ECGA

ECGA Annual Report 2012

European Carbon and Graphite Association

Foreword

The year 2012 was expected to still be a year of recovery and for the first half of the year that seemed to be the case. However, towards the end of the year the economic development weakened again and the last quarter was the weakest since the second quarter in 2009. In general, manufacturing and services saw again a serious contraction which of course had an impact on the metals industry and hence also on the graphite industry. This was also reflected in the employment rates in Europe continuously dropping in 9 consecutive months.

At the same time for many industries the input costs in terms of raw materials and energy continued to rise which stretched the economic viability of many operations.

Despite all of these developments the graphite industry continues to invest into their existing installations on the one hand and into research and development of new products.

The sector responds to political and societal challenges and increases its energy and resource efficiency, although the room for manoeuvre is limited having mad major efforts in the past which resulted in efficiencies in both areas. It should not be forgotten that graphite electrodes are an indispensable part of Europe's steel recycling industry and that many specialty graphite applications are key to Europe's mobility and other technical and social services.

Energy is a key cost in producing synthetic graphite and the European producers are under severe competition from other worldwide producers that do not have energy prices as high as Europe or additional costs such as the CO2 costs imposed by the ETS regulation. Competition from low labour and energy cost countries can only be met by superior quality and short delivery distances. However, high quality in graphite is mainly a result of higher energy throughput and know-how. This becomes a vicious circle.

The graphite industry welcomes the European Commission's initiative to address raw material supply questions for Europe, and is equally looking forward to a revised energy and climate change policy that will combine climate change policies with a successful economic policy enhancing the industries competitiveness for the benefit of Europe.

Dr. Bruno Toniolo, President

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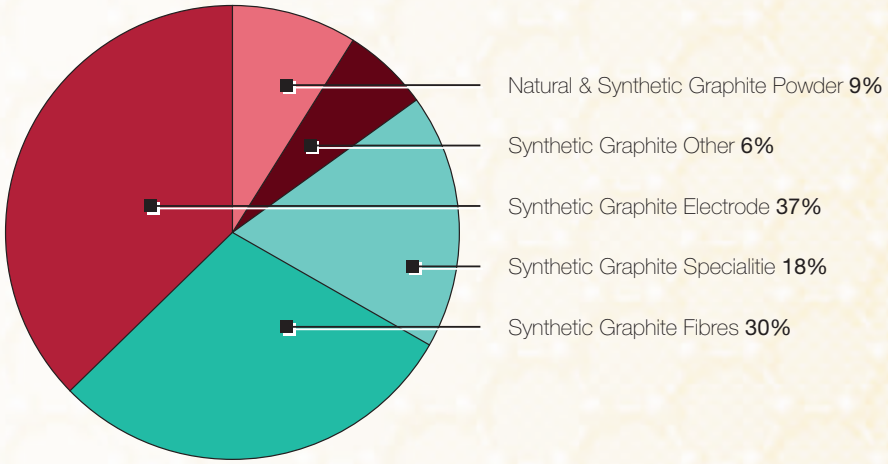
The world and the EU market for natural and synthetic graphite

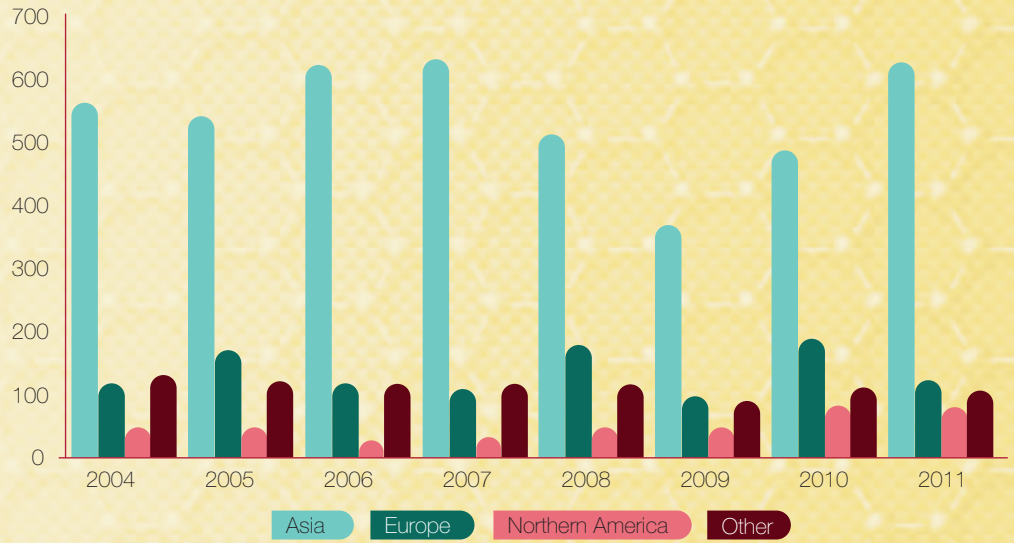
The total worldwide graphite market is estimated to be about 10.2 Billion EUR. It is served by natural and synthetic graphite, most of the time either of them going into distinctive applications since certain applications require specific purities. In some areas both can be used or complement each other.

Total Worldwide Graphite Market Estimated to be: 10.3 Billion EUR



The consumption of graphite varies considerably across the world.

