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ENHANCED ENERGY EFFICIENCY SOLUTIONS FOR INDUSTRIAL BAGHOUSE FILTERS

Gunnar-Marcel Klein (gunnar-marcel.klein@intensiv-filter.de), Theo Schrooten, Tim Neuhaus, Ralf Esser, Frank Ott, and Tobias Daniel
Intensiv-Filter GmbH & Co. KG, Voßkuhlstraße 63, 42555 Velbert, Germany.

Two new technologies for jet-pulse baghouse filters with considerable enhanced energy efficiency (Three E) have been developed. The ProJet mega® – offline technology combines the annular-gap-coanda injection system with an offline filter operation mode and a filter design optimized by CFD. Due to a reduction of the filter pressure drop and low pressure cleaning, a reduction in energy consumption of 30% has been achieved. The ProJet mega® – Three E technology with ProTex filter media enables an energy saving of up to 40% for jet-pulse filters in online operation mode. The new Intensiv-Filter ProTex filter media contain microfibres and are optimized with the criterion of minimizing the residual pressure loss as well as the non-linear increase of the pressure drop curve during the first period after cleaning. Laboratory experiments according to VDI 3926 demonstrate the superior performance data of ProTex filter media compared to conventional needlefelts, conventional microfibre needlefelts and ePTFE membrane media. The Three E operation mode describes a special setting of the operating parameters of the filter system (e.g. cycle time). Validation tests at pilot plant scale show a possible reduction of the pressure difference over the bag plate by a factor of 4 compared to the current standard baghouse filter technology. The huge potential of the Intensiv-Filter Three E technology will be evaluated in field tests in the near future.

INTRODUCTION

Baghouse filters are the most important filter type to separate particles from gases in industrial processes. Applications include all production processes where particle laden gases will occur, e.g. within the industrial branches of cement, calcium, gypsum, steel and iron, non-iron metals, power plants, waste incinerators, and the chemical, pharmaceutical and food industries. The reduction of particles below today's emission limits within a single stage process is the main advantage of this filter type. Several innovation cycles over recent decades were focused on reducing the specific energy demand for the dedusting process. As a result the efficient jet-pulse cleaning mode has replaced earlier types with mechanical backflush cleaning techniques[1]. Figure 1 shows a jet-pulse baghouse filter, Intensiv-Filter design, including the energy flow diagram. The raw gas enters the baghouse in a crossflow mode, which improves the sedimentation of the removed filter cake. A smooth flow distribution is achieved with the help of a deflector plate at the raw gas inlet. 85% of the energy demand is caused by the pressure loss,

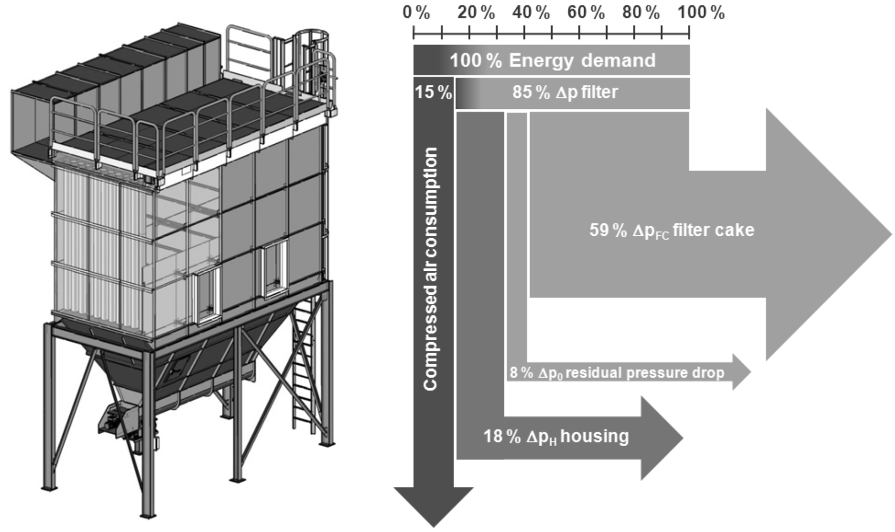


Figure 1: Schematic design and energy flow diagram of a jet-pulse baghouse filter with online operation mode.

