

Port de Barcelona ECOcalculator

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1. Introduction

The Port de Barcelona ECOcalculator is a tool for calculating the CO₂ emissions associated with a particular transport route.

The web version of the ECOcalculator is a simplified version of the emission calculation model developed by the Port Authority of Barcelona and Mcrit SL. The emission model is linked to a Geographic Information System, called SIMPORT, which is the Port de Barcelona's Information and Modelling System for the Hinterland and the Foreland.

SIMPORT makes it possible to calculate distances and travel times for the various possible journeys between the foreland areas and European regions (NUTS3). These distances are then used to calculate CO₂ emissions by applying emission factors and load factors for each vehicle.

Only the emissions associated with the journeys undertaken in the different modes are calculated. The system does not take into account the emissions from cargo handling, or the production of vehicles and infrastructures used in transport.

2. Web ECOcalculator

The web tool was designed to calculate the emissions of a particular route between a foreland port and a hinterland location. On this route there is always an oceanic section between the foreland port and the Port de Barcelona, and an overland section between the Port de Barcelona and the hinterland location. This overland section may be travelled by road or rail, although the last mile is always performed by road.

2.1. How it works:

The web application is sequential, and follows these steps:

- i. Foreland port. Use a wizard to select the foreland area, the country and the port.

FORELAND

Select region-->

Select country-->

Select port-->

- ii. Hinterland location. Choose a European location by entering an address or a name.

HINTERLAND

- iii. Direction of the flow. Select whether the journey is from hinterland to foreland or foreland to hinterland. The resulting routes may be different, since the sea lanes are not necessarily symmetrical.

DIRECTION

European exports



- iv. Land transport mode. You can select a journey that takes place entirely by road or by rail, with the last mile by road. If the mode selected is rail, first select the intermodal station at which you intend to switch between rail and road modes. The system automatically provides the ten closest stations to the hinterland location selected.

LAND TRANSPORT MODE

Road
 Rail

Intermodal Terminal

Select intermodal terminal ▼

- v. Calculate. When you hit the 'Calculate' button, the system draws the optimal path on the map and shows a diagram with the basic data concerning distance and emissions. The   icons allow you to zoom into the overland or the oceanic section of the route.

CALCULATE

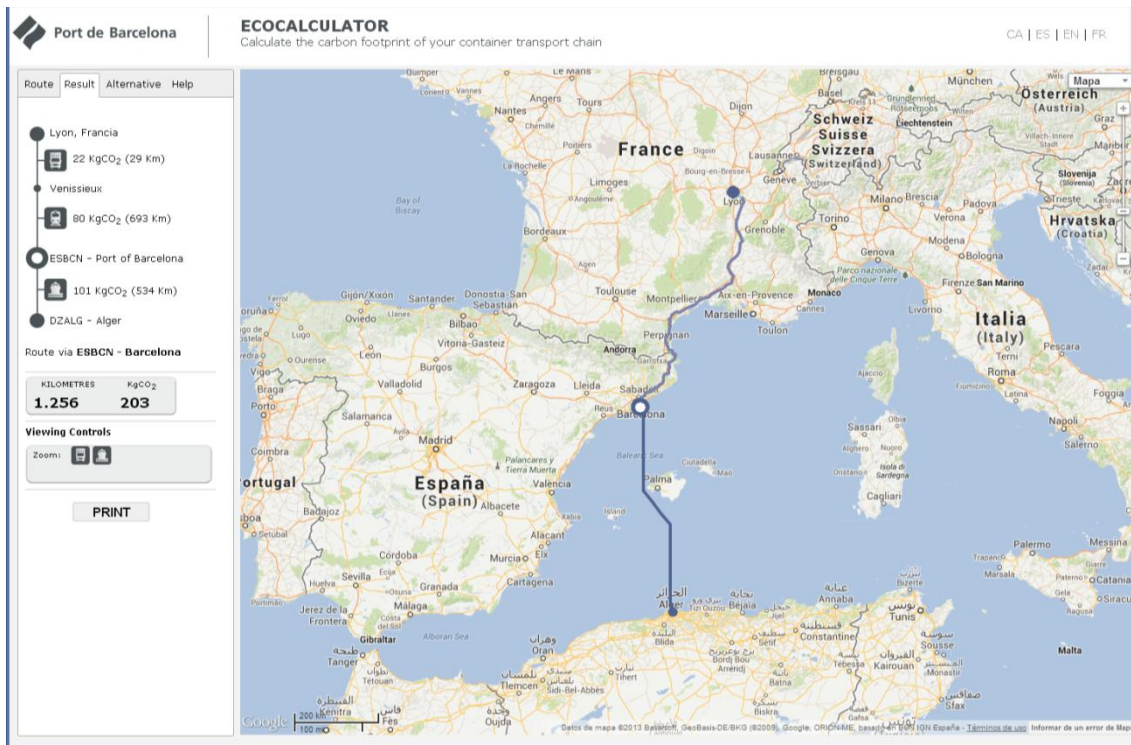
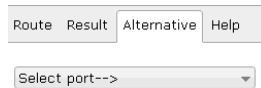


