Rwanda energy landscape

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Abstract

This paper reviews Rwanda's energy landscape. It looked into potentials energy resources, installed capacities and available technologies. Rwanda is well endowed with energy resources, such as solar, biomass, hydro, and methane gas and geothermal, though most of these resources remain untapped. Energy is considered the most powerful keys for a country to measure its economy development. Therefore, the inter-paly between energy production and consumption, and is preccussor of the level of development. The access to clean energy is very paramount and brings along with it a lot of socio-economic benefits to the citizens in terms of poverty reduction, cost effectiveness and safeguarding the environment. As a result of improving the service sector with emphasis on energy, regulatory, legal and institution framework measures, Rwanda has been, in 21st century, one of the ten fastest growing economies in the world. Among others, has fast growing energy accessibility rate of 8 % in 2008 that is currently standing at 23 %. Rwanda has an ambitious target to be achieved 70 % access rate by 2017/2018. Hydro remains the major source of electricity; followed by solar which has high potential; biomass, at 85 %, is Rwanda's primary energy source; and lake Kivu methane gas is the new source of energy.

Introduction

Currently, energy security, energy equity and environment sustainability have dominated the most of the countries developmental agenda objectives worldwide. These objectives are highlighted and taken into consideration while developing energy sector. However, their positions on the developmental matrices differ from country to country based on regions and whether the country is developed or developing. The European's top priority is energy security while African countries (Sub-Saharan) energy equity (accessibility and affordability) are top priorities (IEA, 2014). Africa is currently intensively engulfed developing its sectors, i.e. infrastructure, while at the same time strengthen its economic with emphasis on energy as a major catalyst of economic development (Minecofin, 2007). Similarly, the level of country energy consumption, including African countries, determines the country development (IEA, 2014), (Minecofin, 2007), (Azad, Rasul, Khan, Ahasan, & Ahmed, 2014). Rwanda, as one of African countries, is a sovereign country in Central/East Africa and on the African mainland. It is one of the smallest countries with an area of 10,169 sq. miles (26,338 km^2) similar to Netherlands. The country is divided into five provinces which are subdivided into thirty-one districts, further divided into sectors, cells and villages at the lower level. Rwanda is one of the most densely populated countries in Africa with a population of 11.46 million (Minecofin, 2002). Rwanda is also highly elevated, dominated by mountains in the west and savannah to the east, in the great lakes region of Africa. According to the Word Economic Forum's Global Gender Gap Report, Rwanda has more than 8 % economic growth rate per year, and was ranked 6th in 2015 among the Africa fastest growing economies (Armbrecht, 2016). Rwanda's GDP per capita, US $643, as one of the smallest countries in Africa is one of the fast-

est growing in the world. The Government has plans to reach 11.5 % growth rate by 2018. The government reform and improved business regulations have been key drivers for country economic growth. Rwanda's services sector, i.e. wholesale and retail, transport, storage, and communications, real state, and business service, has supplanted the agricultural sector by contributing a high proportion to the GDP (Jabara, 2014). This has in turn led to increased demand on energy. In Rwanda, installed electric power generation capacity is very low and stands at 41.25 MW from both hydro and power plants running of heavy fuel oil or diesel. Hydropower accounts for 26.74 MW, while Thermal power generation is now at 14.5 MW.

Rwanda is rather well-endowed with domestic energy resources though most of these resources remain untapped. The access to electricity in Rwanda was 23 % in 2015 (Mininfra, 2015). Energy sources for electricity generation include: hydropower; geothermal; methane gas; peat; solar; wind and waste energy. Renewable energy resources such as hydro, solar and biomass play a major role in the country's energy mix. The primary energy balance in Rwanda consisted of Biomass at 93.1 %, Fuel 6 %, and electricity 0.9 % (Safari B. K., 2010). In the biomass category, wood fuel consumption stands at 80.4 %, charcoal at 1.9 %, while agricultural waste and peat occupy 10.8 %. However, there is also potential for wind energy utilization which remains unexploited. Generally, the use of environmental-friendly energy sources is at low level due to inadequate technologies and poverty. The following sections provides more insights on the about current situation in terms of total energy production and consumption by sector, environmental sustainability, projects and investments on renewable energy in Rwanda.

