Internet Journal of Society for Social Management Systems Vol.10 Issue 1 sms15-5121
ISSN: 2432-552X
ORIGINAL ARTICLE

Assessing the Capacity of the Public Work Service Infrastructures in Ho Chi Minh City to 2025 in the Context of Migration and Climate Change

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Abstract: Economic and industrial development has led to massive immigration into Ho Chi Minh city (HCMC) in recent years, an average of 200,000 people per year from 2007 to 2013 (GSO, 2015). This has created certain pressures on the city's infrastructures. Over the past several years, HCMC has experienced both direct and indirect impacts by climate change. Among those are impacts on the infrastructures and an increasing immigration into HCMC. This study aimed to assess the capacity of the three public work service infrastructures (PWSIs) of HCMC including electricity, water supply, and municipal solid waste (MSW) management to 2025. It was based on an average consumption of electric power and water per capita, and the MSW generation rate per capita in the current situation and in HCMC's plans to evaluate the demands of the PWSIs by 2025, taking into account the increased population due to climate change. The study showed that the capacity of electric power supply and sanitary water supply was tremendously threatened. By 2025, domestic electricity consumption would triple as much as planned, at 55.4 billion KWh.year^{-1}, equivalent to 5,000 KWh.capita^{-1}.year^{-1}. To meet with the target water supply of 180 litter.capita^{-1}.day^{-1}, the total need for domestic water supply would be 2.380 million m^{3}.day^{-1}, an increase of 493,000 m^{3}.day^{-1} compared with the city's plan. Meanwhile, the solid waste management system would still guarantee the capacity to handle an amount of 13,300 tons of MSW per day by 2025. In addition, an increase of 390,000 immigrants in 10 years from 2015 to 2025 (Oanh *et al.*, 2015) would demand an amount of 2.04 billion KWh.year^{-1} of electric power, 88,000 m^{3}.day^{-1} of sanitary water supply, and would dispose 500 tons of MSW.day^{-1}.

Keywords: public work service infrastructures, immigration, climate change.

1. INTRODUCTION

1.1 The city's population as a big concern

Ho Chi Minh City (HCMC) is the center of economy, healthcare, education, science and technology of Vietnam. The city's economy with a significant contribution to GDP of Vietnam at about 21%[1], and leading in monthly average income per capita at 2,765 USD per year (GSO, 2015), is a driving force of immigration. According to statistical data from 2010 to 2014, the population growth rate of the city was 2.10% per year (GSO, 2014), of which the net-migration rate contributed more than half, at about 1.12% per year[2]. Over the past ten years from 2003 to 2013, the city's population had increased by 1.877 million people with an average rate of 200,000 people per year, of whom 65% was immigrants (about 130,000 people per year). By the end of 2013, the city's population reached 7,939,752 people (HSO, 2014). The possibility to access higher quality urban services and infrastructures was the main motivation for immigration to HCMC (Phuong and McPeak, 2011), and this trend was projected to continue (Thanh, 2008). In addition, the Law on Residence has offered chances for household registration in the city. This is a positive factor contributing to the increase in the city's population these years as well as in the future.

The socio-economic master plan of the city[3] was developed to meet the demand of a projected population of about 9.2 million by 2020 and 10 million by 2025. It was based on the situation of socio-economic development and statistical population data of the previous years but it disregarded the impacts of climate change leading to an add-in immigration. This was because climate change impacts showed unobvious signs and had not been studied in depth at that time.

Those impacts such as salinization, natural disasters and sea level rise in the Mekong Delta and the coastal areas of central Vietnam appearred as another driving

[1] Caculated with data from the Statistical Yearbook of Vietnam (GSO, 2015) and HCMC Statistical Yearbook (HSO, 2014).
[2] Caculated with data from HCMC Statistical Yearbook (HSO, 2014).
[3] This plan was enclosed with the Decision No. 2631/QĐ-TTg dated 31/12/2013 on approving the master plan on socio-economic development of HCMC to 2020, with a vision toward 2025.

Received: 2015.09.15 / Accepted: 2016.02.09

Internet Journal of Society for Social Management Systems Published Date: 2016.12.20

force of immigration to HCMC (Hoang et al., 2008, Minh and Paul, 2009). According to the latest study by Oanh et al. (2015), the number of immigrants due to climate change was projected about 208,000 people by 2020 and approximate 390,000 people by 2025, which accounted for 14.5% to 15.3% of the total immigrants of the city. Consequently, the population of HCMC in 2020 and 2025 would be 9.391 million and 10.580 million, respectively. The additional population would be equal to the population of an average-size district in HCMC.

1.2 Pressures on the city's public work service infrastructures

Besides trading and service development as a pressure on the city's infrastructures, there are additional ones including industrialization, population growth, and climate change (Viet, 2014). Climate change affects both directly on the infrastructures due to natural disasters, flooding, salinization, increasing temperature, and so on, and indirectly through the increase of immigrants from other regions of Vietnam which are vulnerable to climate change.

