Towards Zero Emissions Multiplier Event
Project number: 2019-1-ES01-KA202-065523

Erasmus+

Date: Thursday 27th February 2020; Time: 15.00-17.30, Venue: Warwick University
Organiser: Centre for Factories of the future (C4FF)
Contact information: Professor Dr Reza Ziarati, reza.ziarati@c4ff.co.uk

Towards Zero Emissions

Keynote Lecture – Future of Transportation – 25 Minutes

Professor Dr Reza Ziarati BSc (Eng), PhD (Eng), Cert Ed, CMechE, CElecE, CMarEng, CEng, FIMechE, FIET, FIMarEST; Centre for Factories of the Future (C4FF), UK

Supporting Presentations – 40 Minutes

Professor German De Melo – Application of Quantum Physics in ICE – UPC, Spain
Associate Professor Kayvan Pazouki – Clean Shipping, Newcastle Univeristy, UK
K6 – A New Universal Engine Concept
Captain Heikki Koivisto – Latest Developing in Efficient Shipping, SAMK, FI

Panel Discussions – 25 Minutes

Going Electric – Is This a Wise Solution?

There are pressures on manufacturers of engines in all sectors; marine, automotive and rail/traction to seek solutions to reduce exhaust emissions and reduce fuel consumptions. This visit and lecture will report on the work of Centre for Factories of the Future's (C4FF) and several leading national and international research centres in shipping, automotive and rail/traction and focuses on findings of several recent and ongoing projects in engine design and constructions as well as new types of engines viz., hybrid, gas and electric. The intention is to learn about innovations in all three sectors which may be transportable from one sector into another. Use of new fuels and electrification as well as gasification of propulsion systems have led to remarkable breakthroughs. Special references are made to a new type of engine concept. Some of the ideas which were thought crazy not so long ago, such as application of quantum theory in emissions control and energy usage, are included. The workshop is expected to lead to the verification of job specification and course design for those responsible for energy efficiency and emissions reduction in all three sectors.

The revolutions in transport systems and digital twinning as well as hybrid propulsion are the key topics of the lecture which includes a visit to Warwick University battery's facility.

Institution of MECHANICAL ENGINEERS

Supported by Institution of Engineering and Technology and Institution of Marine, Science and Technology

C4FF Developing the Future

C4FF Developing the Future

Towards Zero Emissions

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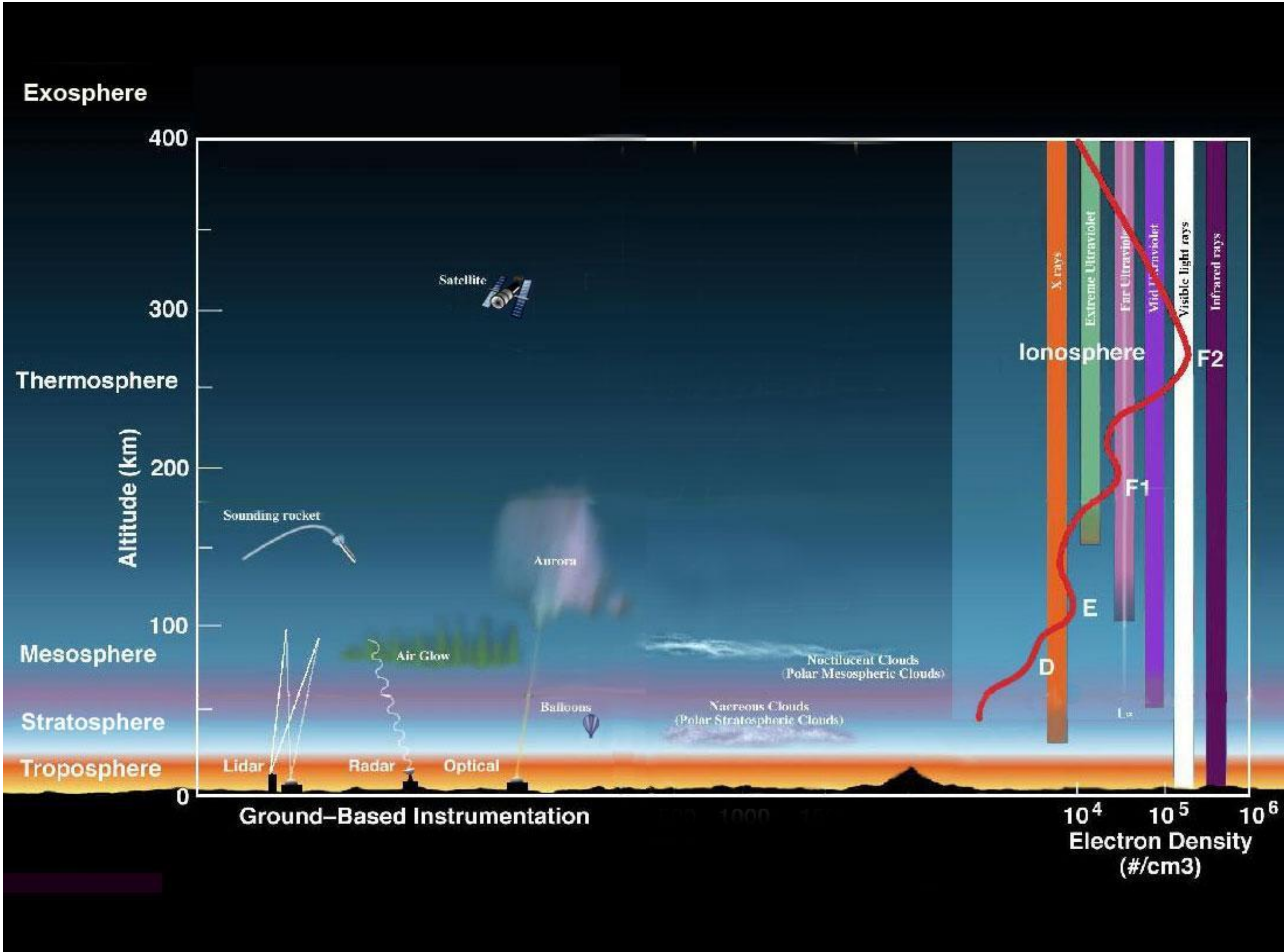
In collaborations with GreenShip Project Partners

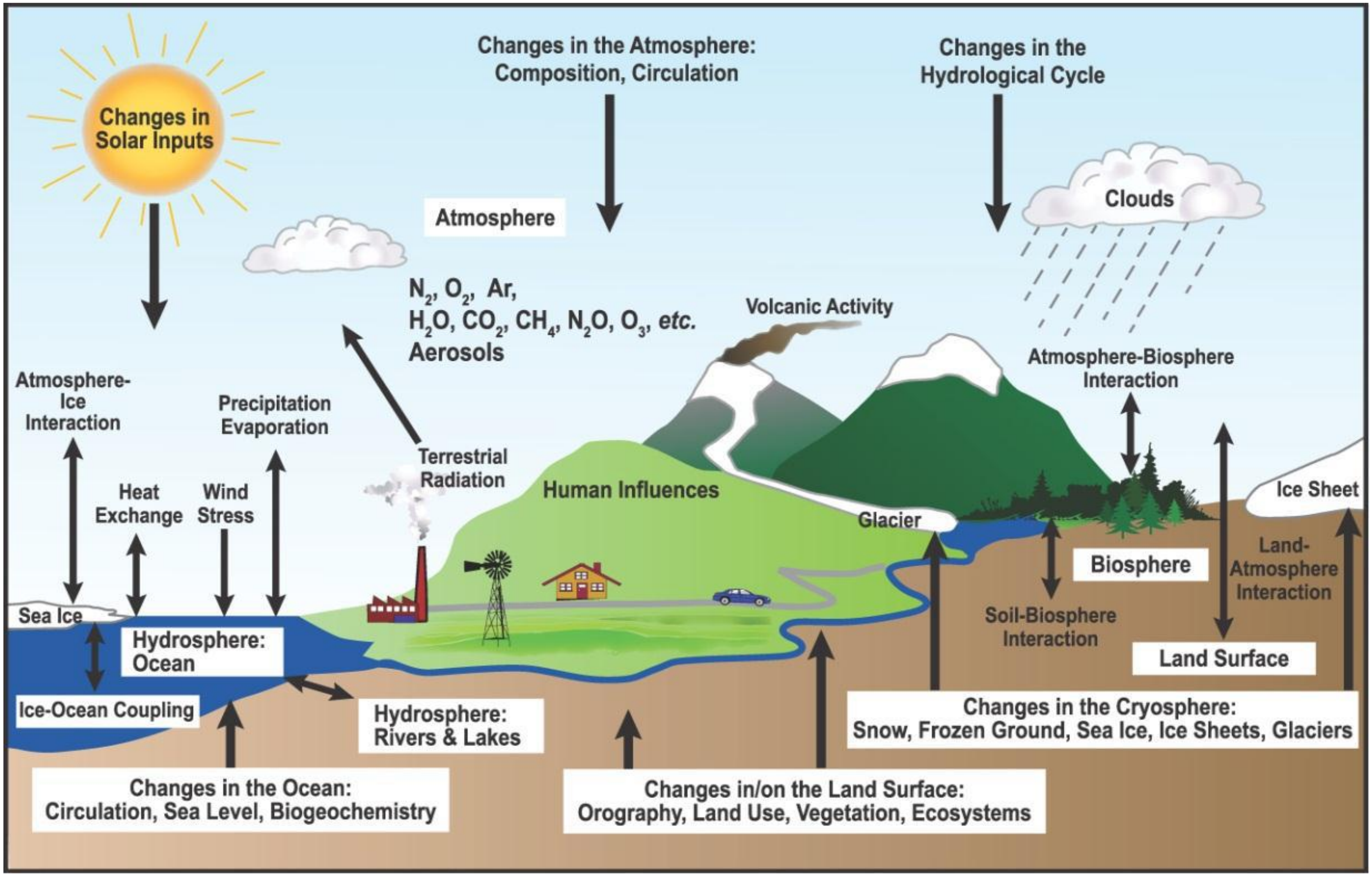
Summary of the Lecture

- Part 1 – Climate Change
- Part 2 - Automotive and Traction
- Part 3 - Shipping

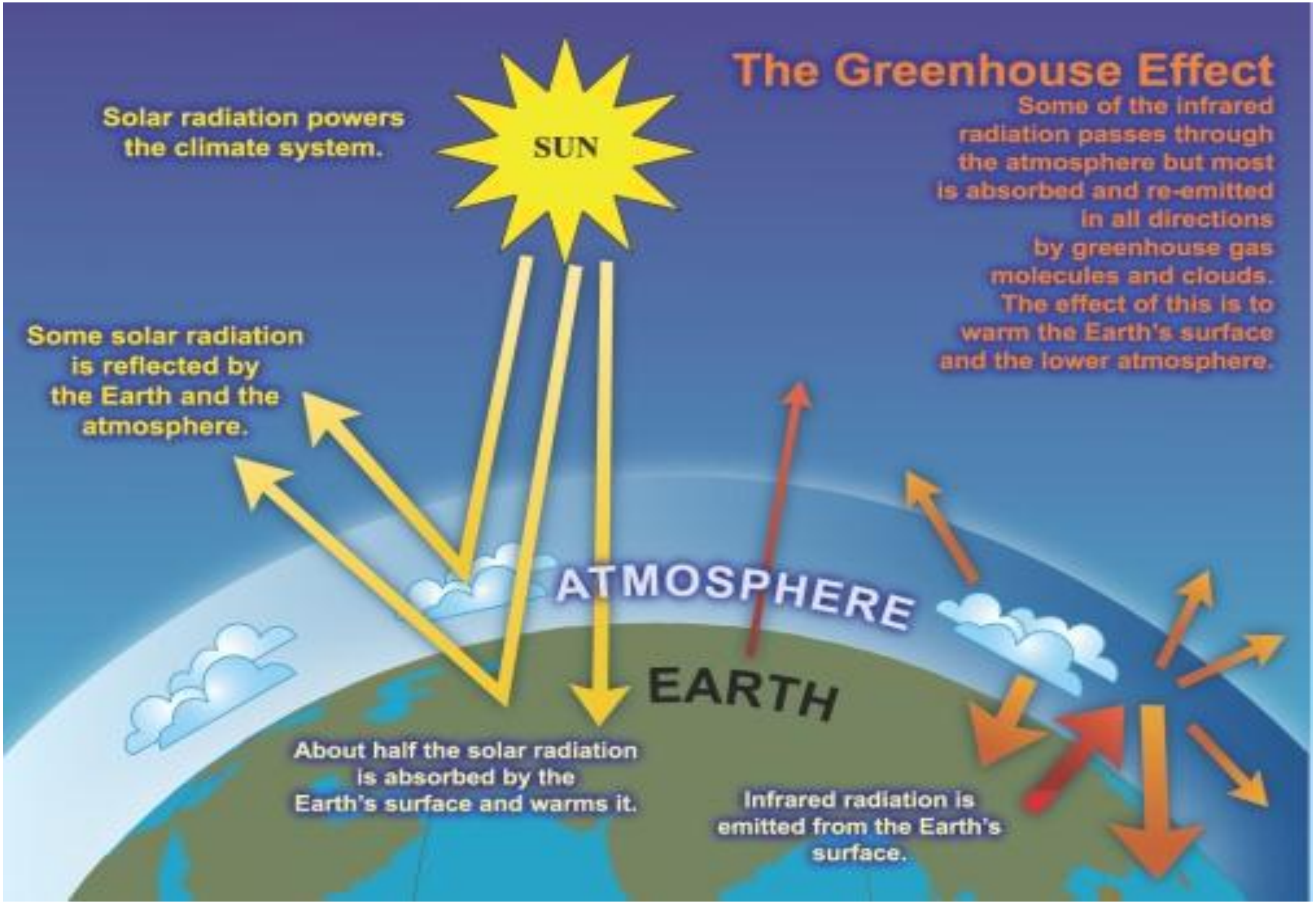
DIAGRAM OF THE LAYERS WITHIN EARTH'S ATMOSPHERE [HTTP://WWW.NASA.GOV/MISSION](http://www.nasa.gov/mission), ***(C4FF SCHOOL ASSIGNMENT – 2019)***

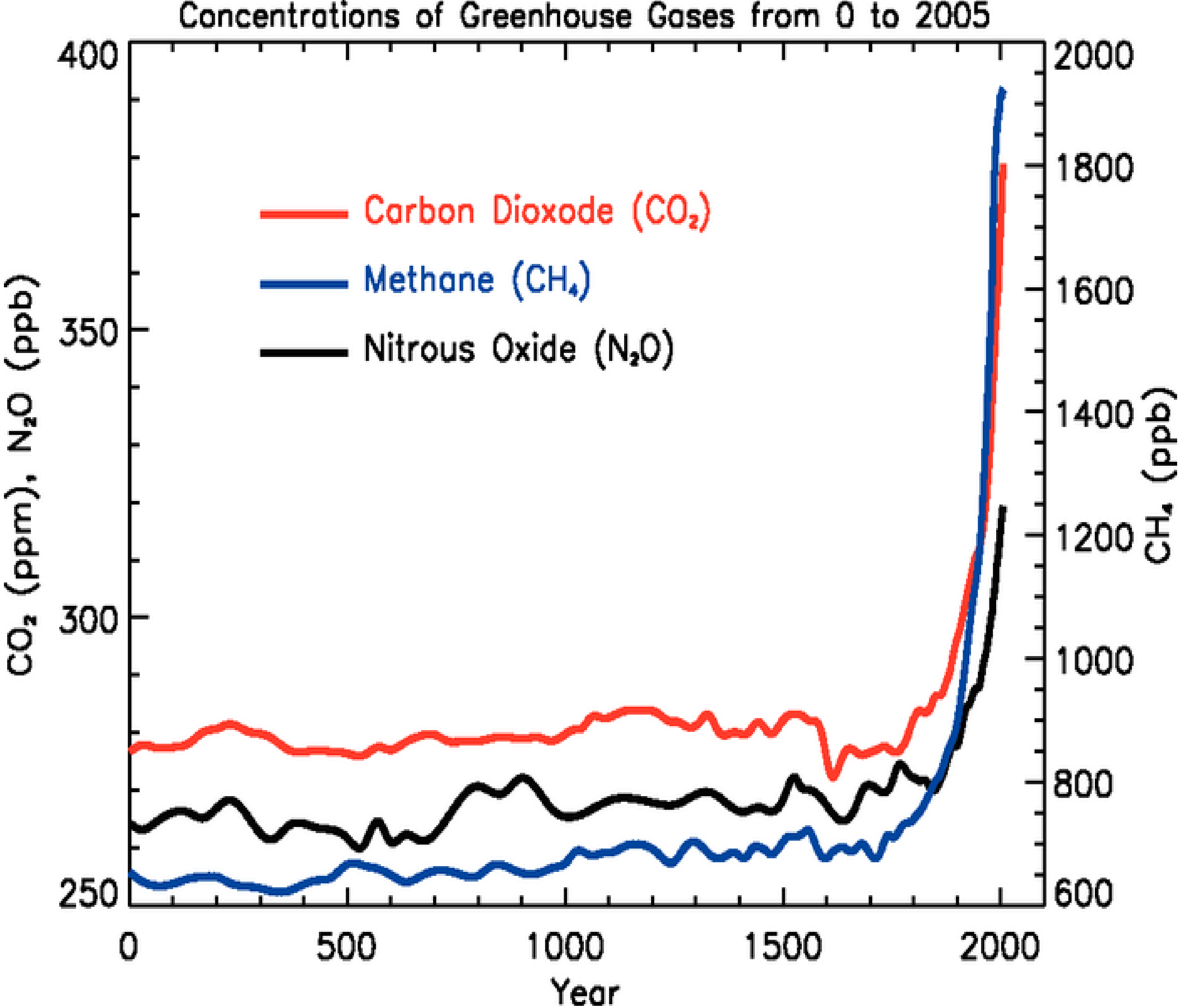


SCHEMATIC VIEW OF THE COMPONENTS OF THE CLIMATE SYSTEM, THEIR PROCESSES AND INTERACTIONS [IPCC FOURTH ASSESSMENT REPORT, CLIMATE CHANGE 2007 (AR4) WG I] (C4FF SCHOOL ASSIGNMENT – 2019)



An idealised model of the natural greenhouse effect [Source: IPCC AR4 WG I] – (C4FF School Assignment)

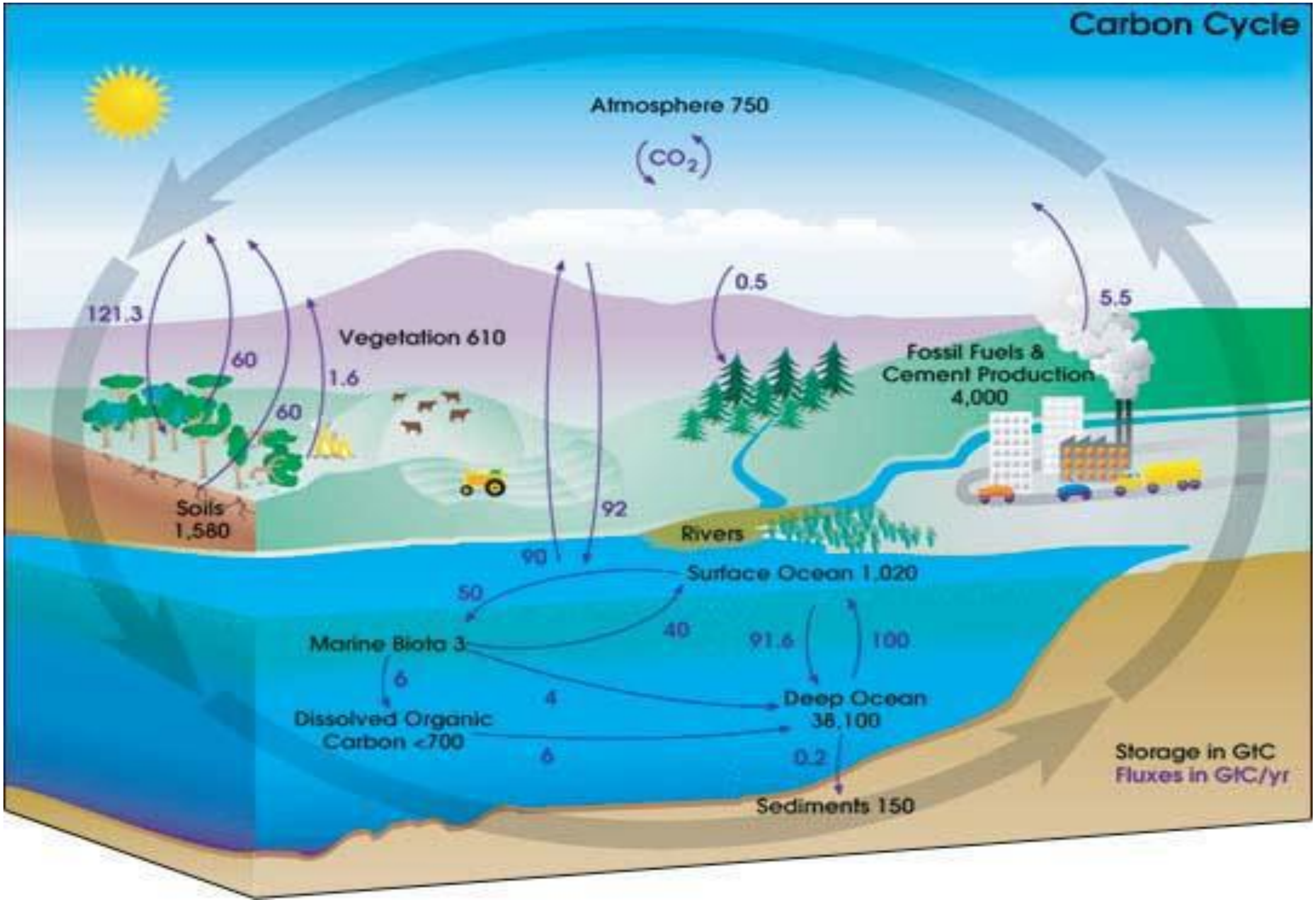




Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO2)
Methane (CH4)
Nitrous Oxide (N2O)
CO2 (ppm), N2O (ppb)
CH4 (ppb)
Year
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000

Major Carbon pools and fluxes of the global carbon balance [FAO website]

- (Karl T.L. et. al., 2009). C4FF School Assignment



Historical Developments – Need for A global respose

The great smog in UK& US OF 1950s and 1960s

The groundings of Torrey Canyon (1967) &

Amoco Cadiz (1978)

Acid rain in the 1970s

Poisonous release of chemicals in Bhopal (1982)

The nuclear accidents of Chernobyl (1986), Fukushima (2011),

Demonstrate the rising "risk to society" of modern industrial activities. The existence of such risks plus wider evidences of impacts of air emissions on human health, global temperature and ecosystem have fully shifted the individual and social perceptions of risks and

History of Global Efforts

- **The United Nations Conference on the Human Environment (UNCHE) - 1972**
- **The United Nations Environment Programme (UNEP)**
- **Intergovernmental Panel on Climate Change (IPCC)**
- **The United Nations Framework Convention on Climate Change (UNFCCC)**
- **Kyoto Protocol -** Monitoring emission targets, Registration, Reporting, Compliance & Adaptation,
- **The Paris Agreement -** Efforts to limit global warming it to 1.5°C
- **COP 25 and 26 –** Implementation of Paris Agreement

United Nations Framework Convention on Climate Change

Kyoto Protocol (Article 2.2)

