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An assessment of a major European-based air cargo terminal energy management: The case of Frankfurt Cargo Services

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Abstract: This study has examined Frankfurt Cargo Services (FCS), a major European-based air cargo terminal operator, energy management. The study period was from 2008 to 2019 and was based on an in-depth qualitative longitudinal research design. The company uses both direct non-renewable energy sources (diesel and gasoline), and indirect renewable energy sources (electricity and district heating). The company's largest energy consumption is electricity, followed by district heating, diesel, and gasoline. Frankfurt Cargo Services annual purchased direct energy consumption oscillated over the study period, reflecting varying vehicle and ground service equipment (GSE) consumption patterns. The annual direct energy consumption per workload unit (WLU) generally showed a downward trend. Frankfurt Cargo Services (FCS) annual indirect renewable energy sources consumption also oscillated throughout the study period. Frankfurt Cargo Services (FCS) annual purchased indirect energy consumption per workload unit (WLU) generally displayed a downward trend the company's annual electricity consumption fluctuated over the study period reflecting differing consumption patterns. The annual consumption of electricity per workload unit (WLU) also oscillated over the study period reflecting differing electricity requirements and air cargo tonnages handled. Frankfurt Cargo Services (FCS) annual district heating consumption was influenced by winter heating requirements, and thus, varied throughout the study period. The case study revealed that Frankfurt Cargo Services (FCS) use of direct non-renewable energy sources has displayed a general downward trend throughout the study period. In contrast, Frankfurt Cargo Services use of indirect renewable energy sources displayed a general upward trend throughout the study period, reflecting the greater use of renewable energy sources.

Keywords: Air cargo, cargo terminal operator, case study, energy, Frankfurt Cargo Services GmbH.

1. Introduction

The world air cargo industry has grown rapidly in recent decades and now forms an integral part of the global economy, carrying goods valued at around $USD 6.8 trillion on an annual basis. This represents around 35 per cent of world export trade (by value) [1]. One of the very important actors in the air cargo supply chain is the air cargo terminal operator [2-4]. This is because more than 90 per cent of world air cargo is handled in special warehouses, which are known as air cargo terminals [5]. Air cargo terminals are facilities in which individual air cargo consignments are processed into cargo loads ready for loading onto an airline's aircraft and, following transport to their destination, are broken down again into individual shipments for delivery to the ultimate customer [6].

Like airlines, air cargo terminals are extremely energy intensive. The objective of this study is to examine how a major air cargo terminal operator manages its energy sources and consumption. A further aim of the study is to examine the energy sources and the annual amounts of energy consumed by a major air cargo terminal operator. A final objective is to identify whether a major air cargo terminal operator can use more environmentally friendly renewable energy sources.

One such major air cargo terminal operator that has sustainably managed their air cargo handling operations is Frankfurt Cargo Services GmbH, Frankfurt Airport's largest neutral air cargo handling agent [7-8]. Since 1999, Fraport AG, a major shareholder in Frankfurt Air Cargo Services GmbH, has been regularly audited and validated by government accredited and inspected environmental auditors. Frankfurt Air Cargo Services GmbH has also been included in these environmental audits and accreditation. As such, Frankfurt Cargo Services GmbH was selected as case company for the study. A further factor in selecting Frankfurt Cargo Services GmbH as the case firm was the readily available case documentation which allowed for the in-depth analysis of the company's energy management. The study period is from 2008 to 2019.

The remainder of the paper is organized as follows: the literature review is presented in Section 2, and this sets the context for the in-depth case study. Section 3 describes the study's research methodology. Section 4 presents the case study based on Frankfurt Air Cargo Services GmbH energy management. Section 5 presents the study's conclusions.

2. Background

2.1 The role and functions of an air cargo terminal

The objective of an air cargo terminal is to serve as a temporary storage facility before the next operation can be performed, that is, loading the air cargo consignment onto its assigned flight [9]. The cargo terminal operator (CTO) provides the handling facilities necessary to accept air cargo consignments from international air freight forwarders and shippers; checks shipment weights; and prepares aircraft load plans. They also store consignments until they are cleared for export by the customs authority or held for at least 24 hours at the terminal for safety reasons, in the event of such a requirement. The cargo terminal operator (CTO) then arranges for the consignment to be loaded onto the designated aircraft [10]. At the destination, an air cargo terminal operator accepts cargo from incoming flights and stores the cargo until it has been cleared and released by the receiving country's customs authority. A freight forwarder then typically thereafter collects the consignment and arranges delivery to the end-customer [11].

The air cargo terminal provides for three principal cargo handling activities: (1) the import activities (for example, arrival of the cargo load from the aircraft, breakdown, storage of cargo pending delivery, cargo retrieval and cargo delivery), (2) the export activities (for example, unloading the cargo from customer's trucks, export cargo acceptance, export cargo handling, build-up of cargo, flight processing, retrieval of loaded aircraft unit load devices (ULDs) and cargo assembly), and (3) the transfer activity (arrival of cargo, transfer cargo handling, build-up of transfer cargo, retrieval of ULDs and cargo assembly [12-13]. Aircraft unit load devices, or ULDs, are pallets and containers which are used to carry air cargo, mail and passenger baggage on wide-body passenger and freighter aircraft [14-15]. Prior to being exported, international air cargo consignments must be cleared for export by the relevant Customs Authority. On arrival at its destination, the air cargo consignment will undergo the relevant customs clearance formalities [11]. Domestic cargo requires no customs clearance and proceeds directly from the check-in area to a pre-delivery holding area within the terminal, where it is stored pending arrangement of delivery to the final customer [16].

