On Outlines of Proposed Pilot Projects on Hybrids of Small-Scale Power Developments for Off-Grid Rural Electrification and Needs for Specific Research Topics to Address the Energy Poverty Problem in Ethiopia by Converting Abundant Renewable Energy Sources

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Abstract: The paper presents outlines of proposals for needed pilot projects on hybrids of small-scale initial power as development centers in rural areas of Ethiopia where over 75 per cent of total population lives. The conceptual schemes are based on two aims, namely: off-grid rural electrification, and also on research topics to address the Energy Poverty problem prevailing in the country. One goal is to propose enabling rural communities with off grid electrification for the many non-electrified farming and pastoral populations with rising demands for leapfrogging towards electrification. Secondly, the aim is to provide topics for energy research activities for national capacity building with innovative skills to develop the plentiful but still largely underutilized renewable energy sources of the country, except for the depleting biomass traditional energy resources. One renewable energy source being considered is the abundant wind energy (with wind speeds greater than 5 m/s at 10 m above ground) in the high and low altitudes of the country with a total area of 1.14 million square kilometers. Then, there is also plentiful solar energy for installations of photovoltaics (PVs) with incident power density ranging from 500 to 1,000 watts/m² and providing solar irradiation of 4.5 to 6 kWh/m²/day over many months in a year. If water resources are also available at sites, small-scale hydropower generations will also be included in the envisioned combinations of power schemes. The mixed power projects are being recommended initially to be based on 3-kW to 5-kW power capacities for schools and community or health centers, to be upgraded later to larger power units to provide energy requirements for domestic needs and productive activities. Both proposals are directed at knowledge and information sharing, and technology transfer with basic understanding of costs and funding sources. Parallel with the growing national interconnected grid system, there can thus be affordable and viable options for installing reliable off-grid sub-networks. Then, Ethiopia will also be able to implement policies and strategies to overcome the unfortunate and repeated droughts that have been plaguing the country repeatedly. The specific energy research topics are targeted at overcoming strategically the Energy Poverty problem so as to at least attain partially access to electrification as envisioned despite known and unknown barriers.

Key Words: Off-Grid Rural Electrification in Ethiopia; Energy Poverty; Small-Scale Renewable Power Hybrids; Research Topics on Renewable Energy Sources; Building Innovative Skills.

I. Introduction to Proposed Outlines

1.1 An Overview of Needs of Energy of Development in Low-Income Countries

Modern energy, work and power have been the key foundations and main tools for the survival, progress and advancements for all agricultural, industrial and socio-economic activities as well as for overall growths in human history in every continent, country, city and many villages.
History of human life clearly demonstrates that key and needed progresses were strategically introduced particularly after the decisive socio-economic transformations were achieved with and after progresses of the industrial revolution. Then significant transitions were made in the developed world from dependences on traditional biomass energy sources with transitions to coal, fossil fuels and electricity, notably after advancements from the 16th to the 19th or early 20th centuries. The planned and sought strategic industrial advancements were introduced and implemented and rapid transitions and were strategically made to move fast in producing and exploiting huge energy notably after generation of electricity in the late 19th century and early 20th century. However, Low-Income (or Least-Developed) Sub-Saharan African (SSA) countries are still facing the severe Energy Poverty problem or situation that is hindering the vitally needed advancements to reduce economic poverty. The situation is familiarly or universally characterized particularly in rural Ethiopia by lack of electrification and huge gaps in access to modern energy services and technologies. This is so despite the availabilities of plentiful renewable energy sources comprising hydropower, wind and solar energies as well as geothermal energy potentials. Beyond average human capacities, and in direct relationships to economic and productive activities, the utilizations of energy sources for modern productive services and activities have indeed been the deciding factors behind the fast advancements of all developed economies. In terms of SI (System International) units, energy is measured in joules, which is equal to newton (force) times meter (distance) or kilogram times meter squared over second squared. So, by energy is meant the capacity to do work after conversions from different sources including potential energy, motion, lighting, heating, chemical compositions, electromagnetic energy, photosynthesis and electricity. Then power (measured in watts or joules per second (joules/s)) and equal to volts joules/coulomb times amperes (coulomb/time), which is the time rate of change of energy or work, irrespective of the source of energy, i.e. whether is it is renewable energy, a fossil fuel, a lead acid battery, a photovoltaic panel, a steam driven generator or a wind turbine. The standard power unit employed in all electric power systems are the kilowatt (1 kW = 1,000 watts) and the megawatt (1 MW = 1,000,000 watts), and the standard energy is the kilowatt-hour (with 1 kWh = 3,600,000 joules = 3.6 mega joules). Then levels or volumes of energy consumptions determine the extents and paces of economic developments and production activities in any country. After energy conversion into electricity, electric current flows continuously in amperes (or coulombs/s) as trillions of free electrons flowing in copper, aluminum or steel alloy conductors. Electric potential differences or voltages (in joule/coulomb) provide power to the energy or power technologies or loads to be connected to the supplies range from the incandescent or compact fluorescent lamp, wire heaters, water pumps, motors and all types of communication systems.

