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Modelling and Analysis of Global Energy Scenario

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***Abstract*—Energy scenarios provide a framework for exploring future energy perspectives. It includes a variety of technological combinations and their outcomes. Many scenarios illustrate the effect of energy system developments on global issues. A wide range of energy supply possibilities to meet growing energy requirements is covered by scenarios. Global energy-related CO_2 emissions will increase by 1.7 % per year over 2002-2030 as per the projected trends in energy use in the Reference Scenario. They will reach about 38 billion tonnes in 2030 which is an increase of 15 Billion tonnes, or 62%, over the level in 2002. This rise in CO_2 emission results in global warming causing climate change, acidification etc. Here lies the importance of low carbon economy development and CO_2 emission reduction modelling which is of great relevance in the present energy trends. Our motivation is to obtain self-sustainability by 2050 by improving supply energy efficiency, reduction of CO2, future development of technologies etc. Different methods and tools used for CO_2 reduction modelling are analyzed here from case studies in various regions. Other sectors of modelling including power generation ,transport sector ,oil, gas and coal production modelling are also been dealt with.**

Keywords—Scenario,LowCarbon Economy, Sustainability

I. INTRODUCTION

Sustainable development can be regarded as an apt synonym for desirable transitions into the new developing millennium. Each scenario is treated as one particular image of the future.In this study, our objective is to study about various methods to reduce carbon emissions from various energy sectors and to analyze the importance of renewable energy sources, fuel mix in the present energy scenario.The motivation of this study is focused on attaining self-sustainability in all the energy sectors by 2050 which will also give rise to the development of new technologies.Current energy system trends are unsustainable. The electricity sector will need to be substantially decarbonized through the use of both new and existing low-carbon technologies. We need a global energy technology revolution to meet key challenges like climate change, global energy security and affordable access to energy. Scenarios continue to be one of the main tools for dealing with the complexity and uncertainty of future challenges. These scenarios cover a wide range of possible future developments. The scenario approach is used to examine future energy trends relying on the world energy model.

The world is facingcomplex climate problemscaused by rise inglobal warming due to greenhouse gases emission. The increase in the use of fossil fuels in order to meet the growing worldwide electricity demand, mostly in developing countries, not only counteracts the need to prevent climate change globally but also has negative effect on environment. A major part of the greenhouse gases come in the form of CO_2 which is the result of fossil fuel combustion. Greenhouse Gas(GHG) emissions from the power sector are expected to increase over coming years if no corrective actions are undertaken to improve the situation. The additional technological innovation will be needed to mitigate GHG emissions from the power sector. A transition from an energy system dominated by fossil fuels to a supply system based entirely on renewable energy with a dominating part of intermittent sources like wind and solar, is gaining its importance nowadays. Efficiency improvements are significantly higher in some regions, especially for shorter time periods. These differences in global developments across the scenarios are reflected even in larger regional variations. Another major problem in the future energy system, dominated by intermittent renewable sources is the electric grid stability and the security of supply to electricity consumers.

Electric vehicles have undergone massive technical developments in recent years. Along with the power supply system the electric vehicle may contribute to CO_2 reduction in the transport sector. Energy efficiency offered by these vehicles are high and their impact on environment is very low when compared with the conventional combustion engine vehicles. The flexibility of energy sources and various CO_2 reduction techniques in the electricity system become options for this sector. Hydrogen is a significantpotential future energy carrier which is able to convey the use and application of renewable energy sources in the transport sector. This study is limited to energy path analysis, where electricity from the grid supply Battery Electric Vehicle (BEV) charging is the base for producing hydrogen to operate Hydrogen Fuel Cell Vehicle (HFCV).

This report focus on developing scenario on the basis of various energy sectors: Carbon dioxide emission reduction modelling, Power sector modelling and transport sector modelling. The case studies are done for a few countries. The energy security in those regions are analyzed using an energy model and various energy security themes.

II. ANALYSIS OF ENERGY SYSTEM MODELLING

A vision of sustainable energy system leads us to the various approaches towards scenario modelling. It can be broadly considered as country-wide energy demand modelling based on sector and fuel. These includes power generation modelling, transport sector modelling, carbon-dioxide emission reduction modelling and oil, gas& coal production modelling. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report categorizes the international carbon emission forecasting model into two types, top-down and bottom-up models. Top-down energy models indicates the economy as a whole on either a national or regional level. The main characteristic of a conventional bottom-up energy model is its relatively high degree of technological detail used to assess future energy demand and supply. Bottom up models can capture all the aspects of the energy conversion: from fuels (fossil or renewable) to electricity or to thermal through different technologies.

