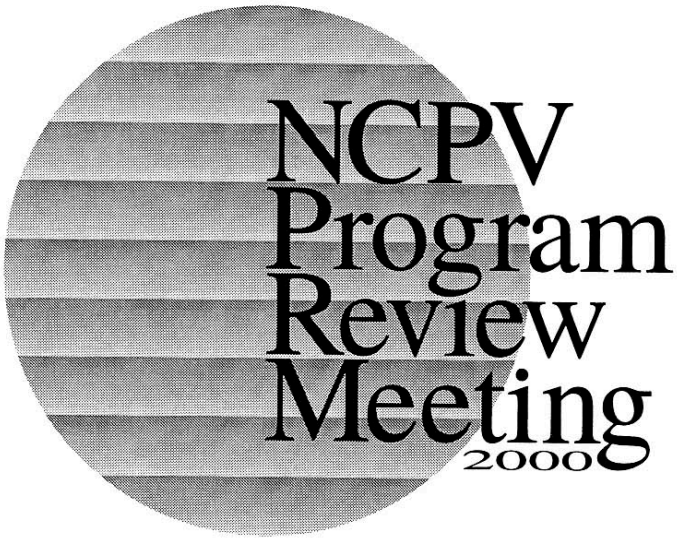
# ADDENDUM TO THE PROCEEDINGS

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# A Perspective on International Photovoltaic Challenges & Opportunities for Rural Development

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## ABSTRACT

International market opportunities for the sale and deployment of Photovoltaic (PV) systems abound and will continue to out-pace domestic, grid-connected opportunities for the foreseeable future. There are presently over 6 billion people on the planet; 4.8 billion, or 80%, live in developing countries. Over the next 25 years, the world's population is expected to grow from 6 billion to 8 billion. And 97% of of the growth will be in the developing world. The opportunity for tapping into this market is enormous, but it will require a multi-year, sustained commitment to a broad systematic approach.

## 1. Setting the Stage

Over 6 billion people presently inhabit the planet; 1.2 billion of these live in the U.S. and other developed countries while the other 4.8 billion, or 80% of the world's population live in developing countries. Three billion of them live on less than $2 per day. Two billion of them live in rural areas. And 2 billion of them do not have access to electric power and the applications powered by electricity. These 6 billion will grow to 8 billion people over the next 25 years, and 97% of these people will live in developing countries. Figure 1 dramatically depicts this increasing shift of the population balance.

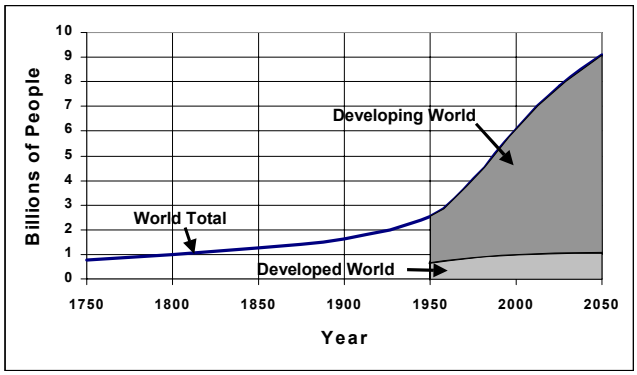


Fig. 1. World Population Growth and Projections (U.S. Census Bureau)

Given this population trend, and the coupled desire for development, at least three things are clear:

- The major market opportunities for renewable energy, PV in particular, are in the developing world,
- The reality of these markets will be constrained by the pace of development in these countries, and
- Accessing these markets will depend on defining and implementing sustainable product delivery pathways.

## 2. Key Market Sectors

The key market sectors for rural PV-based development include home systems, public-area lighting, schools, health clinics, water pumping and purification, micro-enterprise development, rural telecommunications, and diesel-hybrid power-system retrofits. PV is uniquely well positioned to make major inroads into all of these markets. However, more attention needs to be focused on productive uses (local enterprise development) and less on purely consumptive uses (home lighting) if rural economies are going to grow and be able to afford even larger and more productive PV applications. A systems approach that includes attention to policy and markets, as well at technology is required for success.

