Methodology behind the CO2RISM calculator

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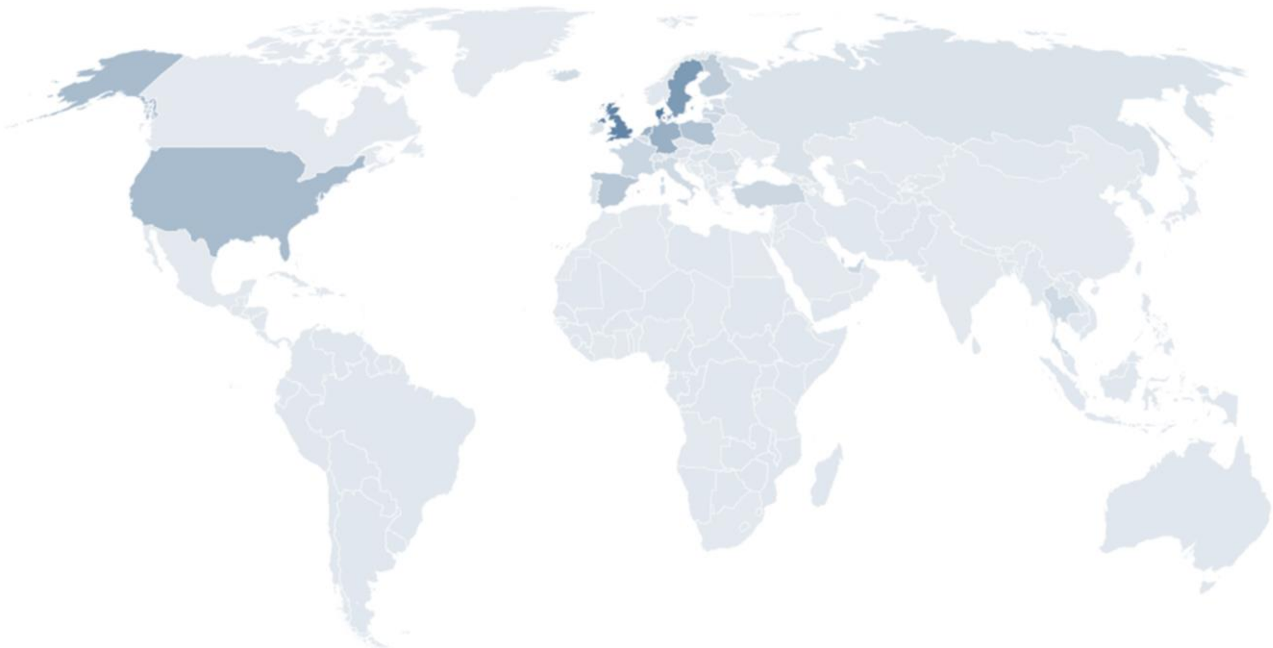

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Summary

The CO2RISM calculator is a tool that provides an estimate of the amount of transport-related direct CO_2 emissions associated with tourism travelling to and in Norway. The calculator targets specific tourist markets, or country of origin, travelling to specific regions in Norway, rather than an individual travel.

The calculator is based on input from data gathered specifically for 2018 for Norway and it covers 6 transport modes, aviation, ferries, trains, car, bus and campers. The transport emissions of each transport mode is distributed to the tourist based on the number of passengers that share the emissions. The resulting output should be seen as a statistical measure of tourist travellers' emissions travelling to, from and at a destination based on the place of origin, destinational region and length of stay of the tourist. In this document, we summarize the method, data and results of the calculator together with its stated purpose and applicability.

1 Introduction

In this context, tourism is defined as “any trip that includes at least one-night stay away from home”, and tourism in Norway requires that at least one-night stay is in Norway. World Tourism Organisation (UNWTO) estimates tourism CO_2 emissions to be 22% of world transport emissions (5% of total anthropogenic), and they project the share of (transport) emissions related to tourism to increase towards 2030 (UNWTO 2019). The current COVID-19 pandemic situation involves strong short-term implications for travelling and probably also, longer-term consequences whith limitations on travel. The calculator would be well suited to e.g. calculate the change in emissions at a destination due to the changes in tourism imposed from this. It can also compare the difference in emissions at a destination of tourists of different origins. With tourism being an important economic industry and making a large contribution to both global Gross Domestic Product (GDP) and anthropogenic emissions, it is of key importance to understand the CO_2 emission differences between the different transport modes, across tourist markets and places of destination.

