Energy and Power Generation Handbook

Established and Emerging Technologies

Editor
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DEDICATION

This *ENERGY AND POWER GENERATION HANDBOOK* is dedicated to:

The late Dr. Baira Gowda, Pittsburgh, PA for introducing me to ASME, in the late 1980s;

Dr. Robert Toll Norman and Dr. Liane Ellison Norman, staunch supporters of the "Green Peace Movement" and Clean Energy at Pittsburgh, PA, where I was in the 1970s and 1980s, in whom I saw firsthand what these movements symbolize;

Mr. VRP Rao, Fellow-IE for encouraging in me interest in actually taking up of this project to cover energy generation sources "other than nuclear," especially *renewable energy generation*, and finally;

Victims and Site Staff of the Fukushima Daiichi Nuclear Plants at Japan devastated by the Tohoku-Taiheiyou-Oki Earthquake and Tsunami of March 11, 2011. This publication is especially dedicated to these and other victims of Japan for the "Fortitude of Japan as a Nation," that shows national strength in their hour of an utterly tragic accident.

ACKNOWLEDGEMENTS

The editor is indebted to several individuals who had directly or indirectly helped in coming up with this handbook.

My thanks are due to all of the 53 contributors whose dedicated efforts made this possible by their singular attention to detail, presentation of graphics, procuring the copyrights for the "artwork" and taking time to research the references to complement the write-up. Even while they succinctly conveyed the wealth of information and knowledge they acquired during their professional career, they followed the guidelines provided for adhering to the page length.

It was challenging to enlist 53 experts from around the world to address varied power and energy generation topics. The editor contacted professionals who knew the worldwide ensemble of energy and generation experts. Efforts were made not to miss any power generation sources, and this was largely facilitated by contacting over 100 practicing professionals and academia before settling down with 53 authors. The formidable task of acquiring the correct authors took over six months and was amply rewarded.

While it is difficult to chronicle everyone the editor contacted, worthy of particular mention are Dr. Gregory J. Walker, University of Tasmania, Hobart, Tasmania, Australia; Mr. V. R. P. Rao F-IE, Hyderabad, India; Dr. Hardayal Mehta of GE Hitachi Nuclear Energy, San Jose, CA; Mr. Richard Bunce of Siemens Energy, Inc., Orlando, FL; Mr. Roger Reedy of REEDY Engineering, Inc., Cambell, CA; Ms. Katherine Knurek Martin, NASA Glenn Research Center, Cleveland, OH; Mr. Clifford Wells of Structural Integrity Associates, San Jose, CA; Dr. Bob Swindemann, Oak Ridge, TN; Mr. Roger Bedard formerly of EPRI; and Dr. E. V. R. Sastry, Osmania University College of Engineering, Hyderabad, India.

This publication was ably supported by the staff of ASME Technical Publishing. My appreciation and thanks to them for their cooperation.

Finally, all of this enduring effort, spread over 18 months, would have never been possible had it not been for the constant help and untiring zeal provided by my wife, Dr. Indira Rao, that included all of the sundry-editorial chores associated with this project.

CONTRIBUTOR BIOGRAPHIES

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Dr. Ravi K. Agrawal is a Senior Process Manager at KBR. He is currently the process manager and work group leader for a 600-MW Kemper County IGCC Project (formerly Mississippi Gasification Project). He has over 25 years of experience in a wide variety of technologies including gasification, syngas production, gas-to-liquids, coal-to-liquids, biomass conversion, bioethanol, carbon capture, acid gas removal, combustion, sour water treatment, and specialty chemicals. He is the inventor of two patents and six patent applications. He is also the author of over 60 technical publications in refereed journals.

Previously, he was with ETEC, Fluor Daniel, Woodward Clyde Consultants, and Argonne National Laboratory. As a principal at ETEC, he developed and executed marketing plans to increase sales that resulted in ETEC being recognized by the Houston Business Journal as the sixth fastest growing small business in 2002. He has been responsible for sales, engineering, construction, and startup of over 41 combustion and air pollution control systems installed at several utilities and refineries. He is a registered Professional Engineer in the states of Texas and Pennsylvania. Dr. Agrawal holds a PhD and a MS degree in chemical engineering from Clarkson University, as well as a B.Tech from Osmania University (Hyderabad, India).

ANDREONE, CARL F.

Carl F. Andreone, PE, Fellow of the ASME is registered in Massachusetts. He was President of Heat Transfer Consultants, Inc. until 2001, but now practices as an individual contractor. He was a Staff Consultant at Stone & Webster Engineering Corporation, Boston, MA, and held several other positions from 1970 to his retirement in 1991. Before joining Stone & Webster, he was a heat exchanger specialist with Badger America and Crawford & Russell Inc.

Mr. Andreone gained broad experience as a maintenance engineer on refinery exchangers at Aramco. His career includes nearly a decade with Lummus Heat Exchanger Division (now Yuba Heat Transfer Corporation) as an application and product engineer on power and process heat exchangers. Mr. Andreone has been continuously active in the heat exchanger industry since 1951. His work in this field has involved specification, design, maintenance, and repair of more than 3000 power and process heat exchangers.

From 1981 to the present, he has assisted in trouble-shooting, failure analysis, repair, modification, and replacement of more than 400 feedwater heaters at various power stations.

From 1982 through 2007, he and Stanley Yokell presented annual seminars on Closed Feedwater Heaters and Inspection, Maintenance and Repair of Tubular Exchangers. He is the author of numerous papers on feedwater heaters and tubular heat transfer equipment. With Mr. Yokell, he has written, *Tubular Heat Exchanger Inspection, Maintenance and Repair*, published by McGraw-Hill Book Company 1997.

Mr. Andreone served on the ASME Power Division Heat Exchanger Committee. He has served on the ASME Boiler and Pressure Vessel Code Committee's Special Working Group on Heat Transfer Equipment, and the ASME Codes and Standards Committee for the ASME/ANSI Performance Test Code 12.1, Closed Feedwater Heaters. Mr. Andreone received the B.Ch.E. from Villanova University.

BAILEY, SHEILA GAYLE

Sheila G. Bailey has been a Senior Physicist working in photovoltaics at NASA Glenn Research Center for over 25 years. Her most recent projects include nanomaterials and nanostructures for space photovoltaics, quantum wire IIIV solar cells and quantum dot alpha-voltaics. She has authored or co-authored over 165 journal and conference publications, nine book chapters and two patents.

Dr. Bailey is on the Editorial Board of "Progress in Photovoltaics". She is a member of the American Physical Society and a speaker for the American Institute of Physics Visiting Scientist Program. She is a member of AIAA Aerospace Power Systems technical committee and the IEE Electron Devices Society Photovoltaic Devices Committee. She was the chair of the 4th World Conference on Photovoltaic Energy Conversion in 2006. She is executive vice president of the Lewis Engineers and Scientists Association.

Dr. Sheila Bailey was an adjunct professor at Baldwin Wallace College for 27 years and is currently an associate faculty member of the International Space University. She has a BS degree in physics from Duke University, a MS degree in physics from the University of NC at Chapel Hill, and a PhD in condensed matter physics from the University of Manchester in England. She spent a post-doctoral year at the Royal Military College (part of the University of New South Wales) in Canberra, Australia.

Dr. Bailey is the recipient of the faculty excellence award from Baldwin Wallace College and the Federal Women's Program award. She is an Ohio Academy of Science "Exemplar". She was awarded the NASA Exceptional Service Medal for her work in space photovoltaics in 1999. She has completed the Office of Personnel Management's Executive Potential Program. She was inducted into the Ohio Women's Hall of Fame in 2003 by Governor Taft.

BALDWIN, THOMAS L.

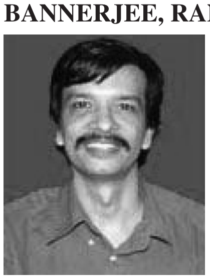
Thomas L. Baldwin, PE, PhD, IEEE Fellow, is a senior engineer at the Idaho National Laboratory. He conducts engineering studies and research in electrical power generation and transmission for the U.S. Department of Energy, U.S. Navy, and EPRI. His research interests are in distribution energy system design, industrial power systems, grounding issues, transformers, and the analysis of power quality problems.

Dr. Baldwin also holds the rank of professor at the FAMU-FSU College of Engineering at Florida State University, Tallahassee, FL, and has conducted research at the Center for Advanced Power Systems since 1999. He is a Registered Professional Engineer in the State of North Carolina.

Thomas L. Baldwin received the BSEE and MSE.E degrees from Clemson University, Clemson, SC, and the PhD degree in electrical engineering from Virginia Polytechnic Institute and State University, Blacksburg, VA, in 1987, 1989, and 1993, respectively.

Dr. Baldwin is a member of the IEEE Power and Energy Society and the Industrial Applications Society and serves on several committees and working groups including Power System Grounding and the IEEE Green Book.

BANNERJEE, RANGAN



Rangan Banerjee is a Professor of the Department of Energy Science and Engineering and currently the Dean of Research and Development at the Indian Institute of Technology Bombay. He was Associate Dean (R & D) of IIT Bombay from 2003 to 2006 and Head of the Department of Energy Science and Engineering (2006 to 2009).

Dr. Banerjee is a Convening Lead Analyst for Industrial End Use Efficiency and a member of the executive committee for the Global Energy Assessment (2008 to 2010) coordinated by the International Institute for Applied Systems Analysis. He is also an Adjunct faculty (Honorary) in the Department of Engineering & Public Policy, Carnegie Mellon University. He was a member of the Planning Commission's Integrated Energy Policy (2004 to 2005) Committee and on the working group for renewable energy and energy efficiency and DSM for the Eleventh Five Year Plan.

Dr. Banerjee has coauthored a book on Planning for Demand Side Management in the Power sector, a book on Energy Cost in the Chemical Industry, and a book on Engineering Education in India. He has been involved in industrial projects with organizations like Essar, Indian Chemical Manufacturers Association, KSIDC, HR Johnson, Tata Consulting Engineers, BSES, Sterlite, International Institute of Energy Conservation and sponsored projects with the Department of Science & Technology, UN, MERC, PCRA, MNES, Hewlett Foundation.

Dr. Banerjee's areas of interest include energy management, modeling of energy systems, energy planning and policy, hydrogen energy, and fuel cells. He has conducted two international training programs on solar energy and several National programs on renewable energy and Energy Management.

BOEHM, ROBERT F.

Robert F. Boehm is a Distinguished Professor of Mechanical Engineering and Director of the Energy Research Center at the University of Nevada, Las Vegas (UNLV). His work has been primarily in the area of renewable and conventional energy conversion. He was on the faculty of the University of Utah Department of Mechanical Engineering prior to coming to UNLV. He holds a PhD in Mechanical Engineering from the University of California at Berkeley.

Dr. Boehm is a registered professional engineer, a Fellow of the American Society of Mechanical Engineers, and has received several awards, including the Harry Reid Silver State Research Award, the UNLV Distinguished Teaching Award, and the Rudolf W. Gunnerman Silver State Award for Excellence in Science and Technology from DRI. He has been an invited lecturer at many institutions here and abroad, and he has published over 400 papers in heat transfer, design of thermal systems, and energy conversion topics. He is the author or coauthor of the ten books. He serves as a technical editor for *Energy—the International Journal.*

BOYCE, MEHERWAN P.

Professor Meherwan P. Boyce, PhD, PE, C.Eng (UK), is the managing Partner of The Boyce Consultancy Group, LLC. He has 50 years of experience in the field of TurboMachinery in both industry and academia. Dr. Boyce is a Fellow of the American Society of Mechanical Engineers (USA), National Academy of Forensic Engineers (USA), the Institute of Mechanical Engineers (UK), and the Institution of Diesel and Gas Turbine Engineers (UK), and member of the Society of Automotive Engineers (SAE), and the National Society of Professional Engineers (NSPE), and several other professional and honorary societies such as Sigma Xi, Pi Tau Sigma, Phi Kappa Phi, and Tau Beta Phi. He is the recipient of the ASME award for Excellence in Aerodynamics and the Ralph Teetor Award of SAE for enhancement in Research and Teaching. He is also a Registered Professional Engineer in the State of Texas and a Chartered Engineer in the United Kingdom.

Industrial experience of Dr. Boyce covers 10 years with The Boyce Consultancy Group, LLC., 20 years as Chairman and CEO of Boyce Engineering International Inc., founder of Cogen Technologies Inc. His academic experience covers a 15-year period, which includes the position of Professor of Mechanical Engineering at Texas A&M University and Founder of the TurboMachinery Laboratories and The TurboMachinery Symposium, which is now in its Fortieth year.

Dr. Boyce is the author of several books such as the Gas Turbine Engineering Handbook (Third Edition, Elsevier), Handbook for Cogeneration & Combined Cycle Power Plants (Second Edition, ASME Press), and Centrifugal Compressors, A Basic Guide (PennWell Books). He is a major contributor to Perry's Chemical Engineering Handbook Seventh and Eight Editions (McGraw Hill) in the areas of Transport and Storage of Fluids, and Gas Turbines. Dr. Boyce has taught over 150 short courses around the world attended by over 3000 students representing over 300 Corporations. He is chair of ASME PTC 55 Aircraft Gas Turbine Committee on testing of aircraft gas turbines and a member of the ASME Ethics Review Board, Past Chairman of the following ASME Divisions Plant Engineering & Maintenance, the Conferences Committee and the Electric Utilities Committee.

Dr. Boyce has authored more than 150 technical papers and reports on Turbines, Compressors Pumps, and Fluid Mechanics.

Dr. Boyce received a BS (1962) and MS (1964) degrees in Mechanical Engineering from the South Dakota School of Mines and Technology and the State University of New York, respectively, and a PhD (Aerospace & Mechanical engineering) in 1969 from the University of Oklahoma.

BRATTON, ROBERT

Robert Bratton is a principle investigator for graphite qualification for the NGNP at the Idaho National Laboratory. He has degrees in Nuclear Engineering and Applied Mechanics and has been employed at the INL for 18 years. He has worked on the NPR MHTGR, Light Water Tritium Target Program, and the National Spent Nuclear Fuel Program. He is a member of the ASME Project Team on Graphite Core Supports, which is developing future design codes for graphite core design.

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Lalit Chordia is the Founder, President and CEO of Thar Technologies, Inc., Pittsburgh, PA, USA. Prior to starting Thar Technologies, Dr. Chordia founded two other companies: Superx Corporation and Visual Symphony. He also holds an Adjunct Research Scientist position at Carnegie Mellon University. He is a world-renowned expert in supercritical fluid technology and has pioneered its applications. Through his technological and commercial leadership, Dr. Chordia took Thar from one employee to a global leader in its field, with four technology groups in Pittsburgh and two international subsidiaries.

Dr. Chordia's company was the recipient of two National Institute of Technology's Advanced Technology Program (ATP) awards. He has been featured in several international publications, including Fortune. Dr Chordia has numerous patents and publications to his credit. He has won numerous awards, including being cited as the 2002 National Small Business Exporter of the Year by the Bush Administration and the 2009 IIT Madras Distinguished Alumnus Award. Dr. Chordia has a BS degree from IIT Madras and a PhD from Carnegie Mellon University.

EDEN, TIMOTHY J.

Dr. Timothy J. Eden joined the Applied Research Laboratory in 1990. He received a PhD from the Pennsylvania State University in 1996. His research interests include development and transition of the Cold Spray process, development and application of high performance aluminum alloys produced using Spray Metal Forming, design and fabrication of functionally tailored ceramic and composite structures, material characterization, process improvement, and material structure–performance relationships.

Dr. Eden is currently head of the Materials Processing Division in the Materials and Manufacturing Office at the Applied Research Laboratory. The Materials Processing Division includes the Advanced Coatings, Metals and Ceramic Processing, High Pressure Laboratory, and an Electronics Materials Initiative. He has participated in several large multidiscipline research programs and has helped transferred Cold Spray Technology to the U.S. Army, Navy, and to industry.

EECEN, PETER

Peter Eecen is research manager of the group Rotor & Farm Aerodynamics at the Wind Energy department of the Energy research Centre of the Netherlands (ECN). His responsibilities are to establish the research strategy and priorities and manage a group of 20 researchers. In collaboration with the ECN Wind Industrial Support group (EWIS), he is responsible for the business development; an important aspect of ECN is to bring to the market the developed knowledge and technologies in renewable energy.

Peter holds a Master's degree in theoretical physics and did his PhD in the field of nuclear fusion at the FOM Institute for Plasma Physics, after which he worked for 3 years at TNO in the field of underwater acoustics.

Dr. Eecen joined the Wind Energy department of ECN in 2000 as manager of the group "Wind and Waves," concerning the wind and wave descriptions for turbine loading and wind resource assessments. After that, he led the experimental department for a year. He has been working in the field of Operation and Maintenance of large offshore wind farms. He started the project of Operation and Maintenance Cost Estimator (OMCE). Since 4 years, Peter is heading the group Rotor & Farm Aerodynamics. This group aims to optimize the aerodynamic performance of the wind turbine rotor and of the wind farm as a whole and reduce the uncertainties in modeling rotor aerodynamics, wake aerodynamics, boundary layers by development of CFD technology, development of aerodynamic design tools for wind turbines and wind farms.

During his career in wind energy, Dr. Eecen performed research in a variety of areas, which include modeling wind and waves, resource assessments, uncertainties in wind measurements, remote sensing, operation, and maintenance. He was responsible for measurements on full-scale wind farms and the ECN scale wind farm.

Peter is active in international organizations like IEA, MEASNET, TPWind, and European projects. He is coordinating the subprogram Aerodynamics of EERA-Wind, the European Energy Research Alliance. Ten leading European Research Institutes have founded EERA to accelerate the development of new energy technologies by conceiving and implementing Joint Research Programs in support of the Strategic Energy Technology (SET) plan by pooling and integrating activities and resources.

GAMBLE, SIMON

Simon Gamble is an accomplished leader in the Australian renewable energy industry, with over a decade of practical experience in the technical, commercial, strategic, and managerial aspects of the renewable energy development business. This leadership was recently recognized through Simon's selection as a Fulbright Scholar, through which Simon will spend 4 months with the National Renewable Lab in Colorado investigating emerging renewable energy technologies and their application in remote power systems.

Currently, as Manager Technology and Commercialization with Hydro Tasmania, Simon is responsible for the development and implementation of Hydro Tasmania's Renewable Energy and Bass Strait Islands Development Strategies; for the assessment of new and emerging renewable energy technologies; for Hydro Tasmania's Research and Development program; and for the preparation of remote area power system project feasibility assessments, project approvals, and business cases.

Simon has a Bachelor of Civil Engineering and a Masters of Engineering Science degrees from the University of Adelaide. He also has a Master's of Business Administration degree from the University of Tasmania. Simon sits on the advisory board for UTAS Centre for Renewable Energy and Power Systems and the Clean Energy Council Emerging Technology Directorate.

GONZÁLEZ AGUILAR, JOSÉ

Dr. Jose González is Senior Researcher in the R&D Unit of High Temperature Processes at the IMDEA Energia Institute. He received his PhD in Physics from the University of Cantabria (Spain) in 1999 and his Habilitation à Diriger des Recherches from the University Paul Sabatier, Toulouse (France) in 2007. Between 2000 and May 2009, he worked as R&D engineer — Project manager at the Center for Energy and Processes — MINES ParisTech. In September 2006, he became associate professor at MINES ParisTech (or Ecole nationale supérieure des mines de Paris, ENSMP).

