Electrifying the Developing World:
An Alternative Using Remote Area Power Systems for Villages

Executive Summary

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A. The Challenge of Electrification for Development in the 21st Century

Although phenomenal technological and material progress has been made in the last half of the 20th century, the monumental experience of human triumph during that period has left the world more globally divided and fractured in the distribution of income, wealth, knowledge, infrastructure

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and, perhaps most importantly, in access to the means which make productive livelihoods possible. The information revolution, which has created a new dimension in the processes of wealth creation, development, and human evolution, represents yet another decisive turning point in the saga of human progress. It guarantees much larger rewards to those with privileged access to knowledge and inevitably will create an even wider divide between the "haves" and the "have-nots"; a divide unlikely to be bridged unless access to basic infrastructure -- especially electricity and telecommunications, in addition to clean water, education and primary healthcare – is provided at an accelerated pace to communities in the developing world.

One reflection of this regrettable reality is that in 1995, over 2 billion people did not have any access at all to electric power. Having no electricity is unimaginable for anyone fortunate enough to reside in the developed world or even in the cities of the developing world. Yet that reality is what two-fifths of mankind has to contend with. Another 2 billion people have access to electricity but to a very limited, unreliable

extent. Their consumption of this basic utility was less than 20% of similar consumption in the developed world. Comparatively, 1.5 billion privileged people living in Western Europe, North America and Japan, as well as in newly industrialised economies in East Asia and Latin America, have as much access to electricity and energy as they want and can afford.

Comparative Electrification Situation Among Countries by Income Class

Income Category	Growth in Electricity Production, 1980-95 (%)	Per Capita Electricity Consumption (kWh)
Low-income countries	8.4	less than 0.5
Middle-income countries	7.8	4.5
Rich countries	3.2	22.0

Source: The World Bank

Note: Low- income countries exclude India and China where the average electricity consumption per capita was 1kWh and 1.8 kWh per day respectively.

The electricity, which is presently made available to almost everyone in rich countries, and to the rich in poor countries, is provided at considerable cost in terms of global welfare. It has resulted in non-renewable resources being consumed at an unsustainable rate. Consequential damage to the ozone layer, fragile ecosystems and to the wider environment is of a magnitude we are only just beginning to fathom properly. When renewable resources have been exploited – such as hydro-electricity – much collateral damage has been done unwittingly by way of forced resettlement, flooding and damage to ecosystems caused by changing the natural course of rivers and the topography of natural river basins.

If electricity was provided to the "have nots" in the same way and in the same intensity as is being provided to the "haves", then the amount of hydrocarbons that would need to be burnt would probably result in environmentally catastrophic consequences for future generations; assuming of course that we did not go in for more nuclear reactors and that the holy grail of nuclear fusion remained elusive for the foreseeable future.

Yet human progress will require the ever-expanding provision of electricity to an increasing number of people. Access to electricity has become almost as basic a human right as access to clean air, water, shelter, clothing and food. In the last 25 years access to sustainable electricity has been provided to over 1.5 billion people; but that access has by no means provided them with the amount of electricity they can afford. And, in that period, the population of the world has increased by about 1.2 billion people.

Moreover, the absence of basic services in rural villages is swelling the tide of urban migration that is engulfing the developing world. For that trend to be arrested and reversed successfully, electricity (along with other essential micro-infrastructure) will need to be provided where most of the developing world's poor still reside. The challenge is to provide electricity on a cost-effective basis to remote villages rather than concentrating on urban and peri-urban areas to justify the high load densities which conventional energy economics demand. In short, electricity needs to go where poor people are; instead of poor people migrating to where the electricity is.

A. The Solution?

Today the electric power industry is being deregulated, corporatised and privatised around the world. In that process real costs, hidden subsidies and cross-subsidies, are being unbundled and becoming more

transparent. It is apparent that such subsidies, once obscured in public budgets, are no longer sustainable or affordable. It is equally obvious that most such subsidies in the past have been skewed to benefit better-off urban consumers rather than being applied to bring electricity to poorer rural communities. Can electricity be provided at an accelerated rate to poor people in villages in the developing world while reducing the burden of unsustainable subsidies which have become characteristic of electrification (and especially of rural electrification through grid extension) throughout the world? Can this be done with existing technology in a cost-effective way? As it happens the answer to these questions is yes. A solution does exist.

The answer is also quite simple – almost shockingly so! It lies in a paradigm shift in the basic business of conventional electricity provision. Instead of continuing with large scale centralized power generation and then distributing electricity over millions of miles of transmission and distribution networks which have only been partially built in the developing world, governments and the international community must

consider resorting in a major way to the opposite strategy for rural electrification : small and medium-scale decentralised power generation and consumption at the village level. The savings resulting in transmission and distribution costs could be utilised, in a measured fashion, to subsidise the initial capital cost of decentralised small-scale generation at the community level instead.

