Center for Energy and Value Issues
CEVI

August 2014 – Volume 6, Number 2

- **From the CEVI board: an article, a book and a conference**
- **Call for Papers 5th CEVI Conference (Istanbul, May 7-10, 2015)**
- **Yared Haile-Meskel takes a detour on using biomass fuel in the cement industry**

ISSN: 2211-8691

http://www.centerforenergyandvalue.org/publications.html

Center for Energy and Value Issues CEVI

Editorial Policy

The Energy and Value Letter brings together academics and practitioners worldwide to discuss timely valuation issues in the energy sector. It publishes news from the Centre for Energy and Value Issues (CEVI), its linked organizations and others (including calls for papers), columns on topical issues, practitioners' papers: short articles from institutions, firms, consultants, etcetera, as well as peer-reviewed academic papers: short articles on theoretical, qualitative or modeling issues, empirical results and the like. Specific topics will refer to energy economics and finance in a broad sense. The journal welcomes unsolicited contributions. Please e-mail to **w.westerman@rug.nl** (Wim Westerman), a copy of a news item, column or a completed paper. Include the affiliation, address, phone, and e-mail of each author with your contribution. A column or news item should not have more than 400 words and a paper should not exceed 3,000 words.

A short note from the CEVI board

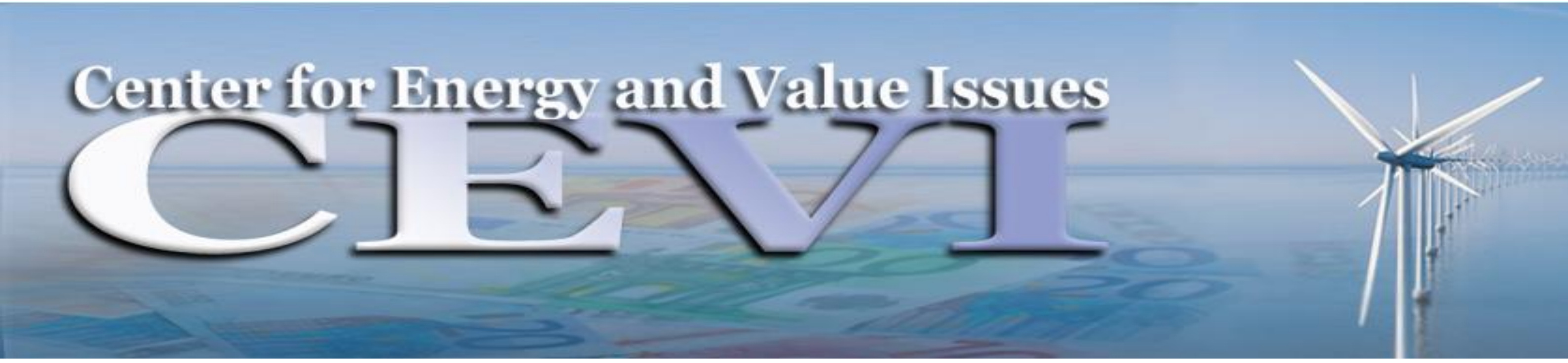
André Dorsman
President of CEVI

VU University Amsterdam, The Netherlands
e-mail: a.b.dorsman@vu.nl

There is always a first time to break rules that have carefully been set up and painstakingly maintained for many years. However, the Energy and Value Letter has a happy reason to break one of its rules, namely that articles should not be longer than 3,000 words. When reading the article by Yared Haile-Meskel you will agree that is worthwhile to read into the issue of using biomass fuel in the cement industry. Of course, biomass fuel applications are interesting, but this as such not a new area for CEVI. Also, its broad focus is not new, since CEVI explicitly strives not to be mono-disciplinary. However, the author focuses on the African country of Ethiopia, bringing in a sub-Saharan view on energy sourcing. Furthermore, the article brings in a technological flavor and in this sense proceeds with using a lens that was brought to CEVI in our fourth conference (Chicago, May 2013).

Technology is also important as a focal area in our fourth book with Springer Verlag, but not just as such. CEVI always a links energy with towards valuation and strives to address policy issues. We adapted the title of the new book to include this. “Energy Technology, Policy and Valuation” more specifically cover its title in three parts to include innovation and shocks, environment and renewables and finally, fossil fuels regulation. At the time of writing, we are almost done with the individual book chapters. This autumn will be used to polish off the book and then it will go into production. It is still our goal to have the book ready before the next CEVI conference in Spring 2015, so that it can be presented over there. Meanwhile, furthering upon idea of Özgür Arslan-Ayaydin, we have started to think about a new book. More about this later, for now I would like to turn to the 2015 Conference.

One of the activities CEVI is to offer a platform for energy-related articles in an unpolished form. We had our first conference in Amsterdam in 2007 and with the biannual rhythm that we picked up since, we are up to have our fifth conference in 2015. It will be special one in that we will have a special focus on Green energy, socially responsible investing and Islamic Finance. The local organizer is Mehmet Baha Karan (Hacettepe University, Ankara). He has brought together a large team of organisers. Next to professor Karan, professor Volkan Ediger from the Kadir Has University in Istanbul and professor Necmeddin Bağdadioğlu from the Hacettepe University in Ankara will serve as conference chairs. Program chairs are Doğan Tirtiroğlu, Özgür Ayaydin-Arslan and Mustafa Kaya. No less than 33 people have agreed to serve in the programme committee. With the help of all, we will make it a great conference! You can find the Call for Papers elsewhere in this volume of the EVL.



"The 5th Multinational Energy and Value Conference"

Organized by:

**Center For Energy and Value Issues (CEVI),
Amsterdam, The Netherlands**

and

The Kadir Has University, Istanbul, Turkey

and

**Energy Markets Research and Application Center of
The Hacettepe University, Ankara, Turkey**

http://www.centerforenergyandvalue.org/

May 7 – 10, 2015, Istanbul, TURKEY

The objective of the conference is to bring together academics and practitioners from all over the world to focus on timely energy finance and investments, financial performance, energy markets and valuation issues in the energy sector. Papers dealing with developed as well as developing countries are welcome. *Specific topics* must refer to energy issues and include, but are not limited to:

Financial Regulation; Financial Markets; Financial Risks; Asset Pricing; Value at Risk; Capital Structure; Sourcing Capital; Corporate (Re-) Structuring; Corporate Governance; Behavioural Finance; Financial Performance; Cost Control; Financial Accounting; Fiscal and Legal Issues.

