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KM3NeT – INFRADEV 2 – HORIZON – 101079679

Report on the proposed procedures for sustainable travel and mobility

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ABSTRACT

This report summarizes the results of the travel sustainability studies within the KM3NeT collaboration, conducted in the context of the WP5 of the KM3NeT-INFRADEV2 project. It consists of two parts. The first one concerns an analysis that has been implemented to evaluate the environmental impact of travelling for KM3NeT collaboration purposes. In the second part, corrective measures and procedures are proposed towards improving travel sustainability within KM3NeT.

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II. DELIVERY SLIP

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IV. APPLICATION AREA

This document is a formal deliverable of the Grant Agreement of the project, applicable to all members of the KM3NeT – INFRADEV2 project, beneficiaries and third parties, as well as its collaborating projects.

V. TERMINOLOGY

CSA	Coordination and Support Action
KM3NeT	Cubic Kilometre (km3) Neutrino Telescope
RI	Research Infrastructure
WP	Work Package
CM	Collaboration Meeting
GHG	GreenHouse Gas
CO_2	Carbon Dioxide

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IX. PROJECT SUMMARY

The Kilometre Cube Neutrino Telescope (KM3NeT) is a large Research Infrastructure (RI) comprising a network of deep-sea neutrino telescopes in the Mediterranean Sea with user ports for Earth and sea science instrumentation. During the EU-funded Design Study (2006-2010) and Preparatory Phase (2008-2012), a cost-effective technology was developed, deep-sea sites were selected and the Collaboration was formed in 2013. This proposal constitutes a second INFRADEV project dedicated to KM3NeT in order to implement an efficient framework for mass production of KM3NeT components, accelerate completion of its construction and provide a sustainable solution for the operation of the RI during ten or more years. Following the appearance of KM3NeT on the 2016 ESFRI Roadmap and in line with the recommendations of the Assessment Expert Group, this project addresses the Coordination and Support Actions (CSA) to prepare a legal entity for KM3NeT, accelerate its implementation, establish open access to the RI and its data and ensure its sustainability by implementing an environment-friendly operation mode and evaluating the Collaboration socio-economic impact.

X. EXECUTIVE SUMMARY

This report summarizes the results of the travel sustainability studies within the KM3NeT collaboration, conducted in the context of theWP5 of the KM3NeT-INFRADEV2 project. It consists of two parts. The first one concerns an analysis that has been performed to evaluate the environmental impact of travelling for KM3NeT collaboration purposes. In the second part, corrective measures and procedures are proposed towards improving travel sustainability within KM3NeT.

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1 Introduction

Transportation is the second most significant source of global CO_2 emissions [1]. Among various transportation modes, road vehicles account for nearly 75% of the total transportation emissions [2]. Recent data, however, indicate a rapid increase in the adoption of electric vehicles [3], a trend expected to continue in the coming years. Rail transport, contributing a share of ~1% to total transportation emissions, is also projected to decrease with ongoing electrification efforts in railway systems. Conversely, aviation poses the greatest challenge in emissions reduction from transportation [4]. Despite advancements in bio fuels, the anticipated development lags behind demand, resulting in an expected rise in aviation-related emissions. Aviation alone accounts for approximately 2.5% of the global CO_2emissions, excluding other greenhouse gas (GHG) sources [5].

In the context of an international scientific collaboration such as KM3NeT, the mobility of members serves, predominantly, two primary purposes: Collaboration Meetings (CMs) and Scientific Conferences. The landscape of conference participation has undergone rapid changes, influenced by the travel restrictions imposed during the COVID-19 era. Many conferences now offer online participation or are conducted entirely virtually. Others are held exclusively with physical presence. Essentially, the mode of participation to conferences is almost entirely in the hands of the organizers; therefore, travel for conferences has been excluded from the scope of this study. Organizing periodic Collaboration Meetings is an efficient means of reporting the status of KM3NeT collaboration according to its scientific goals, as well as coordinating and monitoring the progress of work. This report presents a study aimed at limiting greenhouse gas (GHG) emissions associated with travel within the KM3NeT members.

In Chapter 2, the environmental footprint of travelling between KM3NeT institutions is evaluated for the Collaboration Meetings which took place in the post-COVID era. Information on the methodology is provided, and the results are presented and discussed. In Chapter 3, potential solutions for collectively limiting GHG emissions are explored, considering the geographical constraints of collaboration formation and by restricting the usage of aviation. In Chapter 4, several scenarios are proposed for limiting GHG emissions to align with the reduction goals set by the European Union.

