Gas turbine air filtration – a user's perspective

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Outline

- Gas turbine air filtration – drivers
  - GT OEM
  - Filter OEM
  - GT users
- Case studies
  - E.On filter upgrade from standard to HEPA
  - GDF SUEZ Glow
- Conclusions
- Questions

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GT air filtration drivers
GT OEM

- ❑ Pressure on initial installation cost
  - Low cost filter house, cheap filters
    - E.g. use of coalescer pads on land based machines
  - Achieve performance guarantees

- ❑ No incentive for lowest operational cost or best performance
  - Fuel consumption and spare parts are paid by the customer

Poor initial filter house design

- Coastal, desert environment, 9 months per year fog but no rain
- Yearly replacement of the first stage blades (turbine)





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GT air filtration drivers filter OEM

- Great development from HVAC products to real turbomachinery filters
  - Development of new dedicated media
  - Development of dedicated (reinforced) filter modules

- Mature market with a lot of competition

- Opportunity for GT users for affordable high quality products
  - Focus on end-users more than on GT OEM
  - Customer intimacy

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GT air filtration drivers filter OEM

- Better filter elements
  - Improvement in filter medium
  - Lower pressure drop for same filtration performance …
  - … or better filtration performance for the same pressure drop
- Improvement in filter element design
  - Design for power generation
  - Salt removal
  - Water removal
  - Long lifetime

GT air filtration drivers
GT users

- Strives for the lowest filter cost

- Purchase department
  - Lowest purchase cost

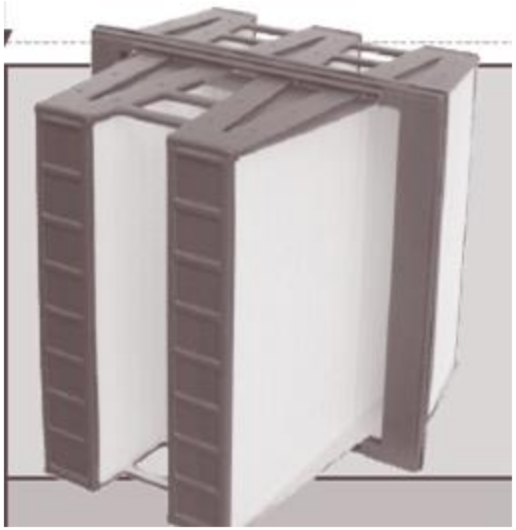
- Engineering department
  - Lowest total cost of ownership
  - Balance between compressor degradation and washing, filter cost, filter pressure drop, …

Pick the lowest cost filter

- Take HVAC filters instead of turbomachinery filters
  - F8 grade is good enough
  - Failure after long period of high humidity

Solutions – can we justify the cost?

Filter house redesign and replacement vs. filter upgrade



Impact of Gas Turbine Filtration Systems

- What we need to consider and Evaluate:

- Compressor Fouling
  - Output power and heat on "whole plant" basis

- Changes in heat rate
  - Filtration Pressure Drop
  - Output power, heat and efficiency changes

- Offline Washing
  - Loss of availability

- Material costs?

- Filter Purchase Costs
  - Function of cost and change frequency

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Impact of Gas Turbine Filtration Systems

- Key impact parameters:

- Pressure Differential

  The differential pressure imposed on the system by the filters reduces electrical and heat output and causes an increase in heat rate.

- Compressor Fouling

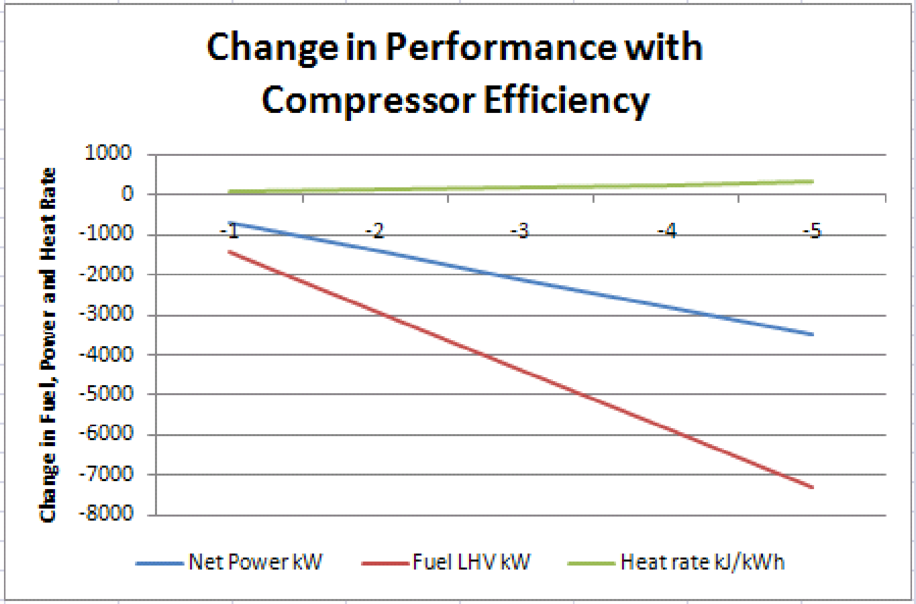
  Particulate matter passes through the filter and deposits on compressor blading causing, most noticeably, a loss of aerofoil profile. This gives output reduction and an increase in heat rate.