The topic of the opening session will be: Green energy, socially responsible investing and Islamic Finance. This session will be chaired by Özgür Arslan-Ayaydin.

The second day of the conference includes practitioner presentations on topics such as; energy strategy, regulation, law and energy security. Senior government leaders from different countries share energy-related business opportunities in their markets.

Updates on the conference will be regularly announced to the conference participants and other parties.

Please submit your papers (completed or nearly completed) or participation interest via e-mail to: centerforenergyandvalue@gmail.com, c/o Mr. Kazım Barış Atıcı, by 01/ December/ 2014. The title page should include the affiliation, address, phone, and e-mail of each author together with the appropriate JEL classifications. Each participant agrees to serve as a discussant of a paper of his/her own area of interest, if needed.

Papers selected for this conference may be submitted for possible publication in a CEVI book, dedicated to this conference by *Springer Verlag*. All submitted papers will be subject to a blind peer review process.

Further information regarding conference organisation and accommodation, travel arrangements, fees and activities will be published on the conference website in due course. The conference also includes a "practitioners day", at no extra costs for conference presenters and discussants.

CONFERENCE CHAIRS

Volkan Ediger - Kadir Has University, Turkey
Mehmet Baha Karan – CEVI and Hacettepe University, Turkey
Necmiddin Bağdadioğlu – Hacettepe University, Turkey

PROGRAM CHAIRS

Doğan Tırtıroğlu - Kadir Has University, University of Waterloo
Özgür Arslan-Ayaydın - University of Illinois, USA
Mustafa Kaya - Hacettepe University, Turkey

PROGRAM COMMITTEE (in alphabetical order)

Ahmet Yücekaya - Kadir Has University, Turkey
Ali Akkemik – Kadir Has University, Turkey
Ali Murat Özdemir - Hacettepe University, Turkey
Alparslan A. Başaran - Hacettepe University, Turkey
André Dorsman – VU University, The Netherlands
Aydın Ulucan - Hacettepe University, Turkey
Bert Scholtens - University of Groningen, The Netherlands
Burak Güler – University of Waterloo, Canada
Burak Günalp - Hacettepe University, Turkey
Coşkun Küçüközmen – İzmir University of Economics, Turkey
Çağlar Özel - Hacettepe University, Turkey
Elif Burcu Günaydın – Energy Market Regulatory Authority, Turkey
Emir Çetinkaya – TURKDEX, Turkey
Emre Çelebi - Kadir Has University, Turkey
Ephraim Clark – SKEMA Business School, Lille, France
Gökhan Kirkil - Kadir Has University, Turkey
Halit Gönenç – University of Groningen, The Netherlands
Hamid Akın Ünver - Kadir Has University, Turkey
John Simpson – Consultant; CEVI, Australia
Kazım Barış Atıcı - Hacettepe University, Turkey
Meltem Şen - Kadir Has University, Turkey
Mustafa Ömer İpçi - Hacettepe University, Turkey
Mustafa Özen – Energy Market Regulatory Authority, Turkey
Okan Yardımcı - Energy Market Regulatory Authority, Turkey
Ömer Gebizlioğlu - Kadir Has University, Turkey
Özgür Orhangazi - Kadir Has University, Turkey
Paul Prabhaker – Northern Illinois University, USA
Paul Pottuijt – TenneT, Apeldoorn, The Netherlands
Sedat Çal - Hacettepe University, Turkey
Timur Gök – PRMIA, Chicago, USA
Volkan Yeniaras - Kadir Has University, Turkey
Wim Westerman – University of Groningen, The Netherlands
Yılmaz Yıldız - Hacettepe University, Turkey

Center for Energy and Value Issues
CEVI

Center for Energy and Value Issues
CEVI

ECONOMIC AND ENVIROMENTAL BENEFITS OF USING BIOMASS FUEL IN THE CEMENT INDUSTRY

Yared Haile-Meskel

YHM Consulting Plc, Ethiopia

Biomass is the oldest form of energy. It has been used since mankind harnessed fire for cooking, lighting and heating. With the advent of industrialisation and the invention of the steam and internal combustion engine, the use of biomass as the principal source of energy has been declining. Yet, today, approximately 10 percent of global energy and approximately 80 percent of the energy in sub-Saharan Africa is generated from biomass. With the growing realisation of the impact of fossil fuels on global warming, there is a renewed interest in the utilisation of biomass as a renewable and carbon-neutral energy source. This paper reviews the available literature with regard to the use of biomass in clinker production in the cement industry, which is one of the largest sources of greenhouse gases.

Also, the article reviews the economic and technological benefits of using biomass and non-renewable waste fuels in cement production plants to reduce CO_2 emission. The biomass resource for example in Ethiopia is abundant, the technology of preparation, feeding, and burning of biomass in cement kilns is widely available and could be purchased to implement a co-firing of biomass along with fossil fuels. Taking Ethiopia as an example, the article makes recommendations for formulating a strategy for integrated biomass technology to achieve not only economic benefits, reduction of emission but also to deliver long-term energy security and sustainable development. Published data confirms that this investment is economically justifiable and environmentally beneficial.

1. Introduction

Biomass refers to biological materials derived from living or recently dead biological materials, encompassing materials from both plants and animals. It includes plant tissues such as wood, charcoal and yarns; farm wastes such as coffee husks, teffe and chat[1]; animal wastes, such as animal fat, dung, meats and bones; and household or industrial biological degradable wastes. These materials are primarily composed of carbon-based organic matter, which releases energy when it reacts or combusts with oxygen. When cultivated or sourced in a sustainable manner (such that the total stock of the resource does not diminish in size), biomass can be regarded as a form of renewable energy (Nicholls, Monerud and Dykstra, 2008).

Although fossil fuels are also made from the remains of dead animals and plants, fossil fuels are not considered renewable on any scale of time that matters to humans (Shafiee and Topal, 2009).

