Financing Rural Infrastructure: Priorities and pathways for ending hunger

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By Laura Turley and David Uzsoki

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Acronyms and Abbreviations

3PL	third-party logistics
DRE	decentralized renewable energy
FAO	Food and Agriculture Organization of the United Nations
FiT	feed-in tariff
FDI	foreign direct investment
HPLE	High Level Panel of Experts on Food Security and Nutrition to the UN Committee on World Food Securit
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
MDB	multilateral development bank
NGO	non-governmental organization
O&M	operation & maintenance
ODA	official development assistance
ODI	Overseas Development Institute
OECD	Organisation for Economic Co-operation and Development
PHL	post-harvest loss
PPP	public–private partnership
R&D	research & development
ROI	return on investment
SDG	Sustainable Development Goal
UN	United Nations
USAID	U.S. Agency for International Development
VGF	Viability Gap Funding
WTO	World Trade Organization

1.0 Introduction

1.0 Introduction

The Sustainable Development Goals (SDGs) are rallying the global community around an ambitious goal to end hunger. The second of the 17 SDGs adopted by United Nations (UN) member states in 2016, is to "*End hunger, achieve food security and improved nutrition, and promote sustainable agriculture*," with specific targets to achieve this by 2030 (United Nations, n.d.). To repeat: the goal is not to halve, reduce, or slow the extent, but to end hunger. Given past failures and successes in addressing hunger at such a scale, governments have arguably never understood the challenges better, known as much, nor been as ready to take this on as a systemic problem.

The harsh reality remains that, in 2017, approximately 821 million people still faced hunger, defined as chronic dietary food deprivation (Food and Agriculture Organization of the United Nations [FAO], 2018),[1] and over 150 million children under the age of five were affected by stunting due to malnutrition (over 22 per cent of children aged 0–5 *globally*) (World Health Organization, 2018). Most of these people live in sub-Saharan Africa and Southern and Central Asia, and the situation is worsening in South America.[2] Furthermore, the most recent report from the Intergovernmental Panel on Climate Change (IPCC) warns that climate change seriously threatens the possibility of achieving SDG 2 to end hunger and, moreover, can reduce the progress already made. The rising global temperatures associated with climate change are expected to have negative impacts on both terrestrial and aquatic food production (IPCC, 2018), deepening the food security challenges of the most vulnerable populations and intensifying competition for land use across sectors of the economy.

Significant and interrelated investments in climate change adaptation, health, education, infrastructure and other areas are all necessary in the global effort to end hunger. This report focuses on just one of these areas: the challenge of financing rural infrastructure. Most people in the world suffering from hunger live in rural areas and engage in agricultural activity, and many lack basic services such as energy and irrigation provision due to a lack of infrastructure. There is global consensus that a productive and sustainable agricultural sector will be key to achieving food security and improved nutrition for all (Gulati & von Braun, 2017). This will require a robust infrastructure base for farmers and rural communities to overcome the many constraints on productivity growth in agriculture, agribusiness and other formal and informal sectors in rural economies.

The global infrastructure deficit is expected to reach USD 90 trillion by 2030 (Rydge, Jacobs, & Granoff, 2015). Policy-makers and governments have tended to use these alarming figures to bolster investment in their urban sectors, addressing the acute challenges posed by rapid urbanization, while rural infrastructure needs have been less in the spotlight. But not only will direct investment in rural infrastructure address rural poverty and hunger, it will slow the urbanization trend to a more sustainable pace. Neglecting both social and physical rural infrastructure has been one of the major contributors to both rural and urban poverty (Khan, 2001).

[1] Definitions of hunger that focused on deficit of caloric intake can be criticized for not accounting for essential micro-nutrients such as vitamins or minerals. As such an effort is made throughout the report to include nutrition more broadly, for example highlighting the importance of cold storage for diversified crop production (FAO, 2018, Section 1).

[2] For more detailed information on global statistics by region please refer to FAO (2018)

Box 1. Infrastructure to end hunger: Some global policy agenda milestones

2005: Trade-related infrastructure is highlighted as one of the four Aid for Trade categories of support, as defined by the Organisation for Economic Co-operation and Development (OECD) and the World Trade Organization (WTO), along with technical assistance for trade policy and regulations, productive capacity building (including trade development) and trade-related adjustment.

> *"Aid for Trade should aim to help developing countries, particularly LDCs, to build the supply-side capacity and* ***trade-related infrastructure*** *that they need to assist them to implement and benefit from WTO Agreements and more broadly to expand their trade" (WTO, 2005, emphasis added).*

2009: L'Aquila Joint Statement on Global Food Security at the G8 Summit

> *"We support public-private partnerships, with adequate emphasis on the* ***development of infrastructure****, aimed at increasing resources for agriculture and improving investment effectiveness" (President of Russia, 2009).*

2016: Adoption of the 2030 Agenda for Sustainable Development

> *Goal #2, Target 2.a: "Increase investment, including through enhanced international cooperation, in* **rural infrastructure***, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries" (SDG Knowledge Platform, n.d.).*

The importance of infrastructure for growth and development has been a focus of economists, development professionals and scientists for centuries. The importance of rural infrastructure for hunger and food security is a specific instance of this long-standing relationship, which is of particular importance in light of the SDGs, and SDG 2 in particular. Consider, for example, how storage infrastructure gives farmers bargaining power: without having the option to store their harvest, whether farmers know market prices or not will not make much difference. To have bargaining power, farmers need to have the option not to sell, or at least to delay sales, or plan them ahead. Or consider how rural roads can increase market connectivity, improve the freshness and quality of the product that reaches the market, improve access to farm inputs, and simultaneously link agricultural and non-agricultural communities (Overseas Development Institute [ODI], 2013). Irrigation infrastructure can double agricultural productivity on a per-hectare basis, compared with rainfed agriculture (Ceres, 2015). Energy infrastructure supports all of this, as well as other on-farm services including communications and cold storage, all while making rural living more livable and appealing. In these ways, and others, rural infrastructure can facilitate the integration of farming households into both agricultural and non-agricultural markets.

Figure 1 lists some typical infrastructure categories that are of direct importance to rural livelihoods generally and to ending hunger more particularly. These are split into two groups of infrastructure types: one that forms the backbone for an entire region and a second that focuses on local and on-farm infrastructure. In the context of climate change, all new infrastructure and refurbishments must be designed and built to be resilient to extreme weather events.

Regional / Backbone Infrastructure

- Major roads
- Railways
- Ports
- Energy infrastructure (centralized generation, transmission)
- Water storage and distribution (reservoirs and canals)
- Post-harvest food storage (collection and distribution, incl. cold storage)
- Wholesale market spaces
- Information and communications technology (ICT) infrastructure (network towers, distribution cables)
- Health infrastructure (major hospitals)

Local, Community, and On-Farm Infrastructure

- Feeder roads
- Energy infrastructure (decentralized generation, distribution)
- Irrigation systems (drip, pivot, drainage)
- Water storage and distribution (small reservoirs, pumps, pipes, canals, ditches)
- Air control/fans/refrigeration
- Storage (on site, including cold storage)
- Processing and milling infrastructure
- Housing
- Health infrastructure (clinics)
- Sanitation infrastructure (capture, storage, transport and treatment of waste)
- Education infrastructure (local schools)

Figure 1. Rural infrastructure assets that affect hunger

1.1 INTERMEDIATE INFRASTRUCTURE: THE MISSING MIDDLE

Hard infrastructure is not, alone, sufficient to transform food availability and rural incomes. The success of physical infrastructure interventions as a means to improve food security, as described in the report, is deeply dependent on complementary services and human capacities, sometimes called "soft infrastructure," to manage the positive linkages. Between the hard and soft infrastructure is the so-called "intermediate infrastructure" that links them, such as transport, logistics, communication, learning and standards-related services, as well as the policies and regulations that support them. The World Bank's 1994 *World Development Report: Infrastructure for Development* made this point: focusing solely on increasing the quantity of installations is not enough, and more should be done on the quality and efficiency of related services. Analyses of rural economic infrastructure increasingly reference the systemic inefficiencies that arise if proper intermediate services infrastructure is lacking (ODI, 2013).

Understanding the importance of intermediate infrastructure highlights the interlinkages among the infrastructure categories discussed in this report. For instance, storage facilities require roads *and* transport services to get crops to collection points, as well as reliable energy services to keep perishables cold; irrigation and storage require energy infrastructure *and* services where pumps or cold storage are involved. Furthermore, the quality—not just existence—of infrastructure and services along supply chains affects the quality of the final product and, therefore, its market value (e.g., potholed roads = bruised produce + longer travel time = reduced shelf life).

In this vein, for each infrastructure category addressed in the report, a corresponding box of information is provided on the intermediate infrastructure needed to ensure the infrastructure investment is put to best use.

1.2 A FOCUS ON FINANCING

Attracting the right type of financing to ensure the availability, quality and affordability of rural infrastructure is the challenge taken up in this report. Given the remoteness, the dispersed populations and the susceptibility to natural disasters that characterize many rural agricultural communities, the "business case" is not obvious. However, depending on the infrastructure type and context, the authors of this report see a role (and often in combination) for three major sources of financing for infrastructure to overcome these challenges under the right conditions: donor aid, public spending and private capital. The following chapters provide specific examples of innovative financing solutions for each infrastructure category—but first a word on these three sources of finance.

1.2.1 Donor Aid

Official development assistance (ODA) and other types of grants can provide an important source of infrastructure funding. When channelled correctly, aid for infrastructure development can increase a country or region's stock of physical capital, potentially improving the ratio of investment to GDP and creating an enabling environment that attracts additional private investment (Akramov, 2012). However, ensuring that donor aid is allocated and used in a manner that delivers long-term benefits presents a persistent challenge. Conventional wisdom is that aid "effectiveness" is highly dependent on governance and accountability in recipient countries. In this report, we suggest that: a) aid is a limited resource and should be used in a smart and efficient way; b) instead of funding infrastructure projects outright, aid should be used to mobilize additional sources of funding; and c) donors should include infrastructure refurbishment and maintenance—not only new infrastructure—in their portfolios. Many of the instruments discussed in the paper rely on some form of grant-based solution that is used in conjunction with other funding.

1.2.2 Public Spending

Addressing the infrastructure deficit is beyond the budget of most governments, making it essential for the public sector to consider ways to leverage additional resources. At the same time, most rural infrastructure is primarily financed by governments—often with the assistance of development finance institutions. As will be discussed in detail in the following sections, public investment can be used effectively at various stages of infrastructure development. Public spending can be best used for: project preparation funding; providing risk capital; making fixed payments to a private contractor (called "availability payments") for the design, construction and maintenance of projects; and providing various fiscal incentives to encourage investment in infrastructure. As a general rule, before committing public funds to finance projects outright, governments should use a *value for money assessment* to evaluate how best to structure financing for infrastructure to deliver the most value for taxpayers.

1.2.3 Private Capital

Private capital plays an important role where public resources are not, on their own, sufficient to cover the costs of building the infrastructure needed. This is in line with the broader 2030 Agenda for Sustainable Development, and SDG 17 in particular, which encourages and promotes "effective public, public-private, and civil society partnerships" that "mobilize and share knowledge, expertise, technology and financial resources" (United Nations, n.d.). The most recent report of the High Level Panel of Experts on Food Security and Nutrition (HPLE) to the UN Committee on World Food Security recognizes the increasing role for the private sector in financing food security and nutrition, to complement government efforts to achieve the 2030 Agenda (HPLE, 2018).

However, private investors—who want to make money—are hesitant to commit capital in regions where risks are higher due to remote locations, lower population densities and higher uncertainties from weather-sensitive economies, all of which can affect their returns. The expected returns of many rural projects are not high enough to secure private sector interest, not least because it is hard to secure a stable revenue stream. Indeed, as one reviewer commented during the public comment period: "some rural infrastructure projects have no good business case."

Innovative financing solutions can address some of these barriers and mobilize more private financing for rural infrastructure projects. Under the right conditions, for example, blended finance (a mix of public and private capital) can be a more effective, and less risky, way to leverage both public and private resources for infrastructure. Generally, IISD recommends that governments and other investors do not look at financial viability in the narrow sense of generating revenue through user fees but in a broader view that a revenue stream must come from somewhere to cover debt servicing, operation and maintenance costs during the whole life cycle (i.e., the long term) of the asset. Notably, fixed payments can come from the government instead of directly from the users themselves, for example through the availability-payment-based solutions mentioned above. Through availability payments, a specified performance level is ensured without the revenues being dependent on user fees or tolls—providing stability to the government and the users. This approach can also have the advantage of motivating the private partner to complete the infrastructure promptly so that payments can begin, all the while ensuring quality and maintenance because their revenue is tied to the ongoing "availability" of the asset.

In general, projects that reach a large number of users who are willing (and able) to pay for their services will more easily secure private financing. There is an important distinction between the users' ability and willingness to pay, which can materially affect the financial viability of the project, as will be discussed later in the report.

When governments are considering engaging private investors in rural infrastructure projects, they might consider: a) the source of (stable) revenue (user fees, subsidies, purchase agreements, availability payments, etc.) to cover the private actor's investment costs and generate a profit; b) whether or not the investment will reach commercial scale, warranting the often high sunk costs involved in project development, including competitive bidding and other fixed legal, regulatory and transaction costs; and c) whether or not the project offers some growth potential for the private party (e.g., with respect to the location, or technology deployed, or the possibility of increased revenues over time).

However, with the goal of ending hunger in mind, it is important to draw inspiration from models based not only on scalability and growth potential. Some authors argue that food security investments should be based on human rights, rather than on purely economic and financial considerations (HLPE, 2018). A middle ground perhaps lies with private investors interested in contributing to projects with high development impacts, so-called "impact investors," who have a mandate that allows them to make investments with sub-par returns if other social and/or environmental gains are large enough. Impact investors can provide both equity and debt financing, and they are often more willing than traditional institutional investors to invest in small-scale projects. Other models might be those that go from the investment phase to a "steady state" phase, allowing private investors to recoup their investment but not necessarily leading to or promising growth.[3] Still other approaches might depend on smallholders' own investments—farmers investing either in-kind or with labour—to keep capital costs down for a new project.

Whatever the model, governments remain responsible for the creation of an enabling regulatory environment, encouraging competition, providing support for accurate demand forecasting, establishing project pipelines, using subsidies wisely, allowing realistic tariff setting (cost-recovering tariffs), and ensuring that the project meets environmental and social requirements. Moreover, enforcing the rights and ensuring the well-being of the population remain duties of the government, not the private sector. As stated by the HLPE, "states remain (…) responsible for adopting effective strategies to eradicate hunger and all forms of malnutrition, and to ensure that the efforts of all stakeholders concur to public interest and to the realization of the right to adequate food" (HLPE, 2018, p. 14).

While similarities exist in financing the different infrastructure types discussed in this report, the solutions are different enough to warrant discussing them separately for each infrastructure category. Moreover, financing solutions need to be further customized depending on whether the asset is a public or private good, the scale of the asset (e.g., across how many communities and municipalities it reaches) and the sophistication of local capital markets. However, it falls outside the scope of the paper to provide bespoke solutions for each specific infrastructure asset presented.

Also, it cannot be emphasized enough that applying the right financial solution does not make a project attractive to private capital in itself, as often there is a critical lack of capacity at the public procurement level, which is essential for a well-structured deal that provides long-term value. A value-for-money assessment should be used by the public sector—before looking for private investors—to evaluate how best to structure financing for infrastructure to deliver the most value for taxpayers. Subsequently, the costs of technical assistance and project preparation need to be sufficiently budgeted for and funded during project planning.

1.3 OBJECTIVES AND APPROACH

Two central research questions guide the thinking behind this report:

1. What rural infrastructure investments can have the most direct positive impact on ending global hunger?
2. How can these infrastructure assets be sustainably financed?

To address these questions, first a literature review was undertaken on rural infrastructure, food security, ending hunger and infrastructure finance. This literature review looked at 14 major reports by international organizations such as the OECD, the FAO and the International Fund for Agricultural Development (IFAD), as well as donor reports from government development assistance programs. The list of these reports can be found in Annex 1. In addition, individual studies on the linkages between infrastructure and food security from

[3] The tourist sector in Cuba was developed in part by private foreign firms on limited contracts that allowed them in to build and develop resorts, stay for a while to recoup and then hand ownership over to the state.

both "grey" and academic sources were reviewed (see Annex 1). This "meta-analysis" of existing research was complemented by phone call interviews with experts from agricultural development, agribusiness, infrastructure finance, rural infrastructure investors from the private sector and other sector-specific authorities. The full list of organizational representatives interviewed for this report can also be found in Annex 1.

