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Subject: Decision Matrix (AVL)			Dissem. Level **PU**

HYBRID COMMERCIAL VEHICLE (HCV) DELIVERABLE D2500.1

DECISION MATRIX

Summary

This document describes the work performed in the HCV task T2510. In this task a decision matrix including details about the investigated electrified auxiliaries and the implementation effort has been collected. In order to create this decision matrix the results of the previous work packages WP2100 to WP2400 have been used. In these work packages a market analysis of different available components for electrified auxiliary sub systems was done in order to choose the most suitable ones for the implementation in the demonstrator vehicles in the HCV project. The decisions on which components to use were based on CO_2 reduction (fuel consumption), cost, packaging requirement and implementation effort for the individual auxiliary.

The decision matrix shows all the available components and the selected components for implementation marked with green background. The details about the selected auxiliaries and implementation effort have been collected in the deliverable D2500.2 [2].

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Abbreviations

AT	Aluminum Titanate
e-A/C	electric Air Conditioning
BSM	Brake System Module
CAN	Controller Area Network
CS	Combustion System
DPF	Diesel Particulate Filter
EBD	Electronic Breaking Distribution (EBD)
ECU	Electronic Control Unit
EM	Electro-Mechanical
EMB	Electro-Mechanical Brake
EPB	Electronic Parking Braking
ESC	Electronic Stability Control
ESP	Electronic Stability Program
FC	Fuel Consumption
HVAC	Heating, Ventilation and Air Conditioning
HEV	Hybrid Electrical Vehicle
NEDC	New European Driving Cycle
NP	Normal Production
RH	Relative Humidity
TRW	Company name

Introduction

Available electrified auxiliary components or systems were investigated based on their possible implementation and performance advantages. The possibility of fuel consumption reduction and therefore CO_2 emission decrease was assessed, to select the component which is ecologically most profitable. Sometimes the costs could be estimated based on existing systems or similar components but in other cases no reliable information on that was available. This is due to the fact that many components were just prototypes and not yet available on the market. In such cases the cost estimation is not possible because the price strongly depends on the possible market volume, additional suppliers, manufacturing costs and so on. In these cases just general guesses about the maintenance and operating costs of the components could have been performed.

Another important factor for the decision which component to select for implementation is their weight. This is also related to their packaging requirement and implementation effort. The best system is not helpful if a proper positioning cannot be performed. Based on these data, the availability of the components and further considerations, the most suitable components or systems were chosen for the implementation.

The information on the available components has been collected from the reports delivered in the work packages WP2100 to WP2400. These reports are listed in the reference chapter.

Technical progress

For each of the investigated electrified auxiliaries a short description of the component and a decision matrix in form of a table will be presented. The selected system to be implemented in the HCV project is marked with green background color. The information in the presented tables was collected from the individual reports from the work packages WP2200 to WP2400 or provided directly by the partner responsible for a specific deliverable.

Electrical A/C Compressors

In general an electrical A/C compressor has just three connection points compared to a standard one: a mechanical (hydraulic), a control and a high power electrical one. The component isn't driven by a belt leading to the fact that the location of the compressor could be chosen without the engine constrain (more freedom of implementation). This leads to reduced pipe length by placing the compressor exactly next to the component, which needs it. Finally the complete e-A/C layout becomes more compact. The investigated systems are presented in Table 1.

Table 1: Comparison of the different A/C compressors (green: chosen compound DENSO 27)

Type	CO_2 Reduction	Costs	Weight	Packaging and Implementation Effort	Additional Information
Masterflux Sierra06-0982Y3	It has the same potential as the others. The major advantage is the independence of the engine's rpm: can improve the CO_2 reduction.	about 800 € (compressor + inverter)	6.5 kg	Inverter is not integrated - The compressor isn't an automotive component so the layout, packaging and technical specifications don't fit with the automotive requirements.	This compressor was a prototype in 2010 it can not be considered anymore, because it never went into production for automotive application.
SANDEN F655 (prototype)	70% higher electrical consumption than the SIERRA one	Prototype - not produced. No Cost indications	7.6 kg	Integrated Inverter	For passenger car application, was prototype in 2010 and never went into production and is therefore not considered. This compressor has a cooling power curve positioned between the two DENSO compressors.