- The Parties included in Annex I shall pursue limitation of emissions of GHG from marine bunker fuels, working through the International Maritime Organization
- Kyoto Protocol commitment period ends 2020

Paris Agreement

- No specific reference to shipping in the final agreement
- Focus on “nationally determined contributions”
- Target is a temperature increase “well below 2^{o}C”

Part 2: Key ares for Efficient Ship project

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- Importance of reducing fuel consumption and engine exhaust emissions through integration of navigation, Engine controls and hydrodynamic optimisation.
- Incorporating the IMO's new SEEMP including the EEDI

Part 2

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Developing the Future

- http://www.c4ff.co.uk/history/papers/One_dimensional_unified_flow_Program.pdf
- http://www.c4ff.co.uk/history/papers/Incidence_Loss_Model.pdf

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http://www.c4ff.co.uk/history/papers/Early_Bath_University_reports.pdf

http://www.c4ff.co.uk/history/papers/AutoTech_95_paper.pdf

http://www.c4ff.co.uk/history/papers/High_pressure_fuel_injection_system.pdf

http://www.c4ff.co.uk/history/papers/Lloyds_support.pdf

Hybrid Car and Bus Design

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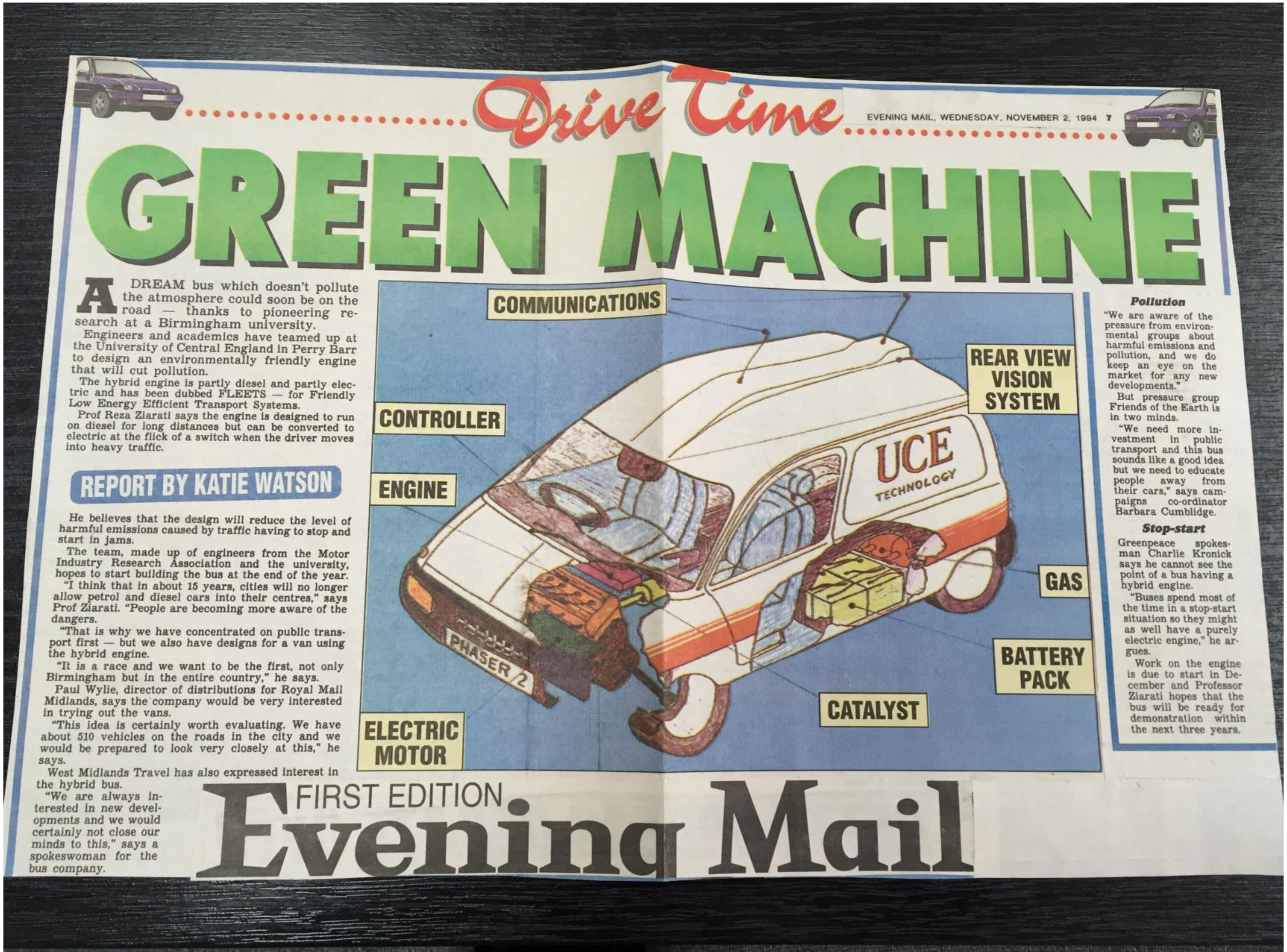

Drive Time
EVENING MAIL, WEDNESDAY, NOVEMBER 2, 1994 7

GREEN MACHINE

A DREAM bus which doesn't pollute the atmosphere could soon be on the road — thanks to pioneering research at a Birmingham university.

Engineers and academics have teamed up at the University of Central England in Perry Barr to design an environmentally friendly engine that will cut pollution.

The hybrid engine is partly diesel and partly electric and has been dubbed FLEETS — for Friendly Low Energy Efficient Transport Systems.

Prof Reza Ziarati says the engine is designed to run on diesel for long distances but can be converted to electric at the flick of a switch when the driver moves into heavy traffic.

REPORT BY KATIE WATSON

He believes that the design will reduce the level of harmful emissions caused by traffic having to stop and start in jams.

The team, made up of engineers from the Motor Industry Research Association and the university, hopes to start building the bus at the end of the year.

"I think that in about 15 years, cities will no longer allow petrol and diesel cars into their centres," says Prof Ziarati. "People are becoming more aware of the dangers.

"That is why we have concentrated on public transport first — but we also have designs for a van using the hybrid engine.

"It is a race and we want to be the first, not only Birmingham but in the entire country," he says.

Paul Wylie, director of distributions for Royal Mail Midlands, says the company would be very interested in trying out the vans.

"This idea is certainly worth evaluating. We have about 510 vehicles on the roads in the city and we would be prepared to look very closely at this," he says.

West Midlands Travel has also expressed interest in the hybrid bus.

"We are always interested in new developments and we would certainly not close our minds to this," says a spokeswoman for the bus company.

Pollution

"We are aware of the pressure from environmental groups about harmful emissions and pollution, and we do keep an eye on the market for any new developments."

But pressure group Friends of the Earth is in two minds.

"We need more investment in public transport and this bus sounds like a good idea but we need to educate people away from their cars," says campaigns co-ordinator Barbara Cumblidge.

Stop-start

Greenpeace spokesman Charlie Kronick says he cannot see the point of a bus having a hybrid engine.

"Buses spend most of the time in a stop-start situation so they might as well have a purely electric engine," he argues.

Work on the engine is due to start in December and Professor Ziarati hopes that the bus will be ready for demonstration within the next three years.

FIRST EDITION
Evening Mail

Best IRTE Lecture 1996

http://www.c4ff.co.uk/history/papers/Emerging_transportation_system.pdf

Key factors and Limits of Thermal Efficiency

Enthalpy vs Entropy

- **Enthalpy** - a thermodynamic quantity equivalent to the total heat content of a system. It is equal to the internal energy of the system plus the product of pressure and volume – Fossil Fuel, LNG, GAS!

- **Entropy**- a thermodynamic quantity representing the unavailability of a system's thermal energy for conversion into mechanical work, often interpreted as the degree of disorder or randomness in the system – Reducing losses.

Engine Optimisations
Review of Experiments

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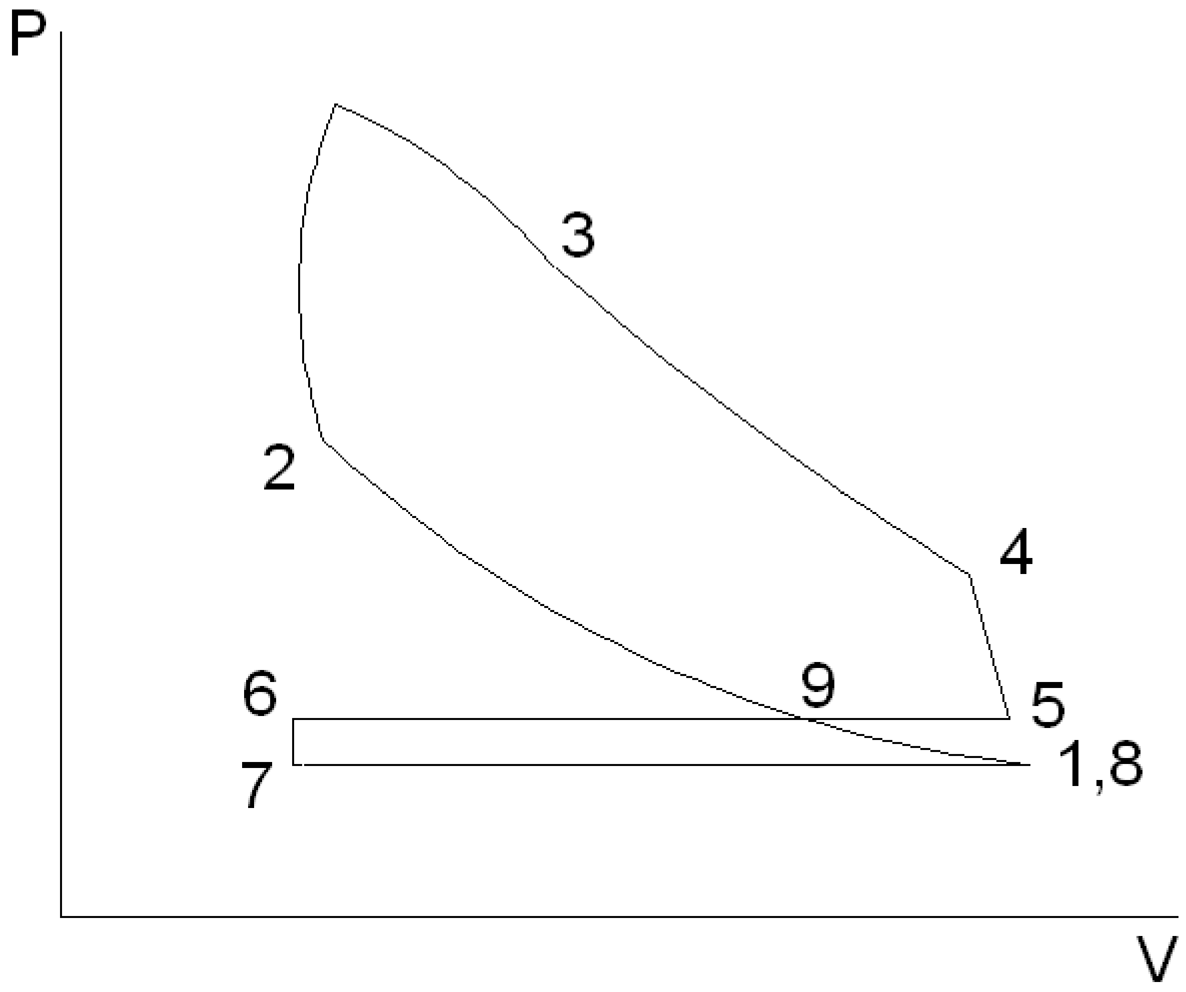
Developing the Future

- Thermal efficiency
- Hybrid propulsion
- Alternative fuels
- Fuel cells/batteries
- Catalysts
- Exhaust recirculation systems
- Exhaust treatment
- Multi-Stage inter-cooling
- Variable Geometry Diesels
- Lighter materials
- Efficient bearings
- Water injection
- Novel injectors
- High injection pressures
- Common rail systems

DESCRIPTION OF THE MODEL – MODIFIED AIR STANDARD CYCLE



THE CYCLE IS SUBDIVIDED INTO:

Closed Cycle Considerations:

- Compression period (1-2)
- Combustion period (2-3)
- Expansion period (3-4)

Open Cycle Considerations:

- Blow down period (4-5)
- Exhaust period (5-6)
- Overlap period (6-7)
- Suction period (7-8)
- Pre-compression period (8-9)

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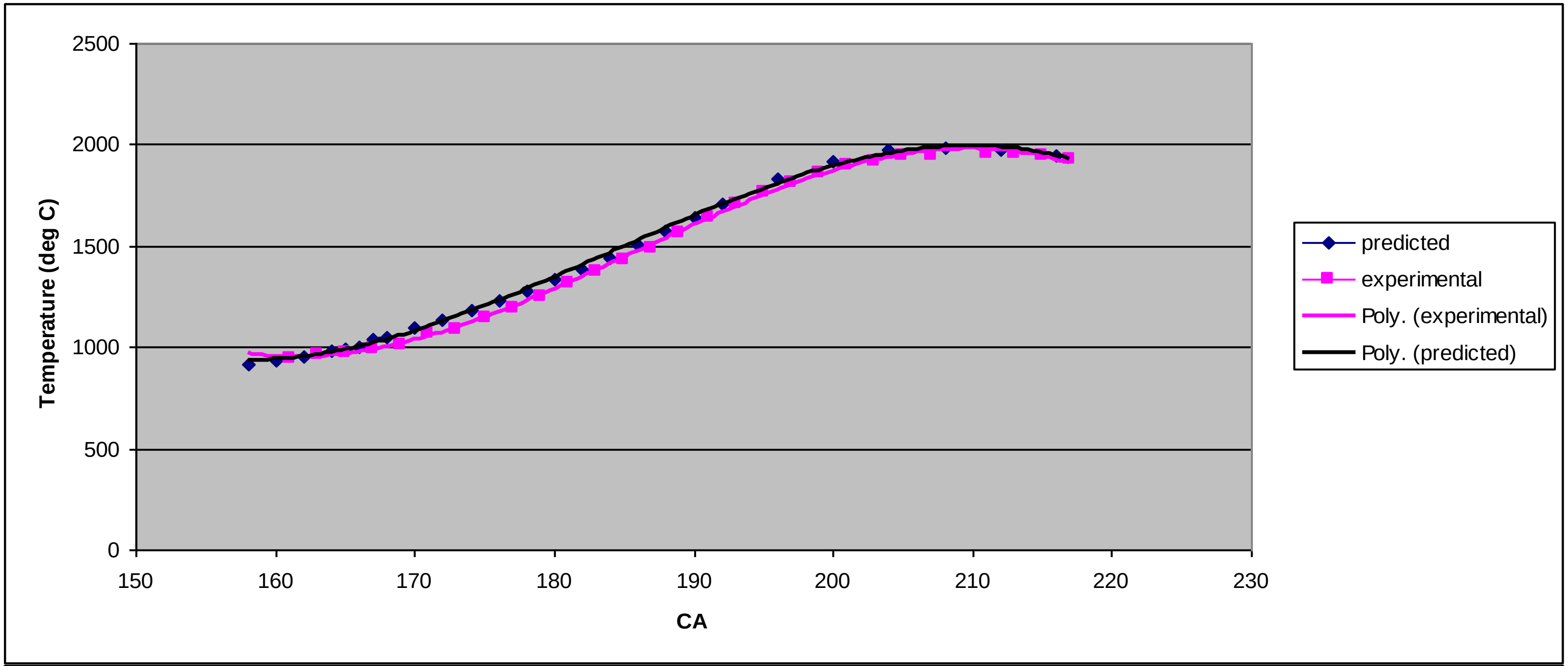
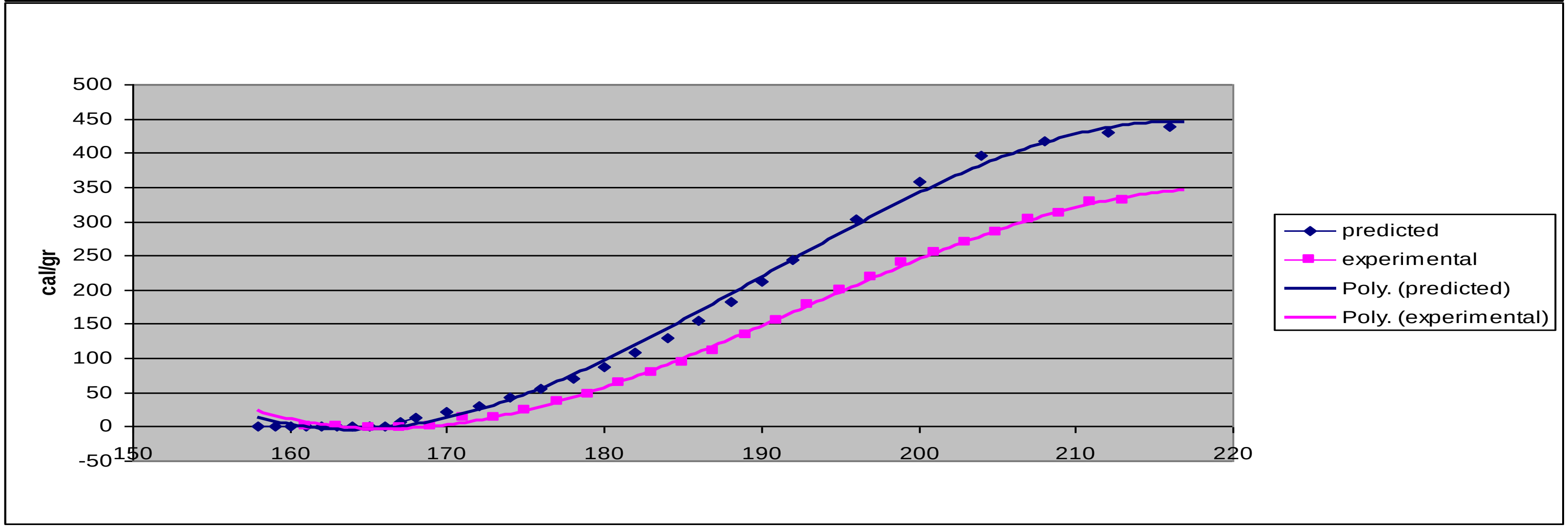
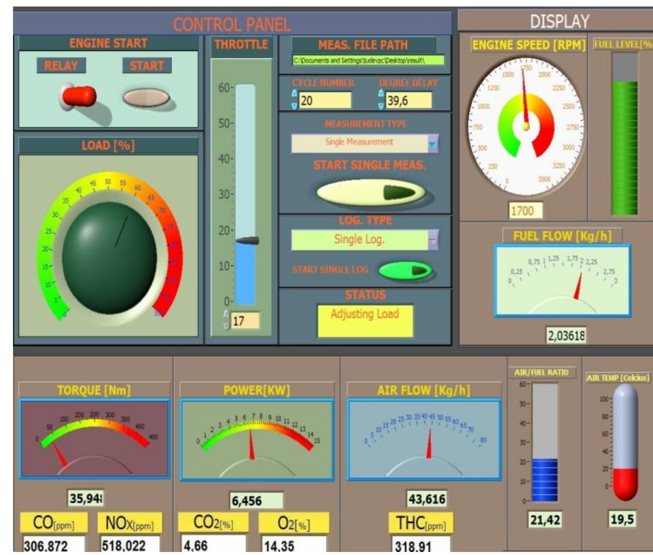
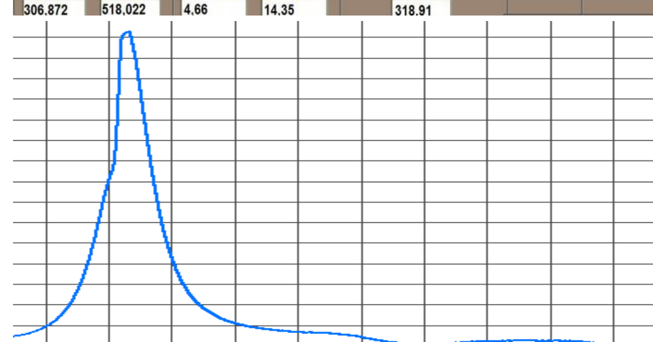
Ziatati et al., 2009, 13th Congress of Intl. Maritime Assoc. of Mediterranean, IMAM 2009





ZIARATI ET AL, (2009), DESIGN AND DEVELOPMENT OF A COMPUTER CONTROLLED MARINE DIESEL ENGINE FACILITY FOR MARITIME ENGINEERING RESEARCH AND TRAINING – IMLA 2009



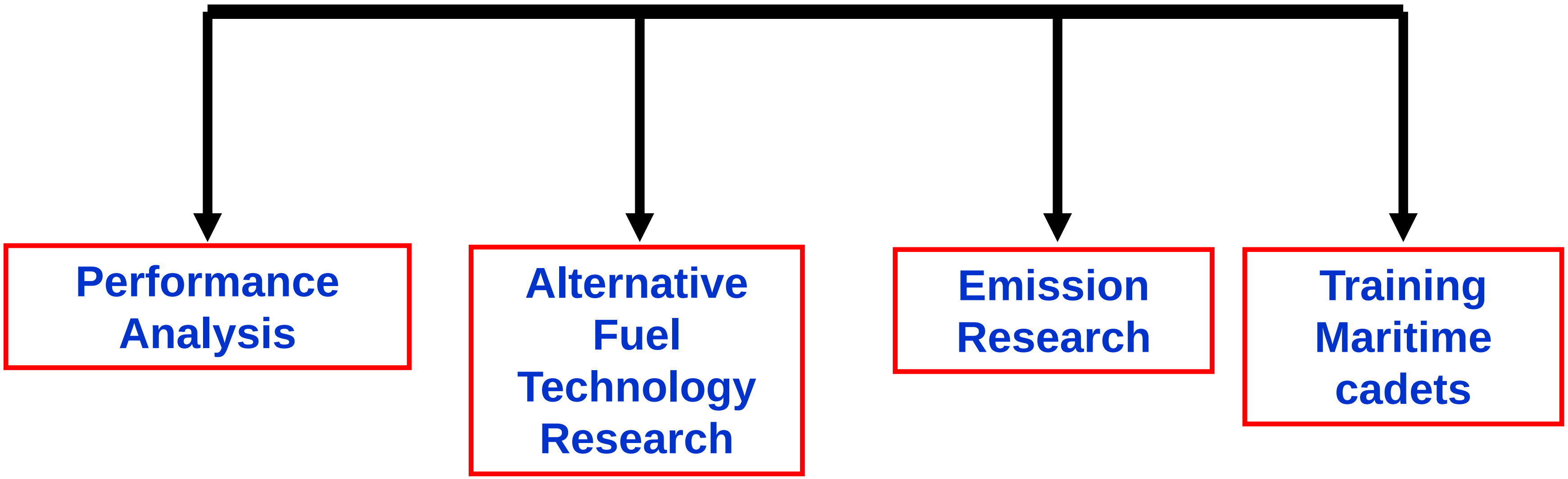


The application of diesel engines in automotive and marine industries and its use as stand alone power units have been rapidly increasing in recent years mainly due to the development and applications of new technologies. These developments on diesel engines are focused on:

