EcoDesign 2020 – Green Design requirements and implementation in the aircraft-industry

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Aviation is an essential element of today's global society, bringing people and cultures together by moving more than 2 billion people annually worldwide, thus creating economic growth across the globe. Globally about 32 million jobs are dependent on air transport, out of which about 5.5 million are in the aviation industry. Aviation's global economic impact is estimated at US$ 3.560 billion representing 7.5% of world Gross Domestic Product (GDP)[1].

The air transport industry is paying a lot of attention to growing public concern about the environmental issues of air pollution, noise and climate change. Although today air transport only produces 2% of man-made CO_2 emissions (equal to 628,000,000 tons/a), this is expected to increase to 3% by 2050. Not only environmental impact during aircraft operations, but also during production and end-of-life phases is being discussed today. This is of major importance, as a doubling of the commercial aircraft fleet from today to 2050 is expected. Current European R&D has adopted the Advisory Councils for Aeronautical Research in Europe (ACARE) 2001 goals, covering the reduction of fuel consumption and CO_2 emissions by 50% per passenger kilometer, of NO_x emissions reduction by 80%, of perceived noise reduction by 50% and to make substantial progress in reducing the environmental impact of the manufacture, maintenance and disposal of aircraft and related product[2].

Speeding up new, greener design is essential to protect the environment for aircraft on-ground operations. It should be kept in mind that aircrafts have a 30-year service life, and that new aviation design takes more than a decade to develop. This leads to manifold requirements for eco-design - starting with green design and production, withdrawal, and closing the loop by recycling of aircrafts and their components originating from repair actions, by minimal use of raw materials and energies thus improving the environmental and even the social impact of the whole products life cycle. However, the field of eco-design for aircraft and its effects for the whole lifecycle as well for society have not been explored thoroughly.

This paper will present the requirements and latest developments in the Eco Design research and development project, which forms a part of the 1.4 billion Euro R&D umbrella program “Clean Sky”. We will have a closer look at the Eco Design requirements, processes and methods for implementation. Starting with a state-of-the-art review – also in comparison to other branches

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1 Clean Sky Joint Undertaking; 2012
2 Woidasky, J.; et al.; 2010

like automotive or shipbuilding industries we will address the steps necessary to greening of aircraft operations, and finally analyze the stakeholder impact and matters of dissemination. This is done by analyzing first results from the CleanSky work focusing on eco-design guideline as well as from a literature review and expert interviews on societal belongings within the aircraft industry and its stakeholders. Technical aspects and implementation approaches will be presented in order to ensure an actual Eco Design impact in the aircraft industry.

Key words:
Eco Design; Aviation industry; Stakeholder impact; Eco Design Guidelines;

1. State of the Art in Green Design

1.1. Green Design Definition

Design for Environment, Eco Design, Clean Design, Life Cycle Design and Green Design are synonyms for basically considering the environmental impacts during the design phase. Product designers are focusing on different objectives: Designing in a material-efficient way is ensuring that for each stress the appropriate product geometry and material distribution will be applied, and additional attention is being paid to using renewable resources or at least secondary raw materials. An energy-efficient design is focusing amongst others on the reduction of energy consumption during production, use phase, and possibly end of life-phase, whereas low-pollution design is requiring minimal use or formation of hazardous substances during the whole product life. Additional design aspects may be long life (e. g. avoiding one-way products), easy disposal, or transport requirements which are demanding specific product properties like maximum geometries, minimal weight, or nesting capabilities. Especially focusing on the end of life phase, Design for Recycling creates requirements for a product which are for example[3]:

- Easy to dismantle
- Easy to obtain clean and pure material fractions,
- Minimise materials mass
- Marking or labelling of materials, to simplify sorting process
- Avoiding surface treatment, to retain the materials cleanliness

Environmental legislations like REACH[4], RoHS[5], WEEE[6] and the directives on energy using (EuP) as well as energy-related products (ErP) are first steps to rethink product design and production processes from an environmental and potentially sustainable point of view.

The design process can be divided in four phases. Knowing the product requirements and company´s environmental strategy before designing a product is as necessary as identifying the pollution source of the product to outline design improvements[7]. The optimal product concept, as output of this process, leads into the third phase, where the materials and production processes are selected to ensure the highest eco-efficiency. Finally, the product needs to be tested to prove the success of implementing Eco-Design principles.

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[3] McAloone, Tim; Bey, Niki; 2011
[4] European Commission; 2006
[5] European Commission; 2002
[6] European Commission; 2002
[7] Fargnoli, M.; Kimura, F.; 2007

Information on production processes, materials used, Life and End of Life performance of the product are used to perform a Life Cycle Assessment and require data on products environmental performance. Using these data to improve the environmental performance of the product, communication of its positive effects to the customer during commercialisation can improve the producers image.

1.2. Implementation of Green Design in industrial branches

1.2.1. Automotive Industry

After introduction of End of Life Vehicle regulations[8] in leading industrial countries including producer responsibilities, automotive manufacturers started rethinking materials use and their designs. LCA tools were used to choose materials and material combinations to ensure a proper environmental performance during production and use phase as well as an appropriate treatment during the final phase of their products life. A small overview on assessment tools used by car manufacturers is given in Table 1.

Table 1: Overview on LCA tools and used by automotive industry

Acronym	Name	User
ECO-VAS	Eco-Vehicle Assessment Systems	Toyota
GaBi-software	Ganzheitliche Bilanz (engl. Holistic Balance)	VW, BMW, Fiat
OPERA	Overseas Program for Economic Recycling Analysis	Renault

Manufacturers used the LCA data for optimization of their internal processes and introduced new trade names to label and communicate their increasing environmental performance. Using these data for their internal processes, companies can explore potential impacts and solutions before introducing new materials or processes[9]. To environmentally improve the process of materials selection and meet the requirements set by manufacturers and legislation, OEM are using the International Material Data System (IMDS) which contains detailed information on materials and substances used in automobile parts[10].

