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Interreg Italy - Croatia GUTTA

EUROPEAN UNION

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1. Executive Summary

An automated tool for discovering ferry routes of minimum CO_2 emissions has been developed in the frame of the GUTTA project and is available online at www.gutta-visir.eu. The tool makes use of operational marine forecasts and delivers the amount of CO_2 which can be saved on each route. Daily updated marine forecasts are used and the computations are carried out on HPC facility. The strategic added value of the optimal routes is also quantified in terms of Carbon Intensity Indicators (CII). CII are part of a measure adopted at the International Maritime Organization (IMO) for kicking-off the process of decarbonization of shipping.

This report documents, for the first version of GUTTA-VISIR, the key structure of the technological infrastructure enabling the service, including both its back- and frontend components, as well as some results provided through the web application.

2. Introduction

According to the decisions taken at the MEPC 76 meeting of the International Maritime Organization (IMO), all ships will be requested to contribute to the reduction of Greenhouse Gases (GHG) through an enhancement of their energy efficiency. In particular, in June 2021 the IMO approved a legislative framework called "CII rating", meant to induce a pathway of reduction of carbon intensity of emissions from shipping. The CII rating includes both reference lines and slopes. The CII reduction slope will be -1% per year from 2020 to 2022 and -2% per year from 2023 to 2026. The ships are left free to choose the most appropriate way to reach this objective (e.g.: installation of energy savings devices, operational measures) [IMO-MEPC76].

The European Commission released in July 2021 a package of legislative proposals called "fitfor55" to support a union-wide decarbonization ambition. It includes a revision of the EU emissions trading system (EU ETS), including its extension to shipping. If the fitfor55 package were combined with the proposed amendment of the MRV legislation [MRV-amend_2020], which requires to lower the carbon intensity of shipping by 40% by 2030[1], they would realize a financial mechanism for favoring decarbonization of the existing fleet, at least at regional level.

The latest upgrade of the VISIR ship routing model (VISIR-2) can keep into account both wave and current forecasts for computing optimal routes which minimize the CO_2 emissions. Furthermore, both the CO_2 and the CII savings relative to the least-distance route are computed by VISIR-2 [Mannarini_2021]. VISIR-2 was validated in its capacity to compute shortest path routes vs. its predecessor VISIR-1 and through direct comparison to analytical benchmarks. As for the vessel speed loss in waves and the CO_2 emission rates, VISIR-2 makes use of a look-up-table based on data collected at the ship simulator installed at the University of Zadar. Details of this system were reported in GUTTA deliverable D.4.1.1[2].

This VISIR-2 version powers an operational service developed in the frame of the GUTTA project, and which is openly accessible at the URL: www.gutta-visir.eu. The tool was called GUTTA-VISIR (GV), as it brings the advancements of the VISIR ship routing model[3] at the level of an operational service of the GUTTA project.

[1] The baseline of this reduction still needs to be specified in a delegated act, but should be based on EU-MRV data, which collection started in 2018.
[2] https://zenodo.org/record/4778523
[3] www.gutta-visir.eu

Scope of this report is to document version 1.2.1 (hence termed just v1) of GV, which was released on November 3rd, 2021. The report is structured into a section describing the technological infrastructure enabling the web service (Sect.3) and a section with a sample of results obtained through it (Sect.4).