- Improved Performance
- Emission control

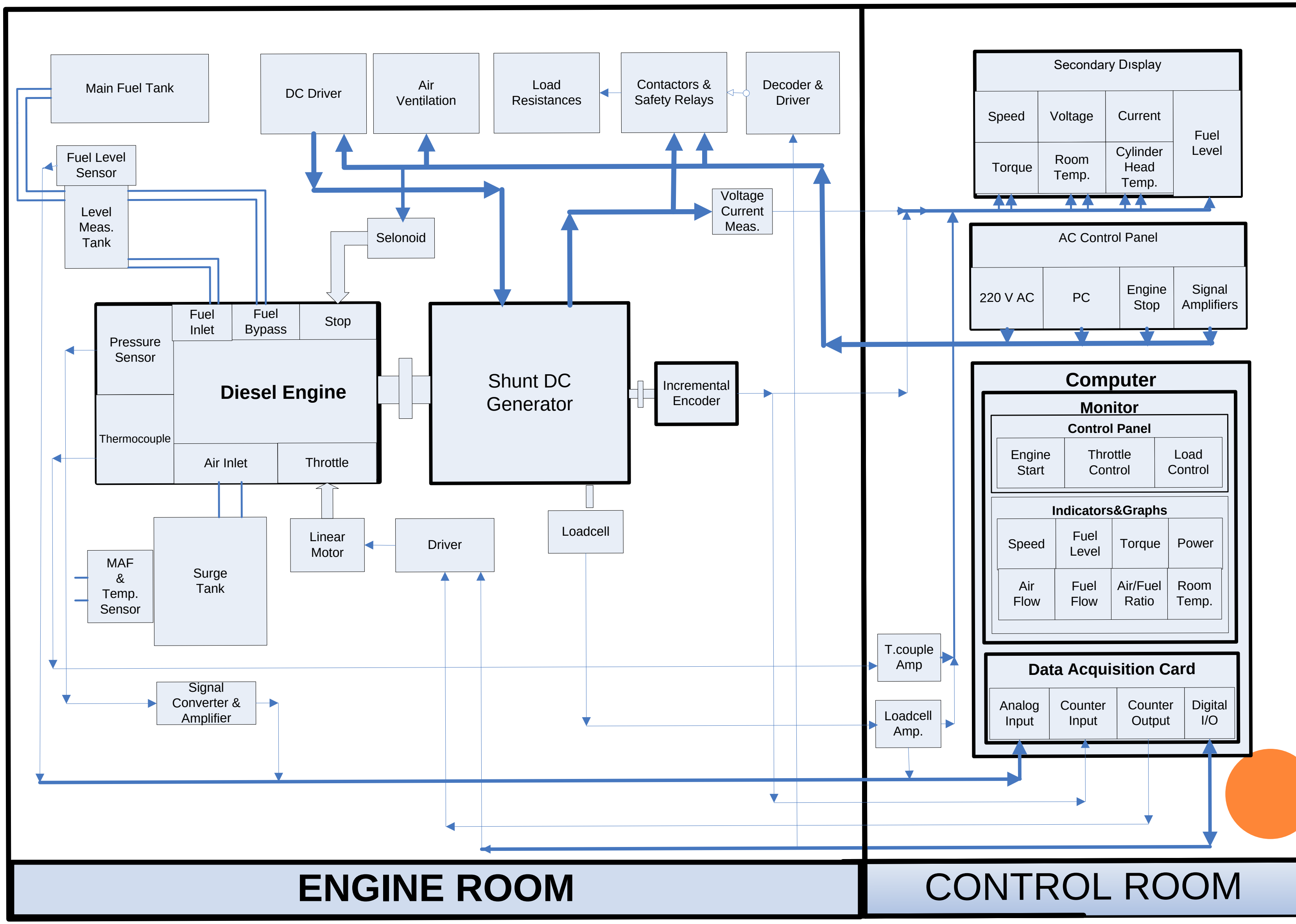
Therefore, a reliable and functional diesel engine test rig is required for research and training of merchant navy cadets.

DIESEL ENGINE TEST RIG CAPABILITIES



This computer controlled diesel engine test laboratory was established at Piri Reis University. The research facility is fully instrumented using a range of sensors and a computerized data processing and analysis system.

Diesel Engine Test Rig Block Diagram



The laboratory is separated into two facilities, one holding the instrumented engine and the other computing and display units with a view to improve safety and to decrease noise.

Engine Room

1. Diesel Engine
2. DC Generator
3. Inlet air surge tank
4. Air mass flow meter
5. Load rezistances panel
6. Rezistance box
7. Emission analyser
8. Encoder
9. Load cell
10. Generator fan
11. Micro stepping motor
12. Engine air inlet
13. Exhaust
14. Driver
15. Amplifier (for pressure sensor)
16. Pressure sensor cooling pump and tank
17. Pressure sensor
18. Fuel tank
19. Fuel level sensor
20. Main fuel tank
21. Selenoid for engine stop

Control Room

1. Screen for engine controls and indicators
2. Screen for graphical output
3. Data acquisition connection box
4. Keyboard and mouse
5. Indicator panel
6. Electrical control panel

Generator

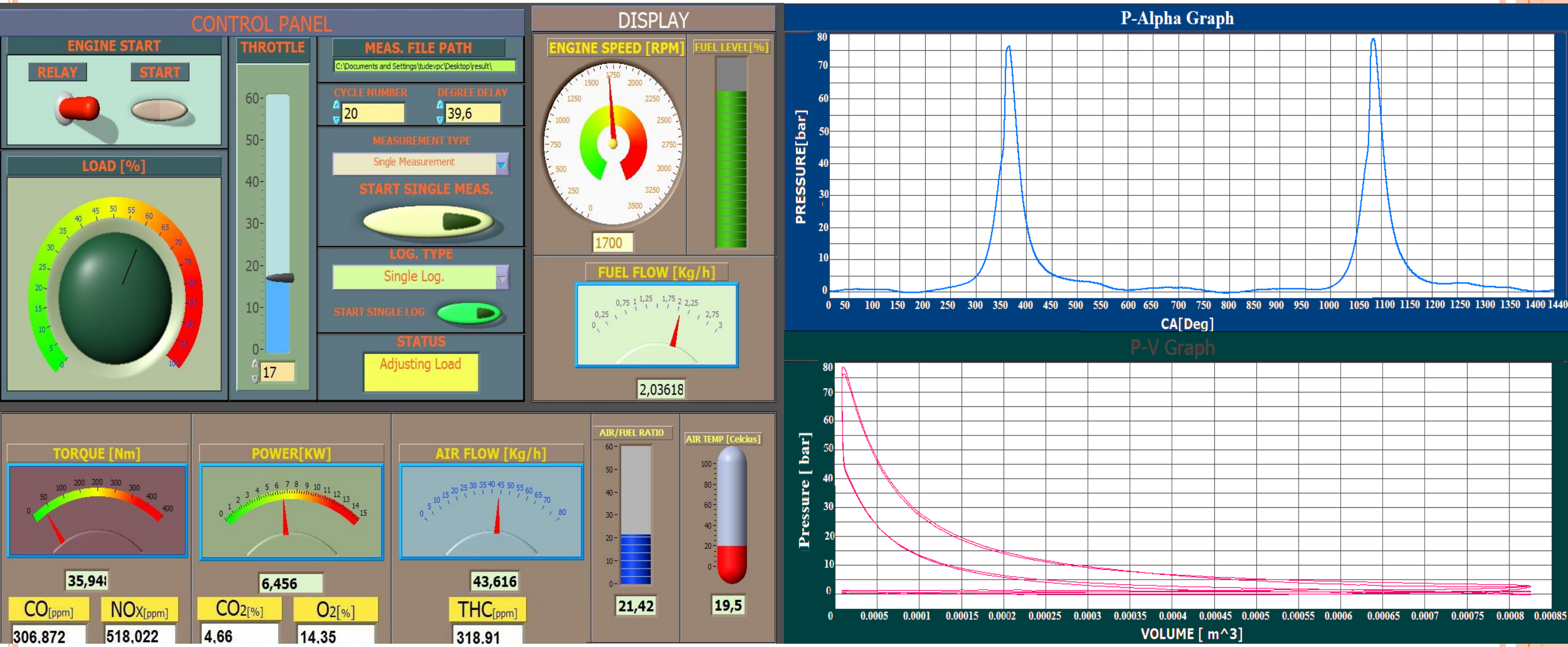
Diesel Engine	
Make	Antor 4LD 820
No. Of Cylinders	1
Volume	817 cm^3
Engine Speed	2600 rpm
Power	17 HP
Max. Power	5 Kg-m @1600 rpm
Generator	
Type	Shunt DC
Armature Current	38 A
Armature Power	15 kW
Field Voltage	200 V
Field Current	2,8 A
Max. Speed	3500 rpm

GRAPHICAL USER INTERFACE

A graphical user interface program was developed using Labview®. This program has several control functions, it displays measurement results and records the data on the hard disk. The graphical user interface consists of three parts;

- Control panel,
- Indicator panel,
- Chart panel.

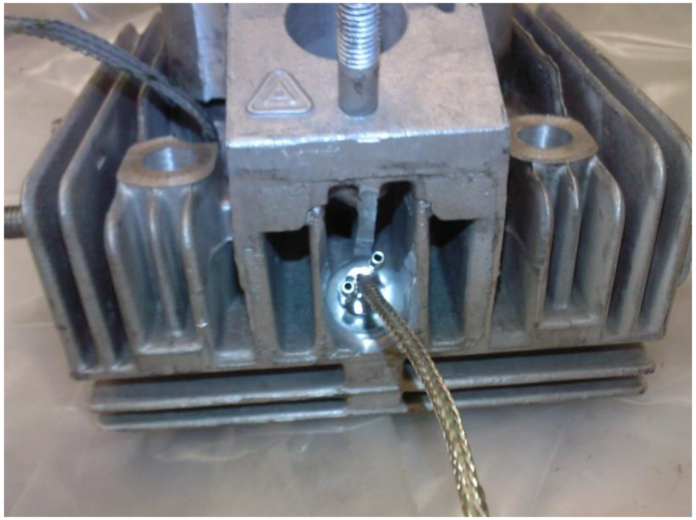
GRAPHICAL USER INTERFACE



Cylinder Pressure Measurement

A piezoelectric pressure sensor is mounted in the cylinder head and connected to a charge amplifier to measure the cylinder pressure. Cylinder pressure is measured using the trigger signal from encoder's zero pulse and at a sample rate (0,1º).

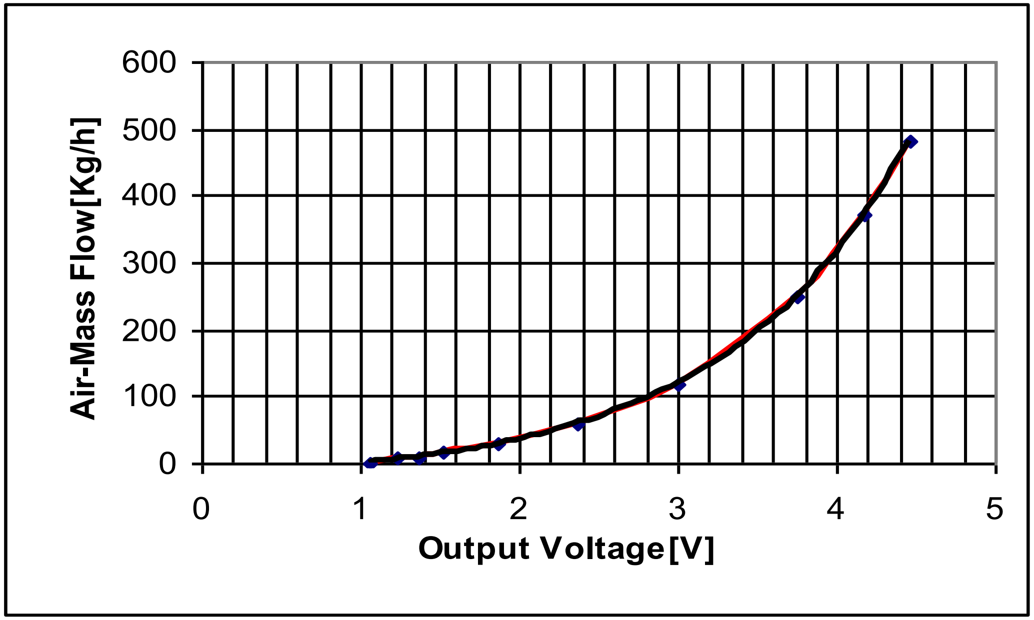
Pressure sensor



Pressure sensor mounted on the cylinder head

Air Flow Measurement

Air flow and inlet air temperature are measured using Bosch mass air flow meter (MAF)

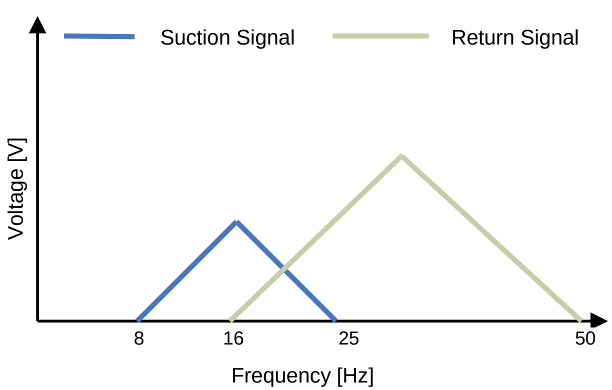


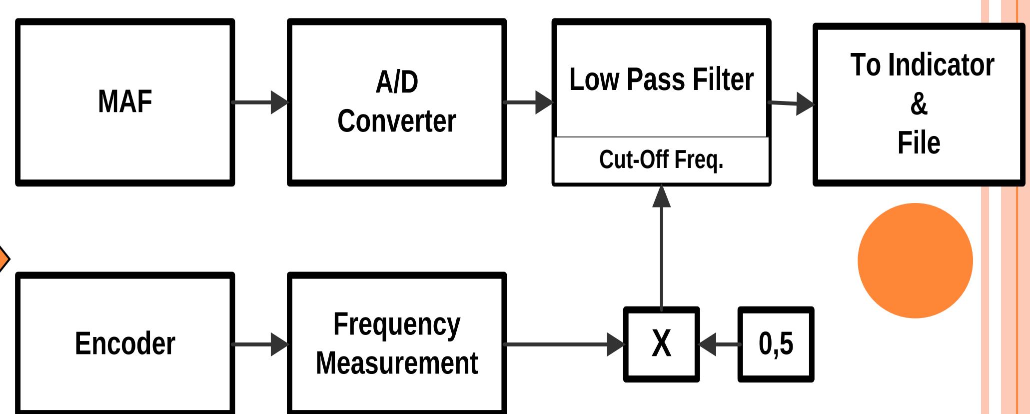
MAF's output voltage according to the air flow is shown above.

Air Flow Measurement

Problem: Since single cylinder diesel engine is used, some amount of suction air returns back to the surge tank again

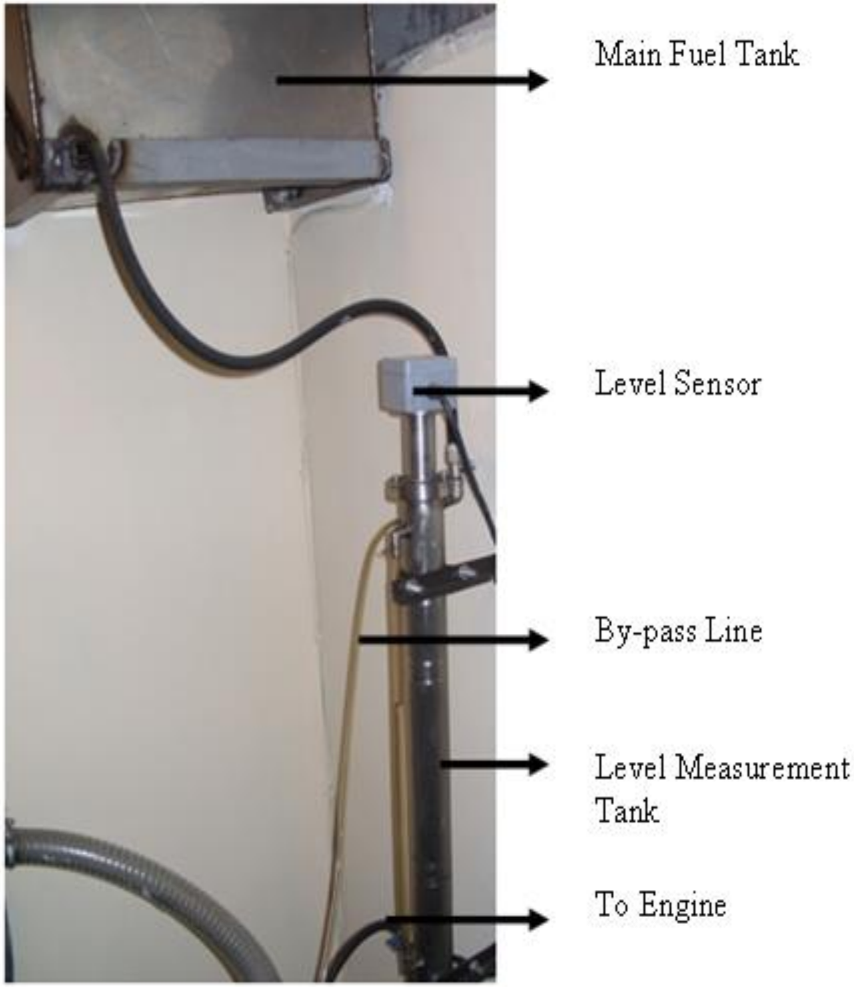
Solution: Suction signal frequency has to be the half of the engine speed frequency. Therefore, the MAF output is examined in frequency spectrum to realize filter for return signal. Low pass filter whose cut-off frequency is changed according to engine speed is used to measure suction air flow.



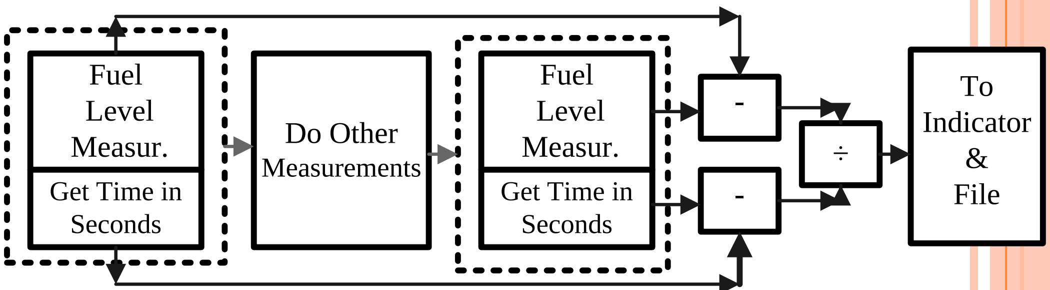


FUEL FLOW MEASUREMENT

A level sensor is mounted in a cylindrical fuel tank to measure fuel flow



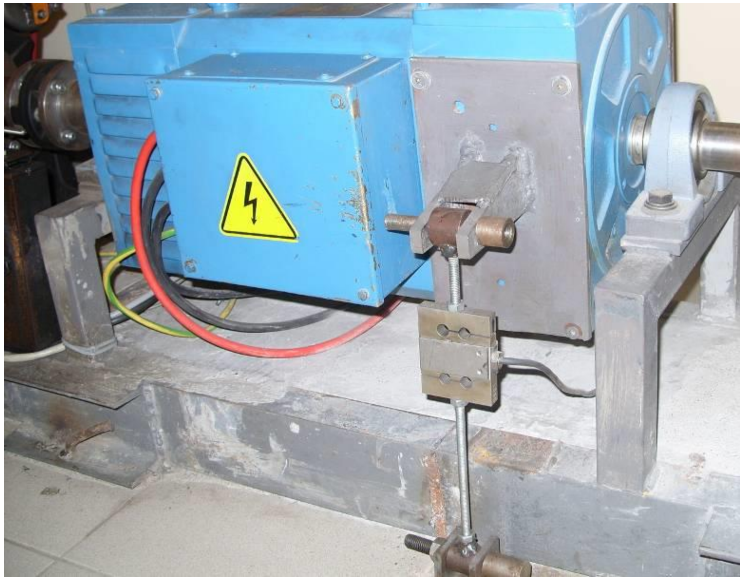
The block diagram for fuel flow measurement can be seen below:



Torque and Power Measurements

- A loadcell is mounted to DC generator's frame to measure the break torque

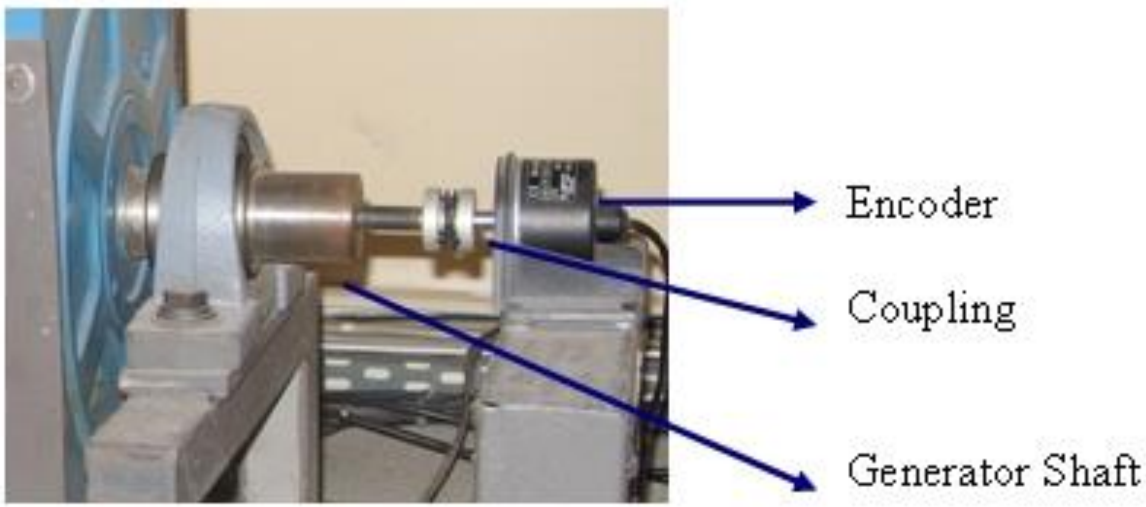
- Armature current being consumed by load resistances is directly proportional to rotational force of field winding fixed generator body. For this principle, break torque can be measured from generator's body.



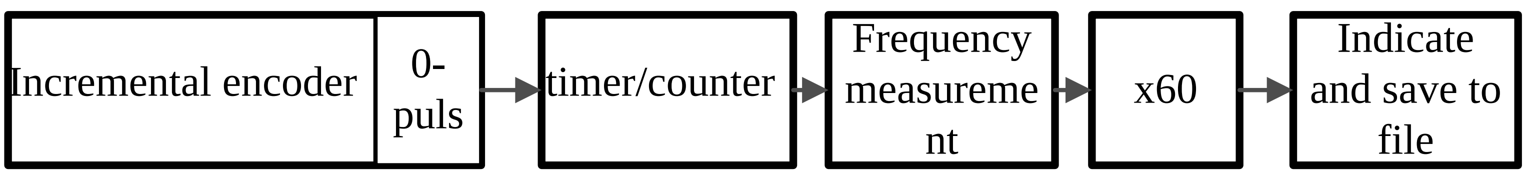
Load cell

Engine Speed Measurement

An encoder with a resolution of 3600 puls/rev is used.