DENSO ES34	The fuel consumption of this A/C compressor depends significantly on the control strategy.	1000 € for CRF prototype	6.7 kg	Easy - independent on the engine's position - mounting → more degrees of freedom and decreased pipe length; integrated inverter; reduced connection points	For Minibus application this compressor has the most comparable properties to the SANDEN at medium rotational speed and therefore the best choice; it has higher power than the DENSO ES27 and therefore higher power consumption.
DENSO ES27	The fuel consumption of this compressor depends significantly on the control strategy. Energy consumption reduced by 40 % compared to mechanical one. Possibility to reduce discharge pressure and radiator fan activation.	1000 € for CRF prototype	5.9 kg	Easy - independent on the engine's position - mounting → more degrees of freedom and decreased pipe length; integrated inverter; reduced connection points	For passenger car application this A/C compressor has the most comparable properties to the SANDEN one and therefore the best choice; high performance.
DENSO ES14	Same considerations as for the other DENSO models.	1000 € for CRF prototype	4.7 kg	Easy - independent on the engine's position - mounting → more degrees of freedom and decreased pipe length; reduced connection points	For Small Car Applications (A segment).
DELPHI	No data --> No baseline available		less than 160 kg	roof mounted	Note: Total different system; weight not comparable to the other ones.

Electrical Air Compressors

For the electrical air compressors three different main working systems were compared as shown in Table 2. These are the reciprocating compressor, vane compressor and screw compressor. After comparing the three compressor type it was found that the vane compressor is the most suitable for the HCV project requirements. The selected model is a Hydrovane V6T vane compressor. For more details concerning these systems refer to the reports of work package WP2200 [3].

Table 2: Properties of the different electrical air compressors (green: selected component - the Hydrovane V6T vane compressor)

System	Type	CO_2 Reduction	Costs	Weight	Packaging and Implementation Effort	Additional information	Considerations
Reciprocating compressors	Wabco 912 518 205 0	SOLARIS estimated a fuel consumption potential of 10 % using electric compressors	1,100 €	25 kg (powered by diesel engine)	built in e-motor	Standard solution delivered with the combustion engine.	Not chosen - not possible to use this solution in electric and hybrid vehicles where electric engines are assembled.
Vane compressors	Hydrovane V6T vane – compressor	SOLARIS estimated a fuel consumption potential of 10% using electric compressors	1,640 €	32 kg (with e-engine)	very compact and simple (direct transmission ratio of power and the flexible clutch -->possibility of positioning the compressor at the air inlet location in the direct vicinity of the work stands - no expensive pipes - reduced length); built in e-motor - SIEMENS three-phase engine	blade durability > 100 000 hrs, no repairs just typical inspections; lowest maintenance costs	Chosen - When hybrid bus drives on the electric motor then e-compressor is necessary to provide air to the bus systems.
Screw compressors	No supplier	SOLARIS estimated a fuel consumption potential of 10% using electric compressors	-	-	built in e-motor	This is a very popular solution for commercial applications.	Not chosen – No supplier of screw compressors for hybrid buses has been found

Electrical Heating System

Concerning the electrical heating two different systems were compared. Implementing a fully electrical system in a bus with a diesel engine can be performed using the PEDRO SANZ Frontbox plus an electric heater. A comparison between the two electric heating systems (GRAYSON and SPHEROS) and the combustion heating system also from SPHEROS has been performed in the work package WP2200. Some details on the comparison can be found in report D2200.2 [3] and on the implementation in report D2500.2 [2]. The different systems/components are presented in Table 3.

