Policy Research Corporation

Tourist facilities in ports

The environment factor

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I. INTRODUCTION

Europe's coastlines, stretching over 89 000 kilometres[1], have been of great value to the European continent throughout its history. Europe's colonial power originated from its connectivity with multiple seas, oceans and intercontinental rivers. Several great empires were built upon its maritime expertise and the resulting economic trade. Today, that greatness is represented in Europe's beautiful cities, which are a major attraction for travellers from all over the world.

The diversity of the continent makes the European Union (EU) an ideal holiday destination. The EU offers a wide range of cultural activities, natural heritage and leisure activity. In the past decade, the EU has welcomed a relatively new phenomenon into the EU tourism industry: namely cruise tourism. Due to its large expanse of coastlines, historical sights and variety of cultures, the EU makes an ideal cruise destination. As the cruise industry is adding significant economic value to EU Member States, cruise tourism is an important sector for coastal regions and islands to attract.

I.1. TOURIST FACILITIES IN PORTS

As well as adding significant economic value, cruise tourism can also give rise to unwanted externalities as cruise ships create air emissions, waste and noise in EU ports and seas. The Communication "An integrated Maritime Policy for the European Union" (COM (2007) 575 final) stresses the importance of reconciling economic development, environmental sustainability and quality of life within coastal regions and islands. The Action Plan accompanying the Communication (SEC (2007) 1278) acknowledges the importance of promoting the development of quality coastal tourism and states that, as a first step, the Commission intends to assess the benefits for ports to invest in infrastructure and facilities for receiving tourists, in particular through cruise tourism.

Taking the positive and negative effects of cruise shipping into consideration, the following research question arises: '*How to increase economic benefits and job creation in coastal regions and islands*

1 http://ec.europa.eu/research/infocentre/article_en.cfm?id=/research/research-eu/sea/article_mer27_en.html&item=Environment&artid=7348

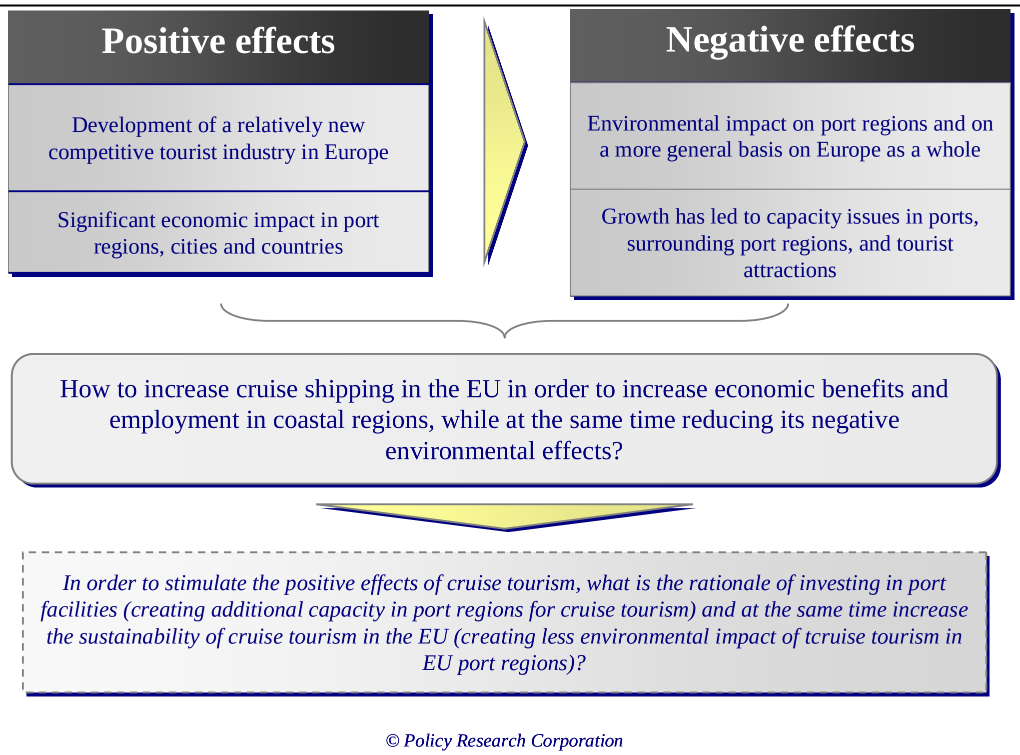
particularly through cruise tourism, whilst reducing its negative environmental effects'? The study addresses this research objective by looking at the following aspects:

- Growth and development opportunities for coastal regions and islands through cruise tourism;
- Cruise tourism and the environment;
- Cruise tourism and the economy.

The outcome of the study will be a quantitative indicator to clarify the return on investment in tourist facilities.

Figure I.1 shows a graphical overview of the relevance of this study and its main objective.

Figure I.1 : Overview of the study



Source: Policy Research Corporation

In the research assignment, the study is subdivided into four tasks.

Task 1: Tourist facilities in and around ports: the environment factor

Increasingly ports are having to adapt their operations to ensure that their activities are sustainable. The process is to a large extent driven by EU legislation that imposes norms in order to protect the environment. More visits by tourists, particularly those arriving on cruise ships, will increase the pressure on the quality of the environment in ports. This trend will translate into additional environment-related costs, which will have to be considered when investment decisions are taken.

Port facilities may eventually also be adapted to promote the use of more sustainable infrastructure and equipment in place of the current systems (e.g. shore-side electricity[2]).

The objectives of Task 1 are to:

- Provide an assessment of the economic rationale of investing in sustainable infrastructure and equipment and, in particular, the use of shore-side electricity;
- Establish cost indicators for compliance with environmental legislation associated with tourist facilities in and around ports.

Task 2: Economic drivers for tourist facilities in ports

This task will clarify the economic rationale for investing in tourism facilities in ports, taking into account the opportunities and risks, and the direct and indirect effects, in terms of growth and job creation, including related activities in and around the ports.

The key goal of Task 2 is to collect relevant information from both the demand and the supply side to strengthen the factual base for a SWOT analysis of tourist facilities in ports, including both direct and indirect economic effects. The facilities to be analysed include tourist facilities that receive cruise ships and ensure their transit to the main tourist centres, including berths, terminals, guides, excursion organisers, tug boats and land transport.

In addition, developing access to the port for tourists may have an effect on other activities, which may need to be reallocated as a result. Therefore, the issue of competition between land and maritime uses in the coastal environment will be addressed.

Task 3: Testing of results

This task is designed to validate the results from the first two tasks. The key goal of Task 3 is to gain acceptance (buy-in) of stakeholders for cruise tourism in EU Member States for the results presented in this study

Task 4: An indicator to clarify return on investment in tourism facilities

A quantitative indicator of the return on investment in tourism facilities in ports can raise awareness of the economic opportunities and risks that may exist in these markets and can make it easier to compare the tourism market with alternative land use options in and around the ports.
The aim in this task of the project is to devise and calculate an indicator for the average return on investment when financing tourist facilities in ports.

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[2] Shore-side electricity is generated by power plants; the use of hydro, wind, solar or nuclear power is preferred, since the generation of electricity using coal, for example, still leads to air emissions

This report deals with all research items that are part of *Task 1*.

I.2. OUTLINE OF THE CHAPTERS

This report assesses the environmental impact caused by cruise tourism in EU Member States. *Chapter II* sets out the research methodology on which the analyses and calculations in this report are based. *Chapter III* contains an overview of the activity and density of cruise tourism in EU Member States. Subsequently, *Chapter IV* assesses the environmental impact caused by cruise tourism. The final two chapters of this progress report will analyse the scope for reducing environmental impact. *Chapter V* discusses a range of options for reducing environmental impact. *Chapter VI* presents a cost benefit analysis of these options, combined with a technical feasibility assessment. Finally, *Chapter VII* sets out a number of conclusions and recommendations on investing in sustainable port facilities.

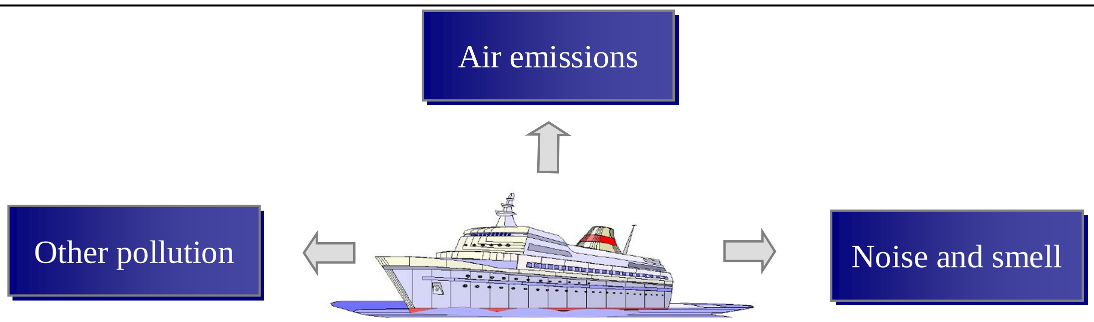
II. RESEARCH METHODOLOGY TASK 1

In order to assess the environmental impact of cruise tourism, a specific research methodology is constructed. This chapter provides an insight into the methodological choices made in order to provide an in-depth response to these research questions.

II.1. RESEARCH QUESTIONS AND SCOPE

The environmental impact of sea cruise tourism[3] in the EU is investigated. As depicted in *Figure II.1*, the environmental impact of cruise ships consists of three different effects: emissions, noise and smell, and other waste.

Figure II.1 : Environmental impact of cruise ships



Source: Policy Research Corporation

Research questions

Two main research questions are formulated:

1. *What is the environmental impact of cruise tourism in the EU?*
    - What are the different kinds of air emissions?
    - What is the impact per type of emission?
    - How must this impact be addressed?
    - What other types of waste can be distinguished?

[3] River/inland cruises and ferry activities will not be taken into account in this study.

2. *How can the environmental impact be reduced most effectively and efficiently?*
   - What methods are available and at what cost?
   - What is preventing both operators and ports from investing in environmental impact reduction methods?
   - What are the most cost-efficient reduction methods?

Noise and smell are identified as unwanted externalities of cruise tourism but quantifying these externalities in monetary cost to society is too complex. Noise and smell will therefore be incorporated qualitatively as unwanted side effects.

Scope

The environmental impact of cruise tourism may differ regionally, nationally and globally. The focus in this research is on studying the environmental impact in a specific EU port region and at a total EU-level. This distinction is made because the severity of the environmental effects depends on regional density and varies according to whether the cruise ship is sailing EU seas or hotelling (i.e. at berth in an EU port). Moreover, environmental legislation differs from region to region (for example, in sulphur emission control areas (SECAs) the environmental impact needs to be assessed per region).

Key concepts

- *Cruise tourism*: This is defined as a sea voyage of at least 60 hours on a vessel that transports only passengers and visits at least two ports (excluding the port of embarkation). It does not include transportation by luxury ferries;
- *Emissions from shipping*: any release of substances from ships into the atmosphere or the sea;
- *Fossil fuels*: Engine fuel, this covers fuel intended for combustion purposes for propulsion or operation on board a ship, including distillate (marine distillate oil (MDO)) and residual fuels:
    - *Distillate oils*: MDO / (marine gas oil (MGO)) refined distillate of oil used for maritime purposes;
    - *Residual fuel*: the heaviest fraction of the distillation of crude oil, with high viscosity (i.e. pre-heating is necessary, and therefore residual oil can be used only in large ships) and a high concentration of pollutants (e.g. sulphur). Its combustion produces a darker smoke than other fuels and it needs to be at a specific temperature for storage and pumping. Due to these drawbacks, residual fuel is also the cheapest liquid fuel on the market[4].
- *Itinerary*: The proposed route or journey of a cruise ship;
- *Transit call*: A cruise call into a port where passengers and crew are effectively day visitors. A transit port is referred to as a destination on the itinerary of a cruise ship;

[4] Some residual fuel is also low sulphur and therefore can be used in SECAs

– *Turnaround call*: Refers to a cruise call at a port where the cruise begins or ends and where the cruise passengers embark or disembark. A turnaround port is the port where an itinerary starts or ends.

– *(Unique) Passenger*: Refers to an individual cruise tourist

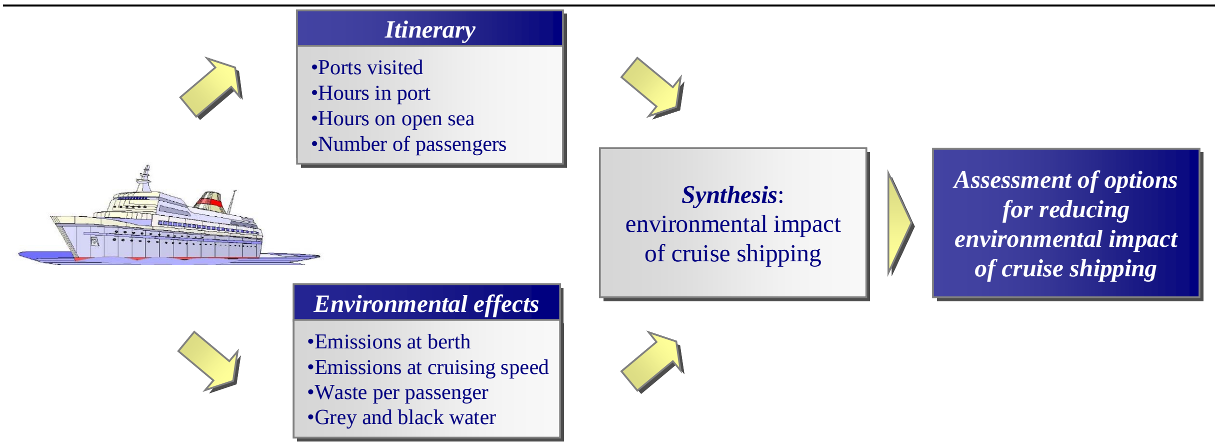
– *Passenger visit*: Refers to a visit by a cruise tourist to a certain port. During a cruise a turnaround port can receive two passenger visits by a single passenger.

II.2. Research design

In order to answer the first research question, '*What is the environmental impact of cruise tourism in the EU?'*, it is necessary to synthesise data on the itineraries of all cruise ships berthing at EU ports and data on the environmental effects of emissions at berth and at cruising speed. *Paragraph II.2.1* outlines the methodology of researching the itineraries of all cruise ships berthing at EU ports. As determining the environmental effects of emissions at berth and emissions at sea (while cruising) is a difficult task, which requires detailed research, *Paragraphs II.2.2 and II.2.3* will look into that methodology in detail.

After determining the environmental impact of cruise tourism in the EU, it is possible to assess different options for reducing the environmental impact of such cruise tourism. This exercise will answer the second research question: *"How can the environmental impact be reduced most effectively and efficiently?"* The specific methodological choices made in order to answer this research question are set out in more detail in *Paragraph II.2.4*. *Figure II.2* depicts the research design of Task 1 in graphic form.

Figure II.2 : Research design of Task 1



Source: Policy Research Corporation

II.2.1. CRUISE ITINERARIES - METHODOLOGY

Assessing the actual density of cruise tourism in EU ports and regions is a difficult task, as cruise ships sail a number of different itineraries per year, which leads to differing berthing frequencies at EU port regions. Firstly, *Policy Research* researched the cruise ships that actually sail EU seas and call at EU ports. As the itineraries of each of these cruise ships were tracked via desk research, *Policy Research* mapped the movements of the individual ships over a period of one year[5], which resulted in a database containing over 1 400 itineraries. While mapping the itineraries, special attention was paid to whether a port can be referred to as a turnaround port or a transit port. This distinction is made because turnaround ports and transit ports have different characteristics, which determine the environmental impact the cruise ship has in a port region. For instance, the duration of the cruise ship's stay in a port varies, as cruise ships tend to spend more time in a turnaround port than in a transit port[6]. The environmental impact of a turnaround call is therefore perceived to be greater than that of a transit call. Some itineraries contain multiple turnaround ports; in this case, all itineraries were mapped separately.

By tracking the itineraries of each individual cruise ship, an overview of the number of calls per EU port region is generated. Moreover, since the capacity (number of passengers) of each cruise ship is known, a calculation is made of the number of passengers disembarking from the cruise ship at each EU port region. Accordingly, by gathering data on cruise itineraries in the EU, the following determinants necessary for calculating the environmental impact of cruise tourism in the EU are assessed:

- Total number of cruise calls at each EU port;
- Duration (the duration of a cruise ship's stay in a port in hours);
- Time spent on EU seas;
- Number of passengers embarking / disembarking at turnaround ports, or getting off the ship in transit ports.

Timeframe

All calculations in this report are based on a timeframe of one year. The cruise ship activities (number of calls and passengers in EU-destinations) are based upon a database that was created by *Policy Research* and contains the itineraries of all 177 cruise ships travelling on EU destinations from October 2008 to September 2009 inclusive[7].

5 Timeframe: October 2008 to September 2009 inclusive. and/or January 2009 to December 2009 inclusive
6 Not for all cases, some transit calls last longer than the average length of a turnaround call
7 For cruise ship itineraries unknown in the period from October 2008 to December 2008 inclusive, a timeframe from January 2009 to December 2009 was incorporated.

II.2.2. DETERMINING ENVIRONMENTAL EFFECTS – METHODOLOGY FOR ASSESSING EMISSIONS

Cruise ships cause air emissions, both in a port (including at berth) and on the open sea. Emissions at berth are inevitable (in the current situation) because cruise ships need a substantial level of power for their restaurants, pools, air conditioning equipment, etc. This power is generated by the ship's main and/or auxiliary engines.

Cruise ships cause different kinds of air emissions which are dispersed in the environment from the exhausts of a ship. The four most relevant emission types are outlined in *Table II.1*.

Table II.1 : Type of emissions caused by cruise ships

Type of emission (chemical abbreviation)	Description	Main effects
NOx	Nitrogen oxide	• Health impacts • Acidification of rain • Global warming
SO_2	Sulphur dioxide	• Health impacts for human beings • Acidification of rain
CO_2	Carbon dioxide	• Global warming
$PM_{2.5/10}$	Particulate matter	• Health impact for human beings

Source: C.f. Cooper, D.A. (2003) 'Exhaust emissions from ships at berth; The European Environmental Bureau et al. (2004) 'Air pollution from ships'

A wide variety of methods are available to quantify shipping emissions. The method used in this study is based on a method designed by ENTEC, a British consultancy firm specialised in the assessment of emissions. It is commonly accepted and widely used for quantifying emissions in Europe. ENTEC conducted a range of studies for the European Commission, specifically DG Environment, concerning the emissions generated by ships. The formula created by ENTEC[8] for calculating emissions is shown in *Figure II.3*.

[8] ENTEC: CONCAWE: Ship emissions inventory- Mediterranean Sea, April 2007

Figure II.3 : Formula for calculating emissions

$$E\ (\text{substance}) = (ME \cdot Lf_{ME}) \cdot Ef + (AE \cdot Lf_{AE}) \cdot Ef$$

E: emission in gram per hour for a substance (NOx, SO_2, CO_2, VOC, PM)
ME: installed main engine power in kW
L*f*: average load factor in %
E*f*: emission factor in g/kW
AE: installed auxiliary engine power in kW

Source: ENTEC

An emission factor is the weight in grams of an emission type that is emitted when generating one kilowatt of power. The emission factors are specified for each emission type and depend on the engine type, fuel type and engine speed. As cruise ships generally sail at different speeds, and thus use varying amounts of power, the emission factors are calculated by means of an accurate approximation.

