SNV

End user affordability for agricultural PUE: the role of demand-side subsidies

Discussion paper

May 2024

Executive summary

This discussion paper was initiated as an internal document to contribute to SNV's programme designs in the energy sector under its productive use of energy portfolio. The financial support for this research was under the organisation's priority investments in addition to investments in its five strategic directions outlined in our 2030 SNV strategy. These internal priority investments are meant to both support SNV positioning, to enable continued impact delivery, and to strengthen our operational robustness. At the completion of this process, it was determined to make this discussion paper public, invite discourse, and contribute to ongoing efforts in tackling end user affordability. This paper was developed by Karin Sosis via a literature review and interviews with selected energy and agriculture stakeholders. The entire process was co-developed with support from SNV Global Energy team.

This discussion paper looks at the role demand-side subsidies (DSS)[1] can play in mitigating end-user affordability constraints that hinder the uptake of agricultural productive use of energy (PUE) equipment. We consider DSS as an umbrella term that encompasses a range of *subsidised financial interventions*, of which an end user subsidy (also called a price discount) is one of several delivery options. Our intention is to suggest a more nuanced approach to subsidy design that matches subsidy tools to the prevailing affordability constraint(s) in a given market ecosystem.

Productivity gains in smallholder agriculture can improve rural livelihoods – but the use of productive equipment is limited by affordability constraints.

This approach is introduced in three parts. First, we present the nuances of 'affordability,' which serves as a basis for thinking how subsidies could solve for *specific* end user[2] affordability challenges. Second, we explore how agricultural PUE (agri-PUE) ecosystems differ in terms of maturity, which allows us to consider how specific affordability challenges and specific subsidy tools might manifest themselves in different settings. Finally, we present a conceptual framework to support decision making on when to match demand-side subsidies to ecosystem maturity.

Increased agricultural productivity happens in several ways: by mechanisation of agricultural production, processing, storage or transport; by replacement of energy-intensive diesel equipment with efficient electric alternatives; or by preservation of value through cooling or drying. All of these productivity benefits can be delivered with electric equipment solutions. But uptake of electric agri-PUE technologies remains low in developing countries.

Electric agri-PUE are expensive assets in a price-sensitive market. Interestingly, while governments have long subsidised other agricultural inputs such as seeds and fertiliser, there has been less in the way of subsidy support for the productive equipment needed for mechanisation or value addition. Increasingly, electricity stakeholders are coming to the same conclusion around equipment affordability, albeit from a different angle, as it becomes clear that energy access on its own is insufficient to drive economic growth, and productive uses of electricity may not happen organically or may take years if not decades.

Affordability is a multi-faceted concept (Box 1). For electric agri-PUE equipment it can be the (lack of) ability to pay the up front price, to access or qualify for a loan, to pay a loan deposit or meet collateral requirements, to pay high interest rates, to pay back a loan at regular intervals or within a certain timeframe, or to pay the expenses of operating the equipment.

Box 1: Costs of agri-PUE equipment

The total cost of agri-PUE equipment can include:

Capex:
Up-front purchase price
Deposit + balance payments (loan / lease / rental)
Loan collateral
Repairs + maintenance (e.g. battery replacement)

Opex:
Electricity, fuel, agricultural inputs, labour, theft prevention, asset depreciation

Each of these specific affordability challenges can be solved for by one (or more) of three subsidy mechanisms:

1. A cost reduction, whereby the total cost of buying or using the equipment is less than it would be at market rate,
2. A structural change in cost or payment terms that spreads out smaller payments over time, or
3. Risk mitigation to either an end-user or lender, in order to enable a loan.

[1] A financial benefit to individuals or entities that reduces end user affordability barriers to the use or ownership of (in this case) electric agricultural equipment. 'Demand-side' refers to the buyer's side of a seller-buyer relationship.
[2] End users are individuals, agribusinesses or groups that might purchase (or use) agri-PUE equipment.

We consider these all to be subsidies as they *use public or grant funding to reduce an affordability barrier.* Each mechanism has its pros and cons.

Cost reduction can be deployed as a price discount (of which there are various tools) or as a reduced interest rate. It is an effective and versatile instrument that in some cases is the only way to improve affordability. It can be delivered on its own or in combination with another subsidy mechanism, e.g. a price reduction alongside concessional financing. It can be delivered on an asset purchase, rental or fee-for-service price. It can be particularly helpful in mitigating willingness to pay constraints, such that end users see less of a hurdle and less of a risk to trying a new or unfamiliar technology. On the other hand, it is something of a blunt instrument, in that it can address many affordability challenges but without nuance. As such it may be offered to those whose affordability constraint actually can be addressed with a less interventionist tool. Ideally, an income- or savings-generating asset such as agri-PUE equipment should pay its cost back over time – rendering end user financing preferable, if it is available.

Structural changes can address nearly all affordability constraints for agri-PUE end users. These mechanisms enable payments over time (a loan) or modify loan repayment terms. Ideally, a structural change enables the full cost of an agri-PUE asset to be recouped by the lender. But structural changes can be costly to implement and risky for both the lender and the end user. Also, the ethics of financing expensive agri-PUE equipment must be carefully considered, such that repayment periods are not excessively long (prolonged indebtedness), interest rates not onerous, and capacities of the lender not unduly stretched.

Risk mitigation is only relevant where in-house or third-party financing are available. These mechanisms are 'farthest' from the end user in terms of degrees of separation, and in an ideal situation are established to reassure parties in case of default but are never deemed necessary. As such we consider them to be the least 'interventionist' of the three mechanisms.

Figure 1 shows the range of DSS tools that can be deployed using these three mechanisms. We are focused on the first three columns, which include price discounting and two kinds of end user financing (in-house and third-party). The rationale for including end user financing alongside price discounting is that a subsidy (grant) has either directly unlocked a loan where it would not otherwise have been possible or has covered the difference in cost to the lender such that it can offer concessional terms.

Figure 1: Range of direct and indirect demand-side subsidy tools (Source: author's own)

More direct ← → **Less direct**

Price reduction	Reduced barriers to in-house financing	Reduced barriers to 3rd-party financing	Strengthen the economic rationale	Minimise societal resistance
Mitigate price barriers **Tools** • RBF that requires price reduction • Up-front grant to supplier for price reduction • Public procurement • Voucher or other 'opt-in' for price discount • Post-purchase rebate	Enable instalment payments without overburdening the supplier **Tools** • Value chain financing • Grant/loan to company to enable it to extend credit where it would not otherwise be possible • Loan tenor extension or modified repayment schedule • Reduced interest rat • Reduced depos • Reduced / alternative collateral requirent • Repayment guartee • Weather / crop insurance	Reduce transaction costs & risks so buyers can pay in instalments **Tools** • Grant/loan to financial institution to enable it to extend credit where it would not otherwise be possible • Loan tenor extension or modified repayment schedule • Reduced interest rate • Reduced deposit • Reduced / alternative collateral requirement • Repayment guarantee • Weather / crop insurance	Mitigate costs + risks associated with ownership by encouraging alternative models Create / cultivate market linkages (inputs + outputs) Minimize costs of expensive opex inputs, like electricity or labour	Communicate in local language(s) about direct benefits as compared to the status quo (e.g. diesel to electric) Build end user understanding of how to assess technologies Provide training in financial & technical literacy among end users, suppliers and FIs

Beyond the pro/con assessment of the subsidy mechanisms above, we note here there are pros/cons of the different subsidy delivery tools. These are summarised in Table 1.

Table 1: Pros / cons of three types of subsidy tools

Tool category	Pros		Cons
Price reduction	Sends a direct signal to potential buyers. When well-targeted, it can markedly improve uptake of a product and may be less costly to administer than concessional end user financing.		Does not account for opex, which over time can add up to more than capex.[3] Risk of leakage (subsidised product being bought by those who could afford full-price) and unsustainable price expectations both concurrently (neighbors also want a subsidised price) and chronologically (people are resistant to paying full price once the subsidy is removed). Vulnerable to gaming by all stakeholders.[4] These risks increase in proportion to how heavily the price is subsidised. If the price reduction is relatively modest, so are these risks.
Subsidised in-house financing (IHF)	Specialist equipment suppliers know the technology, which may improve their ability to lend appropriately (non-specialist last mile distributors may be burdened by this, on the other hand). A credit arrangement encourages Know-Your-Customer (KYC), end user data collection and a long-term after-sales relationship, which is beneficial to end users and suppliers alike.[5] For companies that might want to offer products on credit but do not have the patient capital / cash flow to do so, subsidising them can reduce liquidity constraints to lending.	Concessional lending can address the 'poverty tax', which is the premium paid by the poor for the flexibility of buying in smaller units or in instalments. If the repayment period can be extended beyond five years (a timeframe compatible with affordable instalments and greater potential repayment rate), subsidised lending allows either for recycling of repaid funds into new loans or for a net decrease in the total cost of the subsidy as funding is recouped.[6]	The agri-PUE equipment supplier has the burden of assessing the end user's credit worthiness, funding the modified cash flow, and managing payment collection and non-payment.[7] These challenges mean IHF is more likely to be offered by larger, more financially sophisticated companies, which can preclude local suppliers and in doing so limit end user choice.
Subsidised 3rd party financing (3PF)	FIs are designed to disburse loans, whereas equipment suppliers are not.[8] Supporting a revolving fund at a bank for 3-4 years gives the bank an example with which to go to their board and raise more money.[9] Agri-PUE markets need de-risking mechanisms of all kinds to stimulate investment.[10] Concessional 3PF can complement a price reduction, such as to cover the non-subsidised portion of equipment cost.[11]		Administration of concessional 3PF is time and resource-intensive, and Fis may not have the capacity to do it, particularly for agri-PUE equipment they may not be technically familiar with.[12] The process of linking an interested buyer to a lender is not always easy, and many agri-PUE suppliers and last mile distributors have sought out partnerships with third-party financiers with little success.[13] Agricultural credit programmes have long been critiqued as too expensive for the funder, plagued by (non-)repayment Issues and regressive. But 3PF allows for a levelling of the playing field between suppliers who can offer IHF and who cannot.

3 Interview with Village Infrastructure Angels (VIA)
4 GOGLA (2021)
5 ACE TAF (2020) Design principles for demand-side subsidies in off-grid solar
6 Energy Savings Trust (2023), ESMAP (2022)
7 GDC (2022), stakeholder interviews
8 Bloomfield, Z. (2023) Financing and scaling productive use of energy: Challenges and opportunities for catalytic growth. GET.Invest
9 Interview with SELCO Foundation
10 GOGLA (2023)
11 For example, in Uganda, the Micro-scale Irrigation Programme offers farmers a 75% subsidy for solar water pumps (compared with 25% for fuel-powered pumps) alongside financing to cover the balance. The renowned IDCOL programme in Bangladesh pioneered a similar model. (IIED (2021))
12 Energy Savings Trust (2023), GET.Invest (2023)
13 GDC (2022)

These tools can be used in combination as well, though this is beyond the scope of our current discussion.

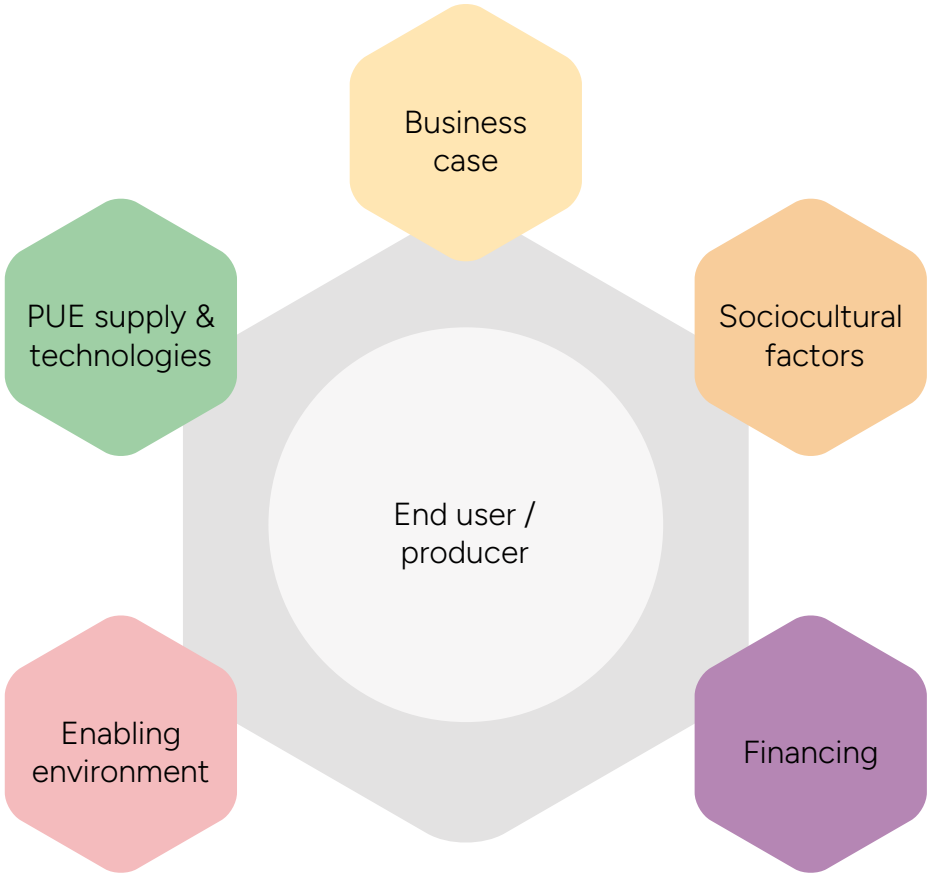
In Section 1 we have presented the notion that a specific affordability challenge can (and should ideally) be addressed with a specific subsidy solution. Next, we look at how specific affordability challenges typically differ across geographies.

End user affordability challenges are likely to differ depending on the maturity of the ecosystem.

We can map basic elements of the agri-PUE ecosystem into five main categories (Figure 2):

- the availability of smallholder-appropriate technologies (which determine their value for money) and robust supply chains (which affect how competitively products are priced);
- the strength of the 'business case' for using the equipment, which entails forward and backward market linkages as well as the 'use characteristics' of the technology that determine whether end users can rent instead of purchase it, move it across locations to share cost burdens, use it year-round instead of during one harvest, and more;
- the accessibility of end user financing, which determines whether an end user has any option other than an up-front purchase;
- sociocultural factors such as language, norms and social aggregation systems, which affect both realities and perceptions of affordability; and
- a supportive enabling environment, which affects product pricing (via fiscal policy that imposes taxes or provides subsidies), product quality and loan terms (via consumer protection regulation), and cross-sector interactions (via the shaping of water, land, mobile money or micro-financing structures in a country).