  Longer term erosion of coatings can occur which accelerates the effects of fouling and allows corrosion to occur. Corrosion can lead to crack propagation and premature failure.

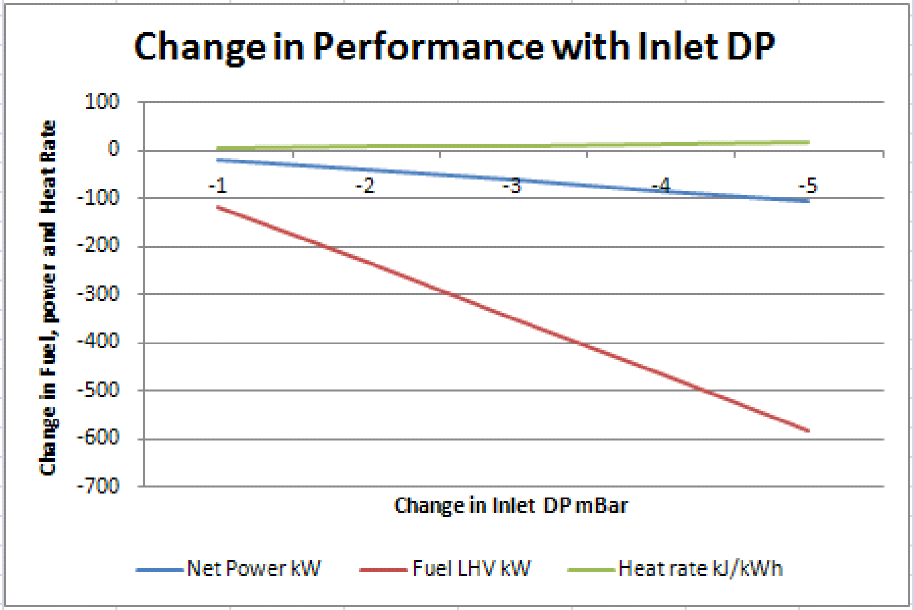
Impact of Gas Turbine Filtration Systems