Modern, reliable and efficient interconnected electric national grids are the timely visions for most Low-Income (or Least-Developed) Sub-Saharan African (SSA) countries like Ethiopia. In the intended process, key lessons and successful experiences in building modern energy systems will have to be learnt from the millions in the Newly Industrialized countries in Asia. Still, in parallel smaller distributed off-grid networks for dispersed rural communities with viable, affordable and reliable generating plants are also being recommended in the proposed outline. In rural Ethiopia, significant progresses are envisioned to be reached towards to over 25 % of national electrification with hybrids of small-scale power projects by developing abundant reawables energy sources. Lessons will also have to be learnt fast through specific research activities and strategic insights and visions as proposed in the Outlines presented below in Sections II and III.
1.2 Rationale and Basic Justifications for the Proposed Outlines

International energy consultants, associations and financing organizations are providing advice and guidelines that the Energy Poverty problem facing all Low-Income SSA countries will need to be addressed fully by local initiatives with serious research efforts. Possibly, additional thoughts could also be given about the benefits and impacts of initiating purposeful energy development centers at convenient rural sites. As envisaged by IDRI, the proposals for small-scale hybrids of off-grid rural electrification projects and specific energy research topics in Ethiopia will have the rationale and five basic justifications as summarized below:

- First and foremost, there are pressing needs to have knowledge and information sharing about the 3,000 years old wind turbines which are still new to Ethiopia, and also about the fast growing and 50 to 70 years old photovoltaics.
- Secondly, there are key technologies and control mechanisms that have been added since the start of electric power generation with wind turbine generators since the late 19th century.
- Thirdly, it will be most beneficial if both renewable energy researchers and representatives of rural community organizations could be cooperatively engaged in small-scale power advancements and developments.
- Fourthly, as envisaged by IDRI, capacity building with innovative skills will be built and strengthened among rural communities if and only if the needed expertise is locally built.
- Fifthly, with visions and strategic insights, supported by policies, plans and specific programs, then the Energy Poverty problem facing rural Ethiopia can be surmounted.

1.3 Brief Introduction to and Summaries of the Proposed Outlines

With ongoing and future electric power developments, Ethiopia's economy is assuredly growing fast by implementing policies urgently needed for socio-economic transformations. Industrial growths and urbanizations are growing fast because of increased power generations. Located with neighboring countries in the Horn of Africa (HOA) over mostly highland and some low land altitudes and based on average climatic and weather conditions, the country enjoys regular rainy and dry months in a year. However, due to low paces of electrification and serious gaps in acquiring access to modern energy services and technologies, the rural communities are also in need of electrification in order to overcome economic poverty and to secure job creations for increasing youths. The country’s rising national population will definitely soon exceed 100 million by 2018, and it will continue to grow at 2.5 % per year. For both economic and technical reasons, the proposed option is being envisaged for definitely enabling the country in overcoming and addressing the long inherited prevailing Energy Poverty situation being continually faced within a relatively shorter period, preferably well before 2035.

Based on strategic insights for sustainable progresses, IDRI, Insight Development Research Institute, a non-profit private energy research and development organization in Ethiopia, is therefore presenting outlines of proposals for urgently needed hybrids of small-scale off–grid electrification in rural Ethiopia, and also for seriously pursuing energy research topics. This endeavor is being focused on launching pilot projects on off-grid rural electrification, and also for urgently needed research topics on developments of renewable energy sources of the country. The outlines are being envisioned to be undertaken as extensively as possible in close cooperation among and with interested national academic universities, institutions and growing research centers in Ethiopia and international energy organizations.
Among many other strategies and programs for development, the main aspirations of IDRI have been to promote national needs to address the reduction of the unyielding Energy Poverty problem prevailing in all Low-Income (or as commonly referred to as Least-Developed) Sub-Saharan African (SSA) countries including Ethiopia. Again, as well-known and fully recognized, the Energy Poverty problem is undoubtedly and fundamentally due to lack of electrification and with huge gaps in access to modern energy services and technologies. The missing amenities typically include absences of electric lighting using even with the old but now relatively inefficient incandescent lamp, as well as heating, water pumping and trading activities. Simple forms of mechanical power for water pumping, and energy for basic telecommunication services are yet mostly none existent among vast rural communities in Ethiopia, with settled or traditional farmers and pastoralists. In Section II and Part One of the Proposed Outlines, IDRI is envisaging and proposing Hybrid Pilot Power Projects by harnessing wind, solar and other available renewable energy sources in initial power capacities of 3 kW to 5 kW. As it is being done successfully in North and South African countries, elsewhere in principle 100 % electrification could also be planned for Ethiopia. However, as carefully seen by IDRI, Energy Poverty is indeed the major barrier standing against reduction of deep-rooted national economic poverty and very slow socio-economic transformations in the country. The Growth and Transformation Plan of Ethiopia for the ten-year period from 2015 to 2025 is aimed at raising the country to a middle class-income level. Accordingly, the growth of the interconnected grid electrification is also to be extended from 2400 MW to 17,400 MW and to cover 75 % of the national electrification strategy. Possibly, the remaining 25 % of national electrification can be envisioned to be supplied with hybrids of small-scale wind and solar power developments for off-grid electrification of villages among dispersed farming and pastoral rural communities. In Section III and in Part Two of the Proposed Outlines, a summarized version of Specific Renewable Energy Research Topics are outlined to advance energy developments in Ethiopia. Interrelated energy research topics are identified and recommended for addressing and seeking solutions to lack of electrification and access to modern energy service with technologies in rural Ethiopia. The fundamental problems will need to be solved by harnessing the plentiful renewable energy sources of the country despite technical and economic barriers to be overcome and financial challenges to be surmounted. Still, as being universally recognized, in the 21st century Energy Poverty is exceedingly prevalent among Low-Income or Least Developed countries in Sub-Saharan Africa (SSA) countries, including Ethiopia. There are known and unknown barriers with bottlenecks to be overcome, and with massive financial and technical challenges to be surmounted. Still, IDRI is strongly recommending that Through Strategic Insights supported by dedicated research and development activities, the needed advancements could be implemented. Most of the outstanding hurdles and obstacles can and will need to be first cleared fundamentally and broadly uprooted at many levels of desired economic structures. In Section IV, in the Closing Remarks on the Prospects of and Opportunities for the Proposed Outlines, interrelated summaries are presented on key and fundamental issues that are the bases for research on energy development in overcoming the Energy Poverty problem facing the country. Finally, Section V of the Proposed Outlines provides Key Sample References on interrelated contributions by different authors in various publications. Focus is laid on research and activities on renewable energy resources in Ethiopia and also on studies of the Energy Poverty situations in Low-Income (or Least Developed) counties. 