There are many types of calculators or reference values available for estimating CO_2 emissions of a journey or part of a journey (e.g., Travel and Climate, 2020; Myclimate, 2020; Framtiden i våre hender, 2020). There are also CO_2 budget calculators for various activities or lifestyles. However, neither of the existing calculators were found to be suitable from the point of view of a tourist origin/destination, accounting for how emissions are dependent on where different shares of tourist come from and how they travel there, which this calculator targets.

One important aspect of the calculator is that the emissions from tourism obtained in this study differs from official emissions reported by Norway. First, the official reporting of CO_2 emissions does not include tourism as a specific sector/subsector, but transport emissions are reported from fuel combustion activities in the transport sector and split per subsector (e.g., on-road transport, navigation, aviation). Furthermore, international aviation and navigation are excluded from the national reporting obligations, and only included as a memo for information purposes (IPCC, 2016). Both aviation and navigation are essential transport sectors for characterizing CO_2 emission from tourism, and therefore an understanding of both the domestic and international movement of passengers is crucial. The calculator provides emissions according to a bottom-up approach, whereas national reporting is per requirement reported based on national fuel sales (IPCC, 2016). This may lead to differences in sectoral consumption, as often, fuel such as diesel are used for a variety of purposes, and the sectoral emissions can thus have a different distribution key than the one obtained by adding up all transport emissions from the calculator.

With widely different availability in input data between transport mode, each mode of transport has required a separate method for calculation. The input data for the CO2RISM calculator input data are therefore an important aspect of the calculator, and a detailed description of the variety of sources and input are described in the following section along with the principles behind the calculator.

2 Method

The CO2RISM calculator provides direct CO_2 emissions from fossil fuels travels both to and from a destination. The calculator considers the distribution of tourist from different markets or country of origin (e.g., 20% Sweden, 5% Australia, 5% China, 8% Spain, 52% domestic 10% Other Markets). There are some details that need to be considered:

- The calculator does not include indirect emissions, biogenic CO_2 emissions or emissions of other compounds that have a climate impact.
- It is designed to only consider travels that involve CO_2 emissions. Subsequently, transport such as walking, cycling or e-bikes are not considered as they have no direct emissions.
- International travel emissions include the complete journey from origin to destination and both directions. This means that the emissions can occur both inside and outside Norwegian territory, and therefore not necessarily compare to official reported emissions by Norway. This is especially true in the case of aviation and/or navigation but applies to all transport modes.

The calculator provides only CO_2 information. CO_2 equivalents ($CO_{2\text{-eq}}$), which is provided by many other calculators, is a measure to compare the radiative forcing effect between different greenhouse gases. Most commonly other compounds are compared to CO_2 by Kyoto / Montreal protocol agreement standards assessing its global warming potential relative to that of CO_2 over a fixed time, typically 20 or 100 years (IPCC 2016). Most other greenhouse gases have shorter atmospheric residence times and while they may be potent greenhouse gases, their impact spans a shorter time than CO_2. In fossil fuel combustion processes, typically more than 90% of $CO_{2\text{-eq}}$ are CO_2. However, air travel, by its altitude of emissions, can have some strong short-term effects, that strongly influence the CO_2 share of $CO_{2\text{-eq}}$. In the CO2RISM calculator we have selected only CO_2. The main reason for selecting CO_2 is that emissions of other greenhouse gases (e.g. NH_4, N_2O) were not available for all modes of transport. There are also high uncertainties related to both the method of conversion and the magnitude of other compounds emitted, as they are not as closely connected to the amount of fuel consumed.

Here we describe the development of the input data for the calculator, i.e., **emission factors as CO_2/tourist per market and Norwegian region of destination**. The input data has been developed differently for two types of trips, holiday and business-related trips. The main reason for this differentiation is that the transport mode share per market have distinct differences between these two purposes. For example are there fewer people per car on buiseness travels than for leisure, and buiesness flymore frequently.

Emission factors (g-CO_2/tourist) were developed for travels between each market and each Norwegian region of destination. Emissions takes into account the travelling transport mode, the corresponding share of transport mode per market type (e.g., typical way of travelling from Sweden, Germany, Other European, Asian or American countries), the passenger capacity factor, travelled distance, and specific emission factors per transport mode (g-CO_2/km). When possible, these variables have been defined at the highest possible level of detail (e.g., emissions factors for specific aircraft flights, vehicles composition other countries than Norway, passenger capacity factor for each transport mode, etc).