Effects of Compressor Fouling and Inlet DP on Performance

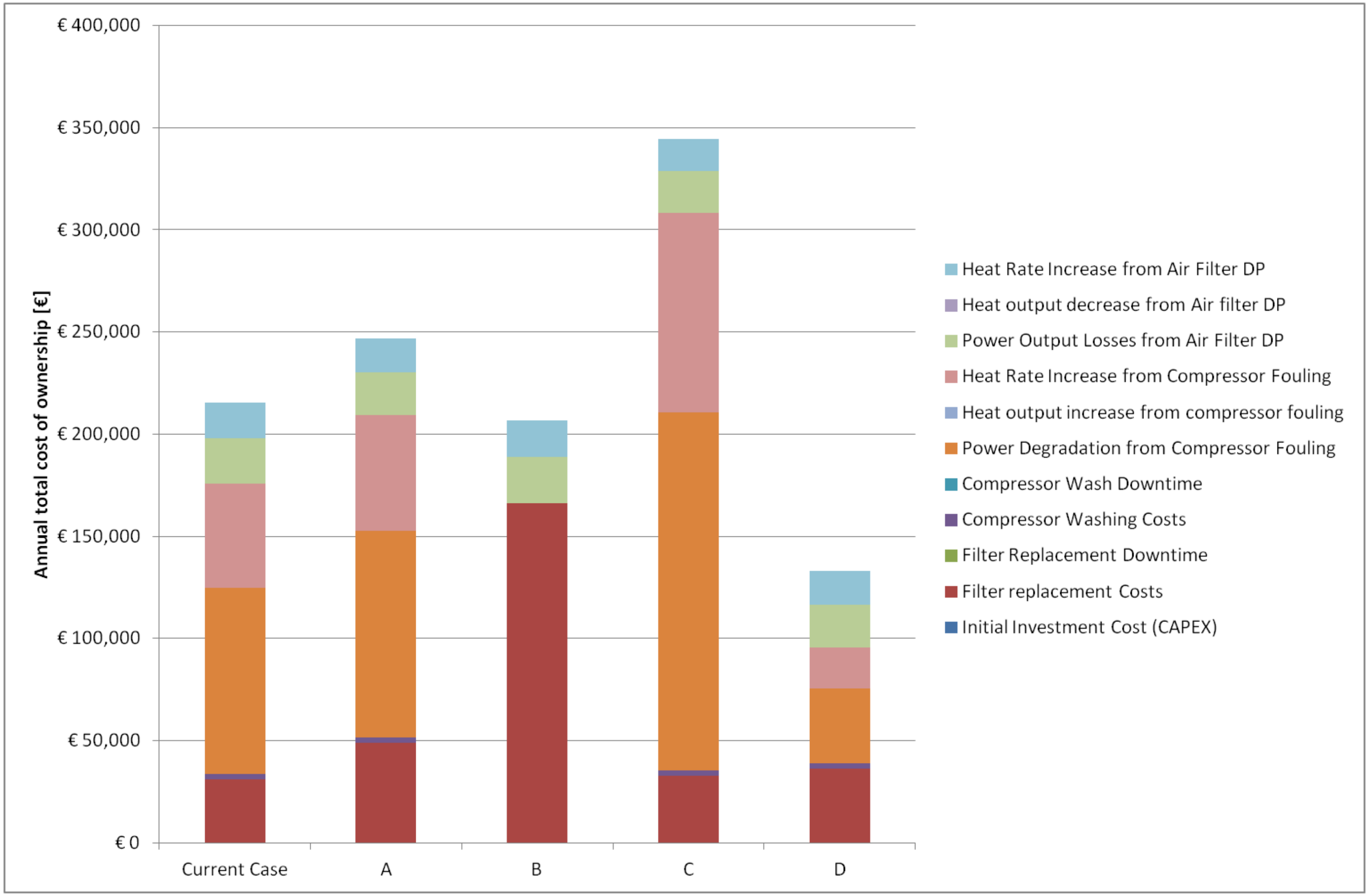
compressor efficiency %	-1	-2	-3	-4	-5
Net Power kW	-702.2	-1404.4	-2106.6	-2808.8	-3511
Fuel LHV kW	-1460	-2920	-4380	-5840	-7300
Heat rate kJ/kWh	59.695	119.39	179.085	238.78	298.475



Inlet Differential Pressure mbar	1	2	3	4	5
Net Power kW	-21	-42	-63	-84	-105
Fuel LHV kW	-116.6	-233.2	-349.8	-466.4	-583
Heat rate kJ/kWh	3.33	6.66	9.99	13.32	16.65



Impact of Gas Turbine Filtration Systems



Case study 1 – E.On

RR RB211 cogeneration plant

- Coastal location (docks)
- Adjacent to bulk coal terminal
- Inlet within 20m of idling diesel locomotives
- Cartridge (pulse clean) filter house
- Change from various F9 synthetics/nano-fibres to E12 ePTFE membrane

Case study 1 – E.On

Heavy fouling from diesel locomotive resulting in loss of output and plant efficiency and frequent surge/stall on shutdown.

