Solar Energy and its Role in Sri Lanka

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Abstract

Solar energy a clean renewable source with no emission and low recurring cost. In past recent years the technology of solar energy and its usage has experienced a phenomenal change and rapid growth. Promotional and encouraging government policies about solar energy, technological improvements in less setup and maintenance cost, growing public awareness in environmental issues, easy way to cutting down the users electricity bills with assured power supply 24x7 are some of the facts that have facilitated and sustained this strong interest in the minds of the users about solar technology worldwide including Sri Lanka.

We all are facing the challenge of climate changes. According to World Bank report release in August 2016, Sri Lanka loses 7.7% of its income due to environment pollution specially from burning fossil fuels[5]. By setting up renewable environment friendly energy sources are aimed to prove countries contribution to global effort and support to reduce the climate challenges. Sri Lankan government's budget proposals for the year 2018 has presented strategies for environmental friendly developments to the country based on the United Nations sustainable development goals.

As a geographical advantageously located topical country close to equator, where sunlight remains 365 days per year, 8 to 10 hours a day, is a great intensity for generation of solar electricity. Therefore solar energy has a great potential as future energy source in Sri Lanka.

Present consumption level of electricity is about 12,000 GWh, with an increase rate of 6.5% to 9% annually[2]. Ceylon Electricity Board had identified that Sri Lanka needs additional 4000GWh by end of 2025 [1]. This amount is planned to be generated through solar energy, other renewable and other indigenous energy resources. Sri Lankan government's aim of electrification 100% of houses became a success. But without adequate supplies of affordable energy at reasonable generation cost, it is impossible to achieve the future targets.

The project "Battle of Solar Power" is a progressive turn to convert customers rooftop into a solar power plant is one major economical green project. Sunlight is a free resource, the foreign exchange spend on fossil fuels will be remain in the country.

Keywords — *Battle of solar energy, solar Sri Lanka, zero emission, renewable energy*

I. INTRODUCTION

Due to economic growth production and industrial development, Sri Lanka is facing an acute power and energy scarcity. Her energy sector has made tremendous progress over the last two and a half decades in bringing electricity to almost everyone in the country. But there's a requirement of diversify the country's energy generation toward more renewable and sustainable sources. She has exploited hydropower resources to almost her maximum economical potential. Only a very few small scale hydropower plants are yet to be developed in the country, which are under various stages of construction.

However, the country remains extremely hooked on to fossil fuels. In 2016, thermal power contributed sixty seven percent of the total power generation compared to hydropower's twenty five percent and eight percent of nonconventional renewable sources. This dependence on carbon-emitting energy sources makes the country prone to unsteady fuel costs, while hampering the government's efforts to reduce greenhouse gas emissions by 20% as part of its commitment to the Paris agreement.

The Year 2014 became a landmark in the thermal generation, with the addition of Norochchole Coal Plant, with 600MW to national grid. In recent years, the Sri Lankan government has increased its generation power based on renewable energy sources, with a 20% of electricity generation targeted from NCRE by 2020[1]. Sri Lankan government target's an addition of 200MW to the grid by 2020, increase up to 1000MW by 2025 from solar power generation projects.

II. GROWTH OF POWER DEMAND AND GENERATION IN SRI LANKA

A. Access to Electricity

By the end of December 2014, approximately 98.4% of the total population had access to electricity from the national electricity grid[2]. Some planned electrification schemes are implemented and some are finished. Figure 1 shows the percentage level of electrification district wise as at end of 2014 [1].

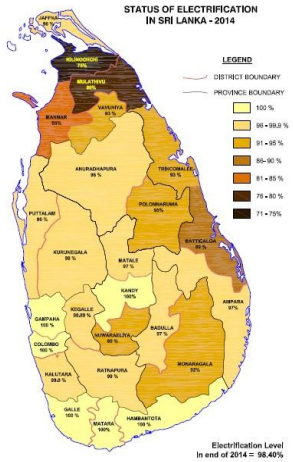

Figure 1

B. Electricity Generation

Many countries including Sri Lanka, blessed rivers and waterfalls have harnessed their inherent kinetic energy through hydro-electricity in fulfilling their energy desires. But the rising demand for electricity and the restricted generation potential of existing hydro plants, reduced the relative contribution of hydro power generation. As a solution to the limitations given above, Sri Lanka had taken a policy decision to move towards thermal and coal electricity generation. However, this leading to issues, such as rising electricity prices and contributes to negative environmental externalities.