In order to calculate the emissions per ship, a database is constructed containing data on the technical details of all cruise ships berthing at EU ports. These data were extracted from the Seaweb - Lloyd’s Register of Ships 2008 and for the most part have been validated by the industry. The database contains details of cruise ships in relation to:

- Type of engine (main engine, auxiliary engine);
- Fuel type (residual oil/marine gas oil or marine diesel oil);
- Engine speed (slow, medium, high speed), RPM;
- The power (in kW) of the main engine and auxiliary engine;
- Passenger carriage capacity and crew information.

The above variables are used to calculate the ‘emissions of a cruise ship at berth’ and ‘emissions at cruising speed’. ENTEC has developed emission factors by type of operational mode (at sea or at berth in port), type of engine (according to its speed) and fuel used. For this report, four different emission factors are used:

- Slow speed main engines, using residual oil, cruising at sea;
- Slow speed main engines, using marine diesel oil, at berth;
- Medium speed auxiliary engines, using residual oil, at sea;
- Medium speed auxiliary engines, using marine diesel oil, at berth.

Table II.2 displays these emission factors. The factors reflect the number of grams per emission type for every kW of engine power used by a cruise ship.

Table II.2 : Emission factors used in this study

Emission factor (grams/kW) for:	NO_X	SO_2	CO_2	PM
Slow speed main engines, using residual oil*, cruising at sea	17.5	10.5	620	1.7
Slow speed main engines, using marine diesel oil**, at berth	13.1	0.4	647	0.9
Medium speed auxiliary engines, using residual* oil, at sea	12.7	12.3	722	0.8
Medium speed auxiliary engines, using marine diesel oil**, at berth	12	0.45	690	0.3

* Residual oil has an average sulphur content of 2.7%, checked by Policy Research Corporation with Bunkerworld

** Marine diesel oil has an average sulphur content of 0.2%. For this study the emission factors have been adjusted to 0.1% sulphur content due to future legislation. Please see paragraph IV.3 for a detailed explanation

Source: ENTEC, adjustments made by Policy Research Corporation

In order to obtain the emissions of a cruise ship the following steps are followed:

- Step 1: multiplication by load factors[8]:
  - For main engines in ports, a load factor of 0.2 is taken;
  - For main engines at sea, the load factor increases to 0.8;
  - For auxiliary engines in ports, a load factor of 0.6 is taken;
  - For auxiliary engines at sea, the load factor decreases to 0.3;
  - For newer ships equipped with diesel-electric power plants, the load factors have been set to 0.3 for port operations and 0.6 for sea operations.[9]
- Step 2: The emission factors are multiplied by the power levels (kW) of the cruise ship engines. This results in four types of emissions in grams on an hourly basis, both at berth in ports and at sea.
- Step 3: The types of emissions per hour are linked to data on the time spent by cruise ships in EU ports. Subsequently, the total environmental impact in ports, caused by multiple and different cruise ships, is assessed. As for the emissions on EU seas, a total level of emissions is assessed on a generic EU-level.

II.2.3. DETERMINING ENVIRONMENTAL EFFECTS – METHODOLOGY FOR ASSESSING OTHER WASTE

The other waste caused by cruise tourism is concentrated on activities on board ship. Passengers and crew create solid waste (litter), waste water (black and grey water that comes from showers, sinks and activities onboard), ballast water (needed for the balance of the ship) and hazardous waste (chemicals

[9] These load factors were validated by cruise line technicians.

used for photo processing, etc.). Based upon existing research, an estimate is made of the waste created onboard. To validate these outcomes, the real average waste streams of a particular cruise ship were provided to *Policy Research* by the industry.

II.2.4. ASSESSING OPTIONS FOR REDUCING ENVIRONMENTAL IMPACT - METHODOLOGY

After synthesising EU cruise movements (itineraries) and the database on the emissions per cruise ship, the following variables of environmental impact caused by cruise ships in every EU cruise port have resulted:

- Emissions per port (per year): distinctions can be made between turnaround calls, transit calls and total calls at a given port;
- Total emissions of all cruise ships in Europe (per year) caused by sailing on open seas;

Subsequently methods for reducing emissions are analysed and evaluated. These methods provide the input for the cost benefit analysis that is conducted in the final part of this report.

III. CRUISE ITINERARIES IN THE EU

There are over 294 cruise ships in operation globally (2008)[10]. Of these, 177 ships berth at EU seaports[11] and sail EU seas. The density of the cruise industry in EU ports is expressed in the number of calls per port and the number of passengers calling at a port per year.

III.1. MOST POPULAR EU CRUISE PORTS IN NUMBER OF CRUISE CALLS

EU cruise ports can roughly be allocated to the following EU seas:

- Atlantic Ocean (including the Canary Islands and the Azores);
- Baltic Sea;
- Black Sea;
- Mediterranean Sea;
- North Sea.

In total, EU ports receive 18 884 cruise calls. Based on the data collected by *Policy Research*, cruise calls can also be allocated to the different regions: 10% of the total calls are in the Baltic region, 5% are in the North Sea region, 13% are in the Atlantic region, 71% of the calls are in the Mediterranean and the final 1% of the cruise calls can be allocated to the Black Sea region. In total, EU ports welcome 27.1 million cruise passengers per year[12].

Mapping the itineraries of the cruise ships calling at EU ports ultimately results in an overview of the number of cruise calls in EU ports. Because of the large number of ports[13] called at by cruise ships in Europe (313 have more than one call), only the top 15 will be shown in *Figure III.1*, *Figure III.2* and *Figure III.3*. With regard to the number of turnaround calls, a distinction was made between itineraries that begin and end in the same port and itineraries that begin and end in different ports.

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[10] In 2009, a number of 305 cruise ships operate globally, this number is based on order books, withdrawals and deployment changes (Cruise Industry News (2008) 'State of the industry through 2015: annual report 2008').

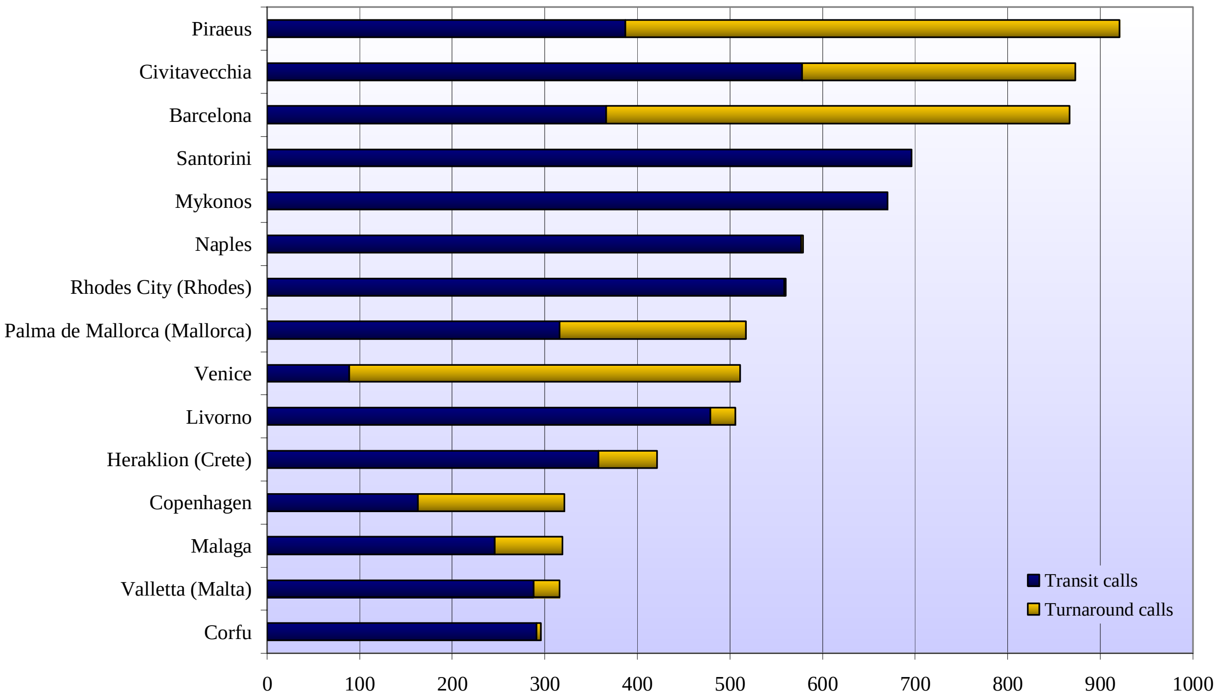
[11] Based on data collected by *Policy Research Corporation*: all itineraries on EU seaports within the scope of one year (see *Annex I B*)

[12] Calculated by summing the number of unique passengers in each EU port

[13] See *Annex I A* for a complete list of ports

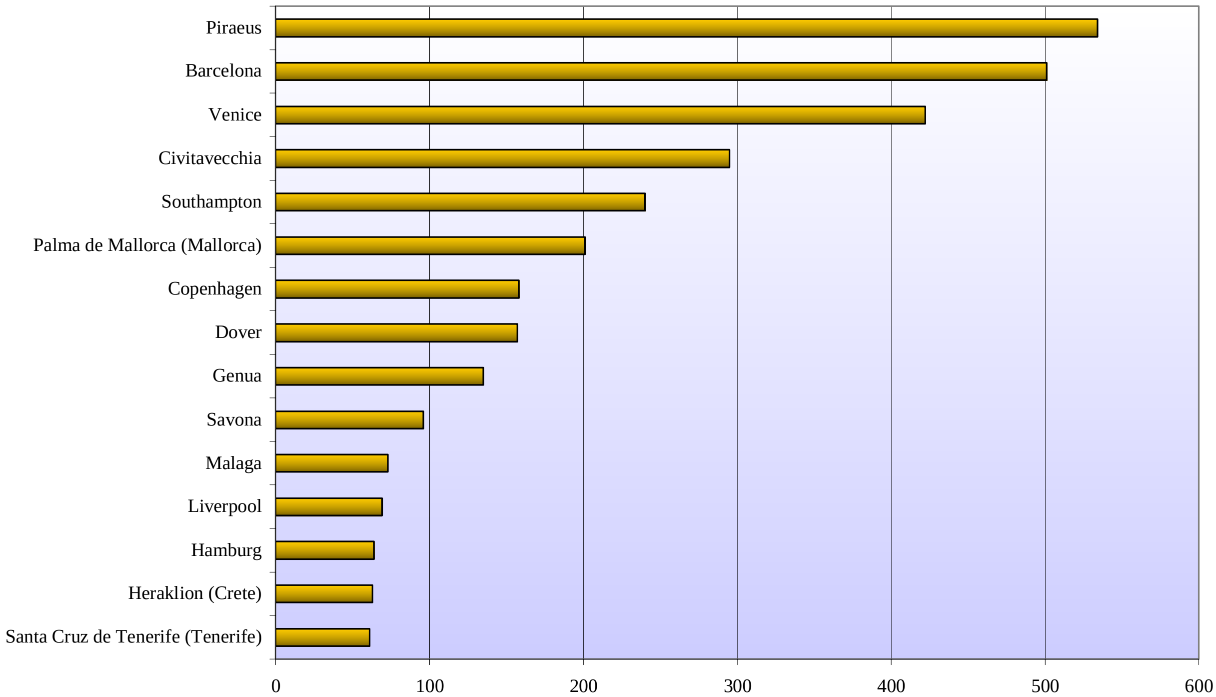
Where the embarkation port is the same as the disembarkation port, only one call is counted. Where the embarkation port is not the same as the disembarkation port, one call is counted for each of the two turnaround ports. The aim of this distinction is to count only the individual cruise tourists in each port.

Figure III.1 : Top 15 EU ports in total number of cruise calls per year



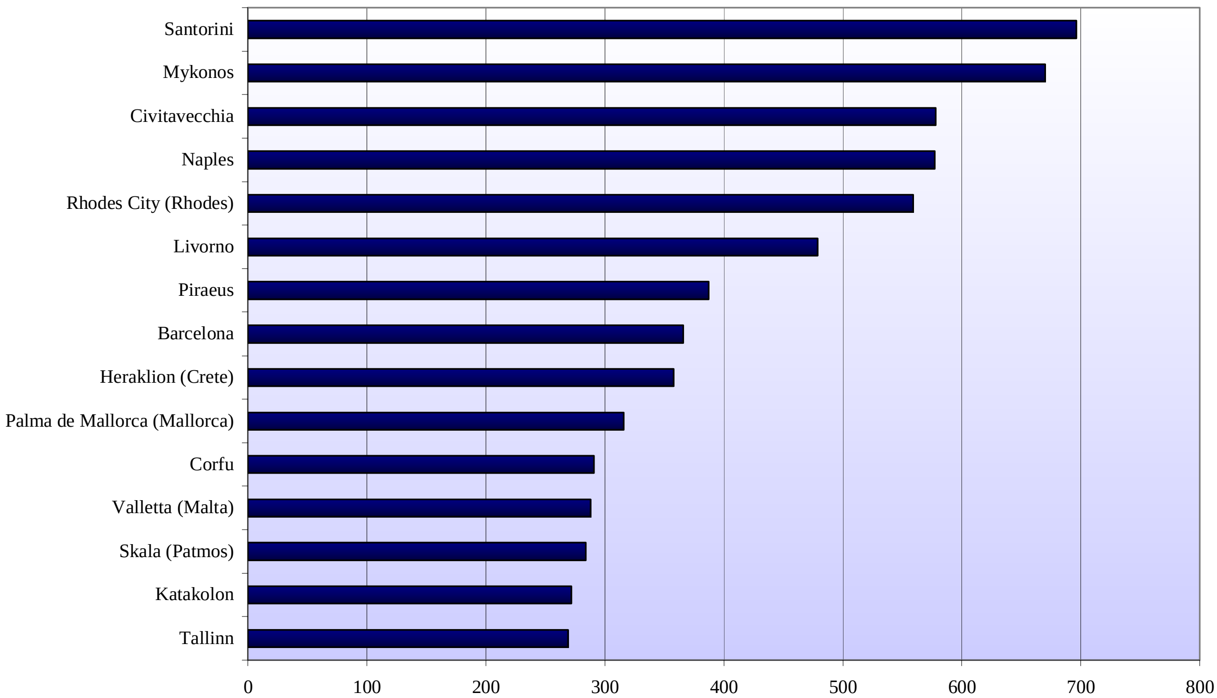
Source: Policy Research Corporation

Figure III.2 : Top 15 EU ports in number of turnaround calls



Source: Policy Research Corporation

Figure III.3 : Top 15 EU ports in number of transit calls

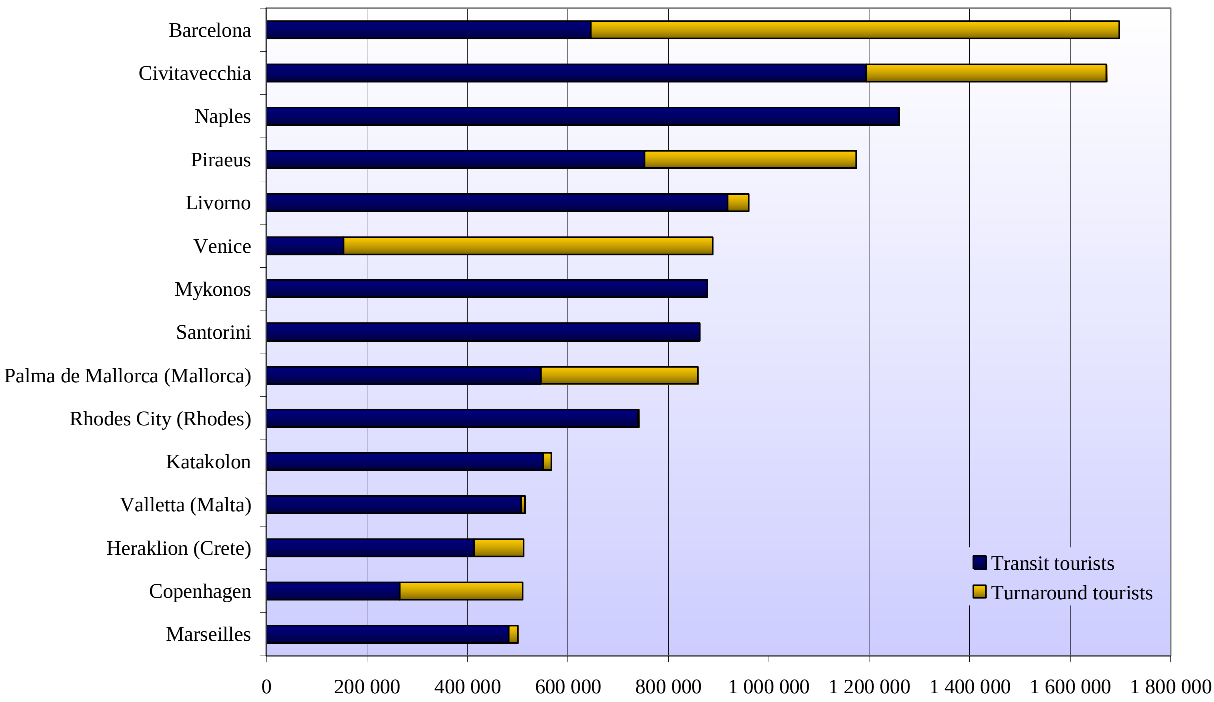


Source: Policy Research Corporation

III.2. MOST POPULAR EU CRUISE PORTS IN NUMBER OF PASSENGERS

Since the capacity in terms of number of passengers of each cruise ship is known, the number of passengers visiting EU ports can be calculated. The most popular EU ports in terms of total number of passengers are displayed in *Figure III.4*. The calculations in this report are based on a 100% capacity of ships. The ship capacity has been validated by the cruise lines for most ships. Calculating on the basis of 100% capacity is an accurate measure, as cruise ships are generally fully booked. Note that this figure does not take crew data into account. On an average cruise ship there tends to be one crew member for every two to three passengers[14].

Figure III.4 : Top 15 EU ports in number of unique passengers



Source: Policy Research Corporation

Table III.1 shows the breakdown of cruise calls and passenger visits over the different sea basins within Europe. The most popular destination in terms of sea basin is the Mediterranean Sea, followed by the Atlantic Ocean (mostly due to the Canary Islands and the Azores). The Baltic Sea accounts for 10% of all the calls per year and is therefore a significant cruise destination. The North Sea and the Black Sea account for the remaining 6% of the cruise calls in Europe.

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[14] Based upon data that was gathered and analysed by *Policy Research*.

Table III.1 : Distribution of calls and passengers to sea basin

Sea basin	Calls	% of calls	Passengers	% of passengers
Baltic Sea	1 947	10%	2 636 959	10%
North Sea	9 80	5%	1 297 929	5%
Atlantic Ocean	2 533	13%	2 830 855	10%
Mediterranean Sea	13 378	71%	20 314 069	75%
Black Sea	46	<1%	30 043	<1%
Totals	*18 884*		*27 109 855*	

Source: Policy Research Corporation

When the distribution of passengers is taken into account, the Mediterranean Sea has an even larger share (75%). The reason for this phenomenon can be found in the relatively larger ships that sail to Mediterranean ports. As these ports are more popular, cruise companies are able to operate on a larger scale.