Base load CHP but OEM/maintainer demanding offline wash every 500hrs

3.47% comp eff reduction
8.67% power loss
3% increase in *whole plant* heat rate

Case study 1 – E.On

E12 ePTFE filtration after more than 22000 hrs with no washing on or offline

Case study 1 – E.On

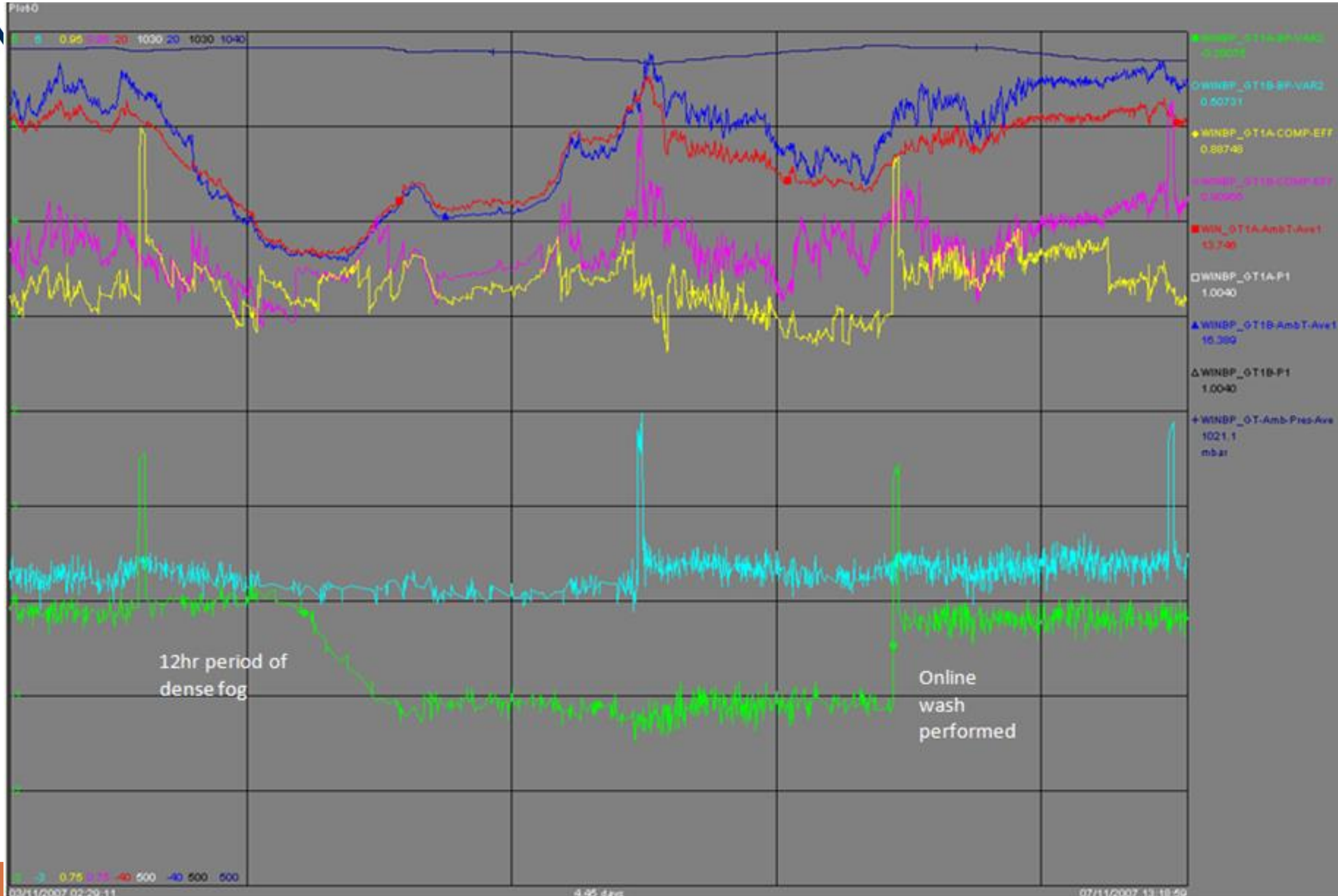
GE F6B cogeneration plant

Industrial/town/motorway network
Supplying soda-ash factory

Reasonably standard 3500m^3/hr/filter airflow although,
Compact design (“W” shape filter banks) with a row of coalescer pre-filter pads followed by further coalescer pad and F9 micro-glass fibre minipleat.
Fouling rate 5% power/3 months

Change to multi pocket pre-filter bags and close-coupled F8/E10 micro-glass fibre final stage.

