Micro Renewable Energy Systems: Synergizing Technology, Economics and Policy

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Abstract **– This paper studies the technological, economic and public policy issues and opportunities in developing a renewable energy economy based on devices of less than 5KW , suitable for retail marketing. The research question is whether such systems can be popularized in the retail marketplace to the extent that families and non-governmental organizations will adopt them on a scale that substantially augments global renewable power generation. The reduction in efficiency of a MRES is discussed with regards to other more prevalent energy technologies and the numerous benefits that warrant further developments are presented. Five concepts using wind, solar, and biomass energy are considered, and of these, the symbiotic solar algae system is explored in detail. Its design, cost and impact are considered. Policy initiatives suggested.**

Keywords **– Micro Renewable Energy, Public Policy, Algae, Biofuel, Energy Efficiency**

I. INTRODUCTION

Micro Renewable Energy Systems (MRESs) refer to the group of systems aimed at generating < 5KwH of power or small-scale biofuel/biomass projects. These are usually individually or community owned and do not aim to compete with commercial energy projects. They function primarily to reduce or eliminate the dependence of MIRES users on commercial non-renewable energy such as gasoline and electricity from fossil fuel powered plants. Therefore the primary qualifying factor for a system to be a MRES is that it serves as a source of heat/electricity to a single user, be it an individual or a community.

Rising energy costs and the imperative to bring down emissions of greenhouse gases (GHG) demand that a substantial proportion of fossil fuel use must be replaced by clean renewable energy sources, in a short time. Policy makers all over the world are faced with planning how to make this happen. The default solution is to adopt designs for the largest plant units employing the most cost-efficient technology, and concentrate these at the best possible locations. This approach drives most nations towards nuclear plants, solar thermal plants, and large wind farms. These solutions have very high costs. Nuclear fuel is a limited resource, and in due course, nuclear energy customers will face the same price dynamics as those of petroleum and "Peak Oil". The prospect of using radioactive waste as fuel appears attractive, but is still a long way off. Nuclear fusion is an attractive long-term prospect, but again faces very high cost barriers. Solar farms are usually located on open barren land, and are probably the least intrusive on the environment. However, power generation is cyclic due to the day-night cycle. Wind farms are already running into community opposition due to noise and impact on birds.

The broader issue is that all these large-plant solutions incur delays, massive investments, and community disruptions. Two high-profile examples are the cases of the German government's drive towards wind power, and the delay in the ambitious off-shore mega wind power plant in the Gulf of Mexico off Galveston, Texas. Even in the best and smoothest scenarios, the time elapsed from project site selection to first power is on the order of years.

If micro renewable energy devices become popular enough for people to buy, the effect on energy independence can be dramatic. Developing efficient, cost-effective renewable power generators at the level appropriate for a single family, is a challenge at the leading edge of technology. Examples of such devices are as diverse as the Mars rovers that use solar power for locomotion and communication, and the new Honda Home Energy Station hydrogen generator associated with the FCX hydrogen fuel cell car concept.

The Dutch windmill of the 18th century is universally recognized, and represents a highly successful element of the European rural economy of past centuries. In aerodynamic terms, this device is very inefficient. The crude wooden blades operate on drag rather than the lift-based turbines of today. The rotor reaches barely above treetop level (there were not many trees around such windmills) and was at the bottom of the atmospheric boundary layer, thus getting only weak winds compared to today's tall towers. The stubby stone mill posed a large obstruction compared to today's slender towers. However, the devices worked. They delivered power directly to the point of use, and hence did not require conversion to electricity, or transmission through lines. The tower was integrated with the user's (very noisy) home. Most routine operations and maintenance were done by the residents, and related trades no doubt provided a stream of employment for locals. In this paper, we try to draw lessons from such systems, and see what can be achieved with today's technology.

The problem presently with MRESs is that they suffer from a lack of commercial viability due to the economies of scale and the reduced efficiency of power generation in small systems. MRESs suffer from lack of research funding, tax credits, grants, subsidies and other such incentives and methods of protections that are usually afforded to larger renewable energy projects.