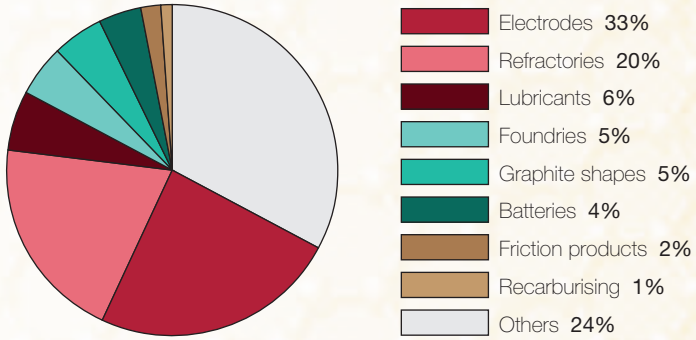
Regional demand for graphite (kt)



Source: Roskill's Natural & Synthetic Graphite: Global Industry Markets and Outlook, 8th Edition 2012

Synthetic graphite – Key markets and new developments

Global demand for graphite, 2011



Source: Roskill's Natural & Synthetic Graphite: Global Industry Markets and Outlook, 8th Edition 2012

World: Estimated consumption of natural and synthetic graphite by region and end-use, 2011 (kt)

	Asia	Europe	N.America	S. America	Others	Total
Electrodes	355	185	130	30	10	800
Refractories	375	50	30	20	10	485
Lubricants	65	35	25	7	4	136
Foundries	60	30	25	10	5	130
Graphite shapes	50	37	21	1	1	110
Batteries	71	4	4	4	2	85
Friction products	21	12	8	7	2	50
Recarburising	20	-	-	15	-	35
Others[1]	256	158	98	36	31	579
Total	1,273	511	341	130	155	2,410

Note: [1] - Including sythetic graphite consumption in foundries, friction materials, refractories and recarburisers
Source: Roskill. Natural & Synthetic Graphite: Global Industry Markets and Outlook, 8th edition 2012

Electrodes

Graphite and carbon electrodes are the largest market for synthetic graphite and account for about 37% of the worldwide graphite market, worth about 3.7 Billion EUR.

Major worldwide manufacturers are located in the USA, Europe, India, Russia and Japan and China.

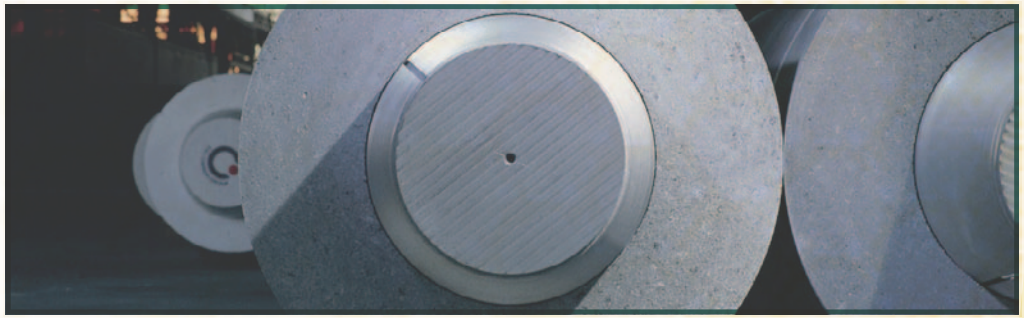
The development in that area continued to improve throughout the first three quarters of 2012, weakening however in the last quarter.

World Steel Market

- 1.8 billion MT of capacity
- 1.5 billion MT of utilization
- Estimated additional capacity of 100 new mills and 350 million MT by 2016
- China accounts for ~46% of steel output

World Electrode Market

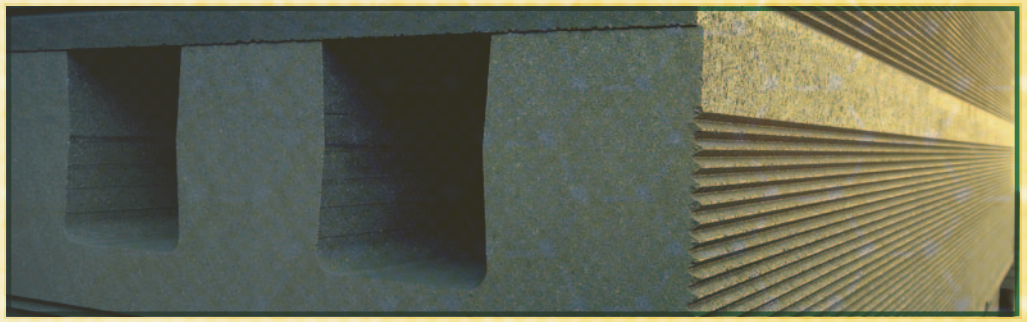
- ~29% of steel is produced in EAF
- Estimated at 3.5 billion USD per year
- Electrode consumption estimated at ~800K MT per year for primary melting



Speciality graphite

Main market applications for synthetic specialty graphite are in the following areas:

- Electronic & Energy Applications
  - Semiconductor production
  - Solar (Photovoltaic) Production of Silicon
  - LED – Light Emitting Diodes
  - Fuel Cells & Nuclear
- Heat Treating, Foundry & High Temperature Metallurgy Applications
  - Furnace Parts
  - Glass
  - Aluminum Processing
  - Casting
  - Extrusion
- EDM – Electro Discharge Machinery
- Other
  - Industrial Diamonds
  - Chemical Processing

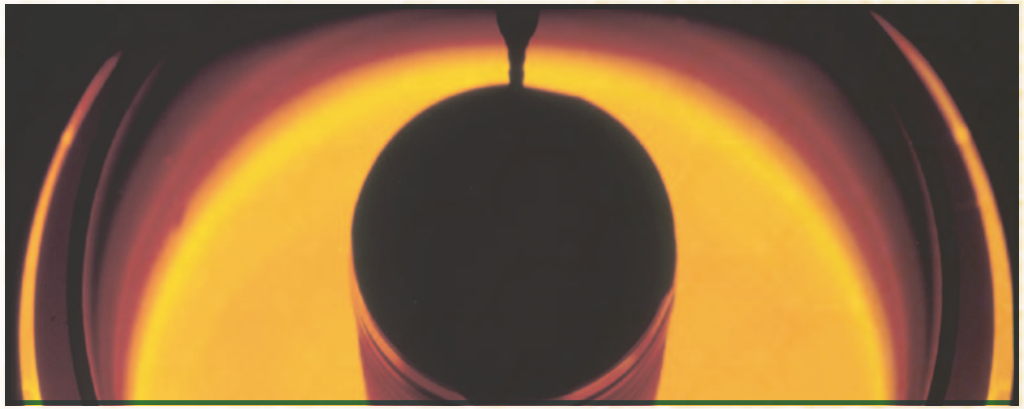


Refractories

The second largest market segment is the synthetic specialty graphite which accounts for 18.0% of the worldwide graphite market, estimated to be around 1.9 Billion EUR.

