ENOUGH

EUROPEAN FOOD CHAIN SUPPLY TO REDUCE GHG EMISSIONS BY 2050

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EXECUTIVE SUMMARY

This report reviews academic literatures and firms' documents about the current business models adopted in food supply chain and related sectors such as energy sector. This is useful to categorise the current implemented business models, their main features and case studies implemented by different firms. It is also beneficial to know different finance mechanism required by different business models and the enables and barriers associated to each category. Furthermore, the report analyses these business model in term of the driving forces which push businesses to implement innovative business models and their sustainability performance depending on inclusion of the social, environmental, and economic dimensions.

The aim of the report is to assess the financial requirements and develop business models to achieve requirements for 55% net emissions cut by 2030 and EU climate neutrality by 2050. The content includes: (1) literature review of existing business models and a business model framework; (2) assessment of financial requirements for 55% net emissions cut by 2030 and EU climate neutrality by 2050; (3) potential barriers to meet the financial requirement, including key drivers and barriers; and (4) potential business models that could be implemented to meet the financial requirements and secure the sustainable delivery for 55% net emissions cut by 2030 and EU climate neutrality of food chain by 2050.

Note: D3.4 will be an updated report of this (financial requirements and business models), which will be submitted by end of Month 46.

Deliverable 3.1

1 INTRODUCTION

Food demand and related energy consumption are increasing significantly due to the continuing increase in population. In addition to the demand side, the food supply is experiencing serious problems due to climate changes. Rising temperatures, drought, changes in precipitation regimes, increase of CO_2 levels are the most serious issues affecting the yields of agricultural production, and these issues are expected to worsen in the next decades. Such changes subsequently result in socioeconomic factors such as the rise of the prices as well as food insecurity. Therefore, to meet such steadily increasing in food demand and reflect the challenges in food supply side, the current food supply chain (FSC) system and activities should be reconsidered. The FSC consists of a chain of activities detailing how a product is produced and delivered to the final consumers. At each stage of the chain, value or values are added to the product by each player of the FSC (i.e., farmers, processors, distributors, and retailers) to produce the final product from fresh food and deliver it to the end users (Nosratabadi et al., 2020)

The food system is responsible for about one-third (34%) of total global Greenhouse Gas (GHG) emissions in 2015 (Crippa, et al., 2021). Of which, 29% emitted from food supply chain activities and the rest (71%) from agriculture and land use (Crippa, et al., 2021). As an essential part of the FSC, food cold-chain systems typically use high Global Warming Potential (GWP) refrigerants, fossil fuels-based grid electricity and diesel-based transport. Delivering social and economic benefits is an urgent challenge that demands to expand cold-chain capacity in a resilient and affordable way, while ensuring minimum adverse environmental consequences. The commitments under the Kigali Amendment to the Montreal Protocol on phasing down HFCs can help mobilise developing and developed countries to work together to use new sustainable food chain systems. These systems are efficient, safe, and use low or zero-GWP refrigerants and renewable energy sources considering the bottom line of social, economic and environment. To consider this triple bottom line, Sustainable Business Models (SBM) need to be employed which place environmental and social goals at the core of businesses and orient firms' activities (Alonso-Martinez et al., 2021).

We reviewed over 67 firms, businesses or projects using different business models which are implemented across different geographic regions around the world, scale, timeline in food chain sector, off-grid energy and district heating and cooling. This is in addition to review different academic published papers that reviewed and gathered data from different firms/companies about business models. We obtained key information about types of business models identified from the review which are categorical in the following main categories:

1) Service-oriented models/Servitisation models
- Pay as You Go (PAYG) model
- Pay per use model (Cooling and heating as a Service, CaaS & HaaS)
- Energy Savings Insurance (ESI) model (also known as Efficiency as a Service, EaaS model)

2) Direct sale/purchase models
3) Rental/Lease models

2 MAIN CATEGORIES OF BUSINESS MODELS

2.1 Service-oriented models/Servitisation models

A concept transition has happened regarding business understanding. Businesses are developing from selling products into delivering services. It is seen that the service market is not only larger, but also more sustainable than the product market. Many technology companies have transformed their business models from selling products to delivering services. Therefore, while servitisation is the usual next step for established companies to ensure sustainability, it also provides opportunities for small and medium enterprises (SMEs). From a supplier perspective servitisation is a way of increasing sales revenues by investing in most efficient equipment reducing energy consumption and maintenance cost. While from the customer's viewpoint, servitisation provides the benefits of equipment usage without carrying any of the related burdens and responsibilities of ownership offering lower risk level and uncertainty. It also reduces process knowledge requirement, liabilities, the requirement for various resources and competence level needs. The servitisation of a product or service shall be envisioned from the customers' viewpoint and not from the supplier's perspective, since perceptibility has a psychological dimension and could be misunderstood when looked at from the supplier's perspective (Tauqeer and Bang, 2018). The key features of service-based business models are (BASE, 2022):

- Consumers/end users can transition to the latest, energy-efficient technology without the burden of high upfront cost and only pay fixed costs per unit.
- Consumers with very low income can also afford energy services and do not have to bear performance risk of the equipment.
- Consumers can reduce their carbon-footprint by using the service of the most energy-efficient technology available in the market.
- In some cases, technology providers install the equipment, maintain a direct relationship with clients, and provide high-quality maintenance services.
- Large companies, who are the technology providers requires asset financing as it is capital intensive for them to provide energy and cooling/heating products as well as financial loans. Servitisation models provide opportunities for partnerships with microfinance institutions or other commercial lenders/investors.
- Large companies who are the technology providers or the finance providers (banks) maintain the ownership of the system in pay-per-use, or pay-as-you store model. And customers can eventually own the technology when they pay off the instalments over a period.
- Technology providers benefit from a continuous source of income from a good relationship established with their clients.
- The model is likely to succeed in communities where telecommunications infrastructure is well established as it makes the payment process very smooth and risk free in comparison to other models.
- The model brings together public and private capital in emerging markets.
- The model balances the payment and technology risks for the company and the customer.

- The model allows preventative maintenance and efficient management and operation of the cold chain appliances and whole system because it is operational throughout the year based on the need/demands of the consumer.

2.1.1 Pay as you Go (PAYG) model

PAYG model was first introduced in the mobile telecommunication sector, which allowed customers the option of flexible payments. Then was adopted in the energy sector where there are barriers to finance for example by utility services, and in the deployment of off-grid solar electrification technologies and clean cooking technologies. Similarly, there are other industries and services who have adopted PAYG payment models, for example parking, on-demand services in hospitality industry, e-commerce platforms, ridesharing in transportation, streaming movies and videos online etc. PAYG model adapts payment structures to the needs of customers with low or seasonal incomes. It allows companies to control access to a product remotely, while managing financial transactions in the form of small instalments transferred via mobile applications. The product connectivity also enables remote performance monitoring, preventive maintenance, and the creation of credit histories for customers, which in turn facilitates end-user access to finance. Customers pay for a service instead of purchasing and owning a technology and/or facility themselves. The service provider retains ownership of the facility being used, and assumes responsibility for its installation, operation, and maintenance (Efficiency for access coalition, 2021).
Customers have flexibility to either purchase a certain amount of credit or top up once the credit runs out, or they can make small payments over the period and in the long run will own the technology. Mobile payment services are usually the modes of payment as it reduces the credit risk as well as burden of cash management.

2.1.1.1 Existing examples/ case studies

Table 2.1 illustrates certain examples of PAYG business model.

Table 2.1 Example of PAYG business models

Institution/ Project Name	Country	Supported value chain	Energy + cooling technology
Danfoss (Danfoss n.d.)	India	Danfoss provided milk cooling as entry service and now moved on to other postharvest services at farm	Targeting areas where electricity supply is intermittent and supplementing with off-grid solar technologies. 9 kW (2.5 TR) using electricity when available on site or by solar panels. Cold storage with ice covering the hours without supply. A bundled plug and play solution are developed which is easy to maintain and install. Provides heat recovery to sanitary water, bundled solutions. Danfoss is responsible for operational and maintenance of the unit.

Promethean Power Systems (Promethean Power Systems n.d.)	India, Bangladesh	Food supply chain	Thermal battery is charged using just five hours of grid electricity and once charged, provides cooling power in the absence of grid power. milk chilling, stationary and mobile cold storage solutions, and refrigerated truck solutions based on its thermal battery technology and now offers a complete solution from farm to fork sustainable cold chain that does not rely on diesel fuel. (Promethean Power systems also run lease and direct sales business models)
ColdHubs Limited (ColdHubs Limited n.d.)	Nigeria	Cold storage for fruits and vegetables	Each cooler has solar panels generating 5.5 Kilowatts (kW) and the refrigeration system draws 1 kW of energy every hour. It is connected to a set of deep-cycle, long-lasting 40 kWh batteries, off-grid and on-grid inverters. The power generated is sufficient to run the hubs in all weather conditions and system are oversized to account for cloudy days. The cold room is maintained at 5 °C 24/7. Farmers pay a daily flat fee for each crate of food they store
Equatorial Power (Equatorial Power n.d.)	Idjwi Island, South Kivu, DRC Rwanda, Uganda Tanzania	Cold storage; data monitoring for the preservation of meat, dairy, and fish	30 kWp Solar PV and supported by storage capacity of 90 kWh lithium-ion batteries 5 tons ice maker is installed and powered at the industrial park. Ice boxes off-grid certified refrigeration/ freezing appliances

2.1.2 Cooling and Heating as a Service (CaaS & HaaS) model

Minimum efficiency performance standards (MEPS) are regulated in Europe and several regions of the world. MEPS are undoubtedly essential to set a minimum standard and energy labels help driving the market towards higher efficiency. However, these rules do neither address energy efficiency beyond the mere product level, nor do they help overcome the barriers that stand in the way of broadly deploying highly energy efficient solutions, beyond the minimum requirements. Such barriers include for example (CountOn cooling, 2021):

- High upfront investment cost for highly energy efficient equipment and prioritisation of investment in core business
- Missing incentives to take an integrated approach based on synergies between heating and cooling, demand side management, etc
- Lack of awareness and trust in the benefits of highly efficient solutions where payback is related to the operation of the equipment.

Service-based business models can be a way to overcome these barriers, contributing therefore to saving energy and fostering an integrated approach. Cooling as a Service (CaaS) and Heating as a

Service (HaaS) are fully service-based models where the customers only pay for the unit of cooling / heating consumed, strengthening incentives for efficient consumption, whereas the technology provider pays for all other services including maintenance, electricity, etc., remaining the owner of the equipment thereby taking on the performance risk of the system. However, technology providers are incentivised to install the most efficient equipment as they are responsible for the overall operation and maintenance. Payments for the heating cooling provided are determined upfront based on the assumed usage. No other payments are required (CountOn cooling, 2021). Example of key actors are certified clean cooling and heating equipment providers, finance providers, and customers, including hospitality, hospitals, commercial and industrial building owners, and agroindustry service/commercial. This business model is cheaper for customers and more profitable for technology providers - due to both reduced electricity consumption and more effective investment in preventative maintenance.

2.1.2.1 Structure and finance mechanism

An example illustrating the CaaS business models, main stakeholders and finance mechanism is shown in Figure 2.1 (Abramskiehn and Richmond, 2019). In this example a sale-leaseback approach is used. A financier (bank or financial institution) buys the equipment and then leases it back to the cooling system service provider for a specified period no more than the CaaS contract term. Additional collateral contract is used between the customer and the provider. An insurance company or a fund can be used to guarantee the payment to the equipment provider in the case of customer payment default. Equipment ownership restores to the technology provider at the contract end, (Abramskiehn and Richmond, 2019).

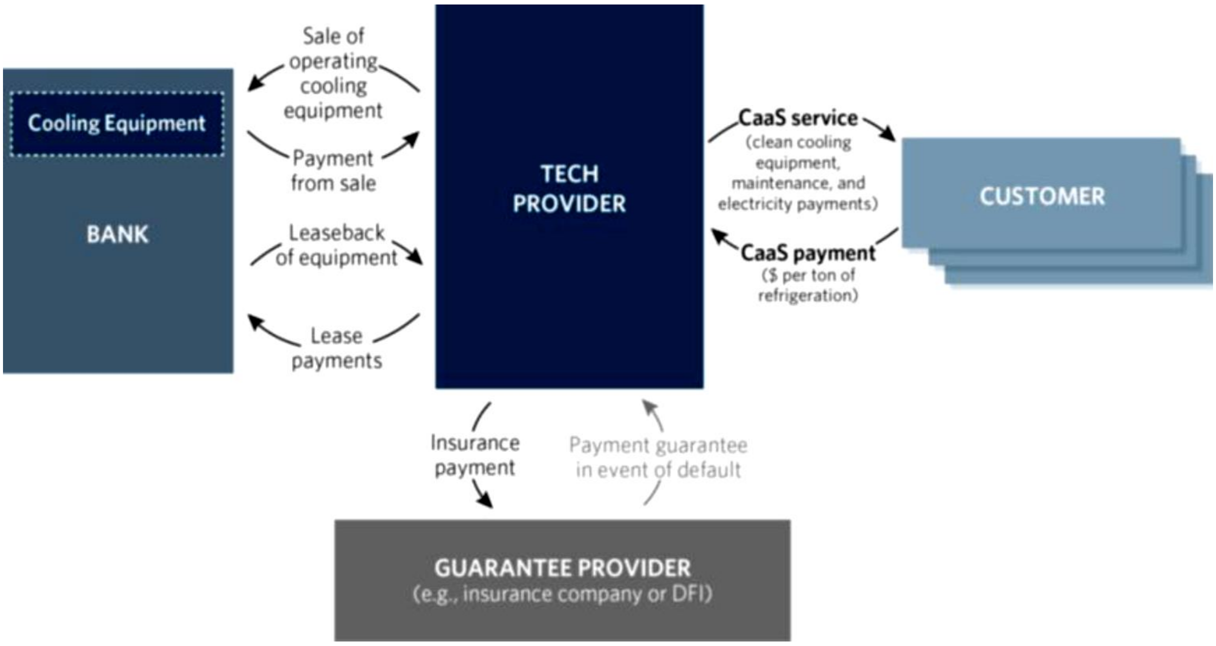

Figure 2.1. Example of business model and finance mechanism for CaaS

2.1.2.2 Main features of business model

CaaS has different features compared to other service-based business strategies such as Energy Service Companies (ESCOs), servitization in air conditioning, and district cooling but they are all instructive for application of CaaS. Table 2.2 illustrates some of these differences (Abramskiehn and Richmond, 2019):

Table 2.2 CaaS compared to other strategies

Strategy	Description	Difference from CaaS
Energy Service Company (ESCO)	A mechanism to improve building cooling efficiency through an array of energy-saving solutions including retrofitting, energy conservation, power generation, and risk management	ESCO payments are dependent on energy savings while a CaaS payment is agreed in advance as a function of actual usage.
Air conditioning as a service	A model offered by Kaer Air, based in Singapore. Under this model, the building owner specifies a required temperature for indoor environment and all aspects of design, installation, and maintenance are delegated to a provider of service.	Air conditioning as a service is provider specific to one company and focused exclusively on developed markets in Southeast Asia, without the use of recapitalization including sale-leaseback and is not applied to other cooling sectors such as refrigeration.
District cooling	An urban utility service where a centralized production of chilled water is piped to industrial, residential and commercial buildings for air-conditioning.	District cooling is focused on the aggregation of demand in large-scale systems while CaaS can be applied without aggregation to a single customer and the payment is structured as a usage fee per ton of refrigeration.

HaaS involves the provision of agreed room temperatures at certain times for a fixed fee, instead of charging for energy use on a per-unit basis. This arrangement enables the operator to remotely manage the heating system to use electricity when it is cheaper, thereby maximizing profits, and exploiting opportunities for 'flexibility' in response to information about the state of the wider power system. Table 2.3 presents some of Haas features compared to Time of use tariff (TOU) (Fell, 2019).

Table 2.3. HaaS features compared with time of use tariff

Time of use tariff	Haas as a service
Standard TOU tariff users may not have, or be able to afford, electric heating system with smart controls	HaaS providers can actively install electric heating systems with smart controls in an affordable way as the cost for the user is spread over time

Response to TOU tariffs relies on customers either actively choosing to change electricity usage patterns in response to pricing, or automating such changes	HaaS providers can promote such responses directly and remotely, with no need to rely on active involvement from customers
Shifting demand has only a small cost saving potential for individual TOU users depending on tariff, likely to be of limited motivational value for many	HaaS providers have a stronger motivation as they benefit from the aggregation of all the small shifts, they can affect, which improve profitability
TOU has an implicit 'compromise' framing, suggesting a trade-off for customers between price and what their preference would otherwise be for use of heating (or doing electricity-using activities)	The central HaaS offering is a non-comprised service regardless of what flexibility-related actions may be taken behind the scenes by the provider, potentially increasing its attractiveness to users

2.1.2.3 Existing examples/ case studies

Examples of implemented cooling and heating projects in Europe adopting service-based business models are listed in Table 2.4.

Table 2.4 Examples of cooling and heating servitisation models

Strategy	Description	Difference from CaaS
Danish District Heating (DH) companies (Chittum and Østergaard 2014)	Denmark	Danish DH is internationally recognized for the efficiency and the integration of high shares of renewables. Besides a favourable economic and regulatory framework, this is mainly since Danish DH is organized primarily in form of community-owned cooperatives. Such an organization offers a series of advantages, including the democratic participation of the users in the decisions of the utility, the prevention of any abuse of power, and the fact that, rather than maximizing the profit, purpose of the cooperative is minimizing the operating costs.
Waste-to-energy district heat network and power (CHP) (Distric energy intiative n.d.)	France, Brest	A waste incinerator that produces 130 GWh of heat and 20 GWh of electricity per year. The waste-to-energy plant serves 85 per cent of the heat demand in Brest Métropole's 25 km heat network with 50% of energy from the renewable energy. The network has plans to double in size by 2017 to 45 km, with additional renewable heat capacity such as seawater heat pumps and biomass boilers added as well as 5 MW of heat storage delivering 2.4 GWh of heat per year during peak demand.
Combined Cooling, Heat and Power (CCHP)	UK, London	Two energy centres are designed to eventually provide a maximum of 200 MW of heat (up from 100 MW today), 64 MW of cooling (up from 18 MW today, reflecting a 4 MW absorption chiller supplemented by two 7 MW ammonia chillers) and 30 MW of low-

(Distric energy intiative n.d.)		carbon electricity (up from 3.5 MW today). In addition, 27.5 MWh of heat storage and 4.7 MWh of cool storage have been developed. The energy centres currently run on gas but are designed to switch between gas and biomass in the future.
Waste-to-energy Bergen's district heating network (Distric energy intiative n.d.)	Norway, Bergen	Bergen's district heating network receives all the heat produced by a waste incinerator owned by BIR Avfallsenergi. This heat, piped to the network through a 12 km pipe, constitutes most of the heat needed in the district system. The waste incinerator produces electricity and heat but maximizes heat delivered to the network to meet demand. The incinerator burns waste as it arises in Bergen, rather than storing summer waste for incineration in winter when heat demand is higher (as Oslo does). Consisting of the pipeline from the incinerator to the city as well as 100 GWh per year of connected demand.
Southeast False Creek Neighbourhood Energy Utility District Heating (Distric energy intiative n.d.)	Canada Vancouver	The network currently captures waste heat from a relocated and expanded sewer pump station that is co-located with the Neighbourhood Energy Utility (NEU) Energy Centre; however, it has been designed to accept heat energy from future new connections of waste heat and renewable energy sources. An estimated 90 per cent of the area's heating floor space is residential (servicing some 16,000 people), in addition to commercial and institutional facilities.

2.1.3 Energy Savings Insurance business models

Energy Savings Insurance (ESI) models is currently implemented in European countries and mainly in the cooling and heating service sectors. ESI can drive investment into energy efficiency for smaller customers (SMEs) that would otherwise perceive such undertakings as too expensive or too risky. Uncertainty associated with the performance of efficiency measures inhibits third-party energy efficiency financing globally. In response, ESI has emerged as a solution offered by a small number of financial institutions, private companies, and insurance companies, to reduce the risk of an energy efficiency project. ESI is particularly useful for Energy Service Companies (ESCOs) or smaller enterprises with poor credit or who lack the means to secure third party financing. ESCOs adopt this model and guarantees a certain amount of energy savings to the customer. The Energy Saving Performance Contract (ESPC) is a contract between the ESCO and the customer where the ESCO implements the project, and the customer pays the ESCO for the performance. Different types of ESPCs exist, depending on who bears the technical and financial risk. Payments for the service provided are determined upfront and depend on guaranteed energy savings (CountOn cooling 2021).

2.1.3.1 Main features of business model

The key features of ESI business model are:

- ESI is a tool to raise awareness and convince SMEs to invest in energy efficient equipment by directly monetizing their savings.
- SMEs must take the initial burden of higher upfront investment cost as the savings will only "appear" during the operation of the equipment. However, they can access 'green loans' due to guaranteed savings. Technology providers install the project, but SMEs pay for the project development, construction, and maintenance costs.
- The technology provider pays the premium for the insurance and provides maintenance services.
- The complexity of contracts creates the potential lack of trust among customers related to the promised savings.
- Customers make service payments that are based on actual energy savings or other equipment performance metrics, resulting in immediate reduced operating expenses.
- Promising model to unlock private investments in energy efficiency.
- The model is integrated by a standardized contract between technology providers and SMEs; energy efficiency insurance policy for SMEs on not achieved energy savings and if provider does not fulfil commitments; technical validation processes by an independent entity; financing from insurance companies (e.g. green financing).
- ESI Model initial funding comes from the leverage of the development agencies, governments or private sector actors which helps in mobilizing demand and stimulate the private investments in energy efficiency.
- Well agreed methodology on how to assess energy savings is often a complex part of the contract and the process of quantifying savings.

2.1.3.2 Structure and finance mechanism

In ESCO energy saving model, ESCO guarantees a certain savings on the client's energy bill. The ESCO takes on the technical risk. The client obtains a bank loan, or uses their own equity, to pay contractually determined fees to the ESCO and the bank and keeps the difference. Countries with ESCOs that use this as the main financing model include the Czech Republic, Denmark, Canada and Thailand. Illustration of energy saving business model and finance mechanism is shown if Figure 2.2 (IEA 2017).

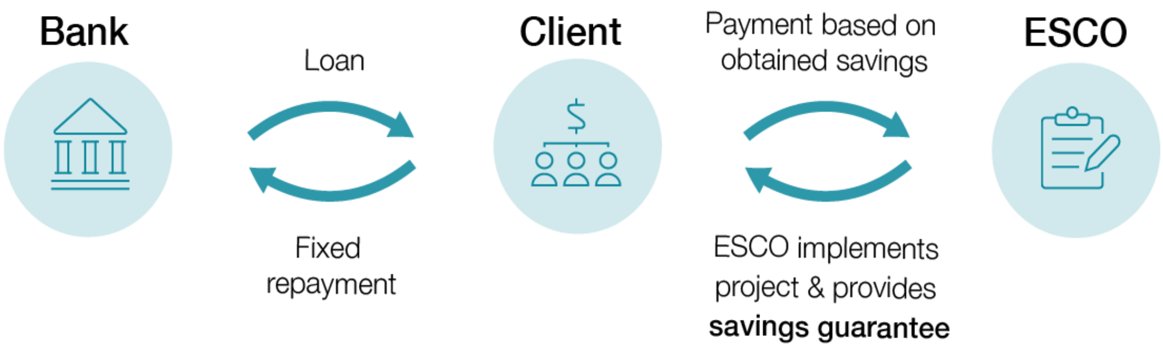

Figure 2.2. ESCO energy saving business models and finance mechanisms

In ESCO energy saving with energy insurance, under the technical package, the insurer covers the ESCO or technology provider if the promised energy savings are not achieved, assuming the technical risk associated with efficiency projects as shown in Figure 2.3 (IEA 2017).