II. Benefits of Micro Renewable Energy Systems

The benefits of a MRES are discussed in this section and Table I. Users generate their own heat/electricity/fuel and rather than buying these from a central/commercial body. In some cases, they may be able to sell off the excess to commercial entities. This increased individual and community participation in renewable energy leads to local job creation and favorably increases the approval ratings of renewable energy (people are less concerned by its cosmetic flaws such as the shape of the windmill or the land consumption of solar farms and more focused on its environmentally and monetarily beneficial effects). This in turn leads to an increased investment in all types of renewable technologies. A second advantage is that the power is generated locally, and to a large extent is independent of external commodity prices. Price stability is extremely important to rural economies. MRESs usually only require initial capital investment, so it is even more isolated from commodity fluctuations and ensures a long term source of cheap fuel/power. Local production eliminates the need for long distance transport of fuel and power, saving cost and reducing carbon footprint.

TABLE II

BENEFITS OF MICRO RENEWABLE ENERGY SYSTEMS

Benefit	Impact
Self generation of power/resources	Significant savings on utility bills. Source of additional income
Increased participation and ownership of renewable projects	Job creation More interest in and higher approval of renewable projects
Local production	Savings in transportation cost No uncertainty of disruptions in supply lines
New source of renewable energy funding	More technological advancements Ideal method of employing an untapped monetary resource
Independence from market fluctuations	Reduced risk of higher bills Price/Value stability

Another advantage of MRESs is the fact that it brings fresh investment into the renewable sector from a demographic which would otherwise not otherwise be heavily contributing to it. Individuals with money to invest would be more comfortable contributing to a local or self owned project as opposed to a large scheme where there is a lack of control or influence. There are not many avenues presently available to court small-scale investments into large renewable projects but their sum contributions to the renewable movement would be too great to ignore. To put it in perspective, 1% of the American population investing in a $300 MRES is an influx of 900 million USD into the renewable sector which otherwise would have no avenue of contributing to the renewable movement. This is equivalent to almost 40% of the budget requested for the DOE's renewable and energy efficiency programs [i].

III. Micro Renewable Energy System Examples in Development

In this paper we discuss five innovative concepts[ii] for micro renewable energy systems, along with the community features and public policy interplays involved in taking these to market success.

Micro Wind Turbine

Of the four concepts under development at the Micro Renewable Energy Laboratory, the vertical axis micro wind turbine is the closest to maturity. Wind turbines are generally classified as "horizontal axis" (the vast majority seen today), or "vertical axis". Horizontal axis turbines have a very mature analytical and usage experience base behind their design. It is easily shown that the larger the turbine, the more efficient it is, and this scaling has driven European designers to machines that are now rated at over 5 MW. Each of the 3 blades of such a machine, is considerably longer (more than 70 meters) than the entire wing span of the largest airliners of today. Each requires a massive concrete foundation and a tower large enough to get well above the disturbed air at the bottom of the atmospheric boundary layer. Such machines are projected to achieve the goal of $1 per installed watt, but currently seem to be costing about twice that much per informal reports.

When the machine becomes small, its aerodynamic efficiency is poor for various reasons, low Reynolds number, low inertia and the low, fluctuating wind speeds available near the ground being part of the reasons. The cost of the non-power-extracting components becomes a larger part of the total, so that the cost per unit installed power becomes high.

In this regime, we project that the vertical axis machine can be made competitive through research. The blades of this machine encounter a large periodic fluctuation in aerodynamic load through each revolution, and in fact only a small portion of each blade's travel actually generates positive power. Most interesting of all, the power curve of a VAWT peaks, at a rotation speed where the blade tip speed is 2 to 5 times the wind speed. To reach this range, the machine must typically be run up to speed using a motor, following which, power is generated and the motor turns into a generator. So the analysis and design of such machines is quite complex, even without the many kinematic mechanisms used on commercial models to optimize blade loads through a cycle.