Several studies have been carried out to examine the impacts of climate change on public service infrastructures in Vietnam, most of which focused on the electricity sector. The study of Bao (2012) attempted to assess the impacts of climate change on the primary electricity productivity due to instability of energy sources (particularly hydropower), influences on power plant performance, electricity transmitting, substations, and end-use equipment. Whereas, ADB (2012) studied the vulnerabilities of a large number of fields including fossil fuel production and transport, power generation from different sources, transmission and electricity end uses to climate change. The study of Phung and Tam (2011) aimed to apply modeling and GIS to calculate the temporary and permanent flooded areas in HCMC under two sea level rise scenarios[4] so that the impacts on infrastructures were quantified as land loss. This research also made projection on the city's water body salinization. However, impacts on other sectors such as water supply, solid waste management have yet to be clarified.

A large number of studies by Loi (2000), Anh *et al.* (2003), Thanh (2006)[5], Liem and White (2007), and United Nation Vietnam (2010) affirmed that immigration would pressure the urban infrastructures and public services. From that understanding, a research by Truong and Oanh (2015) aimed to project the number of immigrants into HCMC as a consequence of climate change due to losses of their residences and livelihoods. In this case, while the right of freedom in residence was regulated by Vietnam's constitution, the city has the responsibility to guarantee the capacity of infrastructures to meet the growing population.

Therefore, the objective of this study is to assess the capacity of the three public work service infrastructures (PWSIs) of HCMC including electricity, water supply and municipal solid waste management to 2025 in the context of migration and climate change. The key research questions are as follows:

1) How climate change would affect the PWSIs in HCMC?
2) What is the capacity of the PWSIs to meet the demand of the city's population in the context of climate change and immigration?

2. METHODOLOGY

This research study was presented in three main contents. It began with an overview of the current situation of electricity supply, water supply and MSW generation as well as the city's socio-economic, industrial and PWSI plans, which focused on the target indicators of each sector. In this section, the two main methods of data collection were adopted including literature review and interview with specialists working in the relevant fields. The next content was a review of climate change impacts on the three PWSIs where influencing factors and both ongoing and projected consequences for each sector were identified through reviewing relevant studies that have been carried out worldwide, in Vietnam and in HCMC. In addition, observations on the PWSI's performance and affected sites, and interview with experts in the research fields were also exerted. The last content was an evaluation of capacity of the PWSIs in context of climate change and immigration to 2025. This was obtained by calculating the demands of electricity, water supply and MSW treatment employing the projected population of HCMC and the infrastructural target indicators mentioned in the first content of this study. The projection of the city's population that encompassed the add-in immigration under climate change context to 2025 was studied by Oanh et al. (2015). Next, by adopting the same indicators from the preliminary assumption, this study specified the contribution

[4] A2 and B1 are the two scenerios to be concerned by the Ministry of Natural Resource and Environment (MONRE) of Vietnam.

[5] Cited in: Anh, L.T.K, Lan, V.H., Bassirou, B. and Esther, S., 2012. An analysis of interprovincial migration in Vietnam from 1989 to 2009, Co-Action, Vol 5, Sweden.

regarding to the needs of electric power, water supply and the amount of MSW generated from the increased immigration due to climate change to the total increased capacity of the PWSIs. Figure 1 showed the two components of the calculation as rectangular tank volumes. They were formulated from three vectors explained as follows:

- "Population" was the size of the city's population by year and measured in *people*.
- "Average consumption per capita" was the amount of electricity and water consumed in *KWh.capita^{-1}.year^{-1}* and *litter.capita^{-1}.day^{-1}*, respectively. For solid waste generation, this was presented in *kg.capita^{-1}.day^{-1}*.
- "Transmission efficiency or distribution efficiency" was applied only for electricity and supply water sectors. For the former, it showed the line losses. For the latter, it was referred to as non-revenue water (NRW) – water that was produced and lost in a distributing network before it could reach the consumer. Both were measured in *% of the total production*.

From those concepts, the current capacity of the PWSIs in 2015 was the rectangular tank volume named as $ABCDD_1A_1B_1C_1$. The total capacity of the PWSIs by 2025 was the volume $AB_2C_2D_2D_3A_3B_3C_3$, whereas the net demands from the migration driven by climate change was $A''B_3C_3D''D'A'B_2C_2$ (the right-handed slice).

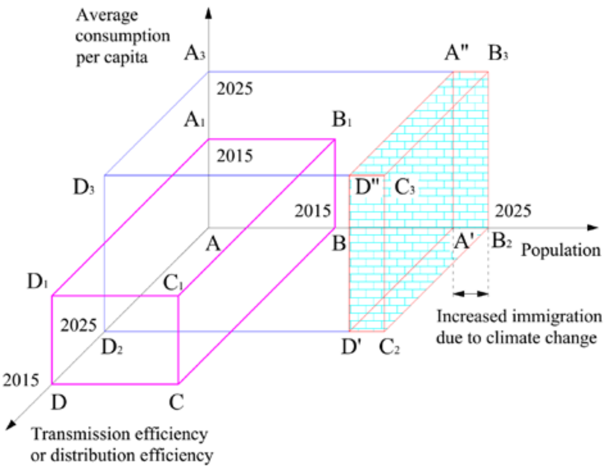

Figure 1 Concept model of the total capacity of PWSIs and the net capacity contributed by the increased immigration due to climate change.

