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ENERGY

Introduction

The whole world faces a daunting array of energy and environment related challenges with the increasing demand for products and services. Energy is the main driver of the development and the increasing energy demand is catered primarily by fossil fuels. Depleting resources of energy are responsible for much spoken environmental impacts.

The considerable growth in energy demand has number of implications both regionally and globally. In the coming decades the energy demand is expected to increase steadily among the developing countries. Although there is a pronounced shift away from nonrenewable towards natural gas and renewable; the energy demand barely rises in developing countries.

The international organizations on climate change highlights that the emission of Green House Gases (GHG) have grown at a higher rate, despite the variety of existing policy efforts and frameworks. Most of the governments are addressing climate change in the context of other national priorities. The policies to mitigate GHG emissions are extremely complex and arise in the context of many different integrated models which requires a diverse portfolio of policies, institutions and technologies. Integrated models identify three categories of energy system related mitigation measures; the de-carbonization of energy supply sector, final energy demand reductions, and the switch to low-carbon fuels. The final energy demand reduction targets are achieved through energy efficiency improvements, conservation and management where most of the countries have higher emphasis on energy efficiency than renewable energy (RE). The main sources of energy in Sri Lanka are renewables as biomass catering for thermal energy and large hydro for electricity generation. Socio-economic growth directly influences the demand for energy. The heavy necessity of imported fossil fuels affects directly on foreign reserves, as well as the economic development and the social and political stability of the country.

Less energy intensive economic development has been proposed to face the challenges for a sustainable development; energy security, environmental sustainability and inclusive socioeconomic growth. Covering the above three challenges Sri Lanka has set targets of achieving electricity generation using new RE, energy saving and reach 100% household which is 96% at present, thus contributing to the national goal of “Electricity for All at All Time” by 2020. With the increasing demand for energy to provide for the country’s economic and social development, total primary energy demand is expected to increase to about 15,000 KTOE(kilo Tonne of Oil Equivalent) by the year 2020 at an average annual growth rate of about 3%.

Over the next 20 year period, as the country’s GDP and the population are expected to increase, the final energy demand is projected to increase at an annual rate of 1.9%. Moreover, the other sectors including residential, commercial, agriculture and fishery will increase slowly while transport and industry demand will increase at a significant rate.

Although the economical exploitable quantity is yet to be estimated; Sri Lanka possesses with several energy minerals for nuclear energy. Moreover, Mannar basin is believed to hold more than 1 billion barrels of oil which needs an additional drilling to determine if the discovery was commercial. Sri Lanka is blessed with several energy resources including biomass, hydro, solar and wind while biomass is the main source of energy which contributes 43.5% of the primary energy supply. Other sources such as geothermal, ocean thermal and ocean wave are yet to be characterized and exploited.

As the interest in bioenergy has been renewed as an alternative for fossils, the government has declared plantation crops such as Gliricidia and some innovative plantation practices are being tested. Moreover, as an alternative to LPG, several innovative biomass cook-stoves for households are already available in the commercial market. Furthermore, 7000 biogas digesters are in operation mainly in suburbs and rural areas. Conversion of Municipal Solid Waste (MSW) into energy still has not materialized due to some technological and lack of awareness issues.

Large hydro power with a total installed capacity of about 1360 MW is the main electricity generation. Renewable source and grid electricity generation is based on the remaining sources namely small hydro, wind, biomass and solar which is primarily promoted through the projects of capacity not greater than 10 MW. Presently a total of 384MW has been commissioned. Nevertheless; the exploitation of RE resources (especially wind and solar) is limited by several techno-economic factors including constraints in national grid in absorbing RE based electricity, lack of dynamic modeling , lack of local capacity for manufacture, lack of R&D efforts and higher initial cost of new REs.

The energy management in the road transport sector is another key sector having energy challenges. Energy intensity in the transport sector is steadily increasing with the increase of individual vehicles in the fleet when compared to the public transport. Among the total number of 4 million vehicles on the roads, majority (52%) is motorcycles followed by three-wheelers and cars accordingly, while only 1% represents busses.

In conclusion, research and development will play a key role in making the required immediate interventions to manage the energy sector in Sri Lanka. In this study, the evaluation and prioritization methodology of R&D programs and interventions are carried out in line with Sustainable Assessment of Technology (SAT).

