An assessment of Energy Efficiency Measures

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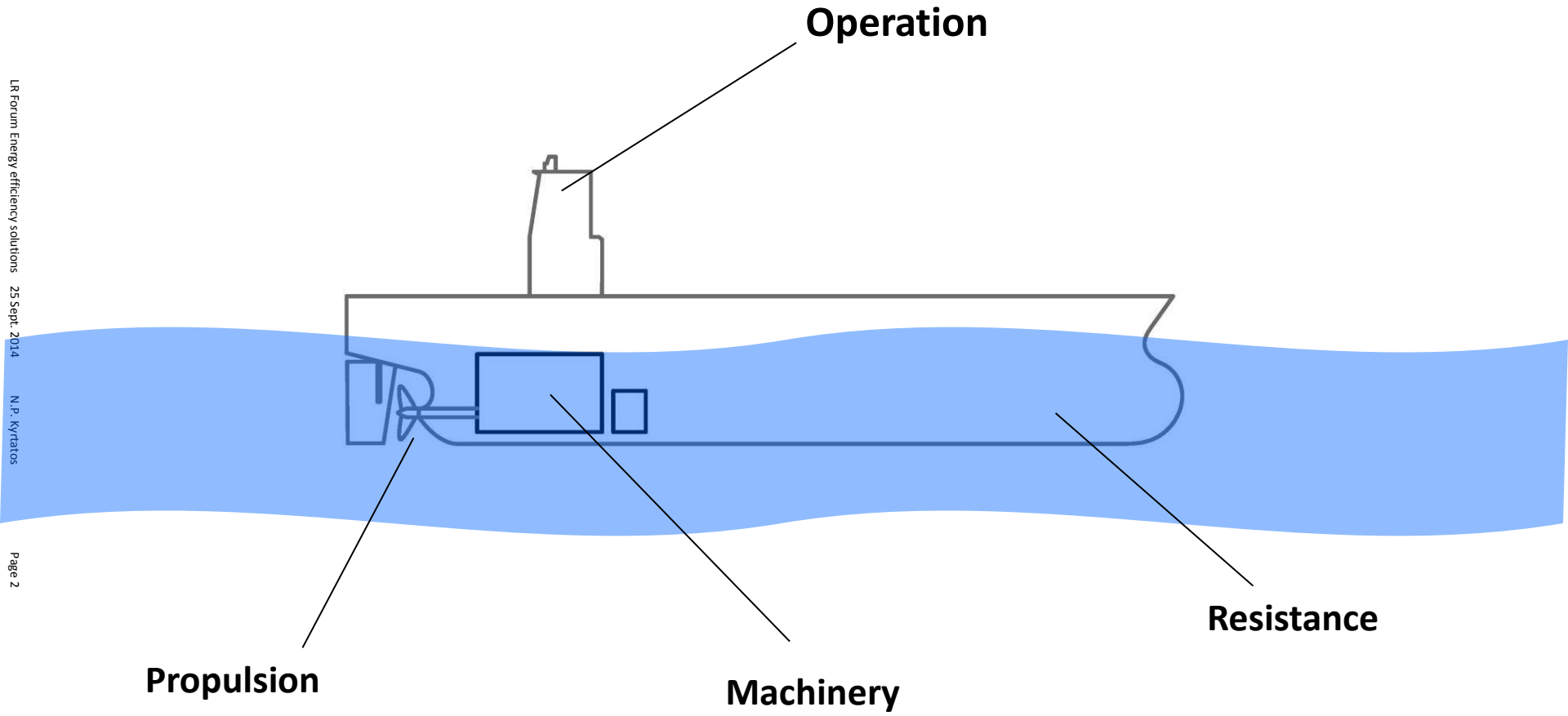
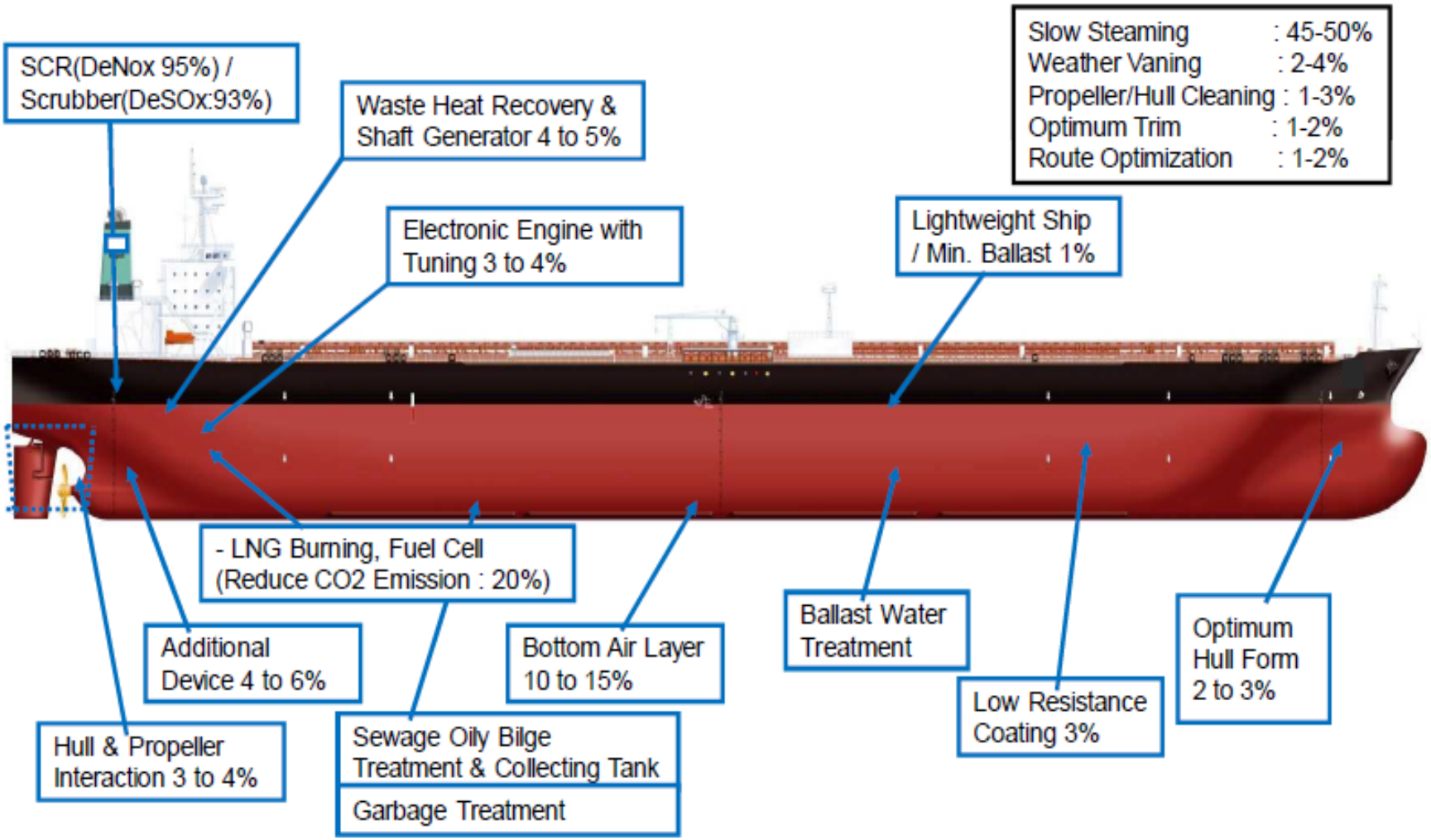
Fuel saving options