2.2 Services provided by air cargo terminal operators

The providers of air cargo handling services can be airlines (self-handling), one airline for another, airport authorities, or independent specialist ground handling firms that obtain a license to operate on the airport's facility. Airlines often service their own cargo (self-handling) and may also provide this service to other airlines (third party handling) [17].

Specialized cargo handling firms offer a range of services from cargo warehousing through to trucking. Dedicated all-cargo airlines may negotiate with these firms for the provision of some or all the services to be provided [17].

The services offered by cargo handling firms include:

1. Warehousing
   Freight acceptance, build-up, and storage
   ULD build-up and breakdown
   Shipment inventory control
   Truck loading and unloading
   Express handling services
   Security services
2. Documentation
3. Handling of dangerous goods, live animals, perishables, and other special cargoes
4. Transport to and from the aircraft
5. Trucking (road feeder services) [17] (p. 168).

The IATA Standard Ground Handling Agreement (SGHA) defines the menu of services that will be offered to clients including general cargo and postal mail handling, document handling, customs control, and the handling of cargo irregularities and ramp services [17] (p. 168).

2.3 Energy requirements of an air cargo terminal

Air cargo terminals are energy intensive. This is because energy is required to operate air cargo handling systems and for lighting, heating, and cooling of the facilities. Electrical energy at airports is normally sourced from various sources and is supplied directly to the airport through dedicated sub-stations [18]. Unlike passengers, who simply require information and directions to navigate their way through an airport passenger terminal, air cargo is inanimate and must therefore be physically moved from landside to air side or vice versa within the cargo terminal [19]. Thus, air cargo handling requires specific loading and unloading equipment and systems as well as specialized skills to operate the cargo terminal. In addition to the equipment and infrastructure required to handle trucks (loading bays), a wide range of cargo handling equipment and systems is required to physically handle air cargo consignments within the cargo terminal. This equipment is determined by the types of cargoes handled [20]. The system utilized to facilitate this physical movement will depend partly on the degree of mechanization to be used to offset the cargo terminal's manpower costs. There are three main types of air cargo terminal designs – low mechanization/ high worker handling, open mechanized and fixed mechanized. Nearly all air cargo terminals will most probably have a combination of these types [16]. Accordingly, electrical power is required to operate the handling systems used in the cargo terminal facility. Air cargo terminals also use various materials handling equipment, such as forklifts and sorting carousels [21-22] all of which require energy.

It is important to note that around a third of the goods shipped by the air cargo mode are highly perishable in nature. These goods include fresh food items and other agricultural produce, medical and pharmaceutical products, and chemicals [23]. Products, such as, food, pharmaceuticals and cut flowers, have a very high risk of perishing from various adversities that may be experienced along the cold chain [24]. The air cargo mode is therefore used to ship a diverse range of perishable products such as high-value horticultural products including fruits, vegetables, flowers and fresh cut fruits and vegetables. Chilled and frozen meat, dairy products, fish, and seafood are also commonly transported by the air cargo mode [25]. Furthermore, in recent years, the biggest cool-chain growth in the world air cargo industry, however, has come from the health care sector [26-28]. Such products require rapid transportation either because they are urgently required, or because they may otherwise perish or deteriorate when being transported over long distances [29-30]. Thus, to handle these perishable air cargo products, air cargo terminal operators provide temperature-controlled facilities (cool rooms), which may operate 24 hours per day, and hence, these facilities consume considerable amounts of energy to run the refrigeration and lighting systems.

Electrical energy is also consumed in the provision of heating, cooling (air conditioning), and lighting other administrative buildings at airports [18]. Cargo terminals often typically operate 24 hours per day, and hence, energy is required for lighting – car and truck parks, security offices, office and terminal lighting and apron lighting. Energy is also consumed in the operation of cargo handling systems and refrigeration (cool room) facilities as well as cooling and heating systems. Table 1 shows the types of air cargo terminal and its key stakeholders energy usage.

Table 1. Key air cargo industry stakeholders' energy usage.

Stakeholder	Energy Usage
Airlines	Office cooling and heating Lighting Power for computers and office equipment, systems, and servers
Cargo Terminal Operator	Lighting for staff, client and customer car and vehicle parking areas Office cooling and heating Office lighting Power for computers and office equipment, systems, and servers Power for cargo handling systems Power for cool-rooms and freezers Power for X-Ray security screening equipment Flood lighting of forecourt area Power to operate security gate and security systems, such as, CCTVs
Clients	Office cooling and heating Lighting Power for computers and office equipment, systems, and servers
Government Agencies	Office cooling and heating Lighting Power for computers and office equipment, systems, and servers

Source: Author

3. Research Methodology

3.1 Research approach

The study's qualitative analysis was based on an in-depth qualitative longitudinal case study design [31-33]. The key advantage of a qualitative longitudinal research design is that it reveals change and growth in an outcome or phenomena over time [34]. A case study also allows for the exploration of complex phenomena [35, 36]. A case study also enables the researcher(s) to collect rich, explanatory information [37, 38].

3.2 Data collection

The qualitative data gathered for this study was obtained from Fraport AG's annual abridged environmental statements. Hence, in this study, secondary data was used in the case study analysis. The study followed the recommendations of Yin [36] in the data collection phase, that is, the study used multiple sources of case evidence, the data was stored and analyzed in a case study database, and there was a chain of case study evidence.