2.1 Principle behind the CO2RISM calculator

For the calculator to perform well for all tourists, we designed a process based on three trip legs for international tourists and two for domestic tourists. The first leg (leg_1) is an international trip and corresponds to the travel to Norway from origin and back. We have selected 15 different markets and an additional two markets to cover "other" countries in Europe and "others outside Europe". The markets were defined based on the available information from the *Turistundersøkelsen* (Innovasjon Norge, 2018) and communication with Innovation Norway. Table 1: Markets for which the co2rism calculator calculate specific emissions for travelling between. shows the international markets considered in this study. The leg_1 trip considers travels from the country of origin to Norway as a round trip for each transport mode for each international market. The share of transport modes is obtained from the *Turistundersøkelsen* (Innovasjon Norge, 2018), for instance it shows that 28% of tourist from Denmark arrives via ferry, 49% of tourist from Sweden arrive by car, most of the trips from other European countries are done via airplane (approx. 60-85%) and 100% of the tourist from Asian and American countries are considered to arrive to Norway by airplane. In addition, different transport mode shares were used for work related trips based on the data from the *Turistundersøkelsen* (Innovasjon Norge (2018). One of the most important differences between holiday and work-related trips are for instance that for business generally 0% of transport is by camper, whereas for instance flights increases significantly. In order to obtain a weighted emission factor per market as g-CO_2/tourist, specific emission factors (g-CO_2/km) and passenger capacity factor per transport mode are defined.

Table 1: Markets for which the co2rism calculator calculate specific emissions for travelling between.

International Markets	Regions of destination
Sweden	Nordnorge
Denmark	Trøndelag
Germany	Vestlandet
Netherland	Østlandet
Belgium	Sørlandet
Switzerland & Austria	Oslo
United Kingdom	
France	
Italy	
Spain	
USA	
Australia	
China, Hong Kong, Taiwan & Macau	
Poland	
Canada	
Other in Europa	

The second leg (leg_2) represent regional trips within Norway. They are constructed the same way as international trips but using data for travels between regions within Norway. For leg_2, we combine the international markets described in leg_1 with Norwegian 6 regions of destination (Table 1: Markets for which the co2rism calculator calculate specific emissions for travelling between.). In addition, each region of destination is an additional market to allow the calculator estimating emissions associated with domestic tourism.

The final (leg_3) travels are local trips (leg_3) which represent travels within the region of destination. These are calculated for movement in kilometre per day rather than by trip and are thus the only emissions affected by the length of stay. Leg_3 represents trips such as transport to and from the airport and/or leisure trips around the region. The travels in Leg_3 accumulate during a stay, but as the local travel activity generally make up a low share of total emissions longer stays have lower emissions per day. The share of movement by transport mode for each market is also for

Leg_2 & 3 obtained from *Turistundersøkelsen* 2018. The data from Turistundersøkelsen is modified for each Norwegian region to adjust from regional differences in especially flying and ferry availability, but also to take into differences between Leg_2 and Leg_3. Most domestic flights are regional flights (Leg_2) and while on the one hand arriving by ferry to Norway (Leg_1) is only possible in eastern Norway, most domestic ferries (Leg_2 & 3) are in the west and north of Norway.

Each tourist arrives to Norway by a means of transport. This is dependent on where the tourist is going to and which market it arrives from. Many tourists arrive and change transport mode for the different legs, all of which are statistically considered by differentiated shares of transport modes per leg. The final emissions of a market emission in a region is described by the equation:

Calculator $E_{M,R} = sum\ (E_{Leg\_1} + E_{Leg\_2} + E_{Leg\_3})$ Equation 1

Where E are the emissions of a tourist from a given market (M) to a region of destination (R), and E_{LEG_*} are the emissions of each leg of the trip. The emissions for each leg are calculated as:

$E_{Leg\_1,\ Leg\_2} = sum(EF_{TR} * D_{TR} * B_{TR} * F_{TR})$ Equation 2

$E_{Leg\_3} = days * sum(EF_{TR} * D_{TR} * B_{TR} * F_{TR})$ Equation 3

Where $E_{Leg\_1,\ Leg\_2}$ are the emissions in leg_1 and leg_2, and EF_{TR} is the emission factor (g-CO_2/km) of each transport mode (TR). D_{TR} is the travel distance of the given transport mode, B_{TR} is the passenger capacity factor for each TR and the F_{TR} is the fraction of tourists from a given market using that TR for that leg. For Leg_3 the distances are assumed daily distances and thus it is multiplied by number of holiday stay days within the region.