This approach, based on existing literature, has the advantage of synthetizing research results from across time and different locations, and summarizing it for researchers and policy-makers, while identifying questions for future research. However, it is also limited in that it excludes knowledge and experience that is not captured in the existing literature. The authors are aware of the limitations of this method, specifically that information is derived from reports that—while informed and often the result of primary research and multistakeholder processes—may not represent farmers and their needs directly. Efforts were made to include research coming from diverse organizations and to speak by phone with leaders of farmer organizations to complement the literature review.

Starting with a "long list" of infrastructure assets that affect rural development, poverty and food security (Figure 1 above), the first goal of the literature review and expert interviews was to pare this list down to a manageable list of **four infrastructure categories**. These categories were to demonstrate the most robust and empirically verified relationships between infrastructure, ending hunger and promoting food security, and also to highlight those categories for which financing poses a distinct and persistent challenge. Our research stresses the **two principal mechanisms** through which people experiencing, or at risk of experiencing, hunger can access more food (and where possible, more nutritious food): 1) by growing more food for own-consumption (i.e., subsistence agriculture) and 2) by generating more income with which to buy more food. Both of these pathways are legitimate and important approaches that co-exist in efforts to end hunger, and each is given equal importance throughout this report.

The four assets that emerged were:

1. **Storage/cold storage**
2. **Feeder roads**
3. **Decentralized renewable energy**
4. **Irrigation infrastructure**

This shortlist selection, informed by the literature review and the expert interviews, was broadly based on the following criteria: the persistence of success stories over decades of research (empirical and anecdotal), along with the strength of the established correlations between the infrastructure and the desired development outcome (i.e., ending hunger), all within the limitations imposed by what existing published information was available. The four assets are not presented in a particular order. They are, however, mutually reinforcing as described above, in the context of "intermediate infrastructure." It is our hope that this analysis will persuade donors and investors who are dedicated to ending hunger that it makes sense to dedicate financial resources to high-impact infrastructure categories.

1.4 METHODOLOGICAL CHALLENGES

As far as possible, this report seeks to assess the efficacy of infrastructure investment as a means to end hunger, that is, to end the chronic dietary energy deficits (which can be anywhere from 100 to 400 kilocalories/day) (FAO, n.d.) that thwart human development and potential. Hunger is most prevalent in sub-Saharan Africa, South Asia, Southeastern Asia, Southwestern Asia and the Caribbean. This is not to downplay the importance of other forms of malnutrition, including chronic micro-nutrient deficiencies that affect mental and physical development, as well as being overweight or obese. But the focus here is on hunger.

While there is much descriptive literature on the positive impact of infrastructure investment on diverse rural development outcomes—such as poverty alleviation, agricultural productivity and food security—a persistent challenge faced by researchers in the field is in confirming the precise causal links between the intervention (e.g., a new road) and its impact (e.g., a reduction in dietary energy deficits). This can largely be attributed to the extensive multiplier effects of infrastructure investment, the benefits of which can be difficult to capture in a simple model (ODI, 2013). Some studies even challenge the "direction" of this causal chain, referred to as *reverse causality*, suggesting that infrastructure development is a response to, not a precondition of, economic growth (Dercon, 2009). Furthermore, some researchers claim that external actors and observers cannot fully understand the rural communities they seek to help, and therefore they cannot fully understand the costs and benefits of a given intervention from the perspective of farmers (Takeshima, Adeoti, & Salau, 2010).

Nevertheless, researchers develop and use methodologies to make these correlations more robust. In the literature reviewed for this report, very few studies explicitly measured caloric intake or another per-capita consumption metric in response to an infrastructure intervention.[4] Instead, other related variables were used to measure the impact of infrastructure interventions, including:

- Agricultural performance/productivity (Mogues et al., 2012)
- Market prices (U.S. Agency for International Development [USAID], 2011)
- Agricultural trade (USAID, 2011)
- Poverty incidence (Pinstrup-Anderson, & Shimowaka, 2006)[5]
- Household income (Mogues, 2007)
- Foreign direct investment (FDI) (Slimane, Huchet-Bourdon, & Zitouna, 2013)
- Food security (Policy and Operations Evaluation Department, Ministry of Foreign Affairs, Netherlands, 2011)

The most rigorous studies reviewed for this report present a counterfactual—that is, they also monitor the change in food security indicators or proxies in populations that did not receive the infrastructure "intervention"—for the sake of controlling variables and allowing comparisons. For instance, the Government of the Netherlands' 2011 *Systematic Review of the Impact of Interventions in Agricultural Production* (Policy and Operations Evaluation Department, Ministry of Foreign Affairs, Netherlands, 2011) selected studies and articles that evaluate and assess the impact of agricultural interventions (including but not limited to infrastructure interventions) on household-level food security and then screened them based on whether they presented a counterfactual. Of the 300-plus studies found after the first search, only 38 studies qualified for the review (Policy and Operations Evaluation Department, Ministry of Foreign Affairs, Netherlands, 2011). This shortlist of 38 studies was particularly valuable in informing the present report. Thus, to the extent possible, the research presented in this paper draws from studies that focus on food security outcomes specifically, but studies and surveys assessing proxies listed above were also considered.

Return on investment (ROI) is another way to capture and compare different types of agricultural investments, where "return" can be defined in terms of agricultural performance, poverty reduction or other proxies. A 2012 working paper published by the FAO (Mogues, Yu, Fan, & McBride, 2012) illustrates how different forms of agricultural investments (research and development [R&D], education, roads, communications, irrigation, etc.) perform comparatively, using ROI in terms of outcomes in agricultural performance (Figure 2) and poverty reduction (Figure 3).

[4] Exceptions were found in the road sector, where such analyses have been undertaken. See Abebaw, Fentie, & Kassa (2010); Jalan & Ravallion (2002).

[5] Various econometric approaches confirming causality between rural infrastructure and poverty reduction were captured in Pinstrup-Anderson, & Shimowaka (2006), including simultaneous equation models and quintile regression models. Through diverse methodological approaches, a positive and significant correlation was found between rural infrastructure investment and rural poverty.

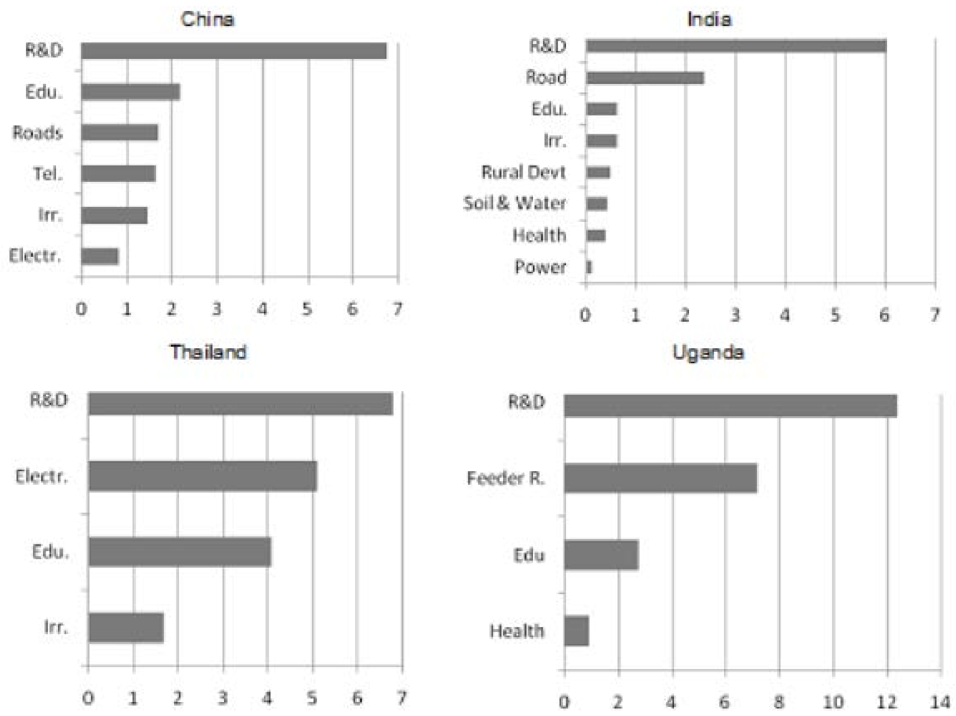


Figure 2. Returns to public spending in terms of agricultural performance

Source: Mogues et al., 2012, Figure 5.1 (CC BY-NC-SA 3.0 IGO)

Notes: Edu. = Education; Tel. = Telecommunication; Irr. = Irrigation; Rural Devt = Rural Development; Soil & Water = Soil and Water Conservation; Electr. = Electricity; Feeder R. = Feeder Roads. The magnitudes are returns to one monetary unit of different types of public spending in terms of (the same) monetary unit of the value of agricultural production or productivity. The agricultural performance variable is measured slightly differently in each country: agricultural GDP in China, agricultural total factor productivity in India, and agricultural labour productivity in Thailand and Uganda.

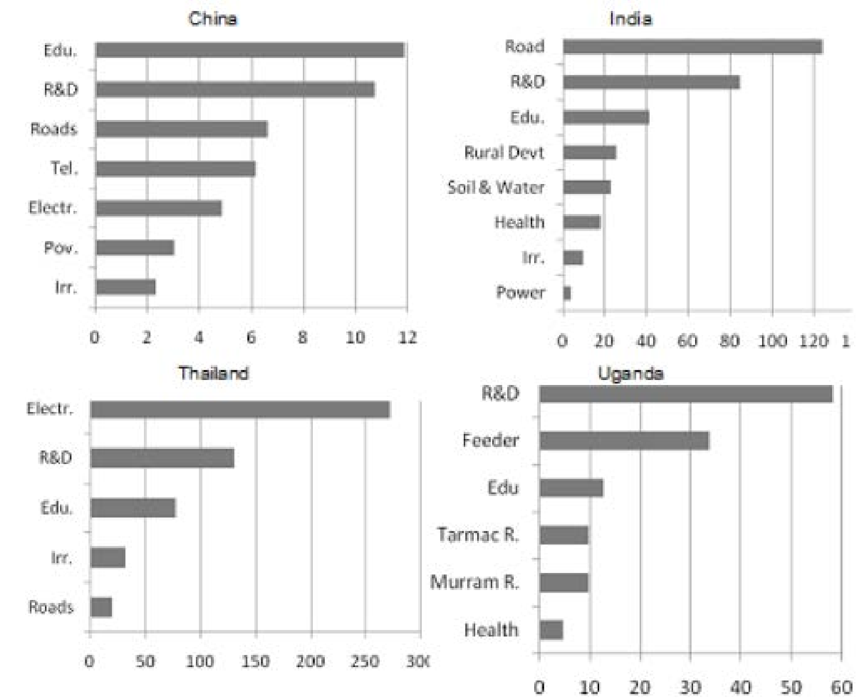


Figure 3. Returns to public spending in terms of poverty reduction

Source: Mogues et al., 2012, Figure 5.2 (CC BY-NC-SA 3.0 IGO)

Note: The magnitudes are the reductions in the population size of the poor per monetary unit spent in each area of spending. The respective monetary units are as follows: THB 1 million in Thailand (that is, number of poor population reduced per THB 1 million spent in different sectors); INR 1 million rupees in India; CNY 10,000 in China; and UGX 1 million in Uganda.

The 2012 FAO working paper study shows that investments in rural infrastructure such as roads, electricity, irrigation and telecommunications all have significant, positive impacts on poverty reduction and agricultural performance. Feeder roads in particular showed the highest returns to public spending in terms of agricultural performance in India, Uganda and China, and a strong correlation with poverty reduction as well. Investment in education had the largest single impact on poverty reduction in China and ranks in the top three interventions across all four countries covered in the study. What ROI might fail to capture in terms of infrastructure, however, is that, because infrastructure is integrative by nature (mediating between people, the environment, workplaces and a range of human activities), the full extent of benefits is not likely captured. Consider the following:

- Infrastructure investment has far-reaching benefits over time on food security and nutrition. The ROI may not therefore be observable until 10 or 20 years after the infrastructure is functional.
- Infrastructure investment can help prevent diminishing returns in agricultural production, which many agricultural investments, including R&D, can experience over time when new variables (e.g., new fertilizer) are applied to fixed factors (e.g., fixed amount of land). Complementary investments in public infrastructure can help slow this decline. For example, road infrastructure may increase the positive effect of agricultural research on farmers' incomes, thus lowering the transaction costs of accessing inputs and marketing outputs. In this example, continued and simultaneous investments into both R&D and infrastructure may mean that the returns to expenditures in the former would not see diminishing returns over time in one sector; this, in turn, would hold investments in the other sector constant (Mogues et al., 2012).
- Infrastructure plays a role in the redistribution of wealth in the economy and can result in higher long-term returns in transforming the larger economy—not just limited to the agricultural sector.
- ROI for repairing or refurbishing existing infrastructure, which may have lower capital costs than building new infrastructure, can be interesting to investors and should not be overlooked.

1.5 PATHWAYS APPROACH

This report proceeds by using a "pathways" approach to map the potential relationships between an infrastructure type (storage, roads, energy, irrigation) and the outcome of interest (ending hunger). Pathways have emerged in the past decade as a way of studying sustainability transitions.[6] The emphasis on a pathways approach is on the existence of multiple alternative ways of arriving at a goal or more sustainable outcome, and it deviates from the study of precise causal pathways. This approach reflects the reality in the literature covered too—that causality is hard to establish, but that there are nonetheless robust studies of socioeconomic changes before and after an intervention, with many potential causal explanations. The beginning of each infrastructure section begins with a visual mapping of these various pathways, inferring but not insisting upon the many possible causal linkages between the intervention and the outcome or its proxies. This choice is neither prescriptive nor normative, but reflects the relationships suggested in the literature and by expert interviews.

It is important to note, however, that just as an infrastructure intervention can lead development down a certain set of pathways with a positive effects on ending hunger, this same intervention can cause potentially negative side effects, or pathways, for another sector or outcome. For instance, the construction of a road can lead to improved market access for remote farmers and improve the quality of the produce sold, which can in turn have a positive effect on the prices fetched. This road might lead to deforestation, which could also have some positive effect on agricultural production (e.g., if agricultural land expands) and could generate some immediate income (e.g., timber). But the deforestation could have other negative side effects (e.g., on various ecosystem services, including water supply and water quality). These negative side effects can, in turn, negatively affect food production in the longer term (e.g., diminished water retention in the soils from deforestation). This example points toward the increasing importance of systems-level thinking when it comes to food and agricultural investments so as to account for complex, inter-related challenges and feedback loops that can occur within and across other sectors.

[6] See for example Geels (2010).

The authors urge our readers to understand that the approach in this report accounts for only a narrow set of potential pathways related to infrastructure interventions. Infrastructure can have many positive multiplier effects for rural livelihoods and for the economy more broadly, which are beyond the scope of this report (e.g., energy for lighting, improving the safety of public spaces at night).[7] Equally, an infrastructure investment may have negative spillovers, as in the example described above, which are also beyond the scope of this report. Transforming the insights from this report into practice requires a careful consideration of the local context. Only then can decision makers identify the true opportunity costs and determine the right sequencing of development investments.