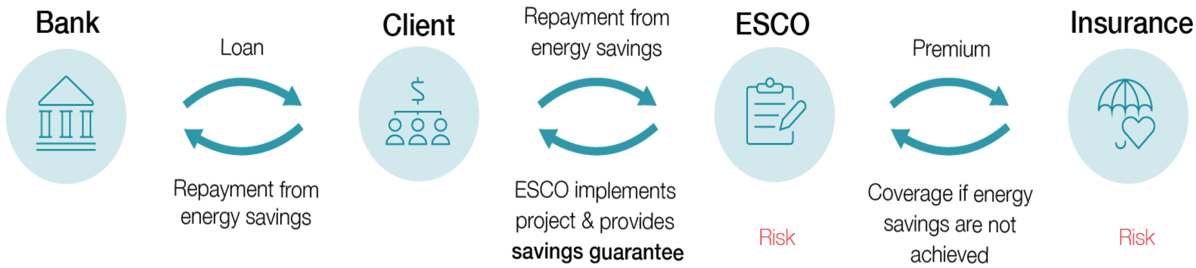

Figure 2.3. ESCO energy saving business models and finance mechanisms

2.1.3.3 Existing examples/case studies

Table 2.5 Examples of energy saving insurance business model

Institution/ project name	Country	Supported program
Energy Service Companies (ESCOs) and Energy Saving Performance Contracts (ESPCs) (CountOn cooling 2021)	Europe	The ESPCs provide the customer with a guaranteed level of energy savings and the ESCO with a reliable source of revenue. ESPCs typically last from two to 20 years, depending on the measures implemented. Depending on the customer's preference and access to capital, the customer, the ESCO, or a combination of the two can be responsible for securing the finance for the project. A direct loan agreement with a third-party lender is an option for both parties.
Basel Agency for Sustainable Energy (BASE) and partners (AGORIA, ANESE and Innoenergy) (Better Buildings n.d.)	Belgium, Spain, the Netherlands	BASE and partners have developed the standardised servitisation contractual agreement (legal, taxes, servitisation framework) which helps technological providers to transition from sale of energy efficiency project to a pay-per-use contract. Support to accelerate the market adoption of energy-efficient solutions by SMEs in heating and cooling sector.
BCSD, Energy Lab and FIRE are partners (Funded by European Commission) (Better Buildings n.d.)	Italy, Portugal, Spain (Developed in Latin America)	BDSD has created a commercial brand- 'GoSafe with ESI' has been registered. The consortium partners in Italy, Portugal and Spain are building the pipeline of energy efficiency investment projects using the brand and delivering capacity building activities for the different key actors in the market: technology providers, financial institutions and SMEs.

EPconnect ESCO-in-a-box (EPgroup, n.d.)	UK	Energy services companies (ESCOs) provide energy solutions and financing support to organisations that want to combat their carbon output. However, it's difficult for small and medium-size businesses (SMEs) to tap into this level of expert guidance. In Oxfordshire, the ESCO-in-a-box initiative is changing this story to bring the benefits of energy efficiency to hard-to-reach businesses via a local one-stop shop

2.2 Direct sale/purchase models

Direct sale or purchase business models have two mainstream business to business (B2B) and business to consumers (B2C) models. Direct sales models are usually suitable for NGOs, cooperatives and individual customers who have the capacity to take the burden of up-front payment. Provider of the equipment or manufacturer provides information and skill-based support to the customers as a part of the sales service to improve the productivity as well as efficiency. There are different model structures and purchasing modes depends on the customers' financial capacity if they can pay directly or get a loan from a finance company as shown in Figure 2.4.

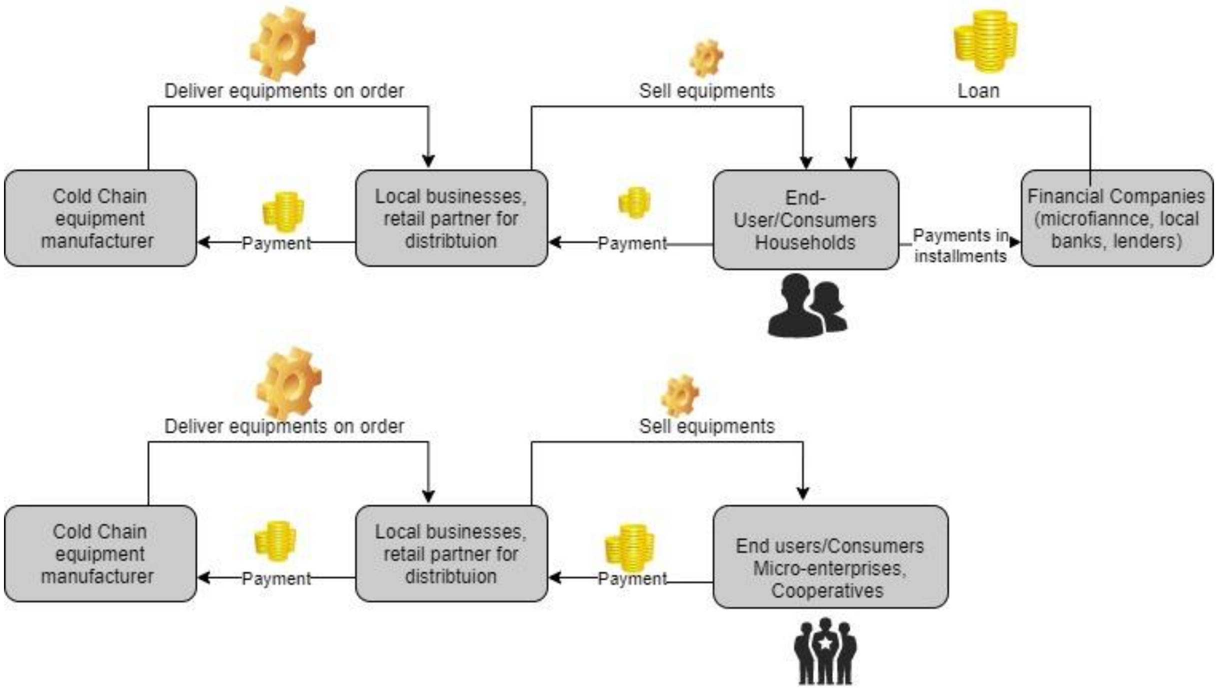

Figure 2.4. Direct sale business model structures

2.2.1 Main features of business model

The key features of the direct sale business model are (GOGLA 2021):

- NGOs/Foundations are providing grant money to SMEs, large cooperatives etc to make the first payment and the rest is supplemented as a loan from microfinance institutes, local banks.
- NGOs/Foundations, financial institutions and government are providing financial support in the form of grants, loan and subsidies to customers to make direct purchase, however there is low

adoption rates, especially in rural areas and this is because of lack of quality assurance, lack of understanding of the benefits of by customers, lifestyles of rural areas etc.

- Customers, large federations may prefer direct purchase models because they like to retain ownerships over the assets.
- Support from government to micro-entrepreneurs in the form of subsidies to adopt the efficient technologies.
- Small farmers find it difficult to purchase cooling equipment using this model despite the financial support because the repayment terms from a traditional financial institution rarely align with the seasonal cashflow cycles of the agricultural sector making it difficult for farmers to pay the monthly instalments back to the bank.
- Direct sales models create possibility for transfer of knowledge around technology through training programs building the skills and capacity of the customers.

2.2.2 Existing examples/case studies

Table 2.6. Examples of direct sale business models

Institution/ Project Name	Country	Supported program
Swiss Sustainable Finance (Swiss Sustainable Finance 2020)	Switzerland	Community Finance allows small retail investors to invest in Renewable Energy (RE) projects and receive compensation in the form of electricity, certificates or origin and interest payments. Direct ownership of generating facility or available infrastructure is the most common form of RE ownership. It excludes a large portion of the population, tenants from RE ownership. However indirect ownership model allows electricity customers to participate financially in RE project and co-operatives are vehicles for consumer co-ownership.
GreenCHILL - Biomass Powered Cold Rooms (New leaf 2023)	India	It is a standalone 3.5 TR refrigeration unit integrated with 10-20 MT cold rooms. The average quantity of agro-waste required per day is 60–90 Kgs to maintain 0° – 25°C temperature in cold room. Cold storage, pre-cooling, ripening & dehydration at First Mile or Point of Aggregation. To promote the technology, the sales are financed by Nationalized Banks (35% credit) and -50% subsidy from Government of India.

2.3 Rental/Lease business models

Rental/Lease models are used at all stages of food supply chain to improve access of small customers to low-carbon efficient cooling/heating technologies and cold chain appliances. This model is widely adopted, for example, to store foods, for refrigerated food transport, or for use of equipment/technology in processing and retail businesses. Ownership of the system lies with the local organizations/companies or the technology provider/manufacturer. The ownership of the technology can be transferred to the customer at the end of the re-payment cycle is completed on the capital cost and recurring costs for operation and maintenance. Figure 2.5 presents an example of rental/lease business model.

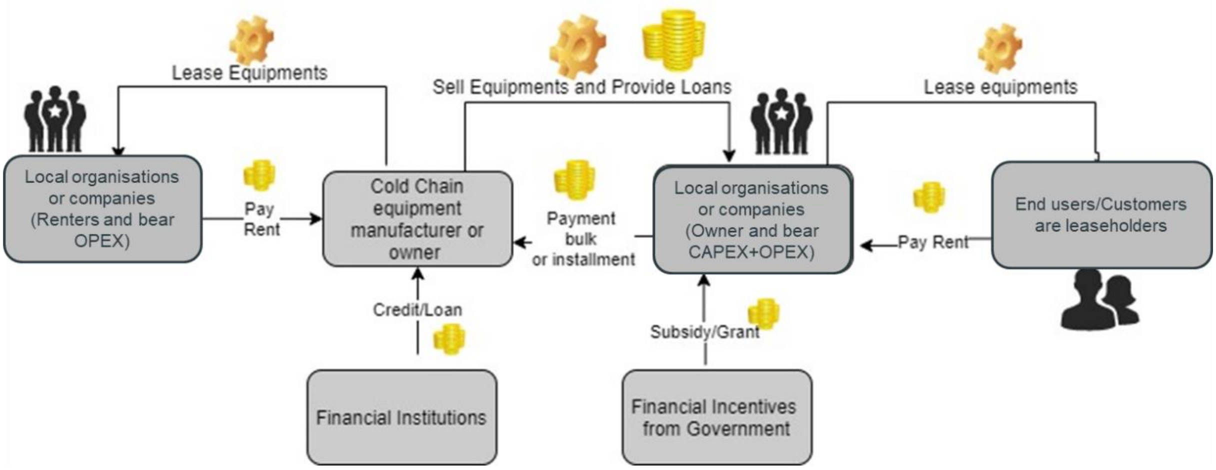

Figure 2.5 A Rental/Lease business model structure

2.3.1 Main features of business model

The key features of the rental/lease business model are (GOGLA 2021):

- Customers who prefer rental/lease models are small companies and small industries because it does not involve high up-front cost and due to lack of credit history or collateral they cannot apply for loans and other finance support.
- Customers of various geographic location and business size can benefit from the models - it suits poor farmers, entrepreneurs, business of various sizes.
- The model allows the flexibility of lease/rent charges based on the quantity of food stored and transported, geographic location, temperature requirements etc.
- Payment risk defaults are high compared to direct sell/purchase models. Companies can adopt a digital payment mechanism to monitor timely payments, especially in remote areas.
- The business ownership can be transferred to the customer by contracting on ''Lease to own model'' after paying the instalments in an affordable way.

2.3.2 Existing examples/case studies

Table 2.7. Examples of Rental/Lease business models

Institution/ Project Name	Country	Supported program
Heat contracting combined with equipment rental	Europe	The customer rents the equipment including the payment for additional services such as maintenance and repair, combined with an energy supply contract based on EUR/kW heat consumed. It removes the necessity to pay a high upfront investment cost and the customer only pays for the heat

(CountOn cooling, 2021)		consumed which is an incentive for the customer to save energy. This model is well-known from other sectors such as car leasing.
SunDanzer Refrigeration Incorporated (SunDanzer, 2023)	Tuscon, Arizona, USA	Solar-driven Farm Milk Coolers uses the direct drive photovoltaic refrigeration (PVR) technology. • The PVR uses vapor compression cooling cycle with an integral thermal storage (ice storage) liner, PV modules and a controller. • The PVR employs a tracking system to maximise the running of refrigeration unit during the daylight hours. • This technology was successfully used in drive vaccine PVRs using ice storage.
Youmma (Youmma, 2023)	India	In weak-grid areas, (i) solar PV with electric battery and (ii) solar PV with PCM thermal batteries based solar refrigerators are being offered by companies. The technology for a 268-litre refrigerator requires a 0.5 kW solar array and two batteries of 120 Ah each. Refrigerators are being provided with AC/DC interoperability functions in weak-grid areas. This provides customers the flexibility to operate a system that supports both AC and DC. This allows them to charge the batteries with grid electricity as well as use the refrigerator on an AC power supply.
Savanna Circuit Tech Ltd. (WB, 2019)	Kenya, East Africa Rift Valley; Central, Western,and Eastern Kenya	Solar-powered milk storage tank mounted on a motorcycle. The company uses aluminium tanks which are connected to a solar panel. The service requires the farmers to download an app—Maziwa plus, that keeps a track of how much milk is sold by each farmer. Each cooling unit has a capacity of 120 litres but can be customized to capacities of up to 1,000 litres. The company switched from direct sales to lease business model to improve access of milk transport facilities to low-income customers. The milk is transported to the bulkers for $0.003/kg. Milk producer, the driver of the transport services and milk collector/bulker are all connected by a mobile app that ensures inclusivity between the parties. The motorcycle milk collectors take the cooling equipment mounted on lease. And provide the cooling services to milk producers so this is a combination of both lease and service models.

3 FINANCE MECHANISMS TO SUPPORT BUSINESS MODELS

Financing sustainable business models includes both current environment-friendly (green finance) and future environment-friendly (transition finance) performance levels. Transition finance is to reduce current high GHG emissions levels or other environmental impacts by financing private investments transitioning to a sustainable and climate neutral economy. Transition finance is an urgent requirement to reduce GHG emissions to net-zero by 2050. It is needed to be carried out gradually over time by companies to achieve their sustainable goals depending on companies' starting points (European Commission, 2023). Currently, there are verity of finance mechanisms utilised to facilitate the adoption of business models depending on their type, Table 3.1 lists these.

Table 3.1. Finance mechanisms (BASE, 2019)

Finance Mechanism	Description
Debt	Borrowers commit to pay to the lender the principal and interest (cost of funding) on an agreed schedule. Borrowers use assets as collateral as reassurance to the lender. Typical debt instruments include credit, mortgages, leasing.
Equity	Equity financing normally implies selling a stake in the company receiving the funding from investors, who expect to share the profits of the company and the investment stake appreciation.
Grants	Grants are non-repayable fund contributions (in cash or kind) bestowed by a grantor (often government, corporation, foundation, or trust) for specified purposes to a recipient. Grants are usually conditional upon specific objectives on use or benefit and might be require a proportional contribution by the recipient or other grantors.
Risk Mitigation Instruments	Financial instruments that are available in the market to mitigate the risks of investing in energy efficiency. The beneficiaries of risk mitigation instruments can be end-users, lenders, project developers, or the government. Insurance and credit guarantee instruments are the most common financial risk mitigation instruments.
Blended loans	Blended loans mix grants or subsidized loans with additional funds raised from other sources (e.g. capital markets). Blended loans might reduce borrower costs and increase the capacity of funds to take higher risks. Blended mechanisms are increasingly used by multilateral development banks (e.g. the World Bank, the Asian Development Bank, the African Development Bank, the Inter-American Development Bank), and bilateral financial institutions (e.g. Agence Française de Développement, or KfW Group).
Green/climate Bonds	Bonds are loans made to large organizations from one or many investors for a specific period and at a particular interest rate. A green bond is a bond specifically earmarked to be used for climate and environmental projects. A bank may sell a green bond to raise money to finance energy efficiency projects.
Convertible debt	A combination of debt and equity: loans are repaid or converted into company shares later.
Securitisation	The process by which a company groups different financial assets/ debts to form a consolidated financial instrument sold to investors. In return, investors receive interest payments, e.g. an energy efficiency company can trade its future cash flow with investors.
Crowd-financing	Is the practice of raising capital through the collective efforts of a large pool of individuals or peer-to-peer lending that can include individual investors, family, and

	friends typically through social media and crowd funding web platforms. Finance offered through crowd funding includes lending, equity, donations, and insurance, among others.
Aggregation	Aggregation refers to aggregating demand, such as communities joining up in cooperatives or pooling energy demand in a region and bulk-procuring services to deliver household energy efficiency systems or aggregating a portfolio of projects (normally small enterprises or projects) with similar technologies or business models. Some of the benefits of aggregation include transaction cost reductions and limited risk exposure because aggregation distributes costs and diminishes the associated risks of a portfolio's execution; that is, risks are distributed if projects underperform.
Performance-based financing	Financing agreement in which a third-party (ESCO) provides funding to cover the upfront costs of high-efficiency equipment for a customer. The customer repays the energy efficiency investment from the energy savings generated by the project, so there is no need for customer upfront capital. Usually, the financing is off the customers' balance sheet.
On-bill financing	A financing option that uses utility bills to collect periodic payments of the beneficiary customer to repay loans.
Owner equity	Owner provides their own capital.

3.1 Servitisation finance Models

- Technology providers (TP) collaborate with microfinance institutions, commercial lenders as upfront cost for TP can be high.
- Donors, NGOs, Foundation provides grants to consumers to make payments. This is great support for women and young farmers who do not have access to cash and assets.
- Increases the accessibility of low carbon energy efficient products and services to wide range of customers with flexible payment options.
- FPOs to get a loan from financial institutions. The FPOs need to show a healthy balance sheet and prove its credit worthiness to the financial institutions to get a loan for setting up the off-grid cold storage.
- SMEs decision-makers are price sensitive and tend to have limited financial resources or access to credit. The implementation of the ESI Model initial funding comes from the leverage of the development agencies, governments or private sector actors and mobilises demand and stimulate the private investments in energy efficiency.
- Under recapitalization approach – a sale-leaseback – a bank or financial institution would purchase equipment and then lease it back to the technology provider over a period no more than the contract period.
- Municipalities provide the mutual with a guarantee that underwrites the risk. This allows it to obtain low-cost financing, for example, 1.5 per cent from a mortgage company (a mutual bank); without the guarantee, it would have to pay 2.5 per cent.

3.2 Direct Sale or Purchase finance Models

- Customers/Consumers take a loan from financial institutions to pay the upfront cost of the equipment/technology to the technology providers/manufacturers. Then the loan is paid back to the financial institutions in small instalments. Third parties sometimes need to foster a relationship between consumers and financial institutions as financial institutions are often unwilling to lend customers who do not have a credit history.
- Government provides subsidies to encourage the uptake of low carbon, low GWP and efficient technologies.
- Innovative funding mechanisms like –revolving funds, concessional loans increase the purchasing power of consumers.
- Limited access to finance, can delay the deployment and adoption of the near-to-market technologies.
- Community finance can provide funding for renewable energy projects and allow small-scale retail investors to invest in renewable energy.

3.3 Lease or Rental finance Models

- Government provides subsidies, NGOs/Foundations provide grants which help technology providers/manufacturers to reduce the burden of risk of default by the renters/leaseholders or risk due to inefficiency of the technology as promised.
- Customers' needs to prove their credit worthiness due to high risk of default. Consumers needs to show some evidence of financial health, collateral etc.
- Technology provider and a finance foundation scale-up their credit facility to finance the acquisition of technology provider assets, such as on-farm cold storage and processing facilities, with terms and conditions that are tailored to the needs and capabilities of agri-businesses. Generally, eligible customers are offered three-year payment terms. The facility can lend up to 80 percent of the total invoice value.

3.4 Energy Savings Insurance finance Models

Investments in energy efficiency is hindered by lack of access to finance and high perceived risks and upfront costs, especially among SMEs. The ESI model has been established to reduce the risks and foster the investments in energy efficiency by delivering a policy to cover customers on not achieved energy savings, and when the provider cannot fulfil commitments. The model is currently under implementation in Europe after it has been developed in Latin America. The implementation of the ESI model requires initial funding for the development of the programme. Development agencies, governments, or private actors can provide the required funding (Swiss Sustainable Finance 2020). Figure 3.1 shows a typical ESI financing structure.

Energy efficiency investments face unique barriers, such as high up-front costs, long pay-back periods and small scale of individual investments. Energy Performance Contracts (EPCs) hold the potential to tackle some of the standing financing barriers in energy efficiency by gathering investments into portfolios to reach the required scale. EPCs also facilitate third-party financing. Institutional investors can become involved by buying receivables allowing ESCOs to undertake more energy efficiency projects. Policymakers, in conjunction with other stakeholders such as the financing community and project developers, should ensure that favourable policies are put in place to enable the development and financing of energy efficiency projects (Swiss Sustainable Finance 2020)

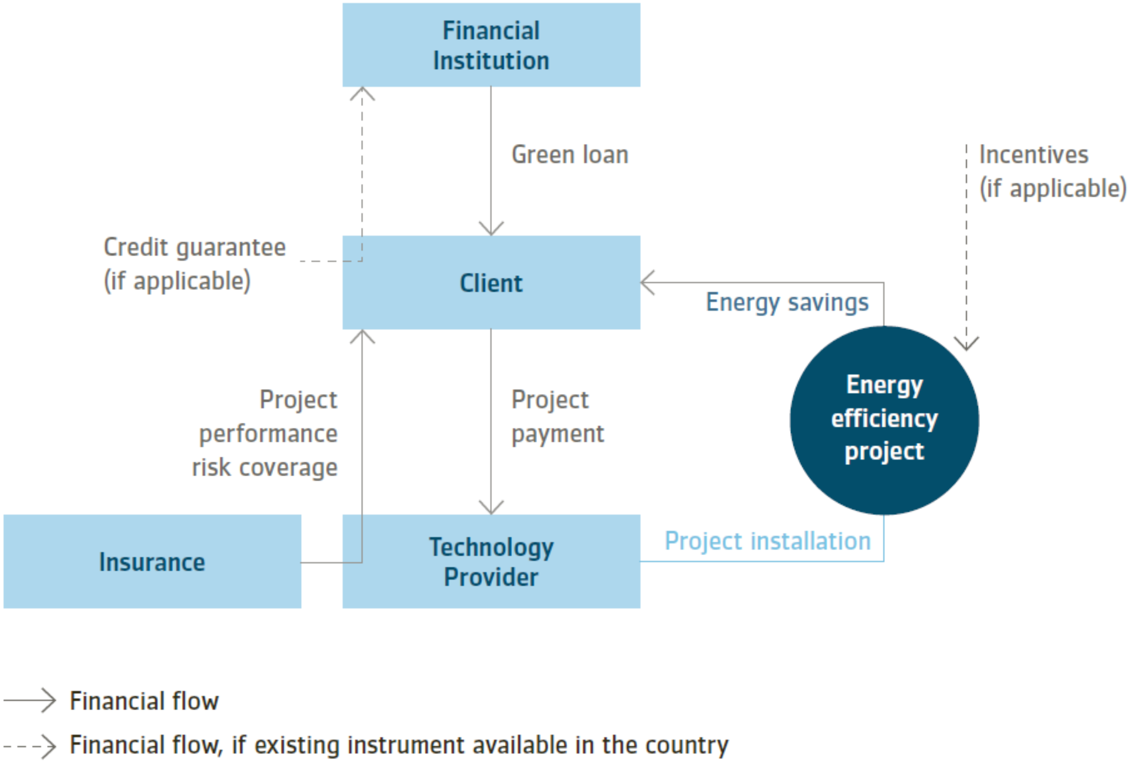

Figure 3.1. Energy saving insurance structure (Swiss Sustainable Finance 2020)

The adoption of EPC models can be supported by Governments through mobilising essential capital needs and lifting institutional barriers. Governments can streamline local regulations for ESCOs to supply customer financing and by authorising, enabling, or providing mechanisms of risk mitigation for these entities such as payment guarantees. With guaranteed savings models, financial institutions can offer loans or sales/leaseback mechanisms to support the capitalization of service providers. Governments can alleviate the risk in lending to SMES. To simplify large-scale execution of energy efficiency projects, "Super ESCOs" has set up and capitalised by some governments to offer financing to private ESCOs and their customers, to support capacity building and project progress practices of current private ESCOs and to implement projects in public amenities (BASE 2019).

4 BARRIERS AND ENABLERS OF FINANCE AND BUSINESS MODELS

There are many barriers related to conventional business models of selling food chain equipment which does not support implementing energy-efficient, clean and commercially available systems. These barriers restrict the implementation of the most energy-efficient technologies including high up-front costs, the risk of high-performance expectation, uncertainties of maintenance cost and other investment priorities. However, innovative business models, particularly service-oriented business, can enable the investments in cleaner and energy-efficient technologies (e.g., using natural or low GWP refrigerants). In upcoming sub-sections, we summarise key barriers and enables of different business models.

4.1 Servitisation Business Models

4.1.1 Barriers

- Ownership of facility not for end users.
- Uncertainty in profit for owner.
- Customers' perception.
- Technology alone is not all the solution.
- Lack of awareness of the potential benefits of energy efficiency.
- For Energy Savings Models -potential lack of trust in the promised savings and complexity of contracts.
- Need of digital payment technologies
- Technology providers/owners take most of the burden of risk and high upfront cost of the efficient equipment.
- Lack of ownership of land where facilities are established by large companies sometimes is a barrier because they might have to move the facilities when the lease of land expires.