Image 1. Example of calculating a route

2.2.Compare

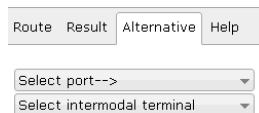
Apart from calculating routes through the Port de Barcelona, you can also compare the route passing through a different port in the "Alternative" tab.

- i. Pass-through port. Select this using a dropdown menu showing various European ports.





The screenshot shows a navigation bar with four tabs: "Route", "Result", "Alternative", and "Help". Below the tabs is a dropdown menu labeled "Select port-->" with a downward arrow.

- ii. Pass-through station. If the overland section includes rail, you must select the pass-through train station.



The screenshot shows a navigation bar with four tabs: "Route", "Result", "Alternative", and "Help". Below the tabs are two dropdown menus. The first is labeled "Select port-->" and the second is labeled "Select intermodal terminal".

- iii. Calculate. When you hit the Calculate button, the system calculates the optimal journey and produces a diagram showing the basic details concerning distance and emissions through the alternative port, and compares this with the results via the Port de Barcelona. The   icons allow you to zoom into the overland or the oceanic section of the route. There are also two checkboxes allowing you to enable or disable each of the two routes indicated on the map.

CALCULATE

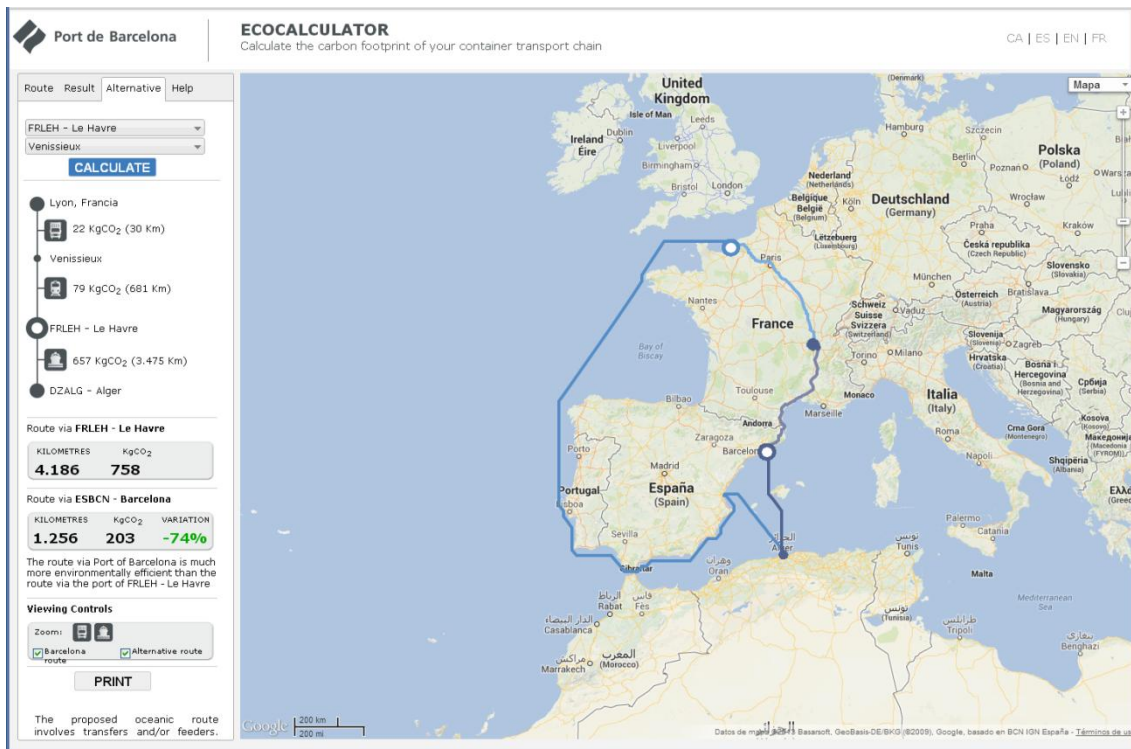


Image 2 Example of calculating a comparative route through a pass-through port

2.3.Print results

The system can generate a summary report of the results of the simulation, which includes a map with the routes.

There are two report models - one for the simulation of the route through the Port de Barcelona and one for the comparison with a pass-through port.

3. Simulation model

The model used for calculating emissions for each mode of transport is described below.

3.1. Oceanic section

For the oceanic section it is assumed that the vessel used is always a container ship. If you do not know the exact size of the ship, a mean value will be applied depending on the route of the journey being analysed.

The theoretical formula used for calculating the power of the main engines for container ships of different sizes, available in the 2010 Trozzi document for calculating maritime emissions (<http://www.epa.gov/ttnchie1/conference/ei19/session10/trozzi.pdf>) is as follows:

