Lappeenranta-Lahti University of Technology
School of Energy Systems
Department of Environmental Technology
Circular Economy
Master’s thesis 2021

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CARBON FOOTPRINT OF EVENTS – OPENING EVENTS OF LAHTI EUROPEAN GREEN CAPITAL 2021

Examiners : Associate professor Ville Uusitalo
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TIIVISTELMÄ

Lappeenrannan-Lahden teknillinen yliopisto
School of Energy Systems
Ympäristötekniikan koulutusohjelma
Master's Programme in Circular Economy

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Diplomityö
2021

61 sivua, 12 kuvaa, 31 taulukkoa, 1 liite

Työn tarkastajat: Apulaisprofessori Ville Uusitalo
Apulaisprofessori Jarkko Levänen

Hakusanat: hiilijalanjälki, tapahtuma, elinkaariarviointi, tapahtumatuotanto

Diplomityön tarkoituksena oli selvittää erilaisten tapahtumien hiiilijalanjälkiä, mistä osista ne koostuvat, sekä yleisemmin tapahtumien hiilijalanjälkeä. Työ sisältää kolme tapahtumaa, joiden hiilijalanjälkeä selvitetään. Ensimmäisessä laskennassa lasketaan mahdollisuutta vähentää jääkiekkojoukkue Pelicansin yleisön liikkumisesta johtuvia päästöjä. Toisessa laskennassa lasketaan Lahden Euroopan ympäristöpääkaupunkivuoden avajaistapahtuman Elämysten Puiston hiilijalanjälki. Kolmannessa laskennassa lasketaan Lahden Euroopan ympäristöpääkaupunkivuoden avajaistapahtuman hiilijalanjälki verkkotapahtumana sekä live-tapahtumana ja niitä vertaillaan keskenään. Tuloksien ja kirjallisuuden perusteella lähes kaikkien tapahtumien osalta, yleisön liikkumien on suurin tai ainakin yksi suurimpia päästöjen aiheuttajia. Tapahtumien kokonaishiilijalanjäljen pienentämiseksi julkisen liikenteen käytön edistäminen ja muut siihen kannustavat teot ovat tärkeässä roolissa. Myös biopolttoaineiden, sekä sähköajoneuvojen käytöllä voidaan saada päästöjä huomattavasti

pienemmiksi. Sähkönkulutuksen aiheuttamat päästöt eri tapahtumista laskevat jatkuvasti, kun verkkosähkön päästöintensiteetti laskee. Lyhyemmällä aikavälillä, tekemällä tapahtumakohtaisia uusiutuvan sähkön sopimuksia, voitaisiin vähentää päästöjä merkittävästi. Verkossa tapahtuvat tapahtumat ovat viime vuosina ja erityisesti COVID-19 pandemian aikana yleistyneet nopeasti. Verkkotapahtumien päästöt ovat vahvasti riippuvaisia katsojien määrästä, sekä maantieteellisestä sijainnista, sillä suurimmat päästöt datan siirrosta syntyvät siirtoverkon ääripäissä.

Tapahtuma sanana käsittää laajan kirjon erilaisia toteutuksia, minkä vuoksi yleisiä ohjeita tapahtumien hiilijalanjäljen pienentämiseen on vaikea löytää. Kuitenkin tapahtumien luonteeseen kuuluu suuret määrät ihmisiä, joko livenä tai verkossa, joten pienet henkilökohtaiset päästövähennykset tai -lisäykset kertautuvat nopeasti. Eritysesti kestävän liikkumisen ratkaisuja tarvitaan enemmän, mikä käsittää yhteistyötä eri toimijoiden kuten tapahtumajärjestäjien, joukkoliikenneyrittäjien sekä julkisten instanssien välillä. Myös negatiivisten ympäristövaikutusten ja niiden pienentämismahdollisuuksien viestintään suurelle yleisölle tulee kiinnittää huomiota.

ABSTRACT

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61 pages, 12 figures, 31 tables, 1 appendix

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Keywords: Carbon footprint, Life cycle assessment, event

The aim on this thesis was to calculate carbon footprints of different types of events, from which subsystems does a carbon footprint of an event compose of and generally find out the areas that most affect the carbon footprint of an event. The first calculation was done to find out possibilities to reduce the carbon footprint caused by the mobility of spectators of a ice-hockey match of the Finnish league team Pelicans. The second calculation was done about a Lahti European Green Capital – 2021 opening event “Park of Experiences”, which was an audiovisual artwork organized in Pikku-Vesijärvi park. The third calculation was a comparison of Lahti European Green Capital – 2021 opening seminar, which was organized online instead of originally planned live-event. The results and literature both suggest that the largest or at single contributor, or one of the largest in some cases, to events carbon footprint is the mobility of the attendees to the event. The promotion of sustainable mobility should be a priority in reducing the environmental effects of events, including the carbon

footprint. The use of biogenic fuels and electric vehicles can also be useful in reducing the carbon footprint. The carbon intensity of electric grid is steadily decreasing, which will itself decrease the carbon footprint of events. In short term, the use of accredited renewable electricity by doing event specific electricity contracts would have significant impacts, especially in events where electricity consumption is large. Events organized entirely online have increased in recent years, especially during the COVID-19 pandemic. The emissions from online events are mostly coming from both ends of the data transfer network. This means that the emissions from data transfer are very dependent on the carbon intensity of grids, number of viewers, quality of video.

The term event is an umbrella term that includes variety of different kinds of implementations. This makes it difficult to find generalization that apply to all or most kinds of events. The nature of events is that large masses of people are participating, either online or live, which means that even quite small adverse effects in person level are quickly multiplied and can cause large effects in total. The focus should be on promotion and development of more sustainable modes of transport to events in cooperation between the organizers, public transport companies and public entities. The way the adverse effects of different subsystems included in events are communicated to the public should be paid attention to, because organizers have limited possibilities to influence the choices the attendee’s make.

ACKNOWLEDGEMENTS

I would like to thank the Sustainable Lahti – foundation (Kestävä Lahti-säätiö), for giving me the opportunity to help them develop their own practices as well as my own expertise. The thesis work was a hugely interesting and truly a learning experience, as has been my whole time at LUT University. I would like to thank Ville Uusitalo and Jarkko Levänen, for support and constructive criticism regarding my thesis.

I would also like to thank my employer Sitowise Oy, for helping me get this subject and for the hundreds of hours that I have been able to spend on this thesis, all thanks to them.

And lastly, I would like to thank my spouse Piia, who has a crucial mental and emotional support during my whole studies, which have been at times very tiring but ultimately very rewarding endeavour.

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LIST OF SYMBOLS AND ABBREVIATIONS

Abbreviations

CFP	Carbon footprint
GHG	Greenhouse gas
LCA	Life cycle assessment
LCI	Life cycle inventory analysis
LCIA	Life cycle impact assessment
IPCC	Intergovernmental Panel on Climate Change
GWP_{100}	Global warming potential in baseline model of 100 year by IPCC

Symbols

a	year
CH_4	methane
CO_2	carbon dioxide
CO_2eq	carbon dioxide equivalent
g	gram
kg	kilogram
km	kilometre
kW	kilowatt
kWh	kilowatt hour
l	litre
m^2	square meter
m^3	cubic meter
MJ	megajoule
MWh	megawatt hour
N_2O	Nitrous oxide
t	ton
%	percent

1 INTRODUCTION

1.1 Background

Climate change has been recognized as one of the biggest challenges for the whole world, and it will affect people's lives and economic activities in the following decades. Climate change will have consequences that affect humans, and environment and it can have significant influence in resource availability, economic activity and human well-being. (ISO14067:2018, 5)

Global warming is likely to be one of the greatest cause of species extinctions this century. The IPCC estimates that a 1,5 °C average rise on global temperature may put 20-30% of species at risk of extinction. If the planet warms by more than 2 °C, most ecosystems will struggle. Our atmosphere works like a greenhouse. The gases emitted to the atmosphere let the radiation from sun through but prevent some of the heat from escaping to the atmosphere. Fossil fuels such as oil, coal and natural gas cause three fourths of greenhouse gas (GHG) emissions. The most important ways to restrain climate change are phasing out the use of fossil fuels, use of sustainable and renewable energy sources, energy saving and efficiency, electrification of traffic, stopping deforestation, increasing the amount of natural carbon sinks ja climate friendly food production and consumption. (WWF, 2021)

Events cause significant environmental impacts, that are often disregarded. By Getz (2007), event is defined as a phenomenon happening in a certain place at a certain time, with special circumstances. Planned events are organized so that for example economic, societal or cultural goals can be achieved. Organization of an event requires planning and implementation of themes, sufficient setting, consumable objects and program, that serve the needs of the participants, guests, performers and other stakeholder groups. Events are categorized by their distinctive features. Festivals, exhibitions, conferences and sports events have distinct associations in people's minds, because people have a societal meaning attached to them. (Getz, 2009)

Events cause significant environmental impacts, that have often been ignored. Both, the ecological systems and physical environment, the event is organized in, suffer as a consequence. Events increase the consumption of energy and water, travelling, and contamination of air, water bodies and soil. The effects extend to nature and whole of its flora and fauna. When assessing the environmental impacts, the event venue including its building should be taken into account. (Getz, 2011)

1.2 Goals and delimitations

The goal of this thesis is to recognize the most significant areas affecting the carbon footprint of events using the European Green Capital – opening events as an example. Once the carbon footprint is calculated and the most important areas are recognized the goal is to present actions and guidelines related to the possibilities to reduce carbon footprint of an event for the event organizers in the region. With the information, the organizers can plan such events in more sustainable way in the future.

The work is focusing on three parts of the opening events: Case 1 is an ice hockey game, to which people can use public transportation for free. Case 2 is the Park of Experiences that is an audiovisual artwork constructed in Pikku-Vesijärvi Park and certain landmarks in Lahti are illuminated. Case 3 is the opening seminar of the Lahti European Green Capital year, that is organized online instead of original live event because of the COVID-19 pandemic.

1.3 Research questions

There are several questions that this thesis aims to answer to. There are case specific questions for each case and more general overarching question. The questions regarding the whole work are: What are the main emission sources of events and how could their emissions be mitigated? For case 1, the question is more specifically, how could the Carbon footprint (CFP) of ice-hockey game be mitigated by increasing the amount of public transport use by offering free public transportation for audience mobility. For case 2, the question is: What are the largest contributors to the CFP in an outside audiovisual event, and what could be done to mitigate the emissions. For case 3, the question is: How does the CFP of live and virtual events differ, and what are the largest contributors to each events CFP.

1.4 Structure of the thesis

Chapter 2 includes a brief literature review of the existing data about sustainability and carbon footprint of events. Chapter 3 describes the relevant standards and carbon footprint calculation methods for different areas of the event. The basics of the ISO standards 14040 and 14044 that focus on the life cycle assessment (LCA) method of environmental impacts assessment is presented. The ISO standard 14067, which is related to carbon footprint calculation of products is presented. Lastly the PAS 2050 guideline is presented, which is UK government guideline for carbon footprint calculation of products and services.

Chapter 4 consists of the goal and scope definition sand inventory analysis of the cases. Chapter 5 handles the impact assessment and sensitivity analysis of the inventory analysis results. Chapter 6 interprets the results and discusses significance of the different areas that the carbon footprint comprises of and gives suggestions and guidelines how the carbon footprint can be mitigated.

2 LITERATURE REVIEW ON SUSTAINABILITY OF EVENTS

It is argued that event organizations must take responsibility for sustainability of their actions, but they may lack appropriate development tools. The purpose of the paper is to study how companies and organizations can develop sustainability process in societal system context and the need for sustainability certification in their events. (Andersson, 2016)

There are several sustainability standards that have been developed for event industry, in the recent decades. The latest standard is the ISO 20121, which is an event management system standard developed to help organizations in the event industry. The problem is that event industry is uncertain about which standard and certification is the most suitable, and how it can be utilized. Some standards make it possible for event organizations to be certified, which can be used as marketing or business tool and as a statement of organizations commitment to sustainability. (Andersson, G. 2016)

There are multiple sustainability standards in Sweden, such as “Swedish Welcome” concept. Only some of these offer organizations an opportunity to be certified. A similar situation can be found in the United States. Strick & Fenich (2013) argue, that while there are significant amount of “green” and “sustainability” certifications designed for the event industry, the good ones will survive and the rest will disappear. The US industry’s first industry standard for the event planning process is composed of nine individual standards regarding such areas as accommodation and transportation, which shows that event organizing is composed of several different products related to the whole tourism sector. (Andersson, G. 2016)

In the study by Andersson (2016), 50 randomly selected event organizers in Sweden were interviewed regarding their plans and interest in implementing sustainability criteria into their organizations and three focus groups were organized for more reflective discussions on the events part of the societal system. In the interviews, event organizers considered sustainability certifications important depending on their important financial and environmental effects on both outside and inside the organizations and their events. However, the affordability of such certifications was a concern especially regarding small events.

According to the conclusions of the study by Andersson (2016), majority of the interviewed event organizers believe that sustainability certification is an important tool for developing a sustainable system that includes the event organization and its events and the surrounding environment. Increasing amount of large event organizations use sustainability-oriented certification. Many event organizers add that the organizations overall positive attitude towards sustainability is more important than a formal certification, but the managers of Swedish event organizations did indicate, that they felt that certification would give a significantly positive image to the market. (Andersson, G. 2016)

Operational issues that need to be considered by an event aiming to improve its green rating relate both to the event itself, as well as its location, inputs and outputs. Selecting location or venue is an opportunity to consider issues such as access to transport, waste management and availability of green power. Other important areas for consideration include type and quantity of materials and products used, logistics and marketing. A number of events also undertake audits to benchmark and improve the environmental performance of the event.
Accessibility to reliable public transport is of increasing interest to event organizers. Travel has been identified as a key issue for event management due to the GHG emissions as well as other adverse effects to local nature such as noise, traffic congestion, visual intrusion and effects on local air quality that are all generated by high amount of cars. (Laing and Frost, 2010)

Waste management is also high on the agenda for events, particularly those that are organized in fragile environments. Many events and festivals implement composting toilets and grey water for flushing toilets as examples of such schemes. Recycling could be encouraged and some events have implemented systems in which cans and mugs purchased include a deposit, that is received when the container is returned. Power options that minimize the environmental impacts include the use of biodiesel fueled generators and solar and wind power. Green power providers have been increasingly participating as sponsors for festivals as a way of recruiting new customers. Some festivals also offer carbon offsets to attendees, to minimize their carbon footprint. (Laing and Frost, 2010)

Developing a green event involves more than just ensuring that the operations and venue are environmentally or culturally sensitive. The event itself can be used to promote a green message, through avenues such as themed displays or stalls, presentations and sale of food and beverages that fit the green theme. (Laing and Frost, 2010)

There is tendency for a disconnection between green intentions and operational practice with respect to events. This is well illustrated by trash disposal practices observed at three events by the authors. When a popular international musician performed at an idyllic regional vineyard, “green” featured in the marketing, but there was no source separation of trash for recycling. Similarly, a family event at a major attraction specifically encouraged recycling and had an educational agenda aimed at changing patterns of behavior, but the catering contractor emptied all their trash into one bin. Thirdly, a major sporting venue introduced recycling bins, but no bin for non-recyclable trash, resulting in the unrecyclable trash ending up into recyclable bins. This suggests that some event organizers lack knowledge on implementing green issues in practical sense and understanding the importance of consistency in sustainable actions across the board. This leaves these event organizers vulnerable to allegations of green-washing. (Laing and Frost, 2010)

Carbon footprinting of events is relatively new practice, but it has been increasing in recent years. In Finland, large festivals like Flow festival and Ilosaarirock have been measuring their carbon footprint through outside consulting companies for years, but the scope of the work has varied significantly in different calculations. In 2014, Helsingin seudun ympäristökeskus produced a guide in how to define the scope for carbon footprint calculations of events. The guide compares the carbon footprint calculation scope definition of three major events and how their approach differs. The guide also compares online carbon footprint calculators from World Wildlife Foundation (WWF) and Julie’s Bicycles IG Tools. The guide focuses on large events such as music festivals, and other so-called mega-events, because they have the largest environmental impacts as single events. The case presented in the guide is Tall Ship Races – event in which large sail ships dock into Helsinki harbor, live music and other performances are organized in the harbor area. This is a relatively large event, and the scope includes direct energy consumption, paper consumption, waste management, water consumption, travel of subcontractors, travel of the visitors, travel of the artists and catering services. The study case for the guide notes that most parts of the scope were handled with sufficient accuracy, but he emissions from catering was the most difficult part to calculate, because the percentage of the vendors that were reached and the quantities of different foods could be estimated, was relatively low. Still, the largest contributor to the carbon footprint of large event like Tall Ship Races, was found to be the travel of the visitors (96,9%). Also, the comparison between the two calculators give quite different results for the carbon footprint, because of the differing emission factors. The emphasis should be on the geographically and temporally relevant emission factors. (Reko, 2014)

