Ford of Europe's Product Sustainability Index

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1 Introduction

1.1 The Challenge of automotive sustainability

Automotive industry is facing a multitude of challenges towards sustainability that can be partly also addressed by product design:

- Climate change and oil dependency. The growing weight of evidence holds that man-made greenhouse gas emissions are starting to influence the world's climate in ways that affect all parts of the globe (IPCC 2007) – along with growing concerns over the use and availability of fossil carbon. There is a need for timely action including those in vehicle design.
- Air Quality and other emissions as noise. Summer smog situations frequently lead to traffic restrictions for vehicles not compliant to most recent emission standards. Other emissions as noise affect up to 80 million citizens – much of it caused by the transport sector (roads, railway, aircraft, etc.) (ERF 2007).
- Mobility Capability. Fulfilling the societal mobility demand is a key factor enabling (sustainable) development. This is challenged where the infrastructure is not aligned to the mobility demand and where the mobility capability of the individual transport mode (cars, trains, etc.) are not fulfilling these needs – leading to unnecessary travel time and emissions (traffic jams, non-direct connections, lack of parking opportunities, etc.). In such areas, insufficient infrastructure is the reason for 38% of CO2 vehicle emissions (SINTEF 2007). Industry has also to consider changing mobility needs in aging societies.
- Safety. Road accidents (including all related transport modes as well as pedestrians) result to 1.2 million fatalities globally - according to the World Bank.
- Affordability. As mobility is an important precondition for any development it is important that all the mobility solutions are affordable for the targeted regions and markets.

All these challenges are both, risks and business opportunities.

1.2 Car technology and integrated approach actions addressing the challenges

Sustainable product design is only one answer to the challenge of sustainable mobility. Looking at the first item listed above, John Fleming, President and CEO of Ford of Europe, stressed:

- **"We**, the auto industry, need to take the **initiative**
- **Accept** that **consumer** not ready to compromise price or performance for green
- **Accelerate** low-CO2 technologies – don't leave the floor to the Japanese and NGO's
- **Communicate** our achievements more constructively and pro-actively
- **Cooperate** with the oil co's
- **Work with governments** (integrated approach) for support through taxation, incentives and infrastructure" (VDA Technical Congress, March 28, 2007)

A lot of efforts have been already done to accelerate low-CO2 technologies. The efficiency of the different technologies is different. Bio-ethanol vehicles have a very high efficiency ratio in Europe if taking into consideration the whole life cycle respectively the well-to-wheel performance. For full hybrid the efficiency is very much dependent on the individual share of driving outside cities (the more motorways the lower the efficiency of current full hybrids).

