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***Tecniche di riduzione dell'impatto ambientale
di porti e aeroporti***

***Techniques to reduce the environmental impact
of ports and airports***

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INTRODUZIONE

Il fenomeno di globalizzazione a cui stiamo assistendo ha portato ad una sempre più fitta interdipendenza tra economie, culture e popolazioni nel mondo. Tutto ciò non sarebbe stato possibile senza un incessante commercio di servizi, merci, tecnologie ed un flusso di investimenti, persone e informazioni. In tal senso il trasporto aereo e marittimo ha un interesse significativo ed è in rapida crescita in tutto il mondo. Dal momento che la sua influenza economica è in costante aumento, deve essere interesse di tutti la creazione di un equilibrio economico ed ambientale, al fine di consentire il cosiddetto sviluppo sostenibile. Porti e aeroporti sono soggetti a crescente interesse in quanto le loro attività possono essere causa di diversi impatti ambientali, portando a problemi globali come ad esempio i cambiamenti climatici o l'inquinamento dell'aria. Sono stati applicati limiti sempre più stringenti in materia ambientale, al fine di trovare il giusto equilibrio tra i valori economici, sociali e ambientali per raggiungere uno sviluppo sostenibile. L'analisi che verrà effettuata in questa tesi partirà da un elenco di tutti i possibili impatti ambientali generati da porti e aeroporti, per poi arrivare alla definizione di strumenti e tecniche di riduzione applicabili dalle varie autorità portuali e aeroportuali, catalogate per impatto ambientale e analizzate in base alla loro efficienza.

Da un punto di vista generale, sono stati effettuati diversi studi confrontando le quattro principali modalità di trasporto (stradale, ferroviario, aereo e navale) in base al loro diverso impatto. Uno in particolare, condotto da TRENDS dal 1970 al 2020 su 15 stati membri dell'UE, si è soffermato sulle emissioni totali dei trasporti. Dalle analisi fatte, è venuto fuori che il trasporto aereo e marittimo ha subito una crescita incessante nell'orizzonte temporale considerato, ed è destinato a svilupparsi ulteriormente negli anni avvenire. Questo sviluppo incessante porta tuttavia ad una potenziale distruzione dell'equilibrio ambientale dovuto (tra le altre cose) alle emissioni di CO₂ e NO_x, rendendo quindi necessaria un'attenta analisi sulla questione ambientale.

Un porto efficiente è vitale per lo sviluppo economico della sua area circostante, ma il relativo traffico navale, la movimentazione delle merci nel porto, la sua distribuzione nell'entroterra e in generale, tutte le sue attività possono causare una serie di condizioni ambientali negative. Le questioni prioritarie identificate includono: gestione della qualità dell'aria; risparmio energetico e cambiamenti climatici; gestione del rumore; gestione dei rifiuti; gestione dell'acqua. L'obiettivo principale dei gestori dei porti è fornire un servizio di alta qualità agli

utenti (compagnie di navigazione, armatori e importatori) e non danneggiare l'ambiente. Tutte le attività portuali sono responsabili delle emissioni di inquinanti atmosferici e in particolare: CO₂, NO_X, SO₂, idrocarburi (HC), composti organici volatili (COV), piombo e particolato (PM). L'inquinamento acustico è uno dei problemi ambientali più gravi perché le persone si sentono più direttamente colpite dal rumore rispetto a qualsiasi altra forma di inquinamento. Nei porti, possiamo identificare due problemi principali con il rumore: l'impatto sull'uomo nelle aree vicino ai porti e l'impatto sugli animali marini. L'energia da combustibili fossili come carbone, petrolio e gas naturale porta alle emissioni di CO₂ ed influenza il nostro clima, generando un impatto irreversibile, come lo scioglimento delle calotte polari e un aumento a lungo termine del livello del mare. Possiamo riassumere i principali fattori di inquinamento delle acque marine in tre categorie: introduzione di sostanze e rifiuti tossici; dragaggio del fondo marino, disturbi termici. I porti sono luoghi molto frequentati, poiché ospitano molti passeggeri e attività industriali. Tutto ciò porta alla generazione di moltissime frazioni di rifiuti, per cui i porti si trovano a gestire sia rifiuti ordinari sia materiali dannosi.

L'impatto ambientale delle attività e delle operazioni portuali ha ricevuto crescente attenzione negli ultimi anni; per questo motivo, è consigliabile che i porti elaborino una strategia verde per una crescita e uno sviluppo sostenibili, garantendo il giusto equilibrio tra obiettivi ambientali ed economici. Il primo strumento a disposizione del porto per diventare un cosiddetto "green port" è la collaborazione con queste quattro categorie di stakeholder: operatori di mercato, responsabili delle politiche pubbliche, stakeholder interni e comunità. I porti devono anche mantenere una buona immagine pubblica, tenendo conto di terze parti e stakeholder. Ciò ha portato ad attività congiunte istituite e finanziate dai principali partner portuali, grazie alla collaborazione tra settore portuale, istituti di ricerca e organizzazioni specializzate. Affinché i porti possano raggiungere e dimostrare un miglioramento ambientale continuo, sono disponibili due strumenti di autodiagnosi chiamati SDM e PERS. Il primo è uno strumento di supporto per i gestori dei porti per rivedere regolarmente la gestione ambientale nei loro porti; il secondo differisce da SDM perché si concentra principalmente sulla possibilità di mettere in evidenza le prestazioni di gestione ambientale dei porti. Infine, le autorità portuali dispongono di KPI (Key Performance Indicator), indicatori di prestazione ambientale ed energetica per controllare il miglioramento del loro sviluppo sostenibile. Le tecniche di riduzione sono suddivise in cinque categorie in base allo specifico impatto.

Qualità dell'aria:

- utilizzo di carburante privo di zolfo per il funzionamento della flotta di navi e attrezzature galleggianti: produce miglioramenti in termini di consumo di carburante, di manutenzione delle navi, di salute umana e protezione ambientale;
- utilizzo di LNG: il suo contenuto di zolfo è ben al di sotto dei limiti di legge, la sua combustione è pulita, produce minori emissioni di anidride carbonica, ossido nitrico, composti di zolfo e particelle durante la combustione;
- elettrificazione a terra delle banchine (cold ironing): le navi si collegano a una fonte di alimentazione a terra, spegnendo i loro motori inquinanti.

Riduzione del rumore:

- layout del porto: i porti possono ridurre l'inquinamento acustico se le loro attività più rumorose vengono dislocate lontano dalla zona della città;
- misure sul traffico: il traffico lungo la costa che va e viene dal porto può essere fatto confluire in aree meno sensibili e la sua velocità può essere ridotta attraverso l'installazione di ostacoli fisici;
- flotta di macchinari più silenziosa: le autorità portuali possono introdurre nuovi macchinari elettrici e ibridi, per rendere più silenziosa l'operazione di movimentazione delle merci;
- tasse portuali differenziate: una possibile soluzione di gestione del rumore, proposte per incoraggiare l'uso di navi a bassa rumorosità e per scoraggiare l'uso di navi ad alta rumorosità;
- misurazione dei livelli del rumore: riduzione del rumore attraverso innovativi dispositivi di misurazione.

Efficienza energetica:

- completa o semi-automazione di apparecchiature terminali: maggiore ottimizzazione dei flussi di container, che porta a un minor consumo di energia, a costi inferiori, all'estensione della vita dell'apparecchiatura e alla conservazione delle risorse;
- TAS (Truck appointment systems): sono in grado di ridurre i tempi di inattività dei camion fuori dai cancelli del terminal, massimizzare il tasso di utilizzo delle attrezzature del cantiere container e quindi ridurre i tempi di consegna dei camion;

- sistema di illuminazione dinamico: sistema di controllo centralizzato che gestisce sensori di movimento in modo tale da utilizzare intensità di luce diverse in base alle diverse condizioni;
- ibridazione: è possibile migliorare le prestazioni ambientali ed energetiche dei porti intervenendo su apparecchiature terminali e veicoli portuali;
- elettrificazione: completa elettrificazione delle attrezzature di trasporto e movimentazione dei container, verso l'obiettivo generale delle operazioni a emissioni zero;
- carburanti alternativi: un uso di LNG comporta una riduzione dei costi energetici, un aumento del consumo di energia e un miglioramento in termini di emissioni di CO₂, PM e SO_x. L'uso di alimentazione con batterie a idrogeno nei porti, invece, è ancora in fase di sperimentazione;
- edifici portuali: uffici amministrativi, terminal, magazzini e altri servizi di stoccaggio, officine di manutenzione e riparazione, possono essere convertiti in edifici ad alta efficienza energetica;
- energia rinnovabile: sfruttamento di diverse forme di energia rinnovabile (energia eolica, solare, geotermica, da biomassa e dalle onde) al fine di coprire una parte importante delle esigenze energetiche dei porti.

Gestione delle acque:

- rifiuti galleggianti: raccolta di tutti i rifiuti come plastica e detriti galleggianti nelle acque riparate dei porti, sfruttando diverse tecnologie;
- acqua piovana: utilizzo delle migliori pratiche e tecnologie per la gestione e il trattamento delle acque piovane inquinate dalle attività portuali;
- acque reflue saline: l'esperienza ha dimostrato la necessità di raccogliere e trattare questi flussi di acque reflue a causa delle loro elevate concentrazioni di sale;
- gestione della qualità delle acque: maggiori sforzi per prevenire incidenti di inquinamento attraverso la riduzione dell'impatto sull'ambiente marino causato da una fuoriuscita a terra;
- trattamento delle acque: necessità di trattare le acque di deflusso delle banchine.

Gestione dei rifiuti:

- valore dei rifiuti: un grande passo verso la sostenibilità può essere la riduzione dei rifiuti in discarica e l'aumento del riciclaggio dei rifiuti;
- gestione dei sedimenti dragati: i prodotti dragati devono essere gestiti attraverso modalità innovative e soluzioni appropriate;
- navi da crociera: le navi da crociera trasportano enormi quantità di rifiuti liquidi e solidi, è quindi necessario che i porti facciano in modo che siano gestiti correttamente;
- sistema tariffario: i porti hanno installato impianti di raccolta, piani di gestione dei rifiuti e sistema di incentivi basato su tariffe.

Nel corso degli anni, molte ricerche hanno riconosciuto il ruolo fondamentale dell'aviazione, in quanto si ritiene che gli aeroporti non solo siano il più grande generatore di attività economica nelle regioni in cui operano, ma anche contribuiscono alla crescita economica e ai benefici sociali del mondo moderno. Tuttavia, il funzionamento degli aeroporti comporta molte attività che possono avere un impatto negativo sull'ambiente. Le emissioni di gas serra e di inquinanti atmosferici, insieme ad altre preoccupazioni come l'inquinamento acustico, l'inquinamento dell'acqua e del suolo, la gestione dei rifiuti e il consumo di energia possono avere effetti a livello globale e locale. L'aviazione e le attività ad essa associate sono una fonte chiave di emissioni di gas serra e inquinanti atmosferici (CO₂, SO₂, NO_x, COV, PM e O₃). Possiamo trovare emissioni da motori aeronautici, operazioni a terra, trasporto stradale per l'accesso superficiale, produzione di energia e riscaldamento delle strutture aeroportuali. Oltre agli impatti negativi generali sulla salute umana, le attività di trasporto aereo contribuiscono al cambiamento climatico, in quanto le emissioni di NO_x, SO₂ e di carbonio nero sono responsabili degli effetti indiretti di riscaldamento e raffreddamento globale. L'inquinamento acustico è probabilmente il più ovvio poiché è frequente, facilmente percepibile e fastidioso. Gran parte del rumore, sebbene certamente non tutto, è legato agli aerei (motore e fusoliera), ma non è trascurabile la porzione legata al traffico veicolare e ferroviario da e per l'aeroporto. All'interno dell'area dell'aeroporto ci sono molti edifici e strutture che richiedono un'elevata energia elettrica. Il raggiungimento dell'efficienza energetica parte da un'attenta analisi del consumo di energia, con gli investimenti in progetti di energia rinnovabile che sono spesso la soluzione giusta per ottenere risparmi in termini di

costi ed emissioni. A differenza del settore marittimo, l'aviazione non costituisce un pericolo diretto per le acque. Tuttavia, le acque piovane che scorrono sulle superfici aeroportuali, se non gestite correttamente, possono accumulare una vasta gamma di contaminanti e inquinanti, prima di raggiungere corsi d'acqua, fiumi o acque costiere. Negli aeroporti vengono eseguite varie operazioni responsabili della generazione di notevoli volumi di rifiuti come rifiuti solidi urbani (RSU), detriti da costruzione e demolizione (CDD), rifiuti da voli di aeromobili, rifiuti compostabili, rifiuti industriali e rifiuti di servizi igienici. Inoltre, è possibile trovare negli aeroporti rifiuti pericolosi, che meritano particolare attenzione poiché possono contaminare il suolo e l'acqua e possono anche rappresentare una minaccia per la salute umana.

Un aeroporto può essere considerato sostenibile attraverso l'implementazione di un quadro politico e diverse iniziative volte a raggiungere l'obiettivo. Come per altri sistemi di trasporto, il quadro aeroportuale deve portare al giusto equilibrio tra sviluppo economico dei trasporti e protezione dell'ambiente. In generale, il processo decisionale si basa su principi quali partnership, integrazione delle politiche, libertà di informazione e processo decisionale aperto. Per avere successo, la scelta politica deve essere orientata verso la gestione della domanda, il principio di precauzione e, ultimo ma non meno importante, il miglioramento ambientale continuo attraverso, soprattutto, il principio "chi inquina paga". Ci sono diversi strumenti per perseguire questo processo decisionale. Infatti, è possibile adottare indicatori di sostenibilità, sistemi di gestione ambientale, redigere un rapporto sullo stato dell'ambiente, valutazione ambientale strategica e valutazione degli investimenti, fornire informazioni ambientali, istruzione e formazione. Il raggiungimento di obiettivi specifici è generalmente limitato entro un periodo di due anni e consiste nella valutazione di indicatori precedentemente fissati come emissioni minime accettabili di CO₂, per chilometro, passeggero o unità di tempo. È importante per un aeroporto, avere un rapporto diretto e un dialogo costante con i clienti dell'aeroporto; preoccuparsi della qualità della vita non solo nelle comunità locali, ma anche a livello nazionale e internazionale; essere ben informato sui nuovi sviluppi e tecnologie, soprattutto in termini di impatto sull'ambiente esistente; infine mostrare trasparenza nel rilascio di informazioni sull'impatto ambientale creato.

Come per i porti, le tecniche di riduzione sono suddivise in cinque categorie in base allo specifico impatto:

Qualità dell'aria:

-free route airspace (FRA): definendo uno spazio aereo all'interno del quale gli utenti possono pianificare liberamente una rotta, è possibile ottenere una riduzione del consumo di carburante e delle emissioni, e il miglioramento dell'efficienza di volo;

-electric green taxiing system (EGTS): sistema che consente agli aeromobili di fare retromarcia e rullare senza richiedere l'uso dei loro motori principali o il supporto dei servizi di rimorchio aeroportuale;

-electrofuels: classe di combustibili carbon neutral che vengono prodotti immagazzinando energia elettrica da fonti rinnovabili nei legami chimici di combustibili liquidi o gassosi;

-Continuous Climb and Descent Operations (CCOs and CDOs): operazioni di salita e discesa continue, sono tecniche operative che portano ad una grande riduzione in termini di consumo di carburante, costi associati ed emissioni di inquinanti.

Riduzione del rumore:

-Continuous Descent Approach (CDA): procedura di arrivo automatizzata progettata per l'atterraggio di aeromobili, in grado di ridurre i livelli del rumore sulle comunità situate sotto il percorso di avvicinamento a una pista;

-programma di utilizzo preferenziale della pista: procedure di selezione per l'uso di ciascuna pista, per ridurre al minimo l'impatto acustico sulle aree residenziali vicine;

-operazioni a terra: programma volontario con l'obiettivo di limitare l'uso del contropinta; limitazione delle attività di run-up a terra attraverso norme e regolamenti; uso di motori singoli o della potenza del taxi al minimo per il rullaggio;

-barriere antirumore: misura efficace per l'abbattimento del rumore;

-restrizioni di accesso all'aeroporto: impatto del rumore cumulativo, livelli di rumore certificati, livelli di rumore per singolo evento o ora del giorno possono essere presi in considerazione per limitare l'accesso all'aeroporto.

Efficienza energetica:

-sustainable aviation fuels (SAFs): ottenuti da materie prime a base biologica diversa dal petrolio, costituiscono una delle opzioni più importanti per ridurre significativamente l'impronta di carbonio del settore e la dipendenza dall'industria petrolifera;

-installazioni solari: consentono all'aeroporto di generare energia da fonte rinnovabile in loco e di beneficiare di un'energia priva di carbonio;

-energia geotermica: l'energia termica generata da fonti di calore geologiche e immagazzinata nella Terra può essere considerata un'energia alternativa e rinnovabile;

-energia eolica: è un'energia rinnovabile e sostenibile e può essere utilizzata per fornire energia meccanica attraverso delle turbine eoliche.

Gestione delle acque:

-misurazione del consumo d'acqua: gli sforzi degli aeroporti si basano sul controllo dell'uso dell'acqua (in particolare dell'acqua potabile), della domanda di acqua e delle perdite;

-sanitari a risparmio idrico: servizi igienici o orinatoi che richiedono un minore consumo di acqua, apparecchiature di limitazione del flusso su rubinetti, orinatoi senza acqua, rubinetti per lavabo a sensore, doppio meccanismo di lavaggio;

-riutilizzo acqua piovana: consente di combattere la scarsità qualitativa e quantitativa delle risorse idriche e di ridurre i costi utilizzando l'acqua piovana in diversi tipi di attività;

-riutilizzo acque grigie: pur presentando una concentrazione di inquinanti inferiore rispetto alle acque reflue domestiche in quanto provenienti da bagni, lavatrici e lavelli da cucina, devono comunque essere trattate con processi fisici, chimici e biologici in grado di rimuovere solidi sospesi, materiali organici e tensioattivi;

-riutilizzo di acqua di mare: può essere una soluzione praticabile solo per gli aeroporti situati vicino alla costa;

-riutilizzo acque reflue e scarichi fognari: potenziale soluzione per sopperire alla crescente carenza di acqua, in quanto l'acqua di recupero può essere utilizzata per l'irrigazione, lo scarico dei servizi igienici, la pulizia, il riutilizzo industriale e il miglioramento ambientale.

Gestione dei rifiuti:

-gerarchia dei rifiuti: gerarchia decisionale per la gestione dei rifiuti negli aeroporti;

-rifiuti di cabina: la gestione dei rifiuti di cabina sta riscuotendo un interesse crescente da parte delle compagnie aeree e degli aeroporti, verso una riduzione della loro impronta ambientale;

-segnaletica dei rifiuti: grazie al riconoscimento di colori, icone e termini, gli utenti degli aeroporti possono ordinare rapidamente il loro riciclaggio;

-riciclaggio dei rifiuti: operazione rispettosa dell'ambiente, poiché consente di ridurre il consumo di energia, le emissioni di gas a effetto serra e i rifiuti in discarica;

-discarica e inceneritori: alcuni aeroporti dispongono di discariche e inceneritori per gestire i rifiuti in loco, quantomeno risparmiando sul trasporto dei rifiuti.

Il trasporto intermodale consiste nell'integrazione di diverse reti di trasporto utilizzando modalità più rispettose dell'ambiente. È applicabile sia al sistema passeggeri che a quello merci, attraverso l'interconnessione tra trasporto aereo, marittimo e terrestre.

-trasporto intermodale delle merci: consente di trasportare merci dallo spedizioniere al destinatario utilizzando due o più modalità di trasporto, all'interno di grandi scatole rettangolari chiamate container. Diversi vantaggi possono derivare dalla scelta del trasporto intermodale;

-porti secchi: il terminal intermodale interno (porto secco) ha un collegamento ferroviario diretto con un porto marittimo, quindi i clienti possono lasciare e / o ritirare le proprie merci, come se fosse un porto marittimo. Il porto secco può fornire servizi simili a quelli del porto marittimo, come lo stoccaggio, il deposito, la carreggiata, la manutenzione dei container;

-hub di trasporto: punto di interscambio per passeggeri e merci che utilizza diverse modalità di trasporto. Garantisce un sistema di trasporto più efficiente, integrato e rispettoso dell'ambiente, contribuendo a ridurre l'uso dell'auto privata;

-bus on demand: gli aeroporti possono implementare sistemi di trasporto intelligenti, come ad esempio un servizio di autobus facile e veloce per i viaggiatori aerei e per i lavoratori aeroportuali.