4.1.2 Enablers

- Contracting using BOOT (build-own-operate-transfer) or BOLT (build-operate-lease-transfer) schemes to transfer the ownership to FPOs, NGOs, Government, or costumers.
- Digital payment mechanism to ensure the timely receipt of payments and remote monitoring.
- Use of behaviour change programmes that have proven an effective way of changing energy consumption behaviours and product choices.
- Engaging costumers with the solution and build good relationships with customers.
- Using mobile facilities that can be moved from one place to another easily.
- For technology providers, service-based models can be a way to increase profitability by re-assessing the design and material choice of their equipment in view of simplifying maintenance, repair, recycling, and reuse.
- ESI is a tool to raise awareness and convince SMEs to invest in energy efficient equipment by directly monetizing their savings.
- SMEs can access 'green loans' due to guaranteed savings using ESI model.
- ESI has emerged as a solution to reduce the risk of energy efficiency projects.
- Energy efficiency insurance policy for SMEs on not achieved energy savings and if provider does not fulfil commitments; technical validation processes can be done by an independent entity.
- ESPCs are a powerful tool to raise awareness on the benefits of energy efficient equipment by directly monetizing these savings.
- Under CaaS model, the provider has significant incentives to achieve high-quality preventive maintenance, reduce corrective maintenance costs, and improve system energy efficiency.

4.2 Direct sale/purchase models

4.2.1 Barriers

- Minimum levels of performance
- Highly skilled personnel needed for the operation and maintenance of the equipment.
- Bad credit history, Access to finance
- Technology complexity, technology upgrade, scaling-up capacity
- Circular economy, End-of-life reuse, and recycling
- High upfront capital costs of the technology for customers with limited access to capital
- Customers, who are the owners take all the risk of technology.
- Investments in less efficient technologies

4.2.2 Enablers

- Adding hardware and sensors and connecting the product, opportunities open for suppliers to remotely support the product. By adding more sensors and being able to monitor operations from a far, the required inputs, skill set, and training are reduced.
- Funding or subsidy support from government or NGOs, Crowdfund, Private Bank Financing Scheme, Government Program, aid agencies, private sector fund and national and international grants.
- Technology and technical interventions and training programs
- Insurance and after-sale support
- Standards and regulations, such as Minimum Energy Performance Standards (MEPS), building codes with energy performance standards, energy conservation laws can encourage investments in more efficient technologies.

4.3 Rental/Lease business models

4.3.1 Barriers

- No strong incentive for manufacturers to propose highly efficient equipment as consumers may shy away from related high rental rates.
- Repayment terms from a traditional financial institution rarely align with the seasonal cashflow cycles making it difficult for end users to pay the monthly instalments back to the bank

4.3.2 Enablers

- Funding or subsidy support from government or NGOs, Crowdfund, Private Bank Financing Scheme, Government Program for, aid agencies, private sector fund and national international grants.
- Digital payment mechanism to ensure the timely receipt of payments and remote monitoring.
- Policies and regulations to encourage the investment and use incentives like tax exemption, etc.

• Risk is shared, that balances risk of payment and technology for the company and the customer.

5 BUSINESS MODEL INNOVATION DRIVING FORCES

Scholars (Nosratabai et al., 2020) reviewed 72 published documents to investigate how the Business Model Innovation (BMI) provides solutions to improve the Food Supply Chain (FSC) performance. They reported the most essential factors as driving forces which push different actors throughout the FSC to change their business into innovative business models. The study reported that the innovations in value proposition, value delivery and value creation processes of business models are the effective approaches proposed in food industry.

Key findings from the review are:

- Rural female entrepreneurs and urban and social restrictions are the most influential drivers affecting farmers to reassess and innovate their business models. Women not only play vital roles in designing and implementing a sustainable business model in the farms but also raise the demand for sustainable products by increasing awareness of local food in communities.
- For food processors, the environmental issues and innovation and new technologies are the main driving forces to innovate their business model.
- Digitalization has disruptively altered the food distributor models introducing a digital food hub, which is an online marketplace, to connect the local food producers and consumers.
- Internet-of-Things and E-commerce models are concluded as the essential elements pushing retailers to innovate their business models.
- Product quality and safety and consumption demand are two key factors concerning the business models of all the firms working in the FSC whatever their positions in the chain. In parallel, consumers' behaviour is changing profoundly.

Figure 5.1 below shows these drivers of business model innovation throughout the food supply chain.

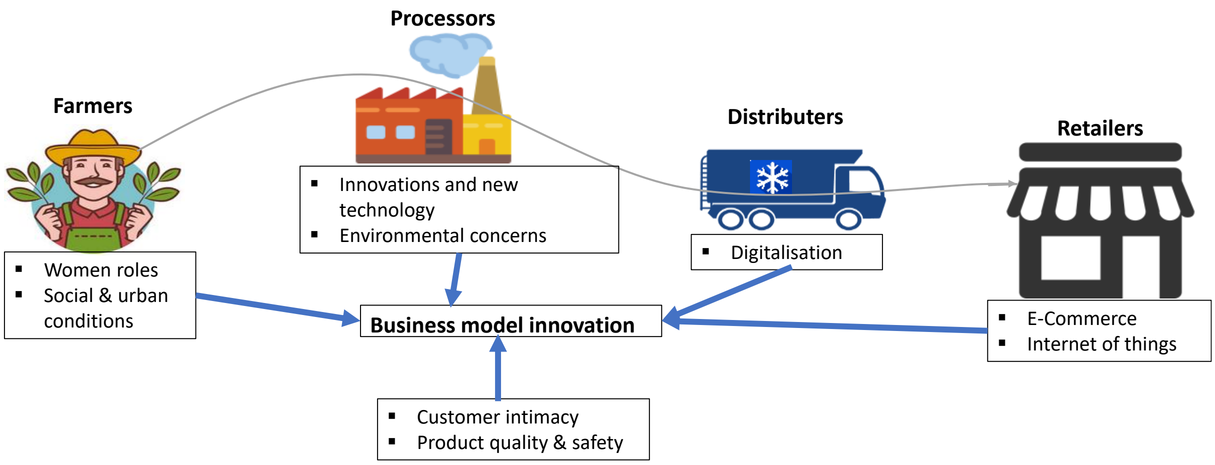

Figure 5.1. Drivers of business model innovation throughout the food supply chain

5.1 Examples of business models innovation and their drivers

Table 5.1. Business models innovation case studies

Institution/ Project name	Country	Innovation	Drivers of innovation	Project Description
The Grange Farm, north west Cheshire	England	Pasture-fed beef; sustainability; adding value; food assembly	Internet of things (IoT), E-commerce; Digitalisation. Customer intimacy. Product quality	The Grange is a 100-hectare grass-based livestock farm in the Green Belt east of Chester. A key to the farm's success is direct selling of their beef to a range of markets to reduce risk. The farm is developing a new farm shop and sells through a box scheme, local farmers markets and more unusually via a food assembly. This is a retail model from the continent where 750 assemblies already operate successfully. Customers order the exact products they want online to pick up weekly from a central location in Chester. This helps the farm to minimise its waste, sell a wide range of cuts and to meet and get feedback from their customers. (The Campaign to Protect Rural England 2016)
REKO retail and distribution model	Finland	Improve profitability of farm production. social and economic sustainability	Women engagement; Social rural-urban connecting; IoT; Digitalisation; Customer intimacy; Product quality	Retail and distribution model offers consumers a way of buying products directly from the producer (e.g. farmer), without the need for middlemen (e.g. grocery stores). The products are ordered online and picked up from a certain place at a certain time. In other parts of Europe this type of retail and distribution models are called food-coops or online-sale. The REKO model contributes to the rural (-urban) services network. The REKO rings operate via Facebook as closed groups, where orders and deliveries are agreed upon. Basically, anyone can start a REKO group in Facebook following the instructions on the REKO website (Natural Resources Institute Finland 2020)

European project i-REXFO	Europe	Reducing the amount of landfilled food waste	Increases consumers' awareness on food waste reduction; Environmental restrictions; waste to energy use.	i-Rexfo reduce of 17,340 ton/year of food waste landfilled from wholesale/retail, HORECA, food processing and farming sectors through demonstrative and self-sustained actions in warehouses, supermarkets, etc.; decrease of 41 tCO2eq/year of GHG deriving from food waste landfilling; decrease the water consumption due to avoided waste food of 2,150,000 m^3 per year; decrease the land use consumption due to avoided waste food of 1.080 ha per year; 10.650 MWh/year of energy saving due to avoided food production; produce 14.250 MWh/year of renewable energy (Liberti, et al. 2018)
Sainsbury's world's first to trial truck cooled by liquid nitrogen engine	UK	Food refrigerated trucks cooled by liquid nitrogen	Innovations and new technology. Environmental restrictions. Digitalisation	Supplied by cooling technology specialists, Dearman, and its partners, Sainsbury's has become the first company in the world to introduce a refrigerated delivery truck cooled by a liquid nitrogen powered engine, which will eliminate all emissions associated refrigeration. Traditionally many refrigerated trucks require two diesel engines, one to power the vehicle and one for the refrigeration unit. By replacing the latter, Dearman believes that a more sustainable solution for refrigeration may soon be widely adopted on Britain's roads. During the three-month trial the vehicle will save up to 1.6 tonnes of carbon dioxide; the equivalent of driving over 14,500 km in a modern family car, 37 kg of nitrogen oxides and 2 kg of particulate matter, compared to a similar diesel system. (Sainsbury's 2016)

6 ANALYSIS OF BUSINESS MODELS SUSTAINABILITY PERFORMANCE

Alonso-Martinez et al. (2021) collected data from a sample of 64 sustainably oriented firms certified and established in Italy, Spain, and the UK. These firms are described as organisations in which environmental and social goals drive firms' behaviour and strategic choices, adopting a hybrid organisation approach to achieve sustainable development goals rather than achieving 'private' economic benefits. The data was collected to assess the sustainable performance of the firm's business models.

They developed an online questionnaire targeting firm's founders and sustainability managers. The collected data was used to proposed nine Sustainable Business Model (SBM) archetypes and further classified in three higher-order groupings – depending on the major focus of the SBM innovation (environmental, social, or economic). Each of the identified SBMs is expected to create value in a different manner, putting emphasis on the environmental, social or economic dimension. These nine archetypes or indicators, 3 each for environmental, social, and economic performance of the business models, are presented in Table 6.1.

Table 6.1. Sustainable performance indicators of business models Alonso-Martinez et al. (2001)

Environmental performance	Social performance	Economic performance
Material and energy efficiency Improving products and processes to generate less waste and fewer emissions as respect to products that deliver similar functionalities	Functionality over ownership Delivering functionality through pay-per-use rather than product ownership, allowing reduction in resource consumption and enhanced efficiency in the use and durability of products	Social and environmental benefits Maximizing the social and environmental benefits of full integration of the firm with all stakeholders and therefore aims to drive global economic change
Circularity in resource use and less waste Transforming waste into valuable inputs, closing the loops of the renewable resources and/ or non-renewable materials cycles	Encouraging stewardship Ensuring the long-term health and wellbeing of all stakeholders through the manufacture and provision of products/services, tackling sustainability along the supply chain, community development and employee welfare	Sustainable scale-up Developing sustainability solutions on a large scale for multinationals, which include franchising, licensing and collaborative models
Renewable energy Modifying products to include renewable (non-finite) resources, using environmentally friendly materials, and developing renewable energy solutions	Reduce overconsumption Radically reduce overconsumption by improving product durability and longevity and implement activities to educate consumers and enable second-hand consumption	Inclusive value creation Allowing sharing of resources and ownership, creating value for previously under-addressed user and customer segments

We proposed performance metrics to assess the sustainability of the three business model categories, servitization, direct sale and lease/rental considering the three dimensions of social, environmental and economics. Adopting the above nine business models sustainability indicators concluded by Alonso-Martinez et al. (2001), the metrics marks a sign of ''++'' (high-performance) if the business model category can completely achieve the indicator, ‘’+’’ (medium-performance) if can partially achieve the indicator and ‘’-‘’ (low-performance) if can’t achieve the indicator. These performance metrics are listed in Table 6.2.

Table 6.2. Sustainability performance metrics

Performance level	Metrics
High performance	++
Medium performance	+
Low performance	-

6.1 Environmental performance of business models

Table 6.3 presents a comparison of the environmental performance between the three business models categories using the three environmental performance indicators from Table 6.1 and the performance level metrics from Table 6.2. It is concluded from the comparison that the service-based business model outperforms others by providing high environmental performance level for all the three performance indicators. While the lease/rental model and direct sale business models deliver medium and low performance level for all the three performance indicators, respectively as explained in Table 6.3.

Table 6.3. Environmental performance of business models

Service oriented models	Direct sale or purchase models	Lease or rental models
Energy efficiency (++) Allows opportunity for both big and small businesses as well as individuals to adopt energy efficient and lower GWP cooling equipment/ technology without burden of up-front high cost. This also improved maintenance and hence the performance and the reliability of the system.	Energy efficiency (-) Small scale consumers are sensitive to high upfront cost in direct purchase models. They need assurance for socio-economic benefits of the energy efficient and lower GWP technologies and does not always want to take the risk	Energy efficiency (+) Consumers have an opportunity to choose the energy efficient and lower GWP alternative available in the market but the choice they make will be guided by cost they have to bear. In cases where the ownership ultimately transfers to consumers after payment of all instalments, they might opt for more energy efficient options.

Circularity in resource use (++) Technology manufacturers/providers are responsible for the overall operation and maintenance including the end of the life disposal and recycling of the cooling equipment/appliances. This can be an important driver in the context of the circular economy, promoting reparability, recycling and re-use of components and parts.	Circularity in resource use (-) Not all consumers at small scale have the capacity, knowledge and resources to take care of the removal at the end of the life or repurpose the waste into resources.	Circularity in resource use (+) During the lease period, technology providers can transfer the knowledge to consumers about possibility of closing the loop by turning waste to resource
Renewable energy (++) Model allows the possibility of adoption of off-grid or on-grid renewable energy technologies as the big companies can take the burden of transition with help from financial institutions. They can easily deploy technical and financial resources required to connect remote and rural farms to off-grid power supply systems.	Renewable energy (-) Customers cannot always take the burden of transition to low carbon renewable sources in the absence of financial supports in the form of subsidies and concessional loans.	Renewable energy (+) With some support like grants and subsidies, consumers can choose renewable energy options for energy supply.

6.2 Social performance of business models

Table 6.4 presents a comparison of the social performance between the three business models categories using the three social performance indicators from Table 6.1 and the performance level metrics from Table 6.2. It is concluded from the comparison that the service-based business model outperforms others by providing high social performance level for two performance indicators whereas the third one (reduce over-consumption) is medium social performance level. While the lease/rental model and direct sale business models deliver medium and low performance level for all the three performance indicators, respectively as explained in Table 6.4.

Table 6.4. Social performance of business models

Service oriented models	Direct sale or purchase models	Lease or rental models
Functionality over ownership (++) Promotes functionality of the energy and cooling system over ownership. Operation and maintenance of the energy efficient	Functionality over ownership (-) Usually popular among consumers who wants to	Functionality over ownership (+) Owners will focus on maintaining the functionality of the products /technology

low carbon technologies is highly prioritised which improves the durability of the system.	have ownership of assets and have the affordability.	as consumers may default on payments and discontinue paying for the services if quality is not maintained.
Encourage stewardship (++) Increases access to products and services for the marginalised and poor communities, which not only helps the supply chain but also improves the overall well-being stakeholders.	Encouraging stewardship (-) Ownership is usually controlled by large cooperatives, farmers organisations and local companies which may not be very effective in increasing access to marginalised and poor communities who does not have capacity to pay.	Encouraging stewardship (+) Small and flexible payment plans depending on the economic capacity improves the access of products and services, which engages all types of stakeholders across the supply chain
Reduce over-consumption (+) Models creates opportunities to change consumption habit of the consumers and engage them in innovative activities by educating them, across the supply chain, which will reduce overconsumption of the resources.	Reduce overconsumption (-) Consumers who have ownership may overconsume without taking into consideration its consequences on other stakeholders.	Reduce overconsumption (+) Consumers may be more conscious about how they use the resources because it directly reflects on their payment installments, so controls over consumption

6.3 Economic performance of business models

Table 6.5 presents a comparison of the economic performance between the three business models categories using the three economic performance indicators from Table 6.1 and the performance level metrics from Table 6.2. It is concluded from the comparison that the service-based business model outperforms others by providing high economic performance level for all the three performance indicators. While the lease/rental model and direct sale business models both have medium performance level for one indicator and low performance level for the other two indicators as explained in Table 6.5.

Table 6.5. Economic performance of business models

Service oriented models	Direct sale or purchase models	Lease or rental models

Maximise social and environmental benefits (++) All stakeholders involved in the supply chain have now improved access to product and services which creates an environment where social and environmental benefits.	Maximise social and environmental benefits (-) Social and environmental benefits may not be shared equally across all stakeholders as ownership of the asset creates an environment of imbalance of power over decision making process.	Maximise social and environmental benefits (+) Despite the inability to bear the capital cost, consumers can still make small flexible payments and get access to the products and services. Therefore, creates an opportunity for social and environmental benefits.
Sustainable scale-up (++) Creates environment for collaboration where sustainable solutions can be developed in large scale.	Sustainable scale-up (+) Direct purchase does not always create a collaborative environment as resources are under control of people who have economic ability. However, depending on favourable local policy, market and capacity of the local stakeholder's consumers who have ownership of the products may be able to scale up sustainable solutions.	Sustainable scale-up (-) Leaseholders or renters does not have any power over decision making process therefore there is no collaborative environment between technology providers /manufacturers and users.
Inclusive value creation (++) Model brings all marginalised consumers into the supply chain. This creates inclusive value for all types of stakeholders.	Inclusive value creation (-) Does not create a same opportunity for all types of stakeholders therefore inclusive value creation is difficult as resources are not equally shared among all stakeholders.	Inclusive value creation (-) Owners of products/asset takes most of the decision, therefore the decision may not create inclusive value for the renters, as decisions are often economically driven.

Therefore, from the above analysis, we can conclude that the servitisation business models offered the best sustainability performance in all the three dimensions, social, environmental and economic. It provided a high-performance level for all the sustainability performance indicators though out all the three dimensions except a medium-performance level for ''reduce overconsumption'' indicator which is a performance indicator in the social dimension. The second-best sustainability performance was offered by the lease/rental models while the direct sale models provided the worst sustainability performance.

7 ASSESSMENT OF FINANCIAL REQUIREMENTS

7.1 The Europe pathway to climate neutrality

Typically, emissions from the food supply chain will include agricultural production and power (e.g. farming and animal husbandry), food processing and packaging (industry), transport and distribution of food (transportation), and storage and retailing of food (which may be categorized as construction or commercial activities), and food loss and waste.

Climate change and environmental degradation pose a serious threat to Europe and the world at large. In response to those challenges, the European Union had launched the European Green Deal, which aimed to transform the Union into a modern, resource-efficient and competitive economy (European Commission 2024). It ensures net-zero greenhouse gas emissions by 2050, decouples economic growth from resource use, and guarantees that no one and no place will be left behind. The European Green Deal is also a key support for the EU's recovery from the new crown epidemic. One third of the EU's Next Generation Recovery Programme and seven-year budget of some 1.8 trillion euros will be used to fund the measures of the European Green Deal.

The purpose of the EU classification is to facilitate the flow of funds to projects and activities that are key to achieving the objectives of the European Green Deal (European Commission 2024). The agreement aims to follow a set of principles and objectives to ensure the environmental sustainability of the EU economy.

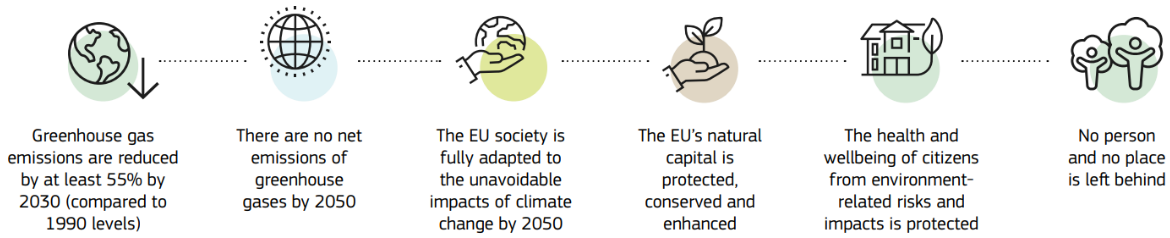

Figure 7.1 Key Principles and Objectives for an Environmentally Sustainable EU Economy (European Commission 2024).

The EU Classification is a classification system designed to help companies and investors identify and invest in economic activities that are considered environmentally sustainable (European Commission 2023). These activities should make a significant contribution to at least one of the EU's climate or environmental objectives, not cause serious harm to any of the objectives and fulfil certain minimum safeguard criteria. While this taxonomy does not oblige investors to invest in specific projects, nor does it set mandatory requirements for the environmental performance of companies or financial products, it is expected to drive the transition of investments towards sustainability in support of the EU's environmental and climate objectives.

What the EU Taxonomy is	What the EU Taxonomy is not
A classification system to establish clear definitions of what is an environmentally sustainable economic activity	It's not a mandatory list to invest in
Tool to help investors and companies to make informed investment decisions on environmentally sustainable activities for the purpose of determining the degree of sustainability of an investment	It's not a rating of the "greenness" of companies
Reflecting technological and policy developments: The Taxonomy will be updated regularly	It does not make any judgement on the financial performance of an investment
Facilitating transition of polluting sectors	What's not green is not necessarily brown. Activities that are not on the list, are not necessarily polluting activities. The focus is simply on activities that contribute substantially to environmental objectives.
Technology neutral	
Fostering Transparency by disclosures for financial market participants and large companies related to the Taxonomy	

Figure 7.2 Overview of the EU Taxonomy: What It Is and What It Is Not (European Commission 2023)

On 5 January 2023, the Corporate Sustainability Reporting Directive (CSRD) came into force, which updates and strengthens the rules on the social and environmental information that companies must report (European Commission 2023). Sustainability reporting is now required for more large companies as well as listed SMEs. In addition, some non-EU companies will be required to do the same reporting if they have revenues of more than €150 million in the EU market (European Commission 2023). These new rules are designed to ensure that investors and other stakeholders have access to the information necessary to assess a company's impact on people and the environment, and to help them evaluate the financial risks and opportunities presented by climate change and other sustainability issues. In addition, by standardising disclosure, companies are expected to have lower reporting costs over the medium to long term. The first companies to apply these new rules will begin to do so in fiscal year 2024 and will publish their reports in 2025.

Reaching net-zero emissions by 2050 would require significant changes in all five sectors (power, transport, industry, agriculture, and buildings). These changes can be grouped into eight categories (or levers) that range from reducing energy or resource use to switching to zero-carbon fuels or changing land-use and agricultural practices (as shown in Figure 7.3. below).