As governments worldwide, but especially in Europe, are focusing more and more on reducing greenhouse gases emission, efficient use of fuel and reducing the dependencies on hydrocarbons, investment in alternative solutions like electronic vehicles, hybrid technologies, hydrogen or biofuels are increasing rapidly. Along with the development of new technologies, several problems arise. Electrical vehicles for example are in general being regarded as environmentally friendly, as they do not emit any greenhouse gases, nor other VOC. Taking into account the energy being used for refueling of these cars, the grid mix becomes the crucial

[8] European Commission; 2000
[9] Landmann, Ralf; et al.; 2009
[10]MDS; 2012

question to electro-mobility. as coal, gas and oil incineration are most relevant greenhouse gases. Additionally, it is hard to meet the goals of the End of Life Vehicle law with current recycling technologies for carbon fibre reinforced polymers (pyrolysis) and batteries (thermal treatment), Therefore manufacturers are working on optimized recycling processes as well as on reuse options for their products, as there is currently a lack of demand on recycled fibres as well. Regarding the production, automatic carbon fibre processing and battery production technologies are under development, to decrease production costs by increasing the output per time unit. Recycling of automobiles is being checked in the process of type certification. The recycling quota have be met in this process, which mainly is based on a manual, laborious process in a lab environment. Moreover, in practice little use of the “design for recycling” activities can be observed for end of life activities, as dismantling is of little importance for cars, except for spare parts recovery. Meeting the recycling quota today requires post shredder technologies, i. e. after few draining and dismantling steps which are focusing on spare parts, the car is being shredded to recover steel and copper, and the remaining mixture is treated to separate the mineral fraction, some polymer mixture feasible as secondary fuel, and a fibrous fraction which may be used for dewatering and which is eventually burnt. This process does not require design for environment, as it is robust to treat all cars of all ages regardless of their age or design.

1.2.2. Railway Industry

Rail transport is covering large parts of passenger and freight transport in industrialized countries, but is even more important for developing and emerging nations. Furthermore, rail transport has by far the lowest emission record of all transport modes with only 0.6 % for diesel emissions and together with electrical traction a total less than 2 % including its electricity production[11].

During the General Assembly of the Community of European Railway and infrastructure Companies (CER) held in 2008 in Brussels, the members agreed on a sector-wide target on reducing the specific emissions (carbon dioxide per passenger or ton kilometre) from rail traction about 30 % by 2020 from the 1990 baseline[12]. EU Directive 97/68/EC on emissions from non-road mobile machinery (NRMM) is listing railcar engines in compression ignition (CI) category and defines emission standards for diesel engines. These standards are divided in the current stage IIIA, the stage IIIB coming into force 2013 and stage IV, which will be norm for new engines from year 2014 onwards. The directive defines emission reduction goals as well as minima for durability periods for these stages. Stage IIIB for instance is pushing new engines

[11] Ledbury, M.; Orsini, R.; 2008
[12] UIC; 2009

to reduce particle emission from 0.2 g/kWh to 0.025 g/kWh, and NO_x emission should not exceed 2 g/kWh[13].

In 1998 Brite and Euram started the EU funded RAVEL project, to develop a web-based tool for the railway sector ensuring that new products meet the environmental requirements. Making these results available for the whole railway sector, was the objective of the companies Deutsche Bahn, Alstom, Bombardier, UNIFE, SEMCON, UIC and IMI when they were forming the “Rail sector framework & tools for standardizing & improving the use of Environmental Performance Indicators & Data formats” (REPID) project. The outcome was a standard for using Environmental Performance Indicators (EPI) and data formats. Additionally, the partners started but still are discussing a consensus list of prohibited and hazardous substances for the railway industry; in cooperation with the company SEMCON this database was integrated in CatiaV5 to enable the exportation of product structures and material information. As IT regulations of most companies are too strict, external suppliers do not have access to contribute data to the database resulting in a very limited use by manufacturing companies[14].

Inspired from this, other companies developed their own software. The German Railway Industry association (VDB) for instance developed the Railway Industry Substance List (RISL), to guide suppliers avoiding prohibited materials and limiting restricted ones[15].

The recycling of railcars is mainly driven by metal prices. Deutsche Bahn for instance is not selling retired trains to other competitors, even in case they are still operational. The railcars are being drained and scrapped by german partners selected by a call for proposal process. The dismantling process is strictly observed by the owner and in most cases performed by car shredders, as after cutting the train in smaller parts the treatment processes used are similar.

1.2.3. Shipbuilding Industry

Eighty per cent of world trade are carried out by shipping, thus reducing environmental impacts from this sector would improve the environmental performance of world transport significantly. The Marine Environment Protection Committee (MEPC) is responsible for the prevention of marine pollution by ships and is launching regulations and industrial standards to push ship companies to increase their environmental behaviour. The “International convention for the prevention of pollution from ships” was created in 1973 and updated in 1978 as Marpol 73/78 (Marine pollution 1973/1978). It is one of the most important outcomes of MEPC and is dealing within its six annexes with following marine pollution topics:

[13] European Commission; 1997
[14] Andriès, Véronique2007
[15] UNIFE; 2011

- Annex I - Oil
- Annex II - Noxious Liquid Substances carried in Bulk
- Annex III - Harmful Substances carried in Packaged Form
- Annex IV - Sewage
- Annex V - Garbage
- Annex VI - Air Pollution

Through amendments in Annex VI in 2011, the Energy Efficiency Design Index (EEDI) for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships became mandatory. Both are expected to be implemented in 2013. The performance-based EEDI is measuring the CO_2 emission per ship and unit, while the SEEMP is a living document containing a specific plan of actions, targets and responsibilities for managing the operational energy efficiency of the ship[16].