Rwanda Energy Resources by Sector

WIND

To date in Rwanda, wind energy has been used at only two sites. That is to power the Frequency Modulation transceiver antenna of the National Radio and Television, and was destroyed during the 1994 Genocide; and for a wind turbine in Gabiro, to pump water (3 m^3/h). In Kigali there is also a 1 kW wind turbine, developed privately, which supplies electricity to a cyber-network. With the growing demand of electricity, the Government of Rwanda is trying to diversify its energy sources by exploiting wind energy development under the Electricity Access Roll out Programme (EARP). EARP is divided into two components, grid and non-grid. Grid component, falling under the Rwanda Electricity Corporation (RECO), deals with distribution and connections to the national grid, and focusses on thermal and hydroelectricity. The non-grid component, under the ministry of Infrastructure (MININFRA), deals with electrification of institutions that are at least 5 km away from the national grid network. The targeted sources of power, in this case, are solar and micro hydropower. In EARP and MININFRA activities, wind does not feature prominently as a possible source of energy. This is because most parts of Rwanda have low wind speeds but Eastern province particular Kayonza district has annual mean wind speed of 5.5 m/s (Maniraguha, 2013). However, isolated sites such as Kigali, Gisenyi and Kamembe, have annual wind power densities of 13.7 W/m^2, 18.4 W/$m^2$and 24.4 W/m^2 respectively. It is evidently clear that these places have low wind speeds suitable for small-scale wind power generation especially at Kamembe site.

HYDRO POWER

Rwanda's major source of energy is hydropower although the full potential of this energy resource is not full quantified. The country has a good hydropower potential in Northern, South and Western Provinces. According to the Hydro power Atlas, prepared in 2007, Rwanda has 333 known hydropower locations with a potential ranging from 50 kW and several megawatt (DPEA, 2009) (AfDBG, 2013); and 69 sites of Micro and Pico hydro power plants with 15 MW estimated capacity (Nyamvumba & Gakuba, 2014). The power stations, are scattered all over the country of which can be classified into three groups. The first group includes the first installed plants; Ntaruka commissioned in 1959 with a capacity of 11.25 MW; Mukungwa commissioned in 1982 with 12 MW installation capacity; Gisenyi built in 1969 with 1.2 MW installation capacity; and Gihira built 1985 with 1.8 MW installation capacity (Hove et al, 2011), (MININFRA, 2009). The second group of imported power through cross-border interconnections covers about 18.5 MW; from Congo (15.5 MW) and Uganda (3 MW). The third group includes new installed hydro power plants from 2000 up to 2015, and there are summarized in Table 1.

Currently, there are ongoing projects which are expected to generate electricity soon in different districts; Akanyaru regional hydro project is expected to be commissioned in 2016 with 3.9 MW installation capacity, Giciye II with 4 MW to be connected to the national grid by 2016 (REG, 2016). In addition, Rwanda Energy Group is planning to develop 20 potential mini-grid and the sites survey will start soon and the financial support has already received (REG, 2016). Rwanda's share of regional hydropower is estimated at about 60 MW of which Rusumo Falls, on the border with Tanzania, and Rusizi III (145 MW) which will come online by 2018 and the Rusizi IV (205 MW estimated capacity), on the border with the DRC, are scheduled for joint development with Tanzania/Burundi and Burundi/DRC respectively (AfDBG, 2013). Rwanda, working together with its regional neighbors has in the pipeline grid extension projects. For instance, the Rwanda-Uganda, 230 km

Table 1. New installed hydro power plants 2000–2015.

Project's Name	Capacity (MW)
Rukarara I&II	*11*
Nyabarongo	28
Giciye	4
Rukarara V	5
Nyamyotsi	0.075
Kivumu-Mwange	0.105
Mpenge	*0.128*
Murunda	0.105
Musarara	0.438
Mazimeru	0.25
Various Plants	17.03
Total	**66.131**

Source: (Safari B. K., 2010), (MININFRA, 2009), (DPEA, 2009), (Nyamvumba & Gakuba, 2014).

220 kV line between Birembo and Mbarara (African Development Bank financing), Rwanda-Burundi, 109 km 110 kV line between Kigoma and Rwegura (ADB financing), Rwanda-DRC, 220 kV line between Mukungwa and Goma (Africa Development Bank (ADB) financing) and Rwanda-Tanzania, 220 kV line between Birembo, via Bugesera to Rusumo (World Bank financing) (MININFRA, 2009).

