CEDRO
Empowering Lebanon with Renewable Energy

March 2015
Exchange Issue 14

Energy Use and Efficiency Opportunities in the Lebanese Industrial Sector

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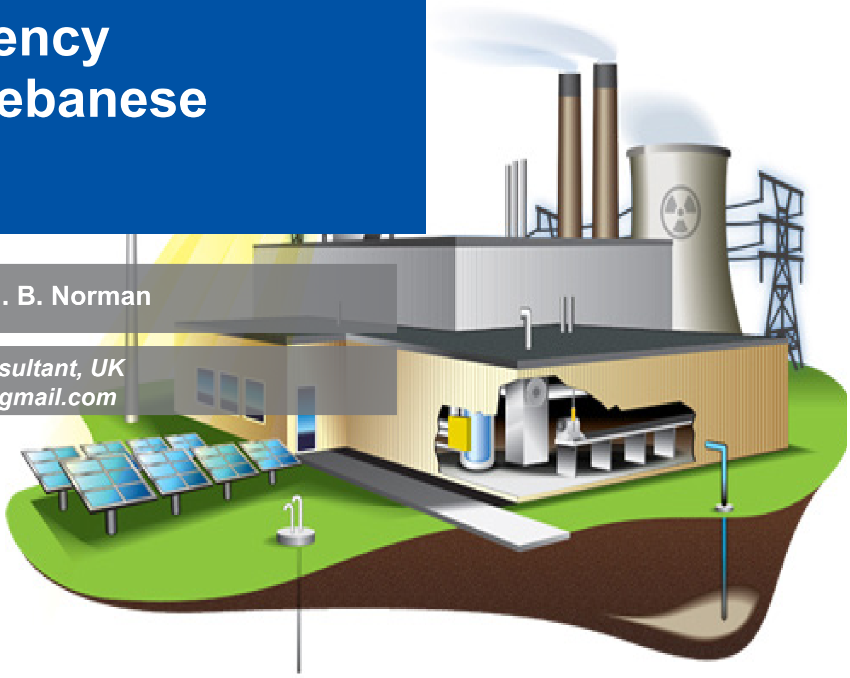

1 Introduction

The industrial sector is a major contributor to world energy demand and CO2 emissions. In 2005 the sector accounted for almost one-third of world primary energy use and approximately 25% of world energy and process-related carbon dioxide emissions (IEA 2010). Energy efficiency measures can reduce the relative energy use and emissions associated with industrial activities. Such measures are often both technically and economically viable. Efficiency is therefore favoured as the first step in reducing emissions, before aiming to meet the reduced energy demand in a low carbon manner (The Institution of Engineering and Technology 2007).

The current report aims to shed light on energy use and improvement potential in the Lebanese industrial sector. This starts with a discussion of energy efficiency indicators for the industrial sector, the energy use and efficiency opportunities within the Lebanese sector are then examined, the report closes with a discussion of wider systems issues and concluding remarks, including recommendations for data collection within the Lebanese industrial sector.

Measuring energy efficiency

Energy efficiency is generally measured as a useful output per unit of energy input (although the reciprocal is also often reported, i.e. energy input per unit of useful output). Energy input is normally measured thermodynamically (i.e. in Joules or similar units), either in terms of final or primary energy. Energy input can also be measured in economic terms, although a thermodynamic measure is preferred when measuring efficiency and technical improvement potential, as it is objective and unaffected by energy prices. There are a number of methods to measure useful output in the industrial sector:

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• ***Thermodynamically***: the useful output can be measured in thermodynamic terms. The efficiency indicator is then given as a percentage. This is appropriate when analysing a well-defined process or component (e.g. an electric motor). A thermodynamic output indicator can also offer insights when examining a subsector of industry, or the whole industrial sector [for example see Hammond et al. (2009)], but such measures rely on considerable assumptions.

• ***Physically:*** the useful output of many sites, subsectors, or even processes is usually a product, for example tonnes of steel or litres of milk. Such a measure allows efficiency indicators to be compared across time periods, between sites or production methods, and internationally. However the summing of heterogeneous outputs cannot easily be undertaken in a meaningful manner. Adding a tonne of steel to a litre of milk is not possible in a common unit. This limits the use of physical output measures to well-defined subsectors of industry.