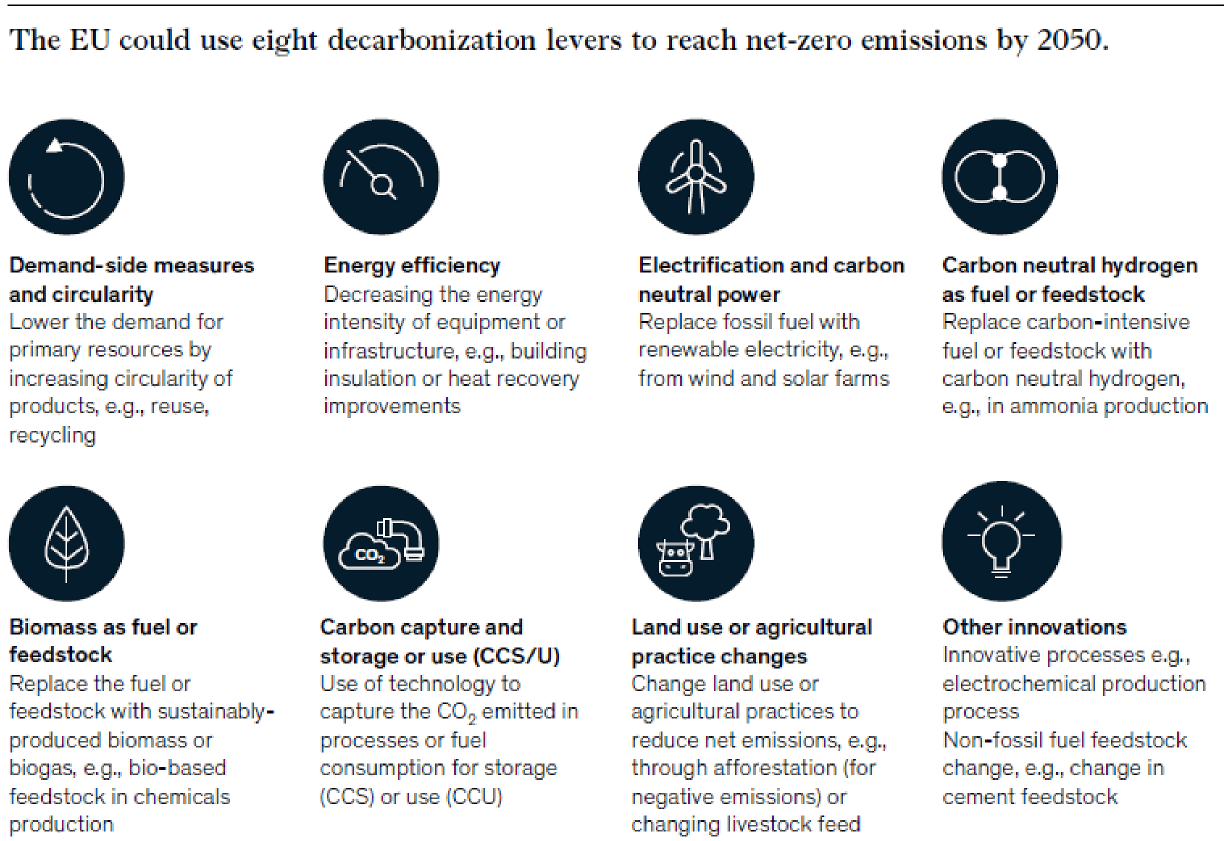

Figure 7.3. The eight decarbonisation levers EU could use to reach net-zero emissions by 2050 (D'Aprile et al. 2021)

Land use emissions are not included in this project. So, we don't consider the decarbonization cost related to it. Each of the eight levers contains several specific measures, and some of those measures span more than one category. For example, BECCS is an abatement technique that involves using biomass as fuel (one lever) and CCS to capture and store the resulting CO_2 emissions (another lever).
According to Mckinsey Company's (2020) report, from 2021 to 2030, over 65% of decarbonization in Europe will be achieved through two levers: improving energy efficiency and electrification. For the food supply chain, key measures include transitioning transportation modes, reusing waste heat from buildings and industries, increasing the use of hydrogen, and increasing the use of biomass etc.
As we move towards 2040, the opportunity for direct electrification will begin to reach its full potential. To meet the 2050 emissions reduction targets, solutions besides electrification will be needed. It is expected that by 2050, 45% of Europe's total emissions will be reduced through a shift from fossil fuels to electrification, with a further 30% of reductions to be achieved using hydrogen, biomass and carbon capture and storage (CCS) technologies. The specific emission reduction pathways are shown in Figure 7.2 below.

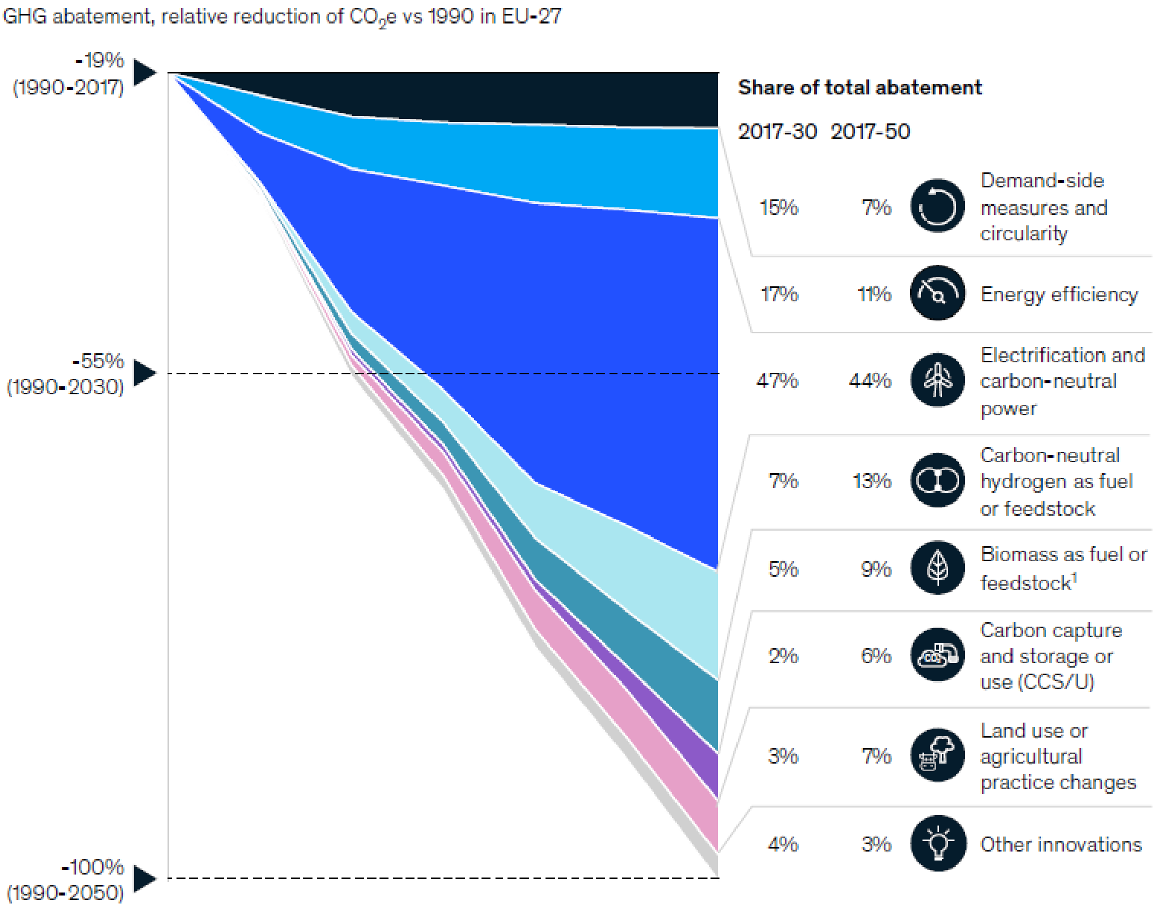

Figure 7.4. GHG abatement, relative reduction of CO2e vs 1990 in EU-27 (D'Aprile et al. 2021)

7.2 Uncertainty for achieving Net-zero in Europe

Uncertainty remains about how human behaviour will affect the EU's efforts to reduce emissions over the next 30 years. However, by changing behaviour, such as reducing meat consumption and car use, European emissions could be reduced by up to 15% (D'Aprile et al. 2021). Encouraging such behavioural change not only reduces the demand for fossil fuels and other sources of GHG emissions, but also significantly reduces the reliance on more expensive technological measures (e.g. implementation of Carbon Capture and Storage (CCS) in industry) to achieve decarbonization targets. Generally, such behavioural changes are more cost-effective than technology-driven changes. The 12 behavioural changes that are not included in McKinsey & Company's cost-optimal abatement pathway (2020) but could potentially reduce EU emissions by around 15% are shown in Table 7.1. below.

Table 7.1. Behavioural changes not included in the cost-optimal pathway model (D'Aprile et al., 2021)

12 behavioural changes not included in the cost-optimal pathway model could lower EU emissions another 15 percent.	
Power	Enhanced demand flexibility

	Over 10% of additional power demand from transportation and buildings are flexible intra-day
Transportation	Reduced car usage in urban areas Shift 20% of urban car PKT1 to buses Last-mile delivery interventions Reduce LDT/MDT2trucks VKT3 by 15% Modal shift from air to rail Shift 95% of short-haul flights PKT to rail
Buildings	More attentive energy use Lower room temperatures by 2°Celsius; reduce electricity demand by 10% Increased uptake in smart meters Over twice as many smart meters by 2050 (90% vs 40% in base)4 Shift to independent energy sources 25% of detached houses move off-grid
Industry	Wood displacement of cement Over 65% of cement demand replaced by CLT Higher plastics recycling rate Up to 70% plastics recycling
Agriculture	Diet shift away from meat 50% of EU citizens become flexitarian5 Reduce food waste by half (5-15% wasted today in different categories) Additional LULUCF Using 12 Mhaof land freed up from productivity gains and 15 Mhafrom above two levers for LULUCF
1.Passenger Kilometres Travelled (PKT) 2.Long-Distance Truck (LDT); Medium-Distance Truck (MDT) 3.Vehicle Kilometre Travelled (VKT) 4. Expected to lead to reduction in energy use as heating turns off when you are not at home 5. Eating meat once per week	

7.3 The capital investments required

To calculate the financial requirements for the European food supply chain to achieve net-zero emissions for each country in Europe by 2050, we followed the formula, and we assume that the pace and decarbonization cost in the food supply chain are consistent with all sectors overall:

TC= Σ TCE x WAPDi X WADCFi Equation. 1

Where,

i refers to time bracket, 2020-2030, 2030-2040, 2040-2050; TC refers to total CAPEX for achieving Net-zero 2021-2050 of each country in Europe; TCE refers to total carbon emission of food supply chain of each country in Europe; WAPDi refers to weighted average pace of decarbonization for all sectors of each time bracket, 2020-50; WADCFi refers to weighted average decarbonization cost for all sectors of each time bracket, 2020-50.

Table 7.2. Total CAPEX by sector 2021-2050, in EU-27, bn EUR (total within time bracket) (D'Aprile et al. 2021)

Sectors	Total CAPEX by sector 2021-50, in EU-27, bn EUR bn EUR (total within time bracket)		
	2020-2030	2030-2040	2040-2050
Total	8400	10000	9400
Power	7%	8%	12%
Transportation	38%	45%	44%
Buildings	36%	28%	27%
Industry	1%	1%	3%
Agriculture	15%	14%	11%

Table 7.3. Average decarbonization cost by sector 2021-2050, in EU-27, EUR/t CO2 (D'Aprile et al. 2021)

Sectors	Average Decarbonization cost by sector 2021-50 in EU-27, EUR/t CO2		
	2020-2030	2030-2040	2040-2050
Power	-31	18	145
Transportation	-92	-149	-70
Buildings	-66	37	40
Industry	30	86	120
Agriculture	-27	-121	35
Food supply chain	-62.105	-71.33	4.85

WADCFi = ADCij x MSDCij Equation. 2

Where i refers to time bracket, 2020-2030, 2030-2040, 2040-2050; j refers to sectors, power, transportation, buildings, industry, agriculture; MSDC refers to market share of decarbonization cost of each sector in each time bracket; ADC refers to average decarbonization cost of each sector in each time bracket.

Table 7.4. Market share of carbon emission by sector in 2017, in EU-27 (D'Aprile et al. 2021)

Sectors	Current emissions Mt CO2e, 2017	Market share of Carbon emission by sector
Total emissions	3850	1
Power	930	0.241558442
Transportation	820	0.212987013
Buildings	490	0.127272727
Industry	1,140	0.296103896

Agriculture	470	0.122077922

Table 7.5. The pace of carbon emissions-reduction by sector, in EU-27, 2020-2050 (D'Aprile et al. 2021)

Sectors	Pace of Decarbonization		
	2020-2030	2030-2040	2040-2050
Power	60%	30%	10%
Transportation	30%	65%	3%
Buildings	30%	65%	5%
Industry	35%	60%	5%
Agriculture	5%	0%	45%
Food supply chain	0.356753247	0.471298701	0.106649351

WAPDi= Σ MSCEj x PDij Equation. 3

Where MSCE refers to market share of carbon emission by sector in EU-27 in 2017; PD refers to pace of decarbonization by sector in each time bracket in EU-27; WAPDi refers to weighted average pace of decarbonization for all sectors in EU-27 in each time bracket.

Finally, reaching net-zero GHG emissions in the EU-9 (Norway, Germany, Italy, France, Belgium, Lithuania, Austria, Poland, Hungary) and UK by 2050 would require €17 billion investment in clean technologies and techniques (Figure 7.5).

TCT= Σ TE Equation. 4

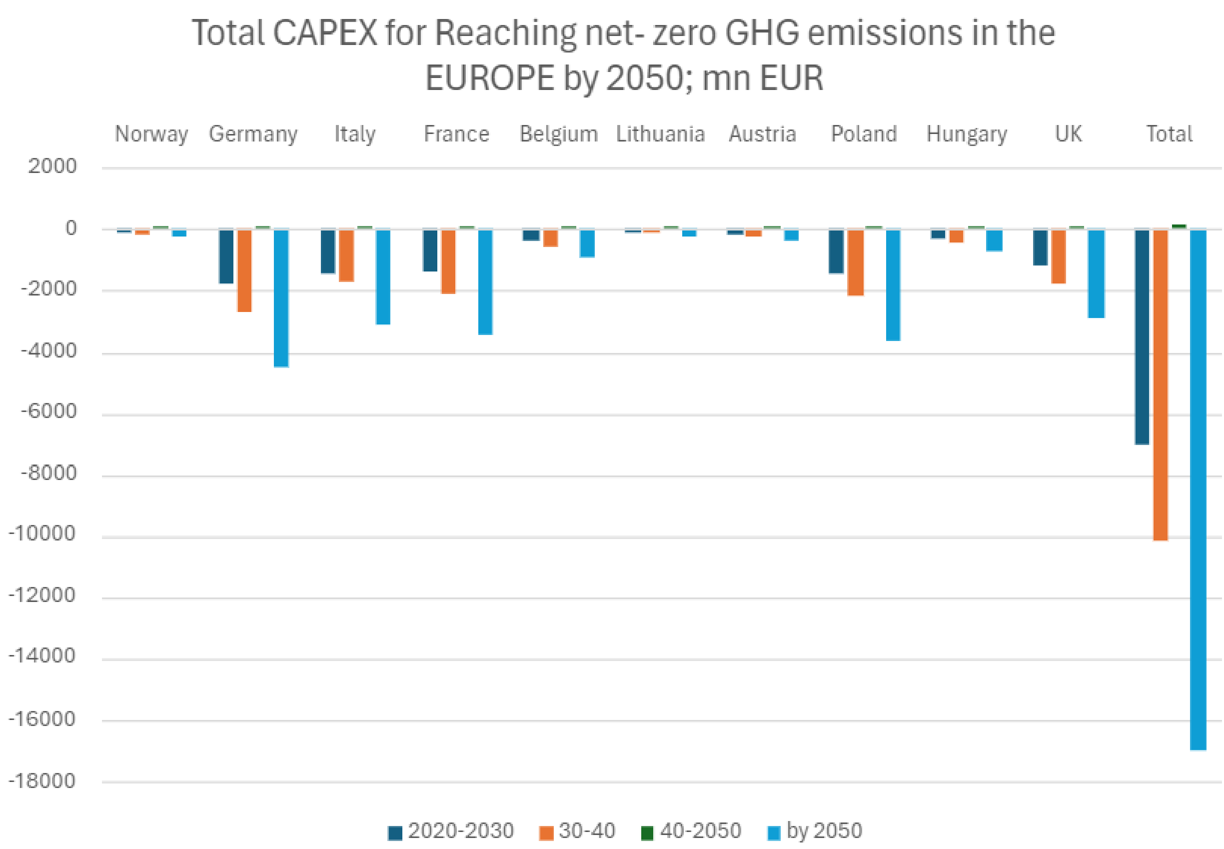

Figure 7.5. Total CAPEX for reaching net-zero GHG emissions in the Europe by 2050 (authors' own elaboration)

8 POTENTIAL BUSINESS MODELS

8.1 Thermal storage across the food chain

Overview:

A financial business model for the implementation of thermal energy recovery from waste heat sources is presented in this report which is based on a scaled-down 1 MWh system. The business model provides useful information about the thermal energy storage (TES) project's financial performance and possible returns, making it an invaluable tool for strategic decision-making. The cash inflows and outflows over the project's 15-year life give us an understanding of the viability of the project. Please refer to the following details for a brief background for building this business model:

Assumptions:

We start with a brief overview of the process involved in developing the business model for the 1MWh TES unit. First, we have estimated the capital expenditure (CAPEX) for a 1MWh TES unit, systematically considering costs such as major equipment and bulk material required with an estimation of construction and erection spending. The total capital cost was computed as the sum of all these expenses. Further, this estimated capital expenditure was phased in two years, allocating 75% of the total costs to be incurred in the 1st year and a balance of 25% in the 2nd year to reflect the projects financial demands accurately. The broader assumption for the construction period is 15 months and the life of the project is estimated at 15 years.

Incorporating the construction period and project life into the business model allowed for a holistic assessment of the project's financial implications from inception to maturity. This comprehensive approach ensures that stakeholders have the necessary insights to make informed decisions and optimize project outcomes over the long term. Throughout this duration of 15 years, we projected revenues, operating costs, and financial outcomes to provide a comprehensive view of the project's financial performance over its entire lifecycle. Further, capacity utilization rates (e.g., 30%, 75%, and 90% in the 1st, 2nd, and 3rd years respectively) are used for the gradual ramp-up of TES units.

Revenue built-up

The revenues are estimated based on the overall energy savings by 1MWh TES unit. The unit thus saved is multiplied by the Business Gas and/or Commercial Electricity rates depending on the UK energy service providers resulting in total savings (i.e. potential revenue) from the TES unit. The utilisation of the TES unit is gradually ramped up from year 3 onwards at 90% of its capacity upto the 15th year of its life. The earnings from carbon pricing and EUETS forecast carbon pricing for 2025 were calculated based on regulatory frameworks or internal pricing mechanisms. The Annual revenue was then determined for each scenario as a total of annual savings plus earnings from carbon pricing.

Costs

The variable operating costs and fixed operating costs are estimated as a percentage of capex. The annual variable operating cost is estimated at 1% of the overall capex and fixed operating costs are estimated at 2% of the overall capex.

Financial Results

The operating profit before tax and depreciation is calculated by subtracting both variable and fixed operating costs from the revenue generated from sales. The depreciation is calculated based on the 15 years of the life of the TES unit. The Tax was computed based on the applicable corporate tax rate in the UK (in this case, 25%). Finally, the net profit is determined by deducting taxes from the profit before tax.

The above comprehensive financial model offers insights into the TES project's financial performance, highlighting key cash inflows and outflows over the operating periods. It helps us calculate the project's Internal Rate of Return (IRR), Net Present Value (NPV) and Payback Period (PP) and serves as a valuable tool for making investment decisions on the adoption of the technology.

Net Present Value (NPV):

NPV is the most commonly and widely used method for evaluating the attractiveness of a project or an investment. It is the sum of all discounted future cash flows (positive and negative) over the life of a project or an investment. It is used to determine the quantum of funds required to make an investment into a project or assets. It is an all-encompassing metric which includes revenue, costs and other expenses, capital expenditure associated with it. Refer Equation.5 to calculate NPV of future cash flows:

$$NPV = C0 + C1/(1+r) + C2/(1+r)^2 + \cdots Cn/(1+r)^n \quad \text{Equation. 5}$$

C0 = Cash flow in year 0

C1 = Cash flow in year 1

Cn = Cash flow in year n

n = number of period (year)

r = required return or discounting rate/factor

Internal Rate of Return (IRR)

The IRR can be defined as the discount rate at which the NPV of a project or an investment is Nil. It is the compound annual return an investor expects to earn (or earned) over the life of a project or an investment. In capital budgeting, IRR is a method that allows us to compare and rank projects based on its projected yield. The investment with the highest IRR is usually preferred. It is widely used in analysing investments for private equity and venture capital, which may involve multiple cash investments over the life of a business/project and an exit value in the end.

$$NPV = C0 + C1/(1+IRR) + C2/(1+IRR)^2 + \cdots + Cr/(1+IRR)^r = 0 \quad 3 \quad \text{Equation. 6}$$

(The Actual calculation of IRR usually involves trial and error3)

C0 = Cash flow in year 0

C1 = Cash flow in year 1

Cr = Cash flow in year r

r = number of time period (year)

IRR = Internal rate of return

Payback Period (PP)

The Payback Period (PP) is used to calculate how long it takes for a business/investor to recoup an investment in a project or asset. This analysis allows us to compare alternative investment

opportunities and decide on a project that returns its investment faster. The payback period is like a breakeven analysis in terms of the amount of time required to return an investment.
The payback period is often used as an initial analysis, it is a simple measure of risk, as it shows how quickly money can be returned from an investment in an asset or a project. However, there are additional considerations that should be considered when performing the capital budgeting process. It only shows us how much time it takes for the return on investment, it does not show what the return on investment is.
Payback Period= (Initial Investment)/ (Cash Inflows) Equation. 7

Table 8.1 Summary of Key Assumptions

0.79 GBP to USD Exchange is used, and 5% inflation rate is used for the calculation.

Particulars	Amount (GBP)
TOTAL CAPITAL COST	25,440
SALES REVENUE (ANNUAL)	
Scenario 1 (100% Business Gas)	5,000
- CARBON PRICING (100% Business Gas)	759
- EU ETS FORECAST CARBON PRICING for 2025 (100% Business Gas)	873
Scenario 2 (100% Commercial Electricity)	14,300
- CARBON PRICING (100% Commercial Electricity)	991
- EU ETS FORECAST CARBON PRICING for 2025 (100% Commercial Electricity)	1,140
VARIABLE OPERATING COST (Annual)	254
FIXED OPERATING COST (Annual)	509

Based on above, financial results are calculated, with anonymised data input from an industry partner that the research team worked with.

Table 8.2 Results comparing the four scenarios – two of Business Gas and two of Commercial Electricity

	Scenario 1a (100% Business Gas; Savings + Carbon Pricing)	Scenario 1b (100% Business Gas; Savings + EU ETS Forecast Carbon Pricing for 2025)	Scenario 2a (100% Commercial Electricity+ Carbon Pricing)	Scenario 2b (100% Commercial Electricity+ EU ETS Forecast Carbon Pricing for 2025)
NPV (£)	13,512	21,539	88,875	95,841
Payback Period (years)	9.8	8.5	4.7	4.6
IRR	7.9%	10.9%	29.9%	31.6%

Energy Storage as a Service (EsaS):

We summarise the rationale to invest in TES technologies in Figure 8.1 and the USP for EsaS business model for TES in Figure 8.2.

