EUROPEAN TURBINE NETWORK

CAPEX versus OPEX

Increasing combustion turbine performance and reliability through enhanced air quality.

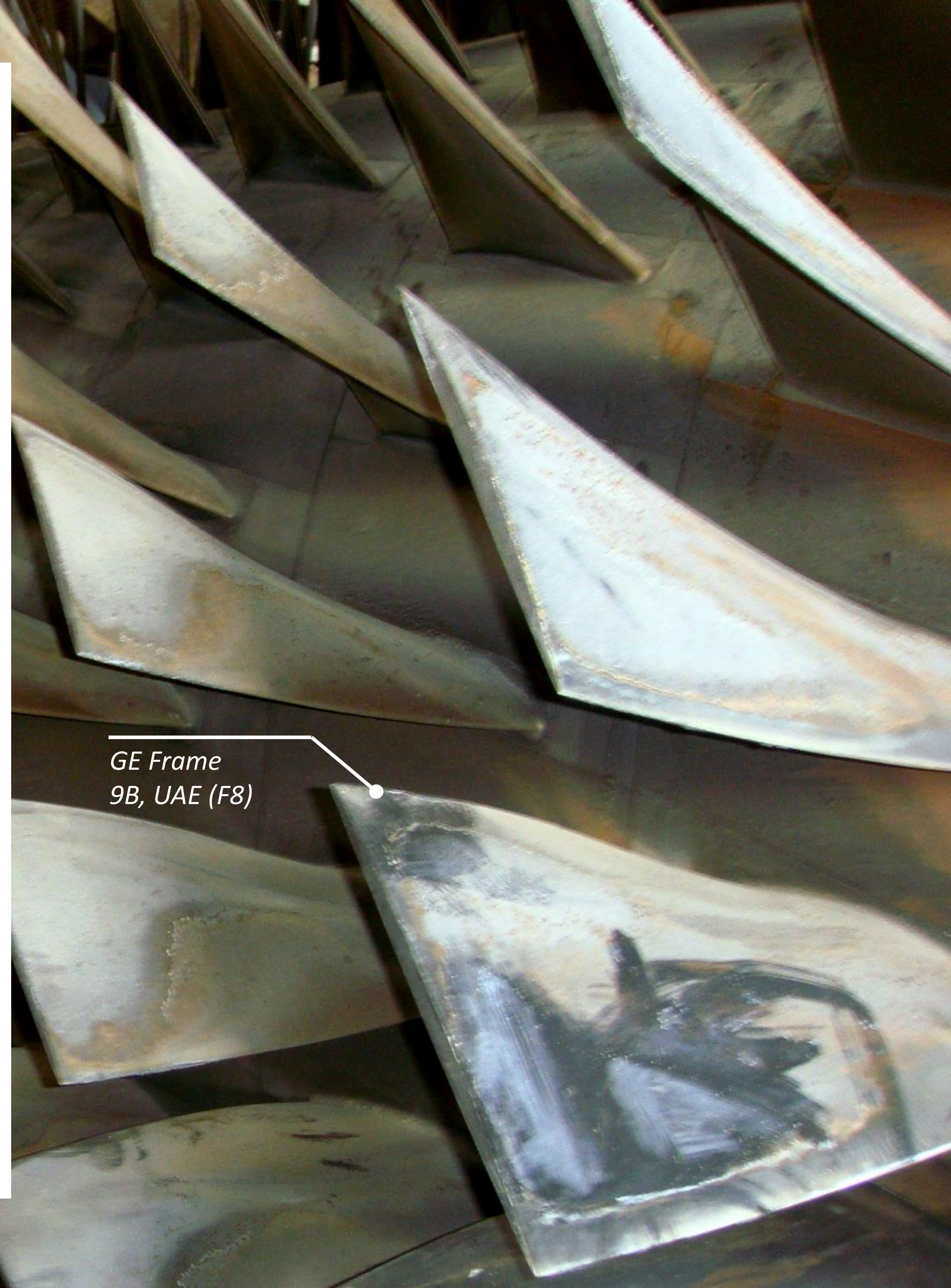
Gas Turbine Performance Potential

If during inspection of your gas turbine the compressor of the machine(s) resembles the photo on the left then it could be losing your business tens of thousands of Mw/hrs in power output, and costing hundreds of thousands of BTU's in fuel costs.

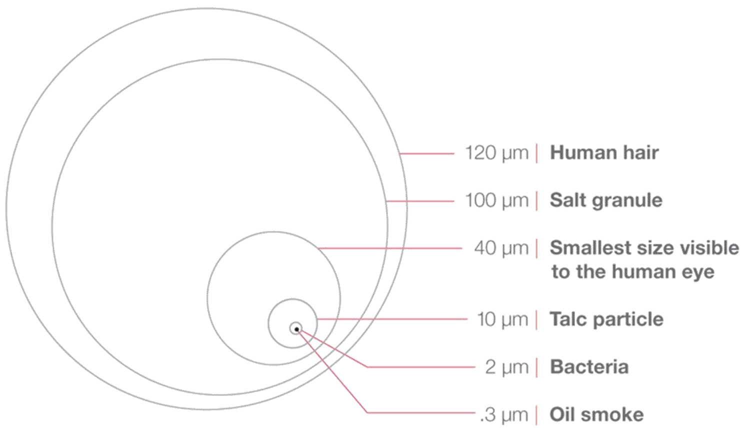
The photo on the right demonstrates the machine condition post 8000 hours running time with no water wash on or offline with HEPA / EPA classification filters installed.

Operational impact of turbine fouling

- Compressor fouling reduces engine power output
- Forces water wash reducing availability
- Dirty engine more likely to trip
- Fuel efficiency is reduced leading to higher costs
- Expensive damage to compressor and hot-end components Increases maintenance costs.