Sub Areas, Issues and Relevant Interventions

Table 1: Sub Areas and Justifications

Sub Areas/Sector	Justifications
(A) Indigenous Energy Resources and Technologies (Renewables, Nuclear, Fossil)	
1) Assessment of indigenous energy resources (RE, Fossil, nuclear)	Comprehensive information on energy resource maps/inventories is required, not only for energy planning at national / local levels and setting realistic targets, but also for identifying suitable locations for development of individual projects for optimum exploitation of resources and prioritizing them.
2) RE technology development for electricity	Electricity is the most versatile and cleaner energy carrier for the consumers and the use of RE for electricity generation could contribute not only for the energy security, self-generation and rural electrification but also to mitigate adverse environment effects associated with the use of conventional fossil fuels.
3) RE technology development for Thermal Energy	Thermal energy, generated through conventional methods, is the main end-use application in domestic, commercial and industrial sectors. Wide variety of improved RE resource-technology and process options are available as better alternatives to them. However, transfer of such technologies and adaptations are yet to reach acceptable levels. The deployment of RE technologies for thermal energy applications would help local industries to reduce the risk of price shocks due to both fuel price increase and currency depreciation.
4) RE technology development for Transport	Transport sector heavily depends on fossil fuels. Introducing RE based transport systems heavily reduce the importation of fossil fuels. Development of such systems is needed to be considered seriously in the country. Many initiatives and best practices could be seen in several other countries in this regard.
5) RE for other energy uses and non-energy services	In addition to conventional energy applications, RE could provide opportunities for much wider areas of interventions including generation of multiple products (energy, fuel, material – in case of biomass) or energy services (co-generation, tri-generation), non-energy services (e.g. water), etc., leading to more productive and efficient systems. Such approaches are receiving more attentions, particularly with new economic development models (circular economy).
6) Resource development	Development of RE sector depends critically on availability and sustainable supply of the resources (particularly biomass/biofuels and hydro). Interventions for resource enhancement are required for the long term sustainability.

7) Effective energy storage systems	Providing uninterruptable supply of power for small scale applications of wind and solar power, effective energy storage systems are needed. In case of grid electricity generation, the demand pattern (with evening peak and late-night valley) poses limits for absorbability of renewable energy. This also requires a storage mechanism.
8) National Electricity Infrastructure / Grid Architectures	Although abundantly available, wind and solar energy generation experience variability and location dependency issues. This causes a challenge to wind and solar energy generation. Therefore, optimum dispatch planning based on weather and resource forecasting, modelling and controlling are required to improve this.
(B) Energy Efficiency Improvements, Conservation & Management	
9) Domestic sector	Ever increasing cost of energy is affecting the quality of life of majority of the population, while significant energy wastage could be seen in the domestic sector due to use of inefficient appliances as well as use of appliances inefficiently. Therefore, energy efficiency improvements, conservation and management become vital in coping up with household energy budget.
10) Commercial and Industrial sectors	Energy efficiency of processes, plants & machinery, buildings, particularly life-cycle-analysis, RE options and waste management are not considered adequately in the development and management of businesses, industries and commercial establishments especially those employ energy intensive processes. Improved energy efficiency or reduced energy intensity is a fundamental requirement for enhancing market competitiveness.
11) Power sector	Energy efficiency improvements and loss reduction in generation, transmission and distribution of electricity are vital for the improved and satisfactory power sector performance (technical and financial), benefits of which can be readily transferable to all sections of the economy.
12) Transport sector	Transport sector is almost entirely depend on imported fossil fuels, and energy efficiency / fuel economy aspect of the transport sector has not been properly dealt with, resulting over-burden in relation to energy/fuel consumption and thereby to development sustenance. Degradation of mass transport systems, intermodal and non-motorized transports together with increased in private vehicle has led to high congestion and loss of resources. Immediate interventions are required to mitigate the adverse effects on the economy and environment arising from transport sector performance.
13) Energy Efficient Communities /Zones	More efficient use of energy and exploitation of RE resources are the basic approaches of sustainable energy driven economy, for which the power of community could be used in adopting holistic approach where public and private sectors make a collective commitment and work towards inclusive socio-economic development.
14) Smart metering	With smart metering and dynamic pricing the electricity demand of end user could be managed more efficiently.