A. Energy System Model

The scope of an energy system model can vary depending on its purpose. Engineering models covering the processes of a specific component (or sub-components) come at one extreme, while comprehensive models covering energy-economy interactions at both national and international levels come at the other extreme. A number of models found are systematically used to analyze the energy system. Different types of energy system models are:

1) Bottom-up, optimization-based models such as Market Allocation (MARKAL).
2) Bottom-up, accounting models such as Long Range Energy Alternatives Planning Systems (LEAP).
3) Top-down, econometric models such as Department of Trade and Industry energy model
4) Hybrid models such as world energy model (WEM)
5) Electricity system models (such as Electricity Generation Expansion Analysis System (EGEAS)).

The bottom-up accounting type of framework appears to be more appropriate for a developing country because of their flexibility and limited skill requirement. These models can capture rural-urban differences, traditional and modern energies. Regarding the mathematical form, bottom-up energy models have been developed in the form of simulation or optimization models. Optimization models try to define the optimal set of technology choices to achieve a specific target at minimized costs under certain constraints leaving prices and quantity demanded fixed in its equilibrium. In current top-down modelling approaches, efforts are made to extend the energy demand forecasting framework of the existing models to include technological and economic feedbacks.

The MARKAL model analyzes energy demand as well as supply on a country level basis using a bottom-up, dynamic modelling approach. There are several versions of the original MARKAL model which includes a small macroeconomic model, a microeconomic model, and numerous additional features. Another energy supply optimization model used frequently in literature is MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impact). Major distinctive features of this model are load regions considerations for electricity demand, the separation of resources into cost categories, and the concern of the environmental impact of energy supply strategies. The model output describes scenarios of energy supply.

B. Carbon dioxide Emission Reduction Modelling

Different methods are adopted for CO_2 emission reduction modelling and their analysis. In our study we have considered amine based capture method, energy security analysis using 'MESSAGE' model and examination of the role of Carbon Capture and Storage technology(CCS) by 'AIM' model.

The amine-based post combustion carbon dioxide capture has become a technology which is adopted widely for reducing large-scale CO_2 emissions, thus helping in mitigating global warming. This capture system operation is a complicated task to perform as it involves monitoring and manipulation of sixteen components associated with over hundred parameters like flow rate, temperature and pressure. To improve CO_2 capture efficiency, artificial intelligence techniques were applied to develop a knowledge-based expert system for proper monitoring and control of the capture process. The expert system helps to enhance performance of capture system by reducing the time for diagnosis if an abnormal condition occurs. The expert system can also be used as a decision-support tool to help inexperienced operators in process control. This post combustion capture technology is widely used in chemical processing and natural gas processing industries to reduce industrial carbon dioxide emissions [3].Since this monitoring and control task control and diagnose the capture process.

Inferential Modelling Technique (IMT) is used for developing knowledgebaseand is implemented using Delta V simulate. Knowledge base include two parts: domain knowledge and task knowledge. The domain knowledge defines the constructive components of the capture plant and the fluids circulating in the plant. The task knowledge gives the information on the possible malfunctions, diagnosis and remedial control for various parameters of the plant. The three level knowledge hierarchies of the reaction instruments, fluids, and control devices can be easily mapped into the hierarchy of Delta V simulate. The hierarchy of Delta V simulate include five levels: plant area, module, algorithm, function block and parameter. The plant areas are logical divisions of the processcontrol systems and consist of modules. Each module is a logical control entity to configure the control strategies. Functional block diagrams are used to continuously execute the control strategies. Each functional block contains user defined parameters and areused to perform its calculations and logic.

In domain knowledge there are three categories of objects: 1) reaction instruments 2) control devices and 3) fluids. There are sixteen reaction instruments and these are again divided into subclasses. The fluids circulating in the plant includes amine solvent, water and gas. Control devices include pumps and valves which are used to regulate the flow of fluids.