Table 2: Estimations of annual CO_2 emission reduction for 2020 and 2030[17]

Year	**CO_2 reduction in Mio. tonnes**	**Percentage in comparison to normal operation**
2020	200	10-17
2030	420	19-26

As EEDI and SEEMP do not cover all ship types and sizes, it was agreed to continue measuring energy efficiency of ships. Table 2 is presenting the estimated reduction of annual CO_2 emissions by shipping industry for the years 2020 and 2030.

Maritime organisations and shipbuilding companies are using LCA since a decade to analyse and assess the environmental impact of a ship. Different design tools were invented during this time like Jiven did for evaluating the energy efficiency of ships[18]. The National Maritime Research Institute of Japan developed a SimaPro-based tool (sustainable ship design - SSD) to assess the environmental impact of a ship or its subsets comparing the impact of different green technologies throughout the ships life[19]. To assess a baseline for the environmental impact of a ship, it is pre-modelled according to a normal bill of materials. Material and energy flows associated with components production and life performance are evaluated and summarized to ships total environmental impact[20].

To ease the work of designers inexperienced in environmental issues, CONVENAV tool is merging the environmental and designing step. Choosing between different technologies, the

[16] Warris, Anne-Marie; 2011
[17] IMO; 2011a
[18] Jiven, K., et al.; 2004
[19] Kameyama, M.; 2004
[20] SSD; 2010

tool is calculating the environmental impact and enables the designer to choose the most suitable and most environmental friendly design[21].

Ship dismantling in recent years was mainly performed in south-eastern Asia under low environmental, health and safety standards. The ships were being anchored near some beach and cut by hand with e. g. welding torches. Thus, the International Maritime Organization (IMO) has developed the Hong Kong International Convention for the safe and environmentally sound recycling of ships[22]. To bridge the time needed for being ratified by 15 countries or countries which form 40% of the gross tonnage of the world's merchant shipping, the Maritime International Secretariat was publishing the "guidelines on transitional measures for ship owners – selling ships for recycling" in 2009[23]. These documents are setting a minimum standard for the designing and recycling of ships. The convention will force ship owners to provide for a ship specific list of hazardous substances and the dismantlers to meet minimum environmental and safety standards.

1.2.4. Aviation industry and Green Design

Aviation industry is one of world's most important economic and ecologic industries, representing 7.5 % of world Gross Domestic Product (GDP). 32 million jobs are dependent directly or indirectly from this industry. Regarding the worldwide growing number of flights, especially through growing prosperity in Asia and South America, an increasing percentage from 2 to 3 % of worldwide man-made CO_2 emissions is estimated until year 2050. These emissions are equal to 628 Million tons/a. Besides the contribution to global warming, other local concerns regarding aircraft transport are raised by public and politicians, such as new runways at airports. Noise and respirable particulate matter emissions are another two main reasons why German as well as residents from other European countries are concerned about growing air traffic.

In year 2000, key stakeholders of the Aviation Industry met to discuss how European aviation can better serve the society's needs resulting in the report "European Aeronautics: A Vision for 2020". During Paris Air Show 2001, the Advisory Council for Aviation Research and Innovation in Europe (ACARE) and its over 40 members approved on developing a Strategic Research Agenda (SRA) to achieve the Vision 2020 goals presented in Table 3. ACARE used these goals to give recommendations for research topics within the 6th and 7th framework program (FP) of the European Union published in 2000 respectively 2008. In 2011 ARCARE

[21] IMO; 2011b
[22] Maritime International Secretariat Services Limited; 2009
[23] Princaud, M.; 2010

published its new vision beyond 2020 horizon towards 2050 and is currently working on a new SRA to be published in 2012[24].

Table 3: challenges and associated goals of ACARE 2020[25] [Quentin 2007]

Quality and Affordability	• Reduced passenger charges
	• Increased passenger choice
	• Transformed freight operations
	• Reduced time to market by 50%
The environment	• Reduction of CO_2 emissions by 50 %
	• Reduction of NO_x emissions by 80 %
	• Reduction of perceived external noise by 50 %
	• Substantial progress towards 'Green multi material design (MMD)'
Safety	• Reduction of accidents rate by 80 %
	• Drastic reduction in human error and its consequences
The efficiency of the air transport system	• 3x capacity increase
	• 99 % of flights within 15 min of timetable
	• Less than 15 min in airport before short flights
Security	• Airborne – zero hazard from hostile action
	• Airport – zero access by unauthorized persons or products
	• Air navigation – No misuse. Safe control of hijacked aircraft

As of today, there are no legal necessities beside REACH and RoHS which force the aviation industry to become more environmental friendly. The main influence on the producer behavior is generated by the market itself, as airlines have to compensate growing kerosene and tax costs. The development of less fuel consuming aircrafts and especially engines was increasing the order stock of e. g. Airbus to € 495 Billion by today [Fasse 2012].

2. Steps for greening the aircraft industry - The R&D project CleanSky

To meet the ARCARE goals and the REACH as well as RoHS requirements, the European Union and the aviation industry set up the € 1.4 billion R&D project CleanSky.