3. OVERVIEW OF THE PUBLIC WORK SERVICE INFRASTRUCTURAL PLANS OF HCMC

3.1 Electric power supply

Most recently, commodity electric power productivity of HCMC was approximately 18 billion KWh.year^{-1} (HSO, 2014). The city's average electricity consumption per capita was over 2,000 KWh.capita^{-1}.year^{-1}, which is 1.82 higher than the country's average index (1,174 KWh.capita^{-1}.year^{-1}) and about 41.7% less compared to Bangkok - Thailand (at 4,800 KWh.capita^{-1}.year^{-1} in 2005)[6]. Electric power transmission and distribution loss for Vietnam was 8.49% of the output, higher than that of Thailand, at 6%.

According to the Decision No. 2631/QĐ-TTg dated 31/12/2013 on approving the master plan on socio-economic development of HCMC to 2020, with a vision toward 2025, the target electric power consumption per capita was about 2,600 – 2,800 KWh.capita^{-1}.year^{-1} in 2015, increasing to 4,800 – 5,000 KWh.capita^{-1}.year^{-1} in 2025. The city planned to reduce electric power loss to 4.8% by 2025. In order to achive the targets, the commodity electric power productivity for all sectors was projected to reach 48.5 – 50 billion KWh.year^{-1} by 2025. This would be achieved by investigating more hydro power plants and thermal power plants, developing renewable energy, nuclear power, and importing electricity from neighbouring countries such as Laos, Cambodia, and China (Decision No. 1208/QĐ-TTg dated 21/7/2011 on approving the plan on national electric power development from 2011 to 2020, with vision to 2030).

3.2 Water supply

Until July of 2015, 82.5% of the city's households (1.55 in total of 1.88 million households in HCMC) could access to sanitary water (Ta Lam, 2015). The total water supply capacity of HCMC is currently 2,120,000 m^3.day^{-1} (DONRE, 2015), which guarantees an average consumption of water per capita about 141 litter.capita^{-1}.day^{-1} (SAWACO, 2014). This is as much as 60% of water consumption in urban Thailand, at 250 litter.capita^{-1}.day^{-1}. Water loss through the distributing pipelines at the end of 2014 was still very high, at about 33% (SAWACO, 2015 and Nam, 2015), thus it did not meet with the target for 2015, at 32%.

According to the Decision No. 729/QĐ-TTg dated 19/6/2012 on approving the water supply plan of HCMC to 2025, the city aimed to assure 100% of sanitary water access in both urban and suburban areas and to reduce water loss from 32% (2015) to 25% in 2025. It was indicated in the Decision No. 2631/QĐ-TTg dated 31/12/2013 that average water

[6] The World Bank, 2011. Cities and climate change: Responding to an urgent agenda.

supply per capita was subjected to increase from 152 litter.capita^{-1}.day^{-1} (2015) to 180 litter.capita^{-1}.day^{-1} in 2025. The planned water supply capacity of about 3,700,000 m^{3}.day^{-1} would be achieved by investigating three more water plants (WPs) along with upgrading the existing WPs, and the future sources of water would be mainly from Dong Nai and Sai Gon rivers (as indicated in Decision No. 729/QĐ-TTg).

3.3 Municipal solid waste management

The current rate of MSW generation in HCMC is about 0.7 – 1.0 kg.capita^{-1}.day^{-1} (DONRE, 2015). The MSW composition which is high in the fraction of biodegradable food remnant, at about 60.1 –70.0% by wet weight (Dieu *et al.*, 2014), can be recycled by biological processes. In comparison, the rate of MSW generation in Bankok – Thailand, at 1.5 kg.capita^{-1}.day^{-1} (Alice and Janya, 2012), is much higher than that of HCMC but the content of biodegradable food refuse in the mixture is quite similar, on average of 63.2%. The total amount of collected MSW in HCMC is 7,400 ton.day^{-1} which is treated by landfilling (70.3%) and composting technology (29.7%) (DONRE, 2015).

It was projected by Oanh (2012) that the rate of MSW generation would reach 1.26 kg.capita^{-1}.day^{-1} by 2025. The Decision No. 2149/QĐ-TTg dated 17/12/2009 on approving the national strategy for integrated management of solid waste to 2025, with a vision to 2050, stipulated the rate of recycling MSW for energy recovery or organic fertilize production of 85% in 2020 and this rate for 2025 should be 90%. So far, there has been no official plan of solid waste management in HCM.