Incremental Encoder



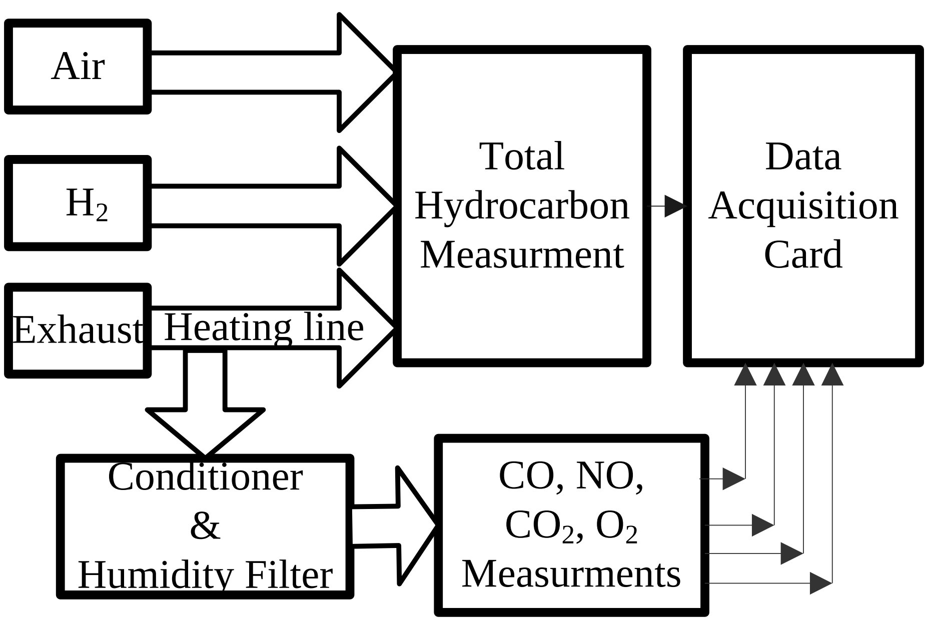
Engine Speed Measurement Block Diagram

Exhaust Emission Measurement

•Siemens Ultramat 23 NDI (non-dispersive infrared) analyser measures CO, CO2, NOx and O2 emissions

•Siemens Fidamat 6 FID (flame ionization detection) analyser measures THC (total hydrocarbons) emissions

•The exhaust gas passes through a heated line to avoid condensation.

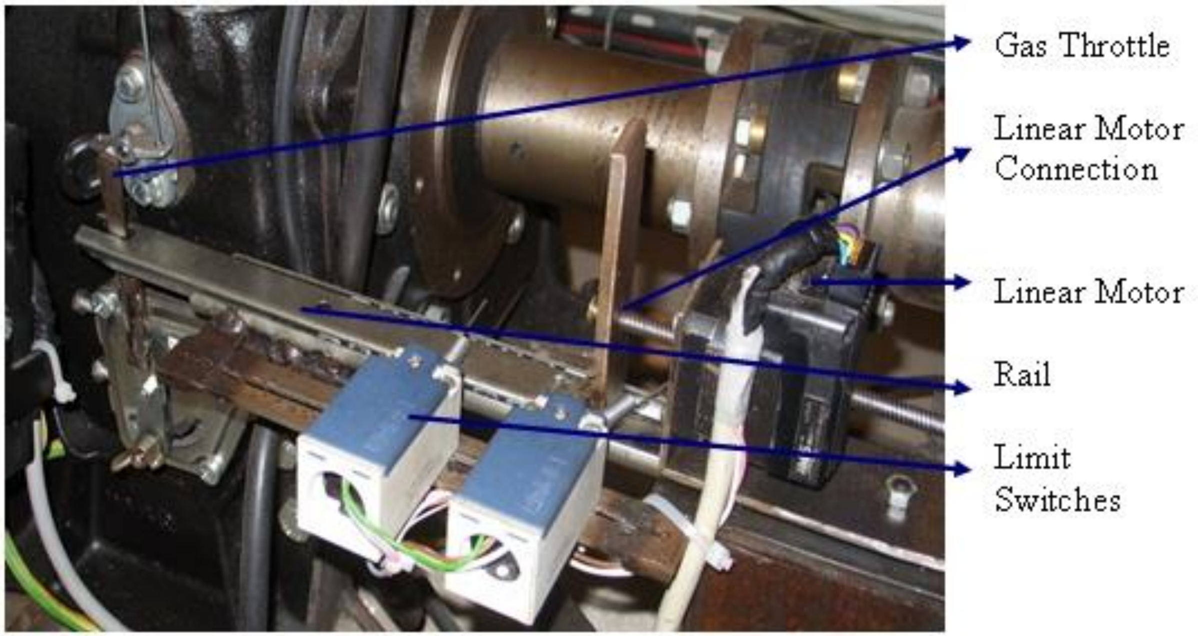


CONTROLLERS

Throttle Control

- Throttle is controlled by using micro stepping motor with linear actuator

- Data acquisition card's counter/timer and digital output is connected to micro stepping motor driver to enable motion and its direction

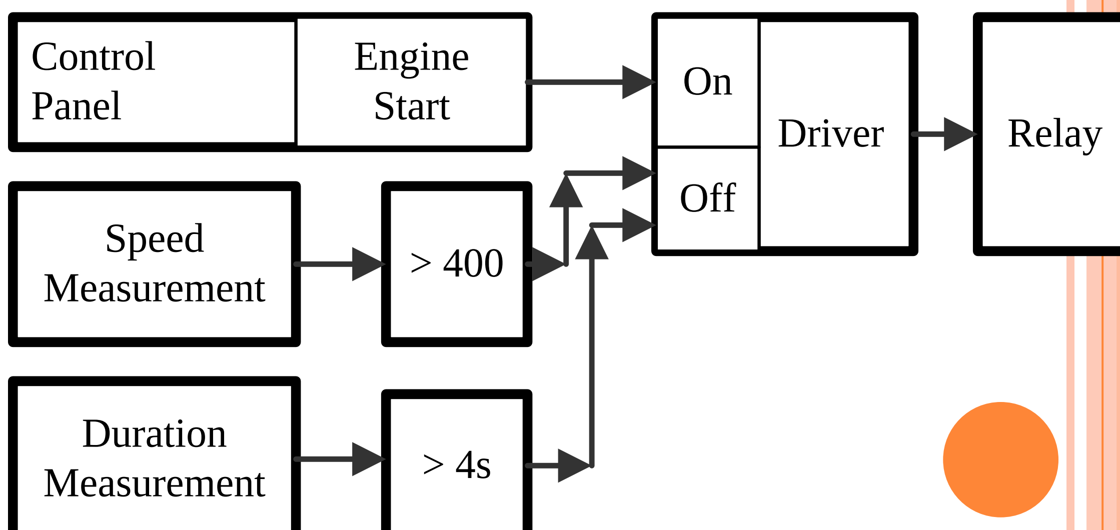


Load and Start/Stop Controllers

There are 16 resistances (1 kW each) which are controlled by the data acquisiton card.

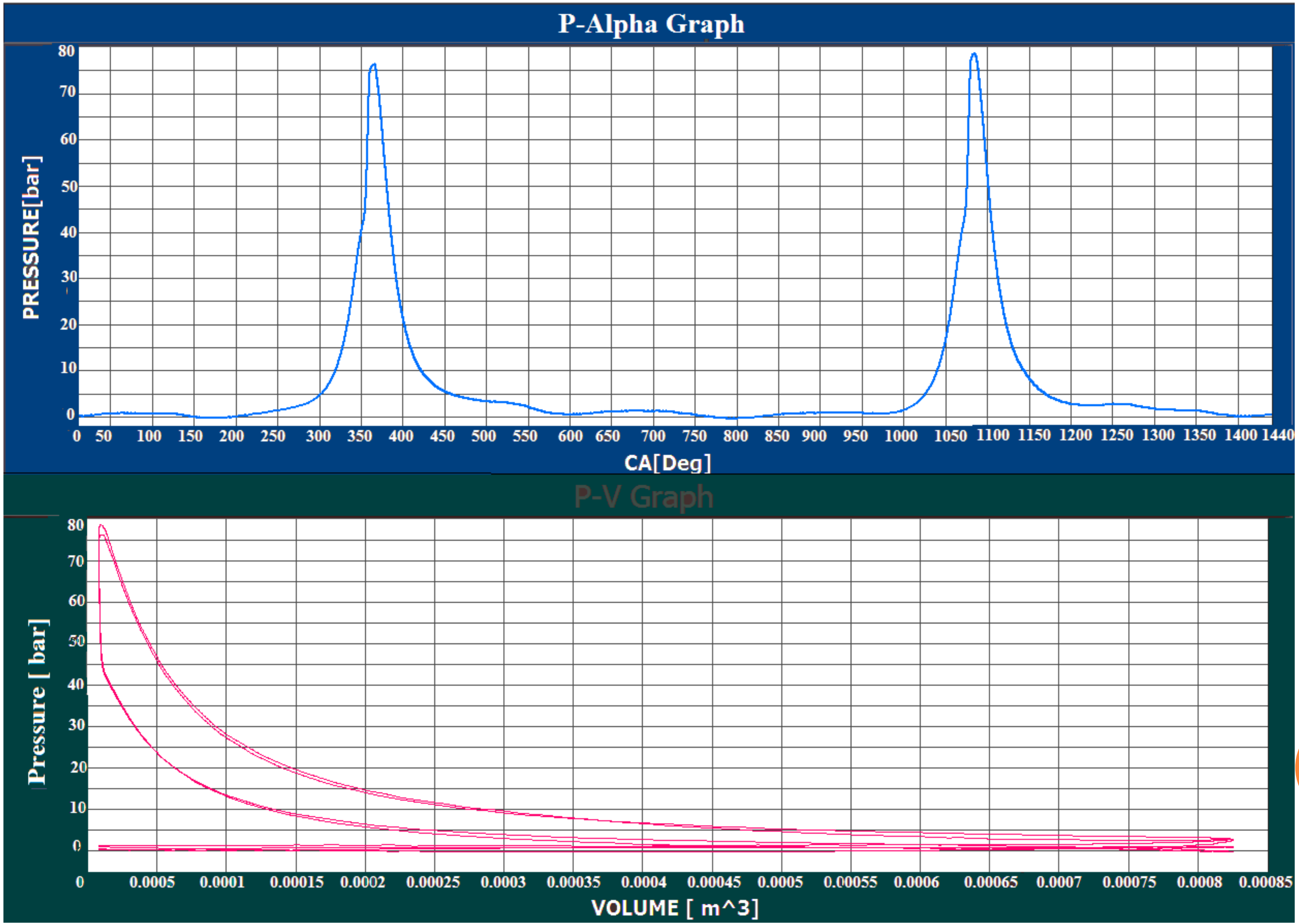
A relay and its driver are connected to data acquisition card which are used to start the engine.

A solenoid is connected to the engine's stop valve to stop the engine from the control room.



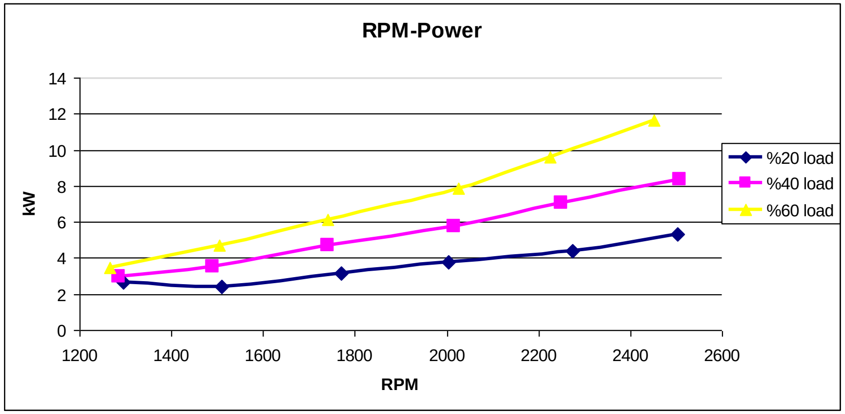
RESULTS

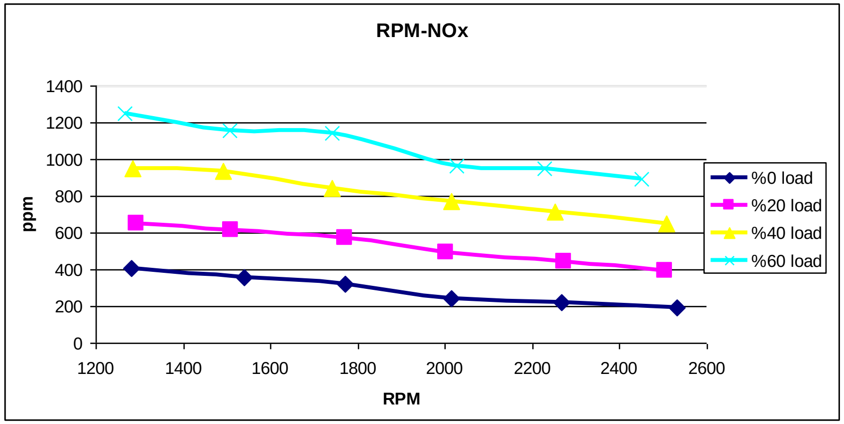
Also pressure data versus crank angle and indicator diagram of the diesel engine can be seen below:

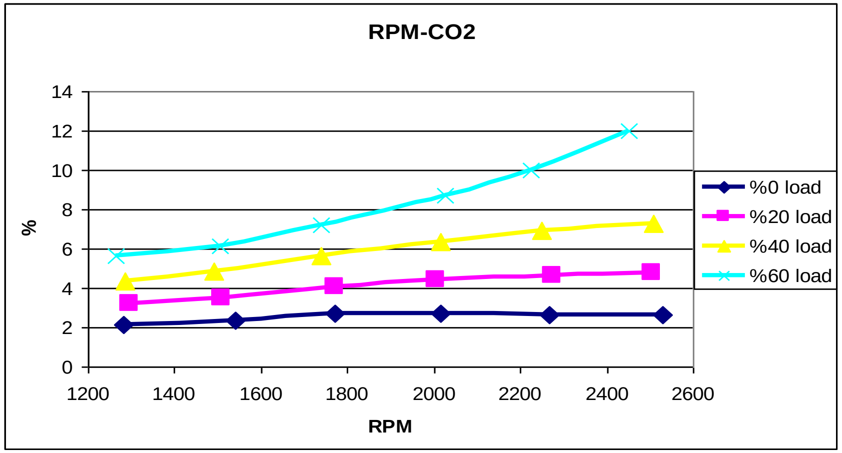


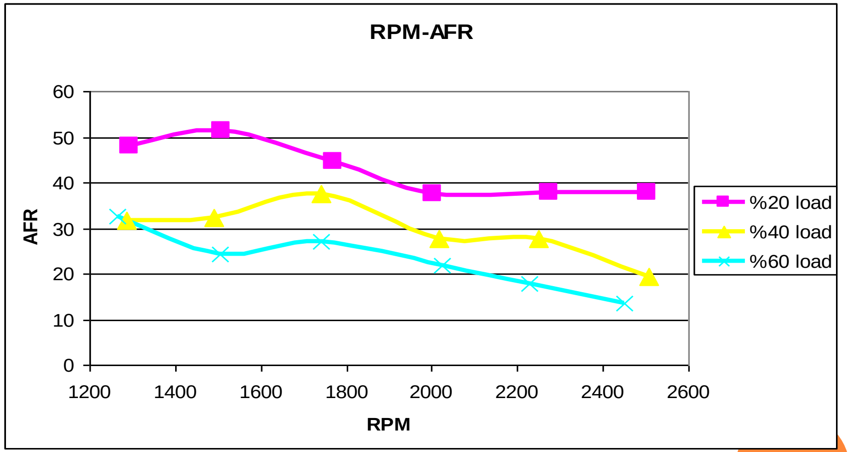
RESULTS

Sample results obtianed from the engine test rig are below :



