The IMPACT of CLIMATE CHANGE on the ELECTRICITY MARKET: A REVIEW

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Abstract

The Impact of climate change on Electricity market is the future challenges on organizational development on electrical energy applications. In a broader sense it is a new research field opportunity, enhancing efficient planning and operation of renewable and non-renewable power plant. In the future it could be the guideline in mitigating diverse impact by catastrophic climate changes. This paper discusses the effect of climate change on economy of electricity markets in terms of demand and supply scenario. It was also already pointed out in few reports, news and various awareness campaigns that higher temperatures are expected to raise electricity demand for cooling thereby decreasing the demand for heating. Increasing consumption of electricity annually finds supplies of electricity from renewable energy problematic, thus pressure on non-thermal sources increases. Recently, the progressive study on this topic has significantly extended knowledge, even then to mandate improve understanding of volatility of climate change on the electricity market, further research is necessary in terms of filling up gaps, common policy regulatory and sustainability of electricity market.

Key Words : *Impact of climate change on electricity market, Impact on demand economy, Impact on supply economic, Impact on transmission and distribution, resources, consumption and output.*

1. INTRODUCTION

The 21st century societies encounter problems of acquiring an efficient and environmentally friendly complete supply of energy for present and future generations (Wittmann, 2008). Hu (Hu, 2013) pointed out that electricity is widely used for commercial activities, industries, agricultures, transportation, and even in daily life, for instance, information technologies cannot operate without electricity supply. Globally, all economic spheres like production and operation in the society solely depends upon electricity supply, if interrupted or inadequate, straight away affects industry production as well upsets people's life resulting in social chaos. In a recent incident in Argentina, `state of emergency` were declared by official in Buenos Aries during heatwave, resulting in power and water supplies failure, killing three people and many hospitalized(Euronews, 2013).

However, Ali (2013) mentioned that owing to the climate change, serious risks and reservations position as to how the economy of Electricity will respond to these unpredictable and irreversible changes in environmental conditions. Firstly, their influence in the electricity generation and consumption pattern are complex and slow, and secondly they are irreversible. Recently, the 5th IPPC report on October 15, 2013, indicated that high greenhouse gas (GHG) emissions now may result in global sea level rise by 52-98 cms by the year 2100. Even with the forced emission reductions, the highly optimistic scenario with rise by 28-61 cms were predicted. The major impact on coastal areas due to sea level rise include flood and displacement, coastal erosion and land loss, increased storms, flooding and damage. Therefore, larger population on earth are getting affected. **Fig.1** clearly indicates the locations of important cities along the coastal area.

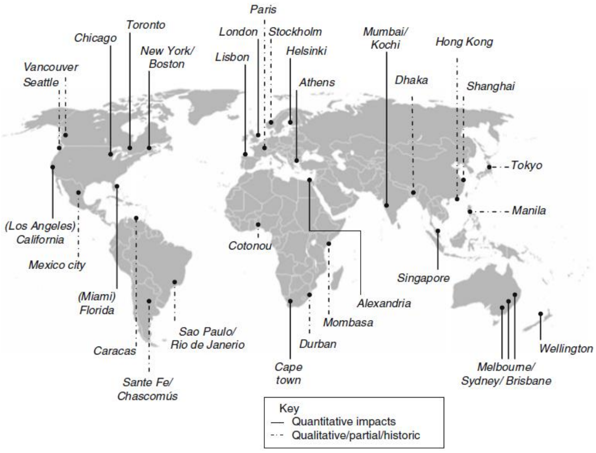

Fig. 1 Geographical location of selection of major city studies by (Watkiss 2011, p16)

The epicentre of national or international key socioeconomic activities of human including the massive electricity consumers are located along the coast, containing large human populations around 5 million (approximately 70% of total world population). Among all global regions, Asian cities are found to be particularly the most threatened, as they are low-lying. Usually the most defenceless coastal urban environments comprises of deltas, low-lying coastal plains, islands, barrier islands, beaches, and estuaries. At present glacier melting water (Orlove, 2009) is the main contributor to rise in sea-level globally which is around 30 percent. After all "if we don't pay heed, we may have to take the heat" (Econ, 2006)

This paper will focus on two review papers and a book (Hu, 2013, Mideksa and Kallbekken, 2010, and Hunt and Watkiss, 2011) updating, combining and adding additional information with regard to electricity market volatility due to catastrophic climate change.