However, these machines can be located close to the ground, and are hence more portable and accessible. They survive bad weather and high winds better. The centrifugal stresses are small compared to those on the blades of the horizontal axis machine, and the consequences of blade failure are far more benign. For these reasons, we chose to focus on VAWTs. Our approach is to build the blades out of materials commonly available in less developed areas of the world, and to adapt the construction to the traditional skill sets of the local, rural population[iii]. Thus, the shaft bearings come from bicycle parts. The blades are currently built from PCV pipe and PVC roof flashing sheets. The frame is currently of aluminum, but this is easily changed to wood or other material depending on the locality (in many places, metal work is a traditional skill). At wind speeds of 25mph, this small turbine currently produces enough electrical power to keep a compact fluorescent lamp lit, equivalent to a 40-watt incandescent bulb, or slowly charge a battery. It has a long way to climb in efficiency to reach its theoretical potential.

Figure 1: Vertical Axis micro Wind Turbine testbed at the Georgia Tech 42" Wind tunnel.

Solar Thermal Generator

The second is a solar thermal generator sized for a footprint compatible with roof terraces in the developing world – or an American urban high-rise balcony. It uses a reflective trough (aluminum sheeting formed by a simple wooden truss, covered with 99% reflective Mylar and coated with "Saranwrap" heat-resistant, non-polluting plastic sheeting) to focus sunlight onto copper tubes that form the heating element of a gaseous heat engine. Here the emphasis is again on minimizing cost and construction complexity, and then obtaining the best Figure of Merit consistent with those decisions. Thus, tracking motors and exotic collector shapes are avoided.

Hybrid Wind-Solar Device

The third is a hybrid wind-solar device that improves the usage factor of the electrical generator. This combines a micro windmill and solar panels for optimal efficiency where winds and sunlight, both intermittent, are available. Hybridization refers to integrating the power conversion/ control equipment and modifying the geometry so that the collector serves a dual role as an inlet for the turbine. Increases in both capacity factor (the percentage of time that the machine is producing its rated power) and efficiency are sought.

EduKitchen

The fourth is "EduKitchen", a device that improves the efficiency of a slum-dwelling kitchen woodstove, generates enough electrical power to (a) a feedback-controlled fan to drive fresh air through the fire, improving combustion efficiency to reduce fuel needs and pollutants, and exhaust pollutants out of the kitchen, and (b) LED lights, enough for a child to read and do homework, without having to leave Mom's supervision. This device would have the biggest immediate impact due to the reduction in soot levels and other harmful pollutants like carbon monoxide from incomplete combustion. Soot levels are thought to be extremely high in rural countries using woodstoves which in turn heats up the atmosphere a lot due to the heat absorbing properties of black carbon. Health, education and general quality of life in rural areas in much of the less developed world would benefit; however, the device will have to be provided to such families by government or non-government agencies. A strict design criterion here is that the device must be an add-on that can be tailored to the shape of the "stove" used by the family, rather than try to sell them a complete stove. Attempts elsewhere to provide readymade new stoves have failed because the recipients felt that food cooked on the shiny new devices lacked the "flavor" that came from their old "stoves".

IV. SYMBIOTIC SOLAR ALGAE SYSTEM

A fifth system which is being developed in collaboration with the Honors Program at Georgia Tech is the symbiotic solar algae farm. This system is described in greater detail; however, most of the policy initiatives and changes outlined will be relevant to most MRES.

A. Algae Based Biofuels

Algae based biofuels have been hailed as the future. It is easy to see why given the huge benefits and potential to quickly and sustainably replace fossil fuels. Algae grow extremely fast given the proper medium and conditions of sunlight and temperature. A doubling in volume is seen in anywhere from 2 to 7 days [iv]. Also, due to its fast rate of growth and high oil content, algae can effectively replace other biodiesel crops like soy, palm or rapeseed. In fact, algae have been reported to have an oil yield almost 50-100 times higher than these terrestrial crops [v]. This means that the entire world consumption of 31 billion barrels of oil could be provided for by 4% of the land in the United States [5]. It also does not require fertile land and so can be grown anywhere in specially developed systems as long as it has access to appropriate levels of sunlight.