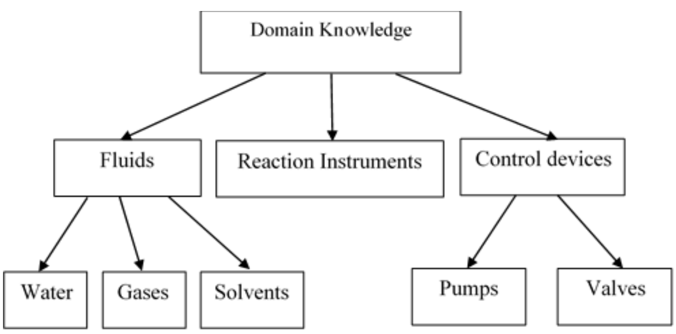

Fig. 1. Domain knowledge for CO_2 capture process

By the different methods used for CO_2 emission reduction modelling it is possible to develop an expert system for monitoring the carbon capture.

Energy security is the availability of energy supply sources at an affordable price. Here we analyze the effect of CO_2 emission reduction from the power sector on energy security of Thailand and Sri Lanka. Both countries have been modelled by using a bottom-up integer based model called MESSAGE. This two countries have been modelled as individual single region case studies including five scenarios each with CO_2 reduction of 10%, 20%, 30% and 40% in comparison with the reference scenario. Energy security is measured using three main themes namely oil security, gas security and sustainability. A low carbon society (LCS) is an economy which has a minimal output of greenhouse gases. In addition to the reference scenario the other scenarios modelled are LCS1 corresponding to10% reduction in carbon dioxide emissions, LCS2 and so on up to LCS4 [10].

Oil security is an important term to be considered as almost all countries extensively depends on oil for transportation and electricity generation though in recent times the use of oil for electricity generation has declined. The sub indicators in terms of oil security are Oil Supply Risk Indicator (OSRI),Oil Import Intensity(OII),Oil Intensity(OI),Oil Share(OS) and Net Oil Import Dependence(NOID).OSRI is positively correlated with energy security and rest four are negatively correlated with oil security i.e. higher values of those indicators means lesser security.

There are five sub indicators to measure gas security and they are Gas Supply Risk Indicator (GSRI), Gas Import Intensity (GII), Gas Intensity (GI), Gas Share (GS) and Net Gas Import Dependency (NGID).

Sustainability is a vital element in conceptualizing energy security. The sub-indicators used to assess sustainability are Primary Energy Intensity (PEI), Primary Energy per capita (PECap), Diversification of Fuels (DoFS), Non-Carbon Fuel Share(NCFS),Renewable Fuel Share(RFS),CO_2 Emissions Intensity(CEInt) and CO_2 emissions per capita(CECap).

Examination of Role of CCS by 'AIM' Model

In this study, AIM/End use model to examine the role of Carbon Capture and Storage technology (CCS) to reduce carbon dioxide emission in Indonesian power sector. Power sector is the most important contributor of carbon emissions in most developing Asian countries.The Asian Pacific Integrated Model(AIM)/End use model includes the end use driven scenario analysis including end-use technology,energy consumption etc.The present study will analyze the implications of introducing CO_2 emission reduction target in Indonesia during 2000-2035 by considering various technologies particularly CCS.

Input Data and Scenario Description

Input data are taken from various sources and this data comprises of agricultural,commercial ,residential ,transport and in industrial data.Five scenarios are considered in this study with a base case and four alternative scenarios which consider three different Emission Reduction(ER) targets.The base case scenario is defined as a business-as-usual,i.e. continuation of current economic,demographic and energy sector trends and there is no mitigation policy.The base year is taken as 2000 and end year of planning horizon is 2035.Four ER cases which targets to reduce carbon emissions by 5%,10%,20% and 30% are considered.Hereafter,these cases are referred to as ER5,ER10,ER20 and ER30.The 2013-2035 period is taken as the mitigation period in the study.Introducing emission reduction target in power sector in Indonesia would affect the selection of clean coal technology(CCT) [2].The AIM/end use model is dissegrated into four levels of tree structure:primary energy,secondary energy,demand service and service demand.The model will select the technology,which is based on the annual capital cost and running cost of technologies including the enrgy cost in a given year.The objective function of the model is to minimize the total cost.The total cost is optimized using certain constraints which involves emission constraints that set limitations to some of the pollutants.