Case study 1 – E.On



Case study 1 – E.On

GE F6B cogeneration plant

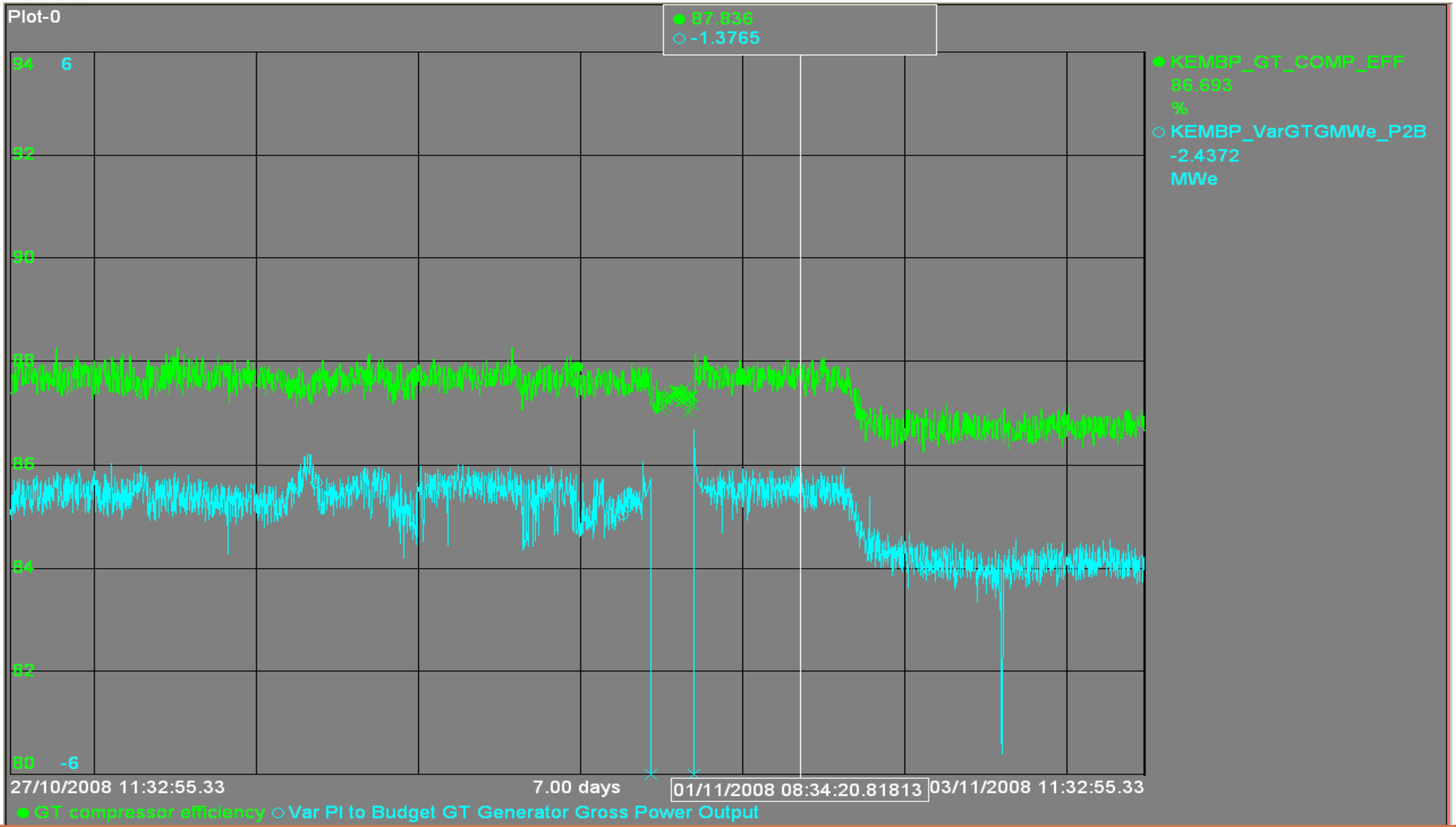
Industrial/town/coastal
Supplying paper making industry

4200m³/hr/filter airflow
Compact design (“W” shape filter banks) coalescer pad and F9 micro-glass fibre deep pleat.
Fouling rate 4% power/3 months

Change to new filter house with multi pocket pre-filter bags, then F8 and E11 micro-glass fibre final stage. All at 3500m³/hr/filter in a flat wall design

Case study 1 – E.On

Case study 1 – E.On



Case study 1 – E.On

So what is happening with micro-glass fibre media at EPA levels that does not happen with membranes?