4. CLIMATE CHANGE IMPACTS ON THE PWSIs OF HCMC

4.1 Impacts on the electricity supply system

Energy infrastructure was pointed subject much to climate change (IPCC, 2001). Referring to the studies of Jan *et al.* (1998), ADB (2012), and Bao (2012), objects of exposure and vulnerability to climate change were not limited to electric power sources but also generation facilities, substations, transmission and distribution systems as well as end-use equipment.

Impacts on hydropower plants

Hydropower was the second largest source of electricity of Vietnam, composing 42,0% of the total capacity (Hoang, 2015). In general, changes in prepicitation would affect directly the river flow regime and indirectly the productivity of hydropower plants. A study by Neumann and Price (2009) found a 1% change in precipitation would result in at least a 1% change in electric power output. Referring to the study by Bao (2012) at Tuyen Quang, Hua Na and Tri An hydropower plant, the changes in flow regime would create impacts on the plant’s productivity. Electric power output per annum would increase 0.56% and 0.21% as much as compared with 2009 for Tuyen Quang and Hua Na plant, respectively. Whereas, that for Tri An would fall -1.13% as less due to changes in flow.

Impacts on thermal power plants

Thermoelectric power is the greatest source of electricity in Vietnam, at 51.6% of the total capacity (Hoang, 2015). Changes in air temperature would affect the efficiency of thermal power plants. A study on climate change impacts on Pha Lai (a coal-based thermal power plant) and O Mon IV (a combined cycle gas turbine thermal power plant), carried out by Bao (2012), showed that a 1ºC increase in the air temperature due to climate change would result in a 1% reduction of thermal efficiency. Increasing water temperature would also affect the cooling system, which might inhibit the cooling water standard compliance.

A studied by ICEM (2010), with O Mon IV thermal power plant as a case, attempted to quantify the loss in performance efficiency and productivity in response to climate change impacts. The plant’s power output was of 4,500 GWh.year^{-1} under normal condition. During the project life cycle of 25 years, it would experience a net reduction in efficiency of 0.28% and a loss of 0.8% in power output due to increasing river water and air temperature. Whereas, structural damage caused by flood and storm was claimed insignificant because the management systems would have capacity to respond to the increased extremes. Influence caused by bank erosion had yet well studied.

Impacts on transmission and distribution systems, substations and end-use equipment

Transmission and distribution systems could be affected by inundation, strong winds and storms, increased humidity and temperature, and salinity (ADB, 2010).

It appeared very often in HCMC that electric power lines were damaged during storms and floods every year. According to a study by ADB (2010) on HCMC adaptation to climate change to 2050, Phu My and Hiep Phuoc power plants would lie within the projected flood zone and Thu Duc power plant would be at 0.1 km distance from the projected flood zone by 2050. In case of extreme flood[7], the operation of those facilities could be interrupted. In addition, it was projected that four 500 kV substations together with four 220 kV substations would be exposed to extreme flood and two other 500 kV substations would be at very high risk of being affected without a control project. About 52% of the numerous 110 kV substations, 60% of the 500 kV lines without a control project, 600 km of 220 kV lines and 310–350 km of 110 kV lines with or without a control system would be in the extreme flood zone.

Bao (2012) showed that there would be a loss of 1.0‰ of electricity on transmitting lines for every 1°C increase due to climate change, considering the ambient temperature in range of 30°C - 40°C. For transformers, the loss would increase by 1% for every 1°C increase in temperature. As one of the most affected end-use equipment, air conditioning system was chosen for examination. As a result, a 1°C increase in condensation temperature would lead to 2.17% decrease in the cooling coefficient (it meant power consumption was 2.17% as much more). The study also indicated that electricity consumption would depend on geographical regions, the number of air conditioner users and income of households. In HCMC, electricity consumption would be 8.7% as much more for each 1°C increase in temperature.

4.2 Impacts on the water supply system

Surface water quality

Research studies of IPCC (2008), Anne-Claire *et al.* (2011), Phung and Tam (2011), Dat and Thu (2012) showed that climate change would adversely affect water resources through salination and deterioration.

It was reported by SAWACO that salination had affected some water plants (WPs) of HCMC such as Tan Hiep and Binh An in recent years[8]. According to a research by Phung and Tam (2011), fresh water zone of 1 PSU[9] in Dong Nai river would move closer to Thu Duc WP at a distance of 7.3 km to 2020. The distance would shorten to 6.5 km and 3 km in 2030 and 2050, respectively. For Tan Hiep WP, which exploited water from Kenh Dong (Cu Chi - HCMC), the distance between the plant and the nearest fresh water zone of 1 PSU was 17 km in 2020, subsequently reducing to 16.2 km and 15.3 km in 2030 and 2070, respectively. Thus, without relocation of water exploitation point or improving water treatment technology, water supply for the city would be threatened in the future. In the other words, HCMC would soon face water shortage especially in dry season due to declined rainfall and increased saltwater intrusion.