With such impressive possibilities, the main obstacles to mainstream acceptance appear to be in scaling up the system to 'commercial viability', an adequate source of carbon dioxide to bubble through the system, the inability to grow a pure sample in pre-existing open ponds, difficulties in large scale harvesting and the high initial cost of specially designed algae growth systems (known as photobioreactors) [vi]. Our symbiotic solar algae system addresses all these issues. The "symbiosis" came out of the philosophy of "hybrid MRES" – seeking multiple technologies to integrate and synergize. Specifically, it is an example of how to co-use land for agriculture and for power generation.

The symbiotic algae system was developed due to the need to find a cheap and local source for algae production. We did so by first starting with small scale algae growth and then envisioned a network of these producing the same output as a large scale farm but with reduced complexity. The main issue still remained providing enough carbon dioxide to the algae growth units and ensuring that there was no contamination. At present, carbon dioxide is provided to algae from the emissions of power plants. Transporting this carbon dioxide is difficult and expensive and it is usually preferred to have the algae farms next to the power plants. This also may not be possible due to land availability and cost. Another issue is the storage of this carbon dioxide at the algae growth facility which is a further expense. The only way to partially offset this cost is via carbon credits.

Open ponds are a cheaper method of large scale production in comparison to the large costs of setting up photobioreactors, however, open ponds can have their algae contaminated by a variety of undesirable substances that include bird droppings, fungi, bacteria and harmful microbes [6]. Photobioreactors are extremely capital intensive but give purer products and are easier for harvesting. However, cost is a much stronger driving force than any other and proven economic viability is the key to sustained investment and growth.

B. Design Methodology and Setup

Our solution was to grow algae in small batches but through a large network. Most importantly, we dealt with the issue of carbon dioxide production but harvesting it from naturally occurring sources so that the entire process is carbon neutral. We investigated the collection and decomposition of cow manure to obtain methane rich gas which could be burned for electricity and heat and the emissions of carbon dioxide we obtained could be bubbled through the algae. The 2nd option we looked at and eventually ended up testing was growing algae in symbiosis with mushrooms. Mushrooms are quick growing fungi which release a lot of carbon dioxide as they decompose organic material. This carbon dioxide would be passed through the algae. Solar panels would be placed in between each algae-mushroom unit to provide whatever electricity was required to keep the algae agitated and other tasks like monitoring the samples.

The initial setup had the mushroom seeds (mycelium) suspended in bags with wet straw above the algae with 12 hour cycles of light and dark imposed on the algae. This was thought to be the most efficient setup since carbon dioxide that was produced; being heavier than air would sink and interact with the algae water. There was also a control group set up with no mushrooms but similar light conditions. Algal growth began at a faster speed in the mushroom filled set up but before noticeable measurements could be made, the mycelium from the mushroom bags took over the setup. They competed with the algae for water and eventually absorbed all the water provided and killed the algae in the process. To deal with this issue the 2nd set up had the mushrooms and algae grown in opaque and transparent boxes, respectively.

The goal for the first set of experiments is to determine the amount of carbon dioxide released from the growing mushrooms (using CO_2 sensors) and determine if it is sufficient to support algal growth. While the experiment is still continuing, initial results were very promising with high algal growth rates reported.

C. Commercial Design and Viability

The commercial design is currently planned to be based around the 2nd setup. It has so far proven to be the most effective use of space. Solar panels are placed on the sun facing side of the mushroom box on as a separate unit in between subsequent rows of the mushroom-algae boxes. The solar panels provide the electricity required to operate the air pump and agitators in addition to the sensors. Each symbiotic solar algae system unit would therefore consist of 1 mushroom and algae box, the solar panels on the mushroom box or next to it and all the associated sensors, pipes, pumps and other hardware required to make the system function. The sensors for CO2 and light could be further de-scoped to reduce the cost per unit. This system also qualifies as an MRES due to the fact that each unit is a self contained system.

In the fact that each unit is self sufficient and self contained lies the biggest advantage of this system. It can be bought by the end user in any quantity and the farm size could be assimilated upwards easily. Also, due to the system design, a smaller farm would be as efficient as a large one. It also is suitable for urban users for rooftop or balcony cultivation. Each collection of small farms or individual units would be serviced by a collection and processing plant that would buy back the algae from the producer and extract oil and other substances. This would in effect be a spoke-hub model utilized in many industries. The closed boxes required for each unit would be manufactured from cheap plastic in a large scale but local facility where need existed.