However, the development and operation of hydro power plants in Rwanda faces some challenges. Namely, Implementation the least-cost electricity generation mix with clear timelines, Securing the necessary funding for planned electricity projects, including ensuring sufficient private sector investment (both local and foreign); Development of the legal and regulatory framework to support the implementation plan; Development of conducive policies including appropriate incentives and tariffs to attract private sector participation; Development of human resource capacity to implement the planned electricity generation projects; Involvement of local communities, to the extent possible, in developing energy projects.

To mitigate against these challenges the Government, working together with the private sector and cooperating patterns, initiated a set of incentives and measures. Key, among the measures, is that the transfer agreement is in a form of renting where the private investors pay the rental fees to Government in instalments at a specified period of time; splitting of the Government utility Energy Water and Sanitation Authority Limited (EWSA Ltd) into Rwanda Energy Group (REG) and Water and Sanitation Corporation (WASAC) (DPEA, 2009); encouraging private public partnerships in the rural electrification projects and activities; creating enabling environment for international, and national financing, including donor financing, of energy projects (Nyamvumba & Gakuba, 2014).

BIOMASS

Biomass such as wood, agriculture residues, charcoal, peat and organic gas account for 93.1 % of which wood covers 80.40 % of the total energy consumption (Safari B. K., 2010). By 2004, the demand of wood fuel was estimated at 7,562,231 m^3 with annual extraction potential was 3,186,700 m^3 corresponding to a decline rate in forests of 7 %. Biomass is mainly used for cooking and boiler fuels and low level energy consumption for power generation and transport. In 2013, Biomass counts 85 % of primary energy used in Rwanda (AfDBG, 2013). This is in form of firewood, charcoal, and agriculture residues. The wood fuel is more used in rural areas, it is estimated that about 1.8 million tons of wood fuels consumed each year, for cooking, boiling water and space heating. In urban area wood and charcoal are sources of fuel for cooking. The biomass consumption is putting pressure on standing stokes of biomass with about 870,000 tons or 4,375,531 m^3 of wood deficit as of 2009 (MININFRA, 2015). Excessive use of biomass, especially wood fuel leads to ejection of CO_2 in the atmospheric, soil degradation, droughts due and extinction of fauna and flora that depend on biomass ecosystems. To deal with this, in 2010 the Government adopted regulation of providing tree harvesting license whereby prior to harvesting wood (MINIFOM, 2010). Similarly, has put in place a policy of three tree planting every tree harvested and encourages the use of alternative forms of energy. All these is aimed at reducing biomass conservation and depletion from 85 % to 55 % by 2017; and to 50 % by 2020 through improved charcoaling, and stoves technologies; and use of biogas, LPG, Kerosene, peat, coffee husks; and papyrus briquettes (AfDBG, 2013).

Biogas

Biogas is another source of energy used in Rwanda albeit on a small scale. The National Domestic Biogas Program (NDBP), established in 2007, promotes the use of biogas and construction of digesters in rural settings and for Government institutions. Biogas digesters, in Government institutions, are mostly used in prisons and schools, where gas is produced from the latrines wastes. Conversion of human waste into biogas alleviates human waste disposal and the remains, from the digesters, can be used as agriculture manure when properly treated. In 2008, the Government of Rwanda rolled out biogas program by the constructing biogas digesters in all schools, hospital centers and in prisons. Currently 11 out of 14 prisons use biogas for cooking. This has reduced the costs of cooking in prisons by 50 % in comparison to using electricity. In 2012 over 2,700 biogas digesters were constructed, over 200 masons trained and approximately 40 were actively involved in the program with a target of constructing 100,000 digesters for rural households by 2017/2018 (Nyamvumba & Gakuba, 2014). Since the beginning of the program 3,687 domestic biogas digesters have been constructed and 68 institutional digesters have been installed in households, schools, hospital and prisons. This has been achieved due to government subsidies and use of local micro finance for low rate interest loans. The program has reduced wood fuel usage by 60 % and 40 % in schools and prisons as well as substantially improved hygiene conditions apart from the costs benefits and sustainability of the biomass standing stokes.