The main research area of Dr. González is focused on the study and development of high temperature processes for energy and environmental issues, with special emphasis in concentrating solar systems and plasma technologies. His expertise includes process simulation from systems analysis (flow sheeting) to computational fluid dynamics. José González has participated in 15 national and international research projects, published 26 papers in peer review journals, two international patents, and a French patent, and he is author of more than 50 communications in national and international conferences.

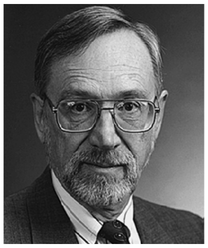
HASEGAWA, KUNIO

Dr. Kunio Hasegawa graduated from Tohoku University with a Doctor of Engineering degree in 1973. He joined Hitachi Research Laboratory, Hitachi Ltd., over 30 years back. During his term at Hitachi, he was also a visiting professor of Yokohama National University and Kanazawa University for several years. Since 2006, Dr. Hasegawa serves as a principal staff in Japan Nuclear Energy Safety Organization (JNES).

Dr. Kunio Hasegawa is a member of Japan Society of Mechanical Engineers (JSME) and is a past member of the JSME Fitness-for-Service Committee for nuclear facilities. He is also a member of ASME and is involved in ASME Boiler and Pressure Vessel Code Section XI Working Group, Subgroup and Subcommittee activities.

He has been active for 3 years as a Technical Program Representative of Codes and Standards Technical Committee in ASME PVP Division. He has been involved with structural integrity for nuclear power components, particularly, leak-before-break, fracture and fatigue strengths for pipes with cracks and wall thinning, and flaw characterizations for fitness-for-service procedures. Dr. Hasegawa has published over 100 technical papers in journals and conference proceedings.

HEDDEN, OWEN F.



Owen F. Hedden retired from ABB Combustion Engineering in 1994 after over 25 years of ASME B&PV Committee activities with company support. His responsibilities included reactor vessel specifications, safety codes and standards, and interpretation of the B&PV Code and other industry standards. He continued working part-time for that organization into 2002. Subsequently, he has been a part-time consultant to the ITER project and several other organizations. Prior to joining ABB, he was with Foster Wheeler Corporation (1956 to 1967), Naval Nuclear program. Since 1968, Mr. Hedden has been active in the Section XI Code Committee, Secretary (1976 to 1978), Chair (1991 to 2000).

In addition to Section XI, Owen has been a member of the ASME C&S Board on Nuclear Codes and Standards, the Boiler and Pressure Vessel Committee, and B&PV Subcommittees on Power Boilers, Design, and Nondestructive Examination. He is active in ASME's PVP Division. Mr. Hedden was the first Chair of the NDE Engineering Division, 1982 to 1984. He has presented ASME Code short courses in the United States and overseas. He was educated at Antioch College and Massachusetts Institute of Technology. His publications are in the ASME Journal of Pressure Vessel Technology, WRC Bulletins and in the Proceedings of ASME PVP, ICONE, IIW, ASM, and SPIE. He is an ASME Fellow (1985), received the Dedicated Service Award (1991), and the ASME Bernard F. Langer Nuclear Codes and Standards Award in 1994.

HOFFELNER, WOLFGANG

Wolfgang Hoffelner is currently manager of the High Temperature Materials project at the Swiss Paul Scherrer Institute. He represents Switzerland in the Generation IV System Steering Committee and in the Project Management Board for VHTRs. He supports as PSI volunteer in the current ASME Sect III Div. 5 Code development. He is also Managing Director of RWH consult LlC, a Swiss-based consulting entity for materials and energy-related consultancy. In this function, he acts as task advisor and materials data analyst for ASME LlC. Wolfgang has been Senior Lecturer for High Temperature Materials at the Swiss Federal Institute of Technology since 1986, and he is currently responsible for the materials education within the Swiss Master of Nuclear Engineering Program.

Wolfgang received his PhD in Physics and has an MS in mathematics at the University of Vienna. He started his work as a research fellow at the same place. He improved his skills in structural materials and mechanics during his time at ABB (formerly BBC), where he was working in different positions ranging from a scientist in the Research Laboratory, Group Leader in the Laboratory, and Head of Section Mechanics and Materials for Gas Turbines and Combined Cycle Plants. In 1990, he joined the Swiss Company MGC-Plasma Inc. as a Board member, where he was responsible for technology of metallurgical and environmental applications (including low-level nuclear waste) of thermal plasma.

Dr. Hoffelner is member of ASME, ASM, and TMS, and he has published more than 120 papers in scientific and technical books and journals.

JACOBSON, PAUL T.

Paul T. Jacobson is the Ocean Energy Leader and a Senior Project Manager at the Electric Power Research Institute. Dr. Jacobson is also a faculty member in the Zanvyl Krieger School of Arts and Sciences, Johns Hopkins University, where he teaches a graduate-level course in ecological assessment. He holds a bachelor's degree in biology from Cornell University and MS and PhD degrees in oceanography and limnology from the University of Wisconsin-Madison. Dr. Jacobson has been engaged in assessment of electricity-generation systems and living resources for more than 30 years. Much of his work over this period has addressed the effects of electricity generation on aquatic ecosystems.

JENNER, MARK

Dr. Mark Jenner is a biomass systems economist with the consulting firm, Biomass Rules, LLC and the California Biomass Collaborative. Jenner creates and adds value to biomass through his expertise in biomass production and conversion technologies, as well as environmental and energy policies.

Since 2009, Mark Jenner has been studying the adoption economics of purpose grown energy crops with the California Biomass Collaborative, located at the University of California Davis. In 2003, he began his consulting firm Biomass Rules, LLC, which conducts feasibility studies on value-added biomass projects and biomass inventories. In 2006, Mark wrote the BioTown, USA Sourcebook for the State of Indiana. Since 2007, Mark Jenner has written the biomass energy outlook column for BioCycle Magazine.

Mark Jenner has a PhD in agricultural economics in production systems, two MS degrees in manure management, a BS in agronomy, and 30 years of professional biomass experience spanning three continents.

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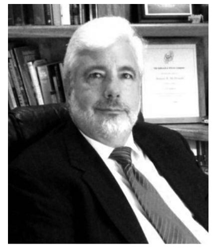
Kevin W. Lyons is a Senior Research Engineer within the Manufacturing Engineering Laboratory (MEL), National Institute of Standards and Technology (NIST). His current assignment involves supporting the Sustainable Manufacturing Program in formalizing manufacturing resource descriptions, manufacturing readiness modeling, and simulation. His research interests are design and manufacturing processes for sustainable manufacturing, simulation and modeling, and nanomanufacturing. From 2004 through 2006, he served as Program Director for the Nanomanufacturing Program at the National Science Foundation (NSF). From 2000 to 2004, he served as Program Manager of the Nanomanufacturing Program at NIST. From 1996 to 2000, he served as Program Manager with the Defense Advanced Research Projects Agency (DARPA), where he managed advanced design and manufacturing projects. From 1977 to 1992, he worked in industry in various staff and supervisory positions in engineering marketing, product design and analysis, factory automation, and quality engineering.

MARTIN, HARRY F.

Harry F. Martin retired from Siemens Energy Corp as an Advisory Engineer at the Orlando Florida Facility. He has over 40 years of engineering experience in the power industry. Most of this related to turbo machinery. His engineering career started at Westinghouse Electric Corporation in Lester, PA. At Westinghouse, most of this experience was related to steam turbines. However, he also had assignments relating to gas turbines and heat exchangers. Harry held positions of various levels engineering responsibility and management. With Siemens, his efforts focused primarily on steam turbine design and operation.

Mr. Harry Martin has a Bachelor of Mechanical Engineering degree and Masters of Science Degree in Mechanical Engineering. His experiences include design, product and technology development, and operation of steam turbines. He has published 16 papers. These have included the subjects of turbine design, blading development and operation of steam turbines including transient analysis. He has ten patents. His technical specialization is in thermodynamics, fluid mechanics, and heat transfer. He is past Chairman of the Turbines, Generators and Auxiliaries Committee of the Power Division of the American Society of Mechanical Engineers.

MCDONALD, DENNIS K.



Denny McDonald is a Technical Fellow, Advanced Technology Development & Design, The Babcock & Wilcox Company.

Denny is currently responsible for the technical development and design of oxy-combustion within B&W. He has led the conversion of B&W's 30 MWth Clean Environment Development Facility for oxy-coal testing and is deeply involved in oxycombustion performance and cost studies, process, and equipment design improvements, and emerging associated technologies. In addition to advancing the technology, he provides technical support for demonstration and commercial opportunities.

Mr. McDonald joined B&W in 1972 and has worked in various engineering capacities through his career. Up to 1985, he worked in various positions of increasing responsibility in the fields of mechanical design of boilers, field problem resolution including involvement in startup of a large utility PC plant, and development of design standards. From 1985 to 1995, he managed B&W's New Product Engineering department and had technical responsibility for B&W's scope of American Electric Power's CCT-I Tidd PFBC Demonstration Project. From 1995 until assuming his present position in late 2006, he served as Manager of Functional Technology responsible for development of B&W's core performance analysis and thermal hydraulic technologies including design standards and software, boiler performance testing, advanced computational modeling, and technical support of contract engineering and advanced coal-fired technologies including ultra-supercritical boilers. In recent years, he has contributed significantly to B&W's mercury removal program as well as oxycombustion development.

Denny McDonald holds BS and MS degrees in Engineering and is a licensed Professional Engineer in the State of Ohio. He has published over 40 technical papers, authored chapters in the 40th and 41st editions of B&W's "STEAM — its Generation and Use" and holds eight U.S. patents.

MEHTA, HARDAYAL S.

Dr. Mehta received his BS in Mechanical Engineering degree from Jodhpur University (India), MS and PhD from University of California, Berkeley. He was elected an ASME Fellow in 1999 and is a Registered Professional Engineer in the State of California.

Dr. Mehta has been with GE Nuclear Division (now, GE-Hitachi Nuclear Energy) since 1978 and currently holds the position of Chief Consulting Engineer. He has over 35 years of experience in the areas of stress analysis, linear-elastic and elastic-plastic fracture mechanics, residual stress evaluation, and ASME Code-related analyses pertaining to BWR components. He has also participated as principal investigator or project manager for several BWRVIP, BWROG, and EPRI sponsored programs at GE, including the Large Diameter Piping Crack Assessment, IHSI, Carbon Steel Environmental Fatigue Rules, RPV Upper Shelf Margin Assessment, and Shroud Integrity Assessment. He is the author/coauthor of over 40 ASME Journal/Volume papers. Prior to joining GE, he was with Impell Corporation, where he directed various piping and structural analyses.

For more than 25 years, Dr. Mehta has been an active member of the Section XI Subgroup on Evaluation Standards and associated working task groups. He also has been active for many years in ASME's PVP Division as a member of the Material & Fabrication Committee and as conference volume editor and session developer. His professional participation also included several committees of the PVRC, specially the Steering Committee on Cyclic Life and Environmental Effects in Nuclear Applications. He had a key role in the development of environmental fatigue initiation rules that are currently under consideration for adoption by various ASME Code Groups.

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Thomas R. Miles is the President and Owner of T.R. Miles Technical Consultants, Portland, Oregon, which designs, develops, installs, and tests agricultural and industrial systems for fuel handling, air quality, and biomass energy. Energy projects include combustion and gasification of biomass fuels such as wood, straws, stalks, and manures. Mr. Miles conducts engineering design and feasibility studies and field tests for cofiring wood, straw, and coal. He has sponsored and hosted internet discussions on biomass energy since 1994 (www.trmiles.com).

MORTON, D. KEITH

Mr. D. Keith Morton is a Consulting Engineer at the Department of Energy's (DOE) Idaho National Laboratory (INL), operated by Battelle Energy Alliance. He has worked at the INL for 35 years. Mr. Morton has gained a wide variety of structural engineering experience in many areas, including performing nuclear piping and power piping stress analyses, completing plant walk downs, consulting with the Nuclear Regulatory Commission, developing life extension strategies for the Advanced Test Reactor, performing full-scale seismic and impact testing, and helping to develop the DOE standardized spent nuclear fuel canister. His most recent work activities include performing full-scale drop tests of DOE spent nuclear fuel canisters, developing a test methodology that allows for the quantification of true stress-strain curves that reflect strain rate effects and supporting the Next Generation Nuclear Plant (NGNP) Project.

Mr. Morton is a Member of the ASME Working Group on the Design of Division 3 Containments, is the Secretary for the ASME Subgroup on Containment Systems for Spent Fuel and High-Level Waste Transport Packagings, a Member of the ASME Working Group on High Temperature Gas-Cooled Reactors, a Member of the Subgroup on High Temperature Reactors, a Member of the Section III Subgroup on Strategy and Management, and is a Member of the ASME BPV III Standards Committee. He has coauthored over 25 conference papers, one journal article, coauthored an article on DOE spent nuclear fuel canisters for *Radwaste Solutions*, and coauthored Chapter 15 of the third edition of the *Companion Guide to the ASME Boiler & Pressure Vessel Code.*

Mr. Morton received a BS in Mechanical Engineering degree from California Polytechnic State University in 1975 and a Masters of Engineering in Mechanical Engineering from the University of Idaho in 1979. He is a Registered Professional Engineer in the state of Idaho.

NOTTINGHAM, LAWRENCE (LARRY) D.

Lawrence D. (Larry) Nottingham is a Senior Associate, Structural Integrity Associates (SI), Inc. at Charlotte, NC. From June 1995 to the present, he has been with Structural Integrity Associates. From 1993 to 1995, he was Founder, President, and Managing Director of AEA Sonomatic, Inc., Charlotte, NC. From 1986 through1993, Larry was with Electric Power Research Institute at Nondestructive Evaluation Center, Charlotte, NC. From 1972 through 1986, Larry was with Westinghouse Electric Corp. as Manager at Steam Turbine Generator Division, Orlando, FL and Senior Development Engineer, at Large Rotating Apparatus Division, Pittsburgh, PA.

Mr. Nottingham graduated with a BS Mechanical Engineering degree in the University of Pittsburgh in 1971. His Professional Associations and Certifications include Nondestructive Evaluation (NDE) Level III Certification in Ultrasonic Testing, Penetrant Testing (PT), and Magnetic Particle Testing (MT).

Mr. Nottingham has been involved in design, design analysis, maintenance, and nondestructive evaluation of turbines, generators, and other power plant equipment and components since 1972. His experience covers all aspects of design and design analysis including finite element stress analysis, fracture mechanics, materials testing and characterization, failure modes and mechanisms, metallurgy, and nondestructive evaluation. He has extensive experience in the development and delivery of advanced nondestructive evaluation systems and procedures for numerous power plant applications, with emphasis on turbine and generator components, including boresonic and turbine disk rim inspection systems.

At Structural Integrity (SI), Mr. Nottingham continues to provide broad-based engineering expertise. Until 2007, he managed all engineering development efforts for both nuclear and fossil plant inspection services. In his role as Development Manager, he developed SI as a recognized technological leader in the power generation NDE services community. He also has remained active on a number of EPRI projects involving fossil power plant components, generator retaining rings, generator rotors, boiler tube, and most recently developing guideline document for inspection and life assessment of turbine and valve casings. In 2007, Mr. Nottingham assumed responsibility for SI's turbine and generator condition assessment efforts, with aggressive growth objectives.

Mr. Nottingham has published over 70 technical papers, reports, and articles. He has been an invited presenter at numerous conferences, workshops, and seminars on NDE and lecturer at a number of training courses. He provides training for advanced nondestructive evaluation technologies and has been invited lecturer at the United States Naval Academy. He currently holds 14 U.S. patents related to turbine and generator component designs and NDE systems. He is also a member of SI's Board of Directors.

O'DONNELL, WILLIAM J.

Bill O'Donnell has Engineering Degrees from Carnegie Mellon University and the University of Pittsburgh. He began his career at Westinghouse Research and Bettis, where he became an Advisory Engineer. In 1970, Bill founded O'Donnell and Associates, an engineering consulting firm specializing in design and analysis of structures and components. The firm has done extensive work in the evaluation of structural integrity, including corrosion fatigue, flaw sensitivity, crack propagation, creep rupture, and brittle fracture.

Dr. O'Donnell has published 96 papers in engineering mechanics, elastic-plastic fracture mechanics, strain limits, and damage evaluation methods. He is Chairman of the Subgroup on Fatigue Strength and a Member of the Subcommittee on Design of the ASME Code. He has patents on mechanical processes and devices used in plants worldwide. He is a recognized expert in Failure Causation Analyses.

Dr. O'Donnell has given invited lectures at many R&D laboratories, design firms, and universities. He is a registered Professional Engineer. He received the National Pi Tau Sigma Gold Medal Award "For Outstanding Achievement in Mechanical Engineering" and the ASME Award for "Best Conference Technical Paper" in 1973 and 1988. The Pittsburgh Section of ASME named Bill "Engineer of the Year" (1988). He was awarded the ASME PVP Medal (1994).

Dr. O'Donnell received the University of Pittsburgh Mechanical Engineering Department's Distinguished Alumni Award (1996) and Carnegie Mellon University's 2004 Distinguished Achievement Award for distinguished service and accomplishments in any field of human endeavor. He is a Fellow of the ASME and is listed in the Engineers Joint Council "Engineers of Distinction," Marquis "Who's Who in Science and Engineering," and "Who's Who in the World."

PIEKUTOWSKI, MARIAN

Marian Piekutowski is a recognized leader in the field of power system planning and analysis including transmission, generation, and economic analysis. He has been instrumental in development of wind integration strategies for Hydro Tasmania. With more than 30 years of working experience, he has developed extensive understanding of regulatory environment of electricity markets and of the requirements for efficient management and operation of an electricity utility.

During the last 2 years, Marian has been involved in demand, supply, and regulatory aspects of frequency control ancillary services. This work includes improvement of dynamic response of hydro turbines, improvement governing, new modes operation of hydro machines, and impact of low inertia on the frequency control.

Marian has been involved in integration of renewable energy sources to remote power systems with an aim to minimize diesel consumption and reduce emission of GHG. His recent work included energy storage (VRB, flywheels, diesel UPS), applications of power electronics to maximize penetration of wind generation, control strategies for operation of small islanded systems, and improvement of grid stability and reliability.

Marian has been the lead technical advisor for the connection of Woolnorth stages 1 and 2 wind farms in Tasmania as well as Cathedral Rocks in South Australia. Marian has also been instrumental from the developers perspective in development of fault ride through capability on wind turbines. He has led studies to determine maximum viable wind penetration in Tasmanian power systems with the main sources of limitations being low inertia and low fault level.

POLING, CHRISTOPHER W.

Mr. Poling is currently the Program Director for The Babcock & Wilcox Company's Post-Combustion Carbon Capture product development project. He joined B&W in 2002 and has worked in areas of increasing responsibility including Lead Proposal Engineer for large Flue Gas Desulfurization projects and as a Principal Engineer in B&W's Technology department. Prior to his experience at B&W, Mr. Poling worked for 7 years at Ceilcote Air Pollution Control in Strongsville, Ohio as a Product Manager for industrial wet scrubber systems. Mr. Poling earned his bachelor's degree in chemical engineering from the University of Toledo. Mr. Poling also earned his Executive Master's in Business Administration from Kent State University.

MUTHYA, RAMESH PRANESH RAO

Mr. Ramesh holds a Master's degree in Mechanical Engineering from the Indian Institute of Science from Bengaluru, India, and a Master of Science from Oldenburg University, Germany, in Application of Renewable Energy Technologies.

