FSG REIMAGINING SOCIAL CHANGE

Hardware Pioneers

HARNESSING THE IMPACT POTENTIAL OF TECHNOLOGY ENTREPRENEURS

Harvey Koh, Nidhi Hegde, Chandrima Das

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By Harvey Koh, Nidhi Hegde, and Chandrima Das with the assistance of Michael Murray, Mahesh Nayak, and Vishnu Rajeev

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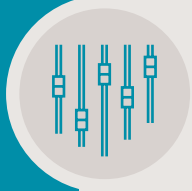

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How We Arrived Here

In the 2012 report *From Blueprint to Scale*, Harvey Koh, Ashish Karamchandani, and Robert Katz turned the spotlight firmly on the **'pioneer gap'**—the lack of patient, risk-tolerant support in critical stages for impact enterprises pioneering new business models. The report described how these pioneer firms shouldered a heavy burden as they blazed risky new trails without the prospect of extraordinary returns at the end of the road. If successful, these pioneers could pave the way to a whole new potential market, attracting more firms and creating brand new industries with the promise of improving the lives of millions.

Four years on, this is a lens that is increasingly used by donors, intermediaries such as incubators and accelerators, and impact investors in targeting their efforts and tailoring their approaches to support inclusive models. We are pleased to see that more of the right kind of capital appears to be flowing in now to help close the pioneer gap.

As activity has picked up, further questions have emerged. One particularly interesting question was posed by The Lemelson Foundation in late 2014. The Foundation's focus on what it calls 'impact inventing'—leveraging the power of invention for social impact—led to the question: **how can we more effectively nurture and scale impact enterprises with innovative hardware-based technologies and solutions?**

We were intrigued. As practitioners working to build markets that benefited the poor, we had always been interested in the power of these kinds of solutions across a range of sectors—from energy to agriculture, and from sanitation to healthcare. But we could also see that businesses producing and selling innovative hardware—physical *things*—had particular needs that were quite different from those of businesses pursuing non-hardware-based models, in ways that we had not always appreciated.

As we explored this question further, it became clear that the ecosystem working to support hardware pioneers did not always fully understand these specific needs either. And even where these needs were understood, they might not yet be effectively addressed. This is a problem: if we apply the wrong expectations, support mechanisms, and investment capital to hardware-based pioneers, we will only be courting frustration on all sides, and, ultimately, failure.

In this report, we share our early findings on the needs of these *hardware pioneers* and how best to support them towards their full potential. How do we nurture them in the critical early stages? How do we even 'spark' their journeys to begin with? As they begin to grow and move towards scale, how do we accelerate them on their way? And how might we be able to amplify their ultimate impact by leveraging powerful networks and partners? By sharing our findings, we hope to help us all move a step closer to realizing the immense potential of technology to improve people's lives everywhere.

1 Harnessing Technology for Development

Our current reality is characterized by highly unequal progress towards the Sustainable Development Goals.

In 2015, the world renewed its commitment to sustainable development. After two years of extensive global consultation, the United Nations adopted the 2030 Agenda for Sustainable Development, setting out 17 Sustainable Development Goals (SDGs) ranging from the eradication of poverty to ending hunger, from ensuring the availability of water and sanitation for all to making sure that everybody has access to modern energy. These goals reflect grand ambitions for all of humanity, not just a few, enshrining the principle that no country should be left behind.

Our current reality, of course, is characterized by highly unequal progress: developed countries have already made huge strides towards meeting these goals over the past century, while they remain a fantasy for billions of poorer people across the developing world.

One of the clearest examples of this gulf between the richer and poorer worlds can be seen in the role played by technology in our lives. In the richer world, our lives are touched by technological ingenuity from the moment we wake up, from the first light we turn on, to our comfortable and sanitary flush toilets, to the refrigerator keeping milk fresh for our morning tea and coffee, made with safe drinking water straight from the tap. Technological inventions have not only made our lives more comfortable, they have also helped to improve our health, lengthen our lifespans, and raise our productivity.

Yet many of these technologies remain out of the reach of the global poor.

While people living in the developed world have enjoyed the benefits of electric lighting since the late 1800s, nearly 1.3 billion poor households in sub-Saharan Africa and South Asia continue to live in the dark today. Lack of access to electricity also means that many poor households are not able to make use of household appliances that are common in the rich world, like refrigerators, televisions, or computers, even if these were made much more affordable.

Modern sanitation technologies—flush toilets and sewerage systems—are another example. These have existed for hundreds of years, but are still not available to 2.4 billion people around the world. This lack of sanitation infrastructure leads to contamination of water sources across large stretches of South Asia and Africa. Because many of these populations are also not served by water purification technologies, this leads to the spread of disease, often with fatal consequences: water-borne diseases such as cholera, typhoid, and dysentery claim 3.4 million lives every year.

Modern machinery and information technology have also changed the way we work, increasing productivity and driving economic prosperity. In advanced economies, large commercial farms enjoy the benefits of improved seed varieties, farm machinery, modern irrigation systems, and post-harvest storage systems. In stark contrast, however, many smallholder farmers in developing countries lack access to some of the most basic technologies, severely curtailing their crop yields and livelihoods.

TECHNOLOGIES FOR THE POOR

Against this challenging backdrop, an emerging wave of inventors and entrepreneurs is working to develop new breakthrough products that are tailored to the needs of the global poor, some of which are described in more detail in Table 1. From water to sanitation, energy to healthcare, these pioneers are pushing the boundaries of technology and business to improve the lives and livelihoods of people across the developing world.

An emerging wave of inventors and entrepreneurs is developing new breakthrough products tailored for the global poor.

Some of these products meet the material needs of the poor and improve their physical well-being. Others are tools that enable them to improve their productivity and raise their incomes, typically in agriculture or other manual activities. Yet others are used not by the poor themselves, but by intermediaries that seek to reach the poor with improved services, such as health workers who use low-cost portable diagnostic devices to deliver higher-quality care to remote villages.

Importantly, these pioneers are not merely stripping features and costs from existing solutions established in the affluent world. Instead, they are applying technology and design skills to develop products that meet the specific needs, desires, and constraints of the poor. Sometimes these products might even require additional features compared to those made for the rich, such as where electrically powered machines require battery back-up because of unreliable electricity supply. In other cases, entirely new products are invented to address problems that disproportionately affect the poor, such as insecticide-treated bed nets to prevent malaria.

In this report, we use the term *hardware* to refer to these types of technology solutions, to call attention to the fact that they are tangible products that consist wholly or largely of physical components. This is not surprising given the needs that these

products serve and the environments in which they are used: clearly, there is no such thing as a virtual toilet or a software-based mosquito bed net.

This is not to suggest that software or information innovation might not also play a part in delivering valuable solutions to the poor—of course they do. But solutions that involve key software or information elements, such as agro-climatic information systems or mobile health applications, will typically still require new hardware to be installed and maintained in order to deliver on their intended benefits. The ubiquity of powerful smartphones and other similarly sophisticated devices in the richer world today should not cause us to forget that these are still unaffordable for billions of people around the globe.

However, exciting though it is to see the emergence of hardware pioneers such as those described in Table 1, the reality is that we are only just beginning to tap the potential of technology to improve the lives of the poor.

In part, this is because many much-needed breakthroughs have yet to be made.

Without robust business models, strong teams, and effective delivery channels, the promise of technology will not be realized.

In 2014, the Institute for Globally Transformative Technologies at the Lawrence Berkeley National Lab (LIGTT) in California published its *50 Breakthroughs* report, which sets out 50 desirable technology breakthroughs that would help to accelerate sustainable global development.[1] The list runs from affordable sub-$50 smartphones to microbicides to protect women from HIV, from nutrient-dense supplements for infants to low-cost solar-powered irrigation pumps. The report makes clear that greater, focused investment is needed, as well as more effective approaches to research and development (R&D). This might include, for example, leveraging existing repositories of research and intellectual property in industrialized countries and introducing incentives for universities to develop these technologies.

But what about the breakthroughs that *do* emerge? The problem there is that many technical breakthroughs fail to progress from the lab into the market in a way that allows them to reach and benefit the people who need them the most. Great technologies alone are not enough—without robust business models, strong teams, and effective delivery channels to take technologies to those who need them, the promise of technology will not be realized.

[1] LIGTT, *50 Breakthroughs: Critical Scientific and Technological Advances Needed for Sustainable Global Development.* LBNL Institute for Globally Transformative Technologies, Berkeley, CA, USA, 2014.

Table 1: Pioneering Solutions

ENERGY ACCESS

Solution: Pay-as-you-go solar home electricity system
Pioneer: M-KOPA Solar

M-KOPA's solar home systems combine mobile and solar technologies to create a 'pay-as-you-go' electricity solution for off-grid households. The mobile device embedded into these systems allows households to pay a very small amount daily for electricity while gradually buying into ownership of their device, rather than paying for the whole device up-front in cash. M-KOPA remotely controls the system, monitors its performance, and troubleshoots issues.

Solution: Solar micro-grid
Pioneer: Mera Gao Power (MGP)

Mera Gao Power's solar micro-grids are bringing electricity to remote Indian villages through custom-designed micro-grids. These micro-grids are regulated by smart meters and are monitored remotely. They can automatically cut off power in case of excessive loads.

AGRICULTURAL PRODUCTIVITY

Solution: Automated irrigation system
Pioneer: RITEC

RITEC's automated irrigation system helps small-holder farmers in Peru, where different areas have distinct microclimates with vastly varied rainfall patterns, by optimizing their water use with automated irrigation schedules. It provides an agro-climatic information system that programs field irrigation schedules through automated remote sensors and a web platform.

Solution: Rapid milk chiller
Pioneer: Promethean Power Systems

Promethean Power System's rapid milk chilling machine helps small dairy farmers in India to store and sell milk that would otherwise be wasted due to insufficient chilling facilities. The incorporation of a patented thermal battery means that the machine requires only five hours of electricity a day, making it well-suited to rural areas that do not have a constant power supply. This also leads to operating costs that are just a third of those of diesel-run chillers.

HEALTHCARE

Solution: Low-cost, portable diagnostic device for kidney disease
Pioneer: Biosense Technologies

Biosense's uChek helps healthcare providers that serve low- and middle-income communities in India conduct lower-cost urine analysis in order to diagnose kidney-related diseases, which affect nearly one in five Indians. uChek is a smartphone-based portable diagnostic system that can perform multiple analyses with comparable accuracy to mainstream devices but at a mere 2.5 percent of the cost.

Solution: Insecticide-treated bed net
Pioneer: A to Z Textile Mills

A to Z Textile's insecticide-treated bed nets prevent the transmission of malaria, which kills nearly 1 million people in Africa every year. A to Z's low-cost bed nets are treated with long-lasting insecticides and kill mosquitoes on contact. The nets last for up to five years and do not require the regular re-treatment needed by conventional bed nets.

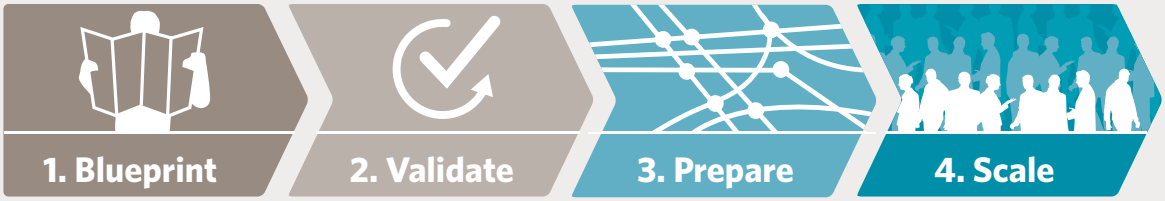
Images courtesy (from top to bottom):

http://www.m-kopa.com/
MGP — Facebook page
NESsT — YouTube page
http://www.coolectrica.com/
http://www.biosense.in/
http://mnhtech.org/

THE PIONEER GAP

Monitor Inclusive Markets has identified the following four stages of pioneer firm development:

Figure 1: Four stages of pioneer firm development



- » Understand customer needs
- » Develop initial customer proposition
- » Develop business plan
- » Develop core technologies and/or product prototypes

- » Conduct market trials
- » Test business model assumptions
- » Refine business model, technologies, and/or products as required

- » Stimulate customer awareness and demand
- » Develop supply chains, upstream and downstream
- » Build organizational capability to scale: systems, talent, plant

- » Move into new geographies and segments
- » Invest in assets and talent
- » Enhance systems and processes
- » Exploit scale efficiencies
- » Respond to competitors

In the young field of inclusive business, most pioneers are still in the early *Blueprint*, *Validate,* and *Prepare* stages, so this is where disproportionate support is needed. Unfortunately, few impact investors seem prepared to do this: Monitor's Africa research in 2011 found that only six of the 84 funds investing in Africa or across regions offer truly early-stage capital.

This is entirely rational. In the *Blueprint* and *Validate* stages here, unlike in the case of angel or venture capital investing in mainstream business ventures, there is limited potential for outsized financial returns within a timeframe that is acceptable to investors (typically five to seven years) in order to compensate for greater early-stage risk and small deal sizes. In the *Prepare* stage, where new categories or value chains are being created, the initial spending on market preparation may not be recouped by the firm and its investors because much of the benefit flows to new entrants, or to customers or suppliers.

How will promising inclusive business models get to these later stages where they become investable if no one will support them earlier on in their journey? **We call this critical gap in support the 'pioneer gap', and we believe that this is a key factor constraining the availability of investment opportunities for impact investors.** Unless we address this pioneer gap, impact capital will fail to achieve its potential as a catalyst of powerful new market-based solutions to the problems of poverty.

Excerpt from H. Koh, A. Karamchandani, and R. Katz, *From Blueprint to Scale: The Case for Philanthropy in Impact Investing—Executive Summary.* Monitor Group in collaboration with Acumen Fund, 2012.

THE HARDWARE PIONEER

Any firms that are blazing new trails rather than walking tried-and-tested paths face a greater degree of challenge and take on a greater level of risk. Firms that are pioneering inclusive business models for the poor in the difficult conditions of the developing world shoulder an even heavier burden: these markets typically suffer from poor infrastructure, fragmented value chains, a hard-to-reach consumer base, and, often, weak demand for innovative, socially beneficial products.[2]

This heavy burden, combined with the lower likelihood of lucrative financial returns down the road, is the reality that led to the identification of the *pioneer gap* in the 2012 report *From Blueprint to Scale* (see sidebar The Pioneer Gap). To close the pioneer gap, the report called for greater levels of *enterprise philanthropy*—catalytic, early-stage donor funding to establish pioneer models, into which return-seeking capital can then be invested to drive scale.

Hardware pioneers face another critical challenge compared to other kinds of pioneers: **they also seek to create value from hardware-based technology and design innovation.** This means that they need to build up relevant technical skills and expertise in science, technology, design, and manufacturing. They also need access to the right tools, laboratories, workshops, components, and materials to develop, test, and refine prototypes. Typically, these resources are expensive and are required over extended periods, meaning that the cost of pursuing this kind of technological development is high. To top it all off, there is no guarantee of success at the end of this long road. This makes securing any kind of funding at the outset difficult, and tapping actual investment capital a fantasy.

Hardware pioneers seek to create value from hardware-based technology and design innovation.

Fundamentally, these challenges also exist in the richer world, but one key difference is the availability of the right kinds of capital: in particular, vast amounts of public funding have served to defray the risk of R&D work in more advanced economies. A remarkable analysis by the economist Mariana Mazzucato has highlighted how a mind-boggling array of 'commercial' technologies—from microprocessors to molecular antibodies, from Google's search algorithm to the Internet itself—has emerged from publicly funded R&D. Some of this has been done at universities and government laboratories, but much has also been done within corporate units (such as Xerox PARC and AT&T Bell Labs) with government co-funding.[3] Government funding has also flowed directly into the richer-world equivalents of our hardware pioneers: research shows that US government programs have provided 20–25 percent of total

[2] Many socially beneficial products are not readily desired or demanded by consumers who may not recognize the problem a product aims to solve, or who may not understand how it solves that problem, or both. Thus, these 'push products' face a tougher challenge in the marketplace and in moving towards scale. For example, clean cookstoves create significant health benefits for households because they emit less smoke than traditional cookstoves. However, because the severe health effects of indoor air pollution from cooking are not recognized by many consumers, they cannot fully appreciate the value proposition presented by clean cookstoves.

[3] Mariana Mazzucato, *The Entrepreneurial State: Debunking Public vs. Private Sector Myths*, Anthem Press, 2013.

THE CHALLENGE OF HARDWARE

The process of developing, manufacturing, and distributing hardware itself presents particular challenges. This is reflected, for instance, in the higher development costs and longer development cycles for products with a strong hardware aspect relative to products that are purely software oriented, as illustrated in Figure 2 and Figure 3.

Product development cycles are generally longer for hardware, since each iteration—even for a simple hardware product—might involve the fabrication of new units or even the sourcing of new materials and components, rather than changes to lines of code in the case of software products. Once developed, even the most basic hardware product must then be physically manufactured and distributed, often reaching the customer weeks or months later, unlike a web-enabled application that can be easily downloaded in a matter of minutes.

The high costs of hardware stem from the physical assets that must be invested in at each stage. Hardware prototyping requires fabrication tools, components, and materials, as well as physical space in which to work. Manufacturing would require much the same elements but at greater scale.

In contrast, software development often requires no more than a laptop computer and, as a pure information product, can be replicated at low cost once developed. Meanwhile, the distribution of hardware products depends on transport logistics and inventory management, while many software products can be rolled out quickly to end users through electronic channels such as the Internet.