3. Technological Infrastructure

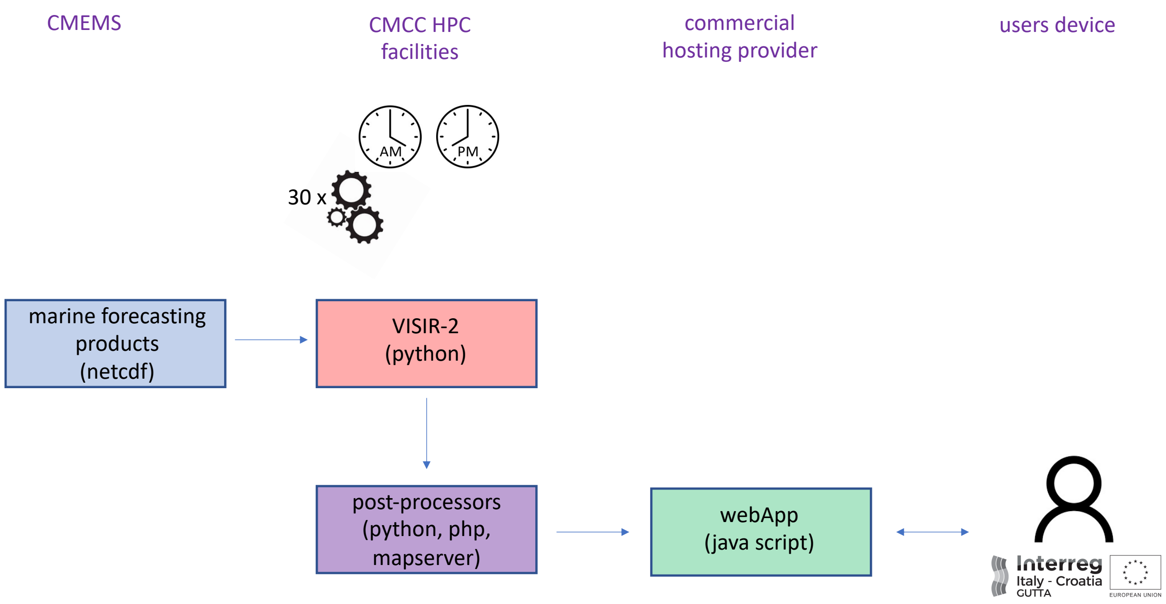


Figure 1 Overall architecture of GUTTA-VISIR

The description of the technological infrastructure enabling the GV web service is split into a backend (operational computations of the optimal routes and rendering, Sect.3.1) and a frontend part (bringing data to the end-user and providing a browsing capacity, Sect.3.2).

Fig.1 provides an overview of the system, from the marine forecasting products to the end-user. The wave and sea current forecasts are obtained from the Copernicus Marine Environment Service (CMEMS[4]). They are then ingested by the VISIR-2 model for computation of least-CO_2 ferry routes. More detail on this step is provided in Sect.3.1. The outcome of these computations is made available to a

[4] https://marine.copernicus.eu/

web application (reachable at www.gutta-visir.eu), which enables an interactive browsing of the results by the end-user. The layout and functioning of the web application are described in Sect.3.2.

3.1. Backend

The operational chain for the GV service starts from the forecast fields by CMEMS used in input to the VISIR-2 computations. They are:

a) MEDSEA_ANALYSISFORECAST_WAV_006_017
b) MEDSEA_ANALYSISFORECAST_PHY_006_013

Where a) is used for the sea state (significant wave height of the wind waves and their direction) and b) for sea circulation (surface sea currents and their direction).

The b) forecasts are updated daily, corresponding to the 0Z sea circulation analysis, while the a) forecasts are updated twice a day, corresponding to both the 0Z and 12Z sea state analysis.

VISIR-2 is run at predefined times, at which the freshest a) forecasts are available. These “r-date” currently are:

i. 20:00 local time
ii. 04:00 local time

At each run, optimal ferry routes corresponding to various departure dates and times, as well as ferry engine load values are computed. The engine load values are three: 70, 85, 100% MCR (maximum continuous rating). The departure dates and times are 39 and are listed in Tab.1.

Date	Time							
d		03:00	06:00	09:00	12:00	15:00	18:00	21:00
d+1	00:00	03:00	06:00	09:00	12:00	15:00	18:00	21:00
d+2	00:00	03:00	06:00	09:00	12:00	15:00	18:00	21:00
d+3	00:00	03:00	06:00	09:00	12:00	15:00	18:00	21:00
d+4	00:00	03:00	06:00	09:00	12:00	15:00	18:00	21:00

Table 1 Departure time steps for the route computations. The day GV is run is “d”.

The reference day “*d*” for the first departure time step corresponds to the date of the VISIR-2 run. Should the forecast fields by CMEMS relative to the latest analysis not be available (due to any operational incident), VISIR-2 would look for the second freshest fields available, among the previously issued ones and already available at the HPC archive of CMCC.