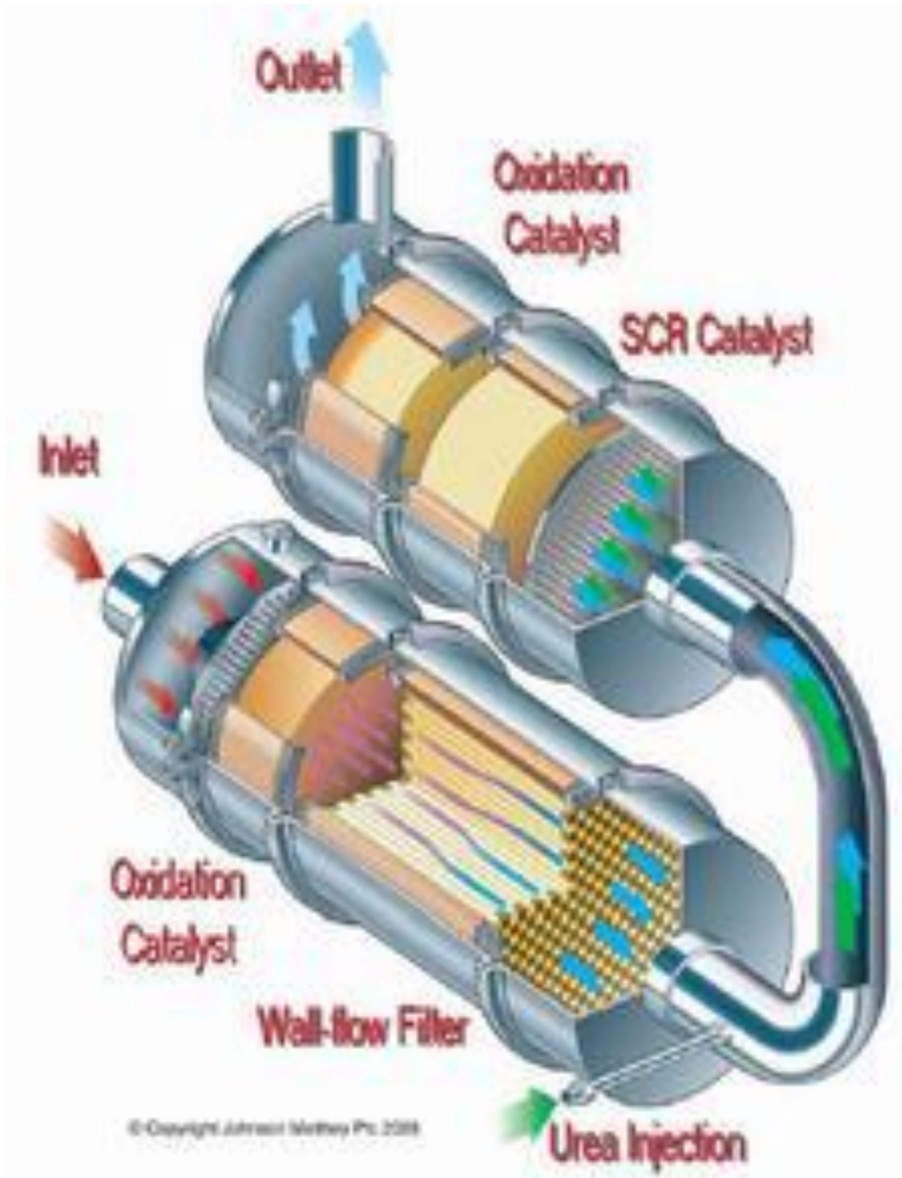




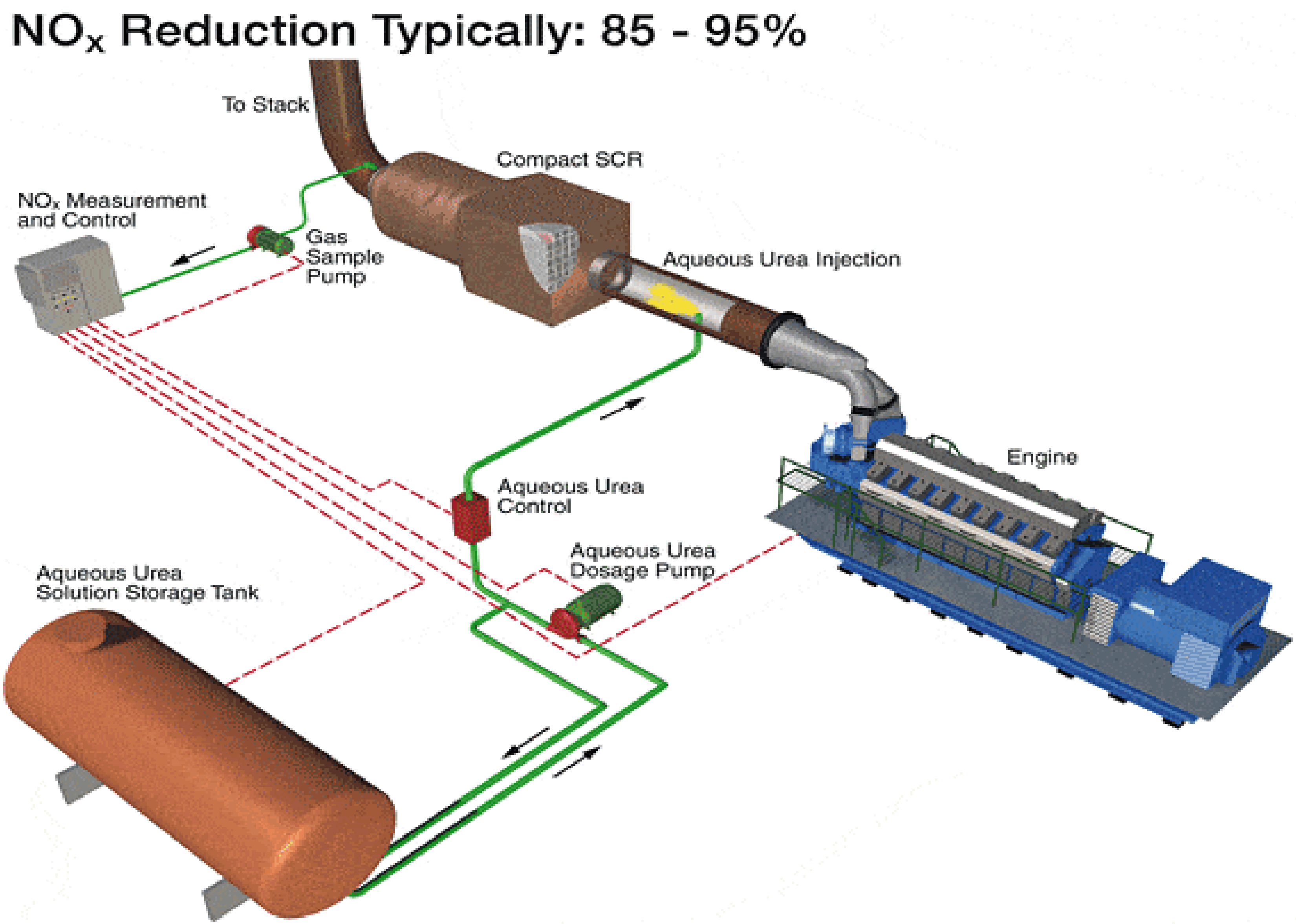


PARTIAL FLOW FILTER, WHICH CAPTURES PARTICULATES COMING OUT OF THE EXHAUST

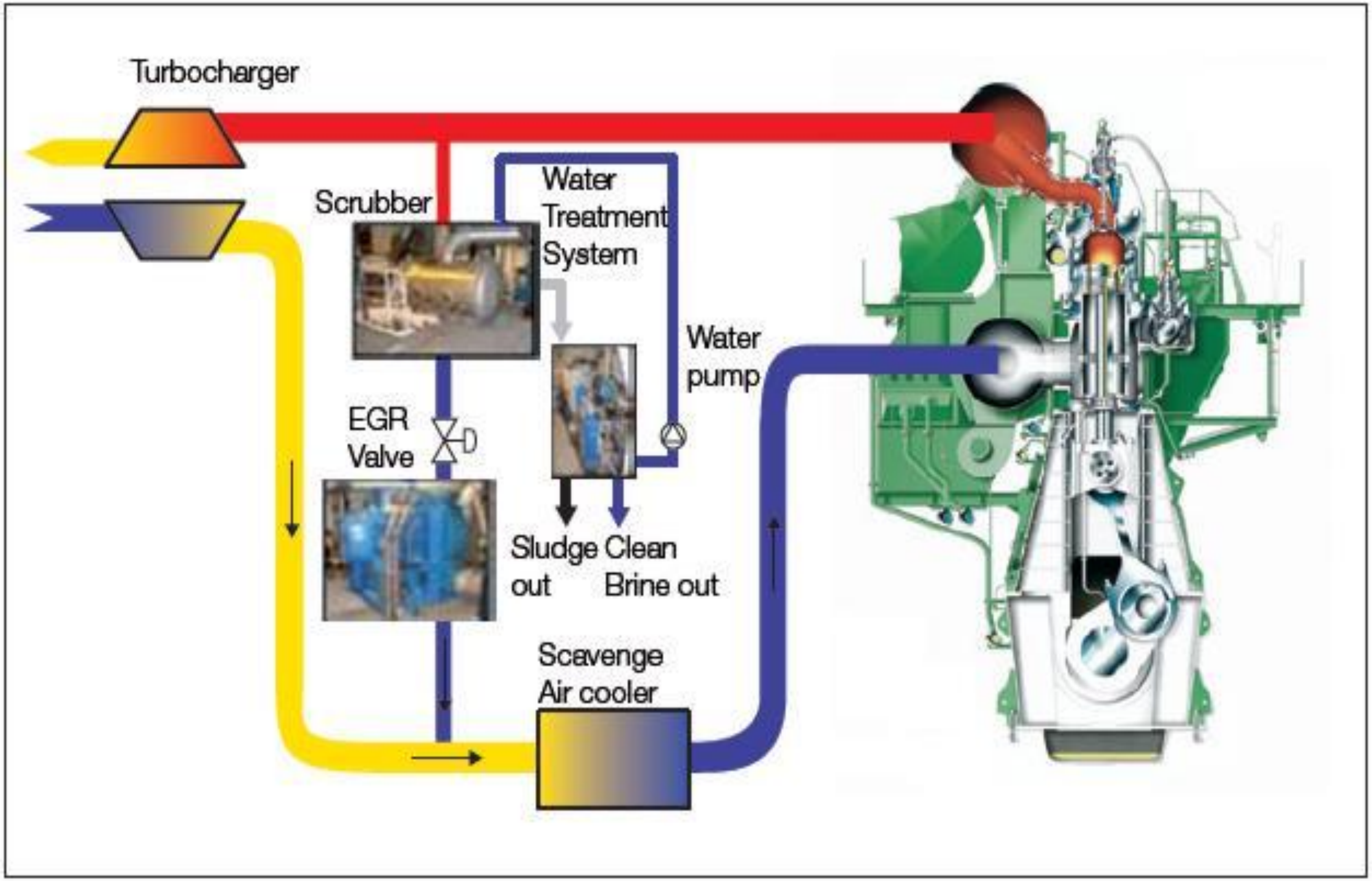
(SCRT), RELATED TO CATALYTIC DPF REGENERATION



Reducing NOx – New concept vs Old



Exhaust Recirculation



CONCLUSIONS - Engine Rig

•The Rig comprised a computer controlled fully instrumented engine test facility.

•The laboratory is separated into two facilities, one holding the instrumented engine and the other computing and display units with a view to improve safety and to decrease noise.

•Analogue/digital control and measurement signals supplied by sensors and actuators are displayed on the graphical user interface using Labview® and logged.

CONCLUSIONS - Engine Rig

•The facilities have proven to produce accurate and reliable experimental results at varying engine loads and speeds.

•The application of Labview ® and the engine software are novel features of the new engine rig.

•The noise of engine and the risk of injury have been decreased and a convenient and safe laboratory environment has been provided.

•The system was then used to model digital twin of automotive, rail and ship propulsion systems.

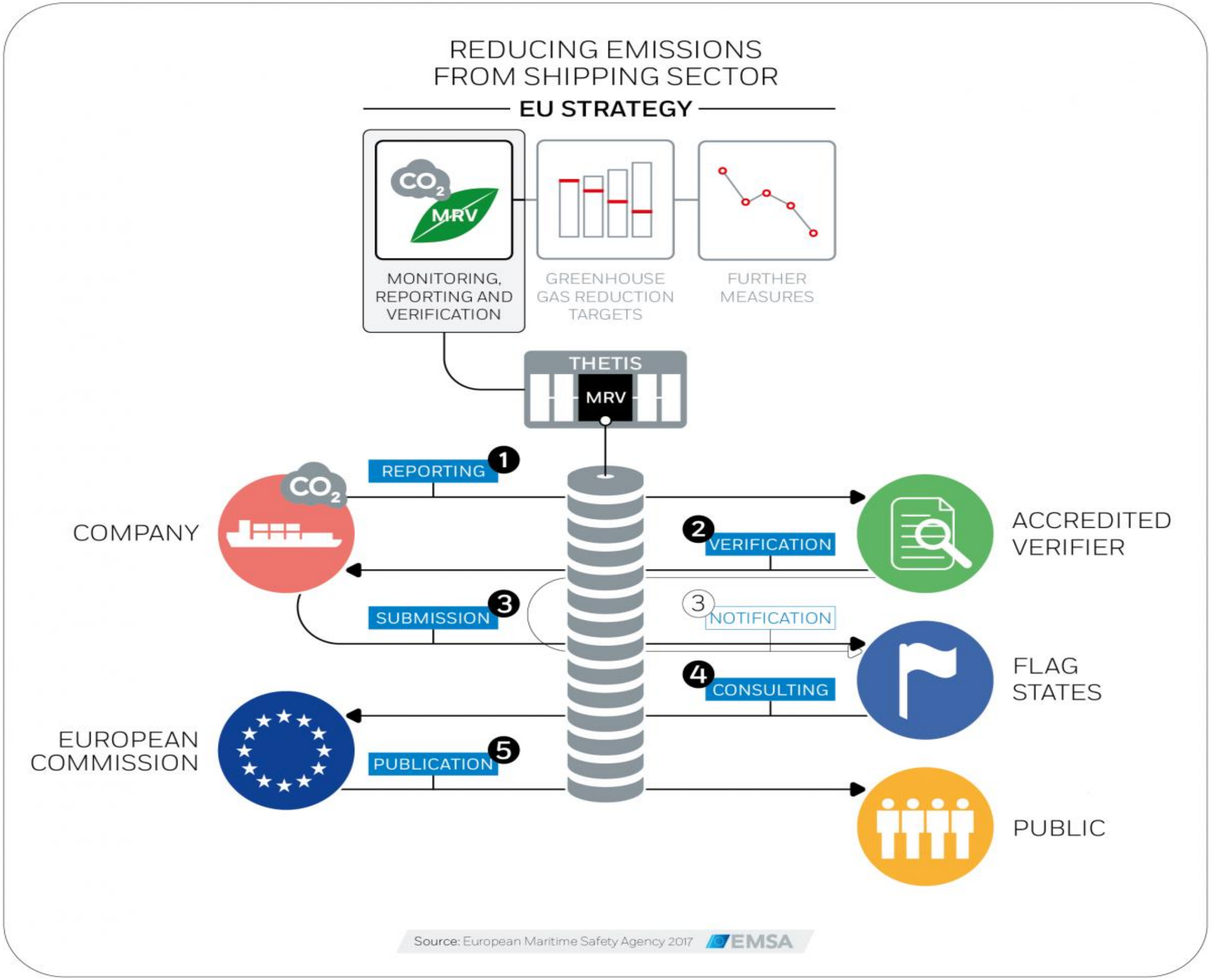
Summary of the Lecture

Part 3

- Ship operations and management – Areas that can be improved and, considering the current and future issues and constraints
- Energy management and international response
- Measures taken in ship design
- Technologies that can help
- Thinking out of the box

NECA´s EMISSION CONTROL ZONES SET BY THE IMO

EU STRATEGY FOR REDUCING EMISSIONS




KMTC LINE
KMTC
NORDSKY
LIMASSOL
IMO8801345
HYUNDAI
NKK


SPRINTER
WERKENDAM
IMO-9423657

Areas for improvement and, current and future issues

- Slow steaming
- Weather routing
- Green energy – wind and sun (Flettner rotor & sun panels)
- Use of sea currents
- e-navigation
- Ballast water management
- Hull and trim optimisation
- Ship-port and port-ship system integration
- Port-road-train-airport system integration
- On-board ship management
- AI and VR applications – Virtual arrival, advanced communications, JIT, predictive requirements

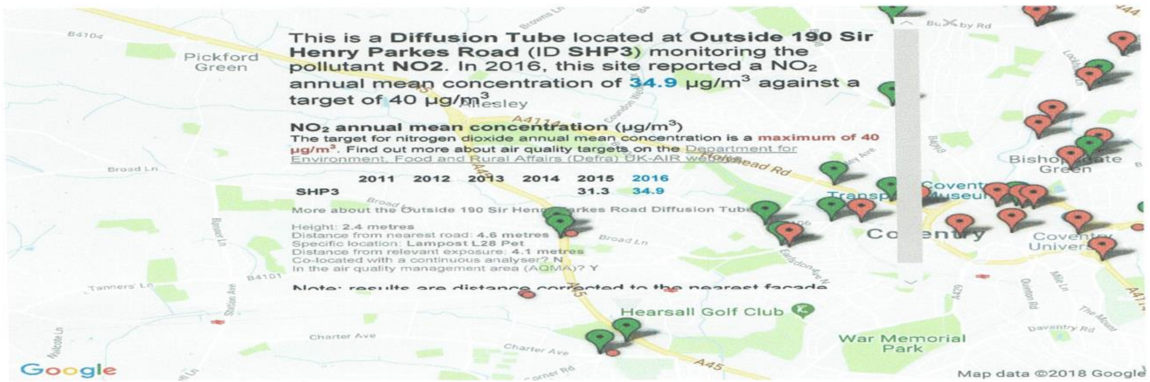
ENERGY MANAGEMENT AND INTERNATIONAL RESPONSE

Cause for concern - continued dependence on fossil fuel

- Energy sources and security
- The impact of air emissions
- Energy management
- IMO efforts – MARPOL Annex VI Chapter 4
- EU efforts

Graph of Coventry Hot Spots 2016

Map of the location of the diffusion tubes around Coventry



AQ Mesh monitors

We are currently trialling two AQ Mesh monitors at one location in the city. These are small, battery operated units that measure nitrogen dioxide. We are investigating procuring more of these monitors in order to monitor at more locations in the future.

Pollution data

Further information on air quality monitoring in Coventry and the West Midlands, including pollutant levels and monitoring results.

« Previous Air quality in Coventry Next » Reviewing and assessing air quality in Coventry

Customer Services

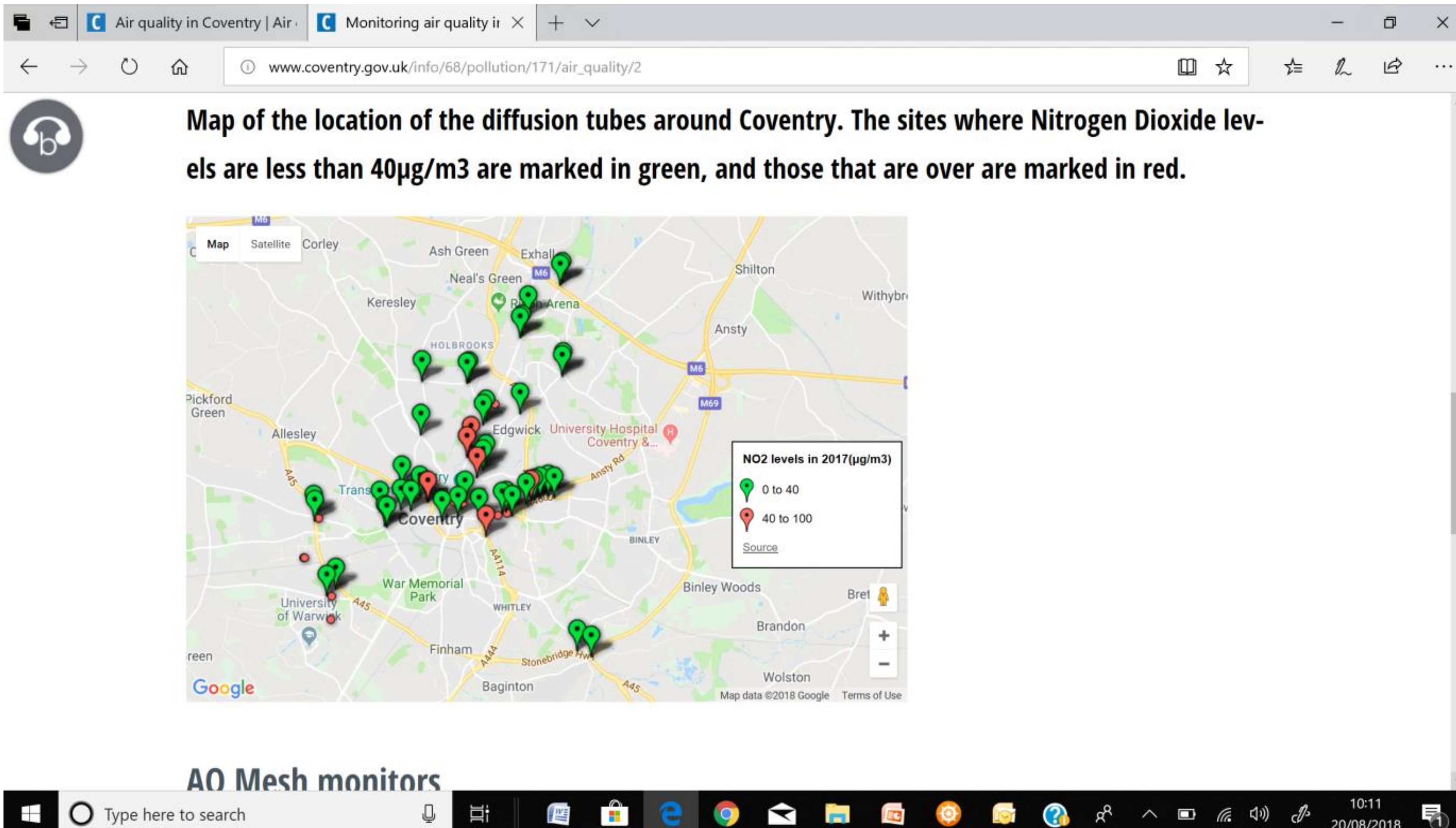
Open 9.00am–5.00pm Monday to Friday (excluding bank holidays)

Email: customer.services@coventry.gov.uk

Tel: 08085 834333

Visit: http://www.coventry.gov.uk/myaccount

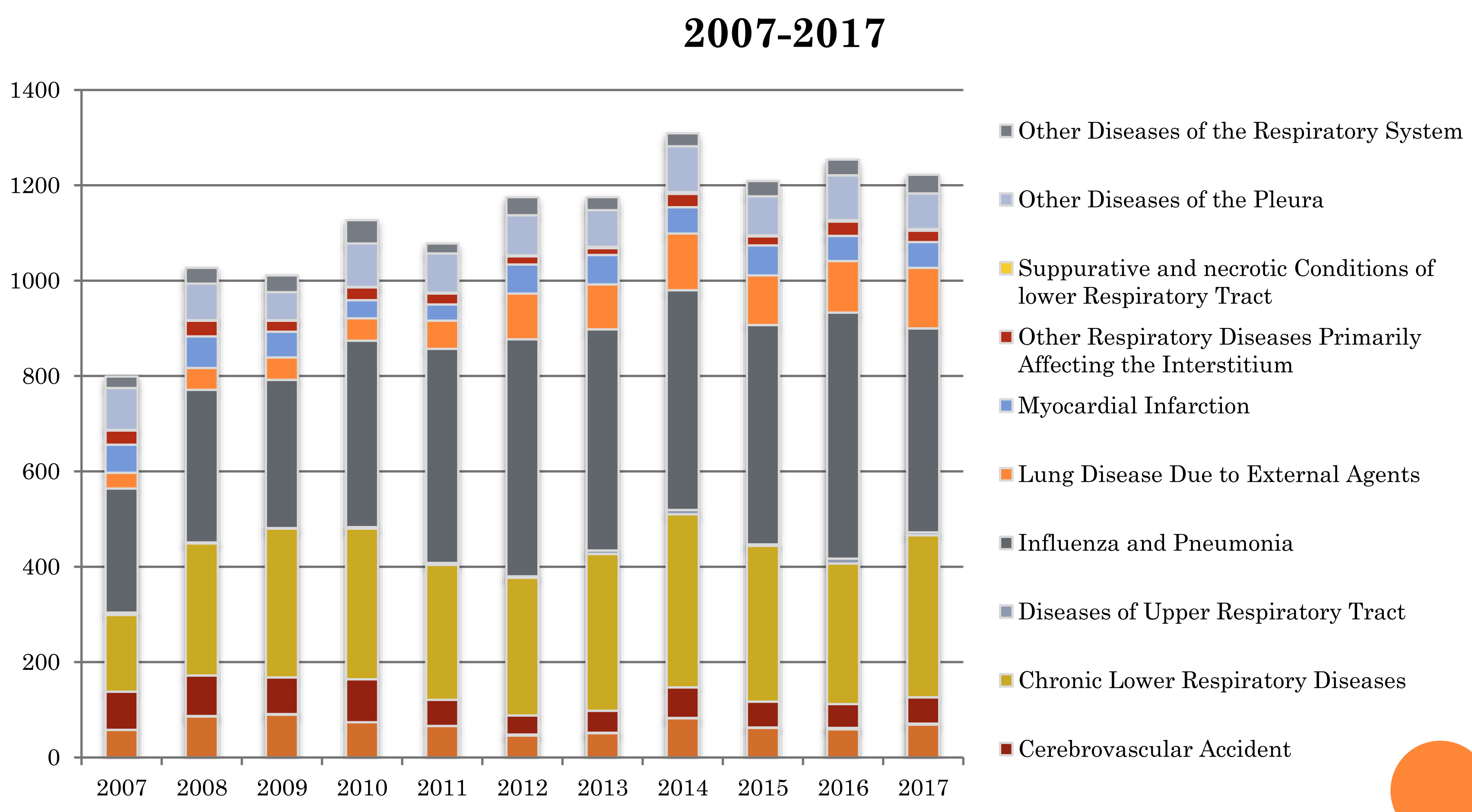
USING ADJUSTMENT FACTORS IN 2017



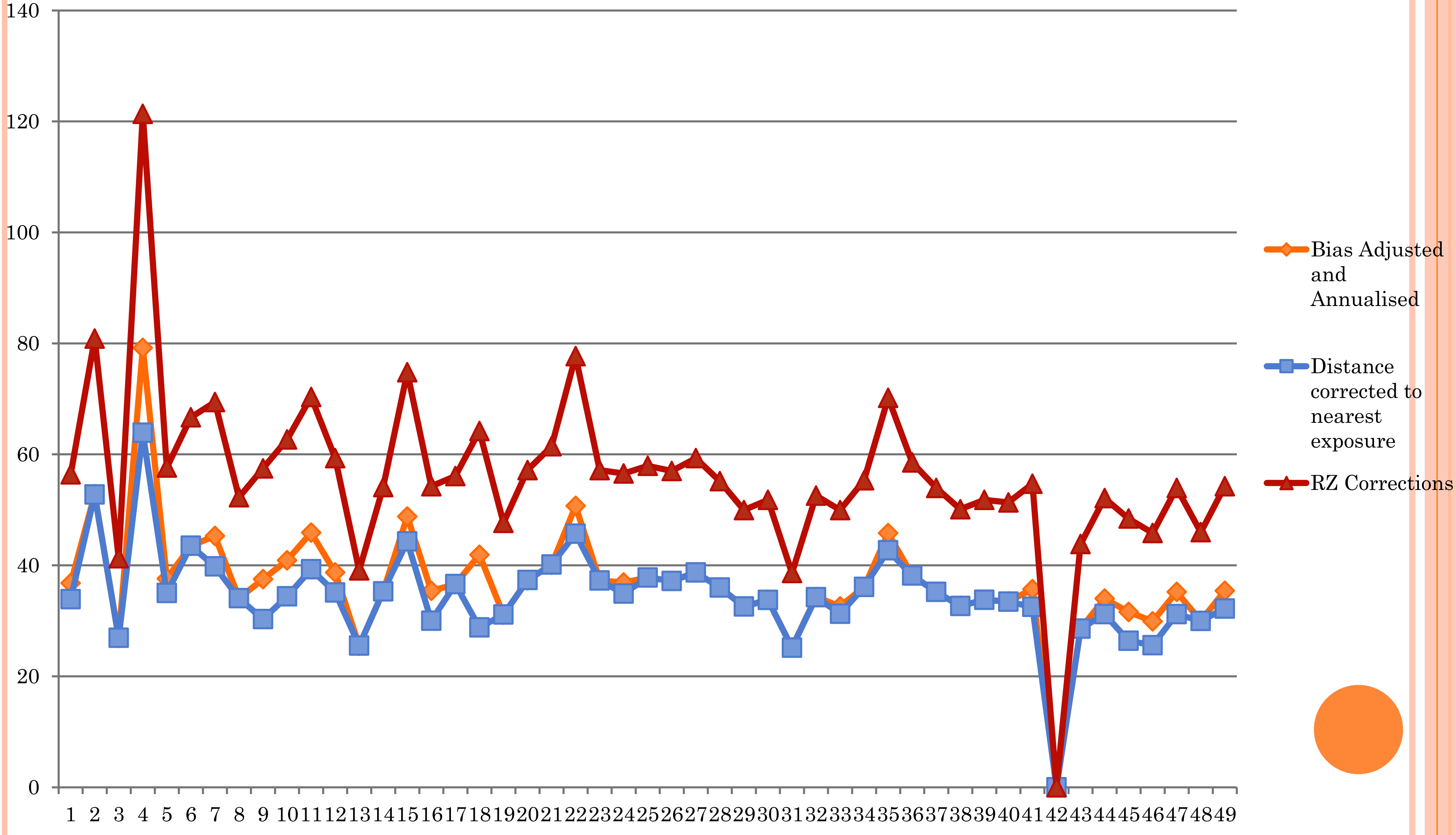
Why 2017 Figures Improved?
A Travesty of Facts