2.2 Input data

Distance

For distances between airports and maritime ports the great circle distance (GCD) is calculated from a geodatabase of ports and airports and used as travel distance. For leg 1, the distance corresponds with the average travel distance from the market main airports to Norway weighted by the number of passengers travelling between each airport and Norway. For leg 2 the distance of the domestic flight routes between each region is used. Leg_2 distance is also averaged over passenger kilometers. The distance is obtained based on a database provided by AVINOR, with flight details of all commercial aviation in Norway in 2018. This database is combined with a list of location of all IATA registered airports and the inter airport GCD distance is calculated. The AVINOR data cover also connecting flight information of the passengers which are used to calculate additional flight distances. For Leg 3 mainly Northern Norway have internal transport by commercial aircrafts, and we use distances accordingly.

For international ferries the GCD between the ports. For Denmark, the only country with more than one route, the ferry capacity weighted average length is used. For markets where there are passengers coming by ferry but no ferry connection between that market and Norway, the calculator uses the ferry from the closest country (most commonly Germany). This way, the transport on the other end of the ferry is not part of the emissions calculations. For Leg 2 inter-city distances between the main population centres in each region is used.

For on road transport and railways, the approximated driving distance from the main cities to Oslo was used. The exception to this is Sweden, which have several points of entry to Norway by car and rail, and an approximation was done to the intercity distances for each of these points. For rail the railway distance is used, but for some markets where routing rail did not give a travel distance, the equivalent driving distance was used. For Leg 2 the inter-city driving distance between the major cities are used, and for Leg 3 distances, we assume slightly lower than national daily driving distance, except for North of Norway where it is somewhat larger as there are longer distances there.

Emission factors

Specific emission factors as g-CO_2/km were estimated for each transport mode. In the case of aviation, emission factors were obtained based on fuel consumption per distance and aircraft type taken from the ICAO CORSIA model (ICAO 2019). Market-specific emission factors were then obtained by taking international flights between Norway and that market (leg_1), then the average emission factor for the flights weighted by passengers were estimated (Table 2: Aviation emissions factors used in the calculator for each market arriving to Norway (leg_1) and for the flights to (leg_2) and within (Leg_3) the region of destination. Units: g/skm, grams of CO2 per seat.kilometer.). The same approach was followed to estimate emission factors to the regions of destination based on domestic flights (leg_2) and flights within the same region (leg_3; Table 2: Aviation emissions factors used in the calculator for each market arriving to Norway (leg_1) and for the flights to (leg_2) and within (Leg_3) the region of destination. Units: g/skm, grams of CO2 per seat.kilometer.).

Table 2: Aviation emissions factors used in the calculator for each market arriving to Norway (leg_1) and for the flights to (leg_2) and within (Leg_3) the region of destination. Units: g/skm, grams of CO2 per seat.kilometer.

Market	Leg_1 EF (g/skm)
Sverige	102
Danmark	95
Tyskland	74
Nederland	90
Belgia	82
Sveits & Østerrike	75
Storbritannia	72
Frankrike	67
Italia	63
Spania	59
USA	69
Australia	89
Kina, Hong Kong, Taiwan & Macau	89
Polen	71
Canada	87
Andre Europa	74

Destination_region	Leg_2 EF (g/skm)	Leg_3 EF (g/skm)
Nordnorge	76	184
Trøndelag	108	230
Vestlandet	114	170
Østlandet	104	185
Sørlandet	126	
Oslo	104	

Emission factors for road traffic are taken from "The Handbook Emission Factors for Road Transport (HBEFA) version 4.1 (Matzer et al., 2019). HBEFA provides emissions factors for on-road vehicle categories and considers the fleet composition of specific countries. For the CO2RISM calculator, emission factors specific for Norway, Sweden, Germany, France, Switzerland, Austria and Check Republic were used to define the emissions factors as g-CO_2/km for passenger vehicles and buses associated with domestic and international tourism. Emission factors were applied to driving conditions in the different Norwegian regions for travels in Norway. The results are specific emission factors per market and region of destination. The emission factors used for passenger vehicles range from 127 to 158 g/km, and for buses emission factors range from 578 to 700 g/km. Emission factors for campers are not specifically available in the HBEFA. Therefore, we selected an emission factor of 300 g/km based on the comparison with vehicles with similar weight.