As presented in Figure 1, it is divided in 6 Integrated Technology Demonstrators (ITD) whereof the Fraunhofer and Dassault Aviation managed Eco-Design (ED) forms the smallest, but the most important one for meeting the goals mentioned above. In addition to that, the Technology Evaluator was implemented to collect data from all ITD and to extrapolate the Clean Sky positive (environmental) impacts to a mission and fleet level on a global scale. This projection will capitalize on Eco-Design Life Cycle Assessment results. Eco-Design is therefore an essential basis for environmental assessment of all state of the art technologies and their alterations developed within this ITD.

[24] ACARE; 2012
[25] Quentin, Francois; 2007

The Eco Design project work is covering both technology development of “greener” technologies, and methodological improvement and focusing of LCA approaches to the needs of aircraft industry and its suppliers. Starting with evaluating and discussing requirements regarding technological, environmental as well as social aspects, especially the social requirements collection proved to be new and not yet undertaken elsewhere. Thus identification of stakeholders was followed by interviews and workshops, to collect and structure societal requirements.

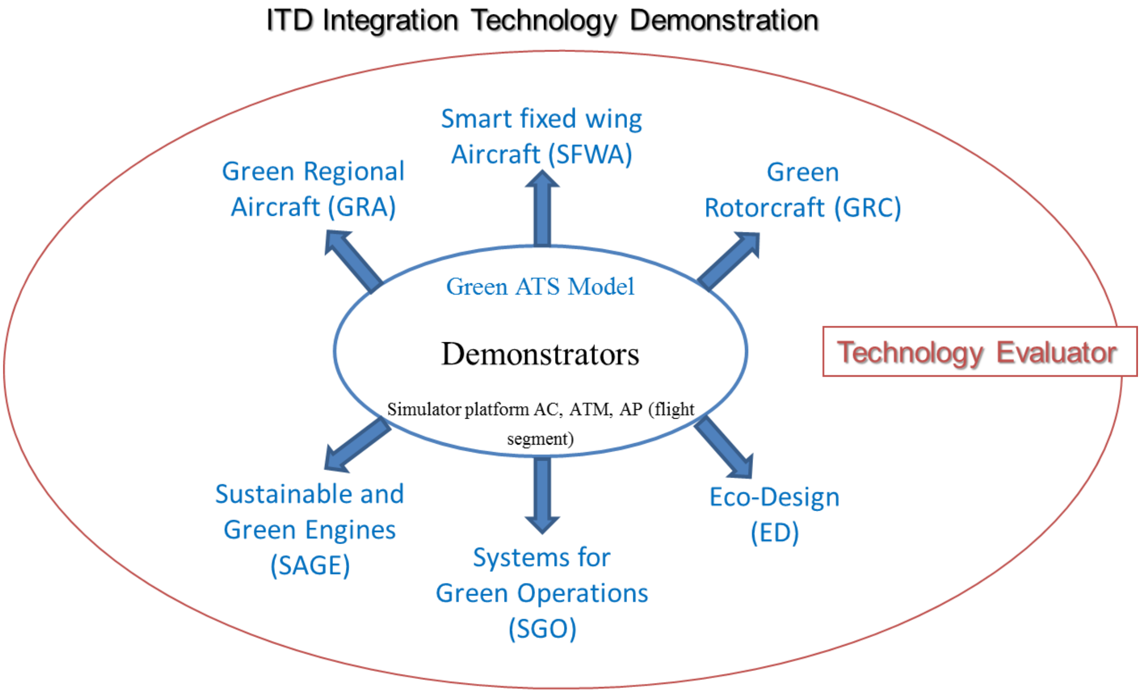

Figure 1: CleanSky Integrated Technology Demonstrators

2.1.1. Stakeholder impact

Understanding the effects of new technologies and materials and integrating requirements into eco design processes means considering social and economic indicators in parallel. This brings it to a strategic level – which was long time claimed for absence, e.g. by Maxwell and van der Vorst (2003) and Charter and Tischner (2001). If sustainability is seen as a global aim, it is not enough just to reduce the environmental impact of a product using a classical eco-design approach on an operational level. It must be completed by social, ethical and economic issues.[26] In detail this requires to understand the effects of new technologies on indicators such as workload, level of qualification, or occupational safety.

[26] Maxwell and van der Vorst, 2003; v. Weenen, 2000; Byggeth and Broman 2000.

Within this section, a brief overview over the relationship between society and technology is given, leading to societal aspects of eco-design and closing with a method of possible integration of socio-economic aspects into strategic decision processes on new technologies or materials, respectively.

2.1.1.1. Society and Technology

The image of technology in society today is characterized by many contradictions. Technology on the one hand is considered to be forward-looking, to secure prosperity and wealth and to increase comfort. However, some effects of technology are recognizable, which are considered to be not desirable. Those are especially negative social impacts stemming from societal and structural change[27] but also ethical conflicts.