Due to the modular, closed system design and local carbon dioxide generation, this system is very effective in addressing the various problems and roadblock to commercial algal biofuel production. The modular single unit design makes scaling up easy while local carbon dioxide production eliminates the need for long distance transportation of carbon dioxide from power plants and long term storage. Costs are kept low with a simple design and contamination is kept in check through the use of closed systems.

Depending on the region and economic conditions, the symbiotic solar algae system can be made more effective through full automation (with exception of mushroom harvesting), entirely manual or some middle ground for operation. For a country with cheap labor like India, China or the countries in the Africa, a manual system would be ideal for maximizing profits while a more automated system would be ideal in the United States and Europe. This issue however only arises when a large farm is created using the solar algae system modules. Individual unit owners would be most benefitted by manually monitoring the system.

There is however still a variety of social and policy issues that prevents it and MRESs as a whole from competing against large scale established power. These will be discussed after a discussion of the economic viability of the system and the conditions necessary to make profitable.

D. Economic Feasibility

The economic feasibility of this system was studied using 2 cases. One was a large scale farm of 10 hectares that utilized 60600 units, had its own processing centre and office facilities. It is completely contained and the final algal oil produced there can be sold to the refinery. Conservative production estimates were taken and the model system is based in a cheap labor country so that the entire farm is manually taken care of. Worker salaries were taken on the much higher spectrum of what a similar laborer would get in that country.

The second case involves an individual user who owns 10 units on an urban rooftop. The final product he sells is the unprocessed algal water to the local collection and processing centre. The relative revenue is much lower but the expenses are also lower since he requires no commercial construction, large scale transportation vehicles, operational costs and manual labor costs

One very interesting detail in the cost analysis is the fact that the large scale farm and the small 10 unit set up had similar profits as a percentage of their investment, thus validating the MRES model for this particular model. There is however about a 5% error in the figures due to the fact that prices for commodities like algae vary a lot from source to source. While the authors do not claim to have accounted for every cost that will arise in the management of such a large farm, conservative estimates have been taken to offset the impact of anyone unforeseen expenses. That being said, a $40000+ yearly profit is projected from the algae component of the system alone (for a 10 Ha farm). If only the algae component were considered, the initial investment would be paid back in 5 years. While these figures are very promising, care must be taken to ensure that certain conditions have been satisfied to meet this described economic viability. Low labor cost is a very critical factor to the success of this system. The wages paid to the laborers might seem low by international standards but is 2 to 3 times what would be paid to similar laborers in their respective countries. Also, factors like a much higher purchasing power must be accounted for into the wage calculations.

There is however a large uncertainty in the costs of the mushroom cultivation and profits from mushroom sales. As of this writing, reliable cost estimates had not been finished. This is due to the fact that mushroom yields per hectare are very varied and highly sensitive to a multitude of factors that could suddenly reduce the yield. Mushroom yields of as high as 60% of the initial investment are realistic but it is a labor intensive product that must be monitored constantly to ensure proper harvests and protected from harmful diseases that it is sensitive to. So, while the mushroom component is definitely profitable, a definite number cannot be provided at this juncture. Prices of commodities like plastic (for the boxes of the unit) are very sensitive to economic conditions and can change by as much as 20-30% with changes in the price of crude oil.

V. POLICY INITIATIVES AND CHANGES

The policy successes of micro renewable energy systems will be perhaps even more crucial than the technological and economical breakthroughs it demands. Reference [vii] concluded that ineffective policies would hurt the industry more than a lack of protection. Policies that attempt to directly influence pricing and demand while helpful need to be accompanied by policies that assure the public that efficiency of renewables is constantly being improved and funded extensively. As is evident from the renewables boom in the 70s and its subsequent bust, failed policies create social mistrust in renewable thus making it even tougher for legitimate renewable technologies to acquire funding [7].