Cruise ship activity and conflicts with other port activities

Although cruise ship activity creates substantial passenger traffic in the European Union, it hardly ever conflicts with other shipping activities in ports. In some cases, cruise ships have to wait for ferries or container ships, as these ships sail on more frequent schedules and therefore must be given precedence over the less frequently scheduled cruise ships.

Cruise ship activity is seasonal (especially in Northern and Western based ports of Europe), with the result that the heaviest traffic occurs during summertime. Moreover, cruise ships tend to berth in the city centre (in most cases, the old harbour of a town or city), while other port activities (like cargo and ferries) tend to be (re)located further away from city centres (Rotterdam, Amsterdam, Antwerp, Barcelona, Civitavecchia, Helsinki).

III.3. Conclusions

The results in this chapter show the density of cruise tourism in EU Member States. The most popular ports are all based in the Mediterranean area, with four ports welcoming over one million cruise tourist visits per year. Moreover, it can be concluded that a relatively small proportion of the ports accounts for a large number of the calls. The top five turnaround ports receive significantly more calls than other ports.

In the following chapter, the data and analyses on the cruise itineraries are used to calculate and assess the environmental impact per EU port.

IV. ENVIRONMENTAL IMPACT OF CRUISE SHIPPING

A cruise ship requires a substantial level of power to operate. At sea, that power is needed to generate the ship's propulsion as well as its passenger facilities on board. A cruise ship offers various passenger facilities, such as air conditioning, swimming pools, casinos, restaurants, shops, etc. These facilities require power while sailing, but also when a cruise ship is at berth in a port. The necessary power is typically generated by the ship's engines. A ship with main and auxiliary engines uses its auxiliary engines at berth to compensate for the main engine, which will be powered down.

Once a ship is at berth, its surroundings - whether this is a city or a rural area - are exposed to a certain concentration of emissions. If a given threshold is exceeded, these concentrations can cause damage to human beings and to the natural environment. The amount of damage depends on a variety of factors, such as the type of emission, the concentration of emissions already in the area (caused by other industries or activities) and the possibility for emissions to disperse into open sea and over land.

The severity of the effects caused by emissions in an area depends on the duration and concentration of emissions in that area. Since emissions have been the subject of much scientific and political debate in terms of their effects on human health and the natural environment, EU law- and policymakers have been inclined to draw up strict legislation for industries that cause emissions.

IV.1. FUEL TYPE AND SHIPPING EMISSIONS

The level of emissions caused by a (cruise) ship depends on many variables, but mainly on the power needed and the type of fuel used. Generally, three different types of fuel are used by the maritime industry: Marine Diesel Oil (MDO), Marine Gas Oil (MGO) and Residual Oil (RO), which is also known as Heavy Fuel Oil (HFO). As the chemical components of these fuels vary, each type of fuel produces different emission values. For instance, MDO has a higher carbon level than MGO and will therefore lead to more CO_2 emissions. RO is the residue of the refining process. It is a thick and highly sulphurous fuel, generally used by larger ships (ferries, container ships and cruise ships).

IV.2. Environmental legislation

When decisions are made in relation to (sustainable) investments in tourist facilities in EU ports, EU environmental legislation needs to be considered[15]. There are various environmental themes into which environmental EU legislation can be grouped[16]. The most important ones for cruise facilities in ports are:

- Air;
- Nature and biodiversity;
- Noise;
- Waste;
- Water.

The next section maps out environmental legislation. As regards to the legislation concerning emissions, compliance costs will be calculated.

IV.2.1. Legislation with regard to air

A substantial body of EU legislation has been adopted in relation to ambient air quality. In 2008, a new directive on air quality was adopted. The lead directive is the Air Quality Framework Directive 96/62/EC.

Air Quality Framework Directive (96/62/EC)

Council Directive 96/62/EC on ambient air quality assessment and management is commonly referred to as the Air Quality Framework Directive. It describes the basic principles of how air quality should be assessed and managed in the Member States. It lists the pollutants for which air quality standards and objectives will be developed and specified in legislation[17]. The Air Quality Framework Directive has four daughter directives:

- ***Council Directive (1999/30/EC)*** relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air (First Daughter Directive);
- ***Directive (2000/69/EC)*** of the European Parliament and of the Council relating to limit values for benzene and carbon monoxide in ambient air (Second Daughter Directive);
- ***Directive (2002/3/EC)*** of the European Parliament and of the Council relating to ozone in ambient air (Third Daughter Directive);
- ***Directive (2004/107/EC)*** of the European Parliament and of the Council relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air (Fourth Daughter Directive).

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15 The legislation applies to EU ports in general and not to the specific case of cruise shipping
16 http://ec.europa.eu/environment/policy_en.htm, last visited February 2009.
17 http://ec.europa.eu/environment/policy_en.htm, last visited February 2009.

Directive on ambient air quality and cleaner air for Europe (2008/50/EC)

This Directive entered into force on 11 June 2008. It comprises the following key elements[18]:

- The merging of most of the existing legislation into a single directive (except for the Fourth Daughter Directive) with no change to existing air quality objectives[19];
- New air quality objectives for $PM_{2.5}$ (fine particulate matter) including the limit value and exposure related objectives – exposure concentration obligation and exposure reduction target;
- The possibility to discount natural sources of pollution when assessing compliance with limit values;
- The possibility for extensions of three years (PM_{10}) or up to five years (NO_2, benzene) for complying with limit values, based on certain conditions and the assessment by the European Commission.

Recommendation on the promotion of shore-side electricity for use by ships at berth in Community ports (2006/339/EC)

Member States should consider the installation of shore-side electricity for the use by ships at berth in ports, particularly where air quality limit values are exceeded or where public concern is expressed about high levels of noise nuisance, and more especially in berths situated near residential areas. The environmental benefits and cost-effectiveness should be evaluated on a case-by-case basis. Member States should consider offering economic incentives to operators to make use of shore-side electricity provided to ships.

Legislation on shipping emissions: SO_2 and NO_x

The European cruise industry is part of the larger and globally operating maritime industry. Since 1948 the International Maritime Organisation (IMO) has been entrusted with the task of developing and maintaining a comprehensive regulatory framework for shipping with regard to safety, environmental concerns, legal matters, technical cooperation, maritime security and the efficiency of shipping[20]. Both the EU and the IMO have developed international legislation on air emissions from shipping. *Table IV.1* shows the legislation currently in force.

[18] http://ec.europa.eu/environment/policy_en.htm, last visited February 2009

[19] Framework Directive 96/62/EC, 1-3 daughter Directives 1999/30/EC, 2000/69/EC, 2002/3/EC, and Decision on Exchange of Information 97/101/EC.

[20] IMO, www.imo.org, last visited December 2008.

Table IV.1 : Legislation in force on shipping emissions

Effective from:	Rules applicable:	Effect to be reached:
July 2000	1999/32/EC	Maximum of 0.2% m/m sulphur content of Marine Gas Oil in EU ports
1 January 2000	Marpol Annex VI	Engines built from Jan 2000 modified existing to comply with Nitrogen Oxide (NOx) Technical code (Tier I, the emission of nitrogen oxides from the engine must be within certain limits, see Revised Marpol Annex VI, as amended on 9 October 2008)
19 May 2005	Marpol Annex VI	Maximum of 4.5% m/m sulphur content of bunker fuel & BDN stating sulphur content and density of fuel delivered (worldwide)
19 May 2006	Marpol Annex VI	Baltic Sea SECA, Maximum of 1.5% m/m sulphur content of bunker fuel
11 August 2006	2005/33/EC	Maximum of 1.5% m/m sulphur content of bunker fuel for Scheduled Passenger Vessels (> 12 passengers) calling EU ports
11 August 2006	2005/33/EC	Maximum of 1.5% m/m sulphur content of bunker fuel for all vessels in the Baltic Sea (SECA)
16 August 2006	1999/32/EC 2005/33/EC	No sale of >1.5% sulphur content of Marine Diesel Oil in EU ports
11 August 2007	2005/33/EC	Maximum of 1.5% m/m sulphur content of bunker fuel for all vessels in the North Sea (SECA)
22 November 2007	Marpol Annex VI	North Sea (SECA), Maximum of 1.5% m/m sulphur content of bunker fuel;
1 January 2008	1999/32/EC 2005/33/EC	Maximum of 0.1% m/m sulphur content of Marine Gas Oil in EU ports; no sale of >0.1% Marine Gas Oil in EU ports
13 April 2008	Marpol Annex VI	All vessels have obtained International Air Pollution Prevention Certificate

Source: EU and IMO

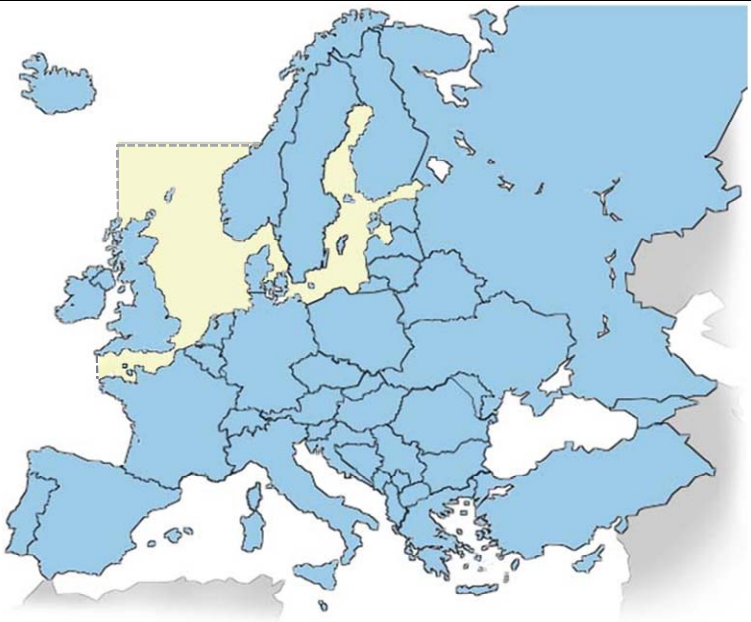
The IMO adopted a protocol in 1997 which included the new Annex VI of MARPOL 73/78, which entered into force on 19 May 2005. The annex sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances. The protocol was amended on 9 October 2008. Apart from the global cap of 4.5% m/m on the sulphur content of fuel oil, Annex VI contains provisions allowing special Sulphur Emission Control Areas (SECAs).

Figure IV.1 displays the areas that are adopted as SECAs, the Baltic Sea and the North Sea (the yellow area). Within these areas ships are only permitted to use fuel with a sulphur content of 1.5% or below (at berth and at sea) compared to the regular content of 2.7% used outside these areas. The average overall sulphur content of bunker fuel provided in EU ports is 2.7%[21] [22].

21 Telephone interview with representative of Bunkerworld, United Kingdom, October 2008

22 Sulphur levels in fuel are dependent on the source of the fuel (crude oil). North Sea crude oil tends to be ‘sweeter’ than other crude oil sources and is therefore less sulphurous.

Figure IV.1 : SECAs in the EU, the Baltic Sea and the North Sea



Source: Policy Research Corporation, based on IMO reports

As from 2010, several legal acts will be established. These are outlined in *Table IV.2*. Maritime industries are subject to increasingly stringent environmental legislation, especially on NO_x and SO_2 emissions.

Table IV.2 : Upcoming legislation on shipping emissions

Effective from:	Rules applicable:	Effect to be reached:
1 January 2010	2005/33/EC	Maximum of 0.1% m/m sulphur content of bunker fuel for all vessels at berth (and inland waterways) in the EU
1 January 2010	1999/32/EC	No sale of >0.1% sulphur content of Marine Gas Oil in EU ports
1 July 2010	Marpol Annex VI *	Maximum of 1.0% m/m sulphur content of bunker fuel in Baltic Sea (SECA) and North Sea (SECA)
1 January 2012	Marpol Annex VI *	Maximum of 3.5% m/m sulphur content of bunker fuel (worldwide)
1 January 2015	Marpol Annex VI *	Maximum of 0.1% m/m sulphur content of bunker fuel in Baltic Sea (SECA) and North Sea (SECA)
1 January 2016	1999/32/EC 2005/33/EC *	Engines built from Jan 2011 modified existing to comply with NOx Tier III, the emission of nitrogen oxides from the engine must be within certain limits, see Revised Marpol Annex VI, as amended on 9 October 2008
1 January 2020	Marpol Annex VI *	Maximum of 0.5% m/m sulphur content of bunker fuel (worldwide). Note that if the production of 0.5% m/m sulphur content does not suffice, the enforcement can be postponed to 2025

* As amended on 9 October 2008. All these standards can also be met by technological equivalence (i.e., high sulphur fuel in combination with abatement technology)

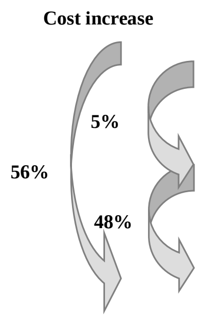
Source: EU and IMO

Compliance costs of legislation on SO_2

As from 2010, new rules on emissions from ships will enter into force. With effect from 2010, the EU requires a maximum of 0.1% on the sulphur content of bunker fuel for all vessels at berth and on inland waterways in the EU. The IMO adds that, starting from 2010, the maximum sulphur content in SECAs will be 1.0%. Effective from 2015, an even lower limit of sulphur will be compulsory in SECAs, as only 0.1% fuel will be allowed for all activities.

In calculating the compliance costs, a distinction will be made between fuel costs while sailing in a SECA, fuel costs to sail in a non-SECA, and the fuel costs while at berth in an EU port. To calculate the compliance costs, the average bunker fuel prices of the first six months of 2009 in the Port of Rotterdam are outlined in *Table IV.3*. Note that oil prices are highly variable. Therefore, the costs of complying with upcoming legislation are to be regarded as estimates.

Table IV.3 : Average bunker fuel prices Rotterdam January - July 2009



As from January 2010:	Average bunker prices Rotterdam January – July 2009	Costs per metric ton in US $
Used by cruise ships in non-SECA	RO (HV) high on sulphur (2.5% – 3.5%)	295.5
	RO (LV) high on sulphur (2.5% - 3.5%)	319.6
Used by cruise ships in SECA	RO (HV) low on sulphur (1.0% - 1.5%)	311.6
	RO (LV) low on sulphur (1.0% – 1.5%)	338.14
Used by cruise ships at berth in EU ports	MDO (0.10% sulphur)	462.3

Note that HV refers to High Viscosity and LV refers to Low Viscosity

Source: Policy Research Corporation based on data from www.bunkerworld.com, 19 January 2009

It costs 56% more to use MDO 0.1%[23] sulphur at berth, as opposed to the approved level of sulphur while sailing in a non-SECA. Moving from RO high on sulphur to RO low on sulphur increases the cost by 5%. Accordingly, the costs of bunker fuel are 5% higher when sailing in a non-SECA as opposed to sailing in a SECA. Moreover, when changing from RO low sulphur to MDO, costs increase by 48%.

Based on data provided to *Policy Research* by the cruise industry, an average fuel usage of 0.13 metric tonnes per MW employed in port operations was calculated. Hence, an average cruise ship using 9-12 MW of power will have a cost increase of € 1 561 - € 2 082[24] per transit call and € 2 342 - € 3 122 per turnaround call outside SECAs. Within SECAs the cost increase is € 1 411 - € 1 881 per transit call and € 2 116 - € 2 821 per turnaround call.

23 The price for MDO is based on a metric tonne of MDO in Rotterdam, the Netherlands
24 Assuming an exchange rate of 1 € = US$ 1,40

For an average cruise itinerary, which has one turnaround call and five transit calls, the cost increase will be between € 7 248 and € 13 382 if a cruise ship switches from 2.7% sulphurous fuel to MDO and between € 6 549 and € 12 090 if a cruise ship switches from low sulphur fuel to MDO.

Consequently, it can be concluded that the compliance costs are reasonably acceptable. As the average 30 – 40 MW ship has around 1 500 – 2 000 passengers, the cost of the trip is increased by around € 5 to € 10 per passenger. The industry can also comply by putting in place technological abatement techniques on cruise ships and by using shore-side electricity at berth in European ports.

National emission ceilings

- Establishment of national emission ceilings for acidification and eutrophication. Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants;
- Directive 2002/3/EC relating to ozone in ambient air.

IV.2.2. LEGISLATION WITH REGARD TO NATURE AND BIODIVERSITY

Where investments in ports are made, both the Habitats Directive and the Birds Directive have to be taken into consideration. Over the last 25 years a vast network of over 26 000 protected areas has been created, covering all the Member States and a total area of around 850.000 km^2, representing more than 20% of total EU territory. This vast collection of sites is known as the Natura 2000 network[25]. The legal basis for the Natura 2000 network comes from the Birds Directive, which dates back to 1979, and form the Habitats Directive of 1991. Together these Directives form the backbone of the EU's internal policy on biodiversity protection.

Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora

The Habitats Directive (together with the Birds Directive) forms the basis for Europe's nature conservation policy. It is built around two pillars: the Natura 2000 network of protected sites and the strict system of species protection. All in all, the Directive protects over 1 000 animals and plant species and over 200 so called "habitat types" (e.g. special types of forests, meadows, wetlands, etc.) of European importance[26].

Directive 79/409/EEC on the conservation of wild birds

This Directive creates a comprehensive scheme of protection for all wild bird species naturally occurring in the EU. It recognises that habitat loss and degradation are the most serious threats to the conservation of wild birds, and therefore places great emphasis on the protection of habitats for

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25 http://ec.europa.eu/environment/nature/index_en.htm, last visited February 2009.
26 http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm, last visited February 2009.

endangered as well as migratory species, especially through the establishment of a coherent network of Special Protection Areas (SPAs) comprising all the most suitable territories for these species. All SPAs have been an integral part of the Natura 2000 ecological network since 1994.

IV.2.3. LEGISLATION WITH REGARD TO NOISE

Directive 2002/49/EC of 25 June 2002

The main aim of this Directive is to provide a common basis for tackling the noise problem across the EU. It requires the use of harmonised noise indicators by the Member States. These indicators must be used to draw up ‘strategic noise maps’ for major roads, railways, airports and built-up areas. The first noise maps to be issued are those for June 2007, which are related to the previous calendar year 2006. The public must be informed about the strategic noise maps as soon as they are drawn up and, where appropriate, adopted.

Noise from equipment for use outdoors (2000/14/EC)

The aim of this Directive is to promote the smooth functioning of the internal market and to improve the health and well-being of the population by reducing the noise emitted by equipment used outdoors. In order to achieve this aim, the Directive provides for four types of action:

- Harmonisation of noise emission standards;
- Harmonisation of conformity assessment procedures;
- Harmonisation of noise level marking;
- Gathering of data on noise emissions.

IV.2.4. LEGISLATION WITH REGARD TO WASTE

Framework Directive on Waste (2008/98/EC)

Directive 2006/12/EC on waste has been revised in order to modernise and streamline its provisions. The revised Directive 2008/98/EC sets out the basic concepts and definitions related to waste management and lays down waste management principles, such as the ‘polluter pays principle’ or the ‘waste hierarchy’. This Directive is concerned with the handling of waste in ports.

Directive on port reception facilities for ship-generated waste and cargo residues (2000/59/EC)

The aim of this Directive, which concerns the handling of waste on ships, is to reduce the discharges - especially illegal discharges - of ship-generated waste and cargo residues into the sea from ships using ports in the EU, by improving the availability and use of port reception facilities for ship-generated waste and cargo residues, thereby enhancing the protection of the marine environment.