Climate change not only directly have an effect on the energy supply and demand of electricity, but also affects energy transportation and infrastructure (Mideksa and Kallbekken, 2010). Some of the generation impacts are on uncertain operation of hydro and wind power generations. The impact on demand as specified by most of the researchers are reduced demand for heating and increased demand for cooling. According to Mideksa and Kallbekken(2010), globally by 2100, the estimated reduction in heating requirement will amount to 0.75% of gross domestic product (GDP) which will benefit the energy sectors, whereas 0.45% increase demand for cooling will have negative impact on electricity sectors. Electricity sectors faces many challenges in mitigating Climate change threats (Mideksa and Kallbekken, 2010), especially with policy response to climate change.

2. IMPACT ON ELECTRICITY ECONOMICS

Hu (2013) presented electricity economics as; Electricity demand economics and Electricity supply economics.

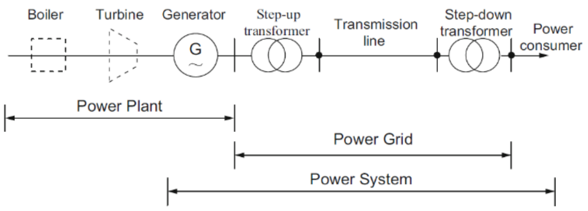

Fig. 2 Schematic diagram of power system (Hu, 2013, p.5)

To categorize electricity demand economics as one branch of various economics, Hu (2013) describes it as production and management, co-relating with input production (Power Plant) and output management through electricity consumption features (Power Consumer). Secondly the electricity supply economics from **Fig.2** can be referred to as power system economics or electric power economics, basically dealing with the ideal distribution of resources and electric power supply.

2.1 The impact of climate change on electricity economic demands

2.1.1 Impacts on managing output (Power Consumer):

Rural and Urban electrification has been an indispensable economic activity for residential lives as per Hu (2013). For an example, an electric pump can help farmers to irrigate agricultural productions and also heating and cooling purposes. Huge electricity consumption is closely linked with commercial and industrial developmental activities such as operation of industrial machineries and equipments, daily operation of commercial businesses such as retail shops, hotels, and restaurants, and electric vehicles running solely on electricity. He asserts that historically, from a wider perception, a country's regional economic development level and people's living standard are known by their electricity consumption rate.

The concept of so called heating degree days and cooling degree days is the study addressing the climate change impact on the demand for heating and cooling, which is logically the temperature difference between the actual temperature and the base temperature, resulting in temperature abnormalities on both heating and cooling.

In Norway 80% of electricity is used for heating commercial buildings and residential homes. Elasticity of electricity demand for cooling and heating makes the power supply system unbalanced and uneconomic. Although the total annual demand for heating and cooling significantly fluctuates regionally and seasonally, (2010) hypothesizes that carbon emission is more in heating degree-days than cooling degree-days.

Mideksa and Kallbekken (2010) found that inspection on energy consumption responds to temperature deviations using panel data techniques of their empirical estimate from the data collected from 31 countries between the years 1978-2000. The result says 1% increase in summer temperature would raise the electricity demand by 1.17% in warmer countries and reduced demand by -0.21% in colder countries reducing heating facilities during winter. Similarly 1% increase in winter temperature would reduce the electricity demand by 0.01% and increase demand by 0.07% in warmer and colder countries, respectively.

Likewise, in 31European countries for the period 1995–2005, using panel data under the IPCCS RES projected changes in heating and cooling degree days. In this data analysis, results computes with the overall electrical energy (KWh); i.e. for heating degree days 1°C change in temperature will fluctuate demand by 2KWh per year per person, while for cooling degree days, a unit rise would alter the demand by 8KWh per year per person. The present growing electricity consumption would differ largely if compared and therefore more depth research are needed.

2.2 Impacts on resource endowments (production/power plant):

According to Hu (2013), factor of electricity production functions needs to be taken into consideration such as manufacture output, sales revenue and profit in terms of quantitative electricity consumption. This relationship can help improve technical skills and their market values. Every country/ region has their own system of developing energy supply system centrally to benefit consumer.