Excessively intrusive and controlling policies also create mistrust in society and reduce funding options. Heavy price control, tariffs and subsidies tend to get highlighted too often as the reason for an industry's survival. Unless a system is economically feasible, technological superiority and policy initiatives will be overshadowed in time. Therefore, while price controls, tariffs and subsidies are required (at least in an infant industry), they must be light and broadly supported by other, less controlling and less obviously intrusive policies. Some specific policy changes and initiative will now be discussed that could improve the success of MRES and thus the renewable sector as a whole.

A. Capacity Dependant Incentive

As suggested in [8], electrical capacity of renewable technologies is directly linked to monetary compensation like subsidies, tax breaks and ROCs (Renewable Obligation Certificates in UK). However the reality is that economies of scale reduced the cost of larger systems such that a MRES gets incentivized proportionally less than a large scale system that has a higher effective generative capability. Therefore, MRES could be proportionally provided higher compensation for unit power compared to a larger capacity facility. This would directly support small scale production and make the industry search for more MRES solutions, since the promise of gain is more. The percentage compensation would gradually decrease with increasing capacity till it is equal to the original amount at the limit where a system is considered large scale. This gradual decrease will also prevent exploitation of this incentive by intentionally decreasing capacity. Capacity Dependant Incentives would effectively mean that the power from a MRES is worth more than power from a large scale system. Also, the likelihood of this policy negatively impacting large scale renewables is non-existent because of the fact that large scale renewables are inherently more cost efficient and profitable and their profit margins are remaining unchanged.

B. Point-of Use Power Incentives

A crucial advantage of MRES is that the power is generated close to the point of use. This power can be extracted and stored in a number of ways, consistent with the user's needs. For instance, a wind turbine located on a field could be used directly in a mechanical pump to boost water flow through an irrigation line, or draw water from a tube well, without ever converting mechanical power to electric. There is no advantage to society from converting this power from mechanical wind power to electric power (with a minimum of 40 to 50% lost as heat), storing in batteries or feeding into the grid, and then converting back to mechanical power, again with substantial losses. So the incentives for MRES should be based, at the user's option, on the actual power (in any form) delivered for use. This idea levels the playing field to a great extent, without doing anything unfair. Specifically, this incentivizes devices where heat that would be otherwise wasted, is recaptured for use.

C. MRES Research Grants

A policy to increase research grants and funding to MRES would be equally effective in the industry and significantly improve public perception of renewable technologies. Constant development and research breakthroughs in the renewable sector will keep private sector investors interested and thus be more effective in increasing inflow of capital. The focused research grants on MRES will lead to technological breakthroughs and eventually inject more money into the MRES sector than a project grant would have.

D. Energy Transport Tax

MRES epitomize the concept of local power generation. We live in a society where large proportions of a country's oil and power are exported from oil rich nations. Not only is this expensive but is especially expensive to transport as well. A possibly effective way of promoting local MRES use would be to tax the long distance transport of all energy and energy related products. This would incentivize local communities to generate their own electricity and produce their own biofuels and reduce the need for large scale renewable and conventional power plants in that particular region or community. This would be a huge victory for MRES but as there is a risk of this being an unpopular policy since it is more strict and potentially unfavorable (atleast in its infancy because individuals would not notice the soon to be gains of MRES.)

E. Individual's Renewables Tax Incentive

Extend the US Department of Energy's Residential Renewable Energy Tax Credit to cover individual biofuel production. It is already a great incentive that provides a 30% tax credit to MRES installed by residential members [viii].

F. MRES Educational Initiative

In keeping with the earlier stated policy of not only increasing productivity and incentives directly but also changing public perception to seem MRES more favorable to society, a multi pronged educational initiative policy would be much welcome. A more favorable outlook on renewables leads to increased private sector funding and this favorable outlook can best be achieved by educating the public on the multiple benefits of renewables and MRES specifically to their quality of life and improving our futures. This education could be achieved through the production of PSAs (Public Service Announcements), creating a user friendly and entertaining website with comprehensive information on the role of beneficial role of renewables. A call for increased focus to renewable energy education in schools as well the providing of scholarships to college students pursuing renewable energy (specifically MRES) related work would also be greatly beneficial in improving public perception of renewables.