Mr. Ramesh started his career in wind energy at the National Aeronautical Laboratory, Bangalore, in 1979. He has many firsts to his credit starting from development of indigenous wind power battery chargers and transferred know-how to industry. He made performance measurements on wind turbines for the first time in India, which resolved many issues of underperformance. In order to extend utility of measured wind information to a larger area, he came up with the idea of localized wind maps superimposed on scaled survey maps. Over a hundred such reports were created and were the basis for wind farming. He holds a patent on passive speed control of windmills with Dr. S. K. Tewari. He introduced small wind chargers in Indian Antarctic station.

Mr. Ramesh took over the position of the first full time Executive Director, Centre for Wind Energy Technology in 2002. He was instrumental in maximizing the benefits of the DANIDA-funded project. He went on to create ground rules for effective, orderly, and sustainable growth of the field by continuous interactions with the industry, the Government, and other stake holders.

After a short stint in Canada as the scientific director/advisor to GP CO, Varrenes, Mr. Ramesh returned to India to help the Indian wind industry. As the founding Managing Director of Garrad Hassan India, Mr. Ramesh brought in some of the most sought-after consulting practices to India that spans across the resource quantification to asset management techniques. One of the least attended to areas in terms of design documentation capabilities in India was effectively addressed by Mr. Ramesh.

He has served as Chairman, Electro Technical committee #42 (ET-42), set up by Bureau of Indian Standards to interact with International Electrotechnical committee on all wind energy-related standardization efforts. He also chaired the committee that brought out draft grid code for wind turbine grid interconnection.

Presently, as the President, Wind Resource and Technology, at Enercon India, Mr. Ramesh is actively involved in bringing in the best practices on all aspects of wind energy deployment in India.

RAO, K. R.

K.R. Rao retired as a Senior Staff Engineer with Entergy Operations Inc. and was previously with Westinghouse Electric Corporation at Pittsburgh, PA, and Pullman Swindell Inc., Pittsburgh, PA. KR got his Bachelors in Engineering degree from Banaras University, India, with a Masters Diploma in Planning from School of Planning & Architecture, New Delhi, India. He completed Post Graduate Engineering courses in Seismic Engineering, Finite Element and Stress Analysis, and other engineering subjects at Carnegie Mellon University, Pittsburgh, PA. He earned his PhD, from University of Pittsburgh, PA. He is a Registered Professional Engineer in Pennsylvania and Texas. He is past Member of Operations Research Society of America (ORSA).

KR was Vice President, Southeastern Region of ASME International. He is a Fellow of ASME, active in National, Regional, Section, and Technical Divisions of ASME. He has been the Chair, Director, and Founder of ASME EXPO(s) at Mississippi Section. He was a member of General Awards Committee of ASME International. He was Chair of Codes & Standards Technical Committee, ASME PV&PD. He developed an ASME Tutorial for PVP Division covering select aspects of Code. KR is a member of the Special Working Group on Editing and Review (ASME B&PV Code Section XI) for September 2007 to June 2012 term.

Dr. Rao is a recipient of several Cash, Recognition, and Service Awards from Entergy Operations, Inc. and Westinghouse Electric Corporation. He is also the recipient of several awards, certificates, and plaques from ASME PV&P Division including Outstanding Service Award (2001) and Certificate for "Vision and Leadership" in Mississippi and Dick Duncan Award, Southeastern Region, ASME. Dr. Rao is the recipient of the prestigious ASME Society Level Dedicated Service Award. KR is a member of the Board of ASME District F Professional & Educational Trust Fund for 2008 to 2011.

Dr. Rao is a Fellow of American Society of Mechanical Engineers, Fellow of Institution of Engineers, India, and a Chartered Engineer, India. Dr. Rao was recognized as a "Life Time Member" for inclusion in the Cambridge "Who's Who" registry of executives and professionals. Dr. Rao was listed in the Marquis 25th Silver Anniversary Edition of "Who's Who in the World" as "one of the leading achievers from around the globe".

RAYEGAN, RAMBOD

Rambod Rayegan is a PhD candidate in the Department of Mechanical and Materials Engineering at Florida International University. Since January 2007, he has worked as a research assistant at FIU in the sustainable energy area. He is also the president of ASHRAE FIU Chapter since May 2009. He has been a member of prestigious Honor Societies like Tau Beta Pi, Phi Kappa Phi, Sigma Xi, and Golden Key. He has published a number of conference and journal papers in energy and sustainability area. Raised in Tehran, Iran, Rambod now lives with his wife in Miami. He has served as an instructor at Semnan University, Iran, for 5 years. He was selected as the best teacher of the Mechanical Engineering Department by students during the 2002 to 2003 academic year and the best senior project supervisor in the 2003 to 2004 academic year. He has served as a consultant in three companies in the field of air conditioning and hydraulic power plants.

REEDY, ROGER F.

Roger F. Reedy has a BS Civil Engineering degree from Illinois Institute of Technology (1953). His professional career includes the U.S. Navy Civil Engineering Corps, Chicago Bridge and Iron Company (1956 to 1976). Then, he established himself as a consultant and is an acknowledged expert in design of pressure vessels and nuclear components meeting the requirements of the

ASME B&PV Code. His experience includes design, analysis, fabrication, and erection of pressure vessels and piping components for nuclear reactors and containment vessels. He has expertise in components for fossil fuel power plants and pressure vessels and storage tanks for petroleum, chemical, and other energy industries. Mr. Reedy has been involved in licensing, engineering reviews, welding evaluations, quality programs, project coordination, and ASME Code training of personnel. He testified as an expert witness in litigations and before regulatory groups.

Mr. Reedy has written a summary of all changes made to the ASME B&PV Code in each Addenda published since 1950, which is maintained in a computer database, RA-search. Mr. Reedy served on ASME BP&V Code Committees for more than 40 years being Chair of several of them, including Section III for 15 years. Mr. Reedy was one of the founding members of the ASME PV&P Division. Mr. Reedy is registered.

Mr. Reedy is a Professional Engineer in seven states. He is a recipient of the ASME Bernard F. Langer Award and the ASME Centennial Medal and is a Life Fellow of ASME.

RICCARDELLA, PETER (PETE) C.

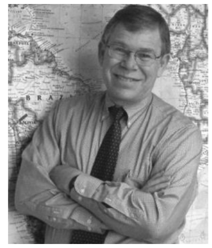
Pete Riccardella received his PhD from Carnegie Mellon University in 1973 and is an expert in the area of structural integrity of nuclear power plant components. He co-founded Structural Integrity Associates in 1983 and has contributed to the diagnosis and correction of several critical industry problems, including:

- Feedwater nozzle cracking in boiling water reactors
- Stress corrosion cracking in boiling water reactor piping and internals
- Irradiation embrittlement of nuclear reactor vessels
- Primary water stress corrosion cracking in pressurized water reactors
- Turbine-generator cracking and failures.

Dr. Riccardella has been principal investigator for a number of EPRI projects that led to advancements and cost savings for the industry. These include the FatiguePro fatigue monitoring system, the RRingLife software for turbine-generator retaining ring evaluation, Risk-Informed Inservice Inspection methodology for nuclear power plants, and several Probabilistic Fracture Mechanics applications to plant cracking issues. He has led major failure analysis efforts on electric utility equipment ranging from transmission towers to turbine-generator components and has testified as an expert witness in litigation related to such failures.

He has also been a prime mover on the ASME Nuclear Inservice Inspection Code in the development of evaluation procedures and acceptance standards for flaws detected during inspections. In 2002, he became an honorary member of the ASME Section XI Subcommittee on Inservice Inspection, after serving for over 20 years as a member of that committee. In 2003, Dr. Riccardella was elected a Fellow of ASME International.

ROBINSON, CURT



Curt Robinson is the Executive Director of the 1770-member Geothermal Resources Council (GRC), headquartered in Davis, California. Since 1970, the GRC has built a solid reputation as the world's leading geothermal association. The GRC serves as a focal point for continuing professional development for its members through its fall annual meeting, transactions, bulletin, outreach, information transfer, and education services. GRC has members in 37 countries.

Prior to his work at GRC, he held executive assignments in higher education and government and has twice worked in energy development. He has also taught at six universities and colleges.

He earned his PhD and MA degrees in geography and a BA with honors, all at the University of California, Davis.

ROCAFORT, LUIS A. BON

Luis A. Bon Rocafort graduated in 1999 from Purdue University with a Bachelor's of Science in Mechanical Engineering degree. During his undergraduate career, he received the National Action Council for Minorities in Engineering Scholarship, which provided for tuition and a stipend, as well as work experience as a summer intern at the sponsoring company's facilities. His work with BP Amoco, at their Whiting, IN, refinery involved plant facilities, cooling tower design and analysis, and pipe fluid flow analysis and modeling to optimize use of cooling water and eliminate bottlenecks.

In 2001, Luis A. Bon Rocafort graduated with a Master's of Science in Mechanical Engineering degree from Purdue University, having received the Graduate Engineering Minority Fellowship, to cover his graduate school as well as provide work experience with DaimlerChrysler. The knowledge gained in the advanced vehicle design group, as well as the concept and modeling group would prove useful in the modeling and analysis realm that he is currently working in. During his time with DaimlerChrysler, he characterized fluid flows inside an automatic transmission engine, wrote data capture modules for a real-time driving simulator, programmed autonomous vehicles for real-time driving simulator, and compared FEA stress analysis results to stress paint-treated parts to determine viability of two methods to real-world tests of manufactured parts.

Having graduated in 2001, Luis A. Bon Rocafort became a field service engineer for Schlumberger Oilfield Services, performing as a drilling service engineer. As a cell manager, providing services to ExxonMobil in the Bass Strait of the Southeast coast of Australia, he performs logging while drilling services and assists directional drilling efforts in order to fully develop a known field that has been producing oil for more than three decades. Using advanced tools and drilling techniques, undiscovered pockets of oils are identified, and drilling programs are developed.

Luis A. Bon Rocafort joined O'Donnell Consulting Engineers, Inc. in 2006. While working with OCEI, he performed static and transient finite element analysis using a variety of elements and methods available through the ANSYS program. Other analyses include, modal analyses, harmonic analyses, vibrations, fatigue life analyses, inelastic analyses, creep analyses, among others. These analyses were done to evaluate vessels or structures to ASME, AISC, and IEEE codes and standards.

ROMERO, MANUEL ALVAREZ

Manuel Romero received his PhD in Chemical Engineering in 1990 at the University of Valladolid for his research on the solarization of steam reforming of methane. At present, he is Deputy Director and Principal Researcher of the High Temperature Processes R&D Unit at IMDEA Energía. Dr. M. Romero has received the "Farrington Daniels Award" in 2009, the most prestigious award in the field of solar energy research, created in 1975 by the International Solar Energy Society, conferred for his intellectual leadership, international reputation, and R&D contributions to the development of high-temperature solar concentrating systems.

In June 1985, Dr. Romero joined CIEMAT, Spain's National Laboratory for Energy Research, working as Project Manager until 2002 with responsibilities on R&D for solar thermal power plants and solar hydrogen. In 2002, he became Director of the Plataforma Solar de Almería, largely recognized R&D facilities for testing and development of solar concentrating technologies, and Director of the Renewable Energy Division of CIEMAT since June 2004 until August 2008 with R&D activities on solar thermal power, photovoltaics, biomass, and wind energy.

During his career, Dr. Romero has participated in more than 45 collaborative R&D projects in energy research, 15 of them financed by the European Commission, with special emphasis on high-temperature solar towers. He is coauthor of the European Technology Roadmap on High Temperature Hydrogen Production Processes INNOHYP, contracted by the EC in 2005, and coauthor of the European Technology Roadmap for Solar Thermal Power Plants, ECOSTAR, contracted by the European Commission in 2004. He acted as member of the experts' committee of the Energy R&D Program of the VI and VII Framework Program of the EC until August 2008.

Dr. Romero is Associate Editor of the ASME Journal of Solar Energy Engineering since January 2007 and at the International Journal of Energy Research (IJER) published by Wiley & Sons since December 2009. He was Associate Editor of the International Journal of Solar Energy since January 2002 until January 2007.

SEIFERT, GARY D.

Gary D. Seifert, PE, EE, is senior program manager at the Idaho National Laboratory. He has responsibility for multiple technical tasks for the U.S. Department of Energy, Department of Homeland Security, the U.S. Air Force, U.S. Navy, and NASA, as well as various power systems upgrades at the Idaho National Laboratory. Renewable projects have included the Ascension Island Wind Project and Ascension Island Solar Power projects, which have displaced a significant amount of diesel generation resulting in major financial and emissions savings.

Gary has been involved in multiple projects improving control systems and adding automation. Other support tasks include Wind Powering America, wind anemometer loan program, wind radar integration, power system distribution upgrades, high reliability power systems, relay system updates, smart substation upgrades, fiber optic communication systems installations, National SCADA Testbed, and the design of process control systems.

Gary is also currently involved in studies for multiple Department of Defense government wind projects and is leading a technical wind radar interaction project for the U.S. DOE and supporting wind prospecting activities in Idaho and surrounding regions.

Gary holds patents in thermal photovoltaic and Electro Optical High Voltage (EOHV) sensor designs. He was awarded a Research and Development top 100 award in 1998 for his work on the EOHV sensor and was instrumental in the implementation of the DOD's first island wind farm at Ascension air station.

Gary has a Bachelor of Science Electrical Engineering degree from the University of Idaho in 1981. He is an Adjunct Instructor Department of Engineering Professional Development, University of Wisconsin since 1991.

SHEVENELL, LISA

Lisa Shevenell was awarded a B.A. in geology at New Mexico Institute of Mining and Technology in 1984 and a PhD in Hydrogeology at the University of Nevada, Reno in 1990. Shevenell conducted geothermal exploration in Central America in the mid-1980s as part of a USGS-Los Alamos National Laboratory (LANL) team. Additional basic and applied research was conducted while with LANL at numerous sites throughout the western United States. Work at Mt. St. Helens evolved into her PhD research on the geothermal systems that formed after the 1980 eruption. Following her PhD, she worked at Oak Ridge National Laboratory for 3 years. Shevenell has been a faculty member at the Nevada Bureau of Mines and Geology since 1993, where she has led numerous geothermal-related research projects and teams in Nevada. She is currently a member of the Nevada Geothermal Technical Advisory Panel to NV Energy, the Science Advisory Board to the National Geothermal Data Center initiative being led by the Arizona Geological Survey, Geothermal Energy Association Technical Advisory Committee, and member of the Blue Ribbon Panel on Renewable

Energy formed by Senator Harry Reid and former Board of Directors member to the Geothermal Resources Council, former member of the Renewable Energy Task Force reporting to the Governor and Nevada Legislature, and former Director of the Great Basin Center for Geothermal Energy.

SINGH, K. (KRIS) P.

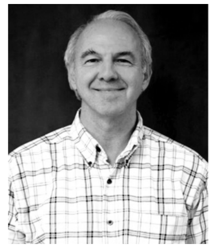
Dr. K.P. (Kris) Singh is the President and Chief Executive Officer of Holtec International, an energy technology company that he established in 1986. Dr. Singh received his Ph.D. in Mechanical Engineering from the University of Pennsylvania in 1972, a Masters in Engineering Mechanics, also from Pennsylvania in 1969, and a BS in Mechanical Engineering from the Ranchi University in India in 1967.

Since the mid-1980s, Dr. Singh has endeavored to develop innovative design concepts and inventions that have been translated by the able technology team of Holtec International into equipment and systems that improve the safety and reliability of nuclear and fossil power plants. Dr. Singh holds numerous patents on storage and transport technologies for used nuclear fuel and on heat exchangers/pressure vessels used in nuclear and fossil power plants. Active for over 30 years in the academic aspects of the technologies underlying the power generation industry, Dr. Singh has published over 60 technical papers in the permanent literature in various disciplines of mechanical engineering and applied mechanics. He has edited, authored, or coauthored numerous monographs and books, including the widely used text “Mechanical Design of Heat Exchangers and Pressure Vessel Components,” published in 1984. In 1987, he was elected a Fellow of the American Society of Mechanical Engineers. He is a Registered Professional Engineer in Pennsylvania and Michigan and has been a member of the American Nuclear Society since 1979 and a member of the American Society of Mechanical Engineers since 1974.

Over the decades, Dr. Singh has participated in technology development roles in a number of national organizations, including the Tubular Exchange Manufacturers Association, the Heat Exchange Institute, and the American Society of Mechanical Engineers. Dr. Singh has lectured extensively on nuclear technology issues in the United States and abroad, providing continuing education courses to practicing engineers, and served as an Adjunct Professor at the University of Pennsylvania (1986 to 1992).

Dr. Singh serves on several corporate boards including the Nuclear Energy Institute and the Board of Overseers, School of Engineering and Applied Science (University of Pennsylvania), Holtec International, and several other industrial companies.

SPAIN, STEPHEN D.



Stephen D. Spain, PE, PEng, is Vice President of HDR’s Northwest Region, Hydropower Department and Director of Hydromechanical Engineering for all HDR and Project Manager, Project Engineer, and Lead Mechanical Engineer for numerous hydroelectric projects throughout North America. Previously, he was the Northwest Regional Manager for Devine Tarbell & Associates (DTA), Duke Engineering & Services (DE&S), Department Manager of Hydro Mechanical and Electrical Engineering for Northrop Devine & Tarbell (ND&T), and Hydroelectric Project Engineer at the E.C. Jordan Company in Portland, Maine. Stephen has served as the chair for the American Society for Mechanical Engineers’ (ASME) Hydropower Committee from 2006 to 2009.

SRIRAM, RAM D.

Ram D. Sriram is currently leading the Design and Process group in the Manufacturing Systems Integration Division at the National Institute of Standards and Technology, where he conducts research on standards for sustainable manufacturing and interoperability of computer-aided design systems. He also holds a part-time appointment in the Information Technology Laboratory, where he conducts research on bioimaging and healthcare informatics. Prior to that, he was on the engineering faculty (1986 to 1994) at the Massachusetts Institute of Technology (MIT) and was instrumental in setting up the Intelligent Engineering Systems Laboratory. At MIT, Sriram initiated the MIT-DICE project, which was one of the pioneering projects in collaborative engineering. Sriram has coauthored or authored nearly 250 publications in computer-aided engineering and healthcare informatics, including several books. Sriram was a founding coeditor of the International Journal for AI in Engineering. In 1989, he was awarded a Presidential Young Investigator Award from the National Science Foundation, USA. Sriram is a Fellow of the American Society of Mechanical Engineers, a Senior Member of the Institute of Electrical and Electronics Engineers, a Member (life) of the Association for Computing Machinery, a member of the American Society of Civil Engineers, and a Fellow of the American Association of Advancement for Science. Sriram has a BS from IIT, Madras, India, and an MS and a PhD from Carnegie Mellon University, Pittsburgh, USA.

TANZOSH, JIM M.

James Tanzosh is employed at the Babcock & Wilcox Company as the Manager of Materials and Manufacturing Technology for the Power Generation Group in Barberton, Ohio. He has worked for B&W for 37 years in a number of technical areas involved with nuclear and fossil-fueled power generation including commercial and defense reactor programs, fast breeder reactor development, and a large range of utility and industrial boilers covering a wide range of fossil fuels, solar power, and biomass and refuse. He is presently responsible for research and development and all aspects of materials and welding technology for the Power Generation Group. He has been involved for the last 8 years with materials and manufacturing development of materials and designs of the advanced ultrasupercritical boiler. He has been a member of the ASME Boiler and Pressure Vessel Code and a member of a number of subgroups and committees in the area of materials, welding, and fired boilers and is presently Chairman of the Subgroup on Strength of Weldments.