2 Estimation of the KM3NeT travel environmental impact

In this chapter, an evaluation of thigh emissions resulting from the mobility of theKM3NeT members in the post-COVID era is performed. The objective is to quantify the related GHG emissions, and use it as a reference point, proposing corrective measures and procedures to be followed. Additionally, qualitative conclusions can be extracted regarding the travelling culture of KM3NeT members, identifying patterns that are already environmentally friendly.

2.1 Methodology

Detailed information on the travel of KM3NeT members is essential to estimate the KM3NeT environmental footprint due to travelling with reasonable accuracy. To collect this information, an anonymous survey was prepared and circulated among collaboration members. The survey requested information concerning the institution site of the participants, and the transportation modes used for travelling to (and from) the four post-COVID era Collaboration Meetings held in Athens (May 2022), Rome (October 2022), Salerno (June 2023), and Paris (October 2023). Information concerning the transportation modes used, including any potential combinations of plane, train, bus, and car, as well as any correspondence between flights or trains was collected using the survey.

To calculate the associated GHG emissions for a Collaboration Meeting, the emissions of the travels of the members who participated were added. This sum of emissions is considered as the total GHG emissions of the Collaboration Meeting. Emissions were quantified as Carbon Dioxide equivalents (CO_2 eq.), providing a convenient way to incorporate other relevant greenhouse gases. To calculate the amount of GHG emissions, the open software *co2calculator* was used [6]. The responses collected from the survey were tabulated into CSV format files, and the latter were provided as input to a software based on *co2calculator*. In Figure 1, the travel details for three collaboration members (anonymously) attending the Salerno Collaboration Meeting are shown as tabulated in the CSV file for Salerno CM. The results are presented and discussed in the following.

```
79;36;student;Athens;GR;plane;ATH;FCO;0;1
80;36;student;Athens;GR;train;Roma Termini,IT;Salerno,IT;0;1
81;37;permanent;Amsterdam;NL;plane;AMS;NAP;0;1
82;37;permanent;Amsterdam;NL;car;Naples,IT;Salerno,IT;1;1
83;38;technical staff;Marseille;FR;plane;MRS;NAP;0;1
84;38;technical staff;Marseille;FR;train;Napoli Piazza Garibaldi,IT;Salerno,IT;0;1
```

Figure 1: Tabulated answers given in the survey. From left to right: Entry index, member index; position; KM3NeT site; country of site; transportation mode; departure; arrival; passengers if car; roundtrip.

2.2 Results

- **Athens CM**: 102 members attended, 73.99 t of CO_2 eq.

  In Table 1, the percentage of KM3NeT members per transportation mode used to travel to Athens for the first post-COVID Collaboration Meeting is presented, as was reported by those members who responded to the survey. Aviation was the dominant mode of transportation for KM3NeT members, as it was used by 81.4% of the participants. Other modes of transportation, primarily trains, were used combined with aviation to facilitate collaboration members' arrival flights to Athens. Table1 contains the information of the percentage of KM3NeT members per transportation mode used and the CO_2 equivalent emissions across the transportation modes used for travelling to the Athens Collaboration Meeting. The data clearly indicate that the dominant source of emissions is aviation, a direct result of the limited accessibility of Athens by train.

Athens CM Modes	Persons [%]	CO2 eq. [t]
Plane only	81.4	60.45
Train only	-	-
Plane + train	11.6	9.14
Other	7.0	4.40

Table 1: Percentage of participants and CO2 equivalent total emissions per transportation mode used for Athens CM, based on 43 survey answers.

- **Rome CM**: 109 members attended, 27.94 t of CO_2 eq.

  The Rome Collaboration Meeting took place in October 2022. Table 2 illustrates the percentage of KM3NeT members per transportation mode used to travel to Rome as well as the CO_2 equivalent emissions across the transportation modes used, as reported by the participants of the survey. Prior to the Rome CM, a training boot-camp for junior KM3NeT members was held in Genova. Qualitative analysis of survey responses indicated that a significant number of members from northern KM3NeT sites travelled to Rome by train, with a stopover in Genova to participate at the boot-camp. This approach appears to have had a positive impact on emissions reduction.

Rome CM Modes	Persons [%]	CO2 eq. [t]
Plane only	62.2	21.80
Train only	24.5	1.45
Plane + train	11.1	4.02
Other	2.2	0.67

Table 2: Percentage of participants and CO2 equivalent total emissions per transportation mode used for Rome CM, based on 45 survey answers.

- **Salerno CM**: 123 members attended, 43.05 t of CO_2 eq.