3.3. Data analysis

The qualitative data collected was examined using document analysis. Document analysis is frequently used in case studies and focuses on the information and data from formal documents and company records [39-41]. In a case study existing documents are a critical source of qualitative data, and these documents may be publicly available or private in nature [42]. The documents collected for the present study were examined according to four criteria: authenticity, credibility, representativeness, and meaning [43-45].

The key words used in the database searches included "Fraport AG environmental management policy", "Frankfurt Cargo Services annual purchased non-renewable energy", "Frankfurt Cargo Services annual diesel consumption", "Frankfurt Cargo Services annual gasoline consumption", "Frankfurt Cargo Services annual purchased renewable energy", "Frankfurt Cargo Services annual electricity consumption", and "Frankfurt Cargo Services annual district heating consumption".

The study's document analysis was conducted in six distinct phases. The first phase involved planning the types and required documentation and ascertaining their availability for the study. In the second phase, the data collection involved sourcing the documents from Fraport AG and developing and implementing a scheme for managing the gathered documents. In the third phase, the documents were examined to assess their authenticity, credibility and to identify any potential bias in them. In the fourth phase, the content of the collected documents was carefully examined, and the key themes and issues were identified and recorded. The fifth phase involved the deliberation and refinement to identify any difficulties associated with the documents, reviewing sources, as well as exploring the documents content. In the sixth and final phase, the analysis of the data was completed [46]. The documents were all in English. Each document was carefully read, and key themes were coded and recorded in the case study [47].

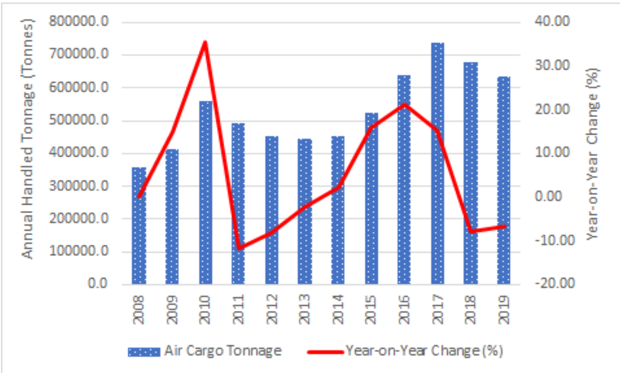
4. Results and Discussion

4.1 Frankfurt Cargo Services GmbH: A brief overview

Frankfurt Air Cargo Services have been providing air cargo handling services for more than 50 years [8]. Frankfurt Cargo Services (FCS) has a state-of-the-art cargo terminal with a total floorspace of 47,000 m² and the company also has an additional terminal of 5,000 m², which is in the "CargoCity South" precinct [48]. Frankfurt Cargo Service cargo terminal is connected to the apron area and there is a 100-metre distance between the freighter aircraft parking positions and the air cargo terminal [8]. An airport's apron area is the location where aircraft stands interface with airport terminal buildings, and they are the location where aircraft are handled whilst on the ground in between flights [49]. The company handles around 50 airlines, which includes airlines operating dedicated freighter aircraft to Frankfurt Airport. In addition, Frankfurt Cargo Services (FCS) deals with around 400 air freight forwarders [8].

On November 2, 2015, Fraport AG and Worldwide Flight Services (WFS) formed a strategic air cargo handling partnership agreement at Frankfurt Airport. Under the terms of the agreement, which was signed in July 2015, Fraport AG sold a 51 percent share in Fraport Cargo Services GmbH (FCS) to WFS [50-51].

Figure 1 presents the total annual air cargo tonnages handled by Frankfurt Air Cargo Services from 2008 to 2019 together with the year-on-year change (%). The air cargo industry is extremely cyclical in nature [17, 29, 52]. This cyclicality is demonstrated in the annual tonnages of air cargo handled by Frankfurt Cargo Services. As can be observed in Figure 1, there was a pronounced spike in handled air cargo tonnages in 2010 (+35.31%). World air cargo traffic grew in 2010 [53]. This growth reflected the recovery from the 2008 and 2009 global financial crisis, which resulted in a downturn in world air cargo demand. Figure 1 shows that the annual air cargo tonnages declined on a year-on-year basis in 2011, 2012, and 2013 before returning to growth from 2015 to 2017. The annual air cargo tonnages decreased on a year-on-year basis in 2018 (-7.80%) and 2019 (-6.56%), respectively (Figure 1). World air cargo traffic fell quite significantly in 2019. In 2019, the air cargo industry recorded its weakest air cargo traffic performance since the global financial crisis in 2009 [54].



Source: Data derived from Fraport AG [55-59]

Figure 1. Frankfurt Cargo Services annual handled air cargo tonnages and year-on-year change (%): 2008-2019.

4.2 Fraport AG Environmental Management Framework

As previously noted, Fraport AG has held a shareholding in Frankfurt Cargo Services and, as such, Frankfurt Cargo Services has been included in Fraport AG's environmental management system (EMS).

From 1999 onwards, Fraport AG, as the manager and operator of Frankfurt Airport, has been regularly validated by government accredited and inspected environmental management auditors. The basis for such audits is the European regulation "Eco-Management and Audit Scheme" (EMAS) [57]. EMAS is a voluntary instrument of the European Union, which enables firms of any size and industry to examine and continuously enhance their environmental performance [60]. Since 2002, Frankfurt Airport's environmental audits have been carried out in compliance with the international standard ISO 14001 [58]. ISO 14001 is a global meta-standard for implementing Environmental Management Systems (EMS) [61-63]. The ISO 14001 Environmental Management System (EMS) has developed over time into one of the most widely used systems for managing corporate environmental aspects [64]. Fraport AG's environmental audits, which comply with EMAS and ISO 14001 standards, also include the following Fraport AG subsidiaries: Fraport Cargo Services GmbH (FCS) since 2008, N*ICE Aircraft Services & Support GmbH (N*ICE) since 2009, and Energy Air GmbH since 2014 [58].