For rail transport, emissions factors were calculated from Norwegian official reported emissions in 2018 (SSB-08940, 2020; Norwegian PRTR, 2020). The share of fuel consumption in passenger trains relative to the total fuel consumption, including goods transport, in 2018, reported by the Norwegian State Railways (NSB, 2018), was used to obtain the passenger train emissions. For instance, fuel consumption in 2018 by diesel passenger trains was 8.9 million litres whereas the fuel consumption in railway good transport was 6 million litres.

The person distance (pkm) reported by Statistics Norway (SSB-10484, 2020) was then used to obtain emission factor, both for the railway, but also for individual railway stretches and regions. For regional and inter-regional train journeys, the ratio of diesel to electric passenger transport was used. The results are emission factors that range from 0 g/km for regions with 100% electric trains to values between 2.5 and 19.6 for regions with a share of electric and diesel fuelled trains.

In the case of navigation, i.e., ferries, emission factors as g-CO_2/km were inferred based on known distances and emissions from passenger and cruise vessels split in gross tonnage groups from Havbase (2020) supplemented with a more detailed data set obtained from the Norwegian Coastal Administration (Kystverket). Emissions factors of about 188, 152 and 348 g/km were obtained for ferries coming from Germany, Denmark and Sweden, respectively. In the case of domestic ferries, an average emission factor of 124 g/pkm was obtained based directly on the data from Havbase.

Passenger capacity factor

The second step of the method is to distribute the emissions from the transport to its passengers. This gives personal emissions of individuals (g-CO_2/pkm) traveling between 2 places by different modes of transport. Passerger capacity factors were therefore calculated for the different transport mode. In addition, different passenger capacity factors were selected based on the purpose of the trip in the case of trips carried out by passenger vehicle.

The passenger capacity factor for aviation was the average capacity factor obtained from a database provided by AVINOR, with flight detailed information of all commercial international and domestic flights in Norway in 2018, including information on the number of seats and passenger per flight. Different passenger capacity factors are used for the different markets and region of destination ranging from 0.63 to 0.86.

The passenger capacity factor for maritime transport (i.e., ferries) was obtained based on an internal database with detailed information on the gross tonnage of the ferries operating in Norway, dimensions and the passenger capacity, and route frequency. This dataset was combined with port statistics (i.e., number of passenger and ferry calls) from Statistics Norway and provided by the Norwegian Coastal Administration to obtain passenger load factor for ferries (SSB-04225, 2020; Kystverket, personal communication). For the calculator, 0.66 was selected as passenger capacity factor for ferries.

The railroad passenger capacity factor was obtained from the number of passengers travelling by train from Statistics Norway (SSB-10484, 2020) along with information on passenger and seat kilometres, and travel distance. This information is available at different resolutions, such as per railroad (e.g., Nordlandsbanen, Rørosbanen and trains crossing the border) or aggregated in local, regional and intercity stretches. The passenger capacity factor estimated was of about 0.32.

The passenger capacity for passenger vehicles travelling for holidays is established at 1.86 based on the number of persons per vehicle travelling in free time (Hjorthol et al., 2014). To our knowledge there is not reported data on the passenger capacity for camper, in this case we assume a higher value at 2.2. For buses and coaches, an average value of 20 passenger per vehicle was used independent of location. For work related travel, a passenger capacity factor of 1.15 was used based on the number of persons per vehicle travelling for work according to Hjorthol et al., (2014).

Cruise tourism

Tourists travelling by cruise ships are not currently a part of the calculator. However, the underlying activity and emission data on cruise tourism is also calculated in the data. An important reason for keeping cruises apart from other is that the data available does not make it directly comparable to other tourists. Cruise tourism as an individual mode of transport will soon be included in calculations in an update version of the calculator.

As for ferries, emissions for cruise ships are obtained from “havbase.no”. The cruise emissions is supplemented by a detailed dataset from Kystverket, where port of entry and origin of all cruise movements in Norway were recorded for 2018. For all cruises the length of the trip is calculated as the GCD between the point of entry into Norwegian Exclusive Economic Zone (EEZ) and the port of origin. Then for each cruise we used the distance travelled within the EEC emissions and a derived an emission factor for each cruise ship to also calculate emissions of ships outside the EEC. This emission factor was used to calculate emissions also outside Norwegian EEZ. For cruises we assumed that all emissions were done by the passengers. The number of passengers were derived from port statistics.

