The Role of Borates in the European Green Deal and Digital Transformation

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INTRODUCTION

The European Green Deal is roadmap for making the EU economy more sustainable. It calls for the EU to reach climate neutrality by 2050 and addresses many aspects leading to a more efficient economy, including transportation, clean energy, agricultural efficiency, energy-efficient building practices, and digital transformation. Borates and materials made from them are integral to many technologies required to reach the goals of the European Green Deal. Some of these are discussed briefly here.

BORATES

The term borate generally refers to oxide compounds of element boron. These occur in nature as a variety of borate minerals. Borates are widely distributed in nature and can be found everywhere in natural waters and soils. In fact, not a single plant can grow without the presence of boron. Although ubiquitous in nature, large economically viable deposits of borate minerals are rare. Borate minerals may be used directly in some industrial processes or converted to refined boron compounds that have a vast range to uses. Borates have properties that are essential to both the manufacture and performance of many products important to modern society, including flat-screen displays for televisions, computer monitors and mobile devices, kitchenware, ceramic glazes and enamels, industrial fluids, lubricants, high-strength alloys, batteries, capacitors, energy-saving fiberglass insulation, and highly durable building materials. Borates are also important agricultural micronutrients that contribute to sustainable food production.[1]

TRANSPORTATION

The European Green Deal promotes aggressive measures to reduce greenhouse gas emissions from transportation, working towards zero emissions sometime in the 2030s. This will require extensive investments in electric vehicles and alternative fuels, such as hydrogen.

Electric vehicles

The Green Deal encourages deployment of electric vehicles and their infrastructure with an objective to allow every family in Europe to be able to drive an electric car. Borates are used in many automotive parts, both electric and conventional, with electric vehicles requiring the greatest amounts. Some components of electric vehicles where borates are found are listed here.

- Magnets for electric motors and braking systems
- Li-ion battery additives and components
- Capacitors
- Lubricants
- Hydraulic fluids
- Polymer additives (wire & cable and automotive interiors)
- High strength steel
- Thermal and acoustic insulation
- Body panels

Magnets. Boron is an essential ingredient in NdFeB magnets. This is the most common type of magnet used in the motors of electric and hybrid-electric vehicles as they possess the most suitable properties including high strength and stability. These magnets are also used in regenerative braking systems and other components of green vehicles.

Batteries. Boron compounds, such as borate esters produced from boric acid, are important electrolyte additives for lithium ion batteries. These are used to enhance performance parameters, such as cycle life. In addition, borate modification of graphite and graphene anodes further improve safety and performance of Li-ion batteries. Recent studies show that boron modification of Li-ion battery cathodes greatly improves their stability. Solid state batteries also show promise for improving the safety, range and stability of EV power systems. This is an area of active research in which boron materials figure prominently.

Supercapacitors. Advanced electric vehicle designs may include supercapacitors in place of or in combination with batteries. Supercapacitors are energy-storage devices that offer high power density, almost instant charging and discharging, and longer lifetimes than Li-ion batteries. While technologies for producing efficient supercapacitors for transportation are currently evolving rapidly, most new supercapacitor innovations require boron materials in their construction.[2,3]

Lubricants. 20% of world energy consumption goes to overcome friction. Up to 40% of this energy can be saved using advanced lubricant technologies. One-third of the fuel energy in conventional passenger vehicles is used to overcome friction in the engine, transmission, tires, and brakes.[4] Although this loss is substantially lower for electric vehicles, lubricants still play a major role in improving their energy efficiency. Borates are traditionally added to automotive lubricants to reduce friction, wear, and corrosion. In addition, advances in lubricant technologies utilize a variety of boron compounds to enable the next generation of highly efficient lubricants.[4,5]

Hydraulic fluids. High performance brake fluids, such as DOT 4 and 5.1, are largely composed borate esters, which are produced from boric acid. These are used to meet increasingly demanding vehicle performance standards. Boron compounds are also added to automotive lubricants to reduce friction, wear, and corrosion.

Polymer additives. Adequate flame retardancy and thermal stability are requirements of polymers used in both electric and conventional vehicles. These include wire and cable insulation, jacketing and sheathing compounds, upholstery, dashboards, trim and other parts. Borates, especially zinc borate, is used as a fire-retardant synergist and thermal stabilizer in these materials. It is also used to improve the safety of electrical connectors made from engineering polymers. Zinc borate is currently manufactured in the EU from imported boric acid.[6]

High strength steel. Boron is used to make ultra-high strength steel alloys. These have exceptional weight to strength characteristics and are increasingly used by automakers, including those in the EU, to reinforce the passenger cells of vehicles. This allows vehicles to pass required crash tests while still being light enough to achieve fuel economy standards. Lightweight performance of structural components is especially important in electric vehicles.

