guest editorial

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evolution of energy

global developments and challenges

THE MAIN CHALLENGES FACING humanity during the next 50 years are 1) access to energy, water, and food, in that order, to supply a fast-growing population and 2) the ability to achieve that access without impacting the environment while coping with climate change. With a world population of around 10,000 million (10 billion by U.S. metrics) people by 2050, the first and most urgent challenge is to have abundant and affordable energy to make life easier and comfortable for the population. With abundant energy resources, sea water could be treated and transported. With abundant energy and water, one could assume that raising enough food would be achievable. Thus, energy is the base of global concerns, and that is clearly recognized today just by looking at everyday events where energy is the root of many of the world's conflicts.

Energy, particularly oil, has played a key role in recent wars in modern history. It has been the cassus belli many times; to mention just a few, Germany invaded Russia during World War II to gain access to the oil in the Caucasus region. The need to secure oil supplies was a deciding factor in Japan's resolution to attack Pearl Harbor. The 1990 Iraqi invasion of Kuwait and the resultant Gulf War was about controlling the abundant oil produced by Kuwait. The oil factor was regarded among the main motives behind the decision of the United States and the United Kingdom to invade Iraq in 2003. The restrictions on oil passage through the Strait of Hormuz are arising as a conflictive matter at this time, and a major oil disruption in the Persian Gulf could result in a war (roughly 40% of all U.S. crude imports sail through the Strait). Not to be overlooked is the parallel path between nuclear electricity production and nuclear bomb development, with conflicts being faced on the matter at present.

The entire concept of nuclear energy, an assumed abundant, economical, and clean source of electricity, is undergoing serious questioning following the Japanese 2011 earthquake/tsunami that severely damaged the Fukushima Daiichi nuclear plant.

We asked experts to review the electricity matrices of different regions and countries worldwide and predict future evolution.

Energy access is a planetary challenge, not one that we can solve within geographic or political boundaries, and even more so in a highly interdependent planet. There are few countries that could ensure the availability of their energy supply from within their borders; energy dependence is a chronic concern, particularly of the developed world where economies can be shattered if an energy supply from abroad is interrupted. Europe and the United States have looked with concern at the recent turmoil in parts of the Middle East and North Africa, creating severe uncertainties in future energy supply reliability.

Finally, energy supply and usage are at the root cause of many of the environmental problems we face. Urban pollution from automobiles using heavily contaminated oil impacts our major cities and the health of their inhabitants. Particles and poisonous gases emitted by coal- and oil-burning industrial installations disable our planet. Acid rain negatively affects our lakes, forests, fauna, and human health. But overall, energy usage has been clearly recognized as the main contributor to the warming climate process that is endangering life on earth, caused by the rapid rise of atmospheric greenhouse gas emissions due primarily to a fossil fuel-based energy society.

It has been argued that the process of climate change may significantly alter our economic systems, ecological structures, and social development if we are not able to achieve the long-term target of limiting the global average temperature increase to 2 °C by the end of the century. Thus, societies must take urgent actions to combat climate change, beginning by substantially reducing greenhouse gas emissions while

Digital Object Identifier 10.1109/MPE.2012.2187228
Date of publication: 19 April 2012

preparing to adapt to the consequences of that change. No nation is protected from the change, and those emitting the least amount will not necessarily be the least affected.

The discussion often arises that securing energy necessarily conflicts with environmental objectives and that economic development may be hurt by actions to reduce greenhouse emissions. How to develop a climate-friendly energy policy is a question arising strongly today.

All these factors are related in a world map of energy that has shifted considerably over the last decade. According to the International Energy Agency (IEA) 2011 *World Energy Outlook (WEO)*, China has consolidated its position as the world's largest energy consumer: by 2035 it will consume nearly 70% more energy than the United States, the second-largest consumer, even though by then per-capita energy consumption in China will be still less than half the level in the United States. And the rates of growth in energy consumption in India, Indonesia, Brazil, and the Middle East are growing even faster than in China, according to *WEO* data. This implies a need for significant global investments in energy supply infrastructure (US$38 trillion in year-2010 dollars required over the period 2011–2035), with almost two-thirds of that in countries outside of the OECD, according to the *WEO*.

With all these concerns and challenges in mind, we chose as the central theme for this issue a long-term view of energy developments worldwide, reflecting the different conditions faced in different regions and focusing essentially on electricity supply. We asked experts to review the electricity matrices of different regions and countries worldwide and predict future evolution considering the international discussions on nuclear energy, renewable energy, energy dependence and security, and global warming emissions. We also wanted to identify challenges being faced in electricity supply, given growing public opposition.

We succeeded in soliciting contributions from the World Bank, the United States, China, Latin America, India and Africa, as well as an overview of the Fukushima accident.

The first article, by authors Marcelino Madrigal, Mikul Bhatia, Gabriela Elizondo, Ashok Sarkar, and Masami Kojima of the World Bank identifies two challenges in the energy sector. The first is to make more energy available at affordable prices to enable all people to use modern energy to meet their basic needs, given that about 1.3 billion people did not have access to electricity in 2010. The second is to slow the world's overall growth of energy consumption through conservation and energy efficiency improvement and to make energy sources more environmentally sustainable, both locally and globally. More so, they argue that many developing countries urgently need to secure a sufficient, reliable electricity supply as one of the top priorities for continued economic growth and social development. But they are pessimistic that globally announced plans will not be enough to bring modern energy and electricity services to underserved populations. To provide

"more, greener, and more efficient energy services for all," they argue that a structural change is needed, with the global power generation mix aimed at almost doubling the share of renewable and nuclear in the next 25 years, increasing from 32% to 62%.