The technology that makes this option technically feasible and economically viable lies in using tailor-designed, hybrid, remote area power systems (HRAPS). Such systems combine a number of different generating components to optimise the capture of energy from all renewable sources of energy available at a specific site – a concept conveniently referred to as "optimal renewable capture". These components can, and often do, include small wind turbines, solar photovoltaic (PV) panels, biomass digesters, mini-geothermal generators, mini and micro-hydro generators and tidal turbines (which are still in an experimental stage). They can be backed up by small diesel generating

sets to ensure the provision of "grid-quality" electricity where the need for it exists and affordability parameters justify it.

The hybrid remote area power systems (HRAPS) approach is the most sensible, economic and technologically optimal option that exists today for widespread application in countries which have not yet made absurdly large investments in transmission and distribution networks. It can be implemented and replicated relatively quickly across the globe without the same massive, concentrated costs – or the very long gestation periods – that conventional energy, generated in large plants and distributed through grid extensions, would necessitate.

It is an approach that also overcomes the risks and costs that have been incurred with the propagation of single-source renewable technologies. Most importantly, small decentralised hybrid systems offer an approach which can rely on mobilising the private capital of the communities which need and demand electricity in a relatively up-front manner without being indefinitely dependent on public or private financing on any large scale.

As a powerful solution to rural electrification, HRAPS addresses five pressing development issues simultaneously; i.e. alleviation of poverty; enhancement of the quality of human development; greater resort to renewable energy; promotion of rural development; and empowerment of poor communities.

An initiative to propagate HRAPS throughout the developing world successfully would address all these priorities in a way which few other endeavours could. Implementing this particular solution to the problem of rapid, large-scale rural and remote area electrification in the developing world will require a sea change in the established mind-sets of a large number of powerful constituencies. These have strong vested interests in continuing with the conventional approach or in backing the development of single-source renewable technologies for application on a large scale on single sites. Such vested interests include public and private groups in the conventional electric power industry and in developed and developing country governments, recent investors in new renewable technologies

which have unwittingly colluded to create monopolies or duopolies (e.g. in the production of solar panels), and the bilateral and multilateral development assistance agencies which have become captive to such interests.

B. The High Cost of Rural Electrification via the Grid

Indeed, when a tried and tested HRAPS alternative is presented to the traditionalists, two or three types of reactions are typically triggered, i.e.; (a) there is no economically viable alternative to grids for "proper electrification; (b) small-scale renewable energy technologies are experimental; and (c) providing electricity to any consumer is the business of large centralised monopolies.

The reality, though, is that the costs of grid electrification for providing electricity to low-load density rural areas can be as high as US$0.70 per

kWh in the initial stages of electrification when load densities are low. This evidence contradicts the convictions of many supposedly well-informed policy-makers who believe that electricity can be provided to rural areas through grids at only a small premium over the cost of providing it to urban customers (which averages about US$0.04 per kWh).

Cost of Grid Electrification in Relations to Load Density, Urban and Rural Areas

Source: Rural Energy and Development, The World Bank, 1996.

The above costs do not fully capture the costs of electricity theft, arrearage-induced losses, and low capacity utilisation levels -- all of which have become endemic problems in most developing countries especially in low income ones. With all the hidden costs embedded in the grid option being taken fully into account, the "real cost" of that option might well be twice the amount estimated by the World Bank. Contrary to the assertions made by national power system agencies and engineers in most developing countries, grid electrification for rural areas is probably the highest cost and least economical alternative of all.

C. Relying on Grid-Connected Power Plants Using Renewable Energy

Supposed policy progress (made under the Montreal, Rio and Kyoto protocols) notwithstanding, the challenge of getting developing countries to rely more enthusiastically and rapidly on renewable energy resources continue to

bedevil global policy makers. Countries such as China, India and Brazil have invested impressively in renewable capacity, but not with great success. Most developing countries have not yet learned as much as they could from the experiences of countries like Denmark, Holland, Britain and Germany which have had signal successes with their policies for encouraging investments in renewable energy. Nowhere in the developing world have targets as ambitious as those in Europe been set for increased reliance on renewable energy resources. Yet it is the developing countries – which do not have transmission and distribution networks with countrywide coverage, nor the demand loads to justify premature investments in grids – which need to rely on renewable energy even more than the developed world. But they need to do so in a way which accommodates conditions prevailing in developing countries rather than mimicking approaches tailored to circumstances in Europe or the United States.