Site Refere	Address	Specific Locatic	Siting Category	Easting	Northing	Tube to receptor	Distance from tube to road	Distance from road	Height	Bias Adjusted (0.87) and Annualised [1]	Distance corrected to nearest exposure	RZ Corrections
CC01*/1N	Holyhead R	Lamp Post	Roadside	432105	279578	4.1	3.1	7.2	2.8	36.8	33.9	56.40
HR1	Holyhead R	Downpipe	Façade	432683	279240	0	5.8	5.8	2.7	**52.8**	**52.77**	80.87
HR2c	104 Holyhe	Downpipe	Façade	432525	279345	0	6.1	6.1	2.1	26.9	26.93	41.27
HR1c	73 Holyhea	Lampost	Roadside	432712	279227	4.2	1.8	6	2.5	**79.2**	**63.9**	121.38
BH1a	Walsgrave	Lampost T1FEA	Roadside	434987	279209	2.9	2.93	5.83	2.67	37.6	35.0	57.62
BH2a	Walsgrave	Window	Façade	435125.972	279286.384	0	3.9	3.9	2.8	**43.5**	**43.52**	66.67
BH4	Walsgrave	Sign	Roadside	435331.002	279358.004	2.2	1.3	3.5	1.8	**45.3**	39.8	69.43
												0.00
BH13	196/198 W	Downpipe	Façade	435507.842	279387.046	0	5.2	5.2	2.5	34.1	34.07	52.26
BH14	238 Walsgr	Lamp post 238	Roadside	435657.77	279356.774	8	1.6	9.6	2.5	37.5	30.3	57.47
BH15i	Walsgrave	Lamp postRoadside		435184	279298	3.5	1	4.5	2.3	**40.9**	34.4	62.68
												0.00
FS1	Fairfax Stre	Lamp Post	Roadside	433569	279233.999	3.9	1	4.9	3	**45.9**	39.3	70.34
												0.00
QV1	Lampost ou	Lamp post L15I	Roadside	433029	278798	2.12	1.95	4.07	2.57	38.7	35.1	59.31
GF1	Greyfriars 1	Downpipe	Façade	433407	278882	0	0.47	0.47	2.59	25.5	25.53	39.08
GS1	Outside Go	Downpipe	Façade	433899	278845	0	9.8	9.8	2.8	35.3	35.30	54.10
LON12	Between 7(	Signpost	Roadside	434073	278459	2	2	4	2.72	**48.8**	**44.3**	74.79
												0.00
SE1	Spon End, 5	Downpipe	Roadside	432083.701	279042.164	2.6	0.1	2.7	2	35.4	30.0	54.25
SE3	97 Spon En	Downpipe	Façade	432302.698	279027.648	0	2.3	2.3	3.1	36.6	36.62	56.09
QAV01	Queenslanc	Lamp post	Roadside	431595	278990.999	5.2	0.1	5.3	2.5	**41.9**	28.8	64.21
QAV12	Queenslanc	downpipe	Façade	431703.653	278680.098	0	4.3	4.3	2	31.1	31.12	47.66
QAV13	Hearsall La	downpipe	Façade	431762.894	278657.464	0	4.9	4.9	2.5	37.3	37.34	57.16
ngford Road												0.00
R5	Foleshill Rc	Downpipe	Façade	433716.001	280502.996	0	3.7	3.7	2.8	**40.1**	**40.13**	61.46
R6	Foleshill Rc	Signpost	Roadside	433609	280246	2.2	2.05	4.25	2.72	**50.7**	**45.7**	77.70
R8	Foleshill Rc	Downpipe	Façade	433992.004	281008.002	0	4.3	4.3	2.75	37.3	37.26	57.16
R9	Foleshill Rc	Lamp Post	Roadside	434059	281105	1.83	3.07	4.9	2.65	36.9	34.9	56.55
LR1	23 Longfor	Downpipe	Façade	434836.002	283030.003	0	5.6	5.6	2	37.8	37.80	57.93
LR2	24 Longfor	Downpipe	Façade	434879.997	283076.999	0	4.2	4.2	2	37.2	37.17	57.01
LR3	Longford R	Downpipe	Façade	435015.892	283515.014	0	8.5	8.5	1.5	38.7	38.71	59.31
												0.00
BRN2	Burnaby Rc	Downpipe	Façade	433604.997	281964.998	0	5.5	5.5	2.75	36.0	35.98	55.17
BRN5	41 Holbroo	Downpipe	Façade	433639.7	281995.91	0	6.7	6.7	2	32.6	32.57	49.96
BA1	Beake Aver	Downpipe	Façade	432526	280806	0	7.5	7.5	3	33.8	33.75	51.80
BA1c	299 Beake	Downpipe	Façade	432544.08	282004.7	0	10.45	10.45	2.04	25.2	25.15	38.62
												0.00
SS1	Stoney Star	Downpipe	Façade	434061.848	280082.127	0	3.7	3.7	2.5	34.3	34.25	52.57
SS2	Stoney Star	Downpipe	Façade	433993.999	279968.999	0	4.5	4.5	2.5	32.6	31.27	49.96
SS3	R/O 21 Torcastle Close (fac		façade	434842.004	281271.996	0	4.5	4.5	2.5	36.1	36.09	55.33
SS5	Lampost L2	Lampost	Roadside	433852	279814	1.8	2	3.8	2.51	**45.8**	**42.7**	70.19
												0.00
												0.00
BELL1	16 Hall Gre	Downpipe	Façade	435849	282211	0	5.7	5.7	2.5	38.2	38.15	58.54
BELL2	314 Bell Gr	Downpipe	Façade	435826	282158	0	2.9	2.9	2.7	35.2	35.20	53.95
FGS2	Select & Sa	Downpipe	Façade	434450	279001	0	2.4	2.4	2.7	32.7	32.67	50.11
FGS3A		Downpipe	Façade	434521	279024	0	5.5	5.5	2.5	33.8	33.78	51.80
GR1	217 Gulson	Downpipe	Façade	434679	278920	0	4.5	4.5	2.5	33.5	33.45	51.34
Grange2		Telegraph Pole	Roadside	435765	284246	1.44	0.3	1.74	2.4	35.7	32.50	54.71
SHP1	257 Sir Her	Downpipe	Façade	430447.4	277080.3	0	9.93	9.93	2.37	/	<25%	
SHP2	262 Sir Her	Downpipe	Façade	430364.1	277059.6	0	12.47	12.47	2.3	28.6	28.58	43.83
SHP3	Outside 19(	Lampost L28 PI	Roadside	430566.84	277231.21	4.16	4.6	8.76	2.4	34.0	31.20	52.11
BL1	Corner Bro	Lampost	Roadside	430043.77	278890.3	9.6	1.5	11.1	2.55	31.6	26.40	48.43
DH1	Outside 58	Lampost L148F	Roadside	430076.25	278789.4	12.67	3.17	15.84	2.45	29.9	25.60	45.82
												0.00
STL1	End of Stor	Lampost L6KGI	Roadside	436203.494	275841.291	9	12	21	2.45	35.2	31.20	53.95
LON8	On no. 703	Downpipe	Façade	436551.238	275703.36	0	17.9	17.9	2.45	30.0	29.97	45.98
												0.00
Grange3	161/163 Gı	Telegraph Pole	Roadside	435791	284285	1.44	0.3	1.74	2.43	35.4	32.2	54.25

Hospital Admissions

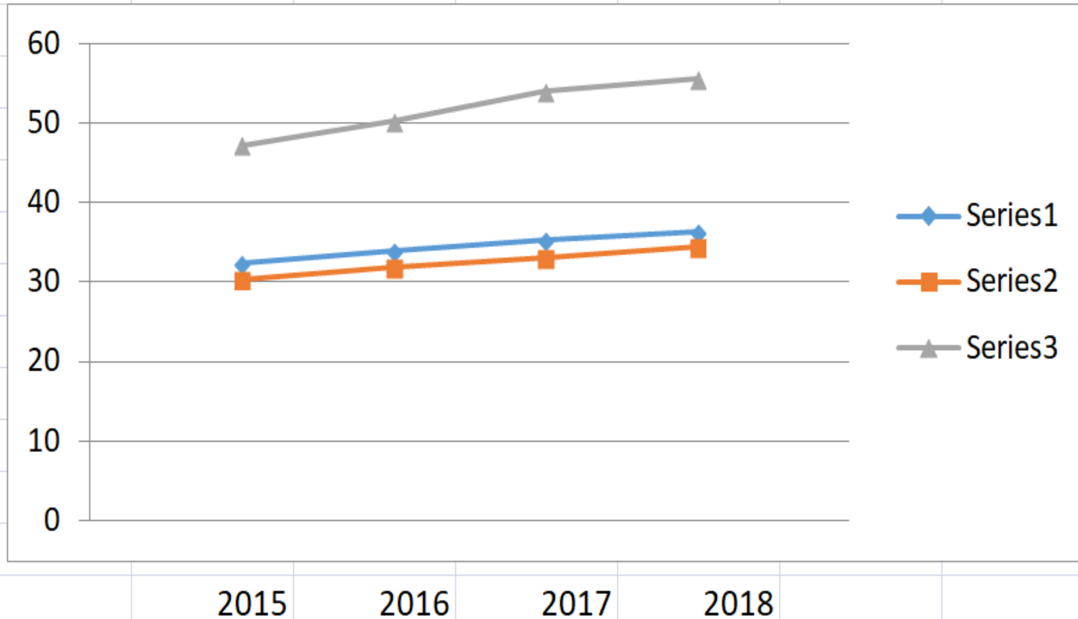


ACTUAL DIFFUSION TUBE READINGS
BIAS ADJUSTED VS DISTANCE CORRECTED VS RZ CORRECTED
NB: RZ FIGURES ARE BASED ON ACTUAL MEASUREMENT SAT ROAD LEVELS



Average Diffusion Tube Reading 2015-2018

2015	32.37	30.35	47.26
2016	33.96	31.94	50.28
2017	35.26	33.16	54.02
2018	36.43	34.55	55.67



Key:

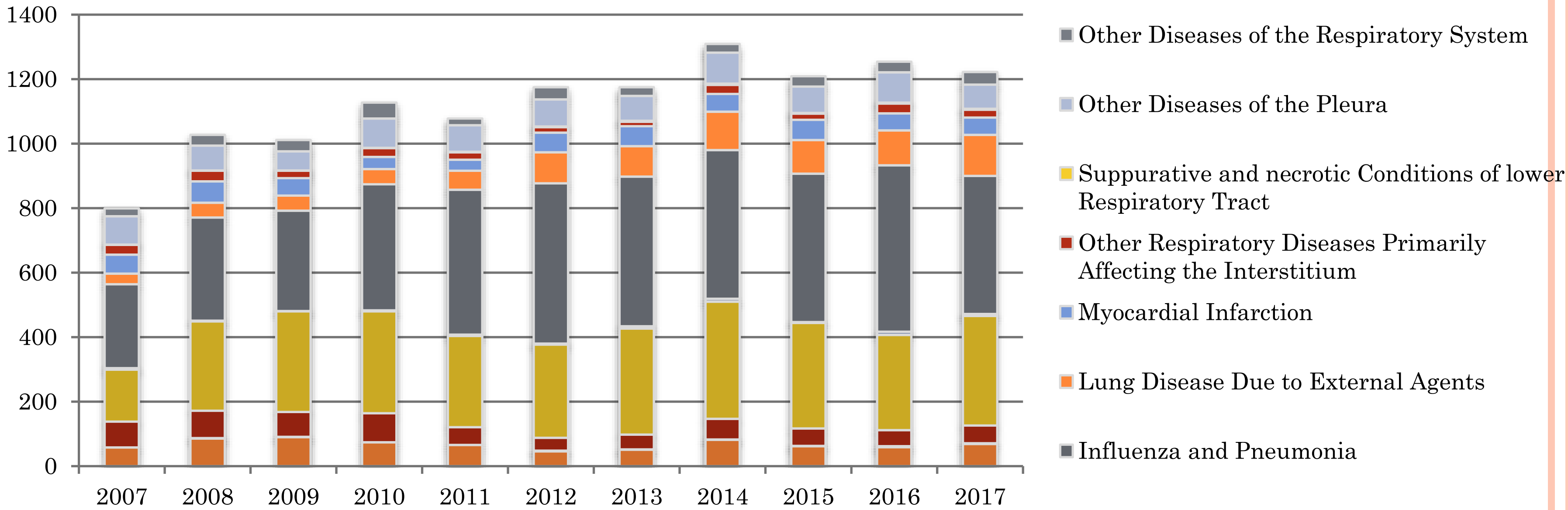
Series 1 - Average - Tube Readings Error Not Adjusted

Series 2 - Average - Error Not Adjusted and Readings Biased and Reduced as per Government Advice

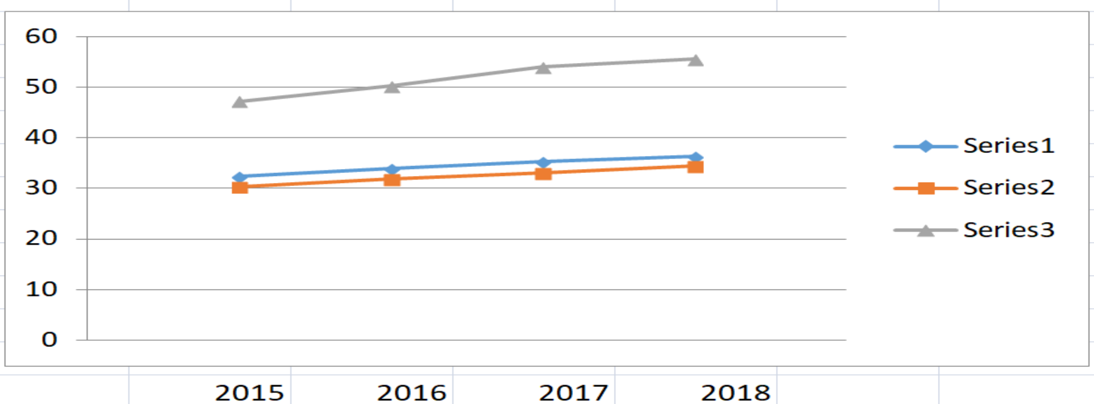
Series 3 - Average Max Possible Actual Values Correlated with Actual Readings at Road Level

Hospital Admissions vs Diffusion Tube Readings

2007-2017



2015	32.37	30.35	47.26
2016	33.96	31.94	50.28
2017	35.26	33.16	54.02
2018	36.43	34.55	55.67



Key:

Series 1 - Average - Tube Readings Error Not Adjusted

Series 2 - Average - Error Not Adjusted and Readings Biased and Reduced as per Government Advice

Series 3 - Average Max Possible Actual Values Correlated with Actual Readings at Road Level

MEASURES TAKEN IN SHIP DESIGN

How to reduce resistance to motion

How to make propulsion more efficient – New vs Retro

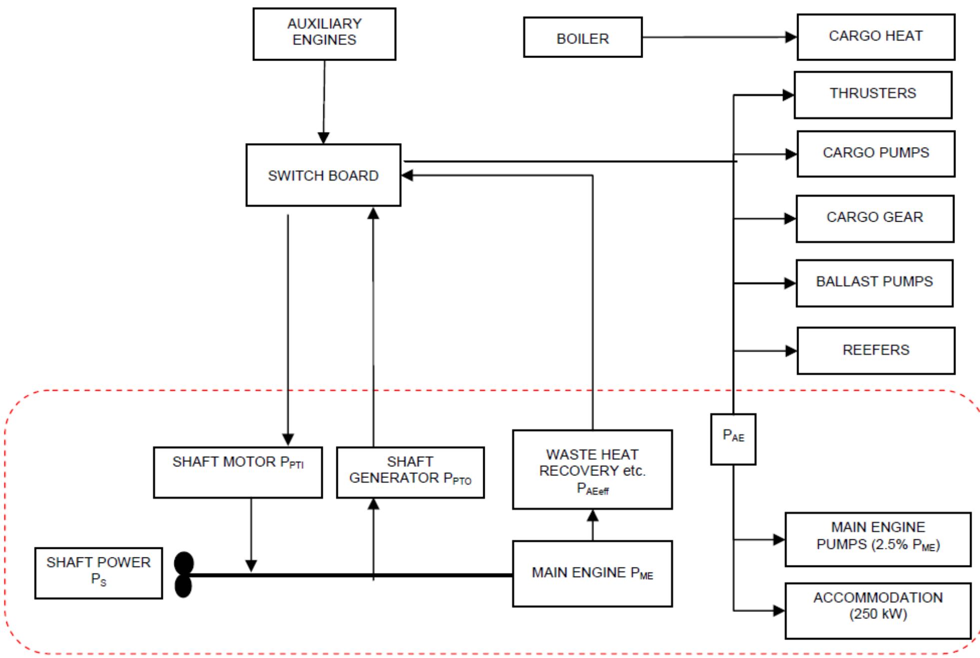
- Propulsion – Gas? Electric? Nuclear?
- IMO SEEMP – Energy Efficiency Design Index (EEDI)
- Predictive ship life cycle – IMO vs C4FF
- Hull coating

IMO work to address GHG emissions from ships

- IMO Resolution A.963(23) –IMO Policies and Practices Related to the Reduction of Greenhouse Gas Emissions from Ships, adopted by Assembly 23 in December 2003
- IMO's work to address GHG emissions has three distinct routes:
  - Technical
    Mainly applicable to new ships –EEDI
  - Operational
    Applicable to all ships in operation –SEEMP
  - Market-based Measures (MBM)
    Carbon price for shipping, incentive, may generate funds

Attained EEDI

A generic and simplified marine power plant



IMO Energy Efficiency Design Indicator (EEDI)

$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}*\right) + \left(\left(\prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}{f_i \cdot Capacity \cdot V_{ref} \cdot f_w}$$

Attained EEDI

$$\text{EEDI} = \frac{\overbrace{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right)}^{\text{Main Engine(s)}} + \overbrace{\left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}*\right)}^{\text{Aux Engine(s)}} + \overbrace{\left(\left(\prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right)}^{\text{Innovative Energy Eff. Power Gen. Technologies}} - \overbrace{\left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}^{\text{Innovative Energy Eff. Propulsion}}}{f_i \cdot Capacity \cdot V_{ref} \cdot f_w}$$

[gCO_2/(tonne.nm)]

e.g. Waste Heat Recovery

e.g. Wind assisted technology

Ship Energy Efficiency Management Plan (SEEMP)

Each ship of 400 Gt and above shall keep on board a ship specific SEEMP.

Operational management tool applicable for all ships of 400 GT and above and includes:

- Improved voyage planning (weather routeing/Just in time arrival at port)
- Speed and power optimization
- Optimized ship handling (ballast/trim/use of rudder and autopilot)
- Improved fleet management
- Improved cargo handling
- Energy Management
- Monitoring tools (Energy Efficiency Operational Indicator)

$$\mathrm{EEOI} = \frac{\sum_j FC_j \times C_{Fj}}{m_{cargo} \times D}$$

TECHNOLOGIES THAT CAN HELP

- Artificial Intelligence (AI)
- Virtual Reality
- Wind Cylinders – Mangus effect (air at right angle)
- JIT
- Novel e-navigation
- Ship Automation

Crazy Ideas?

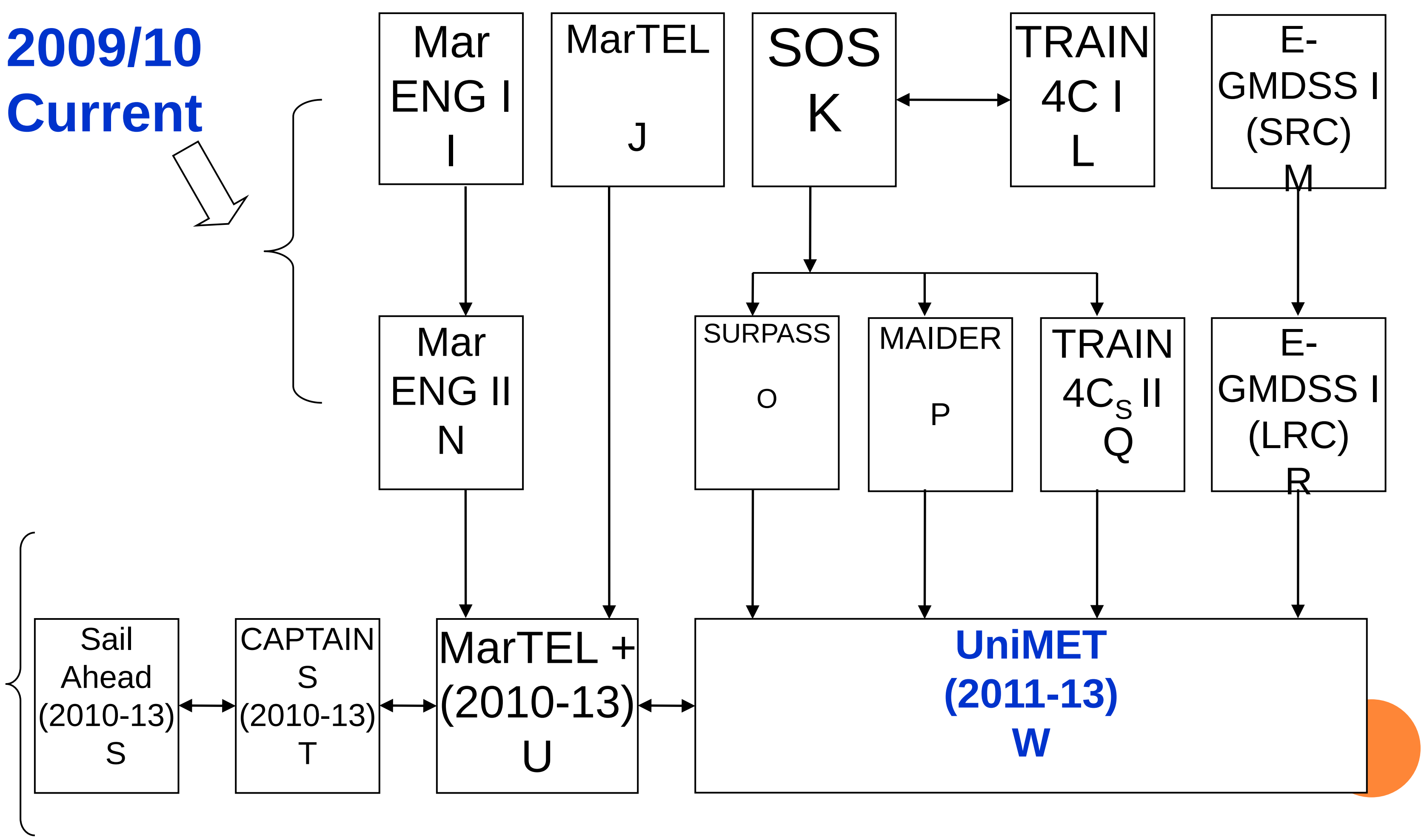
Innovation is ‘not business as usual’

Tolerating crazy ideas, but let us go through not so crazy ideas first.

Story of how it all started and initially got the funds to do the work done so far.

Story starts with the work carried out to clean diesel engines and then how to reduce the resistance to the movement of the ship.

