ACCELERATING CLIMATE TECHNOLOGIES: INNOVATIVE MARKET STRATEGIES TO OVERCOME BARRIERS TO SCALE-UP

CleanEnergyGroup
Innovation in Finance, Technology & Policy

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Disclaimer

About Clean Energy Group

Clean Energy Group (CEG), a national U.S. nonprofit organization, promotes effective clean energy policies, develops low carbon technology innovation strategies and works on new financial tools to stabilize greenhouse gas emissions. CEG concentrates on climate and clean energy issues at the state, national and international levels, as it works with diverse stakeholders from governments as well as the private and nonprofit sectors.

CEG's work is designed to greatly accelerate the commercialization of breakthrough low carbon technologies and to massively scale up existing clean energy technologies as rapidly as possible to strengthen the economy and stabilize climate change emissions. CEG is supported by major foundations, state governments and federal agencies.

Founded in 1998, CEG is headquartered in Montpelier, Vermont, with other staff based in Washington, D.C., Philadelphia, and Chicago. In 2002, CEG created and now manages a separate, national nonprofit alliance of 20 state-based, U.S. public clean energy funds and programs – Clean Energy States Alliance or CESA.
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I. SUMMARY

Following the Copenhagen Summit in 2009, there are two key issues to resolve: (1) how to accelerate breakthroughs in climate technology costs and performance and (2) how developed countries will cooperate with developing countries to speed the development and deployment of climate technologies at the pace and scale necessary to mitigate climate change.

This report makes the case that (1) the barriers to rapid diffusion of new climate technologies are too great for the private sector alone to surmount and (2) targeted public sector interventions are needed all along the technology development pathway to overcome specific technical, financial, and market barriers.

Two of the case studies analyzed here–Off-Grid Portable Solar Lighting (the *Lighting Africa* Program) and Agricultural Markets in Africa–offer successful examples of public-private market acceleration approaches to advance climate technology programs. These strategies tap distributed knowledge to overcome market barriers, unleash innovation, and push products to commercialization. The organizations that lead these projects are public agencies, foundations, and nonprofit organizations that play a neutral broker role with the private sector.

The final marine energy case study proposes a similar approach to accelerate hydrokinetic marine energy technology in global energy markets.

For each case study, we show the gaps to scaling up technology deployment, present the interventions, and recommend how an international effort could more rapidly and creatively accelerate climate technology markets.

The fundamental message of this report is that new innovation strategies are needed to accelerate climate technologies. The opportunity to harness collective global intelligence and fuel innovation for a sustainable energy future is upon us—if the world's policy makers are creative enough to embrace it.

CASE STUDY #1
OFF-GRID LIGHTING IN AFRICA: THE *LIGHTING AFRICA* PROGRAM

More than 500 million people in Africa lack access to electricity and are forced to rely primarily on kerosene-based lighting that is costly, inefficient and dangerous. Less expensive and higher quality off-grid lighting solutions are becoming available, but substantial market barriers have prevented the global lighting industry from successfully delivering them to African consumers. The *Lighting Africa* (LA) program, a joint International Finance Corporation (IFC)-World Bank (WB) initiative, seeks to overcome this challenge by facilitating the acceleration of new off-grid lighting product markets. A market transformation approach enables LA to provide an intentional hand in commercial market devel-opment, supporting the manufacture and distribution of superior off-grid lighting products aligned with market need.

LA identified a series of market gaps for off-grid lighting products that the private sector was unable to overcome. These include:

- Lack of market information and consumer knowledge of products
- Low quality products and absence of performance standards in the market
- Lack of available trade, consumer, and other financing
- Lack of business development support and technical assistance
- Policy and regulatory constraints

To overcome these barriers, LA channels direct support to the private sector through the following activities: (1) Market Intelligence and Consumer Education, (2) Product Quality Assurance, (3) Access to Finance, (4) Business Support Services, and (5) Policy and Public Sector Operations.

Lighting Africa provides market research, consumer education, supports the development of product specifications, builds local capacity for product testing, helps businesses access finance, provides business development support and technical assistance, and removes policy and regulatory impediments.

Through these interventions, *Lighting Africa ac*ts as "bridge" between the producer and the consumer. It fills market gaps as a "matchmaker," for entrepreneurs and local and international stakeholders along the supply chain.

Early evidence indicates that markets for modern, off-grid lighting in Sub-Saharan Africa are accelerating since the launch of the program. From fewer than 8 products developed specifically for this market in 2008, today as many as 71 product types manufactured by 49 com-

panies have found a home on African retail shelves. Now there are many quality products at retail costs far below that of a few years ago—between $25-$50 dollars—and portable solar lighting manufacturing costs are projected to decline by 40% per year.[1]

The *Lighting Africa* example demonstrates that in*dividual firms* cannot and should not "go it alone" to commercialize climate technologies in developing countries. The program underscores the need for an international public partnership to serve as a neutral broker to identify and fill gaps across the value chain, share international knowledge, enable relationship building, and respond to evolving market needs—actions that individual countries and private sector developers cannot do on their own.

CASE STUDY #2
AGRICULTURAL VALUE CHAIN & GAP ANALYSIS IN KENYA AND GHANA: ADAPTATION TECHNOLOGY

The second case study, "Agricultural Value Chain and Gap Analysis in Africa," looks at the market barriers in the production and delivery of cassava, maize, and dairy products to consumers in Kenya and Ghana. This case study is based on findings from a new Gates Foundation-funded project called *Innovations for Agricultural Value Chains in Africa: Applying Science and Technology to Enhance Cassava, Dairy, and Maize Value Chains*.[2] This agricultural project demonstrates a new collaborative product development approach for adaptation technologies.

This project establishes that the current private market for cassava, dairy, and maize in Kenya and Ghana is not working effectively for smallholder farmers. While this case study focuses on specific deficiencies in the cassava, milk, and maize value chains,[3] and is specific to Africa, the types of challenges—especially harvest and post-harvest elements—create inefficiencies across the entire agriculture sector. They undercut farming operations, distort costs, and prevent small farmers from receiving the real value of their commodities. And it is likely that climate change will further reduce agricultural production capacity in Africa and beyond, harming poor farmers even more.

This unique project, led by the Meridian Institute, a US-based, non-governmental organization (NGO), brings together international expertise from non-agricultural disciplines—a form of "open and distributed innovation"[4]—to analyze the problems from fresh perspectives. This interdisciplinary group recommended unexpected and creative technology solutions to overcome value chain gaps and improve markets for smallholder farmers. A key feature of this collaborative approach is its focus on joint research, and product and market development. It resulted in marketable products rather than more studies.

The cassava value chain provides an excellent example of how an open, collaborative approach to market acceleration can work. Cassava is a critically important crop in Sub-Saharan Africa, because of its significance for food security and its potential for value added market opportunities. However, there are major constraints to increasing the efficiency of cassava markets, largely due to problems in the post-harvest systems.

Through extensive consultation between affected farmers and the international science team, the group identified several product solutions to improve cassava production and delivery chains. These include mechanized root peeling and grating technologies, better mechanized dryers, and new cost-effective approaches to drying, including use of renewable energy resources.

Maize and dairy value chains demonstrated similar gaps and inefficiencies across the production process. For them, the Meridian team developed a number of specific technology and product concepts.

Out of the hundreds of innovative ideas generated, twenty-two were selected for further development and five are being refined for future implementation. One of the concepts, for instance, a modified plastic tank for maize storage, is already being prototyped and deployed in Kenya and other ideas are being linked with potential financiers.

Work has begun to identify a possible new public-private partnership to commercialize these technology concepts.

CASE STUDY #3
ADVANCED MARINE RENEWABLE ENERGY TECHNOLOGIES

The final case study reviews the challenges with the development and scale-up of advanced marine hydrokinetic energy technologies (wave, tidal, and current devices). Upstream gaps in the industry development chain and subsequent barriers to full market deployment are identified. The case study then suggests how these barriers could be overcome with more creative and internationally coordinated innovation strategies. Unlike the other case studies, no internationally coordinated project is now underway to accelerate the marine energy industry.

Marine hydrokinetic power technologies could harness a widely available, low-carbon, energy source—and mitigate climate change—in both developed and developing countries.

Despite the large commercial opportunity, marine energy faces a number of significant hurdles. Today, costs are much higher than both conventional power and more advanced renewable power. Moreover, no single technology has emerged as an industry leader and more than 75 device developers are competing globally for limited public and private investments.

Other significant challenges have slowed marine energy development and kept costs high:

- harsh marine environment
- grid access from remote locations
- unknown environmental impacts
- regulatory thickets involving multiple federal and local agencies

Moreover, the industry is dominated by a large number of small, start-up companies, which can lead to a lack of information sharing and a lot of "reinventing the wheel." These small companies do not have adequate funding to bring devices to market in most cases.

The question for policymakers then is: how to catalyze rapid cost reductions and accelerate the market through targeted interventions to overcome these barriers? The answer could be an internationally-coordinated, market acceleration approach that taps distributed knowledge and experience, like those outlined in detail in the preceding case studies, which would support fast learning and could produce radical cost reductions. The UK 2010 Marine Action Plan recognizes this need, concluding, "*There is an immediate need for everyone to work in tandem*."[5]

There are compelling reasons to take an international approach:

- Any setback with a particular device negatively impacts the entire industry. Because the industry is so small, any failures tend to stand out disproportionably to the actual technical challenge. One device developer noted that, "every time there is a failure you lose a couple of months across the whole industry."[6]
- The capital requirements to advance the industry are huge, on the order of US$750 billion by 2020, and costs have proven to be much higher than expected.
- The marine energy market, like all clean energy technologies, is global. Device developers are working outside their own countries and this will continue to be the case.

This paper outlines specific opportunities for international collaboration to overcome the gaps in the marine energy industry. However, while there is some interest on the part of the U.S. Department of Energy to initiate such an international marine collaboration, and despite its promising results in other technology areas, there is currently no project underway to accelerate the marine energy market globally through an innovation systems approach.

CONCLUSIONS

These three case studies show that the private sector alone cannot overcome the market barriers to scale up these new climate technologies.

The message is clear: new innovation strategies—with public and nonprofit "market acceleration" brokers—are needed for commercialization and market uptake of climate technologies. It is time for international programs to look to their example to address climate change at the scale and speed necessary.

II. INTRODUCTION

Following the negotiation of the Copenhagen Accord in December 2009, many questions remain about the prospects for aggressive international climate policy. Two of the key issues to resolve are (1) how to accelerate breakthroughs in climate technology costs and performance and (2) how developed countries will cooperate with developing countries to hasten the deployment of climate technologies at the speed and scale necessary to make a meaningful impact on climate change.

By and large, climate technologies today—both for mitigation and adaptation—are much more expensive than conventional technologies and their markets are undeveloped, in both developed and developing economies. At current rates of deployment, existing climate technologies do not have the capacity or scale to avert projected climate impacts within the time frame that climate models tell us is necessary.

On its own, the private sector, even with meaningful price signals,[7] will not achieve the needed breakthroughs in technology and reductions in production costs required to spawn rapid deployment.[8] What is lacking in the climate policy equation is an integrated approach for technology and market acceleration, underpinned by the following observations:

- Current policy approaches are insufficient to deliver needed technologies in time or at the necessary scale to make a meaningful impact on climate change;
- In many cases, coordinated international efforts are best equipped to address technology market barriers because they can provide the funding levels and networks necessary to scale up technology to meet massive emissions reductions targets;
- Solutions can be found more rapidly if initiatives tap distributed knowledge, experience, and expertise around the globe and across disciplines; and
- Technology innovation in all industries is becoming more global in scope; individual companies and countries can't just "go it alone" to solve these global problems.

There is a long history of conventional information sharing, network building, and other forms of technology cooperation between developed and developing countries. However, there are few examples of

an integrated "innovation systems" approach to accelerate specific markets, linking global expertise with local stakeholders to jointly develop solutions for technology innovation and dissemination.

This report makes the case that meeting aggressive climate emissions reductions goals will require exactly this type of collaboration to support market acceleration, targeting interventions at multiple stages in the value chain, while also addressing specific policy and investment challenges. An ambitious strategy should encompass product development, supply and distribution chains, financing models, and institutional frameworks along with policy requirements. All must be addressed together to generate a step change in climate technology deployment.

The purpose of this paper is to:

- Analyze a number of specific climate technologies to assess the gaps and barriers to full market deployment that the private sector on its own has not yet been able to fill;
- Articulate the interventions that have been or could be employed to overcome them; and
- Demonstrate how a coordinated international effort could more rapidly and creatively solve these challenges in order to speed up technology deployment.

The paper specifically analyzes three important climate technology markets:

- Off-grid solar lighting;
- Cassava, maize and dairy markets in Kenya and Ghana, which will be key to ensure adaptation; and
- Marine renewable energy.

For each market, we provide a *value chain analysis*, identifying gaps and interventions. A "value chain" describes the full range of activities required to bring a product from conception, through the different phases of production to delivery to final consumers. We then point out how these interventions are most creatively identified and most rapidly implemented through an international, distributed approach.

In the case of off-grid solar lighting, an international initiative, *Lighting Africa,* launched by the World Bank Group, is already underway to implement and monitor the impacts of these interventions in Kenya, Ghana, and a handful of other Sub-Saharan countries. And thus we describe the ongoing success of this approach.

In the case of agricultural markets in Kenya and Ghana, a project funded by the Bill and Melinda Gates Foundation, *Innovations for Agricultural Value Chains in Africa: Applying Science and Technology to Enhance Cassava, Dairy and Maize Value Chains* is also underway. To date the

inter-disciplinary project team has identified post-harvest management and process technologies to increase efficiencies for each product for small farmers. The initiative is now considering establishing an entity to commercialize and implement these solutions.

Finally, for the third case study on how to accelerate marine renewable energy technologies: while there is some interest on the part of the U.S. Department of Energy to initiate an international marine collaboration, there is currently no project underway to accelerate the market globally. However, this paper attempts to make the case for such an approach.

The question may arise as to why this paper examines such relatively small-scale markets, mostly in poor countries**,** when the challenge of climate change is global in scope and the biggest culprits are in large developed countries and emerging markets. There are at least two strong arguments for why these project strategies are important not only for developing but also for developed countries.

The first has to do with market failures, which are identified in the projects described here. Imperfect markets in developed countries are often not as evident as they are in developing countries. In developed countries with market failures for new climate technologies, a myth prevails that the private sector will solve all these problems with limited public action.[9] But this is rarely the case, and government intervention in the form of subsidies, pricing schemes, and mandates are used to overcome market failures.

A second, distinct reason to study these projects is that developing countries are increasingly the source of new innovation in many areas, and are likely to be so in climate technologies. A recent special report on innovation in emerging economies in *The Economist* suggests how the markets at the "bottom of the pyramid" will transform all markets. The report highlights how the sheer number of new production, distribution, and technology innovations and even business management strategies—all targeting higher mass production at lower costs—will shape markets in both developed and developing countries. The multinational General Electric (GE) refers to this new disruptive approach as "reverse innovation" and emphasizes that it "requires a decentralized, local-market focus."[10]

The Economist report notes,

> The emerging world will undoubtedly make a growing contribution to breakthrough innovations….People who used to think of the emerging world as a source of cheap labor must now recognize that it can be a source of disruptive innovation as well... The world's creative energy is shifting to the developing countries, which are becoming innovators in their own right rather than just talented imitators. A growing number of the world's business innovations will in the future come not from the "West" but from the "rest."[11]

All of these reasons underscore the key messages of this report: new innovation and market acceleration strategies are needed to accelerate climate technologies, the private sector alone won't fill these gaps, and that donors are already supporting creative innovation initiatives to accelerate climate relevant markets—in the case of *Lighting Africa,* they are seeing tremendous results from the approach. A similar approach should be used more broadly for markets like marine renewables and other climate technologies, where significant market barriers will continue to limit the pace of innovation and deployment without new strategies.