The most sensible approach from both a specific country, as well as global welfare, viewpoint is to encourage developing countries to shift radically their

investment patterns in the electric power sector. They need to back away from premature grid expansion and large scale centralised generating plants, towards accelerated reliance on decentralised small-scale generation and consumption at site. That option is now much more possible than it was in the 1970s or even the 1980s, simply because the technologies and remote area power systems which are now available to ensure grid-quality power were not quite as well developed then.

All these lines of argument are offered not to suggest that there is no role for large grid-connected wind-farms, or large solar panel arrays, or even for large conventional electricity generating plants, or for expanding transmission and distribution grids. There is clearly a case and place for such plants and grids, especially where the expanding electricity needs of urban agglomerations, and of large industrial and commercial users, in the developed or developing countries need to be met.

But the case for resort to such plants and grids in providing electricity to rural areas in the developing world where grids do not exist, is a very weak one. New renewable technologies are making it increasingly possible to tailor design "horses for courses" and to meet rural electrification needs in unconventional ways which have enormous opportunities for positive externalities to be captured and realised. These alternatives should be embraced and developed much more enthusiastically and open-mindedly – without aid agencies and governments preferring one technology over another, instead, letting the market decide and making it possible for different ideas to work – than has been the case thus far.

Caution needs to be exercised by decision-makers in developing countries in avoiding false choices between rural, stand-alone power systems based on a single renewable resource (i.e. only wind, or solar or biomass or micro-hydro, etc.) as opposed to hybrid systems which attempt to capture as much energy as is practically feasible and economical from as many available renewable resources as a given site may have.

As a company with a track record of developing HRAPS, Synergy Power Corporation (Synergy) has found that detailed studies and endless debates about whether one type of renewable technology is superior to another or to the option of installing diesel generating sets (DGS) in a particular location, are futile and diversionary. The reality is that HRAPS invariably combine a mix of renewable technologies in order to achieve "optimal renewable resource capture" at any given site. Unlike renewable energy purists, Synergy has also found that backing up renewable-based systems with small DGS in an HRAPS package is more cost-effective and reliable in providing assured grid-quality power to remote areas. Excluding DGS from such systems results in much larger battery banks or other components being required. That is an uneconomic alternative especially at this stage of battery technology development – a frontier which is continually being pushed forward.

D. Avoiding the Temptation to Propagate Solar Home Systems (SHS) Indiscriminately

A new danger emerging is that of developing country governments and non-government organisations (NGOs) – abetted by the solar manufacturing duopoly and by aid-agencies—indiscriminately pushing minimum-sized SHS to individual households in rural areas as the new "magic bullet". This latest fad has gathered steam with disconcerting force over the last 2 to 3 years in countries like Kenya, Bangladesh, the Philippines and South Africa with funding from the World Bank as well as other bilateral aid agencies.

Like every other innovation SHS have their place in the constellation of solutions for providing rural remote households with affordable and early access to basic electricity. But they also have their technical and economic limitations. These systems are only capable of supplying single-phase DC power and thus, exclude the rural users from the natural migration from low

domestic use of electricity (i.e. for lighting, radio and black and white television) into productive use. For the range of application to expand, SHS users would have to additionally purchase inverters which then inflates the total system cost and consequently, the cost per kWh of power generated.

Again, this is not to suggest the SHS are so flawed as to have no applicability at all. It is instead to suggest that they are not quite the panacea (that they are often portrayed to be) in providing the rural poor with access to electricity. They represent instead a "short-cut" which assuages aid agencies, governments and the providers of these systems that something constructive is being done when the reality may be that SHS are only creating expectations and demands on the part of users which they cannot meet. The resentment and feeling of inequity which are unleashed in small communities through such an approach have negative consequences which are not being taken fully into account.

E. Accelerating Resort to HRAPS as the Preferred Option for Rural Electrification

Developing country governments are at a strategic cross-roads in terms of the choices that confront them for increasing rural community access to electricity. On the one hand they can continue with the traditional option of extending rural distribution grids. But with the emergence of new renewable technologies, the case for doing so is getting weaker and suspect on economic, social, political and empowerment grounds. At the other end lies the alternative of propagating household appliance-type power systems (e.g. SHS). As previously discussed, these systems have limitations and consequences which need to be thought through much more carefully than they appear to have been so far.