II. Part One: On Proposed Outlines of Needs for Off-Grid Rural Electrification with Small-Scale Hybrids of Renewable Power Projects in Ethiopia

2.1 Background to Vast Gaps and Slow Growths for Rural Electrification in Ethiopia

With all other Low-Income SSA countries (with a total population of 550 to 600 million), electrification in Ethiopia is seen to be extremely slow and lagging by all standards set by international energy associations as well as by the financial organizations. While there are minimum
set targets set for 2030 or at the latest by 2050 for all SSA countries, and the challenge are being seen to be full of barriers and bottlenecks involving both financial and technical hurdles. Hopefully, there will also come soon new projects and initiatives for needy SSA counties supported by fair international loans and grants.

Partially similar to what is being done in all of the North and South African countries to achieve 100% electrification for their full populations, Ethiopia is also set on a plan that will be raise its national electrification from about 30 - 54% per cent coverage to a higher level of at least well above 75%.

The country is planning to become a middle-income earning country by 2025, with generating capacity to be raised from 2,400 MW (in 2016) to over 17,400 MW, and possibly going up to 25,000 MW by 2025. The major projects are of course the completion of the 6,000 MW GERD (Grand Ethiopian Renaissance Dam on the Ethiopian Nile River), which is over 70 percent completed by 2016, and another new 2,000 MW hydropower plant also to constructed soon. Then, a new 1,000 MW geothermal plant will also be started soon, with other plants to be built by harnessing additional hydropower plants as well as grid-integrated new wind farms and solar power plants.

As part of the ongoing energy research works being undertaken by IDRI, great attention has also made a review of the historical developments of electric power in Ethiopia the country since the end of the 19th century. In summary, key approximate dates are being found to be as follows:

- The earliest Electrification most likely introduced into Ethiopia under Emperor Minelli II parallel with the Djibouti to Addis Ababa Railway Line and the first installations in the country of the new world’s telephone-telegraph lines in the late 19th and early 20th centuries;
- In the early phases of Emperor Haile Selassie’s rule (1930-1935) when small-scale diesel generators were likely installed to install the first electrifications with diesel generators.
- During the partial five-year Italian Administration from 1936 to 1941, more electrification was introduced into the country, parallel with road constructions of the first small-scale hydropower generators on the Akaki River south of the City of Addis Ababa, and more telephone and telegraph routes were installed.
- After Ethiopia’s victory over the Italian invasion in 1941, and through the continuous reign of Emperor Haile Selassie up to 1974, the Koka I, II and III Hydropower Plants on the Awash River and the Finchaa Power Plant were constructed and fully commissioned.
- Diesel generators were also installed to provide electric power to many small urban centers far from the growing interconnected national grid of high voltage transmission lines and distribution sub-networks.
- Under the Workers Party of Ethiopia (WPE) and the Provisional Military Government of Ethiopia (1974-1991), growths in the power sector was also given full attention, and most notably the Melka Wakena Power Plant was newly built and Gibe I Power Plant was investigated,
- Since 1991, under the EPDRF, Ethiopian People’s Democratic Front, continuous growths of the country’s electric sector has been implemented so as to hasten speedy advancements and promotion of national socio-economic developments and poverty reduction,
- Including the complete construction of the Gil Gibe I Hydropower Plant, more new Hydropower Plants were built on Gill Gel Gibe II and III, as well as the Tana Belles and Tekeze Hydro Power Plants.
- Wind Farms for grid integration were also newly installed in Central and Northern Ethiopia, as well as the GERD Hydropower Project on ETHIOPIA’S Blue Nile River.
- As indicated above, within the 2015-2025 period, the GTP power projects will include all renewable energy sources of the country ranging from hydropower and including geothermal, wind and solar energies.
With energy conversion also by installing wind farms and the increased hydropower plants, it has been possible to raise rapidly Ethiopia’s power generating capacity from less than 400 MW in the early 1990s to 2,400 MW (in 20016) over two decades.

Again within the 10-year period 2015-2015, the power generating capacity of the interconnected national grid from plentiful renewable energy sources will be raised to 17,400 MW, and to exceed 25,000 MW.

Then, the electricity consumption level will also be raised from 200 kWh/capita/year to over 500 kWh/capita/year.

However, except for some initial or rather experimental proposals, there are only preliminary plans to raise extensively or comprehensively off-grid plants for the vast rural and remote electrifications for dispersed villages and rural communities in general.