Since the commission of the first hydroelectric generation plant in 1950 at Laxapana, hydropower has played a major role in power generation in Sri Lanka. In fact, the biggest share of electricity generation came from major hydro development projects till 1990s. Since then, electricity generation has been transferring from hydroelectric system to a mixed hydro and thermal system, presently dominated by oil. Thermal power has presently become the key supply of electricity generation.
Sri Lanka's Public Utilities Commission(PUCSL), the electricity sector regulator, has approved an alternate Least Cost Long Term Generation Expansion Plan (LCLTGEP) 2018- 2037. According to LCLTGEP, Ceylon Electricity Board (CEB) will not setup new coal power plants in future. PUCSL approved 242MW of major hydro, 215MW of mini hydro, 1,389MW of solar, 1,205MW of wind, 85MW of biomass, 4,800MW of natural gas, 330 MW of furnace oil based power and 105MW of gas turbine power to fulfil countries power requirements in 20 years period [12]. Considering all the benefits of solar power to supply the country's electricity requirement from green energy sources, the Ministry of Power and Renewable Energy had decided to introduce one hundred thousand rooftop solar units during the next ten years as a national program.

C. Electricity Consumption

The annual total electricity demand and consumption rate is set to increase much more in next recent years due to ongoing development projects, increasing rural connectivity, increase and becoming popularity of electrical operated vehicles and the planned railway electrification project etc. In this pretext it is clear that a strategic balance between the electricity demand and supply has to be maintained with a long term perspective. Considering this fact setting up new generation plants is very essential to support the shady economic growth.
The amount of energy consumed by each sector from 2004 to 2014 is shown in figure 2, while Figure 3 depicts sectorial electricity consumption share in 2014. These Figures reveal that the industrial and commercial consumption is more than the consumption in the domestic sector. This is a pleasing situation for an economy with ambitious GDP growth projections [17].

The average per capita electricity consumption in 2013 and 2014 were 519kWh per person and 535 kWh per person respectively. [1].

Table 1 - Sri Lanka power generation in GWh with production source from 2010 to 2015

Year / Production source	2010	2011	2012	2013	2014	2015	2016
CEB Hydro	4988.4	3972.6	2726.7	6010.0	3649.7	4904.4	3481.9
Thermal, CEB, IPP and Hired	5063.3	6884.0	8416.4	4819.7	7944.3	6796.4	9630
CEB Wind	2.9	2.6	2.3	2.3	2.1	1.6	2.1
New Renewable Energy	728.4	722.2	733.3	1168.7	1215.3	1466.0	1,157.8
Net-metered Projects	0	0	0	4.7	18.6	38	70.7
Off-Grid,	17.4	18.2	18.7	18.7	18.7	18	18.8
Gross Generation Sri Lanka	10800.7	11599.8	11897.6	12024.3	12848.8	13225.5	14361.3

Source: Sri Lanka Sustainable Energy Authority

Table 2 - Total Electricity Use Sri Lanka (GWh)

Year	2010	2011	2012	2013	2014	2015	2016
Total Electricity Use Sri Lanka (GWh)	9208.5	9989.9	10409.2	10554.5	10996.9	11740.9	12715.0