  The percentage of KM3NeT members per transportation mode used for travelling to Salerno for the Collaboration Meeting, held in June 2023, is depicted in Table 3, along with the percentage of CO_2 emissions attributed to each transportation mode. Since Salerno lacks an airport, KM3NeT members from outside Italy typically flew to Naples or Rome before continuing their journey to Salerno by train (primarily) or car. Meanwhile, Italian KM3NeT members predominantly relied on train travel, given that Salerno is a final station of the high-speed Italian rail infrastructure.

Salerno CM Modes	Persons [%]	CO2 eq. [t]
Plane + train	50.0	28.63
Plane + car	16.1	8.04
Train only	12.5	1.17
Car only	7.1	1.54
Other	14.3	3.67

Table 3: Percentage of participants and CO2 equivalent total emissions per transportation mode used for Salerno CM, based on 56 survey answers.

- **Paris CM**: 132 members attended, 38.15 t of CO_2 eq.

  The Collaboration Meeting in Paris took place in October 2023. Table 4 displays the percentage of participants per transportation mode used, as well as the amount of CO_2 emissions attributed to each transportation mode for travelling related to the Paris CM. A qualitative observation indicates that all members who attended the CM from France, the Netherlands, Belgium and

Germany, opted for train travel to Paris. This choice demonstrates a reduction in CO_2 emissions by favouring train over air travel, with nearly half of the members utilizing train for transportation, while the share of emissions attributed to train usage is 7.0%.

Paris CM Modes	Persons [%]	CO2 eq. [t]
Plane only	48.1	33.60
Train only	46.3	2.49
Other	5.6	2.06

Table 4: Percentage of participants and CO2 equivalent total emissions per transportation mode used for Paris CM, based on 54 survey answers.

2.3 Overview

The total CO_2 equivalent calculated for each of the considered post-COVID era Collaboration Meetings is presented in Figure2, normalized to the number of collaboration members who attended each meeting.

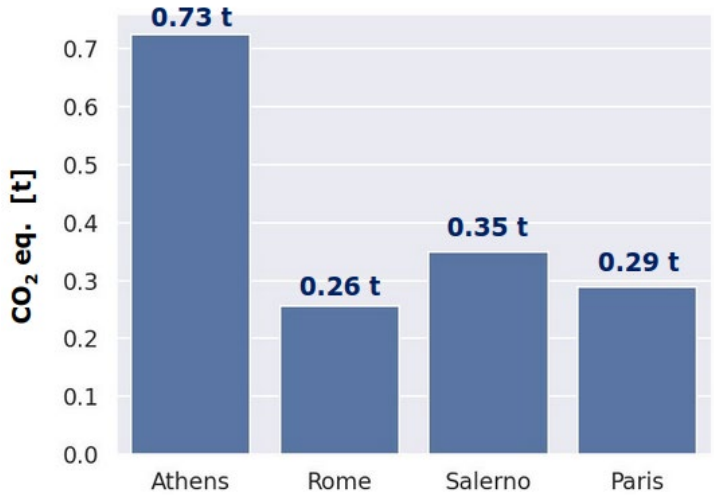

Figure 2: CO_2 equivalent per person for the post-COVID CMs.

The limitation of accessing Athens by any other means besides airplanes, results in a much higher environmental footprint for Athens than for the CMs organized in the rest of the sites. The choice of some individuals from northern KM3NeT sites to travel to Rome via train, with an intermediate stop in Genova for the boot-camp, results in a reduction of GHG emissions

associated with the Rome CM. With a stop for a few days in Genova, it was probably more convenient for members from northern sites to travel by train to Rome, rather than choosing a direct travel plan without a stopover. This fact, most likely, contributed to the lower emissions observed for the Rome Collaboration Meeting compared to other CMs, especially the one in Salerno. Additionally, the notable absence of air travel among members from France, the Netherlands, Belgium, and Germany for the Paris Collaboration Meeting underscores a concerted effort to prioritize more sustainable modes of transportation, and highlights the potential of utilizing train travel and minimizing air travel as effective measures for reducing GHG emissions in travelling.

The software that has been developed to calculate the CO_2 equivalent emissions for the mobility related to a Collaboration Meeting by summing the emissions from the individual members can be used also for calculating the environmental impact of future meetings. This can contribute to the decision of future meetings according to their environmental impact, as will be presented in the following section.