Figure 2: Costs incurred for product development* ($ millions)

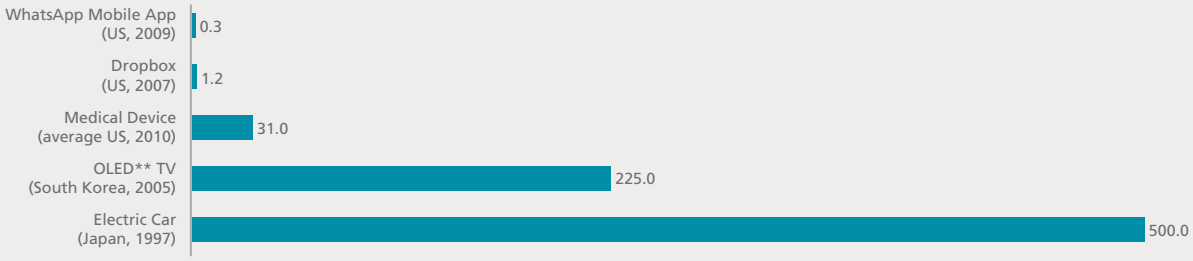
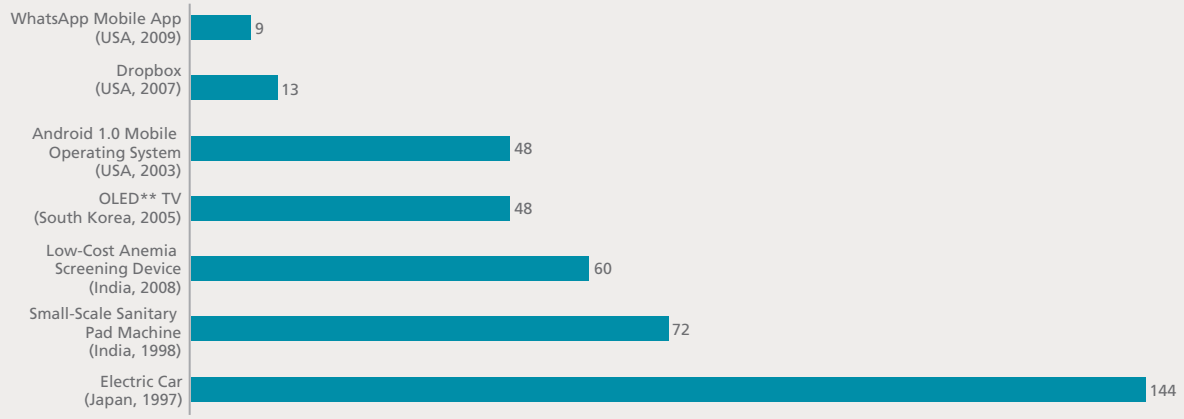


Figure 3: Time taken for product development* (months)



*Estimated product development time until first version is commercialized; **OLED – Organic Light Emitting Diode

Note: Year in brackets denotes start year of product development

Source: FSG research and analysis

funding for early-stage technology firms in the country, far outstripping the amount provided by private venture capital.[4]

Of course, much of the R&D that has been funded in the richer world could also be appropriate for use in the poorer world. However, for the reasons described earlier in this chapter, needs and conditions can be very different between the two worlds. This means that we will continue to require specific R&D that is focused on the poorer world if we care about achieving sustainable development for all. Indeed, the solutions that are needed may be substantially different from one world to the next: the LIGTT *50 Breakthroughs* report assesses that 23 of its 50 desired solutions are commercially attractive only in emerging markets (rather than in industrialized ones), and a further 17 are potentially attractive in emerging markets but only if supported with initial grant funding.[5]

Hardware pioneers cannot lose sight of business realities while striving for technical breakthroughs.

But the hardware pioneer faces challenges beyond funding alone. While striving for technical breakthroughs, the hardware pioneer cannot lose sight of business realities and the need to innovate new models to reach the poorer markets they intend to serve. In addition to strong technical competencies, the hardware pioneer also needs strong business skills in strategy, finance, marketing, sales, distribution, and general management. The hardware pioneer must also ensure that the correct balance is struck between its technology needs and considerations and its commercial ones.

There is an inherent tension between these two sets of abilities as they emerge from different knowledge domains, and, crucially, are rarely present in equal measure in any one individual. Many hardware pioneers are founded by individuals or teams with technical backgrounds, and they are often driven to discover and design ingenious technological solutions to tough problems, rather than to build and manage businesses. One such technical founder described his motivation as seeking the *"joy of solving a difficult puzzle, on top of which you have the spiritual joy of meeting a social need."* Another described himself as being *"driven by my curiosity to see what can be achieved by combining various technologies—it is a fun process!"*

This balance between two domains evolves over the course of the hardware pioneer's journey. In the early *Blueprint* stage, where the initial research and development effort required to achieve the technical proof-of-concept takes place, there is heavier emphasis on the technical aspects of the work. In the *Validate* stage, the pioneer moves into a more active business orientation as they produce, distribute, and sell limited quantities of their products in order to test their proposition in the marketplace. However, a great amount of technical work often still remains to be

[4] Lewis Branscomb and Phillip Auerswald, *Between Invention and Innovation: An Analysis of Funding for Early-Stage Technology Development*. November, 2002, NIST. Quoted in Mariana Mazzucato, *The Entrepreneurial State: Debunking Public vs. Private Sector Myths*, Anthem, 2013.

[5] LIGTT, *50 Breakthroughs: Critical Scientific and Technological Advances Needed for Sustainable Global Development.* LBNL Institute for Globally Transformative Technologies, Berkeley, CA, USA, 2014.

done as technologies and products go through further iterations, based on the feedback coming in from buyers, users, and channels. By the time the hardware pioneer reaches the *Prepare* stage, the emphasis tends to have shifted over to the business side, as the pioneer grapples with issues such as large-scale distribution, servicing, and financing. And yet a significant level of technical innovation still tends to be necessary, as the product offering is often refined and extended.

Of course, it is not only in the enterprise itself that this balance is difficult to strike: very few of us bring the complete set of competencies across both business and technical domains that allow us to readily understand the full range of needs here. Incubators, accelerators, philanthropic funders, and impact investors working with hardware pioneers often find it difficult to bring together the right combination of skills and expertise: those who come from the enterprise and investment domains will tend to focus on business aspects of the pioneer's journey, while those from the world of science and innovation will tend to be drawn more closely to the technical aspects of the work. It is vital that we address our blind spots, on whichever side these lie, and ensure that hardware pioneers receive effective support on both fronts to help them succeed.

Very few of us bring the complete set of competencies across both business and technical domains.

Over the next two chapters, we will address these blind spots by examining the needs of hardware pioneers as they progress through the pioneer gap—in the *Blueprint* and *Validate* stages[6] in Chapter 2, and in the *Prepare* stage in Chapter 3—drawing on in-depth case studies and our survey of hardware enterprises. At the end of Chapter 2, we also consider how we might 'spark' more talented individuals to take the first step on a pioneering journey. Along the way, we will discuss the support needed to help bridge the gap, highlighting emerging practices that could be deepened and broadened.

Later, in Chapter 4, we expand our perspective to recognize the highly networked nature of innovation and scaling today and ask how those could be leveraged in order to amplify the impact of a new idea. We explore the potential for partnerships between the originators of ideas and established companies as well as the pathways by which a pioneer firm's solution might be taken (and often adapted) by others to serve new customers and new markets.

Finally, in Chapter 5, we lay out an initial set of ideas for action by interested stakeholders to support hardware pioneers and strengthen the ecosystem in which they can thrive.

[6] The pioneer gap analysis in *From Blueprint to Scale* focused particularly on the *Validate* and *Prepare* stages. However, our analysis now indicates very-early-stage funding and support challenges for hardware pioneers as they pursue initial R&D, suggesting a wider pioneer gap for them that begins at the *Blueprint* stage.

IMPACT INVESTORS AND HARDWARE PIONEERS

Hardware pioneer Innova Magrini's team in Calca, Peru.

Many investors are daunted by the needs and challenges of hardware pioneers. Omidyar Network, a leading impact investor, recently published a report called *Frontier Capital.* It places hardware pioneers in a category of investing opportunities it terms 'frontier plus' and describes as *"companies with unproven business models that may also be more asset-intensive, target exclusively lower-income consumers, or operate in geographies where exits might be particularly challenging (or all of the above)."*[1]

While acknowledging that this area of opportunity is highly risky and *"clearly not for the faint of heart,"* the report also points to these companies' potential to drive transformative, outsized impact for the poor. The report encourages impact investors to invest more in this area, but counsels them to have longer time horizons of up to 15-20 years, and use a wider range of instruments beyond equity alone, such as venture debt and quasi equity. We will return to some of these recommendations in Chapter 5.

[1] M. Bannick, P. Goldman, and M. Kubzansky, *Frontier Capital: Early Stage Investing for Financial Returns and Social Impact in Emerging Markets,* Omidyar Network, 2015.

2 Nurturing the Hardware Pioneer

COOL SOLUTIONS FOR SMALL DAIRY FARMERS

Image courtesy: http://hdpixa.com/

Vinoda Shenoy lives in a small village in rural Karnataka, India with her husband and two daughters. She wakes up at 5 o'clock every morning to milk her cow, providing an additional source of income for her family. After her kids go to school, Vinoda carries the milk in small containers to a hotel five kilometers away. The hotel buys only a portion of the milk to meet their guests' daily needs. Vinoda reluctantly throws the rest of the milk away; without a chilling facility in her village, the milk would not last through the searing heat of the afternoon.

In recent years, India's demand for milk has been growing faster than its supply, such that the country could become a net importer by 2020. This is being driven by growing consumption of value-added dairy products such as yogurt, which in turn requires high-quality milk that has been chilled soon after collection to prevent spoilage. But the bulk milk chilling units that are commonly used for this purpose require a constant electricity supply. In rural areas where electricity is only available for part of the day, diesel generators are needed for this, adding to the expense. As a result, the many small dairy farmers who live in more remote villages are unable to take advantage of this burgeoning demand for high-quality milk.

A new rapid milk chilling machine from Promethean Power Systems, founded by Sam White and Sorin Grama, promises to change all of this. It chills milk instantly to four degrees Celsius, preventing the growth of bacteria and maintaining the high

quality required by dairy processors. The Rapid Milk Chiller's (RMC) unique advantage over other machines is its innovative thermal battery which allows it to work even in areas where electricity supply is limited or unreliable. The battery can store enough energy to chill 1,000 liters of milk a day using only five hours of electricity supply. This eliminates the need for expensive diesel generators and allows dairy farmers in electricity-poor villages to supply into dairy processors' collection networks.

The RMC can work even in areas where electricity supply is limited or unreliable.

Promethean Rapid Milk Chiller

Born in Romania and raised in the United States, Sorin Grama studied engineering, first at Ohio State University, then at the Massachusetts Institute of Technology (MIT). At MIT, he and a number of fellow students developed a solar micro-generator, an achievement for which they were awarded a prize in the university's Ignite Clean Energy Business Presentation Competition.[7] At the competition event, Sam White, then working at a local software firm, met Sorin. He was so fascinated by the team's idea of a solar-powered generator that he joined the team. With mentorship and funding from the VentureWell E-team program at MIT, Sam and Sorin continued developing their idea.

In 2007, they entered the MIT-100K Entrepreneurship Competition and won a cash prize of $10,000.[8] But the prize was only one of two significant milestones for Sam and Sorin that day. As part of the final event at the competition, Harish Hande, the founder of SELCO, spoke about his work in pioneering off-grid solar products for

[7] Rob Matheson, "Saving rural India's 'liquid cash'," *MIT News*, 7 September 2015, retrieved December 2015 from http://news.mit.edu/2015/promethean-power-india-milk-chillers-0908

[8] *Case Study Series—Promethean Power Systems*, Villgro Innovation Foundation, 2013.

poor communities in India. Sam and Sorin were intrigued by the vast potential of an untapped Indian market for clean energy and inspired to apply their technology to improve the lives of the poor. They reached out to Harish, who encouraged them to pursue their idea and offered to host them in Bangalore while they conducted their initial market research.

"It was the perfect case of an engineer with a solution looking for a market to sell his product."

Using their cash prize, Sam and Sorin travelled to India, where they met with local experts across a range of industries to test their idea and understand where the market opportunity lay for them. Sorin describes this early visit: *"We had actually come to India with a different concept. We wanted to work in renewable energy, not in milk chilling. It was the perfect case of an engineer with a solution looking for a market to sell his product. When we spoke to people there, we realized that no one wanted our solution. But we heard from multiple people, including dairy processors, about the need for refrigeration options for milk and realized that there was a clear buyer and an enormous market. It certainly seemed like a problem worth solving."*

Over the next five years, Sam and Sorin went through several iterations of their idea while gathering feedback from dairy farmers, private dairies, and co-operatives. The solar-powered prototype they had developed at MIT was not suited to the Indian market: it was too expensive and did not work in all weather conditions. One revised prototype used thermo-electricity, but the efficiency of the thermal battery was too low. Another used ice delivered from a central location, but the logistics of delivering ice to remote villages proved challenging.

Finally, in 2012, they landed on a version that seemed to fit the requirements of the market, using a new thermal battery system with a standard condenser and refrigeration compressor.[9] This prototype drew the interest of a handful of private dairies, who bought a number of units to try out in the villages where they operated.

Sam and Sorin's next step was to adapt the prototype for larger-scale manufacturing. As Sorin recalls, *"We had to redesign the components in order to make it easier to manufacture and transport these machines to our first customer. The product we delivered didn't work too well in the field, so for the next nine months we worked to fine-tune our product and see how the components worked under different conditions. This is when we started understanding our product from a commercial usability perspective—having a prototype is very different from having a commercial product."*

This long and costly process of product development was supported primarily by grant funding. While at MIT, Promethean received an initial grant of $20,000 from VentureWell, along with dedicated mentorship, entrepreneurial training, and faculty

[9] A thermal battery can store and release thermal energy, allowing energy available at one time to be temporarily stored and then released at another time.

coaching.[10] A grant of $176,000 from the National Science Foundation in 2011[11] helped them pay for the initial enterprise building and product development, and a second grant of $590,000[12] two years later funded further product development and commercialization. This was followed by a larger $1 million grant from the US Agency for International Development (USAID) through the agency's Powering Agriculture Challenge.[13]

Promethean's early development would not have been possible without these grants, as the company found it challenging to attract interest from investors, who wanted to see a working product and a track record of sales before having serious discussions. Significant time and effort went into raising capital, with the co-founders spending up to half their time on outreach to and engagement with funders and investors.

Building the hardware was the first challenge for the Promethean team, and one for which they were relatively well prepared, given Sorin's background in engineering. The second, and bigger, challenge was to establish a strong business in India, a country that neither Sam nor Sorin was familiar with. To help them with this, VentureWell connected the entrepreneurs to Villgro, a leading social enterprise incubator based in Chennai. Villgro provided valuable guidance to Sam and Sorin in a range of different areas, including initial market testing, selection of local manufacturers,[14] building a robust supply chain, and developing an effective sales and marketing strategy. Villgro also provided critical grant funding to help Promethean produce trial units for early buyers.

Throughout the product development process, the founders split their time between India and the US, conducting field tests in India and doing product research and development (R&D) in a warehouse in Cambridge, Massachusetts. The sophisticated machines and tools needed to build, test, and improve their product were much more readily available in the US.

As the business began to grow, however, the founders realized that they needed to spend more time in India. In 2012, Sorin moved to India to build out the firm's manufacturing capabilities and to begin transferring technical know-how to a local team. Sam continued to split his time between India and the US, with a particular focus on building relationships with investors and funders outside India.

Building the hardware was the first challenge; the second challenge was establishing a strong business in a foreign country.

As the business began to grow, the founders realized that they needed to spend more time in India.

[10] *Case studies in funding innovation: Keeping cool*, Deloitte University Press, 2015.

[11] National Science Foundation website, retrieved January 2016 from http://nsf.gov/awardsearch/showAward?AWD_ID=1113206

[12] Ibid.

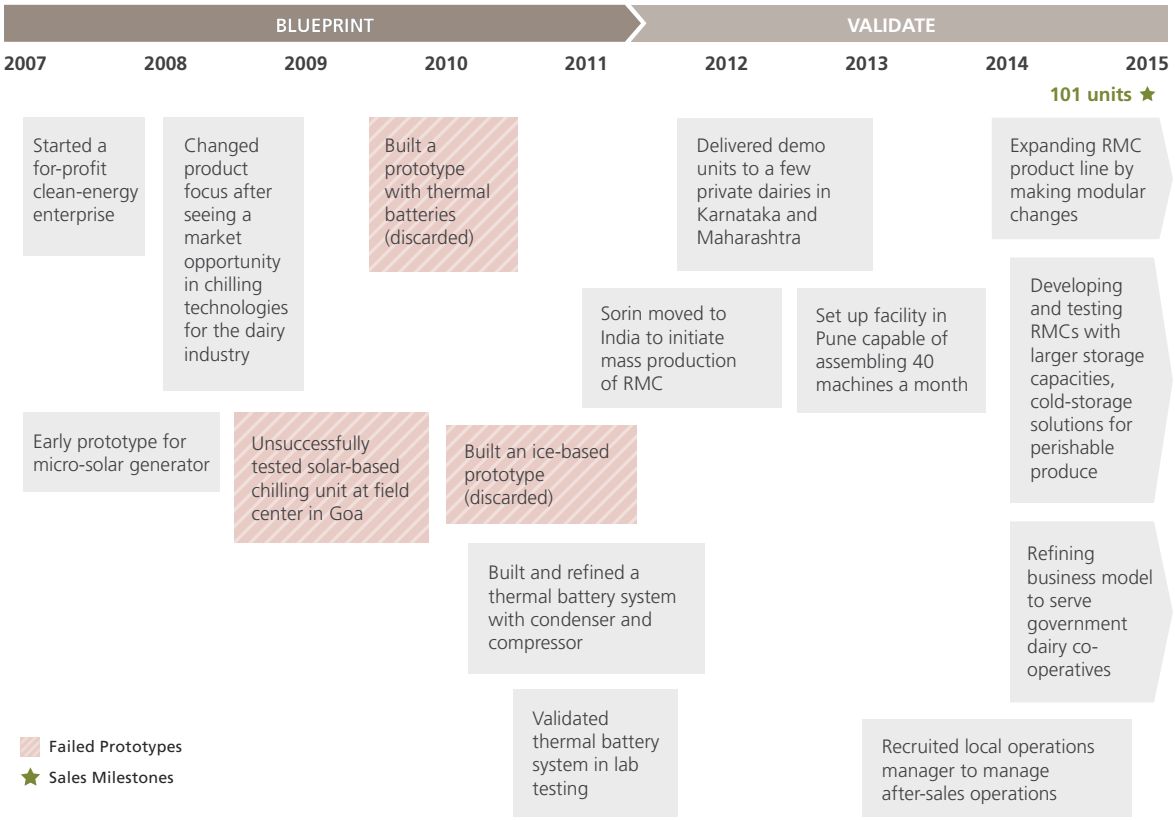
[13] Powering Agriculture website, retrieved January 2016 from https://poweringag.org/news-events/news/clean-tech-innovations-mean-more-milk-africa-india

[14] *Case studies in funding innovation: Keeping cool*, Deloitte University Press, 2015.

By the end of 2013, these efforts had begun to pay off: Promethean had received orders for over 60 units, including 50 units from Hatsun Dairy, India's largest private dairy. To meet increasing demand for their product, the company shifted operations from a small facility in Mumbai to a larger one in Pune with capacity to deliver up to 40 units a month.