1.6 CORRUPTION

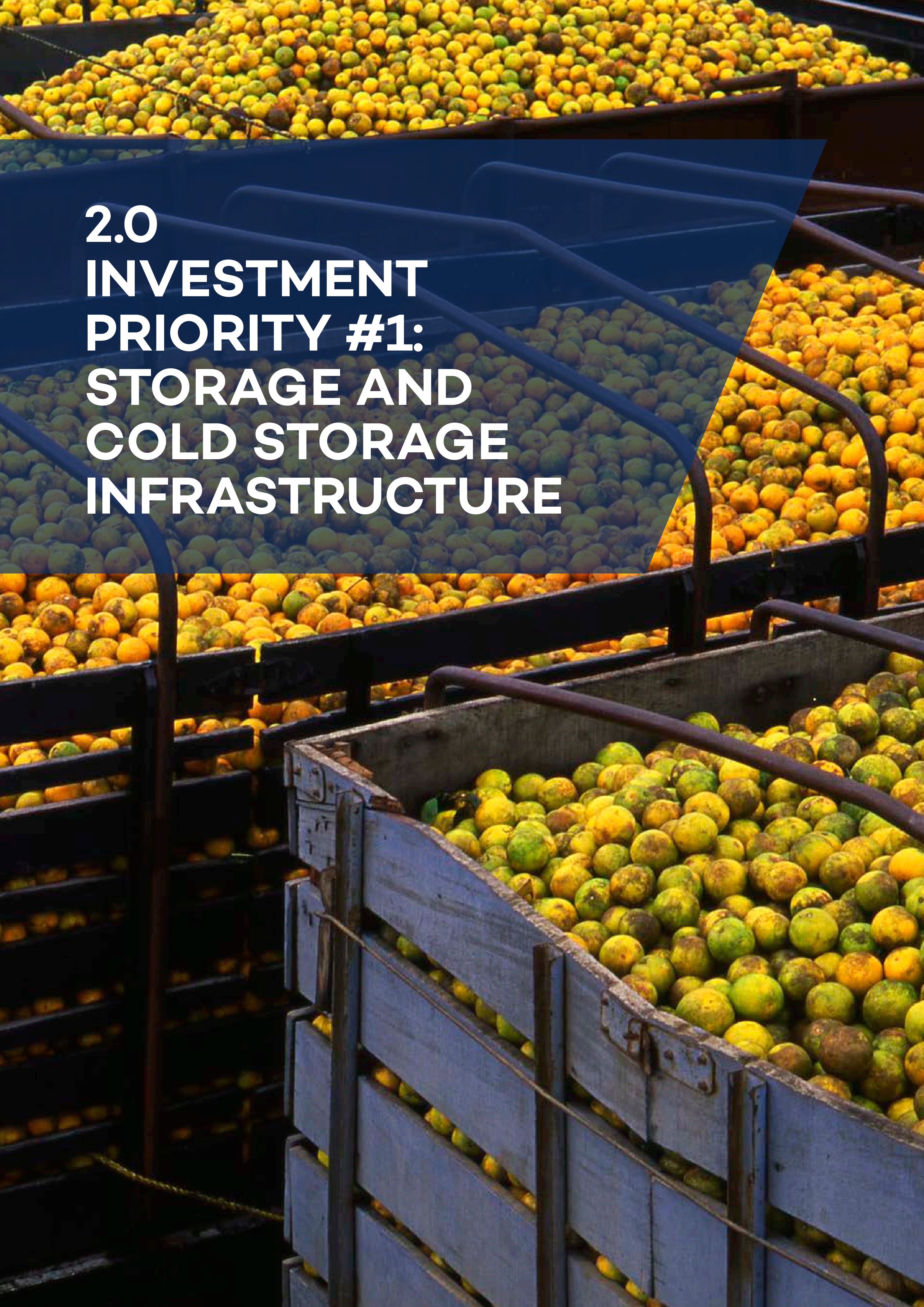
Many low-income countries are characterized by weak institutions, which can hamper public or private investment from realizing the improved livelihoods and development opportunities sought. To succeed, investments in the four asset categories we propose—storage/cold storage, feeder roads, decentralized renewable energy and irrigation infrastructure—need effective oversight by the government at every stage. Inbuilt redundancy of roles (i.e., more than one department overseeing the investment) can be a good thing in this regard, as long as lines of responsibility are clear. The literature on "polycentric governance" suggests that, when decision-making centres have overlapping, functional roles, this can provide a sort of in-built security, or resilience, where failure in one part of the system does not lead to its collapse (Anderies, & Janssen, 2013). Good government oversight should include ensuring a proper procurement process, with procedures in place to deal with unsolicited proposals, as well as clear and transparent methods to assess and award tenders. It also requires scrupulous contract development and execution with careful consideration for the quality of the final infrastructure asset and its sustainability with respect to environmental, social and economic conditions.

Corruption is a serious problem. It undermines the effectiveness of investments such as those we propose, and we encourage governments and other investors to take all possible steps to limit the possibilities for corruption. Bearing in mind the (very) limited economic and political power of the intended beneficiaries of these investments—people suffering from chronic hunger—in almost all circumstances, particular attention must be paid to limiting the opportunities for extortion of the final end-users of the infrastructure projects.[8] Corruption in the public and private sectors has the potential to slow, if not derail, the effort to end hunger as set forth in the SDGs.

[7] For more information on the multipliers of infrastructure in the economy, please see IISD's Sustainable Asset Valuation (SAVi) tool https://www.iisd.org/project/SAVi-sustainable-asset-valuation-tool

[8] See, for example, Chakraborty & Dabla-Norris (2009); Turley (2015).

2.0 INVESTMENT PRIORITY #1: STORAGE AND COLD STORAGE INFRASTRUCTURE



2.0 Investment Priority #1: Storage and Cold Storage Infrastructure

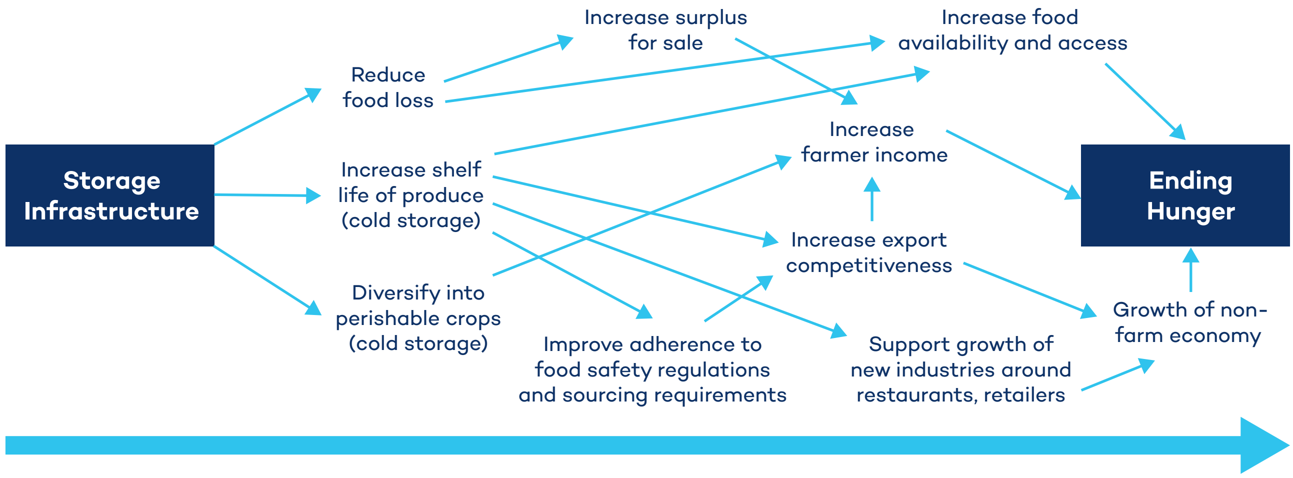


Figure 4. Pathways to food security: Storage infrastructure

2.1 PATHWAYS

Storage facilities such as grain and rice silos, warehouses and cold storage units have a critical role to play in ensuring food security and ending hunger. The FAO estimates that about one third of food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tonnes per year (Gustavsson et al., 2011). The magnitude of post-harvest loss (PHL) can vary across regions and households depending on gender (losses are lower in female-headed households), education (losses are lower in households with post primary education) and climate (losses are higher under hot and humid conditions).[9] Improved storage infrastructure capacity, quality and practices are important for reducing PHL, but the appropriateness of the intervention will depend on the profile and conditions (social, environmental, economic) of each particular farming community.

Effective storage infrastructure can prevent moisture condensation from ruining a crop post-harvest while also keeping out pests such as rodents, insects and birds. It can enable a family or community to better preserve crops on-site for their own consumption, increasing food availability and access. Storage can enable a farmer to raise his or her income by: a) having more unspoiled surplus to sell and b) waiting until off-season to sell, when prices might be higher, thereby improving his or her bargaining power. The many pathways to improved food security are outlined in Figure 4 above.

Cold storage infrastructure is an important piece of the food security puzzle. Many foods are more perishable than we think: it is known that animal-sourced products need to be refrigerated immediately and maintained at a cool temperature on their journey to market, but roots and tubers, such as yams and potatoes, also benefit enormously from post-harvest cold storage. Access to cold storage encourages farmers to produce, or diversify into, more perishable crops that can fetch a higher market price than non-perishables. Longer shelf life translates into greater export competitiveness. In addition, foods deteriorate and lose their nutritional content faster at higher temperatures, so there are nutritional benefits that can accrue also if farmers incorporate more perishable products into their own diets.

[9] Self-reported PHL and national data on PHL tend to be lower than figures generated by the WHO. See World Bank Group (n.d.)

Box 2. Asian Development Bank storage project in Afghanistan

In Afghanistan, an Asian Development Bank (2012) project built 1,100 cold storage rooms across three different districts, increasing farmers' annual sales of potatoes anywhere from 35 to 60 per cent. With access to cold storage, farmers are able to sell and trade potatoes throughout the year.

It should be noted that there are discrepancies in the ways that terms such as "food loss" and "food waste" are used (e.g., some studies include pre-harvest losses and some do not), and methodologies for measuring losses and waste differ (some are based on physical quantities and some on the loss of value in the production chain). From a value chain perspective, however, food is lost at each stage, and strategies must therefore take into account the whole journey from "farm to fork."

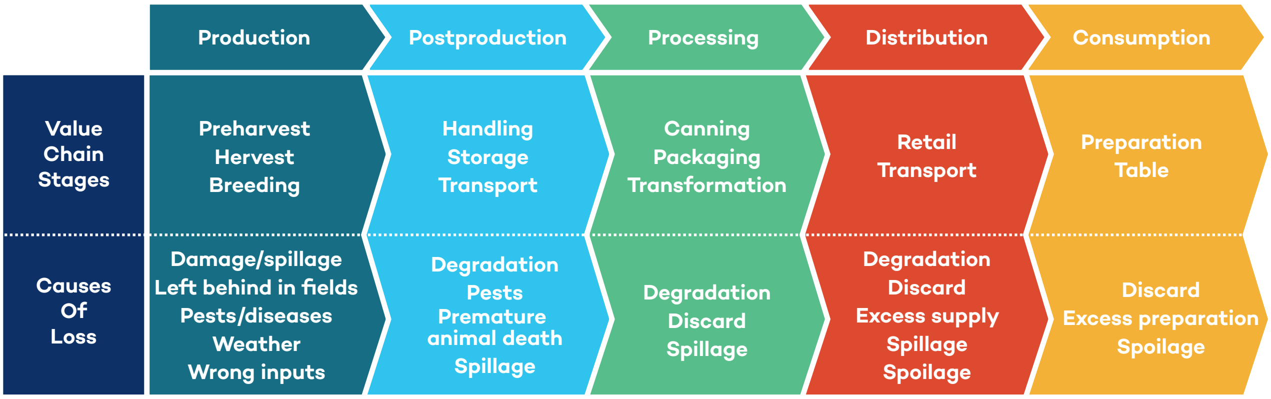


Figure 5. Food losses along the value chain

Source: Schuster, & Torero, 2016.

2.2 INTEGRATED STORAGE INFRASTRUCTURE

Storage infrastructure investment must be approached in a manner that supports value chain strategies. Stand-alone cold storage or processing units will not be effective for addressing the problem of food waste unless they are part of an integrated value chain (Kitinoja, 2013).[10]

There are two important elements to integration in this context: 1) integration across various levels of storage infrastructure (from the household level to larger private or national reserves) and 2) integration with other supporting infrastructures.

2.2.1 Integration Across the Distribution Chain

Figure 6 is a theoretical depiction of the infrastructure required for grain distribution from the household level, through intermediary storage shed or silos, to national distribution centres. Importantly, an integrated distribution network enables the flow of food in both directions (in case of drought or famine, for example). Understanding a particular storage investment in the context of this broader distribution infrastructure is important for identifying gaps, prioritizing projects and making meaningful progress toward food security.

[10]The flower industry is one area that is well established and follows best international practices for exporting. Kenya is a large exporter of fresh cut flowers and accounts for 38 per cent of flower imports into the European Union.

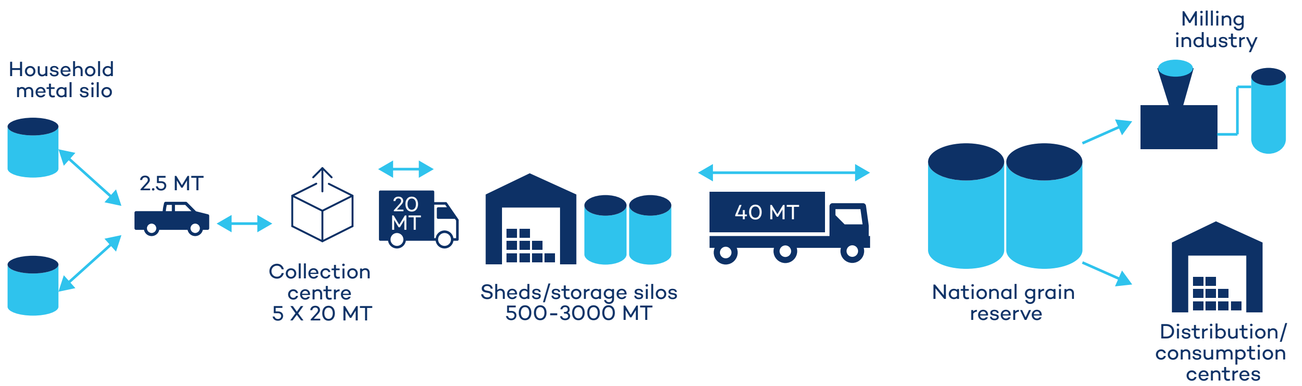


Figure 6. Grain storage and distribution infrastructure

Source: A. Mejia, 2003

2.2.1.1 Household Level

Whether or not farmers have storage capacity on site, the quality of the storage is as important as its capacity and must not be overlooked. Elevated baskets or pits in the ground may serve to store a harvest, but they will not protect the crop from condensation, storms, rodents and other problems. To this end, the FAO has found metal silos to be invaluable for supporting household food security (FAO, 2008). The FAO advocates a small metal bin that can be built locally and that holds between 100 kg and 3,000 kg of grain (to get a sense of scale, 1,000 kg of grain will feed a family of five for one year). The design produces a bin that is airtight, keeps rodents out, avoids the need for insecticides and maintains the quality of the product. A study on the installation of these silos in four Latin American countries between 2005 and 2009 found that the households that adopted silos experienced a significantly greater improvement in their food security, measured as the number of months the households had to buy maize and beans for consumption to supplement their own production, as compared to non-adopters (Bokusheva et al., 2012).

2.2.1.2 Community / District Level

Private companies are very common at different stages of the food supply chain, including in storage and distribution. Large, often international, commodity and agriculture companies tend to build their own intermediary storage facilities in strategic locations in the countries and regions where they operate (e.g., near ports). In some cases, storage sites and units might be shared with other international conglomerates also operating in the region, but usually not with farmers and local businesses who are not directly associated with them. Farmers selling their product to such companies will not likely require infrastructure investment beyond the most local level.

Farmers who are not selling to large companies, and even those who are, might also market and sell their crops through cooperatives that have some form of shared storage shed or silo. These units could either be owned or rented by the cooperative, with co-financing from members or perhaps with the support of an NGO or another donor. Where they exist, cooperative storage may be used for storing crops, or for the storage of seed and fertilizer for its members. Not all cooperatives offer storage, however, and where they do not, lack of finance is often the main barrier. In Ethiopia, for instance, IFPRI conducted a study in 2012 asking cooperatives without storage facilities why they did not have them, and 90 per cent said that they had a need for them but not the funding (Minot, 2012). The following section addresses the financing challenges facing investment in on-farm or local storage and also mentions some approaches to large, national-scale storage.

2.2.1.3 National Level

At the national level, governments generally procure storage infrastructure for one of two reasons:

1) To stabilize global prices and protect the poor from fluctuating market prices
2) To have emergency relief stocks on hand

One way to assess whether government investment in storage is justified is to calculate the value of food loss if that storage is not available. For example, the International Finance Corporation (IFC) estimates that there was 42 million tonnes of storage available in covered warehouses in India in 2010, while there was 61 million tonnes of wheat and rice to store. As rice has priority in India, wheat is largely stored in makeshift facilities that are susceptible to rotting and losses. Considering that 25.4 million tonnes of wheat is produced in India (2010) even a 2 per cent loss costs the government about USD 110 million per year (IFC, 2012a). This example illustrates how the commissioning of storage infrastructure can generate value for money for the government and for taxpayers.