Fuel “saving” options: too many -too complex?

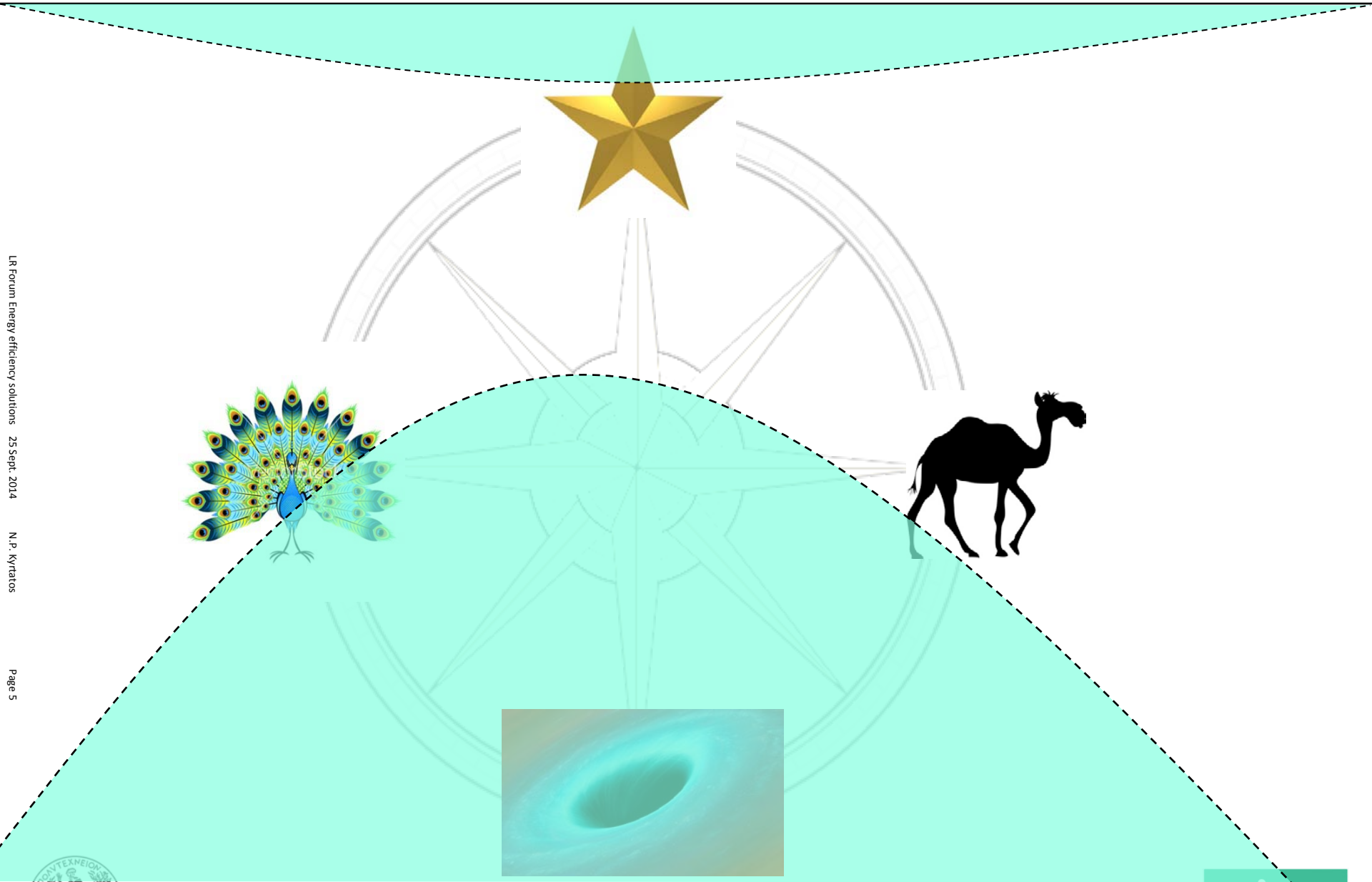


Σ=102% ***Perpetuum mobile?***

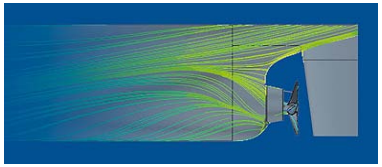
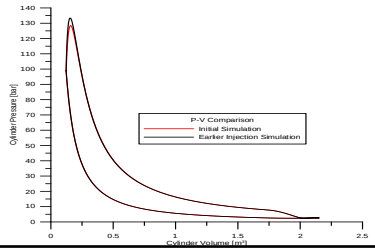
Measures for existing vessels

Resistance	Propulsion	Machinery	Operation
• Hull coatings / paints • Hull openings • Air streamlining • Bubble lubrication	• Flow augmentation - Pre-swirl ducts /fins - Propeller boss cap fins - Prop./ rudder bulb - Vane wheels - Improved rudder - ……. •Propeller change	• Engine Tuning • Energy saving - Speed control pumps - Lighting - …. • Fuel Cells • Sails, Kites, Windmills… • Solar (Photovoltaics)	•Optimisation - Hull/propeller cleaning - Slow/fast steaming - Trim & ballast - WHR - Routeing - …… •Performance Assessment - Monitoring - Measurements - Fault diagnosis

Energy Efficiency Measures… taxonomy



“Reasonable” measures for existing vessels

Resistance	Propulsion	Machinery	Operation
• Hull coatings / paints 	• Flow augmentation 	• Engine Tuning 	• Optimisation • Performance Assessment

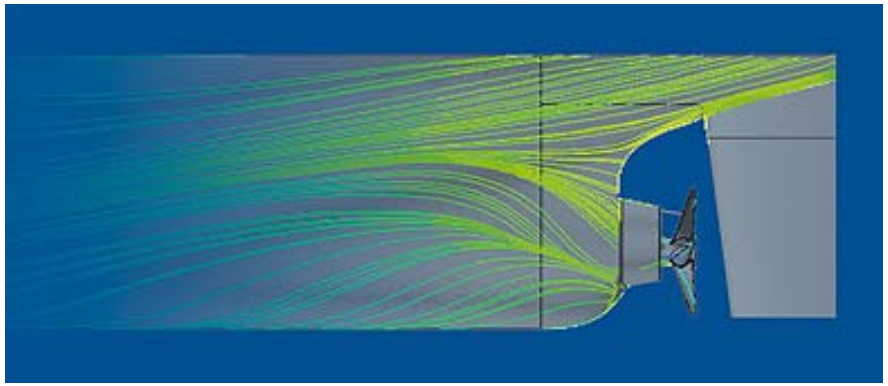
❑Applied Physical chemistry (+Black Magic)

- TBT –free anti-fouling
  - oBiocidal
  - oFoul release
- Hard coatings (+ hull cleaning)
- Innovative (microfibre, nanotech,…)
- Future (bio-mechanical)

➢Selection

➢Verification of performance (accurate measurements?)

