GREEN EFFORTS

Green and Effective Operations at Terminals and in Ports

FP7-285687

[D 4.3]
[Inventory and potential measures]

Organization name of lead contractor for this deliverable: [CML]

Due date of deliverable: [31/03/2013]

Actual submission date: [30/04/2014]

Call (part) identifier: FP7-SST-2011-RTD-1

Funding Scheme: Collaborative Project

Start date of project: 01/01/2012 Duration: 30 months

Revision: 1

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

DOCUMENT INFORMATION

[D 4.3]

[Inventory and potential measures]

Author(s):	FRAUNHOFER CML
Issuing entity:	FRAUNHOFER CML
Document Code:	2014 03 31 GREEN EFFORTS 4.3 INVENTORY AND POTENTIAL MEASURES
Date of Issue:	30/04/2014
Status:	
Revision:	1
Contributing Partners / Authors	
Pages	12
Figures	2
Tables	1
Annexes	0

Record of Changes

This is a controlled document for any changes and amendments done for the deliverable.

Amendment shall be by whole document replacement.

Version	Status	Date	Authorized by
0.1	Draft version – Consortium review		

TABLE OF CONTENTS

DOCUMENT INFORMATION ii
RECORD OF CHANGES iii
TABLE OF CONTENTS iv
LIST OF FIGURES v
LIST OF TABLES v
LIST OF ABBREVIATIONS v
Executive summary 1
1 Introduction 2
2 Inventories on a Container Terminal 3
3 Inventories on a RoRo-Terminal 4
4 Inventories on an Inland Waterway Terminal 5
5 Measures to reduce energy consumption 5
5.1 Behavioral measures 7
5.2 Technical measures 8
5.3 Organizational measures 11
6 Conclusions 11

List of Figures

Figure 1: Shares of electric energy consumption on a medium-sized container terminal........ 6
Figure 2: Shares of diesel consumption on a medium-sized container terminal 6

List of Tables

Table 1: Consumption values of container handling equipment........ 7

List of Abbreviations

AGV(s)	Automated Guided Vehicle(s)
CO_2	Carbon Dioxide
CPU(s)	Central Processing Unit(s)
ENMS	Energy Management System
EV(s)	Electric Vehicle(s)
GHG(s)	Greenhouse Gas(es)
HPS	High-pressure Sodium
HVSC	High Voltage Shore Connection System
IAPH	The International Association of Ports and Harbors
Ibd.	Short for ibidem, meaning "in the same place"
ISO	International Organization for Standardization
KW	Kilowatt
LED	Light Emitting Diode
MW	Mega Watt
NO_x	General Oxides of Nitrogen (NO, NO_2, N_2O_2, etc.)
OPS	On-Shore Power
PM	Particulate Matter
RMG	Rail Mounted Gantry crane
RTG	Rubber Tired Gantry crane
SO_x	General Oxides of Sulfur (SO_2, SO_3, etc.)
TOS	Terminal Operating System
US EPA	U.S. Environmental Protection Agency
Z.E., ZE, ze	Zero Emission

Executive summary

Major consumers of energy in container terminals are handling equipment, but also administrative facilities such as office buildings play an important role. Repair workshop, staff services, reefer storage, coldstores, warehouses, and lighting in the terminal area consume energy to keep the handling processes going on a terminal. As for RoRo and inland waterway terminals, their main work also consists of handling cargo using energy and enrich the environment with emitting particulate matter. This deliverable presents measures to save, reduce or produce energy, further defined as behavioral, technical and organizational measures. These serve to either reduce the consumption of energy, save energy entirely or even produce energy while handling cargo. The Deliverable is based on the findings of GREEN EFFORTS and, therefore, consists of information published in the Deliverables 3.3, 4.1 and 4.2[1], among others. It is designed to support terminals and ports which wish to get a greener energy balance in order to comply with legislation and the public's view on eco-friendly industrial sites.

1 **Deliverable 3.3**: Process Map RoRo Terminal (Restricted to a group specified by the consortium (including the Commission Services)); **Deliverable 4.1**: Energy consumption (Restricted to a group specified by the consortium (including the Commission Services)); **Deliverable 4.2**: Carbon Footprint Calculation Method (Not yet in final status).

