WALK-IN COLD ROOMS, A PRACTITIONER'S TECHNICAL GUIDE

Design and Operation of Walk-In Cold Rooms for Precooling and Storage of Fresh Produce in Hot Climates, in Off-Grid and Unreliable Grid Situations

OVERVIEW

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The main supporting bodies were:

- **ESMAP** is a partnership between the World Bank and 24 partners to help low and middle-income countries reduce poverty and boost growth through sustainable energy solutions. Through the World Bank Group (WBG), ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7) to ensure access to affordable, reliable, sustainable and modern energy for all.
- **The ESMAP Efficient Clean Cooling Program** aims to leverage the World Bank Group's balance sheet to mainstream and integrate efficient and clean cooling in relevant World Bank policy dialogues and lending operations (IBRD and IDA), thus accelerating the adoption and deployment of sustainable, climate-friendly, and reliable cooling solutions. The program works to strengthen the enabling environment, develop the necessary market infrastructure, and design and operate financing mechanisms and business models. It works across multiple sectors such as health, agriculture (horticulture, dairy, fisheries), buildings, and urban spaces in Lower and Middle Income countries, mainly focusing on space cooling (energy-efficient buildings and air conditioning), refrigeration, and cold chains, and the mitigation of urban heat island effects.
- **Efficiency for Access:** Efficiency for Access is a global coalition working to promote affordable, high-performing, and inclusive appliances that enable access to clean energy for the world's poorest people. It is a catalyst for change, accelerating the growth of off and weak-grid appliance markets to boost incomes, reduce carbon emissions, improve quality of life, and support sustainable development. **https://efficiencyforaccess.org**
- **International Institute of Refrigeration (IIR):** The IIR is an independent intergovernmental organisation. It is the only one in the world to gather scientific and technical knowledge in every sector of refrigeration. The IIR is committed to disseminating knowledge of refrigeration to improve the quality of life for all, while respecting the environment and taking into account economic imperatives. **https://iifiir.org/en**

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☛ **The section numbers referenced in this document refer to sections of the main guide, of which this is only an overview.**

Practitioners will find the detail they need to specify, deliver and operate an appropriate and effective walk-in cold room only in the full guide, available from https://efficiencyforaccess.org/publications/walk-in-cold-rooms-a-practitioners-technical-guide or www.iifiir.org

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Overview

1 Why walk-in cold rooms have global significance for food supply

According to the United Nations Food and Agriculture Organisation (FAO), about 13% of the food produced in the world for human consumption is lost; in sub-Saharan Africa, more than 21% is lost[1]. Some estimate much higher losses of around one third. And since 31% of the global population relies upon 'rural and traditional' food systems, with most of them in Africa and Asia, support to smallholder farmers and people living in poverty is essential[2]. Africa could account for three-quarters of the growth in global food demand by 2100[3] and, therefore, rural economies in the Global South must be a major focus to help reduce food waste and improve nutrition.

Availability of cold storage infrastructure can be an effective solution to save perishable products from being discarded and sustain nutritional value. This is because cooling extends the shelf life of perishable foods by a factor of two to three for every 10°C of cooling below the ambient temperature[4]. This means twice the opportunity to sell produce before it spoils, the chance to transport the food further to reach new markets and the opportunity to command better prices for produce that is more attractive to buyers (☛2.2).

Many technology suppliers and researchers are working intensively to develop and deploy appropriate food cooling systems, but there are extreme challenges for walk-in cold rooms (WICR) when operating in off-grid or unreliable grid areas, which are often far from technical support and in a hot climate.

Many good solutions and business ideas to address this have been attempted. But experience to date shows that a cold room installed as a single 'intervention' or part of a fragmented and piecemeal approach in an otherwise traditional Global South farming economy will often, or usually, fail. Nevertheless, much has been learned and the initiative that led to the development of this guide aims to consolidate that learning.

Governments also have a critical role to play in creating an enabling environment for the deployment of cold rooms, including financing and mobilisation of private sector and other capital. They can ensure that as many elements as possible are in place of the systemic and holistic approach laid out in the schematic of Figure 1. Many governments recognise the importance of cooling and are already taking action; many are developing and publishing National Cooling Action Plans. Amongst the first African governments to do this have been Nigeria, Rwanda and Kenya, all of which have emerging markets for walk-in cold rooms.

Wider access to precooling (☛2.3.2) and cold room storage can help to reduce postharvest losses, improve food security, increase income for marginalised farmers and reduce price fluctuations by better balancing supply and demand (☛2.3). The role of governments to set up the enabling environment is beyond the scope of the guide, but it certainly can help a cold room developer to navigate many of the practical challenges they face in the task.

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[1] https://www.fao.org/3/cc1403en/online/cc1403en.html#/12

[2] Source: Socio-technical Innovation Bundles for Agri-food Systems Transformation, Report of the International Expert Panel on Innovations to Build Sustainable, Equitable, Inclusive Food Value Chains. Ithaca, NY, and London: Cornell Atkinson Center for Sustainability and Springer Nature, 2020. See Box on p32 titled 'Box A: Turn Attention to Africa'. Available from: https://www.nature.com/documents/Bundles_agrifood_transformation.pdf

[3] Ibid.

[4] This is referred to as the Q10 Quotient by UN FAO, see Costs and Benefits of Clean Energy Technologies in the Milk, Vegetable and Rice Value Chains, FAO, July 2018, p136. Available from http://www.fao.org/3/I8017EN/i8017en.pdf

Figure 1

Elements of a holistic approach and enabling environment to build cold chain solutions *(Source: ESMAP Efficient Clean Cooling Program, 2023).*

2 A guide to getting the right walk-in cold room and effective operation

This document describes and summarises the guide *"Walk-In Cold Rooms, A Practitioner's Technical Guide - Design and Operation of Walk-In Cold Rooms for Precooling and Storage of Fresh Produce in Hot Climates, in Off-Grid and Unreliable Grid Situations"* Its purpose is to present accessible, practical guidance that enables developers, owners, operators and suppliers to specify, install and operate appropriate precoolers and walk-in cold rooms that are as effective and economically viable as possible in off-grid, unreliable and limited power supply situations. The guide assists the project manager through the process of procuring a cold room, enabling them to have suitable discussions with specialists and suppliers, through to operating the cold room effectively. Through using the guide the primary audience (project managers and buyers) will be able to ask informed questions to suppliers and give them the information needed for good design decisions. The guide will also help suppliers to improve their system designs. Familiarity of the readers with refrigeration is assumed if technical concepts or calculations have to be handled. A secondary audience is managers of aid and technology programmes, to improve insight into necessary technologies and business models.

The International Institute of Refrigeration, with support of ESMAP Efficient Clean Cooling Program and Efficiency for Access has produced the guide, which draws on the practical experience of dozens of leading experts and suppliers across Africa, India and elsewhere. The guide consolidates state of the art experience on designing and operating the type of walk-in cold rooms that are well suited to those markets.

It is available free of charge as a PDF download from https://efficiencyforaccess.org/publications/walk-in-cold-rooms-a-practitioners-technical-guide

Signposts to sections of this guide are used in this Overview.

3 Scope of the guide

The guide covers commercially available types of small walk-in cold rooms designed to precool (☛2.3.2) and store fresh horticultural and agricultural produce (☛2.2) near farms or at rural aggregation centres, communities or markets (☛3.2), using temperature, humidity, and gas-controlled conditions for maintaining quality of produce. An important focus is how to ensure effective cooling when the power supply is limited or unreliable or where no grid power is available at all (off-grid areas) (☛Part 5).

The guide covers walk in cold rooms for:

- Horticultural and agricultural produce (not milk, ice production, meat and fish, refrigerated transport, healthcare nor storage of vaccines)
- Chilled storage only (0°C and above; not frozen)
- Up to around 80 cubic metres (a standard 40ft shipping container), but most advice is also relevant to larger cold rooms
- Site-built and 'containerised' solutions
- Mainstream electrically driven vapour compression technologies and conventional insulated sandwich-panel construction
- Power from reliable grid, limited grid, unreliable grid and off-grid
- Particular focus is on solar photovoltaic energy sources and hybrid solutions, with thermal energy storage
- First mile markets and rural markets

This narrow scope has been chosen because it presents well-established, tried and tested technologies that are commercially available and known to be capable of meeting the extreme demands of cooling capacity, if well-designed and maintained. It is acknowledged that these technologies are expensive for these markets, not easy to source locally and will require innovative financing and business models for most applications. Many other technologies, cold chain solutions and traditional approaches are available and should be considered. 'Passive assist' solutions such as shading and evaporative cooling are noted in the guide but not covered in any detail.

4 Walk-in cold rooms and cold chains for communities

Walk-in cold rooms are best employed as part of a so-called 'cold chain', that includes several links from farm post-harvest to the home of the consumer, to improve or sustain the quality and nutritional value of produce and reduce food loss and waste (☛1.3; 1.4). Decentralised cold chain solutions that are economically viable are continuing to develop and become accessible to Global South communities. Cold rooms can help preserve food safety, quality, nutrition and value (☛2.2), raise standards of living, improve social well-being and support sustainable local agricultural economies.

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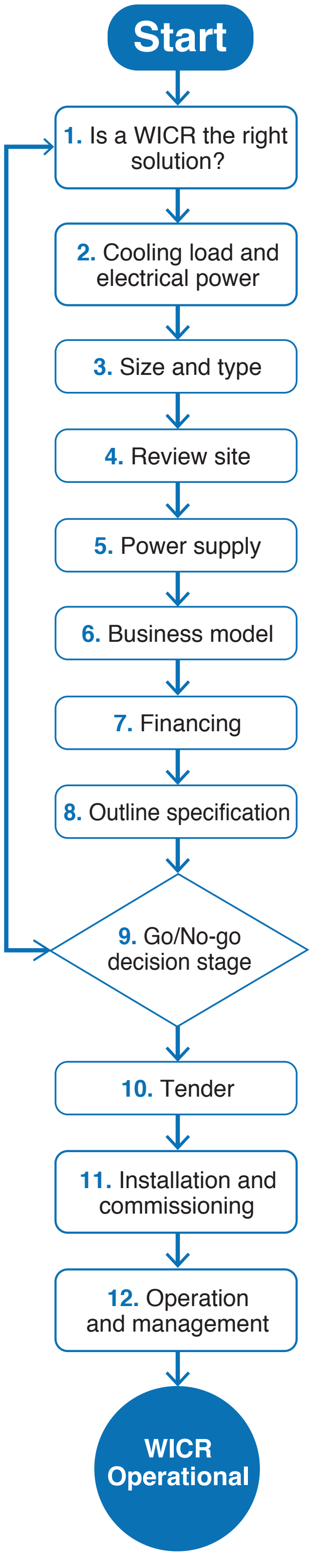

5 A roadmap through the challenges, summarised from the guide

The guide provides a roadmap through the process of specifying, delivering and operating a walk-in cold room, covering both the technical and business perspectives. It starts with the crucial stage of the specification (☛Part 3), with cooling tasks to be achieved, cooling technology (☛Part 4), size of the cold room, site and power supply (☛Part 5). And follows through to business aspects (business models, financing routes, procurement) (☛Part 3), finally to installation, commissioning, operation, and management (☛Parts 6 and 7).