Source: Sri Lanka Sustainable Energy Authority

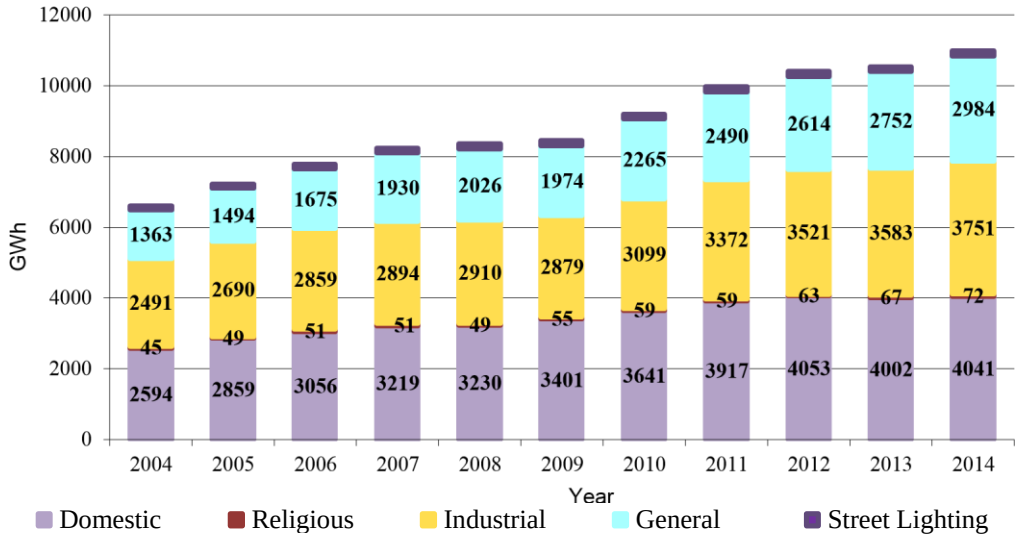

Figure 2 - Sectorial Consumption of Electricity (2004 - 2014)

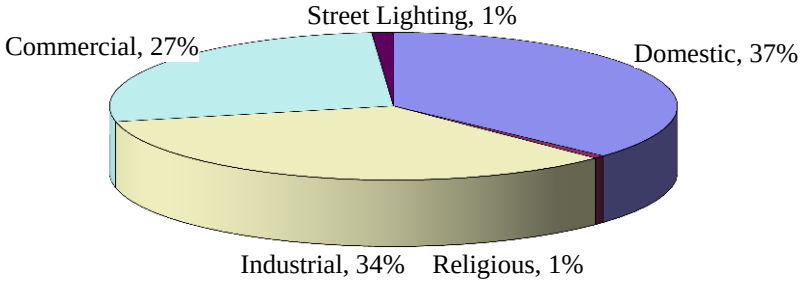

Figure 3 - Sectorial Consumption of Electricity (2014)

D). Key challenges faced by the Sri Lankan power sector

Below highlighted are some key challenges faced by the Sri Lankan power sector and should be proactively tackled to over come countries electricity crises.[4].

- Large investment required for generation, transmission and distribution and its infrastructure development.
- Technical challenges on grid balancing (now only balance through hydro plants)
- Very less number of researches carried out on promoting to local capacity development.
- Slow improvement on rooftop solar plant scheme due to lack of proper education on inverters / customers.
- Limited financial facilities for rooftop solar projects from commercial banks.
- As no solar panel or related equipment's are produced locally, the cost and amount of foreign exchange spend on equipment are high.
- Any variation in the climate pattern hardly hits Sri Lankan energy sector as largely depend on hydro power.

III. GLOBAL SOLAR POWER SCENARIO

Solar energy has rapidly becoming as an alternative energy source across the world due to low generation costs involved as a free natural resource, and the favourable environmental impact with no emissions and environmental degradation.

In past few years new interest has arrived to people's mind, about the use and effectiveness of the renewable power throughout the world. Greenhouse gases and environmental pollution show a continuous increment in quantity. Many countries are giving more emphasis on using environment friendly

renewable energy as their energy source. In 2013, approximately 19.1% of global total energy consumption was provided by renewable energy sources. With a significant progress in all the regions at the end of 2014, renewable resources have supplied 27% of world's total.

By continuing the development activity in solar power generation, USA and China have been able to present themselves to the top places in the world. According to the records as on 30-09-2015, the largest solar power plant in the world is "Solar Star" in USA with a 579 MW generation capacity. While India is installing their largest solar power plant named "Charaka Solar Park" aimed to generate 500MW at full capacity. "Longyangxia Dam Solar Park" is China's largest solar power generation plant with 320MW capacity. while Bangladesh is also rapidly expanding investments in this area with the aim to power 6 million households with solar power by 2018 [6].