3 Results

The results obtained with the CO2RISM emission calculator is total CO_2 emissions associated with an amount of tourist with a specific compositional share of markets or country of origin, whose travel to and in a specific Norwegian region. The transport mode considered are ferry, aviation, train, camper, car and bus. The input data for the calculator to perform the final estimate was delivered by NILU to Innovation Norway and they represent statistical averages on the transport emissions per market as kilograms of CO_2 per tourist (kg/tourist for leg_1 and leg_2) or CO_2 per tourist.day (kg/tourist.day for leg 3).

For most markets Leg 1 will be the largest and Leg 3 the smallest contribution to total emissions. Emissions per tourist from each market largely depend on the distribution of means of transport from that market, and the distance of the travellers to the region of destination. Figure 1 shows an example of average emission factor (g-CO_2/pkm) used as input data in the calculator for obtaining emissions (g-CO_2/tourist) from transport tourist activity within "leg2" (i.e., from the region of arrival to Norway to the final region of destination in Norway). The emission factors are expressed as grams of CO2 per p.kilometer (g/pkm), what allows the comparison between the different transport modes. The highest transport related emission factor is obtained for ferries, followed by aviation, camper, car, bus and train.

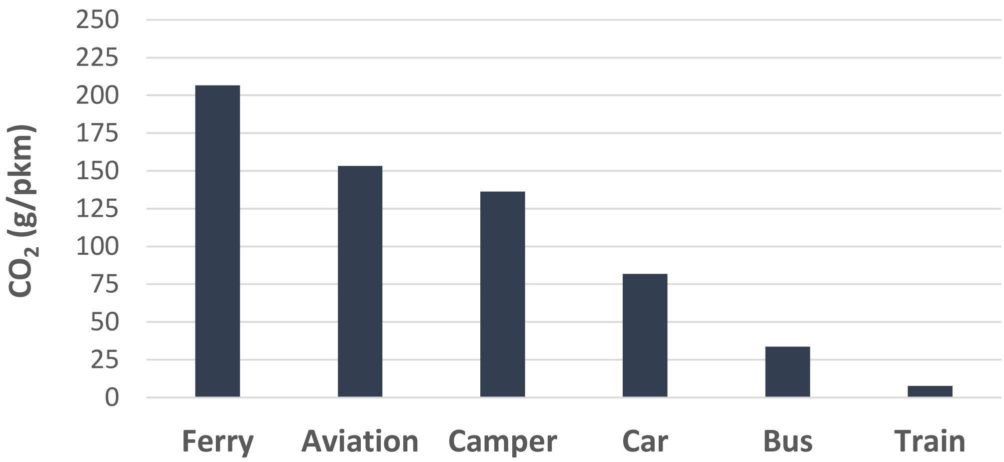

Figure 1: The average emission factor for all modes of transport in Leg 2.

Emissions per tourist will depend on the total distance from the country of origin to the destination, the number of days spent on holidays, the transport mode share and the passenger capacity for each transport mode. Figure 2 shows, as an example, total transport-related CO_2 emissions for different international (A) and domestic (B) markets. We used as example Nordnorge and Vestlandet as final region of destination and a holiday stay of 10 days. CO_2 emissions from internationally tourism as kg/tourist is higher than those associated with domestic holidays. The main reason is that emissions from domestic tourism are only associated with transport within leg_2 and leg_3. The importance of leg_1 on the calculation of emissions can be observed in the distribution of CO_2 emissions among markets (Figure 2A), where tourist from Australia, China, Canada and USA emit the highest CO_2 amount compared with European and Scandinavian tourists. The distance plays also an important role when travelling within Norway. Hereby travelling to Nordnorge will involve higher emissions than travelling to Vestlandet, both for international and domestic tourism (Figure 2).