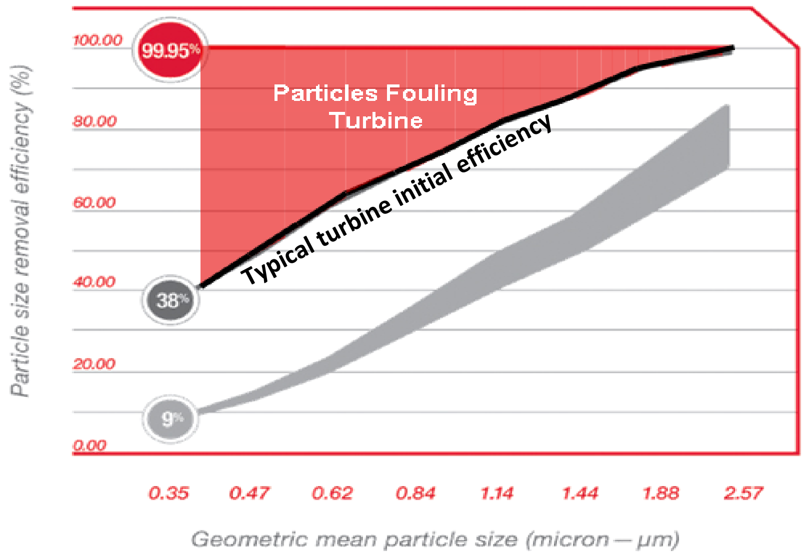
WHAT IS A SMALL DUST PARTICLE



Particle Range	Quantity by Count	% by Volume
10 to 30	1,000	28
5 to 10	35,000	52
3 to 5	50,000	11
1 to 3	214,000	6
0.5 to 1	1,352,000	2
0 to 0.5	18,280,000	1
Total	**19,932,000**	**100%**

Particles in two cubic foot sample (Michigan, USA)

WHY DOESN'T MY PRESENT FILTER PROTECT THE TURBINE?



Magnitude of the problem…..

A 260 MW engine will consume **530m3** of combustion air every second (16m x 8m x 4m)

Air within a typical city environment can contain **350 million particles** per cubic meter