Peat

Peat sites have been identified in Rwabusoro, Akanyaru, Murigo, Gihitasi, Mashya, Gishoma, Rucahabi, Cyato, Cyabararika, Nyirabirinde, Kageyo, Kaguhu, Mashoza, Gasaka, Bahima, Bisaka, Rwuya, Nyabugongo and Rugeramigozi (AfDBG, 2013). Rwanda peat first master plan was developed in 1993 and currently peat is used as input in small industries, cement production, and cook fuel in small decentralized institutions. Rwanda has potential resource of 155 million tons of dry peat which covers 50,000 hectares of land. Power production capacity from peat, is roughly estimated at 700 MW (MININFRA, 2015). There two projects of peat power generation, one is Gishoma peat power plant of 15 MW which was supposed to be commissioned 2013/2014 but still pending. The second project is Hakan Peat Power Plant (Phase I net Output) of 70 MW which will commission in 2017/2018 (MININFRA, 2015). The price of peat is high compared to gas methane due to peat mining with other external cost related to environment. The further study is required related to peat extraction because peat is not environmental friendly.

SOLAR ENERGY

Solar energy presents considerable potentials that can contribute to a large extent to fill the gap of energy needs in Rwanda (Okoro & Madueme, 2006), (Lujara & Kaunde, 2007). There exists a number of technologies that use to harness solar energy (Scheer & Kerrley, 2002), (Sen & Zekai, 2008), (Dunn, 1986), (Edinger & Kaul, 2000), (Wikipedia, 2016) for electric-

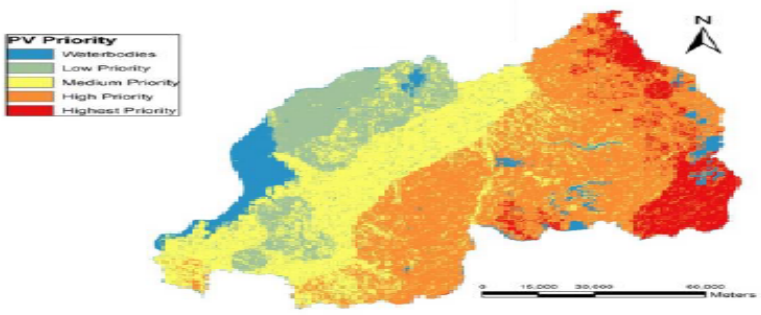

Figure 1. Rwanda Solar map Source: NASA, Rwanda Agriculture and Energy (2013).

ity generation by means of heat engines or photovoltaic systems. Solar power technologies are also used for solar water heating systems. Geographically Rwanda is around the equator with abundant sunshine and the global solar radiation, on horizontal surface, of 4.8 kWh/m^2 day and 5.5 kWh/m^2 day (Safari & Gasore, 2009). The annual daily mean global solar radiation is about 5.2 kWh/m^2 day and solar energy becomes an option. Rwanda Eastern province has the highest potential in solar radiation compared to the rest of the country as Figure 1 shows.

Solar Photovoltaic (PV)

Solar photovoltaic (PV) in Rwanda is almost exclusively used on a small scale to generate off-grid electricity supplied to community centers in remote areas. From 2004 up to date, the Common Development Fund (CDF), the Ministry of Education, with technical assistance from the Ministry of Infrastructure, and financial assistance from different donors such PV systems have been successfully deployed. The main beneficiaries of the PV systems have been rural government administrative buildings, schools, and health institutions. The PV systems are either stand alone or grid tied.

Currently, two solar power plants have been constructed such as Gigawatt solar power plant (8.5 MW) with the cost of $23 million was constructed by Gigawatt Global Company Ltd where solar tracking technology is used (Gigawatt Global, 2016). Mount Jali (Kigali city), with capacity of 250 KWp, was constructed by German state Rhineland-Palatinate (MININFRA, 2016). In addition to that, off-grids have been developed where PVs installed in different Schools, Health centers, Administrative offices and other projects are under way like the Greenfield 10 MW, 10 MW grid connected solar PV Plant in Eastern province (Nyagatare) and (Rwinkwavu) respectively by Independent power producer (MININFRA, 2016).

Solar Water Heater (SWH)

Solar water heating, for households, is the most attractive solar energy system; because of simplicity in construction, maintenance and running costs. Currently, most of the households in urban areas of Rwanda use electricity of heating water. This translated into a huge financial burden on most households. A household, based on the current price of electricity on average, pays about US $400 per year per using 5 kWh to heat a water tank apart from US $200 spent on buying the geyser. On the other hand, a SWH constructed with local materials cost US $1,500 and the energy used is free. By cost implications the SWH are cheater compared to heating water using electricity.