2.2 Needs for Off-Grid Rural Electrification with Hybrids of Small-Scale Projects From Renewable Energy Sources in Ethiopia

Additionally, the IDRI Team therefore strongly recommends the following short strategies and power development programs for close review and considerations:

1. Launching Extensively a National Electrification Program Throughout Ethiopia with the Dissemination of Renewable Energy Technologies (D-RETs);

2. Promotion of rapid Rural Electrification with leapfrogging towards Access to Modern Energy Services and Technologies (A-MESTs) as in many other Low-Income countries including in the neighboring Horn of Africa (HOA); and neighboring HOA countries;

3. As per the IDRI’s Proposed Concept Paper for launching Pilot Projects or Development Centers with Hybrids of Small-Scale Renewable Energy Sources for Off-Grid Rural Electrification in the poor rural regions in Ethiopia facing severe Energy Poverty.

4. Approval and partial or full funding of the Proposed Concept will be sought from international energy associations and organizations in Europe, notably from the Wind Energy Association in Germany, as well as from the USA and Canada.

5. The supports of MIT, Massachusetts Institute of Technology Campaign for a Better World, and MIT-AFRICA will also be sought for guidelines, advice, project formulations and any possible partial funding provisions.

The Proposed Title of the hybrids power models is being recommended as: “Small-Scale Hybrids of Power Project Wind-Solar Hybrid for Off-Grid Electrification to Increase Access to Modern Energy Services and Technologies in Rural Ethiopia”.

Tested hybrids of the off-grid rural electrification schemes using the mix of small-scale wind and solar power units are urgently needed for rural electrification of schools, water pumping and basic electric power needs for various socio-economic applications.

The first recommended renewable energy is the plentiful energy throughout Ethiopia with wind speed of 5 m/s above 10 m above ground.

With air density varying from 0.95 kg/m3 to 1 kg/m3, conventional horizontal axis wind turbine generators with three blades of mounted 15m above ground, with average power coefficient within the range of 0.15 to 0.20 are being proposed.

The small-scale wind turbine generators with power capacities of 3-kW to 5-kW with diameters of 6.5m to 8.5m are to be mounted on towers about 15m above ground.

These are going new and relatively tall structures] for most rural communities in rural communities in Ethiopia, although wind power has been utilized outside Sub-Saharan Africa (SSA) countries for over 3,0000 years old.
Likewise, the slightly more costly solar PVs modules, panels, and small arrays can also be roof or pole mounted, or these can be also installed near ground surfaces.

Solar PVs, currently in 2016 about 70 years old, which were originally very expensive for rural electrification in SSA countries, are now being becoming affordable and viable sources of DC electricity which can be converted into AC with inverters.

With 40-W modules or larger modules, and expecting an insolation of 1,000 W/m² with an efficiency of 15 percent for 5 hours in a day giving a minimum irradiation of 5.5 kWh/m², again the envisioned 3-kW to 6-kW PVs panels or arrays can be installed.

Subject to availability of water sources, micro, pico piezo hydropower sources could also be added to the hybrids of small-scale power sources for off-grid rural electrification for schools and community centers.

Then the Pilot Power Projects or Development Center can be expanded for households, bigger health centers and community with electrifications and access to modern energy services and technologies throughout Ethiopia to meet rural electrification for domestic requirements and basic productive activities.

Therefore the right conclusion that follows is that through careful Strategic Thoughts for Development and Visions, it is possible and necessary to address the extremely pressing needs in Ethiopia for urgently needed modern energy services and services. Then with Strategic Insights for Promoting Energy Development Centers, the Energy Poverty problem in the rural areas of the country will be successfully tackled. This will need to be done by planning seriously Advancements and Developments as being done effectively and successfully in a number of other Low-Income SSA countries in Eastern and Western Africa. And more successfully in the Newly Industrialized Nations in Asia.

III. Part Two: On Outlines of Proposed Research Topics on Needs for Focusing on Development Activities on Harnessing Underutilized and Plentiful Renewable Energy sources in Ethiopia

3.1 Needs for Specific and Planned Renewable Energy Research Activities to Overcome the Prevailing Energy Poverty Problem in Ethiopia

IDRI is strongly recommending to consider seriously the proposed interrelated applications and promotions of key issues to overcome known and unknown barriers and bottlenecks that are being faced in overcoming the Energy Poverty problem in Ethiopia. These range from upgrading the productive activities needed for poverty reduction and the enhancements for job creations through uses of modern energy services and technologies. The thoughts raised in both Parts One and Two of the presentation are aimed at close considerations of the supports between poverty reduction and energy provisions with electrification so as to have developments for all in the country. Needed socio-economic transformations and advancements with intermittent and still freely available Renewable Energy Sources like wind and solar energies are being strongly recommended despite natural intermittences. Besides, the costs of both wind technologies and photovoltaics are decreasing significantly fast for all Low-Income (or Least-Developed) Sub-Saharan African (SSA) countries, again, including Ethiopia.

For this basic purpose, research and development (R&D) activities on leapfrogging and advancing towards utilizations of the still unharnessed and underutilized renewable energy sources of the country are being recommended through: The R&D activities being proposed are on eight key developments, namely:

1. As outlined above, it is very essential to view closely the interrelationships between the Energy Poverty problem and lack of access to modern energy services and technologies

2. Planned and Proposed Research on Promotion of Dissemination of Renewable Energy Technologies (D-RETs);
(3) Research on Needs for Investigating Reliabilities and Performances onof Access to Modern Energy Services and Technologies (A-MESTs) in low-income or least-developed Sub-Saharan African (SSA) like Ethiopia and Neighboring SSA countries;

(4) Basic Research on Technology Transfer and Adaptations of International Standards for RETs;

(5) Proposed Basic Research on Developing Software for Studies on D-RETs and A-MESTs by taking lessons from USA/Canadian organizations and development institutions including the NRE, National Renewable Energy Laboratory in the USA. other Developed, Newly Industrialized, and Advanced Developing, as well as from successful experiences in other SSA countries neighboring Ethiopia; and


(7) Proposed research on upgrading aging parts of power system transmission and distribution networks and sub-systems into “smart grids” and aiming at modern and up-to-date control, communication and instrumentation components, including information, communication technologies and applicable computational, modeling and simulation algorithms and programs being done in many developing countries.

