Working document

Working Group on Advanced Materials Technologies

1 Scope of advanced materials technologies

The advanced materials domain is very broad and its boundaries are not clearly defined. The key segments recognised as such and used by the working group are :

- advanced metals
- advanced synthetic polymers
- advanced ceramics
- novel composites
- advanced biobased polymers

This segmentation, one of many possible choices, was selected after a discussion with TNO, also working for the EC on similar subjects. We considered it useful to maintain some kind of common ground between parallel assignments.

It is important to point out that for certain segments, more particularly advanced metals and advanced ceramics, availability of materials is a challenge. Recently this has been put high on the agenda because of restrictions imposed by China on trade in rare earth metals, but other groups in the Mendeleev table are also vulnerable. By committing to 3 parallel approaches Europe will be able to mitigate raw materials availability issues :

- long term : develop substitution materials
- medium term : design for recycling
- short term : improve access, enhance recycling and develop recycling technologies

Advanced materials technologies play a key role in each approach. While the long term substitution goal can only partly be achieved during the time horizon of the KET exercise, much progress can be made on the other 2 approaches in the 2020-horizon. We will therefore include some recommendations on those 2 in section 6 of this report.

Advanced materials are so strongly integrated in and defined by the applications they are serving that the working group decided that a value chain analysis is unavoidable, and will be the key vehicle in this report. As advanced materials technologies are used in almost all industrial value chains, overlaps with other KET-domains are not the exception but the rule. In the context of the KET exercise this is clearly the case with micro/nano-electronics, photonics and nanotechnology.

2 The vision

As clearly stated in the HLG-guidelines, KETs need to be analysed against the backdrop of the grand societal challenges the world is facing. The advanced materials technologies working group decided to make the impact on societal challenges the main value chain selection criterion. Indeed, while value chain analysis will be the main tool, practicality forces us to restrict our analysis to value chains that are both relevant and representative. Relevancy is understood as positively impacting the grand societal challenges, representativeness as covering the majority of the segments mentioned in section 1.

Following relevant and representative value chains were / are being analysed with the intention of learning about the strength of their foothold in Europe :

- photovoltaics (addressing energy and climate challenges)
- advanced batteries (addressing climate and more generally environmental challenges)
- solid state lighting (addressing energy and climate challenges)
- gas turbines (addressing energy) ; not fully elaborated
- health care (addressing ageing population) ; not fully elaborated

By investigating how these value chains are industrially present in Europe, owned and operated by either European or non-European companies, we hope to shed light on efficiency and effectiveness of potential support policies. Indeed, market pull measures will only be effective in supporting upstream activities such as advanced materials in value chains that are fully intact in Europe, with each segment having sufficient strength. In value chains lacking completeness other mechanisms will be required to reach the advanced materials sectors.

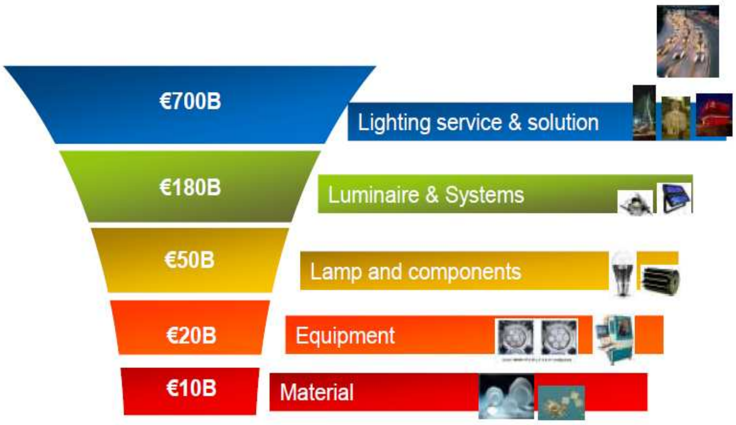
Because of the diverse nature of the advanced materials technologies domain, industrial leadership/presence is also the only pragmatic measure for the strength of the advanced materials technologies serving this value chain. A full blown SWOT analysis for all advanced materials technologies in the various value chains goes way beyond the resources (time, money, people) available to the working group.