Since the food commodity prices in international markets were disrupted (doubling and more between 2007 and 2008, followed by the global financial crisis, and then further episodes of high and volatile food prices), many governments grew concerned that national food security could no longer depend on food imports. They began to take more seriously the possibility of increasing the level of national food self-sufficiency. As a result, some national governments have increased their public stockholdings of grain in the form of strategic reserves (PPP Knowledge Lab, n.d.). National food access is mostly expressed as a balance sheet of tonnes of food in the country, which is the total of food imports, domestic food production, international food aid and food stocks, measured against the size of the population. **One must be careful, however, not to conflate food stocks at the national level with food availability at the household level, as households may not have the purchasing power to avail themselves of this food.**

2.2.2 Integration with Energy and Other Supporting Infrastructures

Storage infrastructure also requires additional supporting infrastructure to be effective and financially viable.[11] Cold storage units, for example, depend on energy infrastructure that may or may not be readily available. In the context of villages without electricity, exciting advances are being made in solar-powered storage units. Though they are only in the prototype phase of development now, researchers and entrepreneurs in India (Jayan, 2017) and across Africa (ColdHubs, n.d.) are demonstrating the potential of solar-powered on-farm and community-level cold storage infrastructure to bring cold storage to remote, rural communities. Where farmers are relying on diesel generators for their electricity, this can increase the operating costs of storage significantly. Certainly, the feasibility of cold storage investments will depend on the energy options available.

Similarly, a lack of roads and other transportation infrastructure can make any investment in storage unattractive by limiting farmers' access to major domestic and international markets and therefore reducing their ability to pay for storage (note the transport required between each level of distribution in Figure 6 above). Again, we stress the interdependency of effective infrastructure interventions and the importance of sequencing.

[11] "Financially viable" does not imply that the asset has to be revenue generating in its strictest sense (i.e., charging user fees), but instead it has to have some form of revenue stream (also including availability-based solutions) to cover debt servicing, operation and maintenance costs during the whole life cycle of the asset.

Box 3. Intermediate infrastructure: Logistics providers

A considerable share of food loss along the supply chain is due to non-optimal cold chain processes and management (Jedermann et al., 2014). Indeed, the challenges associated with linking farmers and their crops to the global market are many and diverse, and relate to communications, logistics, transport, storage and other variables. “Shelf life” is a common term that relates to the number of days that a food product will retain “acceptable quality” and be safe to consume. The shelf life of a product depends on optimal temperature and air flow in transportation and storage conditions (Jedermann et al., 2014).

To address these challenges, there is a need for a competitive market of third-party logistics providers (known as “3PLs”) that are able to, for example, harness the power of the growing cell phone market to schedule pickups and deliveries from small farms dispersed around the country and connect them to regional or international markets.

Governments can help create a supportive environment for 3PLs by taking a holistic approach to storage investment, one in which “hard infrastructure” investments are complemented by building local capacity to monitor storage technology (e.g., environmental parameters like temperature, humidity, and carbon dioxide and oxygen concentrations in storage units and food containers) and to ensure sanitary food handling in compliance with food safety and quality standards. This can also create non-farm rural jobs.

It can also be a prerogative of the state to build synergies with neighbouring jurisdictions (national or subnational) by collaborating on and sharing storage services, as well as logistics and distribution services and infrastructure.

Without a market for 3PLs, the alternative is that investors build their own vertically integrated supply chains, setting up the storage and distribution logistics they require for their specific needs and individual business only. A notable example of this vertical coordination is the cut-flower industry in Kenya. While this approach is not negative per se, in terms of food security it misses an important opportunity to bring value-added activity to the agricultural sector while also supporting the growth of, and transition to, knowledge-based and industrial economies.

2.3 FINANCING APPROACHES

While large-scale storage infrastructure can be structured as a public–private partnership (PPP), PPPs are likely not feasible for small-scale community projects. At a small scale, the associated transaction costs are too high and projects are likely to fall below the minimum investment threshold of institutional investors. To address the financing needs of small-scale storage projects, it is better to support farmers to finance themselves and/or to support an investment from their farming cooperatives. These solutions could be in the form of government-supported incentives such as dedicated storage funds, preferential loans, grants and the use of fiscal instruments such as tax deductions for certain expenses, accelerated depreciation, and preferential import tariffs for specific technologies and products.

2.3.1 Government Incentives

2.3.1.1 Dedicated Funds

One way to ensure that storage does not get neglected is to set up a dedicated infrastructure fund with a mandate to provide financing for storage infrastructure projects. The fund should also be required, or at least encouraged, to allocate a certain percentage of the loans to projects below a certain size, and both private and public entities should be eligible beneficiaries. The storage infrastructure fund can be part of a larger infrastructure scheme, but to be an effective policy tool and achieve the expected outcomes, it should exclusively finance storage projects.

For example, as part of the Warehousing Scheme of the National Bank for Agriculture and Rural Development (NABARD) in India, a Warehouse Infrastructure Fund was setup in 2013. The purpose of the fund is to provide loans to public and private sector players for the construction of warehouses, silos, cold storage and other cold chain infrastructure for agricultural commodities. When selecting projects to finance, states with a food grain deficit (eastern and northeastern states in India) enjoy a priority. Eligible entities include government agencies, cooperatives, farmers' organizations, farmers' collectives, private companies and individuals (National Bank for Agricultural and Rural Development, n.d.).

2.3.1.2 Preferential Loans

Loans with preferential terms can be provided to farmers and/or cooperatives for investment in agricultural storage. The improved conditions can include lower interest rates, longer tenor periods (time in which payments are made) and longer grace periods (periods without accruing interest). The loans can be provided through a dedicated infrastructure scheme (e.g., the one discussed above) or through a partner bank, in which case the government makes up the difference between the market and preferential interest rates.

For example, the U.S. Department of Agriculture's Farm Service Agency provides low-interest loans for farmers to build storage units, to upgrade and expand their existing storage, and to purchase mobile storage facilities. Tenors are between seven and 12 years for a maximum amount of USD 500,000 with a rate in line with U.S. government bonds (bond rates are typically lower than prevailing commercial rates) (National Sustainable Agriculture Coalition, n.d.).

2.3.1.3 Grants

Grants can be a particularly effective tool to encourage infrastructure development. Often their role is not to finance projects outright, as the cost quickly becomes prohibitive, but to serve as a basis from which to mobilize other sources of funding. Lending institutions are often hesitant to finance projects in agriculture due to the sector's inherently high risks. A lot of what can go wrong for an agricultural enterprise—such as bad weather or a pest infestation—will typically affect many farms in the same region, which means risks can both be high (because the whole crop is affected) and wide-spread (everyone is affected at the same time). These characteristics make private insurance schemes for agriculture expensive. This often results in insufficient access to finance in rural areas, either because none is offered or because it is offered with prohibitively high premiums attached. For economically and socially important projects, such as storage in grain-deficit areas, grants reduce the financial risk by reducing the value of the loan in relation to the cost of the project, making banks and investors more likely to provide financing. Grants can be from domestic funds channelled through a scheme or fund structure, such as a Viability Gap Fund. Alternatively, grants can be sourced internationally.

As a recent example, the Government of India commissioned the study, *Assessment of Quantitative Harvest and Post-Harvest Losses of Major Crops and Commodities in India*, which concluded that the annual value of harvest and post-harvest losses of major agricultural products at the national level is about USD 13.6 billion. This prompted the government to introduce a series of measures to address the shortage in storage infrastructure. One of the initiatives was to make modern storage projects eligible for the Viability Gap Funding (VGF) scheme of the Ministry of Finance, which provides grants to priority infrastructure projects (Press Information Bureau, Government of India, 2016).

2.3.1.4 Fiscal Instruments

Farmers and cooperatives face a wide range of challenges when financing modern storage facilities, including the rising cost of land, establishing land title, fluctuating demand for storage, high interest rates and stringent asset-based lending requirements. Governments can use various fiscal incentives to overcome these challenges. These include tax exemptions for the life cycle of the asset, accelerated depreciation, tax deductions for certain expenses, and preferential import tariffs for technologies and products needed from foreign suppliers during construction. Incentives can vary for different regions depending on the need for storage facilities and the state of existing assets. Based on prevailing policy objectives, incentives can also be differentiated for types of projects and project sizes.

India has implemented a wide range of fiscal instruments specifically aimed at stimulating investment into storage infrastructure. In the 2015/16 budget, the following items are exempted from service tax: services for pre-conditioning, pre-cooling, ripening, waxing, retail packing, labelling of fruits and vegetables as well as the construction of greenfield post-harvest storage projects for agricultural products. The government has also extended project import benefits to cold storage, cold room, industrial projects for preservation, storage as well as processing of agricultural, horticultural, dairy, poultry, aquatic and marine produce and meat (Press Information Bureau, Government of India, 2016).

2.3.2 Public–Private Partnerships

Large-scale storage infrastructure, usually commissioned at the national level, can be structured as a PPP. The private partner will have a role in one or more aspects of designing, financing, operating and maintaining the infrastructure. Well-prepared PPPs, with careful risk-sharing provisions, can offer a range of benefits to governments:

- Efficiency gains can be realized during the operation of the infrastructure if the private partner has a financial interest in minimizing costs and maximizing revenues.
- The partnership can be designed to bring access to the latest and most suitable technologies and expertise.
- The partnership can be designed to ensure that technical capacities and know-how are transferred from the private to the public sector.
- The government can limit their upfront spending, and maximize the use of its own limited resources in a targeted way (e.g., through availability payments and project preparation costs)
- The government can consider (at the time of structuring) whether it wants to keep the asset at the end of the commission period. For example, if the need for storage decreases due to a change of market conditions, the government does not need to be stuck with an asset that it does not need or cannot operate profitably. On the other hand, it may want to keep the asset in public hands if there is an expectation of ongoing demand. The economics of operating the storage facility will change once the cost of construction has been recouped, and the partnership can build this calculation into its business model.
- Project risks are allocated to the party that is best suited to manage and mitigate them.

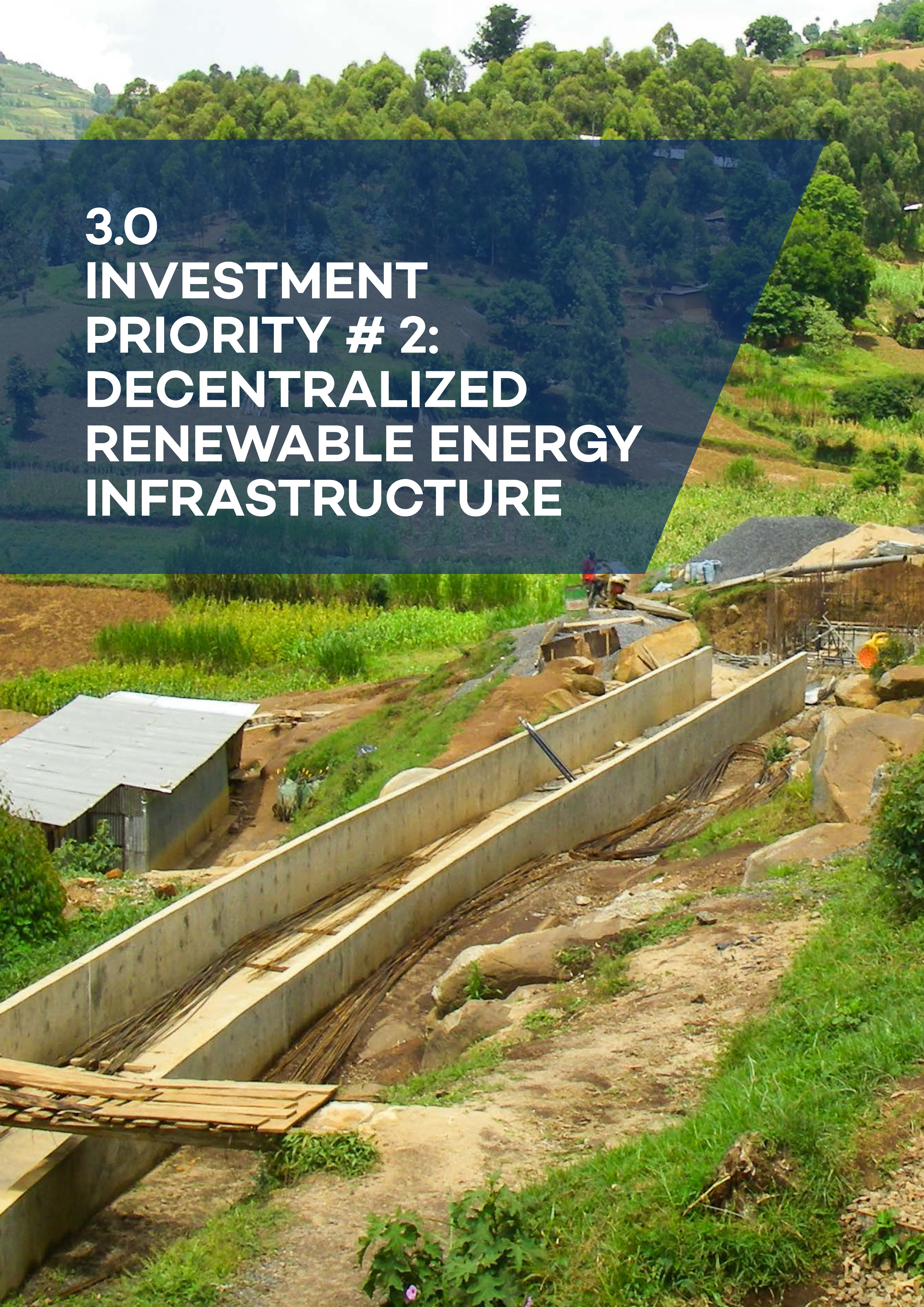
The Government of Punjab together with the IFC of the World Bank structured a successful grain storage PPP in 2010 that appears to have satisfied all partners and reduced grain losses. LT Foods, the private partner, won a 30-year concession to build and operate temperature-controlled steel grain silos with a capacity of 50,000 tonnes (IFC, n.d.). While we were not able to find any independent assessment of the project's results, the IFC claimed the following benefits shortly after operations began:

- Grain losses from weather, rot and pests were reduced significantly, mitigating purchasing and storage costs.
- The transaction mobilized USD 7 million in private investment.
- Savings during the concession period are estimated to be USD 6 million (IFC, 2012b)

2.3.3 Necessary Conditions

Storage infrastructure can pay for itself if certain conditions are met. To achieve commercial viability, the projects need a supportive policy and regulatory environment, complementary infrastructure (as discussed) and to operate at a large enough scale to cover operating costs. In many developing countries, these preconditions might be missing. In those cases, the government can help to create the conditions needed to make projects financially viable and attractive to private investors, including to local producers and processors.