III. Case Study #1: *Lighting Africa*- Catalyzing Markets for Off-Grid Lighting

Problem Identification

Energy Access, Economic Development, and Climate Change Mitigation

Over 1.6 billion people worldwide do not have electricity, a challenge that is not likely to recede in the foreseeable future. By 2030, absent significant policy changes, the International Energy Agency (IEA) predicts that at least 1.4 billion will continue to lack access to electricity.[12] The problem is particularly acute in Sub-Saharan Africa, where a projected 88% of the rural population and 45% of the urban population presently lives outside grid connectivity.[13] Over the next 20 years, Africa is projected to rapidly surpass Asia to become the largest un-electrified market in the world, with approximately 700 million people living off-grid.[14]

In lieu of the grid, the nearly 500 million "energy poor" in Africa live in darkness or rely on traditional forms of energy including biomass, charcoal, candles, and predominantly fuel-based sources such as kerosene to meet their lighting needs. The quality of light emitted from traditional lighting sources is very poor, rendering many activities impossible or extremely inefficient after dark. Street vendors and other small entrepreneurs, for example, struggle to keep their businesses afloat with insufficient evening illumination. Families, especially women and children, are equally deprived of sufficient lighting, leaving little time for studying and social activities. Fuel-based lighting also poses significant threats to the environment, human health, and safety by releasing dangerous greenhouse gases (GHGs), contributing to indoor air pollution, and starting fires that can too often result in burn injuries.

The cumulative effect of 1.6 billion people without access to electricity using kerosene and other biofuels for lighting contributes heavily to global carbon emissions. Based on the official household consumption of kerosene world-wide, consuming 470 million barrels of oil per year releases 190 million tons of CO_2 globally, with Africa accounting for at least 30% of this total, or 60 million tons of CO_2 annually.

Expenditures on fuel-based lighting also pose a considerable burden on consumer finances, straining low incomes but providing little lighting value in return. Users of off-grid lighting can pay 150 times more per unit of useful lighting service than grid-connected customers for low-quality, fuel-based lighting products, which deliver a mere tenth of the light output (lumens) as modern off-grid lighting.[15] Conversely, modest increases in access to sustainable lighting contribute to major increases in disposable income and, in turn, substantial improvements in economic opportunities and quality of life.[16]

Evidence of superior lighting quality: Shoe vendor in Tanzania

Kerosene Lamp

LED Lamp

Once considered a low priority on the international agenda, increasing energy access for the poor has earned a spot as a key development priority for poverty alleviation, requiring global cooperation to succeed. As stated by UN Secretary-General Ban Ki-moon at a UN energy summit in April 2010:

> *"Energy services are essential for meeting basic human needs, reducing poverty, creating and accumulating wealth and sustaining advances in social development. Access to adequate, affordable and basic modern energy services is thus crucial to achieving sustainable human development*."[17]

In tackling this challenge, development leaders agree, as they professed in the culmination of the World Summit on Sustainable Development, that what's needed is to:

> "***take joint actions*** *to improve efforts* ***to work together at all levels*** *to improve access to reliable and affordable energy services for sustainable development sufficient to facilitate the Millennium Development goals*."[18]

In an effort to bridge the energy gap in Sub-Saharan Africa by making modern, off-grid lighting products available to the millions of people without electricity, the *Lighting Africa* Program, jointly managed by the World Bank (WB) and International Finance Corporation (IFC), was launched in the fall of 2007.

The near-term goal:

- Transform the lives of 2.5 million people by 2012 by mobilizing the private sector to develop commercial off-grid lighting markets across Africa.

The long term goal:

- Establish a broader commercial platform that will provide the market architecture to reach 250 million people with access to modern, off-grid lighting products by 2030.
- Adapt the program model for scale-up and replication to develop new markets in other countries and continents.

Lighting Africa Market Acceleration Goal

- 2.5 million people by 2012 (~ 500,000 products)
- 250 million people by 2030 (~50 million products)

Program Approach: Catalyzing Markets for Off-Grid Lighting

Recent technological advancements have enabled the development of new, innovative, off-grid lighting solutions that have the potential to replace fuel-based lighting and meet consumer needs. Their development is supported by strong consumer interest and willingness to pay (WTP) for improved lighting, which is perceived as a highly-valued household commodity and a gateway to opportunity.

Despite technological readiness and established market demand, substantial market barriers have prevented the global lighting industry from penetrating the off-grid lighting sector in Africa. *Lighting Africa* seeks to overcome these barriers by providing targeted support to the off-grid lighting industry based on specific needs and evolving market dynamics. This "market transformation" approach enables *Lighting Africa* to support markets to deliver quality off-grid lighting products to African consumers at price points that they can afford, therefore improving lives and reducing the impacts of climate change.

Lighting Africa is built on the premise that the dominant approaches of the past, namely top-down policy and regulatory reform coupled with attempts at subsidizing and liberalizing energy markets, have not been enough to make a significant dent in the electrification challenge. They have largely left the private sector out of the equation, assuming the status quo "business-as-usual" market economics will drive the market to develop on its own.

Lighting Africa acknowledges the shortcomings of expecting the private sector to act alone; it is not delivering the desired technologies fast enough or with enough volume to reach the hundreds of millions in need. There are simply too many barriers along the development chain that the industry cannot overcome

on its own. Technologies are available now that can substantially improve the well-being of millions of people immediately.

Under a business as usual scenario, the African market is expected to experience exceptional growth over the next 5 years, resulting in a 25% increase in annual sales growth (2 million African households owning solar portable lights by 2015).[19] Lighting Africa is built on the assumption that penetration could be significantly accelerated (40-50% growth in sales by 2015), potentially following the growth trajectory of the mobile phone market in Africa, provided that current market barriers can be overcome.

International Collaboration in Market Transformation

Lighting Africa is built on the following assumptions:

1. The market is not meeting customer needs due to a common set of barriers preventing the industry from taking full advantage of the unmet market opportunity.
2. The risk and transaction costs of overcoming these barriers are cost prohibitive for the private sector to overcome on its own.
3. These market risks are further amplified by the fact that the business environment in Africa is unique. Given this, conventional approaches will likely not suffice to sufficiently open new markets; standard ways of doing business in developed economies (or when targeting higher-income segments in developing countries) may fail when applied to the low-income African context.
4. The modern, off-grid lighting industry, like other new climate technology industries, is largely undeveloped, misunderstood, and is competing with an established (and often subsidized) fossil-fuel industry (kerosene).
5. To move consumers away from traditional fuels towards new climate-friendly technologies will require a massive cultural shift (substantial education across the value chain) and technology solutions that are specifically tailored to consumer need.
6. There is a significant role for an international body or coordinated bodies, capable of leveraging resources and intellectual capital, to support nascent market development by filling gaps in the market. This entity can reduce barriers that individual countries and industry players cannot overcome on their own. Rather than "go it alone" to solve global climate problems, use collective knowledge and put the drivers in place to collaboratively create a sustainable future.

The *Lighting Africa* experience supports applying this kind of "distributed innovation"[20] approach to accelerate climate technology development by dipping into global knowledge hubs for collective betterment. This process

could be facilitated by an entity or group of international entities that take responsibility for building a sustainable commercial platform to help drive technologies into the market. Accepting the role of a "neutral broker," this international body could essentially work "for the market," identifying the weak points along the value chain continuum and bridging gaps between upstream technology development and end-user consumers.

In effect, the task of overcoming market barriers can be viewed as an essential "public" role required for leveling the playing field and unleashing healthy market competition to build lasting markets. The end result: new climate technologies (or the energy produced by them) are funneled into the hands of end-users, conditions for local populations and the climate are improved, and progress towards a more sustainable global energy future is made.

Lighting Africa's ability to be an effective agent of market transformation is largely tied to its capacity to facilitate international collaboration—its ability to link the various actors across the value chain by bridging alliances and providing opportunities for partnership-building to fill voids across the value chain.

Lighting Africa is not developing a "business" so much as it is building a "market" and a vision of the future. This demands a position of impartiality and a commitment to establish commercial discipline in favor of long-term market growth. The interdisciplinary nature of building markets also requires an approach that works across technical, financial, economic, social, political, and regulatory systems to create an enabling business environment capable of supporting the rapid adoption of new, unfamiliar, technology offerings. To build sustainable commercial markets for off-grid lighting products in Africa, the industry must innovate—customizing market entry strategies that move beyond imported business models and marketing tactics from the West.

Barriers to Market Penetration Along the Value Chain

Through extensive industry consultation, desk review, and field work, the project team identified a number of market barriers preventing the uptake of new off-grid lighting technologies into African markets.

Manufacture/Producer

- Upstream, at the level of the *Manufacturer/Producer*, a number of barriers have been identified. First, there is a general lack of understanding of the size of market opportunity. Because the off-grid lighting market is highly undeveloped and untapped, the transaction costs to gain market comprehension are expensive and beyond what the industry wants to invest.
- The business environment is perceived as inherently risky and target segments are often misunderstood and undervalued as a viable market. In part, this is because the vast majority of base-of-the-pyramid populations operate primarily in the large, but hidden, informal

economies that are not recorded in official gross national product (GNP) or purchasing power parity (PPP) statistics.[21] Across the globe, it has been estimated that the informal sector includes more than $9 trillion in hidden (or unregistered) assets, an amount nearly equivalent to the total value of all companies listed on the main stock exchanges from 20 of the most developed countries.[22]

- A lack of product testing and technical support services makes it difficult for manufacturers to overcome technical hurdles and obtain guidance to improve product designs. Firms need to be able to deliver the "right product" at the "right place" at the "right time" and the "right price" in order to succeed in the marketplace. If one of these elements is lacking, such as product designs that misjudge the market environment or are priced outside of consumer purchasing power, market failure is likely. The Solar Home Systems introduced in the past, for example, were never able to earn widespread adoption in low-income market segments in Africa, in-part because the first-cost barriers were insurmountable.
- A general lack of resources and diversified financing sources prohibits ideas from transforming into market-ready product lines. Initial capital for both R&D and fixed assets for production costs are lacking as well as opportunities for accessing growth and working capital, increasing the threat that good ideas will become orphaned from the realization of achieving commercialization.

Buyer/Wholesaler/Importer

- At the level of the *Buyer* (importers, bulk purchasers, government regulators), the largest barriers relate to a general lack of market information and insufficient information flows. Buyers need reliable and rapidly accessible information to make informed purchasing decisions (for e.g. to decipher good quality from poor performing products) and source suppliers.

- Policy and regulatory impediments often result in unnecessary cost build-ups and prevent the movement of off-grid lighting products and components across state lines, causing a bottleneck for importers trying to bring products in.

- Wholesalers have difficulty accessing working capital to cover the transport costs from the manufacturer, which are typically high and include insurance coverage (10-15% of manufactured costs).[23]

Distributors / Retailers

- Similar to the information deficiencies upstream, *Distributors and Retailers* are also constrained by a lack of knowledge to effectively weigh the opportunities and trade-offs among the wealth of products coming down the pipeline. This disables distributors from gaining sufficient confidence in the opportunity and may dissuade them from

carrying off-grid lighting products, since they do not have an established brand identity like the other consumer goods they stock.

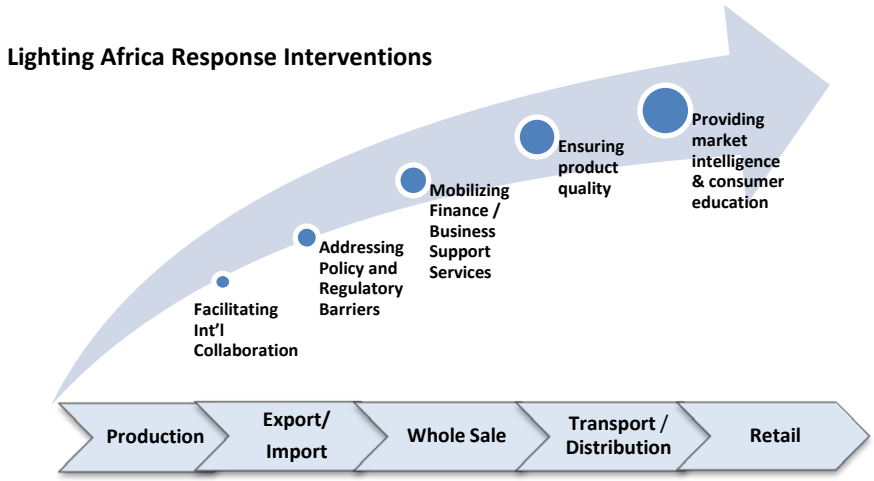
- There is little to no documentation of conventional and alternative distribution networks, proven business models, or marketing strategies for effective product delivery, particularly to the low-income rural poor.
- The lack of information to decipher good quality from poor performing products poses significant risk for distributors and retailers, again adding costs that they are often not willing to take on for what are already perceived as a risky investments. The inability to identify and secure working capital and to access supplier networks and retail outlets are other interrelated hurdles that have been identified by distributors as inhibiting them from sourcing products.
- Even if delivery models can be identified, a lack of access to partners to move products from the warehouse to retail shelves causes an additional value chain bottleneck.

Consumers/End-Users

- Downstream, on the demand side, *Consumers* are disempowered by a lack of sufficient information needed to make value judgments to both discern "the good from the bad" on retail shelves and match products to their specific performance needs. As with other buyers further up-stream, consumers lack the ability to both compare and contrast new products against each other, and to compare new lighting products with the traditional fuel-based products, in which they have already invested.

- Significant cultural and generational hurdles must to be overcome to help low-income consumers understand the benefits of new lighting products versus kerosene-based lighting. The fuel-based lighting market is familiar and friendly to them, often allowing them to pay for fuel in installments or other payment schemes tailored to their budgetary restrictions. Replacing kerosene lighting, "the energy backbone of rural Africa,"[24] with modern lighting that integrates foreign technologies (e.g. photovoltaics) and involves specialized charging requirements, will require substantial consumer education.

- Although prices are coming down and a range of quality products are now retailing between $25-$50 dollars, with some products coming in at even less, many of the poorest consumers may still require finance support, especially since they are used to paying small installments over time for kerosene rather than a one-time, upfront investment. Access to consumer finance such as micro-finance options and alternative financing schemes may be needed to enable consumers to obtain modern lighting products.



Lighting Africa's Response Interventions

Lighting Africa's program interventions are structured around five program areas, each designed to reduce the specific market barriers identified above and promote rapid market acceleration for off-grid lighting products: (1) *Market Intelligence and Consumer Education,* (2) *Product Quality Assurance,* (3) *Access to Finance, (*4) *Business Support Services,* and (5) *Policy and Public Sector Operations.* Through the implementation of these program areas, *Lighting Africa* acts as "bridge" between the producer and the consumer, filling market gaps and serving as a "matchmaker." By facilitating international collaboration, *Lighting Africa* is able to link multiple local and international stakeholders together to support collective market development for all.

1. Market Intelligence And Consumer Education

Barrier: Lack of Market Knowledge and Inefficient Information Flows

Although not commonly perceived as a viable market segment, the nearly 500 million people living outside of grid-connectivity in Africa spend exorbitant sums —as much as 10%-30% of annual household income—on fuel-based lighting.[25] In aggregate, this amounts to as much as $10-$17 billion per year in Sub-Saharan Africa and approximately $25-$38 billion globally (out of a $185 billion global lighting market).[26] However, this information and general information about consumer behavior and market characteristics are largely undocumented and difficult to attain. As a result, the lighting industry has not been able gain confidence that it can earn the returns needed to substantiate the costs of doing business in this market. Two years of extensive pre-program consultations revealed that while private sector interest in market exploration existed, perceived risks and costs outweighed interest in market penetration.

