

# Centre for Energy and Environment

## ACADEMIC CURRICULUM

### M. Tech. (Renewable Energy)

Teaching Scheme					Contact Hours/week			Exam. Duration (Hrs.)		Relative Weightage (%)				
S.No	Subject Code	COURSE TITLE	Subject area	CREDIT	L	T	P	Theory	Practical	CWS	PRS	MTE	ETE	PRE
<b>1<sup>st</sup> YEAR</b>					<b>I SEMESTER (AUTUMN)</b>									
1.	RET 601	Photovoltaic and Fuel Cell Systems	PC	3	3	0	0	2	---	20	---	40	40	---
2.	RET 602	Design of Solar Thermal Systems	PC	3	3	0	0	2	---	20	--	40	40	---
3.	RET 603	Wind and Hydro Energy Systems	PC	3	3	0	0	2	---	20	---	40	40	---
4.	RET 604	Energy and Environmental Policies	PC	3	3	0	0	2	---	20	---	40	40	---
5.	RET 605	Sustainable Buildings	PC	3	3	0	0	2	---	20	---	40	40	---
6.	RET 606	Renewable Energy Lab	PC	3	0	0	6	-	3	--	60	--	--	40
<b>Sub Total</b>				<b>18</b>										
					<b>II SEMESTER (SPRING)</b>									
1.	RET XXX	Elective - 1												
2.	RET XXX	Elective - 2												
3.	RET XXX	Elective - 3												
4.	RET XXX	Elective - 4												
5.	RET XXX	Elective - 5												
6.	RET XXX	Elective - 6												
<b>Sub Total</b>				<b>18</b>										
<b>2<sup>nd</sup> YEAR</b>					<b>III SEMESTER (AUTUMN)</b>									
1.	RES-615	Seminar	PC	4										
2.	RED -616	Dissertation	PC	16	--	---	---	---	---	---	---	---	---	---
<b>Sub Total</b>				<b>20</b>										
					<b>IV SEMESTER (SPRING)</b>									
1.	RED -617	Dissertation (contd. from III Semester)	PC	16	--	---	---	---	---	---	---	---	---	---
<b>Sub Total</b>				<b>16</b>										
<b>Total</b>				<b>72</b>										

## Program elective

Code	Course name	Credits	Teaching scheme (L-T-P)
RET 607	Solar passive heating and cooling	3	3-0-0
RET 608	Biomass energy systems	3	3-0-0
RET 609	Grid connectivity and smart grid	3	3-0-0
RET 610	Life cycle assessment of renewable energy systems	3	3-0-0
RET 611	Management and modeling of environmental systems	3	3-0-0
RET 612	Instrumentation and control of energy systems	3	3-0-0
RET 613	Industrial energy management	3	3-0-0
RET 614	Energy Simulation	3	1-0-4
RET 617	Advanced Energy Storage Technology	3	3-0-0
RET 618	Advanced photovoltaic technologies	3	3-0-0

## **RET 601 Photovoltaic and Fuel Cell Systems**

### **Course Outcomes:**

- CO1 To discuss the aspects of the basics of solar radiation, PV system, semiconductor technology to enable learners to analyze and estimate solar Photovoltaic power at different locations
- CO2 To dissipate the knowledge for estimating different losses in solar energy systems
- CO3 To discuss theories and parameters for designing small or large solar power plant
- CO4 To discuss theories and parameters for designing different types of fuel cell

### **Course Content**

Solar PV systems: Fundamentals of solar cell, semiconductors as basis for solar cells materials and properties, P-N junction, sources of losses and prevention, estimating power and energy demand, site selection, land requirements, choice of modules, economic comparison, balance of systems, off grid systems, grid interface, Preparing DPR, Supporting structures, mounting and installation, battery storage, power condition unit, selection of cables and balance of systems, planning with software, maintenance and schedule, Monitoring, Data Management, Performance Analysis and Financial Analysis

Solar PV power plants: Array design, inverter types and characteristics, Power conditioning system: working algorithms, performance analysis; design of stand alone, hybrid and grid interactive plants, commissioning of solar PV plant

Fuel Cells: Thermodynamics of fuel cells; free energy change and cell potentials; effects of temperature and pressure on cell potential; energy conversion efficiency; factors affecting conversion efficiency; polarization losses; important types of fuel cells (hydrogen-oxygen, organic compounds-oxygen, carbon or carbon monoxide-air, nitrogen compounds-air); electrode types; electrolytes for fuel cells; applications.