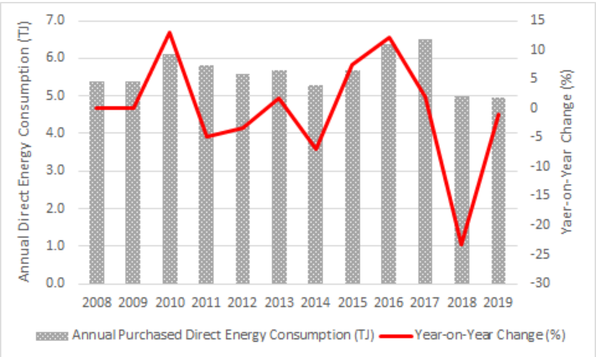
4.3 Frankfurt Cargo Services energy sources

In providing its air cargo handling services, Frankfurt Cargo Services consumes both purchased direct non-renewable energy sources (diesel and gasoline), and purchased indirect energy from renewable sources, these include electricity and district heating. The annual trends in the company's energy consumption are presented in the next section of the paper.

4.4 Frankfurt Cargo Services direct energy consumption

4.4.1 Frankfurt Cargo Services annual direct energy from nonrenewable energy sources consumption

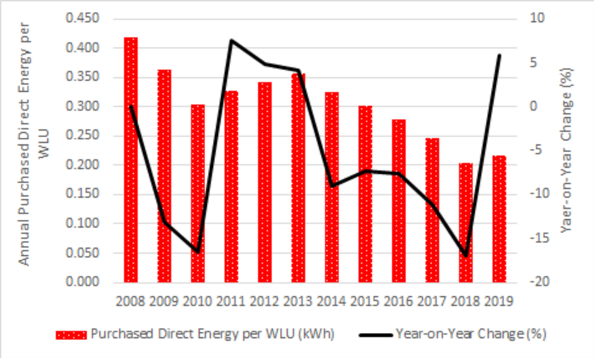
Frankfurt Cargo Services annual direct purchased nonrenewable energy sources consumption and the year-on-year change (%) for the period 2008 to 2019 are presented in Figure 2. As can be observed in Figure 2, the annual purchased direct energy consumption has oscillated throughout the study period reflecting differing vehicle and ground service equipment (GSE) energy patterns. Ground service equipment (GSE) refers to vehicles and equipment that are used in the airport precinct to service aircraft whilst they are at the gate in between flights [65]. Cargo terminal operators use tugs to tow the cargo loads for a flight from the cargo terminal to the apron area. These tugs collect inbound air cargo loads and transport them from the airport apron to the cargo terminal for processing. The largest single annual increase in the company's purchased direct energy consumption occurred in 2010, when it increased by 12.96% on the 2009 levels. Figure 2 shows that there were two pronounced annual reductions in direct energy consumption in 2014 (-7.01%) and 2018 (-23.31%), respectively. Smaller decreases were recorded in 2011 (-4.91%), and in 2019 (-1%) (Figure 2).



Source: Data derived from Fraport AG [55-59]

Figure 2. Frankfurt Cargo Services annual purchased direct nonrenewable energy consumption and year-on-year change (%): 2008-2019.

Figure 3 presents Frankfurt Cargo Services annual direct purchased energy consumption per workload unit (WLU) and the year-on-year change (%) for the period 2008 to 2019. One workload (WLU) or traffic unit is equivalent to 100 kilograms of air cargo handled [66-68]. Figure 3 shows that the annual purchased direct energy consumption per workload unit (WLU) decreased from 0.419 kWh/WLU in 2008 [55] to 0.217 kWh/WLU in 2019 [59]. The overall downward trend is demonstrated by the year-on-year percentage change line graph, which is more negative than positive, that is, more values are below the line than above. Figure 3 shows that this metric increased on a year-on-year basis in 2011 (+7.56%), 2012 (+4.89%), 2013 (+4.08%), and in 2019 (+5.85%), respectively. Figure 3 shows that there were significant decreases recorded in 2009 (-13.12%), 2010 (-16.48%), and 2017 (-11.15%). The overall downward trend is very favorable and indicates that the company has been able to reduce its purchased direct energy consumption per workload unit (WLU) whilst at the same time increasing the amount of air cargo tonnages handled.

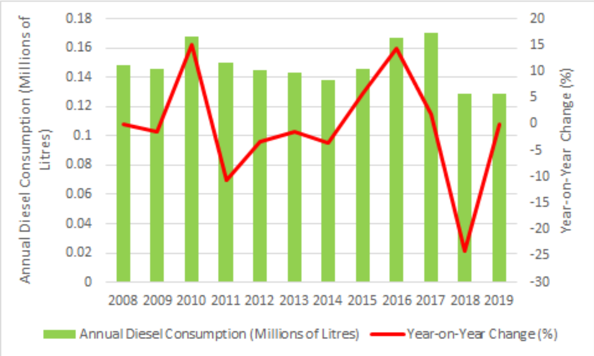


Source: Data derived from Fraport AG [55-59]

Figure 3. Frankfurt Cargo Services annual direct purchased nonrenewable energy consumption per workload unit (WLU) and year-on-year change (%): 2008-2019.