Figure 2: Elements of the agri-PUE ecosystem



These elements play out in various permutations in different ecosystems[14]. For example, weak ecosystems are typically characterised by high product prices, low market linkages, and limited access to micro-financing options. Table 2 outlines what a weak, transitional and commercially mature ecosystem might look like.

Table 2: Characteristics of less and more mature ecosystems[15]

Element		Ecosystem maturity		
		Weak	Transitional	Commercial
End user status	Type of farming	Subsistence	Subsistence + local market	Subsistence + commercial
	Degree of mechanisation	Manual	Manual + diesel	Diesel or electric
	Affordability	None/low	Low/mid	Mid/high
Elements of the ecosystem	Sociocultural | Willingness to pay / awareness	None/low	Low/mid	Mid/high
	Supply & technologies | Equipment availability / pricing	Low / non-competitive	Mid / comparable	High / competitive
	Business case | Input & output linkages	Limited	Adequate / developing	Robust
	Business case | Demand aggregation	Risk management Self-help, village savings groups	Risk management + entrepreneurial Cooperatives	Entrepreneurial + commercial Cooperatives, purchasing groups
	Financing | Access to financing	None/weak	Weak/some	Some/many

The purpose of mapping what different ecosystems look like is *to assess what the specific affordability constraints are likely to be* and *what the most appropriate available subsidy mechanisms could be* – at a scale that could be investable by a subsidy provider.

The question is not, 'which subsidy tool is best?' but rather, 'which subsidy tool is best for the ecosystem in which we're working?'

In a weak ecosystem, neither in-house nor third-party end user financing is likely to be available. Options therefore are limited to some form of cost reduction, to incentivising lending if there are local fIs, or to incentivising suppliers to enter the market The role of DSS here should be to build resilience as part of a long-term safety net, to incentivise an FI or supplier to enter the market, and for agri-PUE to help build the local economy.

There is greatest potential for DSS to have immediate and lasting impact in a transitional agri-PUE ecosystem, where the 'wraparound' context is sufficiently viable that end users can do something productive with equipment. Here, the role of DSS should be to strengthen the ecosystem and graduate out over the course of 5-20 years. In this kind of setting, *where all subsidy mechanisms are possibly relevant*, stakeholders will have to do more thinking around what is appropriate now and proactively anticipate changing strategy as the ecosystem matures. As the ecosystem gets stronger, support should shift from more 'interventionist' pricing discounts (cost reduction) to less interventionist third party financing (with risk mitigation). This applies both to the adaptation of a subsidy within a given programme and to the identification of appropriate interventions over time. A subsidy should be designed not only to improve end-user affordability but to strengthen the agri-PUE ecosystem as well.

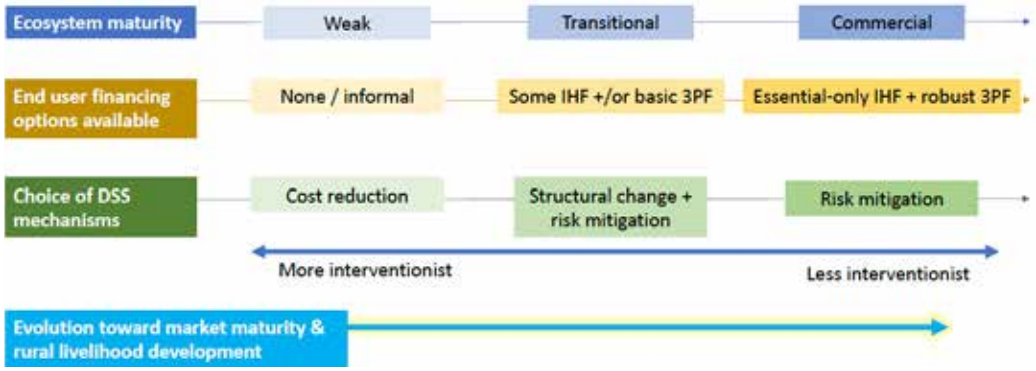
The role of DSS in a commercial market should be limited to (a) prioritising a new technology or (b) promoting energy efficiency, for example to improve environmental outcomes through switching from diesel to electric. It can be done through any of the mechanisms and tools, but should focus on the least interventionist to achieve objectives, and be positioned as an 'incentive' rather than a 'subsidy'.

[14] All of these elements can differ sub-nationally except the enabling environment.

[15] Sources include stakeholder consultations, EnDev (2021) *The Vulnerability Access Index (VAI): A pro-poor approach to develop solar markets in rural and vulnerable areas of Tanzania.* Africa Clean Energy and Open Capital Advisors (2020), *Demand-Side Subsidies in Off-Grid Solar - A Tool for Achieving Universal Energy Access and Sustainability*, GOGLA (2021), SNV (2021) Localization of financing for off-grid energy, SELCO Foundation (2020) *Financing basic energy access*

The goal, overall, should be to shift the ecosystem over time. These conclusions are illustrated in Figure 3.

Figure 3: DSS options shift as the ecosystem matures (Source: author's own)



Considerations to guide DSS decision-making

Stakeholders should approach the agri-PUE situation with open mind around what DSS tools are most appropriate and for how long support may be needed. Here are some questions to start with:

1. What is the prevailing end user context? Seek to understand seasonal agricultural needs and outputs, specific value chains, electricity access and both observed and stated affordability constraints. Do the communities in focus want electric agri-PUE? → *Guiding principle: DSS decisions must be defined and driven by end user needs.*

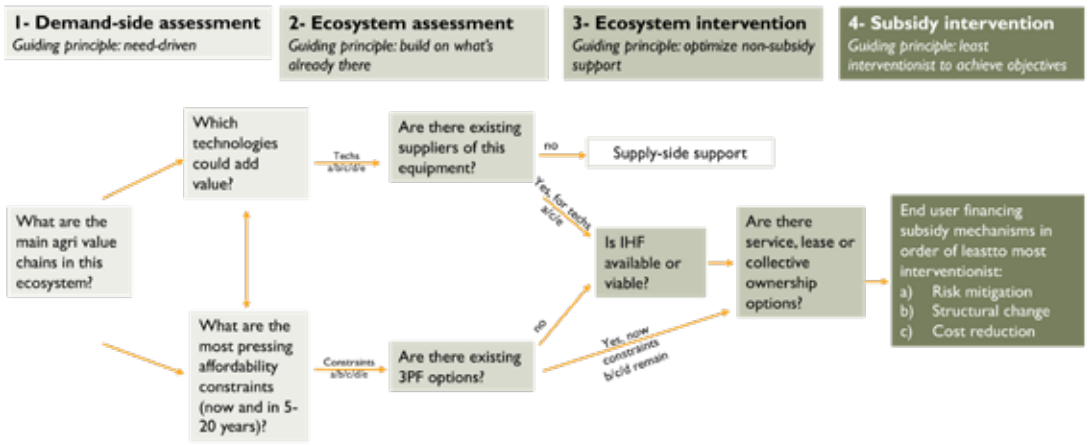
2. What characterises the five ecosystem elements (PUE supply & technologies, business case, enabling environment, sociocultural factors, and financing) right now? To what extent do end users have access to technology and financing options? How strong are market linkages and social groups are → *Guiding principle: Build from what is already in place, rather than introducing an entirely new 'solution' to the market.*

3. Are there demand-side ecosystem interventions that could improve end users' options prior to or in conjunction with DSS? How can we strengthen the ecosystem with a view to graduating out the subsidy? High impact leverage points include demand aggregation through existing social structures, technical assistance to FIs, market linkage support. → *Guiding principle: optimise non-subsidy support.*

4. What DSS tool(s) are appropriate? This merges the contextual cues above with top-down constraints e.g. budget or data limitations, other supply and demand-side interventions, national food security priorities. Stakeholders should strive to match the available DSS tools to the observed affordability constraints. Impact may be achieved using various combinations of mechanisms. → *Guiding principle: choose the least-interventionist option(s) to achieve objectives.*

Keep an open mind around what DSS tools are most appropriate and for how long support may be needed. Figure 4 provides a (highly) simplified decision tree.

Figure 4: Initial questions and guiding principles for choosing DSS (Source: author's own)



Key messages

End user centricity. Any decision to subsidise agri-PUE should originate in a clear and stated need by end-users. There is a difference between "we need this" and "you should have this." As a recent paper on PUE from IIED and Hivos noted, "the desire for upward mobility is assumed, but many smallholders are not seeking to grow their businesses… [just] simply to provide for their families[16]. Affordability matters, but the 'use case' for new equipment matters more. This means that a decision around which equipment is appropriate should rest with the end user.

Ownership Models. Prior to planning any subsidy, stakeholders should closely evaluate whether lease, group ownership or service models can replace individual purchase options. This may warrant some supply-side support (to develop an appropriate business model) or non-financing demand-side support (for example to aggregate end users into a group, or to help a cooperative with its agri-PUE equipment financing plan). The value of demonstration for agri-PUE equipment is priceless for all parties – the end user, the supplier and (if applicable) the lender. Before any subsidy, the equipment should be piloted.

A long-term view is essential. This includes adapting as the ecosystem develops and replacing 'exit' thinking with 'graduation.' Replace 'exit' thinking with 'graduation'. Subsidies should be phased out in accordance with ecosystem development, with the option to reinstate them in case of economic shocks, poor harvest, etc.[17] A subsidy should adapt as the ecosystem develops and take a realistic view as to how long the challenge(s) might remain and how much it might cost to realise objectives.[18]

Consider the entire agricultural value chain. Improvements in production, processing, or conservation at one point in the value chain are wasted if upstream inputs aren't optimised or downstream outputs are lost. Electric equipment can and should help at various points.

Define success from the start. Stakeholders should agree on long-term objectives, both to know when DSS have been successful and to guide prioritising around inevitable trade-offs (e.g. if stakeholders deem that demand aggregation and a sharing or hire-out model is the best form of support and this presents a mis-match to equipment suppliers' higher volume sales targets or 'market building' objectives). It could be on economic terms: if a subsidy costs less than the (monetised) social value of its benefits, it's been a success.[19] It could be on relative terms: if an end user financing subsidy is a more efficient use of public funding than price discounts to overcome affordability constraints, it's a success.[20] If it measurably improves agricultural outputs, even an entire rural economy, it's a success. Or: a subsidy is a success if it renders itself obsolete, or if it successfully graduates from more interventionist to less over the course of however long it takes for an ecosystem to mature.

[16] Perera et al (2020)
[17] REF
[18] Tearfund (2020), Energy Savings Trust (2023), GOGLA (2021)
[19] Chirwa & Dorward (2013)
[20] Energy Savings Trust (2023)

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Acronyms and definitions

Acronym / abbreviation	Term	Definition
-	Agribusiness	A business working in farming and farming related activities.
Agri-PUE	Agricultural PUE	Equipment used in agricultural value chains to improve output quality, volume or efficiency.
Capex	Capital expenditure	The cost of buying or extending the life of an asset. Capex usually refers to a business's long-term, major costs.
CCF	Concessional consumer financing	A loan made on better-than-usual terms. Consumers are called 'end users' in this paper.
-	Credit	A loan.
DSS	Demand-side subsidy	A financial benefit to individuals or entities that reduces end user affordability barriers to the use or ownership of (in this case) electric agricultural equipment. 'Demand-side' refers to the buyer's side of a seller-buyer relationship.
-	Deposit	An initial payment made to secure a loan, typically as a percentage of the total loan value. Also called a down payment or margin payment.
-	Ecosystem	A complex network or interconnected system.
-	Enabling environment	The framework of policies, regulations, permits, licenses and other legal guidelines that supports a given economic activity.
-	End user	An individual or entity that is the ultimate user of productive equipment. Can be a household, small or medium-sized enterprise such as an agri-business, or group (cooperative, community facility).
-	Equipment	A productive, energy-dependent, physical asset. Also called an appliance (which tends to be smaller), machine(ry) or technology.
FI	Financial institution	A company that facilitates monetary transactions.
IHF	In-house financing	A loan (sometimes called credit) offered by a company involved in the supply chain for a product or asset.
-	Interest / interest rate	The fee charged for borrowing money, usually as a percentage of the value of the loan.
-	Liquidity	Availability of money in cash or another easily exchangeable format.
-	Loan tenor	The agreed timeframe for repayment of a loan.
MFI	Micro-finance institution	A financial institution that provides smaller value loans than regular FI.
-	Off-grid	Not related or connected to a national electric utility's distribution grid.
Opex	Operating expense	Day-to-day costs of running a business.
PAYGO	Pay-As-You-Go	A form of in-house financing whereby the end user of an asset pays the supplier in instalments. The payment models vary; it can refer to a regular payment (e.g. weekly) or a payment made only when the end user needs the asset. In the off-grid solar sector PAYGO is usually digitised.
PUE	Productive use of energy	Activities that involve the utilisation of energy (both electric, and non-electric energy in the forms of heat or mechanical energy) that enables productivity, income generation and improved livelihood conditions. Also called PURE (productive use of renewable energy) and PULSE (productive use leveraging solar energy).[21]
RBF	Results-based financing	Payments made based on achievement of pre-defined milestones.
SSS	Supply-side support / subsidy	Support provided to the seller's side of the seller-buyer relationship.
-	Subsidy	A benefit (usually a payment) given to an individual or entity to remove a burden or to correct a market failure or externality.[22] It is sometimes called an 'incentive' (with less controversy!).
-	Supplier	The seller of a product or service.
3PF	Third-party financing	A loan provided by a financial institution in its role as a 'third party' to a seller-buyer transaction.
-	Value chain	The series of consecutive steps that go into the creation of a finished product.

[21] GOGLA (2023) Powering lives and livelihoods: Scaling productive uses of renewable energy (PURE) – Handbook for governments and development partners, Lighting Global (2019) The market opportunity for productive use leveraging solar energy (PULSE) in Sub-Saharan Africa

[22] Various definitions from Investopedia

1. Introduction

1.1 Objective

The productive use of energy (PUE) in agricultural value chains can build end users' livelihoods through cost savings, improved yields and new value addition. SNV seeks to increase end user access to agricultural PUE (agri-PUE) assets that drive rural development.