Before 1994 several domestic SHW systems were installed in Butare city and are currently no functional and need replacement or maintenance. Some studies have also been conducted on the potential of using water heaters for domestic and industrial applications. Other programs include the SolaRwanda Program (2012–2015) supported by Global Environmental Facility (GEF-World Bank Fund) and the Nordic Development Fund (NDF) to provide subsidies and loans to former Energy Water and Sanitation Authority (EWSA) customers to purchase SWHs. SolaRwanda Program aim was to promote the widespread use of SWHs in residential areas through financial incentives, and other supports measures, with a goal of installing 12,000 SWHs by the end of the year 2015 with an estimated yearly saving of 23,328 Mwh after installations (EWSA, 2012a). The Government of Rwanda has also obtained a grant from NDF of 4 million Euros for development of SWHs market in Rwanda.

GEOTHERMAL SECTOR

This energy is available in form of hot springs or steam or heat and it can be exploited for electricity generation, industrial processes, space heating, drying of agricultural products (EERE, 2016). Rwanda is located in the East Africa Rift Valley, a region of intense volcanic and seismic activities. There is existence of geothermal fields, in Rwanda, that can be harnessed for energy generation purposes. Rwanda has an estimated potential of 700 MW of geothermal resources in the form of hot springs along the belt of Lake Kivu. Up to now Rwanda is still conducting exploration of economically viable geothermal sites (UNEP, 2014). Three sites at Cyangugu, Kibuye and Gisenyi were identified in the 1980's with geothermal energy potential between 170 and 300 MW based hydrological and geological studies of the sites. Further studies were conducted by Chevron in 2006, confirm potential for two geothermal sites. However, to date no investment has been made in this area as power generation using geothermal energy is considered an expensive process. A summary of our possible geothermal resources is detailed in Table 2.

LAKE KIVU METHANE GAS

Lake Kivu is located in African rift zone between Rwanda and DRC and the resources equally shared between those two countries. The lake size is about 2,400 km^2 and is estimated to contain 55 billion m^3, of which 39 billion economically exploitable, i.e., 32 million of PET (petroleum equivalent tone), with high concentrations of naturally occurring methane and carbon dioxide. The highest concentrations occur at depths ranging from 270 meters to 500 meters (Mininfra, 2014) which is estimated to generate 120 to 250 million m^3 of methane (CH_4)

Table 2. Potential area for geothermal resources.

Geothermal Prospect	Karisimbi	Gisenyi	Kinigi	Bugarama	Other areas	Total
Resource area (km^2)	25	30	25	50	20	150
Developable area (km^2)	8	5	5	2	2	22
Number of wells per km^2	10	10	10	10	10	50
Average well productivity (MWe)	4	4	4	1	1	14
Resource potential (MWe)	**320**	**200**	**200**	**20**	**20**	**760**

Source: Energy sector strategic plan (2013–2018) ministry of infrastructure.

annually (EWSA, 2012b). This year (2016), the Government of Rwanda commissioned a pilot methane electricity plant. The plant uses a floating platform of 130 kilometers off shoreline that employs a vacuum suction of methane from 300 meters below the waterline instead of drilling. Methane, after being separated from water and carbon diode, is shipped to the shore via an underwater pipeline and excess carbon dioxide is pumped back into the lake (Dailymail, 2016).

PETROLEUM PRODUCT

Rwanda imports all her petroleum products from outside, through Kenya and Tanzania, because its potential resource is not yet commercial proven and well developed. The oil importation costs increased more than 700 % between 2000 and 2012. The consumption of petroleum also grew by 16 % in the same period and the oil imports in GDP share terms increased from 2.5 % up to about 5.5 % between 2000 and 2012 respectively (MININFRA, 2015). Rwanda has oil and gas domestic storage of 30 million liters to cover, in case of shortage, and the target is to increase the storage capacity up to 150 million liters by 2017. Due to increase of vehicles and air traffic this will increase the petroleum consumption while for transitioning electricity generation from diesel to renewables in order to reduce diesel importations. Table 3 summarizes petroleum importations in 2011/2012. It shows that diesel and petrol dominated the imports with diesel for electricity generation while petroleum was for transportation.