4.4.2 Frankfurt Cargo Services ground service equipment and vehicles diesel consumption

Frankfurt Cargo Services annual diesel consumption, as measured in kWh, for ground service equipment (GSE) and company vehicles and the year-on-year change (%) for the period 2008 to 2019 are presented in Figure 4. Figure 4 shows that Frankfurt Cargo Services annual diesel consumption decreased from 0.148 million litres in 2008 to 0.129 million litres in 2018 and 2019, respectively. The company's highest annual diesel consumption was recorded in 2017, when it consumed 0.17 million litres of diesel. Figure 5 shows that were significant increases in the actual diesel consumption in 2010 (+15.06%), 2015 (+5.79%), and 2016 (+14.38%), respectively (Figure 4). There were quite large decreases in 2011 (-10.71%), and 2018 (-24.11%) (Figure 4) which, reflected changing vehicle and equipment usage patterns.



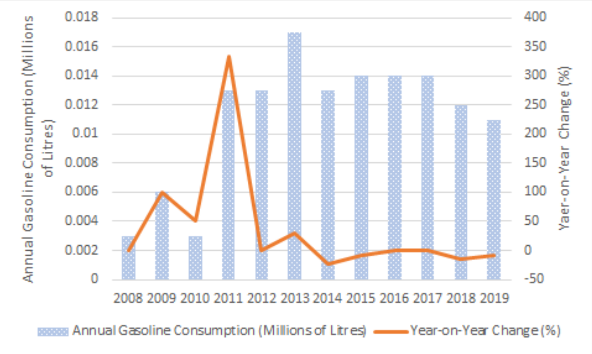
Source: Data derived from Fraport AG [55-59]

Figure 4. Frankfurt Cargo Services annual diesel consumption (millions of litres) for ground service equipment (GSE) and vehicles and year-on-year change (%): 2008-2019.

4.4.3 Frankfurt Cargo Services ground service equipment and vehicles gasoline consumption

Frankfurt Cargo Services annual gasoline consumption, as measured in kWh, for ground service equipment (GSE) and company vehicles and the year-on-year change (%) for the period 2008 to 2019 are presented in Figure 5. Figure 5 shows that Frankfurt Cargo Services annual gasoline consumption increased from 0.003 million litres in 2008 to 0.011 million litres 2019. The company's highest annual gasoline consumption was recorded in 2013, when it consumed 0.017 million litres of gasoline (Figure 5).

Figure 5 company's annual gasoline consumption. These significant increases were recorded in 2009 (+100%) and in 2011, when the annual gasoline consumption increased by 333% on the 2010 levels. There were two significant annual decreases in gasoline consumption in 2014 (-23.52%), and in 2018 (-14.28%), respectively (Figure 5). Like the company's diesel consumption, the consumption of gasoline is driven by the discrete vehicle requirements, for example, travelling from the cargo terminal to the apron area and vice versa.



Source: Data derived from Fraport AG [55-59]

Figure 5. Frankfurt Cargo Services annual gasoline consumption (millions of litres) for ground service equipment (GSE) and vehicles and year-on-year change (%): 2008-2019.

In summary, Frankfurt Cargo Services two purchased direct non-renewable energy sources are diesel and gasoline. The company's largest direct energy source is the diesel which is used to power its ground service equipment (GSE) and company vehicles.

4.5 Frankfurt Cargo Services indirect energy consumption

4.5.1 Frankfurt Cargo Services annual indirect energy consumption

Frankfurt Cargo Services purchases electricity and district heating to support its operations. Frankfurt Cargo Services annual purchased indirect energy sources consumption and the year-on-year change (%) from 2008 to 2019 are presented in Figure 6. Figure 6 shows that Frankfurt Cargo Services annual indirect energy sources consumption oscillated throughout the study period. The lowest annual indirect renewable energy sources consumption was recorded in 2014 (28.2 TJ), whilst the highest was recorded 2010 (41.1 TJ). The largest single annual increase in this metric occurred in 2016, when the company's annual purchased indirect renewable energy sources consumption increased by 30.31% on the 2015 levels (Figure 6). Other significant increases were recorded in 2012 (12.6%), 2013 (13.86%), and 2018 (13.07%), respectively. Figure 6 also shows that the company's annual purchased indirect renewable energy sources consumption decreased on a year-on-year basis in 2014 (-21.22%) and 2019 (-24.08%), respectively.

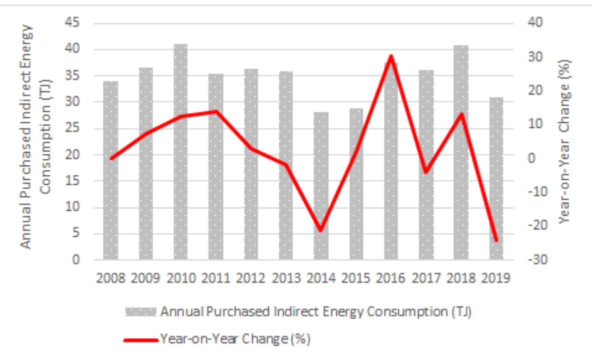
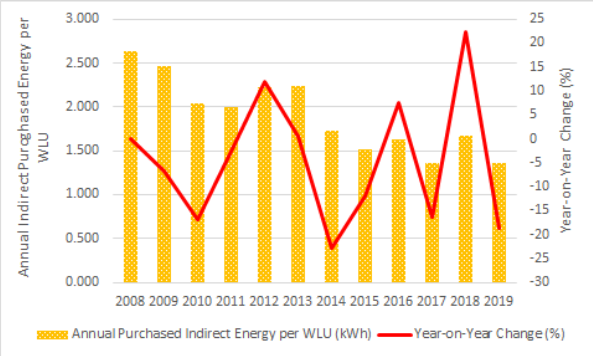


Figure 6. Frankfurt Cargo Services annual purchased indirect energy consumption and year-on-year change (%): 2008-2019.