Table 2: Issues/ Problems, R&D Needs and Relevant Interventions

Sub Areas	Issues/Problems	Research and Development Needs	Relevant Interventions
(A) Indigenous Energy Resources and Technologies (Renewables, Nuclear, Fossil)			
1) Assessment of indigenous energy resources	I) Lack of indigenous RE resource maps/inventories	i) Development of hydro, wind, solar and biomass resource maps, inventories, road maps	**Policy Studies** a) Policy interventions for RE road map with long term targets **Pure and Applied Research** a) Development of RE resource maps, inventory and roadmaps **Information and Communication Technologies** a) Integration of ICT for resource measurements and mappings **Capacity Building** a) Capacity building on modelling/simulation
	II) Inadequacy of information on local fossil fuel resource availability	i) Conducting geophysical surveys for fossil fuel (Gas & Oil) exploration	**Pure and Applied Research** a) Conducting relevant geophysical surveys (gravity, gravity radiometric, magnetic, seismic)
2) RE technology development for electricity generation	I) Lack of technology developments for optimum exploitation of indigenous resources for electricity generation	i) Small hydropower developments: designing of low head small, micro, pico hydropower stations, and turbines & inverters locally	**Innovation** a) Establish small hydropower systems
		ii) Development of wind energy systems locally: design and manufacture of blades, off-grid wind turbines, PMGs, inverters.	**Innovations** a) Establishing wind energy systems locally

Sub Areas	Issues/Problems	Research and Development Needs	Relevant Interventions
3) RE technology development for Thermal Energy applications **RE technology**	I) Heavy dependency on biomass without resorting to efficient cleaner sources such as liquid biofuels and biogas especially in the rural sector	i) Designing of improved/efficient biomass cook stoves – ICSs (both direct combustion and gasification for domestic and institutional applications)	**Pure and Applied Research** a) Design and development of efficient biomass cook stoves (both direct combustion and gasification) **Popularization** a) Commercialization of improved/efficient biomass cook stoves
	II) Slow transfer and adaptation of internationally available renewable resource based thermal energy systems	i) Design and development of biomass direct combustion furnaces and kilns for high temperature industrial applications (including fuel-switching for conventional fossil fuels) through transferring of international available relevant technologies	**Pure and Applied Research** a) Development of technologies for fuel preparation, conversion and emission control **Innovations** a) Development of innovative technologies and processes for fuel preparation, conversion and emission control **Capacity Building** a) Capacity building on modelling/simulation **Popularization** a) Dissemination of information on RE resources

Sub Areas	Issues/Problems	Research and Development Needs	Relevant Interventions
development for Thermal Energy applications (contd.)	III) Inadequate exploration of RE resources and technologies for processing of agricultural and food products	i) Development of solar air collectors for low temperature industrial applications (e.g. drying / dehydration of agricultural and food products)	**Pure and Applied Research** a) Design and Optimization of solar air heaters for different products **Innovation** a) Introduction of innovative concepts / configurations for better performances of solar dryers **Indigenous knowledge and Intellectual Property Rights** a) Study on traditional knowledge / best practices on solar drying technologies **Testing, standardization and Accreditation** a) Development of code of practice for solar dryers **Capacity Building** a) Training on design, fabrication and operation of solar dryers **Popularization** a) Dissemination of information / technology demonstrations
RE technology		ii) Development of biomass driers (direct / indirect) for low temperature industrial applications (e.g. drying / dehydration of agricultural and food products)	**Pure and Applied Research** a) Design & optimization of biomass driers for different products **Innovations** a) Introduction of innovative concepts / configurations for better performances of biomass dryers **Indigenous knowledge and Intellectual Property Rights**

Sub Areas	Issues/Problems	Research and Development Needs	Relevant Interventions
development for Thermal Energy applications (contd.)			a) Study on traditional knowledge / best practices on biomass based drying technologies **Testing, standardization and Accreditation** a) Development of code of practice for biomass dryers **Capacity Building** a) Training on design, fabrication and operation of biomass dryers **Popularization** a) Dissemination of information / technology demonstrations
4) RE technology development for Transport Applications	I) Heavy dependency on imported fossil fuels in the transport sector II) Inadequate emphasis on alternative transport fuels / technologies in transport planning III) Lack of technology road map / targets in the transport sector IV) lack of integration of research outputs for policy making	i) Development and promotion of biofuels for transport applications: biodiesel and ethanol - feedstock, production, processing and blending	**Innovations** a) Develop biofuels for transport applications: biodiesel and ethanol
		ii) Development and promotion of biofuels for transport applications: Biogas – feedstock, biogas cleaning, storage/ distribution	**Innovations** a) Develop biofuels for transport applications: Biogas
		iii) Development of Solar, wind, small-hydroelectricity based charging stations and networks to promote use of electric/hybrid vehicles iv) Development of road map for transport sector	**Innovations** a) Development of Solar, wind, small-hydroelectricity based charging stations and networks **Policy Studies** a) Policy interventions for the development of transport sector road map