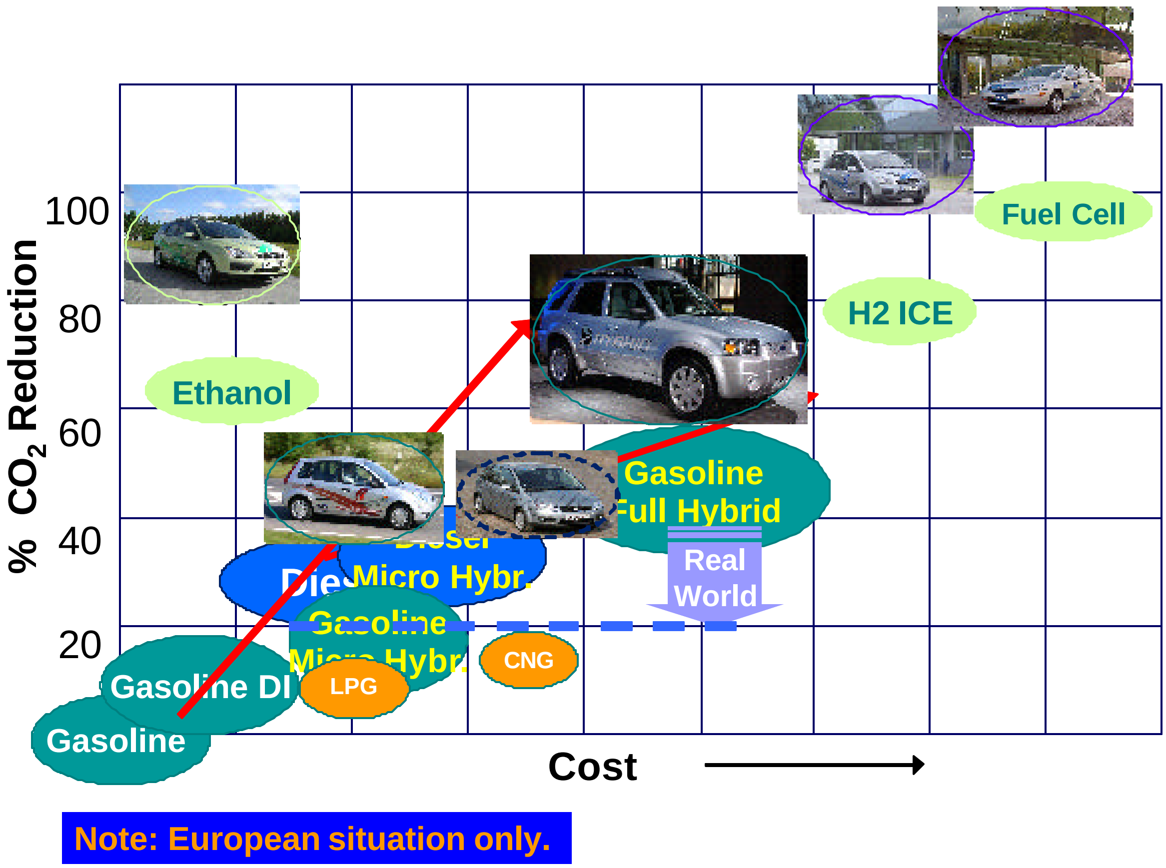

Figure 1: Relation between CO2 reduction and costs for different car engine technologies relative to gasoline engine

This demonstrates the importance of actions by all life cycle stakeholders, e.g. fuel providers establishing the necessary station infrastructure offering sustainable bioethanol. This integrated approach leads also to additional, efficient opportunities to reduce CO2 emissions of vehicles. Examples are eco-driving (can be supported by training (see http://www.ford-eco-driving.de/download/Eco-Driving-Leaflet-ENG-5-2004.pdf) and Gear Shift indicators) as well as infrastructure measures. For example, the Japanese government counts 28Mt CO2 reductions through infrastructure measures in Kyoto plan (additional streets etc.). ERF concluded recently that "measures must now be completed by initiatives in the field of road infrastructure which currently represent an underexploited opportunity for energy efficiency gains", for example by removing bottlenecks and completing missing links "which together cost billions every year in lost fuel" (ERF 2007). These additional measures affect not only new vehicles but also the running vehicle fleet. This is one of the reasons for the high efficiency of these measures.

This integrated approach – covering both, engine / car technology actions as well as eco-driving, infrastructure, biofuel, tax framework and other actions of life cycle stakeholders – will deliver the necessary CO2 reductions from current levels in an efficient and effective way. This is reflected in CARS 21, the stakeholder discussion of the European commission about a competitive automotive regulative framework for the 21st century (EC 2007).

2 From Design for X to Design for Sustainability in the automotive industry – example Ford of Europe

The introduction of environmental aspects into automotive design beyond emission and fuel consumption reductions was initially based on the idea that the mechanical recycling of plastics would be a key for improving the overall environmental performance of vehicles. Dismantling of plastics had been the only known solution in the early 90es. 1993 Ford Motor Company was the first automotive company issuing globally Design for Recycling Guidelines. These have been very much focussed on aspects as part accessibility, type and number of fasteners as well as parts marking (Design for Disassembly; DfD). Also reducing the material complexity and later recycled content targets completed the DfD guidelines to a comprehensive Design for Recycling approach.
However, in the late 90es and the beginning of the 21st century new scientific evidence challenged this traditional approach taken:

- Life Cycle Assessment studies could not confirm that the mechanical recycling of non-metals is significantly improving the environmental vehicle impacts from a holistic environmental point of view (Schmidt et al 2004), etc. In addition, other end-of-life approaches beyond mechanical recycling (feedstock recycling, energy recovery etc.) have been identified as delivering a similar environmental benefit at much lower costs (Nürrenbach et al 2003).
- Real world tests of dismantling times for parts with different accessibility, fastener types etc. could not verify the theoretical link between Design for Disassembly actions and dismantling time (SEES 2005).
- Post-shredder treatment technologies replaced the traditional dismantling approach in several European countries – allowing the recycling and recovery of all material mixes in line with European recycling targets in a more economic way while delivering at least the same environmental benefit as the traditional dismantling based mechanical recycling of non-metals (Krinke 2005).