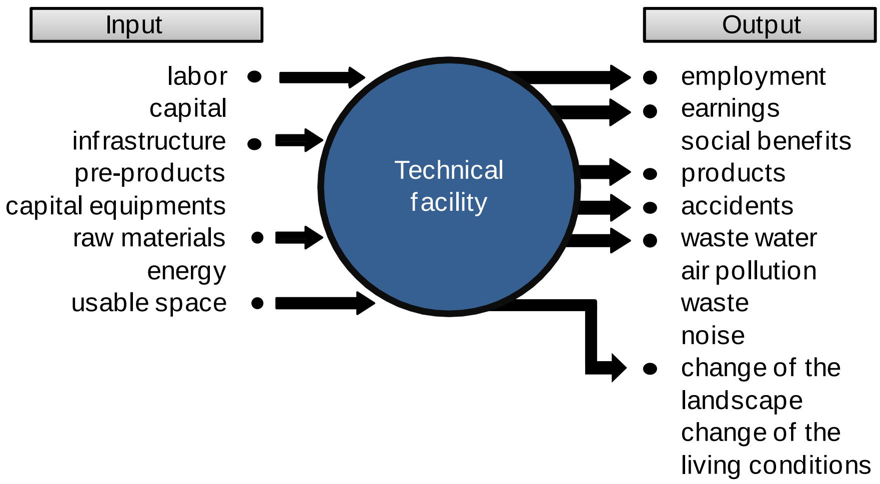

Figure 2: In- and output factors of a technical facility (from Kuhlmann, 1983)

Especially in the industrial revolution in Europe, technology was connected with the ideals of the European Enlightenment. On the one hand it was seen in terms of liberation from the restraints and restrictions of nature by commanding them and allowing human autonomy and self-determination. On the other hand it was seen as a possibility to liberate from the cultural restrictions of the pre-modern societies. Technology simply promised a better life by disburdening the individual from physical work through technical machines and tools, increasing the societal wealth through more efficient form of value creation, as well as through improved medical care and enhanced education possibilities.[28] In the presence technology

[27] Grunwald, 2002.
[28] Grunwald, 2002.

offers humans completely new capacities of acting. The “unavailable” has been driven back further and further and today hardly a single aspect of our environment is not available to human access. Increased wealth, prevention of diseases, securing nutrition supply, mobility, and global communication would not be possible without technology.[29] Modern societies are increasingly dependant on the viability of technology. The computer for instance became an integral part of our work and living environment. Vulnerability by technical failures and other weaknesses can therefore have unwanted consequences for society. Consequences which have an effect on human health can be added to this list. For instance technical failure, emissions, such as noise or harmful substances, and disposal problems might have dangerous effects on health, life and physical condition. However, technology induced advances in medicine and thus in turn has increased life expectancy.

The scientific field of socio-economics often refers to “social costs”, to take into account unintended consequences in the market place. They occur because the market rewards organizations and others players for minimizing costs, as they in turn can offer their products at a lower price. Costs which occur from harming the health of employees and damaging environmental and landscape conditions or rather by remediating them would be at the expense of the society and the state.[30] When making decisions or judgments with regard to the acceptance of technology, reasonableness of technologically induced risks or ethical limits, one must distinguish between the perspectives of decision makers and persons concerned. Technological innovations generally bring about not only winners but also losers. Political decisions concerning regulation for example might influence the boom or downturn of whole industry branches. The balance of different perspectives is thus a typical challenge of distributive justice.[31] It is often a great challenge to judge whether a technology or its consequences are good or bad, as it depends on the point of view what is desirable for the society and what is not.[32]

2.1.1.2. Evaluating Stakeholders’ requirements

First a literature survey on aircraft industry and air traffic led to a set of 4 relevant stakeholder groups:

1) Industry, with raw material suppliers, suppliers, manufacturing, production…
2) Operators (freight and passengers), also including low-cost-carriers and associations
3) People, including worker’s unions, residents, environmental associations…
4) Authorities/ Government

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[29] Grunwald, 2002.
[30] Milk-Horke, 2008
[31] Grunwald, 2002
[32] Kuhlmann, 1983

Therefore representatives from the above mentioned groups have been chosen for qualitative interviews to evaluate the social requirements and effects. Not all chosen stakeholders could participate, but eventually a set of 10 qualitative personal interviews was conducted with representatives from all stakeholder groups. Therefore the results do not claim to be representative but they provide an overview over existing socio-economic indicators and their relevance for stakeholders. Experts have been chosen from industry (3), operators (3) and people (3) because of their almost equal relevance proven by the literature analysis. The group of authorities/government is represented by the German Ministry for Economics (BMWi).

As a next step, an interview guideline was designed, grouping the statements derived from literature by titles and subtitles in order to capture most of the experts' knowledge, experience and thoughts on socio-economical effects of green aircraft. This interview guideline served as an orientation for the interviewers to keep all aspects in mind, but allows going into detail in cases the interviewee shows special expertise.[33] The interview was structured into four main parts:

- Effects from new materials and technologies
- Employment and Staff (current and future effects)
- Health and life quality
- Society and Community

There was a slightly different interview guideline for each group of stakeholders to allow differentiation between the fields of action within the aircraft lifecycle e.g. industry is not involved in operation processes and conditions of employment during the operation phase, people's point of view is limited to discernible risks like diseases, job loss, noise etc., not to risks within the supply chain.

The (direct) effects of materials and technologies were described by the mass of materials that can be replaced by materials with an improved enviromentmental performance ("green materials"), the effects on technical performance, lifecycle and costs, the availability of (raw material) suppliers and possibilities for processing new materials in the European Union. Employment was measured by the current level of qualification and the needs for additional skills that might be necessary for processing and handling of new materials and technologies, by the need for recruiting new staff, age level and labor dismissals. For example, staff with specialized skills might be needed when implementing a new technology. This might increase the level of qualification and also stimulate recruitment if there is no internal training for the present employees. Hence, it might be possible that the age level decreases in the medium term

[33] Perry, 1988

because younger people with a higher technical affinity or different qualifications have to be employed. It could also be the case that processing of new materials makes the jobs of some workers obsolete who cannot be employed at other positions, resulting in labor dismissals.[34] Working with new materials could be safer as many risks will be reduced by substituting toxic materials and process reworking (production and maintenance). Societal effects which cannot be quantified easily as they only have an indirect effect are the level of universitary qualification, influences on politics, 3rd-party-investment and local community by communication, local manufacturing, sponsoring etc..