The above computations are done for 15 return routes in the Adriatic-Ionian basin, see Appendix A1. They are performed in parallel on 30 (=15 x 2 directions of sailing) cores of the HPC facility (see Appendix A2). Additionally, some rendering processes are performed on dedicated nodes of a specialized cluster, also part of the CMCC HPC facility.

The various departures, engine loads, and port combinations result into a total number of 3510 routes computation per run. There are two such runs per day.

3.2 Frontend

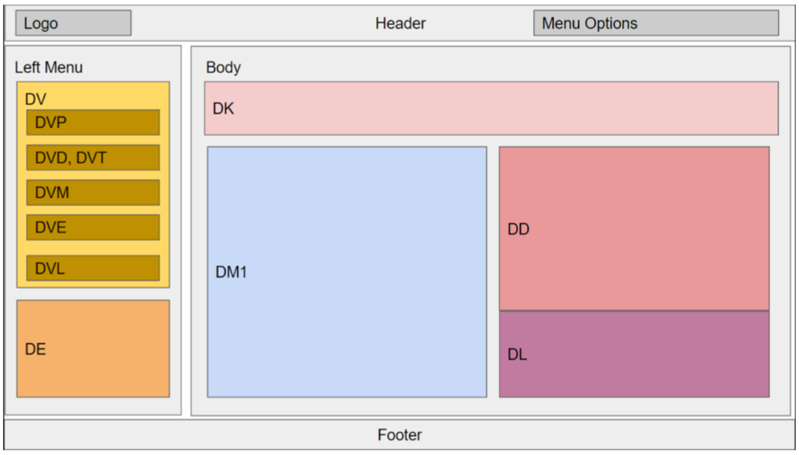


Figure 2 Layout of the GUTTA-VISIR web application, with highlight of the divisions it consists of.

The Frontend part of GV consists in both some rendering services and a web application.

The rendering is distributed between the HPC, a dedicated node on a cluster where a mapserver installation is available, and a specific web service for the route elements (waypoints).

The environmental fields (waves and currents) and the isolines (CO_2, time, distance) are rendered by MapServer[5] and provided to the web application via a Web Mapping Service (WMS). Specific Mapfiles, structured text configuration files, are produced twice a day on the cluster to feed Mapserver. When a

[5] https://mapserver.org

request is sent to MapServer from the web application, it uses information passed in the request URL and the Mapfile to create tiled images of the requested map. The tiles are masked using a global mask, where required, to hide the parts that cover the land. Furthermore, they are rendered and supplied on-the-fly by MapServer, for any zoom level.

The web application was designed starting from its functional requirements. This included producing a general layout as shown in Fig.3 as a first step. This was based on experience with previous services[6] and on the specific data products GV was supposed to make available to the end-user.

The complex interactions between the data and the web application were first formalized in terms of use case diagrams and user stories, then actually coded in both PHP and React (for the web app) and in PHP (for the web service). The cartography is based on OpenStreetMap.

While a responsive layout was chosen, access to GV through a PC is recommended.

4. Results

The GV service enables the user to interact in multiple ways with the outcomes of VISIR-2.

A comprehensive user manual has been published and is available at https://www.gutta-visir.eu/other/help. Therefore, in this report we just provide some screenshots documenting some of the main capacities of GV.