At the onset of this assignment we can only hope that a similarity pattern will emerge from the evaluation of the chosen value chains, allowing for more general policy making.

Before moving on to the analysis-part of this report there are some issues of more general nature that need mentioning :

- as already alluded to in section 1 there is a generic advanced materials KET in which Europe has a leading position. This particular KET addresses the environmental societal challenge, and indirectly also the raw materials scarcity and globalisation challenges. Recycling technology is an important tool that will help shape future industries, and Europe is recognized as world leader, both thanks to its closed-loop mindset and to its powerful industrial recycling plants. Europe may want to consider expanding this leadership by encouraging its companies to include a requirement of efficient and effective recycling into the design of their new products, to be further elaborated in section 6.

- as shown in the picture below, an example taken from annex 3, advanced materials form the base of an inverted pyramid supporting the higher revenue-generating layers of the value chain. Having to rely on the goodwill of advanced materials sources located outside of Europe makes the whole value chain vulnerable.



- it also needs to be emphasised that the shape of a similar graph representing the labour situation would resemble a cylinder instead of a pyramid : advanced materials and the related technologies not only support whole industrial sectors but also create an important amount of high quality jobs, much needed in today's and tomorrow's Europe. In this way they are an important factor in addressing the societal challenge of meaningful job creation.

3 Analysis of the current situation world-wide and in the EU

It was already mentioned that due to the vastness of the industries impacted by advanced materials technologies it is practically impossible to perform a SWOT analysis for each particular case, and certainly to accomplish this within the constraints of the HLG KETs assignment. Indeed, a SWOT would have to be done for advanced materials technologies as they are implemented in each value chain. We therefore have to downscale our ambitions concerning strengths and weaknesses evaluation to the following pragmatic approach : European advanced materials technologies are considered strong in a certain value chain

- if there is a critical mass of Europe-based industrial capacity for these advanced materials, constituting a significant percentage of the global production
- if this industrial presence in Europe is not too dispersed over a multitude of small manufacturers, but also includes one or more world-class producers.

In the remainder of this analysis section we will examine the situation in the selected value chains, not only for the advanced materials segments but also further downstream as European value chain strength in segments between advanced materials and the end products will be an important factor with regard to the effectiveness of support policies.

3.1 Advanced materials technologies in the PV value chain (background information in annex 1)

We already indicated earlier that the PV value chain is to be considered relevant to this exercise as it has the potential to positively impact the energy and climate societal challenges. As shown in annex 1, the PV value chain can also be considered representative as it uses advanced materials covering 4 of the 5 segments defined in section 1.

The PV value chain is specifically relevant for this KET-exercise as it offers a unique opportunity to analyse the impact of both supply side and demand side measures, as both were applied to this value chain in the 2005-2010 period. This opportunity could be further exploited beyond the current report, but if so desired this will require a joint effort by the Photonics- and Advanced Materials- working groups.

Information about PV value chain capacity in Europe is not readily available. Therefore we resorted to a rather rudimentary approach : go through the websites of all EPIA-members and check press releases, annual reports and other publications for European capacity data. This doesn't yield exact data, but it is assumed that the thus obtained accuracy is sufficient for the purpose at hand.

Results for the mature crystalline silicon technology[1] (advanced materials activities in blue) :

	solar grade silicon	c-silicon ingots	c-silicon wafers	c-silicon cells	c-silicon modules
Capacity (GWp)	4.2[2]	2.6	2.8	3.5	3.8
# producers	4	8	10	16	24

The capacity figures need to be compared to a 2009 world production of 7.2 GWp, of which slightly more than 80% crystalline silicon (EPIA Global market outlook for photovoltaics until 2014, May 2010 update). The capacities in the table therefore have to be compared to a global production of 6 GWp, and the obvious conclusion seems to be that the crystalline silicon PV value chain is well entrenched in Europe, with capacities both in the upstream advanced materials section and in downstream devices and assemblies approaching or exceeding 50% of the world production. It is of course evident that not all capacity is being used, and that this usage rate can differ over the value chain. From the bottom row of the table it can be surmised that the risk of idle capacity and a weakened European manufacturing base is the largest downstream in the value chain, where the production landscape is more scattered.