1. INTRODUCTION

We live in an increasingly globalized world, where the interdependence of the world's economies, cultures and population is growing. Cross-border trade in services, goods, technology, and flow of investment, people and information brings this about. Air and sea transport is a fast growing, worldwide industry. Its economic influence is great and it is on the increase. The establishment of a balance between economic and ecological interests will be the most important issue for the next decade for all modes of transport, especially sea and air transport. 'Sustainable development' is the term that summarize the last concept. Of this, the most famous and universally recognized definition is that of the World Commission on Environment and and Development published in *Our Common Future* (World Commission on Environment and Development, 1987). It defines sustainable development as a 'process in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations' (WCED,1987). Sustainable development is thus 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987) (Longhurst, 1996). The main challenge of our time is the application for sustainable development in ports and airports, where we encounter negative environmental impact by emissions of noise, odors, volatile organic substances, and pollution of water and soil by oil chemicals, hull paint and other hazardous material. In recent years, we have seen an increasing interest in the environmental impact of their operations and development due to pressing global issues such as climate change and energy consumption. Aviation and shipping are facing growing challenges since they are subjects to scrutiny in terms of environmental regulatory compliance. The critical issue is to strike the right balance among economic, social and environmental values in order to achieve sustainable development of the port/airport and the local community. In this thesis we will sort ports from airports, and for each one we will analyse every environmental impact brought about their activities, we will investigate tools to assess and minimize such negative environmental impact. Furthermore, it will be addressed the issue of the intermodal transport, as a good solution capable of making transport system sustainable, without affecting the quality of service. Finally, we will list some good practices able to reach the target of sustainability. The aim of this thesis is to study the current situation in ports and airports, thanks to information in their website and literature research, and from

this starting point, we will assess how ports and airports can improve their environmental performance.

2. ENVIRONMENTAL IMPACT FROM TRANSPORT

The economic growth and globalization taken place in recent years was favoured by an efficient transport system. Alongside the increase of transport activities, there have been its undesirable side effects such as air pollution, noise pollution, and harmful emissions. This serious environmental damage is localized in transport infrastructure like roads, ports, airports and railways. Transportation activities create different adverse environmental effects such as emissions of pollutants (CO₂, NO_x, SO₂, PM, etc.) from exhaust of vehicles, accidental spills during transportation of hazardous substances, noise generated by vehicles damaging to the human health. The most important transport modes are road, rail, air and ship. They are different based on their specific mechanism, and they have not the same environmental impact.

Several studies have been made regarding the different impact of each transport mode, to compare their harmfulness, and to define the most polluting mode. In particular, a study of TRansport and ENvironment Database System (TRENDS) has been conducted in 15 EU member state (EU15), in order to calculate the environmental pressure brought about transport, through the identification of indicators. The four main transport modes were compared regarding their air emissions, using common indicators based on transport activities, like 'passenger kilometer' and 'tone kilometer'. The study covers the period from 1970 to 2020, using simple extrapolation for future years. The TRENDS methodology was implemented in a computer model within a PC-based MS access97 environment. This model consists of individual software modules for each transport mode considered in the study (road, rail, maritime and aviation) as well as a synthesis module (TAB) which enables the evaluation of total emissions of transport (Giannouli, 2006). Thanks to Transport Activity Balance (TAB), we have summary schedules of the main data of all the transport modes (traffic activity and vehicle emissions). These displays allow us to make assessments on the current situation, on how we got there, and on what we can do to improve in the coming years.

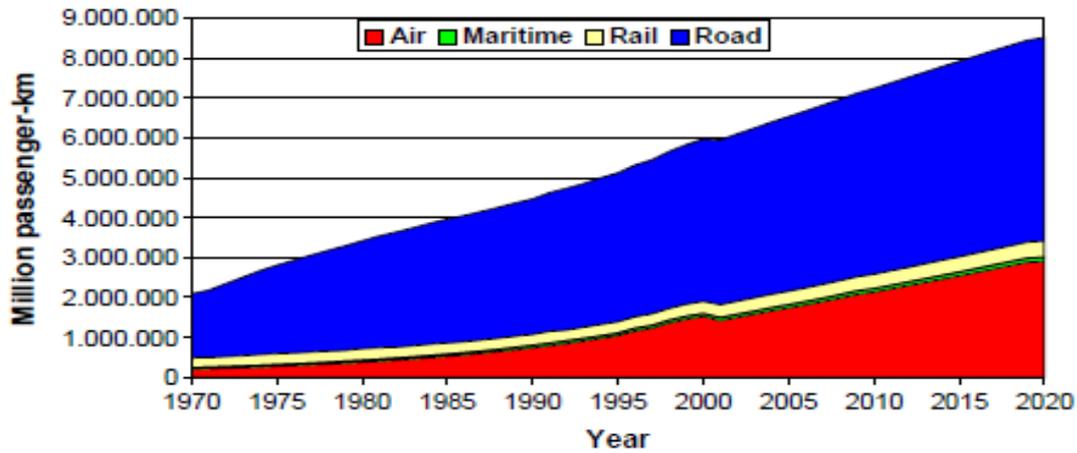


Figure 5: Evolution of passenger transport in EU15 from 1970 to 2020 (Giannouli, 2006)

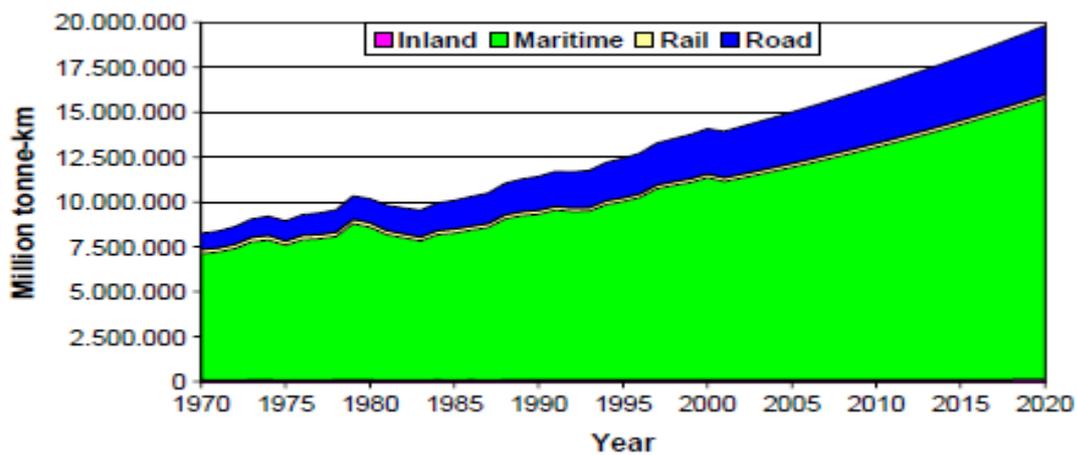


Figure 6: Evolution of freight transport in EU15 from 1970 to 2020 (Giannouli, 2006)

Fig.1 and Fig.2 show the evolution, year after year, from 1970 to 2020, of transport activity regarding passenger (million passenger km) and freight (million tone km), produced by different transport modes for EU15 countries. In particular, according to Fig.1 we can see that air and road are the most widely used means of passenger transport, while from Fig.2, goods are mostly carried by sea and, although to a lesser extent, by road. Moreover, both passenger and freight transport have increased gradually over the projection horizon and is expected to increase in the next years. This incessant growth leads to a potential change in the environmental balance, or to the risk of specific environmental impact.

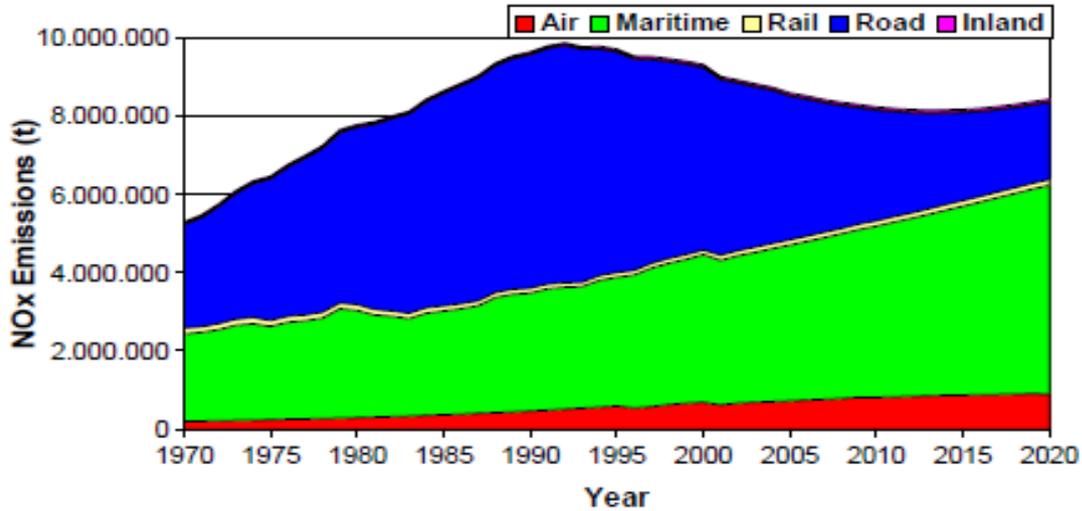


Figure 7: Evolution of NOx emissions [t] in EU15 from 1970 to 2020 (Giannouli, 2006)

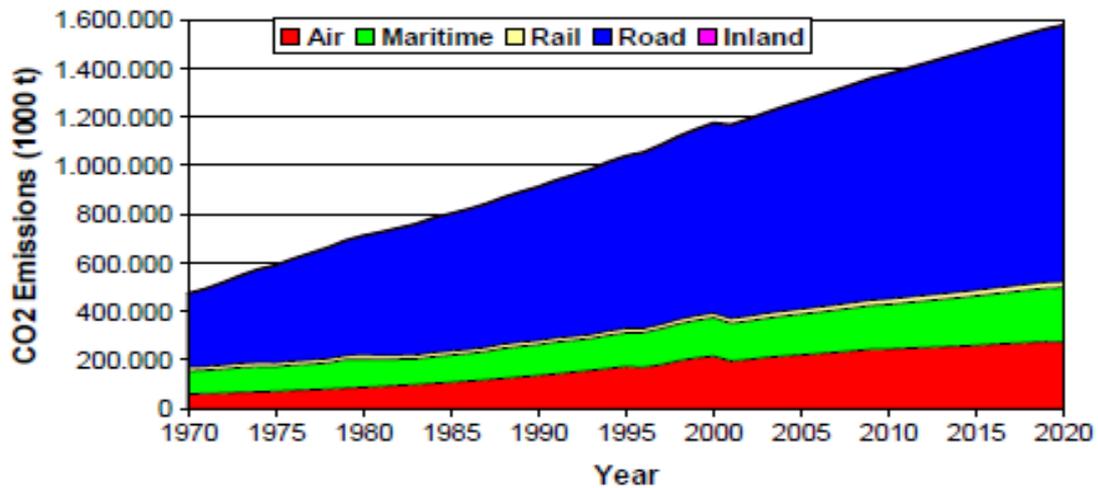


Figure 8: Evolution of CO2 emissions [1000 t] in EU15 from 1970 to 2020 (Giannouli, 2006)

The first consequence of the maritime freight transport's significant increasing (shown in Fig.2) is the increasing growth of maritime emissions. We can also see that maritime traffic has become, year by year, the primary source of NO_x emissions, with the gradual decrease of road transport, which was the biggest source in past years. From Fig. 3 and 4 we can see the steady increase of emissions from air traffic during the entire calculation period. Fig. 3

also show the particular development of NO_x emissions brought about road transport. They rise considerably until 1992, and then drop rapidly reaching relatively low levels, because of the introduction of improved techniques and more stringent law limits. This is not true for the trend of road transport CO₂ emissions (Fig. 4), which increase steadily, because of the increase of road traffic observed in EU15 states. From these figures, ultimately we can see that road transport is the main source of CO₂ emissions and is also responsible for a significant contribution regarding NO_x emissions in EU. However, air and maritime transport represent large source of NO_x and CO₂ emissions, and since they are continually expanding sectors, we need to consider their strengths and weakness on the environment.

3. ENVIRONMENTAL IMPACT OF PORTS

The effects of ports can be wide-ranging, depending on their location and the activities that are taking place either on site or locally. It is clear that an effective port is vital to the economic development of his surrounding area, but the related ship traffic, the handling of the goods in the port, the hinterland distribution and in general, all his activities can cause a number of negative environmental impacts. Shipping has an environmental impact both in port and in the immediate vicinity of the port. Examples of these impacts are harmful diesel emissions, CO₂, NO_x, and SO₂ product from the ship's main and auxiliary engines, noise from ship engines and machinery used for loading and unloading, exhausts of particles, and dust from the handling of substances like grain, sand and coal. The overall aim is to determine vision of port sector concerning the management of its priorities and to demonstrate reactivity and self-regulation in practical terms. The identified priority issues includes:

- Air quality management;
- Energy conservation and climate change;
- Noise management;
- Waste management;
- Water (consumption and quantity) management.

All these issues have immensely increased the complexity of port management, which now has to balance port and broader community interests. The main aim of port managers is to provide a high quality service to users (shipping companies, ship-owners and importers) and not damage the environment. Public authorities at various administrative levels have put in place a wide range of policy instruments to limit negative environmental impacts from ports. The objective of this study is primarily to collect and compare experiences of environmental impacts stemming from port activities and to provide examples of policies used to address these impacts.

3.1 AIR POLLUTION

Air quality is an issue of the highest priority on the environmental and political program. The impacts of air pollutants such as CO₂, NO_x, SO₂, hydrocarbons (HCs), volatile organic compounds (VOCs), lead and particulate matter (PM) vary in scale, and from locally based to regional and global effects. All ship activities are responsible of air pollutants emissions and particularly: ships movement in port, ships activities in hoteling phase (lighting, heating, refrigeration, ventilation...), tanker loading and unloading.

In particular:

- Loading and unloading of petroleum products produce volatile organic compound emission
- Dry docks (evaporative volatile organic compound emissions)
- Passenger car traffic (combustion products and evaporative volatile organic compound emissions)
- Heavy vehicle and railway traffic (combustion products emission)
- Demolition or main modification of ships (asbestos, heavy metals, hydrocarbons, ozone depleting substances and others) (Trozzi & Vaccaro, 2000)

Although port-related emissions contribute only for a part to air quality problems in port and surrounding areas, these problems can affect negatively the image of ports facing their surroundings residential zones and put serious pressure on port development ambitions. The current policy efforts are limited by the increase in transport volumes, the quality of marine fuels in use, and the slower than expected modernisation of vehicles fleets, and the differences observed between vehicle operational emissions and limits prescribed by the standards.

Table 1 summarizes main airborne pollutants and their negative impacts deriving from ports activities.

Table 3. Airborne pollutants deriving from port activities and negative impacts on the environment and human health (TERM 2017)

CONCERN	ORIGIN	NEGATIVE IMPACTS
SO ₂ , NO _x , PM, VOCs	Exhausts gases from vehicle moving to and from the port	Human health (cardiovascular disease, lung cancer, birth defects, environment)
PM	Handling at ports	Human health (cardiovascular and respiratory disease, chronic obstructive pulmonary disease, asthma)
Greenhouse gas, CO ₂ , SO ₂ , NO _x , PM, VOCs	Exhausts gases from ships	Human health (cardiovascular disease, lung cancer, birth defects, environment)

Let us see more in detail the major air pollutants generated by port activities:

CO₂: also called carbon dioxide, it is a gas with a density higher than that of dry air, and it is soluble in water. It is produced by combustion of organic materials, hydrocarbons and fossil fuels such as coal, petroleum and natural gas. The high use of these fuels by man is the reason for the high concentration of CO₂ in the earth's atmosphere. Carbon dioxide is the most common component of greenhouse gases, and it is often considered, according to specialists, a major cause of climate change and global warming.

NO_x: also called nitrogen oxides, the most important for air pollution are *nitric oxide (NO)* and *nitrogen dioxide (NO₂)*. They are usually produced during combustion of fuels (hydrocarbons), at high temperature, especially in vehicle engines. This leads NO_x to be a significant source of air pollution in areas of high motor vehicle traffic, such as ports. These gases are responsible for the formation of smog, acid rain and for the thinning of tropospheric ozone.

SO₂: also called sulphur dioxide, it is produced, among others, by burning of fossil fuels, contaminated with sulphur compounds. It represents a noticeable component in the atmosphere, and it is very dangerous for the human health. Furthermore, it can disrupt the balance of the habitat suitability for plant and animal communities, and its emissions are responsible to acid rain and atmospheric particulates.

PM: particulate matter indicates all substances suspended in air, in the form of atmospheric aerosol. They have size that ranging from few μm to 100 μm . Emissions from internal combustion engines (ground-based vehicles and ships), and residues of road surface wear are some of the causes for the formation of these aggregates suspended in the air. PM has negative effects on the environment (Global dimming) and on the human health (inhalable particles).

VOCs: volatile organic compounds are organic chemicals with a high vapour pressure at ordinary temperature. Some VOCs are hazardous to human health and to the environment. They are produced by using fossil fuels, as products like gasoline, and as by-products like vehicle exhaust gases. VOCs are commonly monitored because they represent a significant factor in photochemical smog.

Ships powered by engines run on heavy fuel oil that is so much cheaper than petrol used in road transport, but it also has a high pollution impact.

International shipping uses heavy fuel oil (residual fuels) with a very high sulphur content. The marine fuel currently in use is on average 2700 times dirtier than the fuel used in the road sector where strict limits have applied for many years. Due to the poor quality of the cheap bunker fuel used in maritime transport, SO_2 shipping emissions are projected to increase and by 2020 exceed SO_2 emissions for all land-based sources (Curtis, 2012).

Added to ships, ports contain a wide range of diesel-powered machines: terminal tractors, forklift trucks, elevators. These diesel engines cause high emissions of various pollutants. In addition to emissions from maritime transport, this makes ports an important net contribution to pollution in wide port cities. Furthermore, ports handle large quantities of bulk materials, such as fertilizer and aggregates. These materials in dry and windy conditions will inevitably lead to dust drift in nearby areas. The dust, because it can be seen, felt and smell by the affected people, can be a big nuisance. Such pollution causes a number of environmental

impacts, can seriously affect workers' health and contributes significantly to regional air pollution. The health effects of prolonged exposure to the major air pollutants include respiratory diseases, cardiovascular diseases, lung cancer and premature death. Another negative health effect is the exposure to inhalable particulate matter. They are small enough to pass through tissues, enter the blood stream, and cause lung and heart failure.

The World Health Organization estimates that long-term exposure to PM_{2.5} is associated with an increase in the risk of cardiopulmonary mortality by 6–13% per 10 µg/m³ of PM_{2.5} (Thongplang, 2017).

3.2 NOISE POLLUTION

Noise pollution is caused by excessive exposure to loud, unwanted and annoying sounds. Because of its negative effects on human health and quality of life, noise pollution is one of the most serious environmental problems.

In ports, we can identify two main concerns with noise: the impact on humans in areas near ports, and the impact on marine animals (EEA, 2017). Environmental noise, caused by transport and industrial activities, can have serious and irreversible human health effects, such as sleep disorders, cardio-circulatory diseases, hypertension, feeling sick and aggressive behaviour. The major noise source in a ship are the main propulsion machinery, the auxiliary engines, the propeller and transverse propulsion unit, and the heating, ventilation and air conditioning system (Trozzi & Vaccaro, 2000). Main and auxiliary machines driven by steam turbines generate less noise than diesel engine. We can identify three main areas where noise sources are localized: road traffic (passenger cars and trucks), goods movement (from machinery), and rail traffic.

Underwater noise is also a concern for the health of marine life, since it can have a range of impacts on marine animals, from subtle behavioural changes to injure and death in extreme cases (EEA, 2015). There are harmful impacts on marine animals that use sound for navigation, communication and travelling. In fact, they have evolved to cope with natural sound, but human-induced noise is now a major source and is exposing these animals to very high-level and ongoing sounds (Simmonds et al., 2014).

Finally, we can say that people feel more directly affected by noise than by any other form of pollution. Noise is a serious social problem and has considerable implications for port operations. It is clear that the main sources of noise in ports come from not only the direct operational activities of the ports, but also from traffic (road, rail, ship) and industry (ESPO, 2012).

The main objective is to raise awareness and share information on port noise pollution among port authorities, private companies involved in port activities, administrations and general public.