[6] E.g. www.visir-nav.com

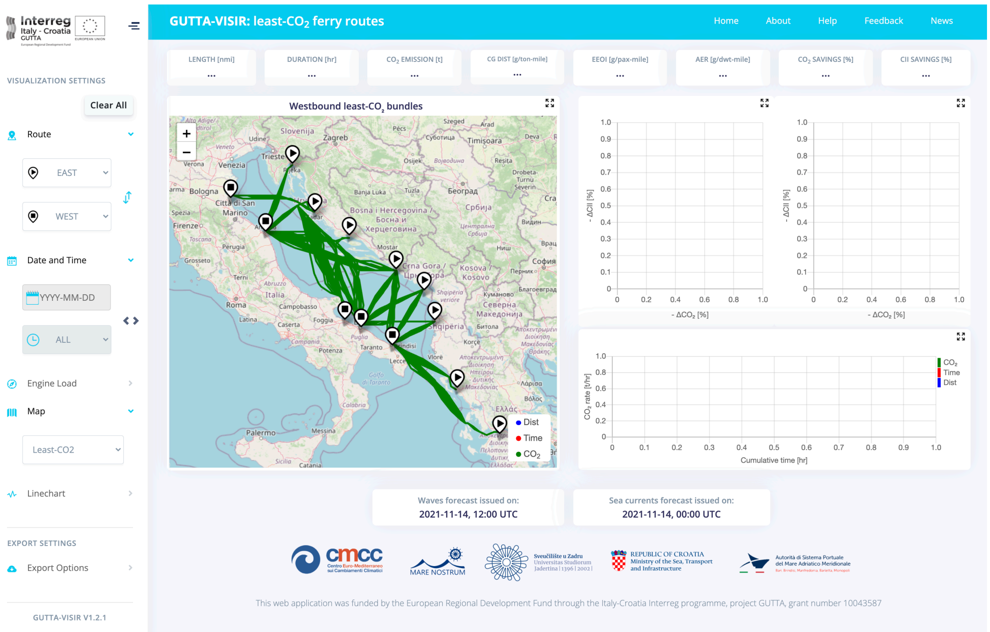


Figure 3 The dashboard of GV, with all Westbound least-CO2 routes selected. The page also displays the time of issuing of the wave and sea current forecasts used for the route computations.

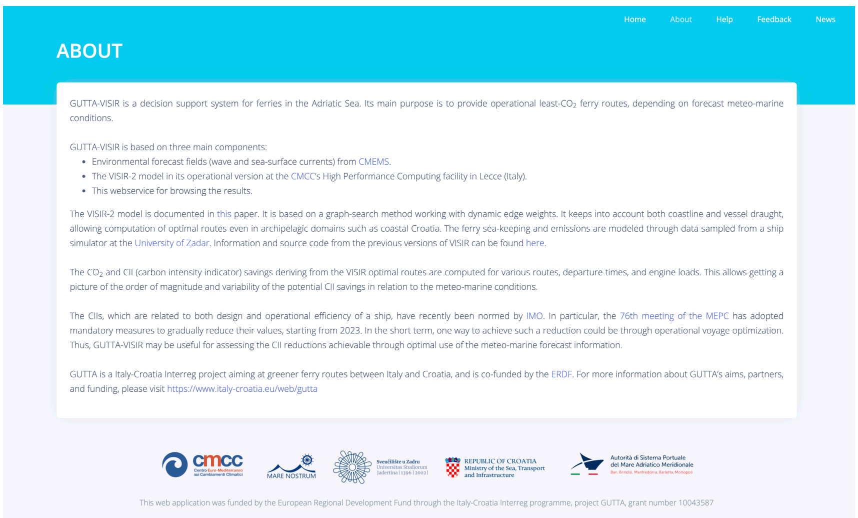


Figure 4 The About page of GV: introductory information to the service, the policy framework, and the modeling tool are provided, along with links for deepening into the subjects.

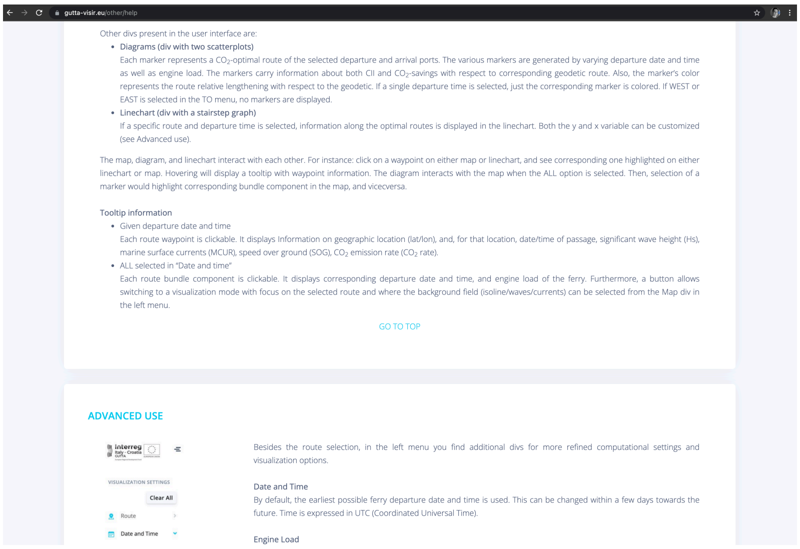


Figure 5 Part of the Help page of GV: The page is structured into a general functioning level, advanced use, and background information.