The undeveloped state of the market and lack of market experience plagues every level of the value chain, from the upstream producer seeking to design to consumer need and establish appropriate pricing, to the end-user trying to

decide which product to buy at the vending shop. Manufacturers simply have too few examples of proven business models to emulate and know too little about consumer needs to realize the unmet market potential or even to offer relevant products. Downstream consumers are equally disempowered by insufficient knowledge, which prevents them from being able to assess the benefits of modern lighting or access the available product options. Because gaining this market insight is very costly and onerous for the private sector to gather on its own (especially the many small to mid-sized enterprises involved in this market), there is little incentive to fill the information gaps and, consequently, they are never filled.

In part, the situation leads to a negative feedback loop: manufactures perceive a limited, high-cost, high-risk market opportunity and decide not to invest in the research needed to refute this belief. As a result, the market is undeveloped, there is no industry experience to document the opportunity, and manufacturers fail to perceive new market opportunities.

For distributors, a similar information gap exists, whereby there is relatively little documentation of conventional or alternative value chains and distribution networks, coupled with a lack of expertise and tools needed to move product to commercialization.

Program Intervention: Providing Market Intelligence

Lighting Africa's response to facilitate market understanding lies in its market intelligence offerings, including market research, country and value chain profiling, and distribution channel mapping.

- **Market Research.** To remove uncertainty from the R&D process and to obtain information that is otherwise difficult and costly to secure, *Lighting Africa* has undertaken a series of in-depth quantitative and qualitative market research studies. Targeting two market segments—households and micro-businesses—in both rural and urban areas, research findings provide detailed consumer insights, including feedback on pricing, design attributes and product performance, payment preferences, power generation needs, etc.
- **Retail Audits.** To both monitor the effect of its interventions and to provide targeted feedback to manufacturers, distributors, and retailers, *Lighting Africa* is in the process of developing a tool to conduct periodic retail audits, to funnel information on sales performance, new product introduction, pricing, and other key performance data points back to these groups to help them improve their business strategies and refine value chain operations.
- **Country profiles** supplement the market research by offering manufacturers, product developers, financiers, lending organizations and others a snapshot of the key country information needed to prioritize points of market entry. To date, country profiles have been completed for Tanzania, Ethiopia, Kenya, Ghana, and Zambia, capturing key data points about the overall energy sector, general market profile, policy environment and regulatory framework.

- **Distribution channel mapping.** Lower down the value chain, importers, bulk purchasers, government regulators and other buyers need quick ways to source suppliers and identify conventional and alternative distribution channels. To fill this information deficiency, *Lighting Africa* has undertaken an extensive analysis of existing and potential distribution networks, which are further supported by distributor education workshops and business development support to link buyers with distributors. If producers can establish rural distribution networks and reduce the number of intermediaries between themselves and their local dealers, they can avoid mark-ups and translate savings into increased sales.
- **Value Chain Analysis.** To support firms to increase efficiency in their value chain operations, *Lighting Africa* has conducted basic value chain analyses of popular consumer goods, starting in Ghana and Kenya, with plans to replicate these analyses across the continent. The analyses assess multiple cost build-ups and evaluate value chain options and opportunities for effective product dissemination targeting specific geographic regions.
- **Information Sharing.** One of the main services the program provides is to constantly fill information gaps to meet market need, for example, channeling timely reports, news, event information, and briefs to increase knowledge sharing.
- **Inviting others to fill their own information gaps.** This information flow is supported by an open source web platform (www.lightingafrica.org) that is designed to facilitate on-line collaboration and knowledge exchange.
- **Consumer Education.** Akin to the information gap issues faced by those upstream, consumers are disempowered by a lack of education and ability to assess product performance. *Lighting Africa* recognizes the essential need to grow and sustain consumer confidence in this new market sector. It does so by supplying unbiased information to consumers in a way that is readily accessible and understandable. A substantial consumer outreach campaign is being planned to help consumers to become knowledgeable buyers.

2. Product Quality Assurance

Barrier: Market Spoilage/ Low-Quality Products

"There are no governing standards on the quality of products that should be in the market so customers don't know which products to trust." (Senegal Wholesaler)[27]

In the absence of product quality standards and performance specifications, manufactures have few metrics to help them in the design process and the market becomes somewhat of a free-for-all. Even in countries where quality measures exist (whether or not they are adequate), they are often not enforced at the national level due to a lack of equipment and the unavailability of

qualified personnel to conduct the test."[28] Given this situation, the chance for market spoilage is quite high.

Already, substantial numbers of poor-quality, off-grid lighting products are making their way into the African marketplace, a situation that is only expected to worsen in absence of quality control measures. The travesty is that manufacturers of high-quality products may actually be penalized at market, when low-cost, poor-performing products quickly absorb market share. The scenario: consumers, unable to decipher quality on the retail shelves, are likely to go for the cheaper (and substandard) products, only to incur significant financial losses when the product breaks soon after purchase. Inferior goods quickly then make a name for themselves in the marketplace, tainting the image of all new technologies, undermining consumer confidence, and contributing to market spoilage.

The potential of this scenario repeating itself is strengthened by the fact that producers have little to no opportunity to access product testing and technical advisory services, often resulting in impenetrable bottlenecks during early development phases. If products are designed poorly and do not gain market share and brand recognition early on, businesses may not have enough capital to come back, especially small firms who likely can't bail themselves out when their products fail to earn market share.

"There have been many substandard or counterfeit solar products in the Kenyan market and the problem is growing, hence most customers tend to be skeptical about solar lanterns in general; the company has to work very hard to build credibility with the customer." (Kenyan Wholesaler)[29]

Low Cost LED Torches for Sale in Kenya

Counterfeit LED torch

Program Intervention: Product Quality Assurance

Lighting Africa is undertaking a number of activities designed to alleviate this barrier and help build quality mechanisms into the marketplace. With careful attention not to "pick winners," *Lighting Africa*'s quality assurance activities seek to provide direct business support to pro-performing companies and help raise the bar for under performers. The key is to maintain a delicate balance between opening markets enough to enable the development of a wide range

of products and restricting them enough to keep the really low-quality products out.

To achieve this goal, the program is undertaking a number of activities, including:

- **Establishing Local Testing Capacity and Linking Producers to Quick Screening Testing Laboratories:** partnering with local institutions (e.g., universities) to set up and train local technicians to offer low-cost quick screening testing services. Firms can then get a preliminary indication of how their products perform and use the test result for marketing purposes. The results may also become a basis for bulk purchasers and other aggregators to evaluate products they might want to source.

- **Developing a Standardized Testing Method for Off-Grid Lighting:** a more in depth (and expensive) testing method enabling those that pass the local "quick screening" to send products to a number of accredited labs for further analysis. Companies that pass this test also receive substantial business support from *Lighting Africa*.
- **Serve as a Clearinghouse for Information on Product Quality:** creating and disseminating relevant technical white papers and periodic briefing notes, for example on "Lumen Depreciation," "Thermal Management for LEDS," "Eco-Design," and other topics of interest to the industry.
- **Providing One-on-One Advisory Services:** (on a cost-shared basis) with companies that demonstrate strong commitment to quality issues
- **Running and Supporting Awards Competitions:** to reward companies which develop high-quality products, providing them with branding rights (e.g., "*Lighting Africa*" endorsed logos on packaging materials), marketing support, and other high-visibility, promotional activities to help them gain public recognition.
- **Partnering with local standards bodies:** starting in Kenya and Ghana, to support the development of quality standards.
- **Establishing an International Off-Grid Lighting Stakeholder Association:** to support the creation of a sustain-able commercial platform for market development. As part of its activities, the Stakeholder Association will support sector growth by developing a quality "seal" and partnering with local standards bodies, governments, and multilateral organizations to develop quality standards, in addition to providing strategic guidance to the other four program areas. This entity will become the home for the eventual transfer of program from the World Bank Group to external ownership.

3. Access to Finance

Barrier: Inability to secure Finance

Lack of financing creates bottlenecks along the entire off-grid lighting market value chain. Lack of liquidity— limited access to long-term growth capital as well as short-term working capital and trade finance—presents significant barriers to market acceleration. The lack of access to working capital and trade finance, for instance, poses significant challenges to distributors and importers trying to stock product. The situation is complicated because credit agencies are unconvinced of the validity of the market and, therefore, are hesitant to lend to distributors. The commercial banks and other financial institutions, which offer lines of credit to the credit agencies, are equally intimidated by a general lack of market comprehension, and thus do not want to support the credit agencies, creating a double negative. "High interest rates (up to 40% in certain countries) negate the fundamental purpose of alternative financing plans, providing little to no incentive for their utilization. Moreover, available financing is often security-based, while most suppliers do not hold collateral."[30]

Consumers are also crippled by their budgetary constraints. Without substantial savings, it is nearly impossible for low-income consumers to come up with the initial investment needed to purchase new lighting products. Products in the marketplace presently retail from $25-$50[31] that, compared to the solar and other off-grid technology solutions of the past, are well within reach. However, first-cost barriers still remain a challenge for some low-income consumers, even though over a few months, most consumers spend the equivalent or more on kerosene than the average cost of a modern, off-grid lighting product. Still, consumers are very often reluctant or unable to make such a large, upfront investment for a new technology, due both to the nature of their available cash flow as well as to the real and perceived risks of investing in an unknown product.

Program Intervention: Access to Finance

Lighting Africa provides access to funding in a number of ways.

- **Prize competitions for seed capital.** The 2008 Development Marketplace Grant Competition, run by the World Bank and themed "Innovations in Off-Grid Lighting Products and Services for Africa," offered up to $200,000 in seed funding to kick start off-grid lighting product development. *Lighting Africa* also supports other initiatives that aim to stimulate the off-grid lighting sector, such as Tanzania's Rural Electrification Agency (REA) initiative this past April.

- **Risk mitigation instruments.** *Lighting Africa* is also building longer-term financing capacity. For example, it is partnering with commercial financing institutions to supply them with information, training, wholesale capital and (when required) risk mitigation instruments to provide financing to different stakeholders along the supply chain. *Lighting Africa* is also exploring the potential for financing and risk-sharing arrangements that could support consumer goods companies and service organizations to offer off-grid

lighting products through their retail channels. By investing in a first-loss partnership to facilitate the acquisition of low-cost, off-grid lighting products through micro-finance institutions or commercial banks, these companies stand to gain from the increased business that will result from lighting product sales.

- **Leveraging International Finance Corporation's (IFC) investments and advisory services**. *Lighting Africa* is looking into leveraging IFC's investments and advisory services to provide working capital and trade finance to manufacturers and distributors. For example, opportunities are being explored to partner with IFC's Financial Market's Group to channel funds to commercial banks that could then supply initial capital to local distributors in Africa. Upstream finance opportunities are also being developed to provide growth capital for manufacturers and systems integrators through a partnership with IFC's Clean Tech Fund.

- **Collaboration with Specialized Fund Providers.** In addition, *Lighting Africa* is also looking into the possibility of collaborating with, and potentially providing direct financing to, specialized fund providers such as E+Co,[32] Acumen Fund,[33] the Grassroots Business Fund,[34] and others. Establishing dedicated internal or joint funds to fill resource gaps for concept development, increased manufacturing, and other upstream needs are also being reviewed. Downstream, collaborations are being established to help accrue working capital for importers through commercial banks and secure microfinance for Small and Medium Enterprises (SMEs) and consumers.

- **Matching SMEs with Financial Institutions (FI).** Some of the primary manufacturers of off-grid lighting products for Africa are SMEs. These companies often face barriers in accessing the growth capital they need, typically because their financing needs are relatively small (approximately $300,000 - $3,000,000) and risk-return profiles are (perceived to be) unfavorable. *Lighting Africa* is in the process of forming partnerships between financial institutions/funds and manufacturers and distributors to raise concessional financing and address working capital and trade financing needs.

- **Building FI market knowledge.** As part of the effort to build options for early stage financing and growth capital, *Lighting Africa* is also helping the identified financial institutions assess and, ultimately, gain confidence in the loan opportunity, for example, by providing firms with market specific assessment reports and product test results.

  "Banks have limited understanding of the solar market and hence are not interested in financing us- it might be useful to educate the banks on the potential of the solar market (Ghanan Distributor)."[35]

- **Partnering with Microfinance Intuitions to Provide Consumer Finance.** To help low-income consumers gain access to finance, *Lighting Africa* has begun to partner with selected International and local Microfinance

Institutions (MFIs) and private sector firms to provide consumer finance. So long as the high transaction costs for loans of this size can be overcome (e.g., securing affordable interest rates), microfinance should provide low-income consumers with financing tools to procure modern lighting products. A range of relevant consumer finance models through MFIs, in addition to savings and credits unions, are being piloted by organizations like Arc Finance[36] in Ghana and Microenergy International[37] in Tanzania.

4. Business Support Services

Barriers: Lack of Industry Consortium & Access to Business Partners; lack of business development support

The lack of access to partners and secure business networks across the value chain were identified as key impediments to business development, preventing early interest in market entrance from materializing into product development and commercialization.

In addition, due to the undeveloped and somewhat unconventional nature of the off-grid lighting business environment, some entrepreneurs find themselves struggling to design the right kinds of products, to create business models that will leverage the right distribution channels to reach target consumers, and to design marketing campaigns that will invoke consumer interest.

Program Intervention: Business Support Services

Lighting Africa helps companies overcome these barriers through some of the following program activities:

- **The Lighting Africa Web Portal:** a social media web platform, offers a suite of virtual networking and information sharing opportunities and tools, such as a member search function to access information on the thousands of registered Lighting Africa members. It also has an internal email system and a thriving business opportunities forum which enables firms to post and receive business leads. Acting as a "virtual home" for the international off-grid lighting stakeholders, the web portal is a one-stop shop for developing business-to-business (B2B) linkages, gaining insight into the latest market trends and technical advancements, and sharing knowledge across the industry. With 40,000 page views and 9,000 "hits" per month, the web portal continues to grow and improve its ability as an effective business support tool. Lighting Africa also uses other social media communication tools such as Twitter and Facebook.

- **Networking activities:** such as conferences and industry workshops, including the bi-annual Global Business Conference and Trade Fair for off-grid lighting, are sponsored by the program.

- **Partnership System:** *Lighting Africa* has developed a three-tiered business support system designed to reward companies with additional business

support services as they deepen their commitment to the market, improve product quality, and meet other market development criteria.

- **Third Tier.** The bottom tier, the *Lighting Africa Network*, includes all manufacturers and distributors (and everyone else) that participates in the program by becoming a member through the website. In return, Network members receive online business support through access to online informational resources. Network members also receive automatic subscriptions to *Lighting Africa*'s newsletter and other invitation only announcements in addition to the ability to access all of the site's interactive social media tools.

- **Second Tier.** In addition to the network member services described above, firms that achieve the second tier of engagement become *Lighting Africa Members* and are afforded the opportunity to receive a higher level of business facilitation support. To achieve this status, firms must have submitted products to one of the local testing centers and successfully passed the "quick screening" quality test. As a reward for companies that achieve this level of quality, *Lighting Africa* provides them with "matchmaking services" by way of a direct introduction to interested financing institutions, product testing feedback, and customized business development support.

- **First Tier.** The top tier, the *Lighting Africa Associate* receives the greatest amount of business support from the program and is covered by a Full Partnership Agreement, including key account management services, product improvement support, capacity building for after sales service and maintenance, marketing assistance, and access to finance through matchmaking with relevant commercial financial institutions. Associates have products that have passed both the local quick screening and international tests by one of the *Lighting Africa* accredited international laboratories.