Key Worldwide Manufacturers (excluding China) are located in the USA, India, Europe, Brazil, and Japan.

Global refractories production was around 42.6 Mt ($22.9 Bn) in 2011 and can grow to 59 Mt ($31 Bn) in 2015. By 2016, the graphite market for refractories could grow to 560,000 tpy. Only a small proportion of refractories contain graphite but the industry is the main consumer of natural material, particularly flake.



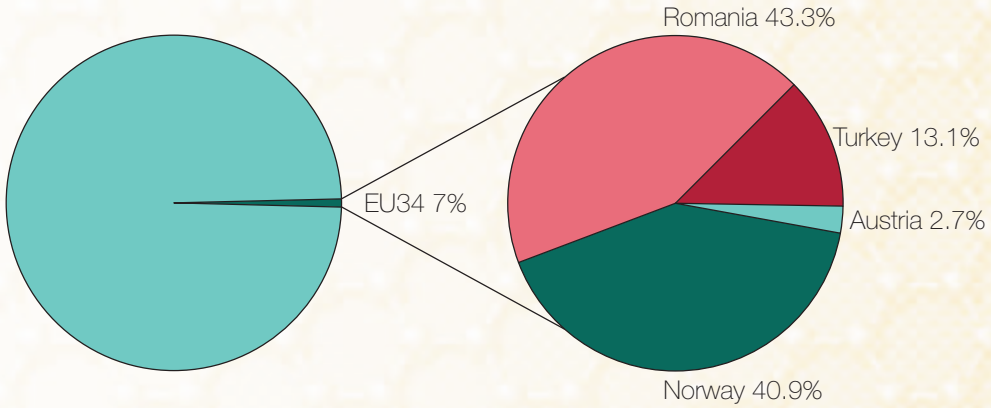
The Forecast for Graphite in Refractories:

- **The opposite trends.** The increase of market for oxide-carbon refractories by BRIC-countries (mainly India and Brazil), increase the consumption of natural graphite. But decreasing consumption for refractories per ton of steel in the advanced economies may lead to decreases in consumption of graphite.
- **Unshaped refractories.** The increase in consumption of unshaped refractory materials also may reduce the consumption of graphite. However there may be increases in the proportion of carbon concrete.
- **New technologies.** There may emerge new types of linings and applications (e.g., GrafTech International and their technology “Freeze Lining”) that will change the type of refractories used. This may lead to a decrease or an increase in the consumption of graphite (e.g. by replacing the natural graphite to the synthetic graphite).
- **The exotic graphite.** In the future applications of the nano-graphite and other exotic types of graphite will increase (e.g., 3D, graphite fibre, etc.). This may significantly reduce the amount of carbon used in refractories.
- **The graphite deposit for refractory companies.** Due to the instability in raw material markets refractory companies are trying to secure themselves with raw materials (e.g., magnesite deposits of RHI, Magnezit Group, Magnesita S.A., etc.). As graphite is a basic raw material for oxide-carbon refractories, refractory players will buy or have already bought graphite deposits

Natural graphite in Europe

The EU's production of natural graphite is very limited. For years the major producers are China and Brazil.

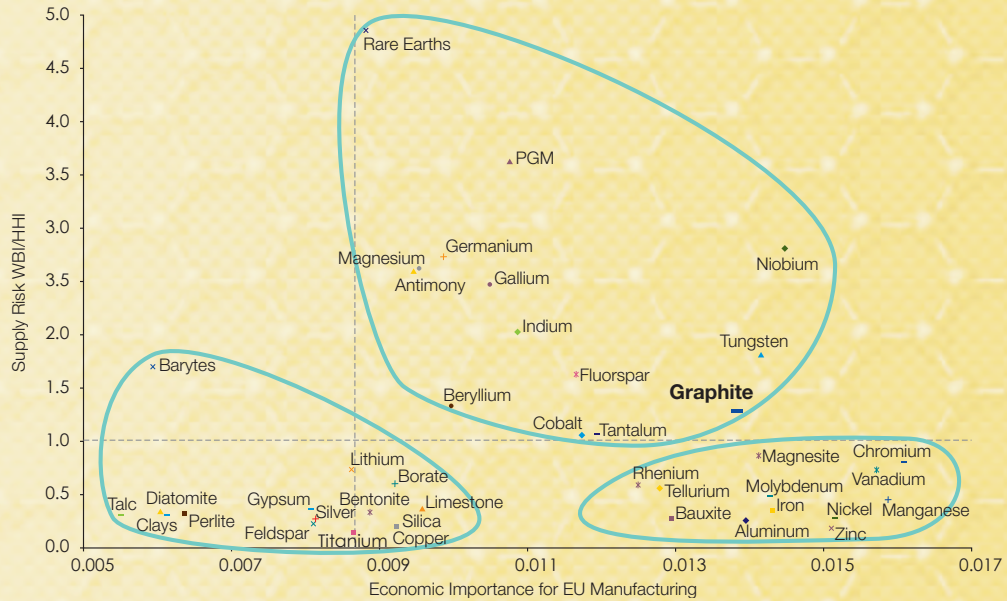
EU34 Production of natural graphite 2010



Source: European Minerals Statistics, British Geological Survey, 2012

- EU consumes 20% of world natural graphite
- EU produces 0.7% of world natural graphite supply in 2010 and is estimated to produce 2.6% in 2012.
- EU has classified graphite as a "critical raw material" based on an analysis carried out by the Fraunhofer Institute, Germany, assessing the risks of supply disruption due to a number of factors, such as geological availability, existing supply structure and political risks of supply.