Propulsion- Flow augmentation

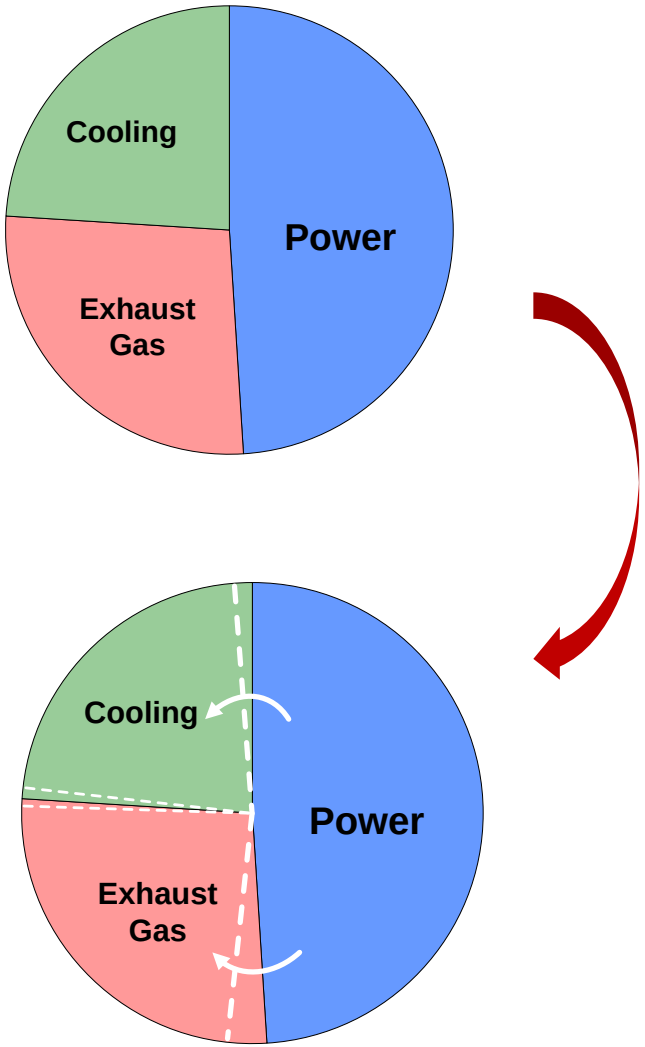


If initial design is poor, then worthwhile

If initial design is good then **not** advisable

- Check hydrodynamics!
  (r-o-t P.C. <60%)
- Selection
- Verification of performance (accurate measurements?)

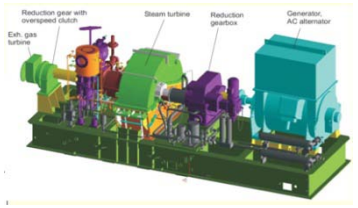
Reduce fuel consumption by Improving engine efficiency



- ❑ (Reduced heat rejection)

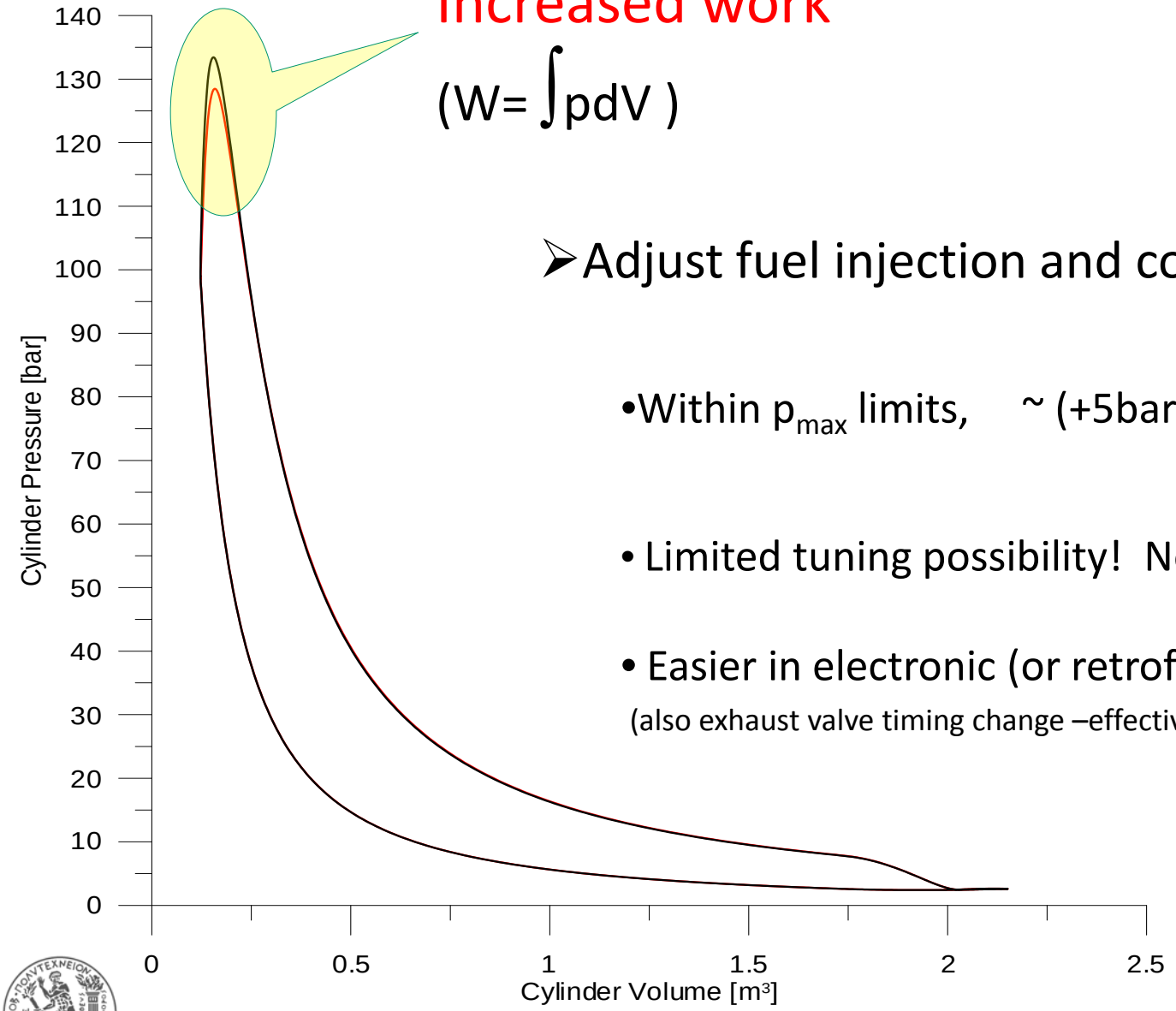
  Practically not possible in existing engines