- **Additional *Lighting Africa* business support services include:**

  - The facilitation of bulk purchase procurements (e.g., by major government and corporate entities such as Unilever Tea, Kenya);
  - The provision of networking and matchmaking services (e.g., between established local distributors and international/local manufacturers of off-grid lighting products);
  - Capacity Building support (e.g., technical assistance to manufactures, business support for distributors, local testing centers, after sales service, technical assistance, etc.);
  - The provision of timely, relevant, business advice to gain market comprehension and inform the design of business strategies (e.g., including quarterly market trends, business analyses, industry lessons learned, value chain analyses, distribution channel mapping, country profiling); and
  - Marketing/Advertising support (for e.g., provision of branding rights).

5. Policy and Public Sector Operations

Barrier: Policy and Regulatory Constraints

Probably the largest and most difficult barrier for the industry to overcome on its own is one of policy and regulatory constraints. In West Africa, for example, where solar lighting products are less prevalent, import duties ranging from 5%-30% and taxes/VAT up to 19% have been recorded, leading to a total tax and duty burden of up to 50% of the end-consumer cost of the solar lighting product in some geographies.[38] Duties, subsidies, and other policy and regulatory hurdles prevent and discourage the movement of new technologies across state lines, often providing disincentives and sometimes preventing their entry outright.

"The company would like to assemble products locally but currently would need to pay duties for all parts on the assembly kit which becomes very expensive- we would need a lot of government incentives around VAT $ duties." (Kenyan Distributor)

"We could reduce price by 20-30% in most West African markets we sell in, if duties and taxes were less onerous." (Senegalese distributor)[39]

While a number of countries have begun to remove or substantially lowered such taxes, suppliers still complain of lengthy procedures at port of entry that stem from customs agents lacking an understanding of off-grid lighting products, corruption, and/or inconsistent treatment of goods at the airport.[40]

Program Intervention: Policy and Public Sector Operations

At the request of industry and governments, *Lighting Africa* launched a policy and regulation program in 2009. The program offers a two-step approach:

1. **Information Sharing:** The first is to gather and share information through industry workshops, in collaboration with customs agents, on policy and regulatory constraints that prevent market uptake of low-cost, off-grid lighting technologies. So far, focus has been directed at eight countries – the Democratic Republic of Congo (DRC), Cameroon, Ethiopia, Ghana, Kenya, Rwanda, Senegal and Tanzania. The workshops will support the industry to gain a better handle on the policy environments in these countries, by documenting successes and challenges of inter- and intra-country policy approaches to market entry. For example, to help distributors overcome difficult regulatory hurdles, *Lighting Africa* is providing them with information on applicable government procedures to better navigate through customs bottlenecks.
2. **Engage Local Governments**: This information will also be used as a basis for *Lighting Africa* to engage local governments in discussions towards the longer-term goal of supporting actual improvements in policies and regulations (e.g., customs, taxes, administrative procedures and regulatory standards that are perceived as impediments by the industry). To support this process, collaborative Policy Advisory Groups (PAGs) have been convened, in both East and West Africa, comprised of local private

and public sector delegates and other key stakeholders, who will lead the government consultation process.

As an overarching policy goal, *Lighting Africa* also continues to seek opportunities to collaborate with other World Bank-financed, rural electricity access projects in several African countries, including Tanzania, Ethiopia, Liberia and Senegal. The World Bank's Tanzania Energy Development & Access Expansion Project, for example, has integrated several pilots promoting the inclusion of low-cost lighting services into the activities of Tanzania's Rural Energy Agency, such as supporting bulk procurements of Solar Home Systems and lighting devices by agricultural cooperatives and integrating LED lanterns and solar charging stations into off-grid electrification expansion programs. Together, these elements enable *Lighting Africa* to synchronize a coordinated push to reducing and removing regulatory hurdles.

The photo on the left shows children studying at night with a kerosene lamp, while the photo on the right shows them studying with a LED task lamp, which offers better illumination, resulting in increased educational opportunity.

RESULTS

Early evidence indicates very encouraging results that the off-grid lighting market is beginning to take hold in Sub-Saharan Africa. The market has accelerated considerably since the launch of the *Lighting Africa* program. From fewer then 8 products developed speicifically for this market in 2008, today as many as 71 product types manufactured by 49 companies have found a home on African retail shelves. Of these firms, *Lighting Africa* has established close relationships with as many as 40 of them (82%), and is providing direct support through ongoing business facilitation services and linkages to access finance.

The products have also undergone a major transformation. In 2008, products retailing above $50 dominated the market. Today, a wide range of products are priced at $25-$50. At the same time, *Lighting Africa* has developed a quality assurance methodology for low-cost solar lanterns that can be readily adopted by African laboratories and standards bureaus. Products meeting the quality threshold will enjoy full market development support from the program, including a suite of services.

Lighting Africa has frequently served as a reference point for quality-related issues, including recent advice to World Bank teams in Haiti and Afghanistan,

as well as to other organizations such as the Clinton Global Initiative. This support has contributed to more than 250,000 Haitians receiving emergency lighting after the devastating earthquake in 2010. Recently, the U.S. Department of Energy and the Asian Development Bank approached *Lighting Africa* with a proposal to fund the internationalization of the *Lighting Africa* approach.

The program's market intelligence products stand as the most comprehensive indicator of the market opportunity and characteristics, and at least eight manufacturers have directly used *Lighting Africa*'s market research and consumer insights in product design. The Development Marketplace Grant Competition winners are recieivng on-going support to roll out their projects, some of which are already demonstrating strong development impacts such as doubling test scores and improving retention rates due to increased availability of lighting for night-time study activities.

The *Lighting Africa* website continues to expand, serving as a virtual home for the international off-grid lighting industry and associated stakeholders and more than 600 participants attended the *Lighting Africa* 2010 Business Conference and Trade Fair, on May 18-20, 2010, in Nairobi, Kenya. Attracting individuals from across the African continent and around the world, the three days of interactive sessions, side events, and trade exhibits had attendees claiming that the conference was the best and most useful of any conference, workshop, or trade event they've attended in the last decade.

Many commented that they wouldn't be working in this market without the program's assistance, with some designing their products wholly around the program's market research findings and testing criteria. Others, close to the end-users, told endless tales and anecdotes—about a woman who had chronic vision ailments her entire life that were instantly cured by the switch from kerosene to modern lighting, a family that had managed to save enough from not having to purchase kerosene to buy their first tomato, or a school that is filled every night with adults who never had the opportunity to learn to read before.[41]

As a result of *Lighting Africa*'s unique hand in market development, entrepreneurs across the value chain are increasingly turning to *Lighting Africa* for collaboration and guidance. The program is responding by offering leadership as a neutral broker on behalf of industry interest, mitigating risk for all market developers across a level playing field. If the international community can continue to join forces to support market acceleration for sustainable, modern, off-grid lighting technologies, then costly, dangerous, polluting, and inefficient technologies will soon become a relic of the past.

IV. Case Study #2: Agricultural Value Chain and Gap Analysis in Kenya and Ghana (Adaptation Technology)

The second case study, "Agricultural Value Chain and Gap Analysis in Africa," looks at the market barriers in the production and delivery of cassava, maize and dairy products to consumers in Kenya and Ghana. This review is based on findings from a new Gates Foundation-funded project called *Innovations for Agricultural Value Chains in Africa: Applying Science and Technology to Enhance Cassava, Dairy, and Maize Value Chains*.[42]

We selected the agricultural project to demonstrate the useful application of collaborative product development approaches for adaptation technologies as well as mitigation technologies. Just as *Lighting Africa* is built on the premise that the private sector is not currently equipped with the market comprehension to deliver the "right" products, at the "right" price points, through the "right" distribution channels, the Agricultural Value Chain Project establishes that the current private market for these products is not working, a classic market failure requiring private and public intervention.

This will case study will:

- Identify the gaps in the value chain for agricultural products in Kenya and Ghana, specifically maize, cassava and dairy;
- Explain the unique process of bringing in outside expertise from non-agricultural disciplines—a form of "open innovation" to analyze the problems from fresh perspectives;
- Summarize the product and market development solutions proposed to overcome these gaps; and
- Suggest how even greater international cooperation could accelerate technology innovation and market development in this space, going beyond the single-foundation funding in place today.

Problem Identification

In Africa, smallholder farmers of crops like cassava earn as little as $1-$2 a day, making them extremely vulnerable to market instability and potentially subsumed by value chain deficiencies. Conversely, small improvements in value chain operations can yield drastically improved profit margins, generating savings that can be reinvested in further efficiencies along the chain. Small measures that improve value chain efficiency can drive products to market faster and at less cost to the producer, as well as boost earning capacity, increase agricultural productivity, and provide savings to reinvest and support greater efficiency gains, closing a positive feedback loop.

Presently, however, the ability to capitalize on these gains is thwarted by systemic inefficiencies across the value chain. While this case study focuses on specific deficiencies in the cassava, milk, and maize value chains and is specific to Africa, the types of challenges—especially harvest and post-harvest elements—are shared impediments across the agriculture sector, serving to undercut farming operations, distort costs, and prevent small farmers from receiving the real value of their commodities. In addition, it is likely that climate change will further reduce agricultural production capacity in Africa and beyond, the result of the double negative of reduced crop yields coupled with agro-economic consequences, which will develop in tandem stifling regional productivity, stimulating fluctuations in global commodity prices, and driving up the prices of agricultural commodities. Ultimately, these consequences will contribute to global hunger and affect the poor most adversely.

These climate impacts make even greater the need to inject an ounce of preventative maintenance into value chain operations to improve efficiency in the near-term; the faster road blocks can be reduced, the more poised Africa, and the world at large, is to adapt to projected climate change scenarios.

Program Approach

The *Innovations for Agricultural Value Chains in Africa* project, led by the Meridian Institute, a U.S.-based non-governmental organization (NGO), uses a distributed innovation strategy to identify and recommend creative solutions to overcome value chain gaps and accelerate specific agricultural markets in Africa. The project took an innovative approach by formulating an international and interdisciplinary team of scientists and innovators with African stakeholders representing the various players across the maize, cassava, and dairy value chains.[43]

The project is embedded in an ambitious, much larger, Gates Foundation program to reduce hunger and poverty in Africa. The Gates Foundation's approach recognizes that there is no single, simple solution to the challenges

small farmers face. Thus they partner with private and public sector organizations and seek input from a diverse range of individuals—"farmers and funders, scientists and environmentalists, policymakers and business leaders."[44] Most of their grants are directed at increasing farmer productivity through improved market access, science, and technology (as in the Meridian project). Only a very small amount of grant funding to date has been dedicated to policy approaches.[45]

The *Innovations for Agriculture Value Chain in Africa* project was initiated in the summer of 2009 when the Meridian Institute aggregated an interdisciplinary science team to travel to Kenya and Ghana to meet with smallholder farmers and various cassava, dairy, and maize processors and undertake site visits to observe value chains for these commodities first hand. The consultative and field experience from those meetings then fed into extensive working sessions focused around identifying innovative post-harvest management and processing technologies, which held the most promise to: (1) provide near term increases in resource efficiency; (2) support immediate improvements in the production, transport, logistics, and storage process; and (3) guarantee better returns on investment and add significant value for small farmers.

By employing international collaboration and "open innovation," the opportunity was ripe to identify out of-the-box, innovative technology options that would add significant value for smallholder farmers, improve value chain operations, and minimize climate change associated risks.

A central premise of the project is that leading scientists from important scientific disciplines have not been adequately engaged as sources of information and innovations for poor farmers in Africa. However, the realization of the direct benefits to producers and the co-benefits to the planet and economy is becoming more widespread. The importance of science and technology to address health, agriculture, communication, and other challenges in developing countries is widely recognized. Donors and others are actively pursuing strategies for increasing overall funding for science and technology. While most new funding will be directed toward building scientific capacity in Sub-Saharan Africa and applying existing technology to well understood problems, *donors and other stakeholders believe there may be many missed opportunities for applying science and technology to crop and livestock value chains.*

Distributed and open innovation **refers to the process of linking together numerous people with disparate expertise working in different institutions and countries, but united together in a single effort focused on product development and deployment.**

Thus, the project seeks to capitalize on this recognition, applying ideas from emerging areas of science and technology to enhance existing technologies and fill gaps where needed, with the aim of increasing value chain efficiency.

The basis for this approach is derived from a comprehensive assessment of the failures of previous efforts that took a linear, product-centric approach to develop and deliver new agricultural technologies to Africa, as opposed to an integrated systems approach.

> *This view of agricultural innovation is grounded in the increasingly influential "innovation systems" approach, whereby, innovation – i.e., an idea, practice, or object perceived as new by an individual or other unit of adoption – is viewed as strongly embedded in prevailing social, political, and economic systems, which therefore determine what is learned, where, and by whom. Farmers, households, firms, and organizations are viewed to innovate not in isolation but rather in interaction with one another, within the context of institutions that span public and private spheres.*[46]

The primary purpose of the project is to:

- Work with local partners to identify bottlenecks and inefficiencies in the cassava, dairy, and maize value chains;
- Facilitate interactions among scientists, Sub-Saharan African farmers, entrepreneurs, companies, other institutions, and agricultural experts to generate and prioritize ideas for innovative applications of science and technology to reduce value chain inefficiencies;
- Develop concept briefs and strategies for turning the most promising technology ideas into real-world solutions; and
- Organize an advisory body to implement the strategies and translate concepts to commercialization.

Gaps Analysis and Solutions Identification: The Cassava Example[47]

Although the project analyzed and responded to deficiencies in cassava, maize, and dairy value chains, this report focuses primarily on the cassava value chain with less attention to the other two, as it provides a clear example of the value of an "innovation systems" approach to market acceleration.

Cassava is a critically important crop in Sub-Saharan Africa, because of its importance for food security, and also for its potential value added market opportunities. Cassava provides a reliable and inexpensive source of carbohydrates for people in Sub-Saharan Africa, where cassava consumption is the highest per capita in the world. Resembling a sweet potato, cassava is a starchy root crop that develops underground. The edible, tuberous root grows between 15 to 100 centimeters and ranges in mass between 0.5 and 2.0 kilograms. It holds the position as a primary food security crop in Africa due to its resistance to drought and disease, flexible planting and harvest cycle, and tolerance of low-quality soils. Cassava can remain in the ground for up to 18 months after reaching maturity (or more in the case of some varieties) and is well suited for a region that suffers both environmental and political hardships. It is highly commercialized in parts of West Africa, but less so in East Africa.

Other benefits of cassava include:

- In addition to the root, the leaves of the cassava plant are edible and rich in protein.
- Cassava can be used as a substitute for wheat, as glue extender for plywood, and for animal feed.
- The potential to significantly increase smallholder farmers' incomes; if efficiently processed, cassava is likely to gain in domestic demand and as a potential export.
- It uses a production process that requires virtually no use of purchased inputs.

Market Barrier Identification

There are major constraints to increasing the efficiency of cassava markets, largely due to problems in the post-harvest systems. One overarching challenge is the presence of toxic, cyanogenic compounds in raw cassava roots. Although many millions of people safely eat cassava every day, if inadequately processed, the cyanogens have the potential to pose a serious health risk to consumers. If ingested in significant quantity, cyanogenic compounds can lead to acute intoxication, causing nausea, dizziness, vomiting, and sometimes death.

This possibility relates to the second overarching challenge to efficient cassava markets which is the lack of grades and standards to distinguish the quality of the cassava root and resulting products. Quality varies widely and variations in drying, processing, and storage can have major impacts on product quality. There is potentially a high return to well-graded, processed cassava. Ideally, farmers and distributors would be able to earn greater compensation for higher quality products, but to date there are no systematic methods of determining product quality.