Table 3: Electrical heating system

Component	Manufacturer	CO_2 Reduction	Costs	Weight	Packaging and Implementation Effort	Additional Information	Considerations
Frontbox (variable air duct system)	Pedro Sanz - For combustion heater system	Powered by Spheros Thermo 300 (4 kg/h)	303 €	19 kg	Mounted under the driver cabin. There is the air intake duct from the outside (it works in closed / opened loop)	Brushless frontbox with variable speed control	Reference unit
	PEDRO SANZ – For electrical heater system	100% emission free. Powered by electric energy.	1,096 €	16 kg	Front mounted; inbuilt heat exchanger	Brushless frontbox with variable speed control with additional heating function.	This is a prototype device. Fully functionally compatible with standard frontbox. Doesn't require changes in the bus construction.

Component	Manufacturer	CO_2 Reduction	Costs	Weight	Packaging and Implementation Effort	Additional Information	Considerations
Heater	Combustion heater Spheros Thermo 300	Fuel consumption of 4 kg/h	728 €	19 kg	Fueled heater. Assembled in the engine compartment	The standard device used in the non-hybrid buses	Reference unit
	Thermal Resistor GRAYSON	convert electric energy to heat energy - no fuel energy needed	1,115 €	13.5 kg	Installation in the engine compartment. The special workspace preparation is required to apply this device.	Easy to install and use.	Not chosen: This unit requires structural changes in the bus construction.
	Electric heater SPHEROS Thermo AC/DC	100% emission free. Powered by electric energy.	1,950 €	16 kg	AC/DC powered unit. Assembled in the engine compartment	Maintenance and life cycle costs are minimal; no odour nuisance from exhaust fumes, no noise disturbance; high level of reliability and efficiency (98%) - can be operated at very low ambient temperatures	Chosen: Mechanical installation 100% compatible with the standard one (Thermo 300) and without a change in the bus construction. Without risk of damaging other components. Without fuel supply.

Electrical Mechanical Braking System

To get closer to an electrification of the braking system an Electrified Vacuum Pump is necessary. This pump just operates on demand if the vacuum level in the braking system is too low. This system enables independence of the combustion engine's operation (for more details refer to the reports from WP2300 [4]).

The systems for electrification of the braking operation provided by suppliers and compared in Table 4 can be divided in these categories:

- Electro-Hydraulic Brake – EHB
- Electro-Pneumatic Brake
- Electro-Mechanical Booster
- Electro-Mechanical Brake – EMB

An electrified vacuum pump is necessary to be independent on the combustion engine's operation and achieve additional control by activating the pump only when necessary. For implementation in the HCV project the Hybrid Electro-Mechanical Braking system was chosen. This system still includes the standard hydraulic braking circuit for the front axle while two electro mechanical brakes shall be installed on the rear axle replacing the conventional circuit for rear axle.

The standard architecture on the front axle guarantees to fulfill the safety requirements without excessively increasing the system redundancy, whereas the rear electro-mechanical brakes allow having many advantages, with respect to the standard architecture, in terms of layout, functionalities, comfort, performances… These benefits can not be expressed in terms of fuel consumption reduction, but the electrification of the rear braking system has many benefits:

- ✓ Possibility to integrate the EPB on the rear axle on the electro-mechanical actuators
- ✓ Hydraulics pipes from ABS/ESP module to the rear axle callipers and, in case of EPB integration, the hand brake cable and lever are totally removed
- ✓ Improvement of the total system safety by virtue of two hydraulic separate circuits on front axle (in case of X architecture)
- ✓ Possibility to downsize the pneumatic vacuum booster, the tandem MC pump and the ABS/ESC hydraulic circuit by virtue of the reduction of the hydraulic circuit absorptions.