• ***Economically:*** output can be measured in economic terms. This allows the easy aggregation of outputs across different subsectors of industry. However comparison over time periods, or internationally, requires the use of appropriate price indices and conversion factors. These can be difficult to measure accurately. There are various options when measuring economic output, including the value of shipments, value of production and value added. There is not a consensus around which is best used as an efficiency indicator, with data availability often dictating the choice. If using an economic output measure to track efficiency of a collection of subsectors over time it should be noted that changes in the structure of output can influence the efficiency indicator. For example the same value of economic output could be produced in two time periods, but if the basket of goods comprising this output differs it can affect the efficiency indicator with no change in the production processes. Techniques such as decomposition analysis [see, for example, Hammond and Norman (2012)] can be used to separate the effect of such structural change from energy efficiency change.

The choice of output measure is dependent on data availability and the boundary of the study. Different indicators will likely be used if the subject of a study is a process, industrial site, or subsector. In the majority of studies of industrial efficiency physical output is favoured, however if a single indicator for a number of subsectors is required economic output may be used. Another possible indicator of efficiency is the level of uptake of a certain technology in a subsector of industry. For example the proportion of motors in use that are of a certain efficiency standard. Such measures may be useful in setting targets for industry but may overlook more effective improvement measures if used in isolation.

To be of value a comparison is required for any efficiency indicator, the current measure of efficiency may be compared across time periods, across nations, to best practice, or to theoretical minimums. It is important that the boundaries of compared indicators are identical. An understanding of the sector under study and the operations taking place is therefore vital when performing such a comparison of efficiency indicators. A more complete discussion of efficiency indicators is covered in Norman (2013).

Energy use in the Lebanese industrial sector

Information on energy use in the Lebanese industrial sector was not available in thermodynamic terms at the time of writing. However economic data (Republic of Lebanon Ministry of Industry 2010) allowed some assessment to be made. The industrial sector is a major user of energy within Lebanon, accounting for around 60% of electricity use (including that self-generated) and 22.5% of oil demand (World Bank 2009).

Figure 1 shows the energy expenditure by subsectors of Lebanese industry [1]. The use of economic data for assessing the importance of energy use in thermodynamic and environmental terms is limited, as a dollar of electricity will not have the same energy content as a dollar of oil. Additionally the price paid for energy will not be uniform across time periods, or across industrial companies, with larger energy users typically paying less per unit of energy. However economic data on energy use can still offer some insight. Over eighty-five percent of energy expenditure is comprised of the six subsectors identified in Figure 1. Other non-metallic mineral products and Food and beverages particularly dominate the Lebanese industrial sector. Oil products are the most prevalent energy source delivered to Lebanese industry, as

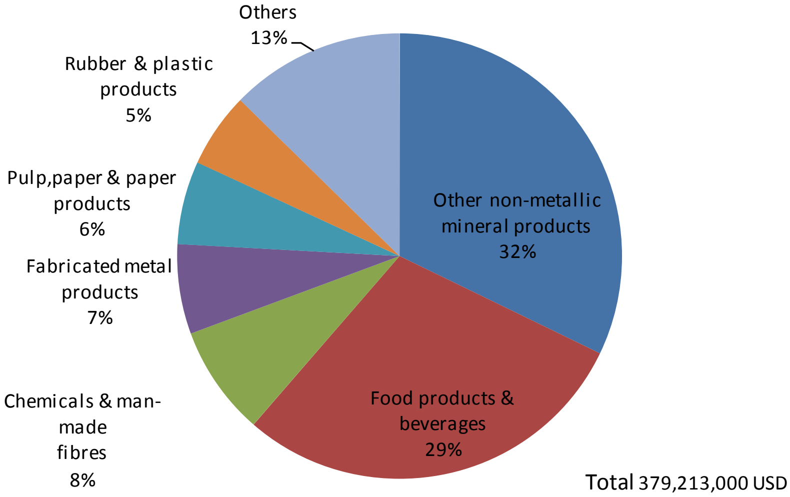

Figure 1: Energy expenditure in the Lebanese industrial sector during 2007. Source: Republic of Lebanon Ministry of Industry (2010).