3 Reduction of the environmental impact in KM3NeT travelling

3.1 Introduction

In our effort to reduce GHG emissions related with the mobility within KM3NeT, the promotion of sustainable transportation modes emerges as a pivotal strategy. We consider that the recognition of the environmental benefits inherent in train travel, amplified by the increasing electrification of the European railing network and aiming for the establishment of distance thresholds that mandate the use of trains for journeys falling below a certain distance limit as an efficient strategy. This measure seeks to leverage the efficiency and eco-friendliness of rail transport while simultaneously reducing the carbon footprint associated with aviation.

The accessibility of train networks is crucial for the transition from air to rail travel. While the primary goal of reducing environmental impact remains a critical focus point, it's vital to adopt an approach that recognizes the specific complexities present in each geographical area. In contrast to the well-established railway network in central European countries, the distance between Athens, Bucharest and Tbilisi (three of the KM3NeT member cities) and central Europe is considerable, as well as the lack of extended railway systems along the whole possible travel route, makes it difficult to choose efficient and fast rail itineraries. Taking into account this geographical constraint, the exclusion of individuals originating from Athens, Bucharest, and Tbilisi from our analysis of CO_2 emission reduction through train travel is considered appropriate.

3.2 CO_2 emission reduction by restricting aviation

To quantify the GHG emissions related with a CM, the sum of the emissions of all individuals was calculated, with a mandatory train use below a certain threshold on the distance between a participant's site and the site that hosts the CM. The total amount of CO_2 equivalent emissions of a CM is calculated using the formula:

$$Total\ CM\ emissions = \sum_i \rho_i \cdot \langle N \rangle \cdot (CO_2\ eq.)_i$$

The index iterates over the 21 KM3NeT sites with members that participated to the survey, namely Genova, Rome, Valencia, Nantes, Salerno, Marseille, Caen, Bologna, Paris, Catania, Amsterdam, Erlangen, Bari, Naples, Prague, Leuven, Caserta and Strasbourg, while Athens, Bucharest and Tbilisi members are always considered to travel by plane as explained above. In each case, the site that hosts the CM is excluded from the sum. The factor accounts for the portion of the members from the site *i* that travelled for a CM, calculated from the survey participants by averaging over the four post-COVID CMs. The second factor is the average participation calculated by the four post-COVID meetings, and the third factor is the CO_2 equivalent emission for the travelling of a member from the site *i*, to the site hosting the CM. This last factor is calculated according to a specific distance threshold for mandatory train use. Above this limit, the emission factor concerns aviation, while below this limit, an emission factor for train is considered. As a result, the total amount of emissions associated with a CM is studied as a function of this distance limit. In Figure 3, the CO_2 equivalent emissions are shown for each of the considered sites to host a CM, as a function of a mandatory distance limit for train usage. Rapid decreases of the emissions are noticed in general, also depending on the host site. In Figures 4-6, the same quantity is presented for each of the sites studied to host CM.

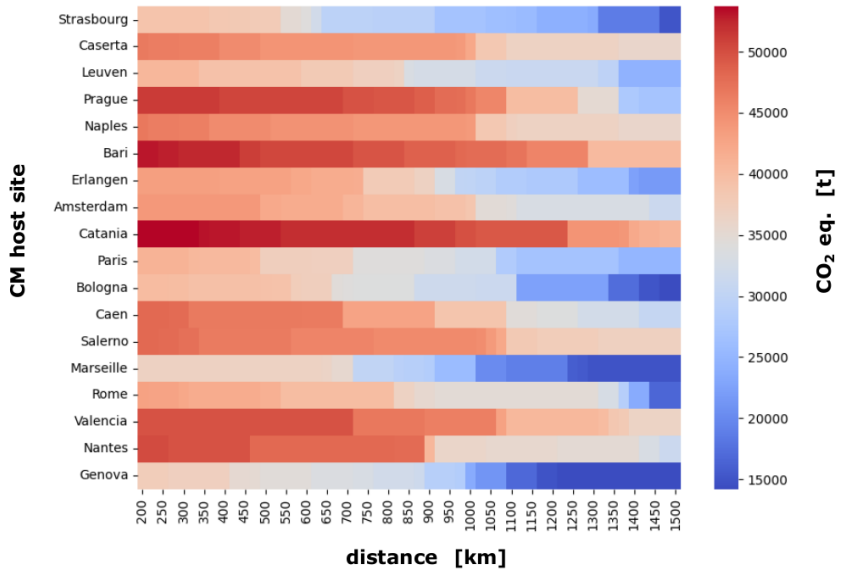

Figure 3: CO_2 equivalent as a function of a mandatory distance limit for train usage.