MariFuture Initiated Funded Projects 2007-2013 – www.marifuture.org



MariFuture Funded Projects 2013-2017 and 2016-2019

MARIFUTURE

- Avoiding Collision at Sea Project ACTS 2013-2015 X
- STCW Revision Implementation 2012-15 Project SeaTALK Y
- Port Security and operation and IdealPort 2013-2017 Z
- Ship Efficiency EBDIG-WFSV and LeanShip 2013-2017 AA
- Making seafaring more attractive Projects SOS and Marİne 2013-2017 BB

Recently concluded project:

- **MariePRO – Marine Evironement Awareness (IMO Model course revised)**

Current projects 2016-2018/19

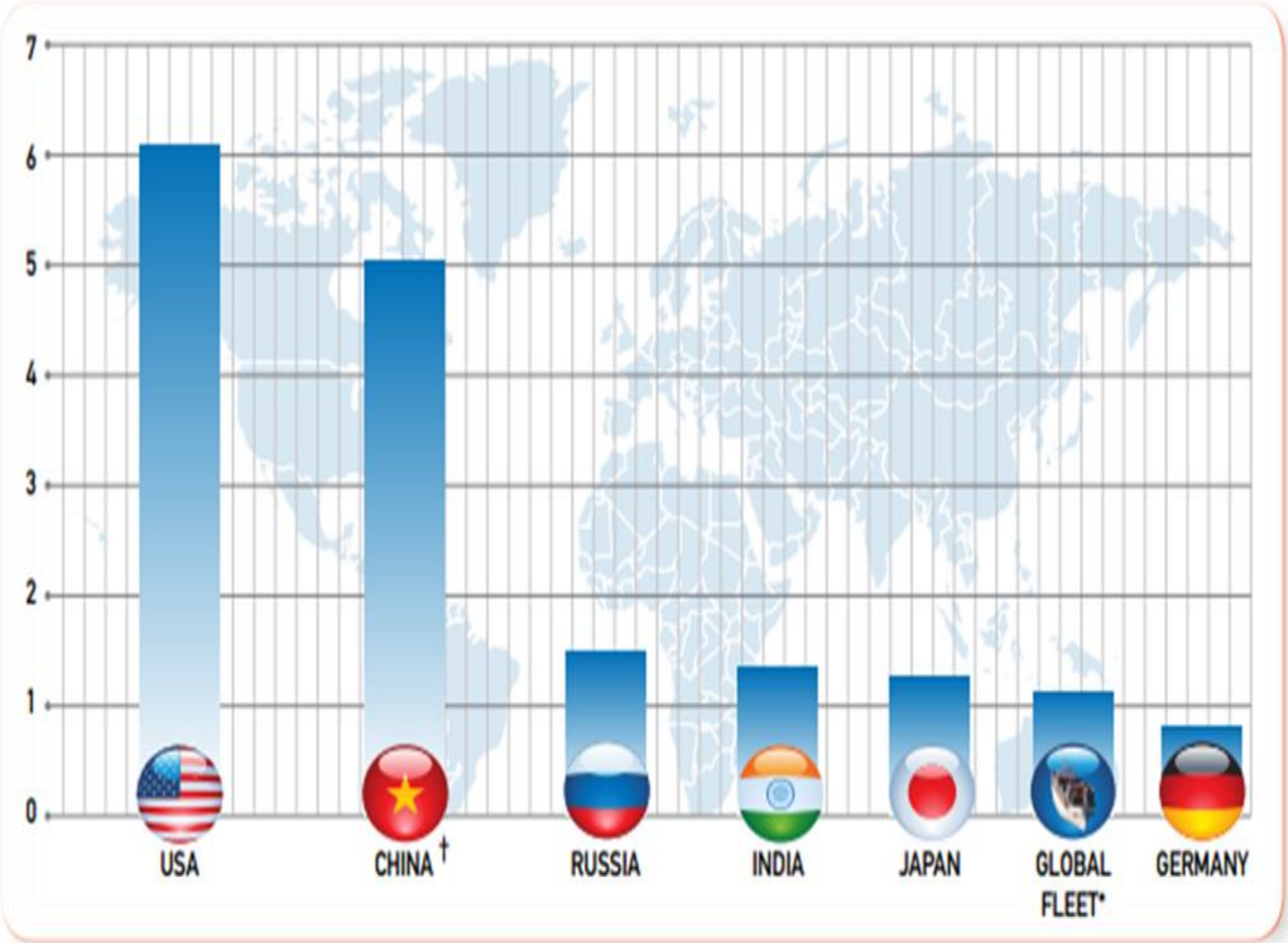
- **<u>MariEMS</u>; MariLANG; ACTS Plus**

Earth and Pollutions

- **Troposphere** – Earth Blanket; reflects Infrared and warms the earth; it contains Ozone depleting substances such as man-made pollutants (FluoroCarbons, CFCs, HFCs. Other cooling agents some radioactive.
- **Stratosphere** – Ozone Layer; Filters UVL
- Concerns - exponential rise in CO_2, N_2O, CH_4, etc.
- **NO2 – Almost equal amount from industrial farming when comparing emissions from fossil fuels.**
- $CO_2 + H_2O = H_2CO_3$ Carbonic Acid
- Many conventions, Kyoto and Paris are most recent.
- **But think if there was no diesels and petrol and coal were used Instead!**

Trees: Good or bad? Which one produces more Oxygen or carbon dioxide?

IN COMPARISON SOURCE: OCEANA



Why MariEMS?

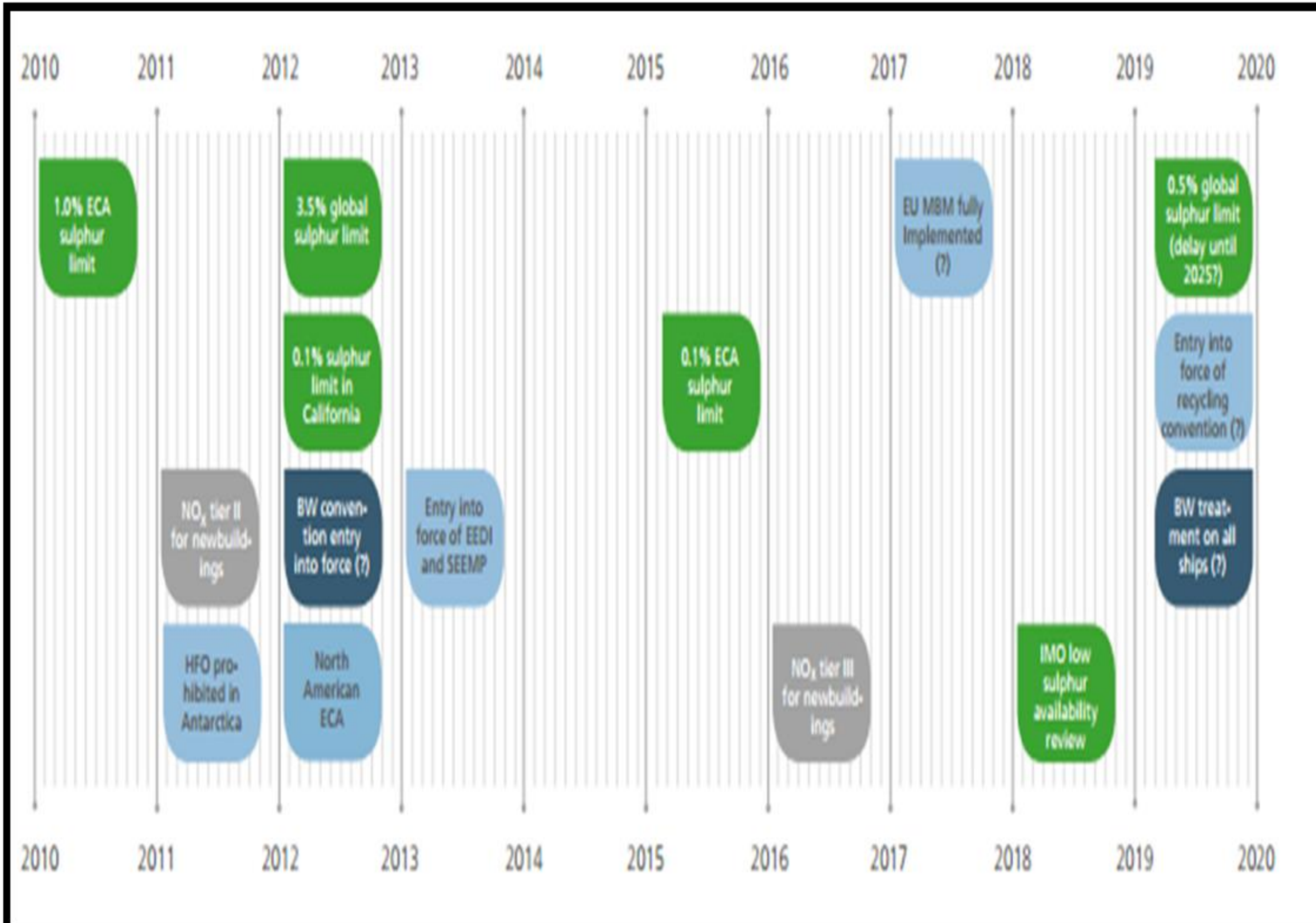
- Maritime Trade accounts for approximately 90% of trade in the world today

- About 870 million tonnes of CO_2 have been estimated to be emitted from the international shipping and it is expected to grow by 200% to 300% by the end of 2050, in the absence of any meaningful regulations - IMO GHG study, Buhang et al (2009)

Yet in 2007 the global shipping industry estimated to have emitted 1,046 million tonnes of CO_2, 3.3 % of global emissions, and in 2015 this reached some 6 % of world total.

The Industry is taking steps to reduce its Air Pollution and Carbon footprint due to recent and upcoming regulations

Upcoming Maritime Regulations Source: GL



EU 2050 Objectives

1. Towards Zero Accidents - prevention

- Collision / grounding avoidance (-30%)
- Fire avoidance (-15%)
- Structural breakdown avoidance (-10%)
- Adverse conditions avoidance (-20%)
- Cargo loss avoidance (-50%)
- Damage stability (-20%)
- Fire resistance (variable)
- Damage stability (-80%)
- Cargo loss avoidance (-50%)
- Damage stability (-20%)

EU 2050 Objectives

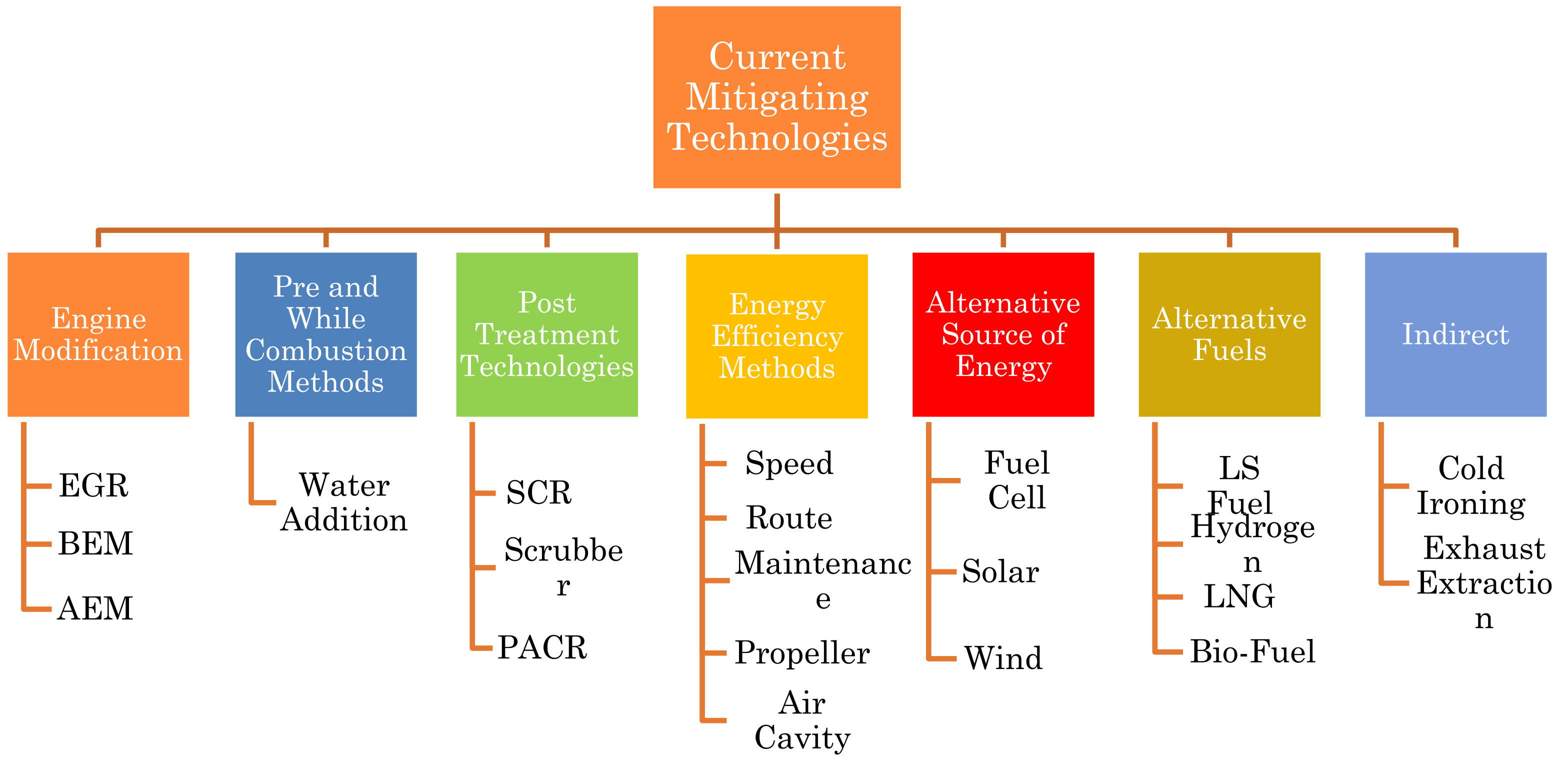
- Structural damage resilience - (-20%)
- Excessive motions and accelerations (-30%)
- **Environmental damage (-50%)**
- Inability to return to port (-50%)
- Casualties (-80%)

2. The Eco---Efficient Vessel Emission

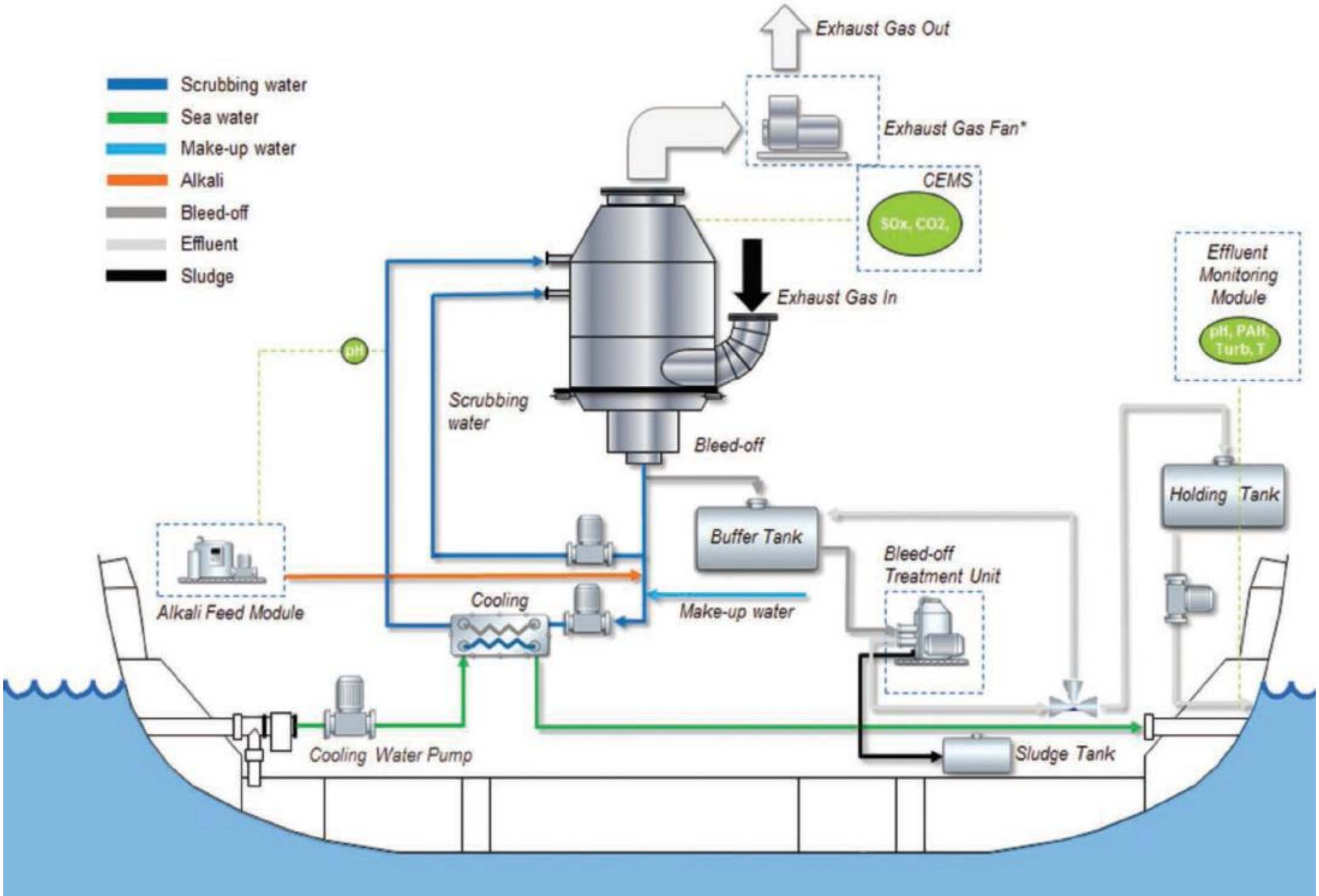
Reduction: CO2, Nox and Sox

- **CO2: >80% (-30% by 2020)**
- **NOx: 100% (-80% by 2020)**
- **SOx: 100% (-80% by 2020)**
- **Noise Reduction: -3dB**

Clean Technologies/Measures



SOX CLEANING SYSTEM - SCRUBBER



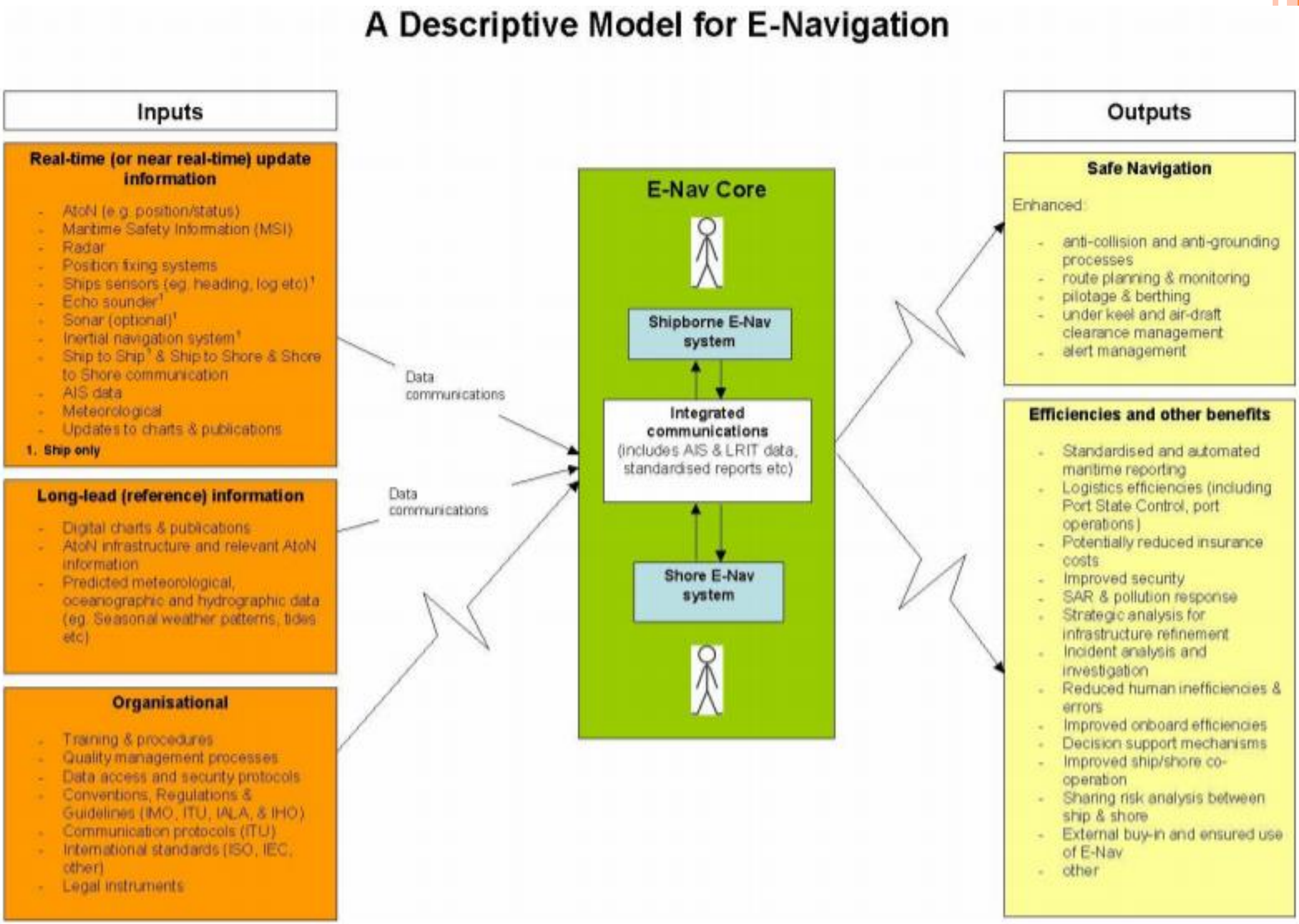
MariFuture - Key Recent Developments

- 2011 An Integrated transport System
- Multi-modal by 2030 – While Paper on Transport
- Connect airports, sea ports, road and railway by 2050 (30% of Road onto Sea)
- Maritime transport emissions reduction of 40% if possible 50% by 2050 compared to 2005 levels
- LNG actions
- Green Paper 2012 - Marine Knowledge 2020
- MILC – 2014/15
- NOx and PMs concerns - 2016
- Recent Developments by C4FF

E-Navigation

- This inspired the development of new technologies such as Automatic Identification System (AIS), Electronic Chart and Information System (ECDIS) Integrated Bridge and Navigation Systems, Automatic Radar Plotting Aids (ARPA), Long Range Identification and Tracking (LRIT) systems, Vessel Traffic Services (VTS) and the Global Maritime Distress Safety System (GMDSS). The aim was to develop a strategic vision for the utilization of existing and new navigational tools, in particular electronic tools, in a holistic and systematic manner. The proposed solution was named e-navigation.