IV.2.5. LEGISLATION WITH REGARD TO WATER

Marine Strategy Framework Directive (2008/56/EC)

The aim of the European Union's Marine Strategy Framework Directive is to protect the marine environment across Europe more effectively. It aims to achieve good environmental status of the EU's marine waters by 2021 and to protect the resource base upon which marine-related economic and social activities depend[27].

The goal of the Marine Strategy Framework Directive is in line with the objectives of the Water Framework Directive of 2000, which requires surface freshwater and ground water bodies - such as lakes, streams, rivers, estuaries, and coastal waters - to be ecologically sound by 2015 and the first review of the River Basin Management Plans to take place in 2020.

Water Framework Directive (2000/60/EC)

This Directive deals with the fragmentation of water policy. Its key aims are to:

- Extend the scope of water protection to all waters, surface waters and groundwater;
- Achieve ‘good status’ for all waters by a set deadline;
- Manage the water resources based on river basins;
- Use a ‘combined approach’ of emission limit values and quality standards;
- Get the prices right;
- Involve citizens more closely;
- Streamline legislation.

IV.3. THE 15 EU-PORTS WITH THE HIGHEST EMISSION LEVELS

In this report, emissions are calculated per ship and per emission type. This calculation is based on an emission factor that reflects the number of grams of an emission emitted per kW/h. For the process of allocating emissions to ports, the emission factors of MDO are utilised. The reason for using the MDO emission factor is threefold:

27 http://ec.europa.eu/environment/water/marine/index_en.htm, last visited February 2009

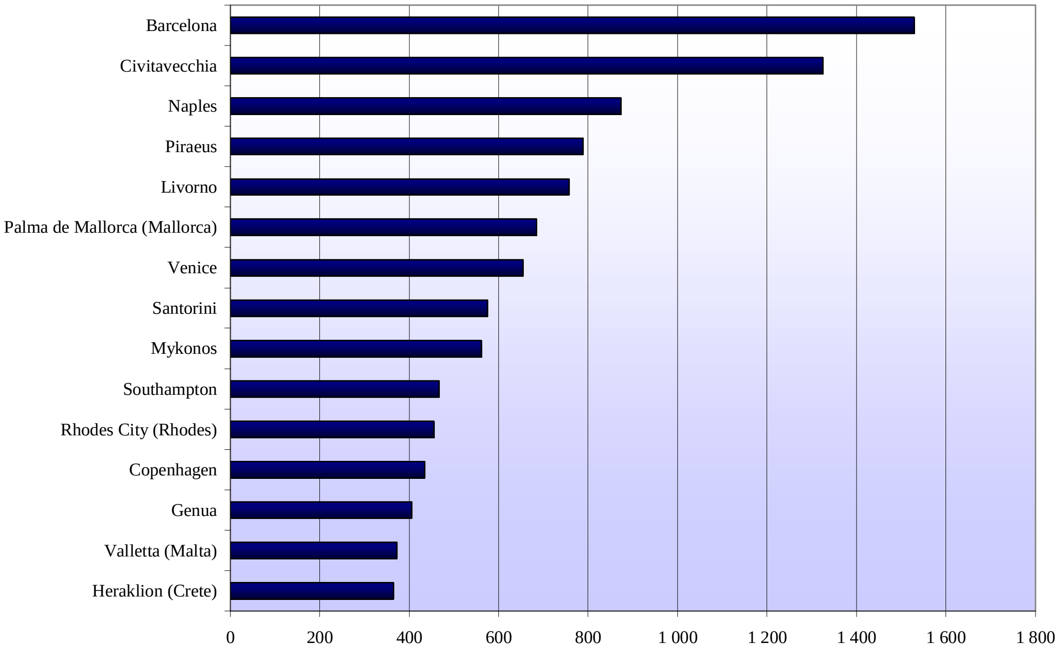
– With effect from 1 January 2010, cruise ships are no longer allowed[28] to use fuel with a sulphur content exceeding 0.1% while at berth in European ports. This means that the sulphur emissions are equal to MDO with 0.1% sulphur content. It would be pointless to base our calculations on a fuel type that will only be allowed for a maximum of six months after the publication of this report (mid 2009);

– The concentration of PM in MDO is significantly lower than in RO. Several sources claim that the level of PM is strongly correlated with the level of sulphur in a fuel[29]. This means that PM emissions will come down if the 0.1 sulphur restriction takes effect from 1 January 2010;

– It is expected that the industry will innovate to a level where emissions from cruise ships will decrease. Using the MDO emission factors for cruise activities in ports will therefore ensure that the calculations are carried out conservatively and, consequently, will not lead to overestimates.

The allocation of ship emissions to individual port results is depicted in *Figures IV.2 to IV.6*. These figures show the results of the 15 ports with the highest emission levels.

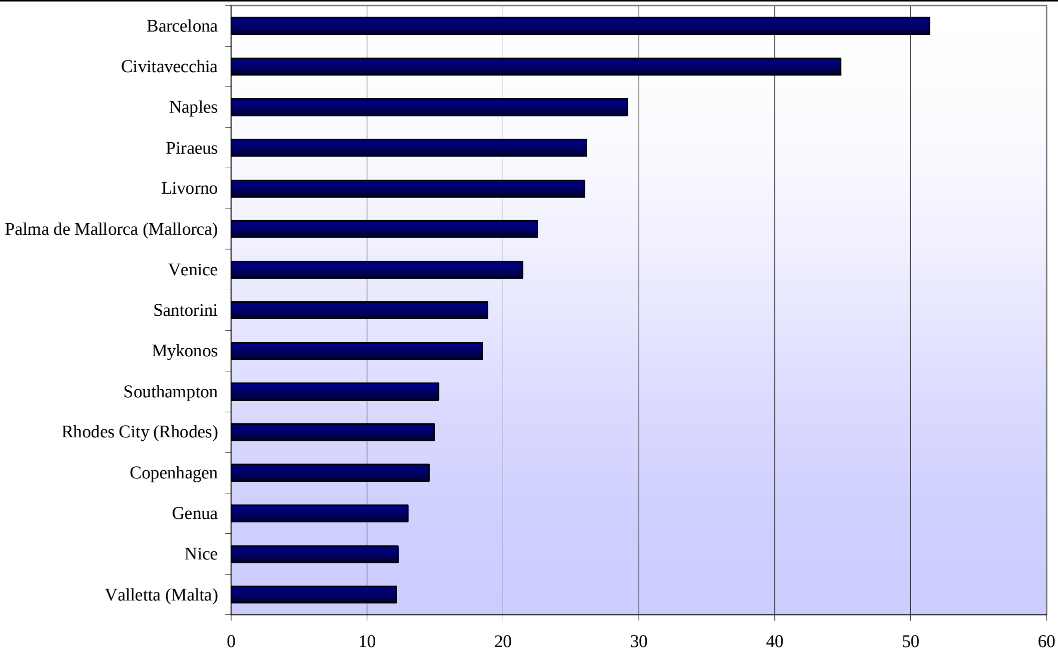
Figure IV.2 : Top 15 EU-ports in tonnes NO_x emissions caused by cruise ships (effective from 1 January 2010)



Source: Policy Research Corporation

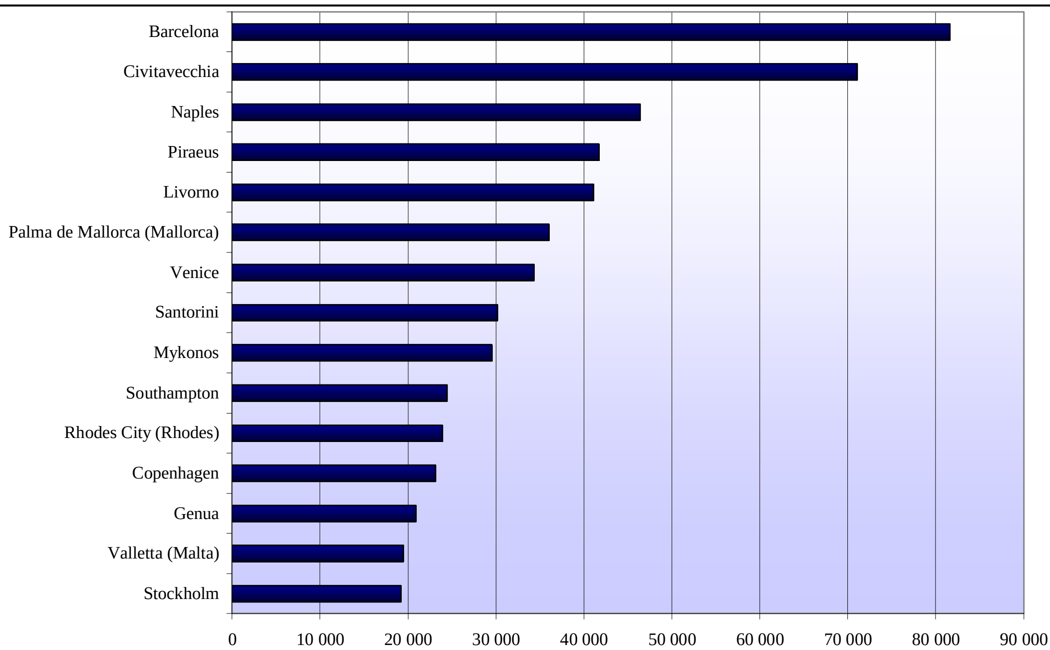
28 Technical abatement techniques for reducing sulphur are also allowed by legislation
29 Sulphur dioxide is a precursor for sulphates, which are respirable particles in the atmosphere.

Figure IV.3 : Top 15 EU-ports in tonnes of SO_2 emissions caused by cruise ships (effective from 1 January 2010)



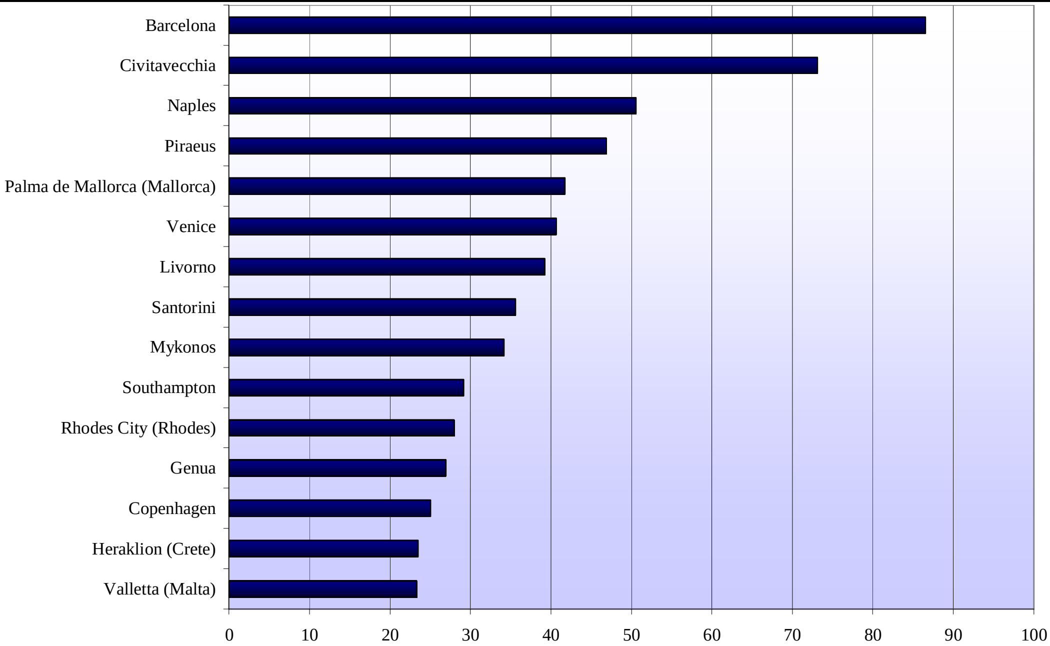
Source: Policy Research Corporation

Figure IV.4 : Top 15 EU-ports in tonnes of CO_2 emissions caused by cruise ships (effective from 1 January 2010)



Source: Policy Research Corporation

Figure IV.5 : Top 15 EU-ports in tonnes of PM emissions caused by cruise ships (effective from 1 January 2010)



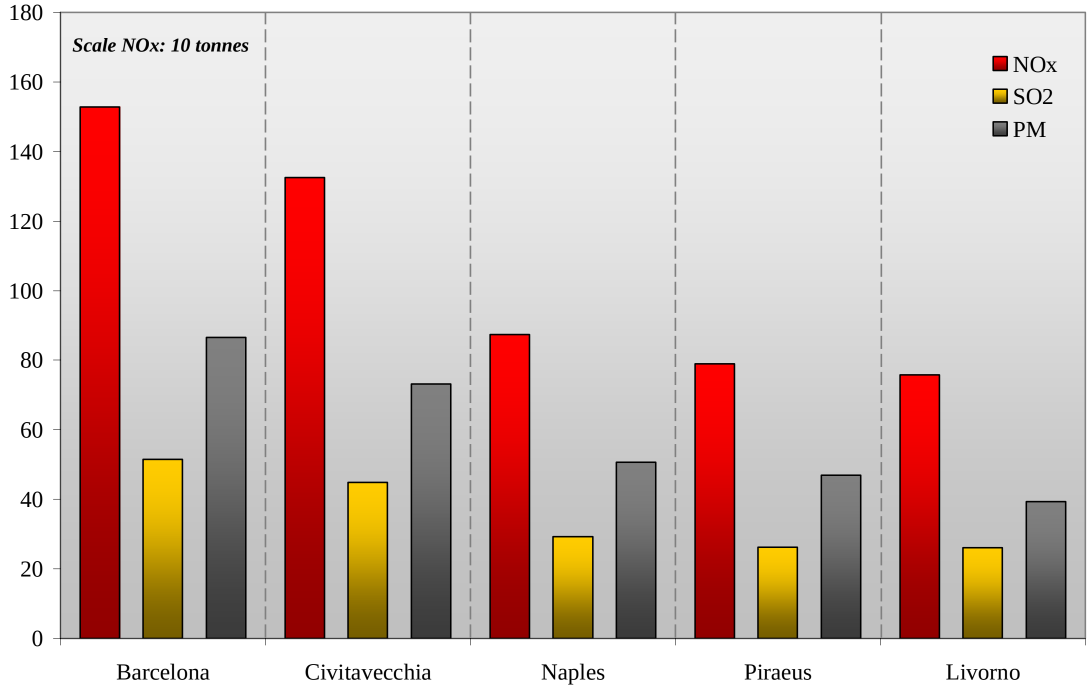
Source: Policy Research Corporation

IV.3.1. EMISSION LEVELS IN PERSPECTIVE

The figures in the previous paragraph show the absolute levels of emissions in the top 15 sea cruise ports of the EU. In this paragraph the figures will be compared with other maritime and/or industrial activities in the area/port concerned, in order to put the emissions that are due solely to cruise tourism into perspective.

Figure IV.6 displays the top five EU ports in terms of emission levels.

Figure IV.6 : Top 5 EU ports in emission levels of three emission types (in tonnes, except for NO_x)



Source: Policy Research Corporation

The five ports shown in this figure are all located in the Mediterranean. This is not surprising since these Mediterranean ports are very popular tourist destinations, with large numbers of transit and turnaround calls. The following paragraphs will place these figures in a broader perspective.

IV.3.1.1. Comparison with other activities and industries

In order to put the air emissions caused by cruise tourism into perspective, the emissions in EU ports are compared with the energy consumption of households and of container ships at berth.

A 30-40 MW cruise ship is the equivalent of about 5 000 - 7 000 households

A cruise ship equipped with a total engine power of 30 - 40 MW (30 000 – 40 000 kW), which is around the average for Europe[30], requires around 9 -12 MW per hour at berth[31] (the average power use at berth is 20-30%[32]). By way of comparison, an average household requires 20.5 kW per day[33] and has an hourly demand of 1.28 kW (based on 16 hours per day). This means that the average cruise ship at berth requires the same power as 4 687 – 7 031 households.

30 Based upon analysis of *Policy Research Corporation*
31 Newer cruise ships have, on average, more power and thus require more power at berth (9-12 MW per hour)
32 ENTEC: CONCAWE: Ship emissions inventory- Mediterranean Sea, April 2007
33 EU Energy and transport in figures 2007-2008: reference consumer corresponds to a standard dwelling of 100 m2 with 4-5 rooms plus kitchen with an annual consumption of 7 500 kWh (daily: 20,5 kWh)

Container ships

Container shipping has seen substantial growth in recent decades. An average container ship of the OECD-countries has a power level of 25 MW[34]; this is 20-60% lower than the average cruise ship, which has around 30 – 40 MW. The load factor of container ships is also lower[35]. At berth, container ships require a relatively low power level compared to a cruise ship, since a cruise ship has to provide significant amounts of power to a variety of facilities (e.g. air conditioning). The emissions per kW caused by container ships are equal to those caused by cruise ships. However, the number of container ships operating in Europe is much higher than the number of cruise ships, although cruise ships tend to berth closer to a city centre.

In 2007, over 7 700 container ships called at the port of Rotterdam[36] (the largest container port of Europe), 7 600 container ships called at the port of Hamburg[37] (the second largest container port of Europe) and 2 265 container ships[38] called at the port of Barcelona, accounting for 17 565 calls altogether. If this figure is compared with all the EU cruise ports, which are called at 18 884 times in the year time frame taken for this study, the container movements in these three ports are almost equal to the total movements of cruise tourism. This fact underlines the relative scale of cruise tourism compared to container shipping in Europe.

Cruise ship activity compared to total port activity

Table IV.4 shows an overview of the cruise ship activity in a selection of ports spread across the EU compared to the total activities in these ports. Even in the three busiest cruise ports (Barcelona, Civitavecchia and Piraeus), the relative share of cruise ship activity is 8.6%, 18.8% and 3.2% respectively of total activities in these ports.

Table IV.4 : Cruise calls as a percentage of total ship calls

Port	Cruise ship activities versus total shipping activities
Amsterdam	1.4%
Barcelona	8.6%
Civitavecchia	18.8%*
Dover	0.6%
Helsinki	2.5%
Piraeus	3.2%
Warnemünde	1.2%

** Based on total number of days at berth*

Source: Policy Research Corporation, based upon port data

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34 Lloyd's shipping register, database 2006-2007

35 The load factor of the auxiliary engines of a container ship at berth is 17%, while the load factor of the auxiliary engines of a cruise ship is 64% (Source: Browning, L (IPC International) & Bailey, K. (U.S. EPA) (2006). Current Methodologies and Best Practices for Preparing Port Emission Inventories)

36 Port of Rotterdam, annual report 2007

37 Port of Hamburg, facts and figures, www.hafen-hamburg.de

38 Port of Barcelona, annual report 2007

Emissions of cruise tourism compared to total emissions in an area

If the emissions of cruise shipping in two of the most popular cruise destinations are compared with the total emissions in their area, the following table results.