Case study 1 – E.On

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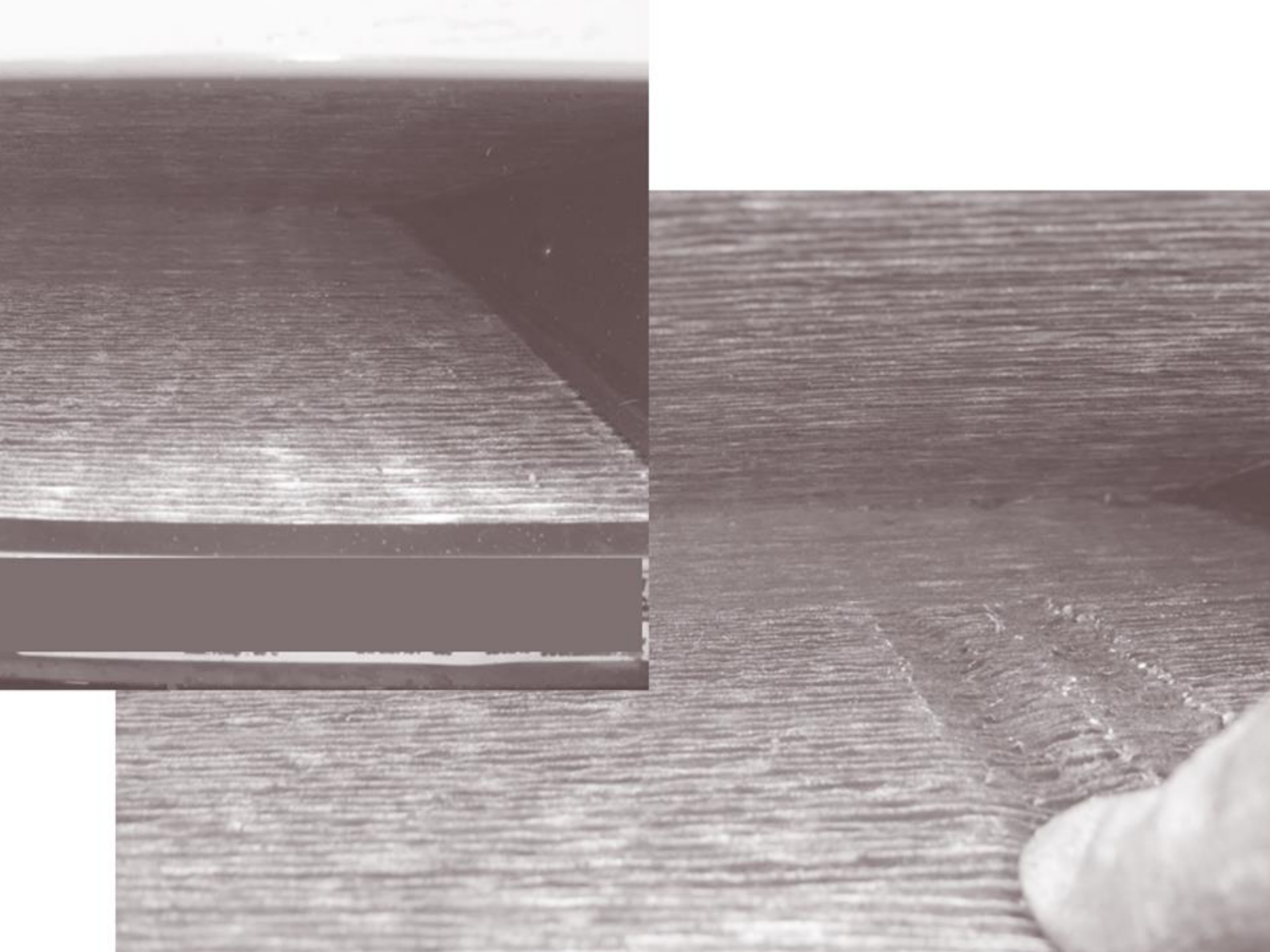
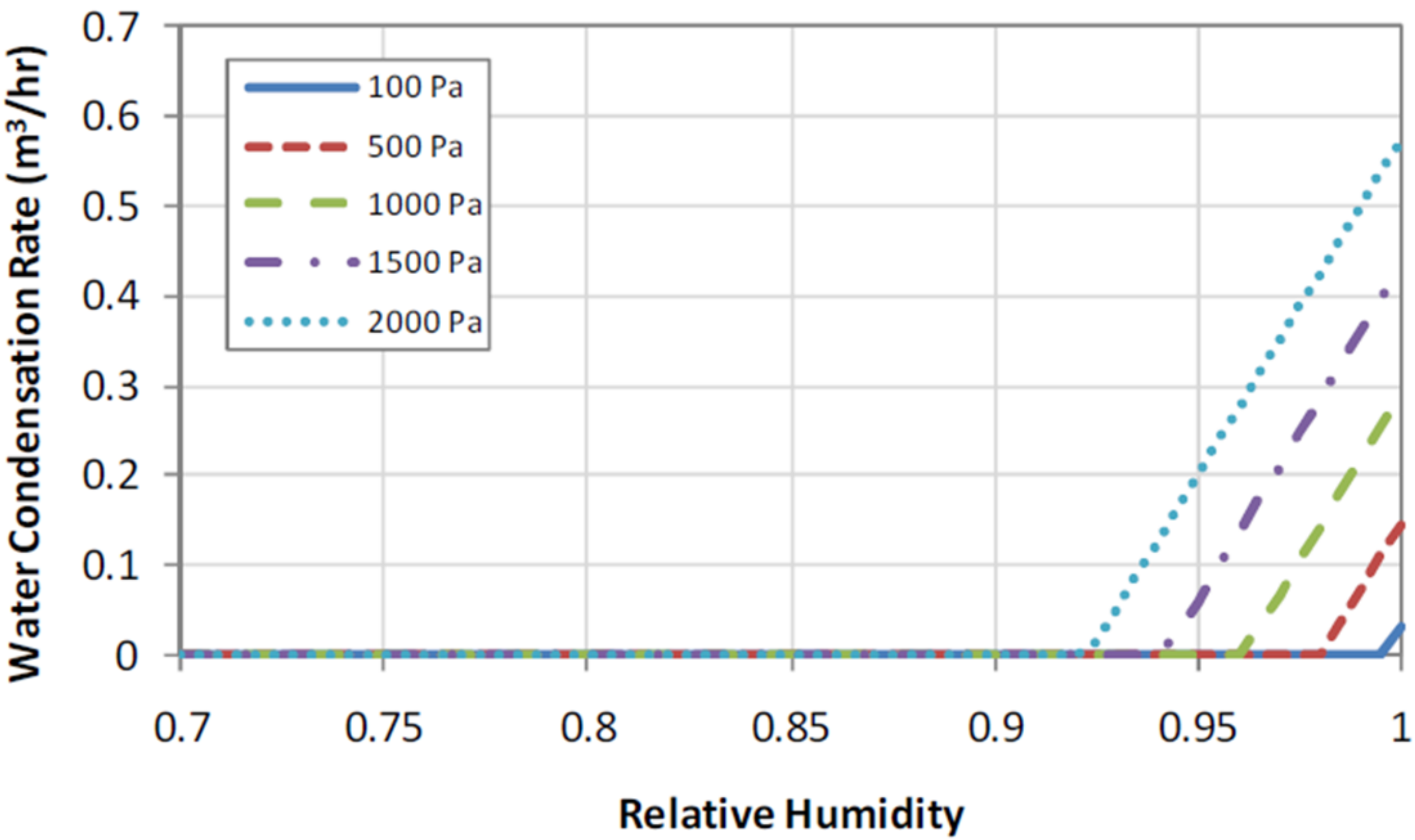