(8) It will also be extremely beneficial for Ethiopia's future Electric Power System to start with research work on preliminary and proposed development activities to upgrade the aging components and expand the growing system expansions into a “Smart Grid”.

As Renewable Energy Developers and Researchers, the researching IDRI Team on energy studies started in Ethiopia since the late 1980s, into the upgrading into the current IDRI in close cooperation with MIT’s Campaign for a Better World and MIT-AFRICA. The IDRI Team is then aspiring to continue with research activities on dissemination of renewable energy technologies (D-RETs). Then it will be possible to support faster access to modern services and technologies (A-MESTs) in order to launch the sought Pilot Projects of Off-Grid of Hybrids Research and Developments on Small-Scale Renewable Energy. These Energy Development Centers will contribute rapidly and reliably to Access to Modern Energy Services and Technologies in cooperation with Departments of Electrical and Computer Engineering (DECE) in interested Ethiopian Universities. The needed backing are seen to provide in particular clear directions and impetus for knowledge sharing and technology transfers in energy for furthering potential and actual contributions for poverty alleviation and economic welfare for counties facing energy poverty like Ethiopia and other interested counties in Sub-Saharan Africa (SSA).

Renewables (i.e. wind power, solar energy, hydropower and geothermal energy) are plentiful in Ethiopia and many other SSA countries. However, access to modern energy services and technologies still remains low and relatively limited in most of these Low-Income countries. With a population heading towards 100 million, annual per capita electricity consumption is estimated to be in Ethiopia within the range of 50 kWh to 75 kWh. Still, the country's renewable resources are plentiful. Currently, there are projects to raise hydropower generation from 2,000 MW to 10,000 MW, and developing wind power up to 400 MW, geothermal power generation from 7 MW to 70 MW, and Photovoltaic (PVs) arrays aimed at 300 MW, all for grid integrations. However, off-grid power generations for distributed semi-rural communities, and at smaller power scales are only beginning to be considered and envisioned at preliminarily reconnaissance or pre-feasibility stages. Also, Ethiopia is now and will be sharing its electric energy productions with neighboring countries in the Horn of Africa, where demand for increased power supply is also rising very fast.

Correspondingly, dissemination of renewable energy technologies (D-RETs) is practically unknown among the farming and other productive communities in Ethiopia. Notably, in a traditionally agricultural country, there are no visible uses of wind mills, photovoltaics, and hydro power units (e.g. even at peso and micro capacities).
The reliabilities of the country's existing and expanding interconnected grid system spread over an area of 1.0134 million square kilometers (and with a population exceeding 100 million by 2018) are also of serious concern for the growing number of potential consumers. There are thus research issues of concern regarding high power losses in the transmission grids and the aging distribution sub-networks. Besides, ongoing national strategies and projects for local assemblies of power system components will definitely benefit from relevant or appropriate research studies undertaken in line with international engineering practices.

3.2 Specifically Planned and Proposed Research on Promotion of Dissemination of Renewable Energy Technologies (D-RETs) in Ethiopia and the Horn of Africa

Working with the collaboration of interested Energy Researchers the scope of the planned and proposed dissemination of renewable energy technologies in less developed economies like Ethiopia will need to be carefully examined first. In the planned research work, focus will be laid on research activities related to:

(a) **Wind power developments** in both wind farms for grid integrations and off-grid distributed; applications for communities, with small–medium scale power units (<10 kW and 10 kW – 50 kW).
(b) **Solar Photovoltaics' (PVs) developments** with roof-mounted panels, and field laid arrays and simple tower mounts subject to:

(i) The availability of water flows with adequate heads, generation of hydropower for distributed farming and other productive activities;
(ii) Viable and affordable Geothermal electric power developments; and
(iii) Other Renewables and technologies that may have been found viable elsewhere.

(c) While the Co-Founder and Co-Director of IDRI has had extensive research work in links working with the World Wind Energy association (WWEA) based in Germany on windfarms for grid integrations, much remains to know about distributed wind power developments as achieved in Canada, the USA, Europe, Asia, South America, North and South Africa. Much more needs to be learnt from the successful experiences immensely accumulated in China, India and other newly industrialized countries. After all, although wind energy conversion method were first introduced and innovated, in Asia about 4,000 years ago, and later taken to Europe after the Crusades, the basic engineering methods had remained unknown in most SSA countries. Then, wind mills and wind generators were extensively used in North America. Could these earliest energy units after biomass—to-heat convertors have been easily adopted also in SSA countries, including Ethiopia? Yes, even if wind energy is intermittent, but air flow always available. Then, for the horizontal axis turbines, the rotors and blades with mechanical and electrical controls could also have been mounted on stable towers for mechanical/electrical power generation. Still there were basic challenges that had to be surmounted.

(d) Using mainly silicon solar cells or photovoltaics (PVs) (derived from sand, silicone oxide), the conversion of solar energy into electric power is obviously a more recent development, possibly hastened since the 1970s, and more recently in the 21st century. Per units of power (i.e. watts and kilowatts), PVs, had remained too expensive for applications in less developed economies like Ethiopia. Now, due to discoveries made (possibly in North America and China), the installation of PVs also appear to be viable and affordable in all developing countries. So installations of PVs in community centers like schools, clinics and water supplying locations appear to be economically affordable. Still, basic research is needed to arrive at definitive conclusions and recommendations. Accordingly, the Research Applicant is planning to undertake key investigations in this regard.