Table IV.5 : Emissions of cruise shipping compared to total emissions in an area

Relative share of cruise shipping emissions compared to total emissions in the area	NO_X	SO_2	CO_2	PM
Total emissions for Spain *(43 758 350 inhabitants)*	1 481 210	1 359 580	359 630 000	2 382 310
Total emissions for Greece *(11 125 179 inhabitants)*	315 620	529 410	109 670 000	675 950
Emissions per inhabitant for Spain	0.03	0.03	8.22	0.05
Emissions per inhabitant for Greece	0.03	0.05	9.86	0.06
Total emissions in the area of Barcelona *(1 615 908 inhabitants)*	54 698	50 207	13 280 414	87 974
Total emissions in the area of Piraeus *(921 211 inhabitants)*	26 135	43 837	9 081 131	55 971
Emissions of cruise tourism in Barcelona	1 528.8	51.4	81 599.0	86.5
Emissions of cruise tourism in Piraeus	789.1	26.2	26.2	46.9
Relative share of cruise tourism emissions in Barcelona	2.795%	0.065%	0.389%	0.054%
Relative share of cruise tourism emissions in Piraeus	2.410%	0.050%	0.376%	0.059%

Source: Policy Research Corporation based on own data and Eurostat emission data (2006), February 2009

In order to assess the impact of cruise shipping relative to the total emission in a city area, the following approach was adopted. The emissions on a country level were taken and divided by the number of inhabitants in the country to give the emissions per inhabitant. These were multiplied by the number of inhabitants of these areas, which provided an estimate of emissions in the area of Barcelona and Piraeus. The emissions of cruise tourism in the ports of Barcelona and Pireaus, obtained from the analysis in *Paragraph IV.3,* were divided by the total emissions in the areas of these cities.

As *Table IV.5* shows, the relative impact of cruise shipping in these cities/areas is fairly small. Even in destinations like Barcelona and Piraeus, the share of cruise shipping on SO_2, CO_2 and PM accounts for less than 0.4% of the total emissions in the area. For $NO_{x,}$ the share accounted for by cruise shipping is 2.4% in Piraeus and 2.8% in Barcelona.

IV.4. ENVIRONMENTAL IMPACT OF CRUISE SHIPPING ON AN EU-LEVEL

Paragraph II.1 defined the scope of this study and stressed that the environmental impact of cruising will be assessed at both port level and EU level. The environmental impact at EU level is seen as the sum of the emissions in all cruise ports, the emissions generated by cruising at sea and the total quantities of other waste, such as waste water from showers toilets and sinks, ballast water, litter that comes from the everyday activities of passengers on board, but also from the cruise ship's kitchen, restaurant, shops, etc.

IV.4.1. EMISSIONS WHILE CRUISING

The moment a ship sails out to the open sea, its main engine load (load factor) will increase from 20-30% of its capacity to 80-90%. Therefore, the emissions generated on open sea are therefore higher than the emissions in ports, but they cause less disturbance to populated areas in the EU. Nevertheless, it is important to quantify these emissions, for two reasons:

- CO_2 emissions from cruise ships do not have a direct impact on ports and surroundings, but they do have an impact on a global scale (global warming)
- Emissions in open sea also cause a direct environmental impact, as emissions contribute to acidification of rain (which naturally also ends up in the oceans)[39].

The results of quantifying these emissions are shown in *Table IV.6*. The total emissions of cruise tourism in EU seas are calculated by multiplying the total number of hours that all cruise ships sailed on EU seas by the emissions per hour at sea of an average cruise ship.

Table IV.6 : Emissions at sea in tonnes per year

Type of emission	NO_x	SO_2	CO_2	PM
Total emissions at sea (tonne/year)	156 521	96 288	6 091 920	15 006

Source: Policy Research Corporation

The emissions can be allocated to the areas that were specified in *Paragraph III.I*. In order to allocate the emissions to these areas, the following approach was used:

- The sum of emissions in ports was calculated. Ports were allocated to a sea basin and the relative share was calculated per sea basin;
- The distribution of cruise calls in sea basins was used to calculate emissions at sea. The relevant figures are 10% in the Baltic Sea, 5% in the North Sea, 13% in the Atlantic Ocean, 71% in the Mediterranean Sea and <1% in the Black Sea. (see *Paragraph III.1*). The number of hours at sea was subsequently distributed over the sea basins. This provided the option of differentiating between emissions in SECAs (Baltic and North Sea) and non-SECAs (Atlantic, Mediterranean and Black Sea) to account for the difference in sulphur emissions.

Tables *IV.7* to *IV.9* show the results of these analyses.

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39 Cooper, D.A. (2003) 'Exhaust emissions from ships at berth'.

Table IV.7 : Annual emissions in EU waters per sea basin

Emissions at sea (tonnes)	NO_x		SO_2*		CO_2		PM	
	Absolute	%	Absolute	%	Absolute	%	Absolute	%
Baltic Sea	16 295	*10%*	6 108	*6%*	634 399	*10%*	1 562	*10%*
North Sea	8 202	*5%*	3 074	*3%*	319 317	*5%*	786	*5%*
Atlantic Ocean	20 957	*13%*	13 827	*14%*	815 634	*13%*	2 009	*13%*
Mediterranean Sea	110 686	*71%*	73 028	*76%*	4 307 758	*71%*	10 612	*71%*
Black Sea	381	*0%*	251	*0%*	14 812	*0%*	36	*0%*

** The SO_2 emissions in the Baltic Sea and North Sea are relatively low due to SECA limits*

Source: Policy Research Corporation

Table IV.8 : Annual emissions in ports per sea basin

Emissions in ports (tonnes)	NO_x		SO_2		CO_2		PM	
	Absolute	%	Absolute	%	Absolute	%	Absolute	%
Baltic Sea	2 169	*11%*	73	*11%*	115 710	*11%*	234	*10%*
North Sea	1 181	*6%*	39	*6%*	62 279	*6%*	137	*6%*
Atlantic Ocean	2 023	*10%*	68	*10%*	107 940	*10%*	219	*10%*
Mediterranean Sea	14 898	*73%*	496	*73%*	789 141	*73%*	1 684	*74%*
Black Sea	25	*0%*	1	*0%*	1 341	*0%*	3	*0%*

Source: Policy Research Corporation

Table IV.9 : Total annual emissions per sea basin

Total emissions (tonnes)	NO_x		SO_2		CO_2		PM	
	Absolute	%	Absolute	%	Absolute	%	Absolute	%
Baltic Sea	18 463	*10%*	6 181	*6%*	750 109	*10%*	1 796	*10%*
North Sea	9 382	*5%*	3 113	*3%*	381 597	*5%*	923	*5%*
Atlantic Ocean	22 981	*13%*	13 895	*14%*	923 574	*13%*	2 228	*13%*
Mediterranean Sea	125 584	*71%*	73 524	*76%*	5 096 899	*71%*	12 296	*71%*
Black Sea	406	*0%*	252	*0%*	16 153	*0%*	39	*0%*

Source: Policy Research Corporation

Table IV.9 shows that between 71 % and 76 % of all emissions caused by cruise shipping in the EU can be attributed to the Mediterranean. The allocation is broadly equal to the distribution of cruise calls over the sea basins, except for SO_2. This is due to the fact that two of these sea basins - the Baltic Sea and the North Sea - are SECAs.

IV.5. SOLID AND LIQUID WASTE

Besides air emissions, cruise ships also discharge waste. This type of pollution is categorised into bilge water, sewage, greywater, hazardous waste, solid waste, and ballast water. In order to clarify these terms, the definitions are listed below[40].

- *Bilge water*: Oily bilge water is the mixture of water, oily fluids, lubricants, cleaning fluids, and other similar wastes that accumulate in the lowest part of a vessel from a variety of different sources including engines (and other parts of the propulsion system), piping, and other mechanical and operational sources found throughout the machinery spaces of a vessel;
- *Sewage*: Sewage from vessels, also known as blackwater, generally means human body wastes and the wastes from toilets and other receptacles intended to receive or retain body wastes;
- *Greywater*: Greywater generally means waste water from sinks, baths, showers, laundry, and galleys;
- *Solid waste*: Solid waste generated onboard a cruise ship typically comprises the materials used for packaging products for transportation or storage, waste generated by passenger and crew activity, and food waste. More specifically, the types of solid waste generated on a ship can include food waste, glass, paper, wood, cardboard, incinerator ash, metal cans, and plastics;
- *Hazardous waste*: Hazardous waste is a subset of solid waste. It is waste that contains hazardous constituents that can be liquid, solid, semisolid, or contained gas. Examples of activities causing hazardous waste are photographic processing, dry cleaning and equipment cleaning;
- *Ballast water*[41]: In order to stabilise and balance a ship (to adapt to changes in the total weight of the ship), ballast water is pumped into compartments in the hull. Because ships load this ballast water at a different location from where they discharge the water, this <u>can</u> have a negative impact on the environment. This negative impact is due to the fact the water may contain non-native plant and animal species. These invasive species <u>can</u> damage native species.

The types of waste discussed and their relative quantities are listed in *Table IV.10*. The quantities per type of waste are gathered from an analysis of various sources that are included in the table.. This leads to an estimate of the range in which an average ship is likely to be positioned. Subsequently, the average value of this range is chosen. The results of this analysis should therefore be considered as an indication only, especially because there is a relatively wide variation in the quantities due to the different sources. Furthermore, the table shows the total amount of waste produced by cruise ships in European waters, which is based on the amount of waste per ship.

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[40] Definitions, except for ballast water, are based on the 'Cruise Ship Discharge Assessment Report (United States Environmental Protection Agency, 2008)'

[41] Definition from: A Shifting Tide, Environmental Challenges and Cruise Industry Responses (Centre for Environmental Leadership in Business)

Table IV.10 : Amount of waste per average ship and total amount of waste in European waters

Type of waste	Amount per ship	*Measurement unit*	Total amount per year in EU waters	*Measurement unit*
Bilge water	15 000	*Liter/day/ship*	480 383	m^3
Sewage	70 000	*Liter/day/ship*	2 241 787	m^3
Greywater	550 000	*Liter/day/ship*	17 614 044	m^3
Solid waste	2.5	*Kg/day/passenger*	104 727	*Tonne*
Hazardous waste	60	*Kg/day/ship*	1 922	*Tonne*
Ballast water	1 000	*Tonne/ship/release*	16 927 000	*Tonne*

Source: Policy Research Corporation based on the following sources: U.S. EPA, Cruise ship discharge assessment report, 2008; U.S. EPA, Cruise ship white paper, 2000; The ocean conservancy, Cruise Control, 2002; U.S. Commission on ocean policy, An ocean blueprint for the 21st century, 2004; Ross K. Dowling, Cruise ship tourism, 2006. In Annex II the ranges for the waste types are given.

Policy Research has also obtained the actual waste streams of a cruise ship which was visited on a field trip[42]. This ship has a maximum capacity of 3 500 passengers and 1 000 crew members. The following table shows the average amount of waste for four types of waste.

Table IV.11 : Average waste production for a specific ship

Type of waste	Liter per month	Liter per week
Bilge water	125 000	31 250
Sewage	5 744 000	1 436 000
Grey Water	22 960 000	5 740 000
Solid waste	675 000	168 750

Source: Policy Research Corporation

Because cruise ships produce significant waste streams, cruise lines have put increasing efforts into reducing waste. For example, water recycling units are installed to recycle grey water, and solid waste is compressed to improve waste handling onshore.

[42] For confidentiality reasons the name of this ship is not mentioned

IV.6. Environmental impact of cruise tourism in Europe, summary

This chapter assesses the environmental impact of cruise tourism in EU ports and on EU seas. The results of the analyses conducted are shown in following table.

Table IV.12 : Overview of emissions in Europe caused by cruise tourism

Emissions (tonnes)	NO_x		SO_2		CO_2		PM	
	Absolute	%	Absolute	%	Absolute	%	Absolute	%
At Sea	156 521	*89%*	96 288	*99%*	6 091 920	*85%*	15 006	*87%*
In Ports	20 296	*11%*	677	*1%*	1 076 411	*15%*	2 277	*13%*
Total	176 817	100%	96 965	100%	7 168 331	100%	17 283	100%

Source: Policy Research Corporation

In addition to air emissions, other forms of pollution result from cruise tourism, as shown in *Table IV.10* and *Table IV.11*.

Although this study focuses primarily on ports, emissions in ports are responsible for only 10 – 15% of the total emissions. For sulphur, emissions at sea actually account for 99% of the absolute values. This is caused by the use of heavy sulphurous fuel while at sea compared to low sulphur fuel in ports. This observation will be taken into account for the purpose of assessing reduction options in the following chapters.

V. REDUCING THE ENVIRONMENTAL IMPACT OF CRUISE TOURISM

This chapter deals with the possibilities of reducing the environmental impact caused by cruise tourism. The environmental impact referred to in this chapter is limited to air emissions and other related environmental impacts, such as noise and smell.

There are several instruments available for reducing the environmental impact of cruise tourism. Two types of reduction methods are known: land-based and ship-based reduction methods. The land-based instrument that is commonly used for reducing air emissions from shipping (container ships, ferries, inland shipping) is shore-side electricity, also known as 'cold-ironing'. Shore-side electricity replaces the power supply of a ship's engine by electricity generated onshore. When a ship uses shore generated power, its engines can be switched to a low usage mode and emissions will be reduced. The noise and smell generated by the ships engines will consequently decrease.

Ship-based instruments are referred to as emission reduction systems. Emission reduction systems are commonly designed to reduce a specific emission type. *Table V.1* shows the available types of emission reduction systems.

Table V.1 : Type of available emission reduction systems

Reduction of NOx	Reduction of SO_x	Reduction of PM
Shore side electricity		
Water cooling of engine • Direct Water Injection (DWI) • Fuel Water emulsion Injection (FWI) • Humid Air Motor (HAM)	Sea water scrubbing Closed loop scrubbing	
Selective Catalytic Reductions (SCR)	Low sulphur fuel	
Gas Turbine		

Source: Policy Research Corporation

Ship-based emission reduction systems reduce emissions at berth and at sea, whereas land-based reduction systems only reduce emissions at berth. This chapter is structured in two parts: the first part will elaborate on shore-side electricity, the second part places the emphasis on ship-based reduction systems.

V.1. CONSIDERING SHORE-SIDE ELECTRICITY FOR CRUISE SHIPS IN EU-PORTS

If a cruise ship is connected to a shore-side electricity facility, its engines will be switched off (or powered down to a minimum). The shore power delivered can be generated in two ways – through the electricity power network or by a gas turbine in a port. This report focuses on shore-side electricity facilities that are connected to the main electricity network.

On 8 May 2006, the European Commission issued Recommendation 2006/339/EC on the promotion of shore-side electricity for use by ships at berth in Community ports, particularly where air quality limit values are exceeded or where public concern is expressed about high levels of noise nuisance, and especially in berths situated near residential areas. The Commission recommends that the environmental benefits and cost-effectiveness should be evaluated on a case-by-case basis. According to the Commission, Member States should consider offering economic incentives to operators to use shore-side electricity provided to ships.

V.1.1. PRACTICAL ASPECTS OF SHORE-SIDE ELECTRICITY

For a cruise ship to be able to use shore-side electricity, both cruise ship and port-interface have to be adapted. On the port-interface side, electricity has to be generated and connected to the ship. Electricity generated in a power plant will most likely lead to waste and emissions, since a power plant is powered by coal, gas or other fuel sources (except for green and nuclear energy). The cruise ship has to be equipped with special installations in order to switch to shore-side electricity. Therefore, some practical obstacles need to be addressed.

A cruise ship requires a substantial level of power. An average cruise ship has a power need of 9 -12 MW at berth[43]. If multiple cruise ships are in a port simultaneously, the power requirements become substantial. Therefore, high voltage infrastructure has to be available to be able to supply the power needed without creating power shortages or blackouts in city areas. This may require a connection to the main high powered net, which involves additional investments on the shore side.

Another important aspect that needs to be taken into account is the power frequency difference between the United States of America and Europe. Europe has a power frequency of $50H_z$, while the United States has a power frequency of $60H_z$. Cruise ships' power installations are based upon the

[43] Newer cruise ships have, on average, more power and thus require more power at berth (9-12 MW per hour)

American power frequency and therefore require a conversion of the power frequency once they are connected to an EU electricity network. Conversion can be done both on board a ship and on the shore side. Conversion facilities require additional investments.

A third aspect that needs to be taken into account is the amount of time needed to switch to electric power when a ship arrives in a port. On average, a ship requires 45 minutes to switch to shore side power, as the engines have to be gradually switched off (although not completely); the same applies to the reactivation of the engines upon departure. On average, this means that shore-side electricity can be fully used for 85% of berthing time in ports.

V.1.2. CURRENT AVAILABILITY OF SHORE-SIDE ELECTRICITY FACILITIES FOR CRUISE SHIPS

The availability of shore-side electricity for cruise ships is limited. *Table V.2* displays the availability of shore-side electricity facilities in ports around the world.

Table V.2 : Ports that have an active shore-side electricity facility to supply cruise ships or other types of ships

Inside or outside Europe	Port	Facility available for cruise ships	Facility available for other ship types
Inside	**Gothenburg**		x
	Stockholm		x
	Helsingborg		x
	Pitea		x
	Lübeck		x
	Amsterdam		x
	Rotterdam		x
	Antwerp		x
	Zeebrugge		x
Outside	**Long Beach**		x
	Oakland		x
	Seattle	x	
	Juneau	x	
	Vancouver*	x	
	Busan**		x

*** Starts in cruise season of 2009***
***** Starts in early 2009***

Source: Policy Research Corporation

In Europe several ports offer shore-side electricity connections, but these connections are not suitable for cruise ships. In Europe shore-side electricity facilities are available for ferries, inland ships and container ships. The only shore-side electricity connections that are available for cruise ships are located in North America: in Seattle (U.S), Vancouver (Canada) and Juneau (Alaska, U.S.).

The ports of Los Angeles and San Francisco are planning to offer shore-side electricity for cruise ships in the coming years. Others (e.g. Hamburg, Barcelona, Civitavecchia) are considering the possibility. Several other ports are also planning to offer shore-side electricity in the near future, (e.g. Oslo, San Diego, Tokyo, Tacoma), but it is unlikely that these connections will be ready for cruise ships.

The number of connections for cruise ships is rather low because it involves some extra difficulties compared to other ship types, such as the high voltage and large demand for power, which were discussed previously. These difficulties give rise to high investments in ports.

V.2. OTHER METHODS FOR REDUCING SHIPPING EMISSIONS

In addition to land-based facilities, ship-based facilities can be installed to reduce emissions. The methods which are described in this paragraph are concerned with the reduction of NO_x, SO_x and particulate matter based on their absolute and perceived effect in ports.

a/ NO_x reduction

Direct water injection (DWI)

By injecting water into the combustion chamber of the engine before the combustion process starts, temperature peaks are reduced. This results in a lower emission of NO_x.

Fuel water emulsion injection

By adding water to the fuel, combustion temperature decreases due to water evaporation. When the water in the fuel-water emulsion evaporates, fuel is simultaneously vaporized. This increases the surface area of the fuel. The lower temperature and the better fuel distribution lead to a lower formation of NO_x.

Humid Air Motor (HAM)

This concept uses heated charge air, enriched with evaporated seawater, to reduce NO_x formation during the combustion process. This system can be considered as an integral part of the engine, since it replaces the conventional engine air inter-cooler.

Selective Catalytic Reduction (SCR)

This process relies on injecting a urea solution (a carbon-nitrogen component) into an exhaust gas stream in combination with a catalyst housing in the exhaust channel.

b/ SO_2 and particulate matter reduction

Sea water scrubbing

The basic principle of this process relies on hot exhaust gases mixing in a turbulent cascade with seawater, so that SO_2 in the exhaust is transferred to the seawater. The sea water is treated by a cyclone to remove solids and oily compounds, and is then discharged. This discharge, called washing water, is currently a topical issue of political debate. The sulphur contents in the washing water end up in the oceans and can lead to acidification (increased pH levels) of the oceans. The extent to which this water can be discharged in open sea is dependent on the alkalinity of the oceans. The IMO and DG Environment are currently working on devising criteria for washing water.