[1] The plant is indigenous to Ethiopia and is known by different names in different languages, being called "Chat" in Amharic, "Kat" in Arabic, "Mirra" in Swahili and "Abyssinian tea" or "African salad" in colloquial English.

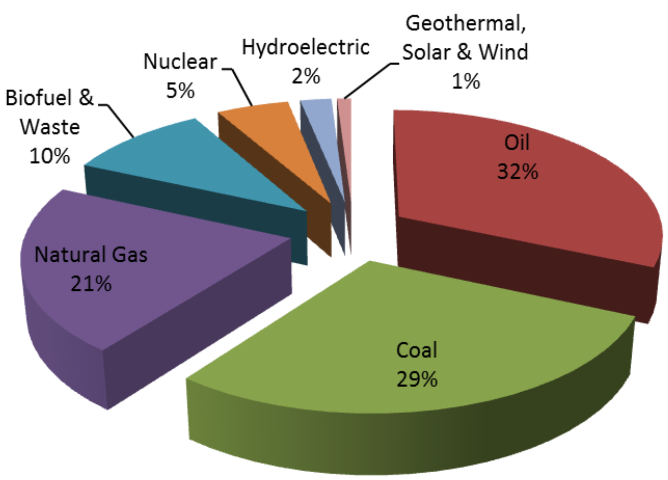
1.1. Biomass as an Energy Source

Biomass is the oldest source of energy, in use since mankind first harnessed fire and used wood as a source of heat, light, and power. For centuries before the invention of the steam and internal combustion engines, most of the world's energy came from biomass. The advent of industrialisation created the need for a large quantity, and more concentrated source, of energy. This led to large-scale exploration and utilisation of fossil fuels (Winandy et al., 2008). Nonetheless, biomass still accounts for 10% of global energy use, which is approximately five times more than the energy generated from hydroelectric power (IEA, 2011). In the United States alone, about 11 gigawatts (GW) of electrical power are generated from bioenergy sources. This make biomass the second-largest US renewable energy source next to hydropower (94 GW), and more significant than wind energy (5 GW) and geothermal energy (2.7 GW) (Nicholls et al., 2008).

In the Less Developed Countries (LDCs), biomass accounts for almost one-third of all energy consumption. In fact, in sub-Saharan countries biomass accounts for more than 80 % of all energy needs, and is primarily used for cooking, lighting and heating (Palz and Kyramarios, 2000).
Figure 1 shows world energy demand by source.

With the growing realisation of the impact of fossil fuels on global warming, coupled with volatile energy prices and an emerging energy security agenda, there is a renewed interest in using biomass as a carbon-neutral and cost-effective alternative. For example, Nicholls et al (2008) state that wood energy could potentially supply up to 10% of U.S energy demand. Currently it is below four percent and is expected to grow to five percent by 2020. Wright (2006) put US biomass consumption at a lower level of 2.8 percent in 2005 and Brazil at the high level of 27.2 percent. Figure 1 shows the world energy demand by source and puts biomass and waste as a source in a broader perspective.

Figure 1: 2011 World Energy Demand by Source



Source: IEA (2011)

Biomass can be used as an energy source in a variety of ways: as a direct combustion feedstock in home stoves, thermal power plants, furnaces and boilers (possibly in combination with coal or other fossil fuels); or as a feedstock for pyrolysis, gasification, charcoal production, briquetting, transesterification or fermentation (the latter two for producing biodiesel and bio-ethanol (Kelly, 2009).

2. *Cement chemistry and impact on the environment*

Cement production is a large user of fossil fuels and producer of greenhouse gases (GHGs) (Worrell et al, 2001). In cement production, there are three sources of greenhouse gases.

1. The first source comes from the inherent nature of cement production. Cements are made from limestone, which predominantly contains more than 90% calcium carbonate ($CaCO_3$). As shown in chemical Equation 1, when heat is applied to $CaCO_3$ it dissociates into calcium oxide, which is the main ingredient for cement, and carbon dioxide, which is a greenhouse gas.

$$CaCO_3 \xrightarrow[\text{Heat} \sim 850^0C]{} CaO + CO_2 \qquad \text{(Equation 1)}$$

For every 100 grams of calcium carbonate heated in a kiln above 750°C, about 44 grams of carbon dioxide and 56 grams of calcium oxide are produced. In effect, for every 56 grams of calcium oxide that is used by the construction industry, about 44 grams of carbon dioxide are released into the atmosphere. According to the European Cement Association (2009a), approximately 525kg CO_2 per tonne of 'clinker' is produced. (Clinker is a solid intermediary cement product that is formed at high temperature through total or partial fusion of cement raw materials). In 2012 alone about 3.7 billion tonnes of cement (USGS, 2013) were produced globally, which means up to 1.94 billion tonnes of CO_2 were released from de-carbonisation of $CaCO_3$ alone into the atmosphere.

2. **The second source** of greenhouse gases comes from the combustion of carbon-containing fossil fuels such as methane, furnace fuel, coal or alternative fuels such as biomass, re-ground tyres, and household and industrial wastes.

The mechanism by which carbon-containing fuel burns to give off carbon dioxide is given in Equation 2 using the smallest hydrocarbon compound, methane (CH_4).

$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O \qquad \text{(Equation 2)}$$

The European Cement Association (2009a) estimates that overall carbon dioxide production from combustion of fuel in the kiln is approximately 335 kg of CO_2 per tonne of cement.

3. **The third source** of carbon dioxide derives from the use of electricity produced by power stations that are burning fossil fuels. This accounts for approximately 50 kg of CO_2 per tonne of cement produced (European Cement Association, 2009a). Countries, such as Ethiopia, that generate a significant fraction of their electricity from hydroelectric power stations do not produce large quantities of carbon dioxide from the use of electrical motors. However, cement plants in these countries do, of course, produce carbon dioxide from the first two sources.

When all the carbon dioxide produced from the three sources is added together, the cement industry releases up to 0.8 tonne of carbon dioxide into the atmosphere per tonne of cement produced. This makes cement production one of the largest sources of greenhouse gases, producing 5 percent of global emissions (Worrell et al, 2001). This is more than the emissions from the global steel industry. According to the Intergovernmental Panel on Climate Change (IPCC), the steel industry accounts for between 3 to 4 percent of total world greenhouse gas emissions (World Steel Association, 2007).