TAO, YONG X.

Dr. Yong X. Tao is PACCAR Professor of Engineering and Chairperson of the Department of Mechanical and Energy Engineering at the University of North Texas (UNT). He is an ASME Fellow and Editor-in-Chief of Heat Transfer Research with more than 20 years of research and teaching experience. Prior to joining UNT, he was the Associate Dean of the College of Engineering and Computing at Florida International University in Miami and a Professor of Mechanical and Materials Engineering. An internationally known researcher in fundamentals of thermal sciences, refrigeration system performance, and renewable energy applications in buildings, he was also Director of the Building Energy, Environment, and Conservation Systems Lab (BEECS) and Multi-Phase Thermal Engineering Lab (MPTE) at FIU.

Dr. Tao has produced a total of more than 154 journal publications, book chapters, edited journals and proceedings, and peer-reviewed technical conference papers over the course of his career and holds two patents. He has received more than 12.2 million dollars of research funding as a single PI or Co-PI in multidisciplinary teamwork projects from the NSF, NASA, Air Force, DSL, DOE, ASHRAE, and various industries. He was the Associate Editor of the Journal of Science and Engineering Applications.

Dr. Tao is also an active member of the American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) and member of Executive Committee of the Heat Transfer Division of ASME, and Editor of ASME Early-Career Technical Journal. He has served on many technical committees for ASME, ASHRAE, and AIAA. He was also the Program Chair for the 2009 Summer Heat Transfer Conference of ASME and, as the Founding Chair, established the first US-EU-China Thermophysics Conference on Renewable Energy held in Beijing in May 2009.

In 2005, he was the faculty leader of the award-winning FIU Solar Decathlon entry sponsored by the United States. In 2008, as Project Director of the Future House USA project, he led a consortium of academics, builders, industry sponsors, and lobbyists to represent the United States in a ten-country, international demonstration project of renewable energy and environmentally friendly construction that resulted in a 3200-sq ft zero-net-energy American House in Beijing, China. On July 16th, 2009, Dr. Tao hosted a visit from the U.S. Secretary of Commerce Gary Locke and Secretary of Energy Steven Chu in the American House and was praised by both Secretaries as playing “vital role in building better collaboration between the United States and China in the area of energy-efficient buildings.”

Dr. Tao has a PhD in Mechanical Engineering degree from the University of Michigan, and a BS and MS in Mechanical Engineering from Tongji University in Shanghai, China.

THAREJA, DHARAM VIR

Dr. Dharam Vir THAREJA is the Director — Technical, SNC-Lavalin Engineering India Pvt. Ltd. since 2009 to date. Previously. he was a consultant with SNC-LAVALIN Engineering India Pvt. Ltd., Institute for Defence Studies and Analysis (IDSA), J&K Power Development Corporation and HP Power Development Corporation.

Dr. Thareja held various senior assignments from 1990 through 2008, chronologically the most recent to the last are Chairman Ganga Flood Control Commission (GFCC), Ministry of Water Resources, Govt. of India (GOI); Member (Design & Research Wing), CWC, Ministry of Water Resources; Commissioner, Indus Wing, Ministry of Water Resources; Chief Engineer, CWC, Ministry of Water Resources; and Chief Project Manager, WAPCOS, Ministry of Water Resources. Dr. Thareja worked previously from 1973 to 1999 in several capacities in CWC and WAPCOS. Dr. Thareja was responsible for several publications that include 21 notable ones.

He earned his PhD IIT, Delhi, India, MSc and BSc in Civil Engineering from the College of Engineering, University Of Delhi, India. Dr. Thareja’s professional affiliations include Fellow, Institution of Engineers (India), Member, Indian Water Resources Society, Indian Geotechnical Society, Indian Society for Rock and Mechanics & Tunneling Technology. He attended several institutions including UN Fellowship; USBR, Denver, Colorado (USA); University of California, Berkeley (USA); University of Arizona, Tucson (USA); University of Swansea, Swansea (UK); and Hydro Power Engineering with M/s. Harza Engineering Co., USA under the World Bank program.

Dr Thareja’s professional work country experience includes the Philippines, Burma, Vietnam, Afghanistan, Bhutan, and India.

TOUSEY, TERRY

Terry Tousey, an Independent Consultant at Alternative Fuels & Resources, LLC and President of Rose Energy Discovery, Inc., has a diverse background in the alternative energy, resource recovery, environmental and chemical industries. He has over 22 years of experience in the development, implementation, and management of hazardous and nonhazardous waste fuel projects and substitute raw material programs within the cement industry. Mr. Tousey has spent most of the last 5 years working on the commercialization of renewable energy technologies including gasification and anaerobic digestion of waste biomass materials for the production of heat and power.

Mr. Tousey was a key member of the management team at two startup resource recovery companies where, among other things, he directed the business development strategy for sourcing waste materials into the alternative fuels and raw materials programs. He has reviewed the quality and quantity of numerous waste streams for use as an alternative fuel or substitute raw material and has researched a number of technologies for processing these materials into a useable form. Mr. Tousey has extensive expertise in managing these programs from concept through startup including permitting, design, construction, operations, logistics, marketing, and regulatory compliance. His work on a wide range of highly innovative alternative energy projects, both captive and merchant, over the course of his career, has made him uniquely knowledgeable in the dynamics of resource recovery and the mechanics of the reverse distribution chain of waste from the generator to the processor.

Mr. Tousey is an alumnus of Purdue University, where he earned his BS Degree in General Science with a major concentration in Chemistry and minor concentrations in Biology and Mathematics. He is a member of the Water Environment Association, New England Water Environment Association, and Missouri Water Environment Association and a past member of the National Oil Recyclers Association and the National Chemical Recyclers Association. He has been an active participant in the Environmental Information Digest's Annual Industry Round Table where Mr. Tousey has given a number of presentations on the use of waste as fuels in the cement industry.

VITERNA, LARRY

Dr. Larry Viterna is a loaned executive to Case Western Reserve University from NASA. At Case, he serves as the Technical Director of the Great Lakes Energy Institute, leading the formation of technology development efforts in renewable energy and energy storage. Most recently at NASA, Dr. Viterna was Lead for Strategic Business Development at the Glenn Research Center, a major federal laboratory with a budget of over $600M and a workforce of 2500. Previously, he was assigned to the NASA Deputy Administrator in Washington, DC, where he coordinated the development of the implementation strategy for Agency-wide changes following the Space Shuttle Columbia Accident. Dr. Viterna was on the team that created the world's first multimegawatt wind turbines starting in 1979. He is the recipient of NASA's Blue Marble Award for aerodynamic models, now named for him, that are part of international design tools for wind turbines and that helped enable passive aerodynamic power control in the wind energy industry. Dr. Viterna has also been recognized with NASA Glenn's highest Engineering Excellence award for his pioneering work in fuel efficient hybrid vehicles. He is certified for the Senior Executive Service and received his PhD in Engineering from the University of Michigan. He has also completed executive education in business administration at Stanford University, public policy at the Harvard Kennedy School of Government, and international management at the National University of Singapore.

WEAKLAND, DENNIS P.

Mr. Weakland has over 28 years of experience in materials behavior and structural integrity of major nuclear components at an operating nuclear power plant. He is recognized to have a broad understanding of materials issues in the Industry by the leadership positions held in several organizations. He specializes in ASME Code compliance, technical and program review, evaluation of Industry technologies for degradation mitigation, evaluation of material degradation concerns, and the oversight of fabrication activities for new or replacement components. His experience with Inservice Inspection and materials programs has provided him with a thorough understanding of nondestructive examination techniques and applications.

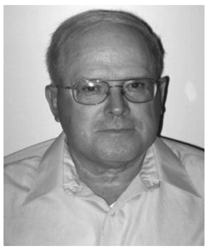
Mr. Dennis Weakland has served in several industry leadership roles, including the Chairman of the Pressurized Water Reactor Owners Groups Materials Sub-committee and the Chairman of the EPRI Materials Reliability Project (MRP). He currently is a member of the ASME Working Group — Operating Plant Criteria and Task Group Alloy 600. He is an alumnus of Carnegie-Mellon University where he earned a BS in Metallurgy and Material Science degree. He also has earned a MBA for the University Of Pittsburgh Katz School of Business.

Prior to joining the nuclear industry in 1982, Mr. Weakland spent 13 years in the heavy fabrication industry in the production of river barges, towboats, and railroad cars.

WEISSMAN, ALEXANDER

Alexander Weissman is a doctoral student in the Department of Mechanical Engineering and the Institute for Systems Research at the University of Maryland. He is currently working on research in design-stage estimation of energy consumption in manufacturing processes. His broader research goals include sustainable manufacturing and design for environment. Prior to this, he worked as a software engineer and developer for an automated analysis and process planning system for water-jet machining. He completed a Bachelor of Science (BS) degree in computer engineering in 2006 at the University of Maryland.

WEITZEL, PAUL S.



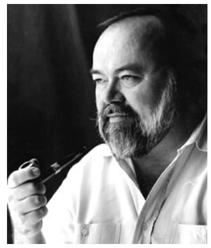
Paul Weitzel is employed by the Babcock and Wilcox Company as a Technical Consultant and Team Leader for New Product Development, Advanced Technology Design and Development, Technology Division, Power Generation Group at Barberton, Ohio. His involvement with B&W spans 42 years, beginning as a Service Engineer at Kansas City starting up boiler equipment and is currently responsible for the Advanced Ultra Supercritical steam generator product development. Early on in his career, there was a time out to serve in the U.S. Navy as an Engineering Duty Officer aboard the USS Midway as the Assistant Boilers Officer and at Hunters Point Naval Shipyard as a Ship Superintendent for repair and overhauls, primarily for the main propulsion plant — always on ships with B&W boilers. Primary assignments with B&W have been in engineering and service roles with a strong technical interest in thermodynamics, fluid dynamics, and heat transfer supporting performance and design of steam generators. He is the author of Chapter 3, Fluid Dynamics, Steam 41, The Babcock and Wilcox Company. He is a member of ASME.

WILLEMS, RYAN

Ryan is a renewable energy engineer working in the Technology and Commercialisation group of the Business Development division of Hydro Tasmania. Ryan joined Hydro Tasmania as an intern in 2005 prior to graduating from Murdoch University with a Bachelor of Renewable Energy Engineering degree in early 2006. Ryan has gained extensive knowledge in the field of Remote Area Power Supply (RAPS) systems in his time at Hydro Tasmania.

Ryan has been extensively involved in RAPS on both King and Flinders Islands and has a considerable level of understanding of the complexities and control of each power station. Ryan has also developed tools for the analysis of energy flows in RAPS systems utilizing a range of control philosophies and has applied his knowledge of renewable energy generation technologies and their integration in the development of this simulation tool. Ryan has also been involved in the King Island Dynamic Resistive Frequency Control (DRFC) project since its inception and has provided significant technical assistance in the design of control logic and troubleshooting during commissioning.

WILLIAMS, JAMES (JIM) L.



James L. Williams is owner and president of WTRG Economics. He has more than 30 years experience analyzing and forecasting energy markets primarily as a consulting energy economist. He publishes the Energy Economist Newsletter and is widely quoted on oil and natural gas issues in the national and international media. His clients and subscribers include major oil companies, international banks, large energy consumers, brokerage firms, energy traders, local, state, and U.S. government agencies.

Jim has an MSc degree in mathematics with additional postgraduate work in math and economics.

Mr. James Williams has taught forecasting, finance, and economics at the graduate and undergraduate level at two universities, testified on energy issues before Congress, and served as an expert witness in state and federal courts. His analysis of oil prices in Texas identified weaknesses in the method the state used to collect severance taxes on oil and contributed to a revision in the system that resulted in higher revenues to the state as well as royalty owners.

Williams' first work in the oil and gas industry was as senior economist with El Paso Company, where he analyzed and forecast petrochemical prices and markets. He modeled and forecast the financial performance of El Paso Petrochemicals division as well as new plants and acquisition targets.

He regularly analyses and forecasts exploration activity and its impact on the performance of oil and gas manufacturing and service companies. His experience ranges from the micro to macro level.

Williams' current research interests include global supply and demand for petroleum and natural gas, country risk, and the influence of financial markets and instruments on the price of energy.

WOLFE, DOUGLAS E.

Dr. Douglas E. Wolfe's research activities include the synthesis, processing, and characterization of ceramic and metallic coatings deposited by reactive and ion beam assisted, electron beam physical vapor deposition (EB-PVD), sputtering, plating, cathodic arc, cold spray, thermal spray, and hybrid processes. Dr. Wolfe is actively working on nanocomposite, nanolayered, multilayered, functionally graded, and multifunctional coatings and the enhancement of coating microstructure to tailor and improve the properties of vapor-deposited coatings such as thermal barrier coatings, transition metal nitrides, carbides, and borides, transition and rare-earth metals, for a variety of applications in the aerospace, defense, tooling, biomedical, nuclear, and optical industries, as well as corrosion-resistant applications. Other areas of interest include the development of advanced materials and new methodologies for microstructural enhancement, design structures/architectures, and coatings/thin films with improved properties. Dr. Wolfe received his PhD in Materials (2001), his MS degree in Materials Science and Engineering with an option in

Metallurgy (1996), and his BS degree in Ceramic Science and Engineering (1994) from The Pennsylvania State University. He has been a member of The Pennsylvania State University Faculty since May of 1998 and currently has a dual title appointment as Advanced Coating Department Head for the Applied Research Laboratory and Assistant Professor in the Department of Materials Science and Engineering. Dr. Wolfe has developed a short course entitled, "Determination, Causes and Effects of Residual Stresses on Coating Microstructure and Properties" and established a world class state-of-the-art Coatings Research Facility at the Pennsylvania State University. His expertise include the development and processing of vapor-deposited coatings as well as materials characterization using a variety of analytical techniques including: X-ray diffraction (XRD), scanning electron microscopy (SEM), optical microscopy (OM), energy dispersive spectroscopy (EDS), tribology, electron probe microanalysis (EPMA), X-ray photoelectron spectroscopy (XPS), secondary ion mass spectroscopy (SIMS), transmission electron microscopy (TEM), etc. Other research interests/topics include defining and developing structure-property-processing-performance relationships. Dr. Wolfe published more than 40 research manuscripts and technical memorandums.

YOKELL, STANLEY

Stanley Yokell, PE, Fellow of the ASME is registered in Colorado, Illinois, Iowa, and New Jersey. He is President of MGT Inc., Boulder, Colorado, and a Consultant to HydroPro, Inc., San Jose, California, manufacturers of the HydroPro® system for heat exchanger tube hydraulic expanding, the BoilerPro® system for hydraulically expanding tubes into boiler drums and tubesheets, and the HydroProof® system for testing tube-to-tubesheet and tube-to-boiler drum joints.

From 1976 to 1979, Mr. Yokell was Vice President of Ecolaire Inc. and President and Director of its PEMCO subsidiary. From 1971 to 1976, he was President of Process Engineering and Machine Company, Inc., (PEMCO) of Elizabeth, New Jersey, a major manufacturer of heat exchangers and pressure vessels, where he held the position of Vice President and Chief Engineer from its founding in 1953. Previously, he held the positions of Process Engineer and Sales Manager at Industrial Process Engineers, Newark, New Jersey, and Shift Supervisor at Kolker Chemical Works, Newark, New Jersey.

Mr. Yokell works in analyzing and specifying requirements, construction and uses, troubleshooting, and life extension of tubular heat transfer equipment. He is well-known as a specialist on tube-to-tubesheet joining of tubular heat exchangers and maintenance and repair of tubular heat exchangers.

He renders technical assistance to attorneys and serves as an Expert Witness. Mr. Yokell's more than 48 years of work in the field has involved design and construction of more than 3000 tubular heat exchangers, design and manufacture of process equipment, consulting on maintenance and repair of a variety of process heat exchangers and pressure vessels, feedwater heaters and power plant auxiliary heat exchangers. From 1979 to the present, he has assisted in troubleshooting, failure analysis, repair, modification, and replacement of process and power heat exchangers.

Each year from 1981 through 2007, Mr. Yokell presented two or three 4-day short, intensive courses on Shell-and-Tube Heat Exchangers-Mechanical Aspects at various locations in the United States, Canada, South America, and Europe. During this period, he has also presented, in collaboration with Mr. Andreone, annual seminars on Closed Feedwater Heaters and Inspection, Maintenance and Repair of Tubular Exchangers. In addition, he has provided in-plant training to the maintenance forces of several oil refineries, chemical plants, and power stations.

Mr. Yokell is the author of numerous papers on tubular heat transfer equipment including tube-to-tubesheet joints, troubleshooting, and application of the ASME Code. He is the author of *A Working Guide to Shell-and-Tube Heat Exchangers*, McGraw-Hill Book Company, New York, 1990. With Mr. Andreone, he has written *Tubular Heat Exchanger Inspection, Maintenance and Repair*, McGraw-Hill Book Company, New York 1997. He holds two patents.

Mr. Yokell is a corresponding member of the ASME Code Section VIII's Special Working Group on Heat Transfer Equipment and is a member of the AIChE, the ASNT, the AWS, and the NSPE. Mr. Yokell received the BChE degree from New York University.

ZAYAS, JOSE

Jose Zayas is the senior manager of the Renewable Energy Technologies group at Sandia National Laboratories. His responsibilities in this role include establishing strategy and priorities, defining technical and programmatic roles, business development, and performing management assurance for the renewable energy-related activities of the laboratory. He manages and develops programs to:

- Bring together key renewable energy technology capabilities to consistently implement a science-based reliability and systems approach
- Leverage Sandia's broader predictive simulation, testing/evaluation, materials science, and systems engineering capability with expertise in renewable energy technologies
- Expand and accelerate Sandia's role in the innovation, development, and penetration of renewable energy technologies

Mr. Zayas joined Sandia National Labs in 1996 and spent the first 10 years of his career supporting the national mission of the labs wind energy portfolio as a senior member of the technical staff. During his technical career, he had responsibilities for several programmatic research activities and new initiatives for the program. Jose's engineering research contributions, innovation, and outreach spanned a variety of areas, which include active aerodynamic flow control, sensors, dynamic modeling, data acquisition systems, and component testing.

After transition to the position of program manager in 2006, Jose has engaged and supported a variety of national initiatives to promote the expansion of clean energy technologies for the nation. Most recently, Jose has continued to lead the organization's clean energy activities and has coordinated and developed the laboratories cross-cutting activities in advanced water power systems. This program focuses on developing and supporting an emerging clean energy portfolio (wave, current, tide, and conventional hydro energy sources). Through developed partnerships with key national labs, industry, and academia, Sandia is supporting and leading a variety of activities to accelerate the advancement and viability of both wind energy and the comprehensive marine hydrokinetics industry. Additionally, Jose is currently leading a Federal interagency research program to address barriers affecting the continued deployment and acceptance of wind energy systems across the nation.

Jose holds a bachelors degree in Mechanical Engineering from the University of New Mexico and a Master's degree in Mechanical and Aeronautical Engineering from the University of California at Davis.