Fresh water scrubbers

The alternative to sea water scrubbing technology is fresh water scrubbing. This system, also referred to as 'closed loop scrubbing', uses fresh water and a NaOH (soda) solution to clean the fumes of sulphur and particulate matter. The advantage of fresh water scrubbers compared to sea water scrubbers is that no water is discharged at sea. The disadvantages of this system are higher operating costs and the need for a storage tank. The higher operating costs are mostly due to the use of the NaOH solution (€ 100 - € 400 per tonne) of which 4 tonnes per day are needed[44]. Moreover, discharge has to be carried out in ports, which will incur additional discharge costs.

V.2.2. REDUCTION POTENTIAL

Table V.3 shows the reduction potential per emission type. These reduction percentages for shore-side electricity are based on the usage of low sulphur fuel (0.10% MDO) which is obligatory in ports from 1 January 2010. The other reduction methods are based on the currently used sulphur fuel (which has no effect on the reduction potential of these methods since NO_x is not affected by $SO_{2,}$ and water scrubbers filter out 100% of $SO_{2,}$).

[44] Wärtsilä, SOx scrubber technology and SECA, presentation on the Service Seminar, 12 December 2006, Gothenborg
Wärtsilä, Sulphur scrubbers, presentation on the Green Solutions Seminar, 26 September 2007, Gothenborg

Table V.3 : Reduction potential per emission type

Reduction method and potential	NO_x	SO_x	CO_2	PM
Shore side electricity (SSE)[1,2]	98%		62-87%	89%[3]
Direct Water Injection (DWI)	50-60%			
Fuel Water Emulsion Injection (FWI)	30-50%			
Humid Air Motor (HAM)	60-80%			
Selective Catalytic Reductions (SCR)[4]	80-90%			
Sea Water Scrubbing (SWS)[5]		100%		80%

[1] SSE reduces emissions only 85% of the time at berth because (dis)connection time has to be taken into account
[2] Dependent on the production facility of the electricity, see paragraph VI.1.2.1 for more information
[3] Reduction of Particulate Matter is averaged for all energy sources (coal, oil, gas, nuclear and renewable energy)
[4] Based on information from Wärtsilä
[5] Reductions based on 3.5% S fuel, (>95% of all marine bunker deliveries globally, source: Krystallon)

Source: ENTEC EC, DG ENV. Service contract on ship emissions, tasks 2A,B&C, August 2005; Cheminfo: Cost benefit Study of Marine Engine, NOx Emissions Control Systems, prepared for transport Canada, February 2005; EC, Policy Recommendation on the promotion of shore-side electricity for use by ships at berth in Community ports :(2006/339/EC)

In the following chapter, a cost benefit analysis will be conducted in order to evaluate these reduction methods.

VI. COST-BENEFIT ANALYSIS

In the previous chapters the environmental impact of cruise tourism in Europe was assessed and options for reducing this impact were suggested. This chapter will now evaluate these options as part of a cost-benefit analysis in order to find a rationale for investing in these facilities.

As this report is mainly orientated towards facilities in ports, it primarily focuses on landside facilities and more specifically on shore-side electricity. The chapter is divided into three sections. The first section is dedicated to cost benefit analyses of shore-side electricity. In the second section cost benefit analyses are conducted for other emission reduction options. The third and final section of this chapter analyses the cost-effectiveness of shore-side electricity as against other options, with the aim of assessing the rationale of investing in port or ship facilities.

VI.1. SECTION I: SHORE-SIDE ELECTRICITY

This section is structured into four paragraphs. *Paragraph V.1.1* elaborates on the costs of shore-side electricity facilities. *Paragraph V.1.2* highlights the benefits that can be gained by investing in shore-side electricity facilities. *Paragraphs V.1.3 and V.1.4* summarise these costs and benefits.

VI.1.1. COSTS OF SHORE-SIDE ELECTRICITY FACILITIES FOR CRUISE SHIPS

Two methods were used to quantify the costs for shore-side electricity installations for cruise ships. First, a recent study[45] carried out on behalf of the port of Rotterdam was used which stressed the costs of shore-side electricity facilities for cruise ships. Secondly, the costs were validated by ABB, a global supplier of energy and automation technology.

Table VI.1 displays the costs of one shore-side electricity facility capable of delivering 12 MW, and supplying shore side power to one large cruise ship or two smaller cruise ships.

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[45] Royal Haskoning, Feasibility study shore-side electricity for cruise ships, Port of Rotterdam, 2007

Table VI.1 : Cost estimates of two types of shore-side electricity installations

	Investments costs	Annual costs
12 MW, 6.6/11kV connection	€ 6 750 000	€ 500 000

* One connection can host one large ship or two small ships

Source: ABB, cost indication for shore-side electricity installations

The costs of shore-side electricity facilities for cruise ships are substantially higher than common shore-side electricity installations for e.g. ferries and container ships. The two parameters that have an impact on the installation costs for shore-side electricity are listed below:

- *Connection to the high capacity electricity grid*: Cruise ships require a substantial level of power. The cruise ship has to be connected to the main power grid, capable of transporting high or middle voltages. To this end, a special high capacity cable has to link the ship and the electricity network. In most cases, excavation and engineering work are required in order to perform the placement. The costs for these works are included, but may differ according to local conditions;
- *Conversion of electricity to adapt to a lower frequency*: The electricity network on board of cruise ships conforms to the North American network, which uses a power frequency of 60Hz. Europe, on the other hand, uses a frequency of 50 Hz. Shore-side electricity therefore has to be converted to 50 Hz using a special converter. The costs for this converter are included in the cost estimates in *Table IV.1*.

In addition to the initial fixed costs, there are annual costs of € 500 000 (maintenance, contract and electricity transport costs) resulting from the use of shore-side electricity. These costs consist of labour costs for port officials handling the facility, costs for transportation of the electricity and maintenance. As most of these costs tend to be fixed, a range of € 400 000 and € 600 000 will apply for ports. This is dependent on the number of facilities offered and the power level that is transported by the electricity network (the costs for using the network, not for the power itself). A single figure of € 500 000 is used for the calculations. All costs are based on ABB cost estimates and annual transportation rates by a Dutch electricity company, specifically for the cruise terminal of the port of Rotterdam; they have been verified by *Policy Research*[46].

VI.1.2. BENEFITS OF SHORE-SIDE ELECTRICITY FOR CRUISE SHIPS

Ports and port areas can benefit in two ways from the installation of shore-side electricity:

- Emissions are reduced, which leads to benefits for the port area (societal/welfare benefits);
- Port authorities can be intermediaries between the suppliers of energy (energy companies) and users (cruise lines) by adding a profit margin on the supply of shore-side electricity (port benefits).

[46] Interview with Mr. De Boer, head of Stedin electricity network administration, Rotterdam, The Netherlands

VI.1.2.1. Reduction of emissions by shore-side electricity

Shore-side electricity has several benefits for reducing environmental impact in ports; around 80% of the emissions in ports can be reduced with shore-side electricity. However, an important constraint is the fact that the installation of one shore-side electricity facility will not reduce the total emissions by 80% in that port (hereinafter: maximum reduction level), as several ships can be in one port simultaneously. One facility can only power one or two ship(s) at a time, which would mean that the other cruise ships continue running on engine power. For that reason, an analysis is made of the number of facilities necessary to obtain maximum reduction levels. This was done by calculating the average number of cruise ships in a port per day, based on the distribution of cruise tourism per month. The results are shown in *Table VI.2*.

Table VI.2 : Distribution of cruise ships in EU-ports

	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
NW EU	0	0	0	3%	13%	24%	28%	24%	10%	0	0	0
Med	2%	2%	4%	8%	13%	11%	10%	11%	13%	15%	8%	3%

Source: Policy Research Corporation

All ports with two or more shore side facilities at which a cruise ship calls more than once a day in any given month (and therefore requiring more than one facility for ensuring maximum emission reductions) were indicated. All the other ports with one facility were also indicated. This provided the input for the cost benefit analysis[47]. *Annex III A* contains the average number of calls per day for the most frequently visited ports. *Annex III B* contains the number of shore-side electricity installations needed to ensure maximum emission reductions in these ports.

a/ Correction for emissions caused by generating shore-side electricity

Shore-side electricity is presented as an environment-friendly alternative to engine generated power. Nevertheless, there is still a need to generate electricity provided by shore-side electricity facilities. Generation of shore power also causes emissions. The level of emissions is dependent on the type of facility in which it is generated (a coal-fired power plant, a nuclear plant or green energy (such as wind and hydro energy).

The benefits obtained by shore-side electricity therefore have to be corrected accordingly for the emissions caused by generating the shore power needed[48]. *Table VI.3* shows the emissions in grams per kWh for onshore electricity production facilities versus ship based electricity production.

[47] Besides a higher intensity of cruise traffic in specific months, the intensity of traffic might also be higher during weekends or other parts of the week, resulting in a need for additional connections to supply all ships with shore power. This additional capacity required for these peak flows are not incorporated in the calculation.

[48] Reduction levels of shore power compared to engine generated power of a MD powered engine.

Table VI.3 : Emissions in gram per kWh for onshore electricity production versus ship based electricity production

Type of production facility	NO_x	SO_2	CO_2	PM
Coal power plant	1.05	2.75	340.56	4.33
Oil power plant	0.46	0.82	266.76	0.01
Gas power plant	0.34	0.002	201.96	0.001
Ship (main + auxiliary engines)	*12.74*	*0.4*	*647*	*0.9*
Ship (diesel-electric)	*11.67*	*0.4*	*690*	*0.3*

Sources: EEA (2008). Air pollution from electricity-generating large combustion plants (N.B. the emissions are weighted country averages); Entec (2007). CONCAWE: Ship emissions inventory - Mediterranean Sea

As can be seen from *Table VI.3*, the reduction of emissions varies according to emission type and production facility. *Table VI.4* shows the reduction potential per production facility. As can be seen from the table, the reduction potential is highest if shore based electricity is generated by gas powered plants. A distinction is made between the engines of the various ships. Newer ships are diesel-electric, having a generator that produces electricity. This electricity is used to power the engines and supply the ship's electrical needs. These generators tend to generate lower NO_x and PM emissions, but higher CO_2 emissions.

Table VI.4 : Reduction potential of shore side produced electricity compared to ship produced electricity

Ship (main + auxiliary engines)	NO_x	SO_2	CO_2	PM
Coal power plant	92%	0	47%	0
Oil power plant	96%	0	59%	99%
Gas power plant	97%	99%	69%	100%
Ship (diesel-electric)	**NO_x**	**SO_2**	**CO_2**	**PM**
Coal power plant	91%	0	51%	0
Oil power plant	96%	0	61%	98%
Gas power plant	97%	99%	71%	100%

Source: Policy Research Corporation

In addition to coal, gas and oil powered plants, it is also important to include nuclear and renewable energy in the analysis. If the total energy mix (i.e. the % of electricity produced per type of facility) according to ENTEC[49] is taken into account, this gives the reduction potential of shore-side electricity shown in *Table VI.5*.

[49] ENTEC, DG Environment. Service contract on ship emissions: assignment, abatement and Market-based instruments. Task 2a Shore- side electricity, 2005.

Table VI.5 : Average reduction potential of shore-side electricity

Susbtance	NOx	SO_2	CO_2	PM
Reduction level	97%	0	> 50%	89%
Average time connected to shore power in a port: 85%				
Net reduction potential	82%	0	> 42%	76%

Source: Policy Research Corporation

Annex IV shows the perceived maximum societal benefits gained by investing in shore-side electricity facilities, corrected for these factors. Moreover, the benefits were corrected for the 85% utilisation rate per call (correction for the time needed to switch engine power to shore-side electricity and vice versa). The end result of these calculations represented the net maximum benefits per port.

VI.1.2.2. Societal benefits: transforming emissions into monetary values

The benefits of reducing emissions are difficult to quantify. Emissions can cause damage to health and nature, which involves costs for society. The relationship between emissions and societal costs has been the subject of much political debate. Although it is not clear what real damage is caused by emissions, there is a general consensus on the fact that emissions should be assessed as negative externalities.

A number of researchers in the past decade[50] have devised methods to convert emissions into monetary values, based on the relationship with societal costs. The conversion of emission values into monetary values depends on the damage done by emissions, which in turn depends on the seriousness of the impact caused by a specific substance, the number of people exposed, et cetera.

In the previous chapters of this report, actual emission levels were assessed on an individual port basis. Using these emission levels, the monetary values can be calculated for each port. More importantly, the benefits of investments in environment friendly facilities can be expressed into actual monetary benefits for each individual port. Based on these values a cost benefit analysis can be conducted in order to assess the cost-effectiveness of investments in environment friendly facilities in European ports.

This report uses monetary values that were assessed at EU level, broken down for each EU Member State. The values are based on emissions in a rural area and can be found in *Table VI.6*. These values vary per country because the EU-countries and regions are confronted with different existing emission

[50] NetCen, Estimates of the marginal external costs of air pollution in Europe, Benefits Table Database created for the European Commission/DG Environment, 2000.

levels. Therefore, the impact of a specific emission in a country may vary in seriousness and consequently in terms of the costs for society.

Table VI.6 : Societal benefits (expressed in monetary values) per ton of avoided emissions

Country	NO_x (€/ton)	SO_2 (€/ton)	CO_2 (€/ton)	PM (€/ton)
Austria	8303	8791	22	17094
Belgium	5739	9646		26862
Denmark	4029	4029		6593
Finland	1832	1184		1709
France	10012	9035		18315
Germany	5006	7448		19536
Greece	7326	5006		9524
Ireland	3419	3175		5006
Italy	8669	6105		14652
Netherlands	4884	8547		21978
Portugal	5006	3663		7082
Spain	5739	4518		9646
Sweden	3175	2076		2076
UK	3175	5495		11844

Source: NetCen, Estimates of the marginal external costs of air pollution in Europe, Benefits Table Database created for the European Commission/DG Environment, 2000. Corrected for price levels of 2008 by Policy Research Corporation

The values of *Table VI.6* are based on rural areas. For SO_2 and PM, a second level of differentiation of the values is needed, as the proximity of a large city causes more health damage. The costs of SO_2 and PM emissions must therefore be increased. A factor[51] was developed to incorporate these extra costs of SO_x and PM emissions for populated areas.

The cost of a ton of CO_2 is equal for each country, since CO_2 causes a global problem and is non-reactive with other substances (like NO_x). The value for CO_2 is based on the emission trading future for 2009[52] and is therefore supported by an actual cost base. *Annex I C* gives an overview of the emissions attributed to ports.

Although the benefits have been expressed in monetary values, they do not reflect actual cash flows. After all, these values reflect costs that have been avoided for society and are distributed across

51 *NetCen, Estimates of the marginal external costs of air pollution in Europe, Benefits Table Database created for the European Commission/DG Environment, 2000. Corrected for price levels of 2008 by Policy Research Corporation*

52 www.co2prices.eu, expectation for 2009 by Société Générale, last visited in July 2009.

individuals, companies and governments. From an investment point of view, these values do not form the basis for a business case; no-one has clear ownership of the benefits gained.

VI.1.2.3. Potential port benefits

As mentioned in the previous paragraph, the benefits gained by reducing emissions are not reflected in actual cash flows. In this paragraph an assessment will be made of hypothetical cash flows that potentially result from the investment in shore-side electricity (societal benefits). An investment made by a port authority in shore-side electricity can also be based on a business case in which the port sells the electricity to cruise ships at a profit. Depending on the profit margin, investment costs and annual costs, a port can make a return on investment. Therefore, a second cost benefit analysis will be conducted, based on real potential cash flows. Also a third cost benefit analysis will be conducted which will include the costs of refitting cruise ships for shore-side electricity, as well as the subsidies that are necessary to compensate for the price difference between fuel and electricity. *Figure VI.1.* gives an overview of the cost benefit analyses

Figure VI.1 : Overview of the cost benefit analyses for shore-side electricity (SSE)

CBA	Costs	Benefits	Result
I	Investment costs SSE for ports	Emission reduction (societal benefits*) based on average reduction percentages	38 ports have a positive NPV for investing in SSE
		Emission reduction (societal benefits) based on the energy mix of each individual member state	19 ports have a positive NPV for investing in SSE
		Emission reduction (societal benefits) based on the 2020 national targets of renewable energy	19 ports have a positive NPV for investing in SSE
II	Investments in SSE for ports with a positive NPV for SSE	Hypothetical profit for ports as resellers of electricity with a margin	For a 25% profit margin there are no positive NPVs; for a 50% margin positive NPV's apply
III	Investments of ports in SSE and costs for cruise lines (refitting ships) + subsidising electricity**	Reduction of emissions	For 38 ports a total NPV (10 years and 6% discount) of € 562 million results

* *Societal benefits are created because the health costs are reduced*
** *Subsidies have been calculated on the basis of 0.1% sulphur fuel. If RO should be applied the amount of subsidies will increase.*

Source: Policy Research Corporation

VI.1.3. COST BENEFIT ANALYSIS I: SOCIETAL BENEFITS VERSUS COSTS

This first cost benefit analysis is constructed from a public perspective, i.e. it calculates only in terms of societal benefits. In order to obtain the input for this analysis, the following steps were followed for all 313 ports in Europe that cruise ships call at:

- For each port, calculations were made of the number of shore-side electricity installations needed in order to achieve maximum emission reductions;
- The investment and annual costs of a shore-side electricity installation were calculated for each port;
- The emissions per port were converted into monetary values;
- Per port a factor was calculated to incorporate additional costs for SO_2 and PM, based on the population density of that specific port;
- Correction factors for the emissions caused by the generation of land electricity were assessed and incorporated for each port;
- The time needed to switch engine power to shore-side electricity (and vice versa) was incorporated in the benefits, in order to assess the gross annual benefits of shore-side electricity.

Consequently, the annual net benefits of each port were assessed by subtracting the annual costs (€ 500 000 for each port) from the annual gross profits. In this way, ports whose profits are lower than their variable costs are not eligible for a shore-side electricity facility. Ports having a positive annual net benefit, of which there are 60 in total, were extracted for a separate Net Present Value (NPV) analysis.

Table VI.7 shows the results for the five biggest cruise ports in Europe.

Table VI.7 : Costs and annual benefits for shore-side electricity in the top 5 ports

Port	# SSE facilities	Investment costs	Annual costs (A)	Monetary values of emissions	Gross annual benefits of SSE (B)	Net annual benefit of SSE (B-A)
Barcelona	5	33 750 000	500 000	35 357 049	29 203 999	28 703 999
Naples	3	20 250 000	500 000	23 095 597	19 456 092	18 956 092
Piraeus	5	33 750 000	500 000	19 390 289	16 252 099	15 752 099
Civitavecchia	5	33 750 000	500 000	15 788 177	13 992 623	13 492 623
Livorno	3	20 250 000	500 000	10 536 863	9 185 235	8 685 235

Source: Policy Research Corporation

In order to make a positive investment case, the annual costs have to be earned back, but so do the initial fixed (investment) costs. Hence, the net annual benefits were discounted for 10 and 15 years, with discount rates of 4% and 6% and subtracted from the fixed costs. Of the 60 ports having positive net annual benefits, 38 have a positive investment case for a 10-year payback period with both a 4% and a 6% discount. *Table VI.8* sets out the NPVs of the five ports with the highest emission levels caused by cruise tourism.