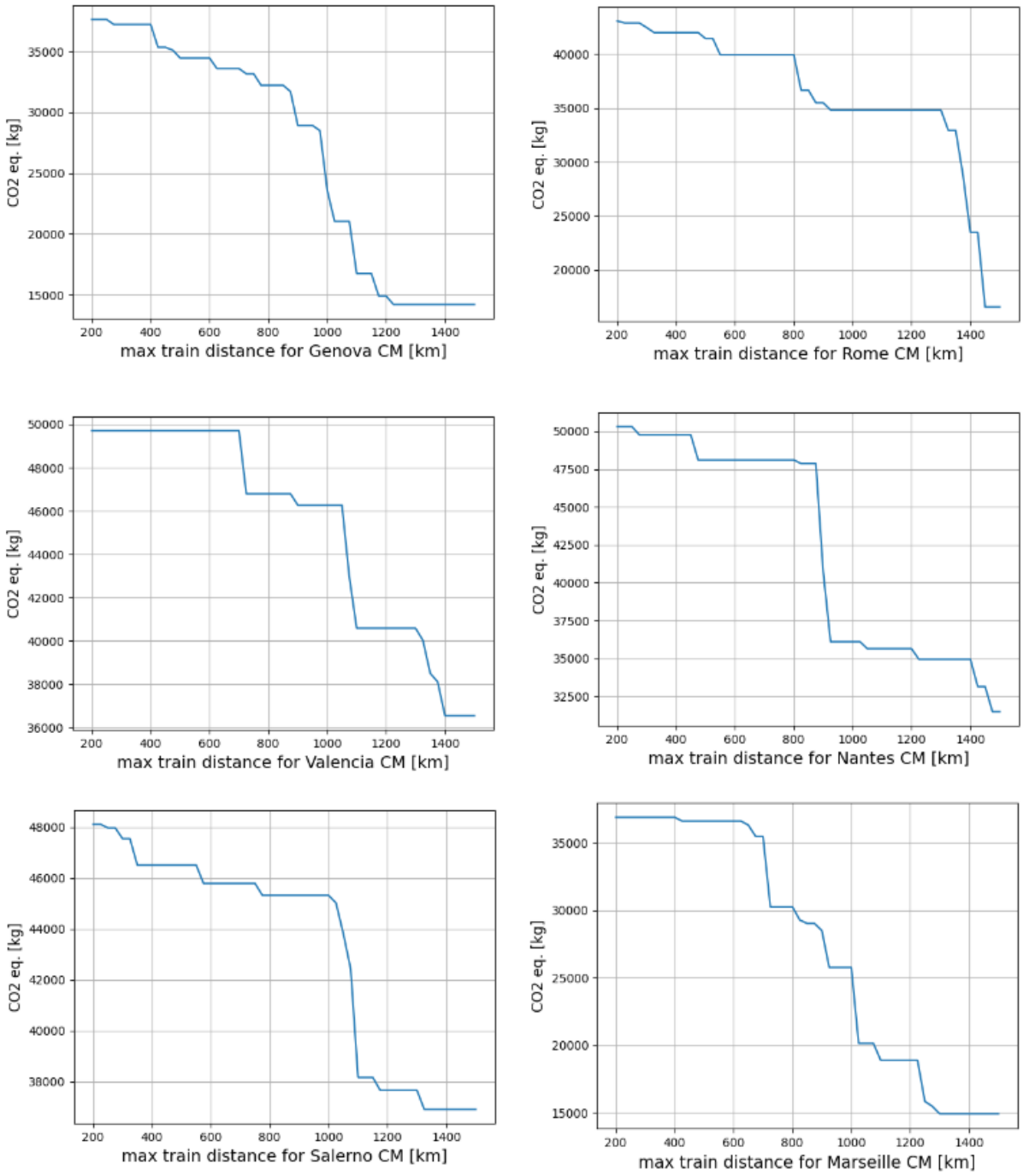

Figure 4: CO_2 equivalent emissions for organizing a CM as a function to a mandatory train usage distance limit, for the following sites. Clockwise from top-left: Genova, Rome, Valencia, Nantes, Salerno and Marseille.