Case study 1 – E.On

So can we simply stop this happening by having good weather hoods, droplet catchers and coalescers incorporated into the filter house design?

Case study 1 – E.On



Effect of relative humidity and pressure drop on water condensation rate

Filter Failure During High Humidity Conditions – Wilcox, Ransom, Delgardo Garibay, ASME Turbo Expo 2010 June 14-18 2010 Glasgow – UK.

Case study 1 – E.On

Where are we now?

We do not believe current micro-glass fibre media is sufficiently reliable to perform over its life at EPA levels in most retrofit applications unless they are protected *and* extremely low flow.

We believe multi layered ePTFE is extremely reliable at E12 but is expensive and therefore not suited to all applications.

We are pursuing the development of new technologies with some manufacturers that can match ePTFE performance but at lower cost.

Case study 2 – GDF SUEZ

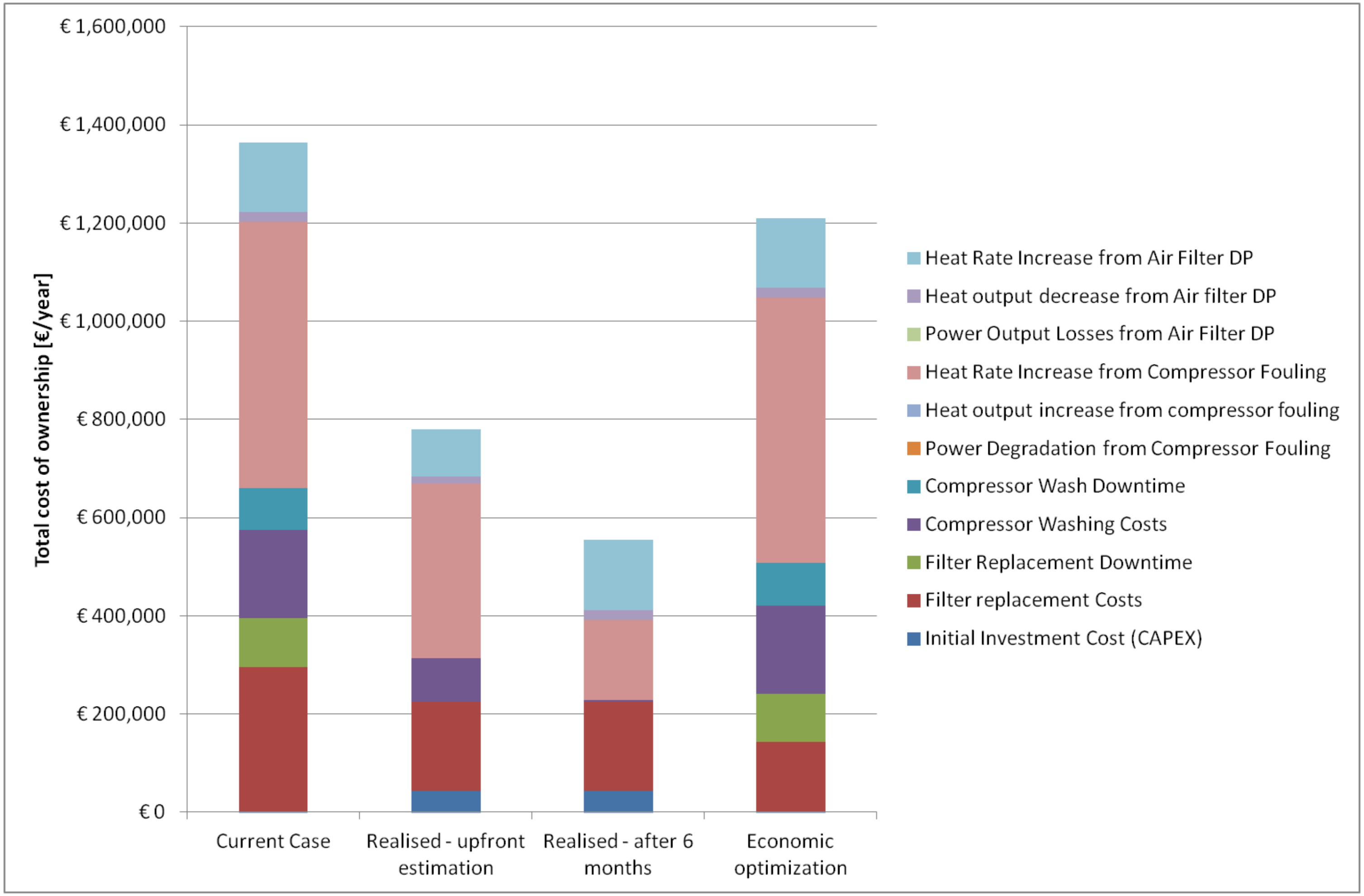
- Glow Power plant in Thailand
  - F-class gas turbine, COD 2011
  - Located in petrochemical industrial estate
  - Next to sea and coal fired power stations
    - Dust + salt + humidity
- Filter combination
  - Pre-filter – evap cooler – coalescer – final filter
  - Initially G4 – G4 – F8
- Off line wash every 4 months, 7 MW recovered

Case study 2 – GDF SUEZ

- Low quality filters installed by GT OEM
  - F8 final filter quality insufficient at chemical site
  - Location of the evaporative cooler between pre- and final filter strange
  - Lowest cost of filter approach

- RFQ to major filter manufacturers
  - More than 25 different options
  - All modelled in Life Cycle Model
  - Estimated benefits in excess of 500 k€ annually

Case study 2 – GDF SUEZ



Case study 2 – GDF SUEZ

- Difficulties encountered:

- Odd filter frame sizes
  - Filter frames have standard sizes … in theory
    - Not all filters fit in the existing frame

- Filter pricing
  - Local agents consider different and high margins
    - Filter elements 40% more expensive in Thailand than when purchased in EU and shipped

- Interaction evaporative cooler operation – filter
  - High humidity → higher pressure losses on final filter
  - Controlled evaporative cooler operation

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Conclusions

- Gas turbine air filters are expensive, especially in case of underperformance.
- Higher final filter efficiencies turn generally in substantial benefits for the GT O&M.
- Water removal is a key factor in proper filter performance.
- A total cost of ownership approach enables the comparison of offers from different filter suppliers.

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Questions

1. Criteria to compare filter products
2. How can we compare two filters?
3. Which tests to perform?
4. Are tests representative?
5. EN tests with lab dust - what about real world?
6. How to relate to the ambient specific for the power station (from lab results to the real world)?
7. How to select the best filter and be sure it is fit for its purpose?
8. For static filters, a lot of evaluation material is available, but what about pulsed cartridges?
9. Which filter efficiency is sufficient to get rid of fouling? E10 or E12?
10. How do different filter media behave under different ambient conditions?

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