IV. WHY SOLAR POWER IN SRI LANKA

Sri Lanka is located near to the equator, therefore receives an abundant supply solar radiation year around. Solar radiation over the island doesn't show a marked seasonal variation.

As estimated in the solar resource map developed by NREL of the USA, over most parts of the flat dry zone in Sri Lanka, which accounts for two-thirds of the land area, solar radiation varies from 4.0 – 4.5 kWh/m2/day[9]. But there are a number of factors that can affect how much electricity will generate from any solar panels installed[10].

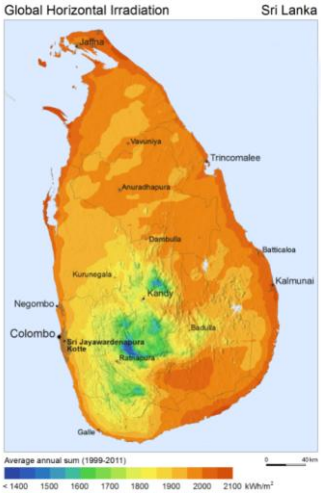

Figure 4 – Sri Lanka annual solar radiation (Source : solar resource map developed by NREL of the USA)

Generation cost comparison in first half of 2015 is given in table 3

Generation type	Generation in 2015 First Half – GWh	Average unit cost (Rs./kWh)
Hydro Power – CEB	2361	3.37
Thermal – CEB plants	3029	11.47
Thermal – Hired / Private	403	34.69
Renewable / Solar	607	16.97

Table 3 : Generation Cost- 2015 January to June
Source : Generation Performance in Sri Lanka - 2015

For any situation incorporating renewable energy within the electricity generation combined or mix to succeed in Sri Lanka, it's imperative that it address the challenges and deploy measures to mitigate them to the furthest extent possible.

V. BATTLE FOR SOLAR ENERGY (SOORYA BALA SANGRAMAYA)

The project "Battle for Solar energy" is a community based electricity generation program introduced to integrate the solar electricity generated in premises of electricity customers through rooftop solar panels to the national grid. This also can express as roof top power station project, every building whether home, industry, institution or commercial establishment can generate some solar power by installing PV panels on their roof tops. The maximum installed capacity is upon to contract demand of that particular customer. Ceylon Electricity Board will sign a contract up to 20 years with the customers who join this program. Studies reported that small solar power plants built on rooftops are highly beneficial. economical, environmental and social benefits can be specially achieved through rooftop solar energy power plants. .

A. Some key benefits aimed by "Battle for Solar energy" mission

- Rooftops small solar power plants are giving tremendous contribution to the balance of the electricity system which are scattered all over the island.
- Transmission and distribution losses are minimal as consumer and generator are close to each other.
- Not only multi-million companies, but also small scale entrepreneurs also can join the electricity production.
- When the customers of electricity have become the producers, their economy will be developed
- Because of these small scale electricity generation roof tops scattered across the island, it positively affect the security of the electricity supply.
- Because of this free source of solar energy, the foreign exchange spend on fossil fuels will be reduced.

- An additional income will come to the hands of the generators hands.
- Planned to add 200 MW to the grid by 2020 and upgrade to 1000 MW by 2025.
- Ability to reduce Carbon Dioxide (CO2) emission from thermal power plants to 1,50,000 MT
- Calculations show customer who joins this scheme is able to receive a monthly income of about Rs.300/= for the first 7 years after paying the bill and interest. Also Rs.2500/= monthly from the 8th to 20th year.
- A large number of direct and indirect jobs with the awakening occurred in this field.

In the mission "Battle for Solar energy" electricity customer has to pay back the loan amount within the first 7 years after the initial investment made for the purchase of solar panels to fix on their roof tops. Hence it is proposed to pay a higher rate for a unit of electricity during the first 7 years to cover their investment capital and the bank interest. For the period of next 8-20 years, it is proposed to purchase the generating electricity at a price offering a reasonable benefit for the customer for their investment.