[1] Figures cross checked and (end-2009) order of magnitude validated with EuPD Research, Bonn
[2] Assuming silicon usage of 8gr/Wp

What is evident from these figures is that, in an industry that was largely created in recent years by Europe / European countries by means of both demand side policies (feed-in tariffs, tax benefits for PV installations) and supply side policies (mainly Structural Funds), Europe has almost overnight become a net importer. Indeed, 75-80% of the new PV power in 2009 was installed in Europe, while the European production was well below 50%.

The situation concerning other than crystalline silicon technologies is less clear as it is still in an earlier development stage. Keeping in mind that the global production is between 1 and 1.5 GWp, it can be seen from the table below that Europe's capacity is significant. In the one segment that has reached industrial maturity, CdTe PV, Europe's production is approximately half of the global production. Any decision process about European support for this technology will have to take into account the desirability of the use of Cd and the limits imposed by materials availability (mainly Te). Other technologies featured in this table are still at pilot plant or small production level, but Europe has certain strengths in several of them.

	TF-Si panels	Non-Si TF panels	CPV
Capacity (GWp)	0.5	0.6	0.03
# producers	7	5	1

As mentioned before any recommendations for the photovoltaic value chain will have to be developed in collaboration with and under the leadership of the Photonics working group.

3.2 Advanced materials technologies in the advanced batteries value chain (background information in annex 2)

With application domains in PV/smart grid and electro-mobility it is clear that advanced batteries are key to climate and environmental challenges. It is also clear from the list in the next alinea that the advanced batteries value chain can be considered representative as it uses advanced materials covering most segments defined in section 1.

In this important technology Europe has traditionally been strong in technology development and was the cradle of most major breakthroughs of the last 3 decades. Sadly these technological strengths have not materialised into strong Europe-based manufacturing. Details about the value chain can be found in annex 2, but it doesn't take a table to describe the European manufacturing base in the battery materials and battery industries : the industrial production in Europe is below 5% of the global production for

- cathode materials
- anode materials

- separators
- electrolytes
- foils
- cells
- packs

The large majority of this industry is located in Asia (Japan, with Korea and China catching up). For certain segments of the value chain European companies are amongst the world leaders, but their production plants are located outside of Europe.

The US has recently launched a massive campaign to increase its production capacity in this important industry sector :
"We are also creating an entire advanced battery manufacturing industry in the United States. We used to have 2 percent of that market. By 2015, we expect to have up to 40 percent of that market," Obama said after touring a Ford Motor Co plant in Chicago. REUTERS NEWS Aug 5 2010
In order to reach this goal more than 1 BUSD of government money has recently been awarded to build an industrial base in battery materials and batteries (9 battery manufacturing projects, 4 of which operational early 2011 ; 11 battery component manufacturing facilities). Certain European companies were able to tap into this government support and are establishing plants in the US.

Europe will have to mobilise its forces in a massive way in order to bring large parts of the advanced batteries value chain within its borders. It needs to be emphasised that state-of-the-art technology is still available in Europe, but European companies active in this domain have located their industrial activities in the vicinity of their main customers and it is to be feared that in coming years large parts of R&D and technology development will also move to the manufacturing plants outside of Europe.

3.3 Advanced materials in the solid state lighting value chain (background information in annex 3)

Solid state lighting is one of the major potential contributors to energy saving and thereby extremely relevant with regard to the energy and climate challenges. Many types of advanced materials and advanced materials technologies are used in the solid state lighting value chain.