G. Need for regulation on advertisement and standardized performance claims.

A major market obstacle to MRES is the experience of customers that many small power systems vastly overstate their performance and return on investment. Recently we had an unbiased researcher (high school student) tabulate and plot the "Rated Power" of each small wind turbine advertised on the internet, against the absolute kinetic energy in the air flowing through the capture area of the wind turbine. For large wind turbines, the rated power comes out to some 20 to 30 percent of the total kinetic energy per second, consistent with their high efficiency of aerodynamic capture and electrical conversion. Shockingly, the rated power of the smaller machines, instead of being well below the value for large machines, actually came out to be as high or greater than the total kinetic energy per second flowing through the space influenced by the machine! This observation fits the experience of many homeowners who have been disappointed with various systems, from solar water heaters to wind turbines.

Strict government regulation under USDOE guidance is essential to rationalize the advertisement claims and specifications. Actual proof must be required before claims can be made. This would gradually undo the terrible reputation of products in this field, and convince customers.

Reference [11] cites ongoing initiatives for certification of equipment and manufacturers, and projects that market forces will make these mandatory. A number of states are cited as making certification a condition for receiving public incentive funds.

VI. Lessons from MRES initiatives

Karekezi and Kithyoma [ix] have studied Renewable Energy Development in Africa. They list the following barriers: poor institutional framework and infrastructure; inadequate planning policies; lack of co-ordination and linkage in the renewable energy program; pricing distortions that place renewable energy at a disadvantage; high initial capital costs; weak dissemination strategies; lack of skilled manpower; poor baseline information; and, weak maintenance service and infrastructure. Co-generation using the heat from sugarcane waste is a major source of renewable biomass energy in Africa, and is extensively used. In Mauritius, such electrical is sold back into the grid. At the small-scale end, bio fuelled stoves are used for cooking, heating and lighting in vast numbers. Charcoal is preferred for cookstoves, because it is storable, has high energy density, and is less polluting than wood fuel. Charcoal production using earthen kilns is a major source of employment. 20 years of effort to develop and propagate energy efficient kilns and environmentally sound cookstoves, has resulted in well over 2 million stoves being distributed.

On the other hand, biogas from animal dung, though apparently a straightforward resource, encountered problems. Dung collection was a problem where herds were not confined to a small area. Small farm operators with small herds were unable to adequately feed the biodigestor unit and ensure a steady generation for lighting and cooking. The investment needed for the smallest biogas unit was beyond the capabilities of most potential users.

Nearly half a million solar photovoltaic systems had been distributed, 300,000 of them in South Africa and Kenya, by 2004, with a rated power of 18 MW. These have primarily benefited wealthy customers. Solar water heaters have been shown to have a payback period of 3 to 5 years. Wind machines in East and South Africa find use primarily for water pumping rather than electric power generation. While small-scale hydro power has vast potential, it had not seen much installation as of 2003.

Advanced and electrical MRES are considered to be unaffordable to the majority of the population. Costly imported components and subsidies are not sustainable unless the technologies also include income generation for the locals. Unfavorable financing requirements such as feasibility study at the applicant's expense, land as collateral, documentation requirements from the vendors are all cited as barriers.

In a completely different environment, experts in the United Kingdom now question[x] the effectiveness of small wind power systems, citing 20-year payback periods, and poor wind access in urban areas. The initial investment of 1500 to 2000 UK pounds, is estimated to result in 50 to 60 pounds of annual savings in electricity costs, but also incurs uncertain maintenance costs. The best use for the smallest turbines is for battery charging. Peter Osborne, managing director of FuturEnergy, is quoted as saying that *"the home wind turbine market is rife with hype, mistruth and overselling… In many instances, homeowners are being sold a myth and being given a wholly unrealistic impression of the energy saving potential of micro wind turbines."*

A different challenge is that technology transfer arrangements accompanying international sales or licensing agreements, often do not provide full freedom to the end user to adapt systems to their experience. This results in frustration and reduced effectiveness of the system.