(e) The key RETs that have been eluding Ethiopia for too long have been utilizations of hydropower units of different capacities. A mountainous country with reasonably abundant rainfalls, a lot of electricity could have been generated using plentiful hydro power sources. These could have ranged from peso units of 1kW to 10 kW capacities; micro power units of 10 kW to 100 kW; mini hydro
power units of 100 kW to 1 MW capacities; small-scale units of 1 MW to 50 MW, and so on. Instead, the consultants working for and with financial organizations opted for small-scale and medium-scale capacities. The simple reason offered was that the issue of financial affordability at the country’s slow economic development had to be considered first. Recently, Ethiopia has been opting for higher capacities. Issues of environmental comparability and climate change could also be considered within the envisaged research activities.

(f) Research on the geothermal energy resources in Ethiopia have been undertaken by different investigators, including by the applicant. Above all, important lessons will need to be drawn from the successful experiences in neighboring Kenya. As indicated above, Ethiopia is also planning to expand its geothermal generating capacity from 7 MW to 70 MW. If time permits, and with available opportunities, more research work could be done on geothermal energy development studies in Ethiopia.

(g) Other Renewables that the IDRI Team had undertaken include basic research work on bioenergy conversion processes. As briefly mentioned above, recently, a research study was undertaken on electric power generation from bagasse-waste in sugar cane factories from combusted sugar cane. If successfully implemented, the basic research has shown that the Sugar Factories in Ethiopia could indeed export baby cogeneration from bagasse-based electric power to the national grid. In the process, there will be energy saving and controls of unwanted environmental impacts. If again time permits, it will be of interest to initiate a study on how urban/industrial wastes could be converted into generating useful electrical power.

3.3 Innovational Research Based on Investigating Reliabilities of Access to Modern Services and Technologies in Ethiopia

In the above indicated research activities, an Applicant Researcher will urgently need the support and guidelines to be kindly provided by energy research pioneers and any designated research associates from Ethiopian and international universities. There are a number of research issues to be investigated, among the key research topics being power loss reductions in medium voltage distribution sub-networks, instrumentation accuracies, and needs for introducing power line communication links. While power losses in the transmission grids, and distribution sub-networks are major research concerns, then also outage management and applications of control engineering with accurate measuring instruments will also need to be considered seriously. Severe power interruptions and shortages will need to be avoided and minimized. Hydro electrical power is the most significant contributor in Ethiopia with wind power generation also being advanced currently. Then, PV arrays and geothermal energy will be added soon. While severe power shortages have not been experienced, power interruptions do occur occasionally in different parts of the country. Ethiopia’s electricity consumption has been expected to grow over 25 per cent per year during ver the period between 2005 and 2030. The country stands to benefit from the ongoing hydropower projects and the other renewables as indicated in the Summary earlier. All power projects are aimed at raising Ethiopia’s economy up to middle class income level. Henceforth, power generation, transmission and distribution in Ethiopia will need to be made as reliable as possible, with reduced shortages, and with irregularities that will need to be avoided as much as possible. Accordingly, research activities will need to be promoted in this regard so as to surmount challenges that force unexpected power shortages.

Coupled with the above issues, inevitable environmental considerations will also need to be continuously researched upon around the major water reservoirs of Ethiopia. Accumulation of siltation in older dam reservoirs and possible water volume decreases limiting power generation will also need to be appraised using appropriate software programs. Similar appraisals must also be undertaken on the other renewable energy sources under differing weather conditions. Any irregularities in power supply will need to be explored by using software techniques, including
power interruptions due to aging or damaged and transmission lines cut. In any case, advice and
guidelines will be sought from interested international sponsors and promoters in undertaking the
planned and proposed research activities on improving access to modern energy services and
technologies, and effects on power generation and supply, including possible power capacity
reductions due to aging facilities.

3.4 **Recommended Basic Research on Adaptations of International Standards for Dissemination of Renewable Energy Technologies (D-RETs)**

Basic Research in Technology Transfers in Renewable Energy Technologies (TT-RETs) will need to be viewed as only one small fraction of what is urgently needed in SS countries in a long and complex leapfrogging process for socio-economic transformations, advancement and finally development. Still, if even successfully implemented and partially achieved, it will only be a portion of the sustainable development goals (i.e. as part of the Millennium Development Goals, MDGs) aimed at reduction of the prevailing underdevelopments and poverty facing SSA countries like Ethiopia. So, the challenge to be posed is whether the technologies needed to design or even possibly try to assemble or manufacture the simplest RETs (e.g. notably wind turbines) could be seriously pursued. After all, great technological developments have been achieved in the great giants of Asia (i.e. by China and India), which are now being called advanced developing countries. Useful lessons could also be learnt from similar experiences in South America, North Africa, South Africa, and the Middle East. So, the Research Applicant is proposing that some basic research on energy technology transfers could be initiated in this regard with the kind permission of the DECEs of Ethiopian Universities, subject of course to approvals by, and active participations by the Ethiopian Ministry of Science and Technology, and interested international Research and Development Institutions. Similarly, from research studies undertaken previously with the WWEA, one key issue constantly raised on wind power units in wind farms for grid integration has been the need for adaptation of international standards. Most likely, it could have been raised also by researchers in the DECEs in Ethiopian Universities. The key questions that need to be addressed are related to needs for gauging reliably of the performance characteristics of various wind power units within different wind speed ranges. Questions commonly posed relate directly to international standards that may have been stipulated to classify wind power specifications for possible comparisons and performance evaluations. If such concerns are seen to be unnecessary by research colleagues, the issue of aiming at international standards could be left aside for a while. However, it still appears that there are similar concerns for classifying standards for comparisons of performances of solar PVs modules, panels and arrays. Again, if the whole idea of international standards for knowing the needed international standards for various RETs is found acceptable, these will need to be made available by undertaking basic research works cooperatively.