Critical raw materials for the EU



Source: Critical raw materials for the EU, Report of the Ad-hoc Working Group on defining critical raw materials; European Commission, 2010

Imports of graphite (tonnes)

Country	2006	2007	2008	2009	2010
Austria	10704	17757	30863	4622	18501
Belgium	1836	2309	3624	5048	7243
Bulgaria	433	250	158	132	66
Czech Republic	3485	5301	6233	2554	3605
Denmark	268	212	185	269	303
France	19430	19250	20618	10376	9981
Germany	45884	54627	62180	33293	56333
Greece	83	111	142	918	219
Hungary	192	178	147	126	113
Iceland	2	-	11	2132	18
Italy	11548	11362	11832	5995	8308
Macedonia	648	1969	1522	761	875
Netherlands	5632	13463	42612	2487	16692
Norway	296	980	561	508	400
Poland	3658	5701	4474	3078	6933
Portugal	1954	2210	1493	73	66
Romania	488	542	304	144	1499
Slovakia	1382	2246	2981	962	1899
Slovenia	161	108	141	89	295
Spain	10143	15582	24284	15669	34268
Sweden	1252	1592	1091	835	1315
Switzerland	722	966	931	306	848
Turkey	6300	6095	13230	6788	11191
United Kingdom	16978	17225	14309	7850	6989

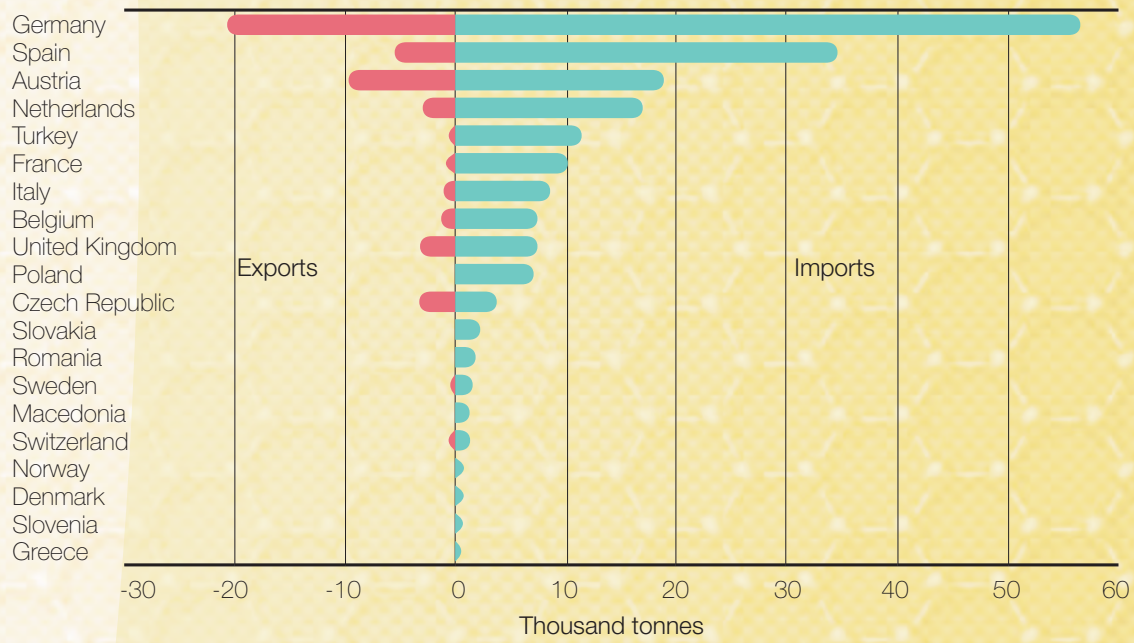
Note(s):
(1) This table excludes synthetic graphite

Source: Adapted from European Mineral Statistics 2006-10 British Geological Survey

The import statistics give a clear indication of the downstream user industries and their location in the various EU countries.

European Natural Graphite Market

Graphite - EU34 trade in 2010



Source: European Minerals Statistics, British Geological Survey, 2012

A contribution to Europe's growth and sustainability

Resource efficiency

The carbon and graphite industry's products contribute actively to the saving of resources and energy through its efficient process management and through its products.

The European Carbon and Graphite industry supports the EU's Imitative on the sustainable access to resources which was published in 2008 and was reinforced by the new Communication in 2011 and which was followed up by the Commission in 2012 with the announcement of the creation of a European Innovation Partnership (EIP) on Raw Materials.

This EIP will address three basic pillars:

- increasing access to resources from world markets;
- increasing access to resources from European sources;
- improving the efficiency of resource use in the EU coupled with the increase of the knowledge base about our resources.

The expectation is that this will give a boost to the development of raw materials and eventually also intermediate products which are needed by the EU's downstream industries.

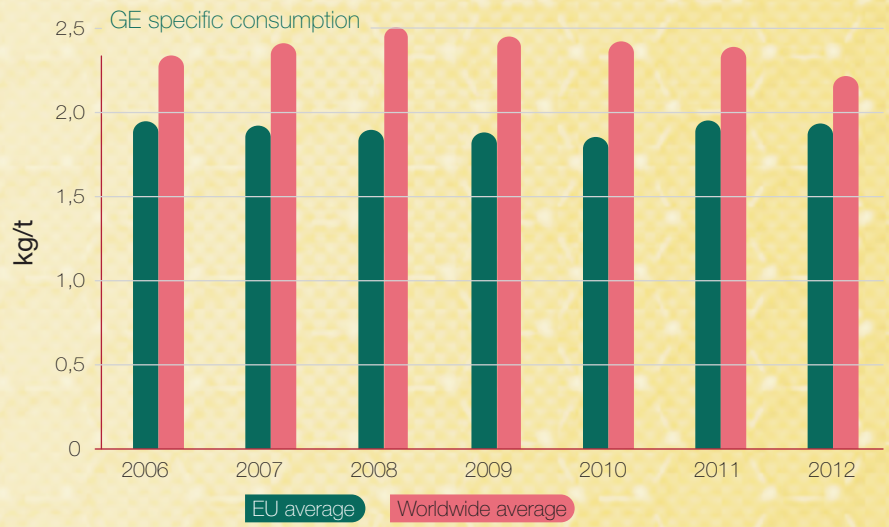
Raw material prices have increased substantially in the past few years and have had an impact on the competitiveness of the carbon and graphite, but also on the downstream user industries.

The carbon and graphite industry has major concerns with regard to the access to natural graphite, but also pet coke.

Since natural graphite had been identified as a critical raw material, increased research into its uses and applications has been launched.

In order to understand the implications of the EU's resource efficiency policies on a sector like the graphite industry it is important to understand that for example higher quality electrodes require higher energy input which however is later saved in the steel furnace due to the longer lifetime of the electrode in the steel furnace.