- ❑ Increased Waste heat recovery
  - Power production (steam)
  - Turbo-compounding (engine shaft)
  - PTO/PTI – Turboshaft



- ❑ *Extra capital investment required!*

- ❑ Increased work



Increased work

($W = \int pdV$)

- Adjust fuel injection and combustion
  - Within p_{max} limits, ~ (+5bar = -1gr/kWh)
  - Limited tuning possibility! Nox, P_{comp} / P_{max} limits.
  - Easier in electronic (or retrofit-electronic) engines

    (also exhaust valve timing change –effective compression)

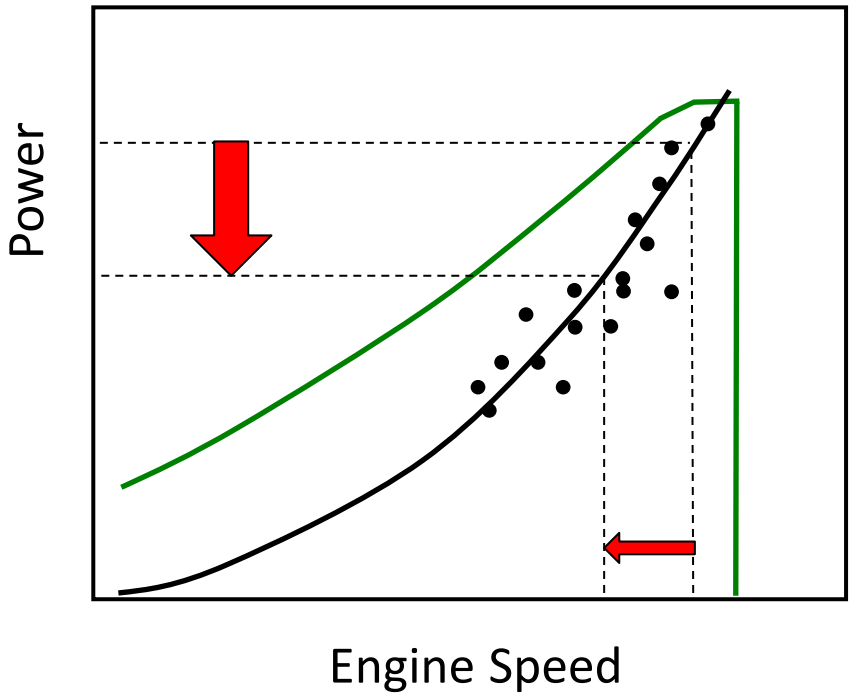
Slow steaming ⇒ lower Power demand ⇒ less Fuel

NB.1. ship capacity scales with speed, fuel cost scales with ~(speed)^3

NB.2. very low speeds w.r.t. safety

NB.3. propeller efficiency vs speed

NB.4. WHR capacity at low loads



If operation at lower load is long-term

Extra **efficiency** benefit, if engine is **re-optimized at part load**.

Increased air amount (Scavenging) and re-tuned P_{max} (easier with electronic engines)

$P_{scav}\uparrow$ …then… $P_{comp}\uparrow$ …then… $P_{max}\uparrow$ …then… $\eta\uparrow$

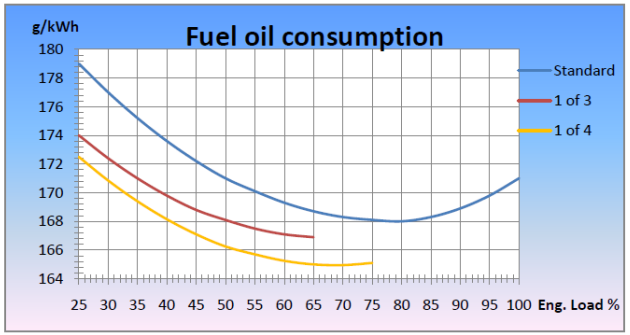
➢ *Moderate Derating*

- Turbo changes (turbine nozzle/ compressor diffuser, trim)
- Retuning

➢ *Large Derating (rpm< 50%)*

- Turbo cut-off (if 2+ turbo's)
- Re-tuning
  - o F. I. timing
  - o E. V. timing
  - o C.R.
- (Variable Geometry Turbocharger)