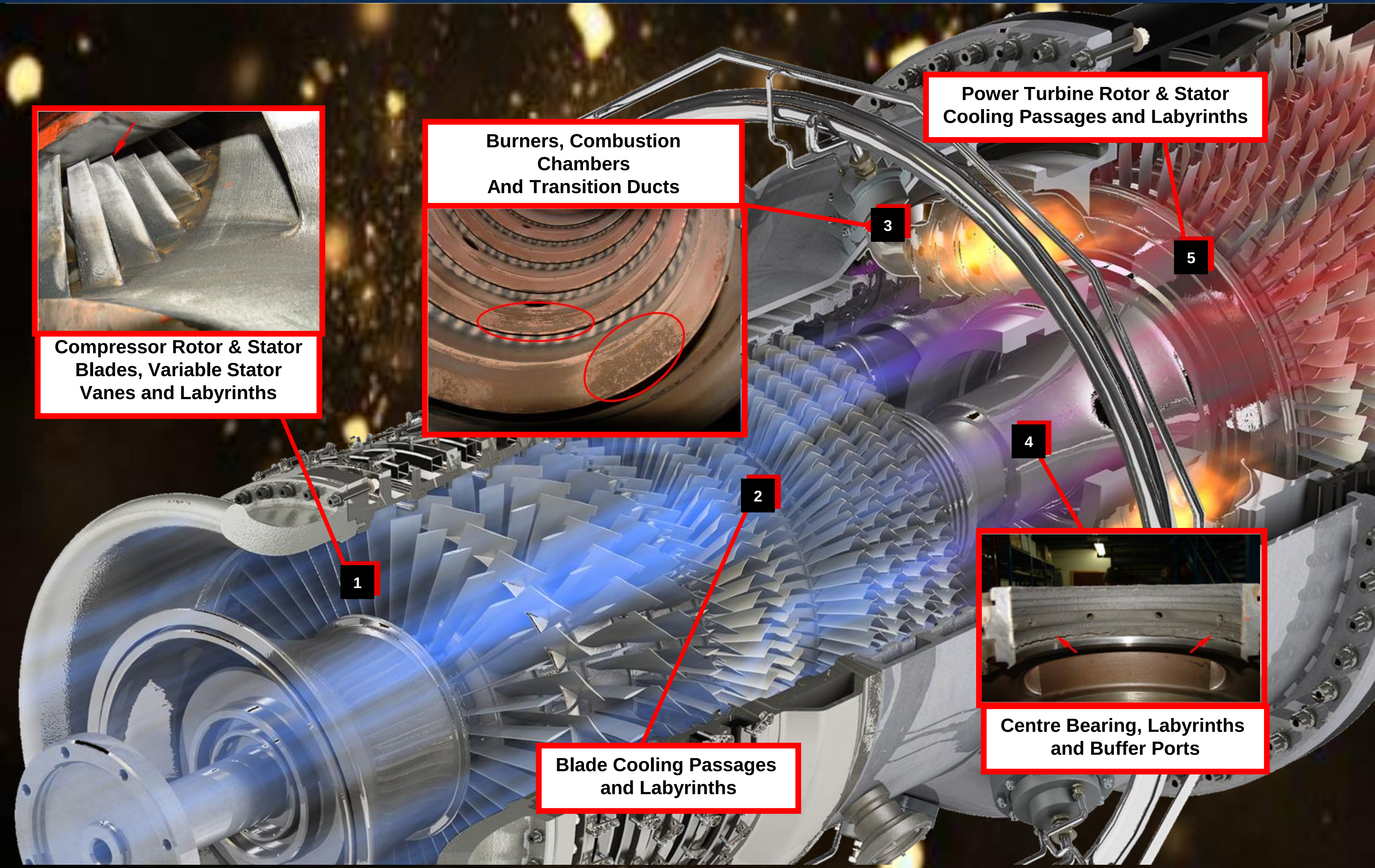
Therefore

A large turbine will consume as many as

One hundred & eighty-five billion
each and every second

EUROPEAN
TURBINE
NETWORK

TURBINE COMPONENT DAMAGE

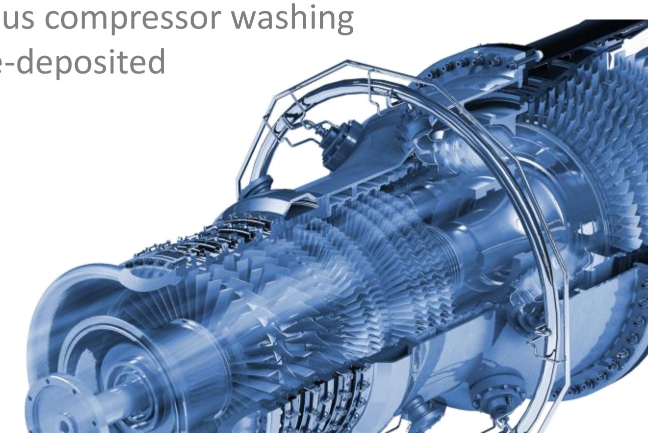


Very Expensive Engine Component Damage

Water Washing is Medicine – Air Quality is Cure

Dark deposits on initial stages of the compressor is fouling caused by hydrocarbons.

Brown scaly deposits on the later compressor stages are deposits from previous compressor washing activities where contaminant is lifted from the front of the compressor and re-deposited on the later stages as the wash water boils away.

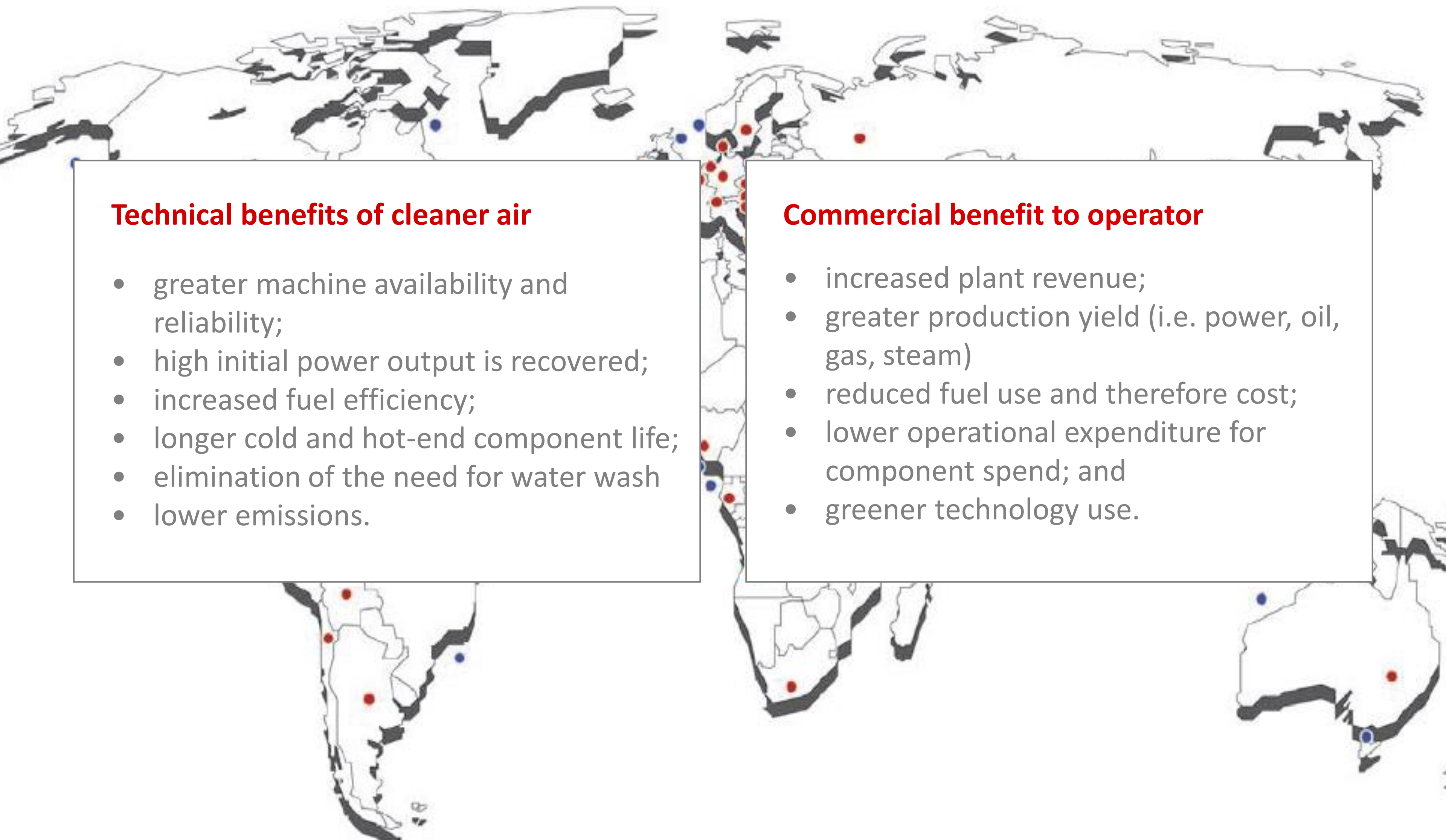


EUROPEAN
TURBINE
NETWORK

TURBINE PERFORMANCE RECOVERY USING HIGHER GRADE AIR QUALITY

EUROPEAN TURBINE NETWORK

Plant / Engine Performance Studies over ten years, hundreds of machines, different environment



Technical benefits of cleaner air

- greater machine availability and reliability;
- high initial power output is recovered;
- increased fuel efficiency;
- longer cold and hot-end component life;
- elimination of the need for water wash
- lower emissions.

Commercial benefit to operator

- increased plant revenue;
- greater production yield (i.e. power, oil, gas, steam)
- reduced fuel use and therefore cost;
- lower operational expenditure for component spend; and
- greener technology use.