If a customer has fixed a solar panel of 1kW on his rooftop, according to Sri Lankan climate conditions he can generate approximately 115 – 125 units per month. According to the proposed rate of payment, he would be able to get an income about Rs.2500/- 2700/- monthly. If the customer had taken a bank loan facility for fixing of solar panes, he has to pay about Rs. 2200/- monthly if the loan period is 07 years and the interest rate is 8% to 13%. According to the proposed payment plan, the consumers will be able to retain about Rs.300/- per month after paying off loan instalment, interest, and the cost of electricity consumption. If the loan scheme is more concessionary, the income level of the customer will be increased. After paying off the loan instalments in 07 years, they will be able to get about Rs.2500/- 2700/- monthly as a net income for a further period up to 20 years.

System Size	Space required	Approx. Cost with warranty* SLR	Approx. annual output
1 kW	7 sq. m (72 sq. feet)	300,000.00	1500 kW/h
2 kW	14 sq. m (144 sq. feet)	500,000.00	2900 kW/h
3 kW	21 sq. m (216 sq. feet)	750,000.00	4250 kW/h
4 kW	28 sq. m (300 sq. feet)	900,000.00	5600 kW/h

Table 5 – Solar investment and out come

* Approx. Cost with warranty conditions for the system
Solar Module : 25 years linear performance , Inverter and structure : 10 years
Source:www.jlankatech.com/, www.khmsolar.com/product-pricing.html, www.ceylonsolarpower.lk/

Considering all the benefits of battle of solar power mission and to supply the countries electricity requirement from green energy sources, ministry of power and renewable energy had decided to introduce and install one hundred thousand solar rooftops as a national programme in next ten years. Once complete this mission at least 18% of electricity to be produced by the electricity customers in Sri Lanka. Present, the generation of solar power at domestic level is mostly restricted among high income and upper middle class people. The reason behind that is the non-payment for the excess electricity customers feed to the network. To attract low income electricity consumers for solar energy mission, ministry had introduced some promotional schemes. Upon these promotion schemes ministry aims another twenty thousand low income families will become producers of electricity. It is expected to produce 200 MW by the year 2020 from the proposed project and increase it up to 1000 MW by the year 2025.It is proposed to setting up roof top power plants as much as possible on government buildings as a government policy. State owned banks and some related organisations offer their maximum cooperation for this program to its success.
Other than to roof tops some large scale solar power plants are setting up with private sector investment. Despite at least half a dozen private companies applying for development permits or working for photovoltaic and solar thermal projects [14].
First commercial scale solar power station was setup in Hambantota, known as Buruthakanda Solar park. The plant is owned and operated by the Sri Lanka Sustainable Energy Authority, a government owned organization responsible for the development of renewable resources in Sri Lanka. Buruthakanda Solar park power station was setup in two stages with generation capacity of 737kW in first stage with a cost of Rs. 1202 million, funded by the Japanese Government. Second stage with 500kW of generation capacity, cost Rs. 637 was funded by the Korean Government. [14]. A generation capacity of 20MW, with an estimated total investment of around Rs.5 billion was setup by LAUGFS Gas PLC, The plant is located Hambantota district[15].
Hatton National Bank head office branch generate 1.3MW of solar power while MAS Holdings unveiling of Sri Lanka's another large rooftop solar plant at the MAS Fabrics Matrix plant inside its Fabric Park in Thulhiriya with a capacity of 1

MW[18]. Another large commercial based at Wellampitiya by Expolanka Holdings PLC Group with 2326 solar panels, an energy production capacity of 651 kw**.**

VI SOLAR THERMAL ELECTRICITY PROCESS

Solar thermal electricity technologies turn out electrical power by changing the sun's energy into hot temperature heat using numerous mirror configurations. This is similar to on-site power plant and used to make electricity through traditional heat-conversion technologies. Solar plant made out of two parts. One collects solar energy and converts to heat, while another converts the heat energy to electricity

A. Solar cell

A solar cell is a semiconductor device that transforms daylight into electricity. Semiconductor material is placed between two electrodes. Free negatively charged electrons are discharged from the material, when sunshine reaches the cell. Which enabling conversion to electricity. This is the so-called photovoltaic effect. In theory, a solar cell made out of semiconductor material only can convert about 30% of the solar radiation energy it is exposed to into electricity. An efficiency of 5% to 12% on thin films and 13% to 21% for crystalline silicon based cells are commercially available in the market. Up to 25% efficiency level has been reached by the use of laboratory processes and some combined testing level multiple solar cells achieved efficiencies above 35percent.