3.0 INVESTMENT PRIORITY # 2: DECENTRALIZED RENEWABLE ENERGY INFRASTRUCTURE



3.0 Investment Priority # 2: Decentralized Renewable Energy Infrastructure

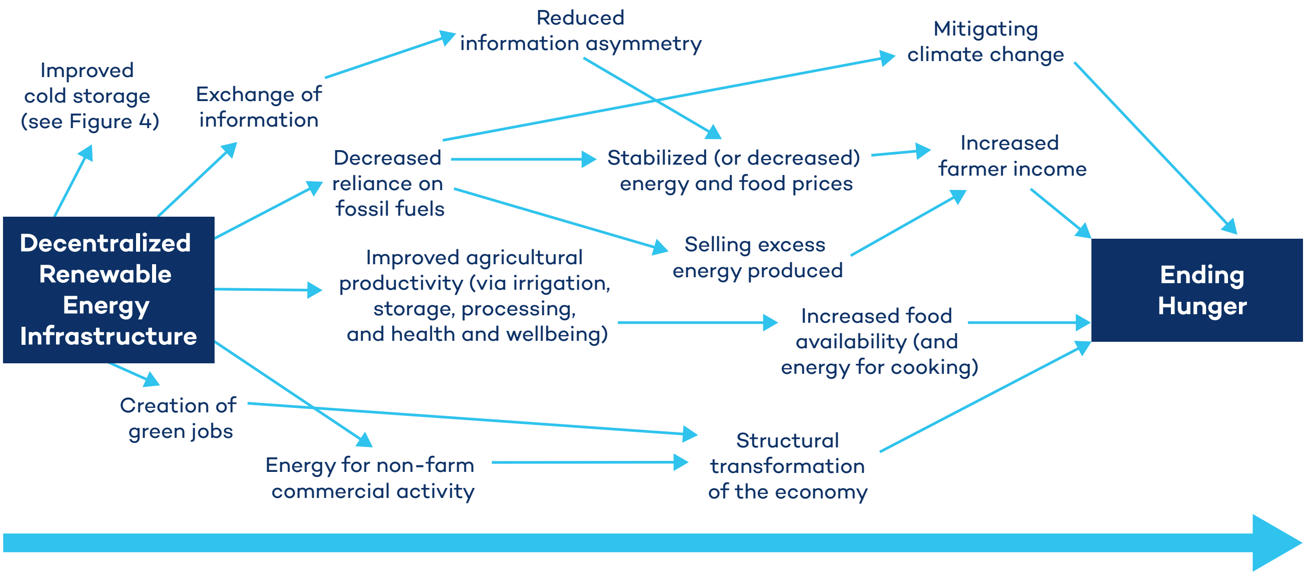


Figure 7. Pathways to food security: Decentralized renewable energy infrastructure

3.1 PATHWAYS

Energy is a game-changer in agriculture. Energy is essential for a range of tasks including: operating machinery such as tractors and irrigation pumps, powering and lighting facilities such as slaughterhouses, refrigeration, cold storage of produce and vaccines, postharvest processing, sterilizing fruit and vegetables, and charging portable telephones and other electronics for communications with markets and support services. The price of energy also has an impact on food security: an increase in energy prices can result in higher food prices, reducing access for poor households (IFPRI, 2016).

Decentralized renewable energy (DRE) is particularly appropriate for targeting food security improvements. The major pathways are indicated above in Figure 7. As much as a **quarter of the world's population**—1.3 billion people—lacks access to electricity and almost 85 per cent of these people live in rural, dispersed communities across sub-Saharan Africa and South Asia (UN Department of Economic and Social Affairs, 2014).[12] Given these characteristics, the extension of national energy grids is often technically difficult, costly and inefficient. There is a growing consensus in the international development community that off-grid renewable energy might be the best way to support inclusive energy access (Rockerfeller Foundation, 2015). Some of the advantages include:

- The infrastructure is more flexible than traditional infrastructure and can be deployed faster in remote areas than a centralized grid.
- The infrastructure's capacity can be upgraded more readily (using easy-to-use, modular designs) to meet a community's increased energy demands and can interface with the national grid when and if the grid reaches the area.
- Technologies can be used on their own—for example, only biomass, hydropower, solar and wind—or combined (hybrid).
- If energy storage systems are included, electricity can be offered 24/7.
- DRE mitigates the efficiency losses in the transmission and distribution of the grid energy.
- DRE reduces reliance on expensive and carbon-intensive diesel generators during blackouts.

[12]For a global dashboard on energy access, efficiency and renewable energy, see https://trackingsdg7.esmap.org/

This is not to say that the expansion of the national electricity grid is not important—both off-grid and on-grid energy production and distribution systems have a role to play in food security. And, of course, outcomes depend on the local context. Vietnam is an excellent example of the expansion of the national grid using investment from revenue in rice production. In the 1980s, the post-war government invested in hydropower infrastructure and high-voltage transmission and distribution lines—and the impacts on agriculture and other industries along the transmission routes have been positive (Asian Development Bank, 2011).

Yet developing and maintaining a nationwide grid is beyond the capacity of some countries' public budgets. The cost of rural grid extension is substantial; estimates suggest that in both Africa and Asia it can cost up to USD 22,000/km (Power For All, 2016). Furthermore, connection charges and tariffs may prevent those living in poverty from connecting to the grid. The model on which the grid is built works best with a fairly significant minimum population density, which is why existing grids are concentrated in urban areas. Areas with lower population density are forced to find other solutions.

It is in this context that off-grid renewable energy is an alternative worth exploring. The International Energy Agency (2011) estimates that 70 per cent of people living in rural areas could be more affordably reached by decentralized energy solutions.

Table 1. Types of DRE infrastructure and how they work

Type of Renewable Energy	DRE Infrastructure Required	How It Works
Solar power	Photovoltaics or "solar cells" Solar water pumps	Solar radiation absorbed by solar panels (mounted on rooftops or on the ground) is converted into electricity. The solar panels are connected to an inverter that converts the direct current (DC) generated by the panels into alternating current (AC) electricity. This AC electricity can then be used by the home/business and/or exported to the electricity grid.
Small wind	Wind turbines	The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity.
Small hydro	Turbine Hydroelectric generator Intake structure on river/stream to screen out floating debris and fish Pipeline to turbine	The turbine converts the flow and pressure of the water to mechanical energy. The turbine turns a generator, which is then connected to electrical loads; this might be directly connected to the power system of a single building in very small installations or may be connected to a community distribution system for several homes or buildings.
Biogas[13]	Biogas digester – brick/concrete structure with versions using fiberglass-reinforced plastic dome covers for improved efficiency	Human and animal wastes are used as feedstock to produce biogas for cooking. Then the biogas slurry and residues can be used as fertilizer in orchards or fields around the farmer's house, while the anaerobic digestion effluents can be used to feed pigs, mixing with fodders.

Source: Authors

[13]Although not taken up in this report, it is important to note the potential competition between land for food production and land for biofuel production. For a comprehensive read on this issue, please see the HLPE (2013) report on biofuels and food security.

Many governments have already recognized the potential of off-grid renewable energy solutions and have set ambitious targets:

1) In Rwanda, decades of energy crises led to a 2015 strategic plan that aimed to increase energy access to give 48 per cent of the population on-grid access and 22 per cent off-grid access by 2018. According to government data, Rwanda's national electrification rate reached 41 per cent (roughly the African average), with 30 per cent on-grid and 11 per cent off-grid by 2018, falling short of the targets but still representing progress from the baseline (USAID, n.d.). Importantly, off-grid energy will be a significant part the future energy mix: the government's goal is 100 per cent access by 2024 (composed of 52 per cent on grid and 48 per cent off grid) (Bimenyimana, Asemota, & Li, 2018).
2) In Tanzania, the government adopted a new regulatory framework in 2008 to encourage low-cost investment in mini grids, called the Small Power Producers Framework, which caused the number of mini grids to double by 2017. The country is becoming a regional leader in mini-grid development. Access to the grid for many rural areas in the region is not economically feasible (World Resources Institute, 2017).
3) The Sierra Leone government has launched an Energy Revolution initiative to supply basic power to all citizens by 2025; 250,000 homes were to be installed with solar power units by 2017. Progress to date is not clear, but much has been done to improve the policy, which encourages private sector development of solar and off-grid solar (e.g., duty-free imports and value-added tax-free sales to encourage a more affordable solar market) (Dumbuya, n.d.).
4) India's renewable energy potential is significant. It is being rapidly developed through Prime Minister Modi's ambitious India Solar Mission. The mission takes a staged approach, first building the enabling environment for solar technology uptake and promoting off grid solutions, then ramping up capacity across the country (Government of India, 2010). The target of 20,000 MW of solar power by 2022 was achieved in 2018—four years early. It will be scaled up to generate 100,000 MW by 2022 (Perera, 2016).

Box 4. Intermediate infrastructure: Training, awareness raising and community organization

The deployment of DRE infrastructure requires both hardware and software elements. Local users need to be adequately trained on the installation, operation and maintenance of the infrastructure, and awareness-raising activities need to take place to develop the local knowledge required for effective and sustainable use. The local capacity of technology suppliers and users is of the utmost importance to the success of DRE infrastructure.

One approach to the effective long-term sustainability of the DRE infrastructure is to build community-based approaches for ownership, operations and maintenance. This can be done by creating inclusive local participation in planning and execution to enable direct control of local players in monitoring and management of resources. This approach leverages the benefits of decentralization, which can increase space for local actors.

3.2 COMMERCIAL AND POLICY CHALLENGES

Off-grid renewable energy faces some notable policy and commercial challenges, which need to be addressed to encourage private financing. One of the main barriers—perhaps *the* main barrier—to the uptake of more DRE infrastructure is a lack of finance. The unit cost of off-grid energy is significantly higher than the unit price of electricity on the grid. This has posed a significant investment challenge, as addressed below. DRE options, however, are getting more and more affordable due to better technology with growing track records of success, better batteries and more targeted government subsidies. There is also the advantage of not requiring the upfront cost of building a grid for relatively few users. The following paragraphs illustrate some of the creative ways the government, private investors, users and donors have financed DRE infrastructure.

3.3 FINANCING APPROACHES

3.3.1 Investment Incentives

While user fees can be charged for DRE, they are often not high enough to fully cover the capital and operating expenditures. More importantly, they are rarely high enough to compensate investors sufficiently for the risks they assume when they finance a DRE project. A variety of investment incentives have been successfully used to create renewable energy capacity in either (and sometimes both) developed and developing countries.

3.3.1.1 Tax Incentives

While their effectiveness is limited on a standalone basis, tax exemptions at the different stages of the DRE transaction can encourage DRE deployment both on the supply and demand sides. An alternative form of tax incentive is *accelerated green depreciation*. It is an accounting method that allows eligible green assets to depreciate faster during the early years of the project, effectively providing a tax break for the sponsor (i.e., the owner of the asset). In practice, this decreases the cost of the asset by "borrowing" from the government in the form of upfront tax deductions.

3.3.1.2 Investment Grants

Investment grants can range from financial aid to providing land usage rights free of charge for a limited time. Only certain asset types and projects with a high economic and/or social multipliers should be eligible for these grants. As with the VGF discussed earlier, this "bridging capital" would enable DRE projects to become financially viable[14] in rural areas. For example, out of the USD 82 million in capital available for rural DRE deployment in India, USD 71 million is available as grant capital, not loans (cKinetics, 2013).

3.3.1.3 Concessional Loans

Loans with preferential interest rates provided either by the government or an international development agency enable DRE projects to have access to finance at a lower cost, with better terms and/or longer grace periods. Concessional financing does not need to cover all the project costs. Instead it can serve to attract additional private financing by creating a strong foundation. For example, the Japan International Cooperation Agency signed a loan agreement with the Indian Renewable Energy Development Agency to provide up to JPY 60 billion in an ODA loan for renewable energy projects (Japan International Cooperation Agency, 2014).

3.3.1.4 Blended Capital

The sustainable energy sector in rural areas is still considered to be unprofitable and high risk by most institutional investors, such as commercial banks, pension funds and insurance companies (Diouf, 2014). However, DRE projects without an attractive risk-return profile can also explore alternative sources of private financing. As these projects usually have a high development impact, they can offer potential investment opportunities for impact investors, whose mandate allows them to make investments with subpar returns if the environmental and social benefits are high enough. Impact investors can provide both equity and debt financing, and they are often more willing to invest in small-scale projects than traditional institutional investors.

Impact investors interviewed by IISD emphasized that their interest in sustainable infrastructure projects is often subject to the participation of the local government or a multilateral development bank (MDB) as investment partners. These entities can provide risk capital (in the form of an equity investment, for example), which reduces the risk for other investors. Or they can signal their confidence in the viability of the project by committing some form of direct capital to the venture (such as equity, subordinated debt, senior secured debt, etc.).

[14] "Financially viable" does not imply that the asset has to be revenue-generating in its strictest sense (i.e., charging user fees), but instead it has to have some form of revenue stream (also including availability-based solutions) to cover debt servicing, and operation and maintenance costs during the whole life cycle of the asset.

MDBs can also encourage the development of DRE projects by providing "enabling capital." As opposed to becoming an investor, development banks can use their balance sheet to create financial instruments that lessen the financial risks of socially important projects. Examples of such instruments include external credit guarantees, where the MDB takes on one or more specific risks associated with the project, such as credit risk (partial credit guarantee), construction risk or political risk. These instruments can provide a more efficient way to leverage the MDB's limited resources. Like impact investors, MDBs have a development mandate, which allows them to take on higher risk projects if the social and economic benefits are big enough.

For example, at the time of writing this report, Argentina was tendering a project for the installation of 7,500 rooftop solar arrays in rural areas across eight provinces. Of the estimated USD 58 million total project costs, 70 per cent will come from the World Bank and the rest from the government. The World Bank's loan features a variable margin, with a 35-year maturity period and a 4.5-year grace period. "Through these projects we intend to close the service access gap between rural and urban inhabitants," said Jesko Hentschel, World Bank director for Argentina, Paraguay and Uruguay. The project is expected to bring solar and wind energy to roughly 725,000 people via small-scale wind and solar projects totalling 200 MW (Project Finance International, 2016b).

3.3.2 Policy Support

The financial viability of renewable energy solutions has improved considerably during the last decade. Technological improvements have decreased construction costs, in turn decreasing the levelized[15] cost of electricity for DREs. While DRE business models have reduced their reliance on incentives and subsidies somewhat over the years, they are still heavily exposed to the risk of policy and regulatory changes, which can materially affect DRE projects' financial viability. These policy risks include uncertainty surrounding various financial incentives for renewable energy, feed-in tariffs (discussed below), fossil fuel subsidies, air pollution laws and plans for future grid integration.

Indeed, investing in DREs is as much a bet on the changes in the local (and in some cases international) policy and regulatory environment as it is simply optimizing the business case for the project. "Decentralized renewable companies still have to work overtime to find capital because of perceived policy risk. This risk gives investors cold feet," said Cathy Zoi, CEO of mini-grid developer Axess Energy (Brent, 2016). Nicole Poindexter, CEO at Energicity, also pointed out that a "policy framework to de-risk financing is the top need to achieve universal energy access" (Brent, 2016).

3.3.2.1 Grid Extension

When it comes to decentralized energy, one of the most pressing questions is what happens when the grid is extended to the rural area covered by the DRE project. The cost of energy from the national grid might be cheaper due to its scale and to the different sources of energy used. This can potentially result in the DRE asset losing its financial viability and eventually being left stranded. DRE investors need to price in this risk unless there is a clear roadmap of how DRE projects will eventually either be integrated into the grid or work alongside it.

For example, in the European Union, the Renewable Energy Directive (European Parliament & Council of the European Union, 2009) clearly says that member states need to ensure that renewable energy sources have guaranteed and priority access to national grids, so DRE producers can sell and transmit electricity in accordance with connection rules at all times. If grid integration is not technically possible, the directive requires that an appropriate financial compensation be given to the producers. Furthermore, the directive emphasizes the important role of renewable energy in promoting technological development and innovation, as well as providing opportunities for employment and regional development in rural and isolated areas.

[15] Levelized cost is the net cost to install a renewable energy system divided by its expected lifetime energy output.

3.3.2.2 Feed-in Tariffs (for Projects with Grid Access)

Once renewable energy producers have access to the electricity grid, feed-in tariffs (FiTs) can also be used to support the development of renewable energy in the region. FiTs set the selling price of electricity at a premium to the market price. The additional costs are either paid by the customers of the utility or funded through a government scheme. FiTs are determined based on the cost of production for the renewable technology used, supporting the deployment of renewable energy solutions.