3.3 ENERGY CONSUMPTION

Attention to waste is the first useful measure to be taken in every buildings and plant systems. On the energetic level, the attention to preserve a source of energy joins to the economic saving derived from it.

We can define energy efficiency as the ability to make the most of the energy available. Realizing the containment of consumption, we can avoid both energy and money losses and also benefit the environment. In fact, greater energy efficiency means that less fossil fuels can be used and therefore the level of greenhouse gas emissions that contribute to local warming can be reduced.

Global warming and climate change are the greatest global environmental concerns associated with transport. In fact, they are the key themes of sustainable development and they are at the centre of attention by public, media and various organizations.

One of the crucial environment issues in ports is the reduction of energy and oil fuel consumption. In particular, ports shall achieve this reduction of consumption per ton of cargo handled. A global overview of future development in energy demand is provided by the World's Energy Outlook of the International Energy Agency (IEA). According to this study, oil would still be the dominant fuel in the primary energy mix, largely due to the growth from the transport sector. At the same time, gas will be more and more used. Coal will remain the mainstay to generate global electricity. Possible solution is the use of renewable energies, but they need public support to enter the mainstream. The expected greater use of biofuels, compared to the share of nuclear power, depends largely on political decisions and support in the coming years.

We can conclude that the demand for energy is high and is expected to increase over the years. Energy from fossil sources like coal, petroleum and natural gas leads to CO₂ emissions and affects our climate, which will have an irreversible impact, like the melting of polar icecaps and a long-term rise in sea levels (ESPO, 2012).

3.4 WATER POLLUTION

We can define marine pollution as the release into the marine environment by man of substances or energy capable of producing some kind of deterioration. Normal operations carried out in ports are the main sources of this environmental issue. In ports and in their surrounding areas there are different sources of water pollution, but we can summarize the main pollution factors of marine waters into three categories:

The introduction of toxic substances and waste: this form of pollution is the most well-known and common, it involves naval discharges causing damage to marine ecosystems. In ports may occur accidental discharges of oil and other chemicals in the sea during ports activities such as dry dock and terminal operations, ships demolition, and fuel deposits. Another source of water pollution consists of storm water run-off from port parking lots, which involves discharge of organic compounds, fine particulate and heavy metals in the sea. A great attention must to be devoted to ballast water, used to stabilize vessels at sea. Ships use a large amount of ballast water, which is often taken in a coastal region (where they have previously unloaded other ships) and then unloaded in another port (where other ships will load). Discharges of ballast water from ship can have a negative impact on the marine environment, since they generally contain plants, animals, viruses, bacteria, and non-indigenous organisms unloaded in places where otherwise they would not be found. This means disastrous consequences for the local ecosystem.

The dredging of the seabed: used to keep navigable areas, dredging consists in the excavation performed by digging machines to remove sand, gravel and debris from the seabed. This activity can be dangerous since the material removed and discharged into the water could contain hazardous substances and thus pollute clean areas and alter marine fauna and flora.

Thermal disturbances: thermal pollution involves a serious threat to the marine environment, although it is often ignored. Water temperature is widely influenced by engines and discharges of hazardous chemicals. This change in water temperature involves an imbalance in the ecosystem's mechanisms. A consequence of this is the phenomenon of eutrophication that is an abnormal growth of algae that exploit all the oxygen present by subtracting it from other organisms (Speziaharbour, 2015).

3.5 WASTE

Port activities produce waste, oily and toxic sludge, from fuel deposits, oil terminals and dry docks operations. Ships demolition is another source of waste if there are not facilities for handling waste residues in the surrounding area of port.

Harbours are very busy places, since they host a lot of passengers and industrial activities. All this leads to the generation of very many fraction of waste, so ports have to handle both ordinary rubbish and harmful materials.

Waste management is an important issue in a port's environmental policy, in fact ports not only have to take care of their own waste, but also provide service to the vessels calling the port. Ship-generated waste is often referred to as harmful waste, such as oil-contaminated materials, petroleum waste, kitchen waste, ash and batteries. Cruise ships are also a notable contributor to the overall amount of waste generated by the shipping sector; although they comprise less than 1% of the global fleet, they produce 25% of all waste associated with the sector (Miola, 2009).

Ships produce solid waste such as glass, paper, plastic aluminium and metal. If these materials are discarded to the ocean, they both can threaten marine and human organisms, and transported to the coasts. Fish, sea turtles, marine birds can be injured and killed by solid water released by ships. Much of the solid waste produced is treated on board (incinerated, crushed or powdered) and discharged into the sea. Today 67% of all waste is burnt in incinerators or dumped in landfill sites. Both of these methods have a negative effect on the environment. They cause air, water, soil pollution, discharging CO₂ and CH₄ into the atmosphere and chemicals and pesticides into the earth and groundwater (ESPO, 2012).

Speaking in a simple way, the ports 'objective is a reduction of waste in an efficient and clean manner. To do this, ports have to reduce total volume of waste and hazardous substances generated, recycle and reuse as many as possible of the materials, and safely incinerate waste that cannot be recycled or reused.

3.6 TOOLS AGAINST ENVIRONMENTAL IMPACT

Environmental impact of port activities and operations has received growing attention in the last few years. In particular, cargo handling activities and port development projects are under scrutiny. At the same time, ports have to provide satisfactory capacity, cost-effective solutions and quality services. For this reason, it is suggested that ports should devise a green strategy for sustainable growth and development, fulfilling the right balance among environmental and economic objectives. In the green and sustainable port framework, various stakeholders plays a vital role. Ports cannot carry out any green port strategy without collaboration from stakeholders, so they need their support. We can classify various stakeholders into four categories (Lam, Van de Voorde, 2012):

Market players: ports are very often key hubs where market players pass through, interact and interface each other. From the collaboration between ports and, for example, shipping companies, several schemes could arise to reduce greenhouse gas emissions, air pollution, and to switch to low-sulphur fuel for ships. Ports can also apply discounted fees to ships that slow down, reducing emissions. This leads to environmental preservation with economic benefits for ship-owners. Port authority can also promote a voluntary agreement, undersigned from the shipping companies and the ship-owners, dedicated to the lower global sulphur cap. Furthermore, ships are recommended to install converters for getting electricity on shore in ports that have implemented the onshore power supply scheme. Green port strategy involves also ground-based operations, so ports can adopt schemes to switch to low-sulphur diesel for vehicles, and to build a green cooperation with inland transport modes like rail.

Public policy makers: represented by government authorities, they have to be actively involved in the ports 'decision-making process, since harbours are considered as strategic resources in a country. Public policy makers support the green port strategy if it is in line with the country's interest. Government represents may be invited by port and stakeholders to attend their meetings, and gradually expand the involvement of the authorities. The governments usually support green ports, but the level of involvement can differ in several harbour areas. Port authority can monitor the overall situation, take corrective actions wherever possible, or serve as the driving force in ports' environmental protection.

Internal stakeholders: they consist mainly of employees, and the green port's development needs their knowledge and enthusiasm. Employees must receive a green education, so they

undergo trainings (provided by ports) to handle more proficiently particular issue such as waste management and energy conservation. Obviously green port strategy takes care of the protection employees 'rights such as their working environment and health.

Community: environmental protection and preservation is a public issue. A green port needs the involvement of the local community, even for port image and sustainable development. The port's efforts are focused on the awareness to the public and the relationship with environmental research institutes regarding pollution reduction.

Finally, we can say that the first tool available to port to become a green port is the collaboration from all four categories of stakeholders.

Let's see now a number of various instruments available to port authorities to address environmental policy issues and to implement environmental objectives (ESPO, 2012):

Port vision: through the collection, combination and aggregation of data, port authorities develop and implement a specific environmental policy. In this 'port vision', global data may contribute to the definition of environmental priorities and action. Port authorities periodically update their port vision.

Spatial planning and infrastructure management: the regulatory plans and the adopted policies can be instruments in order to face the environmental issue in ports. Port authorities have infrastructure management skills and, in particular, skills for the environment, so they can realize environmental objectives such as infrastructure linked to the energy supply on the quay, bunkering system, wastewater treatment.

Tendering and/or concession: access to the port area from the mainland and other port activities are often carried out on areas granted by port authority, which owns/manages land. The property of port authorities of harbour areas returns them in a position to supporting environmental politics. For examples, land-based access to ports may be subject to environmental preconditions.

Port dues: they are the charges for the use of the port, its infrastructure and the services provided by terminal operators and port tugs. Port authorities can use these as policy instruments to promote the use of the most advanced and sustainable technologies, such as less polluting ships.

Enforcing: port authorities can implement local environmental norms, and realize specific plans in order to improve both sustainability and environmental performances inside of the harbour area.

In recent years the concept of environmental management in ports is mainly developed, because of the increased environmental awareness and the growing pressure from environmental legislation. Ports also need to maintain a good public image, taking into account third parties and stakeholders. This has led to joint activities instituted and financed from main harbour partners, thanks to collaboration between port sector, research institutes and specialist organizations. The aim of this cooperation is to create a powerful instrument for the elaboration of a functional frame of reference for effective and efficient solutions, in such a way that ports can achieve and demonstrate continuous environmental improvement.

EcoPorts is the main environmental initiative of the European port sector and it has been fully integrated into the European Sea Ports Organization (ESPO) since 2011. The main objective of EcoPorts is to supply to ports useful tools and methodologies in their environmental management.

The two main instruments are:

SDM: the Self Diagnosis Method is a support tool for port managers to regularly review the environmental management in their ports. It is a useful instrument for developing its environmental management programme, identifying environmental risks and setting priorities for action and compliance. The results of previous years can be compared with the present environmental performance, to assess possible improvement. SDM is a checklist that allows port managers to identify environmental risks in their ports and also to compare their environmental management performance with the benchmark performance of the European Port Sector. The main objective of the checklist is to review management activities and procedures with regard to the environment, and the way the port authority currently deals with its significant environmental aspects (Darbra et al., 2004).

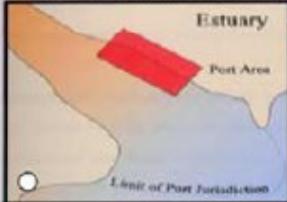
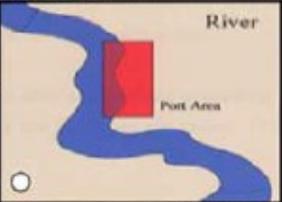
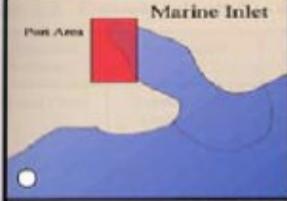
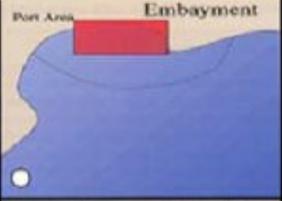
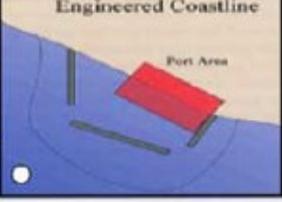
SDM is essentially divided into two large sections: Port Profile and Environmental Management and Procedures.

Port Profile (fig. 5) is also divided into five subsections, in which there are questions on port position, physical characteristics, port traffic and activities, kind of cargoes in transit, and finally on environmental management followed.



Port Location and Port Area

Please tick the geographic setting of the Port

 <p style="text-align: center;">Estuary</p>	 <p style="text-align: center;">River</p>
 <p style="text-align: center;">Marine Inlet</p>	 <p style="text-align: center;">Embayment</p>
 <p style="text-align: center;">Protected Coast</p>	 <p style="text-align: center;">Engineered Coastline</p>

Other location: _____

Please describe the area of the Port

Area of Port's land (km² or specify units): _____

Further detail: _____

Port jurisdiction limit onshore (km or specify units): _____

Further detail: _____

Area of Port's navigable water (km² or specify units): _____

Further detail: _____

Port jurisdiction limit offshore (nautical miles): _____

Further detail: _____

Length, largest vessel (m): _____

Draught, largest vessel (m): _____

Tidal range (m): _____

Maximum draught (m): _____

Total quayage (m) : _____

Figure 5: Port profile (Darbra et al., 2004)

Environmental Management and Procedures is composed by eight subsections such as Environmental Policy, Management Organization and Personnel, Environmental Training, Communication, Operational Management, Emergency Planning, Monitoring and Records, Environmental Review and Audit. They are themselves divided into other subsections, and

they represent the core of the checklist, providing information on environmental management issues.

Once completed the checklist, port authorities present their SDMs for review in order to receive suggestions and feedback on a confidential basis. From the SDM results, port authorities can evaluate possible development of the harbour programme of environmental management. SDM is a very effective tool and it is applicable and useful to ports of different sizes and at different stages of development of their environmental priorities.

PERS: Port Environmental Review System provides the basis for the development of an environmental management system through the application of the best practices recognised at international level. It includes a starting environmental review useful to ports in achieving improvements in their environmental performance, such as costs reduction, energy efficiency, legislative compliance, continuous reduction of environmental impact, better port image etc. PERS assists ports in achieving sustainable development and environmental protection objectives, also encouraging ports to share experiences and knowledge. Port authorities operating in port areas can adopt this methodology, and its application is voluntary. PERS differs from SDM because it is focused mainly on the possibility to put in evidence the environmental management performances of ports. All information, necessary for PERS implementation, allow the compilation of a periodic report on the state of the environment that illustrates the interventions of a sustainable development and environmental protection carried out by the port. PERS certification gives recognition to the good environmental practices of the port.

The document is structured in seven sections: Port Profile; Environmental Policy; Environmental Aspects, Standards and Performance Indicators; Responsibility and Resources related to Environmental Aspects; Compliance with Environmental Legislation and Policy; State of Environment Report; Examples of Best Practice and Solutions to Environmental Problem. Each section consists in introduction, detailed description, guidelines and examples (APAT, 2008).

Finally, port authorities have a strategic managerial instrument, able to support them in making their decisions and managing their activities with respect to environmental sustainability and energy efficiency regulatory. KPIs (Key Performance Indicators) can provide detailed information and data in managing port operations, according to an environmental sustainable perspective. Performance indicators have been recognised as relevant elements used in the environmental and energy management in the port industry (Puig et al., 2017), with a major focus on environmental performance indicators. Using environmental and energy performance indicators is fundamental for ensuring and supporting the respect of sustainable and energy development in the daily port activities and operations (Di Vaio et al., 2018). Port authorities use environmental and energy performance indicators to control the improvement of their sustainable development. Over the years, many indicators have been introduced. They belong to different categories such as air quality, water quality, waste management, energy consumption, oil spills, dust emissions, noise and dredging. Furthermore, port authorities can compare two different amounts (i.e. the gross tonnage of vessel and the garbage tonnage released from it) to produce information and make decisions about the port environmental management plan.

3.7 SOME GOOD PRACTICES

Considering various environmental impacts of ports, good practices are divided into five categories.

Air quality

Sulphur-free fuels

Port authority can switch fleet of ships and floating equipment over to operation on sulphur-free fuel. It produces improvements in terms of fuel consumption and ships maintenance. Thanks to positive results, it can become a permanent policy. It can be also applied to other ships used in inland infrastructure transport, bringing improvements in terms of human health and environmental protection. Until now, the shipping sector has been one of the biggest sources of SO_x emissions, so in recent years many efforts have been made to change this situation.

In this context of growing responsibility and awareness of the value of environmental protection, an example of good practice is represented by ‘Ancona blue agreement’. It is a voluntary agreement focused on the use of the fuel of the ships, promoted from Authority of harbour system of the central Adriatic Sea and undersigned from ship-owners, ferry companies and marine agencies operating in the port of Ancona. While noting that the ships that scale the Doric port use fuels with the parameters imposed from the law and verified from the constant and punctual controls of the harbour office of Ancona, with the signature of this voluntary understanding, ship-owners and shipping companies undertake to operate the main and auxiliary engines of ships with marine fuel with a sulphur content not exceeding 0,1% from the completion of the mooring manoeuvre in the port and up to the departure and exit from the port, compared to the 1,5% provided by the current law (Porto Ancona, 2018).

Tab.2 summarizes the provisions of the agreement comparing with the regulatory limits in force in Italy.

Table 4. Ancona blue agreement (Porto Ancona, 2018)

	Regulatory limits in force in Italy	Ancona blue agreement
<i>Maximum permitted sulphur content for less than two hours in port</i>	1,5%	0,1%
<i>Maximum sulphur content for parking in port over two hours</i>	0,1%	0,1%
<i>Maximum sulphur content from port</i>	1,5%	0,1%

LNG

During the last few years, we have seen the application of very strict environmental stipulations to shipping industry. New and alternative fuels are required to reduce air emissions, so the sector is headed to a multi-fuel future. LNG can become one of the most used shipping fuels of the future. Firstly, it is an appealing choice because its sulphur content is well below law limits and its combustion is clean. LNG (Liquefied Natural Gas) is cooled down to -163° and temporarily transformed into liquid form. In contrast to diesel fuel, LNG produce lower emissions of carbon dioxide, nitric oxide, sulphur compounds and particles, during combustion. It doesn't produce any waste and doesn't pollute the port water, compared with using oil. It takes up 600 times less space than natural gas, so it can be moved over long distances by sea, in special tanks. However, it comprise mostly methane gas- a powerful greenhouse gas, so leakage is a significant environmental issue. LNG port terminals host large ships designed to load carry and unload LNG. They need a gas liquefaction and storage plant, who is connected to gas pipeline connected to on-shore or offshore gas fields. In order to facilitate the use of LNG ship fuel, ports have to create necessary infrastructure. Port authority can also encourage companies operating in the harbour to weigh the advantages of LNG as a fuel.

A virtuous example is port of Gothenburg, which is a hub for shipping, industry and transport in the Nordic region. The LNG Terminal in Gothenburg is the first in Sweden to be built. It was required to reduce Swedish industry and shipping dependence on oil, to reduce vessels sulphur emissions to almost zero, and to make the transport sector more environmentally friendly. With LNG as a fuel, it is possible to meet the increasingly strict emissions

requirements. For example, the EU Sulphur Directive (2015) provides that the sulphur content of marine fuels must not exceed 0,1%, making it necessary the use of LNG, which reduces sulphur emissions to zero. Environmental benefits can be proved by comparing LNG to oil. In fact, LNG produces 25% less of the carbon dioxide emissions, furthermore it produces almost no Sulphur or particle emissions, and other emissions, such as heavy metals, nitric oxide and soot are almost zero (fig. 6). It is evident that the use of LNG as a marine fuel may involve a dramatic fall in climate impact and eutrophication of the ocean (LNG TERMINAL GOTHENBURG).

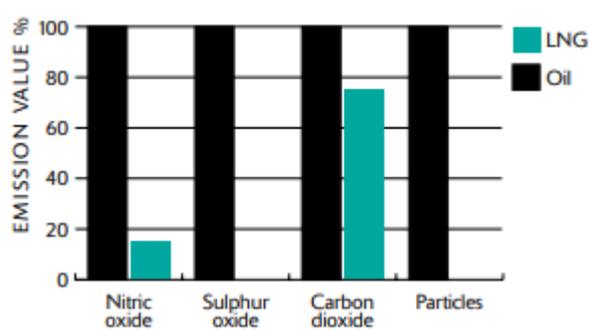


Figure 6: LNG and oil emissions (LNG TERMINAL GOTHENBURG)

Since 2011-2012, the port of Gothenburg launched a campaign by awarding vessels that opt for cleaner fuel. Vessels classified as green shall receive a financial compensation, and shipping companies that invest in the conversion of their vessels to run on LNG or on other alternative fuel, can also apply for financial support.

The Port of Gothenburg apply an environmentally differentiated port charge, in order to encourage cleaner shipping. More specifically, the surcharge, paid by shipping lines that use fuel with a sulphur content higher than 0.5 per cent, is reinvested in shipping lines that are investing in the environment. Different programs are available for port's customers. Shipping lines and operators can be compensated up to SEK 250,000 per year for each vessel in case of use of cleaner fuel within the Gothenburg traffic area. Furthermore, vessels classified as

green according to an international index (Clean Shipping Index) can apply for reimbursement of the port charge up to SEK 60,000 (ESPO, 2013)

Cold ironing

Ports can achieve a wide reduction of pollutants through a ground electrification of the docks. During cold ironing, ships plug into an onshore power source, turning off their polluting engines. The positive achieved effects are in terms of carbon dioxide, sulphur dioxide, nitrogen dioxide and noise emissions. Ships connect their on-board electricity systems to an ad hoc electricity grid onshore, in order to receive electricity to vital devices such as board lights and air conditioning. In this way ships reduce fuel consumption and air pollution associated. An electric utility company can provide land-based power, and its generators can be powered by diesel or renewable energy sources, such as wind, solar and water. Another positive effect of cold ironing is the reduction of residential heating emissions. In fact, ports can deliver heat (produced in the so called co-generation mode) to houses, offices, activities, located in their surrounding areas. Ship-owners must be incentivized by authorities in order to recover their investment as soon as possible, since the cost for the tuning of their ships is high. Furthermore, politics must keep the cost of this energy competitive with the cost of fuel, through regional and national energy plans.