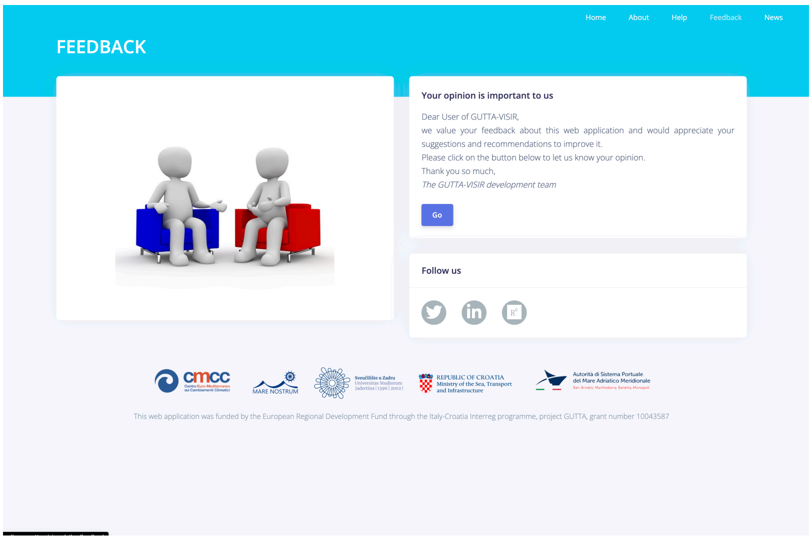


Figure 6 The Feedback page of GV: the button to access the feedback collection form is provided, and links to social media on which groups on GV are available.