Sub Areas	Issues/Problems	Research and Development Needs	Relevant Interventions
		v) Incorporation of research outputs for policy making	b) Formulation of policies incorporating relevant research outputs
5) RE for other energy uses and non-energy services	I) Overlooking the Potential of advanced energy systems (e.g. co-generation, tri-generation, thermo-electric generation)	i) Design of modern high efficient biomass energy conversion technologies for commercial and industrial applications (e.g. cogeneration, tri-generation)	**Pure and Applied Research** a) Research on modern high efficient biomass energy conversion technologies for commercial and industrial applications
6) Indigenous resource development	I) Lack of sustainable supply of resources for RE	i) Development of fuel-wood plantations and management systems (species, plantation practices - intercropping / under-cropping)	**Policy Studies** a) Policy interventions on land-use planning for promotion of biomass **Pure and Applied Research** a) Development of sustainable plantation management techniques with high productivity for sustainable supply of biomass for generation of RE **Innovations** a) Innovations in plantation management for optimum economic output **Biotechnology** a) Application of biotechnology for fuel-wood plantations **Indigenous knowledge and Intellectual Property Rights** a) Exploration and adaptation of indigenous plantation management techniques

Sub Areas	Issues/Problems	Research and Development Needs	Relevant Interventions
			Testing, standardization and Accreditation a) Development of standards for sustainability criteria for bioenergy **Capacity Building** a) Training on sustainable plantation management techniques **Popularization** a) Popularization of sustainable fuel wood plantation techniques
7) Effective energy storage systems	I) Difficulties in absorbing renewable energy resources (wind and solar) due to the electricity demand pattern of the national grid (with evening peak and late-night valley) II) Lack of low cost and efficient options for storing electricity when production exceeds demand and using it during peak-demand periods	i) Feasibility study and design of pump storage systems for large-scale grid electricity storage (both dedicated reservoirs and modified existing reservoir systems)	**Pure and Applied Research** a) Conduct a feasibility study and design of pump storage systems for large-scale grid electricity storage
		ii) Development of advanced battery technologies for medium and small scale grid energy storage (Ni-Cd, Lithium-ion, Sodium-sulphur, Sodium-Ion)	**Innovations** a) Develop advanced battery technologies for medium and small scale grid energy storage
8) National Electricity Infrastructure / Grid Architectures	I) Intermittency, partial unpredictability, location dependency, demand fluctuations in wind and solar electricity generation	i) Design and optimization of national grid with mix of central and distributed generation system for grid integration of Res	**Pure and Applied Research** a) Conduct research on Design and optimization of national grid with mix of central and distributed generation system for grid integration of Res
		ii) Development of advanced electricity generation and supply & demand forecasting tools for	**Pure and Applied Research** a) Advanced supply and demand forecasting tools for optimum grid integration of RE

Sub Areas	Issues/Problems	Research and Development Needs	Relevant Interventions
		optimum grid integration of Res	
		iii) Design of dynamic modelling tools for optimal electricity dispatch for grid integration of REs	**Pure and Applied Research** a) Development of dynamic modelling tools for optimum electricity dispatch for grid integration of RE **Innovations** a) Introduction of innovative concepts for optimum electricity dispatch in grid-integration of RE **Information and Communication Technologies** a) Effective use of ICT for optimum electricity dispatch in grid-integration of RE **Capacity Building** a) Training on dynamic modelling and optimum electricity dispatch
(B) Energy efficiency improvements, conservation & management			
9) Energy conservation in the Domestic sector	I) Lack of local development of energy efficient appliances	i) Design and manufacture of energy efficient lighting products and appliances locally	**Pure and Applied Research** a) Design and Develop energy efficient lighting products and appliances locally
		ii) Design, manufacture of energy efficient LPG stoves and burners	**Pure and Applied Research** a) Design and develop energy efficient LPG stoves and burners
	II) Inability to control marketing of energy inefficient household	i) Development and enforcement of energy efficient labelling of	**Policy Studies** a) Development of energy labelling regulations

Sub Areas	Issues/Problems	Research and Development Needs	Relevant Interventions
	appliances	appliances in the domestic sector (Lamps, A/Cs, Iron, Cookers, Refrigerators, Pumps, Washing M/C)	**Pure and Applied Research** a) Formulation of criteria for the estimation of energy performance of appliances **Testing, Standardization and Accreditation** a) Development of testing standards and accreditation of testing facilities **Popularization** a) Popularization of energy efficient appliances
10) Energy conservation in the Commercial and Industrial sectors	I) Lack of due consideration of energy efficiency of processes, plants & machinery, (e.g. life-cycle-analysis) in the development of businesses, industries and commercial establishments that use energy intensive processes	i) Formulation of mechanisms for the promotion of low energy-intensive processes, plants and machineries (such as energy labelling of equipment)	**Policy Studies** a) Policy formulation and introduction of mechanisms for the promotion of low energy-intensive processes, plants and machineries
	II) Lack of systems for waste energy/material recovery and reuse	i) Design and development of waste heat recovery and utilization systems	**Pure and Applied Research** a) Development and commercialization of waste heat recovery and utilization systems
		ii) Formulation of regulatory procedures and design guiding tools for the establishment of energy efficient (EE) building envelopes (for both existing and new facilities)	**Policy Studies** a) Development of regulations for EE building envelops (both existing and new) **Pure and Applied Research** a) Development of energy performance rating schemes for buildings b) Exploration of innovative concepts for