Cold ironing comes to offer a solution to SO_x , NO_x , CO_2 and particle emissions as well as noise and vibration by auxiliary engines of berthed ships. Using shore electric power, this technology is able to mitigate these issues and thus to reduce air pollution produced from diesel generators. In fact, during cold ironing, berthed ships may turn off their engines without disrupting onboard services, since the ship's power load is transferred to the shore-side power supply through a connection with an onshore power source. It is possible, in this way, to supply emergency equipment, refrigeration, cooling, heating, lighting, and other equipment while the ship loads or unloads its cargo.

Cold ironing is a complex technological system, which consists of numerous elements (fig.7):

- Electrical infrastructure suitable for all types of ports;
- Electrical infrastructure on ships, either retrofits or new builds;
- Connection and control solutions to ensure personnel safety and continuous power transfer;

- A complete onboard system solution to include the necessary power equipment to connect the ship to a shore-side power point;
- Equipment to secure automated power transfer of the ship load from the power plant on the ship to the shore-side source and back (Safety 4 sea, 2019).

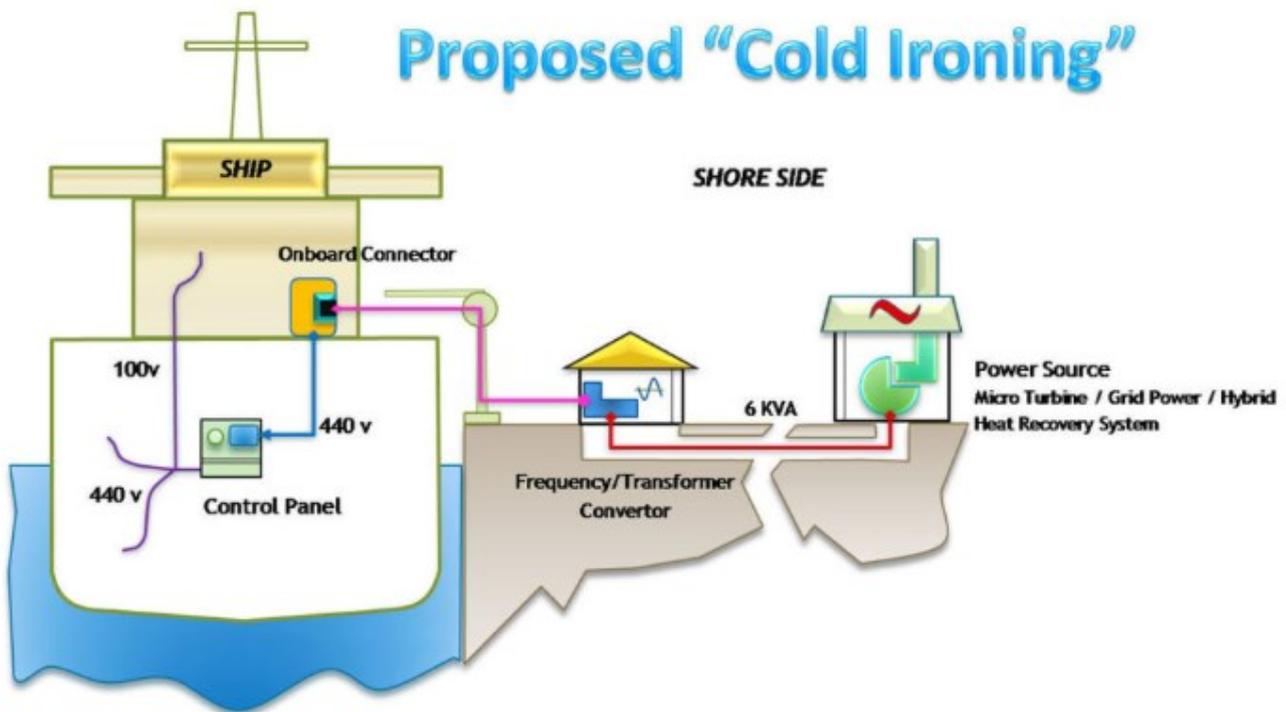


Figure 7: Cold ironing (Safety 4 sea, 2019)

This technology mainly provides environmental and social benefits. Because of the high efficiency of cold ironing, it is possible to save over 30% of CO₂ emissions and more than 95% of NO_x and particulate. It has been shown that, in 10 hours of stop of a cruise ship, its emissions decrease from 72.2 to 50.1 tons of CO₂, from 1.47 to 0.04 tons of nitrogen oxide, and from 1.23 to 0.04 tons of sulphur oxide.

The economic issue also deserves particular attention. In this regard, one study looked at the overall capital cost of installing cold ironing technology to medium-sized ports. It turns out that the cost would be around £6.6 m (€7.4 m), while the system would save annual emissions

of 108 tons of NO_x, 2.7 tons of PM and 4,767 tons of CO₂ emissions worth £1.3 m (€1.4 m). Therefore, in light of the payback of this process, it is possible to recoup the system capital and operating costs in only 7.0 years, or 3.5 years if subsidized 50% by the EU.

Noise reduction

Ports are often situated near the city area, so noise management is a theme of great interest. Ports have to implement various techniques to keep noise as low as possible, since machineries, vessels and cargo-handling activities may be very noisy.

Port layout

The port layout has to be taken into account for noise mitigation. For examples, ports can reduce noise pollution if their noise-producing operations are located away from the city area. The plan phase of a new port has a great importance in this respect. If natural formations like rocks and hills are located in the harbour area, they can be used as noise barriers. It is also possible to intervene on existing ports, building noise walls and barriers.

An example is the 4.8m high and 400m long noise barrier erected in Tallinn port (Fig.8). It is able to lower the noise, at most by approximately 5-6 dB at the distance of the closest residential houses.



Figure 8: Noise barrier at Tallinn port (ESPO, 2013)

Traffic arrangements

Partly related to the previous category, it involves many ways reducing noise pollution. Trucks and cars going to the ships form a significant part of the noise impact of the port, so it is necessary to regulate their traffic. Shore side traffic coming to and going from the ports can be directed in less sensitive areas, and its speed can be reduced through the installation of physical obstacles.

A practical example of this is represented by the Ghent port. Here, in recent years, a traffic study was carried out since heavy truck traffic crossed the villages surrounding the port, causing a lot of inconvenience. The goal was to keep truck traffic out of these villages, while ensuring the access for heavy and large vehicles like fire engines and removal firms. The intervention consisted in enforcing the truck traffic to follow a specific route, through the installation of traffic signs, agreements with GPS operators and directional police controls. This led to an installation of two-pole digital truck gates on the entrance roads to the village centres. In this mode, it is possible to assess the trucks destinations, since the gates register

the truck passage time between entering the village centre and leaving it. The evaluation of these gates was good, so this system has been introduced in other villages around the port.

Under ‘traffic arrangements’, we can include other operations such as disposition of the queuing and parking areas for trucks and cars going to ships in a less disturbing way, and the use of silent asphalt able to reduce noise levels.

Ramp design

This technique is useful to reduce the loud impulse noise generated in the vessel-quay interface. Noise levels vary from ramp to ramp depending on its form and materials. Noise can be eliminated using simple and cheap measures like rubber linings and insulations onto the ramps, also without compromising their functionality in several weather conditions.

Port of Kapellskär, in Sweden, adopted several measures against noise pollution. One of these was to cover vessel flaps and trailer ramp with insulation to reduce noise generated when metal strikes metal or concrete. Another measure was to divert traffic after leaving the trailer ramp which forced speed to be reduced and thus reducing impact sound and noise from the vehicles. The result was reduced impact sound with 10-15 dBA (ESPO, 2013).

Cargo handling methods

Cargo handling operations are one of the biggest sources of noise pollution, so they are under control. For example it can be applied a soft driving, characterized by a lower driving speed. In this mode, a reduction of engine and tyre noise (and of fuel consumption) from the cargo handling vehicles can be obtained. It requires greater awareness on the part of the personnel, through a change of a ‘masculine’ working culture rooted in stevedoring.

More silent machine fleet

Port authorities can reduce noise pollution using particular port machine fleet. In recent years has been introduced new electrically driven and hybrid machinery, in order to make cargo handling operation more silent. However, it is a time consuming change because of the long life cycle for the machinery.

The Swedish port of Trelleborg applied a noise reduction on terminal fleet. In particular, about the reachstackers, port introduced noise trap for cooling fan, noise absorbing aluminium sheet under frame (engine, gearbox), engine speed regulation (night time). Regarding terminal tractors, noise reduction is achieved using: noise absorbing lead rubber carpets, special steel sheets between engine and landing, sealing between driver's cab and frame, further improvement as sheets were replaced by galvanized sheets over gearbox and landing to driver's cab, engine speed regulation (1700 rpm) (ESPO, 2013).

Differentiated port fees

Ports may take into account in the future differentiated port fees as one of the possible noise management solutions, although they are not often used to reduce noise pollution. They are sometimes proposed to encourage the use of low-noise vessels, and to discourage the use of high-noise vessels. The port fees feasibility depends on the market situation of each port.

Hamburg port have improved noise management through green charges for port railway. They involve, among other things, an eco-tariff for low-noise wagons used by companies operating on the port railway network. In this mode, companies are encouraged to use noise-damping brakes on their rolling stock and diesel particulate filters on their locomotive.

Measuring noise levels

It is a solution to improve the noise reduction for the people living in the surrounding areas of ports.

A practical example is represented by Bremen ports, where is used an innovative state of the art technical measurement device. This allows to reduce noise actively, installing a 'noise measuring chain'. More specifically, 16 stations were deployed: 1 immission station in the nearby village, and 15 emission stations on the terminal, to measure port and traffic noise at source. All stations are interconnected by radio and there is a central evaluation unit, which monitors them.

According to the system, every noise sources (traffic, planes, railway, background noise, special impulse, tonal noise) are differentiated. The device monitors the noise continuously

at all stations during the night-time. Once measured noise level exceed defined noise levels, the system first records the audio sequence around the signal, then sends warnings faxes to the terminal operators 30 seconds at the latest after the signal. These faxes contain useful information, including the location of the assumed source. The aim of the central evaluation unit is to prevent the noise as quickly as possible.

Energy efficiency

Energy efficiency is one of the crucial environmental issues of a green port strategy, so ports have to implement technological solutions and operational measures for improving their energy performance. A wide range of practices is available for implementation, regarding port environmental plans, energy management systems, power and fuel used in port, sea and land activities.

Full or semi-automation of terminal equipment

Sustainable operations can be performed using fully or semi-automated terminals. The result is a higher optimization of container flows, which leads to lower energy consumption, lower costs, and lifetime extension of the equipment and last but not least better preservation of resources.

The Massvlakte 2 (Fig.9), situated in Rotterdam port, is the most automated terminal within the European port network. His gates and yards are fully automated, and the trolley and the spreader of quay cranes have a pathway almost completely automated. “The terminal is largely automated, operates fully electrically and uses solely sustainable energy as a power source. This means that current and future generations of container vessels can be handled quickly, safely and efficiently as well as sustainably” (Ben Vree, CEO APM Terminals) (Port of Rotterdam). Other European ports present increasing automation levels, although they are still at an early stage of development.



Figure 9: Massvlakte 2 (Port of Rotterdam)

Truck appointment systems

Multiple benefits can be obtained through the more effective management of truck arrivals at ports. Also called TAS, truck appointment systems are able to reduce the idle time of truck waiting outside the terminal's gates, maximize the utilization rate of the container yard equipment, and thus reduce the turnaround time of trucks. This leads to an important energy saving. TAS must also pay particular attention to the reefer container trade. In fact, in recent years ever greater volumes of this type of container have been handled, in addition those containers are the largest energy consumer in a port area. Including reefer-related information into a TAS, it is possible to realize additional gains in terms of energy consumption, for example, by prioritizing the arrival of trucks piking-up such containers, in order to minimize their dwell time.

Eco-driving of terminal equipment

Ports can improve their energy efficiency also through simple operations while driving terminal equipment. In fact, are available several principles of eco-driving such as to avoid frequent and unnecessary braking and stopping, to retain a steady speed, to shift gearbox at low rpm. In this mode, it is possible to decrease fuel consumption, mitigate the related air emissions, and improve air quality in the surrounding areas of port, obviously without compromising port operational efficiency.

Tangible results (in terms of fuel consumption and cost savings) have been obtained in the ports of Copenhagen and Malmoe, where machine operators were educated and trained to drive in a more environmentally friendly way.

Dynamic lighting system

Terminal lighting has to be taken into consideration because it occupies the third position in energy consumption, behind reefer containers and terminal equipment. In recent years, many full-scale implementations and pilot projects focused on this sector have been implemented, in order to deploy and test dynamic lighting systems covering most of the port areas.

In particular, in the Dutch port of Moerdijk, across its industrial area, we can find a full-scale system composed by 1100 LED street lights. They are able to meet real-time operational needs since they were equipped with motion sensors managed by a centralized control system, in such a way that different light intensities are used according to the different conditions. The result is a reduction of operating and maintenance costs.

Port/terminal equipment and vehicles

It is possible to improve ports environmental and energy performance by intervening on terminal equipment and port vehicles, since they represent the second most important energy consumer in a port area. European port authorities are focusing their efforts on new engine technologies for terminal transport, stacking equipment, tugboats and port vehicles. In particular, we can identify three main measures focusing on port/terminal equipment and

vehicles: hybridization, full electrification and use of alternative fuels. Actually, their energy consumption is huge, but a large improvement potential exists.

Hybridization

Different European ports invested on the hybridization of their equipment, through several orders delivered.

For example, ports of Antwerp and Southampton use several hybrid straddle carriers, with lower fuel consumption compared to the standard units used before. Furthermore, this equipment used in Hamburg port are equipped with a maintenance free regenerative energy system. Such technology has been applied also on other terminal equipment as it happens in port of Helsingborg, where the fleet of reach stackers was updated with a hybrid unit. This has led to a fuel consumption savings, during container handling. Finally, another example of hybrid technology has been tested in the port of Livorno. It consists in a switch from a diesel powered RTG (Rubber Tyres Gantry cranes) to a dual fuel one (diesel-LNG). The result was good not only in terms of reduced fuel consumption, but also in terms of air quality (reduction of Particulate Matter and CO₂ emissions).

Electrification

In recent years, ports have started modernizing their equipment following a full electrification of their container transport and handling equipment. The introduction of all electric and/or remote controlled RTGs, electric straddle carriers, is another step towards the general aim of zero-emission operations.

In this respect, port of Koper implemented five electric RTGs with auto plug-in systems and regenerative power system feeding back energy to the local grid, and port of Oslo ordered eight electric RTGs with automation capabilities.

Electrification may regard other types of terminal equipment, for example in the port of Hamburg twenty-five lithium-ion battery-powered AGVs (Automated Guided Vehicles) are in operation, served by charging stations. In this mode, energy savings and environmental benefits in terms of CO₂ and NO_x emissions can be achieved. Furthermore, AGVs are able to

stabilize the energy grid by receiving or providing appropriate quantities of energy, during the stationing at the charging station.

In addition, terminal tractors may be subject to electrification. The study of a first prototype, carried out in the port of Valencia in 2015, suggested the necessity of a further work on batteries, in order to achieve benefits in fuel consumption, air and noise emission. Since then, this sector has come a long way and electric terminal tractors are available in the market by several manufacturers.

Alternative fuels

In recent years, we have seen a great development in the use of alternative fuels for powering terminal equipment. In particular, the focus was on LNG and on the investigation of its potential exploitation.

In this respect, an LNG terminal tractor and an LNG mobile station for its refuelling were tested at Valencia port in 2013. This experiment was useful to match all operational parameters associated to LNG and diesel. The use of LNG leads to a reduction of energy cost, an increased energy consumption, and an improvement in terms of CO₂, PM and SO_x emissions. It must be also taken into account the payback period of such investment, and the proper training of port workers to the relevant process considering all necessary safety features. The LNG supply can also be applied to other types of terminal equipment. To do this, in recent years RTGs and straddle carriers (both diesel-powered) were retrofitted to LNG supply. This led to a fuel consumption savings (thus reduction in fuel costs) and reductions in air emissions.

The use of hydrogen in ports is still at the opening lines. At port of Valencia is foreseen the first test of a reach stacker and a terminal tractor, both powered by hydrogen batteries. This trial has to be supported by a new hydrogen supply mobile station.

However, energy improvements can also be achieved by taking action on other types of port equipment. In fact, the foregoing with regard to terminal equipment may also applied to other port vehicles. In particular, in 2012, the port of Rotterdam put in use the Europe's first hybrid tug, accompanied by significant reductions in fuel consumption and NO_x, SO_x and hydrocarbons emissions. This has shown the possibility to extend the hybridization in the fleet

of different port, for example to the icebreaker tug at the port of Luleå. Furthermore, the port of Bilbao will soon use, into its fleet, an LNG powered tugboat. This can act as a forerunner to other ports interested in upgrading their existing fleet with more environmentally friendly units.

Electro-mobility has also developed significantly in general purpose vehicles. In fact, some port authorities equipped their administration and security vehicles with electric supply, thus supported by recharging stations built in the port area. In particular, in 2016, the port of Tenerife launched a plan for its air quality improvement. This plan included actions such as installation of port electric vehicles, fast charging points in the port area, Onshore Power Supply, production of solar and windy energy, and other related improvement operations. The goal is to achieve an 85% reduction of CO₂ emissions.

Port buildings

All different types of port buildings can be designed and constructed in order to improve their energy performance. In particular, buildings like administration offices, terminal buildings, warehouse and other storage utilities, maintenance and repair workshops, can be converted into energy-efficient buildings. This is possible by adopting several solutions such as sustainable buildings shells, solar panels on roofs, small wind turbines, energy-efficient indoor lighting. A practical example is located at the port of Ghent, where the main building of port authority was built using advanced insulation and heat recuperation techniques in order not to require air-conditioning and heating installations.

We can find other virtuous examples in two English ports. In particular, at the port of Portsmouth a seawater source heat pump exploiting thermal energy from the sea is used in order to heat and cool the passenger terminal building, while ventilation requirements are covered through wind-catchers and automated louvres placed on the roof. Finally, in 2015, at the port of Immingham was constructed an energy-efficient warehouse equipped with a solar array on its roof. In this mode, all its energy requirements are covered, also fitting any excess energy back to the electrical grid.

Renewable energy

In recent years, there has been an increasing exploitation of different forms of renewable energy in Europe. This has led, in harbour within, to the development of proper infrastructure, able to cover an important part of the ports 'energy needs. In particular, a considerable productivity share can be reached by investing in wind, solar, biomass and wave energy.

The most striking example of wind energy exploitation is represented by the port of Rotterdam, where the capacity of the installed power units (200 MW) leads to a wind energy production equal to 10% of the total wind energy produced in the whole country.

Regarding solar energy, it should be highlighted that solar panels are less expensive and easier to install than other power plants, so they have been more widely implemented in European ports. The largest systems of this type can be found in the ports of Amsterdam, Rotterdam, and Gothenburg, mostly installed on the rooftops of storage warehouses, administrative buildings, and offices of the port authority. Furthermore, the port of Rotterdam has made the way to future investments being undertaken offshore through the implementation of a 100 MW floating solar power system.

In contrast to the previous ones, the exploitation of ocean energy is still developing. In fact, research in wave and tidal energy being still ongoing. Pilot applications and additional tests have been recently planned at different European ports, but the most visible result is reached to the port of Naples, where is placed, since 2016, a typical system of 5 m long, able to produce electric energy and also facilitate the recirculation of water inside the harbour. Compared to a traditional breakwater, such system is not much more expensive and involves a minimal environmental impact.

The exploitation of tidal energy in ports has found even less development. Indeed, tidal streams can be used to produce energy only under favourable conditions in ports. The port of Dover launched in 2015 a pilot project in order to investigate the applicability of this technology, but it was not imitated by any other European port.

Surely geothermal energy has received more success. Depending on the cases, the applications can go from the coverage of energy requirements of individual port buildings, to the supply of heat and cool to different port buildings. The latter is the case of Thassalia, the

first marine geothermal plant placed at the port of Marseille, which leads to a 70% reduction of the associated GHG emissions.