Source: Data derived from Fraport AG [55-59]

Frankfurt Cargo Services annual purchased indirect energy consumption per workload unit (WLU) and the year-on-year change (%) for the period 2008 to 2019 are depicted in Figure 7. Figure 7 shows that the annual purchased indirect energy consumption per workload unit (WLU) decreased from 2.635 kWh/WLU in 2008 [55] to a low of 1.358 kWh/WLU in 2019 [59] (Figure 7). During the study period, there were six years where this metric decreased on a year-on-year basis. These decreases occurred in 2009 (-6.71%), 2010 (-16.76%), 2011 (-2.59%), 2014 (-22.88%), 2015 (-11.97%), 2017 (-16.39%), and 2019 (-18.77%), respectively (Figure 7). The overall downward trend is very favorable and shows that the company has been able to reduce the amount of indirect energy per workload (WLU) over the study period. As discussed below, the trends in the company's annual indirect renewable energy sources consumption reflect its electricity and district heating requirements, with the latter being influenced by the winter weather conditions experienced at Frankfurt Airport.

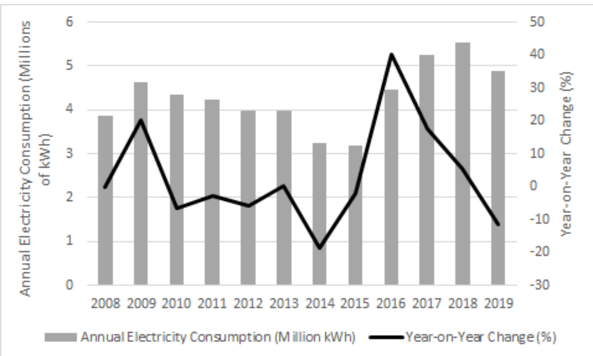


Source: Data derived from Fraport AG [55-59]

Figure 7. Frankfurt Cargo Services annual purchased indirect energy consumption per workload unit (WLU) and year-on-year change (%): 2008-2019.

4.5.2 Frankfurt Cargo Services annual electricity consumption

Frankfurt Cargo Services annual electricity consumption, as measured in millions of kWh, and the year-on-year change (%) from 2008 to 2019 are presented in Figure 8. Figure 8 shows that Frankfurt Cargo Services annual electricity consumption increased from 3.866 million/kWh in 2008 to 4.895 million/kWh in 2019. The highest annual electricity consumption was recorded in 2018 (5.535 million/kWh) (Figure 8). Figure 8 shows there was a pronounced spike in electricity consumption in 2009 (+20.09), 2016 (+40.27%), and 2017 (+17.58%), respectively. There were six years in the study where the annual electricity consumption decreased on a year-on-year basis, with the most significant single annual decrease occurring in 2014 (-18.63%) (Figure 8). There appears to be a close relationship between the annual air cargo tonnage handled and the company's electricity consumption. In

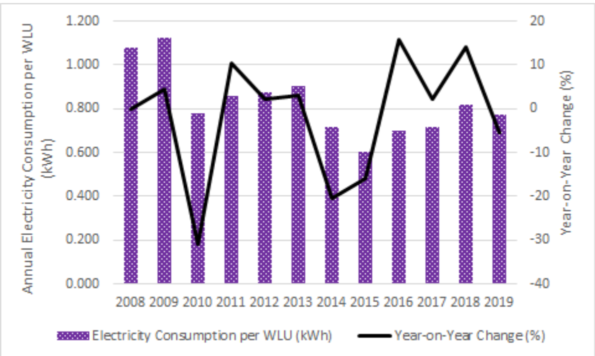


Source: Data derived from Fraport AG [55-59]

Figure 8. Frankfurt Cargo Services annual electricity consumption (millions of kWh) and year-on-year change (%): 2008-2019.

general, when air cargo tonnages have increased there has been a concomitant increase in electricity, for example, in 2017, air cargo tonnages increased by 15.34% and electricity consumption by 17.58%. Conversely, when the annual air cargo tonnages have declined there has been a decrease in electricity consumption. This was the case in 2011, 2012, and 2019, respectively. An exception occurred in 2018, when air cargo tonnage handled decreased by 7.80%, yet electricity consumption increased by 5.58% in the same year.

Frankfurt Cargo Services annual electricity consumption per workload unit (WLU) and the year-on-year change (%) from 2008 to 2019 are depicted in Figure 9. Figure 9 shows that the annual electricity consumption per workload unit (WLU) decreased from 1.077 kWh/WLU in 2008 [55] to 0.772 kWh/WLU in 2019 [59]. The highest annual electricity consumption per workload unit (WLU) was recorded in 2013 (0.902 kWh/WLU) [55], whilst the lowest annual level for this metric was recorded in 2015 (0.603 kWh/WLU) [57] (Figure 9). There were three quite pronounced annual decreases in this metric. These decreases occurred in 2010 (-31.02%), 2014 (-20.5%), and 2015 (-15.89%), respectively. Figure 9 shows that, in general, when the number of workload units (WLUs) increases there are more WLUs to spread the electricity consumption over, which results in lower electricity consumption per workload unit (WLU). Conversely, when the actual number of workload units (WLU) decrease then there are less workload units (WLU) to spread the electricity consumption, hence, the higher electricity consumption per workload unit (WLU), when the latter situation occurs.