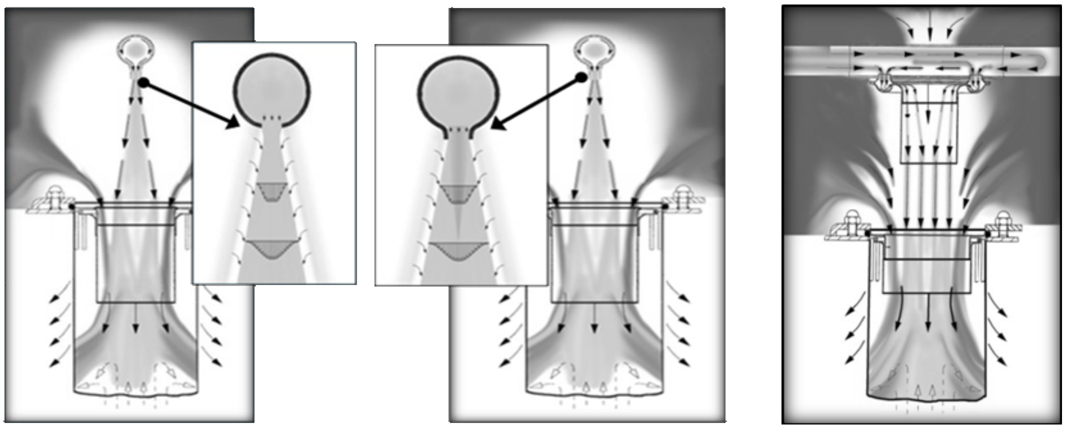
where the deposited cake has the biggest portion; 15% is needed for the cleaning process (online operation, pressurized air at 0.6 MPa). Based on such a 'state of the art' design, this work will show further improvements in energy efficiency.

JET-PULSE BAGHOUSE FILTERS

Offline Operation Mode with Improved Energy Efficiency

The injection system has a significant influence on both the efficiency of removing the filter cake from the bags as well as the consumption of pressurized air per cleaning impulse. The most common injector design consists of a blowpipe with circular holes (nozzle) arranged above an inlet nozzle as the second injector stage. The Intensiv-Filter blowpipe with 'ideal nozzle' and the patented annular gap Intensiv-Filter Coanda Injector system are more modern options (Figure 2), which produce, at a given tank pressure, a significantly higher pressure impulse within the bag (Figure 3)^{2}. With the Coanda Injector, the required bag pressure impulse can be created at a lower tank pressure compared to the nozzle system. Additionally, because of the larger diameter of the inlet nozzle, the restriction for the main flow is reduced. Both measures contribute to the improvement of the energy efficiency.

A further improvement in the energy efficiency is possible by offline or semi-offline operation. During



a) Hole type nozzle and inlet nozzle b) Ideal nozzle and inlet nozzle c) Coanda Injector and inlet nozzle

Figure 2: Functional principle of different jet-pulse injector systems.