Apart from these challenges, a close analysis of the value chain revealed a number of gaps:

- **Non-mechanized Harvest.** Harvesting cassava is labor intensive and non-mechanized in Africa, as compared to Thailand where cassava processing is highly mechanized, and a majority of its cassava is exported to Europe and China.
- **Storage.** Fresh cassava roots will spoil within 48 hours of harvest if they are not processed properly. Because of its rapid perishability, farmers sometimes choose to delay or stagger the harvest until they have buyers for the cassava, which leads to high land consumption for growing cassava and inefficiencies: other crops could be grown in the farmland rather than using it to store cassava. This also means that inefficiencies in the marketing chain (such as transport bottlenecks and repeated transactions) are very costly.
- **Processing Challenges.** Processing cassava involves a number of steps each with challenges:

- **Root preparation:** Peeling and slicing cassava roots is labor intensive and non-mechanized. It is a critical stage in food safety.
- **Size Reduction:** Grating of cassava is done to speed the drying process. It is often mechanized in West Africa, but can be labor intensive if not.
- **Fermentation:** Many cassava end-products are fermented either through mold, soaking or grated root fermentation. Fermentation softens the roots so that they can be easily broken up by hand into smaller pieces for sun drying or passed through a sieve to remove excess fibers. Significant research has been conducted on improved fermentation processes, but little of this research has been put to use in products for farmers.
- **Drying:** Cassava roots are 70% water by volume. Thus, drying is a critical step for many processed cassava products. Currently most farmers rely on the sun for drying, which is difficult during the raining season and can delay processing and shipments. In Ghana, for example, drying during the raining season takes an additional 2 to 3 days more than the usual 7 to 10 days during the dry season. The longer drying period can cause molding and destroy the cassava. For this reason, in Zambia, for example, dried cassava products delivered to market during the rainy season can fall as low as 20 tons, versus 150 tons during the dry season. This has a direct effect on the price of cassava products throughout the year.

- **Transport.** The bulkiness, perishablity, and low value of unprocessed cassava can cause transportation costs to be a large share of the final price, thus most marketing is limited locally. After being dried, chipped, or converted to cassava flour, however, it has a longer shelf life, allowing longer-distance marketing.

Addressing Challenges to Scale-Up: Response Interventions

Raw Cassava Storage. Although cassava roots survive well underground, as noted, this method of storage is inefficient and requires land to remain unproductive.

- **Product Solution Concept:** Deterioration can be delayed by waxing or storage in plastic bags following a fungicidal treatment. The project is focusing on low-cost storage and packaging technologies, as well as low-cost waxing methods. Two specific technology concepts that were conceived by the Meridian team as medium-term solutions are:
    1. "Water Additives for Cassava Storage." Peeled cassava is stored in tanks (concrete, plastic, metal, etc.) that are filled with water and additives to prevent deterioration.

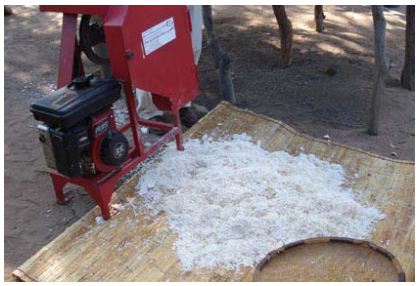
2. "Ca-Say-A Bag." Two component bag liners for cassava that significantly slow deterioration process by blocking oxygen and consuming existing oxygen within bag.

Root peeling. Root peeling represents the most labor-intensive unit operation of the cassava value chain; it is non-mechanized and traditionally done by women and sometimes children. This step is also crucial since peeling removes the outer periderm with highest concentration of cyanogenic compounds.

- **Product Solution Concept:** The project will focus on mechanization of peel removal with special attention paid to root shape, mechanization of slicing where needed for a specific product, and development of abrasion technologies further to reduce product loss and reduce cost. Aim to maintain the highest volume of usable cassava.

Size Reduction (Grating). Grating is often mechanized in West Africa. This step is responsible for increasing surface area for drying and extracting the starch from the root.

- **Product Solution Concept:** The project is considering how to improve the efficiency of existing grating technologies through development of appropriate-scale hand-held, portable or mechanized graters, chippers, pelletizers, and peelers.



MECHANIZED GRATER

PORTABLE GRATER

Fermentation. Grated root fermentation, underwater/soaking fermentation, and mold fermentation represent the three major forms of cassava fermentation in Sub-Saharan Africa. Present research has focused on understanding the microbiology of these fermentation techniques.

- **Product Solution Concept:** The project is focusing on applying the ongoing fermentation research to develop products and processes for farmers that improve fermentation such as the identification of pure cultures, optimal temperatures, pH, and enzymes, and use of isolated starter cultures in product quality.

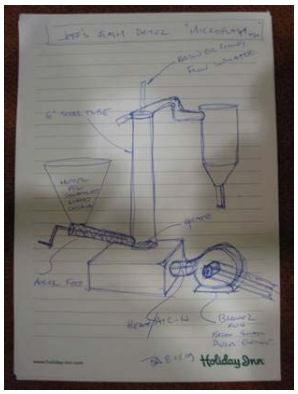
Drying. As noted drying is a critical step for many processed cassava products (e.g., flours, fufu, lafun and non-traditional products such as high-quality

SUN DRYER

cassava flour) and is accomplished mainly through sun drying, although solar dryers and bin-type artificial dryers are also used. More efficient flash and rotary dryers with appropriate capacity for small-scale cassava production have been recently developed in Nigeria but need further development and price reduction.

- **Product Solution Concept:** To those ends, the project is considering improved mechanized (flash, rotary and bin) dryers; new approaches to cost effective and efficient drying; new energy sources for flash, rotary, bin, or other dryers; and improvements to sun drying; and waste water treatment/recycling. Two specific technology concepts were conceived by the Meridian team as medium- and near-term solutions:

  1. **Micro-dryer** (aka "Cassava Tuberator"): the project team conceived of scaling down existing flash drying technologies to develop a micro-dryer. Cassava chips of various sizes would be fed by a tube into a vertical cylinder of forced air which could be heated by various sources. As the chips are dried they would become lighter and rise up in the tube and be ejected once they reached the correct moisture content. With this approach a significant volume of chips could be dried in a matter of hours rather than days and in a more sanitary manner than traditional sun drying. This solution also solved the challenge of the use of expensive fuels in drying: most dryers use diesel fuel that is expensive. The multiple energy source option would provide needed flexibility. And the units could be assembled at various sizes and scales.



MICRO-DRYER CONCEPT

  2. **Integrated Cassava Roaster:** An integrated cassava roasting pan with built in chimney, firebox, and heat exchanger to enable excess heat to be used for other purposes (such as a Tuberator described above for simultaneous cassava flour roasting).

INTEGRATED CASSAVA ROASTER

Quality. Quality control is critically important for cassava products. In traditional processing, quality of products can be variable and will be product specific. Variations in drying, processing and storage can have major impacts on product quality.

- **Product Solution Concept:** The project is considering the development of grades and standards for cassava products to provide unbiased market information and quality assurance so that farmers can gain from improved processing and quality investments.

Cyanogens. As noted, cyanogenic compounds are a potential health risk associated with the cassava. Cyanogens are more prevalent in some varieties of cassava than others. Soaking cassava prior to consumption has proven helpful but not fail-proof.

- **Product Solutions Concept:** Currently, measurement of cyanogens is available only in laboratories. Thus the project is considering low-cost cyanogens detection tools for farmers to ensure that innovations in processing suggested above deliver a safe product.

Dairy and Maize Value Chain Gaps and Proposed Solutions

The project identified similar gaps and technology solutions for maize and dairy products. Of these, a few are highlighted below.

Dairy

As the summary report on dairy[48] for the project notes, dairy is a critically important value chain in Sub-Saharan Africa, because of its potential to be a major asset to smallholder farmers. An estimated 700 million rural poor, approximately 70% of the world's rural poor population, depend on livestock to sustain themselves and their families.

The dairy cow is one of the most important investments a farmer can make to improve their standard of living because of the nutritionally valuable milk produced, the work it can perform, and the way a cow can help diversify farming activities

The key constraints identified in the dairy value chain include feed sources and storage, disease and emerging infectious diseases, erosion of genetic resources, degradation of lands, access to and quality of water sources, milk storage, sterilization and sanitation, road infrastructure, access to markets, access to credit, access to knowledge and development of co-operatives.

The Meridian team however focused on the following market barriers and developed a number of potential solution concepts:

Animal Health and Disease. While this project focuses primarily on "post-harvest" technologies, therapeutics and husbandry should not be ignored.

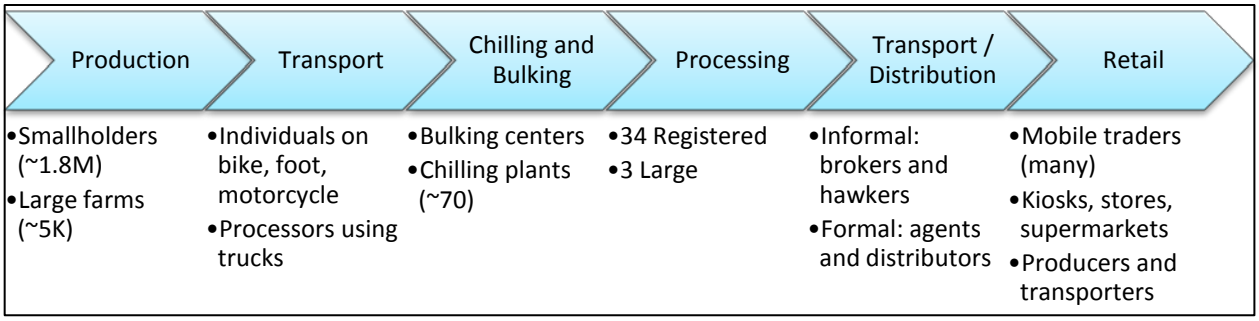
- **Potential Solution Concept:** Available technologies such as dry cow tubes, teat dipping, California mastitis tests, and penside diagnostics for common diseases can help improve animal health. These technologies should be reviewed along with alternative delivery systems (community animal health extension) and efforts to develop appropriately packaged and labeled medicines that smallholder farmers can provide onsite without necessitating veterinary involvement. Specific technology concepts developed include:
    1. A Panel Test for Tick-Borne Diseases: This would provide a point-of-care, panel test capable of differentially diagnosing the diseases via visual readout in a single simple format.
    2. Animal Feed Composition Testing: A low-cost test for point-of-sale testing of animal feed composition.

Milk Production: Genetics and Breeding. Poor genetics and decreasing genetic stock are responsible for higher mortality rates and lower dairy production.

- **Potential Solution Concepts:** The project will consider storage, transport and delivery of semen for artificial insemination; cheap approaches for sexing semen; and cheap pregnancy tests. Specifically, the team identified a rapid, low-cost test to detect pregnancy and cows in-heat as a key technology needed in the medium to long term.

Milk Quality: Quality Testing. Milk is often sold for less than its full value due to inability to transport long distances and spoilage concerns, and unscrupulous traders who add water or other fillers. Since milk is frequently unpasteurized it is commonly boiled before consumption for sterilization purposes. It is not uncommon for milk to be boiled between 2 and 3 times before consumption, drastically reducing taste, economic, and nutritional value.

- **Potential Solution Concepts:** The project will consider inexpensive, digital, quality testing and inexpensive and accurate butterfat tests to enable differentiated pricing for milk quality. There are two simple and cheap milk safety diagnostics systems—a bacteria detector that can coupled with a pH indicator. Both are suitable for rapid analysis of each arriving milk delivery and provide an easy-to-read, qualitative, visual result.



Milk Preservation, Sanitization & Transport. More than 80% of the milk produced in Kenya and Uganda is not pasteurized, and this is common across the continent. Lack of low-cost and accessible sterilization technologies increases rates of spoilage, decreases the distance producers can travel thereby shrinking market access, and increases the frequency of sales at less than optimal prices.

- **Potential Solution Concepts:** The project considered portable UV sanitization techniques, cross-over sanitization methods that could be applicable to purification of water, and other approaches to milk sanitization such as mass spectrometry techniques and nanowire sensor technology. Also considered were alternative energy systems for powering cooling centers; the development of inexpensive, sanitary milk packaging materials; and improved transportation systems. A few specific innovation concepts developed by the team include:

    1. *Bacterial Sieve*: A membrane that filters out bacteria from the raw milk either directly at the farm, at the intake of the collection point/chilling plant, or while the milk is being chilled.
    2. *Stackable Milk Container with Anti-Microbial Properties*: A set of stackable milk containers and an associated transport system that efficiently transports milk and reduces losses from milk spoilage.
    3. *Kenya Cargo Cycle*: An entirely new bicycle designed for cargo that could be built out of local parts and use local manufacturing capacity.
    4. *Milk Bicycle Racks and Extenders*: An improved rack for existing bicycles that reduces losses from dropped bottles and increases delivery speed due to more secure attachment or a frame extender that adapts a conventional bike to carry more cargo.
    5. *GeoChiller*: Creates geothermal cooling system to cool milk and store it safely overnight.
    6. *Rechargeable, Chemical Cooling Packs*: Cooling packs that could be dropped in milk to keep the milk cool during storage and transport and then recharged at the chilling plant.

MAIZE

Maize is a critically important value chain in Sub-Saharan Africa, because of its importance as a food staple and food security crop. Some key facts about maize include:

- While maize is grown primarily as livestock fodder in much of the world, 95% of maize produced in Africa is grown for human consumption.
- Among the 22 countries in the world where maize comprises the majority of the diet, 16 are in Africa;
- Maize contributes about 16% of caloric intake for people in Africa; and
- Maize thrives in regions where the rainfall average falls between 900-1,700 mm, but can grow in as little as 500 mm or as much as 2,500 mm rainfall, making it an ideal crop to adapt to climactic changes.

Key constraints to maize production amongst smallholder farmers identified by the project include:

- Few farmers use fertilizer or purchase improved seeds, adversely affecting production;
- Lack of storage and sharp seasonal fluctuations in maize prices (particularly in remote areas);
- Fragmented sales by small numbers of farmers; and
- Improper drying and lack of standards so that the quality must be checked manually.

The project identified the following set of market barriers and potential technical and innovation solutions:

Spoilage during storage. Post-harvest insect pests jeopardize food security throughout the developing world. Small scale maize farmers, who generally store their grain as whole ears in slatted bins, in adobe rooms, among the rafters of their dwellings, or even in the field, are especially hard hit.

- **Potential Solution Concepts**: New and innovative technologies, for instance: adaptation of metal silos that have been used very successfully in Central America (CIMMYT project funded by the Swiss Agency for Development and Cooperation), or enhancements and adaptation of “super bag” or cowpea “triple bag” technology.

Processing and drying of maize during the rainy season. Maize drying often takes place in the middle of the rainy season. Because the relative humidity remains around 80% for several weeks after the harvest, without additional heat it is difficult to reduce the moisture content of the maize to 13%-15%, at which point it can be stored.

- **Potential Solution Concepts**: The project will consider innovations to reduce the time it takes and the cost of drying maize—innovations to ensure consistent moisture content. Specific innovation concepts included:
    1. *Modified Plastic Tank with Dryer Options*: Small-scale, low-cost maize storage tanks for shelled grain that can be used on farm by small producers, in local co-ops, or in local facilities such as milk-chilling plants, and that could be integrated with a low-cost small-scale drying solution.
    2. *Improved Plastic Bag for Maize Storage*: Existing plastic storage bags treated in situ to prolong the storage of maize.
    3. *ISSB Granary*: Interlocking Stabilized Soil Blocks (ISSB) are the basis of small-scale, low-cost maize storage granaries for unshelled cobs or storage tanks for shelled grain.

Packaging, Labeling, and Marketing. In developed and developing countries alike, maize is processed into a wide array of consumer products ranging from corn on the cob and popcorn to cornstarch, corn oils, automotive fuels, such as ethanol and gasohol, and alcoholic beverages, including corn beer and whiskey. Improved packaging to reduce post-harvest losses after maize processing and through the marketing chain could add value to the end use product.