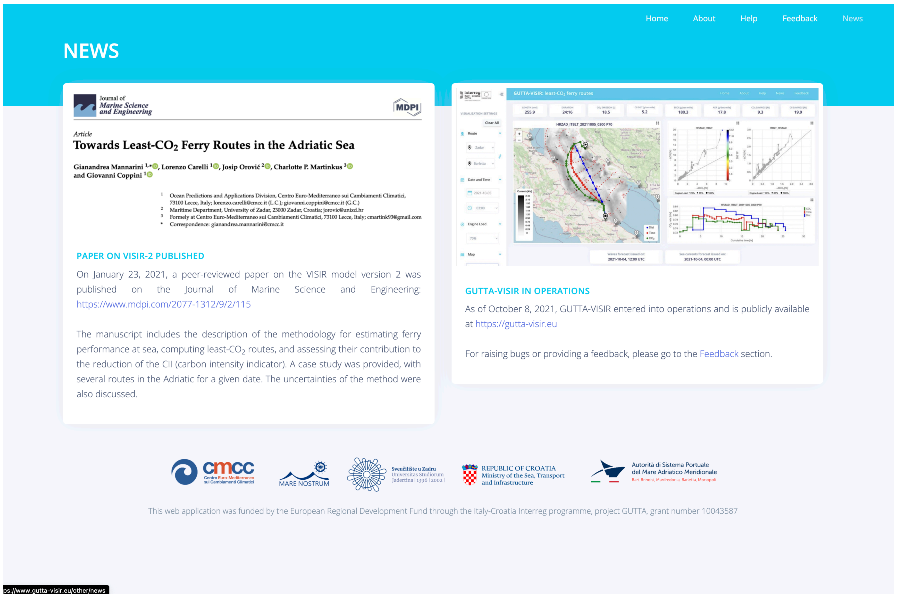
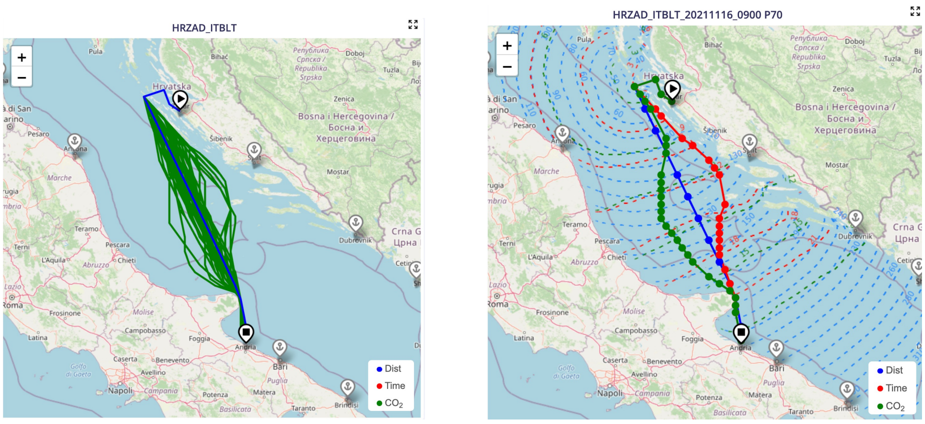
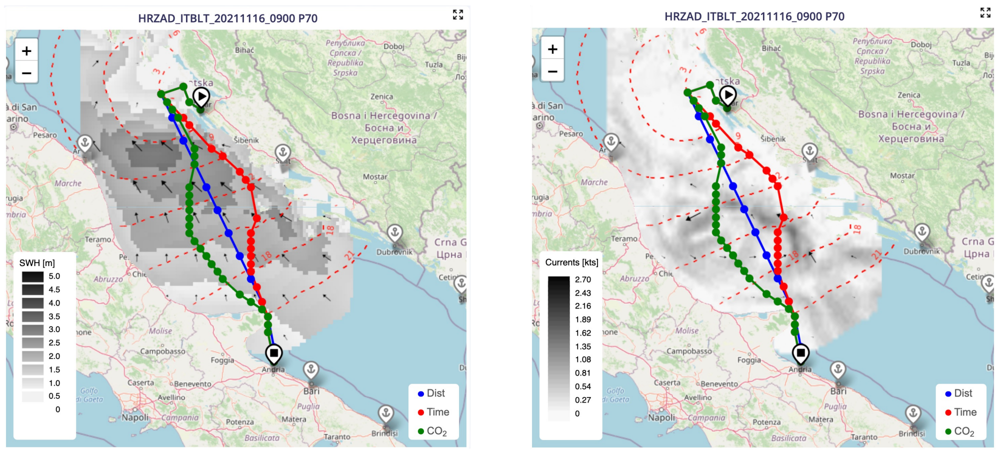


Figure 7 The News section, with post relative to recent milestones related to GV.



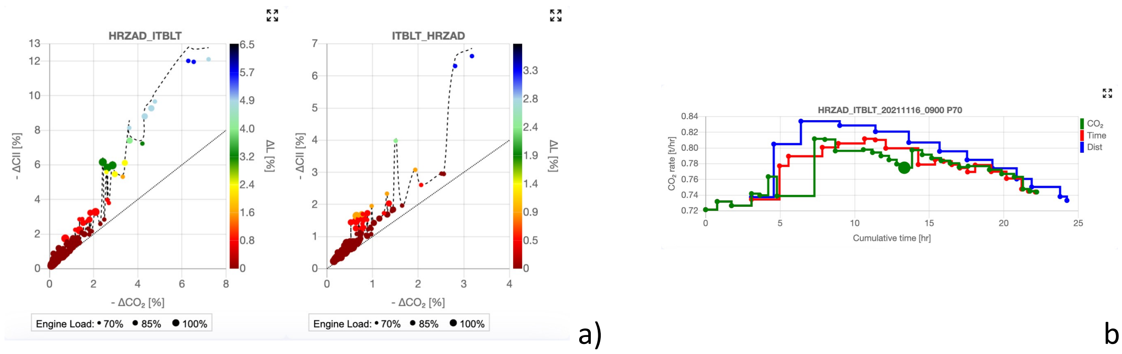
a) b)

Figure 8 a) Example of least-CO2 routes from Zadar to Barletta for all departure times and engine load; the least-distance route is given in blue. b) a specific route from the bundle a), displayed along with corresponding least-time route (in red) and isochrones (see Mannarini_2021 for details).