Some European ports can also use the production and exploitation of biomass in order to cover some of their energy needs. In particular, in recent years ports have investigated the potential of exploiting waste biomass in order to obtain heating, hot water and biogas. Besides the generation of electric energy (and thus the primary energy savings), another vantage is the disposal of different types of waste such as fruits, vegetables, organic fraction, municipal solid waste (Sdoukopoulos et al., 2019).

Water management

A set of good practise are defined in order to improve the quality of the marine waters in ports, limiting the impact of the harbour activities and the marine traffic.

Floating waste

Floating waste such as plastic and floating debris in the sheltered waters of the ports is a huge problem in coastal areas, especially when the port is near the city. It is therefore necessary to collect this waste (both from ships and land) before it can be transported at sea.

In this respect, the procedure used at port of Valencia may be useful. Indeed, a private company performs the collection of all floating waste from the sheltered waters of the service area of the port of Valencia. This activity is carried out with a barge that goes around the port area 8 hours daily and collects all floating waste in its special basket. Obviously, all this floating waste such as plastic, wood etc. will be separated and disposed of with appropriate treatments. Besides the collection of waste, the vessel, on its tour of the port, can also inform the port authority about the presence of accidental spills and leaks from vessels or port users.

An alternative method for collecting floating waste is a robust and simple devise called PortBin (Fig.10). It was launched on the market in 2017 and it is actually in use at ports in Norway and Denmark. The PortBin mechanism works in much the same way as an oil skimmer. It sucks in surface water and debris from surrounding areas, filtering waste into a

basket. When the basket fills with waste, it is easily emptied into a container and fitted back into the PortBin_(The explorer). It is available in different sizes, and it has been tested mainly in Norwegian ports, with great results. In particular, the PortBin is able to collect the floating waste in ports and harbours, in order to clean and make nicer port areas, protect wildlife and lower the cost of waste collection in ports.



Figure 10: PortBin (The explorer)

Rainwater

The pollution resulting from rainwater runoff of the port areas is an important environmental issue. Indeed, port terminals can be centre of influencing activities on the quality of dock water. It is therefore important to prevent and/or mitigate this environmental impact using best practices and technologies for the management and the treatment of waters.

In this respect, the port of Le Havre is a clear example. The presence of coal storage yards in the ore terminal leads to a pollution of rainwater, which therefore has to be collected and treated. In this regard, in 2008, collection ditches and structures with a lamellar clarifier for the storage and the filtration of the rainwater were created. In this mode, it is possible to

collect and treat the rainwater coming from the yards, in order to clean it up before unloading it into the dock. Furthermore, the stored water can be reused for internal processes such as washing vehicles at terminal, washing of machinery in use by the port, cooling foodstuffs, reducing dust. This leads to a limitation in the use of drinking water, since these operations are generally great consumers of potable water.

Saline wastewater

The direct discharge of saline wastewater into fresh surface water is not an environmentally desirable situation. Experience showed the necessity of collect and treat these wastewater flows because of their high salt concentrations. Different solutions are available, but not all are optimal. Indeed, it is not recommended to carry this unpurified wastewater to the closest sewage water treatment plant, since it would be very burdensome. At the same time, building and managing such an installation owned by may reveal not cheap and too complex. The optimum solution is constructing a saline wastewater treatment plant, in order to treat this wastewater separately, also bringing benefits to the companies in the harbour zone producing the waste discharges.

Water quality management

In many cases, ports are not only places of crowding for vehicles and people, but also locations of water recreational activities valued particularly by the local community. Hence, the great importance attached to water quality, whose management is one of the main points of the environmental policy of the ports.

Dover harbour is one of the most active ports in this respect. Indeed, in addition to being the Europe's busiest ferry port, it focuses its environmental objectives and targets in water quality in order to preserve its recreational area for water activities. This awareness has led to greater efforts to prevent pollution incidents occurring through the impact reduction upon the marine environment caused by a landside spill. Penstock valves and interceptors have been installed in the port area in order to improve the surface water drainage. Of similar importance is the emergency plan and the staff training in the case of an oil spill, ensuring adequate preparation for any adverse events. Further prevention is carried out by a state-of-the-art system, which

includes an innovative closed loop wash-down area. It allows to prevent debris from draining back into the port and, from a water management perspective, to recycle and reuse almost all of the water utilised. Furthermore, Dover port is engaged in the monitoring of its water quality. In particular, a government environmental agency is commissioned by the port to evaluate water quality by measuring a list of water quality indicators. The analysis are performed on a weekly basis and the results are made public so that environmental performances and improvements can be visible to all.

Water quality improvement

It is important to specify that not only the ports are responsible for the quality of port waters, but also all land activities whose release contaminants to the sea. Indeed, all inside and outside activities are responsible for the release of wastewater, rainwater and waters from drainage basin which may contain pollutants such as metals, phosphorus, nitrogenous matter, microorganisms. These contaminants end up sooner or later in port docks, resulting harmful to various aquatic activities like swimming, water sports, fishing. Ports have to become aware that they are an interface between land and aquatic world, so they must work to reduce the pollution diffused on its territory.

For example, the French port of Dunkirk shall endeavour to monitor coastal waters, examining in particular biology, microbiology, eco-toxicology and analysing sediments. The aim of port is to evaluate the chemical and microbiological contamination of water samples from the port docks and the outer channel. To achieve great results in terms of water quality, the port put in place several agreements with local industries, aimed at ensuring better management of the wastewater disposal.

Water treatment

Below is the example of French port of Nantes, which is a good runoff treatment practice. Everything starts from the necessity to treat the runoff of the cleaning docks, made necessary by the presence of dust deposits on the ground generated by the handling of dry bulk. In fact, it is not possible to discharge runoff directly without treatment. In this regard, the reduction of environmental impact was achieved through a water treatment plant, which involves an

initial sieving and a subsequent effluent treatment. The latter operation shall be carried out by lamellar settling and injection of chemical reagents. This plant is active since 2012 and allows to reduce organic pollution and to treat phosphorous pollution.

For proper operation, it is good not to include excessive pollution to the water treatment plant. This is regulated by the introduction of a maximum pollution limit, the exceedance of which entails a financial penalty. An important aspect is the partnership created between the port and the nearby city of Saint Nazaire. In fact, the goal of the city was the installation of a wastewater treatment plant for urban water in the surrounding area of port. The best solution for everyone was the installation of a common sanitation plant, which has led to a reduction of the number of buildings and equipment, a sharing of resources for treatment and sludge storage, reuse of treated water produced by the station of the city for the operation of the processing unit of the port (ESPO, July 2013). This project aims to significantly reduce the environmental impact, focusing on the improvement of water quality.

Waste management

Waste management is one of the crucial environmental issues for a green port strategy. Each port infrastructure and all the activities involved in it generate waste, which must then be managed. The large amount of waste produced can be divided into different categories, depending on the type of activity that generated it. In the harbour area we can find waste generated by port's operation, by vessels berthing in the port, by other business entities. In order to avoid and minimise the potential effects of all the types of waste, good practices are available for each ports.

Waste initiatives

A big step towards sustainability of the operations of the harbour authority and those within the port area is recognising the value of waste produced. Indeed, an adequate waste management can lead to an increase in the sustainability of port activities. In this respect, the main objectives that can be achieved are the reduction of waste in landfill and the increase in waste recycling.

The port of Dover is very active in this field, aiming to reach a 90% landfill avoidance for ships and port-generated waste. A greater incentive to segregate and recycle has been provided through waste charges, in order to recognise its value. Particularly useful is the choice to design larger receptacles, which led to a reduction in transport costs and thus in emissions. The port select its main contractors in accordance with their recycling capabilities and environmental performance. Finally, as a demonstration that waste has a value, in 2011, port recycled 82% of all wastes from the framework into clean aggregate, concrete and road sub base.

In addition, the port of Tallinn has made intensive efforts in waste recycling. It is able to reuse or recycle 74% of cruise ships-generated waste. Of course not all of waste is recyclable, so it must be landfilled. Therefore, it is task of the port to maximize the volumes of recyclable waste, in order that they can be transported to the special sorting facility, and here divided by type and material. After they have been packed, the ultimate goal is to reuse, recover or recycle them.

Management of dredged sediments

Among other things, sustainable development also refers to management of dredged sediments. In fact, dredging needs methods and procedures for its proper functioning, and dredged products have to be managed through innovative ways and appropriate solutions.

In this regard, the French port of Dunkirk has implemented a strategy by referring to strategic and operational tools. In agreement with its Dredging Master Plan, uncontaminated sludge is dumped at sea; non-submersible sludge is recycled on land; sand is useful for the coastline. The port applies many innovative solutions for the reuse of sludge. In fact, it can be used in landscape remodelling, road building and concrete producing. In particular, a port's territory re-modelling has been carried forward in order to promote the biodiversity development. Furthermore, in 2012 non-submersible sludge has been misused for the construction of the first port road and, one year on, for the realization of concrete blocks for the defence of territory against the sea. Finally, from this sediment can be obtained aggregates useful against coastline erosion.

Waste management system

An alternative method for waste management in port of Piraeus is presented. This is a virtuous example from different points of view. First, the port has identified the possible source of recyclable waste through an in-depth study within all harbour area. The proper management of these waste streams is set out in a handbook, which contains all the procedures and steps. The latter must be well known and respected by all the harbour operators. Specifically, the procedure stipulates that only the recycling companies authorized by the Hellenic ministry can cooperate with the port. Each activity has its own number and type of waste collection containers. Major operations like waste collection and delivery are under responsibility of designated personnel, which is different for each activity. The recyclable waste collection is accompanied by the issue of the relevant delivery documents. This project started in 2005, and year after year has expanding, including more and more recyclable waste streams.

Countless positive aspects can arise from this type of waste management. In fact, tangible results have been achieved in the reduction of waste landfilled, thus in energy and natural resources saving, and at the same time, in environmental and public health protection. Furthermore, this strategy provides for the record of quantities and types of waste delivered in order to, among other things, avoid of bins overflow and return the port cleaner. Through the assessment of waste generation by each port activity, it is possible to identify any abnormalities and take corrective actions. Additional benefits are related to the reduction of air emissions. In fact, global warming is limited by disposing less waste in landfill. Finally, since the waste delivery is done at the production sites, waste transport is optimized in order to avoid unnecessary internal routes. All along, port employees, to whom a great environmental sensibility is required, carry out an important role.

Cruise liners

Cruise ships carry huge amounts of liquid and solid waste, it is necessary for the ports to see to it therefore that they are properly managed.

In particular, it is a problem that concerns the ports hosting a large number of cruise ships, such as the ports of Stockholm. Unlike the regular ferry services, which manage their own waste, the port encourages the cruise ships to deliver the waste in order to reuse and recycle

it in proper and environmental way. In this regard, the tool available to the port is the application of a differentiated waste fee. The vessels must pay a fee for waste disposal; however, they are entitled to a discount of about one-third of the fee if they sort their waste.

In addition, as a further incentive, every year the best vessel in waste handling and sorting was awarded the Environmental Boy Diploma. In recent years this recognition has no longer been subject to competition, since all vessels deliver their waste in efficient and environment friendly way. The ports of Stockholm are engaged to help cruise liners in waste management. In particular, a man on the quay was instructed to help the contractor, in order to inform the crew about the sorting of waste. Also the same waste sorting is facilitated through the use of special containers equipped with information and labels in several languages, available to the vessels. This practice has enhanced the active participation and the environmental awareness of cruise liners, which arrive in Stockholm ports delivering their waste in sorted fractions.

Fee system

Ports environmental policy involves, among other things, the waste delivery from ships. In this regard, in line with the various environmental directives, ports have installed reception facilities, waste management plans and incentive-based fee system. The solutions adopted by ports are varied and diversified, although all of them comply with the rules.

Among all, the example of Antwerp port stands out, since its tools are presented to other European states. The main points of such system are: strong incentive-based fee system, open market, state-of-the-art monitoring and information system. The results are there for all to see: the waste delivered to the port increases years after years, thanks to the strong incentive that does not provide maximum delivery limits. However, the most innovative aspect is the monitoring and information system. Thanks to this, it is possible to derive data on ship-generated waste, useful for vessels inspection.

General examples

The port of Aalborg is very committed to the production of biogas from waste. His efforts are focused on the collection of organic materials such as corn, soya, pulp, which may escape during their loading and unloading. In particular, the port is able to recover around 300 tons

of organic waste every year. This material is transported at the local biogas plant, in order to produce methane gas.

Port of Setubal and Sesimbra leads the way in the collection and temporary storage of small boats generated waste. The port makes available containers for waste contaminated with hydrocarbons and for used oil, equipped with sump. The aims of the port are therefore: high turnover, ease of use and high safety. This leads to improvements in waste separation and management through the increasing possibility to recover.

The port of Stockholm is equipped with facilities for offloading black and grey water. Shipping companies can make use of 14 stationary facilities in order to offload their black and grey water. Furthermore, cruise ships offload to the docks dedicated to them, free of charge. The connection between several vessels and the sewer system is guaranteed by different adaptors that facilitate reception (Fig. 11). Black and grey water offloading is not subject to specific taxation, but is included in the port fee. For this reason, port must receive black and grey water should the shipping company choose to do that.



Figure 11: Reception of black and grey water in ports of Stockholm (ESPO, 2013)

The Danish port of Kalundborg is an example of easy and convenient wastewater handling. In fact, vessels discharge their wastewater into special reception points placed on the quay. In this way, the discharged water reaches the municipality sewage system through pipeline. This is an odour free solution, equipped with a large capacity.

Groningen seaports support marine litter collection. Actually, it is one of the most important environmental problems affecting the sea; therefore, initiatives in order to reduce litter into the sea have been taken. Groningen seaports stand side by side with KIMO, a foundation engaged in the cleaning of the sea. In particular, KIMO involves the fishing industry through the provision of large bags, where fisherman may deposit marine sourced litter. In this mode, thousands of tonnes of litter dumped into the sea are deposited safely on the quayside and then collected for the disposal. These initiatives serve to raise awareness not only amongst stakeholders, but amongst also each community.

4. ENVIRONMENTAL IMPACT OF AIRPORTS

Over the years, many researches have recognised the paramount role of aviation, both at local and global level. In fact, airports not only are thought to be the largest generator of economic activity in the regions they serve, but also facilitate and contribute to economic growth and social benefits of the modern world. However, the operation of airports involves many activities that can have negative impact on the environment. Furthermore, airports can affect the nearby communities since they have considerable effect on city's urban development, and they compromise the quality of life of residents.

The airport area is very large, and on it are based several activities that create various pressures on the environment. In particular, it is possible to identify the operation of aircraft (cleaning, maintenance, de-icing, anti-icing, fuelling and fuel storage), the operation of motor and passenger vehicles, airport access, and any other construction activity headquartered in the airport landside. All these contribute to a deterioration of environmental quality and an increasing of adverse impact on the environment.

Making a distinction between local and global level, surely climate change is the most important impact on the global environment. Greenhouse gas and air pollutant emissions also have negative impact at a local level, together with other concerns such as noise pollution, water and soil pollution, waste management, energy consumption. Furthermore, airports need the surrounding land in order to build access and infrastructure support services, often clashing with local communities' tolerance, ecosystems and natural habitats.

Airports must comply with increasingly stringent environmental regulatory requirements through the implementation of certain mitigation projects, but without stopping their undergoing expansion.

All these issues are discussed below focusing on several impacts of airports, and describing what is being done to minimize them, both at a practical and regulatory level. This is necessary because aviation is expected to continue to grow rapidly in the coming years, with a consequent increase in emissions, noise and energy consumption.

4.1 AIR POLLUTION

Aviation and its associated activities are a key source of greenhouse gas and air pollutant emissions. Air pollutants are similar to the ones described in the shipping chapter, although the activities related to aviation are different from those typical of shipping. Consequently, major concerns are CO₂, SO₂, NO_x, VOCs PM and O₃. The most important aspect to be preserved is human health, taking into consideration that the most significant pollutants in this terms are particulate matter, nitrogen dioxide and ground level ozone.

As regards the aviation activities, they can be divided into four main categories: terminal and ground operations, flights, airport access, associated projects.

In the surrounding areas of airports (and thus in the nearby urban areas) air quality is influenced by all four types of activities. In fact, we can find emissions from aircraft engines, ground operations, surface access road transport, and energy generation and heating of airport facilities. Aviation activities are dangerous to human health since they are responsible to emissions of particulate matter, nitrogen oxides and volatile organic compounds. From these pollutants, secondary particulate matter and ground-level ozone can be generated in the atmosphere through chemical and physical transformations. More specifically, aviation activities such as taxiing, take-off, landing and cruising at altitude are source of air pollutants.

The same sorts of things can be said about all ground vehicles operating at or around runways, and transporting passengers or freight. Several factors obviously affect the health impact, such as the emission altitude, the proximity to human populations, the type of pollutants and the weather conditions. A list of aviation activities with related air polluted emissions is presented below. Combustion of kerosene (the largest component of the fuel used by aircraft) produces nitrogen oxides, sulphur oxides, carbon monoxides, hydrocarbons, particulates and also carbon dioxide (greenhouse gas). Furthermore, a certain quantity of unburnt kerosene is released since engines do not use all the available power in the early stage. This lead to the formation of volatile organic compounds.

Landings and take offs are the source of particulate matter, because of the burn of aircraft tyres. In case of emergency, aircraft can dump unburned fuel into the air. This occurs only in rare cases, and in any case, the dumping must take place over water and in order that fuel can evaporate before reaching the surface.

Aviation's contribution to air pollution also arises from vehicles and ground service equipment. In fact, there is high traffic in the surrounding area of airport. In this regard, petrol and diesel powered vehicles travelling from and to the airport are responsible for CO₂, NO_x, particulate and O₃ emissions. The same goes for vehicles for ground service such as tugs, lorries, buses and vans, used for aircraft, baggage, passengers and fuel transport.

Different sources of VOCs are located at airports. On the one hand, they can be released by fuel storage tanks and transfer facilities placed in the airport area, on the other their emission is caused by aircraft maintenance activities such as painting, metal cleaning and de-icing. Finally, any construction activity placed in the airport area can release dust, emissions from asphalt laying etc.

Several studies have highlighted the great impact that aviation has on the environment. The contribution of aviation to global greenhouse gases emissions is approximately 1-2% of total emissions (Harrison, 2015). The great expansion of this sector is witnessed by the increase in emissions since 1990. More specifically, in the EU-28 in 2015 emission from aviation accounted for around 13% of total transport GHG emissions and around 3.3% of the total EU CO₂ emissions (EEA, 2017a). Since the sector is expected to continue to grow rapidly in the coming years, it has been estimated through a time projection that aviation may contribute up to 22% of CO₂ emissions by 2050 (European Parliament, 2015). For this reason, it is necessary to take action, enter into agreements and foster the development of good practices in order to reduce the global aviation emissions and thus limit global average temperature rise.

In addition to general negative impacts such as human health, births defects and environment, aviation activities also contribute to climate change. In fact, NO_x, SO₂ and black carbon emissions are responsible for indirect global warming and cooling effects, since they can react in atmosphere with other greenhouse gases like O₃, methane and sulphate aerosols. Although it is a fairly complex matter, an analysis has shown that sulphate aerosols and water vapour can result in contrails and cirrus cloud formation, which can contribute to net climate warming (Brasseur, 2016). As seen for greenhouse gas emissions, air pollutant emissions are increasing in parallel with the demand for aviation. The aim is to make aircraft engines more efficient and environmentally friendly, through the reduction of their emission rates.

Human health is an important issue and subject of many studies. Recent research suggests that, globally, aviation emissions could cause 16000 premature deaths per years because of exposure to particulate matter with a diameter of 2.5 μm or less and O_3 . In particular, 49% of total premature deaths is caused by emissions from landing and take-off. This has an estimated cost of EUR 7.51-8.53 billion per year (Yim, 2015).

Among the substances considered to cause significant damage, ozone deserves a special mention. First, we must distinguish between ozone in the high altitude stratosphere and the ground level ozone. Ozone is generated by photochemical reactions from NO_x and volatile organic compounds, which are pollutants that can be released from aviation activities. Ground level ozone may induce several negative impacts on human health, such as eyes, nose, throat and lungs irritation, death due to heart and lung problems. Furthermore, ozone is toxic to wildlife, forests, crops and plant communities, and it can also damage several materials like masonry and plant. For this reason, many evaluations of air quality impacts have focused on the impact of ozone. Unlike the ground level ozone, the ozone in the stratosphere provides essential natural shields against hazardous ultraviolet radiation from the sun. In this regard, halon is a substance considered to destroy the molecule of stratospheric ozone, expanding the ozone hole. Halon has been used in aircraft as extinguishing agents, because of its effectiveness in fighting the spread of flames. European commission and EASA researches are focusing on alternative firefighting equipment, in order to gradually phase out of halon in aircraft.