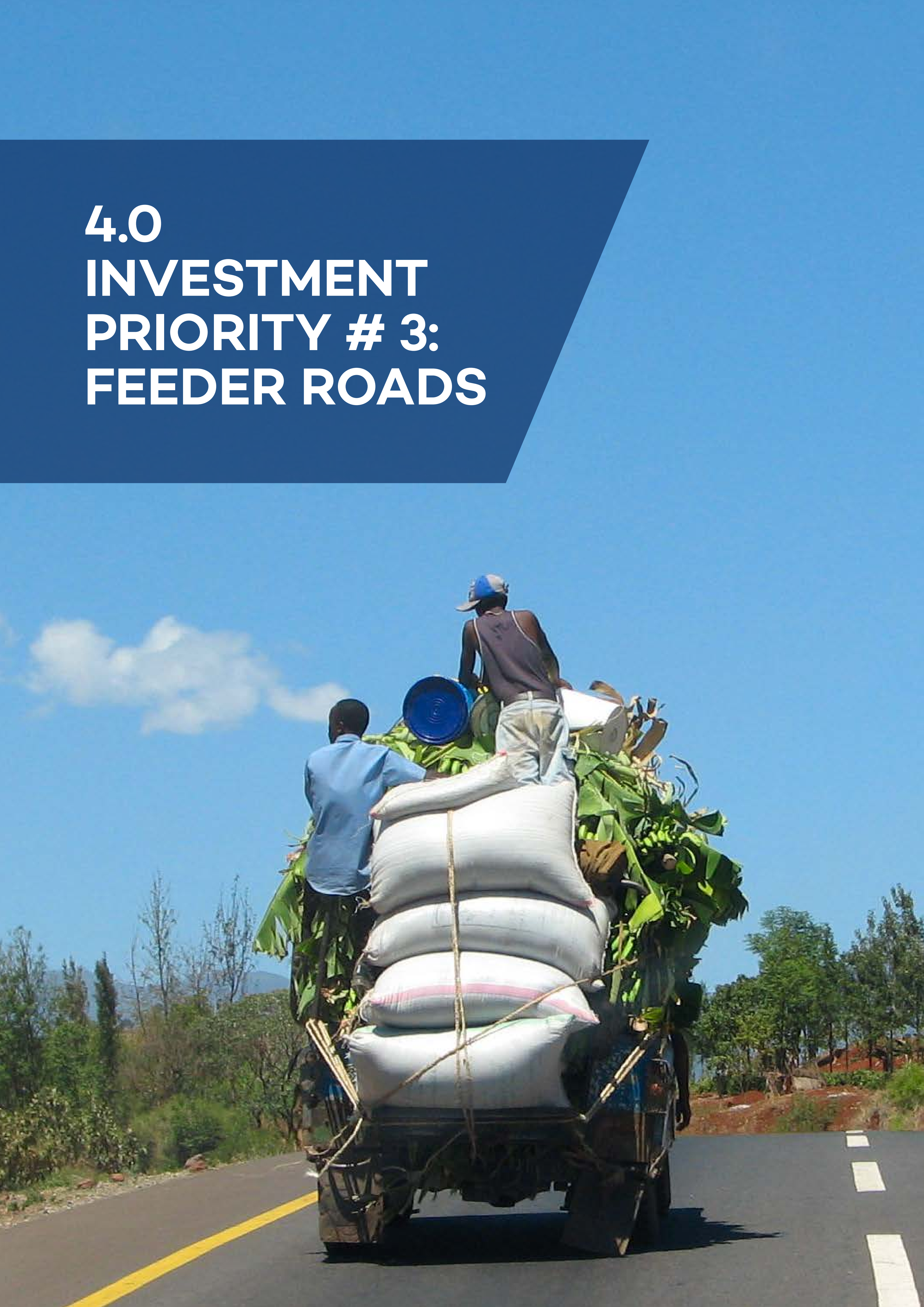
Like power purchase agreements, FiTs can lock in the sale price of energy for the long term, which decreases the output price volatility of the project. The European Commission claims that FiTs are the most efficient and effective support scheme for promoting renewable energy (Commission of the European Communities, 2008). For longer-term FiTs, however, it is important that the tariff is decreased over time to adjust to the changing costs and risks as the technology matures.

For example, Kenya first implemented FiTs in 2008 (with revisions in 2010 and 2012). They cover wind, biomass, hydro, geothermal, biogas, solar and municipal waste energy. Utilities are required to connect renewable energy producers to the grid and to guarantee priority purchase of the electricity generated. Utilities may recover 2.6 cents/kWh from their customers. The scheme offers price certainty for investors by guaranteeing the sale price for 20 years (subject to inflation). To accommodate smaller installations, a standardized power purchase agreement was created for renewable energy projects with a capacity of up to 10 MW (Ministry of Energy, 2012). The provision for smaller installations is especially important for rural areas.

3.3.3 Necessary Conditions

Decentralized renewable energy, as a revenue-generating asset, should be easier to finance than assets for which charging a user fee is neither economically nor socially feasible. While not without some inherent challenges, there is a functioning business model here for private investors. This characteristic of DRE projects also implies that the government's role will be different than the one discussed earlier for roads. In this case, the government's main focus should be on how to mitigate the major project risks on the policy and regulation side and to identify the incentive schemes that will work best given the national and regional context. Incentives will improve the financial viability of these projects and can help make the levelized costs more competitive against fossil fuel solutions.

4.0 INVESTMENT PRIORITY # 3: FEEDER ROADS



4.0 Investment Priority # 3: Feeder Roads

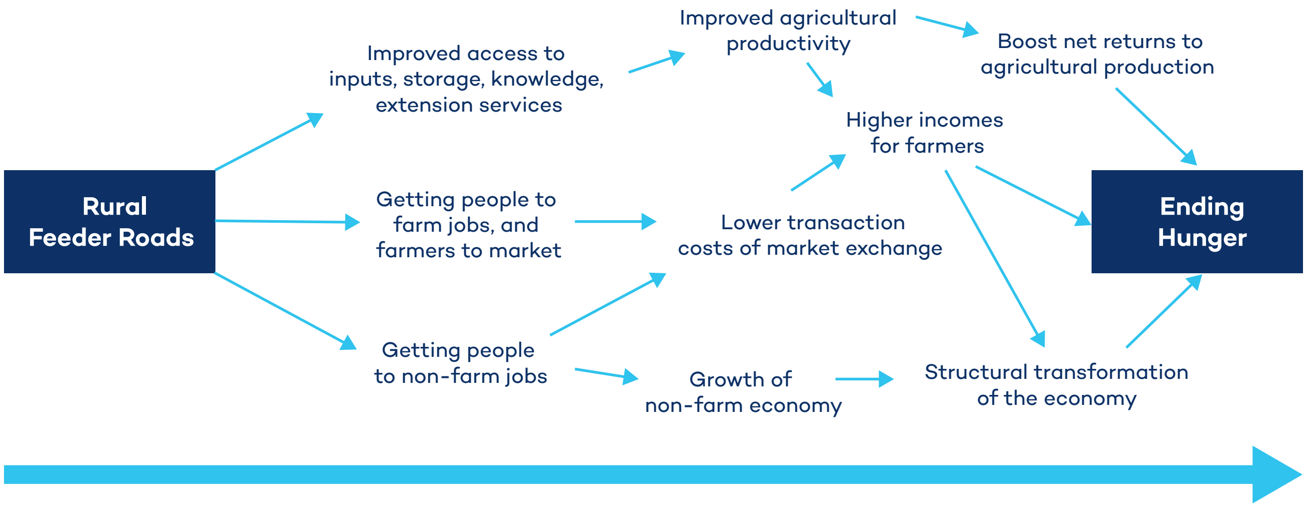


Figure 8. Pathways to food security: Rural feeder roads

4.1 PATHWAYS

It is common sense that roads are important for rural development. Without access routes to obtain inputs and reach markets, other food security investments (such as technical assistance, improved storage, access to finance) will underperform. Storage, for example, will help local food security even without a road, but the presence of a road transforms the value of the investment. Without rural transportation systems, other development initiatives are constrained. This point is well established in the empirical literature, and even after decades of researchers, NGOs and development institutions arguing for more investment in roads, it remains a neglected infrastructure category that continues to lack investment despite its importance for food security and nutrition (Juma, 2015).

Figure 8 above summarizes the many links between new or improved feeder roads and food security. These pathways include (but are not limited to): linking producers to markets, thereby supporting market integration (improving the effectiveness of price mechanisms); bringing improved inputs and extension services to the farm, thereby improving agricultural productivity; and increasing non-farm employment opportunities and rural wages, thereby supporting the growth of the non-farm economy. Since roads are a foundational infrastructure that support the success of other interventions (such as storage and distribution), the linkages to food security are likely to be greater in number and more varied in nuance than is presented above.

Within the broad category of roads, *feeder* roads are emerging as a particularly important investment for food security. Feeder roads connect more travelled roads to farm plots and remote villages, often using more basic road infrastructure to connect remote areas to the wider transportation network. Feeder roads demonstrate a robust correlation to poverty alleviation and agricultural productivity, performing better than higher-quality tarmac roads according to a comprehensive FAO study that included cases from China, Uganda, Thailand and India (Mogues et al., 2012). In another more recent study in China, the cost–benefit ratio for national GDP was four times greater for feeder roads than for high-quality roads (Juma, 2015). Moreover, in terms of welfare, the study found that, for every Chinese yuan invested, feeder roads raised significantly more rural and urban people above the poverty line than did major roads. And this has been found to be true for other countries as well (Juma, 2015). Feeder roads can be a win–win strategy for growth, poverty alleviation and food security.

Box 5. Roads and poverty

A 2002 study found that road density was one of the significant determinants of household-level prospects of escaping poverty in rural China: for every 1 per cent increase in the number of kilometres of roads per capita in poor regions in China, household consumption increased by 0.08 per cent (Jalan & Ravallion, 2002).

A 2001 study showed that a 1 per cent increase in road investments is associated with a 0.3 per cent decrease in the incidence of poverty in Indonesia (Kwon, 2001).

4.2 MAINTENANCE OF FEEDER ROADS

The quality of roads is important for food security (Ulimwengu, 2009). Road quality is related, for example, to maintaining the quality of fruit and vegetables on the way to market, as rutted and potholed feeder roads will damage produce during transport and reduce their sale price. Furthermore, where poor road quality adds significant travel time, it can lower the value of the product to retailers. Long transit times will also increase the risk of intermediate points in the distribution system rejecting the produce for not meeting quality standards. Especially in the absence of cold transport, the lag time to refrigeration decreases the shelf life of many products.

Feeder roads do not have to be low quality. Although feeder roads are more likely to be gravel roads than paved roads (due to the high upfront costs of paved roads), the condition of the road is also related to how often the road requires grading and spot repairs, the quality of the drainage, the strength of the side slopes and the appropriateness of the roads' initial construction for local weather conditions. In monsoon climates, for example, gravel roads deteriorate more quickly than in drier climates. It is thus important for infrastructure providers to think about and plan for maintenance from the beginning, taking weather conditions into account. All weather access should be ensured through regular maintenance and rehabilitation of the road surface.

While the upfront costs of sealed roads are greater than for gravel roads, they can (more than) pay for themselves in the lifetime cost of the asset—not only through the mitigated costs of maintenance, but also the social and economic benefits of 24/7 road access. Furthermore, local community members can, and should, be involved in the construction and maintenance of rural feeder roads where possible. Box 7 below presents an example of the use of local community members and local materials in the construction and maintenance of paved rural roads.

In the early stages of road planning, public officials from the transportation agency or its equivalent must use feasibility studies and analyses to find out:

- What the strategic locations are, to maximize food security and minimize negative consequences to ecosystems and surrounding communities.
- Whether the construction of new roads or improving the quality of existing roads (e.g., resurfacing) is a priority for food security in a given region.
- The projected life-cycle costs of construction and maintenance and the anticipated present and future costs to users.
- The traffic projections, which can determine maintenance decisions.
- The maintenance schedule for the different road types under consideration.[16]

[16]Unpaved roads follow a fairly linear rate of deterioration if not maintained. Paved roads deteriorate in a non-linear fashion. For the first two thirds of their life cycle, paved roads undergo little visible deterioration. After that, there is a period of rapid deterioration towards structural failure. See World Bank (1988).

Box 6. Roads and poverty reduction in Ethiopia

A 2006 study examined the impact of roads on poverty reduction in Ethiopia. The authors found that access to all-weather roads or quality roads—defined as roads capable of supporting truck traffic, and therefore trade, and bus traffic, therefore facilitating the movement of people in all seasons—increases consumption growth by 16.3 per cent and reduces the incidence of poverty by 6.9 per cent (Dercon et al., 2006).

Box 7. Green Road Procurement in Assam, India

The Public Works Road Development Agency of the Government of Assam, India, took a multi-pronged approach to implementing sustainable road infrastructure in rural areas.

- First, a green policy for roadside vegetation was put in place, whereby local vetiver grass (with a deep root system) was used to stabilize soils and protect slopes alongside roads—as opposed to the more energy-intensive crushed stones for the roadside. A community-based cultivation program was put in place to prevent theft, destruction and any pilfering of the grass and other plants.
- Second, a green road surfacing technology was used to lower carbon dioxide emissions, in which cold mix technologies for bitumen is used instead of the traditional hot mix systems. The road surfacing was undertaken in collaboration with local communities and created many work days.
- Finally, some innovative funding avenues were leveraged for green roads in Assam: set asides from the central government for states that adopt green technologies, as well as funding through carbon credits in the Clean Development Mechanism carbon credit mechanism.

Box 8. Intermediate infrastructure: Transport services

The need for logistics infrastructure and competition in services is perhaps most pronounced (certainly most studied) in the case of road infrastructure. An analytic review of roads in developing countries by the ODI (2013) gives a comprehensive overview of the compelling research conducted in this area. Their findings show that competition in transport services seems a critical precondition for development and accessibility to the poorest.

Where there is a lack of competition in the provision of transport services, rent-seeking can be persistent and end up accounting for a significant portion of end-market prices—putting remote farmers at a particular disadvantage. One study cited by ODI is a 2011 USAID analysis, showing that the transport and logistics costs of moving maize and livestock along key trading corridors between Burkina Faso, Ghana and Benin account for approximately 59 per cent for maize and 18 per cent for livestock of the end-market prices. Of these, transport costs—fees paid to transport-service operators and losses in transit—were found to weigh most heavily on the end-market price along the corridors studied (USAID, 2011).

Furthermore, a study conducted by the International American Development Bank confirmed a positive and statistically significant association between transport-logistics infrastructure and foreign direct investment. This is because corporations look to operate in locations with adequate transport and logistics infrastructure to reduce delays and disruptions in the supply chain, inventory holding costs, depreciation costs and handling costs (Blyde, & Molina, 2012). While "distance" is a frequent measure used by corporations to inform their investment decisions, this report showed that the quality of the logistics system in place is also an important factor in the location decisions.

In as far as improved transport services enhance farmers' income and purchasing power, there is a need for this "pathway" to food security to be supported. Governments must pre-empt these challenges when they invest in new road infrastructure by: a) simultaneously creating supportive competition policies for transport services to reduce the costs of transport; b) improving and harmonizing regional transport programs and policies to build investor confidence; and c) including clear specifications on the quality and maintenance of road infrastructure in their tendering process to ensure its longevity and reliability for the most vulnerable populations.

Similarly, donors must be aware of the political economy of freight logistics when investing in roads and have constructive dialogues with governments and other funders on how best to deploy their funds in a way that can target food security.

4.3 FINANCING APPROACHES

4.3.1 Alternative Financing Solutions

The inability to charge users directly for the usage of the asset does not preclude a project's financial viability[17] nor its potential to attract investors. Different financing schemes exist in which the government, or a government-related entity, fills this revenue gap.

4.3.1.1 Availability Payment

Under an availability payment scheme, the public party pays a predetermined amount on a regular basis (annual or semi-annual) to the private party for the operation and maintenance of the asset for as long as the asset meets pre-agreed performance requirements. As the government transfers the performance risk to the concessionaire, it limits its own liabilities and, through the fixed payments, it caps the return of the private party. Under this setup, the public entity retains the demand risk, so irrespective of the use of the asset, the public entity will have to pay a fixed amount. Note that this approach creates the risk that the public entity will overpay for the service provided.

The Ostregion Motorway in Austria had a similar setup. The 52-km road project, completed in 2010, had a concession period of 33 years with 70 per cent availability payments and 30 per cent shadow tolls. It was awarded the Best European Project to Sign award in 2007. Another more recent example of availability payments was the 4G highway in Colombia (the financial deal for the project closed in 2015). USD 1.2 billion of the USD 1.68 billion project cost was financed through debt. Tolls backed by a contingent guarantee from Agencia Nacional de Infraestructura (the government agency) and annual availability payments from budgetary allocations from the government serviced the debt (Project Finance International, 2016a).

4.3.1.2 Shadow Toll

A notable challenge in financing toll roads is demand risk, that is, anticipating traffic demand accurately. Furthermore, some national and local governments have requirements to offer alternative routes to citizens where toll roads exist, making demand risk a particular challenge.[18]

If the government is unwilling to assume the demand risk of the road project, it can enter into a shadow toll agreement with the private party. In this setup, the government pays a predetermined amount per user (depending on vehicle type and distance travelled) on an annual basis for the construction, operation and maintenance of the asset. This scheme was first implemented in the United Kingdom under Prime Minister Margaret Thatcher in the 1980s. As the concessionaire only gets paid once the asset is operational, it has a strong incentive to expedite construction. The limitation of this approach is that traffic can be difficult to measure accurately and, depending on the technology used, it can notably increase project costs. Also, as additional risk is allocated to the private party, the risk premium demanded will be higher, raising the cost of finance for the project.