a) b)

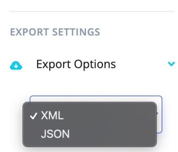
Figure 9 As Fig.8b, but with the wave field (a) or the sea currents field (b) displayed in background.



a) b)

LENGTH [nmi]	DURATION [hr]	CO_2 EMISSION [t]	CG DIST [g/ton-mile]
238.3	24:05	18.5	5.5
EEOI [g/pax-mile]	**AER [g/dwt-mile]**	**CO_2 SAVINGS [%]**	**CII SAVINGS [%]**
193.7	19.1	4.8	9.7

c)



d)

Figure 10 a) CII vs. CO2 savings diagrams, for routes with given endports and opposite sailing directions (route lengthening as marker color). b) linechart for the routes in Fig.9; c) key figures for the selected least-CO2 route; export menu for the route.

5. Conclusions

A web tool for the computation of eco-routes for ferries between Italy and Croatia has been designed and realized in the frame of the GUTTA project. The service, called GUTTA-VISIR ("GV" in short), is available online, with free and open access policy, at the URL www.gutta-visir.eu .

The route computations of GV are based on the VISIR-2 model. The ferry representation, its involuntary speed loss in waves as well as its CO_2 emission rate, are based on data collected at the ship simulator. The input marine forecasting products are available at the HPC facility of CMCC in Lecce, where all the operational computations are carried out.

GV is probably the first operational tool to not only compute least-CO_2 routes based on operational marine forecasts, but also assessing their carbon intensity savings. This information is provided though the CII indicators, recently adopted by the IMO.

Even some routes currently not covered by the commercial ferry operators are provided by GV (cf. Appendix A1).

Appendix

A1. List of routes

The 30 routes computed by GV for each departure date, time, and engine load are given in Tab.2. In total, 16 of these routes are currently not covered by the commercial operators.

Table 2 List of routes covered by GV, with indication if they refer to already sailed routes.

No.	Departure	Arrival	Existing?
1	Ravenna	Zadar	N
2	Ancona	Rijeka	N
3	Ancona	Zadar	Y
4	Ancona	Split	Y
5	Ancona	Dubrovnik	N
6	Barletta	Zadar	N
7	Bari	Split	N
8	Bari	Dubrovnik	Y
9	Bari	Dürres	Y
10	Bari	Bar	Y
11	Brindisi	Dubrovnik	N

12	Brindisi	Bar	N
13	Brindisi	Dürres	N
14	Brindisi	Igoumenitsa	Y
15	Brindisi	Patras	Y
16	Rijeka	Ancona	N
17	Zadar	Ravenna	N
18	Zadar	Ancona	Y
19	Zadar	Barletta	N
20	Split	Ancona	Y
21	Split	Bari	N
22	Dubrovnik	Ancona	N
23	Dubrovnik	Bari	Y
24	Dubrovnik	Brindisi	N
25	Bar	Bari	Y
26	Bar	Brindisi	N
27	Dürres	Bari	Y
28	Dürres	Brindisi	N
29	Igoumenitsa	Brindisi	Y
30	Patras	Brindisi	Y

A2. Computational facilities

The GV service is provided thanks to combined use of HPC facility and a cluster. Their features are described below.

HPC

The HPC facility is hosted in Lecce (Italy) and consists of a Lenovo ThinkSystem SD530, with Intel Xeon Gold 6154 processors. There are 12,528 cores, with a peak performance of 1,202 TFlops. Each computational node hosts 2 processors and a total of 36 cores, and the memory per node is 96 GB. Infiniband EDR interconnection is available. Operating system is Linux CentOS 7.6 x86_64, with a LSF batch queueing system.

Cluster

The cluster used for rendering and some post-processing services consists of a IBM System X3550M4 Double Proc. 12C with Intel Xeon 12C E5-2697v2 processors with a rating of 2.7 GHz. One node is used for GV. Each computational node hosts 24 cores and the memory per node is 192 GB. Eth interconnection is available. Operating system is Linux CentOS release 7.9.2009 (Core).

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