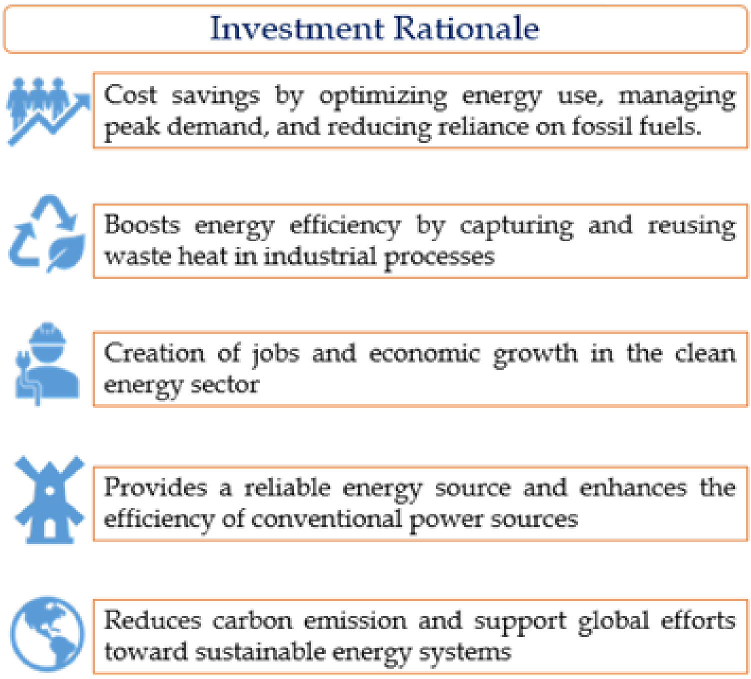

Figure 8.1. Reasons to Invest in ES Technology (authors' own elaboration)

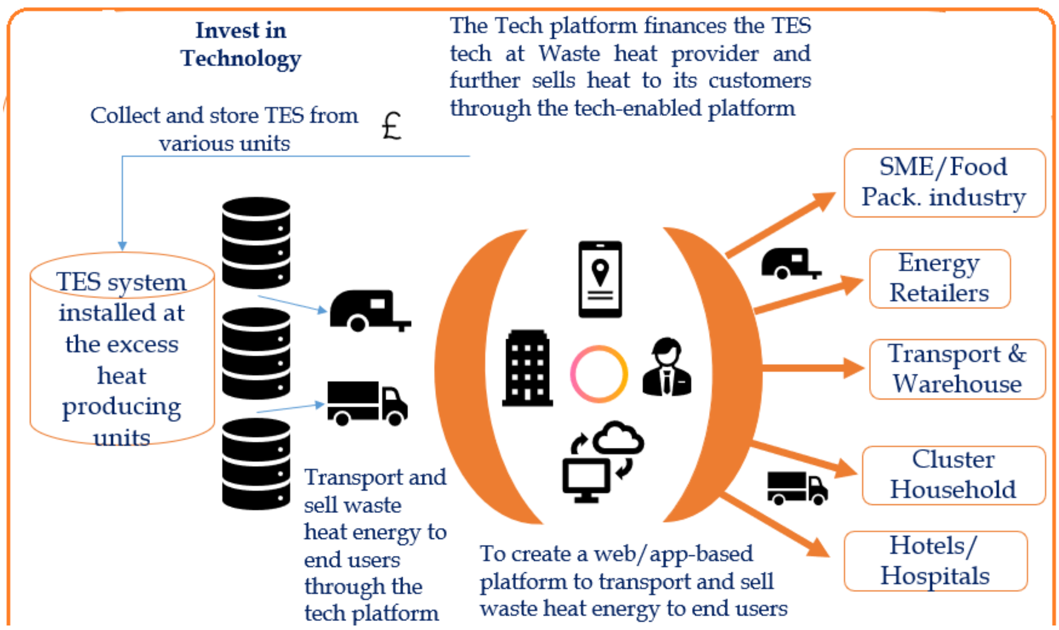

Figure 8.2. USP of ESaS potential business model (authors' own elaboration)

The USP of business model lies in:

○ Selling the waste heat/coolth in ES to end-users, thereby promoting circular utilisation of energy

- Reduces the usage of fuel (gas/electricity) with significant carbon emissions reduction.
- Creating an additional source of revenue with the otherwise wasted resource.
- Allowing for a real-time demand/supply match in the industry

Challenges

- The ability to transport heat at a lower cost compared to gas/electricity.
- Investment required to create a fully integrated web portal.
- Additional cost to transportation and loss of heat during transportation

Stakeholders

1. Research and Development Institutions: Organisations involved in R&D such as universities and RTO will contribute to the continuous improvement of TES technologies, exploring new innovations and enhancing system efficiency. They will be conducting research on different TRLs, developing new technologies, and collaborating with TES service providers to integrate cutting-edge solutions.
2. Technology Suppliers and Manufacturers: These companies will supply TES equipment, components materials, and technologies that meet industry standards, and will partner with TES service providers to offer the necessary hardware and components.
3. Environmental Consultants: Environmental consultants will assess the environmental impact of TES projects, ensuring that they align with sustainability goals and meet environmental regulations. They will conducting environmental impact assessments, providing guidance on sustainable practices, and ensuring compliance with environmental standards.
4. TES Service Providers: These companies will offer TES technology as a service by designing, installing, and maintaining the TES systems for clients as well as assist with the financing, installation, monitoring, maintenance, and ensuring the performance of the TES systems.
5. Maintenance and Monitoring Providers: Companies specializing in maintenance and monitoring of TES systems will ensure the ongoing performance and reliability of TES installations through regular inspections, preventive maintenance, and monitoring system performance to address any issues promptly.
6. Utility Companies: They will be involved by collaborating with TES service providers and by integrating TES into their grid management strategies. Collaborating on energy demand management, providing incentives for load shifting, and ensuring grid compatibility etc.
7. Financial Institutions: Banks, financial institutions, and investors will provide financing for TES projects and will play a crucial role in facilitating the upfront capital required for TES technology deployment by offering loans, financing arrangements, and investment options for funding.
8. Regulatory Authorities: Government agencies and regulatory bodies will establish the guidelines, standards, and incentives to influence the adoption of TES technology and offer subsidies, tax credits, or other incentives to promote sustainable energy solutions. They will develop and enforce regulations, provide incentives, and create a supportive policy environment for TES technology.
9. End-User Clients: Businesses, industries, and organisations that will utilise TES technology as a service to meet their energy storage needs and optimize energy consumption will collaborate with the TES service providers, providing necessary infrastructure access, and ensuring effective integration with existing systems.

10. Community and Public Advocates: NGOs, community groups, and public advocates will promote the adoption of TES as part of sustainable energy practices. They will raise awareness and advocate for policies to support TES initiatives.

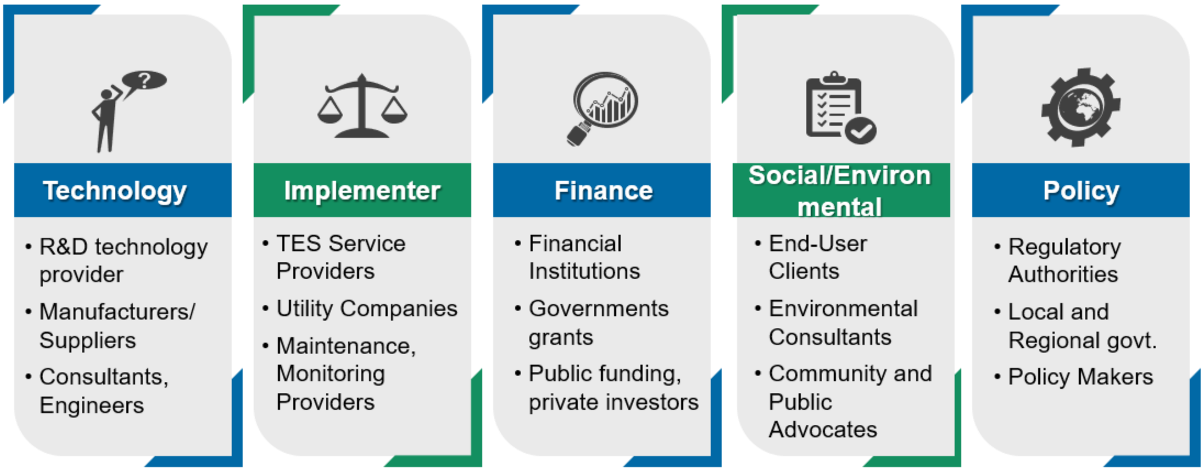

Figure 8.3. Stakeholders for ESaS business model (authors' own elaboration)

Stakeholder Influence
○ Primary stakeholders: those who have a direct impact or high power on the product or project (e.g. employees, customers). E.g. the technology providers and the implementers
○ Secondary stakeholders: those who have an indirect impact on the product or project (e.g. shareholders). E.g. funders and government organisations.
○ Tertiary stakeholders: those who have a potential impact on the product or project (e.g. industry experts).
○ Quaternary stakeholders: those who have no direct impact or low power on the product or project but may be interested in its success or failure (e.g. media).

8.1.1 TES applications

The estimated energy use for refrigerating food accounts for 8% of the global power usage and is responsible for a 2.5% of global GHG emissions, when including both direct and indirect emissions.
The global cold chain expands; the total capacity of refrigerated warehouses in 2016 was 600 m^3, with an annual growth rate of 4.2% (GCCA, 2016).
The global refrigerated vehicle fleet stood at 4 million in 2015 and could grow to 18 million by 2025. An anticipated 31 GW of extra power generation is expected to be needed to supply the projected increase in fridges in developing countries (Birmingham Energy Institute, 2015). TES can play a role in ensuring that these power needs are met by renewable generation sources.

8.1.1.1 Clean process heat for food & beverage production

Case Study: ENERGYNEST Thermal Battery™ storage solutions

It offers clean heat from excess renewable electricity/concentrated solar thermal for process heat/steam production on-demand. Energy Nest AS is a Norwegian technology company specializing in high-temperature thermal energy storage for energy-intensive industries and thermal power plants. The company helps entire energy system to maximize the value of their energy, from conventional thermal power plants to energy-intensive industries.
The Thermal Battery can be directly integrated with combined cycle power plants to provide added flexibility to the existing Rankine cycle. During installation, the modules are combined hydraulically in series (vertical direction) and parallel (horizontal direction).

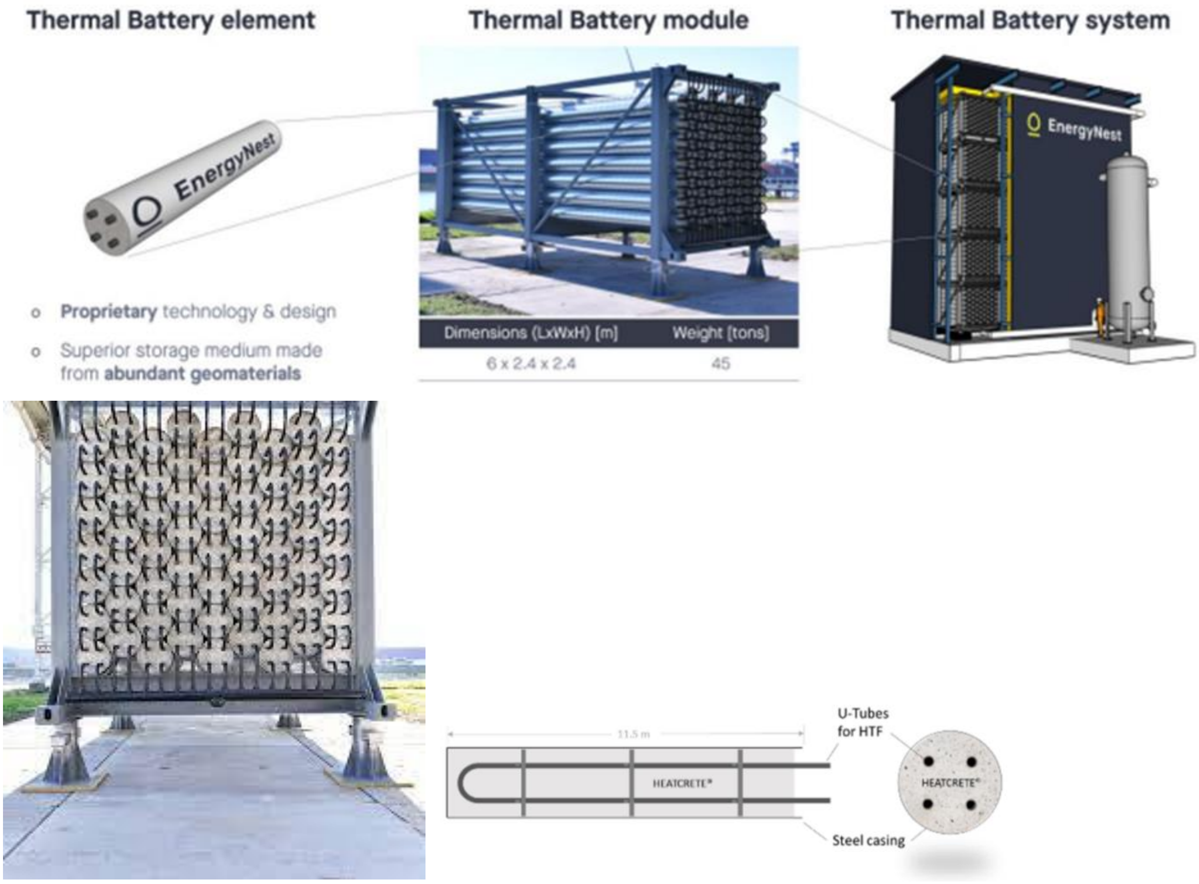

Figure 8.4. Multiple thermal storage elements combined in 20-foot container-sized modules. Modules are the basic units that make up the EnergyNest storage system.

8.1.1.2 Clean process heat for Retail Demand-Side Management

Smart Refrigeration provides Demand-Side Management services at Commercial Retail Sites in the USA. TES for smart refrigeration at retail sites/supermarkets provides peak-shaving using PCMs to provide energy management solution for high refrigeration-based energy loads. Refrigeration battery stores off-peak electricity in a frozen saltwater solution at night. During peak hours, when electricity and demand charges are highest, the system discharges to provide cooling. This significantly reduces peak load for the building.

A cloud platform evaluates the energy use and electricity rates to optimise system operation and maximise savings. This product has been deployed twice at pilot scale for two major US supermarket chains.

The California Demand Response Auction Mechanism (DRAM) allows customers to generate revenue from the power they can reliably offset during periods of high-grid demand. DRAM is a pay-as-bid program that helps the grid maintain its reliability. Created in 2014 under the guidance of the California Public Utility Commission to harmonize utility-based reliability demand response with CAISO, the state's grid operator. The programme seeks to allow CAISO to add reliable demand response resources to areas of California where electric reliability may be at risk. It offsets rising energy costs with revenue earned from using less energy when the grid is stressed.

8.1.1.3 Cooling for food storage & transportation

TES technologies such as ice, and commercially available PCM are used in refrigerated vehicles and static chillers across the cold chain. Growth in electrified refrigeration is expected to significantly increase demand on networks, especially in emerging economies (hot climates). As these economies grow, they will have to develop cold chains in a clean and cost-effective manner. TES could particularly support the production, storage, transport, and retail segments of the cold chain, meaning TES can couple power, cooling and mobility. Another segment that could benefit is off grid renewably supplied refrigeration, to enhance food and medicine supply chain efficiency.

TES can be used to displace diesel-powered refrigeration in cold-chain transport, and can help to couple the transport, cold chain, and power sectors. Several examples of companies serving markets in Africa, China, Europe, India, and the Middle East that integrate engineered PCMs into refrigerated vehicles and containers for food and vaccine transport and/or storage. E.g. United Kingdom developed a PCM cooling system to maintain low temperatures in interchangeable road and rail containers (UoB, 2018). In the next five years material and operational improvements, as well as better integration, could increase efficiencies and lower costs in the use of other PCM systems.

Due to high energy density and minimal thermal losses in absorption systems, cold can be stored for both short and long timescales (such as inter-seasonally) for space cooling in the cold chain. For longer term, liquid air could be used to both power vehicles and keep them cool. The use of water tank TES with solar thermal plants for low-temperature heat generation/storage is growing especially in mining, food and textile sub-sectors. The key markets are Austria, China, France, Germany, India, Mexico, and Spain (Weiss and Spork-Dur, 2019).

In future, renewable thermal energy can generate cooling with absorption systems that can be stored as TES. Innovative technologies for sensible, latent, and thermochemical TES are also undergoing trials to store high-grade heat.

Innovation potential

o Short term (5 years): material, operational improvements, and integration, could increase efficiencies and lower costs in use of ice/PCM systems. Linking of cold chain assets across sectors could deliver synergies.

o Medium term (5-10 years): sub-zero storage temperatures and passive cooling could be achieved with next generation PCMs.

o Long term (>10 years): use of liquid air energy storage could bring down costs and open up new applications, particularly in combined cold and power systems. Retrofit of existing fossil fuel refuelling network to deliver TES-stored renewably generated cold could facilitate significant decarbonisation.

8.1.1.4 Add about Eutectics

ATC eutectic plates consist of two alloyed steel cold formed and moulded, containing a special solution that freezes and melts at a constant temperature (eutectic point). The external surface of the steel is covered with Thermal metallization with Alu-zinc sprayed by a special designed robot. Inner Serpentine system without welded innovated by ATC in worldwide and Unique system.
Applications include eutectic cooling plates, ice cream cases, solar energy systems, energy storage batteries, different eutectic cooling systems, special ice cream sales vehicles, cold storages, cooling panels, refrigerated body, cooling compressors - cooling spare parts supply and turnkey solutions.
Eutectic refrigerated bodies are acknowledged on the market as the most performing technology, and more and more are recommended as the right solution for the multitemperature requests as well as for fresh food deliveries. ATC eutectic plates are mainly installed by companies skilled in providing insulated bodies with cooling equipment.
Efficiency: Static air temperature is immediately broken down at every delivery avoiding product cooling shock. At every stop for every delivery the cold is always returned by the plates even when engine is off, and doors are open.
Low operation cost: low maintenance costs because the cooling unit has no mechanical parts running while moving and it is independent from the vehicle engine. Environmentally friendly and easier deliveries in town centres are performed securing cold at the right temperature even with engine off.
Safety: it is simple to use needing only to connect cooling unit to the power supply when returning to warehouse. Stops automatically when completely frozen. Higher reliability because the cooling system is not working while travelling (ATC and Eutaectic, n.d.).
The Eutectics is a successful decarbonisation example of TES application in food cold chain.

8.2 Low Emissions Transport Business Model

Overview:
As part of the Fit for 55 Package, which sets ambitious 55% reduction in emissions by 2030 compared to 1990; the European Union commission's transport sector decarbonisation agenda already used a bottom-up model to evaluate the required numbers of electric vehicles, charging points, grid reinforcements and renewable energy mix. Specifically, transportation masterplan indicates that:

1) About €280 billion investments would be required on infrastructure including - private charging infrastructure (~30%); public charging infrastructure (~30%); grid upgrades (~15%), and renewables (~25%).
2) The EU 27 countries would need 42. 8 million electric vehicles by 2030.
3) Specifically, trucks will require 279,000 charging points, of which 84% will be in fleet hubs while the rest will be needed at public highways and public overnight charging points.

Hence, a financial model for the achievement of low/zero emissions refrigerated transport within EU is presented in this section. The financial model details information on zero-emissions refrigerated transport financial performance and possible returns on investments.
The business model is based on servitisation business approach where the inhibitory total cost of ownership is taken off the shoulders of the service users. This will fast-track adoption and deployment of low emissions refrigerated transport systems. By this approach, the technology provider owns, builds, maintains, and decommissions the technologies while end users pay per service. It will also help with circularity as technology provider would have to think of reuse and end-of-life disposal during product design. The features of each of the model is presented in the Table 8.3.

Table 8.3. Electric HGV business models

Refrigerated vehicle electrification business models			
Section	Fleet hub	Highway	Highway
Section overview	Retail, Rentals and transport companies	Regional and long haul	Intercity distribution
Proposed technology	Combined Charging System	Megawat charging system	Panthograph
Technology solution overview	It is a type of EV charging connector used for fast and rapid charging. They are regarded as an enhanced version of the Type 2 charger, providing two additional power contact points to facilitate rapid EV charging.	Work out requirements for a new commercial vehicle high power charging solution to maximize customer flexibility when using fully electric commercial trucks and trailers. Infrastructure for 1000V/500A medium power supply	Entirely or partially charged to build electric contacts between electric equipment and contact lines and realize collection and transmission of electric energy required by electric vehicles.
Proposed business approach	Servitisation Business model where technology solutions provider provides, operates, maintains, and decomissions technology at the end of life	Servitisation Business model where technology solutions provider provides, operates, maintains, and decomissions technology at the end of life	Servitisation Business model where technology solutions provider provides, operates, maintains, and decomissions technology at the end of life
Capacity	500 kw + vehicles	1000 KW	
Vehicle types	New BEV trucks	New BEV trailers	Hybrid battery electric truck

Economic indies	Total Cost of Ownership, Net present value and payback period	Net present value and payback period	Net present value and payback period
Case study country	United Kingdom	Netherlands, France, Denmark, Germany, Sweden	Germany,United Kingdom, Sweden, France.

8.2.1 Case study 1-Electric truck and charge station for a fleet operator

Business case assumptions and overview:
The UK Government's 2021 Net Zero Strategy made a commitment to 'ensure the UK's charging infrastructure network is reliable, accessible, and meets the demands of all motorists and about £1.9 billion investment was designated for electric vehicles (EV) and charging infrastructure (Concha 2021). However, uptake of it is still relatively low mainly due to the initial cost of purchase of EV, mileage, and availability of charging infrastructure. Hence, an end-to-end solution will be required especially for businesses.
A technology solutions provider will be based on a retailer's business requirements, provide battery electric trucks and charging infrastructure within the retailers' premises. The charging facility can as well be located to serve many outlets of the food retailer. The technology provider will source for the fund, build and operates the facility while retailer pays per service. The system is expected to have the features presented in Table 8.4. with financial and institutional relationship detailed in Figure 8.5.

Table 8.4. Feature of sustainable transport model for a tertiary food distribution.

Charge station	A 500-kw electric vehicle charging facility including 2 level 3 combined charging system and 4 Level 2 charging systems.
Electric trucks	The business case model is evaluated for 10 trucks using the Total Cost of Ownership which include the initial cost to purchase, routine truck maintenance, repairs and part replacement, end of life salvage value of the truck and price of fuel. The TCO for the EV truck is taken as $1.5.
Life span	15 years
Operation	Retail or a third-party logistics company

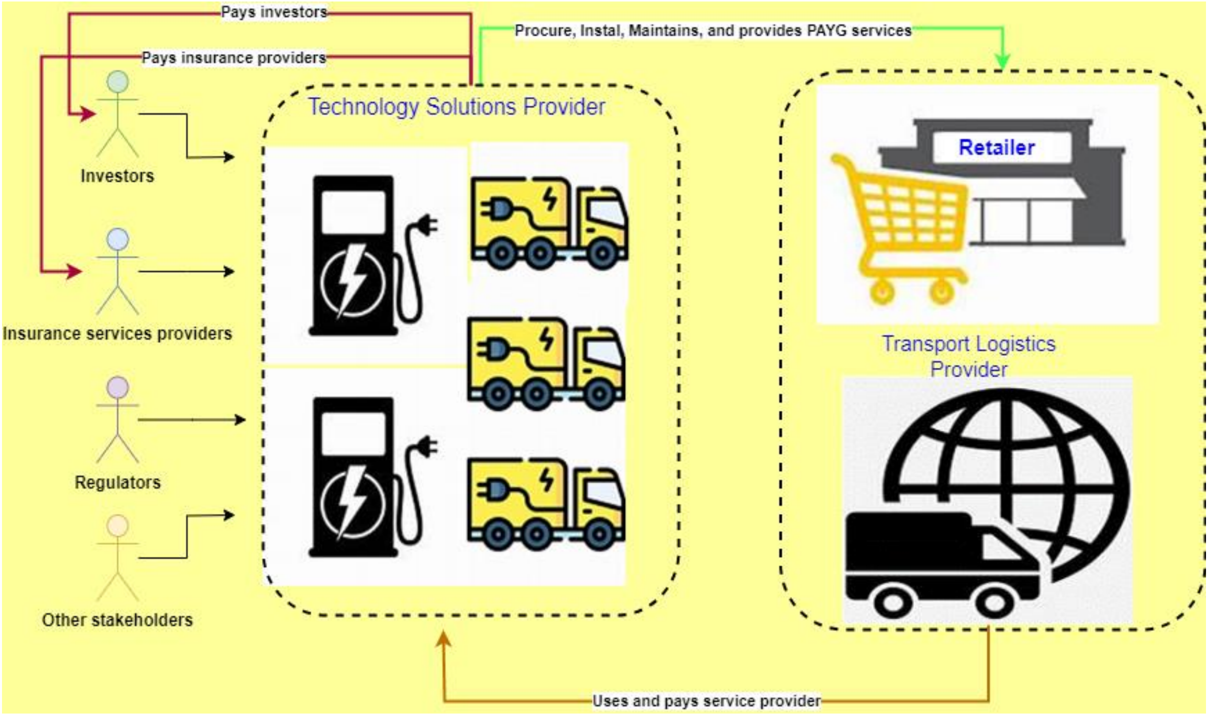

Figure 8.5.: Stakeholders' relationship for a sustainable transport business model （authors' own elaboration)

Profitability: According to the UK's Competition and market Authority (UK government, n.d.) and Springer Energy (Spirit Energy, n.d.), the payback for an electric vehicle charging station varied between 2-9 years depending on the technology, locations and operational use. Besides, a 2022 study on about 23 battery electric trucks used for last-mile delivery Paris, Berlin, Rome, Amsterdam, Warsaw and London suggests that, given the currently available subsidies, battery-electric trucks are economically viable in Paris, Berlin, Rome, and Amsterdam. However, Electric trucks operating in London and Warsaw are expected to reach total cost of ownership (TCO) parity by 2025 and 2028, respectively. The concept of TCO parity involves considering all the costs of owning and operating a vehicle over its entire lifetime, including the initial purchase price, maintenance costs, fuel or energy costs, insurance, and potential resale value. Achieving TCO parity means that the lifetime cost of owning and operating these electric trucks will be comparable to that of diesel trucks, thanks in part to the subsidies provided for their purchase. Achieving TCO parity is critical because it makes electric trucks financially neutral in comparison to diesel trucks, thus facilitating the adoption of electric vehicles for both economic and environmental reasons (International Council on Clean Transportation 2022). Meanwhile, the Total Cost of Ownership per mile of electric trucks e.g. with a 375-mile range operating in the US has been shown to be 13% less than diesel driven trucks and with payback periods around 3 (Phadke et al., 2021).

8.2.2 Case study 2: Electric Road system vehicle for food transport

The electric road system (ERS) is a branch of technologies that allow vehicles to charge while in motion. Hybrid HGV trucks are expected to be deployed for this purpose. The vehicles' powertrain will use electricity while on highway and battery between highway and distribution centres. Hence, smaller capacity of battery would be required. A conductive overhead cable system is suggested for the purpose due to its technology readiness level, cost effectiveness and ease of incorporation with the existing road infrastructure (Ainalis et al., 2020).

In this model, a technology solution provider will get investor for retrofitting of an existing highway with pantograph, assemble electric trucks, operate and deal with maintenance of the systems while food distribution companies use the facilities on a Pay-as-you-Go bases. The business and investment stakeholder are as indicated in Figure 2.