Therefore, the previous Design for Recycling approach was replaced by a more comprehensive Design-for-Environment approach (Gottselig, Schmidt 2001), (Schmidt 2001), (Quella, Schmidt 2003).
But also that approach did not fit into the challenges of sustainability summarized above. Therefore, first economic elements have been introduced in Design-for-Environment (Schmidt 2003). Then all important aspects of sustainability – as listed above - have been tackled with the target to establish a sustainability management tool for the product development of passenger cars (Schmidt, Taylor 2006). This process ended in Ford of Europe's Product Sustainability Index (PSI) that is presented in this paper. This has been the first time in automotive industry that all three dimensions of sustainability have been combined in a comprehensive set of metrics for steering the vehicle development.
Note: the publication of most aspects have been delayed, i.e. the internal progress was years ahead of the publication dates.

Sustainable product design aims in merging good design and sustainability.
Design has in particular the dimensions of function and aesthetics (ratio and emotions). Good design is the prerequisite for market success as often only an emotional design attracts customers – in particular looking at luxurious products. Good functionality of a design is

important for the use intensity of the product. Aesthetics should follow function or vice versa – depending on the perspective.
Sustainable development is defined by meeting 'the needs of the present without compromising the ability of future generations to meet their needs' (United Nations, 1987). Normally, this approach refers to three dimensions – environmental, social/societal and economic. Other definitions mention 8 or more dimensions of sustainability - physical, properties, environmental, economic, social, equity, cultural, psychological, ethical (Bossel, 1998). However, also the organisational aspects are of importance.
Sustainable Product Design is a subset of a broader approach towards a Sustainable Product Development that looks beyond product design aspects also at other strategies to improve the sustainability of meeting needs – by products, services and/or organisational aspects (e.g. Sustainable Life Cycle Management (Schmidt 2006))

3 Sustainable Vehicle Design and Product Sustainability Index

3.1 Context of Sustainable Vehicle Design

Besides the general positioning of sustainable vehicle design within a sustainable life cycle management also the organisational context has to be clarified. It is of utmost importance in complex, big corporations to make the individual departments / organisations directly responsible for that specific aspect of sustainability that can be impacted by their area of responsibility.
Main affected departments include Product Development, Manufacturing but also Human Resources and External Affairs. Each main functional group translates the meaning of sustainability to their own area. This is the best way to allocate understanding, ownership and responsibilities in a complex organization. In the case of automotive products Product Development needs very long lead times, longer than any other of the above mentioned functions – changes in methods take several years to trickle through buy-in, cycle planning, kick-off, development and launch. PD also has a greater impact on automotive products compared to other organisations of automotive manufacturers.
Sustainable vehicle design is a challenge looking at the complexity of the passenger vehicles where engineering management as well as design engineers need to cope with a global supply chain, a as well as thousands of technically challenging components linked with sever quality, technical, process and infrastructure constraints. This requires a company-specific solution rather than a one-size-fits-all approach. One of Ford of Europe's solutions for managing a sustainable product development is the Product Sustainability Index (PSI).

3.2 Ford of Europe's Product Sustainability Index (PSI)

While there is so far no international standard for measuring the product sustainability there is a common understanding that life cycle thinking should be the basis of such an approach (VDI, 2006). Therefore, the chosen PSI indicators are partly based on ISO14040 (Life Cycle Assessment) and the current work of SETAC Europe on Life Cycle Costing (SETAC, 2006). Part of the additional guiding principles for the inclusion of indicators in the PSI had been the following management directions (Schmidt and Taylor, 2006):

- Key environmental, social, and economic vehicle attributes only
- Controllable (mainly influenced by the Product Development department, not by other functions).
- No additional data need (regular status tracking possible based on readily available product development data).
- Bottom-line issues only (no technologies as alternative fuels but the overall life cycle impact).
- Reduce to a manageable amount of indicators.

