Cells, Molten Carbonate Fuel Cells, Solid oxide Fuel Cells, Polymer Electrolyte Fuel Cells, Direct Methanol Fuel Cells, Alkaline fuel cells). Fuel Cell Applications: Stationary Power Plants. Automotive Power Plants, other Applications.

REEN 544: Selected Topics in Hydrogen Technology 3(3+0) (elective course)

Materials selection, Catalyst Preparation including nano catalysts, Characterization of catalysts, Infrastructure and distribution of hydrogen, Economic aspects of using hydrogen, Innovation in hydrogen technology

REEN 545 Materials characterization 3(3+0) (elective course)

Structural characterization (XRD, XRF, XPS, SAX, Auger, SIMS, etc), Electrochemical characterization (CV, EIS, E-I curves, etc), Morphological characterization (SEM, TEM, AFM, STM, etc), Thermal and mechanical properties, Spectroscopic characterization (UV, VIS, IR, Raman, etc), Electrical properties and Optical properties.

REEN 551 Energy Economics and Policy 3(3+0) (elective course)

Economic issues: Elements of economic principles, Economic calculation, Conventional energy resources and costs, Renewable energy resources and costs, Direct and indirect costs, Pricing system, Contracting, Project management, World energy trend. Funding and sponsoring facilities: International organizations, National possibilities, Regional facilities. Development and ecological growth: Energy needs for economic growth and regional development, Increase in value creation, Basic needs, Ecological, ethics and utopias, Sustainable future. Policy Issues: Market development, Government policies, Climate change issues. Environmental Impact Assessment: Module production, Energy analysis, Life cycle analysis, CO_2 emissions.

EE 534 Power Semiconductor Converters 3(3+0) (elective course)

Semiconductor devices: Driving, snubber and protection circuits; Resonant converters; Switching D.0 power supplies; Power conditioners; Applications in the fields of electrical energy utilization.

EE 612 Design and Technology of Solar Cells 3(3+0) (elective course)

Standard silicon solar cell technology: raw material to single crystal silicon; Improved silicon cell technology: solar grade silicon; silicon sheet; cell fabrication; Design of silicon solar cells: major considerations; doping of substrate; back surface fields; top layer limitation; top contact design; optical design; Spectral response. Other device structures: homojunctions; hetrojunctions; MS, MIS, Other semiconductor materials.

EE 613 Design and Applications of Photovoltaic Systems 3(3+0) (elective course)

Components of a photovoltaic system: introduction; PV modules (construction, I-V characteristic, performance); Energy storage (batteries for PV use, performance); power conditioning, Design of stand-alone PV systems: introduction; system sizing, Applications of stand-alone PV systems, Residential and centralized PV power systems.