B. Solar photovoltaics

Solar photovoltaic is a derivation from the combination of words. Where photo suggests the word light and voltaic suggests the word electricity. Highly-purified silicon materials are used as photovoltaic material that, converts sunlight directly into electricity

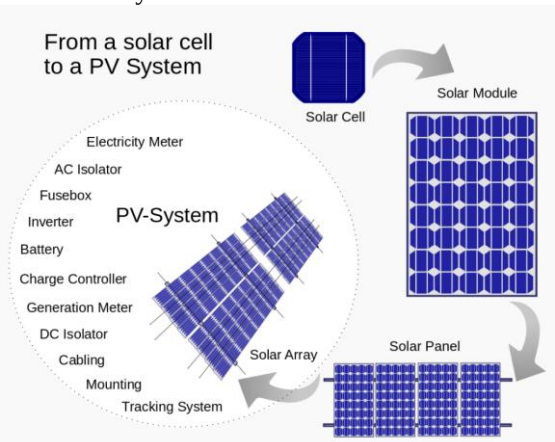

Figure 5 - From a solar cell to a PV system.
Diagram of the possible components of a photovoltaic system
https://en.wikipedia.org/wiki/Solar_cell

3. Annual output calculation in PV system
Formula given below is used to calculate the estimated electricity generated in a photovoltaic system.

E = A * r *H * PR
Where,
E = energy (kWh)
A = total solar panel area (sq. m)
r = solar panel efficiency(%)
H = average solar radiation absorbed by panel (per year, shading not considered)
PR = performance ratio

Performance Ratio one very considerable value when evaluating the quality of a photovoltaic installation. This gives the performance of the installation independently of the orientation, inclination of the panel. It includes all losses such as Inverter losses, Temperature losses, DC cables losses, AC cables losses, shading, looses at weak radiation and dust etc ...
Some calculated losses considered for the PR value is as below
- Inverter losses (4% to 10 %)
- Temperature losses (5% to 20%)
- DC cables losses (1 to 3 %)
- AC cables losses (1 to 3 %)
- Shadings 0 % to 80% (specific to site)
- Losses at weak radiation 3% to 7%
- Losses due to dust... (2%) and
- Other Losses (to be measured)

VI. ECONOMIC IMPACT

Sri Lanka totally depend on the import of fossil fuels as no fossil fuel deposits. This results in high unbearable import costs. Historically, Sri Lanka has to import 46% to 50% of its total energy used annually. This is a major burden on countries economy, which can be offset by shifting focus to renewable energy sources.[4]

A. Electricity and Economy

The growth rate of Sri Lankan economy and its electricity demand has most of the times revealed a direct correlation. Somehow the elasticity of electricity usage with respect to GDP is less significant in the recent past. Figure 6 shows growth rates of electricity demand with GDP for past ten years period.

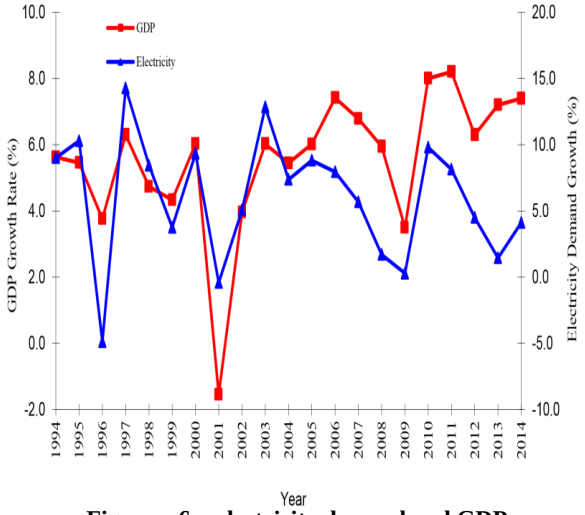

Figure – 6 - electricity demand and GDP
Source – Annual Report 2014 – Central Bank of Sri Lanka

B. Economic Projections

The Central Bank of Sri Lanka expects 8% average GDP growth rate in real terms in the four years from 2015 to 2018. The Central Bank GDP growth rate forecast is depicted in Table 5.