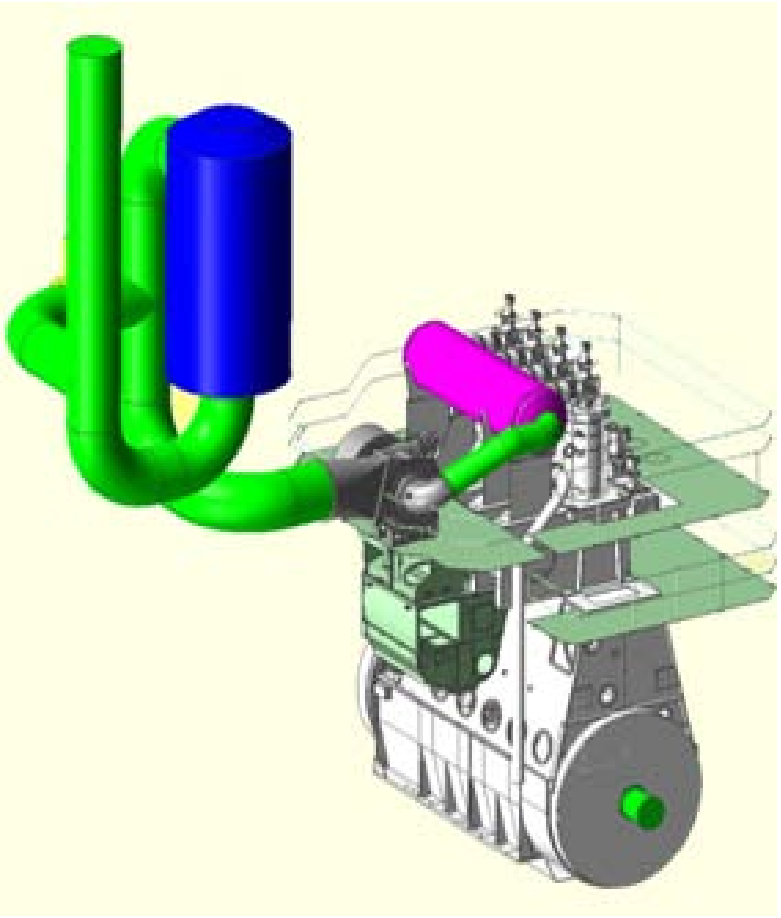
o *Part load η ↑*
o *Tradeoff NO_x / CO_2*
o *Part load temp reduction: Reliability ↑*
o *Tropical cond. heat load decreased*

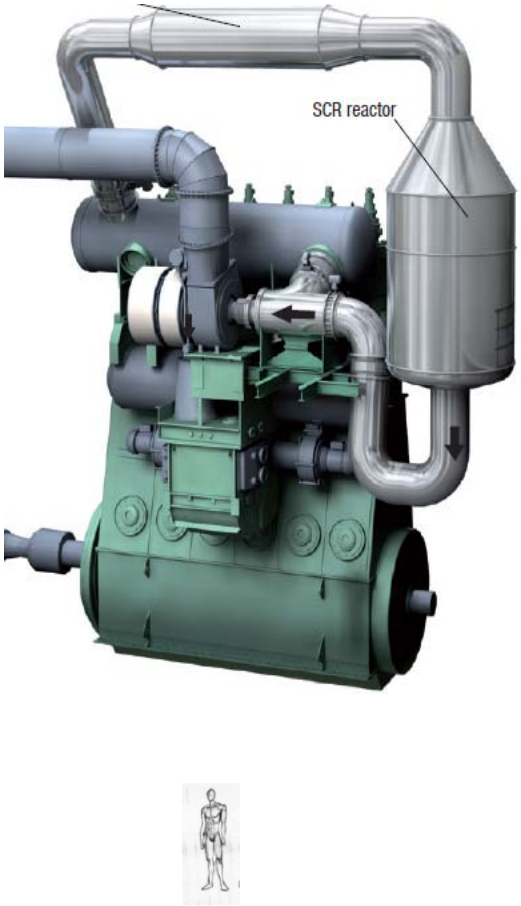


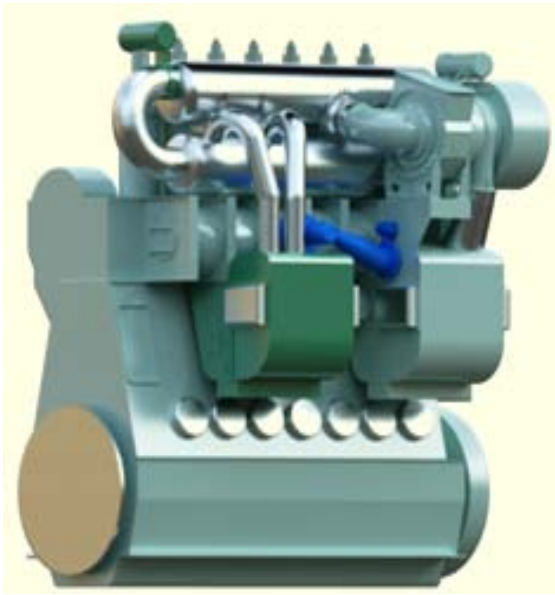
Fuel-oil consumption versus engine load

any retrofits require proper analysis & design!