Specifying a cold room and planning its integration into an agricultural or horticultural value chain is complex and so consider getting independent advice. Bear in mind that a viable operational solution that works in one geographical area and market cannot be 'copy-pasted' to work in a different area. Project managers should seek professional, trusted and preferably local advice on any aspects on which they lack confidence. This guide will help prepare for productive discussions with experts but cannot provide a universal solution. The guide will help the project manager to know what questions to ask, what essential information about the needs and situation must be decided and shared.

The steps in the roadmap are shown in the flowchart in the side panel of this brochure and are listed in simple terms below. Some key points from each step are described in this summary, but there is not room here to give enough detail nor explain how it is done in practical terms – the full guide explains far more of the important information needed to get the steps right:

1. Is an electric powered walk-in cold room the right solution for the situation?
2. Describe and quantify the cooling loads; estimate electrical power
3. Estimate indicative size and type of cold room required
4. Review the site for the cold room
5. Select a power supply type
6. Choose the most appropriate business model
7. Identify financing routes
8. Draw up the outline technical specification
9. Go/No-go decision stage
10. Run the tender or procurement process
11. Installation and commissioning
12. Operation and management

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5.1 Is an electric powered walk-in cold room the right solution for the situation?

Electrically powered walk-in cold rooms using vapour compression refrigeration and insulated panels are expensive solutions and alternatives are available, so choose carefully. The WICRs covered in this guide are only feasible if affordable and if investment costs can be recovered (☛3.2; 3.10).

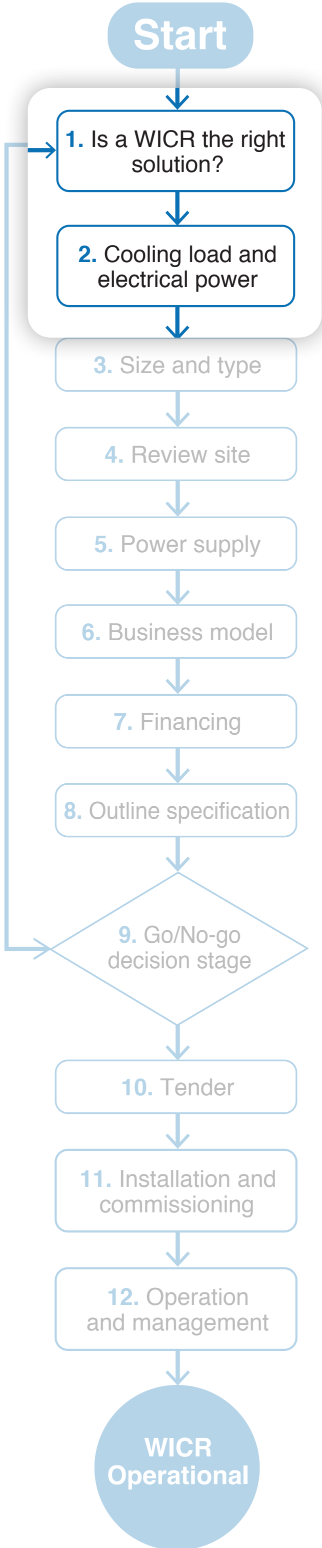
It is often cheaper to extend the production season, implement irrigation, process food (e.g., by drying) or improve market connectivity, rather than using cooling. It is crucial to assess whether cooling is a viable option, for example using the Postharvest Assessment Methodology by Wageningen University[1].

Three crucial questions should be asked when considering the suitability of a cold room:

1. Does the business plan consider how the cold room adds value to the entire value chain, while achieving a profitable utilisation rate?
2. Is the affordable cooling capacity of the refrigeration plant and air movement in the room sufficient to cope with the expected throughput of produce? This may have to cover precooling produce before it is stored.
3. Are suitably trained and equipped staff available to install, maintain and repair the cold room once it is in operation?

In practice to date, successful implementation of this type of cold room in hot climates in the Global South is mostly seen for crop-specific processing and storage facilities, or for high value export markets such as flowers or herbs. But as the technology solutions become better established and accessible, there is enormous scope for innovative and effective usage.

Alternatives to electrically powered WICR cooling include natural ventilation, evaporative cooling and ice cooling (☛3.2).



5.2 Describe and quantify the cooling loads; estimate electrical power

Importance of precooling

A major decision on estimating the heat loads and sizing the cooling plant is how much capacity should be reserved for precooling of produce. This means removal of the heat it contains after being out in the field, perhaps being in direct sunshine for some of its journey, even if best practice is to harvest produce early in the morning and keep it in shaded and ventilated areas. The ways in which this precooling is achieved are described in the guide. Ideally, a dedicated chiller should be used to precool, separate to the main cooling system. Without a dedicated chiller, the rate of cooling can be slow and quality of produce already in the cold room will be compromised by the heat brought in with the warm produce (☛2.3.2; 4.3.4; 7.7.4).

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[1] *Available from: https://doi.org/10.18174/582556*

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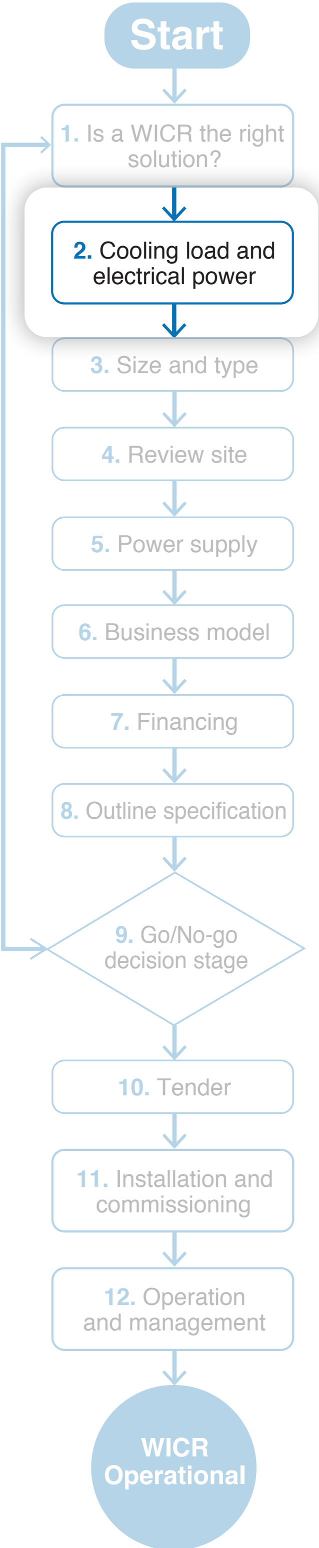


Decide what the 'Design Day' is

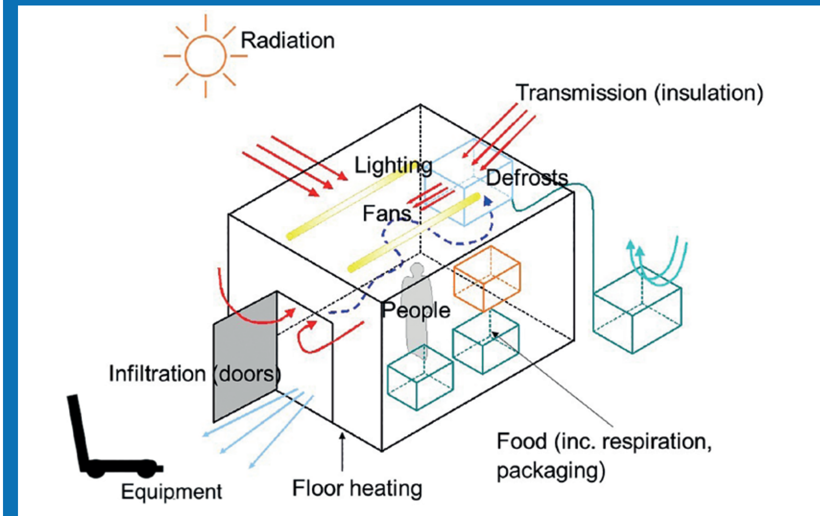
Judgement is needed on what conditions might be on a 'typical day' as well as what the harshest (peak) conditions might bring. The larger the cooling capacity of the system, the more expensive the system will be. Therefore, a compromise must be made between the purchase and running costs of a system with the chosen cooling capacity versus the business revenues that the system enables. Discussing this with your designer or supplier, it should be possible to agree on a 'Design Day' load, around which decisions on capacity can be made. The Design Day conditions would be somewhere between the Average and the Peak: closer to the peak if the business is able to invest more; but either way designed for harsher conditions than the average day (☛4.4).

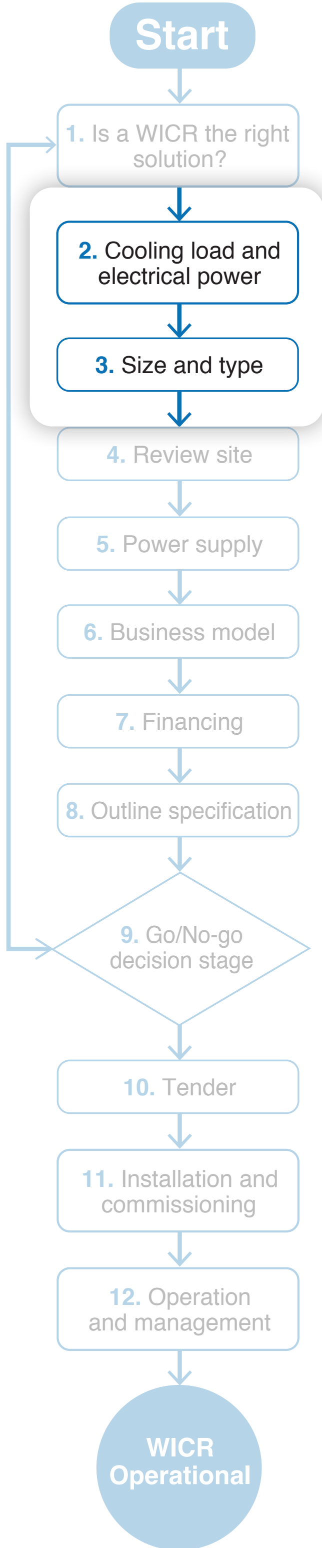
Estimate the heat load to ensure the cold room can do its job

A common reason for failure and disuse of cold rooms in hot climates is that they cannot cope with the cooling demand expected of them in service. If the plant is under-powered, temperatures and produce quality will suffer, they may even become unhygienic and pose safety risks and the investment in the cold room will not be worthwhile. Whilst design details and way of operation can reduce the heat load, they cannot compensate for a refrigeration plant that is fundamentally under-powered for the task. Estimation of the likely heat load in its own situation and usage is therefore essential (☛4.4; 4.14; 4.5).