The international policy of greenhouse gas emission reduction allocations as per TRES (Total Renewable Energy Scenarios) will affect the country/regions capability to meet the reduction level, due to limited technology present in developing country, therefore desire for fossil fuel remains the same. As illustrated, the International Energy Agency implies a scenario of achieving 46% *of* global power from *r*enewable sources by 2050 to reduce the Greenhouse gaseous emission (GHG). Furthermore, one-third of all coal-fired power plants needs to be closed down before the end of their technical life if the plant do not have the system of capturing carbon and storing it.

2.2.1 Hydropower

Hydrological cycle is the vital key to Hydropower generation; therefore water resource availability directly affects the power output. Precipitation with evapotranspiration turns into Runoff River where most of the SHS's (Small Hydro Scheme) are functioned. From General Circulation Models (GCM) basically using seasonal pattern precipitation and temperature projections. Schaeffer, *et* al. (2012) indicates the possibility impacts of climate change on runoff-river, especially in a snow melting region where annual Hydrological cycle varies, Hydro Power harshening get effected.

Lately, the risk of landslides and Lake Outburst floods associated with glacier retreat has increased along with other climate change impacts according to Orlove (2009), making it difficult in regularization of hydropower production, for instance, in Andes (Chacaltaya glaciers drastically reduced), Switzerland, Lake Tsho Rolpa in Nepal and Peru incident in 1970's. Lake Tsho Rolpa's size has grown by more than sevenfold and a large hydropower plant under construction would have been destroyed by an outburst of flood if US$3 million spent in digging channel to lower the lake had not been carried out by Netherlands Development Agency, the Nepalese government consulted experts.

2.2.2 Wind power

Power generation obtainability and consistency from wind power rely on weather and climate conditions. Global climate change impacts wind energy donations mainly from ever-changing in geographical circulation and the unpredictability of wind speed.

2.2.3 Solar energy

Reference in Schaeffer, *et* al. (2012) considers change in atmospheric water vapour content, cloudiness and cloud characteristics due to the consequences of climate change, affecting solar energy resources for photovoltaic and concentrated solar power (CSP) arrays by drop in solar radiation. IPPC (Intergovernmental Panel on Climate Change) project reports probable reduction in solar radiation over sub-Saharan Africa and increase over the Middle East, likewise positive solar radiation of 5.8% in south Eastern Europe and negative/decrease trend in incoming solar radiation in Canada.

2.2.4 Marine energy

Climate change impact on marine energy resources would be similar to wind power, as the variation in wind speed indirectly causes impact on wave formation. Schaeffer, *et* al. (2012).

2.3 The impact of climate change on electricity supply Economic.

The supply of power from both thermal and non-thermal power plant depends upon climate variables such as temperature and precipitation. Schaeffer, et al. (2012) He also added that the demand GHG mitigation has less potential in the short run, while the supply appears to have more potential in the long run.

2.3.1 Thermal power

Mideksa and Kallbekken (2010) explains that thermal power plant technologies such as coal, natural gas, oil, nuclear, geothermal and biomasses cycle efficiency and cooling water requirements get affected by change of global temperature. This happens because all this power plant either operates on Rankine or Brayton cycle, which means by maintaining heating and cooling temperature differences according to average ambient condition like water availability, pressure, humidity and temperature itself. In case of larger scale coal-fired and nuclear power plants (Rankine cycle) a modest deviation in ambient temperature may perhaps represent a significant drop in energy supply (2010). Brayton cycle operated Gas-fired power plants, the variations in ambient temperature and humidity affects their turbine power output and efficiency, thus leading to a decrease in generation or higher fuel consumption. According to Arrieta and Lora (2005) energy consumption in the compressor increases due to upright air specific volume with temperature rises, resulting in reduced net energy generated in the cycle.

For instance, in France since 2003 summer, to meet the terms of thermal pollution regulations, France had to face power reductions from nuclear power plants. The indication of 1°C increase in water temperature may decreas the power output by 0.45%, thereby increasing the water demand for cooling.