1 Introduction

A terminal is a complex environment where many processes are executed in a parallel manner. Terminal equipment and terminal workers are both essential to carry out handling and storage processes as smoothly as possible. To achieve this, terminal equipment needs to be either fueled or electrified. This deliverable deals with inventories on a terminal and potential measures to reduce the energy consumption.

In general, ports have a great need for energy and can account for high amounts of energy used in a community. Related emissions of port operations include CO_2, NO_x, SO_x and other greenhouse gases (GHG). It is wise to assume a good potential for energy reduction in ports is given. Viewed from a global perspective, it is already quite obvious that many ports have tackled the challenge by implementing saving measures and projects to reduce consumption to comply with international climate treaties.

The structure of this deliverable is as follows: Part 2 lists all the inventories that can be found on a terminal, Part 3 shows options to reduce the input. Part 4 deals with the conclusions that can be drawn from the measures.

Potential measures are clustered in

- Technical measures, in particular use of hybrid or full-electric cargo transportation systems;
- Process optimization; and
- Behavioral and managerial changes.

When independently producing own energy with biomass the replacement of renewables with waste is a further measure that needs to be taken into account when proposing to tackle high energy consumption. Albeit, studies have shown that energy made of biomass still emits CO_2 since trees store it and then release it when the wood is burnt. The amount of freed CO_2 equals the amount the tree has absorbed during its lifetime.

Projects that are designed to establish energy reducing measures are initiated by ports, port cities and administrations, communities, nations and regions worldwide. A growing number of new initiatives is constantly evolving. The same can be said about new technologies. Therefore this deliverable can only provide a glimpse at the current measures and initiatives for a container, RoRo and inland waterway terminal.

Pollution can be manifold. In case of a container terminal the pollution can affect the (1) air quality by particulate matter and the (2) water quality by leakage of cargoes and rainwater run-off.[2] However, physical protection is required by regulations. A further pollution can be caused by noise, but this aspect is left out in the following discourse.

The findings of this paper base on the results of GREEN EFFORTS' Deliverables 3.3, 4.1 and 4.2 where energy consumers and suitable reduction measures were thoroughly introduced.

2 Marks, Richard: Making container terminals greener. Port planning for the 21st century – aspirations and innovations. 2012.

2 Inventories on a Container Terminal

Inventories on a container terminal comprise[3]:

Handling equipment

- Rubber Tired Gantry Cranes
- Rail Mounted Gantry Cranes
- Mobile Harbor Cranes
- Terminal Tractors
- Forklifts
- Straddle Carriers
- Ship-to-shore cranes
- Automated Guided Vehicles
- Reachstackers
- all types of marine auxiliary engines

Lighting

- HPS (High-pressure sodium) lights
- LEDs (Light emitting diodes)

Services (are usually the responsibility of ports)

- Reefer connections
- Waste Reception Facilities
- Shore-Based power supply

Other inventories

- Garages
- Office buildings
- Showers
- Canteen
- Vehicles tied to administrational issues (such as security vehicles, or staff shuttles)

3 For consumption figures please refer to Deliverable 4.1.

3 Inventories on a RoRo-Terminal

A RoRo-Terminal has some different equipment than a container terminal. It generally offers all services for rolling cargo. Consequently, RoRo terminal processes are rather uniform all over the world. Nevertheless, it needs to be taken into account that terminals are individually different depending on layout, equipment and hinterland connections. The arriving ships have their own ramp over which the rolling cargo is brought on / off board. The cargo that is handled can be either driven without further equipment (self-propelling cargo unit: e.g. cars, agricultural equipment, trucks, tanks etc.) or by RoRo-tractors (e.g. semi-trailers) on board / off the ship. The difference regarding the self-propelling cargo unit is about whether the units have own drivers (tourist cars, buses) or not (caterpillars). Rolling cargo without an own engine encompasses for example all kinds of caravans or trailers. To complete the cargo range, non-rolling cargo without own engines also is handled on a RoRo terminal (e.g. paper rolls or swap bodies). The necessary equipment of a RoRo terminal comprise:

Handling inventories

- Reach stacker
- Chassis
- Forklift
- Ramp
- Tug master (also called RoRo truck)
- Terminal trucks

Other inventories

- Vehicles tied to administrational issues (such as security vehicles, or crew transporter)
- Combi Terminal
- Garages
- Logistics centres
- Warehouses
- Canteen
- Showers
- Ship waste reception facilities (usually in the responsibility of ports).