HCMC is also facing deterioration of water resources. On the one hand, increasing precipitation intensity upstream of Dong Nai and Sai Gon rivers, which supply over 90% water for HCMC, has led to soil erosion and thus an increase in water turbidity. As reported by SAWACO[10], Dong Nai river had experienced the turbidity of over 100 NTU and the colour of over 600 Pt-Co. The increasing turbidity in waterbodies had affected water treatment facilities due to higher cost of chemicals for pH adjustment, coagulation - flocculation, and disinfection (Hong, 2011 and Khoa, 2010), and increased operating costs for filtration facilities and sludge treatment. On the other hand, upstream of Sai Gon river, which supplied approximate 25% of sanitary water demand for HCMC in 2025 via Tan Hiep I, II & III WPs, had experienced BOD_5 level of over 4 mgO_2/L[11] since 2007 (MONRE, 2012). This places a threat on water treatment technology for those three WPs of HCMC in the future.

Water treatment facilities and distribution network

Water supply facilities such as pumping stations, water treatment plants, and distribution pipelines would be affected by flooding, erosion, and saltwater intrusion. Currently, the rate of water loss in HCMC is still maintained at 33% (SAWACO, 2015 and Nam, 2015), which is primarily caused by leakage on and break of pipelines due to physical impacts from road upgrading, soil subsidence, erosion and corrosion. Therefore, supply water is contaminated and this would be exacerbated in projected extreme flood conditions (ADB, 2010). Life expectancy of water supply infrastructure is also reduced by increasing temperature.

4.3 Impacts on the solid waste management system

According to Jonathan Berbb and Jim Kersey (2003), ADB (2010), and USAID (2012), climate change would affect solid waste management infrastructure in many ways with different levels.

[7] In extreme flood events, only land more than 4.5 m high would not be flooded and sea level rise was of between 26 cm and 1 m (ADB, 2010).
[8] Cited at: http://moitruong.xaydung.gov.vn/moitruong/module/news/viewcontent.asp?ID=3115&langid=1.
[9] PSU: Practical Salinity Unit, as a limitation level for water supply.
[10] Cited at: http://moitruong.xaydung.gov.vn/moitruong/module/news/viewcontent.asp?ID=3115&langid=1.
[11] Maximum allowable level in surface waterbodies for water supply purpose according to QCVN 08:2008 National technical regulation on surface water quality.

Changes in precipitation pattern such as 90% of the annual rainfall concentrating in 6-month rainy season with an increased intensity (ADB, 2010) would result in higher leachate volume accumulated in landfill cells that would cause structural damages such as break of landfill cell walls, bottom liner, internal roads, and thus polluting the neighbouring environment. This was experienced by Phuoc Hiep 1, Phuoc Hiep 1A and Phuoc Hiep 2 landfills, which were full and closed, over the past 15 years.

Both existing sanitary landfills of HCMC are located in weak soil and one of them is in low land at about +2m above sea level. As a consequence, the two landfills are exposed to soil subsidence and one faces extremely high risk of flood due to sea level rise. ADB (2010) warned that Phuoc Hiep landfill would be subject to flood over 10% of its surface by 2050 and 65% of its surface under extreme flood, whereas Da Phuoc landfill would completely be flooded under regular or extreme flood.

As a result of our observation over the past 5 years and interiews in 2015 (by authors), both with MSW collectors and an officer from solid waste management division of HCMC, heavy rain has caused flood that obstructs roads, inhibits collection and transfer/ transport activities, as well as soaking MSW with water that is drained along and causes unsanitary conditions on the roads. Rising temperatures accquires more frequent collection schedule of MSW and more stringent landfill operation such as leachate treatment, control of odor, pathogens, rodents and flies. Since the first outbreak of flies in 2009 when Da Phuoc landfill was a hot topic for arguments, it has been a source of nuisance in southern part of HCMC.

5. CAPACITY OF THE PWSIs IN THE CONTEXT OF MIGRATION AND CLIMATE CHANGE

5.1 Projection of the demands for electricity, supply water and MSW treatment to 2025

This section presents the projection results of future demands of domestic electric power, water supply, and MSW treatment. The calculation was based on the city's population projection taking into account the number of add-in immigrants into HCMC under average emission scenario (scenario B2) and salinity level of $4^{o}/_{oo}$, which was conducted by Oanh *et al.* (2015). It also adopted the target indicators by 2025 regarding to each sector that were presented in previous sections. Those data included:

- Projected population: 10.580 million people by 2025;
- An increased immigration due to climate change of 390,000 people by 2025;
- Electric power consumption: 5,000 KWh.capita^{-1}.year^{-1}; electric power loss rate: 4.8%.
- Sanitary water consumption: 180 litter.capita^{-1}.day^{-1}; water loss rate: 25%; 100% population could access the service;
- MSW generation rate: 1.26 kg.capita^{-1}.day^{-1}; 100% MSW would be collected and treated.