EUROPEAN TURBINE NETWORK

Correlating a link between Engine Performance and Dirty Air

Figure 3: MW (ISO) versus Compressor Efficiency

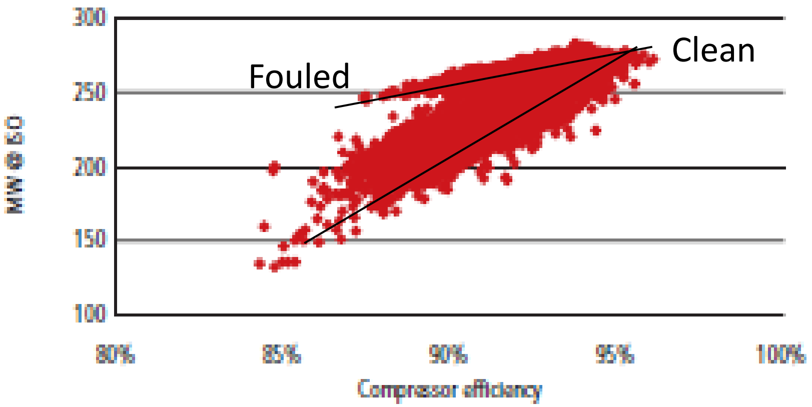
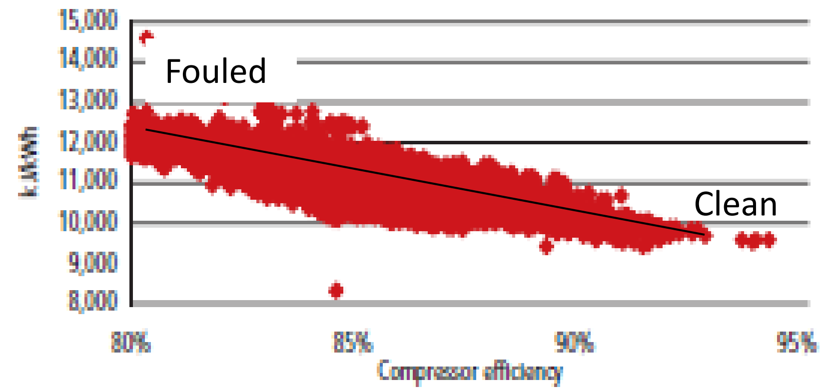


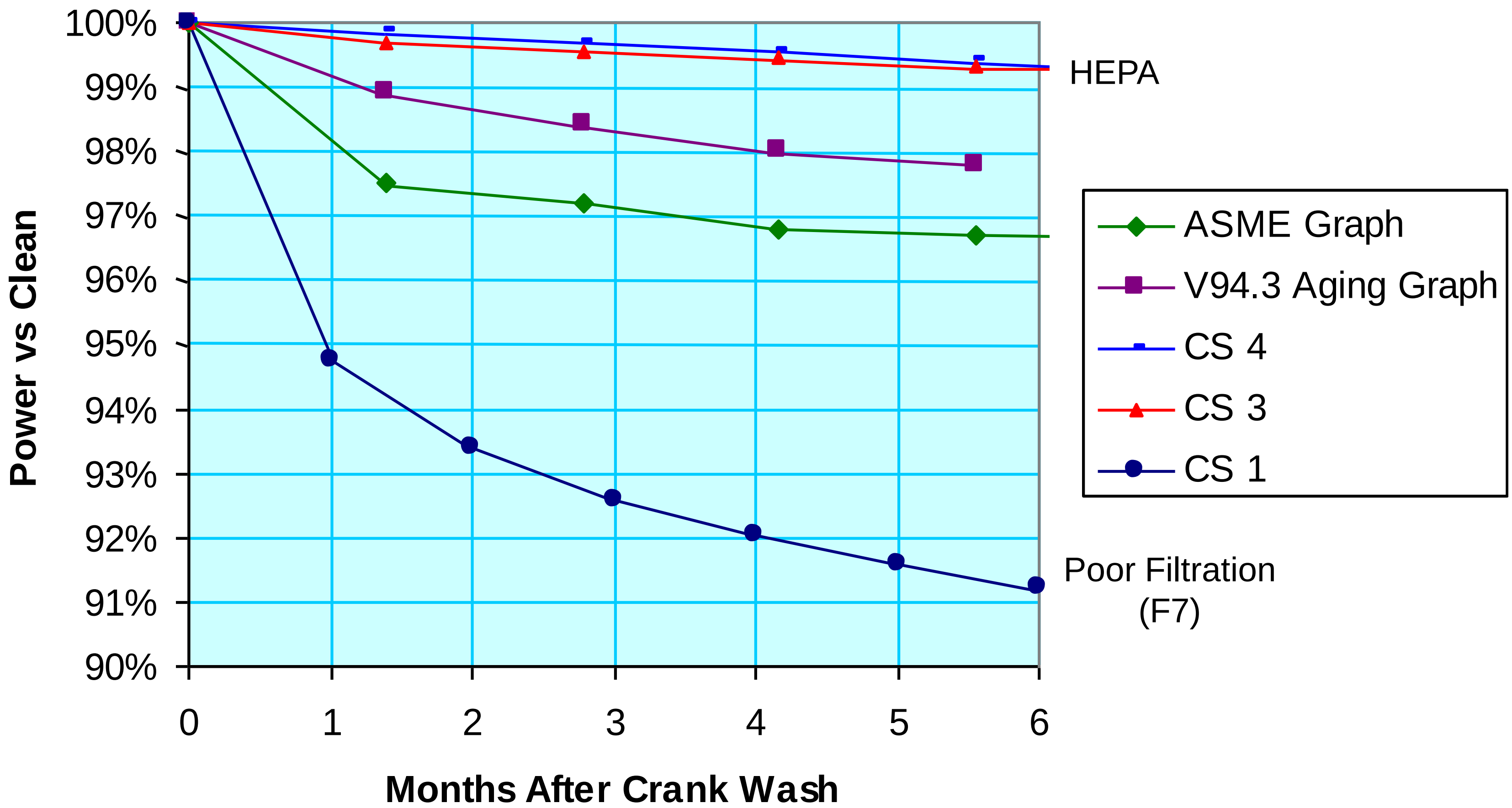
Figure 4: Heat Rate versus Compressor Efficiency



The Brayton Cycle is used to assess engine performance and it is used to directly link combustion air quality, compressor efficiency, heat rate and power output.