Much has been published in recent years on the constraints posed by lack of affordability of agri-PUE. This discussion paper looks specifically at the role demand-side subsidies (DSS) can play in mitigating affordability constraints. In particular, it seeks to contribute to the dialogue on PUE financing by expanding the DSS discussion beyond pricing discounts.

1.2 Scope and approach

This discussion paper looks at agri-PUE affordability from both energy and agriculture sector perspectives. In doing so we recognise that the smallholders and agribusinesses that are referred to as 'producers' by agricultural stakeholders are the very same 'end users' of agri-PUE equipment from the energy stakeholder's point of view. It helps as such to see these individual households and small businesses as integral actors in both energy and agricultural value chains. Our focus is agricultural PUE – that is, equipment used within agricultural value chains and not appliances used by rural households at home or otherwise separate to their agricultural activities. Our emphasis is on electric PUE for off-grid end users, but we do not delve at all into the electricity source, cost or function. There is a very wide range of costs and sizes of assets usable by smallholders (individually or through groups); here we made the generic assumption of a local retail price somewhere in the range of $500-$50,000.

Other important topics we do not address include the environmental (e.g. water, biodiversity, climate)[23] and economic (e.g. staple food production, export food prices) considerations around agri-PUE; the agri-energy nexus topic of bioenergy; nor the the large body of literature on financial inclusion, access to finance, financial technologies ('fintech') and sharia-compliant financing.

Additionally, although it is flagged throughout the paper, it is worth highlighting that affordability is just one of many potential barriers to the uptake of agri-PUE, and DSS are just one of many potential actions that can be taken to improve uptake. Our specific focus, on DSS to address affordability constraints, must be understood within the holistic context of where these challenges exist.

This paper's geographic scope is Sub-Saharan Africa (SSA), though we draw on examples past and present from around the world. We have relied on a literature review and interviews with selected energy and agriculture stakeholders.

2. Scene setting: the opportunity, the challenge and context

2.1 The opportunity: driving livelihoods

Climate change and population growth – among other global factors – are forcing us to improve the way we use land and grow food. A regenerative agriculture sector is one of the lynchpins of a healthy ecosystem; around the world, governments and partners are looking at how to increase farm productivity, reduce land conversion and maintain (or improve!) biodiverse and fertile rural land systems.

Figure 5: The transition to "green" (electric) agri-PUE includes mechanisation, decarbonisation and preservation

[23] Re-purposing agricultural subsidies to account for environmental impacts is a major concern. See FAO, UNDP and UNEP (2021) *A multi-billion-dollar opportunity – Repurposing agricultural support to transform food systems*. Rome, FAO (link), Springmann, M. and Freund, F. (2022) *Options for reforming agricultural subsidies from health, climate and economic perspectives* (Nature Communications) (link) or Cassou, E. (2018) *The greening of farm support programs: International experience with agricultural subsidy reform* (World Bank) (link).

Productivity gains in smallholder agriculture can improve rural livelihoods, by improving outputs, reducing costs, or adding new value. This happens in several ways:

Mechanisation of agricultural production, processing, storage and transport has wide-ranging impacts, including that it can enable women to take on previously male-dominated work. More recently, attention is being paid to environmental impacts of the sector and to 'regenerative' agriculture, a core feature of which is the practice of no-till farming, which requires specialised equipment to penetrate the soil surface in a more targeted way so to preserve soil structure.[24]

Decarbonisation is the replacement of energy intensive diesel equipment with efficient electric alternatives. Shifting smallholders and agribusinesses away from diesel mitigates carbon emissions, albeit from a low baseline, and minimises end users' financial exposure to volatile fossil fuel prices.[25]

Preservation through either cooling (refrigeration or freezing) or drying enables agribusinesses to retain more value of outputs for longer.[26]

All of these (can) involve electric solutions. The opportunities for electric PUE in agricultural value chains are wide ranging (see Table 3) and, if they emerge alongside other trends such as farm consolidation and formalisation, potentially transformative[27]. Despite these opportunities, agri-PUE uptake remains low in developing countries. For example, the rate of smallholder mechanisation in Sub-Saharan Africa is under 10%; in Asia, 30-40% and Latin America 40-50%.[28] Where mechanised, the majority of value is produced with diesel-powered equipment.[29] And much of this value is wasted as an estimated 14% of food produced globally rots before getting to the market.[30] This substantially depresses value in the agricultural sector. Knowing the opportunities that agri-PUE present, how can we facilitate more people using efficient electric equipment?

Table 3: Opportunities for PUE in smallholder agricultural value chains (not an exhaustive list).
*Denotes technologies that are available in electric versions.[31]

Agricultural stage	Production	Processing	Conservation, storage & transport
Temporary crops (planted each season) Cereals, pulses, root + tubers, sugar crops, oil-bearing crops, fibre, vegetables, tobacco, fodder Permanent crops Fruits + berries, nuts, oil-bearing crops, spices, condiments + aromatic herbs, coffee, cocoa, tea, rubber, hops, sisal, hemp	*Water pump / irrigation system *2-wheel tractor for ploughing / tilling, planting *Soil testing kit *Pesticide / herbicide sprayer *Weeding, harvesting	Cleaner[32] Thresher *De-husking / shelling / hulling machine Pounding Grinder *Mill Pulper *Press / oil extractor	*Dryer *Refrigerator *Freezer *Packaging machines (weighing, sealing, labelling) *(Cold) transport
Livestock + fisheries Cattle (beef + dairy), sheep, goat, pig, rabbit, chickens + poultry, work animals (horse, oxen, donkey, etc.), freshwater + ocean fisheries	*Water pump *Napier grass cutter *Milking machine *Egg incubator	*Pasteuriser *Steriliser	

[24] Sims and Kienzle (2017) Sustainable agricultural mechanization for smallholders: What is it and how can we implement it?, Goyal (2023) *How can energy access practitioners energise regenerative agriculture settings?* (Efficiency for Access)

[25] IRENA and FAO (2021) *Renewable energy for agri-food systems – Towards the Sustainable Development Goals and the Paris agreement*. Abu Dhabi and Rome (link)

[26] Daum, T. (2023) *Mechanization and sustainable agri-food system transformation in the Global South: A review*. Agronomy for Sustainable Development 43:16 (link)

[27] For example, a 2020 study by Borgstein, Wade and Mekonnen of the Rocky Mountain Institute (RMI) estimated the potential for electric PUE to generate $4 billion in annual value by 2025 in just six value chains in Ethiopia alone, at a supply-side (sales) value of $380 million. (Source: Borgstein, E., Wade, K., and Mekonnen, D. (2020) *Capturing the productive use dividend: Valuing the synergies between rural electrification and smallholder agriculture in Ethiopia.* Rocky Mountain Institute (link))

[28] Figures from FAO (2018) referenced in SELCO Foundation (2023) 175 *Livelihoods: Sustainable energy driven applications*. But exact figures are difficult to know as estimates are usually made by proxy of 'number of tractors per 1000 farm workers', which disguises various nuances including around sharing and service models, as well as other types of equipment. (Daum (2023))

[29] IRENA and FAO (2021)

[30] Ibid.

[31] Sources include FAO website (Link), Efficiency for Access Coalition (Link), SELCO Foundation (2023), Avila, E. (undated) Productive use report: Evaluation of solar powered agricultural technologies for productive-use applications – a modelling approach. Access to Energy Institute (A2EI) (link)

[32] The example of the Chinese appliance manufacturer Haier is a wonderful reminder that equipment is not always used as its designer intended. Around the year 2000 a farmer complained to the company that his Haier washing machine was full of dirt and not working properly. The technician dispatched to service the machine discovered that it had been used not for washing clothes but for cleaning potatoes the farmer had harvested. Haier subsequently released a new model that could wash both clothes and potatoes. (Sources: interview with Stewart Craine; Forbes (June 17, 2010) Haier: A Chinese Company That Innovates (link))

2.2 The challenge: unaffordable equipment

Governments have long recognised the affordability of agricultural inputs as a barrier (though certainly not the only one) to increased productivity in the sector. Many industrialised and emerging economies have offered subsidised seeds and fertiliser to 'producers' (farmers and agribusinesses).[33] Developing countries, however, have done this much less; instead, they have opted to subsidise food consumers rather than producers.[34] Though agricultural equipment is an important input, there is relatively little written about equipment subsidies in developing countries.[35]

Increasingly, electricity stakeholders are coming to the same conclusion around equipment affordability, albeit from a different angle. Energy access practitioners in Asia and Latin America have known for decades that electricity access, on its own, is insufficient to drive economic growth, and that productive uses must be supported. But early lessons did not translate widely into PUE-integrated planning.[36] In Africa, electrification continued to be seen as an end in itself until fairly recently.

In recent years, as off-grid solar and renewably powered mini-grids expanded their reach in rural areas, stakeholders began to pay more attention to the question of how to increase demand for newly installed power, with focus on the revenue base of the power supplier. Now the dialogue is evolving further to look at how to power agricultural livelihoods with electricity. As part of this shift, electricity and electric equipment suppliers must grapple with the affordability challenge facing their potential customers.

Electric agri-PUE equipment are potentially expensive assets in a price-sensitive market. The concept of 'affordability,' however, consists of more than just 'low-income' end users and 'expensive' products and services. It varies based on household characteristics, cultural norms, seasonality of income and a range of other factors.[37] For agri-PUE equipment, end user affordability includes:

- Capital expenses (capex) and operating expenses (opex)
- Liquidity, cash flow, variability of income
- Cost of and access to savings options
- Cost of and access to capital
- Opportunity costs, uncertainty and risk aversion
- Costs of switching from prior method(s), 'stacking' or sub-optimal use

The 'affordability gap' for agri-PUE is the difference between the total cost of owning or using a piece of equipment (Box 2)[38] and the end user's ability and willingness[39] to overcome the various constraints listed in bullets above.

Box 2: Expenses associated with using agri-PUE

The total cost of agri-PUE equipment can include:

Capex: one or more of the below asset costs
Up-front purchase price
Deposit + balance payments (loan / lease / rental)
Loan collateral
Repairs + maintenance (e.g. battery replacement)

Opex: electricity, fuel, agricultural inputs, labour, theft prevention, asset depreciation

As means of mitigating affordability constraints, demand-side subsidies have gone in and out of fashion, with justified concerns over effectiveness, cost and market distortion. But the agriculture sector is far more accustomed to supporting its producers and end users than the energy sector. For perspective: globally, both on-grid and off-grid electricity 'producers' (utilities, mini-grid developers, or off-grid solar companies) and on-grid 'end users' (buyers of kilowatt-hours (kWh)) have long been subsidised[40].

[33] Chirwa, E. and Dorward, A. (2013) Agricultural input subsidies: changing theory and practice. From Oxford Academic: Agricultural input subsidies: The recent Malawi experience, chapter 2, pp15-45 (link) | A farmer or agribusiness is an agricultural producer and an energy/equipment end user.

[34] Baliño et al., 2019 as referenced in FAO, UNDP and UNEP (2021) *A multi-billion-dollar opportunity – Repurposing agricultural support to transform food systems*. Rome, FAO (link)

[35] A 2018 systematic review of agricultural input subsidies in low- and middle-income countries found no examples of equipment subsidies. (Hemming, D., Chirwa, E., Dorward, A., Ruffhead, H., Hill, R., Osborn, J., Langer, L., Harman, L., Asaoka, H., Coffey, C., Phillips, D. (2018) *Agricultural input subsidies for improving productivity, farm income, consumer welfare and wider growth in low- and lower-middle-income countries: a systematic review*. Campbell Systematic Review (Link)

[36] ESMAP (2022) *Accelerating the productive use of electricity: Enabling rural energy access to power economic growth.*

[37] SELCO Foundation (2022) Financing for SDG7 Driven Livelihoods, Gill-Weihl, A., Ray, I., Kammen, D. (2021) *Is clean cooking affordable? A review*. Renewable and Sustainable Energy Reviews 151 (Link), SE4ALL and Climate Policy Initiative (2022) *The role of end user subsidies in closing the affordability gap*

[38] Includes insights from Greencroft Economics

[39] Willingness to pay and related concepts including risk aversion, uncertainty, lack of awareness, and sociocultural factors are major components of an end user's decision to buy (or use) agri-PUE equipment. This paper does not delve into these topics; our focus is on ability to pay.

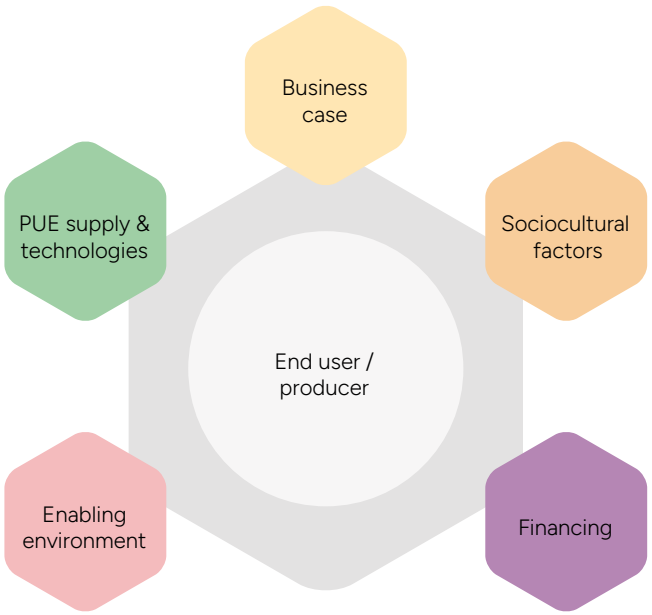
[40] Nash, S. and Khinmaung-Moore, J. (2020) D*esigning sustainable subsidies to accelerate universal energy access: A briefing paper on key principles for the design of pro-poor subsidies to meet the goal of sustainable energy for all.* (Tearfund)

But the energy sector in developing countries has generally balked at off-grid asset 'end user' subsidies, even as off-grid energy users typically pay high per-kWh costs compared with on-grid end users.[41] Electric agri-PUE companies have received supply-side support, but sales volumes for even the most popular technologies remain orders of magnitude below projections of what is a serviceable market. At this point in the dialogue around PUE, and for purposes of this work, the question has evolved from 'should we' subsidise to 'how to' subsidise.

2.3 The context: the agri-PUE ecosystem

Affordability constraints are shaped by five over-arching elements in the agri-PUE ecosystem: PUE supply & technologies, the business case, the enabling environment, sociocultural factors, and financing.[42] The maturity of the ecosystem determines what demand-side support may be appropriate – a question we'll examine in Section 4. First, we look at these five elements briefly.