According to the calculation, the demand of domestic electric power was estimated at 55.4 billion KWh.year^{-1}, domestic water supply at approximately 2.380 million m^{3}.day^{-1}, and the amount of MSW for treatment of 13,300 ton.day^{-1}, by 2025.

Contributing to the population growth, the immigrants due to climate change would raise a need of 2.04 billion KWh.year^{-1} of electric power, 88,000 m^{3}.day^{-1} of sanitary water supply, and approximately 500 tons of MSW.day^{-1} to be handled by the city.

5.2 Capacity of the city's PWSIs in context of migration and climate change - How much is sufficient?

The following assessment was made on basis of comparing the demands of the three public work services as projected with the target capacity shown in infrastructural plans, from which conclusions would be drawn on the capactity of each sector to meet the city's demands in context of migration and climate change.

Electricity supply

Statistical data on electric power consumption from 2010 to 2013 showed that average domestic electric power consumption accounted for about 39.8% of the total electricity output (EVNHCMC, 2013). According to the Decision No. 2631/QĐ-TTg dated 31/12/2013 on approving the master plan on socio-economic development of HCMC to 2020, with a vision toward 2025, the total comodity electricity for all sectors would achieve 48.5 - 50 billion KWh.year^{-1}. Assuming that the share of domestic electricity would maintain in the future, at 39.8% of the total, the amount of domestic electric power would be approximately 19 – 20 billion KWh.year^{-1}.

From previous calculation, the demand for domestic electric power of 55.44 billion KWh.year^{-1} by 2025, which included power losses, would be sufficient for the city's population with add-in immigrants. By comparing the planned and projected data, an additional amount of 35.44 – 36.44 billion $KWh.year^{-1}$, about 2.8 – 2.9 times as high as planned by 2025, should be produced. Therefore, this sector would perceive a significant pressure by climate change and immigration in the next 10 years. This was, on the one hand, because the city's government was supposed to improve the standard of living of the citizens. Particularly in energy sector, electric power consumption per captita would change from 2,600 – 2,800 $KWh.capita^{-1}.year^{-1}$ in 2015 to 4,800 – 5,000 $KWh.capita^{-1}.year^{-1}$ in 2025. On the other hand, an increased population regarding the immigrants driven by climate change of 390,000 people (Oanh *et al.*, 2015) also contributed an amount of 2.04 billion $KWh.year^{-1}$, which made up 5.6 – 5.8% of the total increased need.

Water supply

Referring to the Decision No. 729/QĐ-TTg dated 19/6/2012 on approving the water supply plan of HCMC to 2025, the planned capacity for domestic water supply by 2025 would be of 1,887,000 $m^3.day^{-1}$. The demand as projected by this study was 2,380,000 $m^3.day^{-1}$, an increase of 493,000 $m^3.day^{-1}$ as much. The projection of water demand accounted four factors: a risen water consumption from 152 $litter.capita^{-1}.day^{-1}$ (2015) to 180 $litter.capita^{-1}.day^{-1}$ in 2025 due to projected higher living conditions; a reduction in water loss from 32% (2015) to 25% in 2025; an increase in population of 2.304 million from 2015 to 2025 (Oanh *et al.*, 2015); and 100% of sanitary water access. If considering the immigrants due to climate change in particular (390,000 people), an amount of 88,000 $m^3.day^{-1}$ would be sufficient, which shared 17.8% among the total additional need.

It was planned that the total water needs for HCMC including domestic activities, industry, commerce and service, and water losses would be 3,570,000 $m^3.day^{-1}$, whereas the capacity of supply could reach 3,700,000 $m^3.day^{-1}$. Thus, in order to meet the total demand of water consumption, HCMC would need to provide 363,000 $m^3.day^{-1}$ of sanitary water as much more. This number was derived from the following equation:

$$493,000\ m^3.day^{-1} - [3,700,000\ m^3.day^{-1} - 3,570,000\ m^3.day^{-1}] = 363,000\ m^3.day^{-1}.$$

The increased amount of water is equivalent to an average capacity of one water treatment plant, assuming that the water supply projects would be implemented as scheduled, and no significant disturbance would occur to affect water resources such as natural extremes, war, etc.

Municipal solid waste management

As a result of the caculation, HCMC would generate about 13,300 ton of $MSW.day^{-1}$ by 2025. The increasing amount of MSW was due to a higher rate of MSW generation in relation to better living conditions, at 1.26 $kg.capita^{-1}.day^{-1}$, and an increase in population. The increased population of 2.304 million and the immigrants due to climate change of 390,000 within ten-year period from 2015 to 2025 would create about 2,900 $ton.day^{-1}$ and 500 $ton.day^{-1}$ of MSW, which contributed 49.2% and 8.3%, respectively, to the total increased generation.