The expert interviews were conducted as semi-structured personal and/or telephone interviews from May to August 2010. Two researchers took part in each interview with duration between 60 and 120 minutes – one to lead the interview and to ask the questions and one to take written notes of the interview. A qualitative contents analysis was chosen to structure the results. This method is preferable because it allows working independently from the written interview text and tries to reduce the volume of information systematically as well as to structure information according to the interview question.[35]

Whilst analyzing the interviews it became obvious that there is no predefined set of stakeholder's socio-economic requirements on green aviation, but a clear request to take social aspects into account on a very early and even on a strategic level. This lead to the idea of integrating stakeholder's requirements (stemming from the above mentioned interviews) into a model to support technical decision processes on new technologies and materials. This model should be easy to apply and to use in combination with pure technological aspects, e.g. in decision workshops on new technologies. Furthermore it should be possible to integrate it into Eco-design guidelines with the aim to ensure considering social aspects at a very early level of product development or re-engineering.

2.1.1.3. Building a Model

The model to support technical decision processes on new technologies and materials should fit to the specific circumstances in the aviation business and at the same time include socio-economic factors and different groups of stakeholders into decision-processes for green technologies all along the product lifecycle. A comparison between standard methods like multi-criteria decision methods, social and socio-economic Life Cycle Assessment (S-LCA) and methods from quality management brought up the following:

1) Multi-criteria decision methods: A prerequisite for processes of participatory technology design and optimization is that the assessment of alternative technological options is transparent

[34] Kruse et al. 1968; Leontief and Duchin, 1986
[35] Perry, 1988

and comprehensible for all parties involved. In particular the potential of existing methods for multi-criteria decision making haven't been utilized for the CleanSky project yet. These methods have been developed to overcome the disadvantages related to "classical" optimization models, which in general are solely focused on minimizing costs considering constraints. However, a monetary valuation of all evaluation parameters, as it is often done in traditional macroeconomic utility models, should be avoided. Alongside with economic efficiency targets, a great range of organizations consider many more aspects, such as ecological and social dimensions, improving the quality of decision making and strategic perspectives respectively. All the more, this is relevant for inter-institutional processes of technology design within the aviation industry, having a wide user spectrum. Accordingly, decisions are rather determined by a single criteria or objective. In fact, the choice between different alternatives frequently includes many controversial aspects which often cannot be measured or quantified with comparable units and have to consider diverse judgments from different perspectives of various decision makers.

The assessment system has to arrange for a multitude of appraisals, and socio-economic aspects are only a fraction of the decision parameters of a full technology assessment based on formal multi-criteria models. Hence, the procedure presented might be too time-consuming and complex for application within a time-limited assessment-workshop for a large number of technologies.

2) S-LCA: A social and socio-economic Life Cycle Assessment (S-LCA) is a social impact (and potential impact) assessment technique all along the life cycle. It assesses social and socio-economic impacts found along the life cycle, as supply chain, including the use phase and disposal, with generic and site specific data. It differs from other social impact assessment techniques by its scope: the entire life cycle.[36] The method is based on a scorecard, a multi-criteria indicator model for a number of social impact categories. This indicator assesses the effort of a company to manage the individual issues, and it calculates a score reflecting the company's performance in a form which allows aggregation over the life cycle of a product.[37] A characteristic feature of this method is that it cannot be conducted comprehensively on a single technology or material level as S-LCA focuses on activities in the life cycle which have an impact on and affect people. Here, it makes little sense to perform the analysis on a process or a single technology level, since most impacts on people do not stem from a single material or technology applied, but from the sum of criteria while using the entire product (airframe). These impacts of entire systems are measurable by an S-LCA analysis. Exceptions may be found in

36 UNEP 2009.

37 Dreyer et al 2010.

processing single materials which have direct occupational health impacts on workers.[38] Therefore, a different approach is needed to meet the project's demands.

3) EFQM: Based on the above mentioned aspects, a discussion of experts suggested the Business Excellence Model of the European Foundation for Quality Management (EFQM) as a promising basis. Although the EFQM provides a less formal method, it promises not only a balanced and comprehensive view on different aspects relevant for a technology assessment, but also helps focusing on the relevant aspects during an assessment workshop for a large number of technologies. The concept of business excellence has evolved over decades. Early concepts include the discussion on business excellence[39] and the differences in manufacturing and quality policies in Japan and the western world.[40] A milestone was the establishment of the European Foundation for Quality Management in 1988 in Brussels and the subsequent development of the Business Excellence Model of EFQM.

The EFQM Model of Business Excellence consists of three elements: (1) Concepts / values guiding management and all other stakeholders to businesses excellence. (2) Criteria that are applied to self-evaluation but also for awards like the European Excellence Award. (3) RADAR-logic for the structuring of improvement projects towards Business Excellence: Results, Approach, Deployment, Assessment and Refinement (cf. PDCA: Plan, Do, Check, Act). The concepts of excellence and the RADAR-logic provide the foundation and the guideline for project management; the criteria provide an information structure to assess the full range of business activities. As this paper does not address project management issues, the RADAR-logic is left out of discussion. In this paper, we refer to the EFQM model used in 2010.[41]

On occasion of introducing the revised 2010 version of the fundamental concepts of excellence, the EFQM further elaborated these concepts: (1) Achieving Balanced Results: Excellent organizations meet their Mission and progress towards their vision through planning and achieving a balanced set of results that meet both the short and the long term needs of their stakeholders and, where relevant, exceed them. (2) Adding Value for Customers: Excellent organizations know that customers are their primary reason for being and strive to innovate and create value for them by understanding and anticipating their needs and expectations. (3) Leading with Vision, Inspiration & Integrity: Excellent organizations have leaders who shape the future and make it happen, acting as role models for its values and ethics. (4) Managing by Processes: Excellent organizations are managed through structured and strategically aligned processes using fact-based decision making to create balanced and sustained results. (5)

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[38] Dreyer et al 2006.
[39] Peters and Waterman 1982.
[40] most popular Womack et al. 1990.
[41] see the documentation of the EFQM or summaries like Neuhaus et al. 2010.