Carbon dioxide (CO_2) from decarbonisation of limestone can be reduced by diluting cement clinker with raw, thermally untreated rocks. Hence, carbon dioxide from decarbonisation of limestone can be reduced – but cannot be fully eliminated – as long as cement is made from $CaCO_3$. There is ongoing research into the development of 'eco-cement' made from magnesium oxide (MgO) which can absorb carbon dioxide and water to set and harden (Harrison, 2009).

However, CO_2 from the burning of fossil fuels can be reduced and, even more importantly, can be made carbon-neutral with the utilisation of biomass as an energy source for pyroprocessing.

To understand how this can be achieved, it is important to understand how cement is produced and the types and amounts of energy needed to make cement.

3. *Cement Production Process*

Cement manufacturing starts with the quarrying of more than one raw material to provide a source of necessary metallic oxides, such as calcium oxide from limestone, iron and aluminium oxides from clay and silicon oxide from sand. Big rocks blasted from quarries are crushed into gravel to facilitate transportation, blending and milling into powder.

There are two processes of raw material grinding and blending. Those are known as the 'wet' process and the 'dry' process. In the wet process, the materials are ground and homogenised as slurry. This method was traditionally preferred to achieve homogeneity of feedstock, but following improvements in dry mixing and blending of powder materials most modern cement factors now use the dry process because it requires less energy per tonne of clinker.

Using the dry or wet process, different types of cement are made for various applications. The most common cement used in civil construction today is Ordinary Portland Cement (OPC), but there are specialist cements such as rapid heat cement, high alumina cement, oil-well cement, quick set cement, etc. For example, the raw material for Portland Cement needs to be predominantly calcareous, rich in calcium oxide (CaO) and with smaller amounts of siliceous (SiO_2), aluminous (Al_2O_3) and iron-rich (Fe_2O_3) content. Most often, between 70-99 percent of this calcareous component comes from limestone deposits. Clay, sand or other minerals are also milled with limestone in the correct proportions.

Once the correct proportions of these chemical compounds are achieved, the material is fed into preheating cyclones to be heated to decompose some of the $CaCO_3$ and prepare it for further reactions that will take place. The temperature of the material reaches around 1,450°C and the air temperature is as high as 2,000°C. During this process of chemical reactions, a black/grey solid mass is formed through partial or total fusion of the raw materials. This is known as clinker (Peter, 2001). Chemical reaction of clinker production

The pre-heated material in the cyclones is dropped into the kiln for complete reaction. As shown in **Error! Reference source not found.**, most modern cement kilns are rotary shafts with a diameter ranging from 3.5m to 5.5m and a length of between 50 to 200m. Coal, gas, fossil fuels or alternative fuels are continuously injected into the kiln to burn and produce heat of about 1,450°C in the clinker production zone.

A typical Portland cement clinker consists of at least two-thirds mass of calcium silicates $(CaO)_3SiO_2$ and $(CaO)_2SiO_2$ and the remainder consists of aluminium oxide (Al_2O_3), iron oxide (Fe_2O_3) and other oxides (Peter, 2001). Once the clinker is formed it drops into a cooler where air is blown in at one end to remove the heat from the partly-softened and molten material and turn it into small pebbles. The clinker is then ground in a cement mill – with or without "extender minerals" such as pumice, gypsum, pozzolan or ground furnace slag – to produce cement.

To carry out these operations a large amount of electrical and fossil fuel energy is used, which will be discussed in the next section.

4. *Energy Consumption of the Cement Industry*

Cement production is one of the largest users of fossil fuels. According to energy consumption benchmarking carried out in Canada, the energy cost of cement production is between 25-35 percent of the total direct cost of cement production. A similar analysis carried out in Poland estimated energy costs to be between 30-40 percent of the total costs of cement production (Mokrzycki, Uliasz-Bochenczyk and Sarna, 2003). Messebo Cement factory in Ethiopia reports that it spends up to 60 % of its total cost of production on imported furnace fuel, which is exceptionally high compared with the industry standard (Addis Fortune, 2007). This figure is probably distorted by cheap labour and other costs. Nonetheless, this high proportion of energy cost has been a major driver for the industry to search for cost-effective and alternative fuels.

Fuel consumption at a cement plant depends on the type of process the plant uses. The total energy consumption used during the wet cement production process is much higher than in the dry process.

Ruth et al (2000) estimate that the most efficient and modern processes could use as little as 3,200 MJ of energy per tonne of clinker produced. Assessing the Polish cement industry, Mokrzycki (2003) derived average energy consumption of Polish factories at around 4,100MJ per tonne of clinker. On average, Mokrzycki (2003) states that the energy required for the production of one tonne of cement are about 120 kg of coal. Another study carried out in Pakistan suggests that about 85 kg of furnace oil is used to produce a tonne of cement (Kazmi, 1996). Ethiopia's cement factories use imported furnace fuel, probably with similar energy efficiency to that of Pakistan.

The scope of this study is to assess the use of fuel directly injected into the rotary kiln to generate flame and heat of around 1,450°C. This heat activates the decomposition of calcium carbonate and facilitates solid state reactions between aluminium, iron, silicon and calcium oxides to produce a new chemical structure substance called clinker. To achieve these reactions, three types of fuels are commonly used.

5. Types of Fuels used in Cement Kilns

In the context of the cement industry, there are three sources of fuels used in kilns. These are fossil fuels, biomass, and non-renewable wastes.

Fossil Fuels: Fossil fuels represent the main sources of energy used in cement production. Principal fossil fuels used are coal, petcoke and petroleum-based fuels such as natural gas and heavy furnace fuel.

Biomass: These materials are, in principle, 'renewable' because they can be re-grown at a rate equal to, or greater than, the rate of harvesting; they are 'carbon-neutral' because plants absorb carbon dioxide as they grow. Biomass waste such as forest products, fuel wood, foliage, shavings, agricultural crops, cotton stokes, rice straw, sugarcane, flower farm waste and wheat straw are widely used as renewable and carbon-neutral fuels. Industrial-scale animal wastes, such as bones, fats, meats and other animal wastes, also fall under the biomass category.