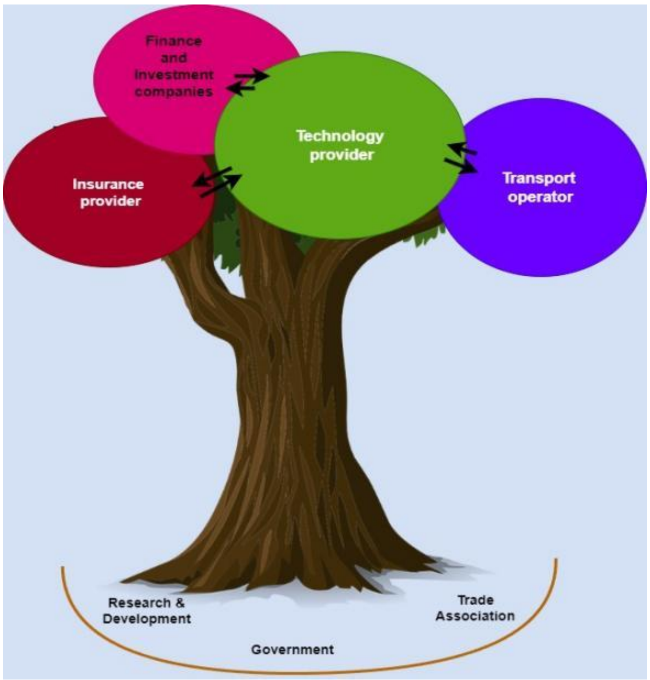

Figure 8.6. Business and investment stakeholder for ERS business model (authors' own elaboration)

Profitability: A study in the UK by the Centre for Sustainable Road Fright6 suggested that the models are profitably possible for the vehicle operators and infrastructure providers and that energy sales can generate substantial revenue for government. The study indicated that investment in pantograph-electric vehicles by fleet operators could pay back within 18 months compared to diesel powered vehicles. However, the analysis further indicates that the payback period for investment in road electrification infrastructure such as pantograph cables, sub-stations, communication, etc is 15 years. However, payback for the transport operators depends on range extender not more than 20% of vehicle annual mile coverage while that of electrification infrastructure providers is function of the electricity excise tax by the government.

A similar study in Sweden indicates that the total cost per kilometre for a truck using electric road system vary between 0.35 and 0.55€/vkm and considerably lower than the TCO for alternative diesel of approximately 0.7 €/vkm. However, this is subject to a minimum daily vehicle traffic of 1200 of ERS trucks (Gustavsson et al., 2021) More so, in France, the TCO for ERS truck is 0.59€/vkm compared to 0.9€/vkm for diesel trucks in 2022. A similar analysis in Germany also indicates the TCO for ERS truck is 0.70€/vkm compared to 1.0€/vkm for diesel trucks in 2022 and TCO of ERS is expected to further fall across EU countries as we approach 2030[1].

8.2.3 Case study 3: Megawatt Charging System for highway food trucks.

Majority of the currently available commercial vehicle charging system is limited to between 150 and 350 kW. More so, the charging time for Level 3 charger varies between 20 minutes to 90 minutes depending on battery acceptance rate (JustWe, n.d.; Power Sonic, n.d.). Hence, there is need for a larger and faster charging system for articulated vehicles as drivers only have 45 minutes allowable resting times on EU highways parking spaces.
In this business model, a technology solution providers source, install, maintains and operates charging megawatt charging station with electric trucks on a dedicated highway. This could be located on busy highway close to food distribution hubs. The location will enable significant numbers of end user to be food operators who then rent the vehicles and pay e.g. per mile. The charging facility can as well be used by other operators. Business stakeholders are like the ones presented in the Figure 2.

Profitability: Depending on location, pricing structure, operational costs, and utilization rates the payback periods for most commercial charging stations ranges from 3 – 6 years. More so, using specific country's data, Andersson et al (2023) adopted 2022 baseline and projected total cost of ownership of diesel driven and battery electric articulated trailers for long haul in some selected EU countries as presented in the Figure 3. Thus, the payback periods of adopting some of these vehicles ranges between 18 months to 48 months. However, this is strongly dependent on electricity retail prices and introduction of differential carbon tax on roads.

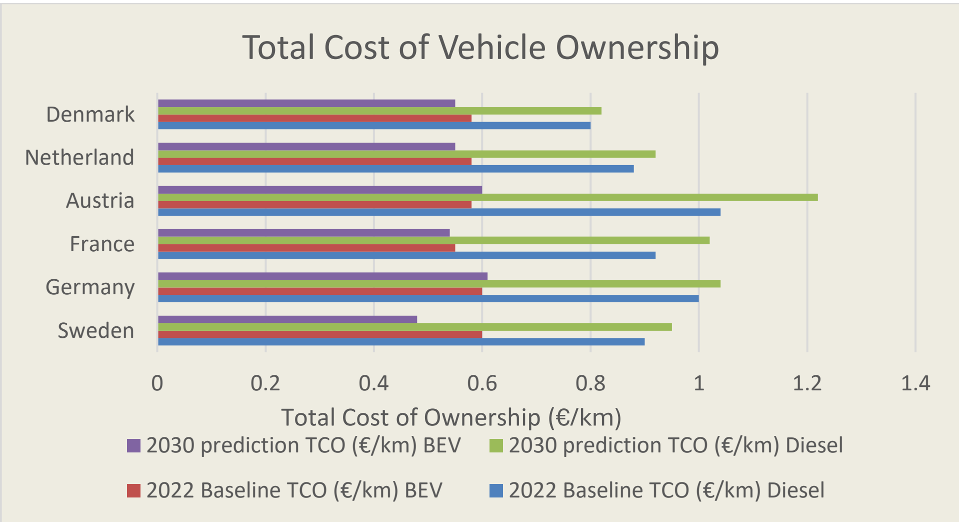

Figure 8.7 Total cost of vehicle ownership across some EU countries (Andersson et al., 2023)

8.3 Natural refrigerants transition of food supply chain

8.3.1 8.3.1 Refrigeration emissions: The Case of the EU

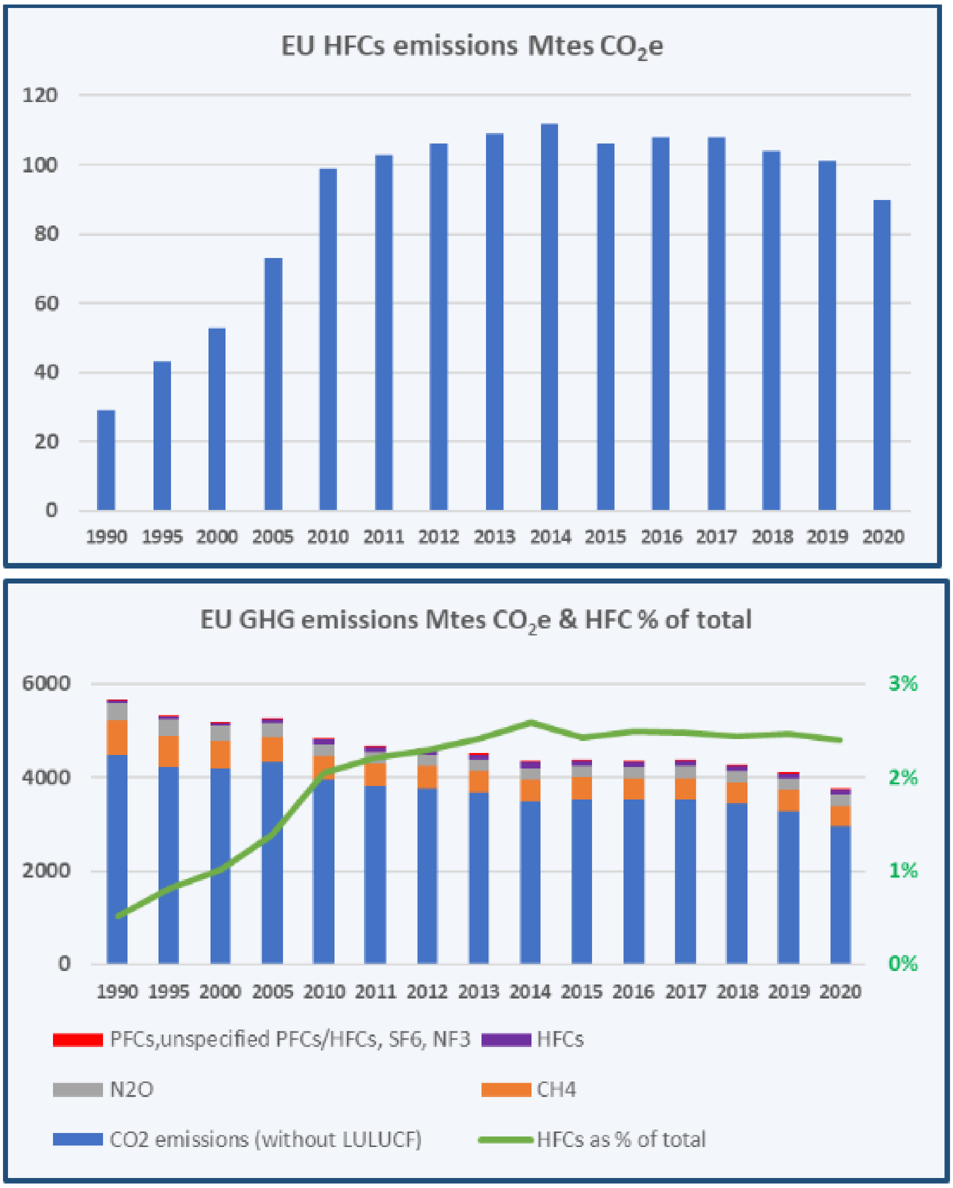

Figure 8.8. The EU reported HFC emissions (EU-27, UK, Iceland), EU GHG emissions trend and HFC emissions as a share of total emissions. Total emissions exclude LULUCF (Land Use, Land-Use Change, and Forestry) (European Environment Agency., 2023)

Key summary:

- Fluorinated GHG (F-gases) made up 2.3% of total EU GHG emissions (2019)
- In 2020, the total supply of F-gases to the EU increased slightly after a continuous decrease from 2015 to 2019.
- Despite a 7% increase in HFC consumption compared to 2019, EU consumption of HFCs in 2020 was 52% below the maximum imposed by the Montreal Protocol’s Kigali Amendment.

- The EU remains on track under the HFC phase-down phase of the EU F-gas Regulation: EU-wide placing on the market of HFCs in 2020 was 4% below the market limit.
- HFC quotas have not been fully needed to cover the demand, the reserve of quota authorisations eligible to cover imports of Refrigeration and Air Conditioning (RAC)/heat pump (HP) under HFC phase-down continues to grow.
- The EU's key objective is to achieve climate neutrality by 2050, with a net reduction target of 55% by 2030 compared with 1990 via a Fit for 55 programmes.

Fit for 55 Package:

- Phase-down of HFCs under the EU F-gas Regulation

In 2020, EU-wide placing of HFCs on the market was 4% below the 2020 overall mark. While the demand for refrigerants remains high, there has been a shift to non-HFC alternatives with lower GWPs. In 2015, the placing on the EU market of bulk HFCs was 85% of the maximum quantity and had decreased by 52% by 2020, a quicker rate of decrease than that for the maximum quantity itself, which fell by 45% over the same period. The balance has been converted into quota authorisations, which can be stored over the years and have been needed by importers of RACHP equipment containing HFCs since 2017. Supply of quota authorisations has exceeded quota relevant RACHP equipment imports in all years except 2017. The reserve of quota authorisations, built up during 2015 and 2016, thus continues to grow (+15% y-on-y by 2020 end). Current size of this reserve accounts for 7 times the amount of actual annual equipment imports in 2020 (111%) of the max. Available amount of HFCs for 2021. However, the amount of quota authorisations in 2020 decreased to 35% below 2019 levels but was still above the levels observed between 2015 and 2018.

Overall demand for F-gases in tCO_2e will decrease until 2030 and increase slightly thereafter until 2050, driven by a decrease in demand for HFCs from 89 $MtCO_2e$ in 2020 to 25 MtCO2e in 2050, while demand for SF6 increases from 28 to 48 $MtCO_2e$. Other F-gases (PFCs, H(C)FOs and NF3 55) are only contributing with less than 1 $MtCO_2e$ per year. Commission prepared proposal in 2011 and estimated that costs would be up to €50/tCO_2e abated economy wide to achieve the old, (less ambitious) climate targets. This threshold was applied to design the measures in the Regulation. Subsequently, it was estimated that these measures would result in F-gas emission reductions of 60% in 2030 compared to 2005.

Abatement costs for HFC sectors so far have been relatively low (on average €6/tCO_2e abated) and due to recent technological developments, there are many areas where further abatement could happen at costs much below that required in other sector. The average price premium (difference of price to the situation without a quota system, i.e. relative to 2014 or to world market price) for HFC in the period 2015-2019 was 8€/tCO_2e. Assuming the 2030 HFC quota limit is maintained until 2050 a worst-case simulation gives a €40/tCO_2e premium on world market price. Latest, the European Parliament approved a legislative resolution for the future F-gas Regulation on 16 January 2024. The Council will now have to formally endorse the text for it to be adopted. The new Regulation enters into force 20 days after the publication in the EU Official Journal.

8.3.2 Refrigeration emissions: The Case of the UK

The F gas Regulation in the UK includes measures to reduce use and emissions of fluorinated GHG includes a legal requirement (set out in Article 21(2)) to review the Regulation by 2022. F gases accounted for 3.02% of UK GHG (2020) and fall into 4 groups:

- HFCs - 95.1%;
- Sulphur hexafluoride (SF6) – 3.25%;
- Perfluorocarbons (PFCs) – 1.63%;
- Nitrogen trifluoride (NF3) – negligible quantities.

The F gas Regulation has succeeded in its objective to reduce estimated cumulative emissions in Great Britain by 13.6-24.3 $MtCO_{2e}$. Monetised gross benefits were measured at £1.9-8.5 billion and total costs at approx. £118 M. The reasons for success are attributed to:

a) HFC phasedown, by curbing low value uses and helping to drive the transition from high GWP HFCs to lower GWP alternatives.

b) Market incentives created by the increased price of HFCs.

Since the peak of F-gas emissions in 2016, F-gas emissions have been reduced by 11%. F-gas usage (emissions, 2020) was：

- Refrigeration, air-conditioning and heat pumps; RACHP (79.5%) - HFC
- Medical inhalers and aerosols; MDIs (9.8%) - HFC
- Electrical switchgear (4.1%) - SF6
- Closed-cell insulation foams (3.3%)
- Fire protection systems (2.5%) and
- Other specialist applications such as semi-conductor manufacture, solvents and tracer gases (0.8%) SF6.

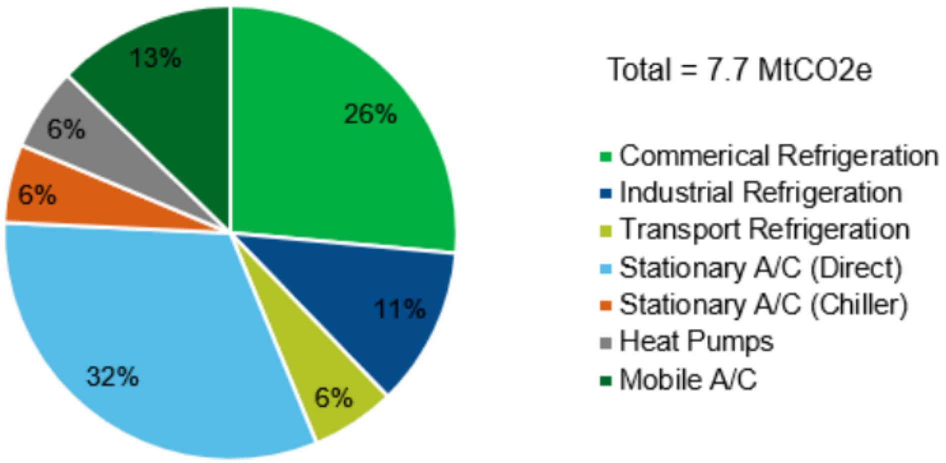

Figure 8.9. UK RACHP emissions in 2021, split by main sub-sectors (% tCO_{2e})

F gas Regulation set out the phasedown schedule which introduced steps reducing the quantities of HFCs placed on the market over time, reaching a 79% reduction compared to 2015 by 2030. Overall, the phasedown was expected to contribute 58% of costs (£658-1,508 million) and 68% of benefits (£2,513-7,542 million). Overall, the UK analysis projected discounted costs of £1.6-2.7 billion and discounted benefits of £3.8-11.2 billion from 2015 to 2035, at 2014 prices. UK RACHP emissions in

2021, split by main sub-sectors (% tCO_{2e}) is shown in Fig. Domestic refrigeration prohibition on HFCs (such as HFC-134a refrigerant and an HFC foam blowing agent) with a GWP >150 resulted in a small cost by transition to hydrocarbon refrigerants. Prior to the F gas Regulation, less than 10% of refrigerators (mostly larger units imported from the U.S.) still used HFC refrigerants. Consultants predicted these would switch to HFO-1234yf, adding £20 per unit at a total cost of £0.6-£1.2 million per year halving by 2025. Analysis predicted a further £1.5-3.3 million per year for hermetically sealed commercial refrigerators, resulting prohibition on commercial refrigeration with around half that expense being the amortised cost of developing non-HFC systems. For other stationary refrigerators there were already cheaper refrigerants that complied with the ban and were more energy efficient. Analysis estimated no cost from adopting the new refrigerants but a saving of £13-30 million a year in energy costs and CO_2 reductions of 70-150 kt per year.

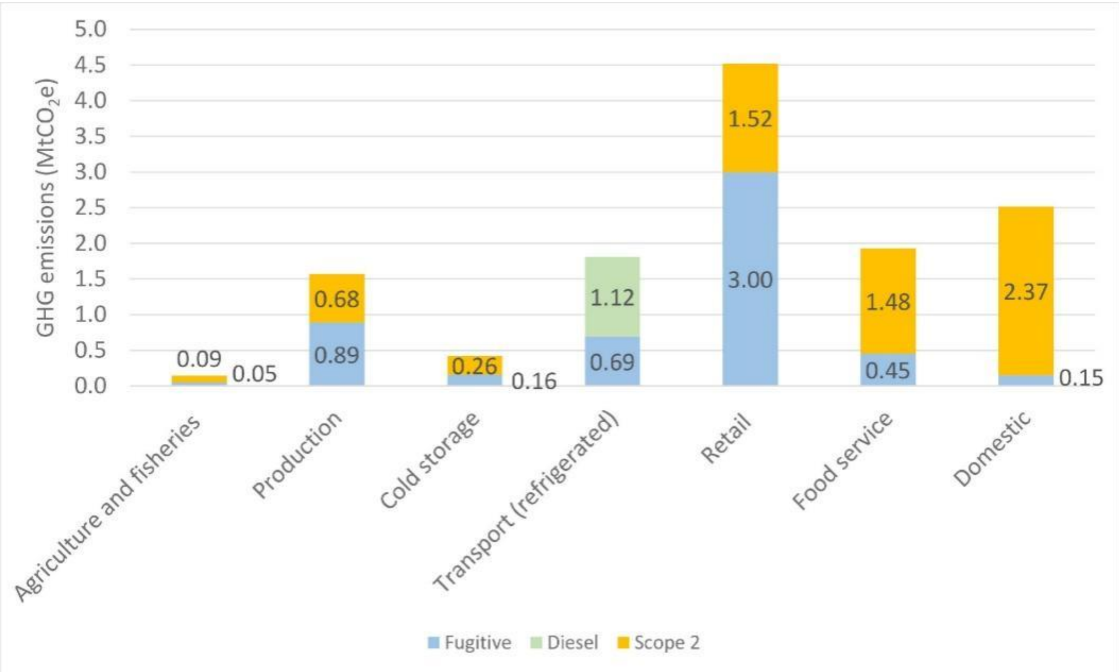

Figure 8.10. UK Scope 1 (fugitive and diesel) and scope 2 emissions for cold chain sectors. (Foster et al., 2023)

Natural refrigeration transition of food supply chain-UK case study

Data from the European Environment Agency (EEA) (2021) indicate that phase-down measures are effectively mitigating the use of fluorinated greenhouse gases. In 2020, the placement of hydrofluorocarbons (HFCs) on the market across the EU is below the market limit of 4 per cent set out in the F-gas regulation. In practice, not all the quota is being used by importers and manufacturers. This indicates that the market is transitioning to a future using low global warming potential (GWP).

In Mitsubishi Electric's 2024 report, it is stated that we are six years away from our 2030 environmental targets, during which time several key incremental reductions will be implemented. Considering this, it is particularly important to analyse and forecast the allowable GWP (global warming potential) levels of HFC refrigerants in the future. The report mentions that in 2013, the average GWP of refrigerants placed on the market was estimated to be 2,300 CO_2 equivalents. Figure 1. provides the basis for calculating the average CO_2e consumption per year, and the table that follows illustrates the potential impact that these figures could have in the coming years.

Table 8.5. Phase-down Schedule and Average CO2e of Refrigerants 2015-2048 （Mitsubishi Electric., 2024）

Time period	Phase-down percentage	Average CO2-equivalent
2015	100%	2300
2016-2017	93%	2139
2018-2020	63%	1449
2021-2023	45%	1035
2024--2026	23.6%	543
2027-2029	10.1%	232
2030	5%	115
2048	2.38%	55

UK example analysis:
RACHPs are the UK’s main user and emitter of HFCs. Since the phase-out of ozone depleting refrigerants (CFCs and HCFCs), HFCs have become the main refrigerants used in a wide range of RACHP applications. For example, supermarket / other food retail refrigeration uses mainly R-404A and other “400 series” blends.
Note: Refrigerants in the “400-series” are blends of 2 or 3 different components. R-404A, R-410A and R-407C are all blends containing HFC components.
Prior to the introduction of controls on HFC use in the 2014 EU F-Gas Regulation, R-404A, R-410A and R-134a represented over 80% of refrigerants used in the UK (Gluckman et al., 2019).
A key drawback in the use of HFC refrigerants is that they are potent greenhouse gases (GHGs). The commonly used HFC refrigerants have global warming potential (GWPs) in the range 1400 to 4000. Table 8.6 illustrates GWPs of various refrigerants for comparison.

Table 8.6. GWPs of Various Refrigerants (Gluckman et al., 2019)

GWPs of Various Refrigerants	
Gas	GWP
R-404A	3,922
R-410A	2,088
R-407C	1,774
R-134a	1,430
HC-600a	3
R-717	0

In 2016, total F-gas emissions from the RACHP sector in the UK were estimated to be 12.6 million tonnes of CO2 equivalent. This accounted for 78 % of the UK's total F-gas emissions for the year. Figure 2. illustrates the dominance of RACHP F-gas emissions in 2016.

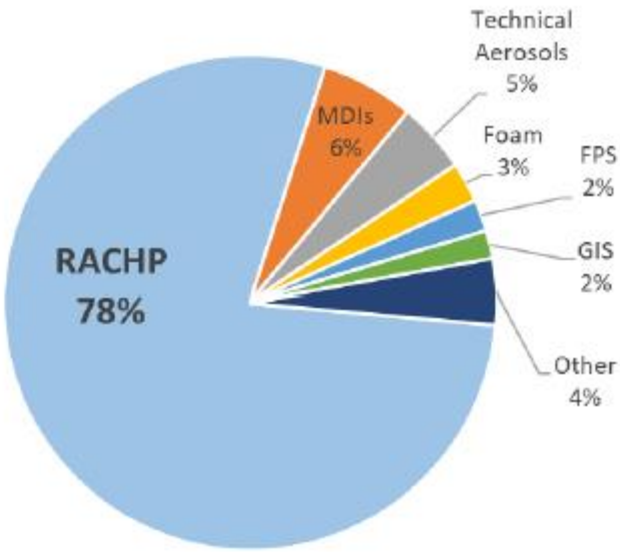

Figure 8.11. Split of UK F-Gas Emissions 2016 (Gluckman et al., 2019)

There are also the relative proportions of the different sources of RACHP emissions over their useful lives, including leaks during operation of existing equipment (i.e., leakage emissions), emissions at disposal from abandoned systems, and emissions during production of new RACHP equipment. As shown in Figure 3, leakage during equipment operation is the most significant component of emissions, while disposal emissions also figure prominently. In contrast, emissions during equipment manufacturing are almost negligible.