Marine Diesel Engines for Tier III & beyond







Increased Technical Knowhow needed by Operators

- Two- stage TC (+VG) (+VVT)
- Increased $P_{max,}$ BMEP
- Increased Stroke/Bore
- Autotuning + Injection rate shaping
- Cylinder cut-out
- PTI / PTO + flexible T/C (cutout)
- Waste Heat Recovery
- SCR
- Water-In-Fuel
- EGR

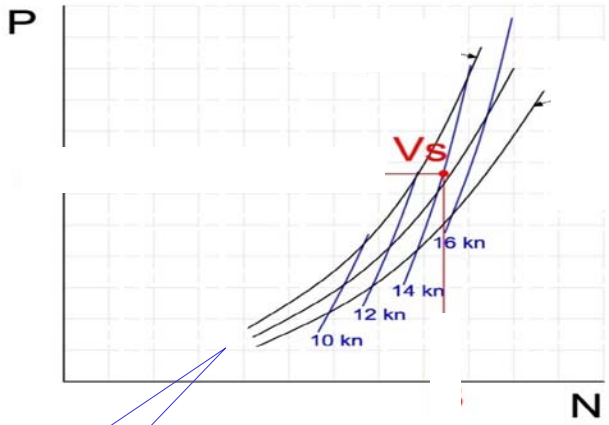
TARGETS

1. EMISSIONS COMPLIANCE
2. IMPROVED EFFICIENCY
3. OPERATIONAL FLEXIBILITY

How these above operate:
-In combination?
-Throughout the load/speed range?

Operation

- Optimisation
  - Hull/propeller cleaning
  - Trim & ballast
  - Routeing
  - Energy usage and WHR
  - …



onboard
DAQsystems

Statistics and models

Measured Data Repository

Needs:

- *Measured reliable Data (lots!)*
- *Data analysis and statistics (tough!)*
- *Reference for benchmarking (tricky!)*

Operation
• Performance Assessment

Retaining *or* ***improving performance and efficiency***

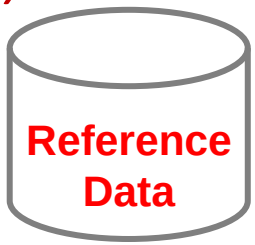
of INSTALLED POWERPLANTS

Requires:

- Monitoring (= *measure*)
- Performance evaluation (= *compare*)

(Are these data reliable?)

- **Shop tests**
- **Sea trials**
  - Do not cover all operating range
  - Particular operating conditions
  - Corrections introduce further errors

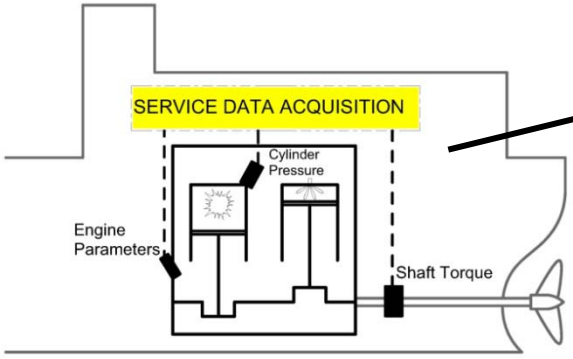


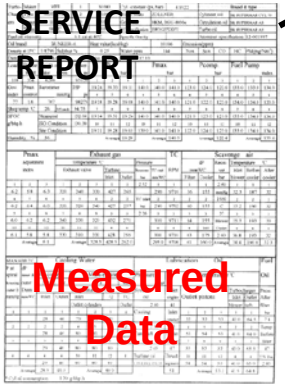
"Expected"

Performance Evaluation

Compare

"Observed"





- Data retrieval, analysis, interpretation, archiving, trending…???
- Information flood !!!

(Are these data reliable?)

- Data collection, sensors, recording, human errors,
- Data filtering, transfer, storing…???