[17] "Financially viable" does not imply that the asset has to be revenue-generating in its strictest sense (i.e., charging user fees), but instead it has to have some form of revenue stream (also including availability-based solutions) to cover debt servicing, and operation and maintenance costs during the whole life cycle of the asset.

[18] In Liberia, for example.

The Bina Istra semi-motorway in Croatia used shadow tolls (and for some parts real tolls). The 145-km road project had a concession period of 32 years and a project cost of EUR 500 million (Kerali, n.d.). Another example of shadow tolling is the Rio Verde-Ciudad Valles highway in Mexico, built in 2008. The cost of the project was USD 201 million for the 112-km highway. Mexico's Ministry of Transport and Communication provided the revenue stream in the form of a shadow toll without guaranteeing a certain level of revenue (which would be the case for an availability payment for example). There was no minimum equity contribution set for the private partner (Project Finance International, 2006a).

While shadow tolls have been mainly used for highways, Australia and the United States have been experimenting with them for rural road projects as well. The Florida Department of Transportation recognized that toll roads in more desolated rural areas would not yield high enough revenues for private capital participation, but shadow tolling could be a possible solution. Its discussions with Santander and other financial institutions confirmed that, with the "appropriate financing and risk-sharing structures, any corridor can be developed with private participation" (Project Finance International, 2006b).

4.3.1.3 Stakeholder Finance

Feeder roads in rural areas can also be financed through the financial contribution of local communities and/or the main users of the road. This type of structure was successfully implemented in Uganda, where a not-for-profit rural development fund was set up to finance and maintain a feeder road network that connected sugar cane farmers with a processing facility. The initial capital for the fund was provided by grants from donors as well as from the processing facility, and a levy was put on each unit of sugar cane sold by farmers to the processing facility, supporting the continued operation of the fund. The responsibilities of the fund included the maintenance and upgrading of existing roads and financing the construction of new roads to facilitate the transportation of sugar cane (Warner, Kahan, & Lehel, 2008).

Community participation in financing and operation does not only make rural PPP solutions more financially viable, but it also has other important benefits such as improved social acceptance of the project, increased local employment and potentially slower deterioration of the asset.

Another example where beneficiaries participated in the PPP structure of rural roads was the Morogoro Village Travel and Transportation Programme (VTTP) in Tanzania. Communities were involved in the design of the projects and contributed raw materials, labour and some cash payments. The local government mainly provided specialized expertise and other resources not available locally. Funding, in the form of grants, came from the central government and other donors, who also provided technical assistance. The private sector was responsible for the rehabilitation and maintenance of the projects using performance-based contracts (Warner et al., 2008).

4.3.2 Funding the Alternative Schemes

All alternative finance schemes discussed earlier rely on some form of government financing. This funding can come from the following sources in the cases of rural road infrastructure.

4.3.2.1 Taxes

To ensure sufficient resources for the construction and maintenance of road infrastructure, there should be taxes specially earmarked for road development. These can be in the form of local taxes, property tax, fuel tax (arguably the most efficient way to raise funds) and/or a levy on agricultural production. As road infrastructure supports economic activity, an increase in tax receipts could be expected over time. The Conference Board estimates that, even if only the construction phase is considered, governments can recover 30–35 per cent of public infrastructure spending through higher personal, corporate and other indirect taxes (Brodhead, Darling, & Mullin, 2014).

4.3.2.2 Road Fund

Innovative financing solutions are only as good as the institutions supporting them. A national road fund, or infrastructure development fund, can provide the necessary credibility and stability to assure investors that their long-term agreements will be kept and that the project risks allocated to the public entity will be credibly mitigated. Indeed, these funds often have an internationally recognized credit rating, allowing them to attract a wider range of private investors to the projects they support.

At the same time, infrastructure funds have the financial capacity to provide funding to economically and socially important projects. The mandate of these funds can set specific targets for funding rural roads (as a percentage of all projects), encouraging investment in road projects with strong links to food security. Road funds can get their own funding from a two-tier tariff system: *access fees* such as vehicle registration fees and *usage fees* including fuel taxes and international transit fees. The involvement of these funds goes beyond the financing of greenfield or brownfield projects, to include the maintenance of the existing road system.

4.3.3 Other Incentives and Solutions

Securing a stable revenue stream, as discussed earlier, is often not enough to attract investors to projects in more challenging economic, social and political environments. Other incentives are needed to make the deal more appealing, finding ways to improve the overall risk-return profile of the project.

4.3.3.1 Co-Financing

When municipalities, national governments or MDBs co-invest in a project, it gives a strong signal for investors about the project's legitimacy and viability. In addition, it shows a political commitment that is essential during both the construction and operation phases. In fact, construction risk, one of the major barriers of investing in infrastructure for many investors, can originate from a lack of political support. For example, construction delays are often due to difficulties in issuing all the relevant permits, which can have a significant impact on the overall financial viability of the project.

Co-financing can take the form of equity, subordinated/mezzanine debt or senior secured debt. Equity or other subordinated capital contribution gives a stronger signal of the MDB's commitment to the project, as this type of capital serves as a first loss provision in the deal structure. Indeed, having a sufficient equity buffer, and thus a lower debt/equity ratio, is often a requirement for debt investors to be engaged in the project and for sponsors to have a lower cost of financing.

4.3.3.2 Viability Gap Funding

VGF is a one-time grant awarded to projects that would otherwise not be commercially viable. VGF should be used selectively; only projects with high economic and/or social multipliers should be eligible. Furthermore, to best leverage the limited public resources, it should be used to unlock additional capital as opposed to funding the whole project. VGF can be applied during the construction and/or operation phases and is usually included in the bidding process, ranging up to 20 per cent of project costs. For example, the Indian Institute of Technology estimates that INR 400 million can be mobilized by the government by providing INR 50 million as a direct VGF grant into a project, with another INR 50 million in equity investment as risk reduction and another INR 50 million as a guarantee for user fees during the initial years of operation (Mahajan, Sahai, and Psrija, 2007).

The Dau Giay–Phan Thiet Expressway project in Vietnam is being financed through a mix of VGF provided by the Govenment of Vietnam, World Bank-linked debt and private equity. A PPP Design, Build, Finance, Operate structure was set up for the development of the 98.7-km highway, with a concession period of 30 years. As part of the tendering, bidders had to submit the amount of VGF they would need to make the project financially viable (Project Finance International, 2013a).

4.3.3.3 Project Bundling

Project bundling is another way to overcome the barriers of financing projects with higher risk and/or limited revenue potential. In this case, a less commercially attractive project is bundled and tendered together with a project (or projects) with a much more favourable risk–return profile. In other words, the investor can only invest in the "good" (high return) project if it also finances the one that is less financially desirable.

Bundling also offers a solution for two important challenges of rural infrastructure financing: scale and revenue uncertainty. Below a certain project size, institutional investors might be hesitant to invest due to the high fixed transaction costs. Indeed, scale is often the single biggest barrier when it comes to impact infrastructure (i.e., projects with high environmental and social impacts), even when the economics of the project are otherwise solid. Project bundling could also serve to diversify other project-related risks, notably the revenue risk. This possibility will depend on how much the assets are correlated. Project sponsors receiving revenues from a toll road and from a feeder road in the form of an availability payment, for example, can rely on the latter when demand for the toll road falls below that forecast at some point of the asset's life cycle.

The U.S. State of Pennsylvania is also exploring bundling as a way to repair its 4,700 structurally deficient bridges. In one of the proposals being considered, the private entity would fund the work in exchange for the right to toll the bridge (Project Finance International, 2013b).

5.0 INVESTMENT PRIORITY #4: IRRIGATION INFRASTRUCTURE

5.0 Investment Priority #4: Irrigation infrastructure

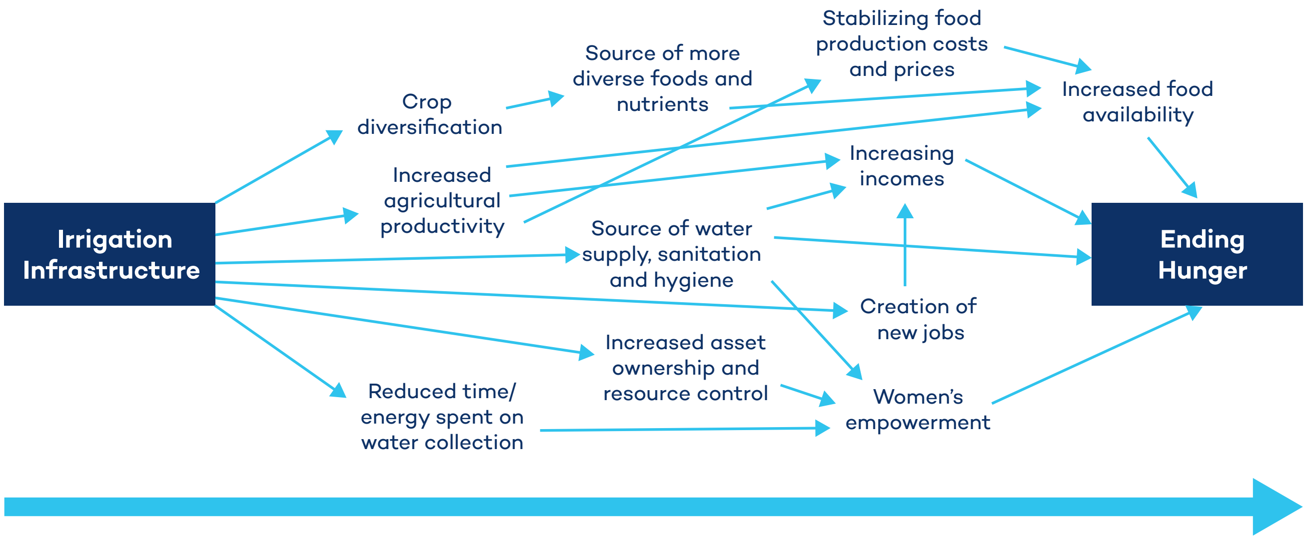


Figure 9. Pathways to food security: Irrigation infrastructure

5.1 PATHWAYS

As depicted in Figure 9 above, increased agricultural productivity resulting from irrigation can lead to increased food availability either for own consumption or for marketing and income generation. Irrigated production is more than twice as productive on a per-hectare basis than rainfed production (Ceres, 2015). In addition, the changes associated with a reliable water source can lead women's empowerment, better sanitation and the creation of new local jobs (see pathways in Figure 9 for more details)—all of which can also have positive food security impacts. It is also observed that the number and type of crops that farmers grow also changes with irrigation—often towards increased production of vegetables (e.g., iron-rich leafy greens) and fruits throughout the year, with important linked nutritional benefits for households. Irrigation used for supporting livestock-rearing can lead to an increased intake of animal-derived (protein-rich) foods (IFPRI, 2015).

As is the case for other rural infrastructure investments, proving a causal link between irrigation and improved food security outcomes is hard. There are a lot of factors to be considered. A 2015 study by IFPRI of countries in sub-Saharan Africa nonetheless identifies five broad impact pathways linking irrigation to both positive and negative nutrition and health outcomes (IFPRI, 2015):

- (+) irrigation as a source of more and more diverse foods (through increased agricultural productivity and crop diversification)
- (+) irrigation as a source of income (from market sales and employment generation)
- (+) irrigation as a source of water supply, sanitation and hygiene (through multiple water use)
- (+) irrigation as an entry point for women's empowerment (through increased asset ownership and control over resources)
- (-) irrigation as a new vector-breeding habitat[19] and a source of water pollution (from agrochemicals)

[19]This can also disproportionately affect women, as they are more likely to take time to tend to the sick.

Box 9. Irrigation, roads and food access in Ethiopia

An infrastructure program in Ethiopia, which involved the construction of irrigation and roads and the organization of beneficiaries, improved food access by 30 per cent, an increase of about 700 kcal/adult/day (Abebaw, 2010).

5.2 WHERE TO FOCUS IN THE WATER DISTRIBUTION NETWORK

In addition to irrigation infrastructure having multiple impact pathways, there are also multiple *types* of irrigation infrastructure and multiple *models* for managing it. Irrigation infrastructure is a broad category, encompassing the entire system of extracting water from its source and moving it to be applied on agricultural crops. This infrastructure includes: dams, canals, pipelines, aqueducts, pumping plants, drainage and flow-regulating structures.

Table 2. Typical types of irrigation infrastructure and associated costs

		Cost	
Type	**Use**	**Operation, maintenance, repair**	**Capital**
Storage	Holds water		
Dam/reservoir		Medium	High
Tank		Low	Medium
Farm pond		Low	Medium
Canals	Delivers water	Low	Medium
Drainage	Removes water	Low	High
Gates	Delivers water	Low	Low
Pumps	Raises water	High	Medium
Pipes	Delivers water	Low	Medium
Wells	Accesses water	High	Medium
Grading	Levels land	Low	Medium
Water application	Delivers water to crop		
Sprinkler		Medium	High
Gated pipe		Low	Medium
Drip system		Low	High
Furrow		Medium	Low
Flood		Low	Low
Barrages	Raises surface water	Low	Medium
Levees	Channels water	Medium	Medium
Computers	Times flows	Medium	Medium
Meters	Measures flow	Low	Medium

Source: Ward, 2010.

One of the major challenges facing investors that want to strengthen food security is the decision about what type of irrigation infrastructure to invest in (some of the choices are depicted in column 1 of Table 2 above). The right investment will depend in large part on the proximity of the recipient farm(s) to a reliable water source, the organizational structure of the local community of farmers, and the availability of other infrastructure for energy, transportation and storage. Irrigated "units" can range from an individual farm to massive integrated schemes that cover thousands of hectares. The management can be public, private, user-run, community based, or some combination of these. Typical management models are (FAO, 2011, Chapter 1):

- Large-scale public systems (e.g., paddy fields for rice production in humid areas or for staples and cash crops in dry areas)
- Small- and medium-scale community-managed systems
- Commercial private systems for cash crops (often large scale)
- Farm-scale individually managed systems

While the infrastructure needed to secure and distribute a reliable water supply (such as reservoirs and dams) is essential, the politics of such "communal" and often larger-scale water infrastructure is often a major barrier. Unlike electricity, water is heavy and therefore expensive to move over long distances. Furthermore, growing urban areas will often pay two to five times more for water than its economic value in agriculture, complicating the economic trade-offs (Ward, 2010). In places that depend mostly on surface water stored in large reservoirs, the timing and volume of releases might depend on the needs of hydropower production and the environmental flow requirements, overriding optimal possibilities for agriculture. These challenges and trade-offs mean that water allocation for the agricultural sector requires funding, political will and cross-sectoral coordination.

In this context, the UN agencies focused on agricultural development (FAO and IFAD) have tended to focus on supporting smallholders that already have access to a local water source or could have such access relatively easily. Their experience shows that this household- or community-level model has been a relatively effective and sustainable approach; farmers will tend to invest in the maintenance of infrastructure that uses their water source, provided they are reaping the benefits of improved agricultural productivity.

This focus on the smallholder does not imply irrigation for subsistence agriculture only. Irrigation supports market-oriented production of cash and industrial crops. Even though the expansion of irrigation for cash crops such as sugar, cotton and coffee does not necessarily lead to more nutritious food production for its farmers, these producers may make more money from such cash crops than from other more nutritious crops, creating another strong food security pathway.

In a particularly positive example from Zambia, the farmers of the Kafue district simultaneously secured irrigation infrastructure for their smallholders to grow food for their own consumption (pumping water from the local river) while also renting out surrounding land to large-scale commercial agriculture. This model is now being rolled out in many communities across Africa by InfraCo and the World Bank (EleQtra, n.d.).

In addition to more "traditional" irrigation infrastructure investments, communities in many parts of the world, particularly in semi-arid and arid regions, have a long tradition of infrastructure invention to capture and store water locally. One notable example is from arid Rajasthan, India, where rural people have been building village ponds (*nadis*), small reservoirs (*talabs*), rainwater harvesting structures (*kunds*) and other tanks (*tankas*) for millennia. This type of traditional infrastructure can play an important role in rural water security today (Mantri Jal Swavlamban Abhiyan, 2015).