4.2 NOISE POLLUTION

Noise, among all environmental impacts of the aviation industry within the airport area, is probably the most obvious since it is frequent, easily perceived and annoying.

In general, it can be said that much of the noise, though certainly not all, is linked to aircraft. In particular, noise comes from both the engine and the airframe and it occurs mainly during landing and take-off. Furthermore, aircraft generate noise during their taxiing and, in some cases, through the application of an optional braking aid on landing called reverse-thrust. This latter is useful to reduce wear on the brakes, but it generates loud noise after touchdown. Engine tests and on-site vehicular traffic are other sources of noise. Finally, noise impacts linked to vehicular and rail traffic to and from airport are not insignificant.

Aviation noise mainly affects the quality of life of members of a surrounding community. Population exposure to aircraft noise can have serious physical and psychological effects. In particular, noise pollution can cause sleep disturbance, loss of concentration, anger, frustration, aggressive behaviour, and cardiovascular effects like hypertension and ischaemic heart disease. This exposure is growing due to the typical growth of the population near airports.

In the EU, aircraft noise is the third biggest source of noise exposure after road and rail traffic (EEA, 2014b), but aircraft generate more annoyance and sleep disturbance than other source (road and rail traffic) at the same noise exposure level (EASA, 2016). Obviously several factors like volume, duration, location, time of the day and frequency of the noise affect the dangerousness of noise pollution. Many studies have shown that noise exposure has stabilized in the past 10 years by advancements in aircraft technology and noise abatement efforts such as technological improvements to engines, fleet renewal and increased air traffic management efficiency (EASA, 2016). However, quieter engine technologies will be needed to stabilize or further reduce in the future aircraft noise, since this is often the principal focus for local communities and non-governmental organizations opposed to runway expansion.

4.3 ENERGY CONSUMPTION

Energy conservation is one of the cornerstones of environmental policy of airports. They can be seen as small or medium sized cities, which have to consume energy in order to operate their facilities and infrastructures and to efficiently provide their services.

Within the airport area, there are a lot of buildings and facilities that need high electrical energy. In particular, it is possible to identify general systems like terminal air conditioning, pre-conditioned air and power at gates, powering of many appliances, and other systems specific to airports like baggage handling systems and airfield lighting. Therefore, airports need economic and reliable provision of electricity, since they function as states of origin for critical link in national and international transportation network. The overall aim of all sized airports is to ensure the safe and efficient operation of flights.

Energy consumption is concentrated into two main points: airport terminal and airport airside. The first one have to provide an efficient service to the consumer through lighting, air conditioning systems, baggage handling systems and terminal bridges. At the airport airside several system are located in order to make flight operations safer. It is possible to find runway lighting, aircraft ground energy systems, ground vehicles and also airside facilities like hangars.

The achievement of energy efficiency starts from a careful analysis of energy consumption. In this regard, airport operator replaces any large source of energy consumption in order to reduce operational costs. Investments in renewable energy projects are often the right solution to achieve cost and emission savings. The most common renewable sources of energy are solar, wind, hydro, geothermal and they can be used to produce electricity, heating, cooling and to fuel various means of transportation. These contribute to replacing fossil fuels such as petroleum, coal and natural gas, in order to move towards a more environmentally sustainable energy mix. Indeed, their burning may cause climate change and air pollution, since they release greenhouse gases and other air pollutants.

4.4 WATER AND SOIL POLLUTION

Unlike shipping sector, aviation is not a direct pollutant of water, except in extraordinary event or accidents.

First, airport can be seen as a set of buildings and facilities providing public services. This leads to increased water demand and consumption, and thus to the production of resulting wastewater, which have to be efficiently managed and treated. Going into the specifics airport activities, since runways, taxiways, aprons and fuel distribution points are all set in impervious surfaces, storm water running through these can accumulate a large range of contaminants and pollutants. In particular, it is possible to find pollutants like heavy metals, hydrocarbons, polycyclic aromatic hydrocarbons, organic solvents and combustion by-products (Sulej, 2012). The pollution load of any runoff varies from airport to airport according to the specific meteorological conditions such as air temperature, local rainfall intensity and volume, event duration and frequency (Freeman, 2015). In cold climatic conditions, anti-skid and de-icing fluids are used in airports to remove or counteract the effects of snow, ice and frost on aircraft and runway surfaces. These treatments include substances such as formates for runway anti-skid treatment and aircraft de-icing fluids (ADF) like propylene glycol to remove snow and ice from aircraft surfaces and to avoid any snow or frost built up in critical aircraft components (Sulej, 2012). However, the use of such fluids adds further to aviation related environmental impacts. Indeed, these fluids, once fallen to the ground, can be carried into streams, rivers or coastal waters unless properly managed (EPA, 2012). For example, ADFs are usually miscible in water and thus highly mobile in the environment (Veltman, 1998). In addition, at airports are used potentially toxic additives such as metal corrosion inhibitors, rust inhibitors, thickening agents and surfactants. Particularly great attention must be devoted to urea, a nitrogen compound used for runway de-icing. Indeed, it can affect aquatic life and underwater organism since the decomposition of urea consumes high levels of available oxygen in surface waters. For this reason, effective drainage systems are absolutely essential in order to capture and treat water contaminated with chemical leakages of de-icing fluids.

4.5 WASTE

Airports are similar to small cities where large amounts of waste are produced. Indeed, there are various operations performed at airports responsible to the generation of considerable volumes of waste.

The volume of waste generated is directly proportional to the growth in passengers and aircraft movements during the last years. For this reason, waste management is increasingly becoming one of the most important environmental issue within airports.

Waste can come from different sources such as the reuse and recycling of disused aircraft or waste generated at airport facilities.

At first sight, it is possible to divide waste into two large categories: the one generated by the landside activities and the other one by airside activities. The first category concerns activities in buildings and adjacent terrain not in the airside precinct, the second one concerns the movement area of an airport (Baxter et al., 2018).

In practice, airport activities generate various types of waste such as Municipal Solid Waste (MSW), Construction and Demolition Debris (CDD), waste from aircraft flights (deplaned waste), compostable waste, hazardous and industrial waste, and lavatory waste (ICAO, s.d.).

Besides the different type of waste generated, the environmental impact is closely linked to waste management practices like collection, treatment, storage and disposal. The aim of airports is to recycle, reuse, compost and introduce wasteless technologies, in order to decrease the volume of waste generated within airport and waste landfilled. This mainly concerns MSW and CDD, for which airports have greater choice of intervention. However, it is possible to find at airports hazardous waste. It can be generated by aircraft refuelling, aircraft maintenance activities, rental car maintenance (waste oil), and emergency power generators. It is very dangerous for airports' environment since it can contaminate soil and water and can also pose a threat to human health. For these reasons, hazardous waste must be handled in specific and safe ways.

4.6 TOOLS AGAINST ENVIRONMENTAL IMPACT

As said for ports, sustainability must be a cornerstone of environmental policy of airports. Indeed, since it can be a meaningful and useful planning and development tool, sustainable development is tested on the most economically advanced sectors of the economy in order to lead to successful outcomes.

The airport sector of the aviation industry is, together with shipping, a key component of Europe's mobility system, so it is necessary to consider a sustainable development for airports.

In this regard, an airport can be considered sustainable through the implementation of policy framework and several initiatives aimed at achieving the goal. Airports may apply a strategy that offers a framework for the efficiency of the service provided and the environmental preservation. As for other transport systems, the airports framework must lead to the right balance between the economic development of transport and the protection of the environment. The whole can be achieved through initiatives forming part of the framework.

It is important to provide for economic and social needs for access in order to reduce the number of travels. Obviously several measures must be taken in order to reduce the environmental impact of aviation industry. Finally it is possible to bring environmental benefits through payment by users of social and economic costs of their transport decisions.

The framework is directed both at surface and air transport. Furthermore, it can be useful to solve problems affecting airports such as congestion, capacity constraints and land use developments. The concept of sustainable development has been written into policy and implementation procedures to the point that a large amount of policy responses and prescriptions are emerging at different spatial decision-making scales.

A lot of valuable information are obtained from the Local Government Management Board (1993). It indeed has defined constituent parts and potential applications of a sustainable development process, although the latter is not clearly and precisely defined. Generally, policy-making is based on principles such as partnership, policy integration, freedom of information and open decision-making. In order to be successful, the policy choice must be directed towards demand management, precautionary principle, and, last but not least, continuous environmental improvement through, above all, the 'polluter pays' principle. As

a result, there are several tools in order to pursue this policy-making. Indeed, it is possible to adopt sustainability indicators, environmental management systems, draft state of the environment report, strategic environmental assessment and investment appraisal, provide environmental information, education and training. Specifically, an airport can accept these requirements in the form of policy framework or initiatives in order to aspire to sustainability. This policy framework needs approval and it is closely integrated with the corporate plans. It also brings together the most important papers to an airport.

A Corporate Environmental Plan describes the airport's environmental commitment in great detail. It is recommended to make revisions to the plan at two year intervals in order to update as much as possible the plan in its ten-year extension. The centrepiece of the plan is the identification of environmental goals, with a related broad management framework, and penalties in cases of failure. The achievement of results in the field of sustainable development is possible through the control of particular indices, which must be clearly enunciated. For example, one indicator may concern carbon dioxide (CO₂) emissions, through the indication of CO₂ emitted or saved. An effective environmental management must be ensured into all levels of corporate structure. Environmental goals must be an integral part both into corporate decision making at all levels and into contractual and other partnerships with other parties. Obviously regional and national planning is unable to escape from environmental matters. The assessment of sustainability is strictly linked to the scale of an activity. For this reason, it is important to distinguish the spatial scale in local, regional and national, since activity sustainability may alter in spatial and temporal terms. Finally, the creation of such a framework requires the participation of the widest possible community of interests within the decision-making process, in order to define plan's goals and indices.

There is no single way to operate following this line of reasoning; in fact, an airport will have to confront many environmental issues. Everything starts from a complex management decision-making, consistent with sustainable development adopted. Different ideas and initiatives are put on the table and implemented in order to mitigate or eliminate every environmental impact. In the case of aviation activity, air quality is one of the most important environmental issue, since the emission of air pollutants can affect the airport area and the wider surrounding region. For this reason, airport policy becomes fundamental to promote initiatives able to directly influence the emissions. The achievement of specific targets is

generally limited within two-year period and it consists of the evaluation of previously fixed indicators such as minimum acceptable CO₂ emissions, per kilometre, passenger or unit time. If an airport decides to follow a sustainable development adopting a Corporate Environment Plan, it will have to engage in some or all the activities, which exist.

National emission policy: airport association is required to participate in the debate upon (for example) air quality, at different scales. More specifically, the national debate may concern total emissions with reference to sector, space and time; instead, the regional debate focuses on the application of direct and indirect emission controls.

Aircraft: this is perhaps the most important issue for an airport. Indeed, the most important goals are to mitigate or eliminate the environmental impact of aircraft, and to promote green and clean technologies in manufacturing and use of aircraft. Participation in international meeting is very useful to an airport for continuous updating, for example in terms of new engine technologies with enhanced efficiency.

Airport operational and infrastructural improvements: many simple techniques are available for airports in order to achieve environmental benefits. These may concern operations in airside such as aircraft taxi and waiting; heating and power systems; building stock; fuel handling.

Policy: it is possible to include environmental policies within the framework. For example, it is advisable to use larger aircraft (thus with higher load factor) in order to operate fewer aircraft. For the same reason are focusing attention on alternative transport systems, in particular high-speed rail links.

Surface transportation: mass transit and public transport have to be supported by airports. In particular, specific policy can be promoted in terms of infrastructures, car parking and employed staff.

The airport's commitment to these activities is a chance to limit or eliminate not only air pollution, but also noise pollution, water and soil pollution, waste production and energy consumption.

Finally, it is possible to list some simple activities that an airport must carry out in order that it can be defined sustainable. It is important to have a direct relationship and constant dialogue with airport's customers, since the service offered to them must always be efficient, but not forgetting the environmental issue. An airport can be helpful in identifying and remedying the environmental problems on its surrounding areas. An airport must care about the quality of life not only in the local communities, but also at national and international level. For this reason, it focuses its efforts on monitoring and reducing its impact on the environment, through setting goals within the policy framework. Furthermore, it should be well informed about new developments and technologies, especially in terms of impact upon the existing environment. Last but not least, transparency is required in releasing information about airport environmental impact. In short, a sustainable airport is one, which is careful of its impacts and obligations in the present day and mindful of the responsibilities it holds for future generations (Longhurst et al., 1996).

4.7 SOME GOOD PRACTICES

A list of good environmental practices put in place by airports is presented, based on their environmental impact reduced.

Air quality

Free route airspace

Free route airspace (FRA) is a specified airspace within which users may freely plan a route. The latter is defined with reference to the airspace availability, through the individuation of an entry and an exit point. Alternatively, intermediate waypoints may be defined. Within this airspace, flights remain subject to air traffic control.

FRA can be seen as an air traffic service, which allows users to have more freedom of action. In fact, the routes are no longer characterized by standard airways, but are subject to only a few limitations such as fixed entry and exit points and the need to avoid danger areas.

Generally, the most commonly used solution is a straight line from an entry point to an exit point. However, in some cases, it is necessary to avoid a danger area, so additional turning points are provided in the form of points of specified coordinates.

European states have gradually introduced FRA. Its implementation did not take place in a single act, but it required a step-by-step process. The introduction of FRA is encouraged by a number of efficiency benefits for the operators, making FRA one of the most cost-effective changes. More generally, it can be said that FRA allows to overcome the aviation sector's efficiency, capacity and environmental problems, through the reduction of fuel consumption and emissions, and the improvement of flight efficiency. The change brought by the implementation of FRA offers significant opportunities to airspace users. Once fully implemented at European level, the most notable benefits should consist of the following saving, compared with the actual situation: 500.000 nautical miles/day since most flights will be using the shortest routes possible. Consequently, further savings can be achieved in terms of tons of fuel burned/day, fuel costs/day and thus CO₂ tonnes emitted/day. Furthermore, FRA leads to significant advantages since it ensures more stable trajectories. For this reason, conflicts can be more easily detected and distributed in the airspace, than in the case of fixed route network (Eurocontrol).

Electric green taxiing system

An electric green taxiing system (EGTS) is a system that enables aircraft to pushback and taxi at airports without requiring the use of their main engines or the support of airport towing services. Thanks to this technology, aircraft can avoid using their main engines during their taxiing since they may use the Auxiliary Power Unit (APU) generator.

EGTS consists of an electric motor powered by the aircraft's auxiliary power unit. It is placed near two of the main landing gear's wheels (fig. 12), and allows the aircraft to push back from the gate and taxi without a tug or its jet engines. This system weights 300 kg, it is a fixed installation on the aircraft and it is used in the moments prior to take-off.



Figure 12: EGTS installed on an Airbus A320 (Wikipedia)

More specifically, an aircraft no longer needs tug assistance and main engines respectively to push back and taxi towards the runway. Consequently, the main engines will be started when the aircraft has reached the runway.

The benefits may also cover the landing operation. In fact, the aircraft can stop its main engines during the taxiing to the terminal and the parking at the gate, since it can use the EGTS through the APU power.

Airlines can reduce costs in this way, since ETGS allows fuel savings compared to current dual engine taxi operation. When an aircraft taxis between gate and runway, it burns a large amount of fuel. The problem is exacerbated when the size of aircraft (and thus the length of the flight) decreases, because of its relatively long time of taxiing. For an Airbus A320, for example, making a 500 nautical mile flight, it is estimated that EGTS will save up to 4% of block fuel costs, compared with standard taxiing procedures (Johnson).

Apart from improving economic and operational efficiency, this system is environmentally friendly through the reduction of carbon and other emissions during the aircraft taxiing. The deployment of one aircraft equipped with EGTS is equivalent to removal of 400 cars from roads in terms of the fuel use and CO₂ emissions, or 300 in terms of NO_x emissions (Johnson). Obviously, the system provides greater environmental benefits if installed on aircraft that operates many taxi operations each day.

Electrofuels

With the growth of aviation traffic and the demand for emissions reduction, the vision of fully sustainable aviation is becoming increasingly important. In this respect, energy sources have to be based on renewable energies and thus their utilization should not lead to any environmental footprint. In other words, emissions of greenhouse gas and local pollutants are not allowed.

Unlike other types of transport, electrically based aviation could not comprise a solution. In fact, the energy storage capacity for direct electrical energy in battery packs is severely limited. For this reason, alternative fuels like the so-called electrofuels have been studied over the years. They can be defined as a class of carbon-neutral fuels that are made by storing electrical energy from renewable sources in the chemical bonds of liquid or gaseous fuels (Goldmann, 2018). Their name stands to indicate the storage of electric energy within the molecular structure of gaseous or liquid suitable fuels.

They exhibit special properties, which make them better than fossil energy resources and direct electrical mobility. Firstly, they can be considered, like says the same definition, to be carbon-neutral. This is possible because electrical energy is itself carbon-neutral, and because

renewable sources like wind power or photovoltaics are used to produce it. This aspect may be a plus for electrofuels, compared to direct electrical mobility.

Although electric energy is assumed to become central in future sustainable transportation, there is a great limitation to overcome (for aviation in particular). Indeed, to date batteries are characterized by a limited on-board energy storage capacity; therefore, their physical boundaries will not allow an adequate energy density. The energy density of electrofuels is typically much higher than that of batteries. In particular, the issue of ‘energy storage’ is maybe the most important aspect of electrofuels, which makes them better than batteries.

Furthermore, this aspect of ‘energy storage’ enables electrofuels production and utilization at different times and places, thus exploiting as much as possible the fluctuating availability of renewable sources.

Another important property of electrofuels is their CO₂ neutrality, although some emissions might be possible during the ground-based storage process of energy in the fuel, because of the use of renewable power sources. Obviously free of carbon electrofuels like H₂ or NH₃ are CO₂ neutral, but the same can be said for electrofuels based on the hydrocarbon structure. This is possible considering the carbon emitted with combustion in-flight, the same taken from the atmosphere during the production process of this fuel. Finally, electrofuels are suitable for aviation thanks to their good storage and transportability properties.

CCOs and CDOs

Continuous Climb and Descent Operations (CCOs and CDOs) are operating techniques, which lead to major environmental and economic benefits. They are flexible and optimum flight paths enabled by airspace and instrument procedure design and facilitated by Air Traffic Control. CCO and CDO are respectively referred to departing and arriving aircraft, allowing it to climb and descent continuously, to the greatest extent possible.

More specifically, CCO allows departing aircraft to employ optimum climb engine thrust and climb speeds before reaching their cruising levels. CDO, on the contrary, allows arriving aircraft to employ minimum engine thrust, in a low drag configuration, in the section corresponding to the descent, except its final segment.

As a result, aircraft spend more time at more fuel-efficient higher cruise levels, thus removing time spent at inefficient intermediate altitudes. This is a great result since it leads to a large reduction in terms of fuel burns, associated costs, and pollutant emissions.

In 2018, EUROCONTROL undertook a wide CCO-CDO study at selected European airports, based on standardized definitions and parameters for measurement. The results of this study revealed that the benefit pool of optimizing CCO-CDO in Europe could result in fuel savings of up to 340000 tons of fuel per year for the airlines (>1 m tons of CO₂) or about 150 million € in monetary savings (Bastin).

Noise reduction

CDA

Continuous Descent Approach (CDA) is an automated arrival procedure designed to landing aircraft. It represents an alternative to the conventional approach. This latter provides for aircraft to descend from 6000-7000 feet to an altitude of typically 3000 feet, and then the aircraft would fly level for several miles before the final descent. This means for the pilot the application of additional engine power in order to maintain constant speed during the period of level flight.

As shown in fig. 13, a CDA procedure is recommended because it avoids any level segments of flight before the glide path. In contrast to a prolonged level flight, a continuous descent requires significantly less engine thrust, thus without the deployment of flaps and landing gear.