Figure 6: Five elements of the agri-PUE ecosystem



PUE supply and technologies | In an ideal market, companies supply appropriately designed equipment to rural sale points at competitive prices. But many developing countries have agricultural regions with under-developed supply chains, and most off-grid electric agricultural equipment is still relatively untested.[43] Many electric agri-PUE are intended for on-grid use by larger commercial agribusinesses, rendering them too big or inappropriately designed for smallholder off-grid use.[44] In the past several years, more off-grid solar and mini-grid companies have begun to sell solar water pumps (SWP), electric grain mills and off-grid refrigerators and freezers. But beyond these (relatively) more popular technologies, many smallholder end users have not seen or even heard of electric agri-PUE.[45]

In major urban centers across the developing world, companies in the agribusiness or energy supply chains carry some, though not many, off-grid electric equipment options. But the logistics of last-mile supply and after-sales servicing can be prohibitively expensive and tend to be a deterrent to operating in more remote areas or less-mature ecosystems. Where they do operate, last-mile distributors have an important but undervalued role in the PUE supply chain as they are often the main interface with the end user, bear costs of end user demonstration and training, and struggle to keep inventory of expensive or niche products. In 2022 the Global Distributors Collective reported that selling PUE products is too risky for last-mile distributors without subsidy.[46]

Equally relevant to technical specifications or retail pricing are the use characteristics of the equipment. The value proposition of electric agri-PUE is highly dependent on its size, traditional usage habits, moveability and frequency of use, as well as whether the process it is used for is power-intensive (requiring a lot of energy) or control-intensive (requiring decision-making)[47]. Moveable assets are harder to use as collateral with lenders, as there is a higher risk of them being resold, stolen or used for something other than their original intended purpose.[48] On the other hand, machines that can be transported easily can be shared, lent or hired out between farmers. End users will also consider how often and for how long at a time they would need to use a machine; something that is only useful part of the year is unlikely to be purchased by an individual. E.g. Sumba Sustainable Solutions found their

[41] Consumer price per kWh can be as high as $0.70-1.00 for mini-grid or off-grid solar power as compared with $0.10-0.20 for grid power. (The latter is subsidised) See Andrew Herskowitz (2017) Rethinking the cost of off-grid power: Let's do the math
[42] IRENA and SELCO Foundation (2022) Fostering livelihoods with decentralized renewable energy: An ecosystems approach
[43] Gorjian, S., Ebadi, H., Trommsdorff, M., Sharon, H., Demant, M., Schindele, S. (2021) The advent of modern solar-powered electric agricultural machinery: A solution for sustainable farm operations. Journal of Cleaner Production, vol. 292
[44] Stakeholder consultations, Avila (undated), SELCO Foundation (2023) *175 Livelihoods: Sustainable energy driven applications*, van Loon et al (2020)
[45] IRENA and FAO (2021)
[46] GDC (2022) *Selling productive use of energy products to last mile consumers: Lessons learned*
[47] Pingali et al quoted in Daum (2023)
[48] Efficiency for Access (2021) *Business model innovations addressing affordability: Case studies*

electric mill clients were lagging in repayments because its use was limited to one crop's harvest cycle. To increase its use, they worked with the manufacturer to design a mill that comes with multiple attachments that could process different commodities throughout the year.[49]

Case study 1: understanding the use-case

We have mentioned some alternatives to the purchase of agri-PUE equipment, including service provision, sharing or rental by either a supplier and/or end user(s). Here we highlight two particularly relevant demand-side 'use-models' – that is, financial and social strategies employed by non-specialised smallholder equipment users to improve the business case for using equipment. These are not typically mentioned in the off-grid electrification or electric PUE literature but are commonly seen in the agricultural mechanisation space.[50]

RENTAL OR SERVICE BY END USER | One use-model is where an individual buyer / end user rents out her equipment to others for a fee. This is different to a supply-side rental or service model in that the buyer-owner is herself an end user, and does not have specialist knowledge of the equipment. This could be done a primary business endeavour or a secondary non-farm source of income. One study in Bangladesh noted that the 2% of farmers in the country that owned a power tiller were able to service the 72% of all farmers in the country that were considered to have mechanised this facet of their operations; similar models were found in Sri Lanka, Nepal and Thailand.[51]

In northern Ghana, one study found that both small and medium-sized farmers had rented out their tractor or provided it as a service to other farmers in order to supplement low returns on their own land, the area of which was too small on its own to warrant purchase of the equipment. Not only were tractor buyers actively considering rental/service opportunities within their communities when deciding to make a purchase, but the additional income was deemed essential for their farm to be profitable, and so was offered competitively by multiple smallholder tractor-owners at prices determined by the market.

An interesting additional point about the Ghana case study is that end users were purchasing second-hand imported tractors despite the availability of a government subsidy for new tractors. Farmers were not interested in the brand(s) of government subsidised equipment, and the subsidised prices were still higher than those of second-hand imports.[52]

END USER AGGREGATION | There are several permutations of this category of use-model. One is a hub where agri-PUE equipment is available for rent by individual end users, which could be owned and/or run by government, a non-government intermediary[53] or a specialised equipment supplier (all 'supply side'), or an end user collective such as a cooperative (demand-side). Equipment might be hired out (removed from the central location and later returned) or operated on-site by a dedicated technician.

Our initial review of agricultural literature indicates that government-run aggregation (e.g. by which an agricultural extension office owns and hires out large equipment) is ineffective and does not say much about supplier-run hub or service models. Conversely, there is increasing interest within the off-grid electrification space in private (supplier) run 'innovative' hub or fee-for-service models and relatively little about government-sponsored versions.

Sims and Kienzle (2017) offer several examples from Europe, such as of agricultural 'machinery rings' (in Germany) or farm machinery cooperatives called CUMAs in France and Benin, where there has been notable success with "highly participatory collective investments."[54]

Self-organised groups such as cooperatives can mitigate various affordability constraints by enabling collective ownership (a hub model) whereby resources are pooled and assets are shared (or rented out), or facilitating individual ownership by improving access to financing (through, for example, shared repayment liability) or bulk purchasing (by which end users can access wholesale or discounted prices).

[49] GDC (2022)
[50] E4A (2023) Business-model-innovations-addressing-affordability
[51] Ahmed 2013 and Biggs and Justice 2015 in Diao et al (2016)
[52] Diao et al (2016) referring to the IFPRI/SARI survey
[53] For example, the Demand Aggregation for Renewable Technology (DART) platform in Nigeria, which is funded by the Global Energy Alliance for People and Planet (philanthropic capital), alongside All On (Nigerian investor) and Odyssey Energy Solutions (private company).
[54] Sims and Kienzle (2017) - CUMA stands for Coopératives d'Utilisation de Matériel Agricole.

These use-models are compatible with, indeed mutually enhancing of, all DSS. Taking it a step further – they should be considered in the first instance as an alternative to DSS. This can be particularly relevant in mixed ecosystems, where (for example) a commercial market has enabled some uptake of agri-PUE equipment, but affordability constraints still limit wider use. Reaching these harder populations could be managed through more targeted price discounting or heavily concessional end user financing – or through facilitation of rental, service or aggregation models

Business case | Indeed, a large part of the 'business case' for the end user – whether it makes financial sense to buy or use the equipment – is how it is used and whether there is a business model that matches this. For example, not all agri-PUE needs to be individually owned – far from it. Most products above a certain size[55] and capacity are very expensive, and best owned collectively (e.g. through a cooperative, which aggregates end user demand), leased or rented (e.g. by the day[56]), or operated by a local business as a service (e.g. where end users can pay a fee to store their vegetables in a walk-in cool room). These models are widely viewed as the way forward, although are not yet mature in the electric agri-PUE sector.[57] When considering how to reduce affordability constraints, this set of considerations is the single most important lever outside of – indeed, prior to – pricing or financing interventions.

Market linkages are the other main factor in a business case, whether they are considered explicitly by the end user or not. The availability of other necessary inputs – e.g. electricity, land, seeds and fertiliser – shapes how easily and cost-effectively an agri-PUE end user can optimise her equipment. Likewise, the downstream connections to buyers, transporters and processors are essential for value to be realised (and converted to cash).[58] Some companies are undertaking these linkages on behalf of their clients, e.g. S4S Technologies which provides inputs support and then purchases + aggregates the outputs.[59] An intervention that mitigates affordability constraints at one 'node' in an agricultural value chain (say, to improve crop yields through mechanisation) can be wasted if the downstream linkages (such as cold storage or packaging) are not optimised. The reverse can also be true; an intervention for cold storage, for example, may be partly 'wasted' if upstream agribusinesses are under-producing through manual labour.

Enabling environment | Agri-PUE affordability is particularly affected by fiscal policy that either taxes or subsidises energy and agricultural products (or neither). If electric agri-PUE equipment is taxed while diesel is subsidised, for example, the price signals to end users will not support uptake. Beyond this, a lack of enforceable consumer protection by government can mean poor quality equipment or 'predatory' loans in the market – a potentially high price to pay for end users. Agriculture ministries may promote mechanisation (by diesel or solar), operate regional or local extension offices, or set purchase prices on key crops – all shaping affordability and willingness to pay. What is needed is integrated cross-sector planning both between energy and agriculture sectors, and more broadly around land management, water use, carbon markets, biodiversity, microfinancing, digital lending & mobile money – all of which have ripple effects on costs and decisions for end users. National (as well as sub-national and regional) frameworks should support 'green' mechanisation while maintaining a holistic vision for rural prosperity that accounts for environmental, social and economic impacts (and trade-offs).

Sociocultural factors | Sociocultural factors such as norms, language and social aggregation systems contribute to both realities and perceptions of affordability. These may have a positive effect on agri-PUE uptake, for example if there are norms around bartering in lieu of cash transactions, collective harvesting community traditions, availability of remittances from younger generations that have migrated to cities, social support and aggregation systems such as for risk mitigation or entrepreneurship, or religious rules such as those prohibiting very high interest rates. They could alternatively have a negative effect, for example, where there are gender codes limiting women's or men's work, language barriers that diminish financial literacy or access to training, or land rights traditions that discourage youth from taking up farming.

[55] SELCO (2022) *Financing for SDG7 Driven Livelihoods*

[56] Lease models could be perpetual, akin to a service model where the product is operated by the end user. Simusolar (Tanzania) offers mobile-payment enabled SWP leasing to farmers. (Source: Johnstone, K., Perera, N., Garwide, B. (2020) *Small business, big demand: Facilitating finance for productive uses of energy in Tanzania*. Hivos / IIED)

[57] Sims and Kienzle (2017) , Efficiency for Access (2021), GDC (2022), van Loon, J., Woltering, L., Krupnik, T., Baudron, F., Boa, M., Govaerts, B. (2020) *Scaling agricultural mechanization services in smallholder farming systems: Case studies from sub-Saharan Africa, South Asia and Latin America*. Agricultural Systems 180 (link)

[58] Examples in Avila (undated)

[59] Efficiency for Access (2021)

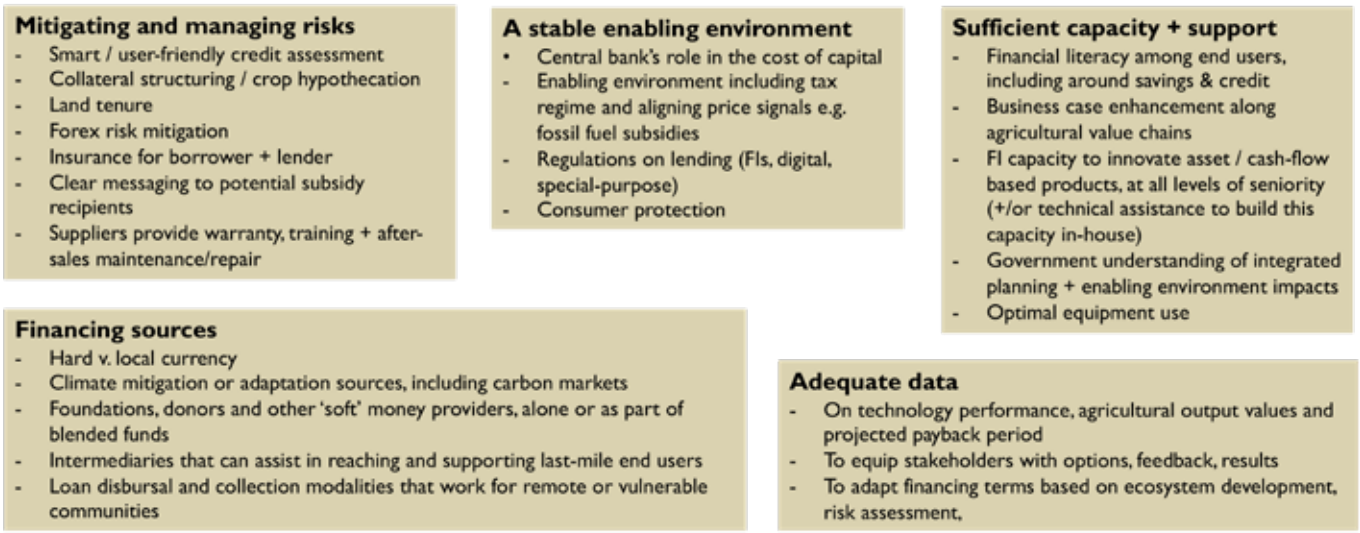
These factors affect awareness of agri-PUE benefits and uses, capacity for new technology adoption, and in-person experience of the technologies – all of which shape end user ability to pay or perception of value (and thereby willingness to pay).

Financing | The financial sector is uniquely positioned to offer solutions to many of the affordability constraints facing (potential) end users – but rarely does. Options must exist for end users to access credit. Though it is more often a challenge in Sub-Saharan Africa than in South and East Asia, the latter places having higher population densities and more mature MFI options[60], and may be easier for cooperatives to access than individuals, third-party asset financing for agri-PUE products is often not available in areas near to end users and on affordable terms. Local FIs that are 'embedded' in local conditions might be willing to lend for smaller ticket items, but balk at larger ticket sizes and/or longer repayment terms, while regional FIs are designed to finance larger ticket items, but lack connection to the borrowers. The penetration of FIs in off-grid areas varies widely between and within countries, meaning third-party financing may not be an option unless there are digital lenders that can fill in these gaps (an increasingly viable option in some countries[61]). Where there is a local culture of micro-lending, either formally or informally, FIs may still run up against a lack of familiarity with the technologies, risk aversion and few (if any) financial products that match the terms needed by potential agri-PUE borrowers.