The second article, by authors Timothy D. Heidel, John G. Kassakian, and Richard Schmalensee, summarizes a recently completed MIT two-year study on the future of the U.S. electric grid, where they indicate that public policies at both the state and federal levels in the United States and a variety of technological and economic changes are poised to significantly alter both the demand for and supply of electricity in the United States over the next several decades. These changes will yield a wide range of new challenges and opportunities including incorporating variable energy sources like wind and solar; adjusting distribution systems to accommodate small-scale, distributed generators; accommodating the charging of electric vehicles and other changes in electricity demand; making the best of new technologies to ensure reliability and efficiency under changing conditions; responding to threats presented by the vast increase of data communications within the grid; and meeting changing workforce needs. They are optimistic that a variety of technologies exist today that can help meet the emerging challenges effectively in the United States, but they warn that the promise of these new technologies will only be fully realized if, among other issues, a number of regulatory policies are changed. They also warn of the need to rejuvenate the power industry workforce to maintain current levels of performance.

The third article, by authors Yunhe Hou and Jin Zhong, from The University of Hong Kong, reports on the world's largest energy consumer, China, a country that has experienced a rapid growth in its economy in the past three decades, with energy consumption coupled to that growth. From 1990 to 2009, the energy average annual growth rate was about 5.3%, resulting in excessive consumption of resources, energy shortages, and severe environmental pollution. After 2001, the annual growth rate of CO_2 emissions reached 12.8%. This is coupled to a population change, with the urban portion dramatically increasing from 26.4% in 1990 to a predicted 70% by 2050, thus leading to a large amount of energy consumption for construction and transportation purposes. The unequal geographic distribution of energy production and consumption exacerbates the challenges

faced, particularly in energy transportation. To tackle its current unsustainable energy growth mode, China is following different paths: energy resources diversification (including renewables integration and nuclear power vigorous development), improvements of current technology, and regulatory and policy adjustments to stimulate efficiency and reduce emissions.

The fourth article, by authors Bernardo Bezerra, Sebastian Mocarquer, Luiz Barroso, and Hugh Rudnick from Brazil and Chile, provides an overview of the Latin-American energy future and the common challenges of energy security and environmental impacts. The authors chose their home countries to describe the different problems faced in Brazil, with plentiful resources but with an important state intervention on energy development, and in Chile, with little indigenous resources but with a fully private sector driving investments. The question of how to transition to a low-carbon society and the hydro vulnerability due to climate change are two of several important issues raised. Common to both countries is the challenge on developing abundant hydro resources, when outspoken nongovernmental organizations (NGOs) argue that hydros are not needed because wind and solar can supply the entire load in the long term. The need to enhance the technical skills of environmental agencies is emphasized, with a regulatory harmonization and joint activities between the electricity and environmental people at the planning stages of the hydro facilities.

The fifth article is by authors Jyoti Parikh and Kirit Parikh, from Integrated Research and Action for Development in New Delhi. With nearly 40% of people in India below the poverty line, 400 million households without electricity, and some 700 million households without access to clean cooking fuels in 2004–2005, rapid economic growth is essential to satisfy India's human development needs. India is short of fossil fuel resources, imports 80% of its oil consumption and is also short of coal; coal reserves will not last for more than 40 years at the present consumption growth rate. In addition, the global concern for climate change would make it difficult to increase considerable coal exploitation. India's hydroelectric resources are large, with potential capacity estimated to be 84,000 MW. But hydropower development faces a number of hurdles, is opposed on environmental and social grounds, calling on proper compensation and resettlement of displaced persons. Renewables, mainly

solar, and nuclear power are seen as alternatives for the future, but in the coming decades coal will remain the major source of power. Reducing energy requirements by demand-side management is a high priority option, both from the viewpoints of climate change and energy security.

The sixth article, by authors Pat Naidoo and Pascoal A. Bacela from South Africa and Mozambique, reports that Africa faces critical questions into its future economic development, particularly in relation to its scarce energy supply and limited access to electricity of its population. Many Africans still rely on the traditional use of biomass for cooking, while in countries like Ethiopia, Nigeria, and Tanzania, large parts of the population are without access to electricity. This happens in a continent that has abundant energy resources, for example, 92% of its hydropower potential is still underdeveloped. It has an abundance of natural gas and oil in North and Western Africa and coal in Southern Africa. In addition, the entire African continent can be regarded as one giant solar panel, with wind dominating the arid desert and coastal regions. However, the darkness of some parts of Africa contrasts with what has been happening in the Southern African region, which could spread to the rest of Africa. Investments in people development are also a priority to maintain and sustain the power infrastructure.

Finally, the "In My View" column has a contribution from author Hugo Altomonte, director of the United Nations Economic Commission for Latin America, who makes an assessment of the impact worldwide of the Fukushima accident on future energy supply and the open question if the 15% nuclear contribution to electricity production will increase or not.

Scenario evaluations and alternative technology costs are provided in several articles, with important factual data to support arguments. But overall, all articles challenge the engineering community worldwide to contribute to solving the technical, economical, environmental, and social problems of energy supply, common to different continents and levels of society development.

We appreciate and thank the authors for the efforts made and articles provided and IEEE Power & Energy Society and *IEEE Power & Energy Magazine* for the opportunity to present these valuable international views. Special thanks to Editor Mel Olken for his continuous and valuable support.