Highly conductive materials such as graphite can reduce energy losses in many electric applications.



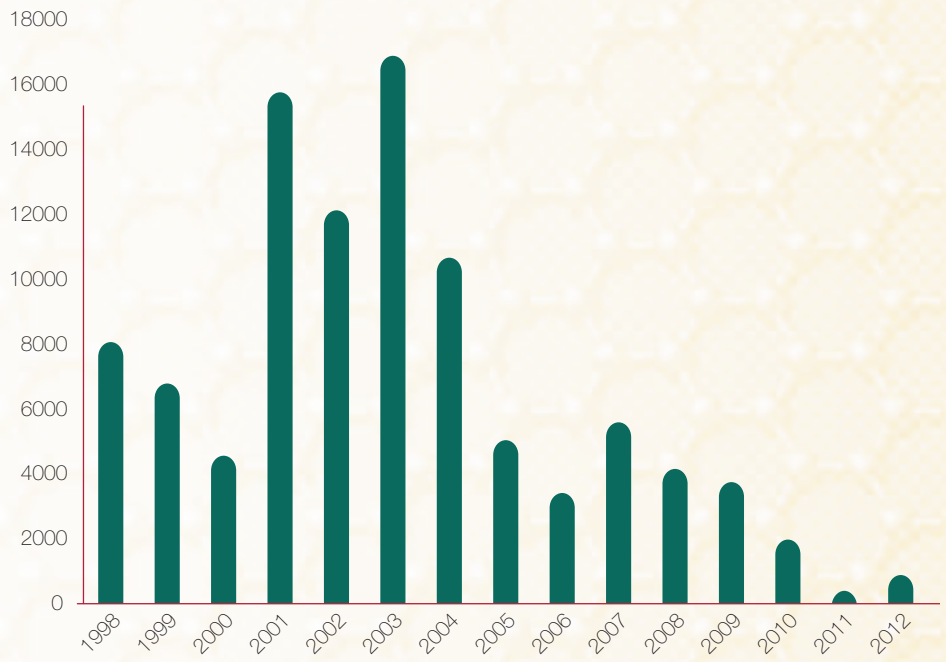
Steel and aluminium are materials which are infinitely recyclable. They fully comply with the overall EU's resource efficiency policies and so does the graphite that is required to produce these metals, be it in the form of electrodes or cathodes.

Improving Health and Safety

In order to continuously improve its sustainability, the ECGA members are striving to reduce their accident frequency and their accident severity. This is achieved through risk assessments at the workplace, continuous training and monitoring of accident rates.

Safety Performance Index for ECGA members

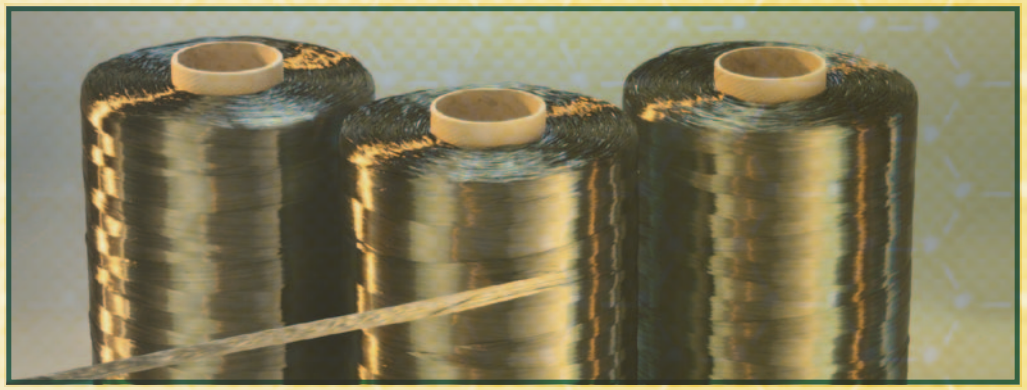
(the overall performance independently of the number of employees)



Following the REACH regulation the sector had submitted a series of REACH dossiers on the substances produced by the sector. The second wave of registrations for the tonnage band below 1000 t was under preparation through 2012 and resulted in further registrations.

At the same time, the sector as a downstream user of HT coal tar pitch assessed the dossier that had been submitted by the coal tar pitch producers and following the discussions with the pitch producers in 2011 developed its own Chemical Safety Report assessing the safe handling of coal tar pitch throughout the carbon and graphite industry.

HT coal tar pitch is an indispensable substance in the production of anodes, cathodes and electrodes and therefore crucial for the carbon and graphite industry. In the past the industry had conducted many times research into substitutes which never yielded any successes. All proposed substitutes so far have are either not delivered on performance, or on environmental, health and safety improvement. Therefore the sector is spending much time and effort on making its workplaces as safe as possible.



A contribution to Europe's climate change and energy policies

The products and their contribution to energy efficiency

The carbon and graphite sector is contributing to the goal of energy efficiency in many different ways. On the one hand through these products and on the other had through a continued strive of the operations to reduce their own energy consumption and optimisation of processes.

Cost of energy and competitiveness

Of equal importance is securing energy at competitive prices for European industries.

In this context in particular the sector, itself also a user of considerable amounts of electrical energy, has been monitoring the rising costs in the past few years which have threatened its competitiveness in comparison to its global competitors.

Parts of the carbon and graphite industry can be considered energy-intensive due to the fact that, for example, the graphitisation step in the production leading to electrodes - an integral part of all types of steelmaking - requires substantial amounts of energy in order to achieve higher longevity of the electrode in the steel furnace.

The EU's climate change policy – the ETS scheme

However, the new proposal for the European Emission trading scheme post 2013 will be another constraint on the competitiveness of the European graphite industry by imposing further costs on the enterprises which competing producers worldwide do not have to reckon with.

It is therefore crucial that energy-intensive industries which face fierce competition are given special allowances in this new scheme.