Out of necessity, agri-PUE equipment suppliers may offer 'in-house' credit terms. The emergence in the off-grid solar sector of Pay-as-You-Go (PAYGO) presents opportunities for agri-PUE both to learn from a decade of experience and (potentially) to add agri-PUE into existing in-house financing portfolios. But capacity to offer credit can differ between vertically-integrated brands (where one company manages the entire supply chain and customer sales relationship) and situations where last-mile distributors are selling equipment from various manufacturers. The latter have run into significant challenges with having sufficient working capital to manage PAYGO credit.[62] Credit terms are sometimes offered within agricultural value chains as well, for example by downstream buyers like supermarkets or off-takers/ aggregators. These companies may see it in their interests to facilitate uptake of agri-PUE equipment by agribusinesses, and may also be in a position to accept agricultural outputs in lieu of cash repayment.[63]

There are myriad factors shaping the capacity and maturity of the financial sector to support agri-PUE. If there are options to aggregate demand for financing, for example, such as through purchasing groups or joint liability groups, this is another affordability solution used widely across the renewable energy space (among others).[64] Some other factors are noted in Figure 7.

Figure 7: Factors shaping the capacity and maturity of the financial sector



The elements outlined above play out in myriad permutations in real life.

[60] Johnstone et al (2020) note that financing has been increasingly available for group borrowing in Tanzania.
[61] Examples of specialist agricultural asset financiers include Apollo Agriculture (Kenya), Farmerline (Ghana), EnerGrow (Uganda)
[62] GDC (2022)
[63] IFAD (2012) Agricultural value chain finance strategy and design: Technical note
[64] Interview with Stiftung Solarenergie; also, the example of the US in the 1930s aggregating demand for electricity and subsidizing electric appliances is widely referenced. (See here, here or here)

Case study 2: affordability is just one piece of the puzzle

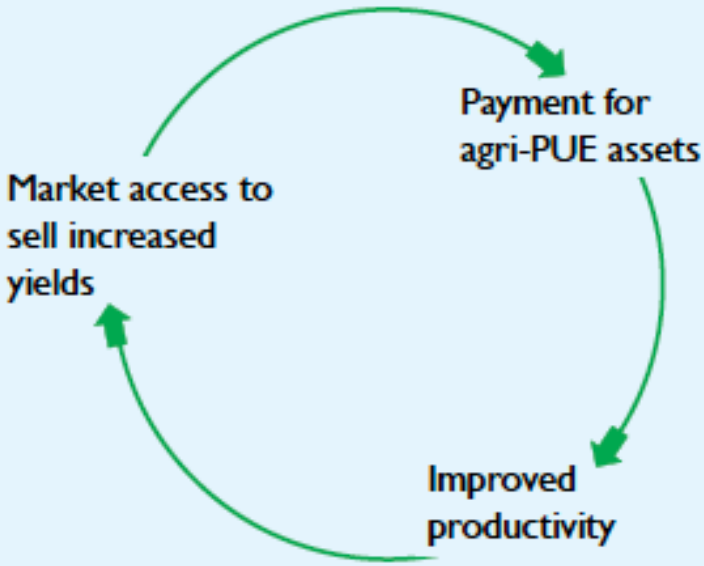
A grant-funded contract farming pilot in Malawi illustrates how important 'wraparound' factors are to the success of a demand-side subsidy for agri-PUE.

The Renewable Energy for Agriculture (RE4A) project (2021-2023), implemented by Modern Farming Technologies (MFT) a Malawian social enterprise, sought to test a contract farming model to give women farmers access to PUE equipment for agricultural purposes.[65] MTO offered women farmers in Chinteche, Malawi a rent-to-own scheme for two agri-PUE technologies (solar water pump and solar-powered refrigerator) alongside an 'end to end' solution comprising access to the technologies, training and extension services, and market linkages.

The products were provided to women's cooperatives with a zero-interest loan that was repaid in increments of 25% of each crop sale value. Analysis of the project finances has indicated that the income generated by participants was sufficient for them to have obtained a commercial loan (17.3% APR, the current rate in Malawi). But banks would almost certainly need reassurance to lend, including in the form of technical support for the farmers and market linkages. (As this pilot did not attempt to link the farmers with financial institutions, there was no mention of the role, if any, of other risk mitigation support needs).

One of the main lessons that emerged was that three intersecting and causally related elements are essential to success. Uptake of agri-PUE technology, the resultant improvements to agricultural production and access to markets for sale of improved products are inseparably linked (Figure 8) – each enables the next.

Figure 8: If one element is missing, the intervention can fail (Source: Practical Action)



[65] Practical Action (2023) Learning brief: Contract farming and access to energy for women farmers in Malawi

2.3.1 Ecosystem maturity – signals and implications

For funders looking at how to support the agri-PUE ecosystem, it can be helpful to recognise differences in ecosystem maturity. Table 4 offers a stylised breakdown of what a weak, transitional, and commercial ecosystem might look like.

Table 4: Characteristics of less and more mature ecosystems[66]

Element		Weak ecosystem	Transitional ecosystem	Commercial ecosystem
End user status	Type of farming	Subsistence	Subsistence + local market	Subsistence + commercial
	Degree of mechanisation	Manual	Manual + diesel	Diesel or electric
	Affordability	None/low	Low/mid	Mid/high
Market ecosystem	Sociocultural | Willingness to pay / awareness	None/low	Low/mid	Mid/high
	Supply & technologies | Equipment availability / pricing	Low / non-competitive	Mid / comparable	High / competitive
	Business case | Input & output linkages	Limited	Adequate / developing	Robust
	Business case | Demand aggregation	Risk management Self-help, village savings groups	Risk management + entrepreneurial Cooperatives	Entrepreneurial + commercial Cooperatives, purchasing groups
	Financing | Access to financing	None/weak	Weak/some	Some/many

We can map sub-national geographic areas to these maturity types when considering demand-side interventions.

[66] Stakeholder consultations, EnDev (2021) *The Vulnerability Access Index (VAI): A pro-poor approach to develop solar markets in rural and vulnerable areas of Tanzania*. Africa Clean Energy and Open Capital Advisors (2020), *Demand-Side Subsidies in Off-Grid Solar - A Tool for Achieving Universal Energy Access and Sustainability*, GOGLA (2021), SNV (2021) Localization of financing for off-grid energy, SELCO Foundation (2020) *Financing basic energy access*

3. Demand-side subsidies for agricultural PUE: a menu of tools

Keeping in mind the context presented in Section 2, we now turn our attention to the range of demand-side subsidy tools.

3.1 Three mechanisms by which demand-side subsidies mitigate affordability constraints

Each DSS tool (Figure 1) addresses a specific affordability constraint in one of three ways:

- Cost reduction, whereby the total cost of buying or using the equipment is less than it would be at market rate
- A structural change in cost or payment terms, or
- Risk mitigation to either the end user or the lender, in order to enable an equipment loan.

These can be used individually or in combination. Table 5 shows how they relate to specific affordability constraints.

Table 5: End user affordability constraints and the three mechanisms that mitigate them

Low ability to pay...[67]	Affordability constraint	Subsidy mechanism to relieve the constraint
Retail price	Capex, access to savings, access to capital	Cost reduction (price discount) or structural change (obtain a loan)
Loan deposit	Capex, access to savings	Cost reduction (reduced deposit cost) or structural change (reduced deposit %)
High interest loan	Capex, cost of capital	Cost reduction (reduced interest burden)
At regular intervals or within a certain timeframe	Liquidity	Structural change (modified terms)
Operating expenses	Opex	This constraint is not directly addressed here, although it is extremely important. Indirectly, any reduced interest burden or flexibility in loan repayment terms would help to mitigate cash flow constraints, in theory freeing up money to pay for opex.[68]
Any of the above	All	Risk mitigation

[67] This table focuses on ability to pay. As noted earlier in this document, willingness to pay (e.g. overcoming risk aversion or lack of awareness) may also be improved by one or more of these mechanisms, particularly risk mitigation.

[68] Opex is an interesting topic that we don't have space to cover sufficiently here. The conventional wisdom is that electric equipment has higher capex but lower opex as compared with diesel. But compared with human or animal labour, this equipment brings new expenses. Electricity, repairs and maintenance, transport, and protection from theft are all possible new expenses.

3.2 Subsidy interventions and tools

3.2.1 Spectrum of demand-side interventions

A range of demand-side interventions can mitigate affordability constraints (see Figure 9). The first three are the focus of our analysis.

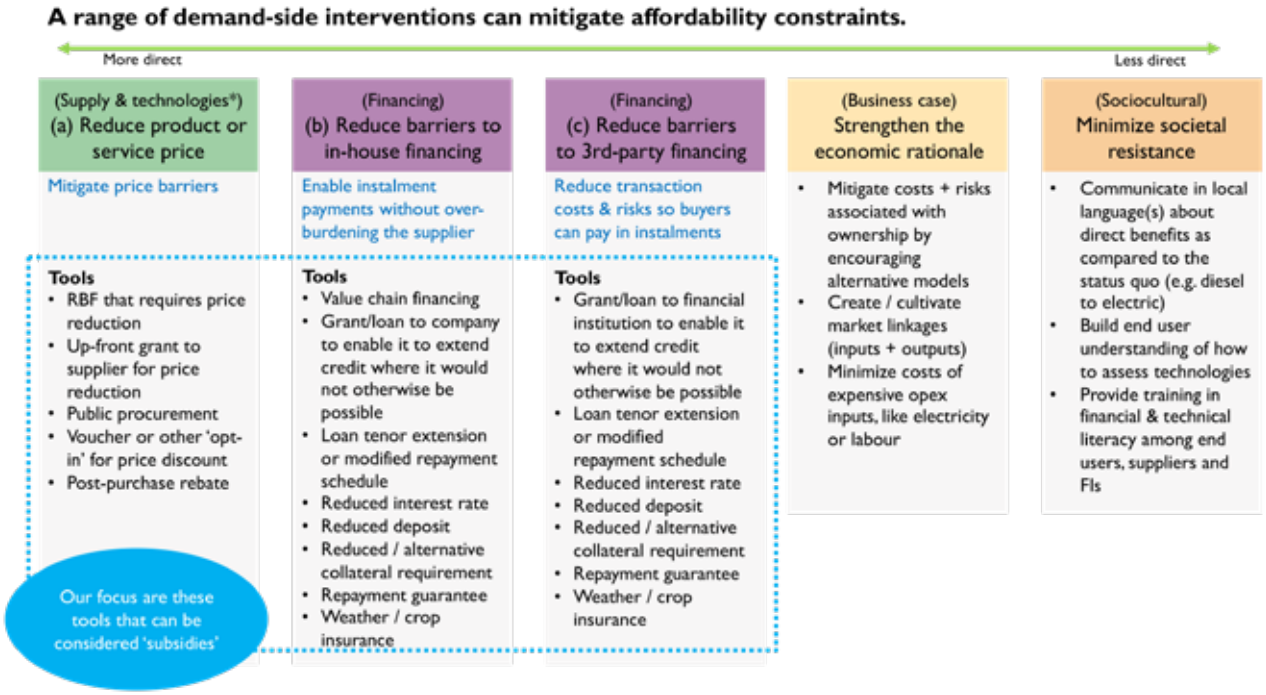


Figure 9: Range of direct and indirect demand-side interventions (Source: author's own)

Energy sector publications use varying definitions. For clarity, here we consider *demand-side subsidy* to be the umbrella term, and *end user subsidy* (called a price reduction below) just one of a menu of DSS options. Additionally, among energy stakeholders there are support mechanisms considered to be 'demand-side' by some and 'supply-side' by others (these include concessional consumer financing and risk guarantees). By our definitions, all of those listed below are demand-side.

3.2.2 Price reduction

A price reduction[69] is the most direct way to increase affordability. This suite of tools is what people *typically* think of as 'end user subsidy.' They reduce the asset cost (capex) or its usage (opex) and in doing so, reduce associated interest costs (if any). A price subsidy should target end users who cannot afford the product ***nor*** access end user financing – e.g. the extreme poor, those living in refugee settlements, those in remote areas.

Stakeholders should consult and consider investors' views before implementing a price subsidy, as it might be seen as positive (a boon to the bottom line or a way of priming the market by early adopters who can then make word-of-mouth recommendations) or negative (encouraging of unsustainable expansion).

Pros | This sends a direct signal to potential buyers. When well-targeted, it can markedly improve uptake of a product and may be less costly to administer than concessional end user financing.

Cons | With this kind of intervention, there is a risk of leakage (subsidised product being bought by those who could afford full-price) and unsustainable price expectations both concurrently (neighbors also want a subsidised price) and chronologically (people are resistant to paying full price once the subsidy is removed). These interventions tend to be vulnerable to gaming by all stakeholders.[70]

[69] We distinguish between price and cost: price is what is made available to the end user, and cost is what is incurred by the end user (which may be different to the price).