- **Potential Solution Concepts**: The project will consider extremely affordable packaging to prevent losses and ensure quality of processed maize; packaging and labeling to create product identity and market product quality are also considered.

Next Steps on Product Solutions

Out of the hundreds of innovative ideas generated, 22 rose to the surface and Science Team members and Value Chain Partners worked to develop these into concepts, noted above. These concepts were presented to the Bill and Melinda Gates Foundation in November 2009. The concepts are organized around the value chain constraint that they address. Meridian, working with Science Team members and Value Chain Partners, is working to further develop many of the concepts.

The specificity of the product suggestions—based on an in-depth value chain gap analysis for each agricultural product—suggests how this interdisciplinary, open science approach to technology innovation can work successfully in developing countries.

Implementation

The project is now proceeding on two parallel paths:

Path 1. Based on their field trip to Kenya and Ghana in August 2009 with the Science Team, 22 unique technology concepts have been identified that could ease friction points in the dairy, maize and/or cassava value chains (most technology concepts are specific to one of the value chains, some cross over). They

are now focused on developing five of those concepts at a deeper level of detail. The consulting firm Arthur D. Little is developing "Concept Briefs" for five of the concepts. These are essentially mini-business/feasibility plans. One of the concepts—a modified plastic tank for maize storage—is currently being prototyped and deployed in Kenya. Members of the Science Team are also working with partners they met on the trip in Africa to help develop some of these concepts. The Meridian team is seeking out investors for these five concepts—for example, some private companies might take on the development costs for the diagnostic concepts because they have a potential market in Africa and developed countries. Meridian Institute has approached other foundations and bi-lateral donors like UK DFID and USAID to support some of the concepts that do not yet have a strong developed country market.

Path 2. Given the large number of technology concepts of interest to the Gates Foundation and others, the Meridian team is also working to develop a structure and strategy that would support commercialization of new technologies that benefit smallholder farmers in Sub-Saharan Africa. The following are elements of the commercialization pathway:

1. Innovation needs identification
2. Concept development
3. Design and prototyping
4. Finance and funding
5. Intellectual property
6. Social, cultural and gender analysis
7. Policy analysis
8. Market definition and cost benefit analysis
9. Distribution, manufacturing and entrepreneurship.

Work is also being undertaken to map out an implementation strategy for each concept in such a way to create a new structure (i.e., organization) to carry through the concept to commercialization. For example, if one wants to support the development of a new dryer for cassava, how would one go about doing the design and prototyping work, the gender analysis and socio-economic analysis, the funding and finance, and distribution?

This is a remarkable initiative that uses philanthropic funds to create market-ready products to alleviate poverty.

This project is now at the stage of beginning the product development process for a number of the concepts. The next step in this process is to identify the potential for a new entity to carry forward the product development processes proposed in the initial survey.

International Cooperation and Technology Development

This project is now solely funded by the Gates Foundation. It involves a team of international experts, but as yet, no joint funding by other partners. The nature of the technology cooperation that has been used to date involves bringing

experts from around the globe in many disciplines to apply their expertise to these intractable problems.

The key feature of this collaborative approach is the focus on joint research and product development. It is not another study, but a project dedicated to jointly develop market-ready products to accelerate poverty alleviation through analysis of market gaps and technology solutions.

This project is an excellent model of how such an approach could be used to develop new products and market models for clean energy in developing countries. It also highlights how real progress might depend on creation of entirely new institutional entities—such as a commercialization organization —to bring these products to market.

V. Case Study #3: Marine Energy Industry Acceleration

For the final case study, we turn our attention to the challenges with the development and scale-up of advanced marine hydrokinetic energy technologies (wave, tidal, and current devices). This section identifies the upstream gaps in industry development and subsequent barriers to full market deployment. The private sector alone has been unable to surmount these significant challenges.

This section also suggests specific ways that these barriers could be overcome with more creative and internationally-coordinated innovation strategies, like those applied in the *Lighting Africa* project. While there is some interest on the part of the U.S. Department of Energy to initiate such an international marine collaboration, there is currently no project underway to accelerate the market globally, unlike the in the previous two case studies.

The Opportunity

Marine hydrokinetic power technologies could harness a widely available, low-carbon energy source—and mitigate climate change—in both developed and developing countries.

Another benefit of marine energy technologies as compared to other intermittent renewable resources like wind and solar is that although marine energy is intermittent, it is predictably intermittent enough that it can form part of the energy system's baseload power to provide bulk electricity to the grid, particularly in the case of tidal energy.

Marine energy technologies also present huge economic development potential, with one study estimating that the value of worldwide electricity revenues from wave and tidal stream projects could ultimately be between £60 billion and £190 billion (US$90-$285b) per year.[49] Thus these technologies offer economic, energy security, and climate mitigation benefits.

The potential market opportunity for marine energy is large enough to merit considerable private investment. However, while interest in wave and tidal energy has increased in recent years, as evidenced by the range of new device concepts competing for investment, none of these technologies has reached

commercialization. Marine energy is lagging significantly behind the development of other renewable energy technologies.

Today, hydrokinetic technology costs are much higher than conventional and more advanced renewable energy power. The Carbon Trust estimates that energy from initial wave energy farms will cost between 12 and 44 pence (US $0.18-$0.66) per kWh, with central estimates for offshore wave farms in the range of 22 to 25 pence (US $0.34-$0.38) per kWh. Carbon Trust further estimates that tidal stream farms have energy costs on the order of 12 to 15 pence (US$0.18-$0.22) per kWh.[50]

The Carbon Trust, however, concludes that marine renewable energy has the potential to become competitive with other electricity generation technologies in the future, but "fast learning or a step-change cost reduction is needed to make offshore wave energy converters cost competitive for reasonable amounts of investment."[51]

An internationally coordinated market acceleration approach, like those outlined in the preceding case studies, would support this fast learning and could produce just such a step change in cost reductions.

The State of the Industry

Despite the tremendous commercial market opportunity, the marine energy industry still sits in an early stage of development, with numerous companies pursuing different device concepts. Many devices are being tested in prototype and demonstration scale projects, but no single technology has emerged as an industry leader. More than 75 device developers are competing globally for limited public and private investments. Of those, about half have performed experimental modeling, 32% have tested their devices in the ocean, and less than 2% have produced a full-scale prototype.[52]

A few technologies have reached the stage of commercial demonstration. At the end of April 2009, the UK had 0.5 MW of wave energy and 1.45 MW of tidal stream installed.[53]

The first (and so far, only) multi-device wave energy installation, a 2.25 MW Pelamis wave farm in Portugal, cost £3,226 (US$4,839) per kW installed. This is approximately four times higher than large-scale wind energy.[54] Regrettably, the Pelamis wave generator was removed from the water within a few months of deployment.

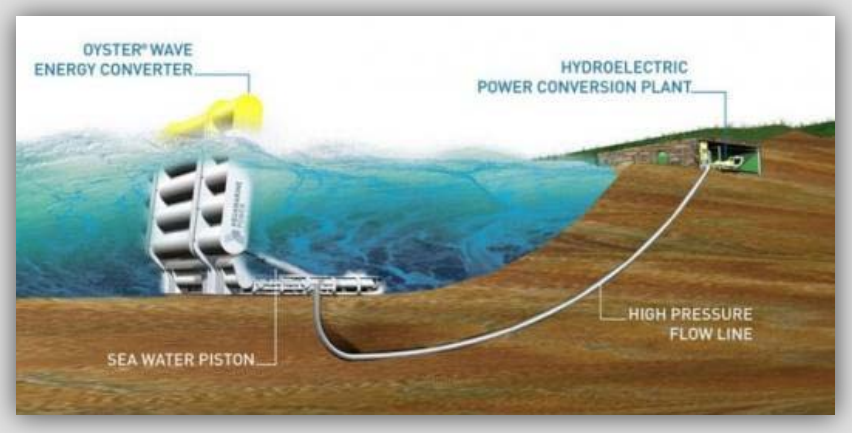
In April 2010, an Israeli-based device developer, SDE, announced that it was nearing completion of a 1 MW wave power plant off the coast of China. SDE claims their device cost US$650,000 to build, translating to about US$650 per kW. The company estimates that the cost of energy will be only US$0.02 per kWh.[55] This has yet to be proven.

The Wide Range of Device Concepts

As noted above, there are currently about 75 different wave and tidal energy companies developing completely different device concepts. This proliferation of radically different concepts slows down the progress of the industry as a whole as each device concept needs to follow its own learning curve. Each concept must be validated and tested at a mockup scale. Moreover, it is much harder to reduce device manufacturing costs through component commoditization. By way of example of the radically different device concepts being developed today, consider three of the most advanced: the Pelamis Wave Energy Converter, the Aquamarine Oyster, and the PowerBuoy.

Pelamis Wave Energy Converter. These converters consist of 150- to 180-meter-long floating tubes that move with wave motions. Generators positioned along the tubes then convert movement through a hydraulic pump system into energy which is then sent ashore through an underwater cable. They need to be in at least 50m depth of water to access their best wave regime; its first installation was 3 miles off the coast of northern Portugal.

Aquamarine Oyster. The Aquamarine Oyster, on the other hand is positioned 500 meters offshore. The devices "flap" which is about 2 stories high opens and closes with waves, driving a piston which directs water through a pipe at high-pressure to run an on-land hydroelectric generator.



PowerBuoy. Ocean Power Technology's PowerBuoy, is a completely different device. Anchored about a mile offshore, it looks like a traditional buoy and produces power by rising and falling on waves between 3 and 22 feet tall, the mooring is anchored to the seabed and this movement drives a hydraulic pump. The pump converts the motion into electricity in the ocean using a generator embedded into its base. The electricity is then transmitted back to shore by way of an undersea cable.

Public Investments

Because of the benefits and the enormous potential, many countries around the world are initiating marine power support programs. The UK has invested tens of millions of pounds in marine R&D and test facilities and recently announced more than £4 billion (US$6b) worth of marine energy leases.[56] The U.S. Department of Energy recently increased marine hydrokinetic support funding to almost US$40 million, up from just $10 million, and has announced support for two new test facilities.

Emerging economies are also interested in the technology. Taiwan, for example, recently announced a consortium agreement to set up a test facility for ocean power generation.[57] However, marine energy technologies will only be relevant in the developing world if installation and operating costs can be reduced significantly.

In an attempt to accelerate the industry, in 2004, the UK launched the £50 million (about US$75million) Marine Renewables Development Fund (MRDF) to support the first devices operating at sea. Forty-three million pounds sterling of the fund was dedicated to providing capital grants and revenue support for devices, while the remaining £8 million was dedicated to supporting environmental research and infrastructure. However, after more than five years, not a

single device has received a solitary disbursement from the MRDF, because they have not been able to fulfill the support criteria requiring at least three months of full-scale, sea trial data.

To address this, the UK government launched a Marine Proving Fund of £22 million (US$33m), the recipients of which were announced in September 2009.

The question for policy makers in partnership with industry stakeholders is how to accelerate learning across the industry, and catalyze the step-change cost reductions to ensure that early projects are successful, learning is rapid, and costs decrease steeply. This will necessitate new strategies for filling industry gaps and overcoming the market barriers described in the following section.

The Challenges for Marine Energy Technologies

The marine energy industry faces a number of significant challenges that have slowed development and kept costs high. The Carbon Trust estimates that over £500b in investments is needed for marine energy to contribute 2,000 TWh/year worldwide. [58]

Marine energy technologies have to battle some of the most challenging conditions on the planet. The ocean environment is harsh and it is particularly unforgiving in areas of high wave and tidal energy resources. Energy technologies must be capable of surviving forces within a range of magnitude—this is true not just for the device itself but also for moorings, electrical infrastructure, and for operations and maintenance considerations. Despite these challenges, it should be remembered that navigation and weather recording buoys, of various sizes, are routinely deployed for extended periods in exposed oceanic locations with acceptable success rates.

Marine technologies face additional hurdles, including:

- Accessing the grid from remote locations,
- Managing unknown environmental impacts, and
- Wading through regulatory thickets involving multiple federal and local agencies.

Industry Gaps Analysis

The marine energy industry faces a number of market barriers, many common to all early-stage, clean energy technologies, while some barriers are particular to the marine environment. This section uses the metric of "technology readiness levels" (TRL) to analyze gaps in the stages of marine energy technology development.[59] It will then analyze the challenges that cut across multiple stages in the development chain.

The UK Department of Energy and Climate Change (DECC) adopted the TRL metric in their 2008 *Tidal-current Energy Device Development and Evaluation Protocol.*[60] The protocol defines the following stages for marine device development:

- **Stage 1** consists of concept formulation, defining research and development (R&D) requirements and establishing basic theoretical models of performance;
- **Stage 2** covers computational analysis, intermediate-scale model testing and laboratory testing of components, whereas;
- **Stage 3** involves large-scale testing of subsystems;
- **Stage 4** covers full-scale prototype testing in the sea, followed by;
- **Stage 5** extended testing of the commercial demonstrator device in the sea; and
- **Stage 6** (not included in the protocol) large scale commercial deployment.

Stage 1 and 2: Concept Definition and Proof of Concept and Laboratory Validation

The first stage involves paper, analytic, and laboratory studies to validate concepts including developing a first order energy capture model that allows for rough order of magnitude cost-to-manufacture and cost of energy projections. Stage 2 involves component and/or system testing at a scale-model level in a laboratory environment. Accurate and reliable computer models are needed at this stage to predict the viability of a concept before investing in costly device testing.

Stage 3: Test facility

At this stage, a well evolved scale-model or prototype system is tested and demonstrated in a test facility capable of simulating the operational environment. The key challenge at this stage is that test facilities are expensive to develop and scaled models do not provide a very accurate assessment of device costs or survivability in the ocean environment. Although the cost of the model device can be lower than a full-scale prototype, the model manufacturing cost will be disproportionate to full-scale power production.

Stage 4: Open water test and validation

The next major challenge faced by developers is deploying the first full-scale devices in the open ocean environment. Deploying a full-scale prototype requires a large capital investment, in the range of US$15 million or more.[61] Many variables contribute to the cost of deployment; installation requires an appropriate weather window and specialist vessels, for which the marine energy industry must compete with established offshore oil and gas industries.

Compounding capital and installation costs, in most cases, device developers face significant regulatory and environmental costs. In one case, a U.S. developer faced pre-installation environmental studies costs estimated at US$1.4 million for a 1 MW pilot project.[62]

The UK is addressing these challenges with the creation and support of two open ocean test facilities, the European Marine Energy Center and Wavehub. Although there are plans in works, the U.S. marine energy industry currently

"lacks standardized infrastructure to deploy and test wave energy conversion devices in the ocean."[63]

Stage 5: System demonstration/operational verification
At this stage, full-scale devices and arrays must demonstrate larger-scale installability, long-term operability, reliability, predictability and survivability. This will require overcoming the following challenges:

- Establishing fabrication, transport, and installation infrastructure;
- Improving offshore access and maintenance;
- Demonstrating cost effective foundations, anchorage, and mooring;
- Developing effective electrical connectors, submarine cables, and adequate electric network integration;
- Demonstrating the ability to survive predicted and surprise extremes in wind, wave and tidal current conditions in any combination;
- Operating reliably over the devices predicted lifetime, maintained as planned; and
- Understanding the resource and device interaction such that it delivers predicted generation and design performance.[64]

At this stage device developers also face complicated regulatory thickets among multiple agencies and levels of government. In the U.S., for example, licensing times just for demonstration projects average between two and four years.[65] The process is somewhat less complicated in the UK where the crown estate controls all marine resources.