As of August 2015, Promethean has installed over 100 RMCs and counts some of India's leading private dairies—Hatsun, AMUL, and Heritage—as customers. The company has also received orders from large dairies in Bangladesh and Sri Lanka and anticipates a significant business opportunity in bringing the product to customers throughout Southeast Asia. The firm has now raised over $4 million from angel investors, venture capital funds, government grants, and private companies, including the National Science Foundation, USAID, Investment Development, Quercus Trust, Gray Matters Capital, and Sangam Capital.[15,16]

Figure 4: Promethean Power Systems' journey



Source: Primary interviews; Promethean Power Systems website; FSG analysis

[15] Sangam Ventures website, retrieved January 2016 from http://www.sangam.vc/

[16] Energy Map website, accessed November 2015 from http://energymap-scu.org/promethean-power-systems/

THE NEEDS OF A HARDWARE PIONEER— *BLUEPRINT* AND *VALIDATE*

The journey of Promethean Power Systems illustrates the specific needs and challenges faced by many hardware pioneers during the early *Blueprint* and *Validate* stages.

1. Leveraging Existing Knowhow and Technology

The technical knowledge and resources that hardware pioneers need is not always easily accessible.

Developing a new hardware product often begins with a new idea, but this does not take place in a vacuum: successful pioneer teams draw on past knowledge, ideas, and inventions even as they work to shape their new products. Past inventions are often integrated as components into new solutions or adapted to meet the specific needs of new markets, particularly for products that are technologically intensive.

For example, solar lanterns for the global poor have only recently taken off, but they are based on decades-old technologies: crystalline silicon solar cells first developed in the 1950s, Li-ion batteries commercialized in the early 1990s, and white LEDs developed in the mid-1990s. Despite the existence of these technologies, households in electricity-poor areas were not able to benefit from them until d.light, a social enterprise, launched its first solar lantern product in India in 2008. d.light's breakthrough was in producing lanterns that were both affordable to poor rural households and durable enough to withstand the tough conditions they would be used in. In order to achieve this, the company leveraged long-established knowledge, technologies, and components.

The challenge is that the technical knowledge and resources that hardware pioneers need is not always easily accessible. Typically, they are located far away from where pioneers are working, and may be scattered across universities, research institutions, individual experts, and industry. It is therefore unsurprising that 67 percent of hardware enterprises we surveyed cited the lack of access to specific technical expertise as a challenge.

Hardware pioneers also need to access appropriate components and materials, and these would ideally be low-cost, high-quality, and easily available in the local area. However, this is rarely the case in reality. Hardware solutions created in poorer countries are often limited by the range of materials and components that are available locally during the prototyping process. Many eventually find ways to work around these constraints, but at a cost. One agriculture technology company reported buying materials and components online in the US and then shipping them to its manufacturing locations in India, incurring massive expenses on transportation. At IDEO.org, teams sometimes take into the field the materials they need to build prototypes, as sourcing materials locally can be expensive and time-consuming.

SUBSIDIES FOR MAINSTREAM INNOVATION

It is easy to forget that many of today's mainstream technologies and related products owe their existence to early-stage subsidies, particularly from the state.

Apple's well-known products are a good case in point, as the economist Mariana Mazzucato describes in her book *The Entrepreneurial State*. The iPod, iPhone, and iPad have transformed the landscape of consumer electronics, but what is less well known is that these products have built on the foundations of a slew of technologies originally developed or funded by government agencies.

Capacitive touch screens date back to research at the Royal Radar Establishment, a British government agency, in the 1960s, and at the European Organization for Nuclear Research (CERN) in the 1970s. Building on this, post-doctoral work in the US in the 1990s, funded by the National Science Foundation (NSF) and Central Intelligence Agency, resulted in FingerWorks, a company with groundbreaking technology for finger tracking and gesture identification. The company was acquired by Apple in 2005, and its technology further developed into Apple's signature 'multi-touch' navigation system.

SIRI, Apple's virtual personal assistant, had its origins in work commissioned by DARPA[1] at the Stanford Research Institute (SRI) to build a virtual assistant for military personnel. TFT-LCD[2] technology was developed with support from the US Army and DARPA, in the absence of support from any computer or electronics companies. Meanwhile, lithium-ion battery technology was developed with funding from the NSF and Department of Energy, among other agencies.

But the devices themselves would be much less useful and enjoyable without their connectivity to

The iPhone 6.

services such as the Internet and GPS[3] that also owe their existence to public subsidies. The origins of the Internet lie in a research program initiated by DARPA in 1973 that resulted in ARPANET, an early prototype network, as well as the fundamental TCP/IP protocol[4] that still underpins the Internet today. Similarly, GPS was developed in the 1970s for military use but later opened up to civilian use. Today, the US Air Force still spends an average of $705 million a year on maintaining the system, excluding the cost of military user equipment.

Government support has also gone into Apple itself, as the company has reportedly claimed $412 million in tax credits related to R&D since 1996.

As this example shows, subsidies are an integral part of the process of creating and commercializing new technological solutions in the richer world. While much of this can be leveraged to create better solutions for the poorer world, there still remains a need for substantial amounts of public and philanthropic funds to support R&D specifically focused on solutions for development impact as needs and contexts can be very different, as we described in Chapter 1.

[1] Defense Advanced Research Projects Agency.

[2] Thin-film transistor liquid crystal display.

[3] Global Positioning System.

[4] Transmission Control Protocol/Internet Protocol — the basic communication language or protocol of the Internet.

If hardware pioneers are not able to connect to the right existing resources, they may end up squandering substantial time, energy, and money in going over old ground, or, worse, fail to make any progress at all.

2. Getting Value Propositions Right for the Customer

The majority of pioneer teams are urban, well-educated, and comfortably above the poverty line. Therefore they belong to a rather different socio-economic context than that of the intended users and buyers of their solutions. This gulf is further accentuated if the founders are trying to work in a country very different from their own, but even those who share a nationality and language with their customers may in many other respects be worlds apart. As P.R. Ganapathy from Villgro says, *"Even within India, one should not expect a person who has been born and brought up in an urban center like Bangalore to automatically understand the context in which a villager in rural Uttar Pradesh lives."*

This is unlike the situation in the mainstream business world where inventors and entrepreneurs often design products for people just like themselves, to meet needs that they themselves understand first-hand. This gulf can easily lead to teams making incorrect assumptions about their customers' context, needs, and desires, and generating ideas that are technically strong but less than compelling with customers. As Sam Altman from Y Combinator, the commercial US accelerator, notes, *"If you're building something that someone else needs, realize that you're at a very big disadvantage. Get very close to your customers. Try to work in their office. Talk to them multiple times a day."*[17]

Some hardware pioneers may be particularly susceptible to these problems because they get so caught up in the heady pursuit of a technological breakthrough that they pay insufficient heed to the real needs and demands of their users and buyers.

In order to close this gap, pioneer teams need to spend time with their potential customers in order to get their input and feedback and refine their product to fit the realities of the market. This can be especially challenging for hardware pioneers as it may mean reevaluating core components of their product or even going right back to the drawing board. Taking this kind of iterative approach is easier said than done for hardware pioneers: R&D and prototyping activities often take place in relatively high-resource environments, far away from the markets that pioneers intend to serve. The distance between where makers make and where customers live—which could range from several hundred miles (Delhi and rural Bihar) to several thousand (Palo Alto and Kampala)—means that iterative testing and refinement can be a challenging process, especially as issues might not emerge immediately but only after months of usage and testing.

Pioneer teams need to spend time with their potential customers and refine their product to fit the realities of the market.

[17] Sam Altman, Dustin Moskovitz, *Lecture 1: How to Start a Startup,* (September 2014), retrieved January 2016 from https://www.youtube.com/watch?v=CBYhVcO4WgI

BRINGING PIONEERS TO THE FIELD

In an attempt to bridge this disconnect between pioneers and their customers, global incubator programs have come up with immersion modules that range from five days to five weeks. The Unreasonable Institute,[1] Stanford University's Design for Extreme Affordability class,[2] and Enactus[3] are all examples of programs that offer students or entrepreneurs the opportunity to travel into the field to connect with the people for whom they are designing solutions and better understand their context. However, while such immersion periods can be a good start to the work of pioneering, a few weeks in the target market will not be enough to develop, test, and refine a new hardware product, much less to build all the other aspects of a business. Sorin Grama advises his fellow pioneers, *"You need to immerse yourself in the local context. I would suggest moving to your target market for a year or two before you even build a product, so that you really understand the market, culture, and people you are trying to serve."*

[1] The Unreasonable Institute website, retrieved December 2015 from http://unreasonableinstitute.org/

[2] Stanford University's Design for Extreme Affordability website, retrieved December 2015 from http://extreme.stanford.edu/

[3] Enactus website, retrieved December 2015 from http://enactus.org/

One case that underscores the importance of truly understanding users and their context is the much-publicized, and then much-criticized, Roundabout PlayPump. This product combined a playground merry-go-round with a water pump, using the spinning motion produced by children playing to pump groundwater up to the surface. However, despite attracting millions of dollars in public and private support, and a number of high-profile celebrity endorsements, the PlayPump ultimately failed to deliver against its promises when implemented in a real-world setting.[18]

In addition to being much more expensive than traditional pumps, the PlayPump produced much less water than had been theoretically projected: one calculation estimated that in order for a PlayPump to deliver its targeted level of water production, children would have to play on it for *27 hours a day*.[19] Apart from the natural concerns raised by a method of drawing water that relies on child labor (and risks injury to those children), it was also problematic that children often did not want to play when adults needed to draw water, and that when it came to work not play, the PlayPump was highly inefficient: one observation in Malawi noted that it took an able-bodied adult male six times longer to draw water using the PlayPump than with a traditional hand pump.[20]

[18] *Safeguarding the World's Water*, USAID, 2009.

[19] Andrew Chambers, "Africa's not-so-magic roundabout," *The Guardian*, 24 November 2009, retrieved December 2015 from http://www.theguardian.com/commentisfree/2009/nov/24/africa-charity-water-pumps-roundabouts

[20] Owen Scott, "The PlayPump II," *Barefoot Economics*, 18 February 2010, retrieved January 2016 from http://barefooteconomics.ca/2010/02/18/the-playpump-ii/

3. Finding Facilities for Prototyping

Hardware pioneers need access to facilities with the right equipment and materials.

One of the defining characteristics of hardware pioneers is that they are developing tangible *things*, rather than intangible services or software. This means that they benefit tremendously from access to facilities with the right equipment and materials needed to prototype their new products. These facilities allow pioneer teams to create, test, and iterate their ideas, without first having to invest heavily in their own space and equipment. They might even bring opportunities to collaborate and partner with other like-minded people.

In many advanced countries, a range of such facilities are available. Colleges and universities are increasingly recognizing the value of makerspaces in fostering innovation among their students. Examples include the ThinkLab at the University of Mary Washington, Headquarters at Rutgers University, the Oshman Engineering Design Kitchen at Rice University, and the Fab Labs, originally at MIT but now present across a number of universities and high schools.[21] Membership fees are modest, with typical rates varying from $40 per month to $175 per month.[22] In return, members have access not only to basic tools (such as welding machines, laser cutters, and lathes) and materials (such as sheet metal and mechanical parts), but also often advanced parts and equipment such as ready-made computer boards and 3D printers.

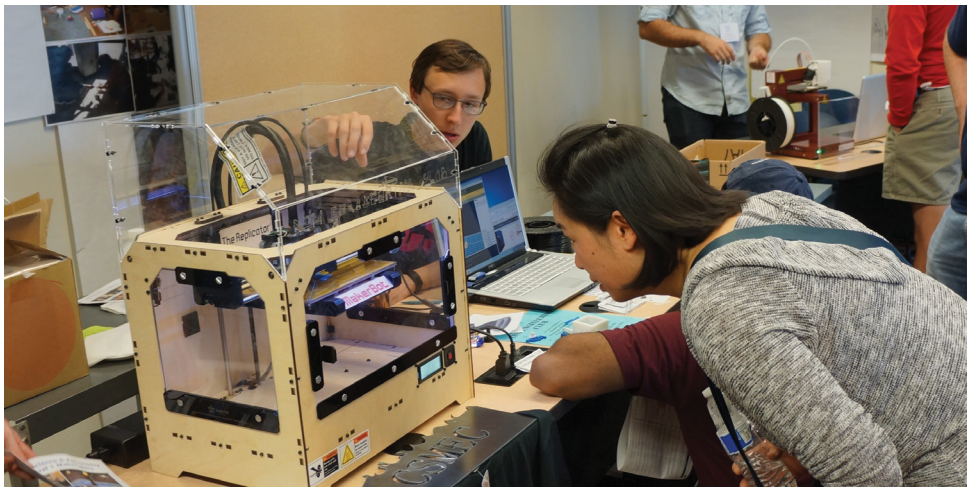


Image courtesy: Library as Incubator Project
3D printer in action at a maker lab in the US.

In developing countries, adequate facilities to prototype new technologies are few and far between.

In developing countries, such facilities are few and far between, and even where they do exist, they may not provide what pioneers need: in our survey, 45 percent of hardware enterprises cited lack of access to appropriate facilities and equipment

[21] Fab Foundation website, retrieved November 2015 from http://www.fabfoundation.org/about-us/

[22] C. Benton, L. Mullins, K. Shelley, and T. Dempsey, *Makerspaces: Supporting an Entrepreneurial System*, 2013, accessed November 2015 from http://reicenter.org/upload/documents/colearning/benton2013_report.pdf

as a challenge during prototype development. The concept of private maker labs is still nascent in developing countries, and it is only in the largest urban centers that facilities are now beginning to emerge, Gearbox in Nairobi and Maker's Asylum in Mumbai being two notable examples. And while university labs are more widely present, they are often equipped with older equipment and technologies and have limited supplies. Many of these labs are also only open to students and faculty, and so may not be accessible to pioneer teams.

This is reflected in the experience of the founders of Biosense Technologies, a medical device pioneer based in India, when they were developing their first product, a hand-held device that screened for anemia without drawing blood. Abhishek Sen, one of the co-founders, says, *"It is extremely hard to get access to labs at engineering schools here—they are not open to the general public, and, at the time, we didn't have any alternatives. We found a way to work around this, by surreptitiously sneaking into the labs of local colleges in Mumbai at night to work on our first device, ToucHb."* While the ingenuity and perseverance of the Biosense team eventually led to success in developing their first product, other pioneer teams may be less fortunate in their efforts to gain access to the facilities they need.

Low volumes of start-up hardware pioneers can make them unattractive to manufacturers and suppliers.

4. Finding Suppliers and Manufacturers

As they prepare to launch their product into the marketplace, hardware pioneers need to find ways to reliably and cost-effectively manufacture the product at a scale that matches their nascent operations. But it can be difficult to find the right manufacturing partners or suppliers that can reliably deliver high-quality, low-cost products or components in many developing countries. Of the hardware enterprises we surveyed, 64 percent cited the lack of access to high-quality, low-cost manufacturing facilities as a challenge.

A hardware pioneer might first seek to produce a small number of units for field testing and then gradually increase volumes, but these low initial requirements make them unattractive for contract manufacturers, and any that they do line up will likely charge them a hefty premium. Those pioneers that are unable to find a manufacturing partner might have no choice but to invest heavily in setting up their own manufacturing facilities.

If pioneers are manufacturing locally, close to the markets that they are trying to serve, one additional challenge is often the sourcing of the necessary materials and components that need to be incorporated into technologically innovative products. These are much less widely available in resource-poor developing countries than they are in developed countries. In our survey, 57 percent of enterprises based in developing countries said they sourced some of their materials from developed countries, and 32 percent sourced *all* of their materials from developed countries.

MANUFACTURING IN CHINA

The last two decades have seen China become the undisputed global hub for manufacturing. Cost-efficient labor, inexpensive raw materials, and the presence of efficient supply chains have driven the attractiveness of southern China in particular as the go-to destination for manufacturing for machinery, electronics, and consumer products.

Early in their journey, d.light and its competitor Greenlight Planet needed to establish manufacturing operations that could achieve the high quality and low cost they required. Unsurprisingly, both decided to manufacture in southern China, and each had a leadership team member—Ned Tozun, the founder of d.light, and Patrick Walsh, a co-founder of Greenlight Planet—relocate to China to get production going. Patrick recalls, *"I went to Hong Kong first and at the time I didn't know anyone except a few students on a foreign exchange semester. I quickly realized my mistake and moved to the mainland. It took me a six-to-eight-month process of trial and error, using Google and Alibaba, to figure out the right manufacturing partner."*

Ned says that the process of identifying the right contract manufacturer was challenging, and when they did come across the right partner who believed in their vision, it was *"almost by pure luck." "We did one thing well though—which was to set a large goal for manufacturing. It helped us attract the right kind of manufacturing partners and build for scale right from the beginning."*

But many hardware pioneers do not see manufacturing in China as a feasible option for them. Many lack the right networks to help them find the right manufacturing partner in China and may also be unable to commit to the large volumes Chinese manufacturers require.

As a result, hardware pioneers often have no choice but to deal with distant suppliers on disadvantageous terms and prices. Government tariffs and import regulations can also get in the way. One early-stage enterprise in East Africa, for example, faced severe delays and additional costs because the raw materials they needed had to be imported and were often held up for long periods at customs checkpoints.*

5. Accessing More, and More Patient, Capital

Like other enterprises caught in the pioneer gap, hardware pioneers find it difficult to access early-stage capital, but the level of challenge is often greater than with non-hardware models.

Where an idea involves a high degree of technological innovation, the pioneer typically engages in R&D for extended periods before it is able to demonstrate a technical proof of concept, and throughout this time bears a significant level of technical risk—the technology might not work as intended, or indeed work at all. It would then take longer still to actually launch the product in the market and begin posting revenues.

*Note: We surveyed 33 enterprises pioneering hardware products for the poor across Asia, Africa, and Latin America to support the analysis presented in Chapters 2 and 3. Majority of responding enterprises were concentrated in four sectors: energy, healthcare, medical technology, and agriculture.

Hardware pioneering is not an 'asset-light' process.

Hardware pioneering also requires unavoidable investment in assets—it is not an 'asset-light' process. In the initial stages, this is driven by the need for physical prototypes, potentially with one's own equipment if suitable shared facilities are not available. Once they begin commercial operations, pioneers then have to build up stocks of their products and might even have to set up their own manufacturing facilities.

This means that significant funding is required: the Enclude/Lemelson report *Catalyzing Capital for Invention: Spotlight on India* suggests that a hardware pioneer might require as much as $25 million in capital over seven to ten years before turning consistent profits at substantial scale.[23] This, coupled with the long time spent refining the product and bringing it to market, means that relatively few investors are willing to provide early-stage capital for hardware pioneers. Of the hardware enterprises we surveyed, 90 percent cited lack of affordable capital as a challenge during product development, and 94 percent said that lack of access to working capital was a challenge during commercialization.