Succeeding through People: Excellent organizations value their employees and create a culture of empowerment for the balanced achievement of organizational and personal goals. (6) Nurturing Creativity & Innovation: Excellent organizations seek, develop and maintain trusting relationships with various partners to ensure mutual success. These partnerships may be formed with amongst others, customers, society, key suppliers, educational bodies or Non-Governmental Organizations (NGO). (7) Taking Responsibility for a Sustainable Future: Excellent organizations embed an ethical mindset in their culture, clear values and the highest standards for organizational behavior, all of which enable them to strive for economic, social and ecological sustainability.[42]

The fundamental concepts of excellence provide a solid foundation for the criteria of the EFQM model of Business Excellence that are used as meta-model to construct a complete and usable "**Information Structure including socio-economic Aspects and Stakeholders**" to assess technologies that may get involved in project's approach towards green aviation.

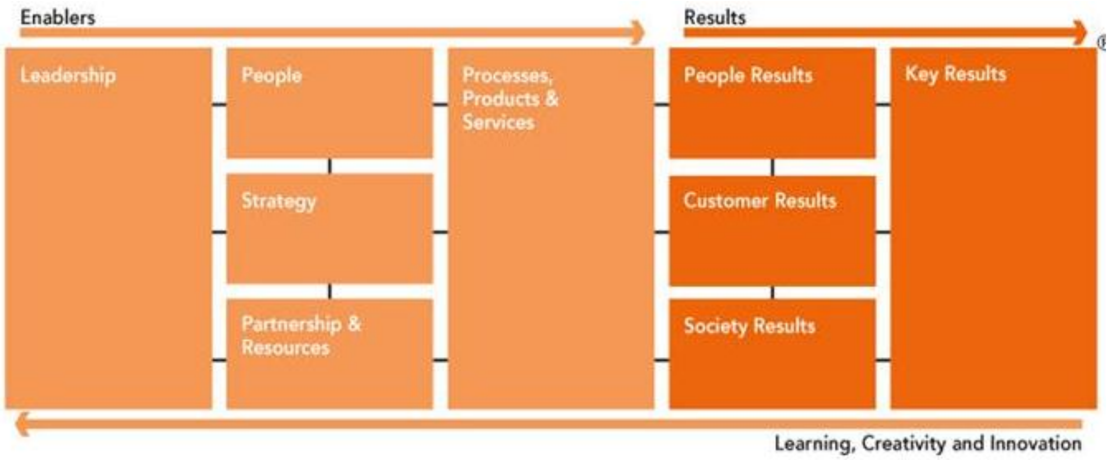

Figure 3: Criteria of the EFQM Model for Business Excellence (EFQM 2010)

The criteria are grouped into the categories "Enablers" and "Results". The first group focuses on the process of manufacturing, operation etc. and the second group focuses on results concerning employees, customers, and other stakeholders. As "Green Aviation" is still an emerging sector of technological development, the following guiding questions (see Fig. 3) may illustrate the importance of the criteria for CleanSky, but are examples and by no means exhaustive.

42 EFQM 2009, pp. 6 ff..

4 Evaluation: The optimization of social, ethical and economic issues is not included in eco-design in its present form.[43] Therefore a simple and pragmatic approach has to be chosen that is easy to integrate into existing corporate systems and that is able to combine strategic and operational aspects. Table 1 shows the above mentioned criteria for the decision process:

	multi-criteria models	**S-LCA**	**EFQM**
less formal method, flexible and easy to apply	-	-	X
suitable for social impact categories	X	X	X
known standard, therefore easy to integrate into corporate systems	-	-	X
assessment for alternative options	X	-	X
suitable for single-technology assessment	X	-	X
product-lifecycle-oriented	possible	X	possible
combination of strategic and operational aspects	possible	-	X
balancing of stakeholders (integration of customers, suppliers, government, investors, people…)	possible	-	X
sensitivity for crosslinks and other dependencies between societal criteria	X	-	X

Table 1: Evaluation matrix

For the special task of integrating societal criteria into eco-design processes, an adaption of EFQM seems to be the most promising way because of the highest accordance with the defined requirements. Therefore it has been chosen for the further process.

2.1.1.4. Result: Information Structure based on the EFQM-model

The "Information Structure including socio-economic Aspects and Stakeholders" developed (Fig. 4) is designed to provide a complete coverage of stakeholders and their requirements, with an emphasis on socio-economic aspects. Compilation of socio-economic aspects of "Green Aviation" includes a multitude of stakeholders, a wide range of possible technological developments and a large range of opportunities, but of risks as well. It is intended to play a fundamental role in the decision making process to achieve a better fit of aviation and the requirements of environment and mankind. Taking this model as organizing device, a list of

[43] Maxwell and van der Vorst 2003.

guiding questions could be generated. This list can easily be expanded to meet the need of further developments of "Green Aviation". The model neither has the goal nor pretends to provide information on the question whether a product should be produced or not. Information on the social conditions of production, use, and disposal may provide elements worth discussing but will, in itself, only provide a single perspective to be taken into account.