Furthermore, more sustainable land practices on and around farms—such as rotating livestock and plants on the same plot of land, reforestation of the surrounding area or the development of agro-ecological zones—can also help lead to more rural water security (with or without irrigation infrastructure), while also supporting the self-sufficiency of rural communities. Technologies and infrastructure for treating domestic and agricultural or industrial wastewater are also increasingly prevalent and can provide a valuable source of irrigation water, though any such project must be carefully assessed in relation to local regulations on public health.

Box 10. Contemporary irrigation "narratives" on the African continent

Irrigation infrastructure has been a particularly important focus on the African continent over recent decades for its potential to boost agricultural and economic growth and to improve security on a continent where currently only 6 per cent of all cultivated area is irrigated. This is in comparison to approximately 37 per cent in Asia and 14 per cent in Latin America (IFPRI, 2010). Over two thirds of Africa's irrigated land is concentrated in only five countries: Egypt, Madagascar, Morocco, South Africa and Sudan.

One of the first major appeals for irrigation investment was the 2005 Commission for Africa report, which called for a doubling of irrigation in Africa by 2015 and emphasized small-scale irrigation. In the years since this report, there have been many other studies to evaluate irrigation needs for food security and other calls for action, too. The most well known is the African Union's 2014 Malabo Declaration, which committed countries to doubling agricultural productivity through irrigation, inputs and mechanization.

Irrigation is also seen as an "adaptive response" to climate change on a continent that is now experiencing changed precipitation patterns and increased extreme hydrological events such as flooding and droughts.

On the other hand, there have been concerns that the expansion of irrigation on the African continent will deprive downstream users of water, including fish and wildlife. And with the enormous increase of land sales and lease agreements with foreign investors over recent years (a phenomenon sometimes called "land grabbing") there are concerns that water demand could outstrip water supply resources were all this land to be used for irrigated production (Mbengue, Waltman, & Turley).

In reality it is likely that irrigation will be neither a panacea for African development nor result in hydrological suicide for the continent. But certainly, improved agricultural productivity in the continent is both desirable and probable, and an important element of this improvement will come from expanding irrigation.

Box 11. Intermediate infrastructure: Irrigation management services

There is broad acceptance in the development community that effective irrigation investment must include not just the physical assets, but equally the supporting services. Logistics and services related to irrigation infrastructure include: managing and maintaining tertiary levels of infrastructure (e.g., canal maintenance), drainage services, coordinating timing and flows across users and user groups, and the monitoring of water use. There is also an important role for real time, reliable and usable weather and hydrological data, which can use communications (ICT, cell phone) infrastructure to share information across rural and farming communities.

Generally speaking, these services are delivered most effectively when devolved from the authority and responsibility of government agencies to either: a) user groups (water user associations) or b) third-party service providers. For the user group approach, the idea is that increased ownership, decision-making authority, and active participation in the O&M of irrigation systems would create or force a binding commitment from water users to be more effective and responsible towards their obligations. There is a large body of literature on effective management of water "commons" by organized user groups (Ostrom, 1992).

Advocates of the third-party service providers argue that irrigation and drainage systems require high levels of professional skill and management, which is best provided by specialized, private sector service providers (World Bank, 2007).

Either model can work, but both require strong institutional structures that oversee and monitor decisions regarding water fees, allocation of water within the community and the maintenance of the infrastructure (FAO, 2009).

5.3 FINANCING APPROACHES

When it comes to funding irrigation infrastructure, a differentiated approach to investment is needed. Individual smallholders who are developing irrigation systems with water from a local source and using their own land might require access to credit for their initial investment, as well as access to training to learn effective techniques for cropping and for maintenance of the infrastructure. Groups or communities of farmers who organize themselves to gain access to a water resource will need larger-scale infrastructure and will have greater upfront need for capital, which may make a public subsidy of some sort useful. In this situation, it will also be important to invest in building farmer-led *institutions*, as farmers will be sharing the resource and the infrastructure and there will be an ongoing need for shared decision making and investments into the future (Ostrom, 1992).

Irrigation projects traditionally include a large social component, which is to say, they rely on public money to deliver water infrastructure (and water itself) to farmers at highly subsidized rates. There is a long history of irrigation subsidies in many countries, including developed countries, often with direct support or cross-subsidies paid for with hydroelectric power revenue. These policies are often part of a larger political strategy to encourage rural settlement, increase food production and promote national food self-sufficiency.

This context reveals a certain irony to the insistence of some industrialized country donors that developing countries must achieve full cost recovery in the construction and operation of irrigation infrastructure projects. In the United States, for example, irrigation infrastructure—in the country's West in particular—has involved large public expenditures since the 1930s, which the government has never fully recovered from the project beneficiaries (Wichelns, 2010). Only in more recent years have these subsidies gained critical attention from citizens and legislators, as freshwater scarcity becomes a pressing problem in some parts of the country.

5.3.1 Pricing and Public Subsidies for Irrigation

Any discussion on financing irrigation infrastructure quickly comes down to the pricing of irrigation water, and the extent to which the capital costs, O&M and future investment—important elements of the longer-term sustainability of the system—can be covered through water tariffs. While most agree that irrigation will continue to play a major role in providing enough food for the world's increasing population, there is debate about whether or not subsidization from the public sector is justified.

On the one hand, if the full cost of irrigation is reflected in farm-level irrigation water prices, this can promote irrigation efficiency within agriculture and increase the likelihood of achieving economic efficiency across the sectors that compete for limited water resources (Wichelns, 2010). On the other hand, other experts argue that irrigation infrastructure and services provide both public and private goods, and merit a degree of public subsidy (Wichelns, 2010). For example, it is often the case that irrigation water serves multiple users (e.g., domestic, agricultural and industrial water consumers) and has diverse beneficiaries (e.g., flood control for those in zones prone to flooding).

Ultimately, while subsidizing irrigation infrastructure and/or water can significantly improve farm incomes and food security in the short term, the longer-term problems associated with financing the maintenance and management of the infrastructure must be addressed as well, for the long-term sustainability of the system.[20]

5.3.2 Separating Capital and Operational Expenditure

For the reasons described above, there is a strong case for financing capital expenditure (Capex) and operational expenditure (Opex) separately, such that the government (or an external donor) covers the former and users incrementally pay for the latter, using the income gains they receive from reliable irrigation. Eventually, ideally once the benefits of improved irrigation are realized by farmers, policy-makers can begin the political process of increasing irrigation tariffs to include a part of the Capex (even 1–2 per cent), thereby gradually reducing the public subsidy to irrigation.

[20] For those interested in calculating subsidies in irrigation, IISD developed a rigorous, transparent and replicable methodology to provide the most comprehensive estimate of subsidies to irrigation, which can be found here: https://www.iisd.org/GSI/irrigation-subsidies/irrigation-resources

Notably, this approach requires robust feasibility assessments that outline (strictly) the costs the government (national, state, local) is expected to incur, the expectations of the user groups and an assessment of whether the projections for longer-term cost recovery are feasible, based on willingness to pay. In any case, a process should be put in place to revisit water rates every five years. As a rule of thumb, the Indian government stipulates that irrigation rates should lie within the range of 5–12 per cent of the gross revenue of farmers in the canal command area (Sur, & Umali-Deininger, 2003).

It is worth repeating that water charges must, at a minimum, cover O&M costs. Without this minimum revenue base, service providers are unlikely to be able to afford the O&M expenditures required to provide reliable services. This results in a "vicious circle" whereby the water delivery becomes less reliable as quality declines, and farmers become more and more reluctant to pay for irrigation, further eroding the revenue base.

5.3.3 Identifying and Targeting Food Security Beneficiaries

Irrigation subsidies must be designed and targeted to support the poorest, least food-secure farmers; this will not just happen on its own. For example, a major finding of a study of irrigation subsidies in India by the World Bank was that the vast majority of poor rural households in India did not directly benefit from irrigation subsidies since they do not use canal irrigation (Sur, & Umali-Deininger, 2003). Only 13 per cent of agricultural households in India used canal irrigation at the time, and few to none of these households were among the poorest or most marginalized (scheduled castes and scheduled tribes).

To focus on food security outcomes, however, what we would need to know from this study is whether these medium and large farms were providing employment to the poorest rural households—thus providing another legitimate pathway to address food security. In this sense, the lesson is not a normative one (i.e., all irrigation subsidies should be designed to target only the poorest) but a call for policy-makers to undertake a comprehensive study of the target population's options and preferences as they determine their food security pathways for themselves.

5.3.4 Public–Private Partnerships

PPPs have been increasingly rolled out in the irrigation sector. The more traditional PPPs engage the private sector in either the construction or maintenance, or both, of irrigation and drainage infrastructure.[21] Increasingly, a range of newer possibilities have emerged, sometimes called "co-investment" schemes, whereby a broader range of partners from ICT/tech, cell phone, satellite, insurance and players from the agricultural value chain come together to improve the timing and volume of water reaching the fields. These partnerships will be more effective if they include local and regional authorities, farmers organizations as well as NGOs or civil society organizations working in the region.

Broadly speaking, the most likely financing scenario for PPPs in the irrigation sector is one in which the private sector "concessionaire(s)" obtain part of their remuneration through fees charged to users and another portion through availability payments. Due to the inherent difficulties in fee collection, the availability payment reduces risk for the concessionaire. And as described in previous sections, availability payments can be based on performance; that is, the private partner(s) is entitled to the availability payments if, during each reporting period, the service is delivered to farmers in a timely and adequate manner. The remuneration should be at least partially variable, according to the rating achieved by the private partner in terms of the various quality and performance requirements stated in the PPP contract. This can also be linked to energy- or water-saving targets. Drought contingency plans should be integrated into contracts, where this risk is present or possible under climate change scenarios.

[21] For a detailed description of PPPs in irrigation, along with a compendium of 29 case studies, see the World Bank's Irrigation PPP Toolkit: https://ppiaf.org/documents/2864/download

In this way, the PPP model can provide for a more targeted use of public sector funds to spur agricultural productivity (World Bank, 2007). It can also be useful to establish the principle of financial autonomy, to raise professional standards by introducing improved management, to improve maintenance of the system, to promote water and energy efficiency, and to relieve the government of some fiscal and administrative burdens. The proper dissemination of innovation will be entirely dependent, however, on the quality and the transparency of the partnership mechanisms used.

6.0 CONCLUSION

6.0 Conclusion

Based on an extensive meta-analysis of the literature on rural infrastructure and its ability to end hunger, complemented by expert interviews, our report focused on four rural asset categories: storage/cold storage, feeder roads, decentralized renewable energy and irrigation infrastructure. The objective was to assist donors and investors who are dedicated to ending hunger to target their financial resources to these high-impact infrastructure categories, as well as to help them understand why these projects are worth supporting and the specific these projects face.

While we cannot provide broad generalizations on whether *specific projects* represent a good investment or not, the many lessons provided in this report should help investors and policy-makers alike tailor infrastructure financing solutions to support parts of the population that are most vulnerable to hunger.

Despite the hopeful SDG goal to end hunger by 2030, the challenges remain acute. Both developed and developing countries are facing large infrastructure deficits: USD 90 trillion in infrastructure investment is needed by 2030, which is more than the value of the entire current stock (The New Climate Economy, 2016). The lack of investment is particularly bad in rural areas, which are often neglected by policy-makers and investors alike. In these regions, infrastructure financing faces a wide range of challenges due to the limited resources of local governments, the uncertainties surrounding revenue streams and the high perceived risks of the projects.

Despite these barriers, with the right use of donor funding and public resources, it is possible to attract private capital to the four infrastructure asset types (storage, decentralized renewable energy, feeder roads and irrigation) covered in this paper. There is a wide range of financial instruments available (some of which have not been deployed to date in a rural context), which enable governments to leverage their limited funds, to de-risk these projects and to mobilize private capital. Governments also need to assess carefully what projects have the highest economic and social multiplier effects and establish project pipelines accordingly. By identifying these multipliers, international donor funding can also be secured more easily. As needed, the international community should assist with the measurement of these impacts and provide the necessary capacity for more robust project development.

Furthermore, donors as well as governments should only commit funds to financially viable infrastructure. Projects not meeting this requirement will disproportionally drain the public resources available, without delivering value for money to stakeholders, and potentially shortening the project's operational life. "Financially viable" does not imply that the asset has to be revenue-generating in its strictest sense (i.e., charging user fees), but instead it has to have some form of revenue stream (also including availability-based solutions) to cover debt servicing, and operation and maintenance costs during the whole life cycle of the asset. Developing financially viable projects also opens the possibility to engage private capital in the financing, which is a key ingredient in addressing the rural infrastructure deficit and ending hunger.

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Annex 1

PRIMARY DATA COLLECTION: PHONE INTERVIEWS

In 2016 phone interviews were undertaken for this report with individuals from the following organizations who represent either a) experts on food security and infrastructure and/or b) investors in rural infrastructure: World Cocoa Foundation, the All-Party Parliamentary Group (AAPG) on Agriculture and Development (UK), Cargill, Harvard Kennedy School, the International American Development Bank (IADB), the International Finance Centre (IFC), the International Fund for Agricultural Development (IFAD), Louis Dreyfus Commodities, Stanford Centre for Food Security and the Environment, Syngenta and the World Bank.

SECONDARY DATA COLLECTION: REPORTS BY INTERNATIONAL ORGANIZATIONS

Table A1. List of reports informing the selection of infrastructure asset categories and causal "pathways" to ending hunger

Organization	Report Title	Year	Access
Overseas Development Institute (ODI)	Targeting Infrastructure Development to Foster Agricultural Trade and Market Integration in Developing Countries	2013	https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8557.pdf
Food and Agricultural Organization of the UN (FAO)	The Impacts of Public Investment in and for Agriculture: Synthesis of Existing Evidence	2012	http://www.fao.org/docrep/016/ap108e/ap108e.pdf
International Food Policy Research Institute (IFPRI)	2016 Global Food Policy Report	2016	http://www.ifpri.org/publication/2016-global-food-policy-report
Policy and Operations Evaluation Department, Ministry of Foreign Affairs, Netherlands	Improving Food Security: A Systematic Review of the Impact of Interventions in Agricultural Production, Value Chains, Market Regulation and Land Security	2011	https://www.oecd.org/derec/49558328.pdf
Food and Agricultural Organization of the UN (FAO)	The State of Food Insecurity in the World	2015	http://www.fao.org/3/a-i4646e.pdf
Food and Agricultural Organization of the UN (FAO)	Market Oriented Agricultural Infrastructure: Appraisal of Public-Private Partnerships	2009	http://www.fao.org/tempref/docrep/fao/011/i0465e/i0465e00.pdf
Department for International Development (UK)	DFID's Conceptual Framework on Agriculture	2015	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/472999/Conceptual-Framework-Agriculture2.pdf
Department for International Development (UK)	Stepping out of Agriculture	2015	https://assets.publishing.service.gov kedia/57a0896ee5274a31e00000a0/EoD_Topic_Guide_Stepping_Out_Agriculture.pdf
Asian Development Bank	Food Security in Asia and the Pacific	2013	https://www.adb.org/publications/food-security-asia-and-pacific

Organization	Report Title	Year	Access
Institute of Development Studies (IDS)-International Fund for Agriculture and Development (IFAD)	Brokering Development: Enabling Factors for Public-Private-Producer Partnerships in Agricultural Value Chains	2015	https://opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/6456/IFAD_IDS_BrokeringDevelopment_final.pdf;jsessionid=F5BB9CCC342703F9D352B15A10CF6E25?sequence=1
World Bank	Africa Can Help Feed Africa: Removing Barriers to Regional Trade in Food Staples	2012	https://openknowledge.worldbank.org/bitstream/handle/10986/26078/733870WP0P12710n0Feed0Africa0Report.pdf?sequence=1
Food and Agricultural Organization of the UN (FAO)	Public–Private Partnerships for Agribusiness Development: A Review of International Experiences	2016	http://www.fao.org/3/a-i5699e.pdf
World Bank	World Development Report 1994: Infrastructure for Development	1994	https://openknowledge.worldbank.org/bitstream/handle/10986/5977/WDR%201994%20-%20English.pdf?sequence=2&isAllowed=y

Additional General Reading

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