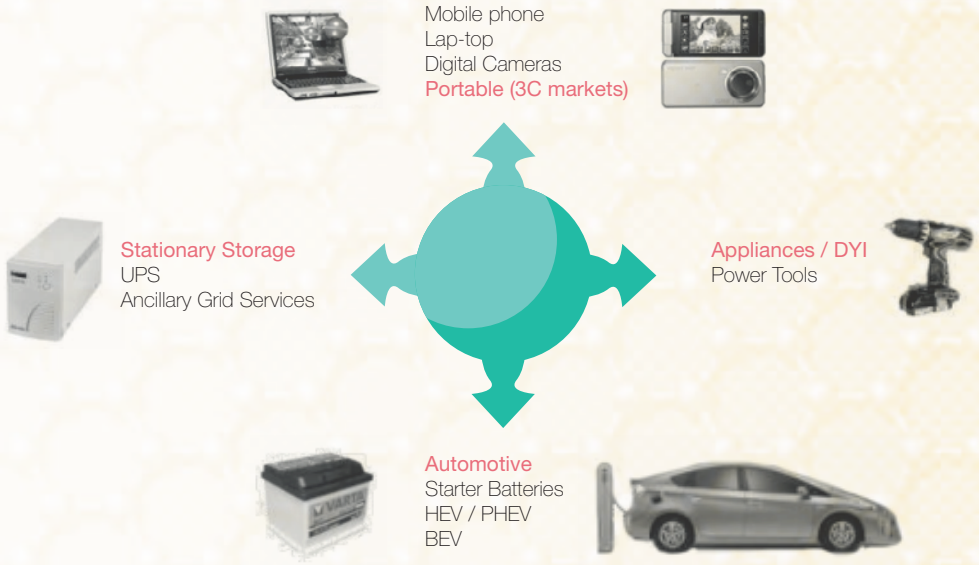
In 2012 the ECGA monitored the implementation of the new rules in the various Member States which were delayed. In 2013 the sector will engage in the revision of the Carbon Leakage List.

The potential impact of the legislation after 2013 is immense and hence the sector will continue to argue its case vis-à-vis the authorities.

The Role of Carbon in energy storage

With the increase in electric and electronic consumer goods the role of energy storage has become increasingly important. From consumer goods to industrial scale batteries have become very important and require new materials to achieve higher performance.

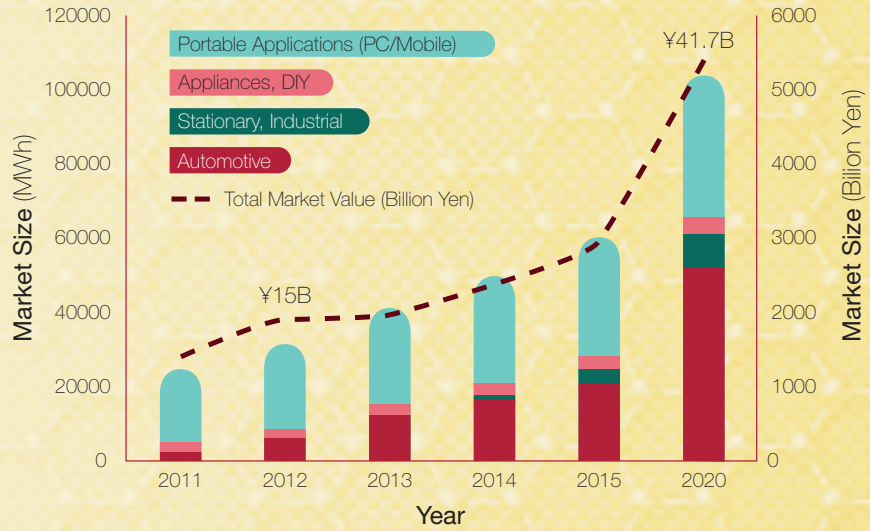
Energy Storage Markets



Source: The Role of Carbon in Lithium Ion Batteries, Dr. Emma Kendrick - Sharp Laboratories Europe, 2011

Worldwide the market in energy storage has increased exponentially and with it the potential demand for graphite.

Global Energy Storage Market Size



Sources:

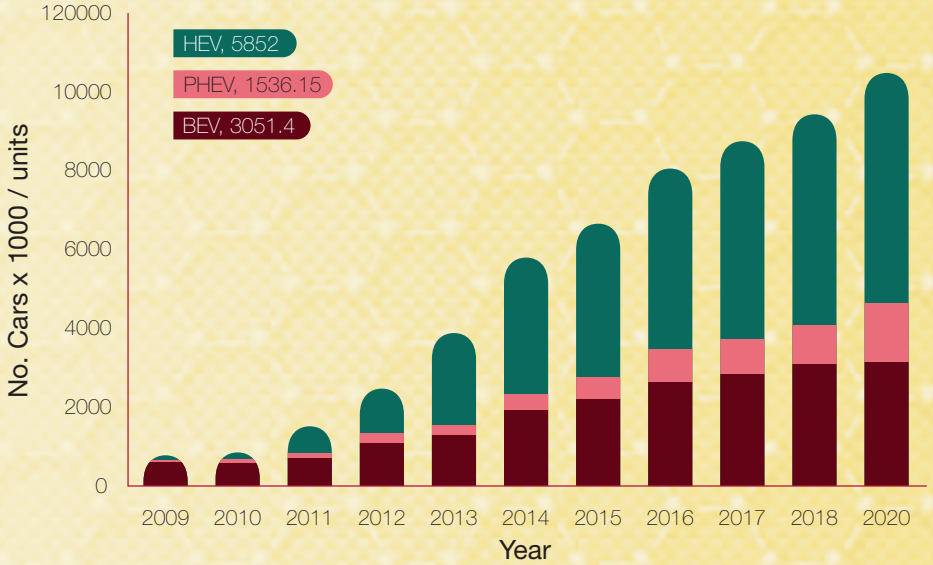
- *The figures for the scale of the automotive market were estimated in 2011 from the company production plan and from 2012 estimated by Nomura Research Institute.(March 2010)*
- *PC, mobile market scale figures estimated from Nomura report (Dec. 2010)*
- *Provisional calculation of storage cell requirements for PV installations as storage cells: 3kWh to PV 1kW.*

The Lithium-Ion Batteries

- Energy Storage Markets
- 3C
- Automotive
- Stationary
- Energy Storage Requirements
- Lithium Ion Batteries
- Electrode Development
- Graphite in Lithium-Ion Batteries

The development of the lithium-Ion battery is driven mainly by the development of electric (EV) and hybrid electric (HEV) vehicles and the intended electrification of the European, but potentially later also Asian market. The continued urbanization is fostering this development.