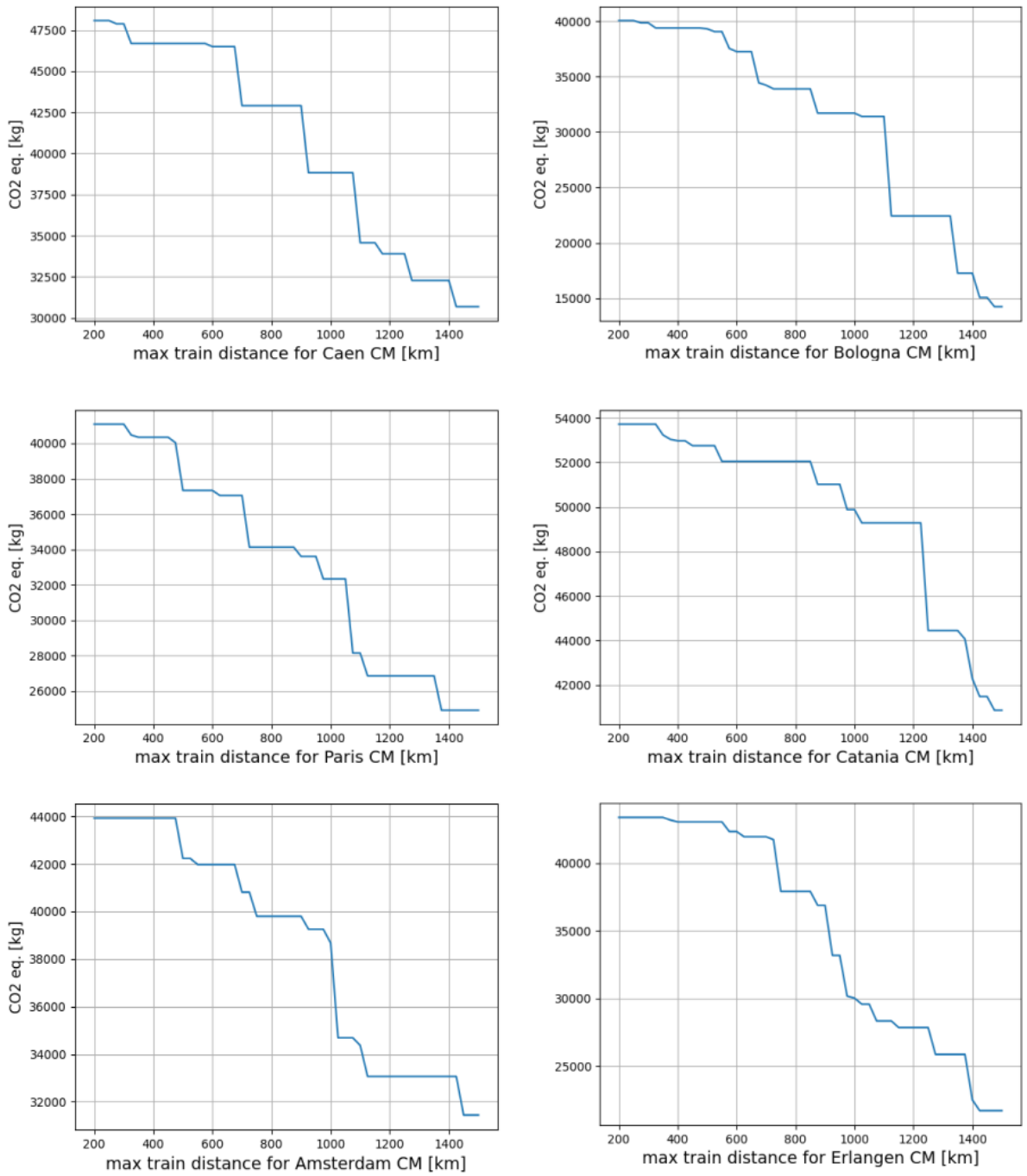

Figure 5: CO_2 equivalent emissions for organizing a CM as a function to a mandatory train usage distance limit, for the following sites. Clockwise from top-left: Caen, Bologna, Paris, Catania, Amsterdam and Erlangen.