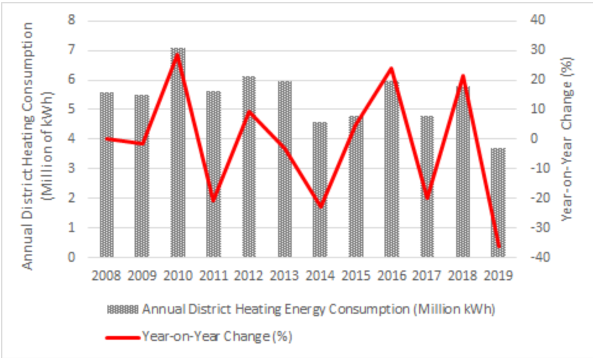


Source: Data derived from Fraport AG [55-59]

Figure 9. Frankfurt Cargo Services annual electricity consumption (kWh) per workload unit (WLU) and year-on-year change (%): 2008-2019.

4.5.3 Frankfurt Cargo Services district heating consumption

Frankfurt typically has a cold winter [69]. Thus, Frankfurt Cargo Services is required to purchase district heating to heat its air cargo facilities. Frankfurt Cargo Services annual district heating consumption, as measured by million kWh, and the year-on-year change (%) for the period 2008 to 2019 are depicted in Figure 10. Figure 10 shows that Frankfurt Cargo Services district heating decreased from 5.583 million/kWh in 2008 to 3.71 million/kWh in 2019. The highest annual district heating consumption was recorded in 2010 (7.067 million/kWh), whilst the lowest level was that recorded in 2019. Figure 10 shows that there were quite pronounced spikes recorded in the company's district heating consumption 2010 (+28.58%), 2016 (+24.1%), and 2018 (+21.3%), reflecting higher heating requirements during these years. The most significant single annual decrease in this metric occurred in 2019, when the annual district heating consumption declined by 36.05% on the 2018 levels. Significant decreases were also recorded in 2011 (-20.56%), 2014 (-22.77%), and 2017 (-19.84%) (Figure 10), These decreases reflect the lower district heating requirements during these years.

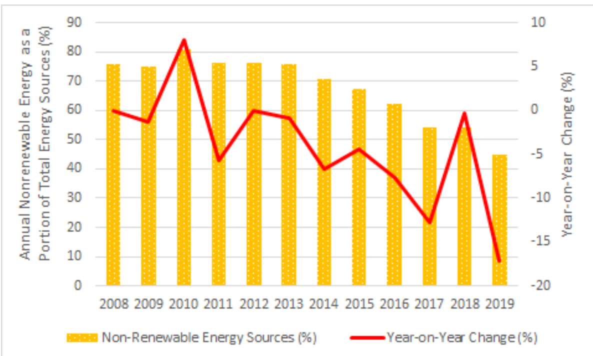


Source: Data derived from Fraport AG [55-59]

Figure 10. Frankfurt Cargo Services annual district heating electricity consumption (Million kWh) and year-on-year change (%): 2008-2019.

4.6 Frankfurt Cargo Services use of indirect renewable energy sources

Frankfurt Cargo Services annual purchased indirect non-renewable power sources as a portion of total energy sources and the year-on-year change (%) from 2008 to 2019 are depicted in Figure 11. As can be observed in Figure 11, Frankfurt Cargo Services use of purchased indirect non-renewable energy sources as a share of total energy sources has displayed a general downward trend throughout the study period. This is demonstrated by the year-on-year percentage change line graph, which is more negative than positive, that is, more values are below the line than above. Figure 11 shows that the company's annual non-renewable power sources as a portion of total energy sources decreased from 76% in 2008 to a low of 44.8% in 2019 (Figure 11). During the study period, there was just one year when this ratio increased on a year-on-year basis. This increase was recorded in 2010 (+8%) (Figure 11). There were three quite significant annual decreases in this metric during the study period. These decreases occurred in 2011 (-5.67%), 2017 (-12.84%), and 2018 (-17.19%), respectively (Figure 11). Figure 11 also shows that this metric remained the same in 2011 and 2012 at 76.4%. The overall downward trend shows that the company has reduced its use of purchased indirect non-renewable energy sources and is instead focusing on the overall use of more renewable energy sources.

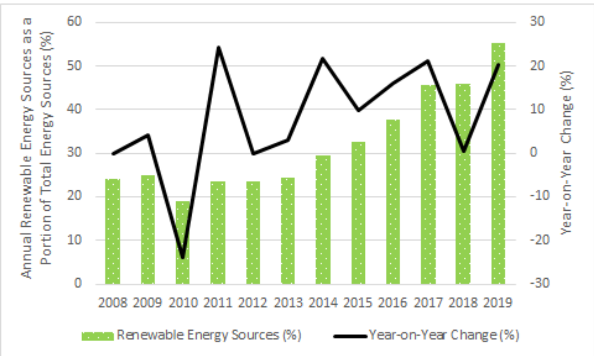


Source: Data derived from Fraport AG [55-59]

Figure 11. Frankfurt Cargo Services annual non-renewable power sources as a portion of total energy sources and year-on-year change (%): 2008-2019.

Power sources as a portion of total energy sources, it is important to note that renewable energy sources, such, as wind and solar power, are environmentally friendly energy sources [70]. The environmental benefits of using renewable energy include the generation of energy that produces no greenhouse gas emissions from fossil fuels. Renewable energy reduces some types of air pollution [71] as renewable energy has lower carbon emissions [70], and hence, has lower levels of greenhouse gases [71]. The use renewable energy sources enable a firm to diversify its energy supply and, where applicable, reduce its dependence on imported fuels [71].