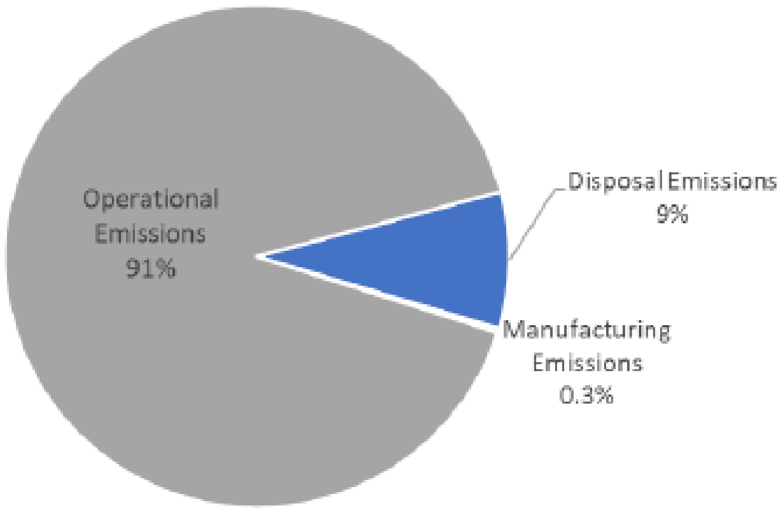

Figure 8.12. Split of RAHCP F-gas Emissions 2016 (12.6 MT CO2) (Gluckman et al., 2019)

Furthermore., Figure 4. reveals the distribution of emissions between the different RACHP market sectors in 2016. Four major sectors accounted for more than 90 per cent of total emissions.

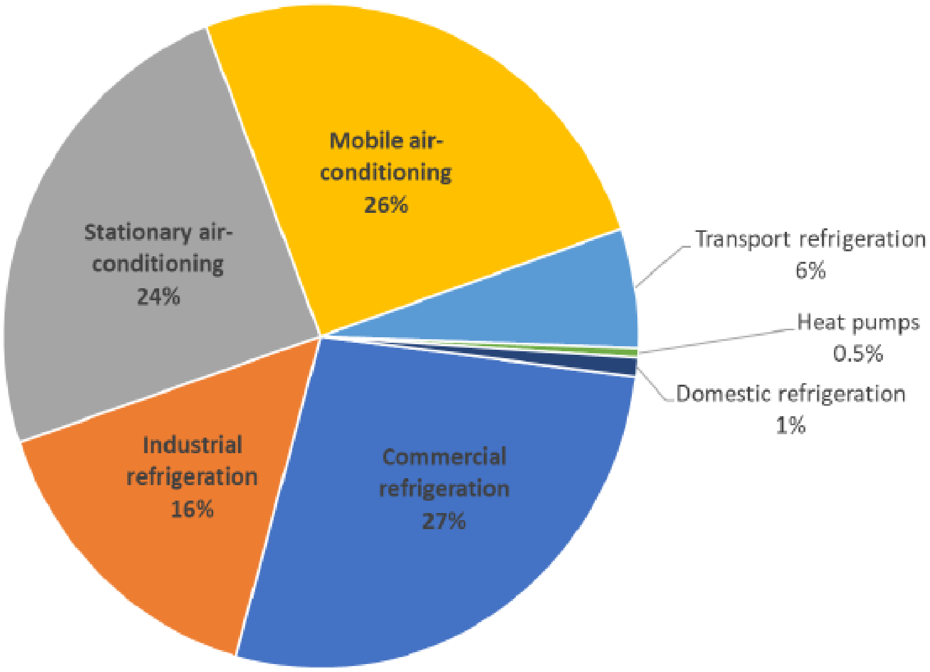

Figure 8.13. Split of RAHCP F-gas Emissions 2016 (12.6 MT CO2) (Gluckman et al., 2019)

The RACHP industry has adopted three strategies in response to the strict EU regulations on HFC phase-out:

Stage 1: Adoption of low Global Warming Potential (GWP) alternative refrigerants in new equipment. This is the most critical measure in the long term - it is likely that current high GWP HFCs will be almost completely phased out by 2050. However, given the long lifespan of some RACHP equipment, it will take a long time to completely replace the existing stock of HFCs.

Table 8.7. Lower GWP Alternatives (Gluckman et al., 2019)

Refrigerant		GWP	ODP[7]	Safety class[8]	NBP[9] (°C)	Alternative to:	Markets, Applications and Other Comments
GWP <10	R-717 (ammonia)	0	0	B2L	-33.3	R-22, R-404A, R-134a	Mainly used in industrial refrigeration applications. Has been used in such applications for many decades, hence good technical experience is widely available. Also suited to large water chillers. Toxicity and materials compatibility issues typically limit applicability to large systems in restricted access areas.
	R-744 (CO_2)	1	0	A1	-78.4	R-22, R-404A, R-134a	Was used prior to 1950s, but replaced by CFCs. Re-introduced around 2005 and becoming widely used in supermarket refrigeration and some other applications. A1 safety classification is helpful, but operating pressures are very high and critical temperature is very low – this requires significant design changes.
	R-290 (propane)	3	0	A3	-42.1	R-22, R-410A	Used in small sealed refrigeration and heat pump systems and in medium and large sized water chillers. Being considered for small split air-conditioning.
	R-600a (iso-butane)	3	0	A3	-11.8	R-134a	Widely used in domestic refrigerators and other very small sealed systems.
	HFO-1234yf	4	0	A2L	-29.4	R-134a	Becoming widely used as an alternative to R-134a in car air-conditioning. Being considered for other R-134a applications.
	HFO-1234ze	7	0	A2L	-19.0	R-134a	Becoming widely used as an alternative to R-134a in medium pressure water chillers for air-conditioning and industrial process cooling.
	HFO-1233zd	4	0	A1	18.1	R-123	These refrigerants are being used in low pressure chillers as an alternative to R-123 (an HCFC). R-514A is a blend of HFO-1336mzz and R-1130 (trans-1,2-dichloroethene) and has properties that are very close to R-123. Both are non-flammable and capable of very high energy efficiency in low pressure chillers.
	R-514A	7	0	B1	29.1	R-123	

Refrigerant		GWP	ODP[7]	Safety class[8]	NBP[9] (°C)	Alternative to:	Markets, Applications and Other Comments
GWP 10-150	R-454C	148	0	A2L	-46.0 / -37.8	R-404A	These are HFC / HFO blends with characteristics similar to R-404A, being considered for use in various lower temperature refrigeration applications e.g. frozen food processing and storage.
	R-455A	148	0	A2L	-56.1 / -39.1	R-404A	
	R-459B	144	0	A2L		R-404A	
GWP 150-700	R-32	675	0	A2L	-51.7	R-410A	R-32 becoming widely used in small split air-conditioning systems and small chillers as an alternative to R-410A
	R-447B	741	0	A2L	-50.0 / -46.0	R-410A	These blends all contain a significant proportion of R-32 (65% to 70%) plus other components including HFOs. All are possible alternatives to R-410A
	R-452B	675	0	A2L	-51.0 / -50.3	R-410A	
	R-454B	466	0	A2L	-50.9 / -50.0	R-410A	
	R-459A	459	0	A2L		R-410A	
	R450A	605	0	A1	-23.4 / -22.8	R-134a	These are non-flammable HFC / HFO blends with characteristics similar to R-134a
	R513A	631	0	A1	-29.2	R-134a	
	R-454A	239	0	A2L	-48.4 / -41.6	R-404A	HFC / HFO blend with characteristics similar to R-404A
GWP 700-1400	R-448A	1387	0	A1	-45.9 / -39.8	R-404A	These are non-flammable HFC / HFO blends with characteristics similar to R-404A. First introduced around 2015 and already gaining a significant market share in countries with HFC phase-down controls.
	R-449A	1397	0	A1	-46.0 / -39.9	R-404A	
	R-449C	1251	0	A1	-44.6 / -38.1	R-407C, R-22	Non-flammable HFO / HFC blend being considered for bus and train air-conditioning
GWP 1400-2500	R-452A	2140	0	A1	-47.0 / -43.2	R-404A	These are non-flammable HFC blends with characteristics similar to R-404A. R-407A and R-407F have been available since around 2010 or earlier and have been used in some commercial refrigeration applications.
	R-407A	2107	0	A1	-45.3 / -38.9	R-404A	
	R-407F	1825	0	A1	-46.1 / -39.7	R-404A	

F-gas emissions in the food supply chain originate in the key sectors of refrigerated storage, cold chain transport, retail and food processing. These sectors rely on equipment using fluorinated refrigerants, which not only consume large amounts of energy during operation but can also lead to significant GHG emissions due to refrigerant leakage. Therefore, we mainly consider refrigerant trends in the following markets, which are shown in Table 8.8.

Table 8.8. Refrigerant Trends (Gluckman et al., 2019)

Main Market	Market Sub-sector	Typical refrigerant charge (kg)	Most widely used HFCs	Progress to lower GWP	Comments
Commercial Refrigeration including supermarkets, smaller food retail and food service (restaurants, hotels etc.)	Small sealed units	0.1 to 1	R-404A R-134a	Very Good Several ultra-low GWP options already available	There is significant use of hydrocarbons (R-290 or R-600a), especially for systems containing <0.15 kg. Some safety standards already allow higher charges and others are under review and may allow higher HC charges (e.g. 0.5 to 1 kg). This market sub-sector is also well suited to ultra-low GWP 2L refrigerants (such as R-1234yf or R-1234ze) or low GWP R-404A alternatives (such as R-454C or R-455A).
	Condensing units	2 to 10	R-404A R-134a	Poor Progress is slow for the medium sized equipment in this market sector.	R-404A (GWP 3922) can be avoided quickly through use of medium GWP non-flammable alternatives such as R-448A and R-449A (GWP ~1400) or R-452A (GWP 2140). The charge should be low enough for successful use of 2L low GWP R-404A alternatives such as R-454C or R-455A (GWP ~150), but more development is required. For chill temperatures (0 to +5 oC) ultra-low HFO-1234yf or HFO-1234ze are possible 2L options. CO_2 systems are currently too expensive in this size range, but prices are beginning to fall and CO_2 could become an option, especially in cool / mild climates. Small sized CO_2 condensing units may lack the

					efficiency required in hot climates.
	Large multi-compressor rack systems	20 to 200	R-404A R-134a	Very Good There is significant progress towards the use of ultra-low GWP options.	Transcritical CO_2 systems are being rapidly adopted in locations with cool / mild climates. In very hot climates cascade type CO_2 systems may be a better option. Some supermarket companies are replacing large central systems with small sealed units cooled by a chilled water loop. The sealed systems are small enough to safely use higher flammability HCs such as R-290. New systems using R-448A and R-449A are becoming common. Retrofit of large R-404A systems with non-flammable alternatives such as R-448A and R-449A is an important option. This can provide quick reductions in HFC consumption and has been shown to also provide very useful energy efficiency improvements
Transport refrigeration	Refrigerated trucks, vans and iso-containers	2 to 10	R-404A R-134a	Reasonable There is some progress but more work is required	R-452A (GWP 2140) is a preferred option as its compressor discharge temperature is similar to R-404A. This provides flexibility for use in a wide range of ambient conditions. CO_2 (R-744) is being trialled and initial results look encouraging, but this is not yet a widely available option. It is not yet clear if 2L refrigerants will be acceptable due to strict flammability rules that apply in some transport regulations.

Industrial refrigeration	Large	100 to 2000	R-404A R-507A R-407C R-134a	Very Good Several ultra-low GWP options already widely available	Ammonia (R-717) has been used in the industrial sector throughout the last 100 years. It is well suited to large industrial systems such as cold storage warehouses, blast freezers, large glycol chillers, providing cost effective equipment and potential for high energy efficiency. Large factories have restricted access, so the toxic and lower flammability characteristics of ammonia can be safely dealt with on large industrial plant. Recently CO2 (R-744) has been re-introduced and it can provide a good alternative to ammonia, especially in cascade systems. Some large industrial applications are cooled with glycol or chilled water secondary refrigerants. A range of ultra-low GWP options are available, including ammonia, propane (R-290) and various HFOs (see section below on water chillers for air-conditioning – such chillers can also be appropriate for industrial plants).
	Medium / small	10 to 100		Poor Progress is slow for small / medium sized equipment	A significant proportion of industrial plant is small or medium sized. This makes it more difficult to use ammonia cost effectively. R-404A (GWP 3922) can be avoided quickly through use of medium GWP non-flammable alternatives such as R-448A and R-449A (GWP ~1400). In the industrial market it should be possible to

					make use of 2L low GWP R-404A alternatives such as R-454C or R-455A (GWP ~150), but more development is required. For chill temperatures (0 to +5 oC) ultra-low HFO-1234yf or HFO-1234ze are possible 2L options. Some industrial processes require very low temperatures (e.g. below -60oC). None of the "mainstream" refrigerants are suitable for such low temperatures and the currently available options have very high GWP. Because these are very small markets there is little development of lower GWP refrigerants for such applications.
Domestic refrigeration	Refrigerators and freezers	0.05 to 0.2	R-134a	Very Good Ultra-low GWP options already widely available	There is widespread use of iso-butane (R-600a) in many geographic regions. Some safety standards allow use of up to 0.15 kg of this higher flammability refrigerant which is sufficient for most sizes of refrigerator and freezer. Hundreds of millions of iso-butane refrigerators are already in use globally. Some countries have had standards or legislation that restricts HC use (e.g. in the USA, where charge was limited to only 0.05 kg) but these are under review and it is likely that iso-butane will be used in the majority of countries in the future. Refrigerators are also suited to ultra-low GWP 2L refrigerants (such as R-1234yf or R-1234-

					ze), although little product development has yet taken place.

For food supply chain, supermarket / other food retail refrigeration uses mainly R-404A and other "400 series" blends, therefore, here we mainly discuss modification of small R-404A equipment. The ban on maintenance services for systems containing more than 10 kg of R-404A will require retrofitting of larger systems, and the RACHP model already assumes that such retrofitting will take place. Between 2020 and 2030, there will still be a large number of smaller condensing unit systems and refrigerated road haulage units using R-404A. after 2030, R-404A emissions will rapidly drop to zero, as few new R-404A systems will be installed after 2016. A proportion of smaller systems may be retrofitted with non-flammable alternatives such as R-448A, R-449A (GWP 1400) and R-452A (GWP 2140). When the European Commission assessed the service ban in 2013, retrofitting small units (<10kg) was not considered cost effective. This has changed for two reasons: a) retrofitting the three gases mentioned above is technically easier - and therefore less costly - than expected; and b) the price of R-404A has risen more rapidly than expected (from £10 per kilogram in 2016 to £100 per kilogram in 2018). The net cost of retrofitting a small system is expected to be between £100 and £200. Retrofitting is likely to result in energy efficiency gains of between 2.5 per cent and 5 per cent - which will offset the cost of retrofitting, making this emission reduction measure cost-effective.

Stage 2: Reduction of HFC use in existing equipment.

Existing RACHP equipment needs to be replenished with large amounts of HFCs due to leakage, and this use can be reduced by investing in leak-proof technologies. Additionally, improving the leak rates further can be achieved by a combination of better equipment design and better maintenance of existing systems. With refrigerant prices rising steeply in response to the HFC phase-down it is reasonable to expect greater improvements in this area. The extra costs of leakage reduction efforts are offset by energy savings, as refrigerant leakage leads to a loss of efficiency.

Table 8.9. Cost of Abatement (Gluckman et al. 2019)

Measure	Cumulative emission reduction 2020 to 2040 MT CO_2eq		Cost of abatement £ per tonne CO_2 saved	
	F-Gas	Electricity	Low estimate	High Estimate
1. Reduced use of R-410A in medium sized air-conditioning using alternative HFC-32 based technologies.	0.2	0.1	Negative cost	
2. More use of propane refrigerant in very small air-conditioning (instead of HFC-32)	0.3	0.1	Negative cost	
3. Reduced use of R-448A and R-449A in small commercial, industrial and marine refrigeration (using A2L blends or CO_2)	1.9	-	0.2	0.4
4. Retrofit of small R-404A equipment	1.3	0.8	Negative cost	
5. Retrofit of R-134a equipment	1.2	-	20	60
6. Leak reductions through improved design and maintenance	2.4	2.2	Negative cost	

Stage 3: Utilization of recovered refrigerants.

HFCs contained in older equipment must be recovered at the end of the equipment's life, and according to the F-gas regulations, these HFCs are not allowed to be vented to the atmosphere. These recovered "used" refrigerants can be reprocessed and reused without being subject to phase-out quotas. While this does not directly reduce F-gas emissions, it promotes maximum gas recovery and helps the industry to meet stringent HFC phase-out targets.

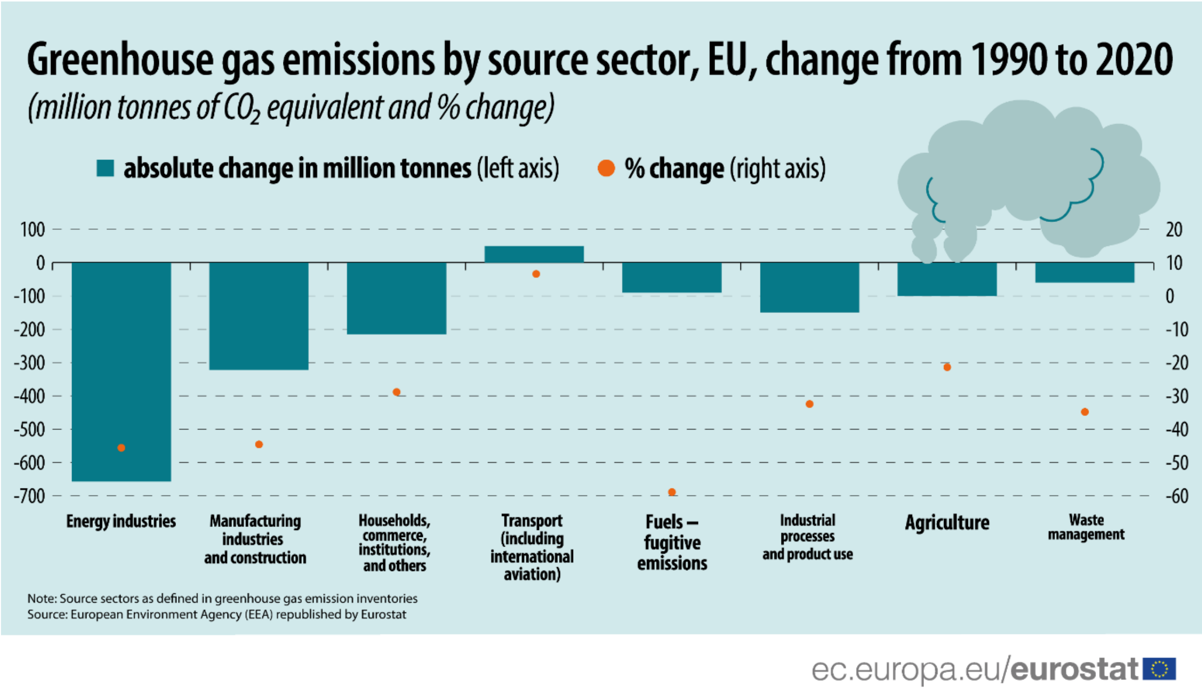

Figure 8.14. Greenhouse gas emissions by source sector, EU, change from 1990 to 2020 (million tons of CO2 equivalent and % change)

9 EMISSIONS TRADING SCHEME (ETS)

9.1 Overview

Emissions Trading System (ETS) is a policy tool and market instrument that is currently widely used in the EU and UK regions. The EU Emissions Trading System (EU ETS) and the UK Emissions Trading System (UK ETS) provide an emissions cap-and-trade system to address GHG emission via setting limits on annual emissions that can be emitted by certain industries or sectors. During the system operation in the past few years, it shows significant emission reduction potential in grid decarbonisation and transportation decarbonisation processes, which are closely related to food supply chain. Please refer to the following details for a brief consideration concerning how the ETS work, mainly focusing on EU EST and UK ETS on net-zero food supply chain.

9.2 Background

Since the signing of the Kyoto Protocol in 1997, the control of GHG emissions through market has been widely recognised as a necessary and effective tool. However, there are different emission reduction policies adopted in various countries, which could be a huge complex barrier to establish a market system. Therefore, it is necessary to find a regulation complemented by multiple countries as a reference policy to achieve global emission reduction through market mechanisms.

In this context, the EU ETS system, adopted by the EEA-EFTA countries, was launched, and progressively implemented in 2005.The EU ETS is one of the foundational instruments of the EU's policy framework for combating climate change and achieving economically efficient reductions in GHG emissions, in line with the objectives of the European Green Deal. The system is designed to assist

the EU in meeting its immediate and long-term emission reduction targets by "promoting emission reductions in a cost-effective and economically efficient manner".
A multitude of important parts of the food supply chain are also gradually being included in the ETS.

9.3 How does it work?
The main features of the system are emission caps and EU emission allowances (EUAs).
“Emission caps” ensures that total emissions are effectively controlled to meet the reduction targets.
“EU emission allowances (EUAs)”, encourages, through a “market hand”, emitters whose emission costs are lower than the allowances to take reductions actions immediately, while others whose emission costs are higher could buy allowances and postpone mitigation actions.
ETS system could effectively control total emissions while enabling enterprises to find the most cost-effective ways to reduce emissions. It helps reduce enterprises pressure on emission control as they have the flexibility to choose how to reduce GHG emissions. And ETS system creates a market for emission reductions, which could promote innovation and development of clean technologies, which is good for long-term costs of combating climate change.
In general, ETS is considered to be one of the most effective policies for promoting low-carbon and sustainable economic development because of its significant advantages of cost-effectiveness, broad coverage, flexibility and a predictable and transparent market environment.

9.4 Development journey
ETS system has been a gradual process, spanning several phases from its inception to ongoing enhancements. Its development path has been divided into stages, four of which have been identified to date. And it is on the fourth stage now. And more stages are expected. Each phase is briefly summarised below:
First Step: In March 2000, the EU presented a “Green Paper” exploring initial design ideas for an EU ETS, laying the groundwork for subsequent discussions. The system directive was adopted in 2003 and launched in 2005. And the allowance caps were expected to be set by national allocation plans.
Phase 1 (2005-2007): EU implemented a 3-year "learning-by-doing" pilot to facilitate the operation of the ETS system. The Stage actions included: (a) only focused on power generators and energy-intensive industries; (b) Almost all allowances were given to businesses for free; and (c) The penalty was only €40 per ton. And it successfully established: (a) carbon price (b)free trade in EU-wide emission allowances and (c) the necessary monitoring and verification infrastructure. However, after 1-year operation, real emissions data indicated that business were allocating too much EUA, leading to an oversupply of EUA and a drop-in price to zero. The system seems not to be working well.
Phase 2 (2008-2012): In response to more specific emission reduction objectives, the EU has applied stricter emission caps. The Stage actions included: (a) approximately 6.5% lower cap on allowances compared to 2005, (b) 3 new countries joined, (c) Nitrous oxide emissions from the production of nitric acid included, (d) Countries held auctions auction up to 10 % of the quota instead of allocating freely, (e) The penalty was increased to €100 per ton, (f) Businesses were allowed to buy international credits totaling around 1.4 billion tons of CO_2-equivalent, (g) the aviation sector was brought into the EU ETS on 1 January 2012. However, the economic crisis of 2008 led to higher-than-expected emission reductions, resulting in a large surplus of allowances and credits that put heavy pressure on carbon prices.

Phase 3 (2012-2020): Huge reforms were witnessed in response to the problems and inherent weaknesses of the system that were exposed during the previous run. The Stage main actions included: (a) a single, EU-wide cap on emissions in place of the previous system of national caps; (b) auctioning as the default method for allocating allowances instead of free allocation; (c) harmonized allocation rules applying to the allowances still given away for free; (d) more sectors and gases included.
Phase 4 (2021-2030): A cap aligned to the EU's (previous) 2030 target of reducing greenhouse gas emissions by 40% compared to 1990 levels. In July 2021, the European Commission adopted the long-awaited "Fit for 55" package. EU ETS to be extended to maritime, construction and road transport.

9.5 Comparing UK ETS & EU ETS

The UK Emissions Trading Scheme (UK ETS) replaced the UK's participation in the European Union Emissions Trading Scheme (EU ETS) on 1 January 2021.
Similar to the EU ETS, UK ETS also applied the 'Cap and trade' approach. A cap is set on the total amount of certain GHG that can be emitted by sectors covered by the scheme. Within the cap, participants receive free allowances and/or buy emission allowances at auction or on the secondary market, which they can trade with other participants as needed. Installation/aircraft operators surrender allowances to cover their reportable emissions annually. The cap is reduced over time, so that total emissions must fall.
The UK ETS applies to: (a) energy intensive industries, (b) the power generation sector and (c) aviation. (Schedule 1 and 2 of the Greenhouse Gas Emissions Trading Scheme Order 2020.) Fuel combustion on a site where a total rated thermal input exceeding 20MW are operated (except in installations where the primary purpose is the incineration of hazardous or municipal waste). But UK ETS provided some simplified provisions for (a) hospitals, small emitters (HSEs). Emissions lower than 25,000t CO_2e per annum, and installation carrying out the activity of combustion has rated thermal capacity < 35MW. These installations will be subject to emissions targets instead of having allowance surrender obligations; (b) ultra-small emitters (USEs) < 2,500t CO2e per annum, not required to hold a permit but are still required to monitor and must notify their regulator if they go over the threshold.
The initial cap is 5% lower than the UK's share under phase four of the EU ETS. As of 2024, it has a cap that is consistent with net zero. The lowest price of €57.91 (7 March 2022) during a period of increased market volatility triggered by Russia's full-scale invasion of Ukraine. The average price reached €80.18 in 2022. The price range was narrower in the first half of 2023, between €75.04 (17 January) and €96.33 (28 February). As of 2021 international carbon offsets are not permitted in the UK ETS.