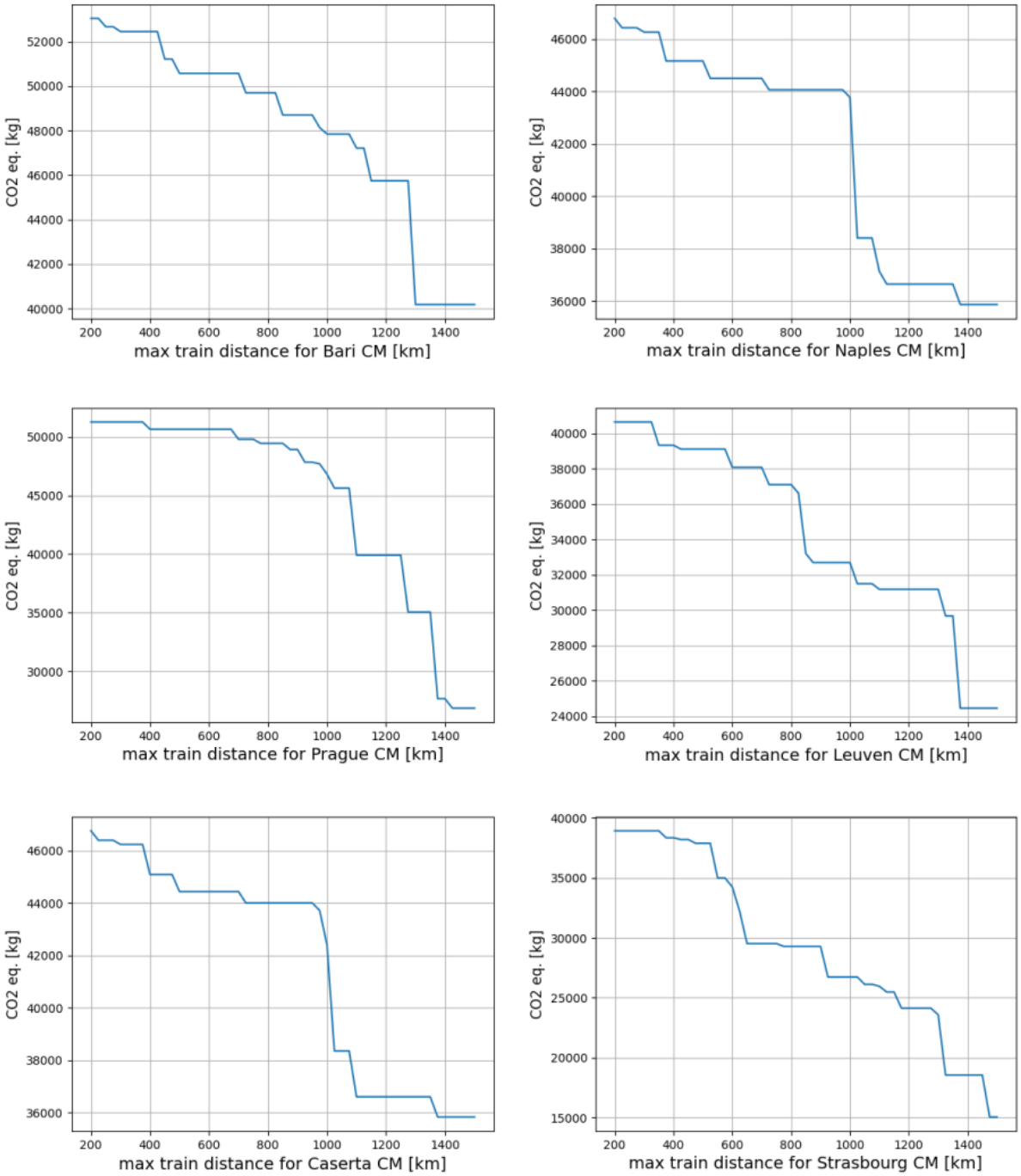

Figure 6: CO_2 equivalent emissions for organizing a CM as a function to a mandatory train usage distance limit, for the following sites. Clockwise from top-left: Bari, Naples, Prague, Louvain, Caserta and Strasbourg.

4 Complying with the EU target for the reduction of GHG emissions

The Paris Agreement [7], signed under the United Nations Framework Convention on Climate Change (UNFCCC), is a landmark international treaty aimed at combating climate change. To date, 197 countries have signed the agreement, signalling a global commitment to address the pressing issue of climate change. Central to the agreement are the Nationally Determined Contributions (NDCs), wherein each country outlines its individual targets and plans to reduce greenhouse gas emissions and adapt to the impacts of climate change. The Paris Agreement represents a significant step forward in global efforts to limit global warming to well below 2 degrees Celsius above pre-industrial levels, with an aspiration to limit it to 1.5 degrees Celsius.

According to the latest update of their Nationally Determined Contributions (released on October 2023), the EU and its member states, acting jointly, are committed to a legally binding target of a reduction of greenhouse gas emissions by at least 55% compared to 1990 by 2030 [8]. This reduction target is adopted in this study, as KM3NeT is a research infrastructure with member institutes mostly from European Union countries.