In 2012, the standard "ISO 20121:2012, Event Sustainability Management System – Requirements with guidance for use" was published. The standard is based on the British standard BD 8901, which was created for the 2012 London Olympic Games. The standard specifies the requirements for an event sustainability management system and has been developed for organizations in the events industry to improve the sustainability of their event related activities, products and services. The standard "describes the building blocks of a managements system that will help any event related organization to: Continue to be financially successful, become more socially responsible and reduce its environmental footprint." The standard applies to all types and sizes of organizations involved in events industry – from caterers, lighting and sound engineers, security companies, stage builders and venues to independent event organizers and corporate and public sector event teams. ISO 20121 was not available for more specific inspection for this thesis, so details of it are not handled. (ISO, 2012)

In 2020, researchers from Tokyo university published an article called "Carbon Footprint Evaluation of the Business Event Sector in Japan". The article divides the business events into four groups Meetings (M), Incentive travel (I), Conventions, and Exhibitions and Events (E), and are together referred to as MICE. The article estimates the carbon footprint of the whole sector in Japan by using input output analysis from the life cycle perspective.
The carbon footprint of business event was calculated by using the estimated total consumption in Japan's MICE sector in monetary terms and gathering data from event participants, organizers, industry groups, and exhibitors, to calculate the consumption per participant. Some data required for the calculations was also collected from UK statistics on the basis of similar economic size of the sectors in both countries. Statistical information about direct GHG emission intensity from each sector was used from Inventory Database for Environmental Analysis version 2, developed by National Institute of Advanced Industrial Science and Technology. The calculation results from events organized by the two

different standards were calculated on aforementioned basis and resulted in similar results regarding the share of emissions of different sectors, although having very different total amounts. Events organized by ICCA (International Congress and Convention Association) standard had total GHG emissions of 804,8 tCO_2eq, from which transportation comprised 56%, planning and preparation 13,2%, accommodation 12 %, souvenirs, shopping, entertainment and sightseeing 10,1% and food and beverages 7,9%. The events organized by JNTO (Japan National Tourist Organization) standard the total GHG emissions of 1714,4 tCO_2eq, from which transport comprised of 54,3%, planning and preparation 14,3%, accommodation 12,9%, food and beverages 7,9%, souvenirs, shopping, entertainment and sightseeing 8,2%. (Kitamura et al., 2020)

Significant body of literature is available on environmentally friendly (eco-friendly or green) initiatives in the tourism and hospitality industries. Still, little research has been focusing on consumers' involvement with green initiatives. The research by Wong et al. 2014, focuses on event attendees' green involvement in food festivals and how it could influence their value perceptions of this type of event.

Being "green" could improve the competitive advantage of the service provider. (Ottman, 1993) It is acknowledged by some authors that consumers are willing to pay more for eco-friendly services but especially regarding event services, little research has documented the amount attendees are willing to pay for such "green" services and initiatives.
The study offers new insight by demonstrating how people's green involvement can be assessed in an event setting. The study also tested the effect of green festival involvement on perceived green value assessment and behaviors toward eco-friendly initiatives.
Based on the results of four different structural models, it was shown that green festival involvement as a second-order construct, significantly influences attendees perceived value of green events. Most respondents agreed that if a festival features green initiatives, the value of the event increases. According to the results of the study, consumers are willing to spend more on a green events if it is perceived to offer better value to the attendees than events that do not include some green components. (Wong et al., 2014)

3 CARBON FOOTPRINT CALCULATION METHODOLOGY

Carbon footprint is nowadays calculated mostly by life cycle assessment methodology, in which the only impact category is global warming potential. LCA is standardized and rigorous method for estimating environmental effects of products or services, that takes into account the inputs and outputs of a product system during its whole life cycle. In this thesis, the carbon footprint of events is calculated with LCA-methodology.

3.1 Life cycle assessment

The increased awareness of the importance of environmental protection, and the possible impacts associated with products and services, both manufactured and consumed, has increased interest in the development of methods to better understand and address these impacts. One of the methods developed specifically for this purpose is life cycle assessment (LCA). (ISO 14040:2006, 5)

LCA addresses the environmental aspects and potential environmental impacts throughout a life cycle of a product, from raw material extraction to production, use and end-of-life treatment, recycling and disposal (i.e. cradle-to-grave). (ISO 14040:2006, 5)

There are two connected standards that are relevant when conducting a life cycle assessment according to ISO standards. These are *ISO 14040:2006 Environmental management. Life cycle assessment. Principles and framework* and *ISO 14044:2006 Environmental management. Life cycle assessment. Requirements and guidelines*. These standards are introduced in chapters 3.1.1 and 3.1.2.

3.1.1 ISO 14040

The ISO standard 14040 defines the framework and principles that life cycle assessments consists of. Life cycle assessment has to be transparent and versatile, and the results need to be as unambiguous as possible. The life cycle assessment made according to the international ISO standard 14040 include four main steps:

1. Goal and scope definition
2. Inventory analysis (LCI)
3. Impact assessment (LCIA)
4. Interpretation

In the first phase: “Goal and scope definition”, the system boundaries of the studied system are set. The aim is to define the sub-processes that are included or excluded from the assessment. The scope, including the system boundary and level of detail, of an LCA depends on the subject and the intended use of the study. The depth and the breadth of LCA can differ considerably depending on the goal of a particular LCA. In this phase, the functional unit should also be defined. The primary purpose of the functional unit is to provide reference to which the inputs and outputs are related. After the extent and level of detail of the study are set, the second phase, inventory analysis can begin. (ISO 14040:2006, 8-12)

The life cycle inventory analysis phase (LCI phase) is the second phase of LCA. It is an inventory of input/output data with regard to the system being studied. It involves collection of the data necessary to meet the goals of the defined study. (ISO 14040:2006, 11-13) In life cycle inventory, qualitative and quantitative information of all unit processes of a product is collected, verified, made relative to the unit process and functional unit, system boundary is specified and possible allocations are made. The results of inventory analysis are used to assess the environmental impacts of a system. (ISO 14067:2018, 8, 28-29)

The life cycle impact assessment phase (LCIA) is the third phase of the LCA. The purpose of LCIA is to provide additional information to help assess a product system’s LCI results to better understand their environmental significance. (ISO 14040:2006, 11-12)

Life cycle interpretation is the final phase of the LCA procedure, in which the results of an LCI or an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition. (ISO 14040:2006, 11-12)

The information gained by life cycle assessment can be utilized in various ways. For example, product development, strategic planning, political decision making and marketing are possible ways of utilizing the information. (ISO 14040:2006, 24, 44-46)

3.1.2 ISO 14044

ISO 14044 defines specific requirements and guidelines how LCA-studies are made. It is based on the main features and principles of a life cycle assessments defined in the standard ISO 14040. ISO 14044 standard defines the requirements for life cycle assessment and guides in defining the goals and scope, inventory analysis, impact assessment, interpretation of results, reporting of the life cycle assessment and critical assessment. It defines the limits of the assessment and in assessment of the relationships between different phases of an LCA and use of value judgements and optional phases. (ISO 14044:2006, 9)

In the first phase of life cycle assessment, goal and scope for the assessment are defined. The end use of the information of the assessment, reasons for carrying out the assessment, target audience and if the results are used in public statements about comparative advantage/disadvantage are defined. The scope needs to clearly state the product system and its processes, the functional unit, system boundaries, allocation methods, impact assessment methods and -categories, interpretation method, assumptions and value choices, limitations, possible voluntary phases and type of critical assessment in applied. Life cycle assessment is an iterative process, so its goal and scope might have to be modified while the assessment is progressing. All possible changes to the goal and scope need to be documented in the report. (ISO 14044 2006, 8-11.)

System boundary definition describes the action or product system that is being assessed. It helps to limit the assessment so that the goals of the work can be achieved. When defining the system boundary, only the sub-processes that are useful for the assessment are included. Also, the requirements for the information used in the assessment need to be defined. (ISO 14044:2006, 8-11.)

The second phase of life cycle assessments is inventory analysis, which includes the gathering of information, calculations and allocation of results. The qualitative and

quantitative information has to be gathered from every unit process that is included within the system boundary. In the inventory analysis phase, the incoming and outgoing energy and material flows are connected to the functional unit. All of the descriptions of the unit processes need to be documented in the process chart. The detailed description of unit processes, listing of used units and description of calculation methods make it easier for consistent and logical assessment of the product system in question. The sources of the information used in the inventory analysis has to be available in the report. These sources include for example surveys and scientific articles. The results of the inventory analysis can be described for example as kilograms or tons per functional unit.
(ISO 14044 2006, 11-16.)

In third phase of the life cycle assessment, the impact assessment is carried out. All of the results gotten from inventory analysis are placed into a defined impact category. Impact category means the environmental challenge that is being handled in the assessment, that can be for example climate change, acidification or eutrophication. The impact category is being impact indicator, that describes the relative size of the impact. Impact category for climate change is infrared radiative forcing (W/m^2). The impact categories and indicators that are selected need to take into account the goals and scope of the life cycle assessment and they need to be internationally accepted. The characterization model is a model reflecting the environmental mechanism by describing the relationship between the LCI results, category indicators and in some cases category endpoint(s). The characterization model is used to derive the characterization factor. Characterization factor describes the environmental impact of the impact category. For example, when the impact category is climate change, the characterization model used is the IPCC Baseline model of 100 years, characterization factor is Global Warming Potential (GWP_{100}) which is defined for each GHG. So, the impact assessment is done to compare GHG-emission concentration effects based on the IPCC 100 years baseline model. (ISO 14044 2006, 16-23)

The fourth and last phase of a LCA is the life cycle interpretation phase. It comprises of several elements such as identification of the significant issues based on the results of the LCI and LCIA phases, evaluation that consider the completeness, sensitivity and consistency checks, conclusions limitation and recommendations. The results of the LCI or LCIA phases shall be interpreted according to the goal and scope of the study and interpretation phase shall include and an assessment and sensitivity check of significant inputs outputs and methodological choices in order to understand the uncertainty of the results. (ISO 14044, 23-24)

3.2 Carbon footprint

The origin of the term carbon footprint can be traced to as deviation from the term ecological footprint introduced by Wackernagel and Rees (1996). Ecological footprint is a term that refers to the biologically productive land and sea that are required to sustain human population. Following the aforementioned concept, carbon footprint was introduced as the land area required to assimilate the entire CO2 produced by humankind during its lifetime. This is an old definition, which is no longer widely used. In recent years the definition has been unambiguously defined for scientific use. The concept has been used for decades as life cycle impact category indicator for global warming potential. Based on survey by Wiedmann and Minx (2007), they defined carbon footprint as a measure of exclusive total amount of carbon dioxide emissions that is directly or indirectly caused by an activity or is accumulated over the lifetime of a product. (Pandey, 2011)

Carbon footprint is a quantitative expression of GHG emissions from an activity or product that helps in emission management and evaluation of mitigation measures. A carbon footprint is the GHG emissions caused directly and indirectly by an individual, organization, event or product and is expressed as a carbon dioxide equivalent (CO2eq). Carbon footprint accounts for all six Kyoto GHG emissions:

- carbon dioxide (CO2)
- methane (CH4)
- nitrous oxide (N2O)
- hydrofluorocarbons (HFCs)
- perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF6) (Carbon trust, 2011)

3.2.1 ISO 14067

The standard “ISO 14067 Greenhouse gases; Carbon footprint of products. Requirements and guidelines for quantification” is a technical specification that presents the principles and requirements for calculating a carbon footprint of a product and how to communicate about it to the target audience. The specification is based on the principles, requirements and guidelines that have been specified in existing international standards ISO 14040 and ISO 14044 regarding life cycle assessment. The life cycle of a product includes the raw material extraction, production, use and end-of-life phases. This specification is made to benefit organizations, governments industries, service providers, communities and other stakeholder groups by clarifying and regularizing the calculation of carbon footprint and its use in communication. The life cycle assessment based on ISO 14067, that has only one impact category, global warming potential, can be used to achieve benefits such as:

- Avoiding the transfer of liabilities from products life cycle phase to another or between life cycle of different products
- It specifies the requirements for CFP calculation
- Enables monitoring of CFP level in GHG-emission reduction
- Helps to understand the concept of CFP, which can enable identification of emissions reduction possibilities and carbon sinks
- Helps to promote sustainable, low carbon economy
- It improves the credibility, coherence and transparency of CFP calculations
- It enables alternative production plan, acquisition option, production and manufacturing method, raw material choice, transport choice, recycle and end-of-life assessment
- It enables development and implementation of GHG management strategies and plans within the whole life cycle of a product and identification of possible beneficial relationships in the supply chain
- It can be used to produce reliable information regarding CFP

(ISO 14067:2018, 6-10)

The general goal of carbon footprint study is to calculate the potential global warming effect of a product in carbon dioxide equivalent (CO_2eq), by calculating all significant greenhouse gas emissions and sinks within a products life cycle or by selected processes based on system boundary definition. (ISO 14067:2018, 23)

3.3 Other relevant standards and guidelines

3.3.1 GREENHOUSE GAS PROTOCOL

The Greenhouse Gas Protocol (GHG Protocol) Initiative is a multi-stakeholder partnership of businesses, non-governmental organizations, governments, and other convened by the World Resources Institute (WRI) and Would Business Council for Sustainable Development (WBCSD). Launched in 1998, the initiative's mission is to develop internationally accepted greenhouse gas accounting and reporting standards for business and promote their adoption. The GHG protocol consists of two intertwined standards, *GHG Protocol Corporate Accounting and Reporting Standard and GHG Protocol Quantification Standard.* First edition of *GHG Protocol Corporate Accounting and Reporting Standard* was published in 2001 and was broadly adopted by business, NGOs governments. This thesis focuses on the *GHG Protocol Corporate Accounting and Reporting Standard*, which guides organizations in GHG reporting. GHG inventory with GHG protocol takes into account all six greenhouse gases defined by the Kyoto Protocol, which are carbon dioxide ($CO_{2)}$, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorinated hydrocarbons (PFCs) and sulphur hexafluoride (SF_6). (GHG Protocol 2004, 2-3)

GHG Protocol sets principles for GHG accounting and reporting to ensure that the GHG inventory constitutes a true and fair representation of the company's GHG emissions. Their primary function is to guide the implementation of the GHG Protocol Corporate Standard, especially when the application of the standards to specific issues of situations is not straightforward. These principles are: relevance, completeness, consistency, transparency and accuracy. (GHG Protocol 2004, 8-9)

The GHG inventory starts by defining the boundaries of the organization. The organizational boundaries limit the activities that are included in the GHG inventory. Next step is to define operational boundaries, that consists of identifying the operations and emissions associated with them and categorizing them in scopes 1, 2 or 3 depending on the emission source. Scope 1 includes the direct GHG emissions caused by the activities of the organization. Scope 2 includes the emissions produced from the purchased energy of the organization. Scope 3 includes all other indirect emissions sources. (GHG Protocol 2004, 26)

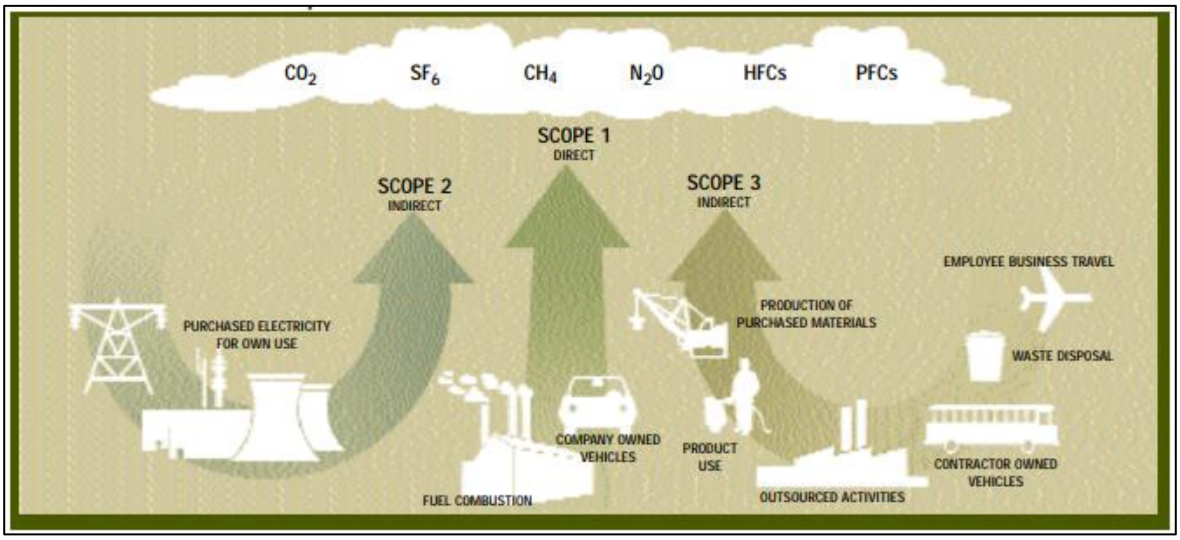

Figure 1. The scopes 1,2 and 3 of emissions created based on GHG Protocol (Source: GHG Protocol Corporate Standard, revised.)