Some hardware pioneers may look to grants to tide them over, but these can be hard to come by, particularly in developing countries. For those who are able to access grant funding, this often comes with monitoring and reporting requirements

[23] The Lemelson Foundation, *Catalyzing Capital for Invention: Spotlight on India*, 2015, retrieved December 2015 from http://www.lemelson.org/sites/default/files/documents/CatalyzingCapitalforInvention.pdf

GRAND CHALLENGES CANADA: BRIDGING THE GAP FOR GLOBAL HEALTH PIONEERS

Grand Challenges Canada (GCC) funds innovations in low- and middle-income countries that have the potential to improve global health outcomes. Through its various programs and partnerships, GCC provides up to $100,000 in proof-of-concept funding to innovators who seek to address health challenges in the developing world. To date, more than 700 innovators have received this grant, of whom some 15 percent are working on hardware solutions.

GCC observed that even after innovators demonstrated proof of concept, they struggled to find funds to support further product development and commercialization of their solutions. To address this gap, GCC launched its Transition to Scale program to provide follow-on match funding, from $250,000 to $1.5 million, which can be deployed in the form of grant, debt, or convertible debt, enabling enterprises to progress along the capital curve towards commercial investment. GCC also provides non-financial assistance, including support in licensing, setting up corporate governance, facilitating introductions to investors, and, in some cases, taking a seat on the board.

Importantly, as innovators need to find another funder or investor that is willing to match Transition to Scale, the program is designed to bring other actors—angel investors, corporates, foundations, NGOs, multilaterals, and public-sector entities—into this space and improve the supply of early-stage capital available to these kinds of innovators in the long run.

that are difficult to meet satisfactorily. For instance, donors often require hardware pioneers to demonstrate specified, tangible results at fixed intervals, but this is difficult because the pace of technological innovation and product development is not always predictable. In fact, only 18 percent of the hardware enterprises in our survey cite philanthropy or academic institutions as a source of early-stage capital support.

Given this situation, it is perhaps unsurprising that two-thirds of hardware enterprises surveyed reported that they mainly used their own funds for product development. Pioneer teams often have to slow down or even halt R&D when their initial funds run out and then have to redirect their efforts toward raising further funds before development work can resume. As a result, pioneer founders can spend a disproportionate amount of their time raising funds instead of developing the product and business, as we saw in the case of Promethean Power Systems.

6. Navigating Intellectual Property and Regulations

Hardware pioneers have a clear interest in safeguarding their intellectual property (IP) so that their products are protected from counterfeiting and duplication. In our survey, 88 percent of hardware enterprises said they had taken legal steps to safeguard their IP, including by filing patents.

The costs of filing and maintaining a patent can be prohibitive.

However, the costs of filing and maintaining a patent can be prohibitive: in India, those costs can run into several thousand dollars. Moreover, the process associated with filing patents in many developing countries is complicated and time consuming and requires a high degree of technical and legal expertise. For hardware pioneers with global ambitions, things are even more complicated: they would need to file separate patent applications in each individual country on the same day or file an international Patent Cooperation Treaty (PCT) application.

But the expenditure of all this time, effort, and money in order to acquire a patent generally does not result in any effective level of protection for the pioneer firm, due to weak implementation and enforcement of IP laws and overstretched judicial systems in many developing countries. Abhishek Sen, co-founder of Biosense Technologies, offers a perspective: *"Filing for a patent in the current legal environment in India is not particularly useful. A larger organization might be able to defend their rights, but I am not sure we would."*

So, why do hardware pioneers file patents in the first place? It is likely that many hardware pioneers filing for patent protection are signaling to funders and investors that they possess valuable and distinctive technology and are therefore an attractive prospect.

Some hardware pioneers also need to navigate official regulatory systems because of the sectors in which they operate. OneBreath, a medical device enterprise, is

Some hardware pioneers have the additional burden of navigating regulatory systems because of the sectors in which they operate.

one such pioneer that has been working on developing a reliable and affordable high-precision ventilator. Unlike existing ventilators, the device tracks the recovery trajectory of a patient and adjusts the level of oxygen accordingly. It therefore does not need a trained medical professional to operate it. At the time of writing, the company is awaiting regulatory approval to begin their first pilot study with patients, expected in 2016. Vijay Simha, ex-CEO of OneBreath, explains, *"The gestation period in the medical devices space is very long due to stringent regulatory processes. It can take up to 60–120 months to actually take a product to market. We are hopeful that we would be able to start commercializing our product in the next 20–22 months. But that would make it one of the fastest products ever to go through the different product development and regulatory stages."*

The regulatory approval process for medical implants takes even longer. Nayam Innovations is an enterprise pioneering an improved, low-cost intraocular lens for use in cataract surgeries. The problem with cataract surgeries is that they often leave patients with sub-optimal vision, leading to a need for further procedures that are both invasive and expensive. The Nayam lens uniquely enables the correction of these post-surgical complications through a non-invasive process, holding the potential to improve outcomes and reduce costs for millions of poor patients. However, before Nayam is able to take it to market, the new lens must be certified to meet International Organization for Standardization (ISO) standards, a process that can take four to six years. Nayam is deploying significant resources to meet these regulatory requirements.

SPANNING THE WORLD

Hardware pioneering is an effort that often cuts across multiple geographies: pioneer teams must spend time in the markets they are seeking to serve, of course. But typically they also wish to access the capital, expertise, components, and facilities that are more abundantly available in the developed world.

Efforts to support the work of hardware pioneers should therefore respond to this transnational dimension. For instance, incubator and accelerator programs could create better pathways of support that bridge different geographies, as happened when VentureWell in the US and Villgro in India worked together to better support Promethean Power Systems. Meanwhile, the Global Social Benefit Incubator at Santa Clara University[1] is applying its considerable expertise and resources to help support pioneering in less well-resourced developing countries. They work closely with local partners that can help pioneer firms identify needs, understand context, and connect to local resources.

[1] Aspen Institute website, retrieved December 2015 from http://www.aspeninstitute.org/sites/default/files/content/upload/CDF%20Summary_0.pdf

7. Building a Team

Building up a leadership team with the right combination of skills and experience is a challenge for any young enterprise, but hardware pioneers face particular hurdles because of the need to bring together two disparate domains—technical and business—that often do not co-exist easily together. As we introduced in Chapter 1, the powerful tension between these domains is what makes hardware pioneer teams special, and it is also what makes them especially challenging to build and run.

Some hardware pioneers have the good fortune of starting out with a set of co-founders with the right combination of abilities, as in the case of the solar energy company Greenlight Planet. When they launched the company, co-founders Anish Thakkar, Patrick Walsh, and Mayank Sekhsaria assumed distinct roles to address both the technical and business needs of the enterprise. Anish, who had worked at the business consulting firm ZS Associates, took on the role of CEO. He took the lead on the firm's commercial strategy and the configuration of its key functions across distribution, sales, marketing, and after-sales service. Patrick, leveraging his engineering background, became Chief Technology Officer, responsible for all aspects of product development from design to manufacturing. Meanwhile, Mayank focused on the operational management from the company's base in Mumbai.[24]

But such situations are relatively rare. Hardware pioneers are much more commonly founded by individuals with a strong technical orientation. The challenge for these *technical founders* is to then assemble the right set of complementary abilities around them as they develop their enterprise.

Hardware pioneers need to bring together technical and business domains which often do not co-exist easily together.

Image courtesy: https://unsettledcity.wordpress.com

Greenlight Planet founding team celebrates a solar lantern sale with their distributor and customer. From left to right Patrick Walsh; Mayank Sekhsari; a customer in Chhapra, Bihar; Anish Thakkar; and a local distributor.

[24] Greenlight Planet website, retrieved December 2015 from http://www.greenlightplanet.com/

Villgro has been working with its portfolio enterprises on these issues for many years, both by helping to develop the abilities of the technical founders themselves, and by helping them find co-founders and key employees. One of the ways in which it has pursued the latter has been through the Villgro Fellowship, where experienced professionals spend nearly a year working in key areas within the enterprise,[25] and then often transition into full-time roles.[26] Fellows come with a diverse range of backgrounds, both in business areas such as finance, sales, and business development, as well as technical ones such as product design and engineering.

Even with support, getting the chemistry right with new additions to pioneer teams can be difficult.

But even with the right support, the desired outcome often remains elusive: getting the chemistry right with new additions to the team can be difficult, and founders are not always ready to share leadership and control of their enterprises. Villgro's model of support recognizes that pioneers will develop at their own pace, so there is no fixed graduation date from the program, and some enterprises have been supported for as long as four years.[27] As Paul Basil, founder and CEO of Villgro, observes, *"Technical innovators entering this space find it very hard to build a business and need structured, long-term support to do that."*

NESsT[28] has encountered many of the same challenges in working with the technical founders in its portfolio. Many of them are grassroots inventors who had seen a need in their local community and developed ingenious solutions to meet them, but lack the business skills to bring those solutions to market, much less take them to scale.

One example is that of Nicasio Uñapillco Ttito from Calca, a village in the Andes. While repairing equipment for local farmers, Nicasio noticed how farmers' productivity was being impaired by their use of farm machinery that was not tailored to their region and their needs. In response, he set up a business to produce machines tailored to local needs, combining his intimate understanding of local farming with his technical skills in mechanics, metalworking, and welding. The business has met with local success, but further growth has been limited as Nicasio continues to devote his energies to developing new products instead of building up the business. He dreams of setting up a factory to mass produce many more machines to meet demand, but he has not been able to clarify the steps needed to get there and secure the capital he needs.

[25] Villgro website, retrieved December 2015 from http://www.villgro.org/

[26] Going forward, Villgro is moving away from its directly-run fellowship program, but will continue to support pioneers by bringing specialized and experienced fellows through partnerships with other fellowship programs.

[27] Villgro website, retrieved December 2015 from http://www.villgro.org/incubation

[28] NESsT supports social enterprises in their journey from start-up to scale through a multifaceted approach, which includes financial investment, capacity support, and social capital. NESsT works primarily in Eastern Europe and Latin America. In addition to catalyzing social enterprises, NESsT also publishes best practice reports and holds meetings for social entrepreneurs and practitioners. See more at: www.nesst.org

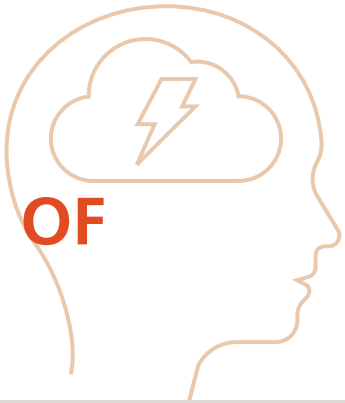
THE 'INVENTOR TO ENTREPRENEUR' TOOL

NESsT believes that it is important to help technical founders reflect on how their leadership team will adapt as circumstances change: building a team is not just a question of finding the right people to join those teams, but also of founders adapting to new roles and dynamics within their organizations that involve sharing control and leadership.

In response to this need, NESsT and the Global Social Benefit Institute (GSBI) have developed a tool to help technical founders assess their skills profile and identify key gaps. The tool also helps those providing support to founders (such as incubator programs) to provide effective feedback and advice, so that founders can be guided towards the path that is most appropriate for them.[1] By assessing the needs of these hardware pioneers and facilitating deliberate, well-informed choices around pathways to market, NESsT and GSBI hope to improve the probability of success for hardware pioneers.

NESsT has further refined how it supports its portfolio entrepreneurs, guided by the results and recommendations assessed by the tool. One entrepreneur who is benefitting from this approach is Isabel Medem, the founder and CEO of X-Runner, a social enterprise providing sanitation systems and services for low-income, urban customers in Peru. Isabel has recognized that she needs a bigger team as the enterprise grows and more support to develop her leadership skills. NESsT is helping her find new talent for her team, and to identify and delegate operational duties which she previously performed. NESsT is also helping Isabel and her co-founder develop a robust governance model with a Board which can provide the knowledge, skills, and network support that they need.

[1] Aspen Institute website, retrieved December 2015 from http://www.aspeninstitute.org/sites/default/files/content/upload/CDF%20Summary_0.pdf



SPARKING THE NEXT WAVE OF HARDWARE PIONEERS

As we described in Chapter 1, many desired breakthroughs that could drive global sustainable development have yet to be achieved. This raises the question of how we might inspire, attract, and support more people with the right skills and talents to even begin the journey of pioneering in the first place — in other words, how could we spark the next wave of hardware pioneers?

A range of existing programs are already working to achieve this, focusing on the intersection of technology, entrepreneurship, and social impact. They acquaint participants with social problems worth solving and teach key design principles. They also introduce participants to co-innovators and co-entrepreneurs who have complementary skillsets and connect them with experienced advisors and mentors.

Many such programs are based out of US universities. Rice University's Rice 360˚ Beyond Traditional Borders program encourages students to use technology and design to solve challenges faced by healthcare providers in low-resource settings. The curriculum introduces students to global health technologies while expert partners help them to identify needs to address and later provide feedback on the designs they developed. One of the solutions to have emerged from the course is the Pumani bCPAP system which treats infants with respiratory distress syndrome.[1]

Stanford's Design for Extreme Affordability class takes graduate students from multiple disciplines across the university and takes them through a human-centered design process.[2] Global partners help these student teams identify needs, and coaches guide them through the design process and help them access resources. The course has sparked a number of hardware pioneers including Embrace, Driptech, and d.light.[3]

VentureWell partners with US higher education institutions to develop and promote curricula focused on new hardware solutions. It has funded faculty to establish new courses and programs where students can develop inventive ideas and gain the critical entrepreneurial skills required to launch new innovative ventures and bring their ideas to market. Its programs are established across 160 US university campuses and have supported hardware-based enterprises such as Promethean Power Systems, Sanergy, and Sarvajal.[4]

These programs are typically found in the developed world and there are a number of reasons why that is. University curricula in many developing countries place less emphasis on innovation and practical skills with fewer cross-disciplinary programs and weaker links to industry. There are some examples of university-based incubators that might cultivate new hardware pioneers, but these are few and far between. Entrepreneurship, especially involving products targeting the poor, is not seen as an attractive career path.

However, there are signs of early progress in changing this status quo. In 2008, Stanford University launched its Stanford India Biodesign program, building on its Stanford Biodesign fellowship program, started in 2000, which trains and supports potential biomedical technology innovators to develop new solutions. Fellows were selected for a team with a combination of engineering, medical, and business

[1] Rice 360 website, accessed November 2015 from http://www.rice360.rice.edu/#!bcpap/ym8iv

[2] Human-centered design is an approach where the design process starts with the users, and places a higher priority on their needs and limitations compared with other targets when designing products and solutions for them.

[3] Stanford University's Design for Extreme Affordability website, accessed November 2015 from http://extreme.stanford.edu/what-extreme

[4] VentureWell website, retrieved November 2015 from http://venturewell.org/whatwedo/

backgrounds right at the outset of the program. They spent part of their time at Stanford in California and part of it training in India. In addition to imparting critical technology, design, and business skills, the program helped teams germinate ideas that they could then take forward.

In 2015, the Indian government[5] launched a successor program, an 18-month fellowship scheme known as the Social Innovation Immersion Program (SIIP). The SIIP encourages fellows to build solutions for unmet needs in the field of maternal and child health using the Stanford Biodesign process.[6] Teams undergo an immersion program at healthcare centers in the National Capital region and are supported by faculty collaborators from various government hospitals.

In Indonesia, Institut Pertanian Bogor, a leading university, has been running its Recognition and Mentoring Program (RAMP) initiative in partnership with The Lemelson Foundation since 2007. Inspired by VentureWell's approach, the program supports a network of around 40 universities across the country in delivering courses on "technopreneurship" where students develop skills related to invention and entrepreneurship, runs a national competition and mentoring program to stimulate the emergence of new hardware pioneers, and runs a national conference on technopreneurship to disseminate knowledge and attract young Indonesians to the field.[7]

Competitions can also be used on their own to raise the profile of hardware pioneering and spark individuals to begin working on 'problems worth solving.' The American Society of Mechanical Engineers' Innovation Showcase is a competition held in the US, India, and Kenya in which winners are awarded cash prizes totaling $500,000 and receive technical support.[8] USAID, Bill & Melinda Gates Foundation, and the Canadian Government through Grand Challenges Canada have launched grand challenge competitions, in which challenges are publicly issued for innovative solutions to defined social problems. Applicants submit proposals describing their approach to solving the challenge and winning innovators receive financing and technical support to develop their ideas. The Grand Challenges model is now being replicated in many countries including India, Peru, Brazil, and several in sub-Saharan Africa.

In the long run, however, growing new generations of hardware pioneers in the developing world will require deeper, systemic change. Young students in schools need a curriculum and an environment that encourages curiosity, application-based learning in STEM,[9] and design from an early age; these then need to be backed up by the resources required to help them explore and create. Current efforts such as SELCO Foundation's school program in Karnataka, India and Global Minimum's programs in Sierra Leone, Kenya, and South Africa are showing the way, but much more remains to be done.

[5] Managed by the Biotech Industry Research Assistance Council (BIRAC).

[6] SPARSH (Social Innovation programme for Products: Affordable & Relevant to Societal Health) website, accessed November 2015 from http://www.thsti.res.in/sparsh/about_sparsh.php

[7] Lemelson Foundation website, accessed November 2015 from http://www.lemelson.org/our-programs/developing-country-programs/education

[8] American Society of Mechanical Engineers (ASME) website, accessed December 2015 from http://www.asme.org

[9] STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics.

3 From Pioneer to Industry

CASE STUDY: LIGHTING HOMES, LIGHTING LIVES

Image courtesy: https://beyondsolar.wordpress.com/

It is dusk in a small village in rural Mymensingh, Bangladesh. Amina sits down next to the kerosene lantern with her homework, reading aloud slowly but clearly from her textbook. She coughs occasionally from the fumes and rubs her tired eyes, exhausted from trying to read by the flickering light. Her mother Zarina is stitching quietly beside her, squinting as she puts needle through cloth.

Solar home systems are a safer, more cost-effective alternative to kerosene.

There are 1.3 billion people around the world who have no access to electricity, and the majority of them live in South Asia and Africa.[29] Households in energy-poor areas spend as much as 30 percent of their income on kerosene for lighting,[30] while others who cannot afford fuel live in darkness. Indoor air pollution is a common result of burning kerosene and kills an estimated 1.5 million people every year from respiratory diseases including chronic obstructive pulmonary disease (COPD) and respiratory tract infections.

Over the last few decades, solar home systems (SHS) have emerged as a safer, more cost-effective alternative to kerosene, particularly in areas that are off the electricity

[29] International Energy Agency website, retrieved January 2016 from http://www.iea.org/topics/energypoverty/

[30] Energy for Development website, retrieved January 2016 from http://www.energyfordevelopment.com/2010/03/measuring-household-lighting.html

grid. Harnessing the sun's energy in this way could save households up to 86 percent of their expenses on lighting and mobile charging.[31]

SHS could save households up to 86 percent of their expenses on lighting and mobile charging.