3.5 **Proposed Basic Research on Mastering Algorithm and Software Modeling and Simulation Methods for D-RETS and A-MESTs Studies**

IDRI is strongly recommending that as part of the Research activities D-RETs and A-MESTs to include and be extended to apply algorithms and basic software models in investigating viably an affordably known lessons and experiences in dissemination of RETs and building modern power and electric energy systems. The needed lessons and ideas will preferably be relearnt from experiences in the USA, Canada and in the Newly Industrialized countries in Asia, as well as from the growing North African economies. It is being proposed that the needed software could be MATLAB-based or on any other equally useful computer programs. Further, lessons could also be adapted with innovations from the experiences and practices in other Developed countries (e.g. the USA, Canada or Europe), and from the Newly Industrialize and Advanced Developing countries in Asia, including also from successful experiences from the Republic of South Africa.
3.6 Proposed Research Activities on Upgrading Aging Parts of Existing Power System in Ethiopia

Ethiopia’s power system has been built over seven decades with 132-kV and 220-kV high voltage transmission and 15-kV distribution networks. There are also 45-kV and 66-kV sub-transmission networks, and recently 400-kV and 500-kV transmission lines have been added. The frequency of power generation is 50-Hz. It therefore definitely appears there are pressing needs to move towards “smart grid system” in which the aging and modern components are interlinked by modern and up-to-date control, communication and instrumentation components. This will include mastery and applications of information and communication technologies with applicable computational, modeling and simulation algorithms and programs. Serious initiatives have already been undertaken at consultancy levels and capacity building. The IDRI Team strongly recommends that the necessary steps be strengthened by adding research and development activities by taking lessons also from the experiences in North and South African countries, as well as from the relatively advanced experiences in the Newly Industrialized countries in Asia.

3.7 On Needs for Leapfrogging Towards A-MESTs and Addressing and Overcoming the Energy Poverty Problem in Ethiopia

Ethiopia’s population as of 2018 will definitely exceed 100 million with up to 75 per cent still residing in rural and peri-urban areas. After the completion of the 6,000 MW GERD project and a new +W Still, 2.7 billion people lack access to efficient and clean energy for cooking and heating, and 1.3 billion lack access to electricity; about 84% of this deprived population lives in rural areas of sub-Saharan Africa (SSA) or Southeast Asia. Recent technological advancements have shown that the costs of modern, sustainable energy services are not major barriers for the rural poor in the SSA countries. Yet, most SSA countries including Ethiopia will still need to prioritize their energy development strategies to bring about sustainable developments to growing rural populations.

3.8 Proposed Preliminary Research Proposals on Upgrading the Aging and Growing Ethiopia’s Power System Into a “Smart Grid”

Ethiopia has already embarked into serious considerations of upgrading its aging and modern growing power system into a “Smart Grid”. By a “Smart Grid” is simply meant a modern power system built with power systems of power generation, transmission and distribution networks interlinked closely with modern information communication technologies (ICTs), and reliable instrumentation infrastructures. in Ethiopia as a whole with an aging and growing interconnected grid power system, three is a pressing need for a “Smart Grid”. All system components will need to be aimed at enhancing efficient and reliable power performances with reduced or allowable losses. Then, in line with international standards, the instrumentation units and control groundworks will provide up dated data and continuous process performances to the full satisfactions of small, medium and large consumers throughout the country.
Still, the concept of a “Smart Grid” is still being seen in SSA countries including Ethiopia as being heavily challenging in many respects. Henceforth, IDRI strongly recommends that lessons be taken through research and careful investigations by at least taking lessons from different sources in North and South Africa and from the newly industrialized countries in Asia. While there are many challenges to be surmounted, IDRI strongly recommends that the applications of “Smart Grid” concepts for Ethiopia’s power system can be fast promoted fast and reliably if four key steps or paths are seriously considered for implementation as follows:

- First and foremost, the viabilities of and needs for a “Smart Grid” in a Sub-Saharan Africa like Ethiopia will need to be appraised preferably and very carefully based on a number of Master of Science Degree Thesis Programs offered by interested graduate programs in Ethiopian universities.
- Secondly, as outlined and proposed earlier, parallel studies are also seen to be undertaken in fully examining gaps and needs for updating and modernizing the instrumentation and communication of the aging and growing power system in Ethiopia by combing research and development activities with routine and standard operation capacities.
- Thirdly, the immediate and long-term benefits of information and communication technologies (ICTs) with advancements of computational capacities and data processing will need to be launched in a new Research center under the coordination or responsibility of Ethiopia’s Nation electric Power System.
- Fourthly, since the whole world of having reliable Power and Communication Systems is becoming critical and crucial in a fast developing economy to allow-Income SSA countries, then through advancements in Information Communication Technologies (ICTs). IDRI also strongly recommends that similar research and development activities will also be similarly launched for modernizing the communication System of Ethiopia.