After the definition of system boundary, the GHG emissions can be calculated with the following steps:

1. Identify sources
2. Choose the calculation approach
3. Collect data and choose emission factors
4. Apply calculation tools
5. Roll-up data to corporate level

Identification of GHG emissions sources means identification and classification of the emission sources to scope 1-3 emissions. Emission sources can be divided into four categories: Stationary combustion, mobile combustion, process emissions and fugitive emissions. The emissions can then be calculated with sector specific calculation tools provided by GHG Protocol or own methods, if they are deemed as or more accurate. In phase 2, the calculation approach used for the calculation is chose. The emission can be calculated for example with mass balance calculation. Activity data can be obtained from information about direct fuel and electricity consumption. When all relevant data is collected, the calculation tools are used. There are several industry specific calculation tools and usually to produce comprehensive report, multiple calculation tools need to be utilized. Finally, all the results from calculations are combined into on report including all levels of an organization. The quality control and inspection are also conducted to verify the reliability of the results.

3.3.2 PAS 2050

PAS 2050 (Publicly Available Specification 2050) is a standard, published by British Standards Institute (BSI), that aims to provide a consistent method for assessing the life cycle emissions of goods and services. PAS 2050 offers organizations a method to produce better understanding of the GHG emissions caused by companies supply chains, but the primary goal of the standard is to provide a common basis for GHG emission quantification that will enable GHG emission reduction programs, that are truly effective. (PAS 2050, 4)

PAS 2050 builds on existing life cycle assessment methods established through BS EN ISO 14040 and BS EN ISO 14044 by giving requirements specifically for assessment of GHG emissions within life cycle of goods and services. These requirements further clarify the implementation of these standards in relation to the assessment of GHG emissions of goods and services, and establish particular principles and techniques, including:

a) cradle-to-gate and cradle-to-grave GHG emissions assessment data as part of their life cycle GHG emissions assessment of goods and services;
b) scope of greenhouse gases to be included;
c) criteria for global warming potential (GWP) data;
d) treatment of emissions and removals from land use change and biogenic and fossil carbon sources;
e) treatment of the impact of carbon storage in products and offsetting;
f) requirements for the treatment of GHG emissions arising from specific processes;
g) data requirements and accounting for emissions from renewable energy generation. (PAS 2050, 5)

PAS 2050 was made to benefit organizations, businesses and other stakeholders by providing clear and consistent method for the assessment of the life cycle GHG emissions associated with goods and services. Specifically, PAS 2050 provides benefits for organizations that supply goods and services by:

- Allowing internal assessment of the existing life cycle emissions of goods and services;
- Facilitating the evaluation of alternative product configurations, sourcing and manufacturing methods, raw material choices and supplier selection on the basis of

the life cycle emissions associated with goods and services and is utilized as a basis for comparison;

- Providing a benchmark for programs aimed at reducing GHG emissions;
- Allowing quantification, managements and potential comparison of GHG emissions from goods and services using a common, recognized and standardized approach to life cycle GHG emissions assessment;
- Supporting reporting

And for consumers of goods and services by providing common basis for understanding the assessment of life cycle GHG emissions when making purchasing decisions of goods and services.

4 LIFE CYCLE ASSESMENT OF CASE EVENTS

In this chapter, the first two steps of a life cycle assessment of an event are described. The goal and scope of the three different events are defined, the data collection for the calculation and the calculation is carried out. The impact assessment and interpretation phase of the results is handled in chapter 5.

4.1 Case 1: Pelicans ice hockey match audience mobility

4.1.1 Goal and scope definition

The goal of this assessment was to calculate, based on the existing carbon footprint report of an ice-hockey team, different scenarios regarding audience mobility to an ice-hockey game. The ice-hockey team Pelicans are aiming to be carbon neutral and their carbon footprint was calculated by LUT-university in 2019. The single largest contributor to the carbon footprint was found to be mobility of the spectators.

The original goal was to estimate the effects of a trial, in which people were allowed to travel to the ice hockey match by local bus for free with a ticket to the game, but because of COVID-19 pandemic, the game was played to empty stands, so the calculation presented is completely theoretical.

From the data gathered by LUT-university in 2019, the theoretical reduction of carbon footprint is calculated when different percentages of population previously travelling by private cars would change to public transportation. Also, the effect of so-called Pelicans-buses from neighborhoods that have high amount of people travelling to the game with private cars was calculated. The functional unit in this calculation is one league game in the Finnish Liiga. The system boundary for the calculation is shown in figure 2.

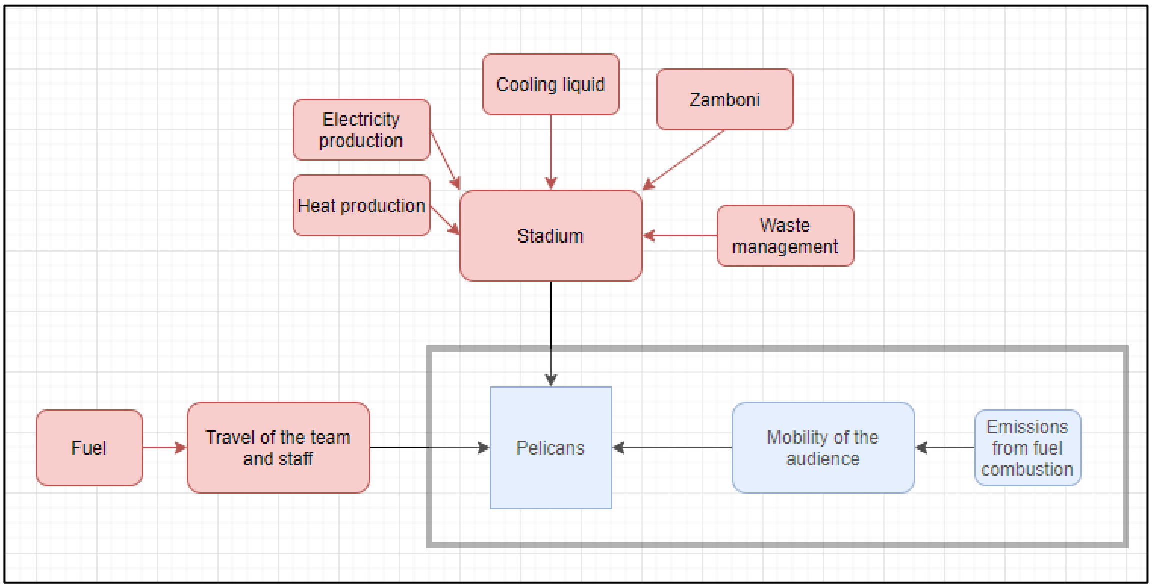

Figure 2. System boundary of the CFP calculation of Case 1.

Because the goal is to calculate the CFP of the mobility, the impact category used is climate change, the LCI results are reported as amount of greenhouse gases per functional unit. The functional unit of the calculation is one ice-hockey game. The characterization model used for the results is the Intergovernmental Panel on Climate Change (IPCC) baseline model of 100 years and characterization factor global warming potential (GWP_{100}) for each greenhouse gas. The indicator result is then reported as kilograms of CO_2-equivalents per functional unit.

4.1.2 Inventory analysis

The information for the calculation was gathered mostly from previously made studies about the CFP on Liiga (Hepo-oja, 2018) and CFP of Pelicans (Hintukainen & Uusitalo, 2019). The previous studies on CFP of ice-hockey used multiple sources such as VTT Lipasto-database for unit emissions, European commission reports and directives. The same data sources were used for the calculations in the Case 1.

The CFP on Pelicans for the year 2019 was calculated to be 472 tCO_2eq (13,9 tCO_2eq per game) and composed of four major parts. These parts are the stadium, travel of the team and staff on away games, travel of the staff and team to the stadium in Lahti and travel of the spectators to the Lahti stadium. From these, the travel of the spectators was identified as largest contributor with 341 tCO_2eq (72%) (10,02 tCO_2eq per game). Figure 3 shows the distribution of emissions by source.

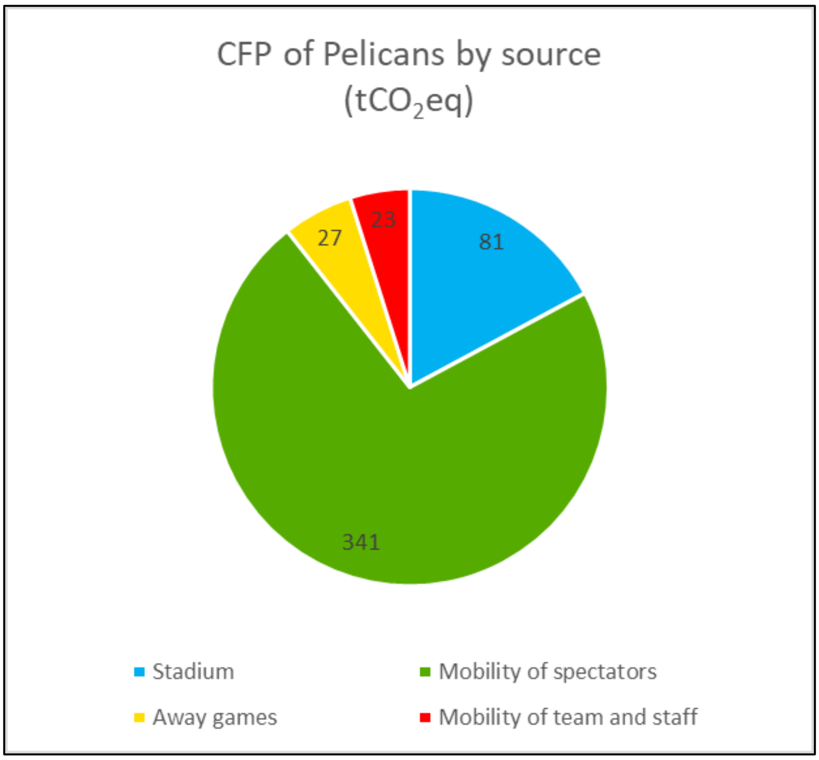

Figure 3. CFP distribution of Pelicans

The emissions from mobility of the spectators was mainly comprised of the emissions from private cars. The shares of different modes on transport to the CFP of mobility are shown in figure 4.

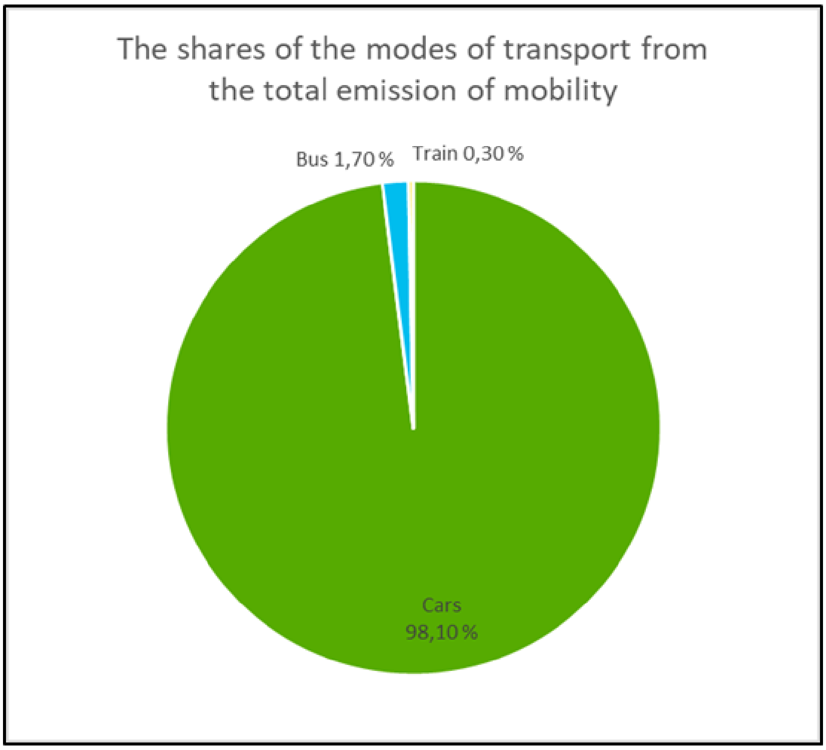

Figure 4. Shares of the emissions sources of modes of transport

The CFP of mobility (Hintukainen & Uusitalo 2019), was calculated gathering answers on web-based survey on one game about the mobility of the spectators and multiplying it to cover the average attendance of a single game. The participants of the survey answered from how far they were coming to the match and by how. Then the person kilometers travelled by different means of transportation were calculated and emission factors were for determined. The survey was answered by 346 people and the average attendance of Pelicans games was 3 976 per game.

Because the raw data of the survey was not available, the data used in this thesis was calculated from the results and emission factor used in the study. The amount of person kilometers travelled by different modes of transportation was broken down and divided so that certain percentages previously travelled by private car would be travelled by bus instead. The data from Hintukainen & Uusitalo 2019, used in the calculations is shown in table 1.

<u>Steady increase in use of public transportation</u>

Table 1. Data used in the calculation

Calculation data					
Mode of transportation	Percentage of total travel emission	Emission of the survey participants ($kgCO_2eq$)	Emission factor (gCO_2eq/km)	Total distance traveled by survey participants to 1 game (km)	Total distance traveled by whole audience to 1 game (km)
Cars	98,1	855	168	5 092	58 512
Buses	1,7	15	33	449	5 162
Train	0,3	3	7	374	4 294

The emission factor for car is based on the VTT Lipasto-database unit emission factors. An average gasoline driven car with 27% street and 73% highway driving has energy consumption of 2,3 MJ/km. The gasoline is assumed to include 15% share of renewable fuel based (Jääskeläinen 2017), the biogenic share of emissions is disregarded from the calculation. The emission factor for average gasoline driven car according to Lipasto-database is 159 gCO_2eq/km, from which the share of fossil gasoline is 135 gCO_2eq/km. For energy consumption the share of fossil gasoline is 2 MJ/km and for ethanol 0,3 MJ/km. For the production and distribution of fossil gasoline, the value 15 gCO_2eq/MJ (European commission, 2015) is used. For production of ethanol, the assumption is that the feedstock is waste, and byproducts and the emissions factor for its production is 12 gCO_2eq/MJ (2009/28/EY). From this, the production and distribution emissions factors for gasoline is 29 gCO_2eq/km and 4 gCO_2eq/km. So, the emission factor for car is 168 gCO_2eq/km. (Hintukainen, Uusitalo. 2019)

For buses, the emission factor was determined by Lipasto-database so, that buses drive both street and highway portions and have an average of 20 passengers in them. Then, the direct emission from bus is 27 gCO_2eq/km. The energy consumption of a city bus is about 0,5 MJ/pkm, so the emission factor for production and distribution of fossil gasoline is 6 gCO_2eq/km. In total, the emission factor for bus is 33 gCO_2eq/km. (Hintukainen, Uusitalo. 2019)

The distance travelled by bus instead of car is estimated to be a bit longer, because the bus routes are not the most direct routes, but instead routes that cover as much areas people living in as possible. The factor 1,2 is used for kilometers travelled by bus. According to the survey, 20% of the participants in the survey had 3 or more people in a car, 45% had 2 people in a car and 35% travelled alone. By this, the average number of people in a single car was 1,85-2,25 (because of the 3-5 people per car). So, it is assumed that every car had an average on 2 people per car, and so the kilometers travelled by bus instead of car is multiplied with a factor of 2 to transform them into person kilometers. From these results the amount of emissions avoided when 10% of the travelled kilometers would change from car to bus. The reduction was multiplied to different percentages of travelled distances from 10% to 100%.

$$
\begin{aligned}
&Emission\ reduction = \\
&Emissions\ avoided\ by\ not\ using\ car - emissions\ caused\ by\ using\ bus = \\
&(distance\ travelled\ by\ car * emission\ factor\ of\ a\ car) - \\
&(2 * 1{,}2 * distance\ \ travelled\ by\ car * emission\ factor\ of\ a\ bus)
\end{aligned}
$$

Use of Pelicans buses

The use of so-called Pelicans buses, would be charter buses for people coming to the game from certain neighborhoods in Lahti and surrounding areas. In the calculation the optimal situation is described, where all of the people from the area coming by private cars would change to bus transport.