CONTENTS

CHAPTER 13 Challenges and Opportunities in Tidal and Wave Power

IV. BIO, WASTE, AND GEO THERMAL

CHAPTER 14 BioEnergy Including BioMass and Biofuels

CHAPTER 15 Utilizing Waste Materials as a Source of Alternative Energy: Benefits and Challenges

CHAPTER 16 Geothermal Energy and Power Development

V. FOSSIL AND OTHER FUELS

CHAPTER 17 Development of Advanced Ultra Supercritical Coal Fired Steam Generators for Operation Above 700°C

PREFACE

Energy and Power Generation Handbook: Established and Emerging Technologies, edited by K.R. Rao, and published by ASME Press, is a comprehensive reference work of 32 chapters authored by 53 expert contributors from around the world. This "Handbook" has 705 pages and contains about 1251 references and over 771 figures, tables, and pictures to complement the professional discussions covered by the authors. The authors are drawn from different specialties, each an expert in the respective field, with several decades of professional expertise and scores of technical publications.

This book is meant to cover the conventional technical discussions relating to energy sources as well as why(s) and wherefore(s) of power generation. The critical element of this book will thus be balanced and objective discussions of one energy source vis-à-vis another source, without making any recommendations or judgments which energy source is better than another.

A primary benefit of these discussions is that readers will learn that neither this nor that source is better, but together they complete the energy supply for this planet. This perhaps could be obvious even without going through the compendium of energy sources covered comprehensively in a book. However, a unique aspect of this publication is its foundation in the scholarly discussions and expert opinions expressed in this book, enabling the reader to make "value judgments" regarding which energy source(s) may be used in a given situation.

This book has the end user in view from the very beginning to the end. The audience targeted by this publication not only includes libraries, universities for use in their curriculum, utilities, consultants, and regulators, but is also meant to include ASME's global community. ASME's strategic plan includes Energy Technology as a priority. Instead of merely discussing the pros and cons of "energy sources," this publication also includes the application of energy and power generation.

Thus, the book could be of immense use to those looking beyond the conventional discussions contained in similar books that provide the "cost–benefit" rationale. In addition to which energy source is better than the other and to which geographic location, the discussions on economics of energy and power generation will portray the potentials as well.

Instead of picturing a static view, the contributors portray a futuristic perspective in their depictions, even considering the realities beyond the realm of socio-economic parameters to ramifications of the political climate. These discussions will captivate advocacy planners of global warming and energy conservation. University libraries, the "public-at-large," economists looking for technological answers, practicing engineers who are looking for greener pastures in pursuing their professions, young engineers who are scrutinizing job alternatives, and engineers caught in a limited vision of energy and power generation will find this publication informative.

Equally important is that all of the authors have cited from the public domain as well as textbook publications, handbooks, scholastic literature, and professional society publications, including ASME's Technical Publications, in addition to their own professional experience, items that deal with renewable energy and non-renewable energy sources. Thus, ASME members across most of the Technical Divisions will find this book worth having.

The discussions in this Handbook cover aspects of energy and power generation from all known sources of energy in use around the globe. This publication addresses energy sources such as solar, wind, hydro, tidal, and wave power, bio energy including biomass and bio-fuels, waste-material, geothermal, fossil, petroleum, gas, and nuclear. Experts were also invited to cover role of NASA in photovoltaic and wind energy in power generation, emerging technologies including efficiency in manufacturing and the role of NANO-technology.

The 32-chapter coverage in this Handbook is distributed into nine (IX) distinct sections with the majority addressing power and energy sources. Depending upon the usage, solar, wind, hydro, fossil, and nuclear are addressed in more than a single chapter. Renewable Energy Resources are covered in Sections I through IV, and Non-Renewable in Sections V and VI; Sections VII through IX cover energy generation-related topics.

Cost comparison with conventional energy sources such as fossil and fission has been made to ascertain the usage potential of renewable resources. This aspect has been dealt by authors while emphasizing the scope for increased usage of renewable energy. Authors therefore dwell on measures for promoting research and development to achieve the target of being cost-comparable.

Preceding all of Sections I through IX, biographical information pertaining to each of the authors is provided followed by Chapter Introductions. This information provides readers a fairly good idea of the credentials of the experts chosen to treat the chapter topic and a glimpse of the chapter coverage.

Section I, Chapters 1 through 6, deals with *Solar Energy* in 114 pages addressed by 10 experts from academia, NASA, and practicing professionals from the U.S., Europe, and India. Global interest in solar energy is apparent not only from the current usage but also from the untapped resources and its potential for greater usage.

The last chapter of Section I, Chapter 6, is authored by experts from NASA who elucidate NASA's efforts in both Solar and Wind energy sectors. This is appropriate since both of these energy sources constitute the most popular of the renewable energy resources.

In addition to the potential of *Wind Energy* already covered in Chapter 6, it is covered in detail in Chapters 7 through 10 of Section II. The increase in usage of wind energy in the past few years in the U.S. as well as in Asia and Europe surpasses any other energy resource. Thus, the potential, like solar energy, is enormous yet is vastly untapped. Global interest in wind as energy resource, although confined to countries uniquely located with wind potential, is limited by technological consequences. Authors from Sandia and Idaho National Laboratories, a research laboratory in the Netherlands, and a practicing professional from India discuss in 71 pages all of the ramifications of wind energy including the public perceptions and ways to technologically overcome environmental considerations including noise and visual aspects.

Section III deals with Hydro and Tidal Energy and has three chapters, Chapters 11, 12, and 13, devoted to *Hydro Power in the USA and Asia* in 40 pages. These three chapters are authored by three expert practicing professionals at the helm of their organizations and EPRI. Potential for this energy source is considerable in the U.S. and developing world, and lessons of experience with considerable "know-how" in hydro power are valuable for use in rest of the world. *Tidal and Wave Power* is unique and knowledge based, a privilege of the developed nations even though rest of the world have enormous potential for this energy source. This is addressed with abundant reference material by an expert from Electrical Power Research Institute (EPRI).

Section IV covers diverse modes of energy and power generation such as Bio Energy, Energy from Waste, and Geo Thermal Energy addressed in 56 pages in Chapters 14, 15, and 16 by practicing professionals and academia.

Bio Energy including Biomass and Biofuels is not exclusive to developed world. Even developing nations are aware of it although not dependent upon this source of energy. Bio-energy technology has been discussed by a practicing professional with expertise in this field in the U.S. and overseas. The author covers the potential of bio energy's future usage and developments, especially co-firing with coal.

Waste Energy has been addressed by a practicing professional with knowledge of municipal and industrial waste in both developed as well as underdeveloped or developing economies. Urbanization and concomitant suburban sprawl with demands for alternative sources of energy generation can release gasoline for automobiles. With the help of several schematics, the benefits and challenges of utilizing waste are covered including waste cycle, the regulatory perspective, business risks, and economic rationale.

This book that has as its target to investigate all "known" energy sources and *Geothermal Power* cannot be discounted now as well as in the immediate future. Even though confined in its application to a few isolated locations in the world such as Iceland, USA, Australia, Asia, and Europe, its contribution for solving global energy and power problems can be considerable, if this partially tapped resource of this planet can be harnessed to the fullest extent. Technological intricacies of this topic are addressed by two authors, an expert from the academia and in-charge of a professional organization in U.S.

In Section V, as part of *Non Renewable Fuels for Power and Energy Generation—Fossil Power Generation* comprising of *Coal, Oil, Gas, and Coal Gasification* is addressed by U.S. experts in Chapters 17 through 20 in 86 pages. The cutting edge of technology concerning the impact of CO_2 emissions, climate change, and coal gasification is addressed by U.S. industry experts in this Section. Both the U.S. and global economy are impacted by energy and power generation from petroleum and gas. This issue is also addressed in this Section by two U.S. economists. Chapters of this section will cover ongoing issues as well as the state-of-the-art technology.

While contributors cover the existing generation methods and technology, they also expound facets that deserve unique treatment. For example, the fossil power generation industry, responsible for 40 percent of carbon emissions, can be addressed with minimal socio-economic impact largely by technological advances. Whereas longer chimney heights and scrubbers were considered adequate technology for coal-fired units, technology has moved far ahead, and there are items worth attention of the readers. 'The Devil's in the Details of these technological advances'!

A discussion about *Fossil Power Generation* is incomplete without an understanding of "global warming," "climate change," and the Kyoto Protocol for dealing with carbon emissions. Authors of Chapters 14 and 15 associated with a premier fossil generation enterprise bring the wealth of their experience in covering the cutting edge of technology related to carbon emissions. If the abundant coal in the U.S. has to continue for coal-fired power plants as a blessing instead of a bane, it has to transform the technology for the use of coal. Authors aware of the efficiency of coal for power generation, to meet the global competition, have, with the help of impressive schematics and examples, implicitly demonstrated the U.S. dominance in this field.

A unique aspect of this handbook is the inclusion of a chapter by two U.S. economists who provide economic rationales for both petroleum and bio fuels. With the help of abundant schematics, authors drive home the point that a value judgment has to include beyond technical considerations economic parameters as well. Scope of coverage will include U.S. and developed economies such as Australasia, Europe, and North Americas and developing economies including countries of Asia, South America, Africa, and Middle East.

Previously, coal was converted to make gas that was piped to customers. Recently, investigation has been progressing for "BTU Conversion." Technological advancement has prompted Coal Gasification, methanation, and liquefaction. Author addressed these state-of-the-art-technologies in Chapter 20 including design issues and cost impacts.

The oil rig exploration on April 20, 2010 in the Deepwater Horizon 40 miles off the coast of Louisiana was the largest accident in the Gulf of Mexico, according to the U.S. Coast Guard. This has not been addressed in the discussions of Section V, since this will distract from the main theme of the subject matter.

In Section VI titled *Nuclear Energy***,** seven U.S. authors and one each from Japan and Switzerland cover Chapters 21 through 24 in 67 pages. Throughout the world, the nuclear industry is experiencing a renaissance. The aspects addressed in this Section will be *self-assessment* of the current generation of Nuclear Reactors as much as covering salient points of the *next generation* of Nuclear Reactors. These and other issues of *Nuclear Power Generation* are taken up by these nine authors with a cumulative professional and nuclear-related experience of over 300 years.

Previous generations of Nuclear Reactors built in the U.S. were criticized for the costs, time taken, and security concerns. All of these factors were instrumental in stalling the pace of construction of nuclear reactors in this country. Self-assessment by owners, regulators, and consultants with the help of professional organizations such as ASME has largely addressed several or most of the items, so that if we were to build nuclear reactors, we are much wiser now than ever before. Several of the issues are technical, whereas some are pseudo-management issues. The authors in Chapters 21 through 24 of this Section VI succinctly chronicle the items for helping the future generation of reactors that will be built. Technological advances such as 3-D FEA methods, alloy metals used in the construction, and several other factors have made it possible by even a slight reduction in safety factors without reconciling the safety concerns; likewise, thinking process on the lines of predesigned and modular constructions has alleviated the time from the initiation through the construction stages up to the completion of a nuclear reactor; the regulatory perspective has also gone beyond the U.S. bounds to countries that use the ASME Stamp of Approval for their Nuclear installations.

The future of the nuclear industry holds immense promise based on strides made in the U.S., Europe, and Asia. ASME Codes and Standards are used globally in building Nuclear Reactors. A discussion about Nuclear Power Generation is never complete without an understanding about the country's energy regulatory structure and decision-making process. In the first chapter of this section, Chapter 21, *A Perspective of Lessons Learned***,** has been addressed by an author with several decades of experience in the U.S. nuclear industry. Hopefully this could be useful in building new reactors.

In Chapter 22, two experts with nuclear background provide a critical review of the "Nuclear Power Industry Response to Materials Degradation" problems, especially as it relates to the new plants. Authors discuss the fleet-wide recognition of these issues.

Experts from Switzerland, Idaho National Laboratories, General Electric, and Japan Nuclear Safety with knowledge of the next generation of nuclear reactors have contributed Chapter 23 summarizing global efforts. Authors provided an assessment of the existing generation and potential for new projects. These recognized experts with several decades of professional and Code experience have addressed the ramifications of the past and current constructions while providing their perspectives for the next generation of nuclear reactors.

An ASME Code expert succinctly addresses in the last chapter of Section VI (Chapter 24) the future of nuclear reactors that seems to be at the crossroads. It is most appropriate that the author provides an open window to look at the current concerns, future challenges, and most importantly the unfinished business to revive nuclear power generation in the U.S.

Recent events such as at the *Fukushima Daiichi Nuclear Plants at Japan* devastated by the Tohoku-Taiheiyou-Oki Earthquake and Tsunami of March 11, 2011 have not been addressed by the authors, since these require a separate treatment and will distract from the main theme of discussions.

Section VII is titled *Steam Turbines and Generators* and has two chapters, Chapters 25 and 26, authored by two industry experts in 52 pages. Interdependency of all the energy sources needs to be addressed, especially as it relates to energy sources that are intermittent, and this has been done in Section VII.

In Section VII, Chapters 25 and 26 will be dedicated to *Turbines and Generators*, since they are a crucial and integral part of power generation, especially as they relate to Wind, Solar, Fossil, and Nuclear Power Generation. Discussions pertain to types of Turbine Configurations, their design, performance, operation, and maintenance. Turbine components, disks, and rotors including non-destructive methods have been covered in the discussions. In Chapter 25, the author discusses generators and crucial components such as retaining rings and failures. Material properties are briefly addressed. In both Chapters 24 and 25, the authors dwell upon the advanced technology and next generation of turbines.

In Section VIII of the book, Selected Energy Generation Topics have been covered in Chapters 27 through 30 in 79 pages. Topics selected for this Section stem from the importance of the topics for Renewable as well as Non-Renewable Energy Generation. The topics include Combined Cycle Power Plants, A Case Study, Heat Exchangers, and Water Cooled Steam Surface Condensers.

A recognized authority in *Combined Cycle Power Plants* with a Handbook on the subject has authored Chapter 27 that covers gas and steam turbines. The author has addressed the availability, reliability, and continuity of energy and power by using the combined cycle power plants.

In Chapter 28, *Hydro Tasmania—King Island Case Study* has been authored by three professional engineers of Hydro Tasmania, Australia, who address the renewable energy integration project. The discussions cover benefits including the development project.

Heat Exchangers are crucial components of Power Generation discussed in Chapter 29 by two recognized authorities with several decades of professional experience. The discussions rally around design aspects, performance parameters, and structural integrity.

A well-recognized authority in nuclear industry with global experience has authored the role of *Water Cooled Steam Surface Condensers* in Chapter 30. The author has covered design aspects, the construction details, and the related topics with schematics and a technical discussion with the help of 55 equations.

Whereas the *preceding groups* can be considered as the "core" of the book, the future of energy sources cannot be overlooked. Indeed, ignorance cannot be considered bliss in overlooking the energy and power generation potentials of the world. Ultimately, this planet's very existence depends on augmenting the energy and power generation resources. This could also imply conservation of energy (also covered in several of the preceding chapters) and harnessing methods that could improve known techniques.

In the last section of this handbook (Section IX), Emerging Energy Technologies have been addressed in 36 pages, in two chapters, by six authors. Use of untapped energy sources and peripheral items such as *Conservation Techniques, Energy Applications, Efficiency, and suggestions for Energy Savings "inside the fence"* is worthy of consideration.

In pursuit of the above statements, Chapter 31, *Toward Energy Efficient Manufacturing Enterprises*, has been addressed by two authors from the U.S. government, an expert from industry and an author from academia. Energy efficiency is implied in conservation and saving of energy, and this has been dealt with by authors in this chapter.

The cutting edge of technology by the use of *Nano-Materials and Nano Coatings* has been dealt with in Chapter 32 by two authors from academia. These experts deal in this chapter the use of Nano Technology in Fuel Cells, Wind Energy, Turbines, Nanostructured Materials, Nano-coatings, and the Future of Nano-technology in power generation.

A publication such as this with over 53 contributors from around the world and nearly 700 pages with rich reference material documenting the essence of the contributors' expertise can be a valuable addition to university libraries, as well as for consultants, decision makers, and professionals engaged in the disciplines described in this book.

For the reader's benefit, brief biographical sketches as mentioned before are included for each contributing author. Another unique aspect of this book is an Index that facilitates a ready search of the topics covered in this publication.

K. R. Rao Ph.D., P.E.
(Editor)

INTRODUCTION

This handbook has been divided into nine ("IX") sections with each section dealing with a similar or identical energy and power generation topic.

Section I deals with Solar Energy, which includes Chapters 1 to 6.

Chapter 1, "Some Solar-Related Technologies and Their Applications" is addressed by Robert Boehm. In this chapter, the source of energy that has been available to humankind since we first roamed the earth is discussed. Some of the general concepts are not new, and several particular applications of these technologies are enhancements of previous concepts.

The discussion begins with the special effects that are possible with the use of concentration. For locations that have a high amount of beam radiation, this aspect allows some very positive properties to be employed. This yields a lower cost, more efficient way of generating electricity. Limitations to the use of concentration are also outlined.

Another aspect discussed is the current situation of solar thermal power generation. This approach has been in use for many years. Previously designed systems have been improved upon, which results in more efficient and more cost-effective means of power production. While trough technology has been more exploited than other approaches (and is still a leader in the field), several other systems are gaining interest, including tower technology. Thermal approaches are the most convenient to add storage into solar power generation.

Photovoltaic approaches are described. New developments in cells have both decreased costs and increased performance. Both high- and low-concentration systems, as well as flat plate arrangements in tracking or non-tracking designs, offer a variety of application modes, each with certain benefits and shortcomings.

The use of solar-generated hydrogen is discussed. This offers an approach to a totally sustainable mobile or stationary fuel source that can be generated from the sun.

The solar resource can be used for lighting, heating, cooling, and electrical generation in buildings. The concept of zero energy buildings is discussed. These are buildings that are extremely energy efficient and incorporate a means of power production that can result in net zero energy use from the utility over a year's period. Locations with a moderate-to-high solar resource can use this to make up for the energy used. Both solar domestic water heating (a concept that has been applied in the United States for well over a century) and building integrated photovoltaic (PV) are also discussed. South-facing windows that incorporate thin film PV could generate power and allow lighting to penetrate the building. Finally, some exciting direct solar lighting concepts (besides windows) are discussed. The author uses 28 references along with 24 schematics, figures, pictures, and tables to augment his professional and scholastic treatment of the subject.

Chapter 2 by Yong X. Tao and Rambod Rayegan deals with "Solar Energy Applications and Comparisons." The authors focus on energy system applications resulting from the direct solar radiation including:

- Utility-scale solar power systems that generate electricity and feed to the electricity grid. There are PV systems and solar thermal power systems; the latter can also produce heat for hot water or air, which is often referred to as the combined solar power and heat systems.
- Building-scale solar power systems, also known as distributed power systems, which generate electricity locally for the building, and may be connected to the grid, or may be stand-alone systems, which require batteries or other electricity storage units. They are primarily photovoltaic systems.
- Solar heating systems for buildings, which are either used as hot water systems or hot air heating systems.
- Solar high-temperature process heat systems for industrial applications, which involve concentrated solar collectors and high-temperature furnaces for producing high-temperature heat for chemical processing of materials.
- Other special solar heating systems for desalination plants and hydrogen production.

There are additional solar energy applications in either the appliance category or even much smaller scales such as solar cooking, solar lighting products, and instrument-level solar power sources (watches, backpacks, etc.) The discussion of those applications is beyond the scope of this chapter. Outer space applications of solar energy technology are also excluded. Investigations primarily undertaken in the United States of America are presented, although some examples from global applications are also discussed to address the potentials and needs for wider applications of solar energy in the United States. The authors use 57 references along with 46 schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

Next is Chapter 3 dealing with "Solar Thermal Power Plants: From Endangered Species to Bulk Power Production in Sun Belt Regions," by Manuel Romero and José González-Aguilar.