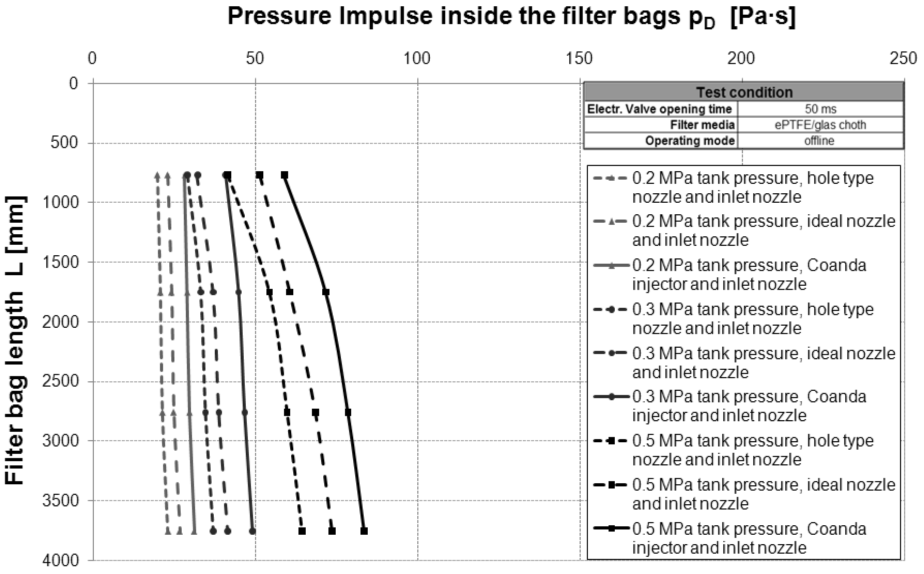


Figure 3: Local distribution of the pressure impulse during jet-pulse cleaning, influence of the tank pressures and injector system.

offline cleaning, the raw gas and clean gas flaps, or the clean gas flaps only (semi-offline), of one filter compartment are closed during the cleaning and dust cake sedimentation phase. For this reason the complete removal and sedimentation of the filter cake can be secured and a possible re-entrainment of already removed dust is eliminated. This leads to a reduction of the average pressure drop due to the filter cake. In parallel, the required pressure impulse is much lower compared to a filter in online operation. The required air tank pressure of filters in offline operation can be reduced from 0.4-0.6 MPa down to 0.1-0.3 MPa. These improvements - as well as a self learning control of the air tank pressure (Intensiv-Filter JetBus controller®) - were realized within a new modular filter line (ProJet mega®), which offers a maximum variability according to the customer needs by having a limited inner design variance (Figure 4). Compared to the benchmark filter (Figure 1) a reduction of the energy demand by 30% can be realized (Figure 4), which equals the energy efficiency level of electrostatic precipitators. The first plants built (e.g. replacements of existing ESP's by ProJet mega® baghouse filters) confirmed this value[3].

A New Method of Pressure Drop Minimization with Online Cleaning Mode (Three E Technology with ProTex Filter Media)

As shown in Figure 4, the pressure loss caused by the reversible deposition of the filter cake is still the biggest portion of the total energy demand required for the dedusting process. For most applications the pressure increase during one filtration cycle does not increase with constant slope (ideal cake filtration), rather it shows a non-linear characteristic, with a convex shape to the pressure loss curve during the first phase of filtration[4]. To study this effect in more detail, test runs with flat sheets of different filter media according VDI 3926 were performed[5] (Figure 5). To eliminate the effect of non-stationary behaviour, the ageing procedure has been increased to 20,000 cycles with 5 s cycle time.

Filter bags made of needlefelt media with a top layer of ePTFE membrane have reached a significant market share, despite their high material cost level. Due to the dense structure of the microporous membrane, these media show a significantly lower permeability in the new condition. Manufacturers of these materials argue that this disadvantage will be over-compensated by a lower level of residual pressure loss during operation, e.g. at steady state condition. In our measurements the residual pressure loss of both analyzed ePTFE media grades (ePTFE/PES1, air permeability = 12 l/(dm^2 min) @ 200 Pa, ePTFE/PES2, air permeability = 18 l/(dm^2 min) @ 200 Pa) exceeds the level of all other tested filter media. Moreover, a convex shape of the differential pressure curve can also be observed for this media type. The conventional PES needlefelt has a low initial (residual) Δ*p* but shows a strong non-linear increase in Δ*p* during the first filtration phase. This leads to a similar level of pressure difference at the end of the filtration cycle for ePTFE and conventional needlefelt media.