The charter bus used can transport 50 people and has emission of 923 gCO2eq/km when driving empty and 22 gCO2eq/pkm when full, street driving. (LIPASTO, 2016)
The consumption of charter bus, street driving, is when empty 39,1 l/100km and 46,2 l/100km when full. The density of the diesel fuel mix in 2016 used is 0,824 kg/l and the energy content 43,2 MJ/kg. (LIPASTO, 2016)

The amount of people coming from different neighborhoods was estimated by the survey done for the CFP on Pelicans. The four areas, from which large amounts of people traveled to the game with a car, were chosen as areas of focus. The four areas where most people were travelling to the game by car are: Ahtiala/Kunna, Pirttiharju/Kärpänen, Nastola/Villähde and Hollola. The areas and estimated distances by cars and buses are shown in table 2.

Table 2. Distances and consumptions of different modes of transportation in different areas

Area ***Variable***	**Ahtiala /Kunnas**	**Pirttiharju/ Kärpänen**	**Nastola/ Villähde**	**Hollola**
Average distance to game and back by car (km)	20	8	30	16
Distance covered by audience with car (km)	2820	1 512	4800	3136
Estimated distance covered with buses to game and back (km)	28	15	38	18
Person kilometers by buses (pkm)	7896	5 670	12 160	7038
Amount of fuel used by buses (l)	148	149,3	205	160,4

The fuel consumption of the buses was calculated, so that the emissions from fuel production and consumption could be calculated. The distance buses travel from and to depot was estimated to be 30 km in total. The distances between neighborhoods and the stadium were estimated with Google Maps, so that the bus drives main routes through the neighborhood and back. The person kilometers are then calculated by full buses travelling estimated distances. The buses are assumed to travel as full for the whole distance for simplification and because the points of entry to bus could not be known and because the bus will probably stop quite often to pick up people. Example of the calculations can be seen from appendix 1, and the results of the calculation in chapter 5.

4.2 Case 2: Park of experiences

4.2.1 Goal and scope

The goal of this assessment is to calculate the carbon footprint of the audiovisual artwork Park of Experiences, implemented in Pikku-Vesijärvi – park on 15.1-24.1. The park is implemented as a part of the Lahti European Green Capital 2021 -year opening ceremony. The system boundary of the calculation is presented in figure 5.

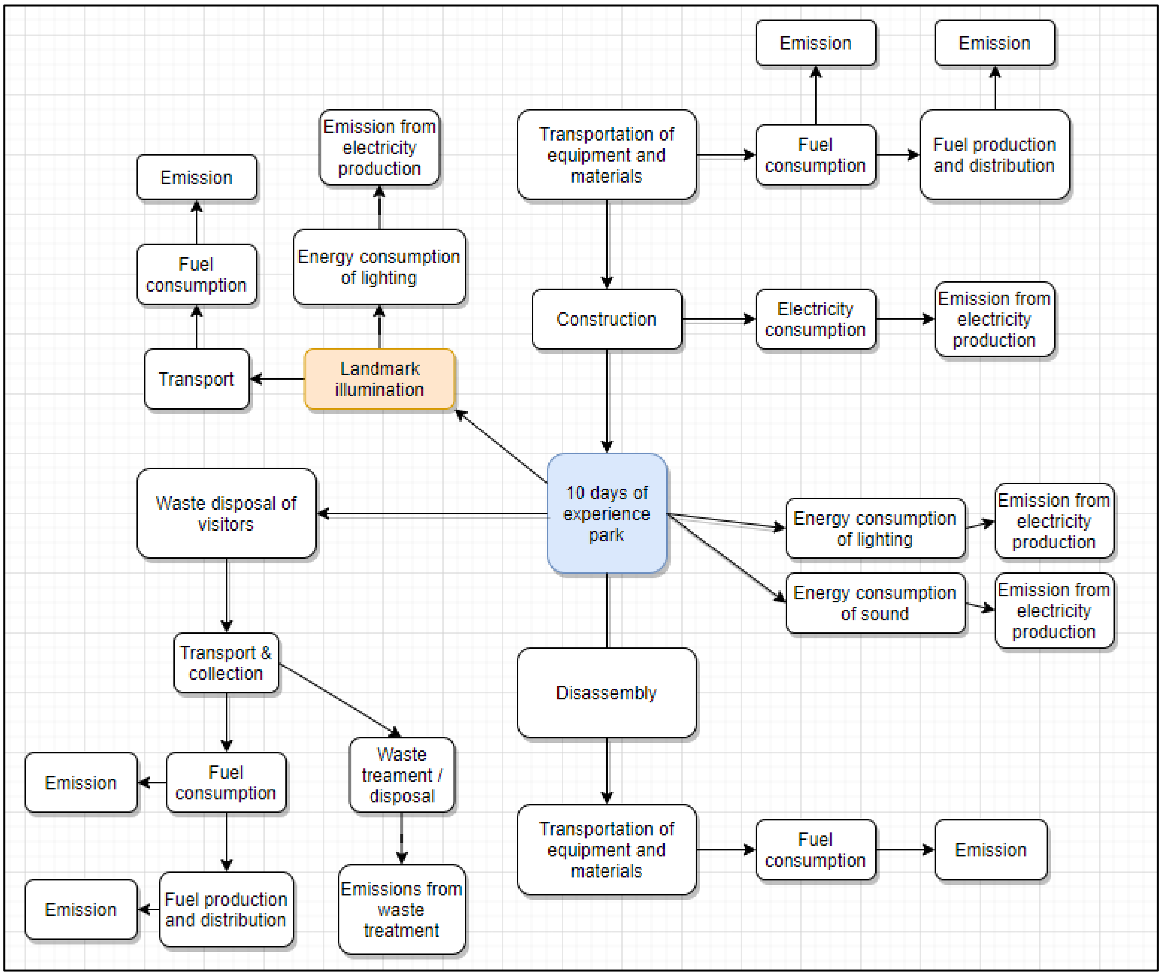

Figure 5. System boundary of Case 2.

Because the goal is to calculate the CFP of the Park of Experiences, the impact category used is climate change, the LCI results are reported as amount of greenhouse gases per functional unit. The characterization model used for the results is the Intergovernmental Panel on Climate Change (IPCC) baseline model of 100 years and characterization factor global warming potential (GWP_{100}) for each greenhouse gas. The indicator result is then reported as kilograms of CO_2-equivalents per functional unit. The functional unit in this case is the 10-day Park of Experiences, including the landmark illumination for the same period of time.

4.2.2 Inventory analysis

Data from the event was gathered by the organizers about transport distances regarding construction and disassembly of the park. The unit emissions from Lipasto-database were used for transport vehicles using internal combustion engine. The energy consumption of the music and illumination in the park was collected from Lahti Energia, about the absolute consumption during the construction and event phases. Waste disposal statistics were collected by event organizers from the waste management company. The information regarding electricity consumption of landmark illumination was not directly measured but estimated from the equipment and information received from organizer.

<u>Transportation</u>

The distances of the Park of Experiences equipment transport were measured and informed by the event organizer and are shown in table 3, with unit emission factors from Lipasto-database and Statistics Finland. From the beginning of the year 2021, the obligation share of biofuels in diesel is 20% according to the Finnish Tax Administration. The biogenic share in the fuel is not calculated into the direct emissions from combustion, but the emissions from production and distribution are. The unit emission factors from LIPASTO include 11,5% biogenic share and they are extrapolated to match the 20% share of the average results for vans and light delivery lorries driving on a highway in the year 2016. Most on the driving was highway driving. The emissions for the electric car are based on the average energy consumption of electric cars 15 kWh/100km (Motiva, 2020). So, the amount of electricity consumed in 640 km drive, is 96 kWh. The emission factor for the electric car electricity is the average emission of Finnish consumed electricity in 2020, 72 gCO_{2eq}/kWh. (Fingrid, 2021)

Table 4. Emissions from transportation of Park of Experiences equipment

Mode of transportation	Distance travelled (km)	Emission factor ($kgCO_{2eq}$/km)	Emission factor ($kgCO_{2eq}$/kWh)	Emission ($kgCO_{2eq}$)
Electric car	640		0,072	6,9
Van, empty	202,5	0,167		33,8
Van, full	202,5	0,188		38,1
Light delivery lorry, empty	202,5	0,249		50,4
Light delivery lorry, full	202,5	0,284		57,5
Total	1450			186,7

The calculation results in table 4, consider only the direct emissions from fuel combustion. The energy consumption of the van and light delivery lorries used are from LIPASTO-database, like the mission factors.

The value used for production and distribution of fossil diesel is the EU average value 18,17 gCO2eq/MJ (European Commission, 2015). The biogenic share in the fuel is not calculated into the direct emissions from combustion, but the emissions from production and distribution are.

The energy consumption of highway driving with van is 2,8 MJ/km when empty and 3,2 MJ/km when full. For light delivery lorry, the energy consumption is 4,1 MJ/km when empty and 4,7 MJ/km when full. (Source: LIPASTO)

Energy consumption divided by mode of transportation and emissions from fuel production and distribution are shown in table 5.

Table 5. Emissions from fuel production of fuel used for the Park of Experiences transportation

Mode of transportation	Total energy consumption (MJ)	Fuel	Energy consumption (MJ)	Emission factor ($kgCO_{2eq}$/MJ)	Emission ($kgCO_{2eq}$)
Light delivery lorry	*1782*	*Fossil diesel*	1425,6	0,018	25,9
		Biodiesel	356,4	0,013	4,6
Van	*1215*	*Fossil diesel*	972	0,018	17,7
		Biodiesel	243	0,013	3,2
Total	2997				51,4

The total emissions from transport of the Park of Experiences:

$$Transport\ emissions, ep = 186{,}7\ \text{kgCO2eq} + 51{,}4\ \text{kgCO2eq} = 238\ \text{kgCO2eq}$$

The transport of the equipment for the illumination of the landmarks, was measured as total of 600 km and fuel consumption reported by organizer was 65 l of diesel fuel. The biogenic share is calculated from the energy content of the fuel, but the differences between the fuels regarding energy contents in relation to density are so small, that for simplification, the share is subtracted from liters of fuel. The 20% biogenic share is not included in the emissions. The emissions from transportation of the illumination equipment is shown in table 6.

Table 6. Direct emissions from transport of illumination equipment

Mode of transportation	**Fuel used (l)**	**Share of fossil diesel in diesel fuel****	**Emission from 1 l of fossil diesel ($kgCO_2eq$) ***	**Emission ($kgCO_2eq$)**
Van	65	0,8	2,66	138,3

*Source: Lipasto-database

**Source: Vero.fi, Biopolttoaineiden jakeluvelvoite (distribution obligation of biofuels)

On top of direct emissions from the fuel consumption, the production and distribution of the fuels is included. The energy content value of fossil diesel used in the calculation is 43,2 MJ/kg and density 0,83 kg/l (LIPASTO). The value used for production and distribution of fossil diesel used is 15 gCO2eq/MJ (European Commission, 2015).

The biodiesel values used are based on the MYdiesel by the company Neste. According to their information, the energy content of the biodiesel is 44 MJ/kg and density 0,780 kg/l. The value used for production and distribution of biodiesel from waste is 13 gCO2eq/MJ (2009/28/EY). The emissions from production of fossil and biogenic shares of fuel used are shown in table 7.

Table 7. Emissions from production and distribution of fuel used for landmark illumination

Fuel	**Consumption (kg)**	**Energy content of fuel MJ**	**Emission factor (gCO2eq/MJ)**	**Emission ($kgCO_2eq$)**
Fossil diesel	43,16	1864,5	18,17	33,9
Renewable diesel	10,14	446,2	13	5,8
Total	53,3	2310,7		39,7

Total emissions from transport of equipment for landmark illumination:

$$Transport\ emissions, lm = 138{,}3\ \text{kgCO2eq} + 39{,}7\ \text{kgCO2eq} = 178\ \text{kgCO2eq}$$

Direct electricity consumption

The energy consumption information for the park was gotten from the energy company Lahti Energia. The electricity used for the park was gotten from two meters and it was divided into electricity used in the construction phase 13-14.1.2021 and actual use phase 15-24.1.2021. The dismantling phase energy consumption was not measured, but it is assumed to be similar scale to the building phase and same value is used. The emission factor used for the electricity is 131gCO_{2eq}/kWh, which is the moving average of Finnish grid electricity for the last three years. (Motiva, 2021) The amounts of electricity consumed and emission caused are shown in table 8.

Table 8. Emissions from direct electricity consumption of the park

Source on electricity consumption	Electricity consumed (kWh)	Emission factor gCO_{2eq}/kWh	Emission (kgCO_{2eq})
Park building phase	317,7	131	41,6
Park use phase	10 345,3	131	1 355,2
Park dismantling phase	317,7	131	41,6
Total	10 663,1		1438,4

For the illumination of the landmarks, the direct electricity use was found to be very difficult, so the amount of electricity used by the lighting was estimated by the power of the bulbs used. The four landmark that were illuminated, types and power of the equipment used are shown in table 9.

Table 9. The amount of power of the landmark illumination

Landmark	Device	Amount	Power (W)	Total power (W)
City hall	Chauvet Batten-Quad 12 LED	24	175	4 200
	Iridium Typhoon PAR RGBWAUV	48	120	5 760
	Flood 10W LEE 124 Dark Green	98	10	980
Water tower	Iridium Touch Washer 40 x 10W RGBW	4	450	1 800
	Iridium Pro Wash 44 x 20W RGBW	2	800	1 600
	Stairville LED PAR Quad IP65 RGBW	12	49	588
Ski jump hill	Starlight Saana Wash RGBW	12	460	5 520
	Iridium Touch Washer 40 x 10W RGBW	8	450	3 600
	Flood 50W LEE 124 Dark Green	14	50	700
	Chauvet Colorado 1-Tri Tour LED	4	93	372
Travel center	Chauvet Colorado 1-Tri Tour LED PAR	50	93	4 650
Total		276		29 770

So, the total power of the illumination equipment is 29,77 kW, and they were used non-stop for ten days between 15.1-24.1.2021. The organizer estimated that the equipment was used roughly on 1/3 of the maximum output. For this calculation, because the exact power or amount of electricity used is not known, ½ of the maximum power is used for calculations, since it is not known, if the energy intensity and light output have a linear relationship. The illumination equipment was used for 240h and the emission factor used was 131 gCO_{2eq}/kWh as introduced earlier. The emission from the equipment is shown in table 10.

Table 10. Emission from landmark illumination

Emission source	Equipment power (kW)	Run time of equipment (h)	Electricity used (kWh)	Emissions factor (gCO_2eq/kWh)	Emission ($kgCO_2eq$)
Landmark illumination	14,9	240	3572,4	131	468,0

Indirect emissions from electricity consumption

The indirect emissions from the electricity consumption are emissions that are caused by importing of electricity, losses on the grid and other variables are calculated by multiplying the total electricity consumed with emission factor of 15 gCO_2eq/kWh. (Source: Y-hiilari, emission calculator)

$$Indirect\ emissions\ from\ electricity\ consumption$$
$$= (10\ 663{,}5\ \mathrm{kWh} + 3572{,}4\ \mathrm{kWh} + 96\ \mathrm{kWh}) * 15\,\frac{\mathrm{gCO2eq}}{\mathrm{kWh}}$$
$$= 215\ \mathrm{kgCO2eq}$$

Waste management

The amount of waste that was collected from the park reported by the event organizers was 120 kg of mixed waste. The mixed waste was transported to the local waste management company Salpakierto Oy, waste handling center in Kujala. The transport distance from the park was estimated to be about 11 km, by diesel driven truck. The two-way distance used for the calculation of emissions from waste collection and transport is 22 km. The waste was collected as part of normal city waste management in the area. The information regarding the emissions from waste collection and transport of waste in Finland were collected from EcoInvent 3.7.1 database. The GHG emissions are reported as emission per 1 ton of waste transported by distance (t*km). The GHG emissions from the database are shown in table 11.