Device developers also have to address significant environmental permitting requirements at this stage. According to an assessment of the industry by the UK Renewables Advisory Board:

> *"Device developers conducting R&D are burdened and distracted by project development tasks. A significant portion of project development costs are associated with environmental assessment and permits…These tasks distract device developers from their main responsibility to develop their device. They introduce delays and project risks that also hinder true R&D. This also means that not only do device developers need to bring in technical skills but they need to acquire project development skills too. Additionally many of the consenting authorities are still learning and rely heavily on device developers to provide information they need."*[66]
> (Emphasis added.)

Stage 6: Large scale commercial deployment
The final stage of the marine energy industry and market development is full-scale deployment in commercial applications. The challenges noted above are relevant for this stage as well as:

- **Demonstrating manufacturability and affordability**. Up to this point, the prototype devices may not have been optimized for manufacture, as the primary purpose was to demonstrate survivability and the ability to capture energy rather than costs and economics. Now the device must be manufactured, installed, and maintained within a lifetime-cost that ensures market access and return on investment.
- **Attracting Investors.** This stage requires very significant capital investments, an order of magnitude greater than the demonstration stage.
- **Components Supply and Skilled Workers**. Access to a supply chain and skilled labor for installation and ongoing maintenance.
- **Access to the Grid**. Adequate grid access is also required at this time. In many cases this will require significant and costly improvements to remote grid infrastructure. The areas with the most abundant marine energy resources tend to be remote from onshore distribution and transmission networks or in areas of limited network capacity.[67] Who pays for this and how is a key question facing local and national regulators.
- **Project Management.** Finally, commercial-scale deployment requires highly-skilled project management teams that can not only manage the technical device requirements, but also handle complicated regulatory, environmental, and stakeholder processes. In fact, lack of management skills may be significantly hindering the commercial development of promising devices. In one study, financial investors commented that "Having a strong management team in the technology developer is viewed as at least as important as the technology itself…not all marine energy companies have good management; there are a few exceptions and it is these exceptions that are viewed as having good commercial prospects."[68]

Challenges Across the Market Development Chain

A number of barriers to the market development of marine renewable energy cut across these stages of development, including resource modeling, detailed environmental impact studies, and the lack of skilled labor (i.e., engineers and technicians trained to work in the marine environment).

A few of these barriers merit more in depth discussion.

Industry Dominated by Resource-Limited Startups

The Renewables Advisory Board (RAB) has noted that the marine renewable energy industry has become "dominated by a large number of small, mostly startup, companies... who may not have all the required technical and managerial resources that are necessary for such complex and potentially dangerous projects."[69]

Developing large-scale marine energy projects requires a multi-disciplinary team with a depth of knowledge that these small companies often cannot afford. Thus because marine engineering expertise is expensive, as one Hydraulics &

Maritime Research Centre (HMRC) study noted, "Often excellent engineers are left to work in isolation when consultation is required."[70]

INADEQUATE FINANCE THROUGHOUT DEVELOPMENT CHAIN

An additional barrier for the marine energy industry is that these small companies most often do not themselves have the adequate funding to bring devices to market. Companies are faced with the challenges of raising funds for day-to-day operations and research as well as the costs of specific project development. A review of past projects by the HMRC showed that "the longest delays in the development timetables are caused by groups having to wait for financing decisions before the work can continue, even when results up to that time have been favorable and encouraging."[71]

Raising capital from the private sector has proven to be difficult because "most private capital is usually nervous of ventures involving the sea, and especially those away from the coast. They are perceived as either very costly or too technically challenging for the expected rates of return involved."[72]

The lack of private investment has usually meant that public support has been necessary, but the level of public funding has been nowhere near the level of support required for these expensive projects. In particular, the industry believes there is a funding gap between capital grants for small-scale prototypes and revenue support for long-term operation, which, in the UK and Scotland, comes in the form of multiple Renewable Obligation Certificates per MW of marine energy produced. In Spain and Portugal, revenue support is derived from feed-in tariffs.[73]

Moreover, most public financing requires some level of matching funds from developers. Some developers have relationships with established engineering firms and power companies but have not been able to secure significant funding through these relationships: "we would certainly like to get more involvement at an earlier stage from electricity generating companies … we have confidentiality agreements with some … but [not] money in the bank, which is what we need to match government funding."[74]

But most utilities still see ocean energy technologies as too risky; there are still too many device concepts and none have been proven adequately. One UK device developer complained that "the utilities have a short-term focus … what they generally do is sit back, see which technologies survive … then come in and cherry pick … UK companies are very much short-term and market-driven."[75]

Thus marine device developers must rely predominantly on venture capital financing, which is poorly matched to the innovation timeframe for capital-intensive clean energy technologies.

THE VENTURE CAPITAL MISMATCH

Investment horizons for venture capital firms do not match the development timeframes for complex and complicated marine energy developments. In most

cases, VCs are not interested in taking a technology through to full commercial markets, which can be on the order of 10 years for new device concepts—whereas VC's investments have a timeframe on the order of only three years before exiting. As one device developer noted: "we have made it clear we believe that it will be seven years plus before we have got something that is beginning to compete … venture capitalists … [are] looking for something big happening in a three year timeframe."

Moreover, many venture capitalists are reluctant to fund marine energy companies because there is not yet a large proven market – "a venture capitalist wants to know 'is there a market?' … you can point to the large electricity market … but it gets a bit more tricky when you [try to] point to the subset of that which is the supported market for marine energy."[76]

Thus many device developers have come to the conclusion that venture capitalists will not fund their development: "Venture capitalists have been ice cold, both in the U.S. and Europe."[77] Those that have secured venture funding are facing their own challenges based on the VC's demands for short-term returns, but at the same time they are often extremely risk averse.

These attributes have the perverse effects of both over-accelerating development schedules and, at the same time, requiring "over-engineering." One study noted that "developers' awareness of financiers' sensitivities to risk means that they undertake expensive 'over-engineering' of their prototype devices, so as to reduce the chances of technical failure in prototype trials." Developers com-plained that "everything costs twice as much because we are not allowed to make mistakes" and, "we are having to over-engineer dramatically because it is much more important not to be seen to fail than design the cheapest possible solution."[78]

Thus, **"marine energy innovation is being driven by small private firms, who operate in an investment climate intolerant of technical risk, yet which imposes high short-term expectations."[79]** For some developers, these conditions are so onerous that they prefer to remain self-financed, but this leaves them with fewer resources for development.

LACK OF ADEQUATE DATA AND INFORMATION SHARING

Another harmful result of dependence on the VC financing model is that developers have admitted to suppressing the release of information about technical problems in prototypes, which if made publically available could lead to more learning for the industry in general. This situation limits the whole industry's ability to learn from mistakes.

There has been limited publishing and sharing of data from research and device testing as well as the knowledge and lessons generated from these activities. Many device developers see this as key proprietary data that was expensive for them to generate, and thus they are unwilling to share it. This lack of sharing means that the industry progresses more slowly. There is a proliferation of device concepts that are only marginally different, each one having to "reinvent the wheel."[80]

Addressing Challenges to Scale-Up: Accelerating the Marine Industry with a Collaborative Approach

"*There is an immediate need for everyone to work in tandem*."[81]
- UK Marine Action Plan 2010.

Because of the slow progress of the marine energy technology industry, in 2008 the UK government commissioned the UK Renewables Advisory Board (RAB) to analyze how these technologies could be accelerated. The report recommends **"a more collaborative approach to R&D projects between industry, academia and Government,** with pro-active and closer management of R&D projects. This will help ensure that projects are focusing on tackling the correct problems, that opportunities for information exchange are taken, that projects are generating relevant research information, and that as many results as possible are published." [82]

There are a number of reasons to encourage a collaborative approach to market development to overcome the barriers listed above.

Impacts of Technology Setbacks. In the current state of the industry, any problem or setback with a particular device, negatively impacts the entire industry. Because the industry is so small any failures tend to stand out disproportionably to the actual technical challenge. "A team's success will primarily enhance its own business plans but a failure will affect everyone."[83] One device developer noted that, "every time there is a failure you lose a couple of months across the whole industry."[84]

Substantial Capital Requirements. A second argument for a collaborative approach is that, as noted above, the capital requirements to advance the industry are huge, on the order of US$750 billion by 2020, and costs have proven to be much higher than expected. Given the current level of technology risk and the challenges associated with private finance noted above, governments will have to play a role in catalyzing the market, including providing significant funds. But these national funds can go much farther if coordinated effectively across countries and if research agendas are optimized across nations. Further, an attempt at international coordination is likely to build private investor confidence in the global market for marine energy technologies.

Global Marine Energy Market. Thirdly, the marine energy market, like all clean energy technologies, is global. Device developers are working outside their own countries and this will continue to be the case. For example Pelamis, a UK-based company, developed its first project in Portugal and OPT, a U.S. company, is planning a significant project in Spain. In addition, increasing global cumulative installed capacity will only speed learning effects, stimulate new ventures, and thereby cost reductions for the entire industry.

Lack of Information Sharing. Finally, the substantial inefficiencies and poor allocation of limited capital that occurs from the general lack of information sharing across the industry continues to prove an exorbitant challenge. This could be significantly relieved via enhanced industry collaboration. The RAB has

concluded that the lack of co-operation across the industry has led to "the same problems being addressed many times in parallel and the consequent inefficient use of available resources."[85] Device developers themselves recognize that they are frequently and at great cost "re-inventing the wheel" because of their unwillingness to share information, and that their "emphasis on in-house innovation, rather than interactive learning, leads to repetition and duplication."[86]

The current venture capital-based financing model is an additional bottleneck that needs to be revisited since it creates a large disincentive for developers to share test results. For almost all device developers, intellectual property (IP) is essential for attracting private finance. Developers' concerns for protecting their IP are a powerful barrier to dissemination of their R&D results and prototype trials. One developer noted that "you have the disadvantage with a new technology that it is unreliable and expensive. But you have the advantage that you own the IP rights. If you are sharing information…you are in an almost impossible situation."[87]

Clearly, developing new financing models beyond the current VC model could improve prospects for information sharing and stimulate technology development. But confidentially for IP need not require total secrecy. There are a number of pre-competitive or non-competitive areas, proposed in the next section, where the benefits of information sharing and collaboration would outweigh the risks even in the current financing climate. Public support can be structured so as to encourage greater cooperation across the industry.

And on a promising note, some device developers did recognize the value of participating in industry consortia for raising their credibility and visibility: "It is very important for us to be in the European network because that gives us a verification that the European Commission believes in our concept. That is an important message to send out to the industrial partners."[88]

Opportunities for Collaboration

Areas where there are clear opportunities for removing market barriers and accelerating the marine energy industry through collaborative approaches include:

- *Modeling* – both device performance and cost assessment as well as resource model assessments and the integration of these model and datasets;
- *Testing facilities* – this is already a shared resource in the UK, but information, experience, and skills sharing across countries could also more rapidly improve testing facilities;
- *Device performance and cost data;*
- *Device components performance;*
- *"Balance of systems" technologies* including installation, maintenance, electrical infrastructure and mooring techniques;

- *Encouraging partnerships* across the industry particularly to provide support to small device developers;
- *Developing new business models, financing schemes, and marketing strategies*; and
- *Managing environmental and regulatory risks.*

MODELING

For device modeling, there could be shared services between universities, not only to assess technical performance but also to develop comparable means of lifetime costing and performance appraisal between devices.

Model development information could be shared internationally between test facilities and university laboratories. This would include sharing economic analysis methodologies as well as computational fluid dynamics models. The UK RAB argued that, "There needs to be a greater focus on…reducing key risks and uncertainties through more computer modeling and intermediate testing of both components and systems."

Building a prototype at a cost of several million dollars is an expensive way to see if a concept will work. It would be much more cost effective if developers were able to more accurately predict prototype performance. This requires improved computer models, which, if plugged into international and distributed experience and skills, could be developed cheaper and faster.

Shared resource models would also reduce development costs. Better resource analysis and weather forecasting, particularly the ability to forecast extreme events, and better modeling of combined waves and currents will also improve predictability of device generation.

TESTING FACILITIES

Testing facilities are expensive. The UK recently allocated £38 (US$57) million for testing facilities. The U.S. recently announced awards to support the development of two new test facilities in Oregon and Hawaii. This money could be better leveraged if there were prerequisites to share data, infrastructure requirements, and learning across the facilities.

DEVICE COST AND PERFORMANCE INFORMATION SHARING

The industry and investors need to know as much device cost and performance data as possible to make sound business decisions. "The more understanding we have in this area, the greater the likelihood of creating a joined up public sector support structure…Further understanding the cost components of marine energy projects will help identify when and where private sector investment from industry stakeholders can also be attracted and expected."[89]

This could be done in an anonymous way to protect the industry but, at the same time, provide a platform for knowledge sharing which benefits everyone. The more device trials that can be aggregated the more easily data can be scrubbed of device specific information and shared neutrally across the industry

on a level playing field. Thus there is a clear benefit to aggregating device performance and cost data in a single global database that can publish the "scrubbed" data publically, in turn advancing the global knowledge base and cultivating new knowledge creation that will reduce transaction costs for information gathering across the industry. As the RAB proposed, "with better communication, cooperation and sharing of research results, it may not be necessary for each device developer to have to construct an entire device to prove its concept."[90]

DEVICE COMPONENT PERFORMANCE

Sharing device component performance results may get too close to proprietary infringement for the comfort of many device developers. However, there are areas of non-core value IP where developers may be convinced that the benefits of sharing information across the industry outweigh any lost proprietary edge. These could include, for example, sub-system components such as establishing a component reliability statistical database or sharing insights on improved sealing and coating.

DEVICE DESIGN

The proliferation and diversity of device concepts currently under development suggests that optimum solutions have not been identified thus far.

In many ways the marine energy industry is in a parallel stage of development to the wind industry in the 1970s, when radically different designs were still being tested and piloted—long before the industry narrowed the scope to the current horizontal axis design. The RAB has gone so far as to suggest that "consolidation of ideas may help a better design to emerge and lessen competition for funds thereby helping investors in the sector to target their funding."

However, it is unlikely that device developers would be willing, without a period of mergers and acquisitions, to fully consolidate ideas at this time—unless some creative incentive structures were developed. But the UK Marine Renewables Roadmap does propose that "standard design codes should be developed so that they can be applied to any new concept to reduce the development stages and reduce cost."[91]

COLLABORATING ON "BALANCE-OF-SYSTEM"[92] COST REDUCTIONS

According to the UK Marine Action Plan, cost reduction will be found not only in device design improvements, but also in improved anchoring and new and innovative ways of conducting installation, operation, and maintenance, as well as electrical infrastructure and power take off.[93] In fact the Carbon Trust estimates that, by itself, the device cost makes up only 20% of the full capital cost of an installed unit.[94] The UK's Ocean Energy Protocol also noted that, "Innovative and original thinking should be encouraged with regard to smoothing/redistributing the high power fluctuations that occur over short time spans [in marine energy devices]."

These are areas where device developers could be encouraged to share information, or where innovative public funding strategies, such as prize competitions, could significantly accelerate learning across the industry.

SOLUTION CONCEPT FOR INDUSTRY STRUCTURE

The marine energy technology industry is currently dominated by small device developers who often do not have either the financial or human resources to drive concepts to market.

To address this barrier, governments can encourage and facilitate partnerships across the industry, especially between small device developers and larger engineering firms and utilities with the financial resources and project development experience to accelerate the technologies. Device developers should also be encouraged to partner more actively with academic institutions. The RAB notes that academic research "could be made more accessible and useful to the industrial community and greater communication and cooperation between the industrial and academic communities would help to define and disseminate the academic research."[95] Public support could also consider assisting small device companies with project management skills development.