UK Emissions Trading Scheme	EU Emissions Trading Scheme
Reduction of the cap to be consistent with net zero targets – reset to 936 million allowances over 2021-2030. 53.5 million unallocated allowances will be brought to market over 2023-27.	Reduction of the cap of 117 million allowances over two years. 4.3% reduction per year from 2024-2027 and 4.4% per year from 2028-2030. Two one-off 'rebasings' of the cap, reducing it by 90 million allowances in 2024 and an additional 27 million in 2026
Free allocation review consultation published by end 2023 to examine changes to free allocation distribution methodology.	For sectors which the EU CBAM applies to, free allowances will be gradually phased out between 2026 and 2034, as the CBAM is phased in.
Aviation: free allocation phased out by 2026 and sustainable aviation fuel policy to be reviewed and beginning to look at inclusion of non-CO2 aviation emissions.	Aviation: free allocation phased out by 2026. The Commission will establish a framework for MRV of non-CO2 aviation emissions as of 2025, then an evaluation will be made in 2027 followed by a legal proposal in 2028 to extend the scope to cover these emissions. 20 million free EU ETS allowances will be distributed to individual aircraft operators to help cover the price differential between fossil jet fuel and eligible SAF.
UK Emissions Trading Scheme	**EU Emissions Trading Scheme**
Expansions: Expansion to domestic maritime from 2026 Expansion to waste incineration and energy from waste from 2028 (preceded by a 2-year monitoring period from 2026) Expansion to upstream oil and gas CO2 venting	Expansions: Expansion to maritime phased in from 2024 until 2026. Applies to 100% of emissions for intra-EU voyages and 50% for voyages into or out of the EU. The Commission will assess and report by 31 July 2026 on including waste incineration with a view to including it from 2028, with the possibility of an opt out until 31 December 2030. 'EU ETS 2' covering emissions from buildings and road transport to launch from 2027.
Stated ambition to incorporate greenhouse gas removals into the UK ETS	
Hypothecation: none	Hypothecation: Innovation Fund, Social Climate Fun

Figure 9.1. Comparison of UK and EU ETS

Neither the EU ETS nor the UK ETS presents a particular focus on the entire food supply chain, but rather the ETS system focuses on specific components of the food supply chain to drive the entire food supply chain system towards net zero. The widespread use of the ETS business model in the power sector, the initial explorations in transport, and the potential for experimentation in agriculture are seen as driving the zero-emission food chain industry to achieve zero GHG food supply chain goals.

9.6 ETS already used in grid decarbonisation

A major part of achieving a net zero economy within the EU is the decarbonization of the national grid infrastructure. Electricity consumption is involved in the entire food supply chain from farm to fork. Grid decarbonization would play an important role in net-zero food supply chain. The grid sector, as a sector that was included in the consideration of the ETS in the first phase, has been presented with a huge potential for zero target. The ETS system is driving the decarbonization and clean energy transition in the grid.

ETS is ideally placed to accelerate the clean energy transition in the power sector. Since 2005, the EU ETS has helped bring down emissions from power and industry plants by 37%. Electricity and heat production account for more than 40% of global energy-related carbon dioxide emissions, with about

30% of those emissions coming from coal-fired power plants. Progress in decarbonizing the global power sector has not been sufficiently rapid, despite the progressively lower costs of low-carbon technologies and relatively low competitive risks.

The high cost of electricity consumption associated with ETS is believed to encourage a shift to low carbon products or a change in electricity consumption patterns. These influences include a) incentives to invest in less carbon-intensive electricity supplies; b) energy efficiency savings to reduce electricity demand; and c) loss of competitive advantage in market competition for more carbon-intensive utilities due to the cost of ETS emission allowances.

According to (Pietzcker et al., 2021), over the next few decades, the power sector will undergo a major transformation within the parameters of the current emissions trading scheme (ETS) emissions caps. Projections indicate that the share of renewable energy sources (RES) in total energy demand will surge from 30 per cent in 2015 to 65 per cent by 2030 and 95 per cent by 2050. While imposing stricter emission reduction targets on the power sector may not change the basic trajectory of its transformation, it will certainly accelerate the process (Pietzcker et al., 2021).

Driven by the ETS, electricity users in the food supply chain will also adjust their electricity consumption patterns and sources of electricity consumption in response to prices. Cleaner electricity that does not require the payment of emission allowances will be prioritized. Especially, food and beverage manufacturers, which contribute one-third (38%) of electricity consumed in grid electricity, would minimize electricity consumption under cost pressures, through technological upgrades or stringent management of electricity use.

9.7 ETS initially used in transportation decarbonisation

Transportation is an essential part of the food supply chain. According to Li et al. (2022), transportation accounts for about 19% of total food-system emissions (stemming from transport, production and land-use change). Focus on efforts of ETS in transportation emission reductions would be meaningful for the zero whole food cold chain objectives.

Aviation, shipping, rail and road transport are four different modes of food transport. Poore and Nemecek (2018) present the the share of global ‘food miles’ by transport method in their study, in figure 9.2. Only 0.16% food come from aviation, while food transportation via shipping contributed to 58.97% food mile. But there is big difference of emission factors between different modes, as shown in figure 9.3.

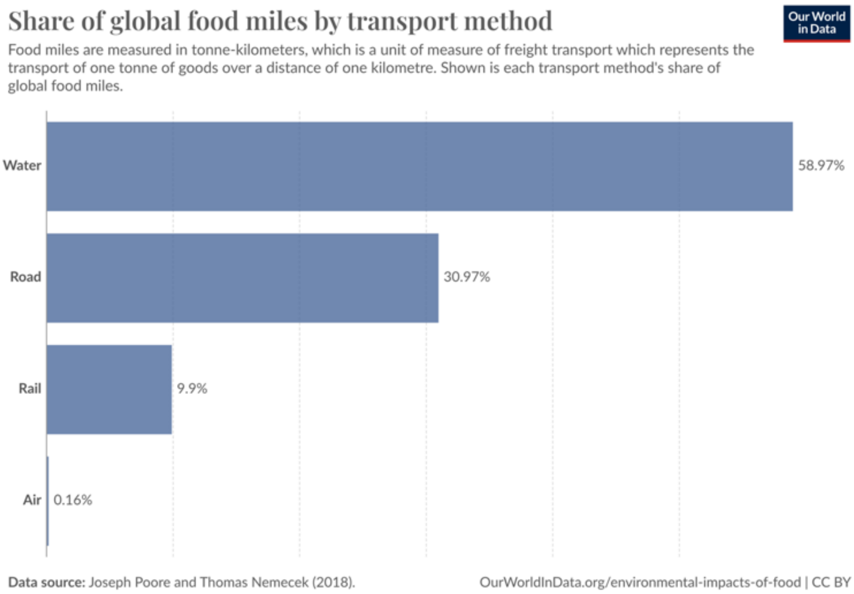

Figure 9.2. Share of global food miles by transport method (Poore and Nemecek, 2018b)

Transport mode	Ambient transport (kg CO2eq per tonne-kilometer)	Temperature-controlled transport (kg CO2eq per tonne-kilometer)
Road Transport	0.2	0.2 to 0.66
Rail Transport	0.05	0.06
Sea / Inland Water Transport	0.01	0.02
Air Transport	1.13	1.13

Table 9.1. Emission factors for freight by transport mode (kilograms of CO_2eq per tonne-kilometre) (Ritchie and Roser, 2024)

<u>Aviation:</u>

Aviation emissions have been considered in EU ETS since 2012, which is the phase 2. And for shipping, the EU recently decided to include it in EU ETS beginning 2024 in the new phase 2. According to ETS 2, which is used in building and road transport (including rail transportation), is expected to apply in 2027 with stricter management on road transport. Although aviation is not a major way of food logistics, it contributes the highest emission factor per food mile.

In 2017, direct emissions from aviation in the EU accounted for 3.8 % of total CO2 emissions. Emissions from aviation accounted for 13.9% of total transport emissions, making it the second largest source of transport GHG emissions after road transport. Prior to the COVID-19 crisis, the International Civil Aviation Organisation (ICAO) predicted that international aviation emissions could triple by 2050 compared to 2015. In addition, aviation has an impact on the climate through the release of gases and particulate matter such as nitrogen oxides, water vapour, sulphates, and soot particles at high altitudes. These impacts could have a significant effect on the climate system.

The EU ETS initially covered all flights departing and arriving in the European Economic Area (EEA). However, in the face of intense national pressure and in line with the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), a measure of the International Civil Aviation Organisation (ICAO), the scope of aviation coverage under the EU Emissions Trading System (EU ETS) has been reduced from 2014 to flights between European Economic Area (EEA) countries (Schinas and Bergmann, 2021).

Since 2012, aircraft operators operating in the EEA have been required to monitor, report, and verify their CO2 emissions and surrender allowances for these emissions. The aviation emissions cap is based on the historical average of CO2 emissions within the aviation sector from 2004 to 2006. Each year's projected emissions will be expected to continue to decrease compared to this baseline. The cap is set at 95 per cent of the historical average emissions from 2013 to 2020. From 2021 onwards, the annual linear reduction factor (LRF) will be capped at 2.2 %.

Emission allowances will be allocated to airlines based on a combination of benchmarking and auctioning. Unlike the grandfathering method used during Phases 1 and 2, where emission allowances were allocated based on historical emissions, from Phase 3 onwards, 82 % of the emission allowances will be allocated to airlines through benchmarking, while 15%t of the EUA will be allocated through auctions, with the remaining 3% allocated as a special reserve for fast-growing aircraft operators and new entrants. The EU-ETS scheme is an open cap-and-trade system, whereby market participants whose emissions remain below the level of allocated allowances can sell their excess allowances.

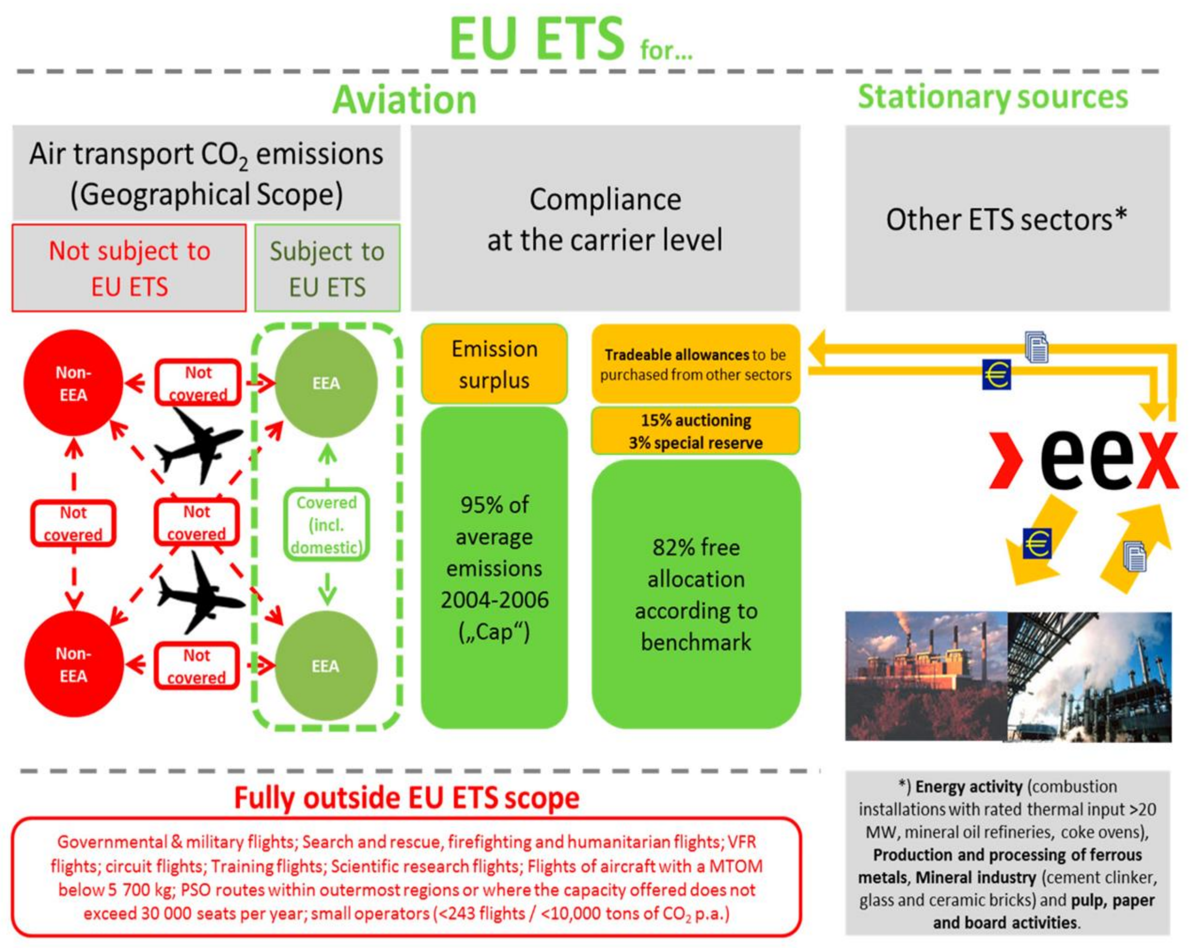

Figure 9.3. ETS Operation Flowchart (Maertens et al., 2019)

According to (Vespermann and Wald, 2011), overall, in the absence of an 'oversupply' of emission permits, the EU ETS will help to make a significant impact on emissions reductions in air transport. Initial projections suggest that it will lead to a 2.7% reduction in emissions in 2012, rising to around 7.5 % in 2020. In fact, Transport & Environment (2019) argued that aviation emissions from routes covered by the EU ETS grew by 1.5 % in 2019. Compared with an 8.9 % emission decrease in other sectors include in the ETS, there are still a huge gap remaining, although the slowdown in emissions growth is to be welcomed.

The aviation industry is expected to be a strong net buyer of additional emission permits due to the expansion of the industry and the reduction of free allowances resulting from stricter emission reduction requirements, with permits coming mainly from other industries (Vespermann and Wald, 2011; Schinas and Bergmann, 2021; Pang and Chen, 2023).

One-way trading under the EU ETS enables airlines to compensate for their emissions by obtaining allowances from more easily achievable and cheaper sectors. However, this weakens the industry's efforts to reduce emissions (Pang and Chen, 2023). The escalating expenditure on the acquisition of emission permits implies a progressive rise in the average financial burden imposed by the Emissions Trading System (ETS) on the aviation sector. Moreover, apprehensions persist regarding its repercussions on the industry's competitive dynamics (Vespermann and Wald, 2011). ETS is believed

to reduce the profitability of traditional airlines. The aviation industry is also expected to develop low and zero-emission technologies in response to cost pressures (Pang and Chen, 2023).
In short term, the greater and efficient reduction expectation would be lower emissions because of reduced demand for air transport and reduced air traffic activity due to higher aviation costs via ETS (Vespermann and Wald, 2011).
Moreover, given aviation's significant reliance on purchasing emission permits, the industry will incentivize other sectors to curtail their emissions. As emission permits migrate from stationary sources to aviation, these sectors stand to achieve more substantial reductions in emissions.
In food supply chain, the potential for ETS emissions reductions in the aviation sector will also have a profound impact on food transport. More importantly, the increased costs of ETS for air transport are believed to be passed on to consumers. This will reduce the demand for "food away from home", which has a higher emission factor on food miles.

Shipping:
Marine transport is the most important way of transporting in food supply chain.
Maritime transport accounts for about 3-4% of the EU's total CO_2 emissions (EP and EUCO, 2023).
The EU ETS will cover CO_2 emissions from all ships entering EU ports with a gross tonnage (GT) of at least 5,000, regardless of their country of registration. The ships included would cover 55 % of all cargo and passenger ships calling at European Economic Area ports and account for more than 90% of EU shipping emissions.
The EU ETS will undoubtedly increase the cost of shipping emissions with the aim of encouraging a shift to alternative fuels and advancing technological and operational changes to improve energy efficiency.
In shipping, auctions will remain the primary method of allocating emission allowances. Auction revenues benefit member nations and, with a few exceptions, should be used to pursue projects exploring emission reduction. Like aviation, reductions in GHG emissions from the integration of shipping into the EU ETS will come from mitigation measures implemented in the maritime sector or in other ETS sectors through the purchase of ETS allowances.
Potential emission reduction measures mainly include operational measures, technical measures, and fuel substitution measures. Pressure from the ETS will drive these methods. The integration of the shipping industry into the EU ETS will have a direct impact on ship owners, who will face increased operating costs due to the need to purchase allowances. The chart below gives an indication of the increased cost of diesel fuel.

Table 9.2. Compared emission reduction in aviation industry and other sectors.

Emission Allowance price, €/tCO2	Additional cost per ton of MGO for a geographical of …	
	50% of incoming and outgoing voyages	100% of incoming and outgoing voyages
20€	31€	63€
70€	100€	220€
90€	141€	283€
100€	157€	314€

150€	236€	471€
200€	314€	628€

This cost will be passed on to the consumer, especially for low value-added products, (in the case of food supply chains for low value-added food products), which may produce a change in demand. The value advantage of food transported over long distances over local food will be diminished or even eliminated, bringing about less demand for food shipping, and thus the choice of lower-emission local food.

Road Transport (including rail transport):

Road transport is another important way of transporting in food supply chain.

A new emissions trading scheme, called ETS2, will operate independently from the existing EU ETS. This novel system will encompass, and address CO_2 emissions generated from fuel combustion in buildings, road transport, and other sectors, notably small-scale industries not covered by the current EU ETS. While the new ETS still relies on the principle of "cap and trade", the new system will take upstream emissions into account. It is the fuel supplier, not the end consumer, who should be the subject of this reporting. The new plan is expected to start in 2027. All emission allowances in ETS2 will be auctioned and a portion of the proceeds will be used to support vulnerable households and micro-enterprises through a dedicated Social Climate Fund (SCF).

ETS potentially used in farming decarbonisation:

Exploration of the discussion on whether agricultural emissions should be included in the ETS is in the exploration stage (Julia et al., 2023).

Concerning scope of attention in the agri-food supply chain, ETS should work on the farm or upstream or downstream in the food value chain. And where the scope of greenhouse gas emissions should be focused is an also a discussion point.

Options targeting the implementation of ETS at the farm level were found to provide more direct incentives for emissions. And options targeting upstream and downstream ETS applications in the food supply chain are considered to promote a broader whole value chain approach to addressing agricultural emissions by stimulating action and innovation both on and off the farm. Due to the complexity of emissions measurement in the food supply chain, potential methods for emissions monitoring, reporting and verification (MRV) have received particular attention. A harmonized on-farm GHG reporting tool is considered necessary before ETS can be practically applied to agriculture. Clear, easy-to-understand and practical communication of emission reduction potential is key.

As agriculture and livelihoods are closely linked. Careful planning is needed to determine the terms of direct transitional assistance in the form of farm subsidies, grants and loans. Revenues from ETS are also expected to be used for the construction of new modern farms.

The role of financial institutions should be emphasized in the transitional phase of promoting the introduction of ETS in the agricultural sector. Risk-sharing mechanisms between public and private financing need to be established. Applying the "polluter pays" principle to agricultural emissions More details will be widely explored.

Establishing an ETS that works directly on the food system is more valuable for moving towards a zero-emission food supply chain than applying an ETS to the grid and transport and indirectly contributing to food system emissions reductions. It will still take a long time to move from exploration to application and then to smooth operation and realization of the expected emission reduction.

The role of ETS in grid decarbonisation: case analysis of China Case

The experience from the operation of the EU ETS and the results achieved by this business model in decarbonization have driven the widespread roll-out of the ETS outside the EU, including in Korea, Japan, China, Australia, New Zealand and the United States. Despite gaps in specific implementation details, the system of total control and emissions trading has indeed led to considerable progress in emission reductions (IEA, 2020). The power sector is commonly chosen internationally as a priority for the ETS system. On the one hand, the power grid has more basic data as a huge emission sector. And proven, commercially available low greenhouse gas technologies underpin the decarbonization transition. On top of that, the lessons learnt from the EU ETS over a long period of time make for a reliable reference for the start-up and operation of the ETS.

China officially launched its national ETS in 2017 and operated it in 2021. Power sector is certainty firstly applied sector, which contributes more than 40% of China's energy-related CO2 emissions. And China expects to expand the market-based instrument to other energy-intensive sectors in the future. China’s ETS currently employs output- and rate-based allowance allocation, whereas mass-based ETSs. It means that allowances are allocated based on a unit's actual electricity generation during the compliance period as well as predetermined emission intensity benchmarks for each fuel and technology. Now allowance is allocated free of charge and auctions may be introduced in the future. Emissions Trading System (ETS) in China could reverse the upward trend of CO_2 emissions from electricity generation. Under more electric demand, ETS with lower benchmarks could effectively contribute to ensuring that emissions from the power sector reach their peak well before 2030.

China currently boasts the world's largest fleet of coal-fired power plants, characterized by its relative youth and efficiency. However, about 50% operational coal-fired power capacity consists of less-efficient units, including subcritical units. Effectively managing this coal-fired fleet will be essential for China to successfully realize Grid decarbonisation. Output- and rate-based allowance allocation method could promote more efficient coal-fired power generation. It means that highly efficient units could sell allowance, while less efficient power plants must buy quotas. Under ETS scenario, ultra-supercritical units are predicted to occupied for 66% of total coal-fired generation by 2025 and 94 % by 2035. More efficient generating units will also accelerate the replacement of less efficient ones. In prediction, 43% more than high-pressure and circulating fluidized bed (CFB) (Lower efficient) units would retire between 2020 and 2030 with the help of ETS. The average power consumption of coal-fired unit will be reduced as well.

The ETS design will facilitate the adoption of Carbon Capture, Utilization and Storage (CCUS) technologies for decarbonization in the power sector. Power plants equipped with CCUS will buy less allowance or sell surplus allowance thereby reducing costs or profits, which lead to cost competitive. It is estimated that CCUS-equipped coal-fired units will generate 3% of total generation, driven by the ETS, and 8% by 2035. And the deployment of CCUS could avoid nearly 300 Mt CO_2 of electricity generation emissions in 2035. More supportive policies are also expected.

Within the current ETS in China, emission allowances are distributed without charge, thereby constraining the incentive to enforce emission reductions. It means that only limited emitters with higher emission should buy allowances, wherein certain emitters may even profit from their sale.

Conversely, transitioning to an auction-based system would necessitate most entities to purchase a specific allotment of allowances, leading higher carbon cost. This framework would consequently incentivize technological advancements and innovation in production processes aimed at curbing emissions. According to China's plan, allowance through auctions will gradually reach 50 % by 2035. It would reduce CO2 emissions from the power system below 2020 levels and increase the doubling of gas-fired power generation, more than 10 % of wind power generation and more than 40 % of solar power generation, according to predication.

This is despite problems with China's existing ETS system, including (a) insufficient incentives for natural gas and non-fossil energy sources, (b) slow progress in reforming the electricity market to match the ETS, (c) the lack of a fixed emissions cap that makes emissions trajectories uncertain, and (d) insufficient coordination with other policy instruments. The ETS business model, however, has really helped China immensely in reducing emissions from the grid system. This also confirms the versatility and effectiveness of business models based on emissions caps and emissions allowance trading in global decarbonization initiatives.

Grid decarbonization is seen as indirectly contributing to zero emissions in the food supply chain. An ETS business model applied to the food system or applied to each front-emitting emission segment of the food supply chain includes emissions caps and emissions allowance trading.

10 CONCLUSION

Overall, servitisation based business model provides the best performance environmentally, socially and economically, therefore should be prioritised for developing business models to achieve the climate neutrality of food supply chain in the EU. The report developed servitisation-based business models for TES across the food supply chain and for transport decarbonisation, with significant contribution for energy saving and emissions reduction. Alongside EU ETS to decarbonise the grid systems and the transport sector, as well as natural refrigeration transition, the EU food supply chain will be able to achieve 55% net emissions cut by 2030 and climate neutrality by 2050.

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