Non-renewable wastes: These materials are wastes or materials at the end of their service lives. They can be burnt in the cement kiln to recover energy and conserve fossil fuels that would have otherwise been used. Some, such as plastics and rubber wastes, can also cause environmental hazards when dumped in landfills. Rubber tyres, plastics, hydraulic oil, grease and hydrocarbon-based household or industrial wastes can be used as an energy source in cement factory kilns.

The European Cement Association (1998) states that "[w]aste is used in cement manufacturing as an alternative fuel and raw material, thereby providing a significant contribution to waste management. Unlike incinerators, the cement manufacturing process "absorbs" all of the elements present in the burnt waste. In this way, it cuts both its production costs and global greenhouse gas emissions. Today, on average, alternative fuels provide about 17 percent (up to 72 percent in some regions) of thermal energy consumption in European cement plants" (European Cement Association, 1998).

Though there are no clear specifications for determining what would be a good waste fuel, Lafarge Cement, for example, has developed the following specifications to protect the environment and conserve the efficiency of their cement kilns (Mokrzycki et al, 2003):

Calorific value – over 14.0 MJ/kg (weekly average)
Chlorine content – less than 0.2 percent
Sulphur content – less than 2.5 percent
Polychlorinated Biphenyls (PCB) content – less than 50ppm
Heavy-metal content – less than 2,500 ppm, out of which:
Mercury (Hg) – less than 10ppm, and
Total cadmium (Cd) and thallium (Tl) less than 100ppm

Most hydrocarbon-based materials are safe to burn in the kiln to provide energy as long as they meet the above guidelines.

As a result of these calorific value differences, the fuels cannot be replaced by each other at a one-to-one ratio. An adjustment has to be made to compensate for the loss of calorific value. For example, an approximate 1:1.4 coal-to-wood ratio is needed to replace coal with wood to achieve similar heat energy in the kiln.

Though the scope of this paper is principally interested in the use of biomass, it discusses non-renewable waste materials as a source of fuels in the cement industry for two reasons:

First, finding a sustainable supply of biomass with uniform calorific value could be challenging from a supply as well as a logistical perspective. This may discourage cement factories from investing in modifications of their systems to burn biomass fuels only.

Second, in some regions the cost of biomass could be higher and there may not be clear cost benefits. Alternative waste fuels are often free, except the cost of collection, transportation and processing of these materials. In some cases, waste may even be 'negative cost', where waste producers pay cement factories to take away their wastes.

6. Real-Life Examples of Biomass Use in Cement Kilns

Burning biomass in cement kilns is occurring more often due to volatile energy prices and environmental benefits. The following are a few examples reported in various publications.

Kenya: A cement firm operating in Kenya and Uganda claims to have cut its "annual carbon dioxide emission by reducing its use of fossil fuels in cement making by 20 percent. The company, which is partly owned by Lafarge Cement, plans to reduce its use of coal by using wood from its own plantations as well as coffee, rice and cashew nut husks. It is targeting a reduction of 132,000 tonnes of CO_2 per annum by 2010" (Reuters, March 11, 2008; Lafarge, 2007).

Uganda: Uganda's Hima cement factory burns coffee husks as a CDM project. This project is expected to save the factory about $3.1 million in foreign exchange per annum (Cement World, 21 May, 2008).

Malaysia: Investigations performed to evaluate the feasibility of using biomass fuels as a substitute for fossil fuels in Malaysia's cement industry have reached the following conclusions (Evald and Majidi, 2004):

- The economic feasibility of using biomass in the cement industry is very good, with a 263 percent financial internal rate of return (FIRR)
- The cement sector is an obvious choice for the use of solid biomass because of the ease of replacement of coal.
- For the cement industry, the combination of a very large volume of fuel substitution involving a relatively small investment cost allows for significant savings from the use of alternative fuels.

Germany: Heidelberg Cement claims to have increased the use of alternative fuels up to 78 percent in one of its plants and 66 percent in another. It uses tyres, plastics, paper residues, animal meal, grease and sewage sludge to replace fossil fuels. It states that the company had to invest EURO 8 million in one plant and another EURO 4 million on storage equipment, homogenization and dosing installations for flexible use of alternative fuels (Heidelberg Cement, 2009a).

Indonesia: Heidelberg Cement's Indonesian subsidiary was approved as the first CDM project in Indonesia in 2005. The company claims to have increased the use of alternative fuels, in particular rice husks and residues from palm oil production, replacing coal (Heidelberg Cement, 2009b).

Poland: Six cement plants in Poland currently use alternative fuels. Lafarge Poland Ltd. has been using combustible fractions of municipal wastes, liquid crude-oil derived wastes, car tyres, waste products derived from paint and varnish production, expired medicines from the pharmaceutical industry, bone meal provided from meat processing plants, coke from the chemical industry and emulsified oil from a refinery (Mokrzychi et al, 2003).

India: Cement companies in India are using non-fossil fuels including agricultural wastes, sewage, domestic refuse and used tyres, as well as a wide range of waste solvents and other organic liquids (Bernstein and Roy, 2007). The Indian Cement firm ACC is using cow dung, old shampoo, soap, plant sludge and municipal waste as alternatives to fossil fuels (Cement World, 2008).

USA: In the United States, approximately 5 percent of fuel used in the cement industry comes from renewable and non-renewable waste fuels such as wood, tyres and other non-hazardous and hazardous materials. Various sources suggest the availability of millions of tonnes of wood that could be used in cement factories to reduce greenhouse gas emissions and minimise forest fires (Mackes and Lightburn, 2003).

UK: Cemex cement factory in Rugby uses alternative fuels such as tyres and 'climafuel', which is derived from household and commercial wastes. The 'climafuel' can contain at least 50 percent biomass, displacing nearly 180,000 tonnes of fossil fuel CO_2 (Cemex, 2009; Cement News, January 2009). The Lafarge plant at Hope uses bone meal (MBM) which is expected to reduce 30,000 tonnes of CO_2 emissions per year (Cement World, October 2008).

Austria: Austria's cement factories were amongst the earliest to start burning tyres (since the 1980s), and have been burning solid waste such as plastics, paper, textile and composite materials since 1993. All nine cement plants in Austria use solid waste to various degrees (European Cement Association, 2009). One of the factories, Wietersdorfer & Peggauer cement plant, claims to have used alternative fuels substituting up to 70 percent of fossil fuels (Zieri, 2007).