Solar thermal power plants, due to their capacity for large-scale generation of electricity and the possible integration of thermal storage devices and hybridization with backup fossil fuels, are meant to supply a significant part of the demand in the countries of the solar belt such as in Spain, the United States of America, India, China, Israel, Australia, Algeria, and Italy. This is the most promising technology to follow the pathway of wind energy in order to reach the goals for renewable energy implementation in 2020 and 2050.

Spain, with 2400 MW connected to the grid in 2013, is taking the lead on current commercial developments, together with the United States of America, where a target of 4500 MW for the same year has been fixed and other relevant programs like the "Solar Mission" in India recently approved for 22-GW solar, with a large fraction of thermal.

Solar Thermal Electricity or STE (also known as CSP or Concentrating Solar Power) is expected to impact enormously on the world's bulk power supply by the middle of the century. Only in Southern Europe, the technical potential of STE is estimated at 2000 TWh (annual electricity production), and in Northern Africa, it is immense.

The energy payback time of concentrating solar power systems will be less than 1 year, and most solar-field materials and structures can be recycled and used again for further plants. In terms of electric grid and quality of bulk power supply, it is the ability to provide dispatch on demand that makes STE stand out from other renewable energy technologies like PV or wind. Thermal energy storage systems store excess thermal heat collected by the solar field. Storage systems, alone or in combination with some fossil fuel backup, keep the plant running under full-load conditions. This capability of storing high-temperature thermal energy leads to economically competitive design options, since only the solar part has to be oversized. This STE plant feature is tremendously relevant, since penetration of solar energy into the bulk electricity market is possible only when substitution of intermediate-load power plants of about 4000 to 5000 hours/year is achieved.

The combination of energy on demand, grid stability, and high share of local content that lead to creation of local jobs provide a clear niche for STE within the renewable portfolio of technologies. Because of that, the European Commission is including STE within its Strategic Energy Technology Plan for 2020, and the U.S. DOE is launching new R&D projects on STE. A clear indicator of the globalization of such policies is that the International Energy Agency (IEA) is sensitive to STE within low-carbon future scenarios for the year 2050. At the IEA's Energy Technology Perspectives 2010, STE is considered to play a significant role among the necessary mix of energy technologies needed to halving global energy-related CO_2 emissions by 2050, and this scenario would require capacity additions of about 14 GW/year (55 new solar thermal power plants of 250 MW each).

In this chapter, the authors discuss, with the help of 21 figures, schematics, and tables along with 72 references, the Solar Thermal Power Plants — Schemes and Technologies, Parabolic-Troughs, Linear-Fresnel Reflectors, Central Receiver Systems (CRS), Dish/Stirling Systems, Technology Development Needs and Market Opportunities for STE. The authors use 72 references along with 27 schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

Chapter 4 has been written by Rangan Banerjee and deals with "Solar Energy Applications in India." India has a population of 1.1 billion people (one-sixth of the world population) and accounts for less than 5% of the global primary energy consumption. India's power sector had an installed capacity of 159,650 MW as on 30th April, 2010. The annual generation was 724 billion units during 2008 to 2009 with an average electricity use of 704 kWh per person per year. Most states have peak and energy deficits. The average energy deficit is about 8.2% for energy and 12.6% for peak. About 96,000 villages are un-electrified (16% of total villages in India) and a large proportion of the households do not have access to electricity.

India's development strategy is to provide access to energy to all households. Official projections indicate the need to add another 100,000 MW within the next decade. The scarcity of fossil fuels and the global warming and climate change problem has resulted in an increased emphasis on renewable energy sources. India has a dedicated ministry focusing on renewables (Ministry of New and Renewable Energy, MNRE). The installed capacity of grid-connected renewables is more than 15,000 MW. The main sources of renewable energy in the present supply mix are wind, small hydro- and biomass-based power and cogeneration. In 2010, India has launched the Jawaharlal Nehru Solar Mission (JNSM) as a part of its climate change mission with an aim to develop cost-effective solar power solutions.

Most of India enjoys excellent solar insolation. Almost the entire country has insolation greater than 1900 kWh/m^2/year with about 300 days of sunshine. Figure 4-2 shows a map with the insolation ranges for different parts of the country. The highest insolation (greater than 2300 kWh/m^2/year) is in the state of Rajasthan in the north of the country. The solar radiation (beam, diffuse, daily normal insolation) values are available at different locations from the handbook of solar radiation data for India and at 23 sites from an Indian Meteorological Department (IMD) MNRE report.

Rangan Banerjee discusses in this chapter, with the help of 24 schematics, pictures, graphics, figures, and tables, the chapter that deals with Status and Trends, Grid-Connected PV Systems, Village Electrification Using Solar PV, Solar Thermal Cooking Systems, Solar Thermal Hot Water Systems, Solar Thermal Systems for Industries, Solar Thermal Power Generation, Solar Lighting and Home Systems, Solar Mission, and Future of Solar Power in India. The author uses 35 references and 24 schematics, figures, pictures, and tables to augment his professional and scholastic treatment of the subject.

Chapter 5, "Solar Energy Applications: The Future (with Comparisons)" is covered by Luis A. Bon and W.J. O'Donnell. This chapter traces the roots of solar energy from 1838 through current technologies from an engineering perspective. Numerous diagrams and photographs are included, illustrating the technical concepts and challenges. Methods of concentrating solar power are described including parabolic troughs, Fresnel reflectors, solar towers, and sterling engine solar dishes. Methods of storing solar energy to provide continuous power are described, including batteries, fly-wheel energy storage, water energy storage, compressed air, and superconducting magnetic energy storage. Current energy use and production in the United States of America and worldwide are quantified. Solar energy's potential future is illustrated by the fact that it would require less than 1% of the land area of the world to produce all of the energy we need. Of course, solar energy's future lies in its integration into the residential and commercial infrastructure. This challenge is expected to limit the contribution of solar energy to <0.1% of the USA energy consumption over the next 25 years.

The final chapter of this section is Chapter 6 "Role of NASA in Photovoltaic and Wind Energy" by Sheila G. Bailey and Larry A. Viterna. Since the beginning of NASA over 50 years ago, there has been a strong link between the energy and environmental skills developed by NASA for the space environment and the needs of the terrestrial energy program. The technologies that served dual uses included solar, nuclear, biofuels and biomass, wind, geothermal, large-scale energy storage and distribution, efficiency and heat utilization, carbon mitigation and utilization, aviation and ground transportation systems, hydrogen utilization and infrastructure, and advanced energy technologies such as high-altitude wind, wave and hydro, space solar power (from space to earth), and nano-structured photovoltaics. NASA, in particular, with wind and solar energy, had extensive experience dating back to the 1970s and 1980s and continues today to have skills appropriate for solving our nation's energy and environmental issues that mimic, in fact, those needed for space flight. This chapter encompasses the historical role that NASA and, in particular, NASA Glenn Research Center, GRC, have played in developing solar and wind technologies. It takes you through the programs chronologically that have had synergistic value with the terrestrial communities. It ends with pointing out the possibilities for future NASA technologies that could impact our Nation's energy portfolio. The technologies that it has developed for aeronautical and space applications has given GRC a comprehensive perspective for applying NASA's skills and experience in energy on the problems of developing a sustainable energy future for our nation. Authors use 70 references along with 32 schematics, figures, and pictures to augment the professional and scholastic treatment of the subject.

Section II dealing with Wind Energy is covered in Chapters 7 through 10.

Chapter 7 is authored by Jose Zayas who addresses "Scope of Wind Energy Generation Technologies." The energy from the wind has been harnessed since early recorded history all across the world, and it has been a viable and dependable resource to support our ever changing needs (pump water, grind grains, and now produce cost-effective electricity).

When the price of oil skyrocketed in the 1970s, so did worldwide interest in wind turbine generators. The sudden increase in the price of oil stimulated a number of substantial government-funded programs of research, development, and demonstration, which led to many of the technology that drove the designs and the industry that can be seen today.

Since the early 1980s through today, wind farms and wind power plants have been built throughout the world, and now wind energy is the world's fastest-growing clean energy source that is powering our industry as well as homes with clean, renewable electricity.

Although the United States experienced a large influx of installations during the 1980s, it is not until recent years that wind energy in the United States has achieved large market installations and continued market acceptance. Through the 3rd Quarter of 2010, the United States has approximately 37,000 MW of installed capacity, which approximately represents 2% of our energy consumption.

Since the beginning, Sandia National Laboratories has had a key role in developing innovations in areas such as aerodynamics, materials, design tools, rotor concepts, manufacturing, and sensors, and today, through continued partnerships with industry, academia, and other national labs, Sandia continues to develop and deliver the next set of technology options that will continue to improve the reliability and efficiency of wind systems. It is difficult to predict what the next generation of technologies will bring to this industry, but we can be certain that as it continues to mature and leverage technologies from other sectors, the resulting turbines will be smarter, more efficient, and they will represent a significant percentage of our energy mix. The author uses 11 references along with 37 schematics, figures, and pictures to augment the professional and scholastic treatment of the subject.

Thomas Baldwin and Gary Seifert cover "Wind Energy in the U.S." in Chapter 8. Idaho National Laboratory (INL) is a science-based, applied engineering national laboratory supporting the U.S. Department of Energy (DOE). INL's mission includes ensuring the nation's energy security with safe, competitive, and sustainable energy. INL's Renewable Energy Program, consisting of wind, hydro, and geothermal energy systems, has conducted wind energy resource assessments, system integration, feasibility studies, turbine selection, and array designs since the mid-1990s. Engineering support has been provided for the U.S. Department of Defense, Wind Powering America, State of Idaho, commercial industries, and regional entities. INL is an international clearing house supporting private parties, industry, and government agencies as an independent subject matter expert on wind power, resource assessment, and renewable energy systems siting. INL has extensive wind analysis expertise, having collected and analyzed wind data for more than 10 years. INL has installed met towers at more than 60 sites and collected data with SODARs. Wind analysis modeling tools experience includes WAsP, WindSim, Windographer, NRG, SecondWind, as well as MS Excel-based models which have been developed internally over several years.

Thomas Baldwin, Gary Seifert, and the engineering team they work with bring a combined total of over 75 years of expertise to the power system integration, wind, solar, and renewable energy field. Gary Seifert has been involved for over 30 years in electrical and power systems projects for the Idaho National Laboratory. He is a Sr. Program Manager in INL's Power and Renewable Energy and Power Technologies Department. His background includes extensive power plants and total energy plants for the DOE and the DOD. These plants have included heat recovery and desalination plants to produce potable water and challenging power system integrations.

Thomas Baldwin has been involved in power system design and energy storage systems for 25 years at ABB, Florida State University, and the INL. His background includes earthing and grounding systems, power quality assessments, applications of uninterruptible power supplies and superconducting energy storage systems, and industrial power system protection. Authors use 34 references along with 26 schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

The next, Chapter 9, is by Peter Eecen which deals with "Wind Energy Research in the Netherlands." The chapter describes the developments within The Netherlands with regard to the wind energy research since the first funding was organized by the National Wind Energy Research Program in the period 1976 to 1985. Wind energy research activities in the Netherlands have been and are predominantly performed at the wind energy department of the Energy Research Centre of the Netherlands ECN and the interfaculty wind energy department DUWIND at Delft University of Technology. Both institutes are involved in wind energy research since the start of the modern wind turbines. These institutes match their research programs with each other so that a consistent research program in The Netherlands is in place.

The research activities in wind energy have a strong focus on international cooperation, where the cooperation was organized through among others the International Energy Agency (IEA), European Wind Energy Association (EWEA), European Academy of Wind Energy (EAWE), the International Electrotechnical Commission (IEC), the European Energy Research Alliance (EERA), and European research projects.

In the Netherlands, the wind energy research is supported by an extensive experimental infrastructure. The Knowledge Centre WMC that has been founded by the DUT and ECN is a research institute for materials, components, and structures. WMC is performing blade tests for large wind turbines to 60 m in length. ECN made available a research wind farm where prototype wind turbines are tested, where a research farm of five full-scale turbines are used for research activities, and where a scale wind farm is located for research on farm control and wind farm aerodynamic research. At DUT, a large selection of experimental facilities is being used for wind energy applications. The most prominent facilities are the wind tunnels, of which the Open Jet Facility is the most recent addition.

The historic overview of the wind energy research activities in the Netherlands is written from the perspective of the research community and provides alternative insights as would be provided by existing historic overviews that focus on the implementation of wind energy and the development of support mechanisms. The description of research activities, the developed advanced design tools, developed knowledge, and intellectual property may provide an alternative source for further activities to reduce the cost of energy of wind power. The author uses 22 references along with ten schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

The last chapter of Section II, Chapter 10, is by M. P. Ramesh covering "Role of Wind Energy Technology in India and Neighboring Countries." The interest in wind as a source of power in the Asian region had an early start in India. Owing to a variety of inhibiting factors, it was a low key activity for a long time. Ramesh, Muthya with his long and close association with the field has treated the subject of wind energy development as a source of power with a thorough understanding of development cycle in dismissive environments that are stronger in developing countries.

Indian engagement with wind power started as early as the late 1950s but was mostly for nonelectric applications. Origins of usage of wind for grid connection started only in the mid-1980s with few small turbines installed at known windy areas. Danida aided 20 MW wind farms paved way for a steady and sustained growth of the field. This is treated with the backdrop of the grid situation and programmatic approach of the support from the government. Approach to resource estimation is also treated rather cautiously in India.

China had been a little slow in taking to large-scale development in renewable energy except for perhaps the biogas plants, which score over the Indian design in many ways. Slowly but surely, the Indian floating collector design is being replaced by fixed dome Chinese design for community-based biogas plants. On wind power use over the last few years, there has been a drastic turn around in the approach to using re-technologies. It has taken just 3 years for China to graduate to the second position in the top ten lists in terms of wind power capacity addition. If one goes by the projections, the number one position may be achieved. In 2007, it was at about 4 GW, and by 2009, the installations touched an astounding 26 GW. With scores of companies undertaking development on a war footing, there is so much happening in China on wind power. A spate of wind turbine designs has been developed, and prototypes are being built and tested. Another paradoxical position is that though it is a country that produces about 40% of all solar photovoltaic devices, domestic utilization is quite small.

Sri Lanka has good wind resource. However, it cannot be expected to reach market sizes that India or China have. The potential and limitations have been briefly described.

In this paper, Ramesh Muthya has attempted to capture some of the salient aspects of technology development and deployment in India in the context of power supply systems management. Main RE technologies dealt with are wind energy sources. Small hydropower adds considerable value for localized grids. Biomass sources work more or less like thermal stations though for limited periods in a year. The author uses 14 references along with 16 schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

Section III deals with Hydro and Tidal Energy and has three chapters: Chapters 11, 12, and 13.

Chapter 11, "Hydro Power Generation: Global and U.S. Perspective" is by Stephen D. Spain. The development of dams on rivers, with associated benefits of water storage for flood control, irrigation, and "hydropower" has played a vital role in advancing civilization throughout history. Of these, hydropower ingeniously, and yet so simply, combines two of the most fundamental components of nature on planet Earth — water and gravity — to help sustain our survival and improve our lifestyle.

This chapter describes the role of hydropower from past to present and into the future. Hydropower has been demonstrated to be a safe, reliable, and renewable energy resource worldwide, essential to the overall power and energy mix, both traditionally from rivers. Recent and growing development of pumped energy storage from lower to upper water reservoirs and evolving in the future with tidal and wave energy from the oceans has also been covered by the author.

Stephen D. Spain discusses, with the help of 18 schematics, figures, pictures, and tables, the History of Hydropower, including in the United States, Hydropower Equipment, Hydropower for Energy Storage, Ocean and Kinetic Energy, and Hydropower Organizations. The discussions also include Hydropower Owners, Worldwide Hydropower, and The Future of Hydropower. The chapter made extensive references to 27 publications.

Chapter 12, "Hydro Power Generation in India — Status and Challenges" is authored by Dharam Vir Thareja. Power generation in India has come a long way from about 1000 MW at the time of independence (August, 1947) to about 160,000 MW as on 31st March 2010 (end of Financial Year). The share of hydropower in the past six decades has also been impressive as it increased from about 500 MW at the time of independence to about 37,000 MW as of March 2010. But the present level of hydropower is only about 25% of the ultimate installed capacity estimated at 150,000 MW.

The hydroproject implementation and ownership remained with the State Governments or with the Power Corporations owned by States or Central Government for about four and a half decades. Owing to slow pace of development and also in line with international stress for liberalization of economy, the Government of India reviewed the policy of power development. In 1992, the power sector was opened up allowing private capital participation in its development along and in parallel with continued development under public sector.

India now possesses the needed financial resources and professional capabilities to utilize the in-house and global capacities for implementation of hydropower projects. The 50,000 MW initiatives leading to identification of 162 projects in a span of 2 years (2004 to 2006) has been recognized as a laudable initiative. The achievement of commissioning of about 8000 MW in the 10th plan period (2002 to 2007), the target of over 15,000 MW in the running 11th plan period (2007 to 2012) and 20,000 MW proposed during the 12th plan period (2012 to 2017) speaks of the ambitious plan of hydropower development. To achieve the targets of 11th and 12th plans, the fund requirement would be of the order of US$ 30 billion of which about 30% would be the share of private sector. The participation of private sector in the investment projections for the 11th plan for infrastructure, which includes power sector, is estimated to be at 30%.

The hydropower that is yet to be tapped, projects with more than 75% of installation, are located in Himalayan region. This region is known for intense seismicity, wide range of geotechnical variability, and extensive hydrologic pose challenges for infrastructure development.

It has been planned to exploit the bulk of balance of hydropotential in the next about two decades. To meet the target, the hydrosector would require investment of US$100 billion requiring an average of US$4 billion per year for another 25 years and, thus, would remain attractive for financial institutions, project developers, contractors, and consultancy organizations.

The role of hydropower in the energy scenario; potential and status of development; small hydro- and pump-storage development; transmission setup and status; constitutional and regulatory provisions; resettlement and rehabilitation policies; techno-economic appraisal procedures; hydropower development in the neighboring countries; response and achievement of private sector; the issues, constraints, and challenges in development; and innovations for future projects are covered in this chapter. The author uses 16 schematics and 48 references to supplement the textual discussions.

The last chapter of this section, Chapter 13, is “Challenges and Opportunities in Tidal and Wave Power” by Paul T. Jacobson. Power generation from waves and tidal currents is a nascent industry with the potential to make globally significant contributions to renewable energy portfolios. Further development and deployment of the related, immature technologies present opportunities to benignly tap large quantities of renewable energy; however, such development and deployment also present numerous engineering, economic, ecological, and sociological challenges. A complex research, development, demonstration, and deployment environment must be skillfully navigated if wave and tidal power are to make significant contributions to national energy portfolios during the next several decades.

A striking feature of the wave and tidal power technologies in various stages of development is their number and diversity. Standardized classification of these technologies, as described here, will facilitate their development and deployment. The principal engineering challenge facing development of wave and tidal power devices is design of devices that can survive and operate reliably in the harsh marine environment. A significant advantage of tidal and wave energy conversion, compared to wind and photovoltaic generation, is the ability to forecast the short-term resource availability.