Table 4: Evaluation of the different braking systems and components (green: chosen Brembo system)

Type	Component	Packaging and Implementation Effort	Additional information
Electro-Hydraulic Brake	Bosch Hydraulic Apply System (HAS)	Replaces pneumatic booster with a hydraulic accumulator, a pump and a master cylinder; the size of the Brake Operating Unit is similar to a normal production master cylinder plus a pneumatic booster, but the Actuated Control Module is added.	In case of failure the brake pedal can push directly the master cylinder
	TRW ESC-R	The size of the ESC-R is slightly larger than a normal ESC; In ESC a simulator unit is introduced to decouple the pedal from the brake circuit, valves are modified; External stroke sensor on the brake pedal required.	
	TRW Slip Control Boost (SCB)	Complete turnkey braking architecture (Master Cylinder + Electro-Hydraulic Control Unit); every regeneration strategy is possible.	In case of failure the simulator is disconnected and the driver directly brakes the wheels
	ADVICS	Similar to SCB	in case of failure the driver can brake directly only the front wheels
	BOSCH ESP	Intended for vehicles with electric motor on rear axle; substitutes the NP ESP / a stroke sensor is introduced on the brake pedal / modified valves in the module	to decouple only the rear axle pressure from the brake pedal

Type	Component	Packaging and Implementation Effort	Additional information
Electro-Pneumatic Brake	Continental – Regenerative Braking System (RBS)	This architecture is quite complicated, and in any case it doesn't permit the split of the front and rear axle pressure.	In case of failure the brake pedal rod presses directly on the master cylinder
	Bosch – Pressure Controlled Actuation (PCA)	Very similar to RBS, but a modified ESP is introduced.	
Electro-Mechanical Booster	Bosch iBooster	Dimensions are similar to a normal booster, with removed crankshaft driven pump; electric motor, a worm gear and a stroke sensor on the pedal needed.	
	Hitachi - Electrically-Driven Intelligent Brake (EDIB)	Similar to iBooster	
Electro Mechanical Brake (EMB)	Brembo	A hydraulic accumulator, a pump and a master cylinder needed; size of the Brake Operating Unit is similar to a NP master cylinder plus a pneumatic booster, but the Actuated Control Module is added.	maximum clamping force of 13kN
	Siemens VDO		wedge principle that exploits the kinetic energy of the car to amplify the clamping force

Power Steering System

Three different available power steering systems were compared in the work package WP2300. The main outcome is presented in Table 5. For implementation in the HCV project the electro-hydraulic powered steering system was chosen. It includes the hydraulic pump BOSCH-REXROTH PGF2-2X/008RE01VE4 (output 11 l/min; weight 3 kg) driven by a 3x400 VAC three phase asynchronous motor. This motor can be powered from the hybrid batteries using a “600 VDC / 3x400 VAC” converter (this is the case for the TAMEL 4 SLg100L-4A-IE2; 1415 rpm/min) or from the on board 24V supply using an appropriate “24 VDC / 3x400 VAC” converter.

Table 5: Properties of the different power steering systems (green: chosen system)

System	Type	CO_2 Reduction	Costs	Weight	Packaging and Implementation Effort	Additional Information	Considerations
Hydraulic power steering system	Bosch / LUK	no decrease in Power Consumption	835 €	57 kg	hydraulic hoses must travel through the vehicle, because the engine is in the back and the steering gear in front of the bus	Are operated via combustion engine and only work when combustion engine is running.	Reference unit: The simplest and cheapest solution to the classic drive buses with diesel engine. Not applicable for hybrid and electric buses.

System	Type	CO_2 Reduction	Costs	Weight	Packaging and Implementation Effort	Additional Information	Considerations
Electro-hydraulic powered steering system	Tamel + Bosch	decreased fuel consumption of about 1 l/100km in urban area, 0.3 to 0.4 l/100km outside	1,380 €	73 kg (electric engine weight: 22kg)	All components are located near the left front wheel arch; less problematic, no hydraulic hoses through the total length of the bus	Used system: BOSCH-REXROTH pump driven by a TAMEL electric engine, ZF steering gear.	Chosen: Preferable solution for hybrid and electric buses, where engine is not present or not working all the time while in motion.
Electric power steering system	No Supplier for this solution	up to 0.33 l/100 km, decrease in CO2 emission of about 8 g/km	significantly lower operating and maintenance costs	> 73 kg due to an electric motor weight	problematic due to large sizes of electric motors	Already used for passenger cars, for trucks TRW is developing a prototype	Not chosen: This solution has many advantages such as no hydraulics, greater driving precision, easier servicing then others. Unfortunately there is no solution for buses /truck due to a heavy electric motor. The size of this solution will have to be so large to provide adequate power assistance.