Tunisia: A feasibility study carried out to study the use of municipal solid waste (MSW) as a replacement for natural gas in the cement industry was found to be unattractive economically due to the high cost involved in collection and sorting of the MSW and government subsidies on natural gas imports (Lechtenberg, 2008).

Canada: St. Mary Cement in Ontario, Canada, wants to replace 13 percent of its fuel consumption with wastes such as paper sludge left over from recycling and plastic films. A factory in British Colombia uses renewable synthesis gas products from its gasifier, enabling it to replace 6 percent of its fossil fuel consumption (Dufton, 2001).

Portugal: Cement producer Cimpor Cimentos de Portugal is using hazardous hydrocarbon waste in its plant in Souselas, Central Portugal (Cement World, 2008).

The list of cement factories using biomass and waste fuels is longer, but the above diverse examples are sufficient to strengthen the argument that:

- Biomass and alternative fuels can be used in the cement industry.
- Biomass, as well as non-renewable waste fuels, can be an economical alternative to fossil fuels.
- There is well-established materials preparation, feeding and burning technology that can be purchased by cement factories to adopt a co-firing technology.

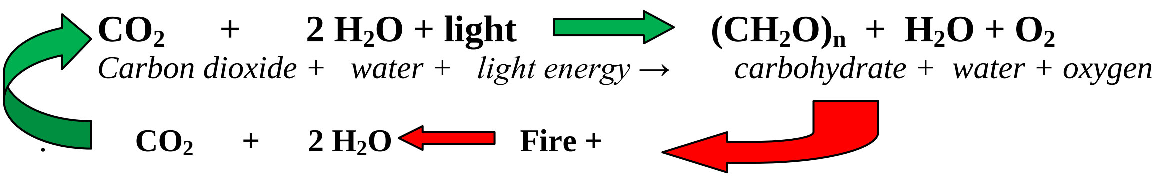
- It is clear that using biomass in the cement industry is possible and achievable. In the following section some of the benefits are discussed.

7. Benefits of using biomass and alternative fuels

7.1. Environmental benefits

Biomass is a renewable energy resource that can be replaced by growing trees, crops or other vegetation to maintain the level of sequestered carbon in the environment. In addition to capturing carbon dioxide, planting vegetation protects land fertility, prevents solid erosion, reduces sedimentation at dams and water reservoirs, provides ecosystems for wildlife and insects, and, of course, produces wood for high-value timber use as well as biomass.

Plants absorb carbon dioxide during photosynthesis. As shown in the following chemical equation, this cycle continues as long as trees are planted to absorb carbon dioxide, to 'cancel out' the carbon dioxide released from combustion of the cultivated biomass. That is why sustainable biomass is considered to be carbon-neutral, with no net increase of carbon dioxide into the atmosphere.



7.2 Benefits of Using Alternative Waste Fuels

The use of waste as alternative fuels in the cement industry has numerous environmental benefits, such as:

- Alternative fuels reduce the use of fossil fuels.
- Contributes towards lowering emissions of greenhouse gases from materials that would otherwise have to be incinerated (with corresponding emissions) or left in the landfill to decompose (and generate methane).
- Maximises the recovery of energy from waste. All the energy is used directly in the kiln for clinker production.
- Maximises the recovery of the non-combustible part of the waste and eliminates the need for disposal of slag or ash, as the inorganic part is incorporated into the cement.
- Improves waste management and public health. High temperatures in the kilns, long residence times and the ability to absorb inorganic residue/ash allow the complete destruction of combustible hazardous waste while recovering the energy they contain in an environmentally sound manner (Hansen, 1990; Van Loo, 2006). For these reasons, the cement industry is recognised by some European governments as an essential part of their waste management policy (European Cement Association, 1998).
- The only viable means of safe, permanent disposal of this combustible waste is by thermal treatment. Cement kilns are not only ideally suited for the safe disposal of this material, but they also can recover the energy to reduce use of fossil fuel.

7.3 Economic Benefits of Using Biomass and Alternative Waste Fuels

- Between 30-40 percent of the total cost of cement production is accounted for by energy needs. Significant cost reduction can be achieved by using renewable and waste fuels. Hence, burning biomass and waste as a source of energy could save significant costs.
- Burning biomass and waste can save foreign currency by replacing imported fuels.

- Provides energy security for land-locked countries such as Ethiopia and hedges against volatile global energy markets.

8 Technology

Biomass burning in cement kilns is a well-established technology, which can be purchased or custom-made in developing countries. Existing feeding systems of alternative fuels into kilns are robust and it is possible to feed in biomass ranging from small pellets to full-sized tyres. For ease of handling and achieving uniform calorific input into the kiln, it is important to reduce biomass materials to manageable sizes. For example, solid woody biomass needs to be chipped into small sizes, pre-dried, and unwanted materials such as stone and metal bits removed (Nicholls et al, 2008).

Alternative and biomass materials can be fed in three principal ways:

- Large-size biomass and alternative waste fuels such as tyres can be fed into the kiln in specially-made gates at the bottom of the pre-calcining region.
- It is possible to grind wood along with cement raw materials to feed as pulverised fuel. However, this process may cause two potential problems (Mackes and Lightburn, 2003). Due to the low ignition temperature of wood, fire may start during the milling process unless special precautions are put in place. It may also affect the efficiency of the mill if the moisture content of the wood is high. Though it may make it easier to feed into the kiln, grinding the biomass adds to costs.
- Companies that use coal as a main source of energy can blend biomass or alternative materials with coal to feed it into the kiln using a coal-feeding system.

Feeding through specially-made gates at the pre-calcination region is the safest choice. There are already rotary valves or screw feeders on the market that can be easily installed. The screw feeder has certain advantages over the rotary valve as coarse materials can easily be pushed into the pre-calcining region and the feed rate of the biomass can be regulated by the speed of the screw.

Conveyer belts are used to transport biomass materials from storage to feeding hoppers. From the hoppers, a screw conveyor feeds the biomass into the pre-calcination region.