The result of assessing many plants is that a direct correlation between compressor efficiency and air quality exists and this can be plotted against engine performance.

Correlating a link between Engine Power Output and Dirty Air against Standards



CS 1 to specifics sample created from engine types and number

FILTER CHOICE AND THE EFFECT ON TURBINE OUTPUT

EUROPEAN TURBINE NETWORK

Side by Side Case Study – Canister Upflow System

System loss due to fouling using F7/MERV 14 canisters is 10% over 2200 hours.

Off-line was required to reclaim lost power.

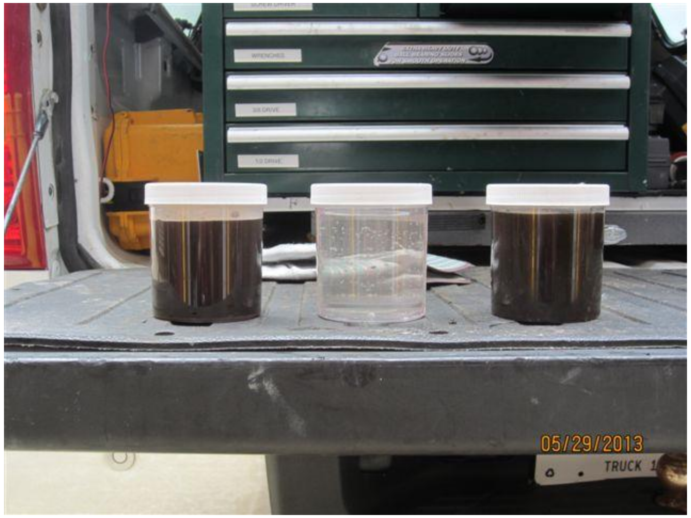
Borescope inspection revealed “severely fouled” compressor blades.

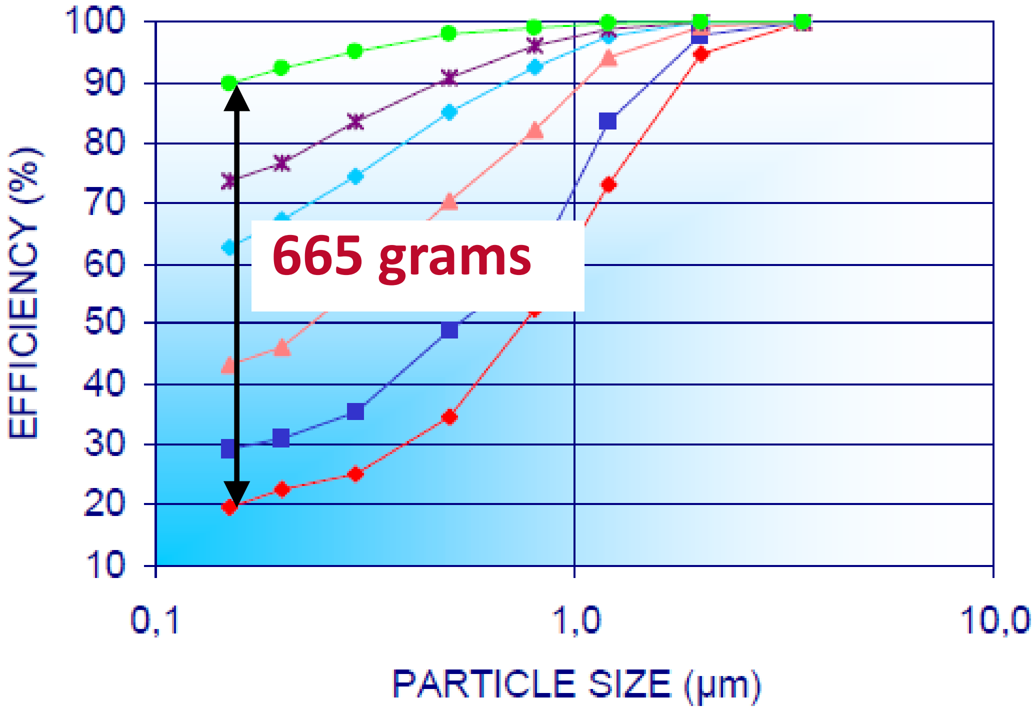
Simultaneous installation of **E12** filters shows a loss of <1% over 3000 hours, with no off-line wash required .

Note that the power outputs include losses to dP.