$$Power = 2.9165 \cdot GT^{0.8719}$$

where GT is the gross tonnage.

The same Trozzi document provides the average value of the container ship speed, which is 36 kph or 20 knots, for which the formula given above is valid.

Furthermore, fuel consumption is related to the energy consumed using the following relationship from the document mentioned above:

$$1kWh = 217g_{fuel}$$

where consumption is expressed as grams of fuel per hour.

This equivalence, the formula for calculating the power, speed of movement and length of the journey are used to obtain the consumption per unit of length, assuming full power in the main engines.

The formula for the relationship between TEU and GT is a statistical regression performed with data from Alphaliner. An analysis is made of the 3,296 container ships available, from which it is possible to obtain the capacity in TEU and the deadweight (with values ranging from 54 to 15,550 TEU).

The relationship between GT and the number of TEU has been obtained by performing a statistical regression of the available data resulting from the following equation, where TEU is the maximum number of containers that can be carried by the ship:

$$GT = -0.00016 \cdot TEU^2 + 13.284 \cdot TEU + 169627$$

The size of the vessel is expressed in maximum TEUs, while it is necessary to know the GT to calculate the consumption (and therefore the CO₂).

The theoretical maximum consumption is corrected firstly by reducing it to 87% because the motors do not run at 100% during the cruise phase. Then consumption is added for the ship's manoeuvring and *hotelling* phases, which according to document ENTEC 2005 corresponds to running the engines at 20% for 0.33% of the travelling time for manoeuvring and 2.33% for *hotelling*.

This consumption is divided by each TEU transported, assuming the vessel is loaded to 80% capacity. The consumption is multiplied by 3.17 to obtain CO₂ emissions (average carbon content of ship's fuel, according to data from CORINAIR).

The emissions obtained are increased by 12% to account for the energy consumption necessary for transporting the fuel.