Table VI.8 : Net present values of welfare benefits by investing in shore-side electricity

Port	Total fixed costs SSE connections	Net annual benefits	NPV 10 years 4%	NPV 10 years 6%	NPV 15 years 4%	NPV 15 years 6%
Barcelona	33 750 000	28 703 999	199 065 143	177 513 930	263 711 326	245 030 384
Naples	20 250 000	18 956 092	133 500 887	119 268 488	179 726 341	163 856 286
Piraeus	33 750 000	15 752 099	94 013 637	82 186 823	119 707 089	119 238 312
Civitavecchia	33 750 000	13 492 623	75 687 260	65 556 881	94 585 356	97 293 715
Livorno	20 250 000	8 685 235	50 195 035	43 674 085	65 530 971	64 103 164

Source: Policy Research Corporation

For the five ports with the highest emission levels, the NPV of the investment in shore-side electricity is positive when an investment period (payback period) of both 10 and 15 years is taken into account. For the 38 ports that have a positive investment case (NPV 4% and 6%, 10 years), total investment costs are € 553 500 000 and annual costs (maintenance, labour, etc.) are € 19 000 000. This will lead to societal benefits of € 221 886 743 annually. If the annual costs are subtracted, the net annual societal benefits of the 38 ports are € 202 886 743. Furthermore, the average payback period for these 38 ports is 3.8 years[53]. For an overview of these ports and a detailed explanation of these figures, see *Annex IV*.

In these analyses, the average EU reduction percentages for shore-side electricity have been used (see *Table VI.5*). These percentages are based on the results of the ENTEC study[54] (conducted for and approved by DG Environment) which uses the average emissions of power plants in the EU 25 countries. By taking the energy mix of each individual Member State into account, a more detailed analysis is provided. The energy mix is the distribution of the total electricity production across the different electricity sources. These sources are coal, oil, gas, nuclear, renewable and 'other'. *Annex V* shows the distribution of electricity production of each power source for each Member State. In *Table VI.9* the results are shown for a selection of Member States.

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[53] Payback period is based on non-discounted yearly net societal benefits; the time value of money is not incorporated.

[54] ENTEC, DG Environment. Service contract on ship emissions: assignment, abatement and Market-based instruments. Task 2a Shore- side electricity, 2005 (http://ec.europa.eu/environment/air/pdf/task2_shoreside.pdf)

Table VI.9 : Energy mix for the top four EU Member States regarding cruise activity compared with two EU Member States with low-emission energy mixes

Country	Coal	Oil	Gas	Nuclear	Renewable	Other
Italy	16%	15%	50%	0%	19%	0%
Spain	23%	8%	30%	20%	18%	2%
Greece	53%	16%	17%	0%	14%	0%
United Kingdom	38%	1%	35%	19%	6%	0%
France	5%	1%	4%	78%	12%	0%
Sweden	1%	1%	0%	47%	50%	0%

Source: Policy Research Corporation based on International Energy Agency figures

When the energy mix is combined with the emissions per kWh of each power plant type, the weighted emissions per kWh of electricity are calculated. These emissions can then be compared with the emissions of a cruise ship per kWh. This allows the actual percentage reductions of shore-side electricity to be calculated.

When these percentage reductions are taken into account, the number of ports that have a positive net present value, decreases to 19. These ports are shown in *Annex VI A*. The costs and annual benefits for the five ports with the highest NPV (10 years with 6% discount rate) are shown in *Table VI.10*.

Table VI.10 : Costs and annual benefits for shore-side electricity in the ports with the highest NPV according to the country specific energy mix

Port	# SSE facilities	Investment costs	Annual costs (A)	Monetary values of emissions	Gross annual benefits of SSE (B)	Net annual benefit of SSE (B-A)
Civitavecchia	5	33 750 000	500 000	15 788 177	10 377 207	9 877 207
Naples	3	20 250 000	500 000	23 095 597	6 834 814	6 334 814
Barcelona	5	33 750 000	500 000	35 357 049	8 386 624	7 886 624
Marseilles	2	13 500 000	500 000	9 810 784	5 127 160	4 627 160
Livorno	3	20 250 000	500 000	10 536 863	5 935 986	5 435 986

Source: Policy Research Corporation

The NPV results for these five ports are shown in *Table VI.11*. The results are considerably lower than those from the NPV calculation in *Table VI.8*.

Table VI.11 : Net present values of welfare benefits by investing in shore-side electricity

Port	Total fixed costs SSE connections	Net annual benefits	NPV 10 years 4%	NPV 10 years 6%	NPV 15 years 4%	NPV 15 years 6%
Civitavecchia	33 750 000	9 877 207	46 362 994	38 947 101	76 068 611	62 179 891
Naples	20 250 000	6 334 814	31 131 018	26 374 784	50 182 919	41 275 293
Barcelona	33 750 000	7 886 624	30 217 586	24 296 240	53 936 542	42 846 857
Marseilles	13 500 000	4 627 160	24 030 409	20 556 297	37 946 553	31 440 126
Livorno	20 250 000	5 435 986	23 840 714	19 759 328	40 189 395	32 545 647

Source: Policy Research Corporation

On 23 April 2009, the European Union adopted the Directive 2009/28/EC[55] on the promotion of the use of energy from renewable sources. The Directive sets targets for all Member States so that the EU will reach a 20% share of energy from renewable sources by 2020 and a 10% share of renewable energy specifically in the transport sector.

By assuming that energy production is the same as the energy consumption in a country, it is possible to estimate the effects of these 2020 targets on the reduction potential[56] of shore-side electricity. This was calculated by increasing the percentage of renewable energy to the level of the 2020 targets (where the percentage of renewable production is already higher than the 2020 consumption targets, the highest percentage was used). This increased percentage was subsequently subtracted from the percentage of the most polluting energy source: coal. If the increased percentage of renewable electricity was higher than the percentage of coal, the remaining percentage was subtracted from electricity generated by oil (followed by gas). *Table VI.12*

Table VI.12 : Energy mix for six EU Member States when the 2020 targets of renewable energy are met

Country	Coal	Oil	Gas	Nuclear	Renewable	Other
Italy	16%	15%	50%	0%	19%	0%
Spain	21%	8%	30%	20%	20%	2%
Greece	49%	16%	17%	0%	18%	0%
United Kingdom	29%	1%	35%	19%	15%	0%
France	0%	0%	0%	77%	23%	0%
Sweden	1%	1%	0%	47%	50%	0%

Source: Policy Research Corporation

55 Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Further information are available at the website http://ec.europa.eu/energy/renewables/index_en.htm

56 The reduction potential describes the percentage of emission reduction if shore-side electricity is installed. If the emissions of energy production are also taken into account, an increase in emission-free electricity production will increase the reduction potential of shore-side electricity

The NPV calculation shows that, once again, only 19 ports have a positive NPV case (based on a 10 year period with a 6% discount rate), but the ranking of the ports has changed. These 19 ports can be found in *Annex VI B*. The results of the net annual benefits for the top five ports are shown in *Table VI.13*.

Table VI.13 : Costs and annual benefits for shore-side electricity in the ports with the highest NPV according to the 2020 targets

Port	# SSE facilities	Investment costs	Annual costs (A)	Monetary values of emissions	Gross annual benefits of SSE (B)	Net annual benefit of SSE (B-A)
Marseilles	2	13 500 000	500 000	9 810 784	8 331 586	7 831 586
Civitavecchia	5	33 750 000	500 000	15 788 177	10 377 207	9 877 207
Naples	3	20 250 000	500 000	23 095 597	6 834 814	6 334 814
Barcelona	5	33 750 000	500 000	35 357 049	8 409 627	7 909 627
Nice	2	13 500 000	500 000	6 205 857	5 266 968	4 766 968

Source: Policy Research Corporation

The NPV results for these five ports are shown in *Table VI.14*. These net present values are similar to the results of the previous analysis of the energy mix. For Italian ports they are the same, since the percentage of renewable production is already higher than the percentage of the renewable consumption target for 2020. French ports are improving their NPV because the 2020 targets would result in electricity production that is virtually emission free.

Table VI.14 : Net present values of welfare benefits by investing in shore-side electricity

Port	Total fixed costs SSE connections	Net annual benefits	NPV 10 years 4%	NPV 10 years 6%	NPV 15 years 4%	NPV 15 years 6%
Marseilles	13 500 000	7 831 586	50 021 180	44 141 157	73 574 611	62 562 316
Civitavecchia	33 750 000	9 877 207	46 362 994	38 947 101	76 068 611	62 179 891
Naples	20 250 000	6 334 814	31 131 018	26 374 784	50 182 919	41 275 293
Barcelona	33 750 000	7 909 627	30 404 160	24 465 543	54 192 297	43 070 266
Nice	13 500 000	4 766 968	25 164 379	21 585 298	39 500 995	32 797 978

Source: Policy Research Corporation

VI.1.4. Cost benefit analysis II: cash flows for ports versus costs

The second cost benefit analysis is presented from an economic perspective, i.e. it calculates the potential yields to be made by port authorities if ports were to sell shore-side electricity. After all, ports can, as intermediaries between electricity companies and cruise ships, add a profit margin to every kWh provided to cruise ships. These potential profits by ports reflect real cash flows and are consequently used as an input for the analysis.

The annual demand in kWh is calculated for each port. The average prices for electricity[57] (business use) in the Member States were entered into the database, with and without VAT per Member State. For every port, the turnover in electricity (kWh * average price per kWh) was calculated. A margin (ranging from 25% to 50%) was added to the cost of electricity.

The fixed annual costs were subtracted from the gross annual cash flow that resulted per port. This gave a net annual cash flow by selling shore-side electricity. *Table VI.15* shows these calculations for the five ports that have the highest positive annual cash flows if shore side power is to be sold with a margin of 25%.

Table VI.15 : Costs and benefits from a port authority perspective if electricity is sold with a 25% margin

Port	# SSE facilities	Annual costs (A)	Total quantity of MWh needed	Cost of electricity per MWh in € (VAT incl.)	Profit margin 25% (B)	Net annual cash flow in € (B-A)
Civitavecchia	5	500 000	107 212	116.60	3 125 242	2 625 242
Barcelona	5	500 000	123 389	70.19	2 217 924	1 717 924
Naples	3	500 000	70 288	116.60	2 048 896	1 548 896
Livorno	3	500 000	61 651	116.60	1 797 155	1 297 155
Venice	3	500 000	52 329	116.60	1 525 418	1 025 418

Source: Policy Research Corporation

For the calculation shown in the table, a hypothetical profit margin of 25% was used. Based on this margin, these ports all have a net annual cash flow. If the cash flows are discounted, the following overview emerges (*Table VI.16*).

Table VI.16 : Net present values of cash flows generated by selling electricity with 25% margin

Port	Investment costs	Net annual cash flow	NPV 15 years (4%)	NPV 15 years (6%)
Civitavecchia	33 750 000	2 625 242	-4 561 531	-8 252 986
Barcelona	33 750 000	1 717 924	-14 649 450	-17 065 089
Naples	20 250 000	1 548 896	-3 028 772	-5 206 734
Livorno	20 250 000	1 297 155	-5 827 726	-7 651 705
Venice	20 250 000	1 025 418	-8 848 994	-10 290 875

Source: Policy Research Corporation

As *Table VI.16* shows, there is no economic rationale for investing if the prices of electricity are raised by a margin of 25%. In order to achieve a positive return on investment, the margin would have

[57] DG TREN: EU energy and transport in figures, statistical pocketbook, 2007-2008

to be significantly higher. Therefore, the possibility of adding a margin of 50% on electricity sold is investigated in *Table VI.17* and *Table VI.18.*

Table VI.17 : Costs and benefits from a port authority perspective if electricity is sold with a 50% margin

Port	# SSE facilities	Annual costs (A)	Total quantity of MWh needed	Cost of electricity per MWh in € (VAT incl.)	Profit margin 50% (B)	Net annual cash flow in € (B-A)
Civitavecchia	5	500 000	107 212	116.60	6 250 485	5 750 485
Barcelona	5	500 000	123 389	70.19	4 435 848	3 935 848
Naples	3	500 000	70 288	116.60	4 097 792	3 597 792
Livorno	3	500 000	61 651	116.60	3 594 310	3 094 310
Venice	3	500 000	52 329	116.60	3 050 837	2 550 837

Source: Policy Research Corporation

Table VI.18 : Net present values of cash flows generated by selling electricity with a 50% margin

Port	Investment costs	Net annual cash flow	NPV 15 years (4%)	NPV 15 years (6%)
Civitavecchia	33 750 000	5 750 485	30 186 130	22 100 150
Barcelona	33 750 000	3 935 848	10 010 293	4 475 945
Naples	20 250 000	3 597 792	19 751 649	14 692 655
Livorno	20 250 000	3 094 310	14 153 741	9 802 712
Venice	20 250 000	2 550 837	8 111 205	4 524 373

Source: Policy Research Corporation

In order for a 25% profit margin to be made on electricity, the net present value (15 years, 4% discount) of the investment made by a private party is negative for all ports. Taking a fifteen-year time frame, 4% discount and a profit margin of 50%, five ports show positive NPVs, which is the same in the case of a 6% discount rate.

VI.1.5. COST-BENEFIT ANALYSIS III: COSTS FOR PORTS AND CRUISE LINES VERSUS BENEFITS

Before a cruise ship can connect to a shore-side electricity facility, it needs to be adapted with special electrical equipment. The average costs of refitting existing cruise ships with this equipment are between € 500 000 and € 1 000 000[58]. In order to attain the results of the cost benefit analysis conducted in the previous chapter, all cruise ships travelling to the selected ports should be refitted with this equipment.

[58] Royal Haskoning, Feasibility study shore-side electricity for cruise ships, Port of Rotterdam, 2007 & ABB Europe

To obtain the maximum benefits, 38 ports show a positive outcome for an investment based on gaining maximum societal benefits. Hence, all ships that call at least once at one of these ports must have a shore-side electricity connection. A total of 157 ships call at these selected ports, which gives an investment by cruise tourism in shore-side electricity connections of € 117.8 million (157 * € 750 000 per connection).

VI.1.5.1. Benefits for cruise lines

If shore-side electricity is available, cruise ships save on fuel. The costs of electricity in ports versus the costs of fuel should therefore be compared. *Table VI.19* shows the costs for electricity in the EU-22[59] coastal Member States.

Table VI.19 : Costs of electricity in EU-22 coastal Member States

Country	BE	BG	CY	DK	EE	FI	FR	DE	EL	IE	IT	LV	LT	MT	NL	PL	PT	RO	SI	ES	SE	UK
Cost of electricity per 100 kWh	7.85	4.19	10.1	9.79	5.85	5.27	5.08	9.79	5.85	10.8	11.7	3.56	5.36	5.87	7.07	5.38	7.68	6.67	6.8	7.19	5.53	7.72
% VAT	21%	20%	15%	25%	18%	19%	20%	19%	9%	14%	10%	21%	19%	5%	19%	22%	5%	19%	20%	20%	25%	5%

Source: Policy Research Corporation

An average cruise ship requires 0.13 metric tonnes (see *Paragraph IV.2.1*, compliance costs) of fuel per hour to generate 1 MWh of electricity. The same MWh of shore electricity costs € 70.59. This rate is based on the average price for electricity in the EU-21 coastal Member States, shown in *Table* VI.19.

Table VI.20 presents the benefits for cruise lines at different fuel prices, based on RO and MDO. RO is the fuel used today in most ports, but from 1 January 2010 ships will be obliged to use MDO in EU ports. Four fuel prices are displayed (per metric tonne): the average fuel price of January – July 2009 for RO ($ 296), the average price of MDO (January-July 2009) and two hypothetical MDO prices of $ 600 and $ 750 metric tonnes per MWh.

[59] European Commission: DG Taxation and Customs Union tax policy, VAT tables, part II Energy Products and Electricity, July 2008

Table VI.20 : Fuel costs compared with electricity in ports, VAT included

Price of fuel	RO	MDO	Hypothetical price MDO	Hypothetical price MDO
Fuel costs per metric tonne	**$ 296**	**$ 462**	**$ 600**	**$ 750**
Euro values (1€ = 1.4 $)	211	330	429	536
Fuel costs (0.13 metric tonnes) per MWh	27.5	42.9	55.7	69.6
Electricity costs per hour	70.59	70.59	70.59	70.59
Difference	-43	-28	-15	-1
Per call of 10 hours, a ship requires 12MW per hour	**-5 173**	**-3 323**	**-1 785**	**-114**
Investment costs for Shore side electricity	750 000	750 000	750 000	750 000
Number of calls needed non discounted	N/A	N/A	N/A	N/A
NPV for 10 years, 6% discount rate				
NPV 50 annual calls	N/A	N/A	N/A	N/A
NPV 100 annual calls	N/A	N/A	N/A	N/A
NPV 150 annual calls	N/A	N/A	N/A	N/A

Source: Policy Research Corporation

If the current oil prices of MDO of $ 462 per metric tonne (€ 330[60]) are taken into account, the costs of electricity outweigh the costs of fuel. Even fuel costs of $ 600 and $ 750 per metric tonne will not reach break-even point compared to shore generated electricity. The main reason is the ratio of the US dollar to the euro, which makes fuel prices low in euro terms. With the current oil prices, electricity would have to cost € 42.9 or less per MWh in order to be as expensive as fuel or less expensive, which is only the case in Bulgaria and Latvia (see *Table VI.19*).

Another determinant is the consumption of fuel at berth. The average value of 0.13 metric tonnes per MWh was used in the previous calculation. The question is what the effects are of higher fuel consumption of ships. Some cruise ships have a consumption of 0.2 metric tonnes per hour. If this consumption is used in the calculation, the net present values start to be positive for fuel prices from $ 600. *Table VI.21* shows the outcomes.

[60] 1 euro is equivalent to 1.40 US dollar, average exchange rate in June 2009

Table VI.21 : Fuel costs (if 0.2 metric tonnes per MWh are used) compared with electricity in ports, VAT included

Price of fuel	RO	MDO	Hypothetical price MDO	Hypothetical price MDO
Fuel costs per metric tonne	**$ 296**	**$ 462**	**$ 600**	**$ 750**
Euro values (1€ = 1.4 $)	211	330	429	536
Fuel costs (0.2 metric tonnes) per MWh	42.3	66.0	85.7	107.1
Electricity costs per hour	70.59	70.59	70.59	70.59
Difference	-28	-5	15	37
Per call of 10 hours, a ship requires 12MW per hour	**-3 397**	**-551**	**1 815**	**4 386**
Investment costs for Shore side electricity	750 000	750 000	750 000	750 000
Number of calls needed non discounted	N/A	N/A	413	171
NPV for 10 years, 6% discount rate				
NPV 50 annual calls	N/A	N/A	-82 104	864 193
NPV 100 annual calls	N/A	N/A	585 793	2 478 387
NPV 150 annual calls	N/A	N/A	1 253 689	4 092 580

Source: Policy Research Corporation

Taxation on shore-side electricity

In order to create sufficient incentives for cruise operators to refit their ships with shore-side electricity connections, the European Commission is considering removing the taxes (VAT) on shore-side electricity. If this is the case, and the benefits of the VAT removal are fully transferred to the cruise operators, the results will reflect those shown in *Table VI.22* below.