4 Inventories on an Inland Waterway Terminal

An Inland Waterway terminal does not have direct access to the open sea. Consequently, it does not have access to water that is suitable for seagoing vessels. Thus, the vessels that arrive at the terminal are inland waterway vessels. Inland waterway terminals usually offer handling, storage, warehousing and can cater to trimodality by offering access to the inland waterway, rail and road. A direct connection to one or more sea terminals is also usually available. The processes on such a terminal include berth operations, quay operations, marshalling, stacking, interchange operations, gate processes, equipment maintenance, administration, off-terminal storage, special services and staff service.[4]

Handling inventories on an inland waterway terminal commonly comprise:

Handling inventories

- Mobile Cranes
- Gantry Cranes
- Reachstacker
- Forklifts

Other inventories

- Vehicles tied to administrational issues (such as security vehicles, or staff shuttles)
- Garages
- Logistics centres
- Warehouses
- Canteen
- Showers
- Ship waste reception facilities (usually in the responsibility of ports)

All of the introduced terminals produce CO_2-emissions, particulate matter and enrich the air with substances that are neither healthy for human beings nor for the environment. In order to reduce those emissions the following chapter *5 Measures to reduce energy consumption* will present ample possibilities to do accordingly.

5 Measures to reduce energy consumption

Probable saving and reduction measurements for port handling equipment and corresponding inventories that are debated throughout this deliverable include recuperation, hybrid technologies, power management, and electrification of equipment. First, to get an idea of the consumers on a container terminal, the most pressing consumption figures are shown in Figures 1 and 2.

According to Deliverabe 4.1, the main consumers of energy on a terminal are: (1) operational equipment and vehicles used at the terminal to handle containers, (2) office buildings, repair

4 Schwientek, Anne: GREEN EFFORTS. Deliverable 3.4. Inland Waterway Terminal Processes

workshop and staff services, (3) reefer storage (refrigerated containers), and (4) lighting in the terminal area.[5] It can be summarized that a total of 12 million kWh (electric power; not counting diesel) are needed by a medium-sized container terminal in a year. Figure 1 highlights the shares that apply to the identified core consumer[6]. It must be noted that the used data is not portraying a typical terminal. Usually, the percentage used for yard lighting lies at around 10 %.[7] Although electric energy itself does not cause any environmental impact, the production of it certainly does.

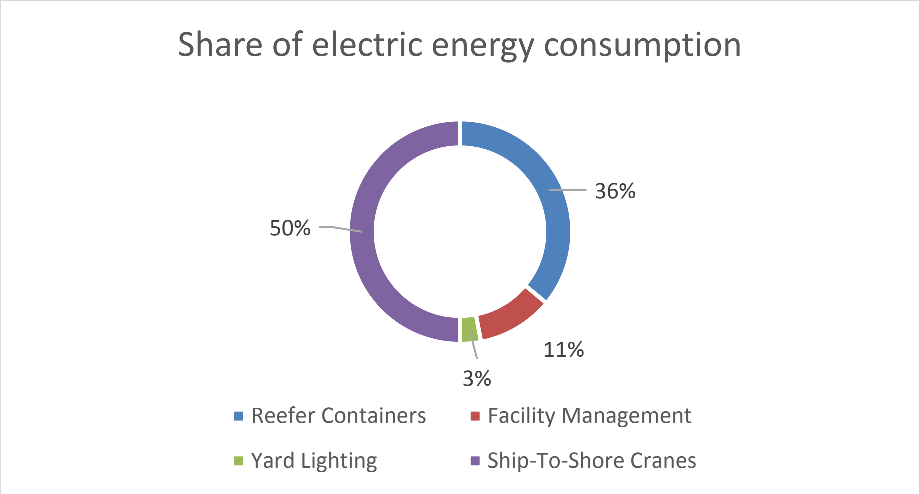

Figure 1: Shares of electric energy consumption on a medium-sized container terminal

As for diesel consumers, the total amount of diesel used by the inventories on a medium-sized container terminal is 3.1 million litres.[8]