Burning alternative fuels is beneficial to cement companies as well as the environment. But there are barriers to successful utilisation of biomass in the cement industry:

- Supply: obtaining a constant and sufficient amount of biomass. In Ethiopia there is a large area that has been taken by invasive trees that can be harvested and used.
- Consistency: the variability in calorific value of biomass may affect the efficiency and output of kiln production.
- Harvesting: although extensive biomass resources are available in many countries, often such biomass is spatially dispersed and difficult to aggregate together.
- Cost: the capital costs for the preparation and densification of biomass at harvesting sites, as well as modifications of the cement factory, may not justify biomass use.
- Accessibility: infrastructure barriers, roads, and transportation.
- Skill barriers. Despite wood-based fuels being used by more than 90 percent of the population in Ethiopia, there are no biomass research centres in the country that study sustainable biomass development, help to upgrade skills, or that can replenish stocks (Mulugeta, 2008).
- Scepticism: Management and decision-makers may regard burning household waste in modern factories with some degree of scepticism. Hence, champions are needed to overcome this resistance to change.
- Unwanted materials: Biomass often contains unwanted materials, such as metal wastes that may damage machines and that need to be removed using metal detectors. The European

Cement Association (2009a) also classify nuclear waste, infectious medical waste, entire batteries, and untreated mixed municipality waste as unsuitable for the cement industry and public health.

9 Adverse effects on the environment

- Deforestation: Industrial-scale usage of biomass may add to already-present stresses on biomass resources, thereby inadvertently encouraging deforestation (Mangoyana, 2009).
- Hazardous substance release: In many developing countries, there may not be stringent regulations, or enforcement of regulations, regarding air quality. This may invite companies to take a less responsible approach to burning chlorine-containing wastes such as PVC pipes and PVC packaging that may lead to formation of toxic dioxins or industrial wastes containing toxic metals (Court, 2005; WHO, 2007).
- Health: In the absence of proper treatment, transportation of household and industrial waste could spread germs and disease.

10 Economic and Environmental Justification for Using Biomass in Ethiopia

A total of 24 companies have permits to invest in cement production in Ethiopia. By 2012, the total amount of cement production in Ethiopia has reached 12 million tonnes per annum and when the projects in the pipeline become operational the production is expected to reach 27 million tonnes. This is going to increase the competition and price pressure on cement factories, squeezing their profit margins. This volume will enable the country to jump from its current position of 78th in the world ranking of cement producers to one of the top 30, placing it above the UK, Canada and Australia.

This will exert considerable pressure on energy supply in the country. The country will probably have 24 cement factories within a short time, increasing cement production from the current level of approximately 12 million tonnes to 27 million tonnes. That means the country will have to import approximately 2.29 million tonnes of furnace fuel. At the current market price of US$400 per tonne, the country may need to spend billions of dollars on furnace fuel alone. This is simply unaffordable in the context of a total national export value of US$ 3.0 billion dollars per year.

11 Strategies and benefits in Ethiopia

- **Invasive Trees:** In the low land there is around 1.2 million hector of land is covered by invasive trees that can be harvested for biomass production.
- **Farm Wastes:** Coffee waste, cotton, oil processing, chat, sugarcane, flower farms and processing plants can be used as seasonal sources of biomass.
- **Commercial Plantations:** Cement factories can start commercial plantations of trees on their own lands. The factories' land could be used to plant trees at the commercial level to harvest for cement production. According to Ethiopian investment law, land for tree plantation is free and no lease fee is paid on it.
- **High-value products:** In addition to biomass fuel, high-value timber can be sold to maximise the return on investment.
- **Public Health:** The capital city, Addis Ababa, has no proper waste management system. Household as well as industrial waste is dumped on open land, causing environmental problems and health risks. Heavy pollution of Koka Lake is a result of waste influx from tanneries, flower farms, industrial facilities and household waste. Having the capability to burn alternative waste could encourage municipalities to invest in waste-processing plants and industries to collect and supply hydrocarbon-based wastes to the cement industry. This would contribute to public health, reduce methane emissions and save energy costs.

- **Hazard management:** Liquid hazardous wastes that are often generated from industrial hydraulics and automotive lubricant can be blended with furnace oil to be burnt in the kiln, preventing the pollution of drinking water and poisoning of aquatic life (Hansen, 1990).
- **Financial incentives:** As international concern over global warming and greenhouse gases arise, government and international organisations may provide financial support for the utilisation of biomass, reducing the burden on the industry. Biomass-switching in the cement industry also has a rich pedigree in the Clean Development Mechanism (CDM).

12 Conclusions

The use of biomass and waste fuels is a growing area based on sound economic and environmental benefits. Biomass fuel-switching is possible, achievable and beneficial to the environment and companies that are willing to embrace it. Once implemented, companies can also benefit from the generation of carbon credits through the Clean Development Mechanism. Countries such as Ethiopia could save foreign currency, create jobs and start a sustainable biomass industry. This would help to reduce deforestation and soil erosion, while simultaneously offering social benefits to rural communities.

References

Addis Fortune, March, 2007, Messebo to Use Coal for Cement Product. Website (accessed 24 February 2009): http://www.addisfortune.com/Messebo%20to%20Use%20Coal%20for%20Cement%20Production.htm

Bernstein, L., Roy, J., Delhotal K.C., Harnisch J., Matsuhashi R., Price L., Tanaka K., Worrell E., Yamba F., Fengqi Z., (2007) Industry. In Climate Change 2007: Mitigation. Cambridge University Press, Website (accessed March, 2009 http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter7.pdf)

Cement World (2008) Kenyan cement firm aims to increase its use of alternative fuels. Cement World.

Cement World (2008) Cimpor makes uses of hazard waste. Cement World.

Cemex cement (2009) Climafuel in the United Kingdom. Website (accessed 13 March 2009): http://www.cemex.com/su/cs/su_ca_en_cc_cl.asp

Court, J. (2005) Alternative fuels at Berrima cement works – Blue Circle Southern Cement. Denistone, Australia: J D Court and Associates Pty Ltd. Website (accessed 17 March 2009): http://www.planning.nsw.gov.au/assessingdev/pdf/bcsc_berrima_report_final.pdf

Dufton, P. (2001) End-Of-Life Tyres - Exploiting Their Value. Rapra Industry Analysis Report Series.

