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Renewable Energy Technologies

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Key Facts

- Inexhaustible and readily available energy can be harvested by Renewable Energy Technologies from sources such as the sun, ocean and wind without the environmental degradation and depletion of finite resources resulting from traditional methods of energy production.
- Renewable Energy Technologies provide promising solutions for mitigating the release of man-made GHGs such as carbon dioxide (CO_2) and methane (CH_4) into the atmosphere.
- The reliable availability of renewable energy sources helps planning and reduces risks through more predictable energy prices.
- Life Cycle Assessments (LCA) and similar methodologies, when applied to product development, aid in recovering minor metals in Renewable Energy Technologies.
- The deployment of Renewable Energy Technologies on a mass scale across the globe will create new jobs through the development of new supply chains and infrastructure.

The Renewable Energy Outlook

According to the OECD / IEA 'Medium Term Renewable Energy Market Report 2013' the share of renewables in total energy production will increase across all regions towards 2018. Total renewable generation equals the sum of bioenergy, hydropower (including pumped storage), onshore and offshore wind, solar PV, concentrating solar power (CSP), geothermal, and ocean technologies.

On average, Earth's surface continuously receives more than 1000 W/m^2 of solar energy. Photovoltaic (PV) materials convert solar energy to electricity, with the conversion efficiency (CE) of a material measuring efficiency of conversion.

Summary

Climate change from man-made emissions is a threat to our current way of life. Sustainable and secure sources of energy will be key for offsetting emissions and reducing the potential consequences.

Renewable energy technologies have grown massively in the last decade, with technology breakthroughs, support from policy makers and development of infrastructure.

Photovoltaic (PV) panel manufacturing has been transformed into a mass production industry in the last five years, in thin-film technologies, as well as in Si-based technologies (thick-film), which currently dominate the sector. Wind energy turbine installations have also grown massively in number in recent years, with an increasing use of Rare Earth Element (REE) permanent magnets for efficiency.

Minor metals* are important raw materials in the production of photovoltaic systems, wind turbine magnetic motors and structures, and will remain so, even with technological advances, due to their unique technical properties. Many minor metals are described by governments and policy makers as 'strategic' or 'critical' due their exceptional characteristics, certain supply constraints and importance for ensuring a sustainable future.

Did you know that one hour of direct sunlight is equivalent to our global annual energy consumption ?

Source : University of Toronto

Wind power density ranges from Class 1 (the lowest) to Class 7 (the highest). Good wind resources (with an average annual wind speed of at least 20 kilometres per hour) are found in many locations. Wind speed is a critical feature of wind resources, because the energy in wind is proportional to the cube of the wind speed. In other words, the stronger the wind, the greater the power.

*The term 'minor metals' encompasses a vast array of metals, including tungsten, titanium, cobalt and molybdenum, to name just a few. Traditionally, minor metals were those metals not traded on formal exchanges, although cobalt and molybdenum are now traded on the London Metal Exchange, along with base metals. Minor metals usually have a relatively low annual production volume, compared to base metals, and very specialist, and often high technology, applications.

The Challenge

To create secure, renewable sources of energy, thereby decreasing dependence on fossil fuels and reducing CO_2 emissions

Carbon dioxide (CO_2) is the largest contributor to Earth's Green House Gas (GHG) inventory, with levels rising dramatically since the start of the Industrial Revolution. These emissions have increased average temperatures, putting the planet at risk from adverse weather events, rising sea levels and less secure food supplies, amongst other serious and destructive effects.

Fossil fuel combustion produces the majority of man-made CO_2, with approximately 25% of all GHGs coming from electrical power generation. Concerns about CO_2 in particular are therefore driving demand for low-carbon and carbon-free sources of energy. Government decarbonisation strategies around the globe reflect the urgency and importance of this issue to society. Development of supply chains and infrastructure, and their associated job creation, is also a key priority for government policy.

Renewable energy resources help to create a secure supply of energy for countries that do not have their own reserves of fossil fuels. Renewable resources mitigate risks of supply disruption from natural disasters or political instability, as well as insulating against price fluctuation.

Global perceptions of renewable energy have shifted considerably over the last decade. Continuing technology advances and rapid deployment of an array of renewable energy technologies have demonstrated that their potential can be achieved.