With current facilities, HCMC has a capacity to handle an amount of 8,200 ton of $MSW.day^{-1}$ to 2030. From 2020 afterwards, the city would have one more solid waste treatment complex located in Thu Thua – Long An province [12] with a capacity of receiving 3,000 ton of $MSW.day^{-1}$ from HCMC (DONRE, 2011). At this capacity, it would have a life time of over 20 years. In addition, there would be four MSW recycling and energy generation facilities with a total capacity of 3,000 – 5,000 $ton.day^{-1}$ with a life time of about 50 years (DONRE, 2015). All of those facilities would make up the total capacity of 14,000 – 16,000 $ton.day^{-1}$ for the city's MSW treatment. Comparing the total capacity of treatment with the projected amount of MSW, it showed that HCMC could guarantee the capacity of receiving and treatment 100% of the MSW generated in the city by 2025.

6. WHAT WOULD BE A REALISTIC APPROACH?

6.1 Electricity supply

The electric power demand of HCMC would almost triple by 2025, whereas the city is short of budget for upgrading the electric transmission and distribution network (especially the project on underground electric transmission lines). Thus, finding a solution to both problems about power demand and budget would be essential. From that point of view, development of renewable energy from wind, solar, geothermal and biomass, which could save operational cost in term of fossil fuels, seems to be an appropriate approach.

According to Tuan (2013), wind power and geothermal power, the two energy sources with great

[12] Thu Thua – Long An complex was planned to receive solid waste from the southern key economic zone as well as from neighbouring provinces.

potential in Vietnam, had low competitiveness due to low purchase price (1,614 VND/KWh for wind power, no support mechanism for geothermal power), whereas the production cost of renewable energy was high (ranging from 1,200-1,800 VND/KWh for wind power and 1,100-1,600 for geothermal power). Meanwhile, generating energy from MSW with anaerobic digestion or incineration technology has shown both possibility and advantages. It could solve partly the need of electricity and reduce costs for MSW treatment by landfilling.

Referred to the study of Oanh *et al.* (2009)[13], 59 m^3 of methane gas, which could be transferred to electricity or for direct use purpose, could be achieved from 1 ton of MSW in mixture by anaerobic digestion (AD) process. Other studies by DENTEMA[14] conducted from 2013 to 2015 on biogas recovery from market biodegradable solid waste and household food refuse applying both dry and wet AD process resulted in 70-80 m^3 biogas per ton of input material with about 50-60% of methane gas. The study by Oanh (2012) showed that energy recovery (for selling) from incineration was 344 KWh per ton of unsorted MSW. A project documented by Hitachi Zosen (2014) indicated that a MSW treatment facility with a capacity of 600 ton of sorted MSW per day would produce about 9 MW of electricity. Although energy recovery combined with incineration was very costly, it would be more efficient to integrate with selling carbon credits (Oanh, 2014). The Decision No. 31/2014/QD-TTg dated 05/5/2014 on supporting mechanisms to develop projects on power generation from solid waste in Vietnam with a purchase price of 10.05 UScent/KWh is a favorable condition to attract investment in this field.

However, introduction of these technologies in practice might face some challenges because technical issues and socio-economic benefits versus shortcomings had not been well defined, said Dieu and Oanh (2015). Therefore, HCMC needs to encourage the implementation of pilot scale and demonstration projects in this field to set a concrete foundation for real renewable energy projects in the next few years.

6.2 Water supply

From the current situation and the need of domestic water supply as presented above, HCMC would definitely face water scarcity in near future. Although the city is putting efforts to identify realistic alternatives in order to supplement and partly replace the water resource from Dong Nai and Saigon rivers, the processes of feasibility study and construction of infrastructural facilities would require several years. Meanwhile, evidences of salinity intrusion, drought, and contamination of surface waterbodies in recent years have been found to occur and threating water security. Therefore, in addition to finding water supply alternatives from Dau Tieng and Tri An reservoir (Trung Thanh, 2015), recovery of stormwater (HCCB, 2015), and intensive education on water saving, HCMC should focus on investigating risks as well as building legal framework of policy and institution to encourage wastewater reuse for appropriate purposes. Reuse and completely treatment of wastewater from processing villages, aquacultivation areas, and manufacturing facilities must be more stringent to protect water resources. Last but not least, improving water treatment technology to cope with saline and contaminated water (especially by organic matters and nitrate nitrogen) would be meaningful for the future of water supply.

6.3 Municipal solid waste management

Currently, about 29.7% of the total MSW of HCMC is recycled into compost product and organic fertilizer, yet to meet the target for 2015. Considering the recently approved projects, the rate of composting and energy generation from MSW would reach 24% and 15 – 30% by 2025, respectively, still far behind in achiving the target for 2025, which indicated 90% of MSW would be recycled. Being explained as the core reason for low recycling rate, unseparated MSW yielded poor quality of compost product because it still contained unwanted materials such as glass and plastic scraps (Dieu and Oanh, 2015). Electricity recovery from incineration of unseparated MSW, which has very high moisture content, would result in very high operational costs, and thus inefficient (Oanh, 2014). In that situation, there would be more room for energy recovery from anaerobic digestion (AD) technology for HCMC thanks to several advantages: MSW with high moisture content; experience in operating AD facilities; landfills could be used as bio-reactors; available supporting regulations; demand of less space (Dieu and Oanh, 2015). However, this technology also needs a relatively "pure" raw materials for a stable operation, which means that MSW should be separated at source.