Sub Areas	Issues/Problems	Research and Development Needs	Relevant Interventions
			enhancement of energy performance of buildings **Indigenous Knowledge and Intellectual Property Rights** a) Exploration of EE building concepts used in traditional buildings **Testing, Standardization and Accreditation** a) Certification and accreditation of EE / green building consultants **Capacity Building** a) Training programmes on EE building designs **Popularization** a) Awareness and popularization of EE buildings
11) Energy conservation in the Power sector	I) Inadequate energy efficiency improvement interventions in power generation facilities	i) Design, optimization and introduction of waste-heat recovery and utilization systems for power plants	**Pure and Applied Research** a) Conduct research on Design, optimization and introduction of waste-heat recovery and utilization systems for power plants
12) Energy conservation in the Transport sector **Energy conservation in the Transport sector (contd)**	I) Inadequate attention to energy efficiency / fuel economy aspects of the transport sector	i) Formulation of fuel economy standards for road vehicles	**Policy Studies** a) Development of regulations on fuel economy standards for road vehicles **Pure and Applied Research** **a)** Development of representative driving cycles covering strategic regions **Innovations** a) Development of innovative approaches for formulation of driving cycles

Sub Areas	Issues/Problems	Research and Development Needs	Relevant Interventions
			Testing, standardization and Accreditation a) Development of testing procedures and accreditation of chassis dynamometer testing facilities **Popularization** a) Popularization of fuel efficient vehicles
		ii) Development of less energy-intensive transport systems: Public transport systems, Bus rapid transit (BRT), Mass Rapid Transit (MRT)	**Policy Studies** a) Development of transport sector master plan promoting public transport systems **Pure and Applied Research** a) Impact assessments of public transport modes on fuel economy and other socio-economic aspects **Innovations** a) Development of innovative approaches in integrating mass transport systems to present infrastructure **Information and Communication Technologies** a) Use of ICT for optimum utilization of public/ mass transports
Energy conservation in the Transport sector(contd.)	II) Inadequate attention on Non-technical options for energy efficient transport systems	i) Development of Non-technical options (supply/demand management) and use of ICT	**Policy Studies** a) Development of policies for promotion of supply/ demand management **Pure and Applied Research** a) Impact assessments of supply /demand management interventions on fuel economy and other socio-economic aspects

Sub Areas	Issues/Problems	Research and Development Needs	Relevant Interventions
			Innovations a) Development of innovative approaches for supply/ demand management in transport **Information and Communication Technologies** a) Use of ICT for optimum utilization of public/ mass transports
	III) Lack of systems to promote inter-modal transport and non-motorized transport (NMT) modes	i) Development of less energy-intensive transport systems: Inter-modal transport systems	**Policy Studies** a) Development of policy interventions for promotion of NMT **Pure and Applied Research** a) Impact assessments of NMT on fuel economy and other socio-economic aspects **Innovations** a) Introduction of innovative concepts for best integration of NMT in present transport sector **Popularization** a) Promotion of NMT modes
13) Energy Efficient Zones / Communities	I) Inadequate attention to the development of energy efficient townships/urban communities	i) Development of mechanisms, guidelines and planning tools to establish energy efficient townships /urban communities (e.g. the concept of liveable cities)	**Policy Studies** a) Develop mechanisms, guidelines and planning tools to establish energy efficient townships /urban communities
14) Smart metering	I) Failure to implement end-user electricity conservation and management through advanced concepts such as smart metering and dynamic pricing	i) Formulation and introduction of pricing mechanisms / incentive schemes for demand peak clipping and valley filling, electric vehicle (EV) charging, and other demand	**Pure and Applied Research** a) Conduct a survey for introduction of pricing mechanisms / incentive schemes for demand peak clipping and valley filling, EV charging and other DSM initiatives.

Sub Areas	Issues/Problems	Research and Development Needs	Relevant Interventions
		side management (DSM) initiatives.	