[70] GOGLA (2021)

Table 6: Subsidy tools to reduce product price

Tool	Description	Comments / examples
1a. Results-based financing (RBF) that requires a supplier(s) to reduce its end user price	• Pre- and post-sale grants given to suppliers that agree to discount their retail pricing for some (or all) end users, often in a specific geographic area or who meet certain criteria (targeting). • Participating companies are identified by the subsidy funder. This enables the funder to control for product quality (only certain products are eligible) but often favours larger, more digitally savvy companies that can administer the cost reduction, targeting and data collection required. • RBFs put onus on company to front the administrative / logistical costs of making the sale.	• E.g. the Nigeria Electrification Project is offering $60 million in post-sale grants that can cover up to 60% of SHS system costs. 20% of the grant (<12% of price) must be used to reduce the end user product price. The grant amount is fixed for each system size and reduced over the course of the programme. The RBF targets 'off-grid locations or underserved populations'.[71] • Companies may struggle once subsidy is removed to return to regular pricing.
1b. Up-front grant to supplier(s) to cover price reduction		
1c. Public procurement	• Government purchases products in bulk (potentially at a discount) and distributes products to a target population either for free or at highly subsidised price. • Government agency (such as an agricultural extension office) purchases and maintains equipment and hires it out.	• The track record of government-sponsored mechanisation support has not been very good [72], with the notable exception of solar water pumping.
1d. Voucher or other 'opt-in' given to end users by which they can access a price discount	• A physical or digital voucher that can be redeemed for a price discount with participating suppliers is given to targeted populations. • Voucher schemes offer end users a choice of suppliers and technologies, while retail prices remain constant.[73]	• E.g. the Togo CIZO programme provides every rural household ~$4 a month toward cost of an off-grid solar product. Verification is important to ensure the same households do not benefit more than once.[74]
1e. Pre- or post-purchase rebate	• Most rebates do not reduce the price paid by the end user up front, but do reduce the cost overall. This tool could be used to reward continued usage or to cover the end user's operating costs. • In many countries this is delivered as a tax rebate, but it could be done on any timeframe (e.g. immediately post purchase) and delivery model (e.g. mobile money). Could be paid by the supplier or by a third party (government, an NGO, etc). • A pre-purchase rebate works as part of replacement or trade-in programmes, whereby a funder targets early replacement of energy-intensive equipment. By turning in the less-efficient model, an end user accesses a discounted price for an eligible new product.[75] • Post-purchase carbon payments could be considered a rebate.	• Particularly relevant for a situation targeting the replacement of a less efficient asset with a more efficient asset. Used widely in industrialised countries.[76] • E.g. Cash for Appliances: A $300 million 2010 US programme to conserve household energy and stimulate the economy. Buyers of eligible highly-efficient appliances got a post-purchase rebate. • E,g. Cash for Clunkers was a 2009 US programme to encourage replacing old cars with high fuel-efficiency alternatives. ~700,000 end users got $3,500-$4,500 toward the cost of a new car in exchange for handing over their old model. The programme boosted new car sales and (some say) helped pull the US economy out of a slump.[77] • E.g. ATEC and MECS are piloting a 'Cook to Earn' scheme whereby households using electric cookers (instead of fuel-based stoves) will earn carbon revenues directly via mobile money.[78]

[71] Nigeria REA
[72] Sims and Kienzle (2017), Interview with Alex Malla, Daum (2023)
[73] ACE TAF (2020)
[74] ESMAP (20220 Designing public funding mechanisms in the off-grid solar sector
[75] Beuttner, T. and Madzharova, B. (2019) *Subsidies for energy efficient appliances: Consumer response and program design*
[76] BASE (2019) *Manual of financing mechanisms and business models for energy efficiency* (link)
[77] Science News, Phys.org
[78] Batchelor, S. (3 November 2022) Blog: *ATEC & MECS to pilot digitized 'cook to earn'* (link)

3.2.3 Reduced barriers to in-house financing

Reducing barriers to in-house financing (IHF) enables end users to pay in instalments. 'In-house' means 'offered by a company involved in the end user's input (equipment) or output (agricultural value) supply chain'. The difference to third-party financing is that IHF is not offered by an FI. Energy stakeholders might think of this as credit offered by agri-PUE equipment suppliers, who could be one of several types of roles within a supply chain: a vertically integrated manufacturer-supplier, a solar or hardware distributor selling electric PUE alongside power solutions, or a last mile distributor selling a range of agri-PUE products and brands. Agricultural off-takers (companies buying agricultural outputs) also may provide credit to producers/end users in order to boost quality or quantity within the value chain.[79]

Subsidised IHF can either enable a commercial end user credit arrangement where it would not otherwise have been possible, or enable concessional terms. Reducing barriers to IHF – whether on commercial or concessional terms – is most appropriate if end users could afford equipment on a modified payment plan but do not have access to third-party financing. It would require for the companies to already be equipped to assess end users' credit worthiness and to manage the administration of repayment.

Pros | Specialist suppliers are well-versed on the technology and its optimal use, which may enhance their ability to lend appropriately (non-specialist last mile distributors may be burdened by this, on the other hand). A credit arrangement encourages Know-Your-Customer (KYC), end user data collection and a long-term after-sales relationship, which is beneficial to end users and suppliers alike.[80] For companies that might want to offer products on credit but do not have the patient capital / cash flow to do so, subsidising them can reduce liquidity constraints to lending.

Cons | The agri-PUE equipment supplier has the burden of assessing the end user's credit worthiness, funding the modified cash flow, and managing payment collection and non-payment.[81] These challenges mean IHF is more likely to be offered by larger, more financially sophisticated companies, which can preclude local suppliers and in doing so limit end user choice.

Table 7 provides a summary of tools that can help a company to extend credit to an agri-PUE end user. With the exception of value chain financing (2c below) these tools are similar to those used by third party financial institutions (FIs), so we shall discuss each tool in the next sub-section.

Table 7: Subsidy tools that reduce barriers to in-house financing

Tool	Description	Comments / examples
2a. Working capital loan for companies to on-lend[82] **2b. Grant or loan to companies to extend favourable credit terms**	• Enables in-house commercial credit where it is otherwise not possible, thereby enabling end user purchase or use; or • Provides favourable (concessional) terms such as reduced deposit amount, reduced price premium (equivalent to interest) or extended repayment period (tenor). • On-lending may be via PAYGO or non-digitised credit. • Can work for both purchase and fee-for-use business models.	• A recent study of concessional consumer financing in the off-grid solar sector found that the most effective way to improve affordability is to lengthen PAYGO payment terms. This would require additional working capital to cover a slower repayment schedule, administrative costs (e.g. consumer engagement to encourage full repayment), a longer warranty and additional maintenance costs (as the equipment ages).[83]
2c. Value chain financing & contract farming	• Agricultural off-takers or others in the agri value chain may offer equipment on credit or hire it out to upstream actors such as farmers or agribusinesses to improve the quality, quantity or timing of outputs. (Re)payment may be in the form of cash or crops.	• Value chain financing instruments include receivables financing, physical asset collateralisation, and various forms of risk mitigation. Ideally this is a temporary measure (like other IHF) to develop borrowing experience and local lending confidence.[84]
2d. Repayment risk mitigation to company	• A repayment guarantee, crop insurance, collateral or other risk mitigation instrument reassures companies sufficiently that they offer (commercial or concessional) credit to end users.	• Credit linked crop insurance is thought to be helpful in unlocking credit, but evidence to support the idea is scant. Agribusinesses or equipment suppliers lending within a value chain may choose other risk mitigation measures like collateral or crop hypothecation.[85]

[79] IFAD (2012)
[80] ACE TAF (2020) Design principles for demand side subsidies in off-grid solar
[81] GDC (2022), stakeholder interviews
[82] This is presented here specifically as something that unlocks in-house (commercial or concessional) credit where it would not otherwise have been possible.
[83] Energy Saving Trust (2023) *The road to zero interest: The potential role of concessional consumer financing in energy access*, interview with Greencroft Economics
[84] IFAD (2012) *Agricultural value chain finance strategy and design*
[85] ILO and IFC (2017) *Unlocking smallholder credit: Does credit-linked agricultural insurance work?*

3.2.4 Reduced barriers to third-party financing

Reducing barriers to third-party financing (3PF) mitigates the cost and risk of lending (or borrowing) so that end users can pay in affordable instalments. 3PF is credit supplied by a brick-and-mortar FI or a digital lender to an individual, agribusiness, cooperative or other entity. FIs range from informal and unregulated (e.g. savings and credit cooperatives) to highly regulated (commercial banks).

This group of subsidy tools enable an end user loan – which may be commercial or concessional – that is otherwise not available to the end user. This is done by solving for specific retail or loan affordability constraints. Concessional consumer financing is increasingly in focus among off-grid energy stakeholders, as it becomes more evident that universal access targets will not be met with in-house financing alone.[86] This suite of tools has been used in government agri-subsidy programmes around the world, e.g. low-interest loan programmes were integral to the Green Revolutions in Asia.[87]

Pros | FIs are designed to disburse loans, whereas equipment suppliers are not.[88] Concessional lending can address the 'poverty tax', which is the premium paid by the poor for the flexibility of buying in smaller units or in instalments. If the repayment period can be extended beyond five years (a timeframe compatible with affordable instalments and greater potential repayment rate), subsidised 3PF allows either for recycling of repaid funds into new loans or for a net decrease in the total cost of the subsidy as funding is recouped.[89] Supporting a revolving fund at a bank for 3-4 years gives the bank an example with which to go to their board and raise more money.[90] Agri-PUE markets need de-risking mechanisms of all kinds to stimulate investment.[91] Concessional 3PF can complement a price reduction, such as to cover the non-subsidised portion of equipment cost.[92]

Cons | Administration of concessional 3PF is time and resource-intensive, and FIs may not have the capacity to do it, particularly for agri-PUE equipment they may not be technically familiar with.[93] The process of linking an interested buyer to a lender is not always easy, and many agri-PUE suppliers and last mile distributors have sought out partnerships with third-party financiers with little success.[94] Agricultural credit programmes have long been critiqued as too expensive for the funder, plagued by (non-)repayment issues and regressive. (Regressiveness can be mitigated by well-designed targeting.)[95]

Table 8: Subsidy tools that reduce barriers to third-party financing

Tool	Description	Comments / examples
3a. Reduced interest rate **3b. Reduced deposit**	• Subsidised interest rates reduce the 'risk premium' paid by low-income borrowers, in addition to other costs built into lenders' fees. • If the deposit amount required for a loan (~20%) is unaffordable, this might be subsidised partially or fully, or restructured to a lower percentage (see 3d below). • Another option is to graduate the borrower from a higher interest rate to zero and then apply 'negative interest' – meaning interest is paid to the borrower. This is typically done by the lender (a bank) but could, in theory, be by a subsidy funder.	• Indian MFIs (for example) have access to lower cost capital, so can lend this money to end users at interest rates around 12-20%. But in much of Africa this rate can nearly double.[96] • E.g. In India, SELCO Foundation as seen that for larger loan amounts, banks will charge higher percentage deposits (whereas for lower amounts, they assume the borrower can't pay a deposit). SELCO will offer to cover the 'margin money' (deposit) partially or in its entirety.[97]

[86] Practical Action (2023) *Can market mechanisms facilitate energy access for people living in extreme poverty? Part 2: The role of market interventions and business models*
[87] Chirwa and Dorward (2013)
[88] Bloomfield, Z. (2023) *Financing and scaling productive use of energy: Challenges and opportunities for catalytic growth*. GET.Invest
[89] Energy Savings Trust (2023), ESMAP (2022)
[90] Interview with SELCO Foundation
[91] GOGLA (2023)
[92] For example, in Uganda, the Micro-scale Irrigation Program offers farmers a 75% subsidy for solar water pumps (compared with 25% for fuel-powered pumps) alongside financing to cover the balance. The renowned IDCOL program in Bangladesh pioneered a similar model. (IIED (2021))
[93] Energy Savings Trust (2023), GET.Invest 2023
[94] GDC (2022)
[95] Chirwa and Dorward (2013)
[96] Interviews with SELCO Foundation, EnerGrow
[97] Interview with SELCO Foundation

Tool	Description	Comments / examples
3c. Loan tenor extension	• As savings / new earnings accrue to the end user over time, the agri-PUE equipment begins to pay for itself. To large extent, this renders a cost reduction economically unnecessary, although whether one is ethically or politically justified is a different consideration. • Other modifications to a loan repayment schedule are possible – these include seasonal instalments, 'pay as you go', or a grace period (moratorium) before repayment begins that allows end users to begin making money off their investment.[98]	• Generally, the most effective lever to increase affordability is to extend the repayment period (tenor), which reduces the instalment payments.[99] This is true even despite greater total interest that accrues because of the longer timeframe (which could be considered a form of poverty tax). For loans that have a tenor of less than five years, a marginal increase in tenor has a significant impact in enabling repayment.[100] A longer tenor at fixed interest means a higher total cost to the end user.
3d. Modified repayment schedule		• A key success for micro-lending in India has been establishment of a loan repayment schedule convenient to the borrower.101 E.g. The Shree Kshetra Dharmasthala Rural Development Programme (SKDRDP) developed equipment loan products that are repaid in weekly instalments over 150 weeks[102]
3e. Subsidised or alternative collateral requirement	• Prohibitively high collateral requirements prevent borrowing even when other terms are favourable. Ideally, the agri-PUE asset itself could serve as collateral – but regulated FIs tend to require 100%+ collateral value and/or legal documentation (e.g. title deed to land, moveable asset registry, off-take contract) which can be hard to obtain. • Whereas collateral is held by the lender (FI) until full repayment is complete, hypothecation is where a borrower promises an asset (such as a portion of future harvest) as collateral but retains ownership of the asset. Crop hypothecation is not dissimilar to contract farming, in that a lender or other intermediary extracts repayment in cash or kind once a harvest is produced. • A carbon credit revenue-sharing agreement could serve as collateral.[103]	• E.g. Malawi and Rwanda have movable asset registries, enabling smallholders to put asset collateral forward, which helps them to secure loans and lenders to reduce risks.[104] • Without targeted support, debt financing is likely to remain an option only for end users with existing assets.[105]

[98] EEP (2019) Powering productivity: Lessons in green growth from the EEP Africa portfolio
[99] Energy Savings Trust (2023)
[100] Jha, S., Patnaik, S., Jain, A. (2019) *Financing solar-powered livelihoods in India: Evidence from micro-enterprises*
[101] Ibid.
[102] Ashden website (link)
[103] SNV and SunFunder (2021) *Why localization matters for financing off-grid energy*
[104] IIED & Hivos 2020
[105] IIED (2021) *Briefing paper: Productive uses of energy for resilient livelihoods in LDCs* (link)

Tool	Description	Comments / examples
3f. Repayment guarantee **3g. Weather or crop insurance**	• A repayment guarantee that covers the FI for some/all of its loan can give them confidence to finance electric agri-PUE assets where they would not otherwise do so. This kind of support would ideally give FIs initial experience in productive asset lending and could eventually be removed. • A facility that was able to 'smooth' an irregular end user repayment pattern could also be a valuable option. • Credit-tied end user or 'meso' insurance[106] that covers force majeure and other shocks is already available in some areas for farmers. An agri-PUE product could be tailored to reassure both borrower and lender that repayments can be covered in case of emergency.	• E.g. GreenMax is piloting the Green4Access First Loss facility by which they're providing local banks in Nigeria, Uganda & Kenya a 20% first-loss guarantee for their portfolio of local currency loans to MSMEs and farmers for the purchase of Koolboks solar cold storage systems and Tulima Solar solar water pumps. Prices range from US$ 440 - 4,500; the PAYGO repayment period is generally up to 24 months with a 20% deposit. The guarantee is given as a cash deposit that can be drawn down even while loans are in arrears (rather than an approval-based external guarantee fund that's activated only when there is a loan default).[107] • E.g. Onergy (India) provides a first loss guarantee itself to the lending institution, covering 50-70% of the asset cost, with the asset itself as collateral. They also help end users organise into "joint liability groups" through which they can get financial literacy training.[108] E.g. NIRSAL (Nigerian Risk-Sharing Agricultural Lending), which guaranteed up to 75% of bank loans for mechanisation and other agricultural investments[109] • Some of the interest rate charged to an agri-PUE buyer is the costing of added repayment risk. If this risk can be brought down, in principle the interest rate could come down. E.g. EnerGrow charge 35% APR for agri-PUE assets in Uganda but are keen for risk mitigation support to bring this down.[110]

4 Discussion: expanding the repertoire of tools to address end user affordability

Section 3 presented a list of affordability improvement tools that go well beyond price reductions. The main critique of 'end user subsidy' – that it spoils markets – can be reasonably addressed with smart design and a nuanced assessment of what type of tool might specifically be needed. This section looks at how stakeholders could 'match' the right subsidy mechanism to the maturity of the targeted ecosystem.