From the previous analysis, the key to solve the problem of MSW management in HCMC is how to

[13] Cited in: Dieu, T.T.M, and Oanh, L.T.K., 2015. Possibilities and challenges to approach zero-disposal of biodegradable organic domestic solid waste in Ho Chi Minh City, Vietnam, International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 7.

[14] DENTEMA: Department of Environmental Technology and Management, Van Lang University.

involve people in the programme on solid waste separation at source (SWSS). However, this has been the most challenging task for HCMC over the past 10 years (Anh, 2015). Since 2005, SWSS had been developed in several districts as demonstration programmes, but it could not be generalized for the whole city. Experiences from Thailand and Japan have shown that the government plays an important and active role in pushing up and maintaining this activity within communities [15]. Therefore, HCMC requires perseverance and investment in terms of finance and policies to achieve this goal. Furthermore, the selection of where to start is very important and strategic. Based on the fact that changing habits of adults is relatively difficult, SWSS should start from the educational institutions to aim at younger generation, the concentrating sources such as markets, commercial centers, supermarkets, state offices and industrial zones where it might be easier to reach a consensus over participants. At the same time, HCMC should make a detail plan for educating, propagating, technical and financial supporting, calling for investments in collecting, transport and recycling facilities that suits with SWSS objective.

7. CONCLUSION

Climate change has affected the PWSIs both directly and indirectly. Immigration is one of the consequences of climate change when people lose their home and livelihoods. Thus, it would place pressures on urban PWSIs and HCMC is the case.

This research study was about the city's plans, impacts of climate change on the three PWSIs including electricity supply, water supply and MSW management, and the demand of each service in context of climate change and add-in immigration into HCMC. The study showed that electricity supply and water supply were the most affected and vulnerable to climate change. As a result, their capacity to meet the demands of electric power and sanitary water were under threats. By 2025, the need of electric power was projected at 55.4 billion $KWh.year^{-1}$, tripled as much as planned; whereas the need for water supply would be 2.380 million $m^3.day^{-1}$, an increase of 493,000 $m^3.day^{-1}$ compared with the plan. Meanwhile, solid waste management system would perceive insignificant impact and it guaranteed the capacity to handle an amount of 13,300 ton of $MSW.day^{-1}$ to meet with the target of HCMC by 2025.

Contributing to the total demands of PWSIs by 2025, an increase of 390,000 immigrants would raise a need of 2.04 billion $KWh.year^{-1}$ of electric power, 88,000 $m^3.day^{-1}$ of sanitary water supply, and 500 tons of $MSW.day^{-1}$ to be collected and treated.

8. RECOMMENDATION

This study provided both qualitative and quantitative data of climate change impacts on the PWSIs of HCMC that could be considered and employed for further investigation and evaluation of the loss or increase in PWSIs' capacity due to climate change impacts. Pursuing those studies as recommended, however, needs a variety of data on individual PWSI facilities of each sector in terms of the geological location, climatic and topographic conditions, capacity, technical and performance process, disaster or climate change response program, and capacity of response. Least but not last, programmes on climate change responses at city and sector levels should concern about the loss or increase of PWSI capacity. Applying a similar concept model as introduced in the methodology of this study (Figure 1), a loss in PWSI capacity due to climate change was described as the rectangular tank volume $A^{\#}B^{\#}C_3D_3D_2A^{*}B^{*}C_2$ as follows:

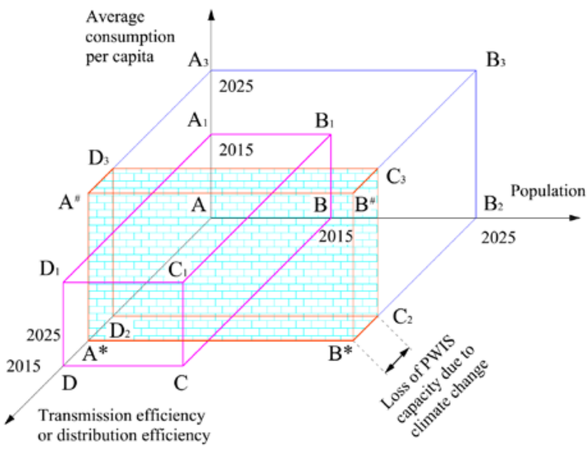

Figure 2 Concept model of the total capacity of PWSIs and the loss in capacity of PWSIs due to climate change.

[15] Referring to experts in the Stakeholder Workshop on Organic Waste Management Plan for HCMC, organized by DONRE in May, 2015.

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