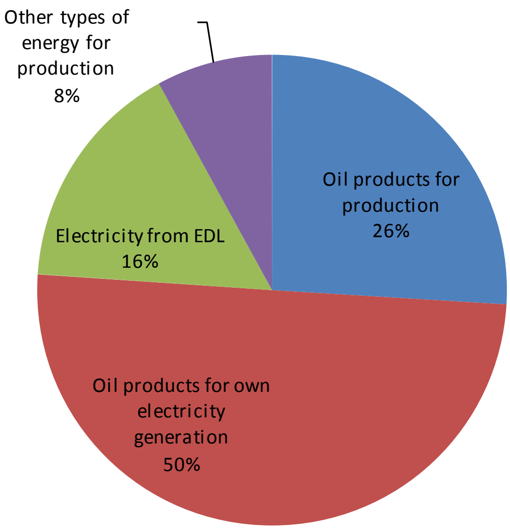

Figure 2: Fuel split of energy expenditure in Lebanese industry during 2007. EDL represents centralised electricity generation. Source: Republic of Lebanon Ministry of Industry (2010)

shown Figure 2. There is a large amount of self-generation of electricity, with half of energy expenditure being on oil products for electricity generation within the industrial sector. The fuel splits shown in Figure 2 broadly agree with those found through a series of energy audits conducted in Lebanese industry (World Bank 2009).

There is considerable variability in the importance of energy to different subsectors of industry. This is illustrated by Figure 3, the expenditure on energy as a proportion of total expenditure ranges from 1.4% in Electrical machinery and apparatus (ISIC 31) to 23.9% in Other non-metallic mineral products (ISIC 26). Within these groupings there is further variability at the site level due to company size, and the specific activities conducted. A survey during 2006 found 4.8% of industries have energy costs of more than 40% of total production costs and 20.8% of the survey respondents had energy costs in excess of 25% of total production costs (World Bank 2009).

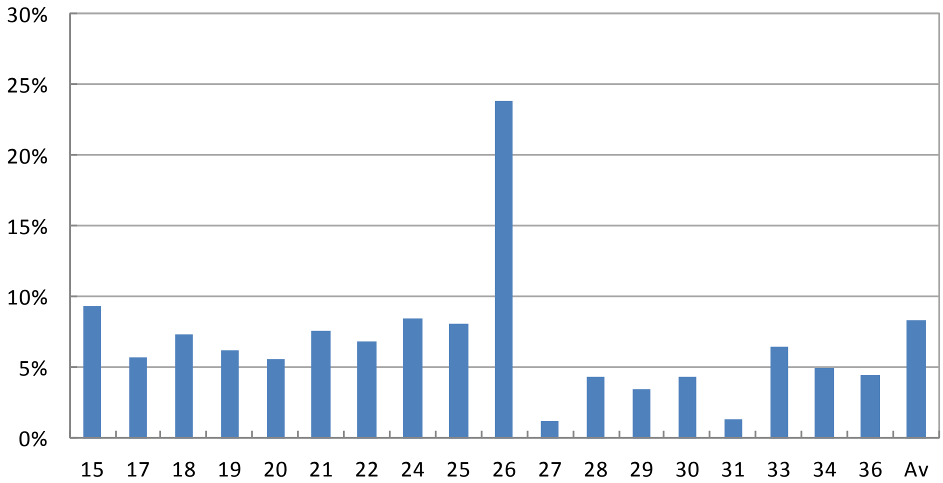

Figure 3: Energy expenditure as a proportion of total expenditure during 2007. ISIC (International Standard Industrial Classification) codes are used. Source: Republic of Lebanon Ministry of Industry (2010).

Figure 4 shows the ratio of economic output from each subsector to the expenditure on energy. This is one possible indicator of energy efficiency, with a higher value in this indicator identifying that more economic output is gained per unit of energy purchased. A comparison with Figure 3 shows that generally those subsectors with a lower proportion of expenditure on energy show a high output per unit of energy purchased, as would be expected. It is obviously meaningless to compare this measure between subsectors, due to the large variability in energy uses. However if such an indicator was tracked over time it may illuminate trends within subsectors (the change of energy prices over time would need to be accounted for in this case). As discussed in the section above an energy efficiency indicator that tracks energy in thermodynamic terms and output in either physical or economic terms would be preferable however.