Growth potential of the related industries is enormous once the necessary maturity has been reached. Europe and European companies have been at the forefront of development work : in the beginning of the new millennium 2 out of 3 main LED producers (Osram Optoelectronics and Philips-Lumileds) were European and had substantial manufacturing activities in Europe. As for most other related technologies, the shift to Asia has heavily impacted this industry. Explosive growth in China is reinforcing this trend, and companies that operated 1 MOCVD reactor in 2005 are now threatening to overtake the former European market leaders.

The information in annex 3 is more extensive compared to the previous value chains, and is quite self-explanatory. It shows that the European manufacturing base is strong in the downstream segments of the value chain close to the application (Philips Lighting and Osram >40% of general lighting manufacturing in Europe), small for LED packaging (11%) and even smaller (well below 10% of global production) for production of devices (LED chips) and advanced materials (compound semiconductor ingots and wafers). It must be emphasises however that there is one important exception to this conclusion : the majority of the key MOCVD equipment for LED chip production is still manufactured in Europe thanks to the global leadership of Aixtron, the German supplier of MOCVD-reactors.

As for previous value chains, we conclude that although much of the initial technology development and industrialisation for all value chain segments originated in Europe less than 10 years ago, the manufacturing fabric upstream from the “lighting solutions” level is weak (exception : strong position in equipment manufacturing as mentioned above). Also in the case of this value chain the technology development competences are still available in Europe but may move to the Asian manufacturing locations within a few years.

3.4 Advanced materials in the gas turbine value chain (background information in annex 4)

An interesting overview of the evolution and challenges is provided in annex 4. The advanced materials aspect of the gas turbine value chain is not easy to assess, developments are often driven by advanced manufacturing processes. The materials divisions within gas turbine OEM’s are in general the developers of advanced materials. They initiate, co-fund and deliver the advanced materials- and its associated process technology to an internal customer (the supply chain unit). This is often due to very clear OEM requirements to the material functionality and a strong impetus on capturing IP. Whenever available, OEMs are quite happy to adopt commercially available solutions, but this is a very rare occurrence and is often more associated to external suppliers of advanced polymers, ceramics and biofuels. A more common scenario has the materials developer placed as a strategic supply chain partner or a partner research institute or university. In this sense, the aerospace industry is a model example of how to successfully deploy novel and innovative technology. Stringent certification requirements and the high risk of implementing new materials technologies impose an approach where the aerospace companies are in control.

If the elaboration of more value chain examples is considered useful in the context of the KET-exercise we will try to complete this value chain analysis further.

3.5 Advanced materials in the health care value chain (background information in annex 5)

An interesting overview of the evolution and challenges is provided in annex 5. However the analysis has not progressed to the level of detailed information on the European manufacturing base. As already mentioned before, if the elaboration of more value chain examples is considered useful in the context of the KET-exercise we will try to complete this value chain further.

3.6 Summary of the analysis section

The (admittedly few) examples in this analysis section demonstrate that it can't be taken for granted that Europe has within its borders an industrial base covering most value chains with high advanced materials technology content. This observation will have important consequences for policies intended to safeguard and strengthen the advanced materials enabling technologies in Europe.

4 Market pull measures

As evidenced by the examples in the previous section, we have to be careful when considering demand side policies as a means towards strengthening advanced materials technologies in Europe and preserving the European advanced materials industrial base. A weak link in the value chain in intermediate value chain segments will re-route European taxpayers money to third countries, and it is far from certain that these third countries will subsequently purchase European-made advanced materials for incorporation in their products.

An example of such early re-routing of public money is provided by the PV industry. In recent years several European countries have provided significant support to end-users of PV systems by means of feed-in tariffs and/or tax advantages. As explained in section 3 Europe became by far the largest installer of PV systems in the world, but the European PV industry didn't grow proportionally. Asian countries, with China in the lead, were very fast and efficient in setting up relatively low-tech module assembly plants, and in a few years time moved upstream into PV cell manufacturing and advanced materials. Only a limited fraction of the advanced materials such as polysilicon (solar grade silicon) and silicon wafers used in European PV installations are produced in Europe. The strong commitment of a few PV advanced materials companies (Wacker, REC, Solarworld, Schott, PV Crystalox, ...) to their European production sites prevents an even worse record in this respect. An element that contributes to the concerns evoked by the PV case is that this industry also received very significant supply side support (Structural Funds), more on this on the next section.