EUROPEAN TURBINE NETWORK

Side by Side Case Study – Canister Upflow System



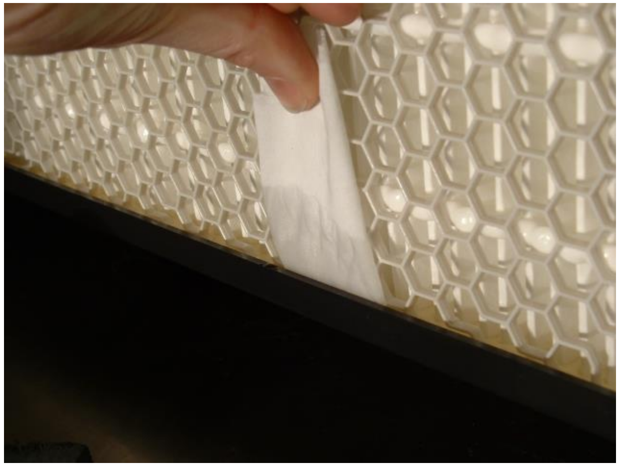


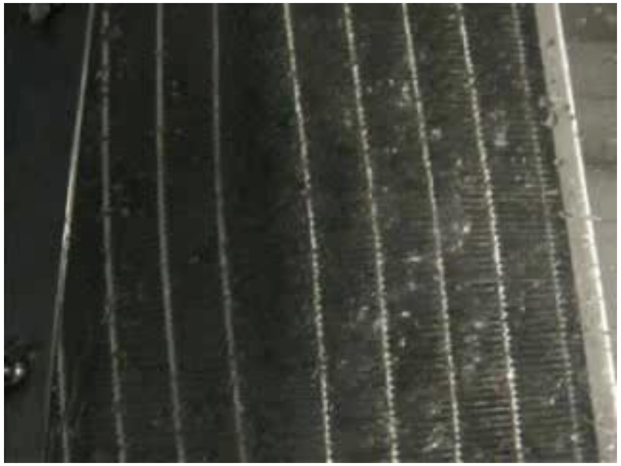
Rural landscape 0.01 Dust Concentration (mg/m^3) compare to 70 mg/m^3 in test therefore to load 665g approximately in field = 650 days therefore active efficiency very low for most of the filter working life

Even at 650gr filter average efficiency nominal 90pc

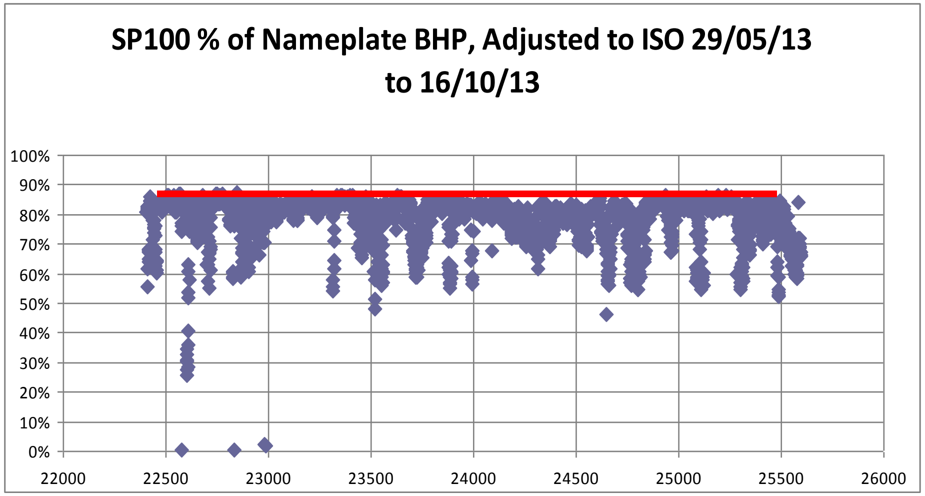
This site was previously changing filters annually

A lot is happening simultaneously during two years



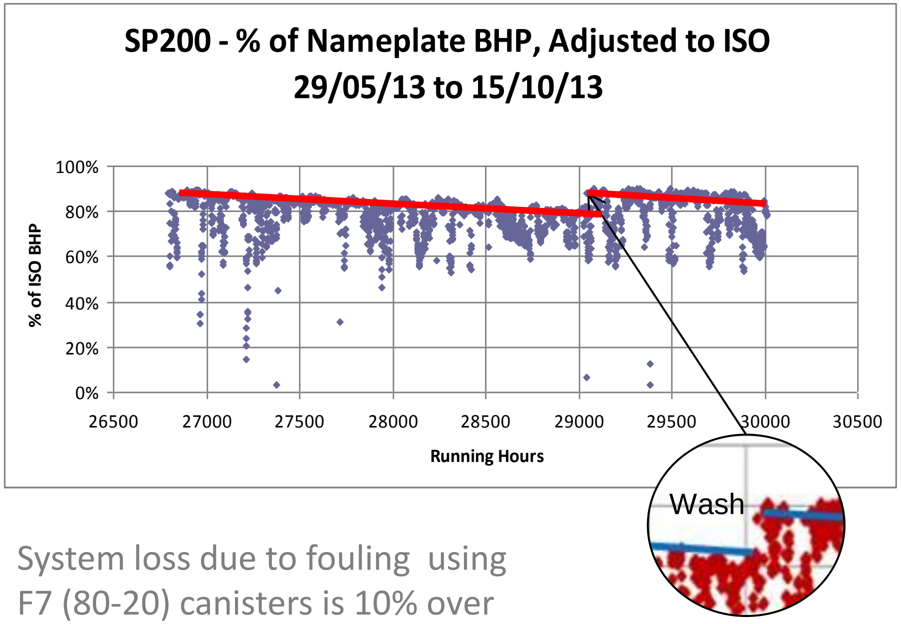


Side by Side Case Study – Canister Upflow System



E12 filters shows a shallow loss of <1% over 3000 hours, with no off-line wash required .

Note that the power outputs include losses to dP.



System loss due to fouling using F7 (80-20) canisters is 10% over 2200 hours – client data verified by OEM.

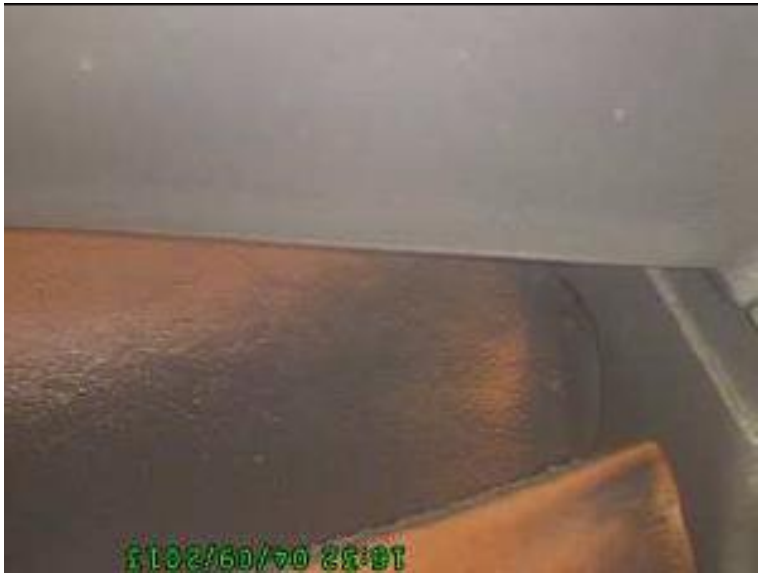
Off-line was required to reclaim lost power. Borescope inspection revealed “severely fouled” compressor blades.