### **References**

- 1.Solar Photovoltaics: Fundamentals, Technologies and Applications by Chetan Singh Solanki, Prentice Hall, India
- 2.Terawatt Solar Photovoltaics, Roadblocks and Opportunities Edited by M. Tao, Springer
- 3.Handbook of Photovoltaic Science and Engineering, Edited by A. Luque and S. Hegedus, John Wiley & Sons, Ltd

## **RET 602 Design of Solar Thermal Systems**

### **Course Outcomes:**

- CO1: To understand different aspects and parameters of solar energy and design solar thermal systems
- CO2: To educate the learner for tackling different issues and challenges of various solar thermal collectors
- CO3: To understand the power generation aspects from solar thermal systems

### **Course Content**

Solar Radiation: Basics of Solar Radiation, instruments for measuring solar radiation, solar radiation geometry, empirical equations, solar radiation on tilted surfaces.

Liquid Flat plate Collector: Basic elements, performance analysis, transmissivity - absorptivity, heat transfer coefficients and correlations, collector efficiency and heat removal factors, effects of various parameters, types of other liquid flat-plate collectors, transient analysis.

Concentrating Collectors: Type of concentrating collectors and their general characteristics, geometry, heat transfer correlations, tracking requirements, performance analysis.

Solar thermal power plants: Concentration and temperatures, error in concentration, parabolic geometries, paraboloid geometries(dish), heliostats, lay out, central receiver ,

Component design: Energy balance of components, design process and parameters, thermodynamic basis for receiver design, tube receiver concept. Volumetric receiver, direct absorption receiver, receiver loss calculations, thermal storage for solar power plants.

Thermal Energy Storage: Basic methods, Sensible heat storage – liquids- solids-analysis, latent heat storage, thermo chemical storage, application of thermal storage.

Solar field design: array design, control of solar collectors, piping layout, pumping requirements condition monitoring and maintenance systems.

Performance analysis of miscellaneous solar applications: Solar Air heaters, solar pond, solar still, solar refrigeration

## References

1. S. P. Sukhatme and J. K Nayak, Solar Energy, 4<sup>th</sup> Edition, McGraw-Hill Education Pvt.
2. J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, Wiley,
3. D. Y. Goswami, Principles of Solar Engineering, 3rd Edition, CRC Press,

## RET 603 Wind and Hydro Energy Systems

### Course Outcomes

CO1: To understand basic of wind and hydro energy systems and resource assessment techniques.

CO2: To create understanding and design aspects of wind/hydro plant, components, operation and control

CO3: To create understanding on wind/hydro power generation, grid integration and environmental impacts.

### Course Content

Wind Energy Basics: Status, Advantages and disadvantages of wind energy systems, Advantages and disadvantages, Types of wind energy converters, local Effects on wind, site selection: roughness length, wind shear, Wind Speed Variability, Obstacles to wind flow, Working principles of wind energy: Energy content in wind, Energy Conversion at the Blade, Wind variations: Weibull distribution.

Components of a wind energy converter: Rotor Blades, Gearboxes, Synchronous or Asynchronous Generators, Towers, Miscellaneous components, Turbine Selection

Operation and Control of Wind Energy Converters: grid requirements, Issue of Noise and Its Control, Power Curve and Capacity Factor, Pitch control, Stall Control, Yaw Control

Hydropower basics: Water Cycle in Nature, Classification of Hydropower Plants, Status of Hydropower Worldwide, Advantages and Disadvantages of Hydropower, Operational Terminology, Legal Requirements

Working principles: Locating a Hydropower Plant, Basics of Fluid Mechanics for hydro power, single and multiple reservoir system, cascaded power plants

Important Parts of Hydropower Station: Turbine, Electric Generator, Transformer and Power House, Structural parts: Dam and Spillway, Surge Chambers, Stilling Basins, Penstock and Spiral Casing, Tailrace, Pressure Pipes, Caverns, auxiliary parts.