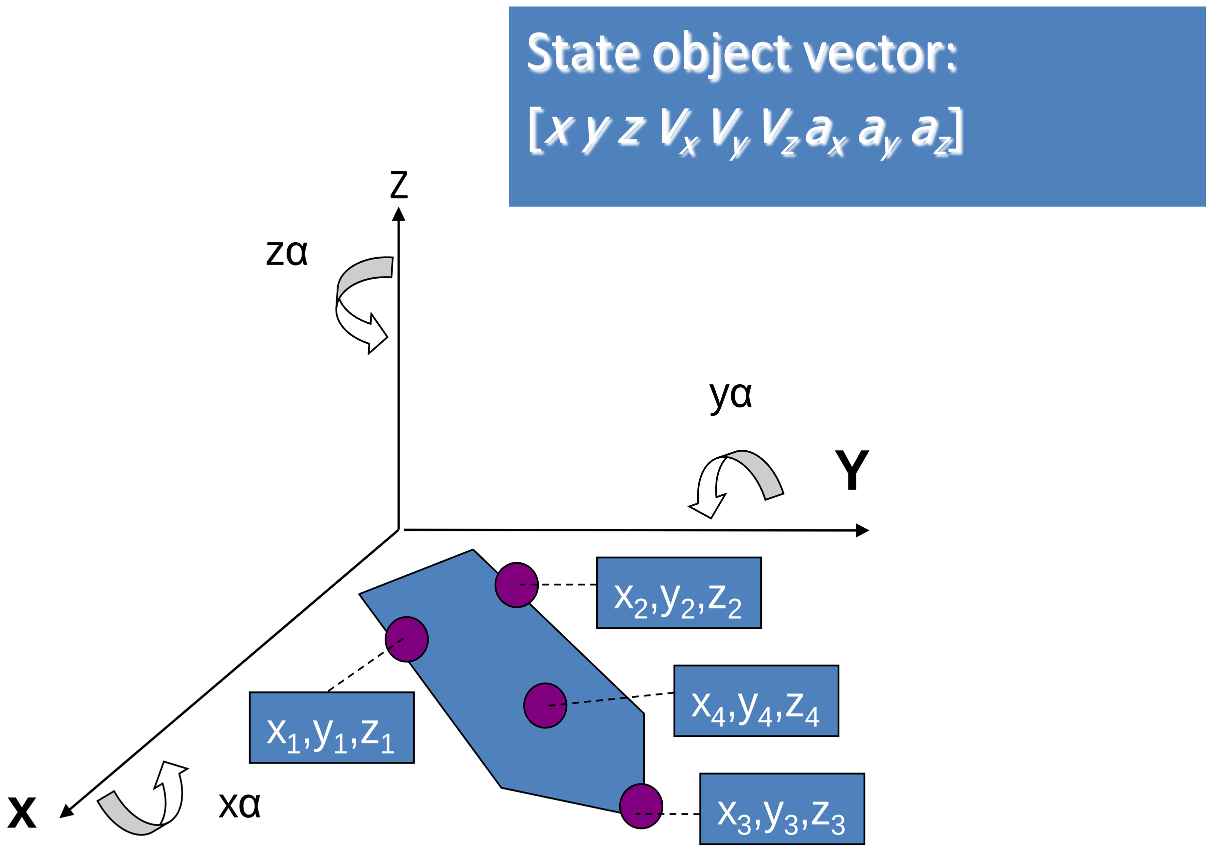
DIAGRAMMATIC PRESENTATION OF E-NAVIGATION



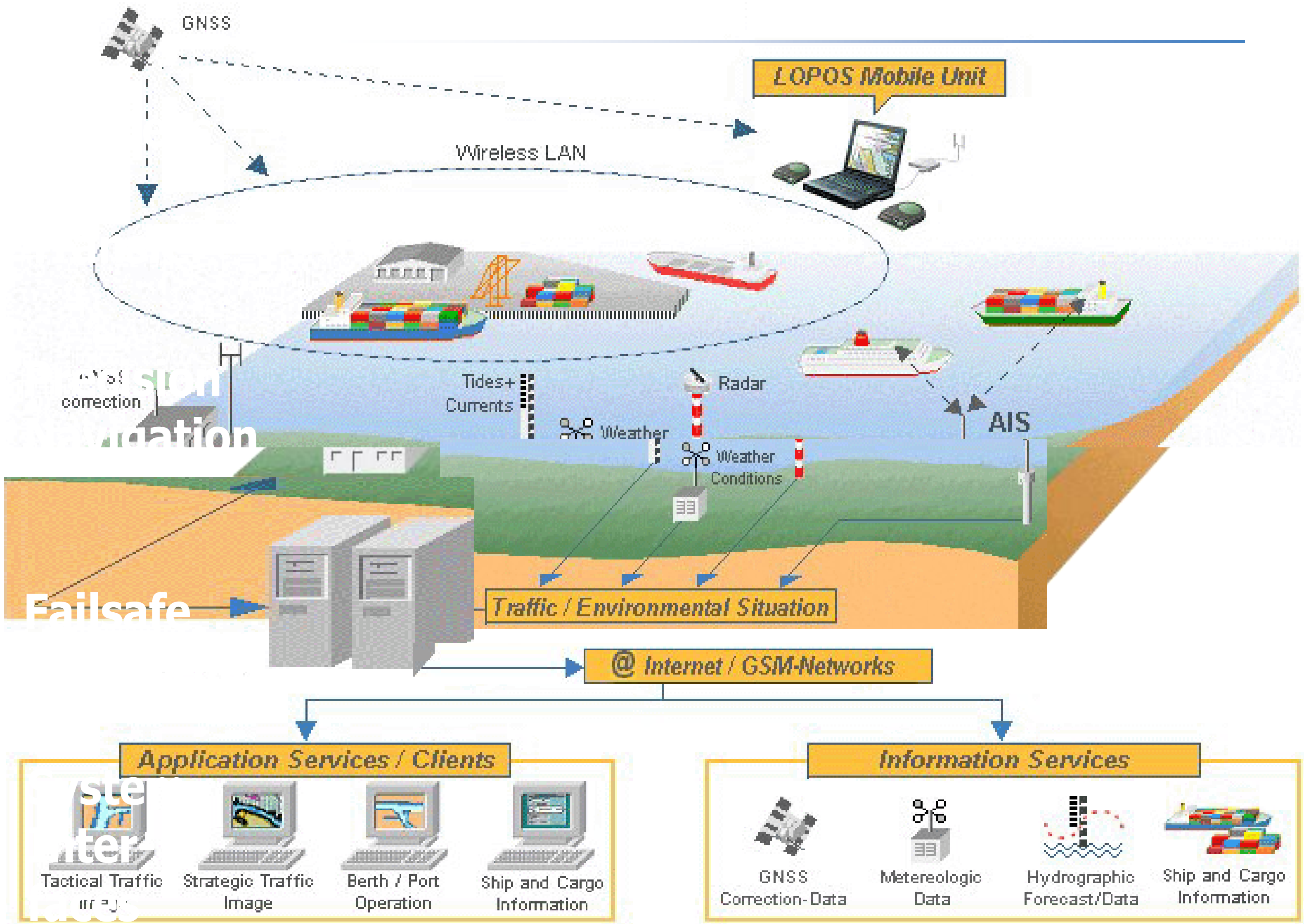
EFFICIENCY THROUGH LESS POLLUTING AND LEANER ENGINES AND OTHER MEANS OF REDUCING FUEL CONSUMPTION AND EMISSIONS

Ship AutoSet Systems

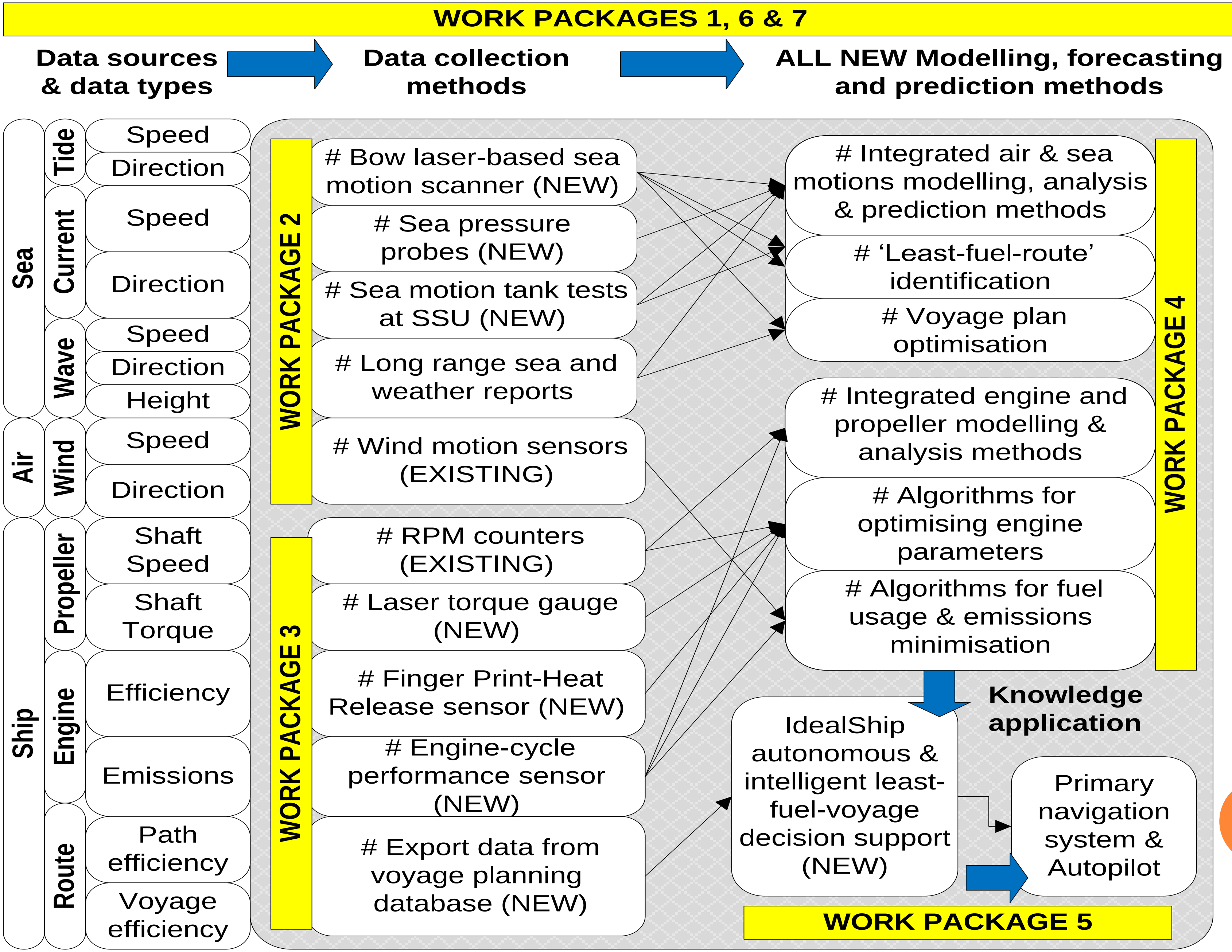
Data fusion from internal sources



Example: Technology



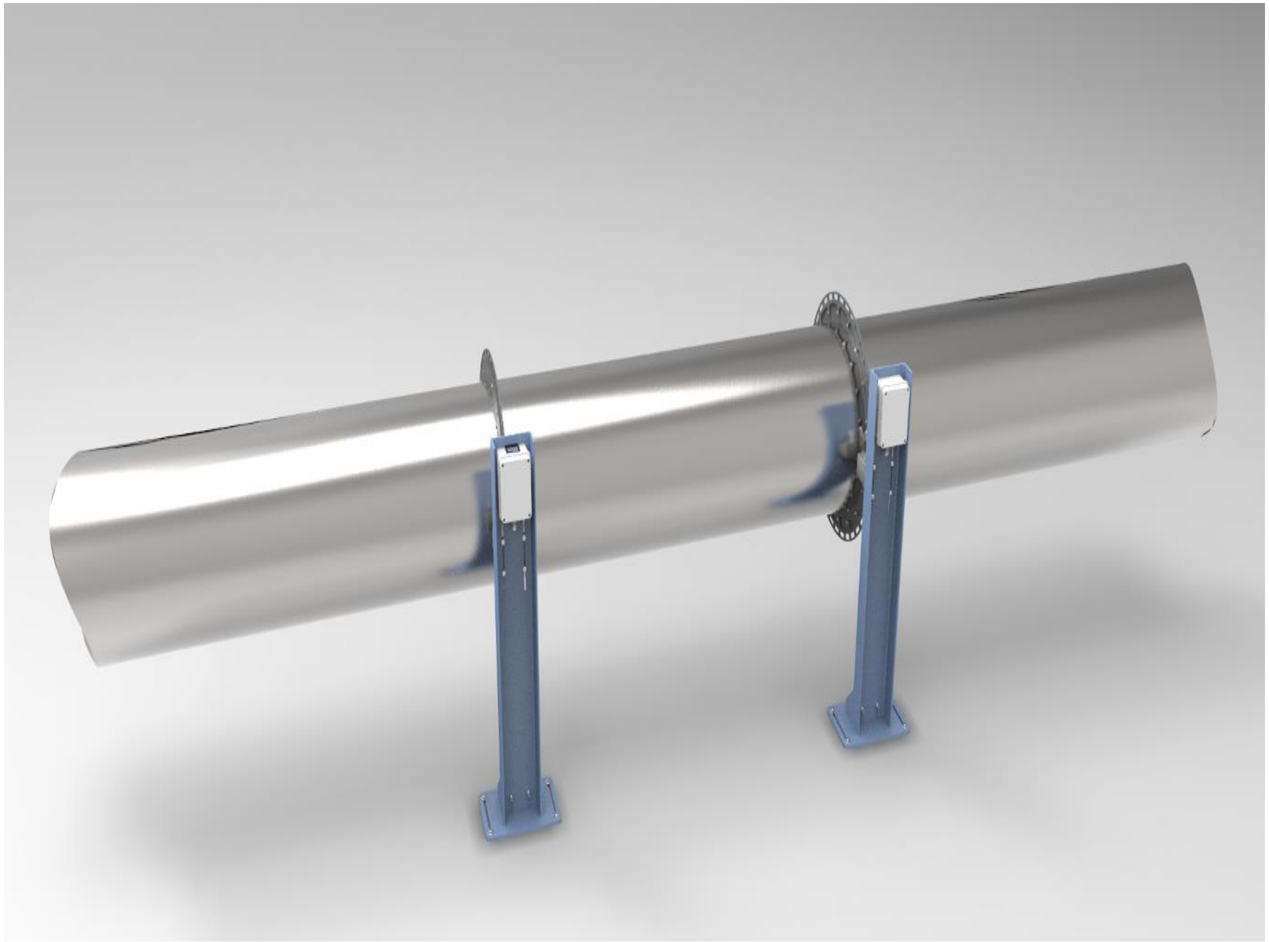
AutoSet Work Packages



NOVEL TORQUE MEASURING SYSTEM

- The C4FF Torque measuring system is mounted on intermediate shafts after the thrust bearing. When a shaft is subjected to a change in thrust due to increased motion resistance, the result is a small strain at the shaft surface. Stain gauses (laboratory setting) and low power lasers (on board) accurately detect these small displacements, in both axial and radial directions. The measured values are transferred continuously from the rotating shaft to the stator part through wireless data connection. Power transmission from the stator to the rotating shaft is performed by means of induction. The stator part consists of a power transmission coil, a data signal receiver and a control box equipped with digital or analogue output connections. These outputs are be linked directly to the vessels data network, monitoring- or

Torque Meter

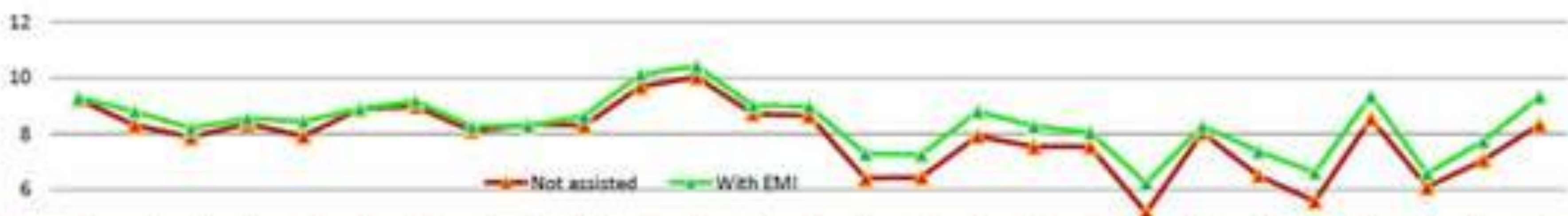


ACTUAL RESULTS - SAVINGS

Daily Consuption Tons x 24h

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Not assisted	33	34,4	33,9	34,3	34,4	32,2	33,2	33,4	33	32,8	33,6	33,3	33,2	38,8	38,9	36,5	35,8	38,2	36,6	39,5	33,4	37,1	40,4	36,4	38,4	36,8	36,1
With EMI	32,8	32,2	32,5	32,3	32,1	32	32,2	32	31,9	32,1	32	31,8	32	31,8	33,5	32,4	32	34,1	32,4	33	32,2	35	36	32	34	31,8	31,7
Wind	SSW 7	SW 7	6	6	SSW4	ESE4	SSE,5	ESE7	SSE7	E5	NNE6	SSE2	2	N6	W6	6	SSW4	6/5	7/6	7/6	NNE 4	6/5	5	6	7	5	5
Wave	SSW5	SW 6	5	5	SSW4	ESE3	SE3	ESE6	SSE6	E4	NNE4	SSE2	2	N5	W7	5	SSW3	NW5	NW5	/5	NNE3	/5	4	5	SW5	4/3	3

Ratio Mls x Tons



Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Not assisted	9,23	8,31	7,88	8,36	7,92	8,88	8,98	8,1	8,33	8,3	9,69	10	8,72	8,65	6,41	6,45	7,92	7,54	7,54	5,19	8,04	6,5	5,59	8,54	6,1	7,06	8,33
With EMI	9,29	8,8	8,2	8,55	8,49	8,89	9,17	8,27	8,29	8,64	10,1	10,4	9,01	8,98	7,3	7,24	8,8	8,28	8,09	6,24	8,27	7,38	6,62	9,35	6,59	7,74	9,34

New PROPOSAL

- C4FF are interested in becoming a partner or establishing a partnership for the new Cleaner Diesels proposal.

- The proposal will include the recent work on C4FF's Clean Diesel Engine which is used by almost all major engine manufacturers and recent EU funded projects on integrating engine and navigation equipment for optimum running and hydrodynamic performance.

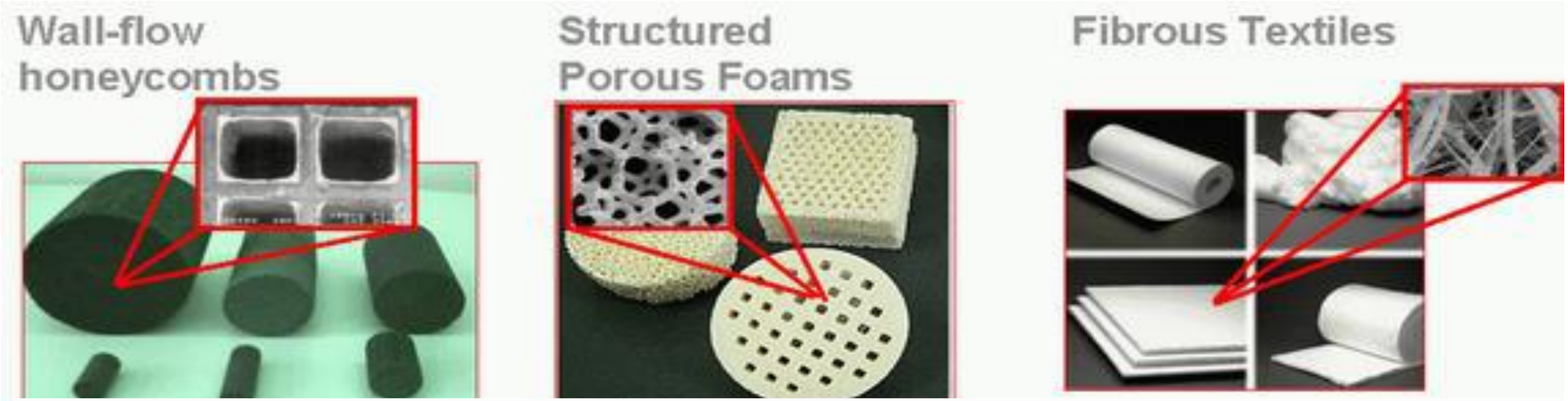
Key Areas for Research

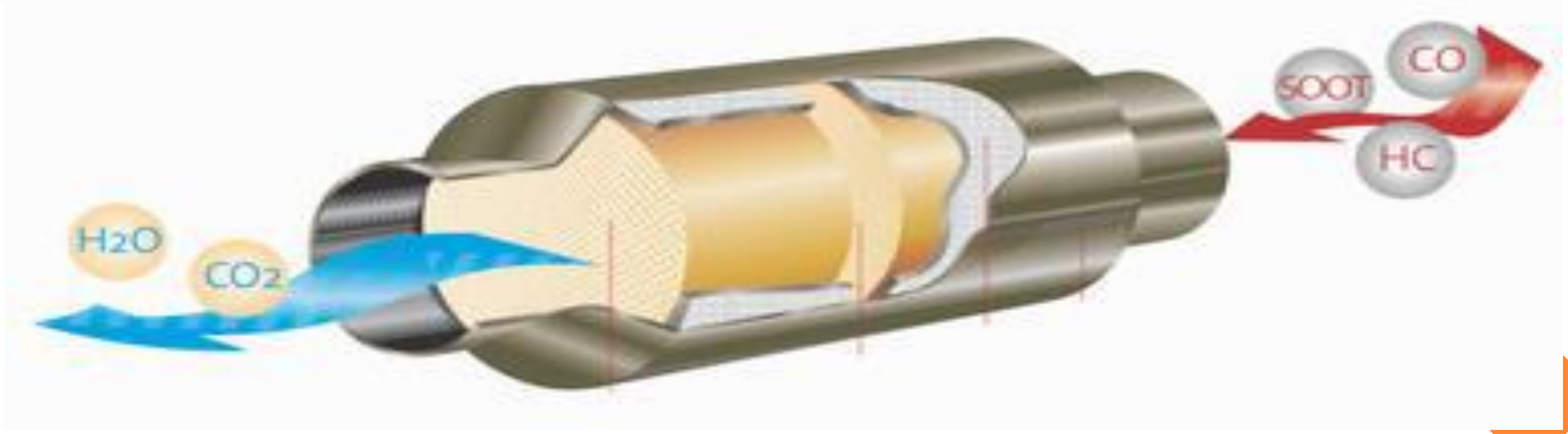
- Low carbon and renewable fuels - LNG and methanol – Short to Medium term
- Hybrid/Electric drives - novel energy storage and DC power and control systems – Short, medium and long term, newer transport systems
- **Development of combined system to reduce engine pollution – Short term with immediate impact**
- Ship design – reducing frictional resistance – Short, medium and long term
- Micro and nano scale Engineering; Novel coating; Equilibrium and non-equilibrium fluid dynamics – to reduce turbulent drag – short term

Development of combined system to reduce engine pollution

- Running conditions to reduce specific particulates
- Novel NOx recirculation and burning systems
- 3-stage inter-cooling
- Variable Geometry turbocharging
- Water injection
- Variable timing
- Engine-Engine component matching
- Lighter engine components
- Dual fuel, novel mixing engines (HCCI/PCCI/RCCI)
- After treatment, exhaust configuration and use of electric booster
- SCR processes (NOx conversion) and PDF (PM) filters
- Some or all above

Different Filter configuration and aluminum titanate (As against Silicon Carbide) Filter system





Why – The intention

All proposed activities will contribute essentially to a more energy efficient and less polluting diesel engines and comply with several EU directives including Directive 2012/33/EU, Directive 2014/94/EU as well as when relating to shipping to MARPOL Annex VI, in a tangible and quantifiable way through the demonstration of significant improvements in fuel efficiency (+15% compared to Best Available Technique), the demonstration to full scale of significant reductions in emissions through a variety of measures and their combinations (-80% for pollutants, -50% for greenhouse gases), and the proof of the full economic and operational feasibility of alternative fuels. Energy use reduction, in addition to its positive environmental impact, will contribute to the significant reduction of operational costs and

Key ares for Efficient Ship project

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- Importance of reducing fuel consumption and engine exhaust emissions through integration of navigation, Engine controls and hydrodynamic optimisation.
- Incorporating the IMO's new SEEMP including the EEDI and EEOI

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THANK YOU FOR YOUR ATTENTION