DEVELOPING ENERGY-RELATED APPLICATIONS AND SOURCES OF NATURAL GRAPHITE

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Introduction

Increasing prices of crude oil and global warming is leading to a demand for new sources of energy. Graphite is a key component of many developing applications in the storage, utilization, and conservation of energy.

Applications include [1]:

Energy Production

Nuclear Solar Wind

Energy Storage

Electrical storage -

Batteries Fuel Cells Supercapacitors

Heat storage

PCM Solar towers

Energy Utilization

Composites Fire retardants Radar absorption

Printed circuits Oils spill adsorbents

De-icing parking garages, aircraft runways

Energy conservation

Thermal insulation

These new applications will require new supplies of graphite. Estimates go as high as 2-3 times the present consumption.

Production of Natural Graphite

China recognizes natural graphite as a strategic material for future development and has placed barriers in the way of its export. China produces 80% of the world supply of 1.1 million tonnes of natural graphite [2]. But of this, only about 400,000 tonnes is flake graphite and not all of that is suitable as a feed for battery and nuclear applications.

Other major producing countries are India, Brazil, Canada, North Korea and Africa. These will have to expand production drastically as China requires graphite for domestic applications, especially in electric vehicles and nuclear power stations.

Developing End Uses

Energy Production

Nuclear energy is the most likely replacement for power plants operated by fossil fuels. Pebble Bed Modular Reactors (PBMR) are promising because they can be built in small modules that can service a limited area. But they can be ganged up to supply major cities. The design is fail-safe.

Because they are modular, the permitting process should be faster and easier.

Installation and operating costs are quoted as lower than conventional plants.

These reactors use uranium fuel granules embedded in graphite. Natural graphite content may be 25% or higher. At this level, a small (110 MWe) reactor requires 100 tonnes of natural graphite for commissioning, plus 19-35 tonnes annually. China has plans to add 104,540 MWe of nuclear generating power. World-wide, 321,488 MWe of generating capacity is planned. If all these reactors are PBMR, this would require 292,000 tonnes of high purity natural graphite for commissioning and 55,500-102,200 tonnes per year for replacement pebbles.

Researchers at West Virginia University estimate that 500 new 100 GW pebble reactors will be installed in the US by 2020 with estimated graphite requirement of 400,000 tons.

Other Developing Energy Production Applications

Solar

In Australia, solar power towers are being built with a graphite target/collector. This holds high temperature heat that can be used to drive a boiler even during the night time.

Graphene is transparent to radiation over a wider range than the indium tin oxide (ITO) presently used as clear electrode in solar cells. ITO costs close to $900/kg. Reserves of indium are forecast to last no more than 10 years.

Wind & Tidal

Wind turbine blades are increasingly being made from carbon composites, because of superior strength and stiffness.

Graphite nanoplatelets for reinforcing polymers are made from expanded graphite salt. These have similar properties to carbon nanotubes but are available in industrial quantities at much lower cost. Another advantage is that platelets reinforce 360^0 in the plane whereas fibers reinforce uni-directionally. Multiple layers must be applied at various angles to give an isotropic planar composite with a reduction of effective strength and stiffness by a factor of 4-6.

The ultimate platelet reinforcement is graphene, available only in laboratory quantities at present, but has potential to be made industrially.

Developing Energy Storage Applications

Batteries

Natural graphite is a common material in batteries. It is used in most battery types to add electrical conductivity to electrode materials that are non-conductive.

The fastest growing application is the use of graphite in lithium-ion cells. These were originally used in button cells, but grew to be used in lap top computers, and lately in portable power tools. The greatest promise for growth is in electric powered vehicles – hybrids (HEV), plug–in hybrids (PHEV) and all electric vehicles (EV).

These developments are triggered by the high cost of fossil fuels and the need to reduce carbon emissions.

Graphite is used in the anode of rechargeable Li-Ion batteries. Lithium is intercalated between the graphite layers when the battery is charged. On discharge, the LiC_6 compound breaks down and lithium ions pass into the electrolyte and thence to the cathode.

Since Li-Ion batteries have superior properties to competitors, they are the power source of choice for electric vehicles.

TRU Group estimates the demand for lithium in batteries to reach 21,000 tons by 2020. Since 24 times as much graphite is needed for use in Li-Ion anodes, demand for graphite would be 500,000 tons.