Renewable energy provided an estimated 19% of global final energy consumption in 2012. Of this total share, modern renewables accounted for approximately 10% , with the remainder coming from traditional biomass* (Renewables 2014 Global Status Report) However, although promising, these figures need to increase significantly if they are to tackle and mitigate climate change, as well as to cope with a rapidly growing global population.

The Solution

Increase the share of renewable energy resources: with solar, wind, geothermal, (modern) biomass and hydropower all classed as renewable energy sources.

Energy demand from non-fossil sources has grown steadily since the late 20th Century and is estimated to more than double in the period to 2050, with the contribution met by solar energy increasing more rapidly.

*Solid biomass, including fuel wood, charcoal, agricultural and forest residues, and animal dung, that is usually produced unsustainably and typically used in rural areas of developing countries

Where minor metals help

Photovoltaics (PV)

Minor metals used in photovoltaics – **silicon, indium, gallium, cadmium, tellurium, selenium**

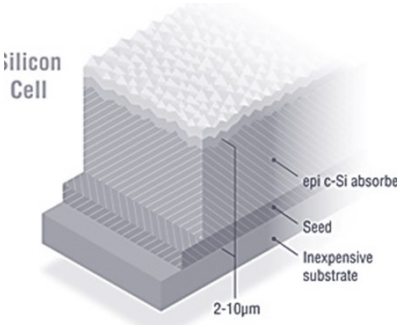

Figure 1 Source: National Renewable Energy Laboratory

Photovoltaic cells (PV) are made up of two semi-conducting layers. One layer containing a positive charge and the other a negative. Photons from sunlight excite electrons into a higher state of energy allowing them to act as charge carriers for an electric current.

The main commercial PV materials today are:

- Crystalline silicon (c-Si)
- Amorphous silicon (a-Si)
- Cadmium telluride (CdTe)
- CIGS (or CIS), an alloy of copper (Cu), indium (In), gallium (Ga) and either selenium (Se) or sulphur (S)
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Technologies based on crystalline silicon use relatively thick and rigid wafers in solar panels, whilst others are thin-film technologies.

Silicon-based cells

Crystalline silicon-based cells dominate PV technology, accounting for nearly 90% of the total global PV market in 2011 (NREL 2011). The main reasons for this are the relatively low price of silicon-based solar cells and a more complex manufacturing process for CIGS solar cells which has to date impeded mass production. Figure 1 shows the typical layers found in a silicon solar cell.

- PV technologies generate jobs throughout the value chain in manufacturing, installation, operation and maintenance of equipment
- PV can be easily installed in remote sites, bringing electricity to underdeveloped regions, vastly improving quality of life
- Small scale PV on domestic roofs localises energy supply and reduces the need for transport / pipelines, as associated with fossil fuels

Share of Market

Indium: PVs make up 8% of the main end uses (2012) (Indium Corporation)

Gallium: In 2010, PVs (CIGs) accounted for 8% of the overall demand for gallium

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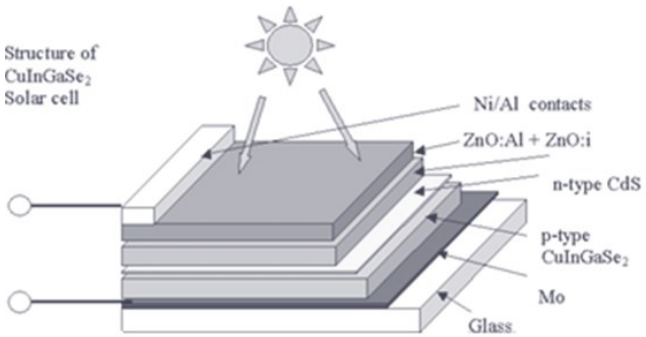
Thin-films

The alternative, thin-film technologies, including CIGS are slightly less efficient than silicon-based cells, but they have the advantage of being lightweight, flexible and durable and can be integrated directly into building materials. Thin-films require less functional material, are manufactured on continuous rolls and can be deposited on to flexible substrates. Apart from CIGS, thin-film technology uses cadmium telluride (CdTe). As of 2011, CdTe accounted for roughly 10% of the total solar PV market, while CIGS market share was still closer to 1% of the market. Figure 2 shows the structure of a CIGS solar cell.