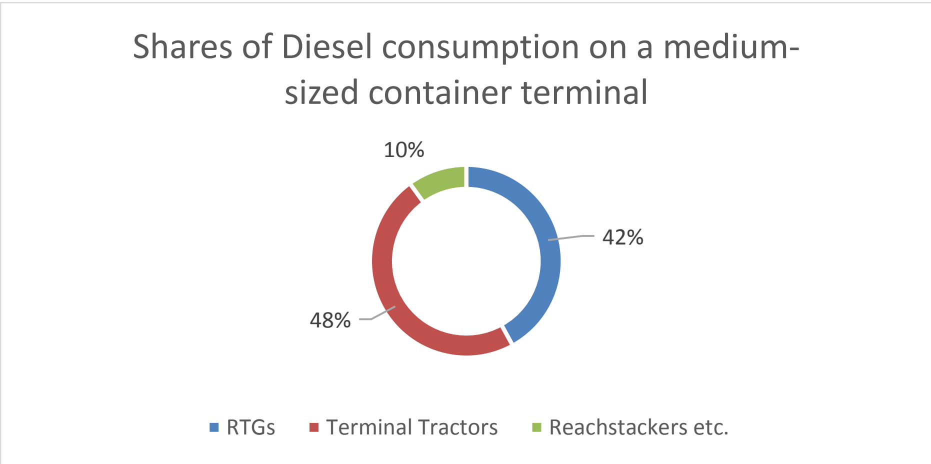

Figure 2: Shares of diesel consumption on a medium-sized container terminal

5 Moser, Jürgen; Lengkong, Indah: GREEN EFFORTS. Deliverable 4.1 Container Terminal Consumers.
6 Froese, Jens; Töter, Svenja: Reduction of carbon footprint of ports and terminals – fiction and reality, a conference paper submitted to GreenPort South Asia conference in Mumbai
7 Froese, Jens. 2014.
8 Ibd.

The following consumption values[9] (s. Table 1) of container handling equipment are calculated according to three different configurations of developed reference terminals within the course of GREEN EFFORTS.

Handling equipment	Energy source	Average Energy Consumption per hour
Automated Guided Vehicle	Diesel	12 lt/hr
ECH	Diesel	9 lt/hr
Quay Crane	Electricity	153 kWh
Reach Stacker	Diesel	15,7 lt/hr
Rubber Tired Gantry	Diesel	20,7 lt/hr
Rail Mounted Gantry (Stacking / Train area)	Electricity	107,5 kWh
Van Carrier	Diesel	20 lt/hr
Yard Train	Diesel	8 lt/hr

Table 1: Consumption values of container handling equipment

Now, having introduced the numbers related to a terminal, the next step consists of introducing potential measures to reduce those numbers in a sensible and rational manner. Measures can be either classified according to behavioral, technical or organizational means. Not all of the below mentioned measures are applicable though since they are either not yet well approved or too expensive to apply.

A distinction that needs to be made between the options to get a greener terminal is as follows:

(1) **Reducing** energy by using an inventory that consumes less energy (i.e. change from diesel to hybrid)
(2) **Saving** energy by avoiding redundant operations or drives (i.e. plan an optimized route with a TOS)
(3) **Produce** energy by i.e. recuperation or photovoltaic modules that are mounted on the roof of a garage.

All of the above help preventing the use of too much energy and the production of particulate matters when handling cargo.

The following approaches push reduction of energy consumption forward divided in (1) behavioral, (2) technical and (3) organizational measures:

5.1 Behavioral measures

The awareness of staff towards an efficient use of energy needs to be strengthened. This can be done by specific training or further education. Possible behavioral measures to be taken into account include[10]:

– Switch off the lighting while not working in that particular area at night or on weekends (activity-related yard lighting)

9 Lengkong, Indah: Greener Energy for innovative ports and terminals. Deliverable 4.1. Reference Container Terminal. 2013.
10 This list cannot be understood as exhaustive since further measures can always be developed.