PSI is not reduced to a single score as sustainability is by definition not one-dimensional but always measured by different indicators. Further reasons have been shared in a previous paper (Schmidt and Sullivan, 2002).

Other sustainable mobility aspects - in particular service aspects - are not covered as not appropriate on the engineering level. Also legal compliance issues as recyclability are not covered within PSI as these are base line requirements. Some recycling requirements may not even add environmental benefits as outlined in a previous paper (Schmidt et al 2004).

The resulting PSI indicators are (Schmidt and Taylor, 2006):

- Life Cycle Global Warming Potential (Greenhouse emissions along the life cycle – part of an LCA according to ISO14040)
- Life Cycle Air Quality Potential (Summer Smog Creation Potential (POCP) along the life cycle (VOCs, NO_x) – part of an LCA according to ISO14040)
- Sustainable Materials (Recycled & natural materials. Note. All materials are linked to environmentally, social and economic impacts and cannot be inherent sustainable. However, recycled materials and renewably grown, natural fibres represent a kind of role model how limited resources can be used in a sustainable way. Overruling is the question whether these materials have – in their specific application –a lower environmental impact along the product life cycle compared to potential alternative materials)
- Restricted Substances (Vehicle Interior Air Quality / allergy-tested in terior, management of substances along the supply chain; 15 point rating).
- Drive-by-exterior Noise
- Safety (pedestrian and occupant)
- Mobility Capability (Mobility capacity (luggage compartment volume plus weighted number of seats) related to vehicle size. This is an indicator in transition towards an indicator covering also aspects of providing mobility services to disabled)
- Life Cycle Ownership Costs (Vehicle Price + 3 years fuel costs, maintenance costs, taxation, insurance minus residual value).

The implementation of PSI has been done in a process driven, top-down approach. Process-driven, as PSI has been linked in the existing Ford Product Development System from the very beginning. For example, Ford's PSI is included in particular in the companies' "Multi-Panel Chart" where all vehicle attributes (craftsmanship, safety, environment, costs, etc.) are tracked, through all the development milestones, against the approved vehicle program targets. Vehicle Integration engineers have been made responsible by the specific vehicle program management to track the performance of the vehicle against the targets. The PSI targets are determined from already existing targets as listed in other sections of the "Multi-Panel Chart" (e.g. fuel economy) as well as PSI specific targets not covered otherwise (e.g. related to the maximal impacts from the selected materials). PSI reflects the overall impact of the different vehicle attributes and makes the trade-offs visible (e.g. between life cycle global warming potential and the life cycle cost of ownership).

In a top-down approach, senior management demanded and finally authorized PSI in autumn 2002. The roles & responsibilities have been agreed in a way that mainly all actions and responsibilities are conducted by Product Development itself without using a central staff organization (exemption: development of methodology). This way, an optimal integration of PSI is ensured – i.e. sustainability is not the responsibility of specialists (within or outside Product Development) but is executed by the same people running other aspects of the vehicle development.

A comprehensive but very simple spreadsheet file has been developed by a Ford LCA specialist to enable non-specialists to track PSI. This tool has been verified against detailed ISO 14040 external reviewed LCAs (Schmidt and Butt 2006). Based on the central input of few and select data, the PSI – including the simplified Life Cycle calculations – are tracked from the very beginning of the vehicle development throughout its end. Almost all data used

had been anyway readily available in the above mentioned "Multi Panel Chart". Few additional data have been needed (for example any material changes and data about air-conditioning systems). With around 1 hour training, the responsible engineers have been in the position to understand the concept, use the above mentioned file and conducting simplified Life Cycle avoid unnecessary bureaucratic burdens or the need for additional resources while ensuring that sustainability is an integral part of the complex product development process.
The described approach is designed to fit perfectly to the Ford design processes and culture. It is not suggested that this approach necessarily fits to other company cultures or markets as the methodologies and approaches cannot be generalized. Any mandatory approaches would be counterproductive. Sustainability can only work based on internal understanding, drivers, motivations and commitment rather than law and order. PSI is a voluntary approach aiming at integrating environmental, social and economic aspects in the product development as part of Ford's commitment towards sustainability and creating dialogue around these issues.