Table 3. Petroleum products importation 2011/2012.

Product	Annual consumption (Liters)
Illuminating Kerosene	15,222,724
Heavy Fuel Oils	33,666,910
JET A-1	12,454,649
Petrol	82,263,817
Diesel	121,937,405
TOTAL	**265,545,505**

Source: MINICOM, Downstream Petroleum Policy, 2012.

Rwanda Energy Projects

The government of Rwanda has made majors efforts to achieve its target of Economic Development and Poverty Reduction (EPRS II), among many completing national needs, by promoting the energy sector as key driver of economic growth. The short, medium and long term goals have been assessed and divided according to the needs and priorities. Power generation, transmission, distribution, region integration efforts and bearing in mind investors are central in satisfying demand and supply of energy in Rwanda. Table 4 summarizes Rwanda's energy projection financial expenditure.

Policy, regulations and institutional framework

Energy is as major key ingredient to achieve sustainable social economic goals. The Government of Rwanda has set energy accessibility target with the intention to galvanize economic growth with the framework of energy policy, legal and regulation institutional frameworks. These institutional arrangements are meant to ensure that power generation increase has no negative effect to biodiversity, ecosystem or the environmental in general. Rwanda energy policy has been developed taking into account the needs and view of stakeholders such as public and private sectors, donors, financial institution, civil society, Non-government organizations (NGOs) working hand in hand with MININFRA. The policy emphasizes renewable energy promotion to mitigate environmental degradation and greenhouse gases emissions resulting from use of fossil fuel. Private sector such as Rwanda energy Group (REG), was divided into two dependent companies. The Energy Utility Corporate Limited (EUCL) in charge of power generation, transmission, distribution and sales to final consumer while Energy Development Corporate Limited (EDCL) is in charge of developing both generation and transmission and superintending on exploiting new energy resources (MININFRA, 2015). Rwanda Development Board (RDB) is in charge of environmental clearance and social impact certification prior to project implementation. Private sector has been heavily lobbied and sensitized to invest in energy sector.

Conclusion

Rwanda is well-endowed with energy resources, such as solar, wind, biomass, hydro and geothermal, though most of these resources remain untapped. Rwanda's energy sector, which has been growing faster for the past few years is related to economic development. As a result of improving the service sector energy accessibility rate which was 8 % (2008) increase to 16 % in 2012. Currently, electrification rate is 23 % whereby the target is to reach 70 % by 2017/2018 with installed capacity of 563 MW plus reserve margin of 31 MW of which 48 % is from on-grid system and 22 % from off-grid system. Public sector, civil socie-

Table 4. Rwanda Energy mix road map projects and investments required.

Category	Short to Medium-Term (2013–2017)	Medium to Long-Term (2018–2025)
Generation (MW)	132 MW (2012)–595 MW (2017)	595 MW (2017)–1,450 MW (2025)
Hydropower	200	310
Methane	100	350
Peat power	115	300
Geothermal	160	460
Heavy fossil oil	20	20
Transmission (km)		
Local interconnection	310	–
Karisimbi to Musanze	65	–
Kibuye–Rubavu–Kigali	180	–
Geothermal Sites (II&IV)–Gisenyi	–	15
Rusizi III–Rusizi IV	–	10
Rusumo–Kigali	–	85
Distribution (km)		
Distribution lines	1,400	2,500
Distribution substations	1,200	2,000
Investment ($ million)		
Generation	1,549	2,796
Transmission	150	250
Distribution	850	1,400
Total ($ million)	2,549	4,446
Average ($ million/year)	**510**	**555**

Source: Rwanda Energy Sector Review and Action Plan (2013).

ty and private sector are all involved in ensuring a win-win situation and policy achieving the target. More effort, is however required in rural electrification where majority of the citizens still rely on biomass in form of fuel wood, agriculture residues and charcoal as sources of energy. The introduction of off-grid system and use of biogas in rural area will be the most favorable path to follow because it does not cost more investment and operational cost compare to on-grid system. That will reduce deforestation, soil degradation and also reduce indoor air pollution which has negative impact on people's life. Reduction of energy loss during generation, transmission and distribution through the use quality of equipment use should be promoted. In addition to that, the mobilization of population on energy conservation and energy efficiency will contribute to use energy effectively and reduce energy demand.

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