Although the status of the PV value chain doesn't guarantee a positive impact of market pull measures for the advanced materials segment of the value chain, the chances of this happening in other value chains are even lower to almost non-existing. In both advanced batteries and solid state lighting, manufacturing Europe is very weak (<5% resp <10%) over an important part of the value chain, including the advanced materials segment and the device segment immediately downstream from advanced materials. In these cases the value chain needs to be rebuilt before market pull measures could resort any effect. In case the costs of re-installing a full value chain in Europe by means of a major market push effort – as the US is currently doing with the advanced batteries as integral part of electro-mobility – are prohibitive one could also advocate counting on the importance of the European market for end products. Indeed, for certain applications such as electro-mobility the importance of the European market will force the end product manufacturers and their tier 1, potentially tier 2, suppliers to establish European based manufacturing operations. It is not clear how far upstream this move will proceed, capital costs (for products in transit) and transportation costs will be determining and different for each value chain. Europe could anticipate and focus efforts in advanced materials and devices, in order to link up with the more downstream activities later. The policies to accomplish this will be supply side measures, therefore more on this in the next section.

As an important conclusion we can state that market pull policies alone will not be sufficient to support and strengthen advanced materials key enabling technologies in Europe.

5 Market push measures

In the sections above it became clear that additional measures beyond market pull will be required to bring / keep Europe in the leading group when it comes to advanced materials key enabling technologies. Market push measures can help but may also not be sufficient when applied without certain accompanying measures. An illustration of this statement can again be found in recent experience in the PV industry.

Since 2005 important supply side support has been provided to the PV industry in Europe. Structural Funds mainly deployed in the Länder of eastern Germany constituted an important vehicle in this context : tax incentives but also direct investment support were instrumental in building PV industry campuses, Thalheim/Bitterfeld in Sachsen-Anhalt being a prominent example. Equipment manufacturers were part of this impressive industrial effort and new, more performing PV-cell manufacturing equipment was developed in close collaboration with the emerging local customers. During the first years of the effort it looked like the combined market push and market pull initiatives towards PV would make Europe the uncontested leader in PV. In 2010 we observe that this global leadership role has been taken over by China, and that European companies that were on the receiving side of EU/regional support are moving PV production capacity to Asia. We therefore need to ask ourselves if things can be done better in the future.

As a privileged witness of this market push-supported expansion of the PV-industry one can indentify 2 issues that were instrumental in the all-too-fast loss of global leadership.

- first of all the (often turn-key) equipment developed in the context of this effort was immediately supplied to Chinese companies. Apparently there was, and there may very well be, no way to delay this transfer of equipment-related IP developed as part of a larger effort paid with public resources. This state-of-the-art equipment combined with abundantly available capital, the Chinese speed of execution and low cost base allowed China to overtake Europe as the main PV manufacturing area.

- secondly Europe should take care not to sacrifice operational excellence for speed of execution, the challenge is to do both in parallel. More emphasis should be placed on operational discipline, reduction of loss and quality systems already in the preparation phase and certainly in the initial industrial activities. We believe that it is worthwhile to raise the priority of operational excellence as a criterion in future supply side support. Illustrating the shift in operating excellence : quotes from REC, one of the global leaders in PV headquartered in Oslo and with an important advanced materials (Si ingots and wafers) production activity in Scandinavia, on their new plant in Singapore :
  - "Singapore plant representing operational centre of excellence – methodology to be transferred to plants in Scandinavia and US" (STATUS OF THE SOLAR INDUSTRY & REC'S POSITION FIRST SECURITIES NORDIC ENERGY SUMMIT, CEO Ole Enger, June 2010)
  - "Singapore expansion 20% under budget, compensates for most of the capex overruns on the Europe and US projects" (REC presentation Eksportfinans April 15 2010)