Figure 2 shows a CIGS solar cell



Solar Panels on domestic roofs

For several years, PV panels, mostly thick-film technology, have been appearing on domestic roofs

Benefits of solar panels according to The Energy Saving Trust are:

- Cheaper bills
- Income earned for the electricity generated
- Excess electricity sold back to the grid
- Reduced carbon footprint

As of January 2014, 500,000 houses in the **UK** had solar panels (Department of Energy and Climate Change)

In July 2013, **Germany** set a world record for electricity produced from solar photovoltaic systems. They had between 1.3-1.4 million systems producing 23.9 GW of power.

One solar system is installed every 4 minutes in the **USA** according to Green Tech Media Research

Where Minor Metals help

Wind turbines – Magnets and Construction

Minor metals used for wind energy - **chromium, manganese, molybdenum and rare earths: neodymium and dysprosium**

Wind turbines are normally grouped together into wind farms, either onshore (which includes along the coast) or offshore. Generally wind turbines produce more energy offshore due to the more constant and stronger wind. Nevertheless, land-based turbines still account for 98% of all installed capacity. Industry and academia agree that the in the future there will be a focus on larger turbines situated offshore.

The basic principle behind wind turbines is that kinetic energy in the form of wind moves the blades, driving a generator. REEs neodymium and dysprosium are used in the generator in permanent magnets. Permanent magnets reduce the size and weight of the generator. Slow-speed turbines generate more electricity at slower wind speeds, but these require larger permanent magnets, which consequently require more REEs.

Wind turbine technology is divided between permanent magnet and electromagnet generators and between geared and gearless transmission. Studies have estimated that 20% of global wind turbine installations between 2015 and 2020 are likely to use permanent magnets, rising to 25% for the years 2021-2030.

The other minor metals mentioned: chromium, manganese and molybdenum are to be found in the steel used to build the turbines, in order for them to withstand sometimes extremely hostile and corrosive environments, particularly in offshore installations where salt spray and high winds test the wind turbines to the maximum.

The use of REEs in permanent magnets is the highest value market sector, and is forecast to increase. The use of Nd-bearing magnets in large wind turbines is a large contributor to this trend. Source: Critical Metals Handbook

Facts from the World Wind Energy Association

- Wind power meets close to 4% to the global electricity demand
- In total, 103 countries are today using wind power on a commercial basis.
- WWEA predicts a wind capacity of more than 700,000 MW as possible by 2020.

Looking Forward

Minor Metals in the Renewable Energy Technology supply chain

New technologies capable of meeting society's environmental requirements have begun to challenge the current power generation practices across multiple industries. Managing and monitoring the life cycles of new products and their materials will present new challenges, as well as opportunities.

Life Cycle Assessments

Life Cycle Assessments (LCAs) provide an opportunity to reduce the environmental impact of a product's supply chain, as well as its life cycle. This methodology measures the material and energy inputs, and the environmental releases of a product throughout its entire life cycle. Some of the largest companies in the world are currently developing LCA evaluation tools with their software partners. The LCA methodology will continue to develop as new techniques are created, and more data is captured for evaluation.

The use of Gallium may increase in the future due to the increased interest in concentrator photovoltaics (CPV). In this technology, sunlight is concentrated on to solar cells. Developments such as improved conversion efficiency will help this technology to become a significant part of the PV market by 2016.
Source: Critical Metals Handbook

Cradle-to-Cradle & Reclamation

A fairly recent approach to product development, cradle-to-cradle, focuses on a product's entire life cycle. It sets out understand and better plan not just for the creation but also for the disposal of products. This is significant because the greater the integration of the entire supply chain, the more chance there is of creating a product with reduced environmental impacts, and decreased costs. For example, if the product design phase considers the end-of-life-cycle disposal process, there is a greater chance of recovering recyclable materials. Given that many of the materials used in renewable energy technologies can be difficult to obtain or expensive, product life cycle planning presents an opportunity to recycle and recover these materials. Therefore, new models for product development, distribution and end-of-life-cycle product recovery will be essential for reducing environmental degradation caused by mining, energy use and waste disposal.

Although the use of Renewable Energy Technologies shows promise for reducing the transmission of man-made greenhouse gasses into the atmosphere, it is equally important to consider the supply chains and lifecycles of these technologies. Without an improvement in these systems, society will experience more difficulty achieving its social and environmental goals.