## 3. Business Challenges

Synergies between programs must also be pursued in order to build sustainable local-business capacity. The project opportunities for delivery of social programs (power for schools and health clinics) must be coupled with the additional vision of providing sales and financing to both individual households and businesses. One of the most important lessons learned over the past decade has to do with the relationship between business density and sustainability. The best current information suggests that the minimum business density (or "critical mass") is several thousand stand-alone installations in a geographically serviceable area (maybe 50 km).

Once this level of business density is achieved, a revenue stream can be created that can maintain the local service capacity. Unfortunately, programs are continuing that focus exclusively on highly dispersed schools or health clinics. While well intentioned, experience has shown that within usually 5 years), the inevitable battery failure, or other minor problems become a major issue without local service capability. NREL international program activities now advocate the delivery of social services as a kind of "anchor tenant" in development and implementation of sustainable delivery pathways. Every effort must be made to build local business capability as an integral part of every new rural PV-deployment program.

Business synergies are also becoming apparent, but we are still at the experimental stage in implementation. One of the most intriguing strategies at the moment is the

possibility of micro-enterprise development coupled with rapid expansion of e-commerce and advanced telecommunications. Rural e-commerce can bring cash into rural areas through access to global markets. Each element of this strategy requires power. Most often, PV power.

## 4. New Analysis Tools for Rural Electrification

From a national electrification perspective, a suite of new analysis tools are becoming available. Until now, rural electrification relied on either grid extension or installation of an isolated diesel engine-generator set. Now a suite of new renewable technologies are becoming available, but the tradeoffs and confusion about what is the best option to pursue can quickly become overwhelming. Even the analysis of retrofit options for rural diesel generators can be a challenge.

Over the past 5 years, the NREL PV program has contributed to the development of a family of computer-based analysis tools that help simplify this problem.

HOMER (the Hybrid Optimization Model for Electric Renewables) is a design optimization model that determines the configuration, dispatch, and load management strategy that minimizes the life-cycle costs for a particular site and application. It is fully functional to evaluate diesel-PV-wind-battery technology options. Code development is underway to include micro-hydro and biomass power.

ViPOR (the Village Power Optimization Model for Renewables) optimizes the power distribution system for a rural village and is being extended to assist with the question: "When should I stop extending the power grid and start considering village-scale hybrid power systems?"

Hybrid 2 is a tool designed to accurately predict the long term performance of a wide variety of power systems made up of conventional fuel generators, wind generators, PV, and energy storage through batteries. It is an engineering analysis tool that allows enormous system configuration flexibility, and the inclusion of company and model-specific technical characteristics.

These analysis tools are becoming increasingly important to the NREL PV and wind international program activities; programs which are now increasingly focused on technical assistance to developing countries. This assistance includes analysis of policy reforms, large scale project preparation, training, resource assessment, and implementation. Figure 2 depicts the multi-dimensional aspects of the NREL international programs.

## 5. Pathways to the Future

As the global experience in rural renewables-based rural electrification continues, it is increasingly apparent that

- Technology availability, cost, performance, and reliability are not the pacing issues, and
- Availability of project and program financing is not the pacing issue.

The pacing issues are clearly defining, developing and implementing the product delivery and revenue collection pathways. There must be a focus on sustainable energy enterprises. A number of increasingly large scale experiments focused on one or another of these sustainable enterprise pathways are underway throughout the world. Each pathway has its own pros and cons, which are different in each country due to cultural, regulatory, policy, financing, technical capability, and "starting point" differences. Possible pathway options include

- Individual retailers and entrepreneurs
- Traditional rural electric cooperatives
- Local village-based power associations
- Rural energy services companies
- Private voluntary organizations

Additionally, some of these pathways lend themselves to a possible franchise model (a "McSolar" type concept), and some may benefit from the concept of rural-geographic concessions that grant the exclusive right-to-serve in return for meeting certain responsibilities (like "universal access").

While we do not yet know which of these approaches will eventually dominate, we do know that the successful approaches will operate efficiently in both

- The delivery of high quality services (for a variety of applications ranging from homes to school to health clinics to local businesses), and
- They will find a way to effectively collect revenues, probably on a fee-for-service basis.

The wide range of services helps meet the business-density requirement, and the fee-for-service approach decouples the revenue from the traditional, often subsidized, low-perceived-cost kWh approach.

For those that figure out how to effectively meet these criteria in a manner that can be replicable and locally sustainable there are huge market opportunities for PV and other renewable technologies throughout the developing world


Fig. 2. The NREL International Programs Activities Cube