Table 11. GHG emissions from waste collection and transport

Greenhouse gas	**Amount emitted (kg), per t*km**	**Impact factors (Lipasto)**	**Emission as $kgCO_2eq$ per t*km**
CO_2	1,06	1	1,06
CH_4	$8{,}46*10^{-5}$	25	0,002115
N_2O	$5{,}25*10^{-5}$	298	0,015645
Total			1,08

Since the amount of waste generated was 0,12t and estimated transport distance was 22 km, the amount of emissions from waste collection and transport is:

$$Emissions\ from\ waste\ collection\ and\ transport = 0{,}12t * 22km * 1{,}08\,\frac{kgCO_2eq}{t * km}$$
$$= 2{,}9\ kgCO_2eq$$

Based on the information received from the waste management company, the plastic and metals are separated by mechanical sorting. According to the company, most of the waste ends up to energy recovery by waste incineration. Because of the small amount of waste, and the fact that most of the waste ends up in energy recovery, all of the waste is considered to be used for energy recovery. WWF Finland Climate calculator (Ilmastolaskuri) includes emission factor 410 gCO_2eq/kg MSW for waste incineration emissions in the capital area in the year 2019. This value was used in this calculation, because it is deemed to be accurate enough for Lahti area incineration plant. So, when all of the waste generated is incinerated, the emission from energy recovery is:

$$\begin{aligned} Emission\ from\ waste\ incineration &= 120\ kg\ MSW * 410\ \ gCO_2eq/kg\ MSW \\ &= 49{,}2\ kgCO_2eq \end{aligned}$$

Total emission from waste management is:

$$\begin{aligned} Emission\ from\ waste\ management &= 2{,}9\ kgCO_2eq + 49{,}2\ kgCO_2eq \\ &= 52{,}1\ kgCO_2eq \end{aligned}$$

4.3 Case 3: Opening seminar

The opening seminar of the European Green Capital - year 2021, in Lahti was planned as live event, but because of the circumstances with COVID-19, it was organized as an online event. The carbon footprint of both types of events were calculated to find out how the results differ between the two.

4.3.1 Live event

The live event was supposed to be organized as a 400 person event in Sibeliustalo at Lahti. From the guests, about 300 would have been coming from the Päijät-Häme region, 20 from capital area and around 80 from Europe, mostly from Brussels and Lisbon. The event would have lasted for about an hour in Sibeliustalo and had speeches and musical performances. After the event, a dinner was supposed to be held for the guests.

4.3.1.1 Goal and scope definition

The goal of the study is to calculate the CFP of live event that was supposed to be held for the opening of the Lahti European Green Capital 2021 -year. The results are then compared with the results from the calculation of the virtual event. By this, the organizers can evaluate and possibly modify their future events to be less carbon intensive.

Because the goal is to calculate the CFP of the event, the impact category used is climate change, the LCI results are reported as amount of greenhouse gases per functional unit. The characterization model used for the results is the Intergovernmental Panel on Climate Change (IPCC) baseline model of 100 years and characterization factor global warming potential (GWP100) for each greenhouse gas. The indicator result is then reported as kilograms of CO2-equivalents per functional unit. The functional unit of the assessment is the live event. The system boundary of the calculation is shown in figure 6.

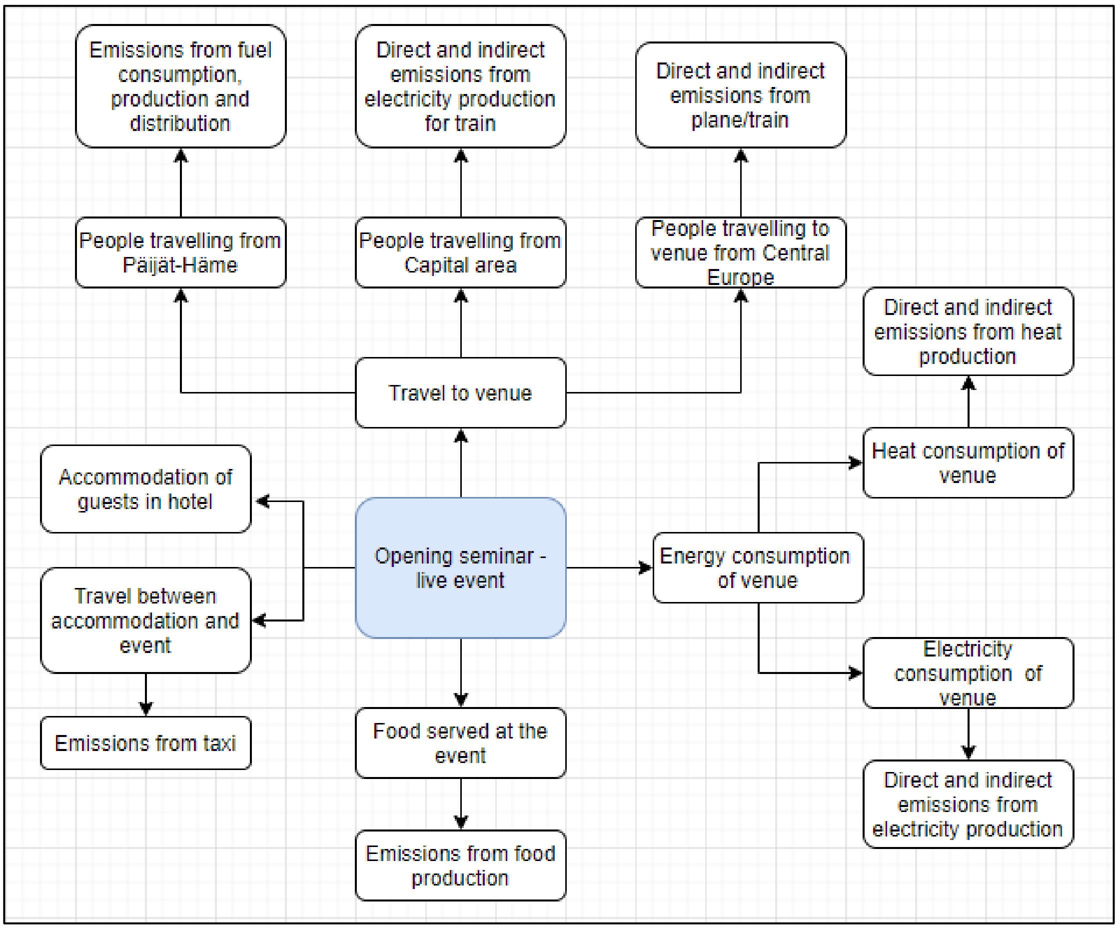

Figure 6. System boundary of the Live event calculation.

4.3.1.2 Inventory analysis

Since this CFP calculation is done by estimating the emissions based on plans, not actual results, lots of assumptions are made. In the inventory analysis, it is assumed that 10 people are travelling from Lisbon to Helsinki and 70 from Brussels to Helsinki, by plane and using train from airport to Lahti. People coming from capital area are assumed to travel to Lahti by train. People from Päijät-häme region are assumed to be coming to the event by private cars, two people per car. People coming to the event outside of Finland are assumed to be staying in a hotel for one night and flying back the next day.

Emissions from flying are estimated with the Finnish Environmental Institute calculator called Y-hiilari, which calculates the direct and indirect emissions. Direct emissions are based on Finnair CO_2-calculator and indirect emissions based in Eco-Invent 3.5 database information regarding the emissions from production and distribution of jet fuel. The results are averages for the most common plane types travelling on the routes. On top of the direct emission from flight, the indirect emissions from fuel production and distribution are included. The emission results for one person from the calculator are shown in table 12. It should be noted that the results only show the results from the use of jet fuel and does not take into account other GWP-effects of flying.

Table 12. Emissions for one person travelling to the event and back by plane

Route	**Distance (km)**	**Direct emissions (kgCO_2eq)**	**Indirect emissions (kgCO_2eq)**	**Total emissions (kgCO_2eq)**
Lisbon – Helsinki – Lisbon	6 740	567,5	90,3	657,8
Brussels – Helsinki - Brussels	3 302	278	44,3	322,3

For comparison, the emissions from a train journey from Lisbon and Brussels to Lahti were also calculated. For a train journey from Lisbon the route would be Lisbon – Madrid – Bordeaux – Paris – Brussels – Frankfurt – Hamburg – Copenhagen – Stockholm – Helsinki – Lahti, from which Stockholm – Helsinki leg would be covered by ship. From Brussels the train journey would be Brussels – Frankfurt – Hamburg – Copenhagen – Stockholm – Helsinki – Lahti, from which Stockholm – Helsinki leg would be covered by ship. The emission factor used for the train travel is the European Environmental Agency calculation of train travel in EU in the year 2018. The emissions factor of 33 gCO2eq/pkm includes both direct and indirect emissions (EEA, 2020). For the ship journey, the emission factor is for ferry on Baltic Sea based on LIPASTO-database. The distances travelled and emission factors used are shown in table 13.

Table 13. Emissions from train and ferry travel of one person

Route	**Distance (km)**	**Emission factor (gCO_2eq/pkm)**	**Direct emissions ($kgCO_2eq$)**
Lisbon – Lahti – Lisbon train	6 836	33	226
Stockholm – Helsinki – Stockholm ferry	800	99	79
Total	7 636		305
Brussels – Lahti – Brussels train	3 194	33	105
Stockholm – Helsinki – Stockholm ferry	800	99	79
Total			185

The emissions from travel of the 300 people coming from Päijät-Häme region, are estimated so that 100 people would be coming from Lahti area with public transportation and their average two-way distance would be 10 km. The rest would be coming with private cars with and the average two-way distance would be 15 km. The emission factor for bus travel is 37 gCO2eq/pkm and for a car 94 gCO2eq/pkm. (Lipasto, 2016) The emissions from fuel production and distribution are for fossil fuels 15 gCO2eq/MJ and for biofuel 13 gCO2eq. The results are presented in table 14.

Table 1. Emissions from people arriving to the event from Päijät-Häme

Direct emissions			
Emission source	**Travel distance (pkm)**	**Emission factor (gCO_2eq/pkm)**	**Emission $kgCO_2eq$**
Direct emissions from people travelling with a bus	1000	37	37
Direct emissions from people travelling with a car	3000	94	282
Indirect emissions			
Emission source	**Fuel consumed (MJ)**	**Emission factor (gCO_2eq/MJ)**	**Emission $kgCO_2eq$**
Emissions from production and distribution of fossil fuel	3 525	15	53
Emissions from production and distribution of biofuel	898	13	13
Total			385

Table 15 presents the emissions caused by the transport of performers and others needed for the organizations of the event and emissions from the direct electricity and heat consumption. Table 16 presents the indirect emissions caused by the use of electricity and fuel production and distribution.

Table 15. Direct emissions from event organization at venue

Emission source	**Travel distance (km)**	**Energy consumption kWh**	**Emission factor (gCO_2eq/km) (gCO_2eq/kWh)**	**Emission $kgCO_2eq$**
Venue electricity consumption	-	432	100	43,2
Venue heat	-	1 387	53,5	74,2
Direct emissions from transport related to event car	125	-	159	19,9
Direct emissions from transport related to event van	216	-	208	44,9
Total	341	1 081		135,2

Table 16. Indirect emissions from event organization at venue

Emission source	**Fuel consumption (MJ)**	**Energy consumption kWh**	**Emission factor (gCO_2eq/km) (gCO_2eq/kWh)**	**Emission $kgCO_2eq$**
Indirect emissions from venue electricity		432	15	6,5
Indirect emissions from transport, Fossil fuel	564		15	8,5
Indirect emissions from transport, Biofuel	144		13	1,9
Total				14,3

For the estimation of emissions caused by hotel accommodation, for Finland the Y-hiilari tool by Finnish Environmental Institute was used. The tool is based on ENVIMAT-model analysis of environmental effects of Finnish national economy material flows. (Seppälä et al, 2009)

For hotel accommodation in Central Europe, a hotel footprinting tool at www.hotelfootprints.org was used for estimation of average CFP of hotel stay for one room. The assumption is that all travellers reside in their own rooms and average stay of one night in Central Europe in 4 – 5 star hotel is 25 $kgCO_2eq$. The variance is large as is the difference between season, but the estimation is deemed accurate enough for this calculation. Guests travelling form Lisbon, before arriving in Finland, would stay two nights in hotels and one night in the ferry from Stockholm to Helsinki. From Brussels, guests would stay in hotel one night and one night in the ferry. They all would stay in a hotel in Lahti for one night and leave the next day and have similar accommodations on the way back. The table 17 shows the emissions from hotel stays

Table 17. Emissions from hotel accommodations

Hotel accommodation	**Nights stayed**	**Price of stay (€)**	**Emission factor ($kgCO_2eq$ / €)**	**Emissions ($kgCO_2eq$)**
Finland	80	100	0,5	4 000
Hotel accommodation	**Nights stayed**	**Emissions, room for one night ($kgCO_2eq$)**		**Emissions ($kgCO_2eq$)**
Central Europe	180	25		4 500
Total	260			8 500

Table 18 shows the emissions from the dinner menu, that was supposed to be served tt the event. Most of the emission factors for the foods are from Foodweb – project which is a project that studied the environmental impacts of food production around the countries with shoreline on Baltic Sea. For alcohol, the emission are calculated with data by Weidema, Saxcé & Muñoz, 2016.

Table 18. Direct emissions from event organization at venue

Food course	**Emissions per person ($kgCO_2eq$/person)**	**Attendance (Persons)**	**Emissions ($kgCO_2eq$)**
Oat bread and parsnip butter	0,05	400	21,7
Smoked roach mousse, dill pancakes and pickled cucumber	0,32	400	126,4
Lamb sirloin, broad bean puree, potato fondant	1,57	400	626,8
Buckthorn ice cream and chocolate mousse	0,13	400	51,8
Drink	0,05	400	20
Wine, two pours	0,06	400	24
Coffee	0,04	400	14,2
Total	2,21	400	885

4.3.2 Virtual event

The virtual event was organized online as Youtube Live stream and was open to everyone to watch. The event lasted for 45 min. The emissions from virtual event are coming from the energy consumption of the whole chain of equipment used in data transfer from server to the consumer electronics while streaming a video.

4.3.2.1 Goal and scope definition

The goal of this case was to calculate the carbon footprint of the virtual opening seminar of the Lahti European Green Capital- year. There are several studies, with different scopes regarding the energy consumption of data transfer. Coroama et al (2015) state that when calculating the energy intensity of data transfer, the energy intensity calculation should be divided into two main categories: the IP core network and a subsystem composed of access network and consumer premises equipment. For the IP core network the energy intensity should be calculated by the data transferred and for the access network and CPE based on the time they are used. On top on these, the energy consumption of the consumer electronics used to watch the video need to be included. The system boundary of the calculation is shown in figure 7.