3.2.Overland section

The overland journey takes into account the road and rail sections.

3.2.1. Road

The COPERT IV formulation model (the base for the CORINAIR methodology) is implemented for road transport. This formula relates fuel consumption to speed, type of technology, size of the lorry, and level of load and makes it possible to use up to 84 different types of vehicle. As a generic case for the analysis where there is no specific information available on the truck used, the system proposes to use a 40-50 tonne articulated lorry with EURO IV technology, as this is the standard vehicle used in container transport.

This is the way used to calculate emissions according to the fuel consumption of the chosen vehicle, which is then multiplied by 3.14 (average carbon content of diesel fuel for lorries, according to data from CORINAIR).

Consumption is increased to simulate the fact that the lorries are loaded to 75% capacity on average, indicating that empty runs are made.

The emissions obtained are increased by 12% to account for the energy required to transport the fuel.

3.2.2. Rail

We assume the hypothesis that rail emissions are caused by indirect sources. This means that all transport is performed using electrical-powered trains, but part of the electricity comes from renewable sources.

First, we obtain the data of 0.028 kWh/tonne-km, using LIPASTO (an emission calculation methodology developed and applied in Finland http://lipasto.vtt.fi/yksikkopaastot/tavaraliikenne/raideliikenne/junat_konttie.htm.) This value applies to a full container freight train and the model assumes that the trains are always full. This information is obtained on the basis of trains running in Finland, but is the only data available; therefore it is assumed that container trains have characteristics that can be extrapolated to the rest of Europe.

As regards CO₂, we apply a value of 0.4127 kgCO₂/ kWh (2005 data) obtained from the European Environment Agency (average emissions per kilowatt-hour of electricity generated in EU27, sourced from http://www.eea.europa.eu/publications/eea_report_2008_6).

Because the consumption is obtained from kWh per tonne transported, it is necessary to convert containers to tonnes. It is assumed that containers (TEU) transport 10 tonnes on average, a value obtained from freight statistics at the Port de Barcelona.

3.3.Example of the application of the model

To calculate the emissions from a particular route, first the GIS is used to obtain the distance of each section of the logistics chain. We choose the optimal route in terms of total cost of transport using a Ford algorithm, which makes it possible to obtain the shortest path between two points in the transport network. For the oceanic section, the length is increased by 13% to simulate actual shipping conditions, as there are stopovers that extend the travel time of the routes.

The lengths of each segment of the chain (ocean, road, rail) and the emission factors described above are used to calculate the associated CO₂ emissions.

- *Oceanic section:*

CO₂ in tonnes/TEU = distance in km · fuel consumption / vessel capacity in TEUs · load factor · manoeuvre factor · *hotelling factor* · 3.17 · fuel transport factor.

3.17 is the weight of CO₂ measured in tonnes, obtained by burning a tonne of ship's fuel. The consumption depends on the size of the ship, which is linked to the exact route, although in general a mean value is applied for each section.

- *Road section:*

CO_2 in tonnes/TEU = distance in km · lorry consumption · load factor ·

$3.14 / 2 \cdot \text{fuel transport factor}.$

3.14 is the weight of CO₂ in tonnes, obtained by burning one tonne of lorry fuel and 2 is the number of TEUs transported by a standard lorry. The consumption depends on the size and technology of the lorry, but in general the hypothesis of a 40-50 tonne EURO IV trailer with capacity for two TEUs is applied.

- *Railway section:*

CO_2 in tonnes / TEU = distance in km · 10 · 0.028 · 0.4127 / 1,000

10 is the average weight of a TEU in tonnes; 0.028 is the average consumption of a train in kWh/tonnes-km; 0.4127 is the weight of CO₂ in kg obtained to generate 1 kWh, and 1,000 is the factor to convert to tonnes.

The model can be applied to a particular flow between a source and a destination or can be applied to an entire matrix of flows between Europe and the rest of the world, making it possible to analyse both the impact of a transport chain and the European transport system in general.