Environmental considerations play a large role in ongoing development of the wave and tidal energy industry. The number and novelty of device types, in combination with the ecological diversity among potential deployment sites, creates a complex array of ecological impact scenarios. Efficient means of addressing ecological concerns are in need of further development, so that the industry can advance in an environmentally sound manner. Adaptive management offers a means of moving the industry forward in the face of ecological uncertainty; however, the potential benefits of adaptive management will be realized only if it is implemented in its more scientifically rigorous form known as active adaptive management.

The ecological assessment challenge facing the wave and tidal energy industry is to acquire and apply the information needed to ensure that systems, sites, and deployment scales are protective of ecological resources. Many reports have identified the range of environmental issues associated with wave, tidal, and other renewable ocean energy projects. The remaining challenge is to prioritize the issues and address the most pressing ones in a cost-effective manner. For individual projects, this requires definition and evaluation of questions required for site-specific permitting and licensing. For the industry as a whole, this requires identification and acquisition of information that is transferable across projects. Several nontrivial activities are outlined that can be taken to address the large array of outstanding issues. The author uses 70 references along with eight schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

Section IV covers diverse modes of energy and power generation such as Bio, Waste, and Geo Thermal energies.

In the leading chapter of Section IV, Chapter 14, “BioEnergy Including BioMass and Biofuels” is addressed by T. R. Miles. He describes biomass fuels and discusses technologies that are suitable for biomass conversion. T. R. Miles draws from more than 35 years experience in the design and development of biomass systems, from improved cooking stoves in developing countries, to industrial boilers, independent power plants, utility cofiring and the development of biofuel processes.

Oil shortages in the 1970s stimulated the development of new technologies to convert biomass to heat, electricity, and liquid fuels. Combined firing of biomass with coal reduces emissions, provides opportunities for high efficiency, and reduces fossil carbon use. Cofiring and markets for transportation fuels have stimulated global trading in biomass fuels. Pyrolysis of biomass to liquid fuels creates opportunities for coproducts, such as biochar, which can help sequester carbon and offset emissions from fossil fuels. This chapter provides an overview of biomass fuels and resources, the biomass power industry, conventional and new technologies, and future trends. Advances in combustion and gasification are described. Thermal and biological conversions to liquid fuels for heat, power, and transportation are described with implications for stationary use.

Topics in Chapter 14 include biomass fuels and feedstocks, heat and power generation, cofiring biomass with coal, and conversion technologies such as gasification, torrefaction, pyrolysis, carbonization, and biofuels. Biomass fuel properties that are important to energy conversion are compared with coal. The effect of moisture, energy density, volatile content, particle size, and ash are related to the selection, design, and operation of biomass boilers. Moisture, particle size, and density are shown to limit cofiring in existing boilers. New technologies can offset these properties enabling more biomass to be cofired with coal. The transformation of ash in biomass boilers is shown graphically in Figure 14-1. Biomass types, sources, and supplies are evaluated including woody biomass, wood pellets, urban residues, and agricultural residues. The infrastructure and logistics of biomass are described. The current state of harvesting systems for crop residues and herbaceous crops is shown to highlight the need for higher fuel density and lower costs. Life cycle analysis is shown to be a common method for evaluating biomass sustainability.

Technologies for heat and power generation include combustion, domestic heat, district energy, small scale, industrial, and utility boilers for power generation. Industrial and utility systems use spreader stokers, and bubbling and circulating fluidized bed boilers. Methods to improve combustion efficiency and emissions are explained. Technology needs are identified such as boilers for low-quality biomass fuels like poultry litter.

Pyrolysis and carbonization are discussed as methods to change the form of biomass to enable increased use. Biochar is considered as a coproduct of pyrolysis or gasification that can be used to sequester carbon and improve soil fertility.

Biofuel development is outlined with attention to the potential benefits of using existing infrastructure in the pulp and paper industry. The author concludes that future developments in biomass energy will depend on public policy decisions regarding the use of biomass resources and on the development of biomass energy as a means of offsetting carbon emissions from fossil fuels. The author uses 65 references along with 16 schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

Chapter 15, "Utilizing Waste Materials as a Source of Alternative Energy: Benefits and Challenges" is addressed by T. Terry Tousey. There are numerous waste streams, both industrial and residential, that contain recoverable energy. However, many of them, in their "as-generated" form are not suitable to be used directly as a fuel. Either they have contaminants that reduce their energy value, or they are not in the proper physical form and need to be processed in order to recover their energy value. The question then becomes, can the energy value of these materials be recovered economically?

In this chapter, we will explore some of the benefits and challenges associated with using wastes and industrial by-products as a source of energy. We will look at how different waste materials are classified by the regulatory agencies and how this affects the economics of using them as a source of energy. We will review the economic and regulatory drivers for recovering the energy value of waste materials, and we will examine a few technologies being used to convert these materials into a usable form of energy, including anaerobic digestion and gasification. We will also address the energy efficiency issues of using the calorific value of the waste to produce electricity versus using it directly in the production of heat. Finally, we will identify some specific examples of industrial and post-consumer waste streams that are currently being used for energy production and look at their fuel characteristics. As part of this, we will explore the benefits and challenges associated with municipal waste to energy projects and we will look at a case study of the cement industry's experience with using hazardous waste fuels.

This chapter strives to give the reader a broad overview of all the aspects of implementing a waste to energy program. This includes not only dealing with the potential operational, regulatory, and community relations issues, but also with the issues associated with sourcing materials and the concept of reverse distribution. It is important to understand that for a waste to energy program to be successful, there must be an efficient mechanism in place to collect, process, and transport the material to the ultimate energy consumer.

Waste to energy will continue to play an increasing role in our future energy needs. These projects are unique in that their economics are almost always driven by disposal cost avoidance or regulatory compliance, and therefore, they are not completely dependent on the price of fossil fuels or government support to make them viable. For this reason, the economics are generally more favorable for these types of projects than a pure renewable energy project. Hopefully, this chapter will give the reader the tools to make an informed decision. The author uses 55 references along with ten schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

Chapter 16 is authored by Lisa Shevenell and Curt Robinson who cover "Geothermal Energy and Power Development." The chapter covers the basic geology of the types of geothermal systems, where they are located, why they are there, and how geothermal systems in nature behave. Brief historical perspectives of geothermal development are presented as background. The authors discuss the three different types of power plants used to generate electricity and which type of power plant should be used to develop the particular type of geothermal systems most efficiently.

Current trends in geothermal development in the United States are discussed. An overview of geothermal exploration methods, historically successful, and new methods is presented. Environmental benefits and consequences and sustainability of geothermal power development are also outlined. Additionally, there is a comparison to other types of renewable energy sources and how geothermal is able to compete in energy markets.

Although the majority of the chapter focuses on power production from natural hydrothermal systems, the authors briefly introduce direct use applications, heat pumps, and enhanced geothermal systems. The authors use 78 references along with 25 schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

In Section V, Fossil and Other Fuels are addressed in Chapters 17 to 20.

In Chapter 17, authors Paul S. Weitzel and James M. Tanzosh cover "Development of Advanced Ultra Supercritical Coal-Fired Steam Generators for Operation above 700°C." The chapter provides a view into the development work advancing the steam conditions to above 700°C for coal-fired steam generation. The term for this technology is Advanced Ultra Supercritical (A-USSC). The European Union, China, India, and the United States, with large reserves of coal providing a major portion of the fuel used in those nations' electric generating capacity, have committed and undertaken programs to solve the materials issues for this fuel. The program in the United States has been ongoing for over 10 years and is sponsored by the Department of Energy and the Ohio Coal Development Office, along with four steam generator vendors that shared costs. This program, "Boiler Materials for Ultrasupercritical Coal Power Plants," addressed what is called the precompetitive data development that was needed for ASME Code qualification of new materials and the supporting technology to fabricate and construct the higher-temperature boiler components.

The service life of materials has been a key factor in the historical development of this generator technology in order to provide satisfactory availability and reliability, and this advancement was built on following these previous lessons learned. The outline of the program and discussion of results, along with an example design, are presented. A summary of the materials selected and the weights of tubing and piping are included. Background on the technology and terminology regarding efficiency and fuel impact comparisons are provided.

The program work has provided a wealth of information that will help assure the future introduction of A-USC technology. It is important to carry forward the advancement of 700°C steam generation and meet the goal of lower cost of electric power generation and achieve the significant reduction of carbon dioxide emissions. The authors use 20 references along with 17 schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

In Chapter 18, "Carbon Capture for Coal-Fired Utility Power Generation: B&W's Perspective" is written by D. K. McDonald and C. W. Poling. Changing climate and rising carbon dioxide (CO_2) concentration in the atmosphere have driven global concern about the role of CO_2 in the greenhouse effect and its contribution to global warming. Since CO_2 has become widely accepted as the primary anthropogenic contributor, most countries are seeking ways to reduce emissions in an attempt to limit its effect. This effort has shifted interest from fossil fuels, which have energized the economies of the world for over a century, to non-carbon emitting or renewable technologies.

For electricity generation, the non-carbon technologies include wind, solar, hydropower, and nuclear, while low-carbon technologies use various forms of biomass. Unfortunately, all current options are significantly more expensive than current commercial fossil-fueled technologies. Although use of wind and solar for power generation are increasing, they are incapable of supplying base load needs without energy storage capacity, which is currently impractical at the scale required. The only technologies capable of sustaining base load capacity and potential growth are coal, natural gas, and nuclear.

As the world grapples with CO_2 management, it is becoming increasingly clear that for the sake of the infrastructure in many developed countries and to provide a low carbon emissions option for developing countries relying heavily on coal, some form of carbon capture and storage (CCS) will be necessary. In a carbon-constrained world, the long-term viability of coal depends on the technical and economic success of emerging technologies for capture and storage. This may first be in the form of retrofit for the existing fleet, but considering the growth rate in emerging countries such as China and India, new plants will also be necessary as soon as practical.

Deployment of CCS is currently hindered by regulatory and social issues related primarily to long-term CO_2 storage. However, capture technologies are in the demonstration phase and are expected to be commercially available in the next decade. Carbon capture technologies are being developed by several companies for use with fossil fuels, especially coal. This chapter provides an overview from B&W's perspective of oxycombustion and post-combustion technologies for coal-fired steam and electricity generation, which are being developed for near-term deployment. The authors use eight references along with 20 schematics, figures, and pictures to augment the professional and scholastic treatment of the subject.

In Chapter 19, James L. Williams and Mark Jenner discuss "Petroleum Dependence, Biofuels — Economies of Scope and Scale; U.S. and Global Perspective." Our purpose is to examine petroleum dependence, identify risks of dependence, methods to mitigate dependence and risks, and provide a methodology for comparison of alternative sources of energy presenting a disciplined approach to the analysis of fuels and distinguishing between the fuel and its carrier or storage device.

The economic behavior of all fuels share many common characteristics. Principles concerning one fuel can be applied to others as the need arises. When comparing fuels, we focus on the cost per Btu and Btu/lb and Btu/ft^3 and emphasize the importance of efficiency in converting Btu's to mechanical or electrical forms of energy.

Fossil fuel economics are profoundly global in nature, and bioenergy economics are local. The two meet and compete directly at the consumer level. For example, biodiesel must be price competitive with petroleum diesel at the pump. The policy questions about whether it is worth subsidizing biofuels to reduce dependence on imported petroleum are central to the issue.

An international shortage of oil, which causes a price spike, can result in as much damage to an oil-dependent economy as an interruption in imports. Dependence can be lowered by either increasing domestic production or decreasing domestic consumption of petroleum.

Substitution of non-petroleum energy resources for petroleum is evident in the changes in the fuel mix in the post WWII era. Substitution is most difficult in the transportation sector because the high Btu content of petroleum relative to its weight and volume makes it an efficient fuel for the purpose.

The economics of bioenergy is much the same as the energy economics of fossil fuels. The frontier nature of the fledgling bioenergy industry adds enormous complexity. Biomass energy feedstocks can be wet, with different levels of moisture, dry, little to no water, or liquid without any water. Fuels can be produced specifically for energy, or they can be a by-product residual from the production of a higher-valued product. Waste-derived fuels bring with them many layers of environmental regulation, further adding to the complexity.

The economic viability of many biofuels depends upon feedstock transportation costs as well as coproducts in the production process. Ultimately, the use of biofuels is dependent on technological innovation, but the rate of innovation and implementation of new technologies is heavily dependent on public policy. Public policy can add incentives to reduce the costs and risks of supplying biomass fuels. It can also add incentives to enhance the demand and market prices for biomass-derived energy. The authors use 61 references along with 92 schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

In the final chapter of Section V, Ravi K. Agrawal discusses "Coal Gasification" in Chapter 20. Fossil fuels supply almost all of the world's energy and feedstock demand. Among the fossil fuels, coal is the oldest and most abundant form of fossil fuel. Coal is widely available with reserves estimated to last over 140 years. Coal is the lowest-cost fuel, and projections of the Energy Information Administration (EIA) indicate that coal is likely to remain the cheapest fuel in the foreseeable future and will likely become cheaper as the price of other preferred energy sources rise. Based on the energy content in terms of price per BTU, electricity commands the highest premium, followed by oil and gas. This price differential is the key driver that determines the interest in coal and its conversion into other energy substitutes.

Since electricity trades at the highest premium, the cheapest source of energy, coal, has been extensively used to generate electricity. About 60% of global electric power is generated from coal, and about two-thirds of coal produced is used for power generation. Unfortunately, coal has the largest carbon footprint when compared to conventional fuels derived from oil and natural gas. Historically, most coal-based power plants are considered to be "dirty" as only a few had controls to lower the emissions of SO_2, NOx and particulates, and even to date, virtually none have controls on mercury and CO_2 emissions. Tightening of environmental regulations in countries like the United States, Europe, and Japan has prompted installation of emission control devices. Future regulations on greenhouse gas emissions will have a major impact on traditional coal-fired power plants. Another drawback of traditional coal-fired power plants is efficiency, which is low, about 25% to 30%. Increasing costs of fuel and emission controls have led to the development of coal gasification as an efficient method to generate power from coal, while minimizing the environmental impact. Coal gasification involves conversion of coal into gas. Gas generated via gasification is referred to as syngas and is rich in CO and H_2. Gasification of coal is typically conducted at high temperature and high pressure with the aid of gasification agents such as air/oxygen and steam. This chapter reviews gasification methods and technologies that are now being actively pursued for coal. The state-of-the-art technology review highlights strengths and weakness of gasification technologies that are currently being marketed.

In addition to generating power, syngas generated from coal can be used for a wide variety of products including chemicals, fuels, and metals. Typical chemicals that can be produced from syngas include hydrogen, methanol, ammonia, acetic acid, and oxygenates. Liquid fuels such as naphtha, diesel, ethanol, dimethyl ether, and methyl tertiary butyl ether can also be produced from syngas. This chapter discusses applications of gasification to produce these products and identifies specialized processing steps necessary to achieve the desired end product. The flexibility of coal gasification plants to coproduce multiple slates of products makes it more attractive than traditional power plants.

Technologies to control contaminants in syngas generated from coal are discussed with emphasis on end-use application. Removal of contaminates from syngas ensures that the emissions from coal gasification plants are significantly lower than those from a traditional coal-fired steam generation units. Future regulations on greenhouse gas emissions will have a major impact on traditional coal-fired power plants. This chapter also provides a review of the greenhouse gas removal technologies from syngas.

The gasification process is complex and requires more capital than traditional coal plants. This chapter discusses technologies available to treat the raw syngas for further processing. Raw syngas gas processing in Gasification Island is discussed as a combination of blocks that combines several unit operations and processes. Several options available to process the raw syngas within the block are discussed identifying efficiency improvements and cost associated with these processing steps.

Even for a known feedstock and a known end application, deciding on gasifier type and the design of the gasification island is a complex issue. The most cost-effective path is not always straightforward. This chapter provides a discussion on options available to resolve conflicting issues between capital cost, operating cost, and efficiency.

Most of the future energy and chemical demands are projected to come from countries such as the United States, Russia, China, India, Australia, S. Africa, and Eastern Europe, and all of these nations are rich in coal. Therefore, incentive for coal usage via gasification as an alternative to meet energy and chemical demand will be strong. This chapter provides an overview of the impacts of global energy consumption pattern and consumption growth areas on coal utilization.

Since 2000, several gasification plants have become operational; most of these plants have been installed in China. Chinese coal gasification activity is due to the encouragement of the Chinese government to develop coal-based fuels and chemicals as a strategic issue due to their reluctance to become more reliant on foreign oil. In recent years, interest in using syngas to reduce iron ore has picked up, especially in India. This chapter provides an outlook and information on recent global activities in coal gasification. The author uses 49 references along with 34 schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

In Section VI titled "Nuclear Energy," four chapters are covered in Chapters 21 to 24.

Roger F. Reedy discusses in Chapter 21 "Construction of New Nuclear Power Plants: Lessons to be Learned from the Past." Without question, the costs associated with the construction of nuclear power plants in the 1970s and later escalated unreasonably. Although this increase was due to many factors, there are important factors that are still prevalent in the nuclear industry today. If these factors are not understood and properly addressed now, the costs associated with new plants will escalate as it did in the past. In order to address the issues of concern, technical changes must be made to codes and standards, but even more importantly, changes must be made to the mindsets that caused the unjustified costs in the past.

The largest mindset modification required pertains to quality assurance. Quality assurance has been implemented on engineering projects since before the time of the pyramids. In simple terms, quality assurance is the method used to assure that dimensions are correct, that calculations are checked, that proper materials are used, that processes used in construction are appropriate, and that work is appropriately inspected. The Egyptians did a great job of controlling their work because the pyramids have stood for thousands of years. The design might be called an overkill, but who knows? They were designed to last forever!

Has the quality control used in the post-1960s nuclear plants enhanced quality any more than achieved by the use of commercial codes and standards? With regard to the technical aspects of the hardware, the answer is "probably not!" However, the cost difference between nuclear and commercial quality assurance is extremely significant. The largest cost has been the cost of administration of the QA program. Most of the administrative controls have resulted in wasted time and money. The nuclear quality assurance programs have concentrated on documentation, which in most cases is subjective evidence, not objective evidence. Very little time or effort was devoted to hardware evaluation. In the future, a more practical approach is required. Chapter 21 addresses this issue.

It is a fact that more than one-half of the nuclear plants operating in this country were designed and constructed prior to the requirements for the nuclear quality assurance programs mandated in the early 1970s. Are the units designed and fabricated after 1971 any safer than the earlier plants using commercial quality control? The record indicates that the answer is no.

There were a lot of other costly issues that arose after 1971 that also increased cost without enhancing quality. These were:

1. Inappropriate interpretation of codes and standards by unqualified personnel
2. Lack of understanding of the necessity of basic engineering judgments
3. Welding rejected by personnel unfamiliar with welding practices
4. Inappropriate record keeping
5. Lack of understanding of tolerances used in design and fabrication

The author addresses these and other issues that must be understood to avoid the mistakes and excessive costs of the last generation of nuclear power plants. The author uses 47 references to augment the professional and scholastic treatment of the subject.

In Chapter 22, Peter Riccardella and Dennis Weakland cover "Nuclear Power Industry Response to Materials Degradation — A Critical Review." In this article, the authors summarize several materials and structural integrity issues in operating nuclear power plants in which they have personally been involved, through their employment in technical and management positions in the industry for over 40 years. The issues include degradation and cracking of pressure vessels and piping in the plants that have collectively cost the industry hundreds of millions of dollars. The article looks retrospectively at the root causes of these problems, itemizes the lessons learned, and recommends an approach going forward that will anticipate and hopefully allows the industry to proactively address degradation issues in the future, for both the operating fleet as well as new plants that are currently in the licensing stages. The authors use 18 references along with five schematics and figures to augment the professional and scholastic treatment of the subject.