Technical example 2: Sources of heat loads

Heat loads come from many sources: transmission through walls, ceiling and floor, solar gain, infiltration when the door is open, heat from fan motors and lights, defrost, heat from precooling produce (may be using a separate cooling plant), heat brought in with produce and packaging, heat generated by respiration of produce, heat from equipment and staff, and also the cooling of thermal storage. See figure below. How to calculate this is explained in detail in the guide (☛Part 4).





Convert heat load (cooling capacity) to an electrical demand

The total heat load is equal to the cooling capacity, after making an allowance for losses between cold room and the refrigeration plant. The cooling capacity can then be converted into an estimate of the electrical demand of the refrigeration plant. The power needs of all other components can then be added to estimate the overall electrical demand – and so specify the necessary power system. Iteration can reduce demand and optimise design to achieve a feasible cost. The process is summarised in the figure 2 below (☛4.7; 4.10.3).

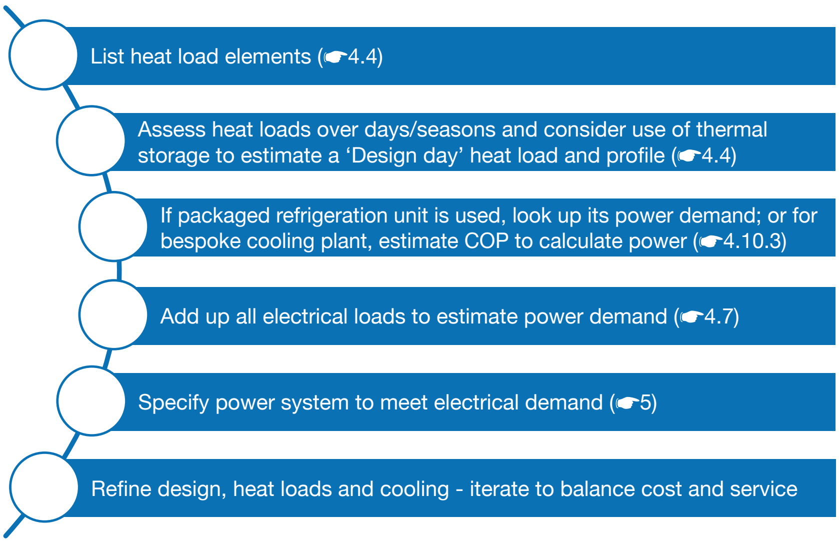


Figure 2

Overview of the process to describe and quantify cooling needs then estimate the electrical power needs of the cold room through the COP: Coefficient of Performance.

5.3 Estimate indicative size and type of cold room required

The decision on size will depend firstly on the quantity of produce to be stored. But the chosen size must take into account layout (racks and aisles), types and sizes of crates, mix of produce types and how individually accessible crates must be. Larger chambers are more expensive but allow for more accurate control of temperature and more efficient use of space. The guide covers site-built and 'containerised' solutions, standalone structures and those within another building.

The most common types of walk-in cold rooms suitable for off-grid and unreliable grid areas are (see Technical example 2 below):

- Pre-assembled cold rooms
- Prefabricated ('flat packed') cold room kits
- Refrigerated ISO containers (reefers)
- Self-built cold rooms
- Converted shipping container cold rooms.

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Technical example 2: Types of cold rooms

Pre-assembled cold rooms

Some commercially available solar photovoltaic driven cold rooms are factory assembled units delivered to site as complete structures, with no on-site assembly required. *(Freshbox)*

Prefabricated ('flat packed') cold room kits

Kits of prefabricated insulated sandwich panels containing all components needed to construct the cold room are delivered ready to lock together with mechanical joints between panels. Use is highly dependent on local specialist expertise and suppliers. *(Giertsen)*

Refrigerated ISO containers (reefers)

Reefers, or refrigerated ISO containers can provide robust and reliable cooling as self-powered, auxiliary power input or with solar modules. Most are 20 ft container sizes (6.09 m long, 33m^3 volume) and offer chilled or frozen operation. Crane access is essential but otherwise little installation work is needed. Doors are heavy and must be modified to allow opening from the inside for safety reasons.

Self-built cold rooms

Small WICR can be self-built using locally available materials and traditional mechanical refrigeration systems if local skills are available. Modified air conditioning units can be used for some simple scenarios. Several training colleges in Africa run courses in design and assembly of walk-in cold rooms and local skills and capacity is essential to keep the cold room running. A study by Efficiency for Access examined the status and scope for increasing localisation of supply chains for WICR[1].

Cold room built primarily from locally available materials near Kirolo, Uganda (Smart Villages Research Group).

Converted shipping container cold rooms

ISO shipping containers (freight, 'dry' or intermodal containers) can be converted to cold room use with considerable effort on insulation, a cooling system and power source. The most common size by far in general shipping use is the 40 ft container, but 20 ft (6.09m long, 33m^3 volume) are usually most suitable as cold rooms with internal dimensions 5.9 m long x 2.35 m wide x 2.39 m high. Doors, or at least closure mechanisms, must be replaced for ease of use and safety (openable from inside).

Example of an ISO shipping container converted into a cold room for use in rural areas (Solarcool).

[1] *https://efficiencyforaccess.org/publications/examining-fiscal-environments-for-increased-localisation-of-solar-products/*

5.4 Review the site for the cold room

A site survey should be done at the planning stage, reviewing infrastructure, availability of staff, and logistical access to deliver the cold room and components and for all future produce that will be stored. The load-bearing capability of subsoil must be established, and site preparation work listed including any foundations and clearing of vegetation. Shaded space must be available to store produce on arrival and electricity sources should be assessed for amperage and voltage quality. If solar energy supply is considered, incident sunshine and a shading analysis must be carried out for the photovoltaic module location. Approval of planning authorities must be sought (☛3.5; 3.9; 3.11).

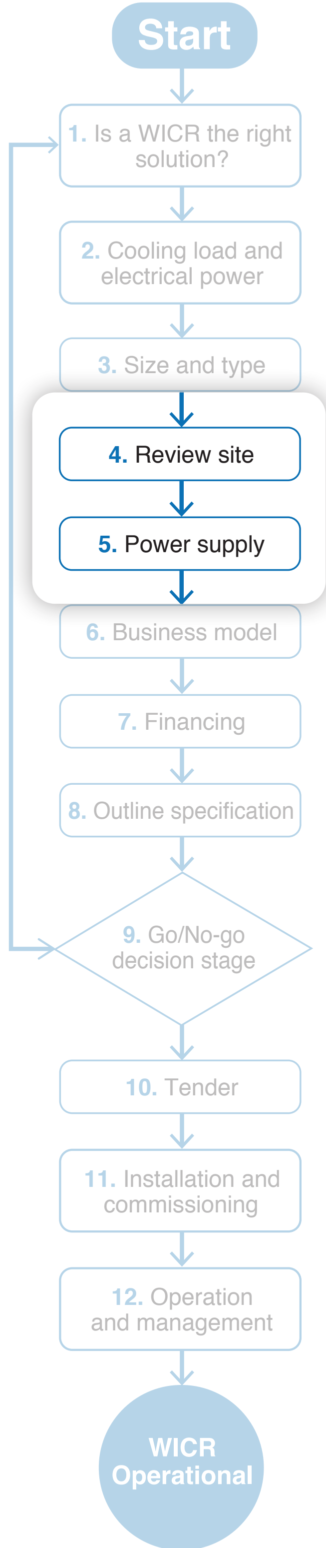
5.5 Select a power supply type

The guide helps ensure reliable electricity to sustain acceptable storage temperatures and overcome challenging electricity supply situations at both grid-connected sites and off-grid sites. Access to an electric supply may be one or more of the following, bearing in mind that it can also vary from day to day or over seasons:

- Reliable grid, meaning an electrical grid connection with sufficient quality of voltage and frequency and continuity of supply so that the cold room can be operated reliably (few outages often with warning; reasonable voltage stability; at least 22 hours power per day)
- Limited supply, meaning an electrical supply of reasonable or good quality but operating hours of less than 22 per day, and for which availability is usually known in advance so that cold room operation can be sustained (examples of limited supplies include solar arrays, renewable source such as wind or a mini-grid operating for limited hours per day, and in all of these cases electrical or thermal storage or other back up measures can be part of the business and operational plan)
- Unreliable grid, meaning a connection to an electrical grid is available but power is subject to highly variable quality and reliability often without prior notice of problems, which prevents any reliable operation of the cold room – some form of electrical or thermal storage is essential.
- Off-grid supply, meaning that no electricity grid connection is available at the site and a standalone generation system is therefore required.

Further information to characterise these supply types is given in Subsection 5.2.1.

The most robust solution would be to connect the cold room to a reliable grid. Choosing to locate the cold room a kilometre or two from the ideal logistical location to get a reliable grid connection is worth considering. However, a backup energy source or electrical/thermal energy storage may be advisable. Grid electricity quality can vary widely so seek advice if a voltage stabiliser should be considered for the site to prevent damage and premature component failure. See Figure 3.



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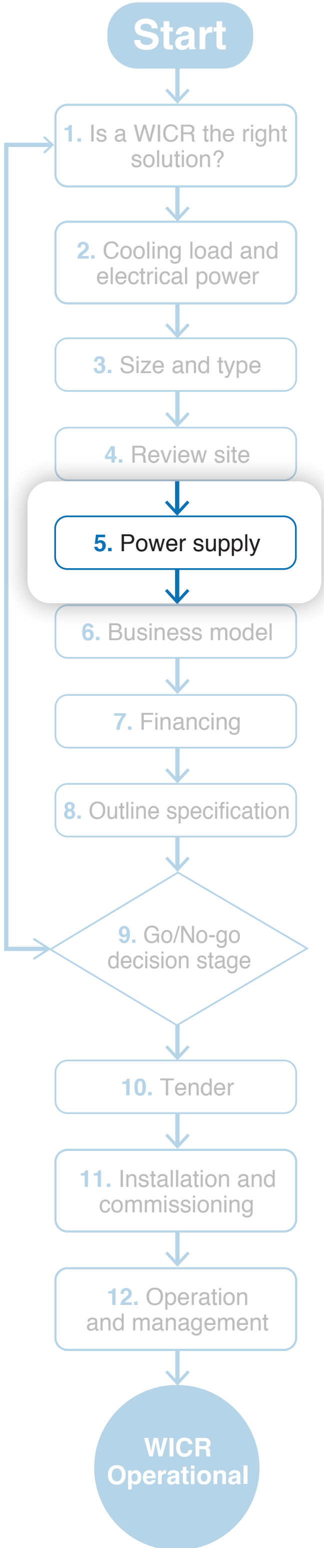


Technical example 3: Relative costs of power back-up strategies

The back-up strategy must consider how long operation without power is necessary – whether for an hour or two, overnight, or for days or more. Valuable and temperature sensitive produce may justify a sustained duration backup; less sensitive or less valuable produce needs shorter duration cover if some losses can be accepted after a lower upfront investment (☛3.3 and Part 5).