Hydraulic turbines: Classification of Hydraulic Turbines, Theory of Hydro Turbines: Francis, Kaplan, Pelton turbines, efficiency and selection of turbine

## References

1. Freris L.L., Wind Energy Conversion Systems, Prentice Hall
2. Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering,

3. Johnson, G.L., Wind Energy Systems, Prentice Hall,
4. James F. Manwell, Jon G. McGowan, Anthony L. Rogers, Wind Energy Explained: Theory, Design and Application, Wiley
5. Paul Gipe, Wind Energy for the Rest of Us: A Comprehensive Guide to Wind Power and How to Use it, Chelsea Green Publishing Co,
6. Brown, G., "Hydro-electric Engineering Practice", Vol. I, II & III, CBS Publication
7. Nigam, P.S., "Hand book of Hydroelectric Engineering", Nem Chand and Brothers
8. Clemen, D.M., "Hydro Plant Electrical Systems", HCI Publication

### **RET 604 Energy and Environmental Policies**

#### **Course outcomes**

CO1: To understand the energy carriers, energy technologies, energy challenges

CO2: To able to know the geopolitics national and international energy and and environment policy

CO3: To understand the relationships between energy, risk, societal safety, sustainable development and energy economics.

#### **Course content**

Introduction to Energy codes and policies: Energy Conservation act, Electricity Act, Solar policy, Hydro policy, Biomass policy

International scenario: world energy outlook, international protocols for energy and environment, governing and nodal national/international agencies and their role

Financial tools: incentives and subsidies, calculation of required subsidy for penetration, concept of shadow price Concept of micro-financing for RE, funding agencies for RE projects in India, application development for RE funding Tariff policies, use of Demand Side Management as a policy tool

#### **References**

1. SC Bhattacharyya. Energy Economics, Concepts, Issues, Markets and Governance, Springer Science & Business Media
2. TF Braun & MG Lisa. Understanding Energy and Energy Policy. Zed Books
3. Kandpal, Tara Chandra, and Hari Prakash Garg. Financial evaluation of renewable energy technologies. MacMillam India Limited,

### **RET 605 Sustainable Buildings**

#### **Course Outcomes:**

CO1: To impart knowledge of contemporary issues pertaining to habitat planning and building construction

CO2: To develop ability to apply knowledge of engineering in design of environmentally sound buildings

CO3: To equip students to function in multidisciplinary teams in development of environmentally sustainable and healthy buildings

#### **Course content**

Concept of green buildings features of green building rating systems in India: LEED, GRIHA. Sustainable site, water, energy, material and indoor environment issues for green buildings;

Intent and documentation for credits/points for green rating systems; difference in evaluation and documentation for new construction, existing buildings, core and shell projects.

Green home rating system, green factory rating, green neighborhood concept; Concept of Net zero energy building, net zero community.

Energy Conservation Building Code: requirements of code, applicability, compliance options: prescriptive, trade-off, whole building performance routes for compliance

### **References**

1. Construction Manual, Ministry of Environment & Forests, Government of India, New Delhi
2. Sustainable Building Design Manual- Volume I & II, The Energy and Resources Institute (TERI)
3. Environmental Impact Assessment Guidance Manual for Building, Construction, Townships and Area Development Projects, Ministry of Environment & Forests, Government of India, New Delhi

## **RET 606 Renewable Energy Laboratory**

### **Experiments related to following topics:**

- Solar water heating
- Solar cooking
- Solar concentrator
- PV module characterization
- Inverter performance analysis
- Wind energy convertor
- Biomass for energy
- Solar passive concepts and thermal comfort

## **Program Electives**

### **RET 607 Solar Passive Heating And Cooling**

#### **Course Outcomes:**

CO1: Understand contribution of various components of heating and cooling load

CO2: Understand methods for reduction of heating/cooling load

CO3: Understand design aspects of passive systems and carry out performance evaluation

#### **Course content**

Heating and cooling load of buildings: elements of heating and cooling load, load reduction approaches, building energy codes, thermal mass

Solar geometry and exposure: sun path diagram, shading analysis, graphical design tools, solar control issues Passive heating: Direct and indirect solar passive heating systems; solarium, trombe wall, trans-wall.