Here we had also discussed about the CCS technology and its role in power sector. The method of measuring energy security and sustainability is studied. Power generation and transport sectors are growing sectors, hence its modelling is of prime importance.

C.Power Generation Modelling

The threat of climate change in terms of economic, ecological and social impacts urges many developing nations to find alternative paths to providing electricity. The importance of power generation modelling by using fuel mix and new technologies lies here. This is done by finding the best fuel mix that can meet the future energy demand by bottom-upinteger based model, the power sector modelling focusing one renewable energy technologies by using MARKAL energy system model.

In the present study, a scenario analysis is conducted for the future electricity system with a large amount of renewable power in Japan using a proposed integrated model with the aim of finding the best mix that produces the least amount of carbon and meets the future electricity demand. The power sources include solar, wind, nuclear, battery, fossil fuel, hydro and biomass.

The best fuel mix for an electricity system needs to be reconsidered in the future where a large amount of renewable energy power and electricity storage facility will penetrate electricity system. Therefore, an integrated analysis model is developed, in which a bottom-up simulation model is used to calculate the electrical demand and load of a zero carbon energy system, and an optimization model is used to conduct an analysis of zero-carbon electricity systems to meet the obtained future electricity demand. In the present study, focus is given on the roles of renewable power in the zero-carbon electricity systems. The calculated electricity demand is then used as a parameter for the scenario analysis optimization model with the aim to find the lowest carbon mix to meet the increasing electricity demand and to realize a zero-carbon electricity system by the year of 2100. The total electrical demand and load are obtained through a bottom-up simulation method based on residential, commercial, industry and transportation sectors and their sub-sectors. The simulation is conducted in several steps based on the base year data, assuming parameters such as efficiency, macro economy, technology improvement etc. [5].

The impacts of fossil fuel burning and climate change are not considered in the existing least cost analysis models which means that these results cannot be considered as realistic. Thus, an optimization model aiming to find the least total CO2 emission solution subject to various constrains is proposed in this study. The optimization solution is calculated using the General Algebraic Modelling System (GAMS).

Here we consider an assessment of future energy supply strategies for the power sector of Bangladesh and prospects for further development by ensuring energy security. In Bangladesh, the power sector alone contributes 40% to the total CO_2 emissions [6]. In this case, it is necessary to develop and promote alternative energy sources that ensure energy security without increasing environmental impacts.

A MARKAL energy-system model for the Bangladesh power sector was developed for an analysis of alternative technological options for the next 30 years for addressing the challenges like projected demands for electricity, limited domestic energy sources for power generation. A base scenario and a renewable energy target production scenario is taken into account. A major part of the work was to develop input parameter values. Three basic sets of input information are required for each time step over the entire period of the analysis: 1) energy demands, 2) supply and cost of primary energy resources 3) the cost and performance characteristics of technologies available for use in the energy system.

D. Transport Sector Modelling

Large-scale integration of electric, hydrogen and hybrid vehicles in the transport sector may in the future significantly reduce the emission of pollutants, and improve air quality. Options in the power sector, as to reduce CO_2-emissions in particular, may become options for the transportation sector as well. Based on assumptions on the future technical development for battery electric vehicles, fuel cell vehicles on hydrogen, and for the conventional internal combustion engine vehicles, scenarios are set up options for thelong-term development of the road transport. We analyze energy, environmental, and electricity market aspects of integrating electric vehicles in the future Danish energy system and impact of electric vehicles on Italian power system.

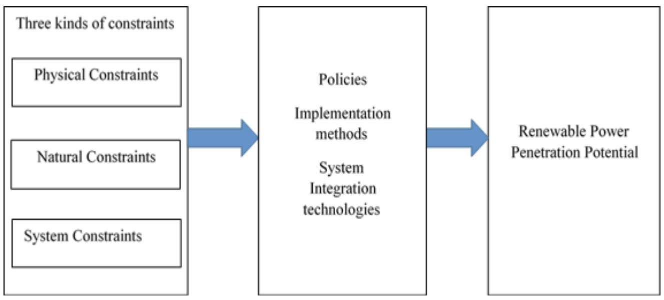

Fig. 2. Constraints of renewable power penetration [5]

The options dealt here concern with the switching towards integration of battery electric vehicles (BEV) , fuel cell vehicles based on hydrogen from electricity (HFCV) and the gradual out grading of the conventional internal combustion vehicle (ICEV).