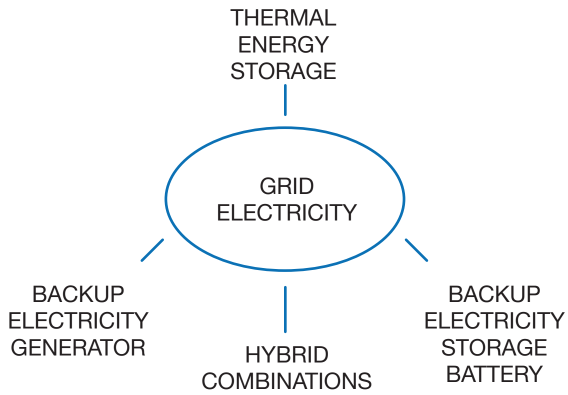


Figure 3

Grid electricity strategies for reliable and limited grids.

For off-grid, limited or unreliable grid, there are options as Fig 4. Portable fossil fuel-powered electric generators have several serious shortcomings, including high maintenance and repair burdens, fumes affecting staff and customers, daily fuel costs, business risks from fuel price rises and availability, as well as negative environmental impacts. Renewable energy resources (e.g., hydro, wind, biomass conversion) are all possible options; however, the most common approach for off-grid cold rooms appears to be the generation of electricity from solar radiation by photovoltaic (PV) systems (Figure 4) (☛5.2.4).

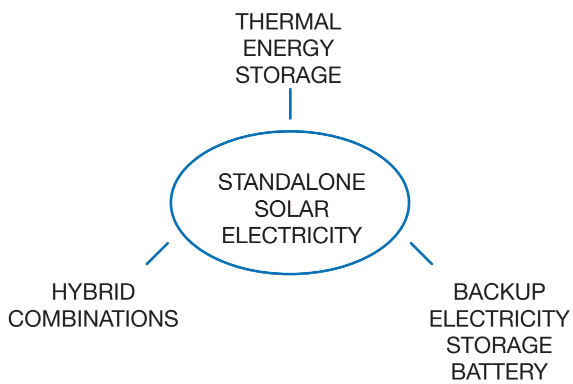


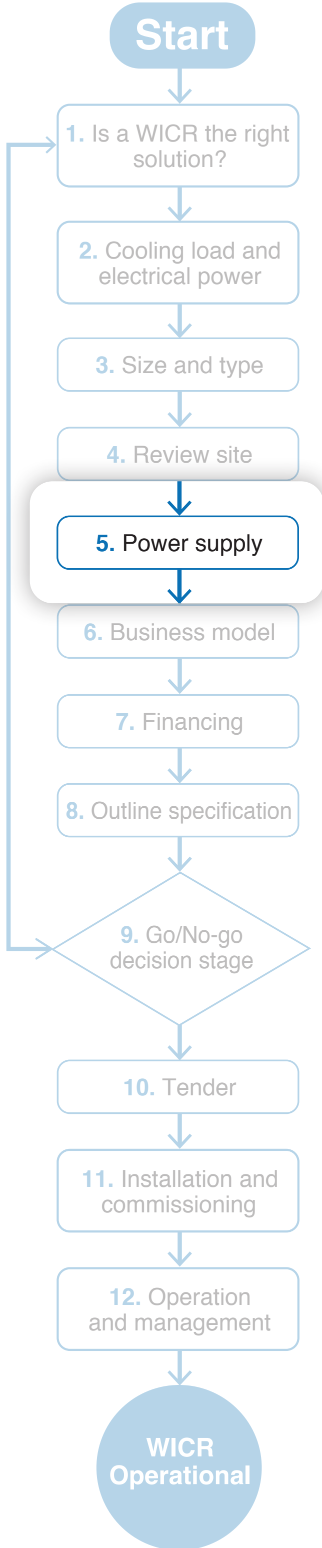
Figure 4

Electricity strategies for unreliable grid and off-grid.

Technical example 4: What is meant by an 'unreliable grid'

'Unreliable grid' covers a wide variety of possible problems with the power supply and careful assessment of the quality of power that is locally available is essential in most Global South, and especially rural, locations. Power interruptions of a second or less can disrupt control systems and are common even in Global North grids; Global South grids can be subject to blackouts of many minutes to hours on a daily basis and can seriously degrade cooling capacity unless an alternative power source, battery and/or thermal storage are provided. Voltage anomalies such as spikes lasting fractions of a second up to 350V or even 450V can cause data loss or corruption and destroy sensitive electronics - surge protection is a wise investment for some regions. But by far the most common anomaly is brownout or supply voltage lower than nominal, which can happen whenever distribution systems are overloaded. Brownouts often last hours or can be permanent with voltage deficits of 10%, 30% and sometimes as low as half the nominal voltage, where grid investment and maintenance is lacking. Brownouts can cause premature failure of motors and inability of the system to start the compressor whenever it is needed; some older designs of variable speed drive are particularly vulnerable; IT equipment can lock or hang causing data loss and system resets; contactors and electromechanical relays can be tripped, and fans deliver lower air circulation than expected. Many voltage problems can be avoided by use of a voltage stabiliser or careful specification of electrical equipment that is immune to these issues – seek advice from other local users, the utility and equipment suppliers.

Solar PV systems have the advantage of using an environmentally clean, renewable energy resource that is reasonably reliable in many Global South economies. The life span of good quality solar PV modules is 30+ years. Whilst PV-powered systems have generally relied on electrical storage batteries to run overnight and through periods of low solar radiation, batteries are costly with maintenance burdens and inevitable replacement costs. Lifespan of batteries varies by type, but even good lead acid batteries may last only five years in tropical conditions. Thermal storage systems however, are technically far less complex and a much lower cost (see box below), in addition to having significantly lower environmental impact. The refrigeration unit has to be oversized to ensure surplus cooling capacity to charge the thermal energy storage units, but some spare capacity is almost always a sound investment to cope with growth, higher ambient temperatures or the unexpected (☛5.3; 5.4; 5.5).



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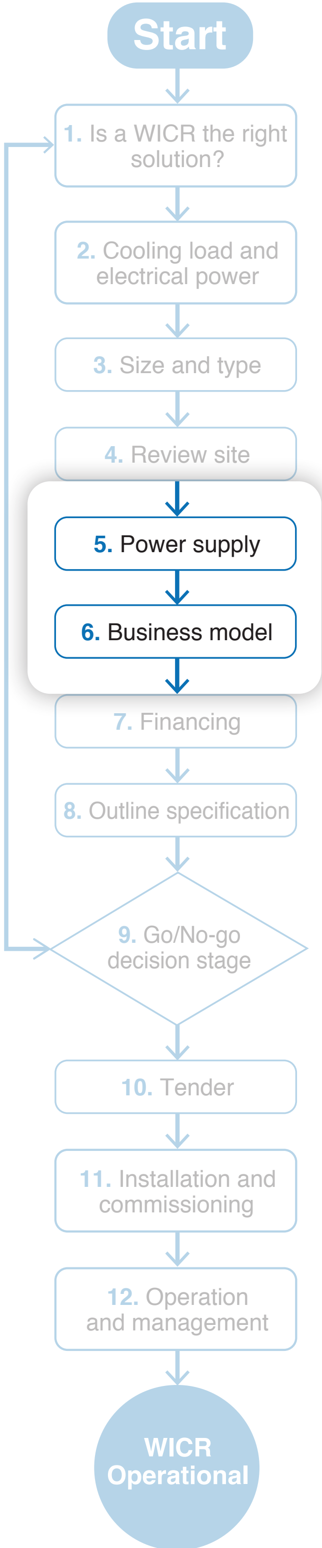


Technical example 5: Comparing battery storage with thermal storage

WHO and UNICEF found that batteries account for most failures of PV solar-powered vaccine refrigerators and inspired the development of thermal energy storage (TES) systems that mean solar PV vaccine refrigerators of today can be battery-free. The cost of a heat exchanger for an ice thermal storage system is at least one order of magnitude lower than the cost of a similar energy capacity lithium-ion battery plus charger and its lifespan is significantly longer than the battery. Furthermore, using a TES allows installing a lower number of PV modules, but the cooling unit has to be larger, to perform TES recharging in parallel to normal operation (☛5.5.2).

Design for energy efficiency and low consumption minimises energy storage system size and cost. Selecting the appropriate electricity source is detailed in 5.2 with advice on solar-powered systems in 5.3.

Batteries can be recharged when surplus energy from solar PV panels is available and is released when solar PV panels are not able to supply sufficient power to run the refrigerating unit, especially when panel power is insufficient to deliver the starting current of electrical motors in compressors. Thermal energy (cold) is stored in high thermal capacity fluids or in Phase Change Materials (PCM) and discharging the thermal storage allows for autonomy (☛5.4; 5.5).

5.6 Choose the most appropriate business model

Business models for WICR are sustainable only if they reflect both the customer and operator needs and can repay the investment. Despite transformational potential of the WICR, volume of produce and revenues generated may not be sufficient to cover the high investment costs or be affordable to the customer such as smallholder farmers. Innovative business models can help to address this challenge, for example through service-based models.

The same WICR technology and type can be used for very different business models but in all cases value-adding high utilisation rates are necessary. Examples include a produce aggregator who buys from various farmers and sells in bulk, or by locating the WICR in a village market for small vendors who pay daily per crate stored. Wageningen's Postharvest Assessment Methodology[1] could be used as a first check of economic feasibility and business model suitability.

At this early stage of market development, the WICR is likely to be the only cooled store around and it is hard to link it into an established cold chain between farm and fork. Global South economies often lack cooling infrastructure, storage and trucks and so it is essential to mobilise private capital and leverage philanthropic and grant funds to support the initial deployment (☛3.7).