In between these two routes relatively unattractive routes lies a more real "third way" – that of electrifying individual rural communities off-grid through decentralised community-based stand-alone HRAPS. By emphasizing power systems tailored to meet the mixed power supply needs of villages and communities rather than of individual households, this option assures the availability of grid-quality power to all types of users in the community – residential, commercial, light industrial and social. HRAPS are also likely to generate a greater immediate multiplier effect in terms of direct and indirect employment within the communities in which they are established – not just in managing the micro-utility but in terms of meeting local contracting requirements, as well as service and maintenance requirements, and enabling commercial activities to be undertaken as a consequence of electricity being made available.

Finally, the HRAPS approach permits these systems to be provided and financed with much greater flexibility for cost-recovery and for the application of subsidies than the other two approaches. If subsidies are to be provided –

and for the poorest rural communities they will have to be for any of these three approaches – the HRAPS option offers the best hope for minimising and containing them. That possibility exists because with the HRAPS, subsidised systems provided to rural communities at the outset can be of a minimum initial size, designed to cater to the most basic of services. As demand loads and incremental community income (through rural industries that HRAPS allow to thrive), these systems can be expanded at the community's own cost with the application of subsidies being partially or fully withdrawn at that point.

The main obstacle to the large scale adoption of this approach does not concern the HRAPS technology involved -- as most policy-makers appear to believe. That technology is proven and tested and the technology risk can easily be underwritten by system suppliers. The real risks lie elsewhere. For decentralised community-based systems to work properly, it is the social, organisational and institutional issues for installing such systems in remote rural communities that pose the greater uncertainties and unknowns.

These kinds of issues are not best dealt with through interminable studies and consulting assignments based on assumptions. A considerable amount of research work has already been done across the developing world, in various conditions and in a variety of sectors, about the organisational, financial, economic and social dimensions of providing micro-infrastructure to remote and isolated villages and communities. Nevertheless in any area where new ground is likely to be broken there is always something new to be learned. That learning occurs best through "learning by doing" i.e. through carefully constructed and evaluated pilot projects and programmes in a number of developing countries.

It is quite unlikely that there will be only one type of micro-utility model which will work under every conceivable instance in various rural communities in every developing country. The models will evolve themselves as communities expand their incomes, diversify their activities, participate in the market

economy, and generally achieve higher levels of development. The trick will be to develop a sufficiently flexible approach in designing such models and learning from early experience what is likely to work best under which circumstances, and how it is likely to evolve.

Whereas HRAPS will provide an effective starting point for rural electrification to be undertaken in an entirely different way, the developmental impulses that a wide-scale application of such systems is likely to generate will see rural grids emerge from the bottom up. In other words, contiguous rural communities may, when conditions are propitious, decide to connect their own local area grids to one another and trade in power when one community can generate a power surplus and another is in deficit. Or, a point will be reached when local area demand loads have become high enough to justify connections to the nearest major transmission lines. Such a demand-driven approach to rural grid development is likely to lead to much more efficient investment patterns emerging in the rural power sector, and in transmission and distribution networks, than is the case at present.

The attractiveness of the HRAPS option as the new paradigm for rural electrification in developing countries is that after the first round of installations, the task of country-wide electrification will automatically devolve to market mechanisms and communities rather than remain with over-extended centrally run public agencies which are dependent on the fiscus. The whole effort is likely to pick up steam once the process has been kick-started with a few pilot programmes in different provinces of each developing country. But it will happen only if basic building blocks are put in place for the market to function. These building blocks essentially comprise: (a) the formation of capable micro-utilities in rural communities, supported by appropriately designed capacity-building and institutional development initiatives for a reasonable period of time; (b) flexible financing mechanisms and facilities, which are initially subsidised, and provided to rural communities through a wide range of competing financial intermediaries and/or NGOs, trained and qualified to make (and supervise effectively) loans, leases and hire-purchase facilities available to rural micro-utilities on a commercial basis;

(c) locally established suppliers of suitable HRAPS equipment; and (d) an elemental, flexible and responsive regulatory framework for remote rural electrification.

F. Conclusion

The HRAPS approach will probably have an impact on the rural electrification industry in particular, and the electricity industry in general, which may be analogous to the impact that personal computers had on the computer industry. It will change rural communities in ways which will be difficult to recognise in retrospect and will unleash forces and initiatives in these communities which are difficult to contemplate and assess, possibly even to imagine, beforehand.

In that sense this new paradigm may offer a far more powerful tool in alleviating poverty and empowering rural communities than can reasonably be evaluated right now. For these and other reasons, it would be irresponsible for any concerned party to act in ways that delayed or thwarted its emergence. Instead, ways need to be found to accelerate the adoption of HRAPS. Discussions and actions to establish the right kinds of public-private partnerships for making that happen have become a matter of urgency.