4.1 Comparing the three subsidy mechanisms

We have identified the three mechanisms by which demand-side subsidies function: cost reduction, structural change, or risk mitigation. Individually or in combination, these address the main affordability constraints facing agri-PUE end users, which are: capex, access to savings, access to capital (loan), cost of capital (interest rate or other premium), liquidity (cash flow) and opex. We begin with some general observations.

Cost reduction can be deployed as a price discount (of which there are various tools) or as a reduced interest rate. It is an effective and versatile instrument that in some cases is the only way to improve affordability. It can be delivered on its own or in combination with other subsidy mechanisms, e.g. a price reduction alongside concessional financing. It can be delivered on an asset purchase, rental or fee-for-service price. It can be particularly helpful in mitigating willingness to pay constraints, such that end users see less of a hurdle and less of a risk to trying a new or unfamiliar technology.

[106] Stakeholder interviews, GOGLA (2023), Meyer, R., Hazell, P., and Varangis, P. (2017) *Unlocking smallholder credit: Does credit-linked agricultural insurance work?* (ILO and IFC)
[107] Communication with GreenMax
[108] Efficiency for Access (2021)
[109] Diao, X., Silver, J. and Takeshima, H. (2016) *Agricultural mechanization and agricultural transformation*. African Center for Economic Transformation
[110] Interview with EnerGrow

On the other hand, it is something of a blunt instrument, in that it can address many affordability challenges but without nuance. As such it may be offered to those whose affordability constraint actually can be addressed with a less interventionist tool. Ideally, an income- or savings-generating asset such as agri-PUE equipment should pay its cost back over time – rendering end user financing preferable, if it is available.

Indeed, a cost reduction is a more common subsidy approach for consumptive – rather than productive – assets. This is because consumptive technologies, such as solar lanterns or mosquito nets, do not earn their users savings or income. These types of equipment are primarily used independently of one's livelihood or income generation, and the justification for subsidising them is more often around equity, health or well-being, rather than economic development. The value of agri-PUE, on the other hand, is *only* in its generating income or savings for the end user. Ideally, it should pay itself back such that the end user and lender recover their outlay over time, though in practice, the price (loan principal) may need to be subsidised as well, for both practical (impact) and ethical (fairness) reasons. Governments (or society more broadly) should intervene to reduce the amount an end user needs to borrow if they want to see transformation at scale (see brief comments in Section 4.2.3).

Structural changes can address nearly all affordability constraints for agri-PUE end users. These mechanisms enable payments over time (a loan) or modify loan repayment terms. Ideally, a structural change enables the full cost of an agri-PUE asset to be recouped by the lender. But structural changes can be costly to implement and risky for both the lender and the end user. Also, the ethics of financing expensive agri-PUE equipment must be carefully considered, such that repayment periods are not excessively long (prolonged indebtedness), interest rates not onerous, and capacities of the lender not unduly stretched.

Risk mitigation is only relevant where IHF or 3PF are actually available. The affordability constraints that can be addressed by risk mitigation are access to capital and cost of capital. These mechanisms are 'farthest' from the end user in terms of degrees of separation, and in an ideal situation are put into place in case of default but never deemed necessary. As such we consider them to be the least 'interventionist' of the three mechanisms.

We look now at how these mechanisms might apply in less or more mature ecosystems.

4.2 Using the three mechanisms in different ecosystems

Our vision of the three ecosystem typologies is that these are sub-national 'market systems' that are most often geographically delineated (e.g. arid areas v. fertile).

4.2.1 Weak ecosystem

A weak ecosystem is vulnerable – perhaps a remote rural area, a displaced persons settlement, or a more fertile and connected region of a very poor country. People are predominantly farming for subsistence, and are reliant on manual or animal labor. There is a low ability to pay for and low awareness of electric equipment solutions. There are low linkages to economic infrastructure (including third party financing), and social groups are more likely to be focused on risk mitigation. This tends to be an unattractive market for suppliers without supply-side subsidies to buy down costs of added logistics and delivery risks.

Table 9: Appropriateness of DSS mechanisms in a weak ecosystem

Cost reduction	Structural change	Risk mitigation
For an individual purchase, a price discount must reduce the agri-PUE equipment cost sufficiently – even to zero – to reach extremely vulnerable end users for whom other life expenses might take priority, and for whom there may be limited options for savings. An alternative would be to reduce price alongside some form of demand aggregation or service model, such that individual purchase isn't necessary or the owner(s) could hire out the equipment as a business. In this case there would need to be an entity willing to do such aggregation or service; the private sector might not be persuaded to enter this market without its own subsidy, and even then, perhaps not permanently.	Requires some form of IHF or 3PF already in the ecosystem; attracting an end user financing option to the ecosystem would require risk mitigation.	Could be used to reassure an IHF or 3PF provider to lend here. But without stronger elements across the ecosystem – interested suppliers, end users' capacity to afford a loan, sufficient linkages to buyers for agri outputs – this tool is unlikely to be helpful.

With no end user financing in place, a price discount is the most appropriate intervention; this could be used in combination with an incentive for suppliers or FIs to enter the market. Low affordability of all kinds would warrant a high price discount per unit of equipment, but there would likely be a relatively low number of units sold (depending on the size and function of the equipment) due to low demand or demand aggregation. Targeting this population could probably be done fairly straightforwardly by identifying a geographic area which would minimise administrative costs. The impact of the subsidy, however, would depend to large extent on the availability and affordability of 'wraparound' factors in the ecosystem – farm inputs, downstream buyers, end user training – and, importantly, to the end user's ability to pay opex. It would also depend on how secure and resilient end users are, such that during stressful times they might realistically continue to use (as opposed to leave unused, or sell off) the equipment. In principle, a price discount should continue to be available as long as needed in this ecosystem. In practice, this is likely to be extremely costly, and most donor funding cycles are far shorter than the amount of time the need will remain.

In a weak ecosystem, the role of demand-side subsidy should be to build resilience as part of a long-term safety net[111] and to demonstrate the technology as part of a deliberate market-building exercise. This setting may take much longer to transition to a fully commercial market.[112] The purpose of subsidising agri-PUE equipment would be to jump-start the local economy to bring people above the poverty line.

Stakeholders should also focus on building the ecosystem through non-financial demand-side support such as awareness building, cultivation of market linkages, financial literacy and, importantly, facilitation of group purchase or service options for accessing essential equipment.

4.2.2 Transitional ecosystem

There is greatest potential for DSS to have immediate and lasting impact in a transitional agri-PUE ecosystem, where the 'wraparound'[113] context is sufficiently viable that end users can do something productive with subsidised equipment. End users here are subsistence farming in addition to selling surplus or cash crops to local markets, intermediaries or off-takers. They are familiar with diesel agricultural equipment and use it in combination with manual/animal labour. There is some supply of electric agri-PUE, though at higher prices than regional average; one or more of these suppliers might offer PAYGo or ad hoc credit terms. End users have decent access to other inputs and there is likely to be sufficient economic activity for some entrepreneurial activities. Importantly, there is more likely to be some form of end user financing available – informal or formal – though it is often limited by lack of local branches, unwillingness (or inability) to lend for agri-PUE, or unaffordable terms.

In this setting there is potential to mitigate affordability constraints using a range of tools across all three subsidy mechanisms. Table 10 looks at considerations for each.

Table 10: Appropriateness of DSS mechanisms in a transitional ecosystem

Cost reduction	Structural change	Risk mitigation
A *price discount* could be designed specifically to expand the addressable market beyond existing end users, encourage early adopters of newer technologies such that they can demonstrate and generate word of mouth buzz, and/or help popularise an existing technology. Even better if used in conjunction with a service or demand aggregation model to minimise need for individual ownership. A *reduced interest* rate on IHF or 3PF could enable an increase in uptake as well. A lower price directly reduces the timeframe for the equipment to earn back its value (payback). In this ecosystem, a lower subsidy per unit would be needed than in a concessional ecosystem, and there would potentially be higher unit uptake. Other costs include administration of targeting and delivery (e.g. vouchers, data collection, monitoring). Costs may be graduated down as affordability improves, but are 'sunk' (not recouped).	Implementing a *loan tenor extension* or *modified payment schedule* is technically possible where options for IHF or 3PF exist. Here, the asset is not directly subsidised. Rather, the lender (supplier or FI) is supported to pass along more affordable credit terms. The end user pays a premium (interest) for the flexibility of a modified or extended schedule, unless this tool is combined with a low- or zero-interest rate. The funder would need to engage prospective financier(s) and end users to understand what is needed prior to and during a change in loan terms, and what terms are suitable for different agri-PUE technologies. The lender may need to technical assistance in designing loan products and assessing credit worthiness, and risk mitigation to cover uncertainties over a longer or lumpier repayment period. Net costs decline over time as lending capacity grows, loans are repaid, affordability improves.	A *repayment guarantee* has potential in this setting to unlock end user financing, if the FI or company finds the terms – and any associated technical assistance – sufficient. It would be drawn down in direct relation to loan default (or delay). *Crop or weather insurance reassures* both the end user and the lender that the loan can be recouped even in the event of stressful times. Either or both of the above risk mitigation tools should be sufficient to minimise any *collateral* requirement beyond the asset itself. Risk mitigation costs are also sunk, but, ideally, decline over time as the ecosystem matures.

[111] SELCO Foundation (2020), Tearfund (2020)
[112] ACE TAF (2020) *Design principles for demand-side subsidies in the off-grid solar sector: Briefing note*
[113] Morrissey, J. (2018) *Linking electrification and productive use* (Oxfam Research Backgrounder)

In a transitional ecosystem, the role of DSS should be to strengthen the ecosystem and graduate out over the course of 5-20 years. In this kind of setting, where all subsidy mechanisms are possibly relevant, a funder will have to do more thinking around what is appropriate now and to proactively anticipate changing strategy as the ecosystem matures.[114] As the ecosystem gets stronger, support should shift from more 'interventionist' pricing discounts (cost reduction) to less interventionist 3PF (with risk mitigation). This applies both to the adaptation of a subsidy within a given programme and to the identification of appropriate interventions over time. A subsidy should be designed *not only* to improve end user affordability but to strengthen the agri-PUE ecosystem as well.[115]

This means that in addition to the subsidy itself, a funder (and its partners) should closely consider factors shaping the financial sector in general (Figure 7) and, more specifically, the health of the end user financing system(s). For example, subsidising local FIs to implement concessional loans might warrant parallel support to build financial literacy among end users, technical assistance to FI staff to understand agri-PUE technologies and payback periods[116], or training on digitalised credit assessment software.

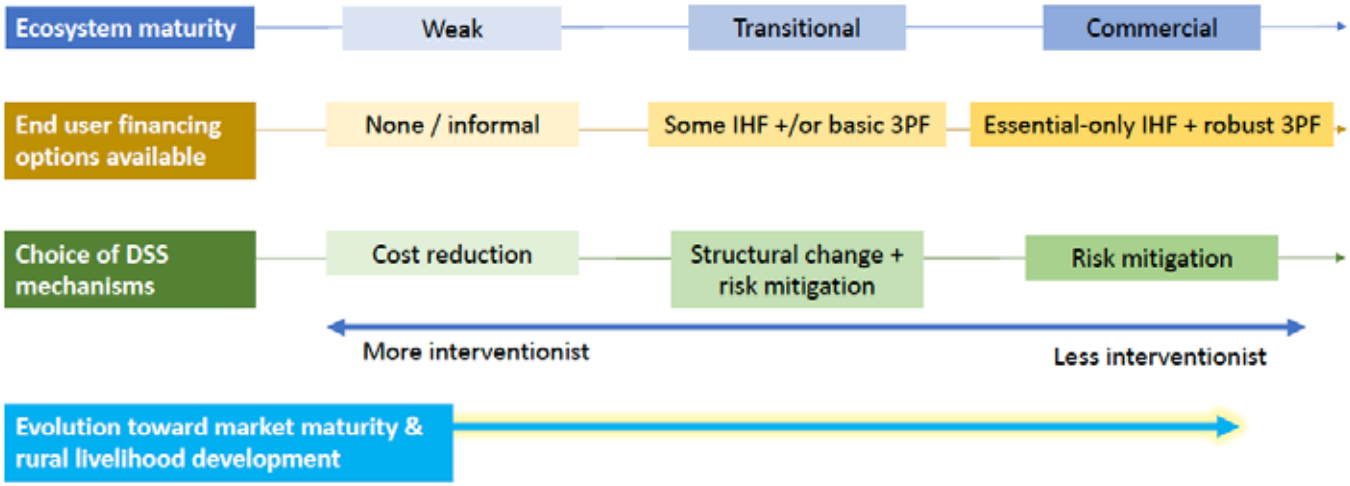
4.2.3 Commercial ecosystem

In a commercial ecosystem, agricultural end users are combining subsistence farming with commercial production. They have well-established linkages to markets and are already using – or familiar with – various productive equipment including solar water pumping, solar cold storage and other electric agri-PUE. People are more receptive to change; entrepreneurial activity is vibrant; and cooperatives are actively working to improve their members' margins. Agri-PUE suppliers consider these markets low-hanging fruit, and there is likely to be competitive pricing on a range of products available at retail outlets. Various 3PF options exist, although end users might encounter similar challenges as in less mature settings – high interest rates (tied both to repayment risk and forex exposure), lack of appropriate loan products, or lack of familiarity with off-grid electric technologies.