As already mentioned in section 4 more downstream manufacturing may find its way back to Europe, either sooner with the help of market pull initiatives or later as new applications (example electro-mobility) mature, but it is unlikely that the more upstream activities will follow. Therefore it is recommended that Europe keeps sufficient focus on supply side measures for these upstream value chain segments. Based on the experience of the working group and on suggestions made during the October 25th Open Day by the advanced materials community, a number of measures should be considered (more details on the measures in section 6) to support selected strategic developments :

- funding mechanisms for advanced materials technologies pilot line / pilot plants. Carrying already important costs (10 < < 25 MEuro) in a high risk situation is often prohibitive for companies. Risk sharing financing by the EU could be very helpful, either in the form of cash subsidies or in the form of loans that only need to be paid back in case of successful industrialisation
- tax incentives for first industrial facilities, as in the case of Structural Funds but not limited to the regions eligible for Structural Funds
- specific support for co-development between advanced materials and device companies, aiming at new IP that is strongly linked to the European co-developing companies / sites.
- encourage European companies to join forces towards conceptualizing and designing value chains incorporating effective and efficient recycling ; advanced materials technologies will necessarily play in important role in such efforts.

One important comment with regard to projects, co-development or other, aimed at product/technology development in the advanced materials technologies domain : these projects have necessarily a long term character. A check of recent advanced materials development indicates following time periods from start to industrial reality :

- new materials, existing processes : 8-10 years

- "quantum leap" process improvements : 10 years
- new materials requiring new processes : 12-14 years

A long term vision is therefore a conditio sine qua non for support to advanced materials technology development efforts.

6. Timetable and roadmap for potential technological development and deployment and for proposed measures

We don't feel to be in a position yet to make detailed proposals, let alone deployment planning. But based on the work done in the first 5 months of the KET exercise we would like to present for discussion and further elaboration following thoughts :

- as mentioned in section 1 advanced materials technologies can contribute to addressing raw materials availability issues by 3 types of actions :
  - long term : develop substitution materials
  - medium term : design-for-recycling
  - short term : improve access, enhance recycling and develop recycling technologies

  A preliminary initiative towards design-for-recycling could already be taken during the 2nd part of the KET-time period : if deemed beneficial contact can be established with the Raw Materials Supply Group to investigate how best to tackle this.
- technology co-development and industrial collaboration across intra-value chain boundaries needs to be stimulated between the advanced materials and device segments including relevant equipment suppliers, preparing for linkage with downstream segments attracted to Europe by means of market pull policies or once application markets mature. This position was also evoked by several Open Day speakers, a quote from the talk of Bruno Smets speaking for Photonics 21 as an example : " vertically integrated initiatives are needed, …, incremental progress over a substantial part of the value chain is worth more than an isolated breakthrough for 1 material". For such policy to be successful attention needs to be paid to following elements :
  - co-development initiatives should build on and expand remaining European advanced materials leadership positions ; examples for silicon-PV, CPV and battery materials can be provided, other industries will certainly be able to provide other opportunities
  - incorporate a strong focus on operational excellence in these co-development initiatives, as Europe is losing / has lost its strong position in this domain ; this may be one of the most difficult challenges as it requires a change in attitude or even culture at all company levels
  - help selected strategic co-development initiatives to cross the "pilot-plant gap" ; as emphasised by several speakers at the Open Day many interesting technological developments don't make it past R&D because the risk is still too high for private funding of demonstrators / pilot plants with a price tag of >10MEuro. EU assistance for high-potential projects, for example by means of risk-sharing EIB loans (repay in case of success only), could remedy this problem.
  - technology development infrastructures combining different but similar advanced materials and device technologies can be instrumental in achieving co-development success (intermediate step between universities and company in-

house) ; an example of how such infrastructure could look like (nano xtrem-fab) was presented during the October 25th Advanced Materials Open Day.

- in support of the first industrialisation stage of selected strategic projects, tax advantages similar to those currently available in the new member states could convince the industry to invest in Europe. The gap with for example Singapore and other Asian countries would not be eliminated by these policies, but it would be an important step.