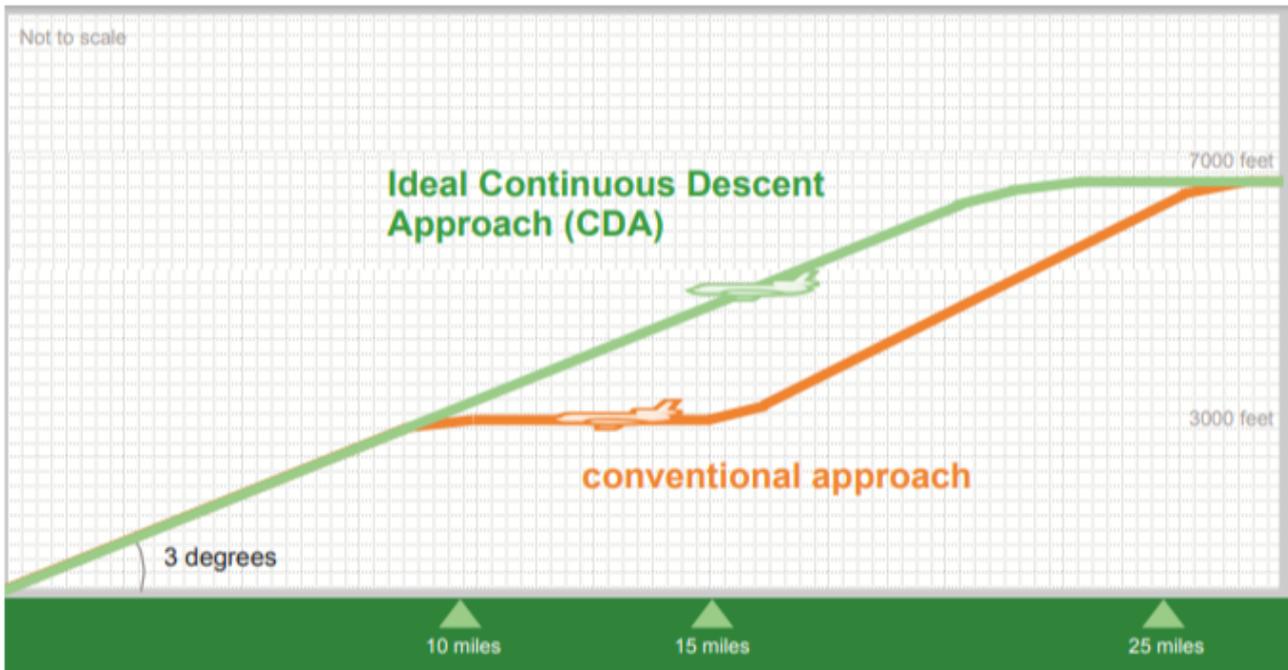


Figure 13: Comparison between a CDA and a conventional approach (Environmental Research and Consultancy Department)

For these reasons, CDA is an environmentally friendly solution. Firstly, the use of less engine power leads to fuel savings and reduced emissions. However, the major benefits are in terms of noise reduction. CDA is able to reduce noise impacts on communities located under the approach path to a runway since the aircraft is higher above the ground for a longer period. A further noise reduction on the ground is possible because CDA does not require the additional engine thrust, typical of the conventional approach. More specifically, procedure provides benefit to communities located 7-15 miles from airport (ACRP, 2009) and, depending on the location and aircraft type, the noise benefit from a CDA compared to a conventional approach could be up to about 5 decibels (Environmental Research and Consultancy Department).

Preferential runway use program

A noise abatement procedure available to an airport is by establishing a preferential runway use program. The aim is to minimize noise impacts on nearby residential areas. Through this program, an airport indicates selection procedures for the use of each runway. It can be either voluntary or mandatory. It is particularly suitable for areas along the approach and departure

routes. So overall, this program manage the noise energy present in those areas through the management of the number of aircraft, which fly over. This leads to noise abatement and thus relief to the population under the preferential routes of flight. This program can, on the one hand, be for the benefit of those people who are not overflown, but, on the other, can create discomfort of those who are overflown. For this reason, the program must take into consideration the correlation of noise exposure to population densities, in order to evaluate the number of person exposed and the different levels of noise under the routes of flight. Wind availability is a key factor for the program. Indeed, a preferential program may indicate his preferred runway only when wind conditions are favourable and runway length is adequate. In the case of a voluntary program, an important role is entrusted to the pilot in charge of the aircraft. In this case, the prerogative as to whether to follow the program suggestion or not rests with the pilot. Therefore, anything can happen with the pilot using another runway for safety purposes, however causing delay to the operations. Finally, preferential runway use program can be limited to off-peak or night-time hours, in order to achieve greater benefits in noise abatement for operation of the airport.

Ground operation techniques

Airport can establish a voluntary program with the aim to restrict the use of thrust reverse. The latter helps jet aircraft to slow down just after touchdown, and it is able to reduce wear on the brakes. However, it may increase noise levels in the direction of the landing. For this reason, airport can ask the pilot, through the voluntary restriction, to limit the use of thrust reverse, utilizing the entire runway for arrival. In this case, it is the pilot's decision, on the basis of weather conditions, runway surface conditions and runway length. In general, this measure benefits those person who live lateral to the runway, being most exposed to the increased noise levels during the use of thrust reverse.

Ground run-up activities can be very harmful for people who live in the surrounding areas of airport. Activities may vary according to duration and power settings, but generally, they may be irritating. For example, an engine repaired during the night-time must be tested in a late night or early morning, in order to operate an early morning flight. This contributes to break the overnight silence and disrupt the sleep of residential populations. For this reason airport can restrict ground run-up activities through lease agreements, rules and regulations. These

restrictions may concern presence, time, duration, power settings or location of run-up activities, and generally benefits the airport neighbours.

The use of single engines or idle taxi power for taxiing is an important step towards achieving noise reduction. Therefore, an airport may request aircraft operators or pilots to use one engine for taxi operations, in order to reduce noise along taxiway routes.

Noise barriers

The use of sound barriers or berms is an effective measure for noise abatement. These barriers are able to interrupt the flow of sound between the source and the sensitive receivers, in order to confine the noise impact to nearby areas.

Ground Run-up Enclosure, also called GRE, represents an example of these technologies. This is a special type of barrier, acoustically and aerodynamically designed. It is a three sided, open top, steel facility, fully lined with acoustic panels. It is generally placed in engine maintenance areas, where noise impact is great and often produced at night. Although standard aircraft maintenance is required and regulated, noise from aircraft engine tests (also called engine run-ups) at airports can contribute to noise impact. GRE is able to dramatically dampen the acoustic impact from high-power engine run-up inspections conducted by mechanics. A noise impact abatement on the surrounding area and community is possible since GRE absorbs parts of engine sound. Toronto city airport has implemented a Ground Run-up Enclosure as one of the key infrastructure (fig. 14). GRE is one of the most important technologies in terms of noise level reduction. Indeed, there are documented cases where the noise level reduction at the airport boundary from a GRE is as much as 20 decibels (ACRP, 2009).



Figure 14: PortsToronto's GRE (PortsToronto)

Airport access restrictions

The restriction of airport access is a feasible option to abate aircraft noise. Each airport may adopt its strategy by restricting aircraft access or operations. Cumulative noise impact, certificated noise levels, single event noise levels or time of day may be taken into account to restrict airport access. It is possible to prohibit the access of certain areas of the airfield, including runways. An airport can deny access to an aircraft exceeding a given noise level while at the same time allow to operate freely to one producing lesser noise levels. There are different types of access restriction.

Aircraft can be categorized based on type or class, and for each one the access may be allowed, limited or prohibited.

The restriction in terms of time of day is the most commonly used. Also called curfew, it distinguishes and limits operations based on type, noise level and aircraft class. An airport chooses the time of its curfew, generally from 10 p.m. to 7 a.m. or from 11 p. m. to 6 a.m. .

Weight and size of aircraft may be taken into account to operate restrictions. Furthermore, an airport can limit the access on the basis of certificated noise levels for aircraft, or apply penalties against aircraft exceeding the established levels.

A particular initiative is the definition of noise budget. This is the total noise energy present at airport, thus each operation owns part of this. In this mode, airport assign higher values of

noise to those operations taking place overnight, in order to limit such operations. At the same time, an airport may encourage the operations using the quietest aircraft during daytime periods, since these receive lower values of the noise budget.

Finally, airport can apply a noise level based operating fee, taking into account the noisiness of the individual aircraft. In this mode airport promotes the use of quieter aircraft, at least to prevent noise-induced expenses.

Energy efficiency

SAFs

The adoption of sustainable aviation fuels (SAFs) by airlines is one of the most important options to significantly reduce the industry's carbon footprint and also reduce the dependency on the petroleum industry.

Also called drop-in fuels, SAFs are a clean substitute for fossil fuels. They are obtained from bio-based feedstocks other than petroleum, so as to reduce carbon intensity and thus mitigate the environmental impact of aviation. Woody, biomass, hydrogenated and fats oils, recycled waste are examples of SAF's sources. In order to use these fuels in aircraft operations, SAFs must have comparable performance to fossil fuel. For this reason, during the combustion process, they have to meet strict fuel specifications. Consequently, key environmental benefits can be achieved during their production process.

Because of their 'drop-in' characteristics, these bio-based aviation fuels can be blended with fossil jet fuel at a blending ratio depending on how the fuel is produced. Once it is blended, fuel needs a certification proving that it has the same characteristics and meets the same specifications as fossil jet fuel. Furthermore, the blended fuel does not require special infrastructure or equipment changes.

Since the first commercial flight operated in 2011, more than 150000 flights were powered by SAF (SkyNRG). To date, the American Society for Testing and Materials (ASTM) has

developed and certified six production technologies of bio-based aviation fuels, blended with conventional aviation fuel.

These technologies vary based on the feedstock, production pathway and blending ratio. Any feedstock-technology combination may be considered, on condition that SAF meets both the technical specifications and sustainability criteria.

The key benefits due to the use of SAF may cover different aspects, the most important of which is the reduction in greenhouse gas (GHG) emissions. While a conventional jet fuel release additional carbon (previously stored in reservoirs), with the use of SAF the CO₂ emitted can be absorbed from the atmosphere during biomass production. This leads to a CO₂ emissions reduction, and, consequently, to an improvement of local air quality. Furthermore, SAF can reduce PM and SO_x emissions compared to fossil fuels. Additional benefits may concern economic and social aspects. Using SAF, it is possible to increase a region's energy security, to reduce fuel price volatility and also to create job and economic development.

Solar installation

Because of its conformation, airport represent the perfect location for solar electricity generating installation. Indeed, it is possible to build solar installations exploiting the large and flat surfaces on the ground and on the top of airport facilities. This allows the airport to generate renewable energy on-site and to benefit from the associated carbon-free energy. The design and the siting of such installations require careful study by engineers in order that reflected sunlight does not blind controllers or pilots.

The Athens International Airport (AIA) is one of the world's best and most innovative in this field. The solar panels are placed on fixed structures in order to withstand strong winds and hail, and have a very low reflectivity factor. This photovoltaic park produces more than 13 GWh of emission-free electricity per year, to provide around 25% of the complex's electricity needs, leading to an average annual CO₂ emissions reduction of 11500 tons (Aviation benefits beyond borders).

This solar project has been taken as a reference point in Greece for the photovoltaic revolution in the years following. And on top of that, AIA is planning to eliminate all ground-based carbon emissions by 2025. Also called Route 2025, the project does not concern emitters of

carbon such as airplanes and passenger cars, but has the goal to meet all of the airport's electricity needs from renewable energy and storage. In this regard, this action program leads to a development of on-site solar power generation and energy storage facilities to meet the international airport's electricity demand, which makes up 91,1% of AIA's current carbon footprint (The National Herald, 2019). The commitment also concerns the search of sustainable alternatives to the airport's other fuel consumption requirements. In case of success, AIA would be the first in Europe to accomplish the goal of 0% carbon ground operations.

Geothermal energy

A growing number of airports heat terminals and other buildings using geothermal energy. This is thermal energy generated by geological heat sources and stored in the Earth. It can be considered as an alternative and renewable energy. It is possible to consider geothermal power like a renewable energy since any projected heat extraction is small compared to the Earth's heat content. Furthermore, geothermal is an example of sustainable power. In fact, the use of geothermal sources of energy respects the principle of sustainability, namely will not endanger the capability of future generations to use their own resources. It is also able to sustain the Earth's ecosystems, and mitigate the global warming thanks to low emissions. A key environmental benefit is the reduction of CO₂ emissions by the geothermal electric plants, in comparison with conventional fossil fuel plants.

Reus airport has pioneered the implementation of a system for geothermal air conditioning in all Spanish airports. The system is located in the aerodrome fire station and exploits thermal energy of the ground for air conditioning installations. Thus, it is possible to collect data and information related to energy saving. The study of this installation has demonstrated the feasibility of such system in other Spanish airports, since the energy saving has been estimated about 50% compared to traditional systems. Furthermore, a careful review of the management and the maintenance of the airport facilities and services has led to a reduction of energy consumption by 24% in just one year (Interempresas, 2013).

Another meaningful example of such technology is represented by the three airports in Paris. Indeed, geothermal energy is one of the most important drivers, which allowed a CO₂ emissions reduction by up to 63% from 2009 to 2016. Since 2011, its use has lead Paris airports to achieve important environmental results. More specifically, geothermal heating of Paris-Orly Airport buildings accounts for 70% of total heating. Its implementation has avoided the emission of approximately 9000 tons of CO₂ per year, and has reduced gas consumption by 4000 tons of oil equivalent per year, which is comparable to the annual heating of 3200 homes. The system consists of two wells drilled to a depth of 1800 meters. The water comes up at 74 degrees Celsius, in order to meet the heat requirements. The overall district heating system is about 35 km long and travels through 108 sub-stations (O'Halloran, 2017).

Wind power

Wind power is a renewable and sustainable energy, and it can be used to provide mechanical power through wind turbines. It may be considered a suitable alternative to fossil fuels because of its much lower environmental impact. With a view to the production of electrical power by facilities supplied by renewable sources, a growing number of airports is specializing in the exploitation of wind energy.

In this respect, in the year 2003 at La Palma airport entered into service a wind power plant constituted by two turbines, property of a state owned company called Aena. The latter simultaneously had a contract with the provider of electric power according to which the power company will meet the demands of airport buildings if two wind turbines cannot, while any extra energy produced will be used to supply other costumers. The results were impressive, since La Palma became the first Spanish airport to supply its own energy, which consequently results in significant cost savings of airport operations. More specifically, between 2005 and 2008, wind turbines produced energy equivalent to 66-95% of the total amount of energy consumed at the facilities owned by the Aena. At La Palma airport, two wind turbines provide most of the energy need of the facilities, they do not disturb the air navigation, and, from 2003 to 2008, they prevented the emission of about 6800 tons of CO₂ (Aena, 2015).

Water and soil conservation

Water consumption metering

The airports goal of achieving the efficient use of water resources begins with a systematic control of the operations and sectors, which require the use of water. Everything starts from a water metering across the entire distribution net, in order to control the water consumption and identify any leaks or losses. Many such actions have been implemented by airports around the world over the years. In general, airports' efforts are based on the control of water use (in particular potable water), water demand and leaks. In most cases, the solution consists of developing a monitoring program through which a real-time control can be performed. More specifically, this system produces operational data (for example, of distribution networks of drinking water) which are delivered to a technology centre, enabling a rapid reaction in case of anomalies.

The Brazilian airport of Confins implemented in 2012 a model consumption management system. It allows you to real-time monitor the consumption of 48 metering points, through an evaluation of data by a software. Thus, it is possible to assess if water consumption is as expected, and to identify any anomalies or leaks. All these things are thoroughly assessed in a report, where are indicated specific policies and measures in order to reduce consumption (de Castro Carvalho et al., 2013)

Water saving sanitary fixtures

Airports can save water and encourage water conservation replacing their conventional sanitary fixtures by water saving equipment. It is possible, for example, thanks to replacing toilets or urinals with ones requiring less water consumption. This can lead to a water saving per flush, so the more the airport is busy, the more the water saving will be greater. Furthermore, the resulted potable water saving guarantees a return on investment in a very short period. Flow limitation equipment on faucets, waterless urinals, sensor-operated washbasin faucets, dual flushing mechanism are examples of water saving sanitary fixtures, able to save thousands of cubic meters of water every year, million litres of drinking water

each year, and to reduce water wastage from toilets. They are likely to significantly increase in importance in the future since they are a requirement in the design of any new buildings at many of the world's leading airports.

Water reuse

Water reuse is, from a general point of view, an environmentally friendly alternative since it allows to use raw material in a rational and smart way, overcoming increasingly stringent environmental restriction. The commitment of professionals has led to the development of technologies for wastewater treatment enable reuse and environmental sustainability. Consequently, this allows protection and maintaining of surface water resources and local economic development, among other social, economic and environmental benefits. However, water reuse must never lose sight of the preservation of users 'health and the consistent compliance with quality requirements related to the use.

Regarding airports, it is possible to use rationally water through rainwater, greywater, seawater and wastewater reuse. However, the implementation of such technologies in airports should be strictly monitored since commercial air transport can spread communicable diseases.

Rainwater use

Rainwater harvesting is becoming increasingly important worldwide since it is a technique that allows to combat the qualitative and quantitative scarcity of water resources and to reduce costs by using rainwater in different types of activities.

In this respect, airports represent great potential for storage of superficially drained water during the rainy season, because of their large amount of the areas of waterproofed soil. However, in most cases, this water shall be treated since it may contain chemicals, which have negative effects on the environment. For this reason, rainwater use is subject to a

comprehensive study of the available technologies eliminating pollutants, and their economic feasibility.

Fraport AG is a transport company, which operates Frankfurt Main Airport and holds shares in the operation of different airports around the world. Overall, it operates a storm water network with a length of approximately 200 km, 23 rainwater containment basins with a storage volume of 100000 m³ and 47 light liquid separators (Fraport AG, 2010).

In two of the Paris airports, it is possible to find a rainwater treatment plant. In particular, Orly airport saves 70000 m³/year of potable water since rainwater is used to supply the air conditioning system, the heating network and partially also the fire control (ADP, 2010).

Another option is to capture water run-off from the roof in order to irrigate using the water collected. In Narita, greywater produced by rainwater treatment facilities are used as chilling water, auxiliary supplies to the central heating and cooling plants, and also for flushing in the passenger terminal toilets (NIAC, 2011).

London Heathrow Airport has implemented the biggest rainwater-harvesting scheme in Europe. Thanks to this, the airport collects 59 m³ of rainwater each year, with the potential to reuse around 85% of the rainfall, providing Terminal 5 with 70% of its non-potable water needs (LHR, 2010).

Greywater reuse

Greywater reuse is one of the most important alternative for reducing potable water consumption. A segregation at source of the effluent generated in a building allows to separate greywater from domestic sewage, in such a way that it is possible to treat and reuse greywater. The latter presents a lower pollutant concentration compared to domestic sewage since it comes from lavatories, washing machines and kitchen sinks. For its recycling, greywater must be treated with physical, chemical and biological processes able to remove suspended solids, organic materials and surfactants.

Greywater reuse is a common technique at worldwide airports. In 2010 Hong Kong Airport treated 1,4 million m³ of greywater collected from aircraft catering facilities, terminal building kitchens and aircraft washing activities, meeting all of the airport's landscape irrigation needs

(HKIA, 2011). Another option is, as in the case of Narita airport, to use treated greywater as flushing water in the passenger terminal toilets.

Seawater reuse

Seawater reuse may be a viable solution, but a number of assessments are needed in this regard. Firstly, saline water must be subjected to proper and onerous treatment in order to remove substances, such as sodium chloride, which are non-desirable for reuse purpose. Furthermore, this technique only makes sense for airports situated near the coast.

The most significant example is Hong Kong Airport, which uses 380000 m³/d of treated seawater for aircraft lavatory waste, toilet flushing and the cooling system. This allows airport to save \$500,000/year (HKIA, 2011)

Wastewater and sewage effluent reuse

Wastewater and sewage effluent reuse is a potential solution to supply the increasing water shortage, since the reclaimed water can be used for irrigation, toilet flushing, cleaning, industrial reuse and environmental enhancement (Isabella de Castro Carvalho, 2013). However, careful analysis and research is needed to evaluate the quality of the effluent produced after sewage treatment, since it may contain pathogenic microorganisms that are hazardous for human health.

Airports around the world have done a great deal to adopt similar practices over the years. A virtuous example is that of Sidney airport, the water treatment plant of which allowed to save in 2011 an average of 580 m³ of fresh potable water each day. Future projections indicate that such data is expected to increase up to a maximum of 1000 m³ per day over the next 20 years. The water treatment receives raw sewage from the International Terminal and its surroundings, and produces two streams of recycled water. One directs recycled water to the International Terminal in order to flush 526 toilets and 212 urinals. The other stream allows to use treated water in air conditioning cooling towers of the Central Services Building (SYD, 2009b).