Passive cooling systems: thermal mass, courtyard effect, wind tower design, earth air tunnel system, evaporative cooling, radiative cooling,

Solar ventilation: stack effect, solar chimney for ventilation, absorber design, stack design, issues in opening design

#### **References**

1. M. S. Sodha, N. K. Bansal, P. K. Bansal, A. Kumar and M. A. S. Malik, Solar Passive Building: science and design, Pergamon Press, New York,
2. J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, John Wiley, New York,
3. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia,

### **RET 608 Biomass Energy Systems**

#### **Course Outcomes**

CO1: To analyze and describe the nature and principles of bioenergy systems.

CO2: To develop, designs and distinguish the bioenergy systems and learn technical analysis.

CO3: To create understanding to critically evaluate the environmental benefits and consequences of bioenergy production.

#### **Course content**

Biomass Resource: Characteristics of Biomass fuel, technologies for using biomass, comparison of direct combustion with other technologies

Biomass Gasifiers: Basics of Gasification and types of Gasifiers, Thermodynamic Analysis Biogas Technology, Sizing/Selection and design of Gasifiers,

Industrial use of biomass: Industrial Boilers, biomass as fuel, co-firing and co-generation, Economic analysis, Testing and Performance Evaluation of Gasifiers, Use of biomass for liquid fuel, Biomass policy Biogas: Types of biogas plants, design and performance analysis, application of biomass

## References

1. Capareda S, Introduction to biomass energy conversion, CRC Press.
2. Brown RC and Stevens C, Thermo-chemical Processing of Biomass: Conversion into Fuels, Chemicals and Power, Wiley and Sons.
3. Vaughn C. Nelson, Kenneth L. Starcher, Introduction to Bioenergy (Energy and the Environment), CRC Press.
4. Yebo Li and Samir Kumar Khanal, Bioenergy: Principles and Applications, Wiley-Blackwell.
5. Ted Weyland, Bioenergy: Sustainable Perspectives, Callisto Reference.

## RET 609 Grid Connectivity and Smart Grid

### Course outcomes

CO1: Know, understand and explain the concept and related infrastructure of a smart grid

CO2: Describe the basic operation of smart grid

CO3: Describe and classify the modern and innovative application fields of distributed generating units and relative merits

### Course content

Introduction to grid connectivity of RE systems, smart grid and emerging technologies, Operating principles and models of smart grid components, Key technologies for generation, networks, loads and their control capabilities; decision-making tools,

Non conventional energy source models grid integration, Micro-turbine model and grid integration, Fuel cell model and grid integration, Energy storage and electric vehicle models and grid integration,

Distribution line models, Communication infrastructures for smart grid operation, Advanced metering infrastructure and advanced control methods,

Economic dispatch, Demand response and demand management, Distribution feeder analysis, Continuous voltage and frequency control, Contingencies and their management, Unit commitment (selection of generators & loads to operate),

Energy constraints: hydro, fuel management and maintenance scheduling, The operational challenges of distributed energy resources, Operation and control issues associated with intermittent generation,

Electricity industry operation in a carbon constrained and 'smart grid' future, Impact of smart grid component integration on distribution network operation, Artificial Intelligence based approaches for estimation, scheduling, management and control of next generation smart grid.

### References

1. Stuart Borlase, Smart Grid: Infrastructure, Technology and Solutions, CRC Press 2012, ISBN 9781439829059.
2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, Smart Grid: Technology and Applications, Wiley, 2012, Print ISBN:9780470974094 |Online ISBN:9781119968696.
3. Mini S. Thomas, John D McDonald, Power System SCADA and Smart Grids, CRC Press,
4. Kenneth C. Budka, Jayant G. Deshpande, Marina Thottan, Communication Networks for Smart Grids, Springer, 2014, ISBN 978-1-4471-6302-2.
5. Henrik Lund, "A Smart Energy Systems Approach to the Choice and Modeling of 100% Renewable Solutions" Academic Press,.



## **RET 610 Life Cycle Assessment of Renewable Energy Systems**

### **Course outcomes**

CO1: To evaluate the financial feasibility of any energy project

CO2: To evaluate the environmental properties of different energy and production systems

CO3: To conduct a simplified LCA as independent work, as well as more complex assessments

### **Course content**

Financial evaluation: simple pay back analysis, return on investment, time based value of money, NPV method, annuity method, calculation of IRR.