The role of DSS in a commercial market should be limited to (a) popularising a new technology[117] or (b) promoting energy efficiency, for example to improve environmental outcomes through switching from diesel to electric.[118] It can be done through any of the mechanisms and tools, but should focus on the least interventionist to achieve objectives, and be positioned as an 'incentive' rather than a 'subsidy'.

Figure 10 illustrates the progression from weak to commercial ecosystem, and the parallel progression from more interventionist to less interventionist DSS options. As noted above, we consider ecosystems as sub-national typologies, such that a given country might have weak, transitional and commercial ecosystems (or multiple of each).

Figure 10: DSS options shift as the ecosystem matures



[114] Tearfund (2020)

[115] Mottaleb, K.A., Krupnik, T., Erenstein, O. (2016) *Factors associated with small-scale agricultural machinery adoption in Bangladesh: Census findings*. Journal of Rural Studies 46 (link)

[116] Interview with GET.Invest

[117] DSS have been demonstrated to improve adoption if people are unfamiliar with a technology – e.g. cookstoves, insecticide treated bednets, water treatment technologies (Das, I., Jeuland, M. and Plutshack, V. (2022) *The Role of Taxes and Subsidies in the Clean Cooking Transition: A Review of Relevant Theoretical and Empirical Insights*. NI PB 22-17. Durham, NC: Duke University (Link)

[118] Subsidies (including both up-front price reduction and post-purchase rebates) for energy-efficient appliances or cars (USA, Europe, China, etc.) are good examples. They were short-term and communicated as 'incentives'.

4.3 Considerations to guide DSS decision-making

4.3.1 Guiding principles and logical flow

Stakeholders should approach the agri-PUE situation with open mind around what DSS tools are most appropriate and for how long support may be needed. Here are some questions to start with:

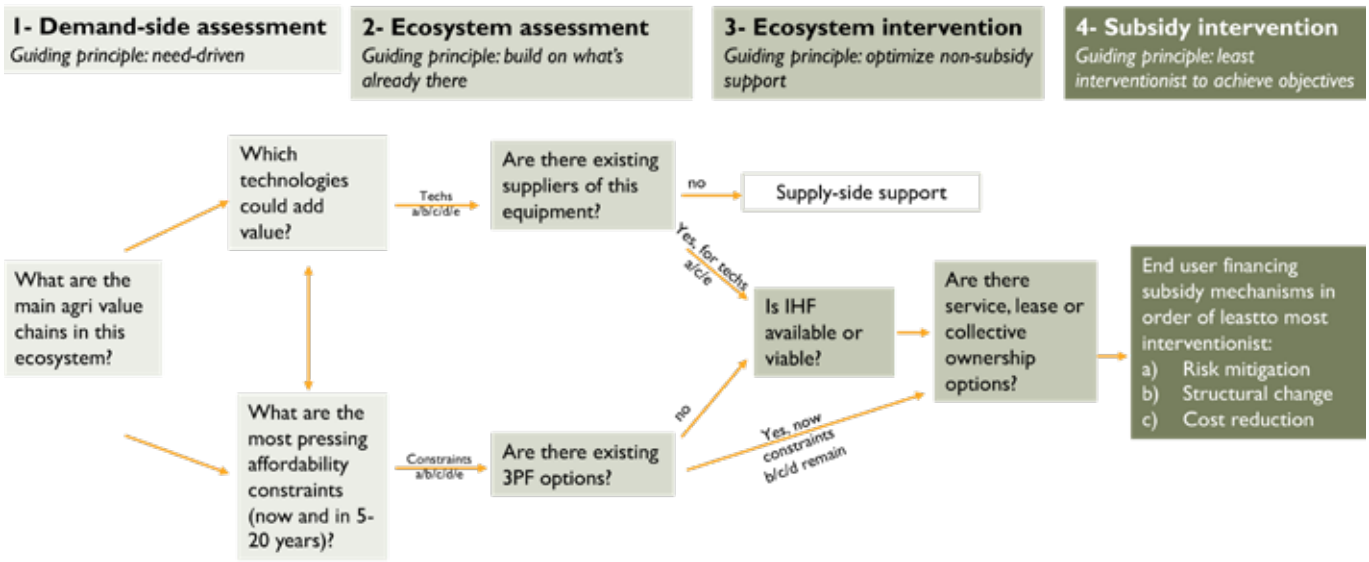
1. What is the prevailing end user context? Seek to understand seasonal agricultural needs and outputs, specific value chains, electricity access and both observed and stated affordability constraints. Do the communities in focus want electric agri-PUE? → *Guiding principle: DSS decisions must be defined and driven by end user needs.*

2. What characterises the five ecosystem elements (PUE supply & technologies, business case, enabling environment, sociocultural factors, and financing) right now? To what extent do end users have access to technology and financing options? How strong market linkages and social groups are (see Table 4). → *Guiding principle: Build from what is already in place, rather than introducing an entirely new 'solution' to the market.*

3. Are there demand-side ecosystem interventions that could improve end users' options prior to or in conjunction with DSS? How can we strengthen the ecosystem with a view to graduating out the subsidy? High impact leverage points include demand aggregation through existing social structures, technical assistance to FIs, market linkage support. → *Guiding principle: optimise non-subsidy support.*

4. What DSS tool(s) are appropriate? This merges the contextual cues above with top-down constraints e.g. budget or data limitations, other supply and demand-side interventions, national food security priorities. Stakeholders should strive to match the available DSS tools to the observed affordability constraints. Impact may be achieved using various combinations of mechanisms. → *Guiding principle: choose the least-interventionist option(s) to achieve objectives.*

Figure 11: Logical flow of decision-making around agri-PUE DSS



4.3.2 Complementarity with supply-side support

Most practitioners agree that some form of supply-side support (including subsidy) (SSS) is needed either prior to or in parallel to DSS. A price discount is typically considered once supply-side support has already brought efficiencies, cost reductions and logistical capacities to companies within the supply chain. That is, when the ecosystem is commercial and the objective is to deepen the addressable market.[119] But in some circumstances, the supply ecosystem may not be commercial for decades, and there isn't time to wait out supply-side improvements. In this situation – which may describe many transitional ecosystems – suppliers may not have much of a market to sell to[120] without supply-side support in parallel to DSS.[121] Table 11 presents some considerations for coordinating different DSS with SSS.

Table 11: Considerations for sequencing or coordinating DSS and SSS

DSS SSS	Price reduction	In-house financing	Third-party financing
Concessional supply chain financing	Working capital is typically not used for establishing operations in new (poorer) locations, where a reduced price might be most needed. In theory a loan could boost a company's HR/admin/data capabilities to go 'deeper' in existing geographies with discounted product, though this would need to be designed and communicated with care.	Working capital to a supplier on terms that match its end user on-lending can enable IHF.	FIs may be reassured to know that a supplier has been incentivised to serve a local population, which mitigates some technology risk.
RBF	RBF can subsidise supply activities and pricing discounts at the same time (e.g. Nigeria). It can encourage a company to distribute in a hard-to-reach setting and enable early adopters there to access discounted products.	RBF could reward a company for selling at concessional IHF terms. This might exacerbate existing working capital challenges (depending on how late in the loan agreement the milestone / payment 'trigger' was set) but could alternatively serve to top-up working capital during the course of IHF.	RBF prior or in parallel to 3PF would ensure supply to meet a boost in demand from end user financing.
Research / demo / pilot grant	Support that allows a company to discount a demonstration unit (or many) and field-test equipment prior to rolling out sales could be very helpful. DSS tools should be piloted before being rolled out, with end user interviews and data collection to validate hypotheses or spur adjustments.		

[119] ESMAP (2022)
[120] Interview with SELCO India
[121] ESMAP (2022)

5 Recommendations for design & implementation

We close here with several main points to keep in mind when deciding upon and designing DSS. This is not a comprehensive discussion on 'smart' subsidy design, about which much has already been written.[122] Rather these are selected suggestions that address electric agri-PUE and the notion of an expanded, ecosystem-based view of demand-side subsidy options.

Listen, listen, listen.

- Funders should take care not to push 'green' (electric) equipment when the appropriate equipment might be whatever is helpful. Though energy use in agriculture sector globally contributes 30% to global energy consumption[123], energy use among smallholders is relatively inconsequential.[124] This matters to overall intervention design and to ensuring that the value proposition for end users to replace the status quo is both valid and evident.

- Any decision to subsidise agri-PUE should originate in a clear and stated need by end users. There is a difference between "we need this" and "you should have this." As a recent paper on PUE from IIED and Hivos noted, "the desire for upward mobility is assumed, but many smallholders are not seeking to grow their businesses… [just] simply to provide for their families.[125]

- Affordability matters to end users, but the 'use case' for new equipment matters more.[126] This means that a decision around which equipment is appropriate should rest with the end user, not with the funder.

Use ≠ purchase. Prior to planning any subsidy, stakeholders should closely evaluate whether lease, group ownership or service models can replace individual purchase options. This may warrant some supply-side support (to develop an appropriate business model) or non-financing demand-side support (for example to aggregate end users into a group, or to help a cooperative with its agri-PUE equipment financing plan).

Seeing is believing. The value of demonstration for agri-PUE equipment is priceless[127] for all parties – the end user, the supplier and (if applicable) the lender. Before any subsidy the equipment should be piloted.

Concerns around market distortion are not insurmountable. The subsidy literature is full of red flags that demand-side or supply-side subsidies distort markets, and that both distort both end user and supplier behavior.[128] Leakage can be mitigated (not stopped) by good targeting and monitoring; price expectations can be managed by clear communication. Concessional end user financing can be targeted to avoid crowding out commercial lenders. A fall-off in demand post-subsidy is a natural result of closing the window of affordability to a higher wealth group.[129] Most end users who adopt free or low-cost products would not have adopted them in the absence of discounts.[130] When well-designed, subsidies can enhance the function of the market, and should be seen as integral – not separate.[131] There is little risk of concessional end user financing crowding out commercial financing if targeting is done effectively.[132]

[122] Chirwa, E. and Dorward, A. (2013) Agricultural input subsidies: Changing theory and practice, Baltzer, K. and Hansen, H. (2011) Agricultural input subsidies in Sub-Saharan Africa (link), ACETAF (2020b)
[123] IRENA and FAO (2021)
[124] See Energy for Growth Hub's Modern Energy Minimum which proposes 700kWh/year per business (Link)
[125] Perera et al (2020)
[126] Stakeholder consultations
[127] Stakeholder consultations, GDC (2022)
[128] Add brief comment on this
[129] Interview with Duke Energy Access
[130] Das et al (2022)
[131] Tearfund (2020)]
[132] Energy Savings Trust (2023)

A long-term view is essential.

- A subsidy should adapt as the ecosystem develops and take a realistic view as to how long the challenge(s) might remain and how much it might cost to realise objectives.[133]

- Replace 'exit' thinking with 'graduation'. Subsidies should be phased out in accordance with ecosystem development, with the option to reinstate them in case of economic shocks, poor harvest, etc. Graduation could have various permutations, such as a declining absolute amount or percentage of retail price; a shift from subsidy to a barter arrangement (e.g. Malawi's 'fertiliser for work' programmes)[134]; or a shift from cash reduction or structural changes to a more light-touch intervention like risk mitigation.

- Longer-term 3PF (more than five years) allows for repayment, which has the significant benefit (as compared with a price discount subsidy) of enabling either a net reduction in the total subsidy cost or a recycling of repaid funds into new loans.[135]

Consider the entire agricultural value chain.[136]
Improvements in production, processing or conservation at one point in the value chain are wasted if upstream inputs aren't optimised or downstream outputs are lost. Electric equipment can and should help at various points.

Implementation details matter. Slow disbursal or farther distances (beyond 5-10 kilometres) to access agri-PUE products, services or financing reduce the incentive to participate.[137] Successful end user financing programmes integrate end user advice, product & supplier accreditation, and the participation of a wide range of suppliers.[138] The funder and its partners should anticipate how other ongoing interventions might improve or undermine DSS impact, as well as how timelines, human resource capacity and other factors will affect implementation.[139]

There is always a 'human' side to DSS decisions and implementation.

- Subsidies can be a highly political redistribution of resources and can be mis-used by any number of stakeholders in the ecosystem. The subsidy literature is rich with warnings of favouritism, misappropriation of funds[140], rent-seeking by nearly all stakeholders, and inputs subsidies continuing for too long because they serve political interests.[141]

- Implicit subsidies are everywhere. These are benefits, favours and advantages that accrue throughout society that may not be widely known or explicitly calculated within pricing of products and services.[142] These affect pricing and social signals that influence end user decision-making, for example around continuing to use diesel machinery or planting different crops.

Define success from the start.

- What is the long-term objective of subsidising agri-PUE equipment? This helps funders to know when it's been successful (as subsidy interventions around the world have failed to keep their ultimate objective(s) in sight and have continued on auto-pilot before being removed) and how to prioritise potential trade-offs, (e.g. if stakeholders deem that demand aggregation and a sharing or hire-out model is the best form of support and this presents a mis-match to equipment suppliers' higher volume sales targets or 'market building' objectives).

- How will we define success? It could be on economic terms: if a subsidy costs less than the (monetised) social value of its benefits, it's been a success.[143] It could be on relative terms: if an end user financing subsidy is a more efficient use of public funding than price discounts to overcome affordability constraints, it's a success.[144] If it measurably improves agricultural outputs, even an entire rural economy, it's a success. Or: a subsidy is a success if it renders itself obsolete, or if it successfully graduates from more interventionist to less over the course of however long it takes for an ecosystem to mature.

[133] Tearfund (2020), Energy Savings Trust (2023), GOGLA (2021)
[134] Chirwa and Dorward (2013)
[135] Energy Savings Trust (2023)
[136] Goyal (2023), EnDev (2021) Productive use of energy: Moving to scalable business cases, USAID (undated) *Energy opportunities for agriculture systems and food security project: Identifying opportunities along the post-harvest agriculture value chain* (link), Interview with SELCO Foundation
[137] ACE TAF (2020) Design principles for demand side subsidies in off-grid solar
[138] Energy Savings Trust (2023)
[139] ESMAP (2022)
[140] GOGLA (2021)
[141] Chirwa and Dorward (2013)
[142] Emery, T. (2023) *Solar Can't Scale in the Dark*. Energy for Growth Hub; Perera, N., Johnstone, K., Garside, B. (2020) *Energy for all: Better use of subsidies to achieve impact* (Hivos and IIED)
[143] Chirwa & Dorward (2013)
[144] Energy Savings Trust (2023)

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