High Power Generator

These main criteria were considered for choosing the Vanner high power generator: Efficiency; reliability; reduced maintenance costs; possible direct replacement of belt driven alternator or in parallel for additional low voltage loads. The investigations on this component have been performed in the work package WP2400. Details about the technical specification can be found in deliverable D2400.2 [5]. The main information on the components is presented in Table 6. Further advantages compared to a system of four alternators:

- 25-30% efficiency improvement
- stable DC power for all temperatures and engine speeds
- precise and maintenance-free integrated voltage regulation
- rugged, reliable performance - constructed to last at least until the bus mid-life
- innovative design and installation location eliminates safety concerns and maintenance problems
- eliminating some maintenance intensive parts"

Table 6: Details for the Vanner high power generator

Component	CO_2 Reduction	Costs	Weight	Packaging and Implementation Effort	Considerations
Vanner high power generator (HVDC)	Potential to reduce power consumption by 30-60 % compared to mechanical one	3,400 €	34 kg	roof mounted, decoupled from engine - no risk of thermal events, more flexibility and efficiency; mounting on a flat horizontal surface not in a zero-clearance compartment (overheating); min 4 inches distance to fan inlet and outlet. Special cable for connection with existing electrics needed.	Chosen: Device recommended by hybrid system supplier. Supplier Statement: "Allison has only validated the VANNER DC/DC converter. Therefore VANNER is, at this point, the only supplier allowed in combination with the Allison Hybrid"

Electrical Fan

In the work package WP2400 the possibility to replace the mechanical radiator fan with electrical fans has been investigated. Details about this components can be found in deliverable D2400.2 [5]. For this investigation the standard hydraulic driven fan system consuming about 14.4 kW was replaced by a unit with six smaller electrical fans located on a common cooling plate (6 x 335 W) leading to a maximum power consumption of 2.01 kW. The main characteristics of the component are presented in Table 7.

Table 7: Properties of chosen the electrical EBM-Papst fan. This fan was chosen because of its good price/performance ratio.

System	Component	CO_2 Reduction	Costs	Weight	Packaging and Implementation Effort	Additional Information
Electric Fan	ebm-papst W3G 300 - ER 38 - 45 (Cummins ISB 6.7 285H + Vossloh Kiepe)	CO_2 emission decreased by 4 %; fuel consumption was 4.6 % lower in test; ev. leading to 1.2 - 5 % FC reduction for real load conditions	-	2.5 kg per unit (18 kg for six units compared to 40 kg of the hydrostatic fan)	A higher amount of smaller electrical fans can be packaged easier and allow much more flexibility in size and packaging; No mounting limitations, integrated brushless electric motor. Smaller size and lower weight than hydrostatic fan.	Rotational speed of the fan is independent from the one of the engine; No hydraulic drive assembly (hydraulic lines, fluid storage)--> weight saving ; lower operating costs;

Electrified Diesel Particle Filter Systems

Various different systems for diesel particulate filters have been investigated as presented in Tables 8 to 10. The chosen system for testing in the HCV project is the BEKIPOR® ST DPF 803 product of Bekaert N.V. employing the metallic fiber fleece material as the filter substrate.