But the modern SHS has a long lineage. It uses decades-old technologies: photovoltaic cells to absorb the sun's energy, a Li-ion battery to store this energy, and a charge controller to distribute power while protecting batteries and appliances. The earliest solar energy pioneers—companies like Solarex in the US—first developed and introduced their products as far back as the 1970s and were on the ground in developing markets by the 1980s. In the 1990s, more donor-funded programs emerged, particularly in Asia, with the World Bank launching programs in no fewer than 12 countries.

By 2000, an estimated 1.3 million systems had been installed around the world, a modest number considering the number of years over which it accrued. A third of this total had been supported by government and donor programs in countries including India, Sri Lanka, Mexico, Bolivia, Guatemala, Zimbabwe, Botswana, and Namibia. While these interventions certainly led to installed units, they failed to result in sustainable, growing markets for SHS,[32] and broader uptake of the solution remained low.

The SHS pioneers and their products had faced a number of critical challenges as they attempted to scale.

Image courtesy: develoPPP.de
Rural household in sub-Saharan Africa lit up by SHS-powered lights.

[31] *Investment and Finance Study for Off-Grid Lighting*, AT Kearney, 2013.

[32] FDJ Nieuwenhout et. al., "Experience with Solar Home Systems in Developing Countries: A Review," *Progress in Photovoltaics: Research and Applications,* 2001.

A critical challenge faced by SHS pioneers was the lack of consumer financing.

One of these was the lack of consumer financing for these relatively costly items. While these systems provided free energy once they were running, very few poor households had enough cash to be able to pay the up-front cost: in 2008, a standard 40 Wp capacity system—which would power 2 LED lamps, a mobile phone charger, a radio, and TV—was about $280. These were larger amounts than microfinance institutions could provide at the time, and mainstream consumer financing companies could not reach the communities where these products were most needed. The difficulty of collecting payments from households scattered across remote rural areas presented a seemingly impossible barrier to overcome: early lending efforts in rural Bangladesh in the early 2000s faced collection costs ranging between 25 and 70 percent of payment amounts.

Installing and maintaining SHS in remote rural areas was difficult.

Another difficulty was the challenge of installing and maintaining these systems in remote rural areas where they are most needed. While SHS technologies are well established in more technologically advanced parts of the world, they are unfamiliar and cannot be readily supported by existing providers in target areas. In many developing countries, poor transport infrastructure makes servicing these areas an unfeasible proposition. Providers could try to build their own teams in rural areas but they would likely struggle to find the right personnel to hire with the requisite skills and expertise, and urban technicians who had these capabilities would be reluctant to move away from the cities. And so, few enterprises moved beyond selling equipment into installation and after-sales service.

However, recent efforts in two countries—Kenya and Bangladesh—are making strong progress in overcoming these barriers. In just 11 years, the total installed base of SHS in Bangladesh has gone from 7,000 households to 3.5 *million* households.[33,34] In Kenya, meanwhile, donor- and government-backed programs started in the early 1980s. Along with commercial players, they had managed to install 300,000 systems over a period of three decades. In recent years, however, the pace of installations has accelerated dramatically, with over 150,000 systems installed between 2012 and 2015 alone. As we explain below, these two efforts use very different approaches, but both of them worked because they correctly identified key scaling barriers and then found ingenious ways to overcome them.

BREAKTHROUGH IN BANGLADESH

In 1996, Grameen Bank, the microfinance institution founded by Nobel Laureate Muhammad Yunus, established a new social enterprise to focus on bringing renewable energy solutions—and solar home systems in particular—to off-grid

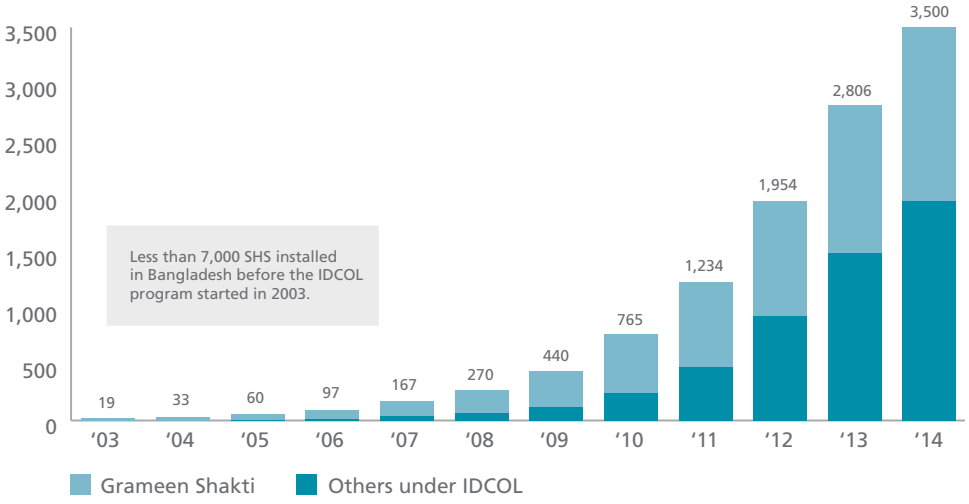
[33] *Bangladesh: Lighting up Rural Communities*, World Bank, 2013.

[34] Pantho Rahaman, "Bangladesh aims to be world's 'first solar nation'," *Reuters India*, 25 January 2015, retrieved December 2015 from http://in.reuters.com/article/bangladesh-solar-idINKBN0KY0O220150125

Bangladeshi households. The new company, Grameen Shakti, began to build a network of field agents in rural areas to educate customers and sell solar home systems. However, Grameen Shakti's early growth and impact was limited by the key scaling challenges already described above.

The breakthrough came in 2003, when Bangladesh's Infrastructure Development Company Limited (IDCOL), a parastatal organization, launched a program to help scale up SHS provision as part of the government's vision of ensuring 'Access to Electricity for All' by 2021.[35] Backed by the World Bank, the Global Environment Facility, USAID, and the UK's Department for International Development (DFID), among others, the new program set out to address the key scaling barriers faced by solar home system companies.

Figure 5: Cumulative number of solar home systems installed under the IDCOL program, 2003–2014 ('000s)



Source: Grameen Shakti website; Arc Finance and FSG analysis

IDCOL's program addressed key scaling barriers for SHS companies in Bangladesh.

At the core of the program was a concessionary refinancing facility offered by IDCOL to providers, such as Grameen Shakti, that were also extending loans to end customers. This infusion of flexible capital into the industry allowed providers to ramp up their own financing activities, with 58 companies eventually taking advantage of the facility. In the initial years, IDCOL also provided an up-front subsidy of $70 for each installation. This helped drive early adoption by households that were almost entirely unfamiliar with SHS technology. As the industry matures, IDCOL has reduced the level of subsidy, and it now stands at $20 per installation.

IDCOL also provided vital non-financial support to the industry as it grew. Capacity-building support to partner companies helped them to develop effective after-sales and maintenance services. To maintain acceptable standards of quality, the program

[35] IDCOL website, retrieved December 2015 from http://www.idcol.org/

also required that partner companies should source components only from the 164 suppliers approved by its Technical Standards Committee. IDCOL would also audit all of its partners every year to ensure that credit was being extended prudently, collections were being made on a regular basis, and systems were being serviced in a timely manner.

Grameen Shakti has developed a network of 7,500 trained staff to install and service SHS.

As the market leader and IDCOL's largest partner, Grameen Shakti benefited tremendously from this support. The scale of investment underwritten by the program allowed Grameen Shakti to press ahead with setting up 45 Grameen Technology Centers (GTC) to train large numbers of technicians and engineers required to deploy and service solar home systems at scale.[36] Local women would be trained to assemble and install solar home systems, and customer households would be trained to operate the systems and perform simple maintenance tasks. Over time, the GTCs have created a large pool of trained field staff, not only for Grameen but also almost certainly for other SHS providers across Bangladesh.

Abser Kamal, former managing director of Grameen Shakti, describes the scale of activity that has resulted from these efforts: *"We have developed a huge network across Bangladesh, through more than 1,000 field offices. There are about 7,500 staff working in the field and most of them are engineers."*[37] IDCOL's multi-faceted investments, Grameen Shakti's infrastructure building, and the efforts of many other SHS providers have resulted in truly impressive growth in SHS installations in Bangladesh, as seen in Figure 5. At the start of 2015, 3.5 million installations were serving over 15 million people, more than 10 percent of Bangladesh's population. IDCOL expects the industry to continue growing strongly, at 58 percent year on year. It aims to generate 220 MW of electricity for previously unserved communities, nearly doubling its current impact to six million installations, and potentially reaching 30 million people by 2017.[38]

MOBILE REVOLUTION IN KENYA

In Kenya, a different, more entrepreneurial solution has been taking shape in recent years.

In 2010, Nick Hughes founded a new enterprise called M-KOPA Solar, having already successfully revolutionized the mobile payments industry with M-PESA while at Vodafone. The new business would leverage mobile payment platforms to solve the problem of cash affordability faced by low-income households interested in buying beneficial but large-ticket products such as solar home systems.

[36] Grameen Shakti website, retrieved December 2015 from http://www.gshakti.org/

[37] "Interview with Abser Kamal, Acting Managing Director of Grameen Shakti," Hedon, 2009, retrieved December 2015 from http://www.hedon.info/tiki-download_item_attachment.php?attId=226

[38] See IDCOL's website for more information on *Solar Home System Program*: http://idcol.org/home/solar

WALLET IN A MOBILE PHONE

In March 2007, a Kenyan mobile telecom operator saw an opportunity to help the poor manage their money. Safaricom, the local affiliate of Vodafone Group Plc, launched M-PESA, a service that allowed anyone with a mobile phone to move money securely through the mobile network. For poor communities with little access to banks, M-PESA and other similar 'mobile money' products allow financial transactions to be conducted with unprecedented ease and security, without the need for bank branches. Users can deposit and withdraw money through a network of airtime dealers and retail outlets acting as agents. M-PESA scaled up quickly, with Safaricom announcing it had 13 million active monthly users in 2015. It also spread rapidly in the rest of the developing world, including Tanzania, Afghanistan, South Africa, India, Eastern Europe, Mozambique, and Egypt.

It was a financing solution—with a twist. Instead of a conventional loan disbursement and collection mechanism, M-KOPA developed a pay-as-you-go solution: the company's plug-and-play SHS unit would come with an embedded mobile SIM and would allow customers to use mobile money credit to pay small amounts on a daily basis over a period of time. They would enjoy the benefit of safe lighting in their homes for as little as $0.45 a day and own the SHS unit outright once they came to the end of the 'leasing' period. Most importantly, customers would no longer have to make a large up-front payment in order to have these systems installed. Meanwhile, the use of mobile money networks, which are now pervasive throughout Kenya, means that the company avoids heavy costs in terms of time, effort, and money that would otherwise have to go into monitoring usage and collecting loan repayments.

M-KOPA's pay-as-you-go solution powered by mobile money has brought SHS technology to 250,000 homes.

In the three years since its launch, M-KOPA has brought SHS technology into 250,000 homes in Kenya, Tanzania, and Uganda. They are adding over 500 new homes each day.[39] Just as importantly, a raft of other companies—such as Azuri Technologies, BBOXX, Off Grid Electric, and BuffaloGrid—have also emerged in M-KOPA's wake to take this powerful new approach to markets across East Africa and beyond.

Now, decades after these technologies were first developed, we are beginning to glimpse the true potential of these solutions to transform the lives of the global poor.

THE NEEDS OF A HARDWARE PIONEER—PREPARE

The story of solar home systems illustrates how, at the *Prepare* stage, we see the emergence of *scaling barriers* that could delay or even thwart the progress of pioneer firms. Indeed, these barriers will typically affect a number of firms with similar

[39] M-KOPA website, retrieved December 2015 from http://www.m-kopa.com/

SCALING BARRIERS

The authors of *Beyond the Pioneer* identified barriers to scale for inclusive industries at four distinct but related levels: the firm itself; the industry value chain, of which the firm is a part; public goods relevant to the industry; and governmental laws, policies, and actions.

In order to accelerate market-based solutions to take them to scale, we need to sharpen our focus on the real obstacles to scaling and become more effective at removing them. In 2012, Monitor and Acumen Fund described one part of this challenge. They exposed the pioneer gap in early-stage capital and support to firms pioneering new inclusive business models, and called for greater *enterprise philanthropy* to help close this gap.[1]

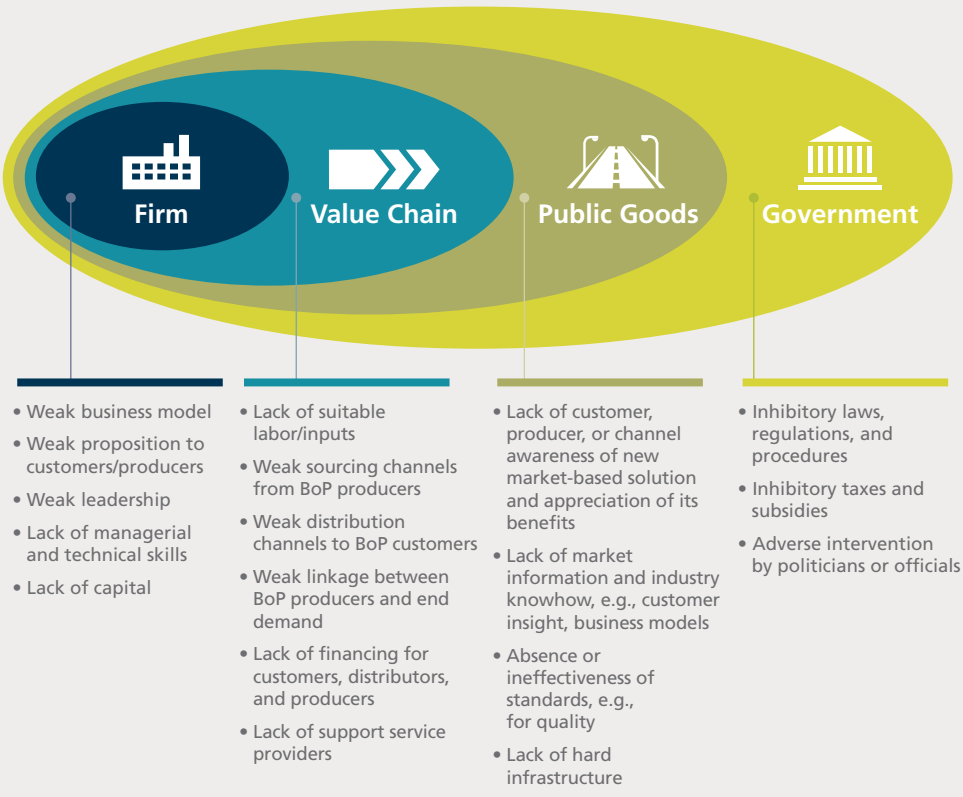
To see the full picture, we need to look beyond the pioneer firm. Scaling barriers are often not at the level of the firm itself, but in the environment around it. For example, customer awareness may need to be created; farmers might need to be taught how to plant new crops; last-mile distribution channels may need to be built from scratch; or onerous government regulations may need to be streamlined. In order to truly close the pioneer gap, we need to resolve all the barriers that are impeding growth.

And we need to expand our focus from just building inclusive firms to building inclusive industries. We believe that diversity of firms in an industry and healthy competition between them drives greater value for customers in the long run. So when we address key scaling barriers, we need to resolve them for the benefit of all firms in the industry, and not just for one or two.

Excerpt from Harvey Koh, Nidhi Hegde, and Ashish Karamchandani, *Beyond the Pioneer—Executive Summary,* Monitor Deloitte, 2014.

[1] Harvey Koh, A. Karamchandani, and R. Katz, *From Blueprint to Scale: The Case for Philanthropy in Impact Investing*, Monitor Group, 2012.

Figure 6: Barriers to scaling



products and business models—in essence, a whole industry—as, by this stage, the original idea will have diffused and spread to other entrepreneurs and teams. The topic of understanding and overcoming industry scaling barriers is comprehensively discussed in the 2014 report *Beyond the Pioneer*,[40] a summary extract of which can be found in the sidebar on Scaling Barriers.

While there is no substitute for a thoughtful analysis of scaling barriers that is grounded in the facts of each situation, we believe that there are a number of typical needs associated with hardware pioneers and their industries in the *Prepare* stage.

1. Building Strong Distribution

Lack of distribution infrastructure and established retail networks prevent new hardware solutions from reaching remote customers.

Getting new hardware products into the hands of customers—particularly those who live in remote rural areas—is no trivial undertaking. The problem is compounded by the lack of distribution infrastructure and established retail networks. In our survey, 52 percent of respondents cite weak distribution channels to poor customers (or producers) as a challenge. Distribution at scale requires heavy investment in experimenting with different models of distribution, and then in building out the models that appear to be working. The company's distribution partners must also be willing to stock and sell new products, which can be a risky move if the product or product category is new and untested in the marketplace.

In some cases, there just are no ready distribution partners that could take the new product to its target areas and communities, leaving the pioneer with only one option: establishing a proprietary distribution channel. But creating a channel from scratch is expensive and time-consuming and introduces additional risk to the pioneer's business model.

Greenlight Planet's initial approach of setting up retail shops in India proved unsuccessful as retailers were not invested in educating customers who were new to these products. However, the company noticed that certain agents were recruiting help in neighboring villages and selling at 10–15 times the rate of their peers and evolved their strategy to build a network of 'Direct to Village' micro-entrepreneur sales agents, which met with greater success initially.[41] In recent years, however, this model has proved difficult to replicate because of the high costs of recruiting and training motivated micro-entrepreneurs in villages. d.light's much less intensive experiments with village-based sales agents came to similarly unsuccessful ends.

Creation of custom sales channels is a common yet flawed approach in the impact sector.

The solar lantern companies' experiences with micro-entrepreneur sales agents are not unusual in the world of social enterprise. While these models can seem appealing because of the touchpoints with end customers and the bonus of helping to

[40] Harvey Koh, N. Hegde, and A. Karamchandani, *Beyond the Pioneer: Getting Inclusive Industries to Scale*, Monitor Deloitte, 2014.

[41] "Marketing Innovative Devices for the Base of the Pyramid," *Hystra*, March 2013.

boost rural livelihoods, it can be extremely difficult to make them work. Another case is that of VisionSpring, a rural eyeglasses enterprise working in more than a dozen countries. It moved from its micro-entrepreneur sales agent channel in 2008 to a franchise model leveraging partners after spending seven years trying to make direct sales work. In the seminal 2009 Monitor Group report *Emerging Markets, Emerging Models*, the creation of custom channels was found to be the most commonly occurring mistake in the impact sector, resulting in uncompetitive product prices and non-scalable models.[42]

Ned Tozun, founder of d.light, says that the solar lantern company *"always knew the harder challenge was distribution."* One of its breakthroughs has been striking up partnerships with channel partners that already have strong reach into its target markets: these ranged from obvious candidates like the social enterprise Living Goods to less likely partners such as the French oil giant Total.[43,44] Through Total's Access to Energy program, d.light (and its competitor Greenlight Planet) are able to retail their lanterns in Total filling stations throughout Africa. While partnerships with large multinationals represent big opportunities for hardware pioneers, they also often require pioneers to step up their own game in terms of product quality and production volumes.[45]

Distribution tie-ups with large corporates are complex to set up and do not always succeed.