2.3.2 Hydropower

Both Schaeffer, et al., 2012 and Mideksa and Kallbekken (2010) explains Hydro power generation dependency on river flow alteration, evaporation, dam safety and design installed capacity. Poor developing country like Nepal and Bhutan as per Orlove (2009) whose economic development exclusively dependent upon Hydro Power generation might have to face unreliability power generation in the near future due to the retreat of glacier which is the source of most run-off river. As already Hydropower plant operates on uncertain load demand or seasonal fluctuations, climate change might significantly affect the flexibility operation of the existing hydropower system. Individual characteristic of power plant reacts distinctly against climate change (Mideksa and Kallbekken, 2010), where small run-off-river plant is more vulnerable because of technically non flexibility operation. However the annual variations in water inflow can be compensated by Reservoir storage plant. But in case of dam safety if the early increase flow management is not included while designing, consequently uneconomical energy lost spill overs would occur.

2.3.3 Wind power

The positive property of wind power plant is that the energy output increases with wind speed, as illustrated by Orlove (2009) that 16W/m2 power can be produced at 3m/s wind speed while 12m/s can generate power at 1305W/m2. Hence, smaller variations in wind speed can have larger effect on power output. Despite this, wind power so far have been technologically designed to operate at 25 m/s speed according to Mideksa and Kallbekken (2010). When higher frequency of extreme wind speed pressure on turbine increases, instead of improving output, it rather reduces as turbines speed thresh hold limits. Report from IPCC SRES discovered high potential of wind power in Baltic Sea region, northern, central Europe and many more. Therefore, there is an urgent need of further research in terms of fluctuating wind speed or direction change on turbine efficiency.

2.3.4 Solar power

It is already well known through many researchers that Climate change increases Global temperature, Lean and Rind (1998), but decreases solar radiation. Energy efficiency from solar photovoltaic (PV) cell reduces with increase in air temperature and also efficiency of concentrated solar power (CSP) get affected because it operates on Rankine cycle principle similar to Gas-fired power plants, such as increased water use and lower efficiency (Schaeffer, el al. 2012). Internationally solar power harnessing is on the process of developmental stages, therefore their cost per KWh is expensive comparing with conventional sources of electricity. However, Mideksa and Kallbekken (2010) argues that comparing with wind power plant, solar power plant has higher potential during summer seasons due to more sun energy and less wind speed during summer.

2.3.5 Impacts on transmission, distribution and transfers

Climate change causes revolution in weather phenomena such as extreme winds and ice loads, combined wind-on-ice loads, lightning strikes, conductor vibrations and galloping, avalanches, landslides and flooding. These directly effects transmission and distribution power line failures because all power lines are either over head or underground cables spread over long distances. Transmission line full loading capacity would reduce with rise in temperature which was discovered by researcher Schaeffer, et al. (2012) while conducting study in State of California. Also the energy distribution system faces problems of supply interruption from high wind leading to falling of trees on lines. Another dangerous failure would be on transformer due to heat waves, for example in USA 2006 summer incident (Schaeffer, el al. 2012).

A recent study indicates that energy disruption can be mitigated with smart grid technology. They also found that during 1994—2004, USA reported cost of power outages approximately 2.5 billion annually which clearly indicates that cost of repair and maintenance on transmission and distribution are very high and scenario of continuous increase in global temperature would potentially hinder country's economy. Henceforth, additional quantitative research is required in this topic to mitigate the future disaster.

3. CONCLUSIONS

In summary, this paper reviews the impact of climate change on Electricity economy, compromising two border areas firstly the impact of climate change on electricity demand economic and secondly the impact of climate change on electricity supply economic (supply system).

Further they are subdivided into Impacts on managing output, resource endowments and impact on different generation, transmission and distribution. Both the economy of demand and supply are interdependent in Generatating and Consuming all sorts of renewable and non-renewable plants. Additional information was on impact of extreme weather condition on electricity demand regarding raw material (resources) requirement. In case of melting of glacier with the rise in global temperature, availability of water resources from mountainous country is uncertain thereby questioning sustainability of future power sources. Likewise, solar, wind and thermal power plant resources degradations includes sun energy, wind energy and coal, respectively. With regard to effectiveness of energy lost and additional cost, the supply economy have issue of efficient output and transfer. With the limited demonstration research on this topic, more awareness is needed by the policy makers and planners in implementing secure future energy to evade unforeseen shock and energy holdups.

To be systematic in overcoming impact by climate change globally, standard international policy, power sustainability, mindfulness, and technologically adaptation to climate change impacts are felt necessary. Past experience on electricity system catastrophes should be the base line reference of impact assessment to intensify information and guidance. Prioritizing the impact of climate change on energy markets is the imminent challenges with the extreme weather occasions.

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