NEW FINANCING MODELS

According to the research quoted above, the current financing mechanism for the marine energy industry, which relies heavily on venture capital funding, may be significantly slowing the learning process across the industry and hindering the innovation process. Thus new models for financing innovation should be developed.

Governments should dedicate more money to the industry but could additionally support new ways of accessing and leveraging private finance and help link the industry to needed funding sources. Again, an approach that encourages greater linkages across the industry and enhances learning from within and outside the marine energy field is likely to increase the speed and scale of solutions for financing.

For example, utilities and large engineering firms are reluctant to get involved in the sector because of continued technology risks. This is due to the continued proliferation of device concepts and the dispersion of device developers. Public financing mechanisms that reduce technology risks could be established, such as insurance and guarantee mechanisms.

Device developers could also be encouraged to engage and share information with later stage market players earlier in the development process, so that they can make more informed and calculated technology risks.

Government support can also play a role in demonstrating clear and consistent support for the market and, again, coordinating and collaborating internationally will demonstrate a global market opportunity to investors wanting to gain confidence in the investment incentive.

COOPERATING TO MANAGE ENVIRONMENTAL AND REGULATORY RISKS

Finally, there is a clear opportunity for public support that encourages collaboration and cooperation in the areas of environmental assessments and managing the regulatory processes. A U.S. study concluded that many industry players "found the lack of knowledge or lack of access to information just as limiting as the lack of funding for studies."[96]

The same study proposed the funding of a gap study to help stakeholders understand what information is currently available and what is needed to move the industry forward. "A collaborative effort could develop consensus on the basic information needs for a technology being deployed in a specific region (i.e., wave energy on the west coast or current turbines off the cost of Florida), evaluate existing data, and identify and fund studies to address gaps in existing information. The results could be used to help developers, agencies, and other stakeholders assess new potential projects. Further, the identified gaps could be used to channel new federal, state, or other funding." [97]

Similarly, a collaborative process on clearing regulatory hurdles could help all companies to accelerate deployment. As noted, current licensing in the U.S. can take as many as four years to secure. This area of information sharing may be more limited to national levels of collaboration, but useful lessons and best practices may be able to be applied across divergent regulatory environments and reduce cost build-ups associated with regulatory processes.

The RAB has proposed targeted government support for environmental assessment. The U.S. Ocean Renewable Energy Coalition has proposed the creation of an adaptive management fund to assist developers with the extensive environmental costs associated with licensing. This funding could go much farther if an international database of environmental impact data and assessments was created and made publically available. Thus, a tool should be developed for transparent data sharing and to serve as a repository for compiling existing information and collecting future data.

MARINE ENERGY TECHNOLOGY ACCELERATION: THE CASE FOR INTERNATIONAL COLLABORATION

As described throughout this case study, the marine energy industry faces a number of hurdles that could be overcome through a coordinated, international effort to accelerate the market by sharing information and tapping into solutions globally. While there is some interest on the part of the U.S. Department of Energy to initiate such an international marine collaboration, despite its promising results in other technology areas, there is currently no project underway to accelerate the marine energy market globally through an innovation systems approach. There are efforts underway under the International Electrotechnical Commission to develop international standards for marine energy devices, with a focus on safety, performance, and resource assessments.[98] The International Energy Agency (IEA) Ocean Energy Imple-

menting Agreement is also undertaking a process for environmental data sharing and there is a proposal under consideration to more effectively share device performance and cost information. However, these IEA initiatives are only at the inter-governmental level and do not directly include industry players like the integrated public-private projects described in the first two case studies.

VI. CONCLUSION

The current approach to prepare emerging markets for the uptake of new climate technologies includes a mix of policy and regulatory interventions designed to "unleash" competition and allow the market take off—without real attention paid to the host of market challenges that might hinder penetration of new technologies and their eventual scale up. Each of the case studies above, however, clearly demonstrates that the private sector alone will not be able to overcome the market barriers that exist all along the technology development chain for new mitigation and adaptation technologies.

The projects highlighted in this report recognize that markets for climate technologies are imperfect and rife with barriers to full and rapid market penetration. As these case studies show, more creative, internationally coordinated and integrated innovation strategies are needed to scale climate technologies at the speed needed to combat climate change. Public-private strategies are needed to complement pricing mechanisms and "enabling" policies. The case studies above present an alternative approach that goes beyond conventional information sharing to technology focused strategies that tap into dispersed, multidisciplinary expertise or "distributed innovation."

As the first two case studies show, many programs are already using distributed innovation initiatives to accelerate climate relevant markets—and in the case of *Lighting Africa* are seeing tremendous results from the approach. A similar approach should be used more broadly for markets like marine energy and other clean energy technologies, where significant market barriers will continue to limit the pace of innovation and deployment without new strategies.

The *Lighting Africa* experience also shows us that these approaches must be facilitated by a funded entity with knowledgeable staff and a mission to assume the role of a "neutral broker"—working on behalf of the market to identify the weak points along the value chain continuum and bridge the gaps between upstream technology development and consumers. In effect, overcoming market barriers can be viewed as an essential "public" role required to level the playing field to build lasting markets (at the scale and speed necessary) to deliver needed products and, at the same time, to support larger goals of combating climate change and encouraging sustainable development.

The case studies presented in this report, particularly the *Lighting Africa* example, provide models on how the international community could advance

effective international collaboration that result in rapid technology commercialization and market creation. We hope that further research and focus on these innovative examples will provide deeper, more detailed insights into how to structure such distributed innovation approaches for other climate technologies.[99]

VII. ENDNOTES

[1] *Lighting Africa*. *Overview of the African Solar Portable Lighting Market for Base of the Pyramid Consumers*. Dalberg Development Advisors. *Lighting Africa* 2010 Business Conference & Trade Fair, May 18-20, Nairobi, Kenya

[2] http://www.merid.org/value-chain-innovations/activities.html

[3] A value chain can be described as a series of sequential activities where at each step in the process, the product passing through this chain of activities gains some value. Generally, the chain of activities gives the products more added value than the sum of the added values of all activities.

[4] Distributed innovation refers to the process of linking together numerous people with disparate expertise working in different institutions and countries, but united together in a single effort focused on product development and deployment. The business literature defines DI as "the process of managing innovation both within and across networks of organizations that have come together to co-design, co-produce and co-service the needs of customers."** The driving objective for distributed innovation is to accelerate the deployment of a specific technology by attacking the problem from multiple intervention points along the value chain, from upstream research to downstream deployment. It involves addressing the technical, market, financial, policy, regulatory and legal issues that arise along this entire chain. Distributed innovation uses creative approaches for reducing risks through targeted funding and finance strategies, and managing intellectual property rights in a manner that that enables collaboration and preserves the power of the market and competition. DI is a new term in energy but one well known in other private and public sectors, from pharmaceuticals to consumer and agricultural products. In fact, DI strategies have been used to develop products, services and scientific breakthroughs as diverse as the iPod, the Linux operating system, the Human Genome Project, automobiles, pharmaceuticals and drought-resistant crops in the developing world.

** Lawrence Dooley and David O'Sullivan, "Managing within Distributed Networks," International Journal of Innovation Management 11, no. 3 (2007): 397.

[5] UK DECC Marine Action Plan 2010 at 11.

[6] Winskel at 481, also "it is crucial for the whole industry that the early developers succeed. If they have a major failure it will damage the whole industry".

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http://www.cleanegroup.org/Reports/CEG_Climate_Course_Copenhagen_Dec2009.pdf

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[13] IEA, *World Energy Outlook 2002* (Paris: International Energy Agency Books, 2002).pp365

[14] Dalberg Development Advisors, "Overview of the African Solar Portable Lighting Market for Base of the Pyramid Consumers," Presentation at the 2010 *Lighting Africa* Business Conference & Trade Fair, May 18-20, 2010; Nairobi, Kenya (full report forthcoming at: www.lightingafrica.org)

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[16] [16] IEA, *World Energy Outlook 2002* (Paris: International Energy Agency Books, 2002).pp335

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[54] BWEA Marine Renewable Energy, State of the Industry Report October 2009. Available at http://www.bwea.com/pdf/marine/Marine_report_enteclogo.pdf.
[55] Renewable Energy World.com, "Making a Splash: PG&E Dives Headlong Into Wave Power Project", available at http://www.renewableenergyworld.com/rea/news/article/2010/05/making-a-splash-pg-e-dives-headlong-into-wave-power-project.
[56] In March 2010, the UK Crown Estate announced the winners of 10 marine energy leases off the coast of Scotland. The ten projects could provide up to 1.2 GW of power by 2020 and will cost up to £5 billion (US$7.5b) to develop plus an additional £1 billion (US$1.5b) of public investment to build out the national grid and harbor infrastructure they will require.
Perhaps what is most exciting about this development is that a number of utilities and large renewable energy project developers have become involved, some to develop the sites on their own, others in partnership with much smaller device developers. Utilities include: SSE Renewables Developments, ScottishPower Renewables UK, part of Iberdrola Renewables, E.ON, SSE Renewables Holdings. See http://cleantech.com/news/5712/six-wave-tidal-energy-developers-pi

[57] http://focustaiwan.tw/ShowNews/WebNews_Detail.aspx?Type=aSOC&ID=201003120027 and http://www.etaiwannews.com/etn/news_content.php?id=1201744&lang=eng_news&cate_rss=TAIWAN_eng

[58] Carbon Trust, *Future Marine Energy*, ibid at 7.

[59] Technology readiness levels, originally developed by NASA and widely used by the defense department, are used by numerous U.S. federal agencies and many private sector companies, as a metric to assess the maturity of evolving technologies in a consistent and uniform manner. The concept has been adopted by both the UK DECC marine program and the US DOE hydrokinetic program. The concept and application of Technology Readiness Levels (TRLs) are discussed in greater detail in the report, *Best Practices: Successful Application to Weapon Acquisitions Requires Changes in DOD's Environment* (GAO/NSIAD-98-56, Feb. 24, 1998) and *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes.*

[60] *Tidal-current Energy Device Development and Evaluation Protocol (*UK Department of Energy and Climate Change (URN 08/1317), released 2008. These are similar to the technology readiness levels recently developed by the US Department of energy's marine energy program, below. However, TRL 4 and 5 would be combined under stage 2.

[61] Marine Energy Action Plan 2010. Available at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/explained/wave_tidal/funding/marine_action_/marine_action_.aspx

[62] OREC, ibid at page 35.

[63] OREC, ibid.

[64] Adapted from UKERC Marine Renewable Energy Roadmap available at http://ukerc.rl.ac.uk/Roadmaps/Marine/Tech_roadmap_summary%20HJMWMM.pdf

[65] OREC, ibid at page 11.

[66] UK Renewables Advisory Board, Marine Renewables: Current Status and Implications for R&D Funding and the Marine Renewables Deployment Fund, (January 2008), at page 12. http://www.oceanrenewable.com/wp-content/uploads/2008/02/uk-govt-progress-assess-02-08-2007.pdf.

[67] BWEA, ibid at page 18. For example, the UK's newly announced Pentland Firth development- an estimated 1.2 GW system- is expected to require as much as £1 billion (US$1.5b) just to upgrade the local distribution and transmission infrastructure, to enable it to deliver power to population centers farther south.

[68] UK Renewables Advisory Board, Marine Renewables: Current Status and Implications for R&D Funding and the Marine Renewables Deployment Fund, (January 2008), at 10. Available at http://www.oceanrenewable.com/wp-content/uploads/2008/02/uk-govt-progress-assess-02-08-2007.pdf.

[69] UK Renewables Advisory Board, Marine Renewables: Current Status and Implications for R&D Funding and the Marine Renewables Deployment Fund, (January 2008), at 12. Available at http://www.oceanrenewable.com/wp-content/uploads/2008/02/uk-govt-progress-assess-02-08-2007.pdf.

[70] *Ocean Energy: Development and Evaluation Protocol* (HMRC, September 2003) at 2. Available at http://www.marine.ie/NR/rdonlyres/870BA9C2-B58E-4230-A4BD-5CE031A276DC/0/deweprotocol.pdf. See http://hmrc.ucc.ie/.

[71] *Ocean Energy: Development and Evaluation Protocol* (HMRC, September 2003).

[72] Ocean Energy: development and evaluation protocol.

[73] In England revenue support for marine energy comes to about 12.8p/kwh when all the income is included. In Scotland where wave energy gets 5 ROCs and tidal 3 ROCs,

this amounts to 17.3 p/kwh and 26.3 p/kwh earlier through the Marine Obligation it was 17.5 for wave and 10.5 for tidal but not a single project received support. Revue support for marine energy in Portugal equals 23 cents/kwh and in Spain project specific support can be 32 cents/kwh. See BWEA at15.

[74] Winskel, M. (2007) 'Marine energy innovation in the UK energy system: financial capital, social capital and interactive learning', *Int. J. Global Energy Issues*, Vol. 27, No. 4, pg 478.

[75] Winskel, M. (2007) 'Marine energy innovation in the UK energy system: financial capital, social capital and interactive learning', *Int. J. Global Energy Issues*, Vol. 27, No. 4, pp.472–491.

[76] Winskel, at 480.

[77] Winskel, at 480.

[78] Winskel, at 481.

[79] Winskel, at 487 .

[80] UK Renewables Advisory Board, Marine Renewables: Current Status and Implications for R&D Funding and the Marine Renewables Deployment Fund, (January 2008). Available at http://www.oceanrenewable.com/wp-content/uploads/2008/02/uk-govt-progress-assess-02-08-2007.pdf.

[81] UK DECC Marine Action Plan 2010, at 11.

[82] UK Renewables Advisory Board, available at http://www.oceanrenewable.com/wp-content/uploads/2008/02/uk-govt-progress-assess-02-08-2007.pdf

[83] Ocean Energy Protocol, at 2.

[84] Winskel at 481, also "it is crucial for the whole industry that the early developers succeed. If they have a major failure it will damage the whole industry"

[85] From UK Renewables Advisory Board, available at http://www.oceanrenewable.com/wp-content/uploads/2008/02/uk-govt-progress-assess-02-08-2007.pdf.

[86] Winskel.

[87] Winkle at 482, also "it cost us a lot of money to get the results of tank testing, and that is part of our IP, which is all the value the companies hold at the moment; obviously … [we] would not want to disclose the details of that."

[88] Winkle at 482.

[89] RAB.

[90] RAB at 13.

[91] UKERC at 20.

[92] According to the U.S. Department of Energy, "In a renewable energy system, a quantity that refers to all components other than the mechanism used to harvest the resource (such as solar panels or a wind turbine) and the application or load. It includes support structures, power conditioning equipment, batteries, and indirect storage. In addition, the balance-of-system may also be taken to include design costs, land, site preparation, system installation, operation and maintenance costs, and related costs." http://www.daviddarling.info/encyclopedia/B/AE_balance_of_system.html

[93] UK DECC Marine Action Plan 2010.

[94] The Carbon Trust, Capital Operating and Maintenance Costs. http://www.carbontrust.co.uk/SiteCollectionDocuments/Various/Emerging%20technologies/Technology%20Directory/Marine/cost%20of%20energy/Capital,%20operating%20and%20maintenance%20costs.pdf

[95] Rab, at iv.

[96] Pacific Energy Ventures, *Siting Methodologies for Hydrokinetics: Stakeholder Perspectives*. March 10, 2010.

[97] Pacific Energy Ventures, *Siting Methodologies for Hydrokinetics: Stakeholder Perspectives*. March 10, 2010.

[98] http://www.iec.ch/dyn/www/f?p=102:7:0::::FSP_ORG_ID:1316

[99] There is one caveat needed: this report is only intended to summarize the elements of these programs. It is not designed to take these lessons and apply them to the broader question of how international climate technology cooperation efforts could adopt these new models to inform a more comprehensive climate technology strategy. The issue of climate technology cooperation will be the subject of forthcoming research and writing over the coming year.