4 Closing Remarks on the Prospects of and Opportunities for the Proposed Outlines

Within the scope of the planned and proposed research outlines as summarized in the above presentation, the closely interrelated energy research studies will need to be undertaken with visions, policies and plans with visions, strategic insights, policies and firm plans. However, as indicated earlier there are going to be known and unknown barriers to be overcome. Besides, there are also challenges to be surmounted in securing funds for developments among rural communities. In closing the prospects and opportunities for key addressing and resolving particularly the Energy Poverty problem facing Ethiopia and many other SSA countries can be summarized for careful review and serious considerations as follows:

- Ethiopia’s current population of nearly 100 million (i.e. for 2016-2018) will be growing at 2.5%, and therefore will exceed 122 million by 2025 at the end of the Growth with Transformation Plan (GTP) with set Sustainable Development Goals (SDGs).
- Then after the successful completion of the Millennium Development Goals (MDGs) by 2015, Ethiopia is launching as of 2016 the country’s urgently needed SDGs to raise the current power generating capacity from 240 MW to 17, 400 MW by 2025.
- Very soon, the GERD 6,000 MW Project on the Abbay River inside Ethiopia near the Ethiopia – Sudan border will be commissioned to benefit Ethiopia, Sudan and Egypt.
- There will be a new 2,000 MW Hydropower plant to be supported by a 1,000 MW Geothermal Plant, and additional Wind Farms, and possibly affordable and viable Solar Photovoltaics Plants, for all for grid integration.
- For the interconnected growing national grid, there are the transmission voltages ranging from 500-kV, 230-kv, and. 132-kV, and sub-transmission voltages of 66-kv and 45-kv.
- Then the 15-kV distribution networks are being installed throughout the country, with 380/220 low-supply voltages supplied to all consumers in Ethiopia at 50 Hertz.
The proposed small-scale power hybrids are seen to be operated at the low-voltage levels, and possibly at the distribution voltages, again to be operated at 50 Hertz frequency.

There will be the necessary AC/DC converters and DC/AC inverters to be reliably built also with elements of power electronics and control and automation mechanisms.

Access to modern energy service and technologies will include first and mainly leapfrogging towards electric lighting with the simplest electric bulb or inefficient incandescent lamp being replaced by compact fluorescent lamps for all rural communities.

Then, there are pressing needs for electric heating, water pumping, basic or most routine telecommunication services by schools and community centers, and workshop activities.

Current electricity consumption level of about 200 kWh/capita/year in Ethiopia will then be raised to over 500 kWh/capita/year and national electrification will be also raised to over 75 per cent throughout the whole country of 1.14 million square kilometers.

Very likely, the remaining non-electrified portion of less than 25 % in Ethiopia will be in dispersed rural communities and villages that can only be electrified with Off-Grid Hybrids of Small-Scale power generators using wind and solar energy sources.

The Outlined Proposals stress needs for knowledge and information sharing and fast energy technology transfers through capacity building for innovative skills with dedicated efforts both rural and partially urban community levels throughout Ethiopia.

Policy and decision makers as well as organized rural communities will need to be unfirmed about fast decaling costs per kW and energy costs per kWh of small-scale hybrids of renewable energy sources.

The needed innovative skills have been learnt successfully among developing countries in North and South Africa and the Middle East, and within the Proposed Outlines there will be opportunities to achieve also similar accomplishments within Ethiopia.

IDR also strongly believes that needed reliable advancements can be implemented with specific energy research activities that need to be initiated as soon as possible.

There are critical needs for both financial and technical supports with fair loans and grants at different scales, in particular for supporting the proposed energy research activities.

The starting points is seen to be a fundamental awareness creation of the numerous known and unknown barriers and bottlenecks that are permanently working against visions of opportunities for overcoming the Energy Poverty problem facing Ethiopia.

Based on extensive research work by IDRI, it is clearly being seen as the underlying cause behind lack of food and water securities, as well as adequate health services and job creation opportunities for productive activities in the country.

The major and most significant contributors to the heeded advancements in access to modern energy services and technologies in Ethiopia are seen to be:

(i) Political leaders, administrators and community leaders at all levels, and private small-scale business enterprises affirmatively interested in energy advancements;
(ii) University educators, teachers, theologians, historians and philosophers;
(iii) Scientists (i.e. biologists, chemists, geologists and physicists), as well as mathematicians and statisticians; and
(iv) Social workers, economists, accountants, managers, architects and engineers.

The proposed specific energy research topics are based on felt needs for extending the interconnected grid expansion in the country with built capacity and innovative skills to manage a modern and reliable power system for a fast national growing economy.
Then, Ethiopia will also soon be enabled to implement fully policies and strategies to recover additionally from the unfortunate and repeated droughts that have been plaguing adversely the economic progress of the country.

The energy research topics are all aimed at fully addressing fundamentally and strategically the Energy Poverty problem facing the country. Known and unknown barriers against needed advancements to access to modern energy services and technologies are seen to be significantly reduced throughout Ethiopia,

Definitely, there are opportunities and prospects for rural communities in Ethiopia and other SSA countries as being foreseen if timely supports with allowable loans and grants could be provided by international developers including the 2016 MIT President Professor Rafael Reif's New Development For a Better World, and the MIT-AFRICA.

5 Key Sample References on Interrelated Publications and Contributions in Energy Research and Studies on Renewable Energy Sources in Ethiopia and on the Energy Poverty Problem in General Facing SSA Countries by Different Authors

5.1 Reference Citations Focused on Developments of Renewable Energy Sources in Ethiopia


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5.2 Additional Sample References on Wind Energy, Energy Poverty and Developments in Ethiopia and Other Sub-Saharan Africa by Differed Authors