From the calculation for the environmental footprint due to travelling for the KM3NeT Collaboration Meetings, it is estimated that the typical three CMs that were organized annually before the COVID era, resulted to an amount of 137.35 tonnes of CO_2 equivalent GHG emissions. After the period marked by the regulations on travelling due to the COVID-19, the KM3NeT Collaboration decided to limit the number of Collaboration Meetings with physical presence to two per year and one meeting held by remote participation, resulting in a reduction by one third. To further reduce the emissions according to the European Union NDCs, the amount of CO_2 equivalent emissions on an annual, should not exceed the limit of 61.81 tonnes.

Employing the outcomes of the study performed in the previous chapter, it is conceivable that planning of future meetings can be done in such a way as to respect the target CO_2 emissions for the whole Collaboration. Given the diversity and multitude of KM3NeT Institute cities, it is possible to devise several scenarios or combinations of Collaboration Meetings, with the aim to keep the GHG emissions below the limit of 61.81 tonnes of CO_2 equivalent. The main formation in the following combinations consist of one remote (online) CM and two in-person CMs, a scheme that has been proven functional after the COVID-19 travel restrictions period. A sample of these is given below, although as already mentioned, the number of possible combinations is quite large. For example,

- CM at Paris with 1000km train limit, ~32 tonnes of CO_2 equivalent, one CM at Erlangen with 1000km limit, ~30 tonnes of CO_2 equivalent.

- CM at Marseille with 1000km train limit, ~26 tonnes of CO_2 equivalent, one CM at Nantes with 1000km limit, ~36tonnes of CO_2 equivalent.
- CM at Genova with 1050km train limit, ~22tonnes of CO_2 equivalent, one CM at Amsterdam with 1000km limit, ~40 tonnes of CO_2 equivalent.
- CM at Bologna with 1000 km train limit, ~32 tonnes of CO_2 equivalent, one CM at Strasbourg with 1000km limit, ~27 tonnes of CO_2 equivalent.

The above four scenarios are only a small sample of a multitude of possibilities.

With the above analysis and arguments, we do not, in any way, want to imply that venues like Athens, Bucharest and Tbilisi, or indeed places outside Europe should be excluded as possible CM hosts. Indeed, in some cases, the choice of CM host city has been dictated by other considerations, like the strengthening of the local group(s), the advertisement of KM3NeT to the local authorities, the facilitation of contact between the local scientific community with the KM3NeT scientists, etc. In cases like these, the necessity of hosting a KM3NeT CM in a non-optimal place (as far as the environmental footprint is concerned) can be counter-balanced by other issues. Even in these cases, however, the knowledge of the actual CO_2 emission impact can act as a guideline for subsequent decisions and choices. For example, such a meeting could be followed by 2 virtual meetings in succession and/or by physical meetings with minimal environmental footprint. These decisions will be in the hands of the KM3NeT Institution Board and the Management team.

5 Conclusions

The environmental impact due to travelling within KM3NeT has been investigated, and proposals have been made for the reduction of GHG emissions. Firstly, an estimation of the environmental impact using past Collaboration Meetings has been implemented, mainly to quantify the GHG emissions, but also to retrieve qualitative features in the travelling culture of KM3NeT members. For this purpose, a software tool has been developed with the aim to make accurate emission estimations based on detailed information about the travelling of the members. This information was collected with an internal KM3NeT survey. A study was subsequently implemented to investigate the reduction of emissions with the restriction of aviation in favour of train usage, showing promising emission reductions concerning the mobility related to CMs. Based on these reductions, proposals are made for the organization of future meetings, with the aim to reduce the GHG emissions complying with the Nationally Determined Contributions the European Union is committed according to the Paris Agreement for the Climate.

XII. REFERENCES

[1] Hannah Ritchie, Pablo Rosado and Max Roser (2020) - “Breakdown of carbon dioxide, methane and nitrous oxide emissions by sector” Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/emissions-by-sector' [Online Resource]

[2] Hannah Ritchie (2020) - “Cars, planes, trains: where do CO_2 emissions from transport come from?” Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/co2-emissions-from-transport' [Online Resource]

[3] Hannah Ritchie (2024) - “Tracking global data on electric vehicles” Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/electric-car-sales' [Online Resource]

[4] Davis, S. J., et. al. (2018). *Net-zero emissions energy systems*. *Science*, 360(6396)

[5] Hannah Ritchie (2024) - “What share of global CO_2 emissions come from aviation?” Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/global-aviation-emissions' [Online Resource]

[6] https://github.com/pledge4future/co2calculator

[7] https://unfccc.int/process-and-meetings/the-paris-agreement

[8] https://data.consilium.europa.eu/doc/document/ST-14286-2023-INIT/en/pdf