Three scenarios are taken into account. The scenarios reflect technical options,expected for the integration of battery electric vehicles and the direct hydrogen fuel cell vehiclesand cover over a period up to 2030 .The scenarios are: 1) BEV scenario which aims to coalescemost energy efficient technologies and to achieve maximum replacement of fossil fuel and per vehicleCO_2 emission reduction. Keeping in view that Battery Energy Vehicle (BEV) is themost energy efficient technology when compared with others, it is promoted for rapid transport fleet integration. About 40% of the fleet or about 1 million vehicles are targeted to become BEVs in the scenario in year 2030. 2) HFCV scenario aims to integrate energy efficient technology, with range per refill fully comparable to the conventional ICEV, to obtain fossil fuel substitution as well as CO_2 emission reduction. The direct hydrogen fuel cell vehicle technology when compared to the ICEV is expected to provide energy efficiency and CO_2 emission reduction gains up to 2010, and from then of the vehicle is promoted for rapid transport fleet integration. In 2030, about 40% of the fleet or about 1 million vehicles are also aimed to become HFCV in the scenario similar to BEV. 3) Combined BEV & HFCV scenario aims to minimize CO_2 emission and fossil fuel usage in the road transport sector via promoting high market penetration of the electricity based alternative vehicles. The scenario aims to lower the CO_2 emission by 2030 relative to the baseline development for the road transport segment taken into account. The third scenario is the combination of the first and second scenarios. By 2030 about 80% of the fleet or about 2 million vehicles are aimed to become electricity-based vehicles, BEV or HFCV [7].

E. Oil, Gas and Coal Production Modelling

Two view points on coal can be considered in global energy systems. The first compares coal and other energy sources in terms of cleanliness, pollution and other adverse effects. Still economies do not avoid coal. Coal can be treated as a significant primary source of energy in the world.Coal is presently a vital energy source with a contribution of 26.5% of world energy [4]. Petroleum liquids and other liquid fuels are two classification of future oil supply. Petroleum liquids refers to crude oil and lease condensatewhich comprises of tight oil, shale oil, extra-heavy crude oil, and bitumen (i.e., oil sands, either diluted or upgraded), plant condensate, natural gas plant liquids (NGPL), and refinery gain. Other liquids refers to oil shale gas-to-liquids (GTL), coal-to-liquids (CTL), and biofuels (including biomass-to-liquids).Natural gas has been the fuel used for new electricity generation capacity for over 20 years. Coal extraction will get more expensive and complicated similar to oil as the coal deposits are depleted, finally leading to a depletion driven decline .The coal and natural gas in electricity generation has probably been competing in the near future. Since natural gas prices are increasingquickly than coal prices, persisting coal plants retrieve the market lost in past years. Because of the relatively low costs and high efficiency,natural gas-fired plants continuously used as new generating capacity over most projection period.

III. RESULT

In amine based CO_2 capture method the case study analysis implies that a knowledge based expert system is developed which helps to enhance performance of the system and efficiency ofCO_2capture by reducing the time for problem diagnosis when abnormal operating conditions occur. While assessing the energy security during reduced CO_2 emissions via MESSAGE model the results shows that the OII decreases in the LCS scenarios when compared to the reference scenario. OII is negatively correlated with oil security i.e. a low value of OII mean high oil security. NCFS also shows considerable improvement in LCS scenarios in comparison to the reference scenarios. Therefore the sustainability increases as it have a positive correlation with NCFS and it can be clearly observed from the tables.