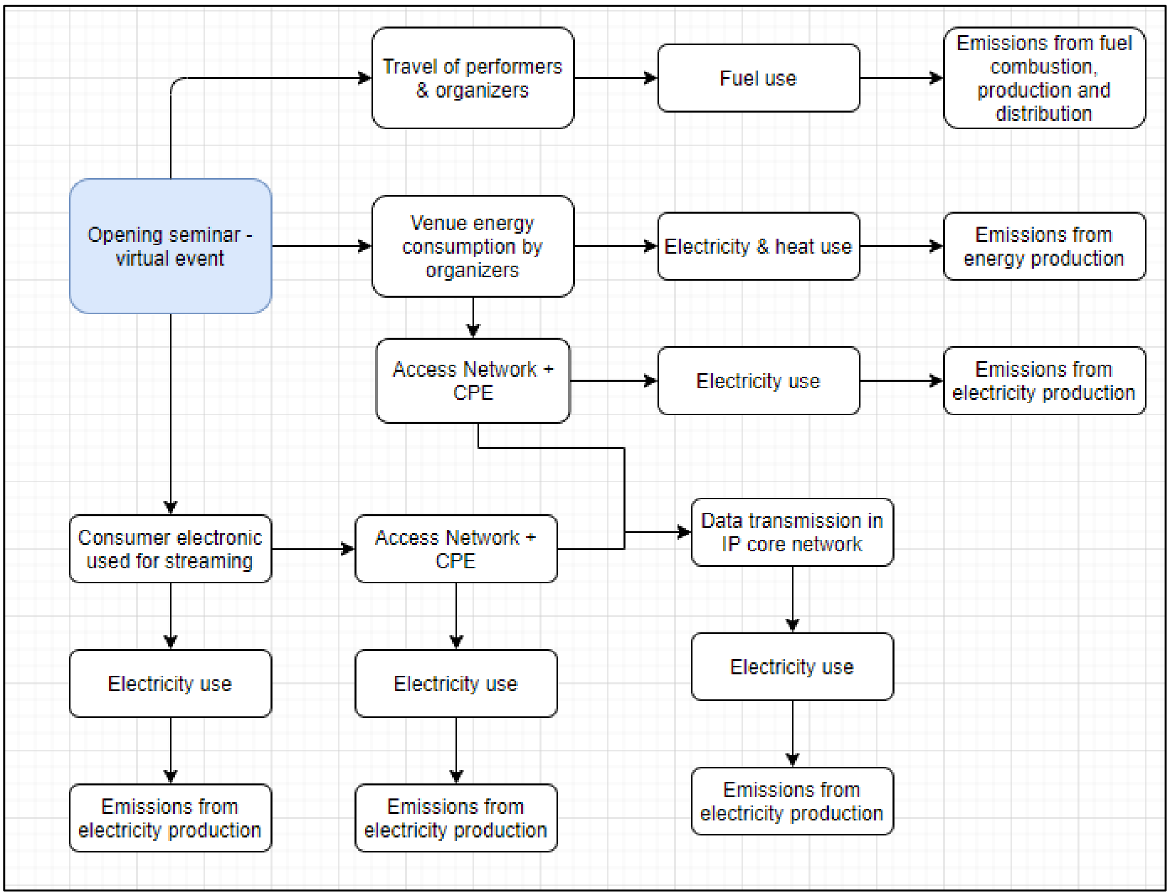

Figure 7. System boundary of the virtual event calculation.

Because the goal is to calculate the CFP of the event, the impact category used is climate change, the LCI results are reported as amount of greenhouse gases per functional unit. The characterization model used for the results is the Intergovernmental Panel on Climate Change (IPCC) baseline model of 100 years and characterization factor global warming potential (GWP100) for each greenhouse gas. The indicator result is then reported as kilograms of CO2-equivalents per functional unit. The functional unit in this case is the virtual entire event.

4.3.2.2 Inventory analysis

The event was organized as an online event, and it was viewable from Youtube for 14 days after the event. The data regarding views was collected from Google analytics. The data contains total amounts of views, the countries of origin for the views, the length of played video per country and device that was used to watch the video. The amount of total views was 5241, and total time watched was 853 h. The results are calculated based on the time that the event was watched, which was on average 9:45 min per view. The data used is presented in more detail in table 12. The event was organized so that minimal amount of people were attending the Sibeliustalo venue. The transport related to the organization and energy consumption of the venue was included in the calculation.

Study by Yan et al (2019), differentiates data transfer types based on the type of activity performed by smartphones. This applies to other ICT-appliances such as tablets and laptops regarding the data transfer system and which services in the transfer system consume electricity. In video play from cloud server, the system has four subsystems that consume electricity: device used to watch video, access network (mobile or landline), core network and data center.

A model structure of the internet is shown in figure 5. The study by Coroama et al. (2015), finds that the largest energy consuming parts of data transfer network are the metro and access networks. Undersea cables have such large transfer capacities that the energy intensity per GB is significantly lower than networks with multiple nodes that the data is transferred through to the access network and ultimately to the end user device. The study suggests a model of calculating the energy intensity of data transfer to be divided into core IP network energy intensity (metro & long haul), energy intensity of CPE and access networks and end user appliances.

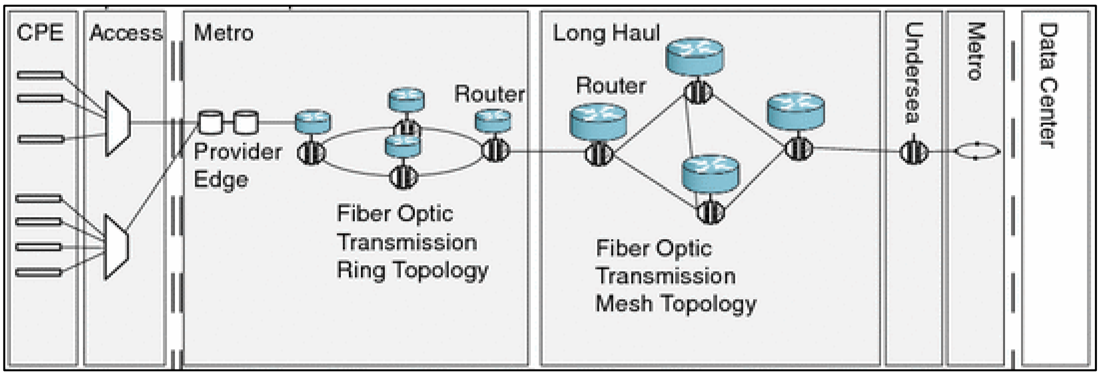

Figure 5. Model structure of the internet. (Coroama et al., 2015)

Coroama et al. (2015) defined the average power use of the access network and CPE (customer-premises equipment) as 52W, when they take into account modems and Wi-Fi routers. The study comprehensively estimated the average use of the equipment active and in standby mode.

The data requested by users of streaming services is distributed to the users by using Content Distribution Networks (CDNs). The purpose of CDNs is to bring the media files geographically closer to the end users, which leads to lower latency and reduces load on core networks. The idea behind CDNs is that the media files are not transferred from data centers every time a user requests for the file. Once a media file is for the first time requested in an area with CDN, a copy of the file is saved to the CDN server, and when another users requests it, it is delivered from the CDN, instead of original location in data centers. This leads to the local networks sharing most of the data instead of the core networks. Google owns its own CDN called Cloud CDN, which is used for Youtube. (Google Cloud, 2020) In a study by Shebabi et al (2014) because of the CDNs, the data centers share of the energy demand of data center in the streaming services process was calculated to be less than 1%.

The energy consumption of the transmission network system used for the calculation is derived from study “Electricity Intensity of Internet Data Transmission” by Aslan et al, 2017. The study analyses different studies done about energy intensity of data transmission between 2000 and 2016. Different studies analyzed varied significantly by the scope of the study, and the value used for internet data transmission access in this thesis was the value describing the energy intensity of transmission network only, excluding such activities as construction of the network. The estimated energy consumption value according to the data gotten from TeliaSonera company in Sweden in 2016 was 0,023 kWh/GB. In an interview given by Stanford University professor Jonathan Koomey, (part of the 2017 study), he estimated that the energy intensity of data transfer in 2020 via IP core network would be around 0,015 kWh/GB including data centers and CDNs, which was used for the calculation. (Datacenter knowledge, 2020)

The event was organized as Youtube live event. Youtube data transfer is calculated based on average transfer rates by Stegner (2019). The values used are shown in table 19. For this calculation, it is assumed that the videos are watched on Full HD 1080p 30fps quality, which is the standard quality in Youtube.

Table 19. Data transfer amounts for different video qualities on Youtube (Stegner, 2020)

Video quality	Youtube data transfer per viewer (GB/h)
480p	0,563
720p, 30 fps	1,24
720p, 60 fps	1,86
1080p, 30 fps	2,03
1080p, 60 fps	3,04
1440p, 30 fps	4,28
1440p, 60 fps	6,08
2160p, 40 fps	10,58
2160p, 60 fps	15,99

The exact energy consumption of the venue could not be measured, so the energy consumption of the events venue was estimated by dividing the yearly energy consumption by the time of the event. The event is estimated to last 3h including setting up and disassembly. The energy consumption of Sibeliustalo was gotten from LUT University master's thesis regarding the carbon footprint of Lahti symphony orchestra by Virolainen (2015). In 2017 the venue changes their lighting to LEDs and the operators told Evento-magazine that it cut the electricity bill by one third. The direct energy consumption of the venue is shown in table 20. Table 20 also includes the direct emissions from the transport required for the virtual event.

Table 20. Direct emissions from event organization at venue

Emission source	**Travel distance (km)**	**Energy consumption kWh**	**Emission factor (gCO_2eq/km) (gCO_2eq/kWh)**	**Emission $kgCO_2eq$**
Venue electricity consumption	-	259	100	25,9
Venue heat	-	832	53,5	44,5
Direct emissions from transport related to event car	125	-	159	19,9
Direct emissions from transport related to event van	216	-	208	44,9
Total	341	1 081		135,2

Indirect emission related to the energy consumption and transport related to the events are shown in table 21. The indirect emissions include the emissions from fuel production and distribution and infrastructure emissions and grid losses.

Table 21. Indirect emissions from event organization at venue

Emission source	**Fuel consumption (MJ)**	**Energy consumption kWh**	**Emission factor (gCO_2eq/km) (gCO_2eq/kWh)**	**Emission $kgCO_2eq$**
Indirect emissions from venue electricity		259	15	3,9
Indirect emissions from transport, Fossil fuel	564		15	8,5
Indirect emissions from transport, Biofuel	144		13	1,9
Total				14,3

For the data transfer of the views, because the data transfer energy intensity value used is the 0,015 kWh/GB, which includes the transfer through the whole distribution network. The energy consumption is assumed to be country specific, based on the amount of data transferred to each country. Since there were six countries that were separable from the data, the EEA 2019 emission factors were used for each country and the rest were calculated with European mean emission factor. The results can be seen from table 22.

Table 22. The emissions from data transfer

Viewer origin	**Views**	**Viewing time (h)**	**Data transfer rate 1080p quality (GB/h)**	**Data transferred (GB)**
Finland	4634	775,7	2,03	1574,7
Great Britain	24	2	2,03	4,1
France	15	2,9	2,03	5,9
Sweden	15	0,9	2,03	1,8
Denmark	14	3,2	2,03	6,5
Hungary	10	0,8	2,03	1,6
Other	529	6,75	2,03	137
Total	5241	853	2,03	1731,6
Viewer origin	**Energy intensity of data transmission (kWh/GB)**	**Electricity consumption (kWh)**	**Emission factor (gCO_2eq/kWh)**	**Total emission ($kgCO_2eq$)**
Finland	0,015	23,6	86	2,03
Great Britain	0,015	0,06	228	0,01
France	0,015	0,09	52	0,005
Sweden	0,015	0,03	8	0,0002
Denmark	0,015	0,1	126	0,012
Hungary	0,015	0,02	212	0,05
Other	0,015	2,5	275	0,57
Total	0,015	26,5		2,6

For the CPE and access network, the electricity consumption is calculated by the hours that the equipment were used to transfer the data. The emission factor is weighted average of all emission factors of emission factors used for the different countries. The weighting was based on the time watched in each country. The results from CPE and access network emissions is shown in table 23.

Table 23. The emissions from CPE and access network use

Viewing equipment	**Viewing time (h)**	**Power (W)**	**Energy consumed (kWh)**	**Emission factor (gCO_2eq/kWh)**	**Emission ($kgCO_2eq$)**
CPE+ Access network	868,8	52	44,4	106,5	4,2

The Google Analytics data also contained data related to the appliances used to watch the event. The data does not specify which appliances were used in which countries. The end user appliance average power demands are estimations from Energy Use Calculator (2021). The weighted average emission factor was used to calculate the emissions from end user appliance electricity consumption. The results from the end user appliance emissions are presented in table 24.

Table 24. Emissions from user appliance use

Viewing equipment	**Views**	**Viewing time (h)**	**Power (W)**	**Energy consumed (kWh)**	**Emission factor (gCO_2eq/kWh)**	**Emission ($kgCO_2eq$)**
Laptop	1787	351,4	60	21,1	106,5	2,2
Smartphone	2694	293,8	0,7	0,2	106,5	0,02
Tablet	475	100,1	15	1,5	106,5	0,2
Smart TV	281	106,9	100	10,69	106,5	1,1
Total	5241	853		33,5		3,6

5 CARBON FOOTPRINTS OF EVENTS

In this chapter, in section 5.1 the impact assessments for the cases are carried out. In section 5.2, sensitivity analyses for all three cases are carried out.

5.1 Impact assessment

5.1.1 Case 1, Pelicans ice-hockey match mobility

The results from the calculation from steady increase of public transportation calculation is shown in table 25 and results for Pelicans buses calculation in table 26.

Table 25. Results of the steady increase of public transportation use.

Distance travelled to the game and back by bus instead of car (%)	Distance travelled to one game and back by bus instead of car (km)	Number of people travelling to the game with bus instead of car	Percentage of all game spectators (%)	Emission reduction per game (tCO_2eq)	Emission reduction from travel emissions of 1 game (%)	Emission reduction from total emission of a game (%)
10	5 851	251	6	0,5	5,2	3,7
20	11 702	501	13	1	10,4	7,5
30	17 554	752	19	1,6	15,6	11,2
40	23 405	1002	25	2,1	20,1	15,0
50	29 256	1253	32	2,6	25,9	18,7
60	35 107	1503	38	3,1	31,1	22,5
70	40 959	1754	44	3,6	36,3	26,2
80	46 810	2004	50	4,2	41,5	29,9
90	52 661	2255	57	4,7	46,7	33,7
100	58 512	2505	63	5,2	51,9	37,4

As can be seen from results in tables 25, increasing the use of existing public transportation could reduce more than a third of the carbon footprint of the ice hockey game, if nobody would use a private car when travelling to the game. This in extremely unlikely, but even if smaller shares like 30% of people would change to public transport, the decrease in carbon footprint would be significant (11,2%).

Table 26. Results of the Pelicans-bus calculation

Emission source	Ahtiala/ Kunnas tCO_2eq	Pirttiharju/ Kärpänen tCO_2eq	Nastola/ Villähde tCO_2eq	Hollola tCO_2eq	Total tCO_2eq
Emissions from cars tCO_2eq	0,47	0,25	0,80	0,5	2,1
Emissions from production and distribution of fuel tCO_2eq	0,1	0,1	0,13	0,1	0,43
Emissions from buses driving empty tCO_2eq	0,17	0,22	0,19	0,22	0,80
Emissions from buses driving full tCO_2eq	0,17	0,12	0,27	0,15	0,69
Net reduction tCO_2eq	0,04	-0,19	0,21	0,05	0,11
Net reduction from total emission of 1 game %	0,4%	-1,9%	2,1 %	0,5%	1,1 %

Using charter buses for the areas where large amounts of people are coming to the game from, does not have significant benefits. The impact can be even negative, if the travel distance is short (like in Pirttiharju/Kärpänen case), and only in long distances driven in main roads would provide significant benefits.

5.1.2 Case 2, Park of Experiences and landmark illumination

<u>Total emission of the Park of Experiences and landmark illumination</u>

The total emissions from the Park of Experiences and landmark illumination is shown in table 27.

Table 27. Results from the Park of Experiences calculation

Emission source	**Emissions $kgCO_2eq$**	**Share of total emission (%)**
Emissions from transportation for Park of Experiences	238	9,2
Emissions from transportation for landmark illumination	178	6,9
Emissions from direct electricity use of the park	1 438	55,5
Emissions from direct electricity use of landmark illumination	468	18,1
Indirect emissions from total electricity use	215	8,3
Emissions from waste management of the Park of Experiences	52,1	2
Total emissions	2 589	100

For Case 2, the largest emission sources found were the direct electricity use of the park and landmark illumination. Together these two composed of almost 81,7% of all emissions caused by the park. As a percentage, significant amount of emissions were caused by the transport of the equipment to the park and back by vans and truck combusting diesel, although the total emission were low.