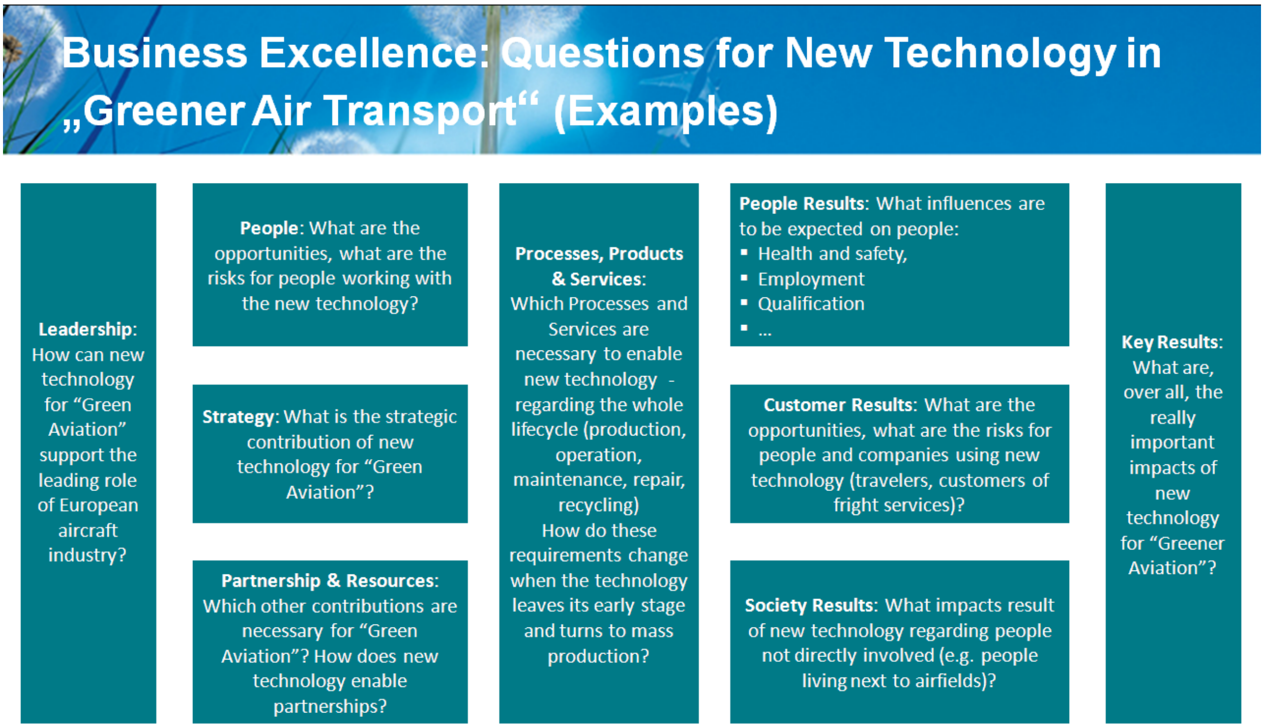

Figure 4: Model of the information structure

2.1.2. Technological and environmental criteria

The Clean Sky Eco Design project part regarding technological and environmental development is divided in four work packages, starting with materials development to substitute e. g. Chromium six from coatings. Secondly, manufacturing processes are optimized to save energy, time and/or raw materials. Development of long life structures shall save raw materials by extending materials and parts life performance. Finally, the end of life of aircrafts is discussed with the main focus on materials recovery and recycling, such as carbon fibre recovering, application of thermoset and thermoplastic composites, recycling of insulation materials, improving aircraft metal recycling and identification methods for materials used in aircrafts.

To present the technical improvements made, the technologies developed are being integrated in demonstrators lateron, which will be the "hands-on" proof of technology and, provide for samples for testing. Besides the technical improvements, the environmental performance is assessed using detailed process data documentation to perform life cycle assessment for each technology and for the demonstrators as well. By considering the whole life cycle (cradle to grave) of the aircrafts, the life stages with the highest environmental impact can be identified and optimized. model to support technical decision processes on new technologies and materials.

3. Way forward – future steps to an Eco Design Guideline

Regarding Aircraft construction, the main focus lays on minimizing cost and weight. Keeping this in mind but considering the high visibility aviation industry has in public, one main outcome of the Eco Design project is the Eco Design Guideline. Whereas compliance to legal requirements such as RoHS and REACH regulations can be regarded as a prerequisite, currently additional steps are being prepared to implement producers responsibility beyond the mere legislative framework. After finalizing, this Guideline can be used by OEM and suppliers to optimize their processes in terms of environmental and social aspects as well as for communication purposes when comparing their improvements to the prior status. It will not lower the importance of saving costs and weight through optimization of production processes and materials, but can help the industry becoming more environmental friendly and to increase its reputation in public and government.

There are different levels within companies to be addressed by this Guideline. Talking about changing the policies of aviation companies, the management level should be addressed to implement the Guideline into the company's strategy. The OEM for example can use this Guideline as basis to set a minimum environmental standard to be met and ask suppliers to improve their environmental performance accordingly. Regarding the design process, the designers' choice of materials and material combinations can be supported and influenced through ensuring an easy to use format for information transfer. It needs to be highlighted that this Guideline is not intended to replace current processes within the companies, but will help to improve them and to make "greener solutions" information available to the designers. Combining the Material and process information with LCA data, the result can be used as third decision-making support besides costs and weight. In case weight and costs of some alternative solution are similar, social or environmental criteria like recyclability or hazardousness will make the difference, thus making the aviation industry "greener" in the years to come.

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