Thermal and acoustic insulation. Electric vehicles utilize various kinds of materials to insulate against heat and noise. These often include insulation fiberglass and nonwoven cellulosic materials. Borate is an essential ingredient in insulation fiberglass (IFG) used in many vehicles. Addition of borate to this glass formulation is necessary to achieve for both performance and manufacturing requirements. IFG typically contain 4-8% B_2O_3 by weight which comes from disodium tetraborate pentahydrate added to the glass batch. In addition, nonwoven insulting pads and gaskets used in various areas of vehicles are often treated with borates to improve their thermal stability and durability.

Light weight body panels. Many electric vehicle designs utilize fiberglass reinforced plastic parts, including body panels. These are typically reinforced using textile fiberglass. Forms of textile fiberglass commonly used in automotive applications may contain up 10% B_2O_3 by weight.

CLEAN ENERGY

The Green Deal includes a commitment to developing renewable energy sources and draws attention to the importance of critical raw materials needed for the transition to a low carbon, resource-efficient economy. Encouraged are non-fossil fuel energy sources and alternative fuels including hydrogen and biofuels.

Hydrogen economy. The Green Deal commits resources to development of low-cost hydrogen production. Attention must also be directed to technologies needed to store and transport hydrogen. A major problem associated with hydrogen is its very low density making it impractical to distribute as a gas. Compressing and liquifying hydrogen are options, but these consume a substantial amount of energy the hydrogen contains. Borates are used in one of the competing technologies for hydrogen storage to help enable the hydrogen economy. In fact, boron compounds can store more hydrogen by weight and volume than any other competing materials. Sodium borohydride, manufactured in the EU from imported boric acid, contains 115 grams of H_2 per liter at room temperature compared to just 71 g/L for pure liquid hydrogen (–253 °C) and can readily release this hydrogen on demand using currently developed catalyst systems. Ammonia borane (NH_3BH_3), a stable solid at room temperature, contains twice as much hydrogen per liter (146 g/L H_2) compared to pure liquid hydrogen. While some hurdles remain to widespread application of boron materials in hydrogen storage, such as development for efficient spent fuel recycling methods, the remarkable hydrogen densities achievable only with boron-based materials make them a relevant option for future hydrogen energy solutions.[7]

Wind energy. Modern wind turbine generators rely on borates in a number of ways. These generators use large permanent magnets. These are typically boron containing NdFeB magnets. Because the large wind blades of these turbines need to be extremely strong and lightweight, they are generally reinforced with textile fiberglass (TFG) containing up to 10% B_2O_3. Wind turbines also have large mechanical transmissions with gears and other moving parts subject to extreme wear. This is compounded by the fact that they sit on towers, often in hostile operating environments, making routine maintenance difficult. In order to prolong service life and minimize maintenance, special high-pressure greases are needed. These often contain borate additives, such as potassium tetraborate, to achieve performance requirements.

Solar Energy. Solar power is crucial to delivering the European Green Deal. About 15% of Europe's total power requirements is expected to come from photovoltaics (PVs) by 2030 and increase further by 2050. The most common types of PVs deployed to meet the growing demand for solar energy in Europe are based on boron-doped crystalline silicon. The boron compounds used to manufacture PVs are made from boric acid. In addition, since borosilicate glass is highly durable and has the required thermal and optical properties, it is often used as cover glass to protect PVs from environmental damage.

Nuclear power plant operation and safety. Although not always included among green alternative energy sources, it is unlikely that the EU's goal of becoming climate neutral by 2050 can be achieved without a substantial contribution from nuclear power. Nuclear power plants currently produce one quarter of the electricity consumed in Europe. *Borates are critical to both the operation and safety of these power plants*. Boron is unique among the light elements in having an exceptionally high cross section for neutron absorption. This property is utilized in many vital aspects of nuclear power generation, including reactor control methods, radiation shielding, and critical emergency shutdown systems. Nuclear power plants maintain stockpiles of borates in various forms for rapid use in the event of a reactor accident. Injection of concentrated borates into the reactor immediately halts the fission process to render the reactor safe. Boric acid, in particular, is integral to the operation of European

pressurized water reactors (EPWRs). Borates are also required in the glass compositions used to vitrify nuclear waste. Borates have no practical substitutes in these applications.