However, distribution tie-ups with large corporates do not always work out, as we see in the case of Embrace, an enterprise pioneering an innovative solution to keep premature infants warm. The Embrace product was much cheaper than conventional infant incubators—between $200–$300 per unit, compared with $3,000–$20,000.[46] It was also able to operate even with interrupted or sporadic electricity supplies, a problem that blights many developing countries.

In late 2010, Embrace appeared to have made a distribution breakthrough by entering into an agreement with GE to distribute its infant warmer through GE Healthcare's distribution network in India and other developing countries.[47] Subsequently, Embrace entered into discussions to partner with other large multinational corporations such as Novartis.[48] Unfortunately, the distribution gains that were promised by these partnerships failed to materialize.

[42] For more, see: A. Karamchandani, M. Kubzansky, and P. Frandano, *Emerging Markets, Emerging Models: Business Models that Work*, Monitor Group, 2009.

[43] "Marketing Innovative Devices for the Base of the Pyramid," Hystra, March 2013.

[44] Other for-profit retail partnerships include LPG distributors (d.light) and ESSMART in India (Greenlight Planet).

[45] Astrid Zweynert, "What happens when a social enterprise and an oil giant join forces?," *Thomas Reuters Foundation*, retrieved December 2015 from http://www.trust.org/item/20130906165711-qt8fp/

[46] Stefanos Zenios, Lyn Denend, Amy Lockwood, and Stacey McCutcheon, "Embrace: Deciding on a Hybrid Structure," *Global Health Innovation Insights*, 2012.

[47] Joyce Routson, "Embracing a Way to Change the World," Graduate Stanford Business School, 1 May 2011, retrieved December 2015 from https://www.gsb.stanford.edu/insights/embracing-way-change-world

[48] L. Davidson, "Do Frugal Innovations Lead to Frugal Outcomes? A Case Study of Healthcare in India," *Wharton Scholar's Journal*, 2015.

Although leadership in GE Healthcare was genuinely committed to the success of the product, the incentives of the on-the-ground sales teams encouraged them to focus on selling products with strong existing demand.[49] A product such as the Embrace infant warmer, where sales staff had to spend more time persuading hospitals and clinics to take a chance on something new, was a low priority for salespeople with big targets and little time to spare.[50]

Moreover, the distribution networks of large corporates may not be appropriately configured to reach low-income markets. Over the years, GE had established a strong network in India to serve hospitals and diagnostic centers in the large cities,[51] but the key customer segment for the new infant warmers were health centers in semi-urban and rural markets. As a result, the partnership failed to achieve what it had originally set out to do, and has since been discontinued.

2. Financing the Chain

Access to finance is a challenge not just for pioneer firms, but also for their distributors, retailers, and customers, particularly in the case of larger-ticket durable hardware. In our survey of hardware enterprises, 76 percent cited the lack of financing for their distributors, retailers, and customers as a significant challenge.

Financing is required not only for the firms themselves but also for their distributors, retailers, and customers.

Distributors and retailers need to have enough capital to build up and maintain stocks of hardware products. End customers with little disposable income, limited savings, and weak access to consumer finance are rarely able to afford larger-ticket durable products upfront. They need appropriate financing mechanisms to help them acquire these. Meanwhile, mainstream financial service institutions, like banks and consumer finance firms, which could in theory help meet this need, are typically poorly prepared to provide loans either to the small-and-medium-sized enterprises (SMEs) that constitute the vast majority of distributors and unorganized retailers in developing countries or to the poor households that wish to buy new hardware products.

The growth of the global microfinance industry has helped to partially bridge this financing gap for consumers. Enterprises offering everything from solar lanterns to water filters have tried to leverage microfinance institutions (MFIs) as financing channels for their products. However, MFIs are not always an effective financing channel for all types of durable hardware products. The loan sizes offered by most MFIs match the costs of products such as solar lanterns and cookstoves but are inadequate for large-ticket items such as farm equipment.

Many MFIs also do not want to take on the risks associated with selling new hardware products that they are unfamiliar with: product failures can erode trust and

[49] L. Davidson, "Do Frugal Innovations Lead to Frugal Outcomes? A Case Study of Healthcare in India," *Wharton Scholar's Journal*, 2015.

[50] Ibid.

[51] GE Healthcare Lifesciences website, retrieved December 2015.

strain relationships with clients, and might even cause them not to repay their loans. Moreover, most MFIs are ill-equipped to pair technically intensive maintenance and service with their collection routines. Therefore, even though MFIs have achieved impressive scale in extending credit to the poor, these channels have seen limited success in providing consumer finance for newer, larger-ticket hardware products.[52]

As we saw in the case of M-KOPA earlier in this chapter, new mobile money-based systems have the potential to allow effective new financing plans. However, it is worth noting that mobile money platforms, while scaling rapidly in a number of countries, are still not the ubiquitous presence that we might like them to be: in India, the development of mobile money has been slow, in part because of restrictive regulatory frameworks that have only recently been eased.

3. Got Hardware? Need Service

While product development, manufacturing, distribution, and sales are standard activities for all hardware firms, there is an additional layer of complexity that some firms have to manage if they are selling durable hardware (or a service enabled by durable hardware, such as electricity supply through a minigrid)—namely, after-sales service and maintenance channels. In our survey, 42 percent of enterprises cited the lack of capacity for after-sales servicing as a major challenge.

Timely and effective after-sales service is crucial for the success of durable hardware models, as the consequences of a product breakdown are greater for low-income customers than for those with higher disposable incomes: these customers are less

Timely and effective after-sales service is crucial for the success of durable hardware models.

An electrical repair shop in Tanzania.

[52] N. Lalwani and M. Kubzansky, *Stretching the Fabric of MFI Network*, Monitor Group, 2010.

likely to have alternative ways of meeting their needs if the product fails, and may even suffer loss of earnings as a result. Such experiences can also quickly erode customer trust and damage pioneers' brand reputations. For example, Promethean aims to repair a broken milk chiller within two hours, preventing loss of income for small dairy farmers and co-operatives.

Clearly, setting up a highly responsive service and maintenance capability with well-trained personnel to serve a customer base that might be widely scattered geographically is a tall order for a young enterprise and requires substantial investment. Is this even feasible for most pioneers? While Grameen Shakti's GTC network (described earlier in this chapter) might represent a gold standard of what can be achieved on this front, the thought of emulating it will seem fantastical to most other hardware pioneers.

One answer might be to leverage partners that have these capabilities and that can do the job more effectively by providing this service across a range of different products and suppliers. There is arguably no more reason to have a proprietary service and maintenance function than to have a proprietary distribution channel. In recent years, we have seen the emergence of companies with the ability to plug precisely these gaps. We call them *last-mile specialists*. They have networks that reach the poor in remote areas with sales, distribution, servicing, and maintenance.

Last-mile specialists have networks that reach remote areas with sales, distribution, servicing, and maintenance.

One example is Essmart, a company that brings hardware solutions such as solar lanterns, non-electric water filters, rechargeable batteries, and clean cookstoves to existing retail stores in rural parts of Tamil Nadu, India. The company's sales executives, hired from the local community, start by building awareness in rural areas by conducting product demonstration events and informing and training rural retailers. Customers and retailers can then place orders from a catalog of over 65 hardware products—from suppliers such as Greenlight Planet, Panasonic, Greenway Appliances, Tata Chemicals, and Essilor—to be fulfilled by Essmart.[53]

An important feature is that Essmart enables convenient returns and replacements for product failures covered by warranty: customers can get replacements through their local shop within two weeks, while Essmart handles the chain between the retailer and the manufacturer. This level of after-sales service, and the trust it engenders in Essmart's brand, helps give customers the confidence to buy new and unfamiliar products. Since starting operations in 2013, Essmart has reached 48,000 customers through 1,200 village stores.[54]

Another company in this space is Frontier Markets, a distribution, sales, and marketing service provider currently operating in rural Rajasthan in India. It focuses on clean

[53] Essmart website, retrieved December 2015 from http://essmart.in/

[54] Ibid.

energy products such as solar home systems and solar lanterns and has partnered with microfinance institutions to help address the financing gap for customers buying these durable products. The company prides itself on providing high-quality after-sales service to customers: after each sale, the customer is contacted on three different occasions to gauge their satisfaction with the product.[55] Frontier Markets sees this direct feedback loop as key to developing a deep understanding of their customers and to allowing the company to develop more effective strategies to drive sales going forward.

4. Quality Matters

As new hardware markets gain momentum, they may begin to attract wider interest, raising the threat that low-quality entrants could destabilize and potentially 'spoil' the market. These 'copycats' produce low-quality versions of the pioneer hardware, seeking to capitalize on the awareness and interest built up by pioneers with customers, in a minimally regulated environment. Their lower cost base allows them to corner the market with lower prices or just extract higher margins at prevailing prices, but at great risk to customer confidence and trust in a fledgling market.

Industry-wide quality standards prevent low-quality 'copycats,' but are hard to implement.

Pioneers in safe drinking water, for example, face these challenges, particularly because consumers are unable to distinguish between water that is purified and water that is contaminated but does not look, smell, or taste bad. We have observed how the early success of high-quality community water plants in urban slums in India then attracts informal players with much less stringent quality standards; if left unchecked, this has the potential to devalue the entire community water plant model in the eyes of local consumers.

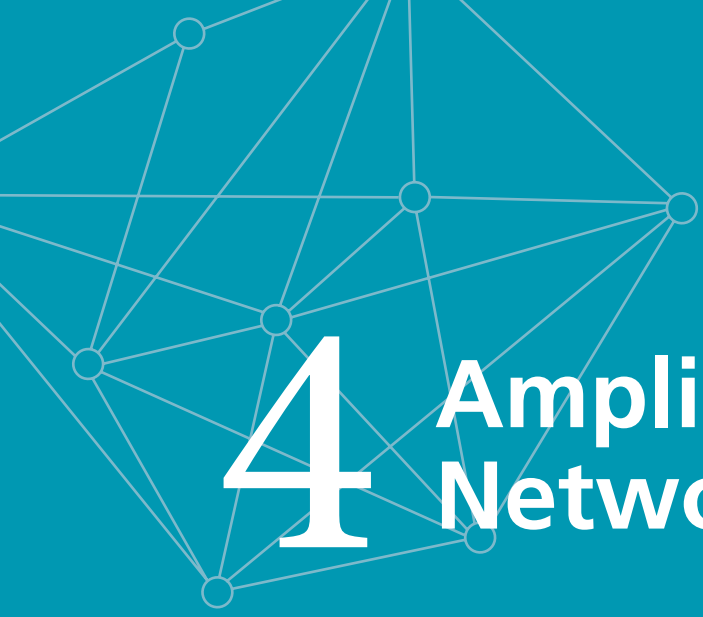
Industry-wide quality standards could be part of the answer, but are not easy to implement. For example, Shell Foundation engaged the Aprovecho Research Center in 2006 to develop quality standards for clean cookstoves, and these then underpinned the Foundation's 'Blue House' assurance mark.[56] However, the 'Blue House' assurance mark was not widely adopted by the industry. In 2010, the Foundation changed tack: it partnered with the UN Foundation to seed an industry facilitator,[57] the Global Alliance for Clean Cookstoves (GACC). As a membership organization comprising clean cookstove producers from around the world, the GACC then worked with the International Standards Organization to develop a set of tiered standards relating to four performance indicators: fuel use, total emissions, indoor emissions, and safety. It is hoped that this consensus will form the basis for more effective quality standards across the industry.

[55] Frontier Markets website, retrieved December 2015 from http://www.frontiermkts.com/

[56] S. Bishop, P. Pursnani, and C. Sumpter, *Social Marketing in India*, Shell Foundation, 2013.

[57] Industry facilitators act to resolve barriers to scaling, at the levels of both the enterprise and its wider business ecosystem, to the benefit of many firms, not just one, from *Beyond the Pioneer: Getting Inclusive Industries to Scale*, Monitor Deloitte, 2014.

Patents could also help in driving quality. In Chapter 2, we discussed the limited value of patents for early-stage hardware pioneers. However, as those pioneers begin to cross the *Prepare* stage, and the industries in which they operate become more crowded, patents could become more valuable. Greenlight Planet and d.light report that counterfeit products are increasingly a problem in the marketplace and have both had to file suits against counterfeiters in China, India, and East Africa. *"If anyone uses our name and sells a low-quality product then it's a big risk for us,"* says Greenlight Planet's Anish Thakkar. The company has filed suits against counterfeiters and has been able to quickly stop them from using its name in India, but it has faced much greater difficulties in East Africa where the implementation of patent law is weaker.



4 Amplifying Networks

For the sake of simplicity, we have thus far described the pioneering journey as that of a single entrepreneurial pioneer firm: one idea, one team, one company. The assumption is that one vehicle essentially takes a new idea all the way from the initial inspiration to ultimate impact at scale.

But the reality is not quite so straightforward.

As we saw in the previous chapter, by the time the hardware pioneer reaches the *Prepare* stage, the journey becomes one with *multiple* enterprises, as other entrepreneurs follow the pioneer's lead and set up businesses based on the same, now proven, idea. This might come about through formal sharing and collaboration, by individuals moving between companies, or just through careful observation and imitation. Often referred to as 'fast followers' in the mainstream business world, these enterprises might operate in the same markets as the pioneer or open up new ones. They might faithfully replicate the pioneer's product and business model or make significant enhancements and adaptations.

We can see this as a process of *scaling out* the initial idea to more enterprises and additional markets, as opposed to scaling up an individual enterprise.

At the other extreme, sometimes the hardware pioneer does not fully form, as the technical founder who originates the new idea does not build an entrepreneurial business of their own. Perhaps they lack the requisite business skills and expertise and are not able to identify co-founders with complementary abilities with whom they would like to team up. Or they might simply have no interest in running a company. Even if they had the interest and the ability, they might think that starting up a business from scratch would not be the best way to get their new product to market and to scale.

In such a situation, the technical founder might prefer to *transfer* their idea to an established business that is better positioned to accelerate product development and get it out to customers.

In this chapter, we will explore and seek to understand these different pathways. We describe a more networked reality in which new ideas are not just propagated but amplified and discuss the implications for what we need to do to maximize the impact of new hardware solutions.

SCALING OUT

Case Study: A Low-Cost Sanitary Pad Revolution

Image courtesy: New Statesman
Adolescent girls on their period, who are seen as unclean, eat outside.

70 percent of women in India cannot afford to buy reliable sanitary pads.

In India, over 300 million menstruating women either do not use any modern menstrual hygiene products or use unsanitary alternatives such as cloth, ashes, and husk sand. This impacts women's health, with poor menstrual hygiene causing 70 percent of reproductive diseases among women. It also adversely impacts education outcomes for adolescent girls whose schooling is disrupted by the lack of access to menstrual hygiene products.[58] While restrictive social norms and lack of awareness have a significant part to play in this problem, one of the most important barriers is the absence of affordable solutions, with 70 percent of women reporting that they just cannot afford to buy reliable sanitary pads.[59]

In recent years, however, there has been a revolution in the area of menstrual hygiene management, led by the somewhat unlikely figure of Arunachalam Muruganantham, a social entrepreneur from rural Tamil Nadu. Muruganantham, as he

[58] "Lack of sanitary protection causes 23% of girls to drop out of school," *InfoChange India*, retrieved December 2015 from http://infochangeindia.org/women/news/lack-of-sanitary-protection-causes-23-of-girls-to-drop-out-of-school.html

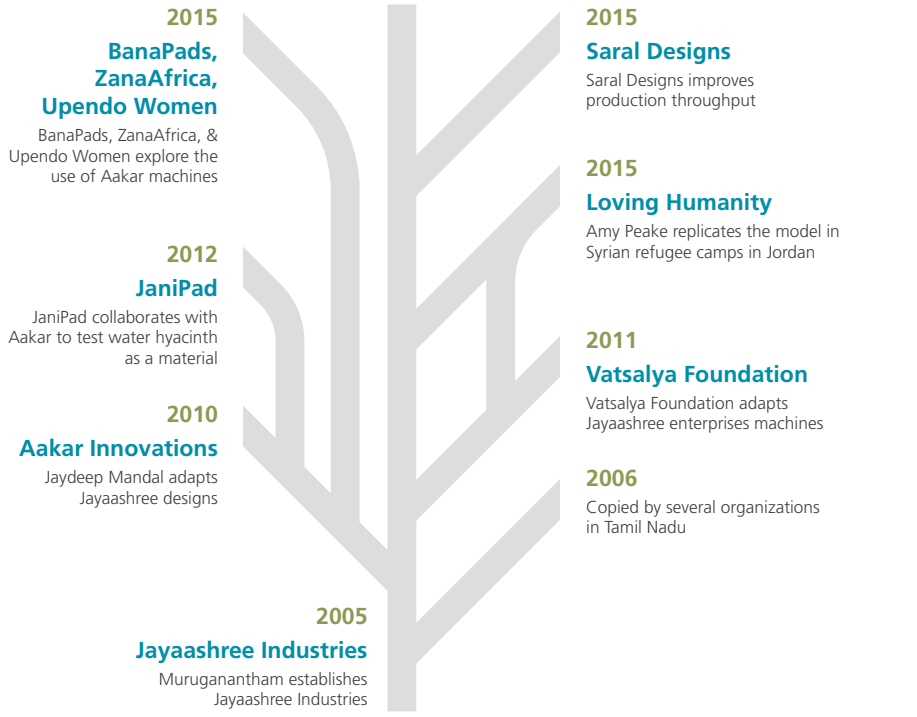
[59] L. Scott, P. Montgomery, L. Steinfield, C. Dolan, and S. Dopson, *Sanitary Pad Acceptability and Sustainability Study*, *Oxford University*, 2013, retrieved December 2015 from http://menstrualhygieneday.org/wp-content/uploads/2014/01/UniversityOxford_SanPads_2013.pdf

is known, has pioneered a breakthrough solution for poor rural women: sanitary pads made from pine-wood pulp that sells for just a fifth of the price of mainstream pads.[60] The key to his breakthrough is an innovative suite of machines produced and sold by his social enterprise, Jayaashree Industries: these machines are affordable to buy, easy to operate, and inexpensive to run, making them well suited to the requirements of women's self-help groups and women micro-entrepreneurs in rural areas.

Muruganantham recognized that the idea needed to scale out beyond him to achieve his vision.