The results show that the filter media have a significant effect on both the residual pressure difference as well as the shape of the Δ*p* curve within one filtration cycle, even at steady state operation. The results also show

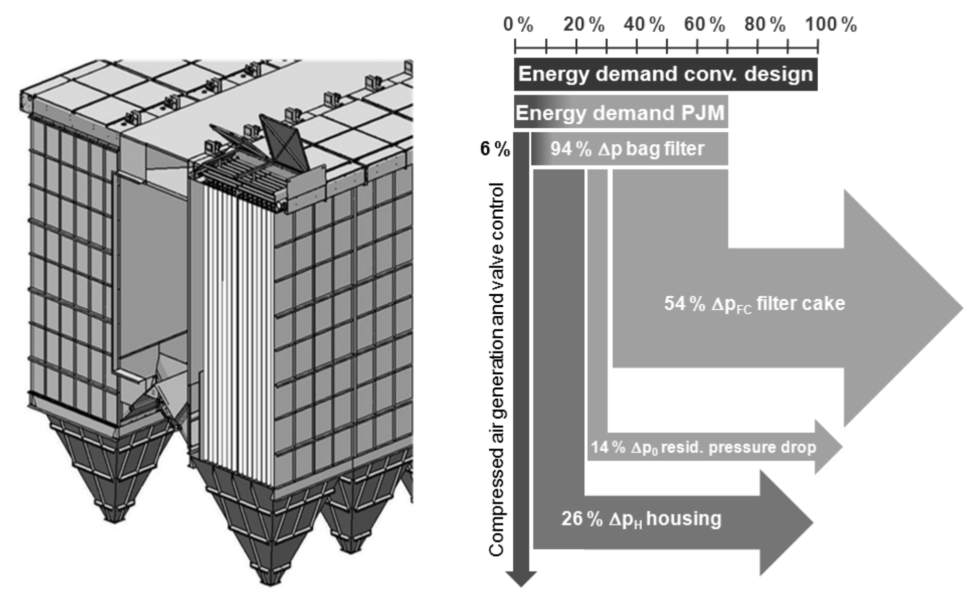


Figure 4: Schematic and energy flow diagram of a jet-pulse baghouse filter with enhanced energy efficiency, offline operation.