FARM-TO-FORK

Agriculture. All plants require boron and a deficiency of this element results in low crop yields and various plant diseases.[8,9] While boron is naturally present in all soils and natural waters, it may occur at concentrations that are suboptimal for important food crops. In fact, suboptimal boron is one of the most significant micronutrient deficiency problems facing global agriculture. In the EU, boron deficiency is especially pronounced in Northern Europe and Scandinavia, including Denmark, Finland, Germany, Norway, and Sweden. Soils in other parts of the EU may be locally deficient for optimal growth of certain crops.

Optimizing crop yields per hectare contributes to preserving the affordability of food while generating fairer economic returns in the supply chain, a central goal of EU Farm-to-fork strategy. Crops that commonly benefit from boron micronutrient application include apples, olives, rapeseed, sugar beets, sunflowers, and wine grapes, to name only a few. Substantial amounts of boron micronutrients are currently used by European agriculture, all of which must be imported. Boron is also important to sustainable forestry and can play a role in afforestation efforts promoted by the Green Deal.

Another aspect of boron use in agriculture is in farm equipment. Machine parts that are subject of high wear and abrasion, such as harvester and tillage blades, are often boronized. Boronization, also called boriding, is a process that uses borates to impart an ultrahard, wear-resistant surface layer on steel and other metal parts. This improves the efficiency of agricultural processes by extending the life of farm equipment. Boronized parts also have enhanced corrosion resistance.

RENOVATION WAVE

The Renovation Wave is a component of the EU Green Deal that addresses improvement in the efficiency of building practices. Borates have an established role in existing energy-efficient and sustainable building materials and offer solutions for building materials of the future.

Thermal insulation. A substantial portion of the energy used by residential and commercial buildings is for heating. Adequate thermal insulation can greatly reduce energy loss. Insulation fiberglass (IFG), a type of borosilicate glass (4-8% B_2O_3) that is currently manufactured on industrial scale in Europe, is highly energy efficient. Although glassmaking is often regarded as an energy intensive industry, IFG typically saves all of the energy required to produce it within a few months in service and continues to conserve energy for years afterwards.

Forestry products. A central goal of the Green Deal is to approach a circular European economy. Extending the service life of building materials contributes greatly to this goal. Sustainable building practices frequently entail extensive use of renewable forestry products, such as oriented strand board (OSB) panels, glue-laminated timber (glulam) I-joints, and cross-laminated timber (CLT) structural beams. Although these composite building materials have excellent engineering properties, they suffer from biodegradation, especially from decay fungi, limiting service life. Borates greatly enhance the durability of wood and wood composite building materials. It is now common practice to incorporate borates into these materials during manufacture to dramatically improve their durability and resistance to insect and fungal attack. Tens of thousands of tons of borates are currently used in such applications on a global basis and decades of data now demonstrates their efficacy. Borates dramatically extend the service life of forestry products allowing for greater economic efficiency.[10, 11]

Agrofiber composites. Among the next generation of renewable building materials are agrofiber-based composites. These can be produced from waste biomass and traditional farm waste, such as wheat straw. However, biomass derived building materials can be susceptibility to decay. Borates offer a proven solution to this problem.

DIGITAL TRANSFORMATION

The Green Deal addresses the role of digital technologies in achieving a sustainable future for the EU. While much of this initiative is directed towards information technology, artificial intelligence, communication systems, and other computer advancements, attention also needs to be given to the raw materials required to physically enable these technologies.

Electronic components. Borates play a critical role in digital technologies and communications systems. The largest use of borates in this area is in flat screen display panels for televisions, computer monitors, smart phones, and other mobile devices. Most modern digital displays rely in a component known as thin film transistor (TFT) glass. This is a high dielectric glass having unique performance characteristics made possible by incorporation of 8-10% B_2O_3. Borate is essential to both the performance and practical manufacture of TFT glass. In addition, electronic circuit boards are constructed with boron-containing textile fiberglass and semiconductors other computer parts that require the use of borates.

A EUROPEAN INDUSTRY

Borates are identified as critical raw materials needed to meet the EU's goals for a climate neutral, energy-efficient economy. Numerous specialized borate products are currently manufactured within the EU. These include high purity grades of borax and boric acid used in the nuclear and pharmaceutical industries, fertilizer borates, sodium metaborates, sodium pentaborate, disodium octaborate tetrahydrate, potassium borates, ammonium borates, zinc borate, boron carbide, boron nitride and others. These products have a wide range of important applications in energy, agriculture, electronics, metallurgy, adhesives, defense and in nuclear power generations and safety. Currently these European borate products are produced using borate feedstocks that must be imported from outside Europe.

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