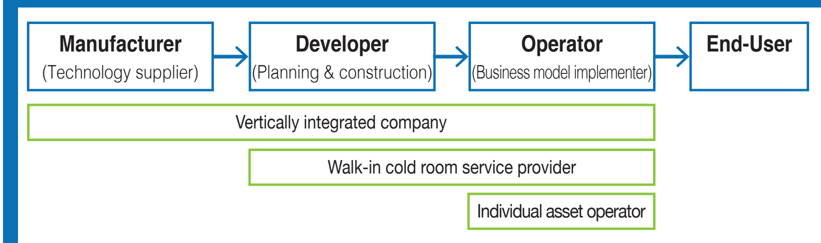
[1] *Oostweche R;J.A., Verschoor J.A., Pereira de Silva F.I.D.G., Hetterscheid S., Castelein R.B., 2022. Postharvest Assessment Methodology: conceptual framework for a methodology to assess food systems and value chaine in the postharvest handling of perishables as a basis for effective interventions. Report 2359/Wagenigen Food & Biobased Research. https://doi.org/10.18174/582556*

Technical example 6: WICR business models

The most promising business models for solar-powered WICRs are below. Full details, case studies and pros and cons of each of these are presented in Part 3 of the guide:

- Rental - Monthly/seasonal fee
- Pay-as-you-store - Daily fee per use (based on kilograms, litres or crates)
- Aggregator - Farmers sell produce to the aggregator; cooling and market linkages managed by the aggregator
- Lease-to-own - WICR repaid over time with individual or shared use (often combined with other business models)
- Upfront payment - WICR is paid in full upon commissioning
- Mobile services - WICR regularly moving (i.e., on a daily or weekly basis) to buy and sell produce

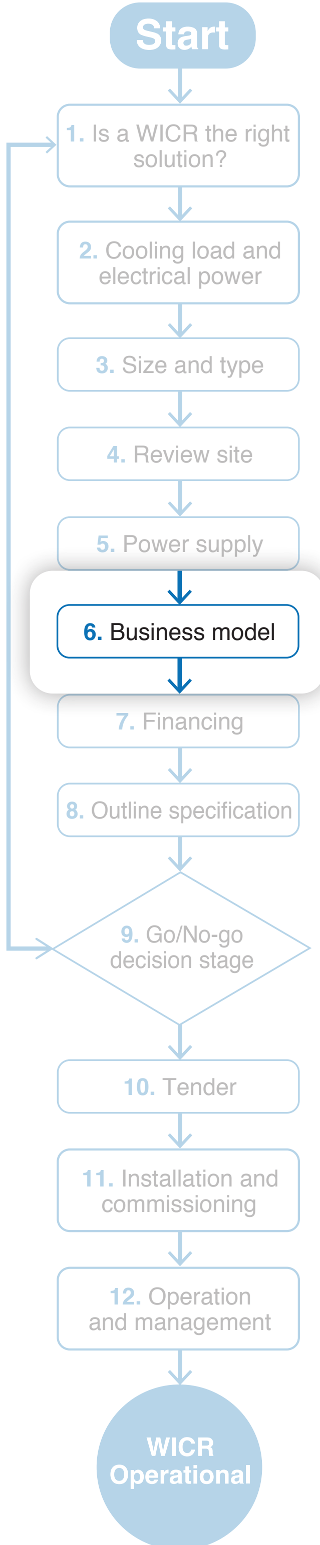
The taxonomy of WICR business models and the main actors are further described in the Efficiency for Access Assessment of the Cold Chain Market in India report[1].



Key business model stakeholders across the walk-in cold room value chain.

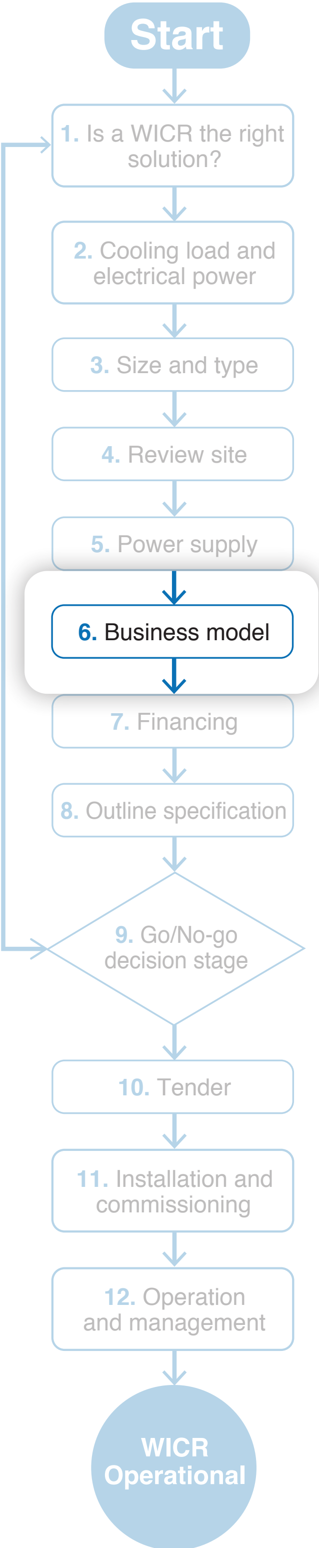
Prerequisites for a sustainable walk-in cold room business (☛3.7.2)

1. **Identify value chains with the highest potential:** value chain assessment pays off. Consider: climate conditions, type of produce for the location, projected volumes, seasonality of supply and demand, pricing plans and projected utilisation rates. A value chain-driven approach is pursued by pioneering WICR organisations[2], who often spend more than six months developing sufficient understanding of the local market dynamics and conditions before the decision on WICR deployment is made.
2. **Ensure reliable market access to create good logistics and operations:** a strategic location and channels to market with access to physical transport infrastructure such as roads and railways that link with clearly identified buyers are essential parts of the business plan. Certification for export may also be required.
3. **Design the operational and business model for high utilisation rates of the WICR:** an acceptable return on investment requires consistently high utilisation rates. For seasonal produce, consider a WICR that can be moved where needed through the growing seasons.



[1] *https://efficiencyforaccess.org/publications/key-cold-chain-infrastructure-markets*

[2] *SELCO Foundation, Sokofresh and others*



Technical example 7: Questions to ask when checking a WICR business plan

a) Added value: Check if the increase in produce price and/or reduction in postharvest losses that cooling enables is/are sufficient to justify the WICR investment. The cooling related increase in sales value per tonne and throughput should be estimated to explore the payback.

b) Market linkage: links can be local to a village market; regional to a large town; or for export or large city but in each case distance, types of roads, means of transport, cost and frequency must all be assessed to estimate the price the vendors might secure and so if they will see value from the WICR.

c) Value chain related: type of produce, seasonality, volume, preferred temperature and relative humidity, storage duration, harvesting practices.

d) Confidence that the chosen system can deliver the necessary cooling: the produce throughput and its needs for precooling and cooling should be quantified and met by the capacity of the equipment. Estimates, calculations or use of rules of thumb from experience should be expected.

e) Type of users: smallholder farmers, farmer groups, producer organisations and cooperatives, marketplace vendors.

f) Profiles of WICR users: number of users, types and diversity of users’ income streams, actual income from farming/trading (e.g., per month/season, ideally cross-referenced with volume and value chain type including any price fluctuations).

g) Courage and experience of WICR owner/operator and users: adopting a WICR for the first time into a farming or produce distribution business requires a completely different approach to traditional means. Business practices must be redesigned, and this takes both courage and investment. Previous experience of the owner/operator and users with WICR is therefore extremely useful.

h) Consider alternatives before choosing a WICR: it might be more economical to keep products in ambient conditions rather than cooling them, accepting some losses. Consider passive cooling, extending the production season and use of greenhouses.

Opportunities and challenges with service-based models for walk-in cold rooms (☛3.7.4)

Rental, pay-as-you-store, aggregator, and mobile services are all service models and will be essential to adoption of WICRs. A service-based approach avoids high upfront costs that most potential users simply cannot afford, but pricing must balance affordability and financial viability.

Advantages of service-based models are:

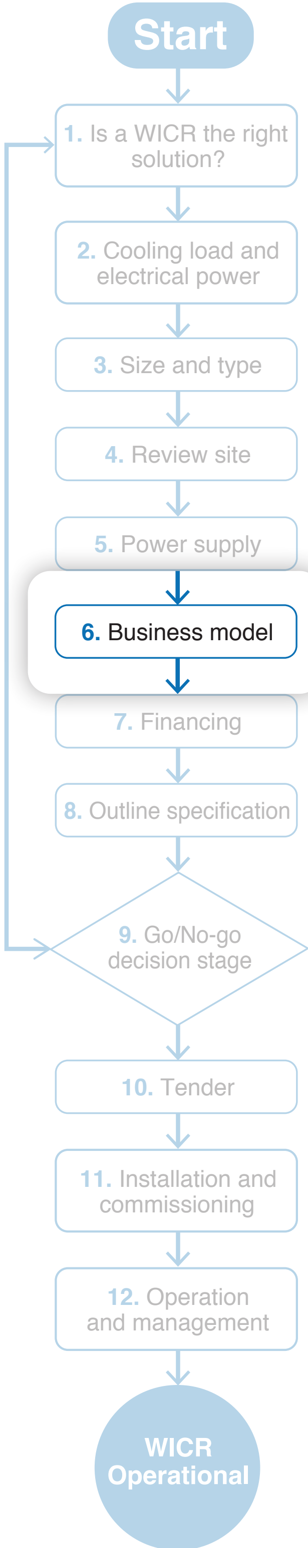
- **Lower barrier for access to cooling:** no upfront investment for users.
- **Building credit history:** users can build credit history through their payments and increase their access to finance in the future.
- **Specialisation and investment in better solutions:** when the asset is owned by a specialist provider there are even better incentives for operational and energy efficiency, use of thermal storage (over batteries), reliability of cooling, regular maintenance, ease of repair, redeployment and reuse of systems and components after use, increased technical capacity and investment for the longer term. This enables increasing use of solar energy and less reliance on diesel generators. Overall, can bring increased economic and environmental sustainability.
- **Increased utilisation rates:** Service-based models can be designed to accommodate multiple users in strategic locations to achieve high utilisation rates to make the most of assets.

Technical example 8: Cooling as a Service (CaaS)

Climate Finance Lab[5] estimates that cooling-as-a-service can reduce emissions from electricity use and refrigerant leakage by up to 49%.

The following barriers to service-based models must be addressed:

- **Securing access to finance:** payback can take several years, which requires access to 'patient' capital for system operators.
- **Dealing with risks:** when the WICR is the sole basis of the business, its operation is crucial. Risk of asset malfunction, lower than expected utilisation, local crop failures, end-user ability to pay, climate impacts, market changes must be mitigated or insured against.
- **Capacity building and training:** a trained and equipped workforce or network is essential to install, operate and maintain the cold room.
- **Cultural norms:** not owning the system and instead paying others for its use indefinitely can discourage users, especially when asset ownership is culturally desirable. Awareness of benefits must be raised, along with transition to ownership where appropriate.
- **The role of digital tools:** advanced digital tools enable tracking performance, using customer data to mutual advantage, optimising operation, collecting payments, monitoring produce prices in real time for better store/sell decisions and transparency of performance to build confidence of financiers. But uptake to date is low.