Other Electrical Energy Storage Applications

Fuel cell bipolar plates are made from graphite, as a flake filler in an injection molded polymer at levels up to 80% w/w to give the necessary electrical conductivity, or are press molded from expanded graphite foil.

The bipolar plates account for 80% of the fuel cell stack weight. The stack in the Honda FCX weighs 67 kg. 1 million FCX vehicles will need 47,000 tons of graphite.

Freedonia estimates the number of portable fuel cells at 9.95 million units by 2018. Graphite needs equal 468,000 tons.

Supercapacitors confer the benefits of very fast charging and discharging. Thus, they complement Li-Ion batteries in electric vehicles, by giving rapid acceleration capabilities.

Thermal Energy Storage Applications

Phase Change Materials (PCM) are being used to store heat in building applications. A problem with PCM is that the solid salts tend to settle out, reducing efficiency. Expanded graphite occludes the salts in both liquid and solid phases and prevents settling out. The graphite also aids in transferring heat because of its high thermal conductivity.

Energy Utilization

Composites are made with flake and expanded graphite. Expanded graphite flakes have a very high aspect ratio thus give better reinforcements for polymers. The ultimate flake with the highest aspect ratio is graphene. Combinations of graphite flakes with carbon fibers overcome their isotropy. Likewise, carbon fibers overcome the lower impact strength of flakes alone. This approach is used commercially in the combination of glass fibers and mica flakes in thermoplastic polyesters.

Fire retardants. In China, unexpanded graphite salt is used in fire-stopping to prevent fire spreading through openings from one room to another. When exposed to fire, the salt expands and seals off the opening, forming an insulating char.

Radar. Graphite composites are believed to be a component of the radar- absorptive skin of stealth aircraft.

Printed circuits are being made experimentally with inks containing electrically and thermally conductive expanded graphite flakes.

Oil spill remediation by the use of expanded graphite is proposed. Expanded graphite absorbs up to 80 times its own weight of oil but only 0.5% of water. Other absorbents are not selective. Oil can be recovered and the graphite re-used.

Conductive concrete can be made by incorporation of graphite. By passing current, parking and runway areas can be made ice-free.

Energy conservation

Thermal insulation can be improved by the incorporation of graphite flakes to reflect IR. BASF has patented the use of 2-8% graphite flakes in its Neopor expanded polystyrene (EPS) thermal insulation boards. This product gives 20% better insulation than conventional EPS.

About 10 million tonnes of EPS are produced annually.

At 5% level, graphite needs would be 500,000 tonnes

Production of Natural Graphite

USGS reports mine production of graphite for 2009 of 1.13 million tonnes worldwide. Growth in consumption has been 5% p.a. and price has doubled from 2004 to 2010

China produced 800,000 tonnes in 2009.

India mined 140,000 tonnes but only 2,000 tonnes are exported.

Brazil mined 77,000 tonnes in 2009, exporting about 20-25%.

Canada mined 27,000 tonnes. 72% is exported, 50% to the US. ***Timcal***, division of Imerys is the sole large scale producer. It is reported to be coming to the end of its mine life.

Eagle Graphite has a small pilot plant in British Columbia, with capacity of 3,000 – 8,000 tons p.a..

Northern Graphite has a pilot plant in Eastern Ontario. Its mine is unusual in having the very large high purity flakes preferred for use in expandable graphite. Only 10% of the property has been drilled, but this contains over 30 million tonnes of graphite. (indicated & inferred reserves)

USA has no graphite mines, only importers/processors.

Conclusions

There is an urgent need to develop new mines for natural graphite for these major developing applications.

Geographically, the shortage will most affect those countries with poor resources of natural graphite, but where the growth markets are most likely to develop:-

USA EC Japan S. Korea

The largest graphite producer, China, has shown its strategy to keep graphite for its own use in developing nuclear reactors and electric vehicles.

Table 1. Potential Large Markets for Natural Graphite

Application	Potential Demand, kilotons
EPS Insulation	500
Li-Ion Batteries	500
Fuel Cells	468
PBMR nuclear plants	400

References

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[3] Olson DW. Graphite (Natural). US Geological Survey. Minerals Commodity Summary: Graphite 2010.

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