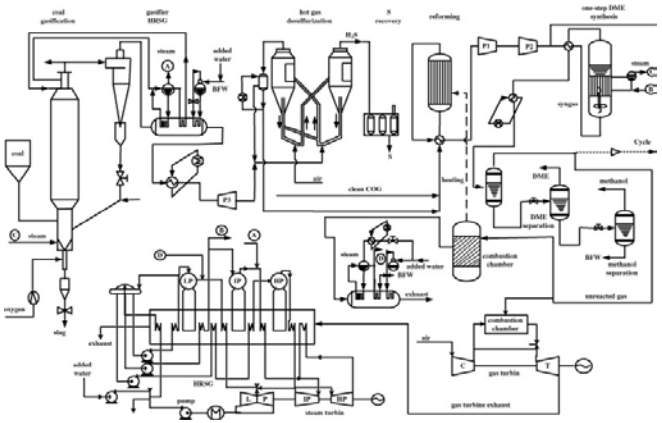
To create reliable **Reference** values, Use **Process models**

has been used in AEROSPACE and PROCESS PLANTS

for 20 years

for PERFORMANCE EVALUATION,

FAULT DETECTION & DIAGNOSIS (**FDD**)



***Process** performance is influenced by **external** conditions*

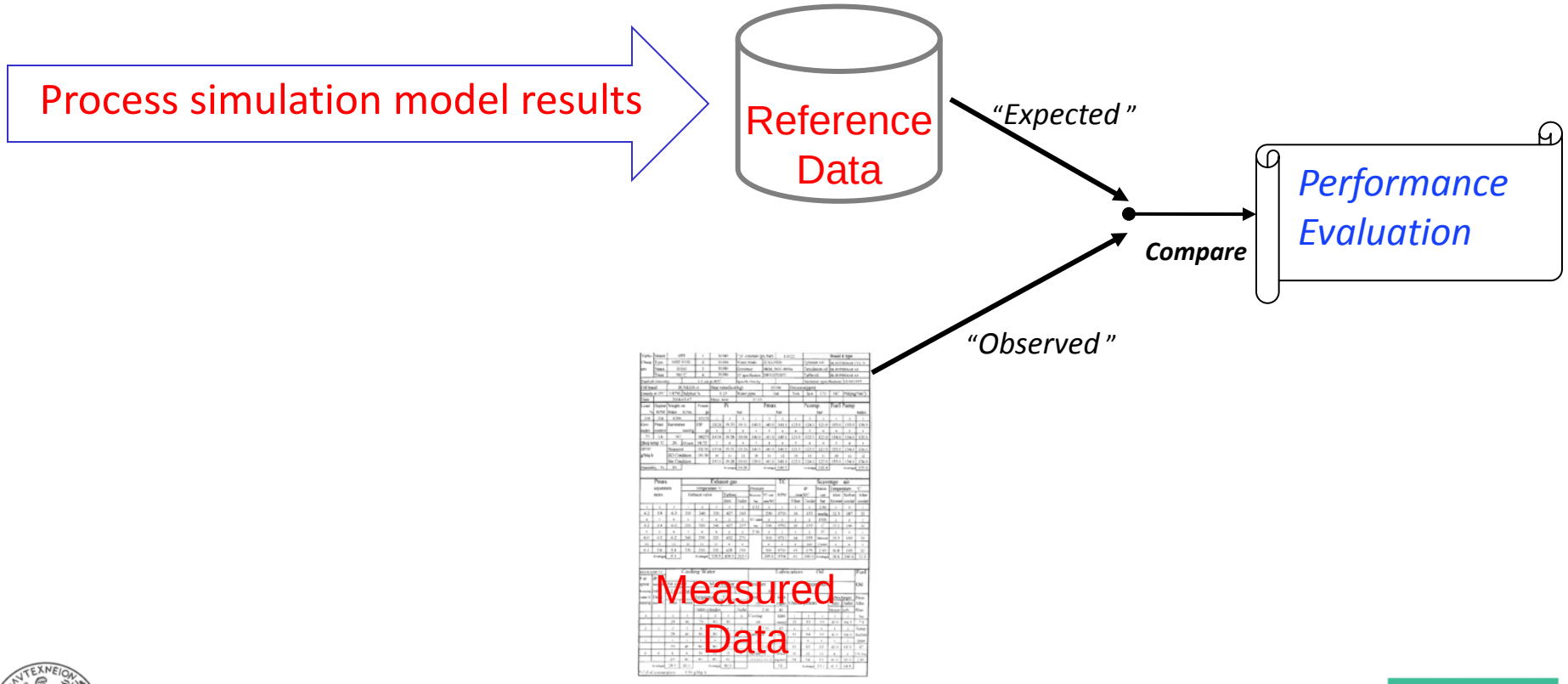
➢Simplified look up tables, corrections and parameter maps from dissimilar operating points cannot be trusted for detailed evaluation.

➢models for process simulation

- can separate **external conditions** from actual **equipment degradation**
- can predict **values** of all parameters at the **exact process operating point**.

- generate "**expected**" values

  for the exact operating condition, as reference to compare with "measurements"



Morale of the story

Investing in an **energy efficiency improvement** scheme must be accompanied by a means to

reliably evaluate its performance prior to **selection**

and subsequently

reliably measure, verify, benchmark and assess its performance after **installation.**

Closure

Marking of Energy Efficiency Measures for existing vessels

MEASURE / CRITERION	Advanced hull coating	Propeller Enhancement	Engine Tuning	Performance Assessment + Optimisation
Difficulty selection & decision	***	**	**	***
Difficulty application	*	**	**	*
Benefit/Cost	**	**	*	***

***	*HIGH*
**	*MEDIUM*
*	*LOW*

END OF PRESENTATION

END OF PRESENTATION