Note that the power outputs include losses to dP.

EUROPEAN TURBINE NETWORK

Side by Side Case Study – Canister Upflow System

Intake protected by E12



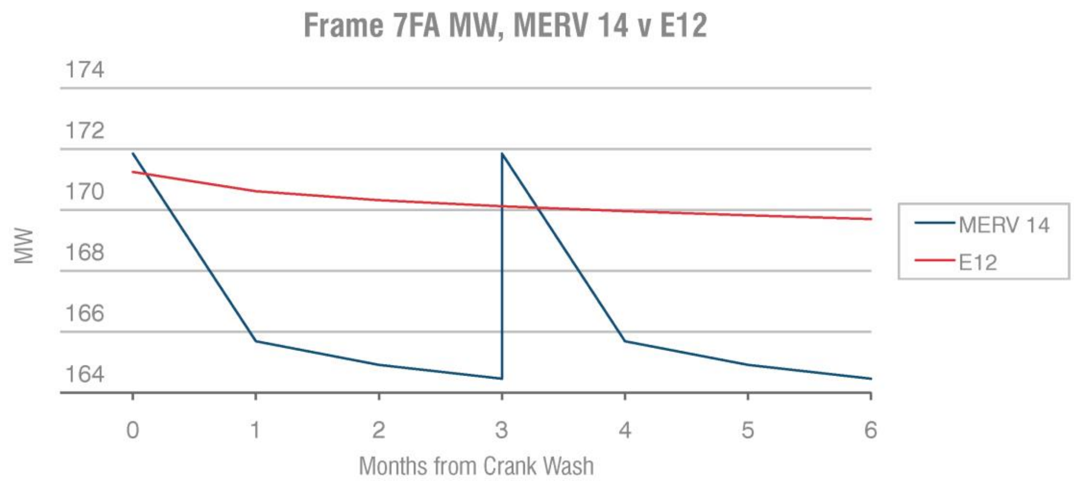
Fouled 2nd stage compressor blades – 80/20 filters

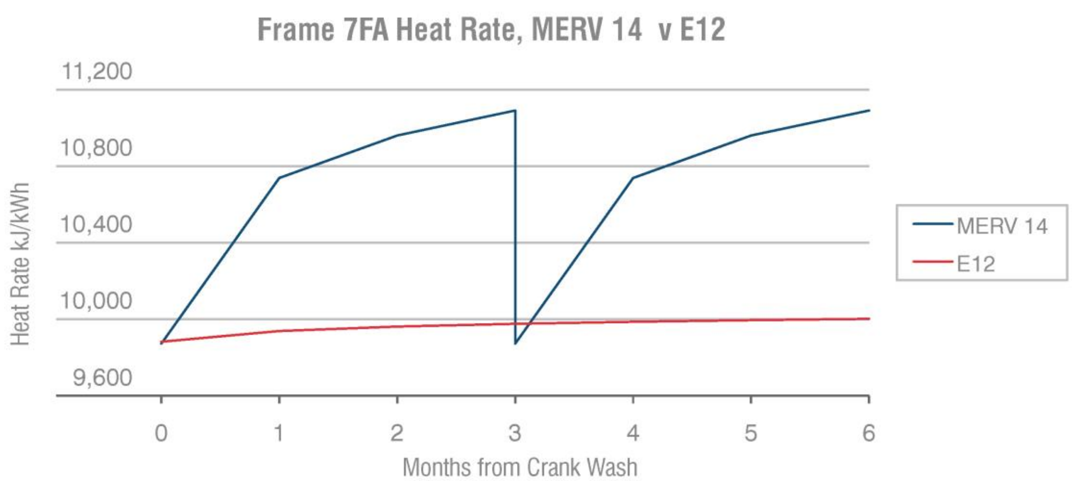
Borescope inspections carried out after 2200 hours indicated no evidence of fouling on the gas turbine protected by E12 membrane canisters.

Severe fouling was reported on the inlet guide vanes and compressor blades of the gas turbine protected by 80/20 media canisters. This required an off-line wash to recover 10% output lost to fouling.

EUROPEAN
TURBINE
NETWORK

Operational Cost to the User for Poor Air Quality POWER





EUROPEAN TURBINE NETWORK

Operational Cost to the User for Poor Air Quality POWER

Example cost benefits of filter upgrade:

Stage 1

F7 filtration leads to output loss >5% and frequent off-line washes.

170 MW GT, annual power output and fuel consumption

Filters	MWh	MMBTU
F7 (MERV 13)	1,173,559	12,672,000
F9 (MERV 16)	1,211,400	12,462,000
Change	37,841	-210,000
Cost	$40.00 /MWh	$4.00 /MMBTU
	$1,513,640	**-$840,000**
	More revenue	**Less fuel cost**

Stage 2

Upgrading to F9 reduces losses to 3% per year and reduces the frequency of off-line washes.

Filters	MWh	MMBTU
F9 (MERV 16)	1,211,400	12,462,000
E12	1,225,500	12,323,000
Change	14,100	-139,000
Cost	$40.00	$4.00
	$564,000	**-$556,000**
	More revenue	**Less fuel cost**

Combined Benefit

Installing E12 filters all but eliminates output loss, and eliminates the need for iinterrupting operation off-line washing.