[5] *Cooling as a Service. Global Innovation Lab for Climate Finance. https://www.climatefinancelab.org/ideas/cooling-as-a-service-caas*

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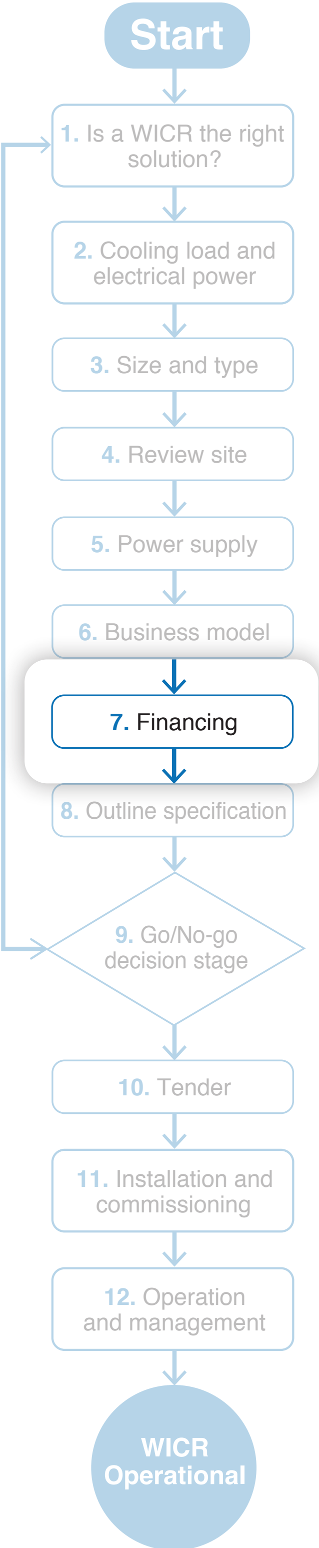


5.7 Identify financing routes

The vast majority of WICRs deployed to date have been supported through grants or leveraged blended finance instruments to de-risk investment for the private sector. Developers have secured grant funding for pilots, but only a small number have yet secured investment to scale up. Securing fit-for-purpose financing options for WICR developers is one of the most important considerations to unlock a wide deployment of WICRs in the Global South and the sector is still emerging. Grants and blended finance instruments will continue to play a catalytic role until the technology and business models are fully proven (☛3.8).

Technical example 9: The challenge of financing

To deploy 100 WICRs could require USD 3 million to meet financing and repay the lender, and the required investment period is longer than financiers in this sector are used to for off-grid solar lights, televisions, solar-powered irrigation and refrigerators. Foreign exchange risks, defaults and late payment risks, costs of payment collection, transaction fees and costs of asset financing must also be addressed, as outlined in the Efficiency for Access Road to Zero Interest report[6].

Different types of WICR developers will have different financing needs. For example, developers who sell their WICRs upfront will seek debt financing with relatively short tenure to meet their short working capital cycles. On the other hand, companies who offer service-based models will generally seek to finance fixed assets that remain on their balance sheet with equity, rather than debt, or secure lease-to-own contracts with the WICR supplier.

The main financing options for WICR developers are as follows, from most common to most speculative:

- **Grants, results-based financing (RBF) and other subsidies.** The Designing Public Funding Mechanisms in the Off-Grid Solar Sector report by ESMAP[7] provides a deep dive into the topic of supply-side and demand-side funding mechanisms. Most off-grid solar WICR grant funding has come from the Efficiency for Access Research & Development Fund[8], Powering Renewable Energy Opportunities[9] and EEP Africa[10], whereas RBF is at the core of other approaches such as SEFFA[11] and the Productive Use Appliance Financing Facility[12].

[6] *https://efficiencyforaccess.org/publications/the-road-to-zero-interest*

[7] *Designing public funding mechanisms in the off-grid solar sector. https://documents1.worldbank.org/curated/en/099300005162263450/pdf/P17515006776e102308e980bb2d798ca5c3.pdf*

[8] *https://efficiencyforaccess.org/grants*

[9] *https://www.preo.org/grant-funding*

[10] *https://eepafrica.org/*

[11] *SEFFA - Sustainable energy for smallholder farmers in Ethiopia, Kenya and Uganda, by SNV, see https://www.snv.org/project/ sustainable-energy-smallholder-farmers-ethiopia-kenya-and-uganda*

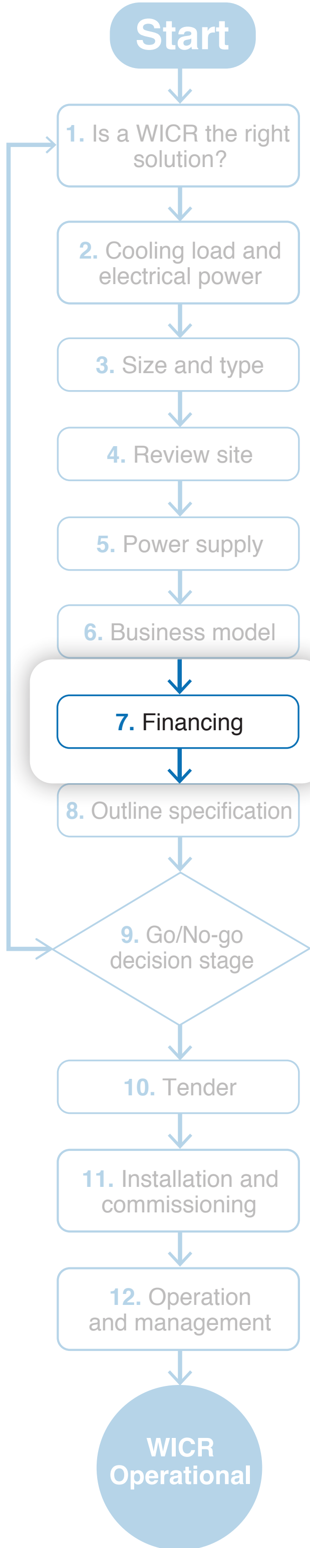
[12] *Innovative financing facility supports 18 productive use companies in Africa. https://www.clasp.ngo/updates/innovative-financing-facility-supports-18-african-companies*

- **Blended finance instruments (typically offering a combination of grants, equity and/or debt)**
  Blended finance[13] combines concessional financing from development finance institutions and/or philanthropic funds with commercial funding from private investors[14]. It allows investors to choose different risk tolerances while participating in the same investment round[15] and has been applied to WICRs already (InspiraFarms from KawiSafi[16] and SokoFresh from Acumen[17]). See also SunFunder's Scaling Energy Access with Blended Finance report[18].

- **Equity**
  Initial investment through a seed round is typically covered through the founders' savings, support from family and relatives, or angel investors. The seed round is then followed by Series A, B and C, which include higher ticket sizes in each round. There is only one off-grid solar WICR company that reached Series C to date – Ecozen who secured USD 25 million in Series C in 2023[19].

- **Debt**
  Debt in the form of a loan, usually from commercial banks or other debt providers, is paid back with interest. However, commercial banks are conservative and WICR developers face high interest rates to cover real and perceived risks. Therefore, debt for WICRs so far tends to come from international investors with expertise in energy access. BASE[20] is actively working to increase bank interest in funding service-based cooling opportunities.

- **Public-Private Partnership (PPP)**
  PPP typically involves a long-term contract between the government and a private company to provide public goods and services[21]. Governments can partner with WICR companies to operate cold rooms where critical need exists and PPP engages private sector expertise and access to essential public services. The bulk procurement PPP enables can bring economies of scale and lower cost per WICR, but very limited PPP examples exist for WICRs. Government National Cooling Action Plans could bring more of this, ☛3.7.1 of the guide.



[13] *https://www.oecd.org/development/financing-sustainable-development/blended-finance-principles*

[14] *What is blended finance, and how can it help deliver successful high-impact, high-risk projects? https://ieg.worldbankgroup.org/blog/what-blended-finance-and-how-can-it-help-deliver-successful-high-impact-high-risk-projects*

[15] *What is blended finance, and why it matters. https://about.bankofamerica.com/en/making-an-impact/blended-finance*

[16] *https://www.kawisafi.com/portfolio/inspirafarms*

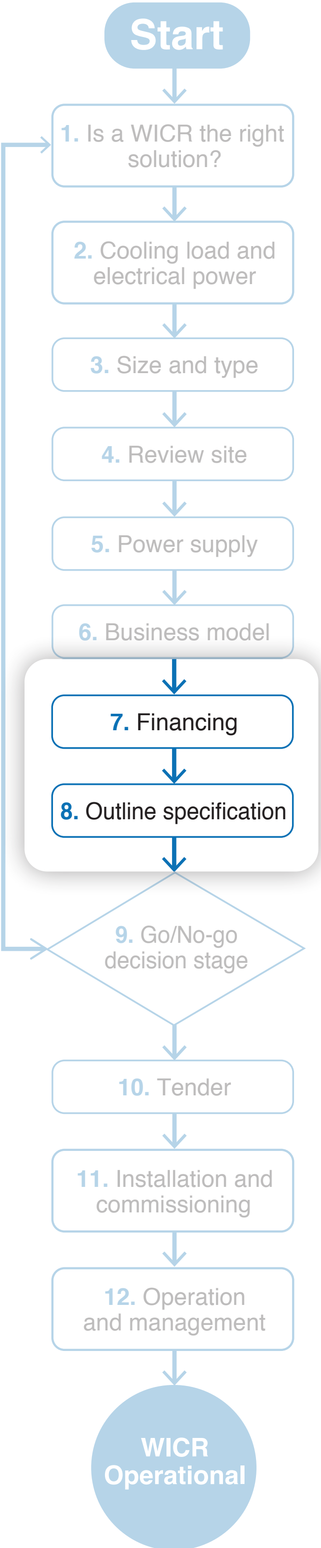
[17] *New investment: SokoFresh reduces post-harvest losses for farmers. https://acumen.org/blog/sokofresh-reduces-post-harvest-losses-for-farmers*

[18] *SunFunder shares lessons on blended finance in white paper. https://www.sunfunder.com/post/sunfunder-shares-lessons-on-blended-finance-in-white-paper*

[19] *Agri-focused cleantech Ecozen closes $25 million in new funding round. https://economictimes.indiatimes.com/tech/funding/agri-focussed-cleantech-ecozen-closes-25-million-in-series-c-round/articleshow/97277383.cms?from=mdr*

[20] *https://energy-base.org*

[21] *About PPPLRC and PPPs. https://ppp.worldbank.org/public-private-partnership/about-us/about-public-private-partnerships*



The Government of India[22] is showing leadership already, albeit for much larger cold storage projects; the smallholder dairy sector in India is a prime example of what PPP can achieve when deployed at scale[23].

- **Carbon credits**
  Monetising carbon credits could potentially play an important role in co-financing WICR developers' portfolio in the future but there have been no examples of carbon credits associated with WICRs to date.