TABLE I. RESULTS OF OII FOR SRI LANKA [9]

NCFS as percentage					
	References	LCS1	LCS2	LCS3	LCS4
2007	50.83	64.48	64.48	64.48	64.48
2010	52.01	72.46	72.46	72.46	72.46
2015	50.03	72.04	72.04	72.04	72.04
2020	54.68	65.08	65.08	65.08	65.31
2025	52.95	54.92	54.89	54.9	54.85
2030	41.92	50.93	54.15	54.26	51.2

TABLE II.RESULTS OF NCFS FOR SRI LANKA [9]

Oil Import Intensity as percentage					
	References	LCS1	LCS2	LCS3	LCS4
2007	7.63	5.88	5.88	5.88	5.88
2010	7.27	5	5	5	5
2015	7.05	4.99	4.99	4.99	4.99
2020	6.56	4.97	4.97	4.97	4.97
2025	6.18	4.94	4.94	4.94	4.94
2030	5.88	4.9	4.9	4.9	4.9

After analysis of CCS technology by AIM model in Indonesian power sector it is found that the shares of generation decreases with introduction of ER target but increases at highest CO_2 emission target with CCS

The analysis results of use of renewable sources and fuel mix after a case study in Japan indicates that non-conventional power can meet around 40% electricitydemand in Japan by 2100. The power sector modelling in Bangladesh arrives to the view that CO_2, coal and renewable scenarios help lower the dependency on fossil fuels, improve the security of energy supplies for the economy and contribute to the reduction of emissions. From the results drawn from transport sector analysis in Danish scenario it is observed that the emissions of pollutants to the air are almost zero for BEV and HFCV, it reflects a highly efficient energy path.

From the above discussions we observe that by reducing carbon emissions we can achieve energy security and hence sustainability. Thus this improves the performance of energy system and is of great environmental concern.

IV. CONCLUSION

Unlike the electricity generation from power plants based on fossil fuel the part of electricity generation from renewable energy dependent power plants are found to rise with increase of CO_2 emission reduction target. The use of renewable energy would increase from 20% at reference case to 54% in ER30 [2].Moreover, the added goal of reasonable energy security can be achieved simultaneously with the emission reduction goal with innovative technologies used in the base scenario. A mix of renewables and fossil fuels with CCS is needed to decarbonize the electricity sector.From energy scenario modelling it is possible to identify effective technologies not only in power sector, transport sector modelling and CO_2 emission reduction modelling but also for coal, oil and gas sector modelling.

Carbon emissions increases by 1.7% every year, while energy demand increases by 2% [1] .Reduction in carbon emissions help to alleviate hazardous effects of global warming which in turn reduce the environmental impacts like climate change, rise in sea level etc.

Power generation and transport sectors are growing sectors, hence its modelling is of prime importance. Based on the different scenarios faced by the energy sector any of the models mentioned here is selected.

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REFERENCES

(1) ClaudeMandil, Global Energy Trends, IEA publications, Paris, France, 2004.
(2) C.O.P. Marpaung,A.Soebagio,R.M. Shreshtha, "The Role of Carbon Capture And Storage And Renewable Energy for CO_2 Mitigation in the Indonesian Power Sector", The 8th International Power Engineering Conference,pp.779-783,2007.
(3) Q. Zhou, C.W. Chan, "Development of a Knowledge- Based System for Monitoring and Diagnosis of the CO_2 Capture Process", Cognitive Informatics (ICCI), 9th IEEE International Conference,pp. 333-338, 2010.
(4) Hook ,Zittel,Schindler, "Global coal production outlooks based on a logistic model",Fuel, 1-27, Vol. 89, 2010.
(5) Q.Zhang ,T.Tezuka, Miguel Esteban and Keiichi N. Ishihara," A Study of Renewable Power for a Zero-carbon Electricity System in Japan Using a Proposed Integrated Analysis Model", pp.166-170,Vol.5,2nd IEEE International conference, 2010.
(6) Md. Alam, H.Mondal, A.K.M. Sadrul Islam "Modelling the Future of Bangladesh's Power Sector Focusing Renewable Energy Technologies", 1-4,"2nd IEEE International conference", 2012.
(7) L. HenrikNielsen , K. Jorgensen "Electric vehicles and renewable energy in the transport sector – energy system consequences" Information Service Department,6-20,April 2000.
(8) A. Herbst ,F.Toro, F. Reitze, and E.Jochem "Introduction to Energy SystemsModelling",Institute for Resource Efficiency and Energy Strategies, Vol. 148,2012.
(9) B.Limmeechokchai ,S.Selvakkumaran ,"Assessment of Energy Security and Low Carbon Society Scenarios in Thailand and Sri Lanka", Utility Exhibition on Power and Energy Systems: Issues & Prospects for Asia (ICUE),1-6,IEEE International Conference,2011