Energy analysis: concept of embodied energy, energy analysis methodologies: process chain analysis, input-output method, inventory method; cumulative energy demand, energy yield ratio, energy payback.

Environmental analysis: concept of carbon footprint of materials and systems, cumulative emission for renewable energy systems, environmental indicators of RE systems.

Data quality of embodied energy, and specific emission of materials

### **References**

1. Basosi, R., Cellura, M., Longo, S., Parisi, M.L , Life Cycle Assessment of Energy Systems and Sustainable Energy Technologies, Springer
2. Kandpal, Tara Chandra, and Hari Prakash Garg. Financial evaluation of renewable energy technologies. MacMillam India Limited,

## **RET 611 Management and Modeling of Environmental Systems**

### **Course Outcomes**

CO1: To design energy systems for engineering applications and model their performance

CO2: To analyze energy systems under design and off-design operating conditions.

CO3: To optimize the performance of different energy systems

### **Course Content**

Human - environment relationship, normative criteria, descriptive and prescriptive models, limits of growth;

Environmental and natural resources economics, pollution control policy, growth in a finite environment; Environmental protection laws;

Numerical/mathematical modelling of environmental systems, subsystems, and pollutant transport processes;

Planning and management of environmental systems: optimization techniques, stochastic modelling, statistical inferences;

Large scale systems; Optimal monitoring network design, identification of sources; Risk reliability and uncertainty in environmental systems;

Topics in groundwater and surface water quality management.

### **References**

1. Andrew Ford, Modeling the Environment: An Introduction To System Dynamics Modeling Of Environmental Systems. Island Press ,
2. M. C. Dash, Concepts of Environmental Management for Sustainable Development, I K International Publishing House Pvt. Ltd,

## **RET 612 Instrumentation and Control of Energy Systems**

### **Course Outcomes**

A student who completes the course is expected to acquire,

CO1: an ability to design experiments and measurement systems

CO2: an ability to identify suitable mechanical and electrical measurement systems and conduct experiments

CO3: an ability to carry out uncertainty analysis of the measured data

### **Course Content**

Basic measurement concepts, Error analysis, transducer classification, static and dynamic characteristics of transducers,

Real time monitoring and data processing, instrumentation for measuring temperature, humidity, radiation, flow, pressure, thermal conductivity, specific heat etc.;

Data loggers: type of loggers, configuring and checking data-loggers

Measurement of electrical quantities: current, voltage, power, power factor, stability, transient analysis of power generating systems

### **References**

1. T.-W. Lee: Thermal and Flow Measurements, CRC Press,
2. J.P. Holman: Experimental Methods for Engineers, McGraw Hill Education;
3. S. P. Venkateshan: Mechanical Measurements, ANE Books,
4. E.R.G. Eckert and R.J. Goldstein: Measurements in Heat Transfer, McGraw Hill,
5. E.O. Doebelin: Measurements Systems: Application and Design.

## **RET 613 Industrial Energy Management**

### **Course Outcomes**

CO1: To identify the demand supply gap of energy in Indian scenario and identify the improvement process through energy management

CO2: To evaluate the techno economic feasibility of any energy conservation technique adopted

CO3: To gain the ability to carry out energy audit of an industry/organization and prepare an audit report

### **Course Content**

Energy consumption in industries: Energy and material flow assessment, specific energy consumption, industry benchmarks for energy consumption.

Energy audit: Process of energy audit, preliminary audit, detailed audit, reporting of energy audit, concept of ESCO, energy performance contracting, instruments for energy audit, management and organization of energy conservation programs in industries

Energy conservation in industrial systems: boilers, furnaces, pumps, fans and blowers, steam system, motors and transformers, power factor.

### **References**

1. Handbook of Energy Audits by Albert Thumann. CRC press.
2. Guide to Energy management, by Barney L.Capehart, Wayne C.Turner, and William J.Kennedy, The fairmont press, INC. Fourth edition

## RET 614 Energy Simulation

### Course Outcomes:

CO1: To learn underlying concepts, modeling inputs and modeling methods of renewable energy systems.

CO2: To understand performance and operation of different renewable energy systems.

CO3: To interpret and validate simulation results.