Guiding questions to navigate the financing landscape:

- What is the required length to bridge the financing gap between procurement and full repayment (also referred to as the working capital cycle)?
- How much financing is required for your project or project portfolio and what is the breakdown between capital expenditure (CAPEX) and operating expenditure (OPEX)?
- What is the cost of servicing your source of finance and how does that align with your anticipated revenue or capacity to satisfy reporting requirements (in the case of public funds)?
- Are there any existing or potential partners to increase the ticket size of your project or portfolio?
- Who are your existing and potential finance providers? What are their risk profile and return on investment expectations?
- Are there any government, donor or philanthropic grant funding opportunities or other subsidies that you are eligible to apply for?
- How does the financing option align with your long-term strategy?
- What is your anticipated period to break even and repay the CAPEX costs of your WICR?

5.8 Draw up the outline technical specification

This section of the guide sets out the elements of an outline technical specification that should be drawn up in the planning process to ensure clear understanding of the requirements and focused discussion with potential suppliers and partners (☛3.9; 3.11). Necessary elements include:

- Legal compliance with local regulations and requirements
- About the site, address, nature of surface, shading, ambient temperatures, solar radiation profile, infrastructure including electrical power provision and road access
- Business and operational plan as it impacts technical design, with role of the cold room and its usage and future development

[22] *https://nhb.gov.in/online_application_nhb_scheme_2020_21.aspx?enc=3ZOO8K5CzcdC/Yq6HcdlxFfgWqd9Zpsh5GgGF2IJ/Sbjhzna+ksD2hsqVFnQhiDh*

[23] *Dodla Dairy, Twiga Foods and Babban Gona: Three model farmer-allied intermediaries. https://www.bain.com/insights/dodla-dairy-twiga-foods-and-babban-gona-three-model-farmer-allied-intermediaries*

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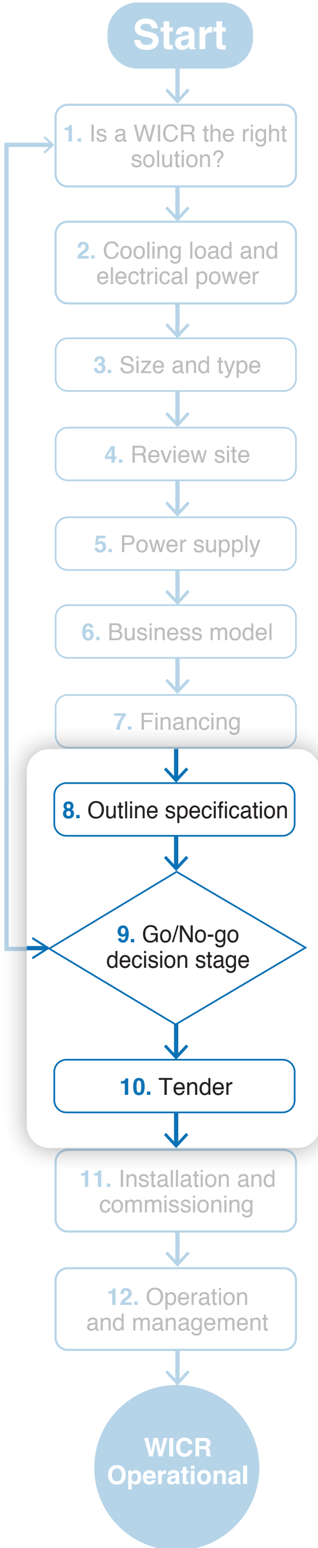
- Cooling needs, with purpose of cooling, with estimate of precooling needs, product(s) to be cooled, temperature range, relative humidity during storage and indication of the 'Design Day' cooling load for which the system is to be designed
- Cold room characteristics, system type, volume, controls, performance monitoring, refrigerant and insulation foam blowing agent, environmental and sustainability, layout, racking, crates
- Solar PV parameters, orientation and shading of solar PV modules, autonomy and type of energy storage
- Maintenance requirements
- Route to procure and contract(s).



5.9 Go/No-go decision stage

Once possible solutions have been outlined based on the target value chain(s), technical options have been investigated with their feasibility and costs, business and financing plans have been drafted, then a decision must be made on the viability of the new WICR. This step is crucial and should involve experts in all the aspects considered so far, as well as an independent advisor. "Showstopper issues" should be examined and all risks considered, building confidence and reworking problems if needed (☛3.10).

When it comes to the choice of the location, key points can be:

- Distance and connections between farmers and customers
- Safety for staff and equipment
- Availability of electrical grid or feasibility of solar systems.

For the choice of the cold room and refrigeration system, key points can be:

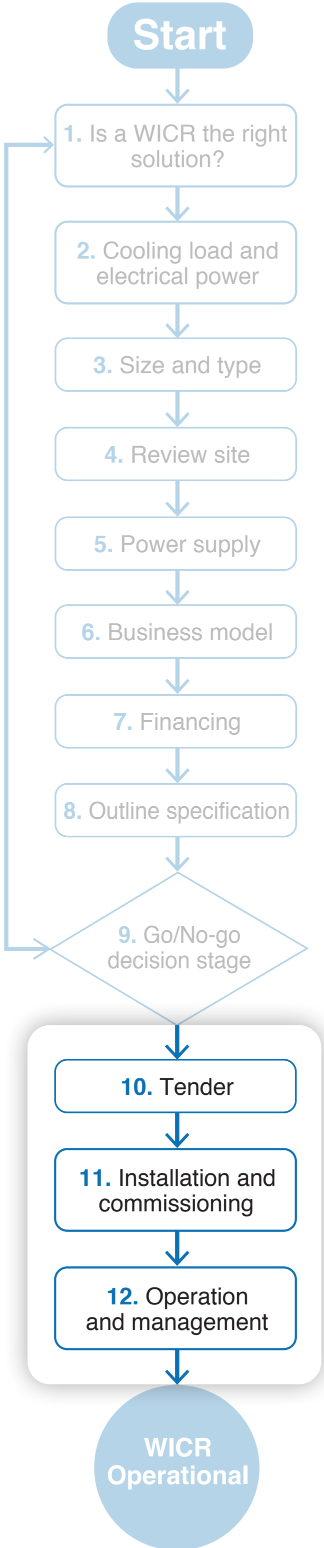
- Size of the WICR suitable for the application
- Its cooling demand, matched with the cooling capacity of the refrigeration system
- Its power needs, matched with power availability and energy storage capability.

For the business model and financial plan, key points can be:

- Effect of the cold room on the value addition to the produce, costs
- Sufficiently detailed business and financial plans, their sustainability
- Risks and challenges with payments from customers

5.10 Run the tender or procurement process

If the decision is to proceed, then the full detailed specification and design must be drawn up, bearing in mind the feedback from Go/No-go discussions. The procurement process of a WICR can be lengthy and demanding, depending on the procurement policies of the institution financing the system.



Whichever way it proceeds, it is important that both buyer and supplier have a common, clear and written understanding of what the need is, what systems and services are included and when it will happen. Necessary elements of the specification are explained in the guide with plenty of inspiration for details that must be considered for a successful outcome.

Once the needs of the end-user are reflected in the specification, discussions can move on to the available systems. The development practitioner should assess and advise on the feasibility of the end-user's requirements and solutions on the market. Procurement is usually in the form of a tender and format will vary but a 'neutral technical specification' is usually required which describes the parameters and performance of the WICR so that the process can be open to all suppliers. Technical evaluation is much easier when scored against a well-written specification, and the contract can be awarded (☛3.11; 3.12).

5.11 Installation and commissioning

A good understanding must be developed between the buyer/manager and contractors so that the final installation is done well (☛6.1). Important considerations for installation, including:

- Import and shipping into the country
- Transport to site using experienced shipping agent(s)
- Preparation of the base/floor of the cold room
- Assembly using staff with skills to handle technical aspects and fragile components
- Preparation and briefing of the installation team, with all tools and equipment. Panel assembly with close and well-sealed joints and minimal thermal bridging
- Installation of the power system
- Cleaning and ventilating ready for first use

The guide covers commissioning and identifies what must be checked, tested and measured as detailed in the commissioning contract. Key commissioning steps include: Structural checks; Electrical, Thermal, Refrigeration system; other system checks, including spare parts and system safety; Sign-off and handover including training, documentation and logbooks. (☛6.2)

5.12 Operation and management

Any cold room must be well-operated and managed to be viable, with careful postharvest management of produce. Understanding what local farmers are producing, when they are producing it, and what volumes they should store for future sale at which point are all critical to a sustainable business plan. Similarly, cold room operators working with market vendors need to understand what produce can be mixed together in the same cold room to avoid food spoilage by cross-contamination.

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The tender for a walk-in cold room should consider the operation and management aspects for the expected service life and ideally include up to five years in the tender contract for design, installation and support its operation. Advice for successful operation and management is given (☛Part 7).

Key aspects include:

a. Staff agreeing an operational protocol with basic rules and processes (☛7.2).

b. Checklists for daily and weekly actions running the cold room that should become automatic (☛7.3; 7.7).

c. A plan for storage temperature setting (☛7.4; 2.3.6).

d. Avoiding co-storage of incompatible produce (☛2.3.6; 7.5).

e. Monitoring temperature using automated and manual checks (☛7.8).

Technical example 10: A temperature is not 'just a temperature'

Be clear what temperature is monitored, i.e., surface of produce, core of produce (using a probe), air - and at the coldest or warmest location or an average? Decide if at an instant of time or an integrated average is needed. Keep records.

f. Plan for high utilisation using creative thinking and involving local producers and sellers (☛7.6).

g. Have a shaded area to briefly store produce during receipt (☛7.7.1 and 3.5).

h. Precool before placing in the cold room (☛7.7.4, 2.3.2 (science), 4.3.4 (technology)).

i. Load and stack carefully to avoid damaging produce and to ensure good airflow; discuss regularly with staff how best to do this (☛7.7.5).