The system consists of 6-8 filter modules (for packaging reasons most likely rectangular ones) and is able to fulfill all requirements concerning soot mass and limits for particle numbers. The filter was investigated in course of the works of the work package WP2400. Further details on the system can be found in the deliverable 2400.6 [6]. The interaction with the hybrid system and the possibility of controlling the regeneration by the usage of the recuperative braking energy and the energy at idle conditions leads to a 50 % energy reduction compared to non-electrical systems.

Table 8: Properties of different investigated DPF Systems 1/3

	Type	CO_2 Reduction	Costs	Weight	Additional Information	Decision
Ceramic Wall-Flow Filters	Silicon Carbide	Baseline. Higher DPF thermal mass than other wall-flow (so more energy for regeneration). Partly offset by higher thermal conductivity and refractory qualities which allow higher soot mass limit.	Low capital cost and (application dependent) operating costs; very low maintenance costs	3 kg material weight for a light truck DPF.	Relatively high filtration efficiency. Useful life determined by ash accumulation. A semiconductor material (electrical resistivity decreases with temperature.) Good overall robustness relative to ceramic wall-flow monolith materials, hoever high coef. thermal expansion forces use of segmented design i.e. more cost.	Potentially compatible with direct electrification but ceramic-to-metal electrical interfacing is challenging / unproven for on-board. Need relatively high (50 - 200 V) and variable voltage and tight control due to negative resistance coefficient of SiC with temperature.
	Cordierite	Baseline. Lower thermal mass makes DPF heat up faster but lower soot load must be maintained due to danger for material thermal damage.	Very low capital and maintenace costs and	2.0 kg material weight for a light truck DPF.	Lightest of the materials. More sensitive to excessive soot load which may cause thermal runaway. Relatively high filtration efficiency.	Not directly compatible with electrification. Lower thermal mass than other wall-flow monolith materials and so faster to heat up. Most suitable of the ceramic wall-flow for shore-power electrical regeneration or with manifold DPF and exhaust diversion valves.
	Mullite	Potentially a slight benefit in regeneration due to higher porosity lower thermal mass.	Very low maintenance and low capital and operating costs	2.0 kg material weight for a light truck DPF.	Material owned by Dow Corporation. Extruded as monolithic DPF. Very unique needle-like (acicular mullite) microstructure. Relatively high filtration efficiency. Some re-entrainment of soot (blow-off) has been observed in bench tests.	Not directly compatible with electrification. Production facilities for the Airify™ filters were closed and product stopped (during HCV project runtime).
	Aluminium Titanate	Potentially significant advantage due to combination of low heat capacity and high thermal conductivity.	Very low maintenance and low capital and operating costs	2.5 kg material weight for a light truck DPF.	Most robust to thermal shock due to low thermal expansion coefficient and specific heat capacity similar to SiC. Relatively high filtration efficiency.	