The American Wind Energy Association conducted a study[xi] of the global market for small turbines in 2008. They found 78% growth in the year, with the largest segment being the 1-10 KW market. They cited Federal incentives, incorporation of mass-production economies of scale, and growing customer awareness of the technology and its features as reasons for success. A Federal "Renewable Energy Standard" for utility portfolios is anticipated, along with some form of green energy trading, as further incentives. Poor or absent procedures for permitting wind turbine installation within zoning laws, was cited as a major barrier. "Unnecessarily restrictive regulations, particularly height limitations" were cited as limiting productivity, discouraging customers and repelling local businesses. The role of "net metering" laws in facilitating micro-renewables has been studied in [xii].

A different experience comes from India, where the electric power grid is notoriously antiquated and unreliable, with rolling blackouts and random blackouts the norm even in the big cities. With new construction coming up swiftly, and a burgeoning middle class consumer economy, bold partnerships are also being formed, between property developers and energy system vendors. A new housing development in Hyderabad "incorporates renewable decentralised energy production, smart grids, home automation and electric cars."[xiii]. Some of the houses have been fitted with 4.2kW PV systems and solar water heaters, connected to automatic and remote controllers.

The emphasis is on the information processing and control system.

Many other less obvious changes have occurred in India. Consumers trying to survive with the poor power grid, welcomed Indian companies that built home-scale storage/inverter systems, usually built around lead acid truck batteries. Thus it is standard practice that these systems draw charge from the grid when it works, and power essential lights and fixtures at other times. Most home computers also add an uninterruptible power supply (UPS) sized to allow orderly shutdown, and refrigerators and TV sets include voltage regulators to protect costly equipment from the wild fluctuations in grid voltage. As a result, the infrastructure to store and exchange power with the grid is already in place, ready for micro-renewable generators. However, the difficulties with matching customer expectations and vendor advertisements apply, and most families still find PV and wind systems to be too ineffective in initial and maintenance costs.

India has set specific annual targets for renewable energy, with 20% of new generation capacity coming from renewables, reaching a total of 10% of total power generation by 2012. A subsidy support system of roughly US$1B is in place, but assumes that renewable power capacity can be added at the ambitious "US $1 per watt" level with only a $0.07 per watt subsidy. While much of Indian renewable power addition comes in the form of wind farms with 0.5MW turbines, and solar-thermal trough plants in the deserts, there are very important grassroots initiatives for biomass energy. Traditionally, biomass resources are firewood, agricultural residues, crop stalks, and animal wastes. Newer additions are the jatropha plant and other biodiesel sources. The very high cost of transportation fuels has generated a willingness to try many technologies, such as compressed natural gas for automobiles.

A vast array of applications for MRES also arise in the military and the emergency response fields, but these are beyond the scope of this paper. The emergency response application is fairly obvious: if small autonomous power generators can be airdropped or carried into areas struck by natural disasters, they can get lights, power equipment, medical refrigerators and field hospitals operating much quicker, saving many lives.

VII. CONCLUSIONS

In conclusion, MRES are an extremely promising and beneficial class of renewable energy systems. Established power grids and cheap utility scale power have in the past relegated micro-renewables to a low priority. However, concerns over rising energy prices and the need to reduce carbon footprint have changed this equation. Low thermodynamic or mechanical efficiency is compensated by the advantages of generation at point of use, scalability, and acceptance of technologies needed to control such devices. When additional benefits such as local employment creation and cheap, sustainable materials are designed into the system, micro-renewables become much stronger competitors.

Five example concepts are briefly surveyed in the paper, with the micro wind turbine being the closest to field readiness. The ideas of hybrid systems where complementing power sources are combined to share the same power conditioning equipment or land footprint, lead to the innovative mix of solar algae/mushroom cultivation.

The solar algae MRES requires a working combination of technology, economics and policy to be successful. Such devices are seen to be as efficient in the small scale as in big and economically viable with the help of a few supports. Experience in different parts of the world is briefly sampled to gauge the issues and the ideas for promoting MRES. These lay out various ideas, but also some hard lessons on how difficult it is to develop products that succeed in the mass market, and how close interaction with community preferences, practices and traditions, in addition to education and training, are essential.

In addition to price supports, green credits and other incentives, strict enforcement of advertising discipline and standards are also necessary to support the faith and initiative of consumers, in order to bring about the mass market success that is at the heart of the MRES approach.

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