Year	2014	2015	2016	2017	2018
2013 Forecast	7.8	8.2	8.3	8.4	
2014 Forecast		7.0	7.5	8.0	8.0

Table 5 - Forecast of GDP Growth Rate in Real Terms

Source: Annual Reports 2013 & 2014, Central Bank of Sri Lanka

Accordingly the power supply also to be increased to fulfil the growth of the demand.

VII. ENVIRONMENT IMPACT

The impact of electricity generation on the environment could be due to one or several factors including: particulate emissions; gaseous emissions (CO2, SOX, NOX etc.); warm water discharges into lakes, rivers or sea; liquid and solid waste (sludge, ash); inundation (in the case of large reservoirs) and changes of land use. Though some of these are common to any developments, particulate and gaseous emissions are one of primary importance in the case of power generation using fuels. But when compare with solar energy systems pollution is far less compared to others. Although some toxic materials and human harmful products are used during the manufacturing process of solar photovoltaics, which can indirectly affect the environment. Nevertheless, solar energy pollutes is very less compared to other alternative energy sources. Hence, the power sector has so far contributed very little to greenhouse gas emissions. Since 1995 this situation has been changing in Sri Lanka.. Proposed expansion sequence predicts an increase in the thermal generation share to 65% by 2034 from approximately 48% to 55% share of present thermal generation. Hence, a substantial increase in the use of fossil fuels in the power sector seems inevitable.

VIII. ADVANTAGES OF SOLAR ENERGY

Solar energy obtained from the sun's radiation and it may be born-again to electricity or heat. It is freely offered and due to advances in technology, will currently harness even a lot of solar power that is continuously offered to us.

Here are most common benefits related to this renewable source of energy. Solar energy has smallest negative impact on our surroundings compared to other energy supplies used by us. It doesn't manufacture greenhouse gases and doesn't foil the water or water sources. It need very little or no water for its maintenance or services. No noise pollution in solar power generation is major benefit, as most of solar rooftop installations are in urban areas. Generating your own electricity means you'll be victimization less from the utility provider. This will in real time translate to savings on your electricity bill. Further provide a path to earn money by selling the unused electricity, back to the national grid. As long as there is sunshine, solar power is deployed from any location. This is particularly useful for remote regions with no access to other source of electricity. Some of the energy, around 3-5 percent**,** is lost during transportation and distribution. Energy losses directly depend on the distances between the production and the supply points, if the distance is longer more energy is lost. Having installed solar panels on the rooftops in regions with high population density or in the yard significantly minimize this transmission distance. Therefore small scale solar plants or rooftop solar generation increasing the efficiency of the electrical system.

Spread out many power plants ensure less blackouts. A grid with high penetration of solar energy has thousands of energy production stations which are spread out all over the country. This also can upgrade the security of the grid in overloading, either by natural or by human-caused disasters. A big part of the capital is associated with solar systems comes from the installation of solar panels. Solar rooftops contribute a lot to local job creation recently..

Out of few disadvantages to be considered are the initial cost of purchasing a solar system, its dependent on weather condition, sunlight to effectively gather solar energy and requirement of , lot space.

IX. CONCLUSIONS

Hence looking at all perspective side's along with future development of our country it is necessary to begin with small baby steps towards getting a clean source of energy like solar to achieve long terms goals with a clean, green environment for future generations. Along with active support from Government by way of friendly policy decision, subsidies. Also the corporate world can help under social obligation scheme. The support of NGO's would be a welcome step too. Least but most important we as the proud citizen's of our country it's our duty to conserve more electricity along with taking active participation in scheme's success for a beautiful, green and happy tomorrow

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