3.3 PSI application for Ford Galaxy and Ford S-MAX

The first design team that used PSI from the beginning developed the new Ford Galaxy and Ford S-MAX. Four vehicles have been assessed:

- New Ford Galaxy 2.0 l TDCi with DPF Trend edition,
- New Ford Galaxy 2.0 l, Trend edition,
- New Ford S -MAX 2.0 l TDCi with DPF Trend edition,
- New Ford S -MAX 2.0 l, Trend edition.

Note: DPF = Diesel Particulate Filter

The environmental, economic and social performance has been compared to the prior Ford Galaxy (1.9l TDI, 96 kW, manual 6 speed version). Within Vehicle Integration engineers have been made responsible for tracking the status based on the input collected in the "Multi-Panel Chart" and few additional key data specific for PSI. The additional PSI data related to the material breakdown of the different vehicles have been derived from complete teardown data of the predecessor models, weight assumptions as well as weight actions and finally International Material Data System (IMDS) data. Towards the end of the development, an additional verification study has been performed by a corporate LCA specialist. The PSI, as well as the internal verification study, has been successfully reviewed by two external reviewers – Professor Dr David Hunkeler (former Universities Vanderbilt in Nashville/USA and Lausanne/Switzerland) and Prof Dr Walter Klöpffer (University of Mainz/Germany) - according to ISO 14040. One of the important findings has been that the life cycle calculations done by the non-experts based on a simple spreadsheet file are fully in line with the results of a more detailed study performed by the LCA expert based on an expert tool (IKP and PE, 2005) (calculated absolute figures are less than 2% below; the relative results are the same).
The PSI application itself (without expert verification study and external review that are not necessary for the internal usage of PSI as a sustainability management tool) is done efficiently. Due to the focus on available data as well as a simple spreadsheet file the incremental resources needed for the management tool itself has been rather low (approx. 10 –15 hours for the whole product development process). However, the efforts for the verification study and the external review are much more significant. This has been only done in this specific case because Ford Galaxy and S-MAX have piloted the PSI application. The verification study allowed to get a better confidence about the accuracy of the PSI calculations while the external ISO 14040 review allowed the publication of the taken efforts.

The PSI status has been tracked for different Gateways (Kick-off (KO), Program Approval (PA), Program Readiness (PR) and Change Cut-off (CC)). Table 3 summarizes the results for the studied diesel powered Ford vehicles.

3.4 Results

Managing a sustainable product development is a challenge including and beyond managing the design in a sustainable way. Ford of Europe's Product Sustainability Index (PSI) can be seen as an example for a sustainability management tool that efficiently guides the development of passenger vehicles. However, this is only one tool in a set of tools covering the different functional areas of an automotive manufacturer.
In addition, an integrated approach is necessary to gain additional improvement potentials. This sustainable life cycle management is a central approach to efficiently improve the environmental and socio-economic performance of products as passenger vehicles.

Table 3: PSI results of diesel powered Ford Galaxy and Ford S-MAX

Indicator	Previous Ford Galaxy 1.9 L TDI	Ford Galaxy 2.0L TDCi with DPF	Ford S-MAX 2.0L TDCi with DPF
GWP [t CO2-eq] (1)	41	40	39
POCP [kg Ethene-eq] (1)	39	37	37
Sustainable Materials (note: figures may change)	Approx 1 kg	Approx 18 kg	Approx 18 kg
Restricted Substances	Substance management, pollen filter	Substance management, TÜV tested pollen filter efficiency and allergy-tested label (2)	
Drive-by-exterior Noise dB(A)	73	71	71
Safety	Reference(3)	Significant improvement (4)	Significant improvement (4)
Mobility Capability	9,9 m², 7 seats, 330l	10,4 m², 7 seats, 435l	10,25 m², 5 seats, 1171l
Theoretical Life Cycle Ownership Costs(5)	Reference	5 % lower costs	10% lower costs