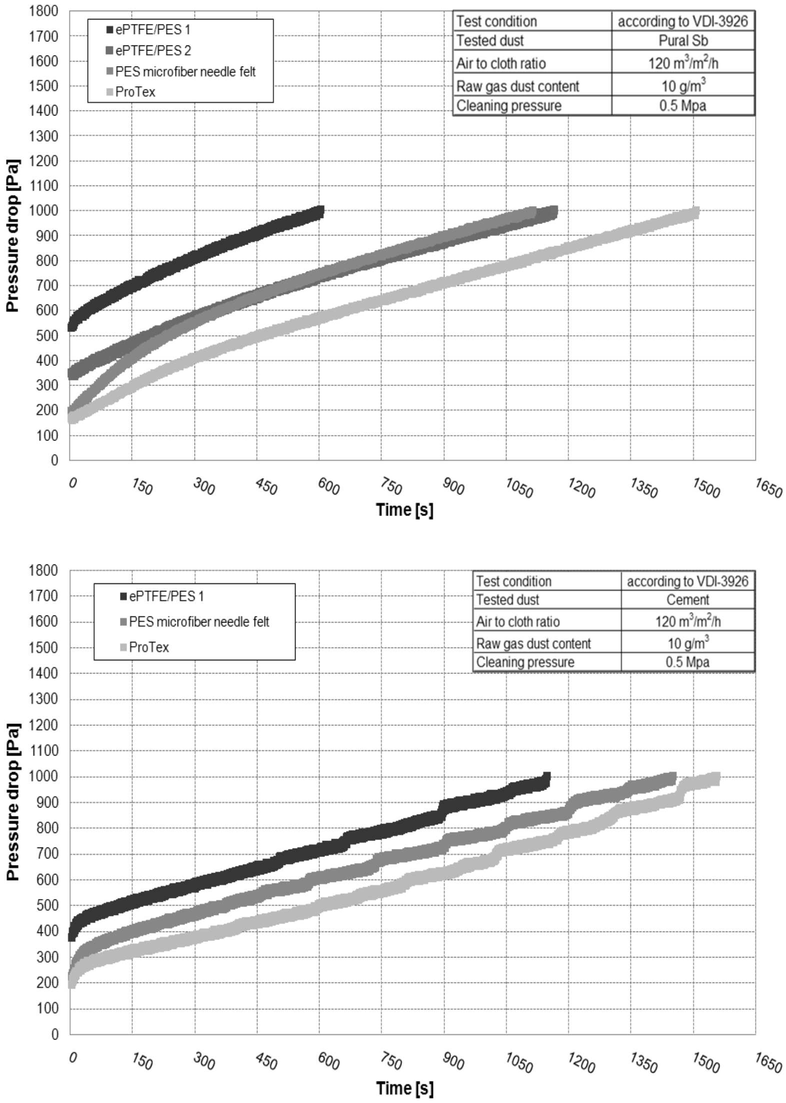


Figure 5: Differential pressure within one filtration cycle at steady state operation conditions (Test acc. VDI 3926, after ageing) for different filter media and two different test dusts.

that membrane type media don’t necessarily have the best performance. The physical mechanisms of these influences are complex and not fully understood, however, the microstructure of the media (pores and fibres) at the raw gas side (e.g. the first 100 µm in depth) play a key role. By analyzing different types of needlefelt media via the described procedure, it can be shown that the lowest levels of the Δ*p* curve can be achieved by so-called microfibre needlefelt media. Further analysis of different microfibre media led to the development of the new Intensiv-Filter ProTex filter media family. ProTex media consist of fibres with a titer ≤ 1.5 dtex, which are arranged between the raw gas side and the supporting scrim of the filter media[6]. ProTex shows a low level of the residual pressure loss as well as a reduced slope of the differential pressure curve compared to other filter media types and even compared to other microfibre needlefelt filter media (Figure 5).

The Three E operation mode makes use of the advantages of ProTex filter media. Three E means simply the setting of the cycle time with minimum operating costs as the optimization parameter. This leads to generally shorter cycle times. Because of the clearly enhanced particle retention efficiency of the microfibre based ProTex media, very low clean gas concentrations can be guaranteed despite the more frequent cleaning. The achievable effects on the Δ*p* between raw and clean gas sides within a pilot plant consisting of 10 bags with 4 m length can be seen in