### Course Content

Introduction to energy simulation tools , Modeling techniques, validation of simulation model  
Simulation of renewable energy systems Simulation for energy efficiency of buildings, Software to be used: EnergyPlus, TRNSYS, HOMER

## RET 617 Advanced Energy Storage Technology

### Course outcome

CO1: To discuss different aspects and parameters of electrical energy storage systems.

CO2: To understand utilization, sizing and operation of energy storage systems.

CO3: To create an understanding on energy storage integration and hybrid energy storage systems.

### Course content

Unit I: Introduction of energy storage technology, requirement for energy storage, Current status, Future prospect of storage

Unit II: Mechanical energy storage systems, flywheel energy storage (FES), pumped hydropower storage (PHS), and compressed-air energy storage (CAES). Comparison and application state-of-arts including principle, function and deployments. Technical characteristics in terms of power rating and discharge time, storage duration, energy efficiency, energy density, cycle life and life time, capital cost etc. Case study/project based on mechanical energy storage.

Unit III: Electrochemical energy storage: Flow Battery, Battery, Fuel Cell, and Capacitor. Comparison and application state-of-arts including principle, function and deployments. Technical characteristics of various electrochemical energy storage systems. Case study/project

Unit IV: Hydrogen energy: hydrogen economy, Hydrogen based FCV, hybrid electric vehicle, maintenance of FCV, safety

Unit V: Thermal energy storage: sensible heat storage (SHS), latent heat storage (LHS) or phase-change materials (PCMs), and thermal chemical energy storage (TCES). Comparison and technical characteristics. Case study/project

Unit VI: Hybrid energy storage systems: capacitor-battery hybrid systems, hybrid PCMs energy storage, hybrid CAES etc.

### References

1. Christopher D. Rahn and Chao-Yang Wang, Battery system engineering, Wiley,
2. DOE/EPRI Electricity Storage Handbook, U.S. Department of Energy and the Electric Power Research Institute in collaboration with the National Rural Electric Cooperative Association.

3. Frank S Barnes, John G Levine, Large Energy Storage Systems Handbook. CRC press
4. Robert Huggins, Energy Storage, Springer Nature;
5. Ibrahim Dincer and Marc A. Rosen, Thermal energy storage systems and applications,
6. Luisa F. Cabeza, Advances in Thermal Energy Storage Systems: Methods and Applications, Woodhead Publishing,

## **RET 618 Advanced photovoltaic technologies**

### **Course outcome**

- CO1: To discuss the aspects of use of different semiconductor materials in solar cells.
- CO2: To disseminate the knowledge of economic aspects for different photovoltaic technologies.
- CO3: To discuss theories and parameters for designing highly efficient state of the art commercial photovoltaic system

### **Course content**

Overview of different types of solar cells/panels. Photovoltaic industries in India and World. International certification of solar panels and Indian scenario.

Wafer based silicon solar cells and its market trend. Cost breakup of wafer based solar panels, future trends Concentrator solar cells, reflector and lens based versions. Performance in Indian climatic conditions. Low, medium and high concentration, combined thermal and concentration PV system.

Semi-transparent solar cells and related materials, applications in buildings (BIPV), thin film and wafer based versions, appearance and structure of thin film solar cells, Flexible solar cells.

Multi-junction solar cells, its working principles.

Hetero-junction with intrinsic thin layer (HIT) solar cells, structure and working principle, comparison with conventional bulk solar cells,

Polymer, organic, dye sensitized and quantum dot solar cells, structure, working principle, present applications, near future trends.

### **References**

1. Terawatt Solar Photovoltaics, Roadblocks and Opportunities Edited by M. Tao, Springer
2. Handbook of Photovoltaic Science and Engineering, Edited by A. Luque and S. Hegedus, John Wiley & Sons, Ltd
3. Practical Handbook of Photovoltaics: Fundamentals and Applications Edited by A. Mcevoy, T.Markvart, L. Castañer, Elsevier
4. Building integrated photovoltaics/a handbook Edited by S. Roberts & N.Guariento, Birkhäuser, Germany
5. Photovoltaics System Design and Practice Edited by H. Haberlin, John Wiley & Sons, Ltd
6. Photovoltaics Fundamentals, Technology and Practice Edited by K. Mertens, John Wiley & Sons, Ltd