Table VI.22 : Fuel costs compared with electricity in ports, VAT excluded

	RO	MDO	Hypothetical price MDO	Hypothetical price MDO
Fuel costs per metric tonne	**$ 296**	**$ 462**	**$ 600**	**$ 750**
Euro values (1€ = 1.40 $)	211	330	429	536
Fuel costs per hour (0.13 metric tonnes) per MWh	27.5	42.9	55.7	69.6
Electricity costs per hour if VAT (17%) is removed	58.6	58.6	58.6	58.6
Difference	-31.1	-15.7	-2.8	11.1
Per call of 10 hours, a ship requires 12 MW per hour	-3 728.9	-1 879.2	-341.5	1 329.9
Investment costs for Shore side electricity*	750 000	750 000	750 000	750 000
Number of calls needed non discounted	N/A	N/A	N/A	564
NPV for 10 years, 6% discount rate				
NPV 50 annual calls	N/A	N/A	N/A	-260 575
NPV 100 annual calls	N/A	N/A	N/A	228 850
NPV 150 annual calls	N/A	N/A	N/A	718 274

Source: Policy Research Corporation

The average rate of VAT (17%) on electricity is calculated by averaging the VAT of 22 EU coastal Member States. As can be concluded from *Table VI.22*, the removal of VAT will make shore side power beneficial for cruise lines if fuel prices are $ 750 or higher. Making 100 calls annually in ports that provide shore side power will build a positive investment case. It can be concluded that the removal of VAT creates opportunities for cruise lines to have a return on the investment of refitting their ships, but it will still mean significantly higher fuel prices than those of today.

The additional analysis with a fuel consumption of 0.2 metric tonnes per MWh is also included for the analysis without VAT. The results are shown in *Table VI.23*. The current price of MDO shows a (small) positive NPV for ports with 150 calls per year. However, very few of these ships have a fuel consumption of 0.2 metric tonnes per MWh or higher.

Table VI.23 : Fuel costs (if 0.2 metric tonnes per MWh are used) compared to electricity in ports, VAT excluded

Price of fuel	RO	MDO	Hypothetical price MDO	Hypothetical price MDO
Fuel costs per metric tonne	**$ 296**	**$ 462**	**$ 600**	**$ 750**
Euro values (1€ = 1.40 $)	211	330	429	536
Fuel costs per hour (0.2 metric tonnes) per MWh	42.3	66.0	85.7	107.1
Electricity costs per hour if VAT (17%) is removed	58.6	58.6	58.6	58.6
Difference	-16.3	7.4	27.2	48.6
Per call of 10 hours, a ship requires 12 MW per hour	-1 952.9	892.8	3 258.5	5 829.9
Investment costs for Shore side electricity*	750 000	750 000	750 000	750 000
Number of calls needed non discounted	N/A	840	230	129
NPV for 10 years, 6% discount rate				
NPV 50 annual calls	N/A	-421 446	449 147	1 395 444
NPV 100 annual calls	N/A	-92 891	1 648 295	3 540 889
NPV 150 annual calls	N/A	235 663	2 847 442	5 686 333

Source: Policy Research Corporation

Cost-benefit model for 38 ports and cruise lines

If the costs and benefits of the 38 ports and the cruise lines are incorporated into a single cost-benefit model, the following costs and benefits should be incorporated:

- Costs for the 38 ports to invest in shore-side electricity facilities (€ 553.5 million[61]);
- Costs for cruise lines to refit 157 ships (145 * € 750 000 = € 117.8 million);
- Societal (welfare) benefits to be obtained by reducing emissions (€ 202.8 million);
- Costs for subsidising electricity up to the price of fuel (€ 70.59 – € 42.9 = € 27.69 per MWh, giving a result of €35.3 million)

Table VI.24 displays an integrated overview of the costs and benefits for both ports and cruise lines. *Annex VI* shows the same table for the 19 ports that resulted from the energy mix analysis and the 2020 targets analysis.

Table VI.24 : Costs and benefits for ports and cruise lines, compensation on electricity

	Investment costs	Gross annual benefits	Annual costs	Net annual benefits
Installation of shore side electricity in 38 ports	553 500 000	221 886 743	19 000 000	202 886 743
Refitting 157 ships	117 800 000	-		
Subsidising 1 276 753 MWh of power		-	35 352 921	
Total	**671 300 000**	**221 886 743**	**54 352 921**	**167 533 822**

Source: Policy Research Corporation

The net present values of investments in shore-side electricity by both ports and cruise lines are shown in *Table VI.25*. In all cases the investment in shore-side electricity facilities proves to be positive. If fuel prices increase, the net present values will increase significantly.

Table VI.25 : NPV models for investing in shore-side electricity by ports and cruise lines, compensation on electricity included

	Investment costs	Net annual benefits	NPV 10y 4%	NPV 10y 6%
Total	671 300 000	167 533 822	687 549 370	561 763 514

Source: Policy Research Corporation

VI.2. SECTION II: ALTERNATIVE EMISSION REDUCTION OPTIONS

In this section, cost benefit analyses are conducted for other emission reduction options, i.e. catalytic reduction (SCR) and sea water scrubbing (SWS). The options of direct water cooling and humid air motors will be left out of the analysis. This is due to the high costs of retrofitting existing engines and the relative newness of the techniques[62]. *Table VI.26* outlines the reduction potential, the investment costs and the annual costs of the two options.

[61] See *Paragraph VI.1.3*

[62] European Commission: DG Environment. Ship contract on ship emissions, task 2b, NO_x abatement, August 2005

Table VI.26 : Reduction methods and investment costs, annual costs

Method	Reduction potential	Investment costs	Annual costs
Selective catalytic reduction	80-90% of NO_x	2 000 000	270 000
Sea water scrubbing	100% of SO_2 80% of PM	4 000 000	40 000

Source: Policy Research Corporation, based on ENTEC, Wärtsilä and Krystallon data. Costs differ per cruise ship (average costs are displayed)

At this point in time, SCR and SWS cannot be used simultaneously. The advantage of these reduction methods is that they also reduce emissions at sea and not just at berth.

VI.2.1. SHORE-SIDE ELECTRICITY COMPARED WITH OTHER METHODS

This paragraph compares shore-side electricity (SSE) with the other reduction methods SCR and SWS. Shore-side electricity has both advantages and disadvantages:

Advantages:

- It reduces the use of fossil fuels in ports;
- It eliminates noise and smell for 85% of berthing time.

Disadvantages:

- It requires substantial investments in ports and on ships;
- For a shore-side electricity to be fully beneficial, dedication between cruise ships and ports is desirable;
- It does not reduce emissions at sea (which account for the bulk of emissions),
- Electricity generation on land also leads to emissions, especially if coal powered plants are equipped;
- The cost of land-generated electricity is higher than the cost of ship-generated electricity;
- Due to large power requirements in ports, the feasibility will have to be studied for each port individually.

The other methods discussed in this report, namely SCR and SWS, have the advantage of reducing emissions both in port and at sea. Moreover, SCR and SWS do not require dedication between port and cruise ships; ports do not need to invest in facilities.

The overall cost effectiveness of the three methods is assessed below. In order to make a fair comparison between shore-side electricity and the other methods, the following investment cases will be compared:

- Investment in shore-side electricity and investments of refitting 157 ships with a shore-side electricity connection at 38 ports;
- Investment in refitting 157 cruise ships with SCR and SWS.

Table VI.27 and *Table VI.28* display the overall reduction potential and economic rationale for each investment case.

Table VI.27 : Overview reduction potential in 38 ports having a positive welfare ROI

Reduction method (in tonnes)	NO_x	SO_2	CO_2	PM
Reduction SSE	97%	0%	50%	89%
Reduction SCR	85%			
Reduction SWS		100%		80%
Emissions in 38 ports	15 882	529	841 913	930
Emissions in all ports visited by 157 ships	20 306	677	1 076 863	1 187
Emissions at sea of 157 ships	149 904	71 911	5 459 393	14 969
Reduction by SSE in ports	13 095		357 813	704
Reduction by SCR in ports	17 260			
Reduction by SCR at sea	127 418			
Reduction of SWS in ports		677		950
Reduction of SWS at sea		71 911		11 975
Total reduction by SSE	13 095		357 813	704
Total reduction by SCR	144 679			
Total reduction by SWS		72 588		12 925

* SO_x and PM emissions at sea are higher due to the usage of 2.7% sulphurous fuel at sea

Source: Policy Research Corporation

Table VI.28 : NPV models of SSE, SCR and SWS

Reduction method	Location	Investment costs	Annual costs	Annual gross benefits	Annual net benefit	NPV 10 y (4%)	NPV 10 y (6%)
Shore side electricity	Port	671 300 000	54 352 921	221 886 743	167 533 822	687 549 370	561 763 514
Selective catalytic reduction	Port	314 000 000	42 390 000	117 605 170	657 677 487	5 020 353 553	4 526 563 556
	Sea			582 462 317			
Seawater scrubbing	Port	628 000 000	6 280 000	119 881 903	558 565 937	3 902 470 101	3 483 093 920
	Sea			444 964 034			

Source: Policy Research Corporation, based on ENTEC, Wärtsilä and Krystallon data

If all ships travelling to these 38 ports (157 ships) need to be refitted with a shore-side electricity connection, the costs to the cruise lines will be € 117.8 million. The investments by the port are € 553.5 million, requiring a total investment of € 671.3 million. The effect of this refitting will be to reduce emissions in European ports by over 370 000 tonnes. This reflects a net annual benefit of € 167.5 million per year.

If all ships travelling to these 38 ports are refitted with SCR, the investment will be € 314 million. This will lead to a reduction of 17 260 tonnes of NO_x emissions in ports, reflecting a monetary value of € 117.6 million. In addition to the emissions in ports, emissions at sea are reduced by 149 900 tonnes, reflecting a value of € 582.5 million per year. The net annual benefit of investing in SCR is € 657.7 million.

Ships on these destinations can also be refitted with SWS. This requires an investment of € 628 million and leads to a reduction of around 677 tonnes of SO_2 emissions and 950 tonnes of PM emissions in ports, representing a value of € 119.8 million. At sea, SWS reduces over 71.9 thousand tonnes of SO_2 and 11.9 thousand tonnes of PM, representing a value of € 444.9 million per year. The net annual benefit of investing in SWS is € 558.6 million.

Table VI.28 shows that the net present value of investing in shore-side electricity is significantly lower than investing in SCR or SWS. In order to be able to compare the methods effectively, return on investment ratios are shown in *Table VI.29*.

Table VI.29 : Return on investment ratios for SSE, SCR and SWS

	SSE	SCR	SWS
Return on investment ratios (present value of net benefits (10 years 4%) / investment costs	2.02	16.99	7.21
Return on investment ratios (present value of net benefits (10 years 6%) / investment costs	1.84	15.42	6.55

Source: Policy Research Corporation

The return on investment ratios show that shore-side electricity has the lowest cost-benefit ratio of the three methods. The investment in selective catalytic reduction has the highest return on investment.

VI.2.1.1. Additional benefits for cruise lines by investing in abatement technology

In *Paragraph IV.2.1* it was stressed that legislation requires cruise ships to use 0.1% sulphurous fuel at berth from January 2010. Alternative measures (technical abatement techniques) to comply with emission standards that equal the usage of 0.1 sulphurous fuel are also allowed by legislation. This will lead to significant costs if the industry is to comply. Since sea/fresh water scrubbers filter 100% of sulphur out of a ship’s emissions (even if residual oil is used), this method represents an alternative to low sulphur fuel, making scrubbers an economically attractive alternative.

Table VI.30 shows these costs, based on today’s fuel prices. With effect from 1 January 2010, ships are obliged to use 0.1% sulphur fuel in ports. The compliance costs of the industry arising from this legislation are € 22.8 million per year for the entire industry. This has been calculated by taking the total power demand in EU ports and multiplying it by the average fuel consumption per MWh. Subsequently the costs were compared for the fuel used today (residual oil) and low sulphur fuel to be used from 1 January 2010. The resulting compliance costs are € 22.8 million for the whole industry. This benefit is currently too small (compared to the investment costs of € 628 million for scrubbers) to build a business case around it. As legislation on sulphurous fuels is becoming more stringent (see paragraph IV.2.1), the business case will become stronger.

Table VI.30 : Compliance costs for the cruise industry: opportunity costs

	$	€
Residual oil high viscosity (2.7%), costs per metric tonne	295.5	211.1
Residual oil low viscosity (2.7%), costs per metric tonne	319.6	228.3
Residual oil high viscosity (1.5%), costs per metric tonne	311.6	222.6
Residual oil low viscosity (1.5%), costs per metric tonne	319.6	228.3
Average costs of residual oil per metric tonne	311.6	222.6
MDO, costs per metric tonne	462.3	330.2
Cost difference per metric tonne	150.7	107.7
Metric tonnes of fuel needed per MWh*	0.13	
Total MWh needed in all EU-ports**	1 631 891	
Metric tonnes of fuel needed in ports	212 146	
Costs for operations in ports if redisual oil is used (A)***	66 099 337	47 213 812
Costs for operations in ports if 0.1% sulphur fuel is used (B)	98 075 017	70 053 584
Compliance costs for the cruise industry (B-A)	31 975 680	22 839 772

* See paragraph VI.1.5.1

** Based on calculations by Policy Research

*** Average price for low and high viscosity residual oil assumed

Source: Policy Research Corporation

VII. INVESTING IN SUSTAINABLE PORT FACILITIES: CONCLUSION

The previous chapter proved that, from a welfare point of view, investments in reduction methods are beneficial. From an economic point of view there is no rational case for investing in sustainable port facilities; however, the story for cruise operators is a different one. This chapter summarises the most important study findings. Furthermore, it contains recommendations for policy makers, ports and cruise operators.

VII.1. SHORE-SIDE ELECTRICITY

The case of shore-side electricity for cruise ships is one that requires extensive consideration and analysis. This study has proved that there are multiple possible scenarios, which are explained below.

Complexity and costs

Because of the substantial power levels that cruise ships require at berth, it is complex to install a shore-side electricity facility at cruise quays. As a cruise ship demands on average the same power as 5 000 to 7 000 EU households, a shore connection should be directly connected to the high voltage electricity grid. This requires (in most cases) excavation and construction works, which are reflected in the price for a shore power connection. In addition to substantial investment costs, annual costs will apply for the transportation of electricity, maintenance and port officials handling the facility.

Limited reduction potential

Most electricity is generated in power plants. As EU power plants are to a large extent still powered by coal and other fossil fuels, the generation of electricity will also lead to emissions. Environmental benefits will therefore only apply if the origin of the shore power is either renewable (solar, hydro, wind, etc.) energy, or nuclear or gas power. Replacing ship emissions by power plant emissions can be locally beneficial if the power plant is located outside the port/city area, although the environmental impact of CO_2 is global and that of SO_2/NO_x is regional.

Another important point to consider is the limited connection time in ports. As it will take around 45 minutes to connect a ship on arrival and around 45 minutes to disconnect a ship on departure (in the optimum case both operations can be carried out in half an hour, making 1 hour in total) the connection time in a port is limited to 85% of the time. This means that during 15% of the time there are no environmental benefits for a port area.

Lastly, cruise ship emissions in ports are only a fraction (10 percent) of the total emissions of cruise ships in the European Union. Therefore, shore-side electricity only reduces a small share of the emissions that are caused by the industry. The investments needed are substantial, especially if the fractional reduction of the total cruise ship emissions is taken into consideration.

Electricity costs

Due to the economic crisis, both fuel prices and the US dollar have fallen significantly. These developments have impacted on the economic incentives for cruise operators to use shore-side electricity. As the current electricity prices in the European Union significantly exceed fuel prices (also due to the lower US $ price), additional costs apply: namely the costs incurred to subsidise electricity. Consequently, these costs had to be included in the cost benefit analyses.

Legislation

Due to EU legislation enforcing a maximum sulphur level of 0.1% in fuel used at berth (effective from 1 January 2010), the societal benefits of investing in shore-side electricity have decreased substantially. Currently, 2.7% sulphurous fuel is used in ports outside SECAs (with the exception of Venice and Civitavecchia) and 1.5% sulphurous fuel is used in ports within SECAs (plus Venice and Civitavecchia). The difference of 2.6% and 1.4% in sulphur content respectively would create significant additional emissions if legislation were not in place. Additional emissions would consequently lead to better reduction potential and greater benefits to society as a result of shore-side electricity.

Societal benefits

The current net figures for investments in shore-side electricity are positive for 38 cruise ports in the European Union, but only when seen from a welfare point of view. The problem with valuing welfare benefits as monetary values is the absence of clear ownership for negative externalities, i.e. emissions. Welfare benefits may reflect monetary values, but real monetary benefits (i.e. cash flows) are absent. The case for shore-side electricity is therefore also viewed from a perspective in which ports can add a margin to make a return on investment by selling the electricity. With today's electricity prices, profit margins of 50% and more are needed in order to make an acceptable return on investment within 15 years. As current shore electricity prices exceed the prices of fuel generated (ship) electricity, there is no economic reason for privately owned organisations to invest in these facilities.

Summing up

Shore-side electricity is a difficult issue for cruise ships, and it requires considerable thought and analysis for each individual port. From an individual port perspective it may still be attractive to invest in shore-side electricity, but the assessment of welfare benefits should be dependent on the origin of the shore energy, its reduction potential and the costs of fuel generated electricity as compared to shore generated electricity.

As cruise ship activity in most ports accounts for a relatively small, seasonal and infrequent share of the total port activities, it may be more beneficial for ports to invest in shore-side electricity facilities for other, frequent and all year round activities (like container shipping and ferries). These ship types require significantly lower power levels, which means that investments are correspondingly lower and acceptable.

VII.2. OTHER EMISSION REDUCTION METHODS

If shore-side electricity is compared with other reduction systems, the cost-effectiveness of shore-side electricity is much lower than the reduction methods of SCR and SWS taken together. These methods have been shown to have several advantages. It is theoretically more cost effective (from a welfare point of view) to refit a ship with SCR and SWS, although it is currently technically unfeasible to install both technologies simultaneously on ships. Furthermore, in the case of SWS, washing water criteria should be developed, making the technology feasible as an economically interesting alternative to low sulphur fuels. Ships that are refitted cause fewer emissions at sea (even if high sulphur fuel is used) which makes it an attractive alternative for shore-side electricity.

For cruise operators it may be worthwhile investing in abatement technology, as this allows them to continue using (cheaper) residual oils. If the restrictions on sulphur and/or nitrogen were to be extended in the future, the benefits of such investment would become even greater. Moreover, the industry/companies within the industry may gain an advantage if a possible emission trading scheme is launched. Ultimately, abatement technologies offer the greatest benefits in the long term, both for ports and for the industry.

Obviously an important factor in the investment decision is the cost of these technologies. From the perspective of cruise lines, investments are capital intensive due to the number of ships that need to be modified.

VII.3. ITEMS FOR FURTHER RESEARCH

The results found in this study have been reviewed and validated in close cooperation with the cruise industry, European ports, port organisations and all relevant stakeholders.

This study was specifically dedicated to cruise ships in EU ports, which is only a marginal part of most ports' activities. It will therefore be interesting to study the case of shore-side electricity (and its alternatives) in relation to a comprehensive set of port activities. In this way insights can be gained into the cost effectiveness of shore-side electricity per port activity. This kind of holistic approach is needed in order to maximise the environmental (societal) benefits for every euro invested.

Another important item for further research will be the impact of possible emissions trading schemes in the future. If emissions are to be traded, a reduction in emissions will reflect actual cash flows. The impact of these trading schemes may offer economic benefits for companies and ports that have invested in reducing their environmental footprint.