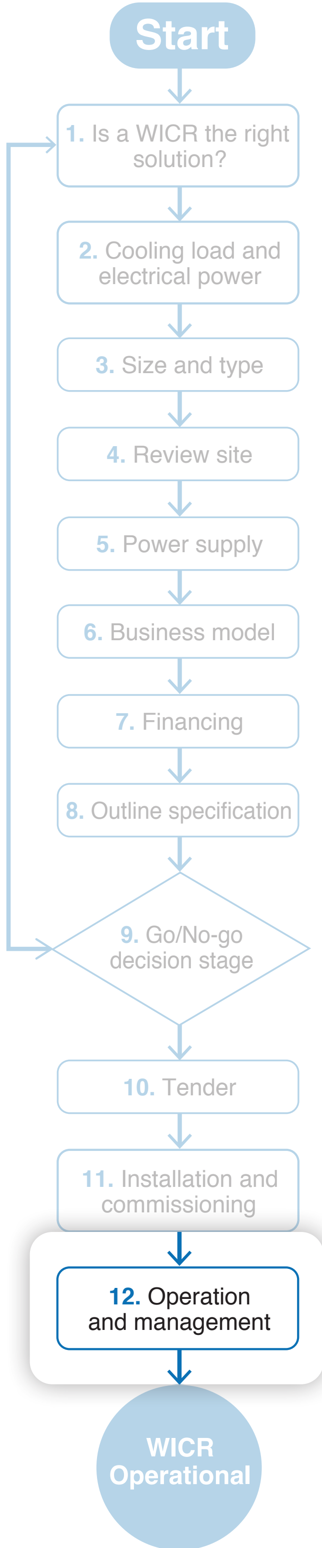
j. Beware overloading the cooling system and respect loading limits; (☛7.7.5).

Technical example 11: Plan for precooling

Without precooling, even a half-full cold room may be severely overloaded and be unable to achieve correct temperatures. Harvest early in the morning and store produce in shaded areas to minimise heat load.

k. Have a system for monitoring technical performance of the cold room: air and produce temperatures; ambient temperature and humidity; energy consumption (and production) (☛7.8).

l. Have a system for monitoring how well the WICR is operating with respect to the business model and food quality, throughput, utilisation, costs and profit (☛7.8).



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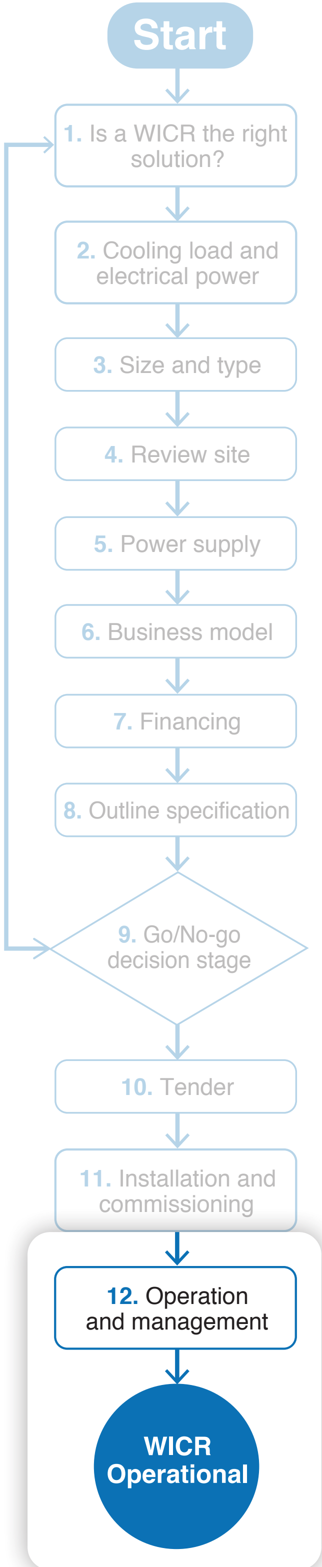


m. Have a system for tracking and managing the inventory either as an app, digital or paper-based, recording stock type, in and out dates, quantities and owner/contractor, even live market prices (☛7.9).

n. Use preventive maintenance to avoid failures at the busiest times. Use a weekly maintenance checklist and one every three or six months as agreed with the supplier (☛7.10).

o. Track the operational expenditure (☛7.11), covering both baseload and variable costs. Review over time and against the budget from the business plan.

6 Conclusion

The dozen steps summarised here and explained fully in the guide itself will help ensure that the business plan is workable, the technical needs are well defined, and the cold room technology is appropriate and capable of meeting those needs to enable effective operation of the business. Following these steps will enable practitioners in the Global South to develop walk-in cold rooms that are efficient, safe, fit-for-purpose and as affordable as possible to end users, while turning post-harvest losses into value addition. These WICRs can play an important role in the development of value chains and cold chains to improve food security and local economies, alongside many other solutions. Furthermore, the substantial community of experts that worked together to make the guide possible is seeking ways to expand their network and continue cooperation and joint working to establish effective and sustainable cold room solutions.

Contact to find out more:

https://efficiencyforaccess.org

www.iifiir.org

7 Key resources

For guidance on all of the issues to meet the many challenges of developing cold rooms for these markets, refer to the actual guide, of which this document is only a summary:

Walk-In Cold Rooms, A Practitioner's Technical Guide - Design and Operation of Walk-In Cold Rooms for Precooling and Storage of Fresh Produce in Hot Climates, in Off-Grid and Unreliable Grid Situations.

It is available free of charge as a PDF download from https://efficiencyforaccess.org/publications/walk-in-cold-rooms-a-practitioners-technical-guide or www.iifiir.org

The guide signposts many other highly recommended resources, but these important starting points for newcomers are recommended:

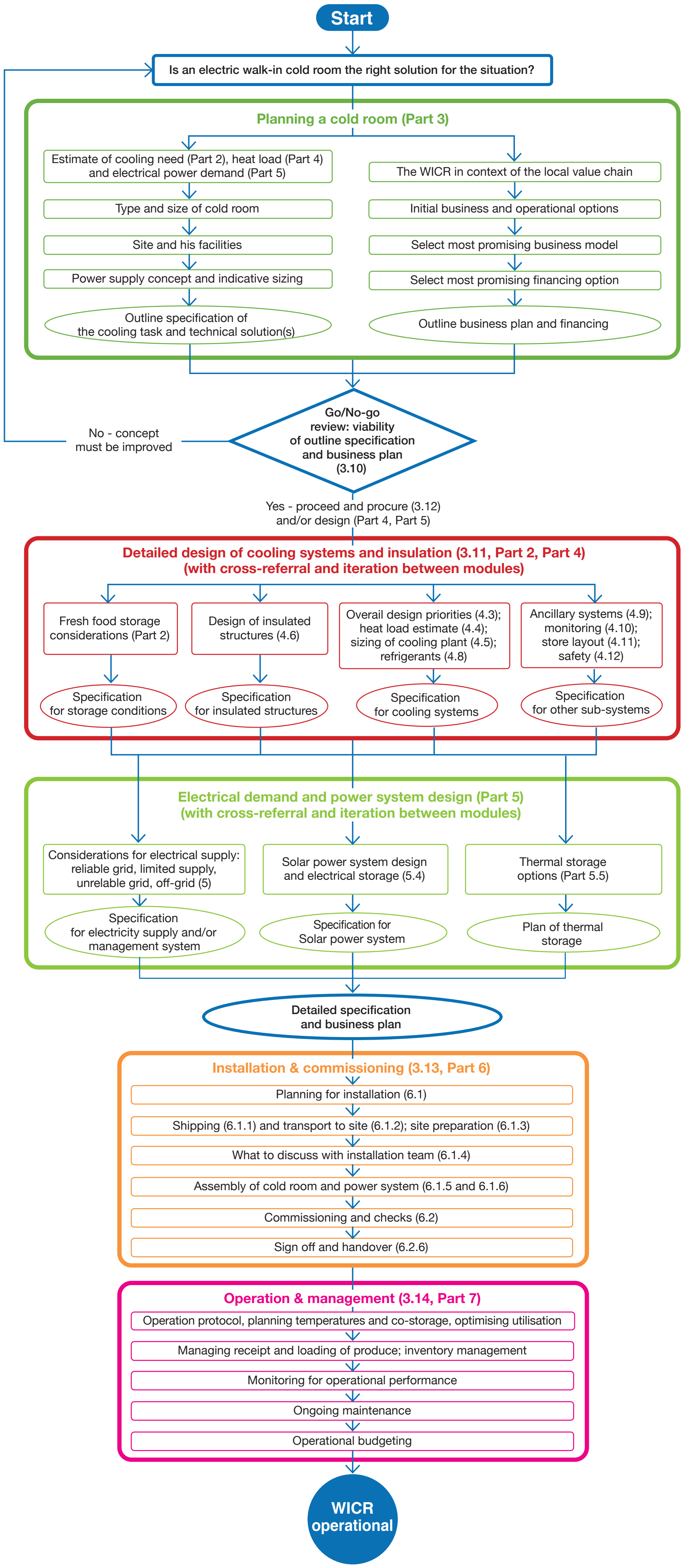
- **Keep it Cool:** Harnessing Cold Storage to Reduce Food Loss & Support Sustainable Food Systems in Emerging Economies
  https://efficiencyforaccess.org/publications/keep-it-cool
- **WICR Solar Appliance Technology Brief, Efficiency for Access, 2021**.
  Available from: https://storage.googleapis.com/e4a-website-assets/EforA_Solar_Technology_Brief_WalkInColdRooms_July-2021.pdf
- **Use of cold chains for reducing food losses in developing countries**
  (No. 13–03; PEF White Paper, Issues 13–03). The Postharvest Education Foundation (PEF), **2013**.
  Available from: http://postharvest.org/Cold_chains_PEF_White_Paper_13_03.pdf
- **Manual for the preparation and sale of fruits and vegetables, from field to market, Food and Agriculture Organization of the United Nations, Rome, 2004**.
  Accessible as an online book at https://www.fao.org/3/y4893e/y4893e00.htm#Contents
- **Environmentally and climate-friendly solar-powered walk-in cold rooms**:
  Technical guidelines, Green Cooling Initiative (GCI) / Proklima; Water and Energy for Food (WE4F), **2022**.
  Available from: https://www.green-cooling-initiative.org/fileadmin/user_upload/220509_WE4F_broschure_cold_rooms_Compress.pdf
- **A Practical guide to Solar Photovoltaic Systems for Technicians, Sizing, Installation and Maintenance, Jean-Paul Louineau, 2020**.
  Available from: https://practicalactionpublishing.com/book/2482/a-practical-guide-to-solar-photovoltaic-systems-for-technicians
- **Postharvest Assessment Methodology**: conceptual framework for a methodology to assess food systems and value chains in the postharvest handling of perishables as a basis for effective interventions, **2022**. Report 2359 / Wageningen Food & Biobased Research.
  Available from: https://doi.org/10.18174/582556

Further resource listings:

- **Efficiency for Access**: https://efficiencyforaccess.org/access-to-cooling
- **SEforAll**: https://www.seforall.org/cooling-for-all/cooling-for-all-secretariat/access-to-cooling-initiatives
- **ESMAP**: https://www.esmap.org/efficient_and_clean_cooling
- **Energypedia**: https://energypedia.info/wiki/Cold_Storage_of_Agricultural_Products
- **The Postharvest Education Foundation (PEF) White Papers**:
  http://www.postharvest.org/pef_training_materials.aspx

Overview of the content of the Practitioner's Technical Guide.

This is shown in the form of a flowchart of the process to specify and deliver a walk-in cold room.



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