Frankfurt Cargo Services annual purchased indirect renewable power sources as a portion of total energy sources and the year-on-year change (%) from 2008 to 2019 are presented in Figure 12. As can be observed in Figure 12, Frankfurt Cargo Services use of purchased indirect renewable energy sources as a share of total energy sources has displayed a general upward trend throughout the study period. This is demonstrated by the year-on-year percentage change line graph, which is positive than negative, that is, more values are above the line than above. Figure 12 shows that the company's annual purchased indirect renewable power sources as a portion of total energy sources increased from 24% in 2008 to a high of 55.2 % in 2019 (Figure 12). During the study period, there was just one year when this metric increased on a year-on-year basis. This decrease was recorded in 2010 (-24 %) (Figure 12). Figure 12 shows that there were four years throughout the study period when this metric increased significantly on the previous year's levels. These annual increases occurred in 2011 (+24.21%), 2014 (+21.81%), 2017 (+21.22%), and 2019 (+20.26%), respectively (Figure 12). Figure 12 also shows that this metric remained the same in 2011 and 2012 at 23.6%. The overall upward trend shows that the company has increased its focus on the on the use of more environmentally friendly renewable energy sources.



Source: Data derived from Fraport AG [55-59]

Figure 12. Frankfurt Cargo Services annual renewable power sources as a portion of total energy sources and year-on-year change (%): 2008-2019.

In June 2020, Fraport AG, the operator Frankfurt Airport and a major shareholder in Frankfurt Cargo Services, concluded a power-purchase agreement for the supply of green electricity [74]. Fraport AG plans to use wind power to source most of the electricity at Frankfurt Airport. This strategic decision was part of its efforts to meet its climate protection targets [75-76].

Fraport AG has also set an objective to produce its own electricity at Frankfurt Airport. In 2020, the first large-scale photovoltaic (PV) plant at Frankfurt Airport was constructed on the roof of a new cargo terminal located in the airport's "CargoCity South" precinct. Once completed, the new PV system will generate more than 1.5 million kilowatt hours (kWh) of electricity each year. Fraport AG has also planned to construct a photovoltaic plant on the parking garage for the airport's new Terminal 3 building. This new PV system would be able to supply the charging stations located in this parking garage with renewable electricity [74].

5. Conclusion

This study has examined how a major European-based air cargo terminal operator manages its energy sources and its consumption. Frankfurt Cargo Services GMH formed the basis of the in-depth qualitative longitudinal case study. The study period was from 2008 to 2019. The documents gathered for the study were examined by document analysis,

The case study found that to deliver its air cargo handling services, Frankfurt Cargo Services sources both direct non-renewable energy sources and renewable energy. The two direct non-renewable energy sources are diesel and gasoline, which is used to power its fleet of ground service equipment (GSE) and company vehicles. The company also purchases non-direct renewable energy. These energy sources are comprised of electricity and district heating, the latter being used to heat its facilities during the winter period.

Frankfurt Cargo Services annual purchased direct energy consumption oscillated over the study period, reflecting varying vehicle and ground service equipment (GSE) consumption patterns. The annual direct energy consumption per workload unit (WLU) decreased from 0.419 kWh/WLU in 2008 to 0.217 kWh/WLU in 2019. The overall downward trend is very favorable and indicates that the company has been able to reduce its direct energy consumption per workload unit (WLU) whilst at the same time increasing the amount of air cargo tonnages handled. The company's annual diesel consumption fluctuated over the study period. The fluctuations in diesel consumption reflect differing vehicle usage requirements throughout the study period. The case study revealed that there were two discrete trends with the company's annual gasoline consumption. From 2008 to 2013, the annual gasoline consumption increased from 0.003 million of litres in 2008 to a high of 0.017 million of litres in 2013. From 2015 to 2019, the company's annual gasoline consumption decreased from 0.014 (millions of litres) in 2015 to 0.011 million of litres in 2019.

Frankfurt Cargo Services annual indirect energy sources consumption oscillated throughout the study period. The lowest annual indirect renewable energy sources consumption was recorded in 2014 (28.2 TJ), whilst the highest was recorded in 2010 (41.1 TJ). Frankfurt Cargo Services annual purchased indirect energy consumption per workload unit (WLU) generally displayed a downward trend decreasing from 2.635 kWh/WLU in 2008 to a low of 1.358 kWh/WLU in 2019. The overall downward trend is very favorable and shows that the company has been able to reduce the amount of indirect energy per workload (WLU) over the study period. The company's annual electricity consumption fluctuated over the study period reflecting differing consumption patterns. The annual consumption of electricity per workload unit (WLU) oscillated over the study period, once again reflecting differing electricity requirements and air cargo tonnage handled. Frankfurt Cargo Services annual district heating consumption declined from 5.583 million kWh in 2008 to 3.71 million kWh in 2019. The fluctuations in district heating are influenced by winter temperatures, and thus, the amount of heating required in its facilities reflect the local temperatures at Frankfurt Airport.

The case study revealed that Frankfurt Cargo Services use of direct non-renewable energy sources as a share of total energy sources has displayed a general downward trend throughout the study period, decreasing from 76% in 2008 to 44.8% in 2019. In contrast, Frankfurt Cargo Services use of indirect renewable energy sources displayed a general upward trend throughout the study period, increasing from 24% in 2008 to 55.2 % in 2019. This upward trend reflects the greater use of renewable energy, which is more environmentally friendly, by the company.

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