Chapter 23 is titled "New Generation Reactors." It is authored by Wolfgang Hoffelner, Robert Bratton, Hardayal Mehta, Kunio Hasegawa, and D. Keith Morton, with Mr. Morton coordinating the chapter write-up. The history of mankind repeatedly provides examples where a need is recognized and creative thinking is able to determine appropriate solutions. This human trait continues in the field of energy, especially in the nuclear energy sector, where advanced reactor designs are being refined and updated to achieve increased efficiencies, increased safety, greater security through better proliferation control of nuclear material, and increased use of new metallic and nonmetallic materials for construction.

With minimal greenhouse gas emissions, nuclear energy can safely provide the world with not only electrical energy production but also process-heat energy production. Examples of the benefits that can be derived from process-heat generation include the generation of hydrogen, the production of steam for extraction of oil-in-oil sand deposits, and the production of process heat for other industries so that natural gas or oil does not have to be used. Nuclear energy can advance and better the lives of mankind, while helping to preserve our natural resources. This chapter provides the reader greater understanding on how advanced nuclear reactors are not a "pie-in-the-sky" idea but are actually operational on a test scale or are near term.

In fact, efforts are currently underway in many nations to design and build full-scale advanced reactors. Many countries including Japan, Canada, China, Korea, the United States, Germany, Russia, France, India, and more have significant ongoing efforts associated with advanced nuclear reactors. This chapter briefly describes the six Generation IV concepts and then provides additional details, focusing on the two near-term viable Generation IV concepts. The current status of the applicable international projects is then summarized. These new technologies have also created remarkable demands on materials compared to light water reactors. Higher temperatures, higher neutron doses, environments very different from water, and design lives of 60 years present a real engineering challenge. These new demands have led to many exciting research activities and to new Codes and Standards developments, which are summarized in the final sections of this chapter. The reader is encouraged to enjoy this chapter, for the future is just around the corner. The authors use 98 references along with 42 schematics, figures, pictures, and tables to augment the professional and scholastic treatment of the subject.

The last chapter of this section is Chapter 24, authored by Owen Hedden and deals with "Preserving Nuclear Power's Place in a Balanced Power Generation Policy." In considering the future of nuclear power for electricity production in the United States, it is necessary to consider the present public perception of nuclear power. It is also necessary to consider public perceptions of the various competing sources of electricity production. These include coal, natural gas, and the several "green" or "renewable" sources, including hydro, wind, and solar.

The most recent nuclear power plant was completed in 1994. No new nuclear power plants have gone on line since then, but nearly 20% of our electric power is still provided by nuclear power.

In 2010, the media view had changed to accept resumption of new reactor construction. Now, however, in 2011, the Fukushima disaster will reverse that. While the number of U.S. nuclear power plants at risk of tsunamis is very small, there will be demands for additional safeguards for emergency diesel generators and their fuel supplies and the need for more flexible switchgear. Consideration of the location and operation of spent fuel pools will also be required. New plant construction will be suspended.

However, the demand for additional supply of cheap reliable electric power capacity will continue. So will the demand for reduction in power plant emission of carbon dioxide. Natural gas is little help in reducing carbon dioxide emissions. Wind and solar facilities do not have the capacity or reliability. That leaves hydro and nuclear. As noted in this chapter, all the good locations for hydro have been taken.

Nuclear power advocates will have to carefully refute claims of damage and radiation risk at Fukushima. At least to date, Fukushima is no Chernobyl. Release of radioactive material at Fukushima is about one-tenth of that at Chernobyl. The cores at three of the six reactors, and the spent fuel rods at one, have been damaged, but no cores have exploded. No immediate deaths due to radiation have been reported at Fukushima versus 30 at Chernobyl. This must be equated to deaths due to other power-generation sources. Consider coal mining and transport, refinery and pipeline explosions, and long-term effects of air pollution caused by coal-burning plants.

There is a greater risk to the public from the other major energy producers than from nuclear. With electric energy needs increasing, nuclear power production must be part of that increase. The author uses 30 references along with one table to augment the professional and scholastic treatment of the subject.

Section VII is titled "Steam Turbines and Generators" and has two chapters: Chapters 25 and 26.

Chapter 25 "Steam Turbine and Generator Inspection and Condition Assessment" is authored by Lawrence D. Nottingham. Modern turbines and generators are large, complex machines that utilize a vast array of materials, are often exposed to high stress levels and a number of potentially hostile environments and which suffer operative damage mechanisms as a direct result. While failures of the massive rotating components are relatively rare events, the consequences of such failures are severe and extremely costly to the owner/operator. Consequently, rigorous programs have evolved for assessing current conditions, for detecting and quantifying existing flaws, and for predicting the remaining lives of the primary components, with an overall objective of providing effective run/repair/replace decision making. In this chapter, the author, who has spent most of his 39-year professional career dealing with turbine and generator condition assessment issues, presents an overview of the state-of-the-art for inspection and remaining life assessment of critical rotating T/G components.

The chapter additionally provides background information on machine design, materials, stress sources, applicable nondestructive evaluation methods, and analytical processes available for predicting remaining life, as related to and appropriate for an overall understanding of the assessment process. The author uses four references along with 23 schematics, figures, and pictures to augment the professional and scholastic treatment of the subject.

Chapter 26 Steam Turbines for Power Generation is written by Harry F. Martin. Steam turbines have historically been the prime source of power for electric power generation. This chapter will focus on steam turbines currently being applied to power generation. The steam conditions will include those currently applied to fossil-fired power plants, combined cycle and nuclear power units. In addition, future cycle pressures and temperature requirements are discussed along with the material requirements for these applications.

The chapter includes steam turbine fundamentals, equipment configurations, various design types and technology applications, performance levels, performance testing, and operation and maintenance. Blading fundamentals are included along with current technology improvements for increased performance. New sealing concepts including brush seals, retractable seals, and abradable seals are discussed. The effects of low pressure turbine exhaust size and diffuser design on performance is included.

This chapter should appeal to many types of readers. The presentation makes use of many references to permit the reader to expand his knowledge on a specific subject while limiting the size of the chapter.

Some of the topics included are seldom found in an overview type presentation. These include moisture and solid particle erosion, turbine heat transfer analysis, stalled and unstalled blade flutter, and limit load.

Concepts of automated turbine control are discussed including rotor stress modeling concepts applied in control systems. The pros and cons of various operating modes such as the use of partial arc and full arc of admission high-pressure turbine designs and sliding pressure are reviewed. The author covers the topic with 22 equations, 42 references along with 35 schematics, figures, and pictures to augment the professional and scholastic treatment of the subject.

Section VIII: Selected Energy Generation Topics and has four chapters: Chapters 27 to 30.

Chapter 27 is titled "Combined Cycle Power Plant" and is authored by Meherwan P. Boyce. Combined cycle power plants are most efficient power plants available today for the production of electric Power with an efficiency ranging between 53% and 57%. A short summary of other power plants such as steam, diesel, and gas turbine plants are given. Combined cycle power plants come in all sizes. In this chapter, we are emphasizing the larger plants ranging in size from 60 MW to 1500 MW. These combined cycle plants have as their core the gas turbine, which acts as the Topping Cycle and the steam turbine, which acts as the Bottoming Cycle. In between the gas turbine and the steam turbine is a Waste Heat Recovery Steam Generator (HRSG), which takes the heat from the exhaust of the gas turbine and generates high-pressure steam for the steam turbine.

The Brayton (Gas Turbine) and Rankine (Steam Turbine) cycles are examined in detail as they are the most common cycles used in a combined cycle power plant. Various modifications of the basic Brayton Cycle taking into account various cooling effects, such as refrigerated cooling and evaporative and fogging effects are examined. Also examined are intercooling, regenerative, and reheat effects.

The Rankine Cycle is also examined in detail, taking into accounts the effects of regeneration, reheat, backpressure and condensation on the performance, power, and efficiency of the steam turbine.

The Brayton Rankine Cycle, which is the basic cycle for a combined cycle, is examined, and the effect of the above-described effects, as they are applied to the combination cycle, is discussed. Various techniques to improve Power and Efficiency, on such a cycle are presented.

The combined cycle power plant comprises of the Gas Turbine, Heat Recovery and Steam Generator (HRSG), the Steam Turbine, and Condensers. Each of these major components is examined in detail, and furthermore, each of the major components are closely detailed to describe their operations.

The gas turbine section examines the various types of gas turbines such as the Aeroderivative Gas Turbine, as well as the large Frame-Type Gas Turbines. In this section, new trends on gas turbine compressors, combustors, and the hot section expander turbine are discussed, and the effect each of these components have on the efficiency and environment are carefully examined to ensure that they are operated as designed.

The HRSG system is a critically important subsystem in a combined cycle power plant. Under this section, the efficiency of energy transfer in multiple pressure steam sections is closely examined as are supplementary-fired HRSGs. Also examined are the Once Through Steam Generators (OTSG) and compared to the traditional drum-type steam generators. Also discussed in this section are the effects of deaerator, economizers, evaporators, superheaters, attemperators, and desuperheaters.

The steam turbine section deals with the reheat extraction and condensing steam turbines with various sections, which match the multiple pressure in the heat recovery steam generators. Various steam turbine characteristics are described as to their effect on power and efficiency.

The chapter closes with a short analysis of some of the major cost centers in a Combined Cycle Power Plant and the Reliability and Availability of such power plant systems. The author covers the topic with 31 equations, two references along with one table, 37 schematics, figures, and pictures to augment the professional and scholastic treatment of the subject.

Simon Gamble, Marian Piekutowski, and Ryan Willems authored Chapter 28 and discuss "Hydro Tasmania — King Island Case Study." Hydro Tasmania has developed a remote island power system in the Bass Strait, Australia, that achieves a high level of renewable energy penetration through the integration of wind and solar generation with new and innovative storage and enabling technologies. The ongoing development of the power system is focused on reducing or replacing the use of diesel fuel while maintaining power quality and system security in a low inertia system. The projects completed to date include:

- Wind farm developments completed in 1997 and expanded to 2.25 MW in 2003;
- Installation of a 200-kW, 800-kWh Vanadium Redox Battery (2003);
- Installation of a two-axis tracking 100-kW solar photovoltaic array (2008), and
- Development of a 1.5-MW dynamic frequency control resistor bank that operates during excessive wind generation (2010).

The results achieved to date include 85% instantaneous renewable energy penetration and an annual contribution of over 35%, forecast to increase to 45% postcommissioning of the resistor. Hydro Tasmania has designed a further innovative program of renewable energy and enabling technology projects. The proposed King Island Renewable Energy Integration Project, which recently received funding support from the Australian Federal Government, is currently under assessment to be rolled out by Hydro Tasmania (including elements with our partners CBD Energy) by 2012. These include:

- Installation of short-term energy storage (flywheels) to improve system security during periods of high wind;
- Reinstatement or replacement of the Vanadium Redox Battery (VRB) that is currently out of service;
- Wind expansion — includes increasing the existing farm capacity by up to 4 MW;

- Graphite energy storage — installation of graphite block thermal storage units for storing and recovering spilt wind energy;
- Biodiesel project — conversion of fuel systems and generation units to operate on B100 (100% biodiesel); and
- Smart Grid Development — Demand Side Management — establishing the ability to control demand side response through the use of smart metering throughout the Island community.

This program of activities aims to achieve a greater than 65% long-term contribution from renewable energy sources (excluding biodiesel contribution), with 100% instantaneous renewable energy penetration. The use of biodiesel will see a 95% reduction in greenhouse gas emissions. The projects will address the following issues of relevance to small- and large-scale power systems aiming to achieve high levels of renewable energy penetration:

- Management of low inertia and low fault level operation;
- Effectiveness of short-term storage in managing system security;
- Testing alternative system frequency control strategies; and
- Impact of demand side management on stabilizing wind energy variability.

The authors cover the topic with 24 equations, 12 references along with two tables, 22 schematics, figures, and pictures to augment the professional and scholastic treatment of the subject.

Chapter 29, titled "Heat Exchangers in Power Generation" has been authored by Stanley Yokell and Carl F. Andreone describes shell-and-tube and plate and frame types of power plant heat exchangers and tubular closed feedwater heaters and the language that applies to them. The chapter briefly discusses Header Type Feedwater Heaters and their application and use. It defines the design point used to establish exchanger surface and suggests suitable exchanger configurations for various design-point conditions and the criteria used to measure performance. It does not cover power plant main and auxiliary steam surface condensers because of the differences in how they are designed and operated The chapter briefly discusses the effects on the exchanger of normal and abnormal deviations from design point during operation. The authors have several schematics and references to supplement their discussion.

The last chapter of this section, Chapter 30, "Water Cooled Steam Surface Condensers" has been authored by K. P. (Kris) Singh. Chapter 30 is devoted to providing a comprehensive exposition to the technologies underlying the design and performance of steam surface condensers used to condense the exhaust steam from the low-pressure turbine in a power plant. The surface condenser is an indispensable component in any power station and is also one whose performance directly affects both the thermodynamic efficiency and the service life of the plant. In terms of sheer size, the surface condenser is the largest of any equipment in the power cycle, which alone makes it an important subject matter in the field of power plant technology.

The specific class of surface condensers considered in this chapter is of the so-called water-cooled type, wherein the condensing of the exhaust steam occurs outside the tube bundle by extraction of its latent heat by the cooling water circulated through the inside of the tubes.

Empirical information on the design and operation of classical surface condensers is provided in the standards published by the Heat Exchange institute, which is an industry consensus document that contains valuable practical guidance. Accordingly, the material in this chapter is not a substitute for a design manual; rather, it is intended to illuminate the thermal-hydraulic concepts underlying the state-of-the-art condenser design technology to possibly serve as the technical beacon for developing designs for new challenging situations such as condensing of noncondensible-laden geothermal steam. Inadequate removal of noncondensibles, flow-induced vibration, entrainment of (corrosive) oxygen in the condensate, excessive fouling, erosion of the tubes from flashing action in the condensate are among the many ailments that can afflict a surface condenser that require an in-depth understanding of the thermal and hydraulic phenomena that are present in its operation. The mission of this chapter is to provide the necessary cerebral understanding to the designer to enable him (her) to navigate through the many challenges that lie on the path to a successful design.

Special emphasis is placed on explaining the efficacy of a type of tube support , called nonsegmental baffles that has not been used to the extent in the industry as its thermodynamic merit would warrant. The mathematical means to quantify the advantage of the nonsegmental baffle configuration over the conventional plate-type supports is provided.

The author covers the topic with 55 equations, 18 references along with seven tables, 11 schematics, figures, and pictures to augment the professional and scholastic treatment of the subject.

Section IX is titled "Emerging Energy Technologies" and has two chapters: Chapters 31 and 32.

Chapter 31: "Toward Energy Efficient Manufacturing Enterprises" has been authored by Kevin W. Lyons, Ram D. Sriram, Lalit Chordia, and Alexander Weissman. Industrial enterprises have significant negative impacts on the global environment. Collectively, from energy consumption to greenhouse gases to solid waste, they are the single largest contributor to a growing number of planet-threatening environmental problems. According to the Department of Energy's Energy Information Administration, the industrial sector consumes 30% of the total energy, and the transportation sector consumes 29% of the energy. Considering that a large portion of the transportation energy costs are involved in moving manufactured goods, the energy consumption of the industrial sector could reach nearly 45% of the total energy costs. Hence, it is very important to improve the energy efficiency of our manufacturing enterprises.

A product's energy life cycle includes all aspects of energy production. Depending on the type of material and the product, energy consumption in certain stages may have a significant impact on the product energy costs. For example, 1 kg of aluminum requires about 12 kg of raw materials and consumes 290 MJ of energy. Several different strategies can be used to improve the energy efficiency of manufacturing enterprises, including reducing energy consumption at the process level, reducing energy consumption at the facilities level, and improving the efficiency of the energy generation and conversion process. While the primary focus of this chapter is on process level energy efficiency, the authors also briefly discuss energy reduction methods and efficient energy generation process through case studies.

In this chapter, the authors introduce the concept of unit manufacturing processes, which are formal descriptions of manufacturing resources at the individual operations level (e.g., casting, machining, forming, surface treatment, joining, and assembly) required to produce finished goods. They classify these processes into mass-change processes, phase-change processes, structure-change processes, deformation processes, consolidation processes, and integrated processes. Several mechanisms used to determine energy consumption for these processes are described. This is followed by a method that describes how to improve the efficiency of this energy consumption through improved product design for injection molding. HARBEC Plastics, Inc. is an innovator in implementing sustainable manufacturing practices. This company, which makes high-quality injection-molded parts, has made a considerable commitment to being green. Various techniques employed by HARBEC Plastics to improve energy efficiency are briefly described. A specific technique — using supercritical fluids — that can be effectively used to improve energy efficiency and to improve processes that generate energy from nontraditional sources is also outlined. Finally, the authors point out how best practices, regulations, and standards can play an important role in increasing energy efficiency.

The authors cover the topic with 58 references along with three tables, 12 schematics, figures, and pictures to augment the professional and scholastic treatment of the subject.

Chapter 32: "The Role of Nano-Technology for Energy and Power Generation: Nano-Coatings and Materials" has been authored by Douglas E. Wolfe and Timothy J. Eden. Chapter 32 discusses a variety of nano-coatings and materials used in the energy and power generation fields. Nano-coatings, nanocomposite coatings, nanolayered coatings, functional graded coatings, and multifunctional coatings deposited by a wide range of methods and techniques and their roles in assisting to generate energy and power for the fuel cell, solar cell, wind turbine, coal, combustion, and nuclear industries are discussed. Chapter 32 provides a brief description of the past and present state-of-the-art nanotechnology within different industrial areas, such as turbine, nuclear, fuel cell, solar cell, and coal industries, that is used to improve efficiency and performance. Challenges facing these industries as pertaining to nanotechnology and how nanotechnology will aid in the improved performance within these industries are also discussed. The role of coating constitution and microstructure including grain size, morphology, density, and design architecture is presented with regard to the science and relationship with processing-structure-performance relationships for select applications. The impact of nanostructured materials and coatings and their future in energy are also discussed with regard to nanostructured configuration, strategy, and conceptual design architectures. Coating materials and performance are also discussed related to materials in extreme environments such as power generation, erosion environment, and hot corrosion. The role of nanotechnology, nanocoatings, and materials for power and energy varies depending on the working environment but, in general, can be classified into the following categories of improved wear resistance, corrosion resistance, erosion resistance, thermal protection, and increased surface area for energy storage. Since not all environments are the same, slight modifications may be required to optimize nano-material and nano-coatings for a particular application. These include composite coatings, functional gradient coatings, superhard coatings, superlattice coatings, metastable multifunctional, solid solution, nano-crystalline, multilayer coatings, and mixed combinations. With all the material choices that we have ranging from binary, ternary, and quaternary nitride, boride, carbide, oxide, and mixed combinations, choosing the optimum coating material and design architecture can be challenging. The approach to materials solutions starts with understanding the system performance, operating environment, maintenance issues, material compatibility, cost, and life cycle. Chapter 32 concludes with a summary of the future role of nanotechnology and nano-coatings and materials in the fields of power generation and energy.

The authors cover the topic with nine equations, 73 references along with four tables, 20 schematics, figures, and pictures to augment the professional and scholastic treatment of the subject.