Waste management

Waste hierarchy

Airports activities produce substantial volumes of waste. Towards reducing their carbon-footprints, the issue of waste management is becoming increasingly important because of the growing number of passengers.

For this reason, Airport Council International's (ACI) provides a decision hierarchy for waste management at airports (fig.15). It is a range of waste management solutions, sorted according to the preference. The primary goal is to avoid as much as possible solid waste generation, but it is also advisable to extract value from remaining waste, in a way that no waste is sent to landfills. The opportunities of waste recycling at the airport and the generation of potential revenue from airport waste can lead to a cost savings and environmental benefits. As it is not possible to completely avoid waste generation, airports can reduce it. A more economical use of materials can lead to a waste reduction, which contributes to cost savings and airport sustainability since transportation emissions and energy necessary to process waste are reduced. Waste reuse and waste recycling are similar environmental options and allow airports to recapture energy and materials and to reduce residual waste and also the demand for new materials. Non-recyclable waste materials can be subject to the process known as "waste to energy". Also called waste recovery, it makes it possible to use this waste as a kind of fuel able to supply energy. Thanks different processes such as combustion (incineration), anaerobic digestion, gasification and landfill gas recovery, airports can get the generation of energy in the form of heat, electricity or fuel. An environmental benefit is the production of a cleaner source of energy compared to conventional sources, which leads to a reduction of the need of fossil fuel for energy and of the total carbon emissions. Finally, waste disposal is the last solution to consider. Indeed, some airport waste must be disposed of in landfills since it cannot be handled in other ways. It is better to avoid as much as possible waste disposal since it does not allow the recovery of materials and energy from waste (ICAO).

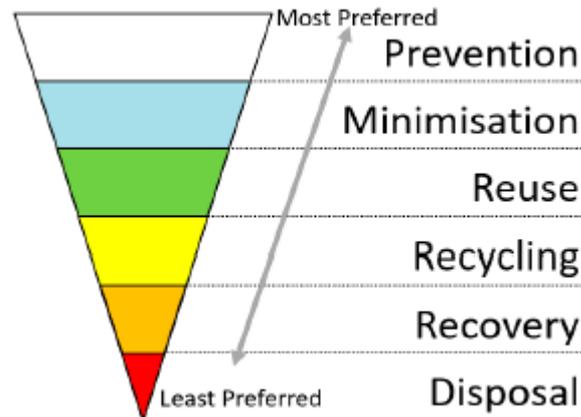


Figure 15: Waste management hierarchy (Baxter et al., 2018)

Cabin waste

The term of cabin waste includes two main categories of waste: cleaning waste and catering waste.

The first group is constituted by leftover rubbish from items given to passengers, such as newspapers, paper towels, plastic bottles, food dropped on the floor, amenity kits and plastic wrapping from blankets and pillows. It also includes the contents of washrooms bins and medical waste such as used syringes.

On the second group there are leftover food, drinks and packaging from inflight meals, snacks and beverages served to passengers. Also called galley waste, it is placed back in the trolleys, in static or compactor bins, and it can contain high volume of liquid from unconsumed beverages and ice.

Cabin waste management is encountering a rapidly growing interest on the part of airlines and airports, towards a reduction in their environmental footprint (IATA).

In this respect, London Gatwick Airport became the first airport worldwide to implement a plant onsite that converts cabin waste into energy. This is a waste-to-energy plant able to turn airport waste such as food and packaging into energy on site. More specifically, the plant disposes of category 1 waste, which comprises food waste or anything mixed with it, such as packaging, cups and meal trays from non-EU flights. The energy won from that will be used

to heat Gatwick's waste management site and power the site's water recovery system. Based on companies' data, it has been estimated that the plant will save £1000 in energy and waste management costs each day it operates. Before putting the plant into service, airport had to transport all category 1 waste offsite in order to incinerate or render it, incurring hauling fees and vehicle emissions. Today, however, airport treats 2200 metric tons of category 1 waste each year (around the 20% of the total generated at the airport). Since the growing generation of cabin waste impacts on the financial position of airlines, the plant becomes essential to reduce environmental footprint and to save airlines money. Towards an increase of its recycling rate, the plant includes a waste-sorting center. The positioning of all activities in one location makes waste transport more efficient, thus reduces local traffic and carbon emissions (Hardcastle, 2017).

Waste signage

At airports, it is possible to increase recycling rates and to reduce contamination using an adequate and consistent waste signage. In fact, thanks to a recognition of colors, icons and terms, airports' users can quickly sort their recycling.

Airports have to overcome the lack of international waste signage standards by promoting the use of a general signage easily identifiable by stakeholders, staff and, above all, international passengers. The problems of linguistic understanding can be overcome using easy to understand icons. Obviously waste signage has to be consistent for all facilities and points of collection and delivery at the airport.

Waste recycling

Municipal Solid Waste (MSW) and Construction and Demolition Debris (CDD) are the main airport waste which can be collected and reprocessed into something new, generally at the airport. However, recycling operations vary based on several types of waste involved. Overall, recycling is an environmental friendly operation, since it allows to reduce energy consumption, greenhouse gas emissions and landfilled waste.

MSW involves materials such as glass, aluminium and paper pulp, which can be reprocessed into new materials. In particular, it has been shown that the recycling of aluminium can lead

to very large environmental and energy benefits, although this material accounts for only 1% of the aviation industry's waste stream. Over the years large airports has made a growing commitment to recycle MSW. Every airport organizes and manages the recycling process in its own way, depending on its policies, space for trash compactors, operational requirements. In order to streamline operations, airport can separate recyclables and all other waste, using bins marked with images that show what should go in them. Airports may encourage recycling offering prizes and recognition. At times tenants arrange their own waste disposal at airports, but the best solution for MSW recycling is the centralization of all waste for disposal for the entire airport. In this way, it is possible to handle more waste and to lower hauling fees for larger loads.

CDD recycling process is very different from that of MSW. It allows airports to achieve substantial financial savings by reusing materials such as concrete and asphalt. In this respect, airports have to engage contractors in the process and produce an early planning indicating standards, specifications and goals. Information useful to track and manage CDD effectively can be found into an airport's Environmental Management System or sustainability plan. Reuse and recycling are encouraged through a financial bonus into contracts, when goals are met. Before purchasing new materials, recycled materials must be taken into account by airports and their contractors. Concrete and steel with high-recycled content are increasingly being used. Whenever materials cannot be reused onsite, airports may donate them to a charitable organization for reuse, in order to minimize wastes and benefit others in the community.

Anyway, behind all of this, there must be a careful analysis by the airport with regard to recycling and reuse costs (i.e. costs for hauling, processing and disposing of materials) compared to potential cost of landfilling waste (ICAO).

Landfill and incineration

Some airports have landfills and incinerators to manage waste onsite, at least saving on waste transport.

A landfill is an area of land where waste is disposed of, and having it onsite may bring economic and logistic benefits to airports. However, it is well known that landfills attract birds, creating the risk of collisions between birds and aircraft.

At the same time, airports may have incinerators for waste management. Although, along with landfills, they are not advisable to dispose of waste, new technologies allow airports to recover the heat energy in the waste.

The placing in service of landfill and incinerators onsite needs some considerations. In fact, vehicles and routes necessary for waste transport must not disrupt aircraft operations. Furthermore, facilities shall be set out so as to not be in the way of flight paths into or out of the airport. Finally, incinerator stacks must comply with technical (minimum heights) and environmental (emissions) requirements, in order not to compromise aviation safety and aircraft flight performance (ICAO).

5. INTERMODAL TRANSPORT

Transportation, as we have said, represents one of the most significant contributors to economic growth and social development, but at the same time may have major environmental impacts. For this reason, it is subject to ever more stringent regulations in order to reduce or minimize its environmental footprint and fossil fuel energy consumption. The aim is to make transport system sustainable, facing the challenge of demand increase without affecting the quality of service.

In this regard, intermodal transport may be a good solution. It consists in the integration of different transportation networks by using multiple modes of transportation. According to studies and experimentations, intermodal transport can enhance overall performance by using more environmentally friendly modes. It is applicable to both passenger and freight system, through the interconnection between air, water and land transport.

Intermodal freight transportation

Intermodal freight transportation allows to transport goods from shipper to consignee using two or more transport modes. The goods are transported within large rectangular boxes called containers, which are made of steel. These durable containers are standardized in order to be easily transferred and secured to special trailers between different modes of transportation, such as trucks, freight trains and ships. In the majority of cases, intermodal freight transportation includes rail, truck, ship and then truck. In particular, the term drayage is used to indicate the form of trucking between the rail terminals and the ocean ports.

An ideal scenario to which the intermodal transport aims can be described by a simple example. An empty container is transported by truck to a shipper, in order to pick up a load. At this point, the loaded container is taken by the truck to a railroad yard, and is then put on a train in order to reach its final destination. Once arrived in the designated city, it is transported by truck to the consignee, where it can be unloaded. On this way, the empty container is ready for another load (AG, 2017).

Overall, intermodal is the right choice for the shipment of goods in load units of less than 25 tons, of freight moving more than 300 miles, and when cargo flow needs to be continuous and in similar quantities.

Different benefits may arise from the intermodal transportation selection.

First, intermodal transport is scalable and flexible. Since a single train can move the equivalent load of 280 trucks, it is possible, utilizing an intermodal framework, to scale logistical operations and to send shipments in response to varying demands.

Intermodal transport is time efficient: its schedules and transit times are subject to less distractions and delays, compared to other transport modes.

The economic aspect is one of the most important issue. As already mentioned, a single train can move the equivalent of 280 truckloads, so intermodal transport is more fuel-efficient, helping shippers save 15-20% on shipping costs. Furthermore, because of the double stacking of containers, a train can carry greater loads, resulting in increased productivity and fuel and freight efficiency.

The reduced use of fuel has implications for the environmental issue, so intermodal is environmentally friendly. It makes it possible to improve carbon footprint, through the reduction of greenhouse gas and carbon pollution.

Compared to road transport, railroads are considered as a safer mode of transportation for hazardous materials.

The economic aspect also concerns the issue of drivers. The road transport is more expensive than intermodal transport since it requires a greater number of drivers and it is affected by a possible shortage of them. On the contrary, intermodal transport optimizes drivers 'capacity, reducing their cost.

Shipping via rail is much safer than road transport, so involves less collisions, fatalities and thus less risks of damages and loss to the goods and more efficient operations.

Finally, a shipment traveling via intermodal is easy to monitor thanks a cloud networked platform which monitor, collect and assess data of the combination of different modes and carriers (AG, 2017).

Dry ports

The continuous growth of container transport volumes has led to consequences that deserve attention. Indeed, an inland flow has come about, comparable to the sea flow, thus creating criticalities in the links with hinterland and in the seaport inland access.

In this respect, a potential solution could be to develop dry ports, in order to reduce the seaport terminal congestion thanks to intermodal transport with dry ports. In general, establishing intermodal logistics centres should contribute to the promotion of regional economic activities, and to the improvement of inland access and local goods distribution. More specifically, inland intermodal terminal (dry port) has a direct rail connection to a seaport, so customers can leave and/or collect their goods, as if it were a seaport. Indeed, dry port can provide services similar to those of seaport, such as storage, depot, track, maintenance of containers. Although intermodal transport is generally considered to be viable on longer distances, in the case of inland intermodal transport the distance must take account of cost of congestion, competition between seaports and growing environmental constraints. Therefore, being very market dependent, inland intermodal transport is often based on short haul rail.

The innovative concept of dry port is movement of seaport's interface inland with shift of flows from road to rail. The immediate consequence is the reduction of road transports to/from the seaport.

The dry port's efficiency is reflected in the quality of access to it and of the road-rail interface. Anyway, everything is subordinated to a scheduled and reliable high capacity transportation to and from the seaport. The latter can benefit from the implementation of a dry port on its immediate hinterland since it can increase its terminal capacity and thus its potential productivity. Indeed, in the optical of intermodal transport, the use of one train can substitute some 35 lorries in Europe (Roso, 2009), leading to a significant reduction of the seaport's congestion from lorries, and hence to the possibility for bigger container ships to make port of call at the seaport. Furthermore, the reduction of the number of trucks on the road is synonymous with lower roads congestion, accidents, road maintenance costs and local pollution.

Everything is designed to create a seamless series of physical and procedural links, which means a smooth transport flow of containers, reducing as much intermediate steps as possible in the transport chain, so as to create a single contact point between seaport and dry port.

Much depends on the level of integration, which can be served by a greater proximity between the two ports, guaranteeing a higher degree of synchronisation. The development process of inland facilities varies according to the two different directions of development between seaport and inland node.

In particular, it is possible to define two types of development: inside-out and outside-in (Wilmsmeier, 2011).

In the former case, it is in the interest of dry ports to seek greater integration with their seaports, also benefiting from public body intervention. Instead, in the other arrangement, seaport authorities or terminal operators use an inland node as a tool to expand their hinterland.

The benefits of implementing of dry ports are numerous and may cover different fields. The modal shift from road to rail on the one hand is affecting road carriers, whilst, on the other hand, avoid the circulation of lorries through cities, reduce congestion of congestion at the seaport gates and external environmental impacts along the route. It also benefits the quality of life, due to the reduction of CO₂ emissions. Ultimately, it can be said that dry ports allow seaports to increase the throughput without physical expansion at the site (Roso, 2013).

Transport hub

A transport hub is an interchange point for passenger and freight using different transport modes. For this reason, it is also called transport interchange. Here it is possible to find train stations, rapid transit stations, bus and tram stops, airports and ferry slips, all part of public transport. Instead, freight transport can make use of classification yards, airports, seaports and truck terminals.

A representative example of this solution is the Trieste Airport Intermodal Hub (Fig. 16). It is one of the key objectives, which the Friuli Venezia Giulia region has specified in its regional strategic transportation plan, in order to connect transport systems nodes, and traffic flows. This strategic hub is the place of an easy and smooth air-rail-road modal interchange, in order to improve the accessibility to all the different transport mode. The facility offers the airport terminal, the new car parks, the bus station and the railway station, all connected with each other by a mid-air pedestrian walkway. More specifically, the project includes a new railway station, a 16 bay bus station, new car parks for up to 1500 cars and an internal road system. Local and regional mobility benefits from this modal interchange among all the

different modes of surface transport. The environmental issue is a priority for this solution. Indeed, the hub ensures a more efficient, integrated and environmental friendly transport system, helping to reduce the use of private car. Thanks to this facility, it is easier to access to the airport and, in general, to the whole region. Through the concept of “park-&-ride”, this hub allows travellers and commuters to reach Trieste and the other main centres of the Region in a more efficient, sustainable and thus environmental friendly way. In fact, this reduce road traffic and congestion, with all the benefits that this brings. The region as a whole is positively influenced, thanks to an easier access and thus to a tourist and economic development. With the entrance according to the facility, Trieste airport has become one of the eight Italian airport directly linked to the railway (Trieste Airport).

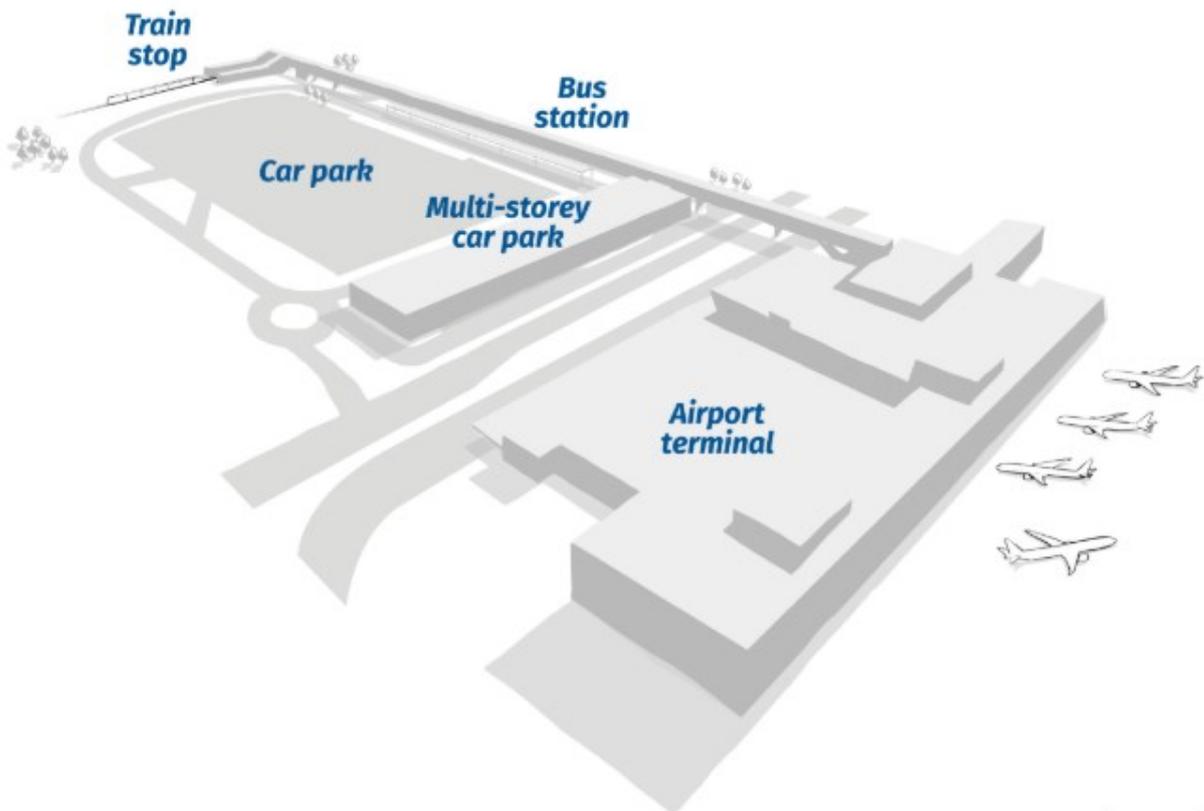


Figure 16: Trieste Airport Intermodal hub (Trieste Airport)

Bus on demand

In most cases, airports are situated close to densely populated areas. Because of the high traffic that its presence can generate, airports can implement smart transport systems.

In this respect, a good example is provided by Barcelona-El Prat airport. In 2014, the Spanish airport implemented what can be called 'bus on demand' system. The latter allows air travelers and airport workers to request bus service in an easy and fast way, such as by pressing a button at the bus station or by logging onto a website. This service encourages a direct link between the city park area and the airport. Local transportation is by urban buses, which link the airport with the city center of Barcelona, its metropolitan area and nearby towns. Among all of the bus lines included in this service, the most representative are the so-called Aerobus A1 and Aerobus A2. They connect directly (despite some stops by the city of Barcelona) downtown Barcelona with, respectively, Terminal 1 and Terminal 2 of Barcelona El Prat airport. The service is encompassed within the Barcelona Metropolitan Transport network (TMB), so through the use of an integrated card of transportation from TMB, it is possible to travel in different mode of transportation, such as bus and subway, or train and bus (BarcelonaAirport, s.d.).

Through the development of this cheap and popular way of transport, it is intended to increase the use of the public transportation among air travelers and airport workers, with the consequent reduction of environmental impacts and congestion, due to private cars.

6. CONCLUSIONS

Any kind of economic and industrial activities has a certain impact on the environment. In the last decades, the environmental issue has received increasing attention from researches, institutions and operators. The growing globalization is linked to a significant demand for aviation and shipping. Ports and airports have to follow the environmental and energy regulations for monitoring and reducing the negative impacts deriving from their activities and operations. The environmental impact caused by port/airport activities is significant because it concerns air pollution, noise pollution, water consumption, soil contamination, waste generation, energy consumption. Therefore, it is necessary to adopt tools and initiatives to minimize such negative environmental impacts. As a result, ports and airports undertake environmental protection projects to lessen the negative impact on the local communities. We analysed different cooperation and sharing of knowledge strategies and best practices between different authorities on environmental issues. However, port/airport authorities differ in objectives, financial capabilities, market power, skills and competences they can rely on when it comes to take action. Further, the present thesis focused on good practises aiming at developing a better communication and cooperation between ports/airports, local communities and their stakeholders. This is producing a more integrated approach to environmental management where ports/airports are influencing city and hinterland's initiatives, and more ports/airports are offering options to influence the greening of shipping and aviation industry. It may reasonably be concluded that intermodal transport is useful for authorities in achieving environmentally friendly and sustainable behaviours. It consists in the integration of different transportation networks by using multiple modes of transportation. Based on this thesis, we can say that the shipping/aviation sectors are able to provide substantive evidences that the environmental performance of these sectors are improving taking into account a wide range of issues such as air quality, climate change, energy efficiency and waste.

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