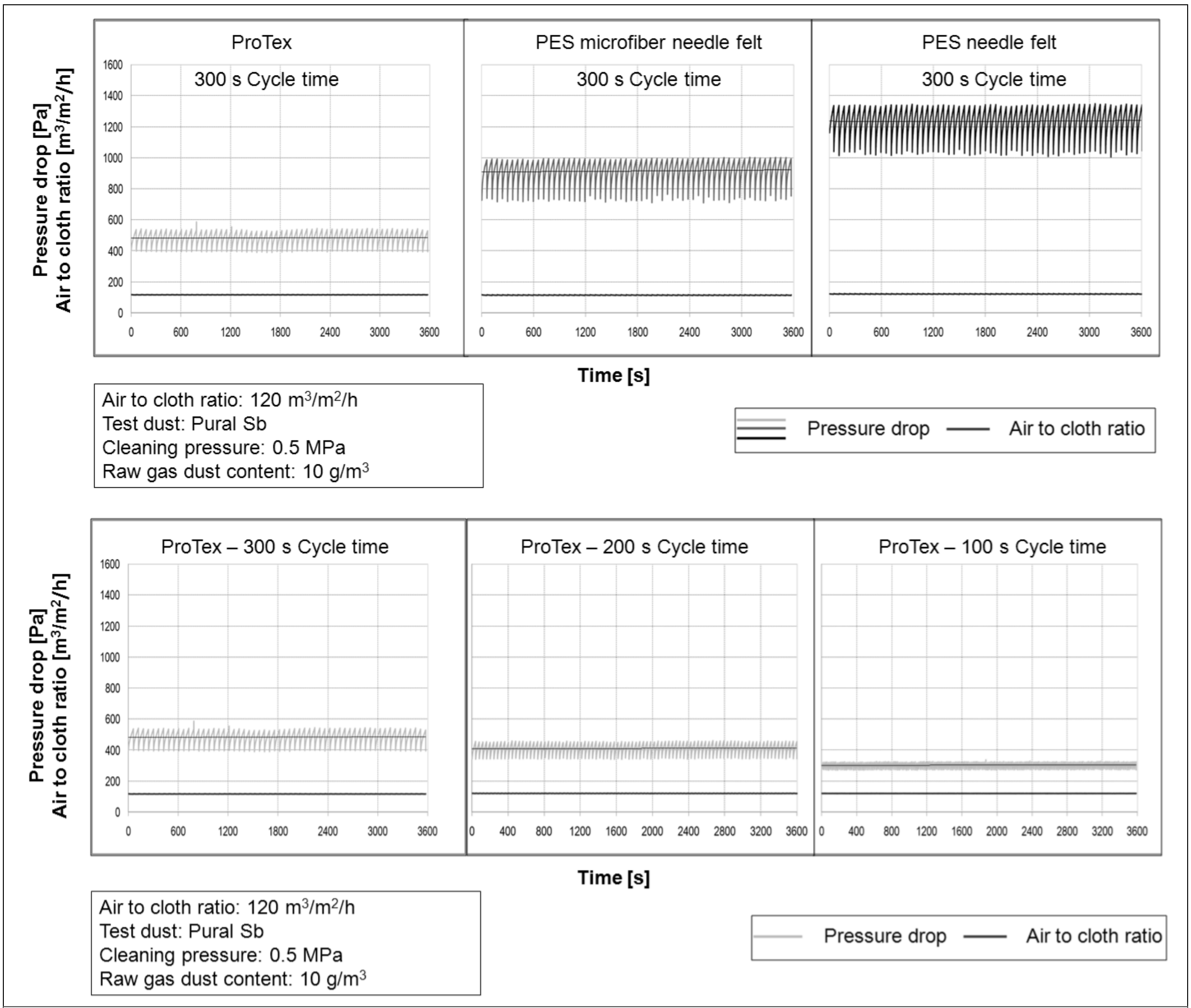


Figure 6: Differential pressure curves with different media and cycle times. Pilot plant with 10 bags (*D* = 160 mm, *L* = 4000 mm).

Figure 6. With a constant cycle time of 300 s, the ProTex filter media have an average Δp of 480 Pa compared to 920 Pa for a standard microfibre needlefelt grade and 1220 Pa for the standard needlefelt. A reduction of the cycle time down to 100 s leads to a Δp of 300 Pa. That is a reduction of the pressure loss over the bag plate by a factor of 4, compared to a current standard PES needlefelt with standard operation conditions.

Figure 7 shows the energy flow diagram of a jet-pulse filter in online operation mode with Three E technology. As described, the main effect is the reduction of Δp_{FC} (pressure loss over the filter cake) created by the reversible particle deposition and thus the required fan energy. Because of the more frequent cleaning cycles, the energy demand to produce the required pressurized air is increasing, but this is highly over-compensated by the reduction of $\Delta p_{FC.}$ It is notable that the increased consumption of pressurized air due to the reduced cycle time is not increasing linearly, because of a reduced tank pressure (from 0.6 MPa down to 0.4 MPa) which is enabled by the use of the Coanda injector and the improved cake release behaviour of the ProTex filter media. Compared to the reference filter shown in Figure 1, a reduction of the specific energy demand per cleaned volume unit of gas of 40% can be achieved.

Parallel to the reduction in energy demand, the operating costs were reduced. Figure 8 summarizes the achievable reductions for both filter technologies with enhanced energy efficiency described above. The ProJet mega® – offline, offers a 30% reduction whereas the ProJet mega® – Three E combined with the new ProTex media allows a 40% reduction in operating costs.