(1) based on PSI calculation that have been verified by an independently reviewed LCA according to ISO14040. LCA done based on the methodology and data described previously (Schmidt et al 2004), (Schmidt and Butt, 2006). GWP – Global Warming Potential; POCP – Photochemical Oxidant Creation Potential
(2) based on an independent TÜV certification, certification number AZ 137 12, TUVdotCOMID 0000007407.
(3) including Euro NCAP safety rating: 3 stars for adult occupant protection, 2 stars for pedestrian protection.
(4) including Euro NCAP safety rating: 5 stars for adult occupant protection, 4 stars for child protection and 2 stars for pedestrian protection.
(5) 3 years Cost of Ownership including residual value, no guarantee.

3.5 Relation to sustainability targets

Of course, a continuous improvement is one important target. However, the results of PSI have not only to be seen in relation to the predecessor. Product development management needs to realize also the relative performance of the new vehicle compared to other vehicles in the own product portfolio as well as competition.
Therefore, a relative scaling of PSI had been used for internal purposes. The scaling of the eight indicators has been chosen according to the following principles:

- The higher the number the better.
- The scaling refers to the passenger vehicle range of Ford of Europe without SUVs - Sub-B (Ford Ka) through V (Ford Galaxy). By doing so, all Ford of Europe vehicles can be compared using the same scaling. Some of the different functionalities (mobility capability, safety) are reflected by the different indicators. NB – The varying levels of comfort are not considered in this analysis. That means a lower PSI

score does not allow the interpretation of preferences since not all relevant aspects could be considered.

- For the life cycle related indicators, the lowest figure (0%) represents the Ford of Europe vehicle with the highest environmental and cost impacts (worse vehicles by other companies are not considered a suitable benchmark).
- 80% is set at the theoretically best in industry vehicle in the Sub-B to V segment.
- 100% is going beyond the current best-in-industry level – leaving room for improvement towards sustainability.

Table 3: *Scaling of PSI indicators*

Indicator[1]	**0 % scaling**	**80% scaling**	**Vehicles**
Life Cycle Global Warming Potential	65587 kg CO_2-eq	17500 kg CO_2-eq	Prior Galaxy 2.8l V6 automatic / 2002 vehicle[2]
Life Cycle Air Quality Potential	58,3 kg Ethene-eq	22,9 kg Ethene-eq	Prior Galaxy 2.8l V6 automatic / 2002 vehicle[2]
Sustainable Materials	0%	14,9%	Worst case / best case assumptions[3]
Restricted Substances	6 points	12,5 points	80% Ford C-MAX
Drive-by-exterior Noise	82 dB(a)	65 dB(a)	Best / Worst homologated value by KBA
Safety	See below[5]	See below[5]	Several vehicles
Mobility Capability	0,216	0,7	0%: 9,94 m², 2 seats, 140 l 80%: 3,75 m², 2 seats, 180l
Theoretical Life Cycle Ownership Costs[4]	€ 35508	€ 10984	Prior Galaxy 2.8l V6 automatic / Ka Student

[1] calculated based on same assumptions, calculation rules and tools for all vehicles. Life Cycle data cannot be compared to other studies due to different assumptions

[2] "Best" performing vehicle sold in Europe in 2002 when the PSI was piloted (no longer on the market).

[3] Worst case assumption: 0 kg natural fibers, 0 kg recycled material
Best case assumption: 15,3 kg natural fibers (best competitor), 25,1 kg actual used non-metallic recycled materials (Ford Mondeo; note: based on narrow definition).

[4] Referring to 3 years of ownership plus vehicle price (representing the up-stream costs) minus the residual value (representing the down-stream cost aspects). Ford Motor Company does not guarantee that the costs reflect actual market conditions.

[5] Internal, complex safety indicator including EuroNCAP rating.