Filters	MWh	MMBTU
F7 (MERV 13)	1,173,559	12,672,000
E12	1,225,500	12,323,000
Change	51,941	-349,000
Cost	$40.00	$4.00
	$2,077,640	**-$1,396,000**
	More revenue	**Less fuel cost**

EUROPEAN TURBINE NETWORK

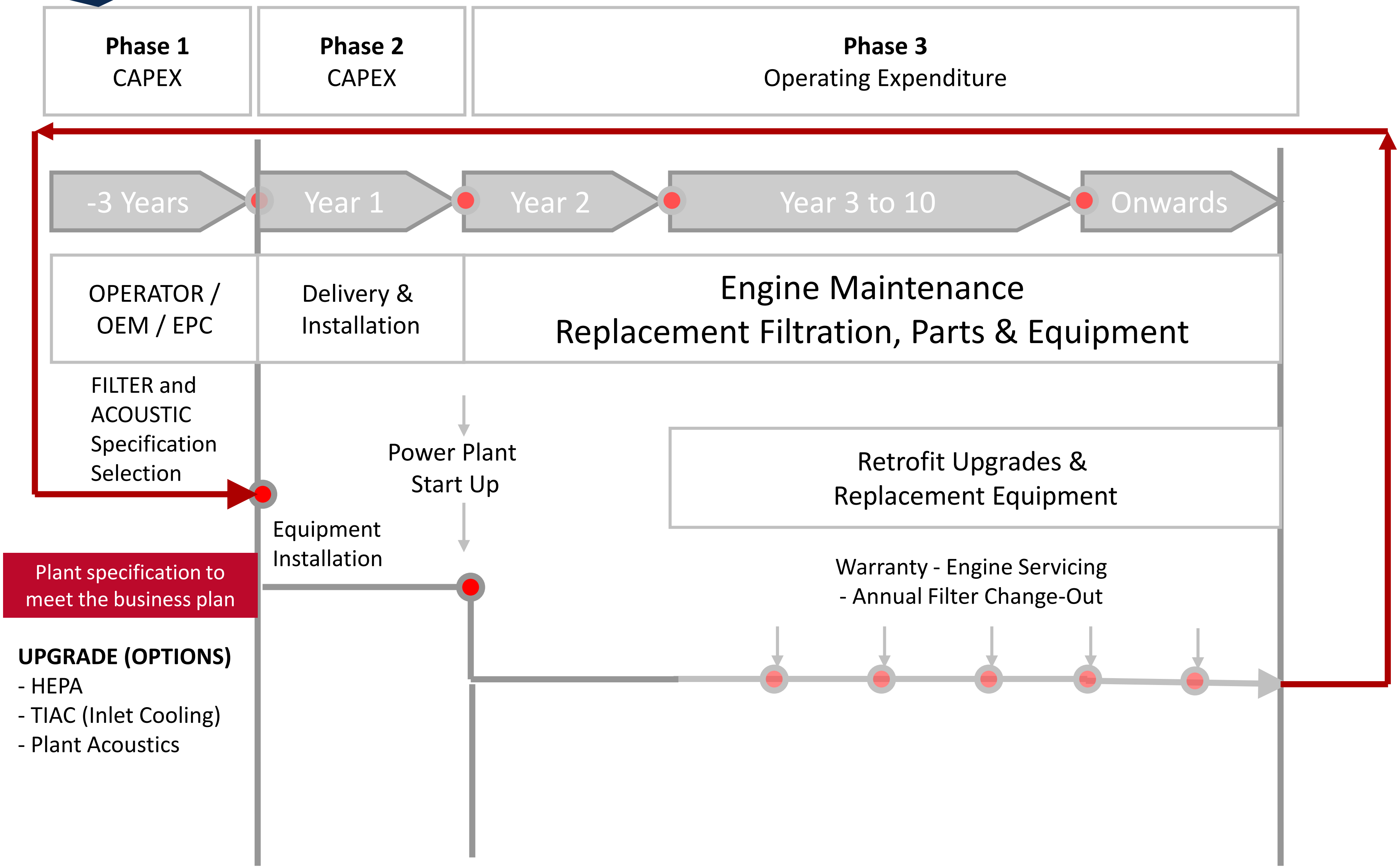
Operational Cost to the User for Poor Air Quality Oil & Gas

Wash Interval	<1,000hrs	1,000hrs	2,000hrs	>4,380hrs	>8,760hrs
Washes /yr	>8	8	4	2	1
Annual Wash Cost	$20,000	$20,000	$10,000	$5,000	$2,500
No. Filters	48	64	64	64	80
Filter Life (month)*	18-24	18-24	18-24	18-24	12-18
Annual Filter Cost	$8,000	$2,100	$10,500	$14,000	$29,000
Annual Lost Production **	$16,800,000	$16,800,000	$8,400,000	$4,200,000	$2,100,000
Total Annual Cost	$16,828,000	$16,822,100	$8,420,500	$4,219,000	$2,131,500
Net Benefit	-	$5,900	$8,407,500	$12,609,000	$14,696,500

*Filter life calculated at max number of months
**$105/boe
Compressor offline wash duration – 24 hours
LM2500+ = 20,000 boe

EUROPEAN TURBINE NETWORK

CAPEX or OPEX



EUROPEAN TURBINE NETWORK

POWER MARKET
Example 1250MW CCGT
Typical x3 260Mw GT's

	Phase 1 & 2 CAPEX Plant Build Budget		**Phase 3 – 10 year period** Operating Expenditure due to performance losses
No HEPA	1 billion Euros		Power Gen (Lost Revenue) = 30k MwHrs = Euro 1.2m/annum Additional Fuel Burnt (Costs) = 278k GJ = Euro 834k TEN YEARS & 3 ENGINES = 61m Euro's
Add HEPA	+ 650k Euro 1%	Negligible Installation Increase Ancillary Engineering costs	E12 Additional Filter Costs 506 elements per GT @ Euro 200 at 3yr increment = 1m Euro's opex increase for 3 GTs

Note typical inlet fiter and duct system for 260MW = nominal 1m Euro
Assumes 8000 hours baseload
MwHr at 40 Euro ~ GJ of Fuel 3 Euro per
Ignores Offline Forced Waterwash and Associated costs / lost revenue
Excludes any savings related to engine parts
10m Euro Typical large retrofit

EUROPEAN TURBINE NETWORK

Thank you for your attention