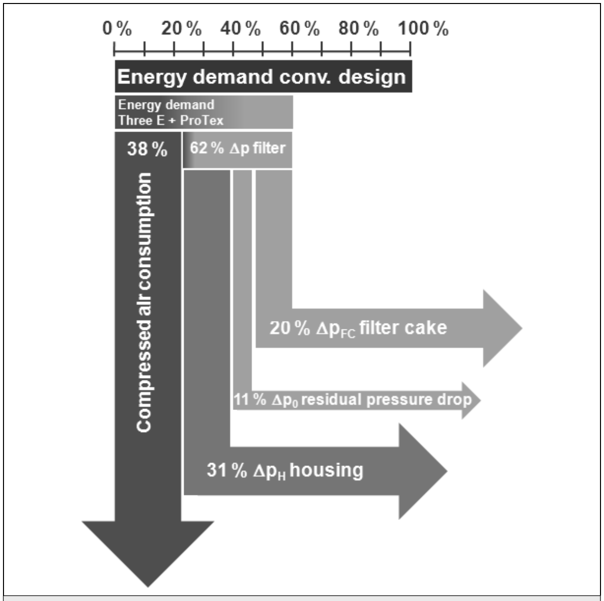


Figure 7: Energy flow diagram of a ProJet mega® filter with online operation mode, Three E technology and ProTex filter media.

CONCLUSION AND OUTLOOK

Two jet-pulse baghouse filter systems were developed with clearly reduced energy demand and reduced operating costs. The ProJet mega® – offline filter series was already in operation and is the favourable choice for the replacement of ESP's. The ProJet mega® – Three E filters with ProTex filter media are now on the way from pilot plant scale to industrial application. A combination of both technologies (Three E technology in offline operation) may lead to further improvements. This will be investigated in the future as well as the extension of the ProTex filter media generation to high temperature applications.

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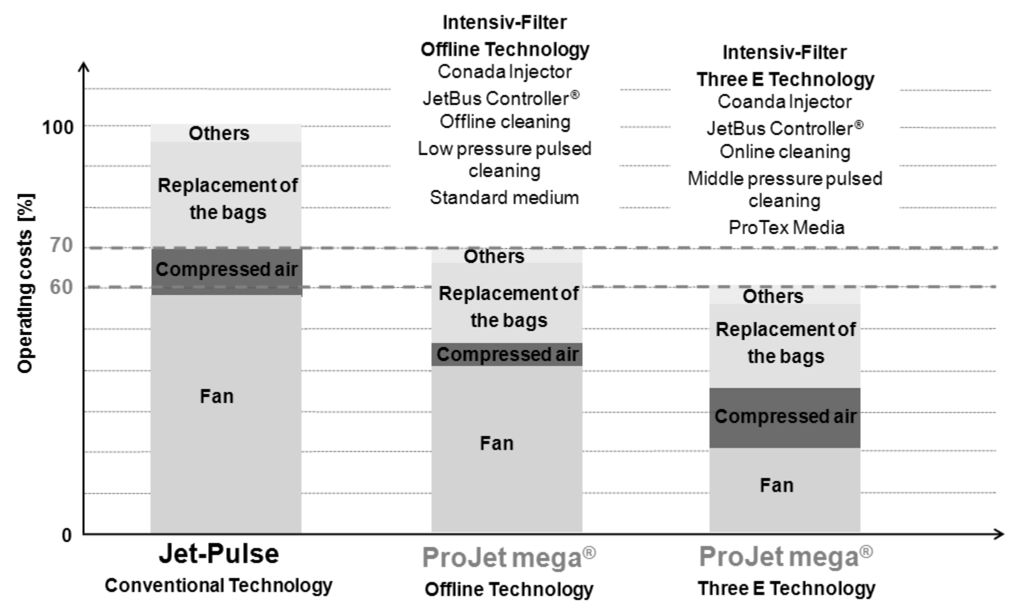

Figure 8: Comparison of the operating costs of a conventional jet-pulse baghouse filter with a ProJet mega® filter in offline operation mode and a ProJet mega® filter in online operation mode, using Three E technology and ProTex filter media.