Traditionally, sustainability indicators are shown in a radar diagram. The bigger the areas described by the different lines the better. There is no weighting between different indicators of Ford of Europe's PSI (see as rationale also (Schmidt, Sullivan 2002)). Transferring the results as reflected in Table 3 in relative PSI performance (according to Table 4) shows that the improvements in most areas are significant (Figure 2). The diagram shows in addition for which indicator represents an absolute strengths or a further improvement needs. No vehicle can currently perform best in all eight indicators of PSI. Bigger vehicles have often a higher mobility capability that is resulting in less favorable life cycle global warming performance (vice versa). Best global warming performance might be compromised by an not appropriate life cycle cost of ownership. Depending on the market segment some PSI pattern are typical. Nevertheless, the scaling of PSI always sends the signal to the product development management that also an excellent performance in that segment might be not the best one looking at all car segments. Thus further improvements are always encouraged.

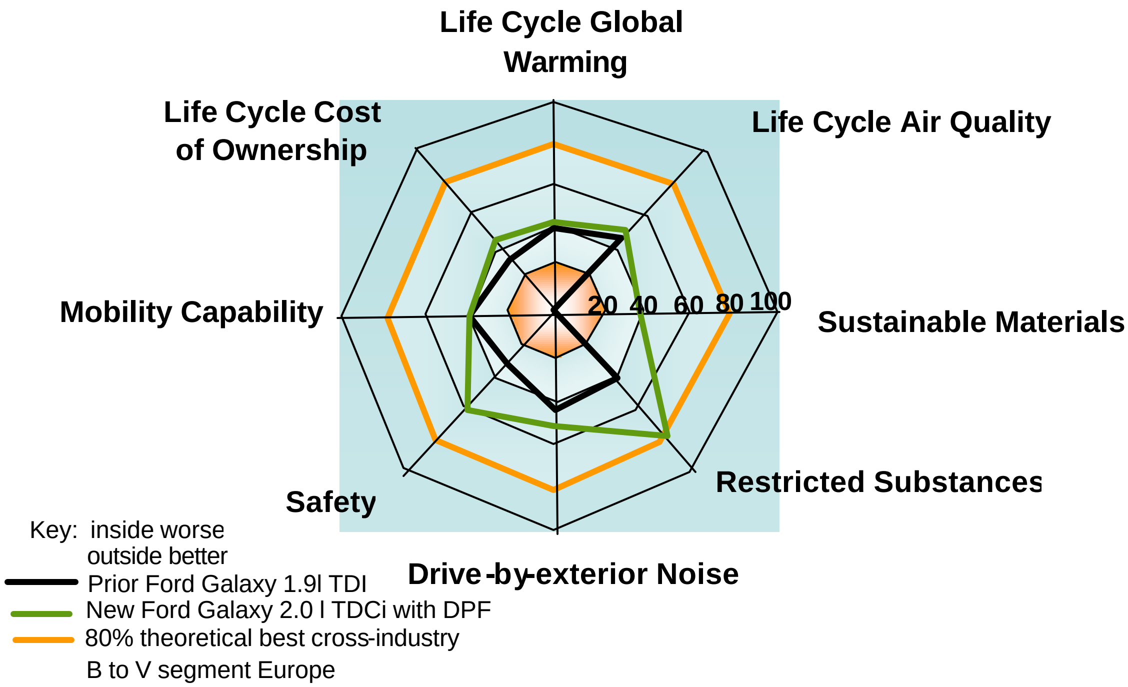

Figure 2: PSI of new and prior Ford Galaxy diesel variants.

4 Conclusion

Ford of Europe's PSI is one of different initiatives to address the sustainability challenge for the automotive industry. PSI is a sustainability management tool that can be easily used by vehicle development engineers and their management. By this approach the department of product development can

- Be made directly accountable for their contribution towards a more sustainable corporation.
- Set vehicle targets that lead to improvements in all areas of sustainability.
- Visualize trade-offs between conflicting sustainability vehicle attributes
- Track the progress along all gateways of vehicle development.
- Relate the vehicle performance relative to the vehicle segment as well as to all passenger vehicles.

This is a good basis to introduce innovative technologies where sustainable.
However, the basis of the PSI approach is that no additional resources are needed due to the lean and tailored approach. Any mandatory, legal duty in this area would add no value but result in higher resource needs due to bureaucratic rules regarding documentation, auditing, non-tailored methodologies. Instead, the regulatory framework should concentrate on supporting an integrated approach motivating all life cycle stakeholders.

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