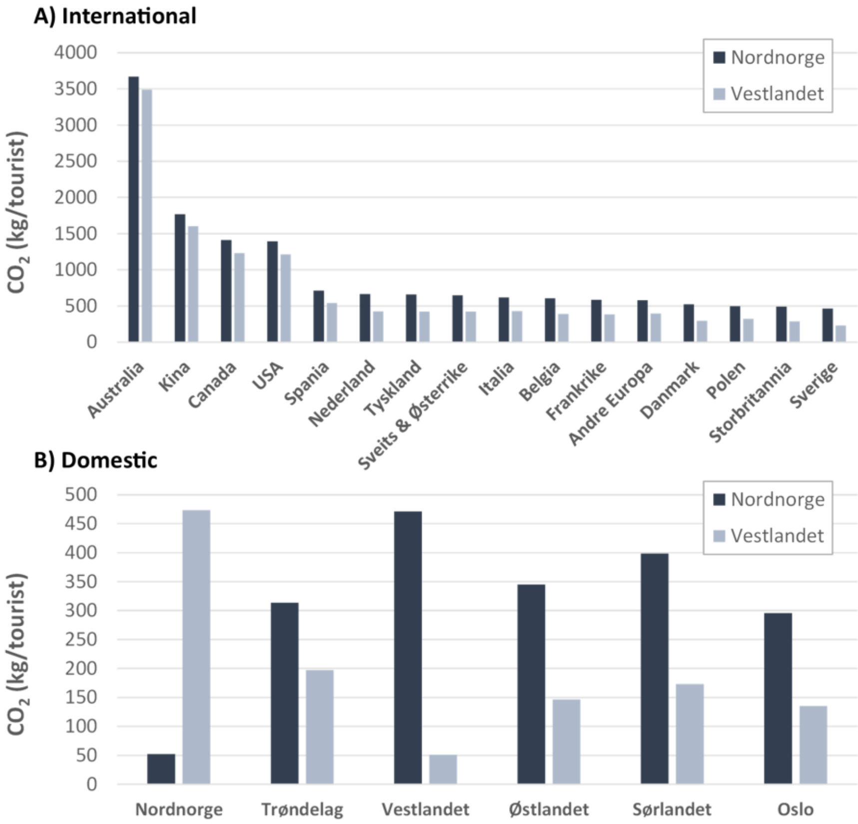

Figure 2: Transport-related CO_2 emissions (kg/tourist) from international (A) and domestic (B) markets travelling to Nordnorge and Vestlandet.

4 Concluding remarks

In this report, we described the principles behind the CO2RISM calculator and the methods behind the input data delivered to Innovation Norway. The CO2RISM calculator provides information on the transport-related total CO_2 direct emissions associated to a group of tourists with a specific compositional share of markets and travelling to a specific Norwegian region. The transport modes considered in our study include aviation, ferries, train, car, bus and campers. The fundament behind the calculation considers emissions from 3 legs trips; 1) leg_1: travelling to Norway from abroad (round trip); 2) leg_2: regional trip from the entrance to Norway to the final region of destination; and 3) leg_3: trips within the region of destination.

Data availability

The sources of data are predominantly obtained from open data sources. All aggregated data and calculations in the model are openly available, either from sources stated below or from Innovasjon Norge/NILU. *Geodatabases* of airports and ports and destinations were collected from various online sources and put together for the purpose of this project. Distance calculations done are part of the calculator internal data and are openly available. *Activity data* for ship and rail were taken from open data sources and used in combination with diesel consumption (reported by VY) for rail and emissions (Havbase.no for shipping) to calculate ship emission factors. For road traffic, activity data include total traffic volume from the NILU road emission model HEDGE, toll station counting from 2018 and 2019 (Svinesundsforbindelsen & Vegfinans) and Statistics Norway Kjørelengderegisteret. Aviation activity is a custom-made database of all aviation activity touching Norwegian airports, provided by AVINOR, for details on this dataset we refer to AVINOR. *Emission factors* for road vehicles are directly taken from HBEFA, which are open data. The ICAO Corsia model used to get individual flight fuel consumption is an open model, and the calculator emissions are derived directly from this. *Passenger and Tourism data* used are collected from open sources. For ferries and cruises, passengers and port statistics were collected from cruiesnorge and individual ports, Eurostat and Statistics Norway trough open portals. Aviation passengers is part of the AVINOR database, whereas passengers in vehicles are taken from Road authotities and TØI publications. Transport mode shares are taken from published data from Innovation Norway's Turistundersøkelsen 2018.

Calculator Updates

The calculator is based on data for the year of 2018. Most data is available also for 2019 and is updated by the data holders every year or faster. Between years, tourist volumes and transport modes change. Also the transport means evolve, generally getting more energy efficient resulting in lower emissions per km. The rate of change in the latter is considerably longer than the former, but both should be updated annually or close to that. With the ongoing travel restrictions from the COVID-19 pandemic, extremely large changes in 2020 are to be expected and should be taken into account.

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