Muruganantham recognized that the idea needed to scale out beyond him in order to achieve his vision of affordable sanitary solutions for all rural women. To that end, he has proactively shared his technology, operating model, and personal story as widely as possible. He has been helped by the media coverage he has received through outlets such as the BBC, *The Guardian* newspaper, and *TIME* Magazine, which featured him in its Top 100 Most Influential People list.[61] He says, *"I want to pioneer a low-cost sanitary pad movement across the globe…*[62] *I am allowing people to copy my machine. I have not filed a patent."*[63]

Figure 7: Evolution of the small-scale sanitary pad manufacturing unit



[60] Center for Health Market Innovations, retrieved December 2015 from http://healthmarketinnovations.org/program/jayaashree-industries

[61] Ruchira Gupta, "The 100 most influential people, 2014," *TIME*, 23 August 2014, retrieved December 2015 from http://time.com/70861/arunachalam-muruganantham-2014-time-100/

[62] Srividya Iyer, "Why the sanitary pad man is a different entrepreneur," *Firstpost*, retrieved December 2015 from http://www.firstpost.com/business/why-the-sanitary-pad-man-is-a-different-entrepreneur-542742.html

[63] Vibeke Venema, "The Unlikely Sanitary Pad Missionary," *BBC News*, 3 December 2015, retrieved December 2015 from http://www.bbc.com/news/magazine-34925238

Over the past five years, Muruganantham has inspired a wave of follower enterprises to apply his idea to tackle the problem of poor menstrual hygiene, and many of these have adapted the original idea to better meet customers' needs and address key scaling barriers.

One of these entrepreneurs is Jaydeep Mandal, who had aspirations to become a social entrepreneur but did not see the need to come up with a new solution himself when numerous good innovations already existed. India's National Innovation Foundation had already catalogued many of these 'grassroots inventions', so he browsed the register to find an idea he could develop and was intrigued by what he found. Jaydeep recalls that *"there were already many innovative solutions out there, but little was being done to support their development into sustainable businesses."*

Jaydeep Mandal saw that he could build a new business around an existing proven solution.

Jaydeep was struck by the impact potential of Muruganantham's idea, and so, as a young business student in 2010, he set up a micro-enterprise in a village in Uttarakhand using one of Muruganantham's machines.[64] As he began operations, Jaydeep observed several issues. The grinding of pine-wood pulp created a large amount of airborne dust, which the women operators then breathed in. He also noticed that pads were being sterilized for only two minutes, significantly less than the 20 minutes prescribed by government guidelines. When he set out to sell the pads, he found that most local women preferred a pad with wings, just like the ones they had seen in television advertisements, but the machines could not add these. Finally, disposing of the pads was tricky, as the pads were not biodegradable.

Women working at a sanitary pad sealing machine at Aakar Innovations.

[64] Seema Chowdhry, "Freedom from shame I An uncomfortable period," *Livemint*, 10 August 2013, retrieved December 2015 from http://www.livemint.com/Leisure/tyQAUWDEmEQtMOVt9saqLP/Freedom-from-shame--An-uncomfortable-period.html

Aakar Innovations and Vatsalya Foundation built on Muruganantham's idea.

In response to these issues, Jaydeep founded his social enterprise, Aakar Innovations, in 2011. Aakar's machines would produce affordable sanitary pads *with* wings. They would use a modified grinder that reduced the volume of dust produced from grinding wood pulp and an improved sterilization machine that could sterilize 240 pads in 20 minutes. Aakar has also developed a compostable version of the pad for more sanitary disposal. Today, Aakar's main focus is on selling sanitary pads to women under the Anandi Pads brand name, but the enterprise is also considering supplying its machines to other operators in Kenya and Uganda. The company is also working with another organization, JaniPad, to explore the possibility of replacing pine-wood pulp with a local material such as water hyacinth.[65]

Swati Bedeker, founder of Vatsalya Foundation, is another innovator who built on Muruganantham's idea. After studying his machines closely in 2010, Swati built a version that was powered by electricity, rather than being manually operated by women, leading to a marked improvement in productivity. Like Aakar, Vatsalya developed a variant that adds wings to hold the pads in place. Vatsalya's machines can also use raw materials other than pine-wood pulp, opening up the potential of using lower-cost or local materials in the pads. The machines can also be used to produce sanitary pads of different shapes and sizes for other uses, such as incontinence pads.[66] Vatsalya Foundation has tried to address the problem of disposal by developing its own incinerator called the 'Ashudhinashak'.

Meanwhile, inspired by the BBC's coverage of Muruganantham's work, Amy Peake founded Loving Humanity to adapt the model for use in Syrian refugee camps in Jordan.[67] In 2014, Amy travelled to India to learn about the model from Muruganantham. However, she realized that the high cost of importing pine-wood pulp would certainly make her project unfeasible, so she worked with Swati Bedekar and others to adapt the machines to use cheaper and more easily available raw materials.[68] At the time of writing, Amy is testing her machines as part of a six-month pilot project in Zaatari, Jordan's largest refugee camp.

[65] Village Volunteers website, retrieved December 2015 from https://www.villagevolunteers.org/volunteer-abroad/initiatives/water-hyacinth-for-sanitary-pads/

[66] Samantha Cowan, "How One Group Plans to Revolutionize Menstrual Hygiene for Refugees," *Yahoo News*, 11 October 2015, retrieved December 2015 from http://news.yahoo.com/one-group-plans-revolutionize-menstrual-hygiene-refugees-231816669.html

[67] Aditi Raja, "Vadodara low-cost sanitary napkin model to be replicated in Jordan refugee camps," *The Indian Express*, 2 October 2015, retrieved December 2015 from http://indianexpress.com/article/india/india-news-india/gujarat-finds-solution-to-syrian-women-refugees-menstrual-problem/

[68] Vibeke Venema, "The Unlikely Sanitary Pad Missionary," *BBC News*, 3 December 2015, retrieved December 2015 from http://www.bbc.com/news/magazine-34925238

Most recently, Suhani Mohan launched her social enterprise, Saral Designs, after seeing the Jayaashree machines in action while on the Jagriti Yatra, an immersive program designed to inspire future social entrepreneurs. As a graduate of the Indian Institute of Technology (IIT) Bombay, Suhani was confident that she could use her training as an engineer to produce an improved machine and created a fully-automated version with a much greater production capacity of up to 10,000 pads a day. Saral pads have wings and are also thinner as they contain the same compact, absorbent materials as mainstream pads. Suhani hopes that creating a low-cost version of sleek mainstream products will spur adoption from her target consumers living in India's burgeoning urban slums.

At the time of writing this report, solutions based on Muruganantham's idea have spread to over 23 states in India and multiple countries in Africa. His direct impact is evident in the 740 Jayaashree machines that are being used by self-help groups, not-for-profit organizations, and corporations in India, giving nearly 3.5 million women access to affordable, safe menstrual protection.[69]

But the fast followers are also beginning to achieve significant impact of their own. In India, Aakar has already served 150,000 women and girls through its 25 operating units, while Vatsalya Foundation has reached over 100,000 women and girls. In Uganda, BanaPads has sold its pads to over 23,000 women. Collectively, these firms are giving rise to a new industry that is bringing affordable menstrual hygiene management solutions within reach of low-income women and girls for the first time.

Muruganantham's fast followers are beginning to achieve significant impact of their own.

TRANSFER

Case Study: Facilitating Easier Births

In 2005, Jorge Odón, an Argentinian car mechanic, developed a simple but remarkably effective birthing device. Inspired by a common technique for removing corks from wine bottles, the device consisted of a plastic sleeve that could inflate around a baby's head to gently pull and ease it through the birth canal. Early evidence shows that it is potentially both easier and safer than conventional methods, as it applies less pressure on vulnerable parts of the mother's and the baby's bodies, does not have hard parts that could cause injury, and has a more widespread distribution of traction force. As some 10 percent of all births globally are assisted deliveries,[70] the device has the potential to improve birth outcomes for millions of mothers and infants.

[69] Perzen Patel, "Disruptive innovations bring on 'The Female Sanitary Revolution'," *Ennovent* blog, retrieved December 2015 from http://blog.ennovent.com/2013/03/disruptive-innovations-bring-on-the-female-sanitary-revolution/#sthash.VdtxoJ3O.dpbs

[70] D. Farine, *New technologies for managing labor*, Walter de Gruyter GmbH, Berlin/Boston, 2015.

In the early days, Jorge worked closely with a medical college in Buenos Aires to create the device and registered a patent for it in Argentina.[71] In 2008, his invention came to the attention of Dr. Mario Merialdi at the World Health Organization (WHO), who saw a demonstration of the device on a visit to Buenos Aires. Subsequent testing of the device using state-of-the-art birth simulators confirmed to WHO experts that the device held outstanding potential to help millions of mothers in need around the world.[72]

Testing by WHO experts confirmed that Odon's device could help millions of mothers.

Image courtesy: Ministerio de Ciencia, Argentina
Early prototype of the Odon device.

But who would get this device to the mothers who needed it? It would be extremely difficult for Jorge—the technical founder—to build a pioneer business of his own that could reach the markets that needed his invention. The breakthrough came when Dr. Merialdi connected Jorge with Gary Cohen, an executive vice president at Becton Dickinson (BD), a multinational medical technology company.[73] Gary became interested in the device as a possible addition to BD's product portfolio because of its potential to reduce maternal and newborn mortality. The talks that ensued eventually led to Jorge signing a license agreement with BD allowing them to manufacture and distribute the BD Odon Device™ and to a clinical studies access agreement between the WHO and BD. The company expects to invest $15 million to bring the product to market, with a commercial launch slated for late 2018.

[71] J.H. Requejo and J.M. Belizán, "Odon device: a promising tool to facilitate vaginal delivery and increase access to emergency care," *Reproductive Health,* August 2013, accessed December 2015 from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3765457/

[72] Vibike Venema, "Odon childbirth device: Car mechanic uncorks a revolution," *BBC World Service*, 3 December 2013, accessed December 2015 from http://www.bbc.com/news/magazine-25137800

[73] Donald G. McNeil, Jr., "Car Mechanic Dreams Up a Tool to Ease Births," *New York Times*, 13 November 2013, accessed December 2015 from http://www.nytimes.com/2013/11/14/health/new-tool-to-ease-difficult-births-a-plastic-bag.html

REIMAGINING EXISTING TECHNOLOGIES FOR THE POOR

Image courtesy: Reuters/Reinhard Krause
Patient at Aravind Eyecare.

Founded in 1976, Aravind Eye Care System is a network of eye hospitals in Tamil Nadu, India, and the world's largest and most productive eye-care services group.[1]

Aravind is best known for having pioneered low-cost, high-volume cataract surgery and for playing an instrumental role in reducing cataract-related blindness in India. During cataract surgery, the clouded natural lens is removed and replaced with an Intra-Ocular lens (IOL). In the 1980s, IOLs were widely available in the developed world but they were expensive at around $200 each. Manufacturers in the US and Europe were happy to donate a limited number of lenses to eye hospitals in the developing world such as Aravind, but, as Aravind's surgery volumes grew, it was evident that they needed a lower-cost, high-volume supply of IOLs.

In 1992, Aravind addressed this challenge by establishing a new unit, Aurolab, to develop and manufacture affordable ophthalmic consumables, including low-cost IOLs. Aurolab found a technology partner that could supply the equipment needed to produce IOLs and train up its own team on the manufacturing process. Initially, Aurolab only supplied Aravind's hospitals, but it soon scaled to serve other eye-care service providers: by 2010, the unit was producing nearly 2 million lenses a year, selling for less than $4 each across 120 countries, and had 7 percent by volume of the global market for intraocular lenses.[2]

The experience with IOLs proved to be a fertile learning ground for Aurolab and helped to create a team skilled in the process of technology transfer and adaptation. This expertise has now been leveraged to adapt several other technologies to the Indian market. Today, in addition to IOLs, Aurolab provides low-cost specialty drugs, suture needles, ophthalmic equipment, and surgical blades required for cataract surgeries to a range of hospitals that carry out eye surgery.[3] Many of these products integrate technologies from the rich world that have been reimagined for the poor, acquired either by licensing patented technologies or reverse engineering of out-of-patent technologies.

The close integration of Aurolab with Aravind hospitals has been a valuable asset in the testing and adaptation of each new solution. But Aravind's greatest contribution is more likely its role in anchoring demand for various low-cost ophthalmic products, which Aurolab could then plan to serve at large scale with the most appropriate technologies.

[1] Aravind Eye Care Annual Report 2014-2015.

[2] Naazneen Karmali, "Aravind Eye Care's Vision for India," *Forbes*, 5 March 2010, retrieved February 2016 from http://www.forbes.com/global/2010/0315/companies-india-madurai-blindness-nam-familys-vision.html

[3] Aurolab website, retrieved December 2015 from http://www.aurolab.com/

While it is clearly early days for the BD Odon Device, it is already possible to discern a number of key factors that have helped this pioneering partnership get to where it is today.

One is the new idea's fit with BD's strategy and capabilities. Prior to the conversation with Jorge, the leadership of BD had made a strategic decision to invest in new products addressing high-priority unmet health needs in emerging markets, such as maternal and newborn mortality. The new device fit well into this effort. In helping to commercialize the BD Odon Device, the company was also leveraging existing strengths and capabilities as it already sells into relevant healthcare institutions and systems around the world. The BD Odon Device, while intended to ultimately benefit poor mothers and children, will not be marketed directly to those populations but to the healthcare providers that serve them, a market BD already supplies.

External supporters can help facilitate the development of good partnerships.

Another is the involvement of an external supporter that can help the technical founder navigate their early challenges, make sense of their options, and guide discussions and negotiations with a corporate transfer partner when they get underway. In this case, Dr. Merialdi and his colleagues from the WHO, along with experts from Des Moines University in Iowa, conducted successful clinical trials of the BD Odon Device using birth simulators, which helped correctly assess the device's widespread potential for impact. Dr. Merialdi and his colleague Dr. Flavia Bustreo from the WHO then connected Jorge with Gary Cohen in a meeting at Davos in Switzerland with the intention of sparking a collaborative partnership.

External supporters can also work in a number of ways to accelerate product development and de-risk the opportunity for the corporate partner. Building on its past support, the WHO is now conducting clinical trials of the device with funding support from Saving Lives at Birth, a consortium that includes the Bill & Melinda Gates Foundation, USAID, DFID, the Norwegian Development Agency, and Grand Challenges Canada. Meanwhile, the International Federation of Gynecologists and Obstetricians is expected to support development of usage guidelines and training protocols.

In addition, the device should benefit from global advocacy for maternal and newborn health innovations provided by the UN Every Woman Every Child initiative[74] and the WHO's Partnership for Maternal, Newborn, and Child Health.[75] It is also expected that donors and NGOs will help support education, awareness, and training interventions to stimulate frontline adoption of innovations such as the device in poorer countries.

Yet another factor is the hard work that all partners have put into establishing a shared vision and understanding. This can be particularly difficult in conversations

[74] See http://www.everywomaneverychild.org/

[75] See http://www.who.int/pmnch/en/

that cut across multiple sectors and contexts, as in this case. Corporate partners, in particular, need to invest time and effort in shaping the right collaborative process and creating an essential foundation of trust: both Gary Cohen and his BD colleague Renuka Gadde have personally invested a substantial amount of time in working closely with Jorge Odón and other partners to ensure an effective development process. This is confirmed by Jorge, who says, *"My relationship with BD is excellent. In addition to patent licensing, they have hired me as a consultant to accompany the optimization of the solution, and this has given me sufficient assurance that my invention is protected well from plagiarism."*

Lastly, the fact that Jorge had a patent from Argentina's Ministry of Science and Technology allowed BD to easily and confidently license his idea. Through this patent and the license agreement with BD, Jorge can expect to receive royalties for his contribution to pioneering this device once it is launched on the market.

AMPLIFYING NETWORKS—NEEDS AND CHALLENGES

The case studies above indicate the strong potential of networked pathways that transcend the archetype of the lone pioneer firm to amplify the power of new hardware ideas.

There are reasons to believe that this opportunity should grow as we move forward. As more entrepreneurial talent and funding moves into the impact enterprise space around the world, the natural potential for scaling out—by connecting more good pioneering ideas with more good entrepreneurs in different markets—should increase.

Meanwhile, as corporates become increasingly interested in shared value strategies[76] that include providing beneficial products for poor and disadvantaged communities, they might also take a keener interest in impact-oriented transfer opportunities. Established impact enterprises that have built up considerable reach into low-income markets could also begin to drive transfer opportunities, selecting new hardware ideas to add to their portfolios.

The alternate pathways of scale out and transfer are not always obvious to those who originate new ideas.

In order to tap this potential, three needs must be addressed:

1. Helping Founders and Pioneers Identify the Right Pathway

These alternate pathways are not always obvious to those who originate new ideas. Many technical founders step on to the entrepreneurial track because they see it as the only path for taking their idea to market and do not see the potential for part-

[76] Shared value is a management strategy focused on companies creating measurable business value by identifying and addressing social problems that intersect with their business. See http://fsg.org/approach-areas/shared-value

nerships with more established businesses. Meanwhile, many small pioneers do not fully appreciate the value of diffusing their ideas to a wider group of entrepreneurs who might then be able to reach many more customers across a greater diversity of markets.

However, it is not always easy to help founders and pioneers to appreciate these alternate pathways. They may not know what skills are required to build a growing business, or they may have an unrealistic sense of their own abilities.

One promising approach to addressing these blind spots comes from the work of NESsT and the 'Inventor to Entrepreneur' tool it developed with GSBI (introduced in Chapter 2). NESsT is now using the tool in its work with grassroots inventors in Peru to help them navigate their way around what it calls the 'Three Ts': transform, team, and transfer. That is, the inventor could *transform* themselves into an entrepreneur by acquiring the necessary skills and mindset, they could *team* up with others who bring in the required abilities, or they could *transfer* their idea to an established business with strong potential to take it to scale. The intentional use of this tool, combined with clarity of choice around different pathways, could help more technical founders achieve success and impact with their ideas.

2. Facilitating Connections and Partnerships

Unlike the well-connected world of technology serving the rich—exemplified by the dense ecosystem of Silicon Valley—the technology landscape of hardware pioneering for the poor is much more dispersed and fragmented, making it hard for potential partners to find each other. Even when two or more parties think they might have a good fit, they might not know how to structure a good partnership or might not have enough trust in each other to reach agreement. A case in point is the pivotal role played by the WHO in facilitating the partnership between Jorge Odón and Becton Dickinson.

Platforms could help facilitate transfer partnerships or collaborations.

Beyond this, there could also be a stronger role for platforms that help originators of ideas and solutions find transfer partners and collaborators or vice versa. One such example is that of the Honey Bee Network, an association in India that is dedicated to furthering the cross-pollination of ideas among innovators and entrepreneurs. Over two decades, the Network has catalogued over 100,000 innovations from local communities. It emphasizes the principles of justice and fairness in its workings: contributions from knowledge providers and grassroots innovators should always be acknowledged and they should also receive a fair and reasonable share of any proceeds in accordance with the value they have added.