- Avoid idle and redundant operations
- Using inventories only when they are actually needed (operational attitude contributes also about 10 – 20 percent of the total energy consumption[11]):
  - Heating
  - Air conditioning
  - Ventilation
  - Appliances
  - Diesel engines during shift change or break[12]
- Make sure to choose the most direct route on a terminal
  - Effective yard management systems (TOS)
  - Container Terminal Simulation Software
- Change of the mode of transport in a port using e.g.
  - barges to organize redirection of cargo
  - electrically powered freight trains

Even if the following measures do not apply to the areas of responsibility of a terminal, they are still mentioned to complete the list of possible measures related to handling of cargo:

- Prevent queues at the gate by
  - pre-notification of truck arrival
  - planning of slot
  - balance of yard equipment and internal transport
  - TOS / computer simulation[13]

5.2 Technical measures

Generally spoken, technical measures to reduce energy consumption comprise the usage of energy-efficient equipment with an energy classification of A or A+ (lighting, engines, generators).[14] Also, stand-by consumption should be closely monitored and if it cannot be reduced with technical measures, should be part of the awareness training of port personnel.

Apart from that, the following possibilities are also important technical measures to take into account:

ACTIVITY-RELATED YARD LIGHTING

Activity-related yard lighting can either be a behavioral measure or a technical measure. It is a technical measure when the activity-related yard lighting is handled automatically with motion sensors.

11 Corbetta, L. et.al., 2011, Energy and Environmental Efficiency in Port and Terminals, PEMA Information Paper, Port Equipment Manufacturers Association, London
12 Ibd.
13 Marks, Richard: Making container terminals greener. Port planning for the 21st century – aspirations and innovations. 2012.
14 Green Cranes: http://www.greencranes.eu/M2Report.pdf. 2013

HYBRID

Converting cargo handling equipment to hybrid electric drivetrains offers another option to reduce air pollution at ports. Although hybrid electric drivetrains raise vehicle costs substantially, they reduce fuel use, emissions and operating costs.[15]

BATTERIES

Future applications look for the utilization of batteries in prime movers. In AGVs and tractors batteries are already in use.

HYDROGEN

Hydrogen (H_2) can eventually be used as carbon dioxide free fuel for example in prime movers. The production of hydrogen has to be carried out synthetically. Mostly, this is done by water electrolysis from electrical current or methane reforming. Since both these approaches use a lot of energy, the locally saved energy (on a terminal) probably does not weight up for the total consumption of energy during the production process.

ELECTRIFICATION

As one of the results that were generated during the course of GREEN EFFORTS, it was established that future solutions for energy efficiency in container terminals is leading towards the use of full electrification of their equipment.[16]

NEW FUEL SOURCES

As for new fuel sources, the following can be named: Methane, Biomethane, CNG (Compressed Natural Gas) and LNG (Liquefied Natural Gas). LNG is the most promising possibility in order to use less conventional fuel.

FUEL CELLS

At present, handling equipment that is driven by fuel cells does not exist on a terminal. Fuel cell trucks were tested at Port of Hamburg.[17]

LED (LIGHT EMITTING DIODES)

The light output of LED is immediately high when being switched on. They can illuminate those spots that are actually needed and do not cause too much stray light.

LEP (LIGHT EMITTING PLASMA)

Light emitting plasma lamps are electrode-less lamps energized by radio frequency power. Typically, these lamps use a noble gas or a mixture of these gases plus an addition of sodium, mercury or sulfur.[18]

15 Cannon, James S., 2009, Container Ports and Air Pollution. GreenPort 2009 Conference
Naples, Italy.
16 Moser, Jürgen; Lengkong, Indah: GREEN EFFORTS. Deliverable 4.1 Container Terminal Consumers.
17 Umweltbewusste Wasserstoff-Technologie im Hamburger Hafenhttp://hhla.de/de/sustainability/ecology/hydrogen-technology.html. 2008.
18 Agarwal, Yogesh: GREEN EFFORTS. White paper. Terminal Lighting by LED and LEP. 2013.

IMPROVED REEFER TECHNOLOGIES

Reefers with onboard management systems[19] *can better monitor the status quo. This can be used to react to necessary changes.*

RECUPERATION

Energy released when braking or lowering is converted into electrical energy by the generator through recuperation. Energy recuperation is possible during the lowering of containers and during deceleration.

TECHNOLOGIES TO PRODUCE OWN ENERGY ON A TERMINAL

Those technologies were thoroughly analyzed by GREEN EFFORTS experts and included, among others: Wind Energy, Biogas, Biomass, Photovoltaic, Geothermal energy and CHP. The results are publicly available under the project's website.[20]

Compared to the other organizational and behavioral measures, the technical measures stick out since it is the only one that has the potential to bring significant ad-hoc results. This can be either done by retrofitting existing equipment or by purchasing new equipment that works more energy-efficient from the start. Immediate savings are possible this way.