Table 9: Properties of different investigated DPF Systems 2/3

	Type	CO_2 Reduction	Costs	Weight	Additional Information	Decision
Metal filters	Sintered metal powder (granular) on a wire mesh	If electrified directly, potential reduction in regeneration energy by 50% due to direct thermal energy deposition through soot contact. Some disadvantage versus metal fibre fleece due to high thermal mass.	The most expensive of the metal filters but cost acceptability proven by non-powertrain commercial applications.	Approx. 5 kg material weight for a light truck DPF system. (estimated 6 - 7 kg with electrification packaging)	Stainless steel alloy wire mesh and interstitial sintered powder - would need relatively low voltages / high current for use as electrical resistance heating element.	Filtration efficiency is not on par with latest formulations of non-woven metallic fleece. Older formulations had better filtration efficiency but approx. double the weight (over 3kg per m^2 of filtration area). Higher thermal mass than metal fiber fleece.
	sintered metal felt/fleece (fibrous)	If electrified directly, potential 50% reduction in regeneration energy due to direct thermal energy deposition through tight soot contact. Low thermal mass DPF wall allows the use of short (5 - 50 sec.) pulses for regeneration.	Very good operating costs, good maintenance cost. Acceptability of capital costs proven by small scale commercial deployment.	High intrinsic density of metal but high porosity wall. Material and module packaging weight of 4 kg for a light truck DPF system.	Available fleece strip (resistance) values easilly compatible with 24-48 V and currents available on-board light truck or heavy duty hybrids. Modular concept is exploited to allow reduce electrical energy needed for regeneration.	Feasibility of regeneration by direct electrification already proven. Fibrous structures are closer to filtration efficiency vs. pressure drop optimum. Advanced formulation of DPF-targetted metal fiber fleece available and in production. Proof-of-concept with older formulation (HiCEPs Project) showed very low energy requirement for regeneration.
	Sintered metal foam (partial filters)	Can improve performance of downstream DPF by acting as flow distributor and by partial soot reduction, thereby reducing regeneration frequency by ≈20% if sufficient NOx / temperature available in exhaust. However, can exhibit high pressure drop at high exhaust volume flow.	Acceptable cost as an auxiliary component of integral DPF system. Higher capital cost than ceramic foam.	Less than 0.5 kg added weight for a light truck DPF system.	For its continuous self-cleaning, requires NOx levels which are less frequently found in contemporary engines' raw exhaust. Would be primarilly considered only as (flow-distributing) replacement of existing flow-through honeycomb DOC.	Partial soot capture function is desirable to assist DPF function. Hoewever, not really compatible in combination with modular electrified DPF where flow non-uniformity is less critical and which is anyway exploited for reducing regeneration energy expenditure.

Table 10: Properties of different investigated DPF Systems 3/3

	Type	CO_2 Reduction	Costs	Weight	Additional Information	Decision
Ceramic Fiber Filters	Cartridges (ceramic fiber wound over metal support tubes - heating elements)	Thermal energy deposited downstream of soot layer with indirect thermal contact. Can only regenerate in low exhaust flow otherwise power and energy needed equals or exceeds fuel post-injection regeneration.	More expensive than the other systems but cost could be acceptable if the electrification brings added value.	Approx. 5 kg weight (cartridge holders and ceramic) for a light truck DPF.	Wound fiber layer microstructure less optimal for filtration than non-woven fleece - susceptible to blow-off.	Compatible with electrification. Wound fibers microstructure and lower filtration area macrostructure potentially not compatible with very high filtration efficiency requirements of new regulations. Regeneration energy requirement higher than electrified sintered metal due to indirect contact between soot and heating element.
Ceramic Foam Filters	Cylindrical or oval wafers of 10 - 20 pores per inch (partial soot reduction / pre-filter)	Can improve performance of downstream DPF by acting as flow distributor and by partial soot reduction, thereby reducing regeneration frequency by ≈20% if sufficient NOx / temperature available in exhaust. However, can exhibit high pressure drop at high exhaust volume flow.	Acceptable cost as an auxiliary component of integral DPF system. Has been commercially applied pre-2010.	Less than 0.5 kg added weight for a light truck DPF system.	Auxiliary component that can be included in a DPF system. Cannot be the filtration medium standalone. Cylindrical or oval wafers (short monoliths) used as oxidation catalyst support, flow distributor and partial soot filter. Probably, required NOx levels for its self-cleaning are no longer available in raw exhaust.	Considered as candidate pre-filter to enhance function of downstream metal DPF (flow uniformity enhances main DPF filtration and partial soot capture gives longer regeneration interval). However, NOT chosen because of incompatibility with low NOx levels of contemporary engines. Also, partial incompatibility with non-round exhaust sections.

Conclusion

For each of the electrified auxiliary which needed to be developed in the HCV project a corresponding hardware component is available on the market. For some components there were more appropriate solutions identified by the corresponding partners. From these available solutions the one suitable for the requirements of the HCV project was selected.

References

[1]	*HCV Report; HYBRID COMMERCIAL VEHICLE (HCV) DELIVERABLE D2500.1, DECISION MATRIX (AVL), June 2013*
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