Electric Vehicles



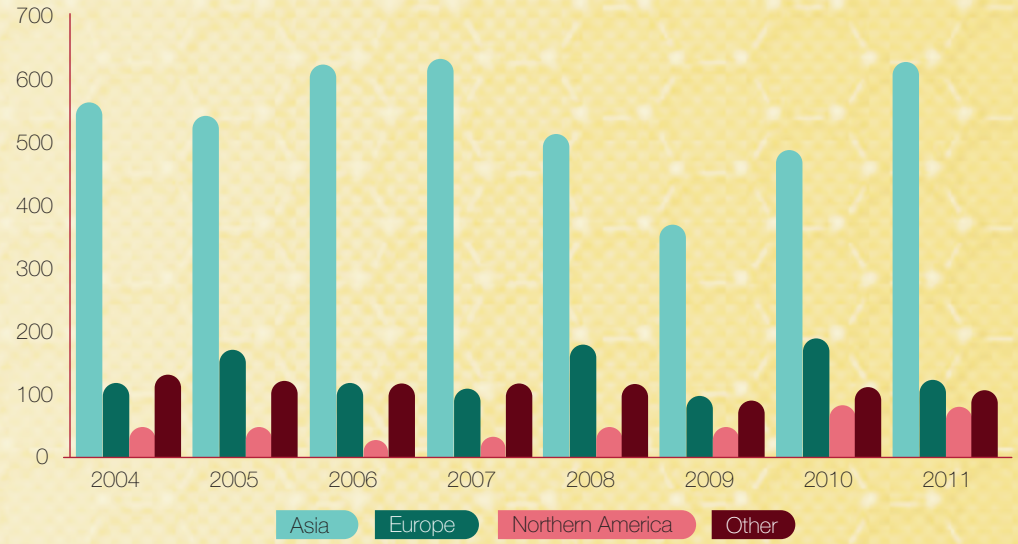
Source: Takeshita tutorial 2011 - THE 28th INTERNATIONAL BATTERY SEMINAR & EXHIBIT
Modified for % EV-type (Takeshita 2009-10)

Current and future trends in EVs and HEVs

Global demand for graphite, 2011

Source: Roskill's Natural & Synthetic Graphite: Global Industry Markets and Outlook, 8th Edition 2012

Regional demand for graphite (kt)

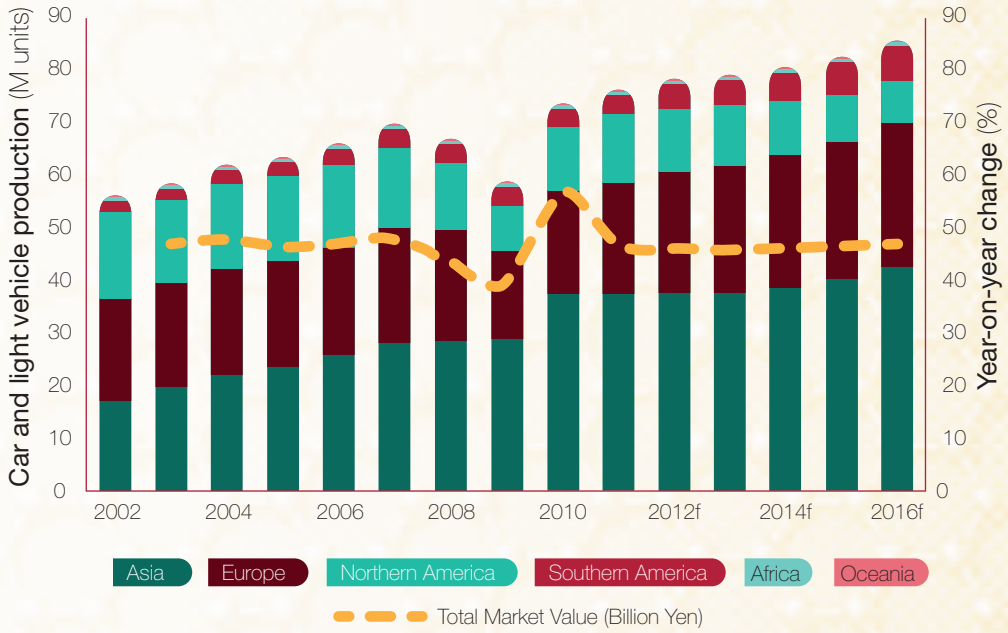


Source: Roskill's Natural & Synthetic Graphite: Global Industry Markets and Outlook, 8th Edition 2012

In 2011 the global demand for graphite in this market amounted to 2.41 Mt and the production was around 2.45 Mt.

Batteries accounted for ~85,000t of graphite demand (65% natural and 35% synthetic) By far the largest graphite demand for use in batteries comes from Asia, around 50-55%. The graphite demand was recovering throughout 2012 coming out of the global economic downturn and future demand could increase significantly if EVs and HEVs take off on a large scale.

World: Production of cars and light vehicles (M units)



Source: Roskill's Natural & Synthetic Graphite: Global Industry Markets and Outlook, 8th Edition 2012

Major uses of graphite in batteries and fuel cells

Battery type	Use of graphite	Types of graphite
Lithium-ion	Anode – main host material	Primary synthetic, spheroidal flake
Primary alkaline	Cathode - additive	Primary synthetic, purified flake and purified expanded flake
Lead-acid	Anode/cathode – additive	
Fuel cell	Bi-polar plates – main filler material	

Source: Roskill's Natural & Synthetic Graphite: Global Industry Markets and Outlook, 8th Edition 2012