Drawing on the Network's knowledge, another institution—the National Innovation Foundation of India (NIF)—has created an even larger database of over 200,000 grassroots innovations. It was by combing through the resources of the NIF that Jaydeep

Mandal came upon Muruganantham's pioneering work on the Jayaashree machines and decided to replicate and ultimately improve upon that idea through Aakar.

3. Supporting Replication and Adaptation

Alongside our support of hardware pioneers in all the ways that we have described so far, we must also support the entrepreneurs who wish to adopt and build on the ideas of pioneers who have come before them. The process of scaling out depends as much on there being other entrepreneurs to take the original idea forward as it does on the origination of the idea itself.

These later entrepreneurs are often referred to as 'followers' or 'replicators' but these convenient labels run the risk of considerably understating the degree of challenge involved: many of these entrepreneurs will still need to exercise a great deal of boldness and ingenuity as they adapt, and often improve on, the original ideas that inspired them. In the case of Aurolab, the team had to take an established technology and completely reimagine it for the specific context of low-income patients and for the medical practitioners who would use it in lower-tech, affordable hospitals. Because of this, their work could well face some of the same challenges as that of the hardware pioneer—for instance, they might need to refine and test new propositions with customers, or build different sales and distribution channels—and therefore benefit from similar supports to help them succeed.

We should support entrepreneurs who wish to adopt and build on the ideas of pioneers who have come before them.

5 Ideas for Action

Enterprise philanthropy is central to the effort of supporting hardware pioneers.

In this final chapter, we offer some ideas for action to overcome the challenges we have described in the preceding chapters and move towards realizing the full potential of technology for the global poor.

We believe that the practice of enterprise philanthropy, as introduced in *From Blueprint to Scale*, continues to be central to these efforts. Private foundations, development agencies, corporate philanthropy, and individual donors could all have an important role to play. This could be in the form of supporting individual enterprises directly or in backing the myriad actors who could provide that support, such as incubators, accelerators, nonprofits, and universities. It could be focused on one area of support or work across the whole spectrum. It could be specialized in one or more specific hardware solution and target one or more particular geography (with the caveat that this work can be very globally interconnected—see sidebar on Global Connections).

We hope that this guide not only helps each actor to find the right actions to suit them, but also that it illuminates the potential for joined-up action between actors to produce even more powerful results.

SPARK

future pioneers to begin their journey through inspiration, education, and guidance

NURTURE

pioneers through challenges in the *Blueprint* and *Validate* stages

SCALE-UP

pioneer models by helping to address key scaling barriers in the *Prepare* stage

AMPLIFY

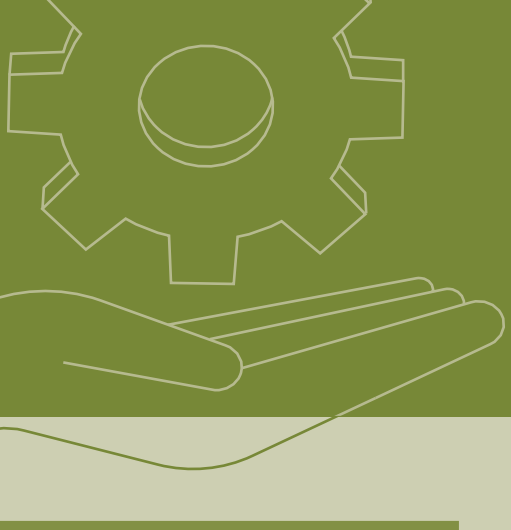
the ultimate impact of new hardware ideas through networks and partnerships

Spark

ACTION	ILLUSTRATIVE EXAMPLES
FUNDERS[77], INCUBATORS, ACCELERATORS, AND NONPROFITS	
Run immersion programs for students and professionals that help them deepen empathy and develop a better understanding of those they are seeking to serve	Jagriti Yatra, India
Share and promote stories of impact by hardware pioneers through mainstream and social media, to inspire and encourage potential founders	Lemelson Center for the Study of Invention and Innovation—Smithsonian National Museum of American History
Generate and disseminate knowledge on 'problems worth solving' and market opportunities, to inspire and guide potential founders	50 Breakthroughs report—Institute for Globally Transformative Technologies, Lawrence Berkeley National Laboratory (LIGTT)
Run high-profile competitions for new solutions that highlight 'problems worth solving' and enhance the incentives for addressing those problems	Grand Challenges Gandhian Inclusive Innovation Awards—National Innovation Foundation India Reinvent the Toilet Challenge—Bill & Melinda Gates Foundation XPRIZE
Catalyze new exploratory research on generating breakthrough technologies specifically intended for the poor	Bill & Melinda Gates Foundation's Discovery & Translational Science program focused on health-related challenges
Provide innovative debt finance based on cashflows rather than collateral, to help meet the working capital needs of pioneers' distributors and other value chain players	IntelleGrow, India SIDBI, India
UNIVERSITIES	
Introduce experiential, design-oriented science and engineering curricula to create opportunities for hands-on learning experiences	Design for Extreme Affordability course—Stanford University Beyond Traditional Borders program—Rice University
Introduce hardware and design-oriented course curriculum and mentoring support at schools and universities in developing countries	Stanford India Biodesign program—Stanford University Recognition and Mentoring Program—Institut Pertanian Bogor (RAMP-IPB), Indonesia
Conduct exploratory research on generating breakthrough technologies specifically intended to benefit the poor	Tata Center for Technology and Design—MIT Institute for Globally Transformative Technologies, Lawrence Berkeley National Laboratory (LIGTT)

[77] Philanthropic funders, multilateral and bilateral aid agencies, corporate social responsibility (CSR) funders.

Nurture



ACTION	ILLUSTRATIVE EXAMPLES
FUNDERS, INCUBATORS, ACCELERATORS, AND NONPROFITS	
Deepen specialization of incubators and accelerators into defined sectors and technologies in order to build deep internal expertise and tailored networks of advisors and mentors	Factor(E) Ventures—Colorado State University (energy sector) Villgro, India (energy, healthcare, education, and agribusiness sectors)
Set up hardware development facilities such as makerspaces and labs in developing countries that support pioneers' prototyping activities	Gearbox, Kenya Maker's Asylum, India
Link organizations with strong community connections to pioneers that need to test their solutions in the field	SELCO's partnership with Simpa Networks, India
Provide tools to collect data from the field in local languages, to make it easier for pioneers to gather and analyze feedback from users and buyers	Touchpoint survey tool—Villgro, India Voice survey service—Awaaz.De, India
Provide substantial amounts of patient, risk-tolerant capital to the pioneer	Shell Foundation funding to Envirofit International USAID grant to Promethean Power Systems
Provide loan guarantees so that pioneers are able to access credit from a wider range of sources, such as banks, to address working capital needs	Development Credit Authority—USAID
Underwrite venture debt finance based on cashflows rather than collateral, to help pioneers address working capital needs	IntelleGrow, India SIDBI, India
Support fellowship and advisory programs that help pioneers to bridge talent and skills gaps across technology, design, and business skill sets	ICats Fellowship—LGT Venture Philanthropy Villgro Fellowship RippleWorks
Support pioneers in protecting their intellectual property and navigating their regulatory environment	Villgro
IMPACT INVESTORS	
Provide substantial amounts of patient, risk-tolerant capital to the pioneer	Sangam Ventures
Provide venture debt finance based on cashflows rather than collateral to help pioneers address working capital needs	IntelleGrow, India SIDBI, India
Consider using quasi-equity instruments for early-stage pioneers	Lundin Foundation, Village Capital, Fledge
UNIVERSITIES	
Enable more open access to facilities for prototype development, such as laboratories and makerspaces, to pioneers who are not students or alumni	University of Illinois, Urbana-Champaign Indian Institute of Technology, Kanpur

Scale Up

ACTION	ILLUSTRATIVE EXAMPLES
FUNDERS, INCUBATORS, ACCELERATORS, AND NONPROFITS	
Support the growth and replication of last-mile specialists that can take on downstream activities such as distribution, sales, marketing, and after-sales service, to resolve distribution and servicing challenge	Essmart Global, India Frontier Markets, India
Support innovative consumer financing vehicles for large-ticket, durable hardware products, to resolve consumer financing challenges	Fullerton India M-KOPA Solar, East Africa Simpa Networks, India
Underwrite innovative debt finance based on cashflows rather than collateral to help meet the working capital needs of pioneers' distributors and other value chain players	IntelleGrow, India SIDBI, India
Support the creation, adoption, and enforcement of quality standards across an emerging industry or sector	Global Alliance for Clean Cookstoves and the International Organization for Standardization (ISO)
IMPACT INVESTORS	
Invest in last-mile specialists that can take on downstream activities such as distribution, sales, marketing, and after-sales service, to resolve last-mile distribution and servicing challenges	Essmart Global, India Frontier Markets, India
Provide innovative debt finance based on cashflows rather than collateral, to help meet the working capital needs of pioneers' distributors and other value chain players	IntelleGrow, India SIDBI, India

Amplify

ACTION	ILLUSTRATIVE EXAMPLES
FUNDERS, INCUBATORS, ACCELERATORS, AND NONPROFITS	
Support pioneers in identifying the right path to take their breakthrough technologies forward, through tools and programs	Inventor to Entrepreneur tool — NESsT and GSBI
Support platforms and networks that help facilitate fair and productive connections between originators of ideas and other entrepreneurs and established enterprises	National Innovation Foundation India and Honey Bee Network Engineering for Change (E4C) Solutions Library
Facilitate learning journeys for entrepreneurs so that they can study and potentially adapt models that have been pioneered in other geographies	Learning journeys to Grameen Bank in Bangladesh that helped seed microfinance institutions in India, supported by Friends of Women's World Banking (non-hardware example)
De-risk and support transfer opportunities from technical founders to established businesses, both corporates and impact enterprises Support technical founders in navigating transfer and scale-out pathways, from patenting technology to negotiating transfer agreements	World Health Organization working with Jorge Odón and Becton, Dickinson and Company
CORPORATES AND ESTABLISHED IMPACT ENTERPRISES	
Seek out technologies from other settings and geographies that could be adapted or re-imagined for local needs and contexts	Aurolab — Aravind Eye Care System, India
Seek out technical founders and inventions that the originators themselves are not well positioned to scale	Becton, Dickinson and Company working with Jorge Odón

GLOBAL CONNECTIONS

Developing countries are where the problems that come with poverty are most acute, so the work of co-creating and testing with customers and communities largely happens in those places, as does the work of integrating into local value chains and stakeholder networks as the business is established. However, developed countries tend to have deeper banks of scientific knowledge, stronger cultures of high-growth entrepreneurship, larger pools of capital, and more sophisticated support networks.

The reality of hardware pioneering is one that is frequently inter-connected across the developing and developed worlds, which suggests that the ecosystem of support should also be arranged in this way. We see much potential for incubators and accelerators, for instance, to create strategic linkages that support this, rather than taking a purely single-country perspective. Likewise, funders should consider where the talent, knowledge, and ideas needed to build pioneers are coming from, as well as the target markets in which these need to be deployed.

INNOVATION IN INVESTING

While holding great potential for impact, hardware pioneering is also fraught with risk, and especially so in the challenging markets of the developing world. These are ventures that require highly risk-tolerant and patient capital. Omidyar Network's 2015 report, *Frontier Capital*, suggests two alternatives to equity that could better suit the needs of many hardware pioneers: venture debt and quasi-equity.[1]

Affordable debt is a challenge for pioneers through the pioneer gap because traditional sources of lending are either unwilling to provide credit to firms without a track record or charge high interest rates. 'Venture debt' addresses this challenge by lending to companies based on project cashflows instead of relying on collateral or established track records. However, innovative approaches such as this are anathema to most mainstream lenders and therefore such financing is in short supply.

'Quasi-equity' offers greater scope for the investor to share in the upside of the business than conventional debt instruments. These instruments allow the investor to take a share of the investee's future revenue streams (also known as the 'royalty' model) or, less commonly, free cash flow; other features — such as initial grace periods and cap on returns — can be added to achieve an optimal structure. This approach is particularly useful in markets where equity investing is challenging due to the difficulty of exits.

[1] M. Bannick, P. Goldman, and M. Kubzansky, *Frontier Capital: Early Stage Investing for Financial Returns and Social Impact in Emerging Markets,* Omidyar Network, 2015.

Glossary of Terms

INCLUSIVE BUSINESS: A business that provides a product or service that is socially beneficial to lower-income households, based on a business model that is commercially viable and ideally scalable.

PIONEER GAP: The critical gap in technical and financial support in the *validate* and *prepare* stages for firms pioneering new models to benefit the poor. This creates a bottleneck in the pipeline of new business models, limiting opportunities for impact investors and ultimately constraining the impact potential of inclusive business.

PROTOTYPE: An early sample, model, or release of a product built to test a concept or process or to act as a thing to be replicated or learned from. In hardware design, a prototype is a model of an easily replicable manufactured product that enables designers to visualize and test the design.

PRODUCT DEVELOPMENT: The creation of products with characteristics that offer new or additional benefits to the customer. It may involve modification of an existing product or its presentation or formulation of an entirely new product that satisfies a newly defined customer want or market niche.

ACCELERATORS AND INCUBATORS: Intermediary organizations that support new ventures to develop their business model by providing a range of business support resources and/or physical space. Their support typically includes coaching, capital, and networking connections for business or future investment. Typically, accelerators work with enterprises in cohorts for a short, pre-defined period, while incubators are less likely to be cohort-based and may not have fixed graduation time frames.

MAKERSPACE: A physical space where potential inventors or technologists can gather to explore, discover, invent, tinker, and build new solutions using a variety of tools and materials.

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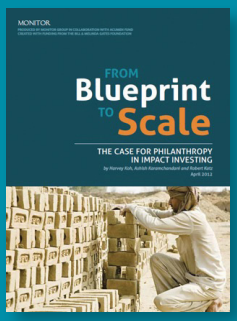
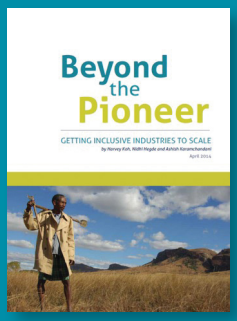
Recommended Reading



From Blueprint to Scale: The Case for Philanthropy in Impact Investing

Harvey Koh, Ashish Karamchandani, Robert Katz (Monitor Group, April 2012)

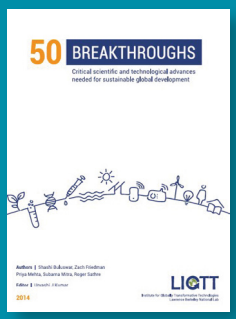
This report describes the phenomenon of the 'pioneer gap' in funding and support for firms pioneering new models of inclusive business and the emerging practice of enterprise philanthropy in closing this gap and establishing new models. The report, published in collaboration with Acumen Fund, analyzes a number of companies from the Acumen portfolio and sets out key recommendations for philanthropic funders and impact investors.



Beyond the Pioneer

Harvey Koh, Nidhi Hegde, Ashish Karamchandani (Deloitte Touche Tohmatsu India Private Limited, April 2014)

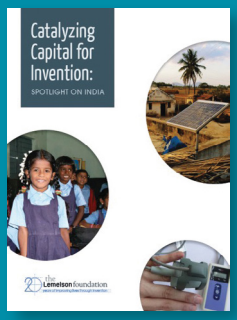
This report explains why few market-based solutions or inclusive businesses have achieved significant scale relative to the problems that they seek to address. It explores the barriers to scaling and highlights case studies of market-based solutions that have achieved scale with the support of industry facilitators.



50 Breakthroughs

Shashi Buluswar, Zach Friedman, Priya Mehta, Subarna Mitra, Roger Sathre (Institute for Globally Transformative Technologies, Lawrence Berkeley National Laboratory, 2014)

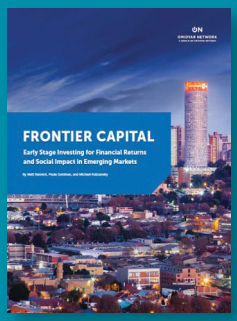
This study describes 50 scientific and technological breakthroughs most critical to sustainable global development. It provides contextual background to potential technologists so they can direct their work to address these challenges.



Catalyzing Capital for Invention: Spotlight on India

(Enclude / The Lemelson Foundation, 2015)

The report examines India's impact ecosystem—the broad network of businesses, funders, and intermediaries that enable impact enterprise—and hones in on challenges within the ecosystem that are currently limiting inventors' potential. It provides actionable recommendations on how to address the capital challenge for early stage enterprises.



Frontier Capital

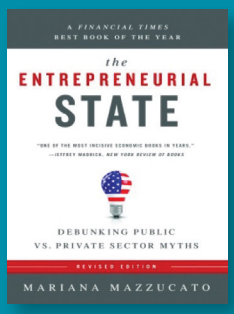
Matt Bannick, Paula Goldman, Michael Kubzansky (Omidyar Network, 2015)

This report focuses on new potential business models to serve low to lower-middle-income people in emerging markets, generating both outsized impact and strong financial returns. It underscores the need to segment these opportunities in lower-middle-income markets by matching the right investor with the right investment opportunity.

Impact Inventing: Strengthening the Ecosystem for Invention-Based Entrepreneurship in Emerging Markets

Alexander N. Pan (Aspen Network of Development Entrepreneurs, 2014)

This report focuses on the differentiated needs of invention-based entrepreneurs, and the support they require. Based primarily on a series of roundtable discussions held in Brazil, India, Kenya, and South Africa, and supplemented by expert interviews and quantitative survey data, it examines gaps in the ecosystem and explores potential actions to fill these gaps.



The Entrepreneurial State: Debunking Public vs. Private Sector Myths

Mariana Mazzucato (Anthem Press, 2013)

This book debunks the myth of a dynamic private sector versus a sluggish public sector by providing a detailed account of the role of the public sector in taking on high-risk entrepreneurial investments, from the Internet to the 'green revolution.'

Engineering Reverse Innovations

Amos Winter, Vijay Govindarajan (Harvard Business Review, July-August 2015)

What Engineering a Reverse Innovation Looks Like

Vijay Govindarajan, Amos Winter (Harvard Business Review, November 2015)

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FSG is a mission-driven consulting firm supporting leaders in creating large-scale, lasting social change. Through strategy, evaluation, and research we help many types of actors—individually and collectively—make progress against the world's toughest problems.

Our teams work across all sectors by partnering with leading foundations, businesses, nonprofits, and governments in every region of the globe. We seek to reimagine social change by identifying ways to maximize the impact of existing resources, amplifying the work of others to help advance knowledge and practice, and inspiring change agents around the world to achieve greater impact.

As part of our nonprofit mission, FSG also directly supports learning communities, such as the Collective Impact Forum and the Shared Value Initiative, to provide the tools and relationships that change agents need to be successful.

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