5.1.3 Case 3, Live event vs virtual event

The results from the live event calculations are presented in tables 28 and 29. The difference between the two tables, is the mode of transport from Lisbon and Brussels is flying in table 28 and rail & ferry combination in table 29. For either mode of transport, the transport composes of clear majority of the emissions produced. For train & ferry travel, the emissions caused by accommodation services increases, because the travel distance increases significantly, and it is assumed that there needs to be hotel stays between the rail transport.

Table 28. Results from the live event calculation with flights

Emission source	**Emissions (tCO_2eq)**	**Share of total emission (%)**
Flights	29,1	84,2
Other transport & travel	0,5	1,4
Use of venue	0,1	0,3
Accommodation	4	11,6
Dinner	0,9	2,6
Total emissions	34,6	100

Table 29. Results from the live event calculation with rail & ferry travel instead of flying

Emission source	**Emissions (tCO_2eq)**	**Share of total emission (%)**
Rail & ferry	16,0	61,5
Other transport & travel	0,5	1,8
Use of venue	0,1	0,5
Accommodation	8,5	32,8
Dinner	0,9	3,4
Total emissions	26,0	100

The results for the calculation of virtual event is presented in table 30. The increase in energy consumption of data transfer rises linearly, when the length of video watched in total increases.

Table 30. Results from the virtual

Emission source	**Emissions tCO_2eq**	**Share of total emission (%)**
Transport and travel	0,075	46,6
Use of venue	0,074	46,0
Data transfer	0,012	7,4
Total emissions	0,161	100

5.2 Sensitivity analysis

The purpose of sensitivity analysis is to alter the variables in the inventory analysis to highlight any uncertainties in the data and analyze how they affects the results of the calculation. Variable that are thought to have the highest uncertainties and to have significant impacts on the results are chosen. For all cases, the sensitivity analysis is made on case specific variables.

5.2.1 Case 1, Pelicans ice-hockey match mobility

The emission factor used for private cars in the calculation of Pelicans game mobility CFP, was the Lipasto-database value for the car fleet in 2016. According to the website Liikennefakta.fi, which is the official website for Finnish Traffic and Communications Agency, the average emissions for the car fleet in Finland in 2020 was 153,5 gCO_2eq/km.
The assumption was that 15% of the fuel was of biogenic origin, but since the distribution obligation has increased the biogenic share to 20% in 2021, it is used for the sensitivity check. The fossil share of the average emission is 80%, which is 122,8 gCO_2eq/km. From the total energy consumption 2,3 MJ/km, 1,8 MJ/km is for fossil fuels and 0,5 MJ/km for biofuel. For the production and distribution of fossil fuel, the value use is 15 gCO_2eq/MJ and for biofuel 12 gCO_2eq/MJ. So the emissions from production of fossil fuel is then 27,6 $gCO_2eq/$ km and for biofuel 5,5 gCO_2eq/km. By this, the emission factor is 155,9 gCO_2eq/km. The total emission of transport of one game with the newer emission factor drops from 10,02 tCO_2eq to 9,32 tCO_2eq.

The same calculations for the reduction of emission with steady increase in use of public transportation are shown in table 31.

Table 31. Results of the steady increase of public transportation use with 2020 emission factor.

Distance travelled to the game and back by bus instead of car (%)	Percentage of all game spectators (%)	Emission reduction per game (tCO_2eq)	Emission reduction from travel emissions of 1 game (%)	Emission reduction from total emission of a game (%)
10	6	0,4	4,7	3,1
20	13	0,9	9,3	6,3
30	19	1,3	14,0	9,4
40	25	1,7	18,7	12,5
50	32	2,2	23,3	15,7
60	38	2,6	28,0	18,8
70	44	3,0	32,6	21,9
80	50	3,5	37,3	25,1
90	57	3,9	42,0	28,2
100	63	4,3	46,6	31,3

The use of the emission factor for the year 2020, changes the results somewhat because the baseline emissions of the private cars are reduced. The variance in the emission reduction results is then 17,3%. This means that while the car fleet renews and the use of biofuels and electric vehicles increase, the reduction in emissions compared to buses using fossil fuels decreases. As electrification and biofuel use increase in public transport, the difference can remain similar in terms of percentage, but the total emissions decrease. This all depends on the rates of car fleet electrification and biogas utilization, which are developing rapidly but geographically unevenly.

5.2.2 Case 2, Park of Experiences and landmark illumination

There are two main uncertainties identified in the Park of Experiences calculation, the emission factor used for the electricity and the electricity use of the landmark illumination, both of which are expert estimations, and not exact. Figure 6 shows the variation of the electricity consumption and real time emission factor during the time the Park was constructed and operated. The data regarding the electricity consumption was provided by Lahti Energia in one-hour intervals and the emission factor variability is provided by the open data from Finnish core network company Fingrid, which provides estimation of the emission factor in three-minute intervals. The emission factor is for all electricity consumed in Finland in any moment. The emission factor was calculated into one-hour average to fit the accuracy of the electricity consumption. Figure 7 shows the difference between the emissions, calculated with both fixed and real-time emission factors. The total emissions with fixed emission factor for the electricity consumption was 1438 kgCO$_2$eq and with the real-time emission factor 1307 kgCO$_2$eq.

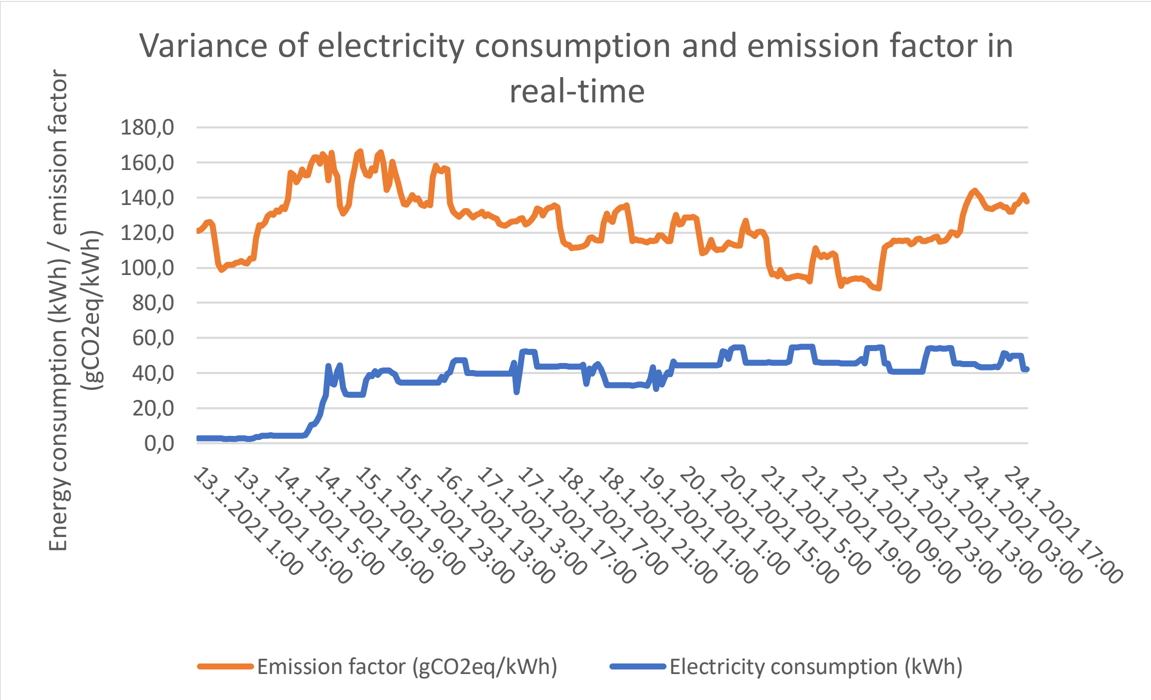

Figure 6. Variance of electricity consumption and real-time emission factor

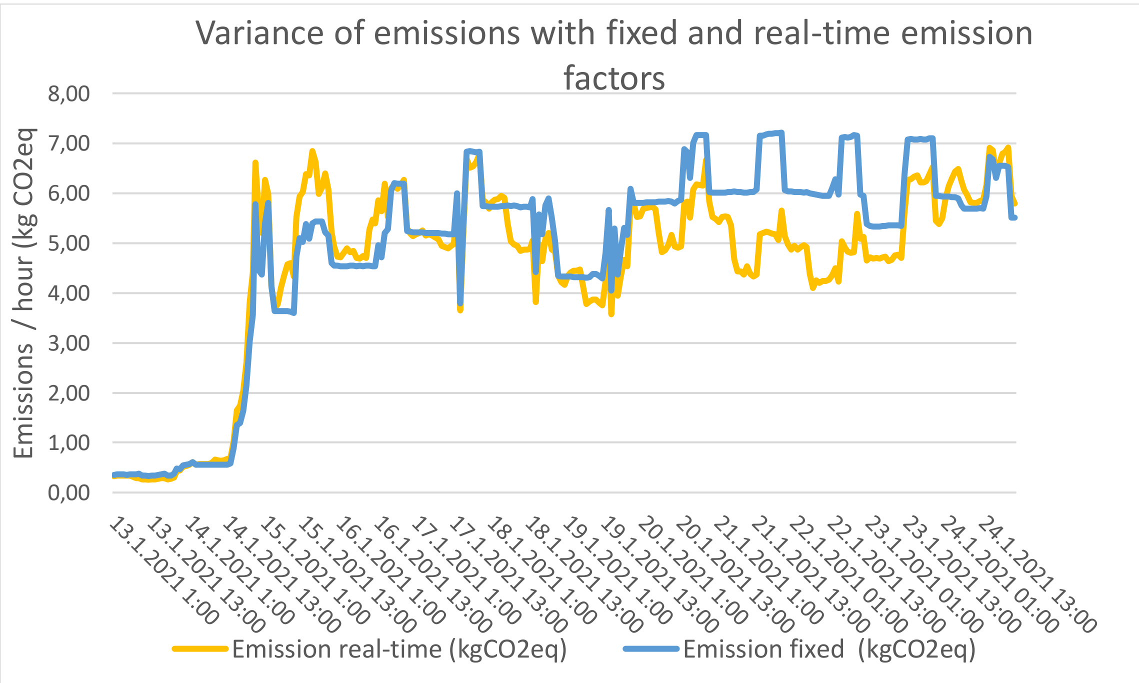

Figure 7. Variance of emissions with fixed and real-time emission factors

Figure 8 shows the variance of emissions when power of the equipment used is increased and emission factor is changes from the three year moving average grid electriciy (131 gCO_2eq/kWh) from to average value of consumed electricity in Finland (124 gCO_2eq/kWh) for the time of the event based on the Fingrid data.

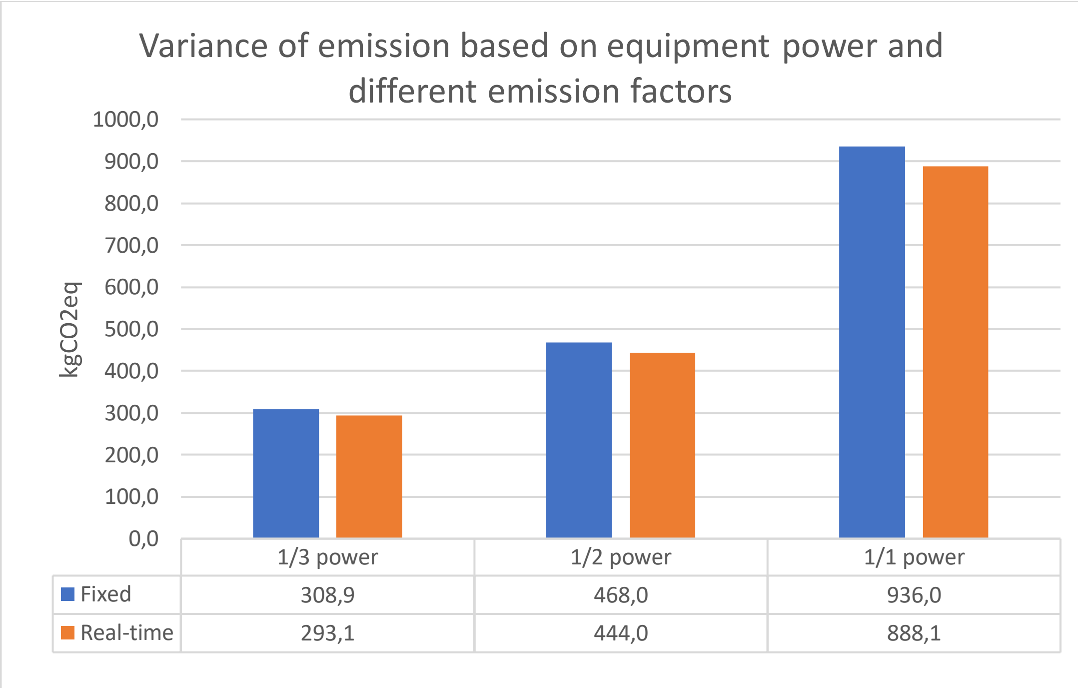

Figure 8. Emission variance between different power demands of the equipment with fixed and real time emission factors

With these two variables changed, the carbon footprint from direct energy consumption would change between 1,3-2,2 tCO_2eq. The largest difference comes from the power consumption of the landmark illumination equipment, the difference between fixed and real-time emission factor is about 0,024tCO_2eq. The variation coming from the change in the equipment power consumption is about 0,6 tCO_2eq. The variance with the two different emission factors is 5,4 %. For the different equipment power consumption, the variance from the total emission is 23% from the total emission.

5.2.3 Case 3, Live event vs virtual event

Live Event

For flying, the emissions are calculated with certain plane type. With Finnair emission calculator, there are three types of planes flying between Lisbon and Helsinki, and six types of planes between Brussels and Helsinki. The emission per person vary quite significantly.

Figure 9 presents the differences in emission for all guests from Lisbon and Brussels depending on the plane type.

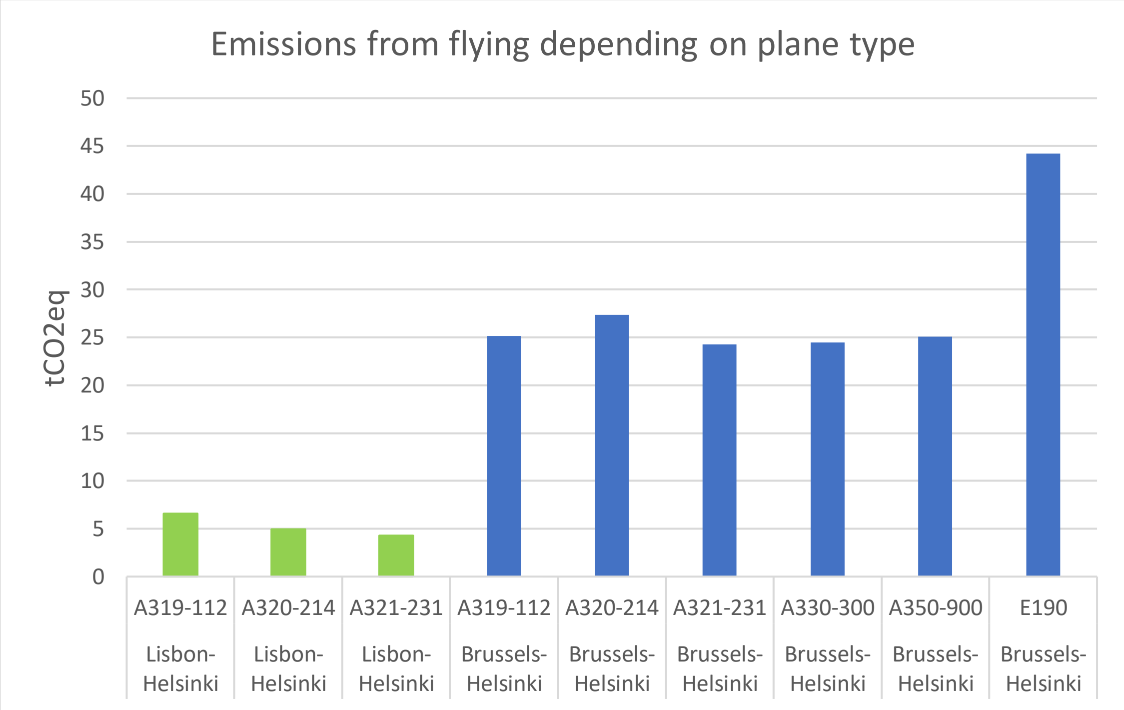

Figure 9. Emissions for all European guests with different plane types

The total variation in emissions between the possible plane type use for the journeys is between 18,6 tCO_2eq and 50,8 tCO_2eq. The variation is quite significant, but the plane type used for the calculation was the most common one, for the journey. The highest variation is coming from a plane type rarely used (E190). With disregarding the E190, the variance is 5,4 tCO_2eq which is 15,6% of the total emission from the event.