Graphite in Li-ion batteries

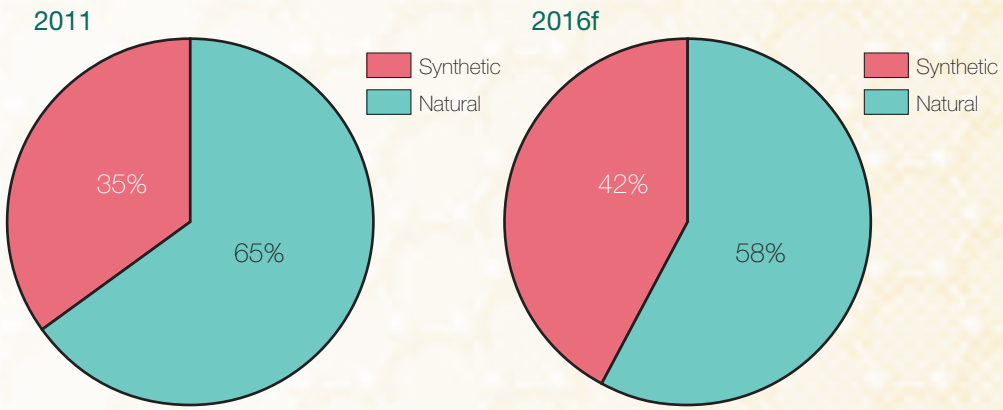
Both high purity synthetic and natural graphite can be used. Natural flake must undergo a high level of expensive processing to change it into spherical-shaped, high-purity graphite. High performing spherical graphites are increasingly produced at a price similar to those of synthetic graphite and so competition is increasing between the two materials.

Li-ion batteries are one of the few industries where natural and synthetic graphite compete. Finally, it often comes down to price and availability, which may depend on the location of the lithium-ion anode manufacturer.

In 2011 >70% of the graphite used in batteries was consumed in Li-ion batteries

The worldwide consumption in batteries is forecasted to increase to about 114,000t by 2016 mainly due to the Li-ions in consumer products, but to some extent from EV/HEV production.

Forcasted global graphite consumption in batteries, 2011 and 2016f

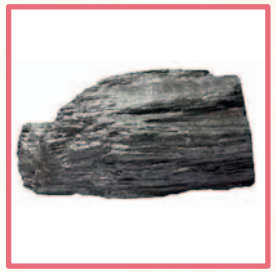


Source: Roskill's Natural & Synthetic Graphite: Global Industry Markets and Outlook, 8th Edition 2012

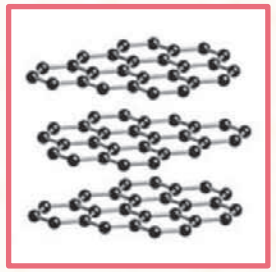
Summary

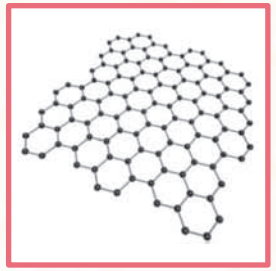
- In 2011 >70% of the graphite used in batteries was consumed in Li-ion batteries
- Graphite consumption in batteries to increase to 114,000t by 2016 mainly due to Li-ions in consumer products, but to some extent from EV/HEV production
- Accelerated growth after 2015/16 as Li-ions take an increasing market share from NiMH batteries in HEVs
- Growth in EVs/HEVs underpinned by the desire to increase efficiency and decrease emissions, both from the consumer and from governments
- Demand will increase both for synthetic and for natural graphite and is already encouraging the development new flake deposits and synthetic capacity

Graphene: the latest innovation



Graphite





Single atomic plane of carbon atoms

The IUPAC (International Union of Pure & Applied Chemistry) compendium of technology states: "previously, descriptions such as graphite layers, carbon layers, or carbon sheets have been used for the term graphene... it is incorrect to use for a single layer a term which includes the term graphite, which would imply a three-dimensional structure. The term graphene should be used only when the reactions, structural relations or other properties of individual layers are discussed."

Graphene is the first 2-dimensional material that humankind has experienced. It holds a wide array of possibilities in advancing thermal conductivity, material strengthening and lighter weight composite applications.

Graphite is a logical source to make graphene scalable. Graphene derived from natural graphite sources may allow natural graphite miners a possible entry into the synthetic graphite market and beyond.

Properties:

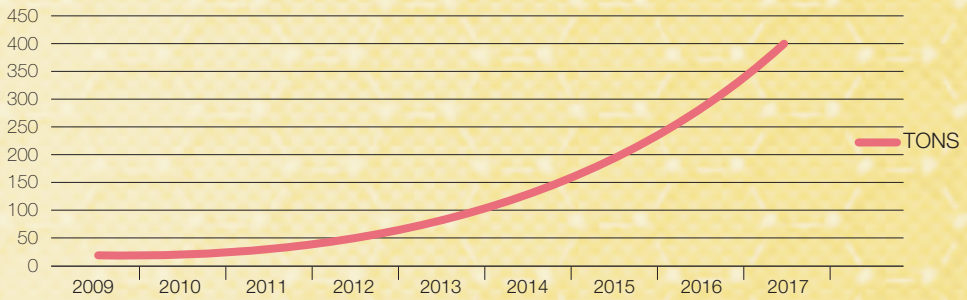
- Thinnest imaginable material
- Good(and tunable) electrical conductor
- Strongest ever measured
- Stiffest known material (stiffer than diamond)
- Highly stretchable crystal (up to 20%)
- High flexibility
- Chemical stability
- High charge carrier mobility (>106 cm2 V-1s-1)
- High transparency (97.7%)

Graphene – Fields of potential application

Electronics	Composites	Energy
Nanoelectronics / Quantum computing	Lightweight & Superstrong materials	Electrodes for batteries and supercaps
Fast photodetectors/Optoelectronics	Epoxy based composites	Fuel cells
Light emitting devices	Polymer composites	Paper batteries
Conductive inks (Printed/flexible electronics) RF tags	Bone regrowth	Replacement for Indium-Tin-Oxide (ITO)
Sensors	Siloxane base composites	Flexible and transparent solar cells

Sources: "The World Market for Graphene 2017", Future Markets, Inc. 2011; Carbon Nanotubes and Graphene for Electronics Applications: Technologies, Players and Opportunities", IDTechEx, 2010

Graphene production, 2009-2017



Source: "The World Market for Graphene 2017", Future Markets, Inc. 2011; "Carbon Nanotubes and Graphene for Electronics Applications: Technologies, Players and Opportunities", IDTechEx, 2010