Energy Innovation Initiative in Canada (2001) Energy consumption benchmark guide: Cement clinker production. Ottawa: Natural Resources Canada. Website (accessed 13 March 2009): http://oee.nrcan.gc.ca/publications/industrial/BenchmCement_e.pdf

European Cement Association (1997a). Alternative Fuels in Cement Manufacture: technical and environmental review. Brussels: Cembureau. Website (accessed 20 February 20, 2009): http://www.cembureau.be/Documents/Publications/Alternative_Fuels_in_Cement_Manufacture_CEMBUREAU_Brochure_EN.pdf

European Cement Association (1998) Climate change: cement and the EU. Website (accessed 21 February2009): http://www.cembureau.be/

Hansen, E R. (1990) New Ways to burn hazardous waste. Website (accessed 18 February 2009): http://www.cadencerecycling.com/pdf/papers2.html

Harrison, J. (2009) Eco-Cement. Glenorchy: TecEco Pty Ltd. Website (accessed 22 February 2009): http://www.tececo.com/simple.eco-cement.php

Heidelberg Cement. (2009a) Germany - ahead in using alternative fuels. Website (accessed 22 February 2009): http://www.heidelbergcement.com/global/en/company/sustainability/case_studies/alternative_fuels.htm

Heidelberg Cement. (2009b) First CDM project in Indonesia. Website (accessed 22 February 2009): http://www.heidelbergcement.com/global/en/company/sustainability/case_studies/CDM_project_Indonesia.htm
Hogan, E. (1994) Overview of Canadian Thermochemical Biomass Conversion Activities, in Advances in Thermochemical Biomass Conversion, Volume 1. Bridgwater, A.V. (eds.), Blackie Academic.
IEA (International Energy Agency). (2006) Key World Energy Statistics 2006. Paris: IEA.
Kazmi, S.H. (1996) The troubled cement industry. Pakistan Economist. Website (accessed 21 February 2009): http://www.pakistaneconomist.com/database2/cover/c96-97.asp
Lafarge (2007) Lafarge in Kenya and Uganda: a sustainable commitment. Paris: Lafarge.
Lechtenberg, D. (April 2008) Tunisia – waste management and the cement industry. Global Cement Magazine, pp. 10-11.
Mackes, K., and Lightburn, C. (2003) Evaluating the use of green wood chips processed from small-diameter trees as an alternate fuel for making cement. Forest Product Journals 53(4)
Mokrzycki, E., Uliasz-Bochenczyk, A., Sarna, M. (2003) Use of alternative fuels in the Polish cement industry. Applied Energy 74: 101-111.
Mangoyana, B.R. (2009) Bio-energy for sustainable development: An African context. Physics and Chemistry of the Earth, vol. 34, pp 59-64.
Mulugeta, Y. (2008) Human capacity and institutional development towards a sustainable energy future in Ethiopia. Renewable and Sustainable Energy Review 12: 1435-1450.
Nicholls, D., Monerud, R., and Dykstra, D. (2008) A synthesis of Biomass Utilization for Bioenergy Production in the Western United States, General Technical Report PNW-GTR-753. Washington, DC: United States Department of Agriculture Forest Service.
Palz, W., Kyramarios, A. (2000) Bioenergy Perspectives in Developing Countries. First World Conference on Biomass for Energy and Industry, 5-9 June 2000, Sevilla, Spain.
Peter, C.H. (ed.) (2001) Portland Cement: Classification and Manufacture. Lea's Chemistry of Cement and Concrete, 4th ed. Oxford: Elsevier Butterworth-Heinemann.
Reuters. (2008) Kenya cement firm details planned CO2 emissions cut. Website (accessed: March 10, 2009): http://www.reuters.com/article/rbssIndustryMaterialsUtilitiesNews/idUSL 1161019120080311
Ruth, M., Worrell, E., and Price, L. (2000) Evaluating Clean Development Mechanism Projects in the Cement Industry Using a Process-Step Benchmarking Approach. Washington, DC: US-EPA.
Shafiee, S. and Topal, E. (2009) When will fossil fuel reserves be diminished? Energy Policy 37: 181–189.
Taye, D. (2008) Production of new cement factories may exceed demand. The Ethiopian Reporter. Website (accessed 25 February 2009): http://en.ethiopianreporter.com/content/view/18/26/
USGS Mineral Programme Report 2013 www.globalcement.com/magazine/articles/822-top-75-globalcementcompany
Van Loo, W. (2008) Dioxin/furan formation and release in the cement industry. Environmental Toxicology and Pharmacology 25: 128–130.
Winandy, J.E., Williams R.S, Rudie A.W., Ross R.J., (2008) Opportunities for using wood and biofibers for energy, chemical feedstocks, and structural applications. Washington DC: US Forest Service.
Wikipedia. (2009a) Greenhouse gases. Website (accessed 22 February 2009): http://en.wikipedia.org/wiki/Greenhouse_gas
Wikipedia. (2009b) List of countries by cement production. Website (accessed 25 February 2009): http://en.wikipedia.org/wiki/List_of_countries_by_cement_production
Worrell, E., Price, L., Martin, N., Hendriks, C., and Meida, L.O. (2001) Carbon dioxide emissions from the global cement industry. Annual Review of Energy and the Environment 26:303-329**.**
World Steel Association (2007) A global sector approach to CO2 emissions reduction for the steel industry – a position paper issued by the World Steel Association, December 2007. Website (accessed 14 March 2009): http://www.worldsteel.org/pictures/storyfiles/Global%20sector%20approach% 20position%20paper.pdf

Wright, L., 2006, Worldwide commercial development of bioenergy with a focus on energy crop-based projects, Biomass and Bioenergy, vol. 30, pp. 706-714

WHO (World Health Organization) (2007) Dioxins and their effects on human health, Fact sheet N°225. Geneva: WHO. Website (accessed 27 March 2009): http://www.who.int/mediacentre/factsheets/fs225/en/

Zieri, W. (2007) Modernisation of the Wieterdorfer & Peggaver Cement Plant. 7th European Conference and exhibitions, Vienna, 19-20 March 2007.