The emission factor for trains used is 33 gCO_2eq, which is the EU average in 2018, but quite high for trains in western and northern Europe. For example, in France intercity trains emission factor is 11,8 gCO_2eq/pkm (Calculation of CO2 emissions on your train journey, 2020). IEAs emission factor for non-urban trains in 2019 in the whole world is 14 gCO_2eq/pkm, which is used for the sensitivity check. (IEA, 2020)

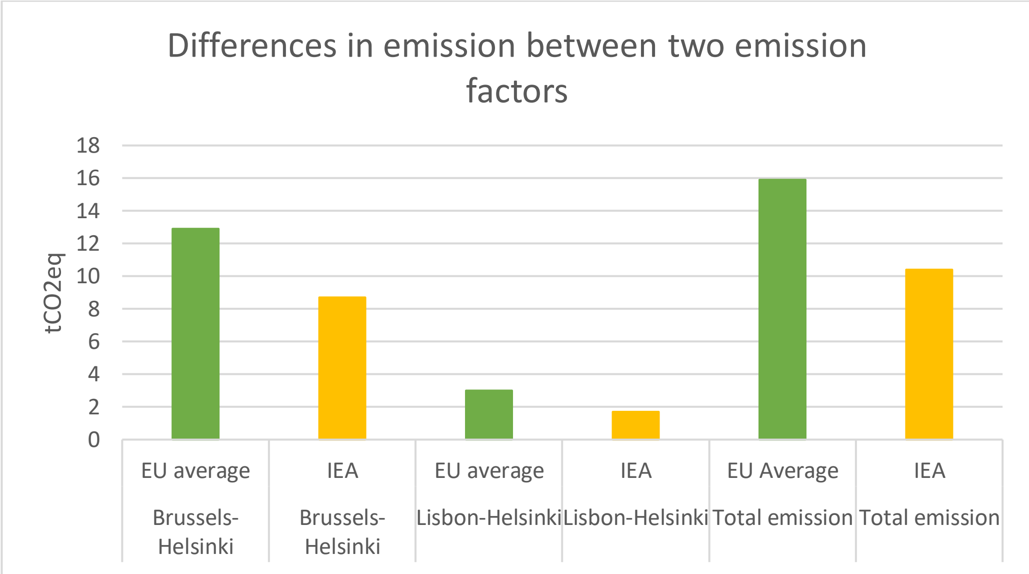

Figure 10. Emissions from train and ferry travel with different emission factors

The train travel emissions are dependent on the type of train used and how large portion of the journey is done with combustion of fossil fuels instead of electricity. The variation between the results from two emission factors is 5,5 tCO_2eq, which is about 21,1 % of the total emission.

Virtual event

For the virtual event, the subsystem with most variance in emissions is the emissions from data transfer. The views, their country of origin and length are known, but the video quality of the stream can alter depending on the viewer. The default video quality was assumed to be Full HD 1080p 60 fps video, which is the most common quality for Youtube videos.
In figure 11, the emissions from data transfer of the event are shown. In figure 12, the same differences of video qualities are shown with change in watch time of the stream so that all viewers would have watched the whole stream.

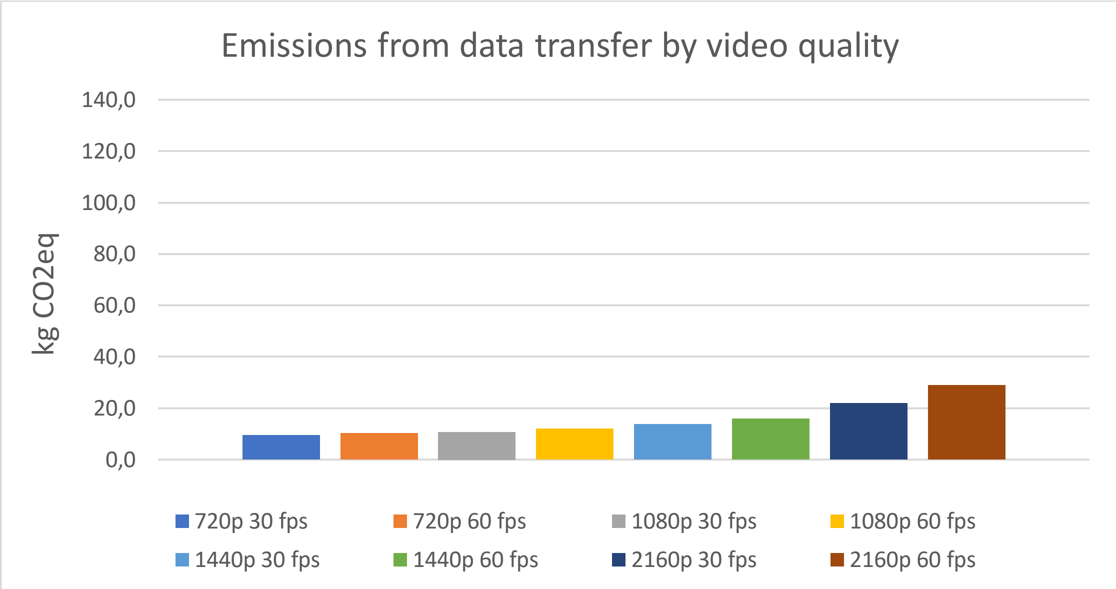

Figure 11. Emissions of data transfer by video quality, with the recorded watch time

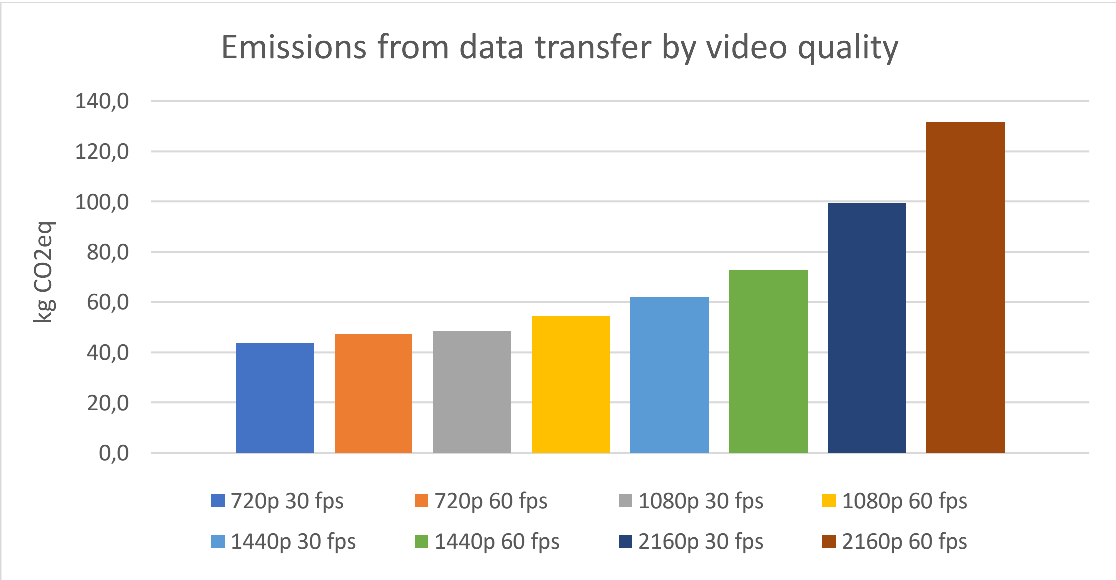

Figure 12. Emissions of data transfer by video quality, with all viewers watching the whole stream

From figure 11 and 12, the gradual increase on the emissions caused by data transfer can be seen. The increase in emissions is becoming faster and faster when the video quality is improving and data transfer is increased. The percentage from previous quality is also higher each time the quality increases, unlike with the view count, for which the increase in emissions is linear.

6 CONCLUSIONS

The purpose of this thesis was to calculate and compare carbon footprints of different kinds of events or parts of the events and try to find actions that could have significant positive effects on reducing the carbon footprints of events. This chapter presents the conclusions and answers to the research questions for each case. The research question for the first case, Pelicans ice-hockey match audience mobility is:

Case 1: how could the CFP of ice-hockey game be mitigated by increasing the amount of public transportation used to travel to the games

According to the results, the most efficient way to reduce the carbon footprint of an ice-hockey game would be the increase of public transport use and use of light traffic options. If even small percentage like 10% of people travelling by private car would change to public transport for the whole season, the yearly effect would be significant (around 17 tCO_2eq).

The research question for the second case, The CFP on the Park of Experiences is:
Case 2: What are the largest contributors to the CFP in outside audiovisual event, and what could be done to mitigate the emissions.

For an event like the Park of Experiences, the largest contributor to emissions inside the system boundary was found to be the direct electricity consumption, which accounted for more than four fifths of the emissions. Unfortunately, the travel of the visitors to the park had to be delimited outside the system boundary because of the lack of data regarding the transport method. Considering the literature regarding events in general, the emission from travel would probably be the largest contributor to emissions, since the attendance was estimated as 38 000 – 49 000 and the event was organized during winter. The total carbon footprint of the event was about 2,6 tCO_2eq, which is very low for an event. Single visitors carbon footprint was about 68-53 gCO_2eq.

The research question for the third case, live- events vs virtual events is:
Case 3: How does the CFP of live and virtual events differ, and what are the largest contributors to each events CFP.

The largest contributors to CFP on live events in this thesis and generally in literature is almost always the travel of the attendees. With virtual events, the travel is not happening, which in most cases reduces the carbon footprint to very small size in comparison to live events. The use of venue and logistics related to the organization of an event differ somewhat, but the difference is not very large. This is of course highly dependent on the type of an event. The energy consumption from data transfer is not very significant in virtual events that are small scale, but it can increase significantly as view count rises. The problem in addressing the problem of data transfer emissions is that most of the emissions from the data transfer are caused by the local metro and access networks and consumer electronics, which puts emphasis on the grid electricity in the country that the stream is viewed from.

The whole thesis:
What are the main emissions sources of events and how could their impact be mitigated?

The difficulty in finding generalized results for the biggest sources of emissions for events, comes from the variety of different kinds of events. Event as a term tells very little about what is happening. The only thing the term event tells, is that somebody is organizing something, that many people find interesting and worth spending their time and/or money on. Events range from online and small inside events with dozens of people, to outside megaevents that host tens of thousands of people. Still, there are some common ground between most events, that are big enough to cause significant environmental impacts. The nature of events is the large amounts of participants, which means that small effects that are caused by all individuals, multiply by the number of attendees and can have significant impacts. The continuous focus on communicating the effects of different individual choice that people make, in terms of their mobility, food and other mundane areas of life, should be emphasized. Also, the event industry could use more guidance from experts and demands from the public, to make the transition to low carbon choices in implementation of events.

7 DISCUSSION

The carbon footprint of the Lahti Green Capital -year opening events were calculated in this thesis. On top of that, some comparative calculations were made especially regarding choices in mode of transport. The events included were all different types and so were the scopes and system boundaries. For the most part, literary sources were used for the emission factors, some were also calculated and/or interpolated from literature factors. All three cases had their own research question, that were related to the specific cases and the overarching research question was regarding emissions of events in general.

For the first case, the conclusions were that the increase in the use of existing public transport as a mode of transport to the games, would have significant impacts on the CFP. The original idea was to see how a public transport ticket included in the game ticket, would affect the share of people using bus instead of private cars. Because of the COVID-19 pandemic caused the games to be played without an audience, the effect could not be estimated. The charter-buses from certain areas, did not have significant benefits regarding the CFP.

For the second case, the CFP on the Park of Experiences was calculated to around 2,1 tCO_2eq, which is very low. The calculation is lacking the emissions from mobility of the audience, again because of the COVID-19 pandemic and changes to the implementation. The venue was easily accessible, but it is estimated that significant portion of the attendees would have visited the park with private cars, having significant effect to the CFP. The extent of the impact is not exactly known.

For the third case, the CFP from the virtual event was found to be just a fraction of the live event. The energy intensity of data transfer has decreased significantly in recent years as have the carbon intensities of grids. The largest contributor to the live event was from travel abroad, with both flight and rail & ferry combination options.

The transport related to events, especially from the visitors, is the largest contributor to event carbon footprint in most cases. The difficulty in reducing event carbon footprint is that the possibility to influence the mode of transportation the visitors use, without making transport to the event too hard, is very limited. The venue location plays a large role as does cooperation with local public transport companies, and local municipality or city.

Considering the research by Wong et al (2014), the emphasis for the organizers trying to mitigate their climate impacts should be on the communication of the impacts of the attendee's choices. Environmentally sound, low carbon event can be a benefit for the organizers since research has showed that environmentally conscious people are willing to pay more for products and services that are seen as environmentally benign. Instead of carbon offsetting, including transport into the price of an event is a practice that is somewhat already utilized, but with more co-operation between transport providers and event organizers could be made more attractive to consumers. Carbon offsetting could also be utilized for the emissions that cannot be reduced. Recent developments in carbon offsetting in Finland, in Finnish fields used for food production would also bring the aspect of local action and improve the environmental and fiscal sustainability of Finnish food production. This could be a significant image booster for events, because of carbon offsetting to the other side of the world seems distant and vague to people not familiar with the process.

The carbon footprint of events will be decreasing constantly as the grid carbon intensity keeps decreasing and the car fleet will be renewing and electrifying. There is still multitude of actions possible and necessary to reduce the environmental impacts in short term. Since the largest single contributor to almost any event is the mobility of the attendees, there are no single technology or other solution. People need to be informed more regarding their choices and their impacts in ways that speak to them and sufficient alternatives need to be offered.

The increase in online events and improvement in the video quality of the broadcasts is a continuing trend and are contributing to the increase in the emissions from data transfer. The emissions from data transfer are mainly coming from both ends of the data transfer route, which means that the emissions are highly dependent on the geographical location the broadcasts are watched from and the amount of data transferred, but in most cases are significantly lower than emissions from live-events.

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APPENDIX 1

Example of Pelicans bus calculation

Cars

People travelling to the game 282, and average amount of people in a car is 2. So 141 cars will travel to the game and the average distance to game and back is estimated as 20km. The distance covered by people arriving by cars is 2820 km. The emission factor is the 168 gCO2eq as introduced earlier.

$$Emission\ from\ cars = 2820\ km * 168\ \mathrm{gCO2eq} = 0{,}474\ \mathrm{tCO2eq}$$

Buses

282 people, requires 6 buses.

$$Person\ kilometeres\ travelled = 282\ p * (2 * 14\ km) = 7\ 896\ pkm$$

$$Distance\ buses\ drive\ empty = 6\ * 30\ km = 180\ km$$

$$Distance\ buses\ drive\ full = 6\ * (2 * 14)\ km = 168\ km$$

$$Emissions\ from\ driving\ empty = 180km * 923\frac{\mathrm{gCO2eq}}{\mathrm{km}} = 0{,}166\ \mathrm{tCO2eq}$$

$$Emissions\ from\ driving\ full = 7896\ pkm * 22\frac{\mathrm{gCO2eq}}{\mathrm{pkm}} = 0{,}174\ \mathrm{tCO2eq}$$

$$Fuel\ consumption = \left(180\ km * 39{,}1\frac{l}{100km}\right) + \left(168\ km * 46{,}2\frac{l}{100km}\right) = 148\ l$$

$$Emissions\ from\ fuel\ production\ and\ distribution$$
$$= 148l * 0{,}824\frac{kg}{l} * 43{,}2\frac{MJ}{kg} * 18{,}17\ \mathrm{gCO2eq} = 0{,}096\ \mathrm{tCO2eq}$$

$$Total\ emission\ from\ buses = 0{,}166\ \mathrm{tCO2eq} + 0{,}174\ \mathrm{tCO2eq} + 0{,}096\ \mathrm{tCO2eq}$$
$$= 0{,}436\ \mathrm{tCO2eq}$$

Net emission reduction by using buses:

$$Net\ emission\ reduction = 0{,}474\ \mathrm{tCO2eq} - 0{,}436\ \mathrm{tCO2eq} = 0{,}038\ \mathrm{tCO2eq}$$