Ports and terminals usually have a very high energy consumption due to the various handling activities carried out by traditionally diesel-powered engines. The activities include the movement of heavy loads at high speeds, recurrent starting and stopping and idle as well as redundant activities. When replacing diesel-powered engines with hybrid or full-electric engines a good amount of energy can be saved and risky air emissions like NOx, SOx, soot and particulate matter can be cut. Especially the lifting of cargo is very energy intensive. Therefore some terminal operators have already fitted their RTG cranes with hybrid diesel-electric drives.
While conventional gas- or diesel-powered engines only convert roughly 17 to 21% of the energy stored in fuel to power at the wheels, fully electric vehicles generally convert roughly 59 to 62% of the electrical energy from the grid to power.[21] This accounts for the assumption that electric vehicles are generally more energy-efficient than those vehicles equipped with internal combustion engines. At present, the costs for electrical terminal equipment are quite high and terminal infrastructure has to be adapted to the circumstance (e.g.: installation of charging stations at a suitable site).

As for RMGs, a variety of electric models are already available. Energy saving potentials go back to the fact that the energy released by braking and load-lowering is fed back to the grid. Up to 70% of electricity cost saving can be reached by this technique (recuperation).[22] Although, it is more in use with Ship-to-shore-cranes than with RMGs.

19 For example: VeriWise. http://refrigeratedtransporter.com/archive/reefer-operations-can-now-get-veriwise-0; RAMS: http://www.identecsolutions.com/wp-content/uploads/2012/09/IDENTEC-SOLUTIONS_RAMS-reefer-asset-management-system.pdf.
20 See www.green-efforts.eu/?q=white-papers for further details.
21 All electric vehicles: http://www.fueleconomy.gov/feg/evtech.shtml.
22 Estimation by Konecranes Brazil.

RTGs that are powered with electricity account for about 20% of the costs that are applicable for RTGs fueled with diesel.[23] Infrastructural changes are necessary in order to get electric RTGs running. These include for example overhead catenary lines, rail-mounted electric supply buses or side-mounted cable reels. By restricting the operational area like this the flexibility will be minimized.[24]

5.3 Organizational measures

Organizational measures comprise techniques that are of organizational matter such as:

REEFER CONSUMPTION (SHADING)

Shading prevents from direct sunlight and heating up of the containers and its immediate surroundings.

ISOLATION

In order to prevent losses, the isolation of windows / glasses and walls should be improved.

Some of these measures are already well established while others are still being tested by terminals.

6 Conclusions

In order to reduce, save or even produce energy on different kinds of terminals (container, RoRo, inland waterway), a couple of measures to achieve this are feasible. These measures can be divided into measures of behavioral, technical and organizational means. Not all of the discussed measures bring positive effects for any kind of terminal, since it also is a matter of financial resources (i.e. invest in photovoltaic or LED) and not all of the discussed measurers are well established or just in the testing phase. But, by taking into account at least the following measures a terminal can well manage its use of energy and tackle unwanted emissions:

(1) Better plan necessary movement on the terminal
(2) The intensive use of renewable energy
(3) Reduce the consumption of energy in total.

The three reference terminals developed within the course of the project as a basis have shown that the hybrid technology and energy recuperation technique have proved to be very effective. In fact, the total equipment energy consumption can be reduced by 45%.[25]

Existing measures that need to be reflected further include engines with start-stop automatism for all vehicles equipped with a diesel motor. This will result in a consumption of fuel that is 10 – 15% less of sole diesel motors without technical alterations. Alternative fuel and power sources such as fuel from algae or power produced from under water power plants. Hy-

23 Kalmar: http://www.kalmarind-latinamerica.com/source.php/1260880/COYK0906E-3.pdf
24 Kalmar: Around the world. Issue 1, 2011.
25 Moser, Jürgen; Lengkong, Indah: GREEN EFFORTS. Deliverable 4.1. Container Terminals Consumers.

drogen fuel, LNG and fuel cells are being tested by various terminals worldwide at the moment. Nevertheless, in the long term, it can be seen that future solutions for energy efficiency in container terminals is directed towards the use of full electrification of their equipment.

As it is with any research project and its achieved results, further investigation is needed beyond the existing developments to reduce the emissions even further.