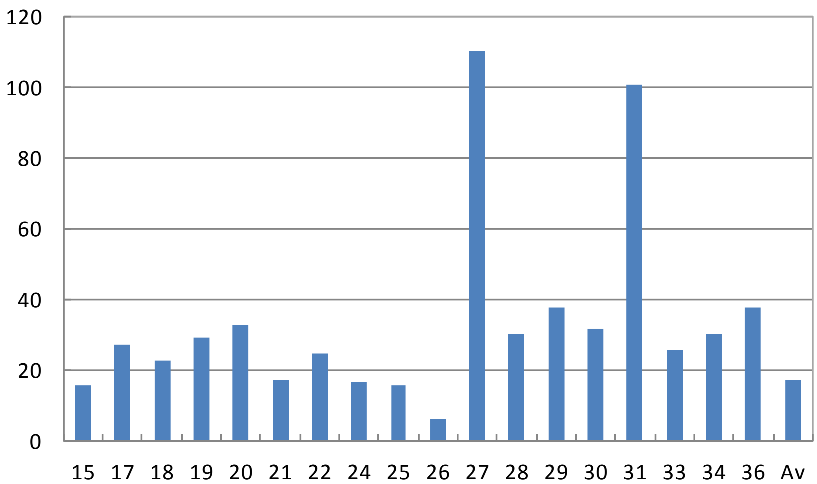

Figure 4: Ratio of economic output to energy expenditure in Lebanese industry, during 2007. ISIC codes are used. Source: Republic of Lebanon Ministry of Industry (2010).

Efficiency opportunities in the Lebanese Industrial Sector

To be able to accurately assess efficiency opportunities within Lebanese industry more information than currently available would be required on the current use of energy. Such information would include indicators that can be compared internationally and to best practice (for example the energy use per unit of physical output) in disaggregated subsectors of industry. An understanding of the energy using processes within the subsectors of Lebanese industry would also be required. Whilst it is therefore not feasible to make a quantitative assessment of improvement potential, or specific recommendations, some general findings from studying the industrial sector of other nations can offer insights.

The industrial sector can broadly be split into an “energy-intensive” subsector, for whom energy is an important production issue, and a “non-energy-intensive” subsector, for whom energy is less important (Hammond and Norman 2012). Examining Figure 3 energy expenditure is going to be considered more important for the Lebanese Other non-metallic mineral products subsector, than for the Electrical machinery manufacturing subsector. In a study of the UK it was found that the energy-intensive subsector had made smaller relative improvements in its efficiency in the period 1990-2007 than the non-energy-intensive subsector (Hammond and Norman 2012). On first impressions this is a somewhat surprising result. It was postulated that this was due to the existence of easily realised energy efficiency improvements in the non-energy-intensive subsector over the period studied. In contrast the energy-intensive subsector, driven by greater drivers to reducing emissions, had already realised the majority of such opportunities. Analysis of the period previous to 1990 supported this conclusion. Whether the situation is similar to this in Lebanon would require further data collation and analysis. However given the significant energy costs of some subsectors (see Figure 3) it is reasonable to assume energy efficiency will have been pursued to a large extent by some industrial subsectors. This is an example of how an analysis of efficiency indicators over time can offer insights into further improvement potential.

Efficiency opportunities within industry are often specific to an individual subsector, and the energy using processes within the sector. However there are also a number of technologies, and associated improvement opportunities, that exist throughout many subsectors of industry. These can be referred to as “cross-cutting technologies”. A general observation can be made that energy use of energy-intensive industries is often dominated by a small number of processes that are specific to that industry. Conversely non-energy-intensive subsectors use a relatively larger amount of their energy demand in cross-cutting technologies. Whilst the processes in energy-intensive industries may be reaching the limits of their efficiency, due to the strong drivers to improve efficiency, as discussed above, there may be “low hanging fruit” within the cross-cutting technologies used in non-energy-intensive subsectors. The term low hanging fruit refers to cost effective, and easily realised improvement opportunities.

Cross-cutting improvement potentials include the optimisation of existing systems such as:

- Steam systems
- Motor systems
- Space heating systems
- Lighting systems
- Cooling systems

The details of improvement potentials available in these technologies are well covered in the literature [for example see IEA (2007)]. There are some general guidelines that apply across these opportunities:

- Match the supply to the required use: for example by not oversizing a boiler or motor at the design stage, and by utilising variable speed motors where appropriate.

- Reduce losses throughout the system: this can be achieved through good maintenance, for example eliminating leaks in a steam system, and at the design stage, for example by optimally designing piping systems to minimise friction (Lovings and RMI 2011) or employing heat recovery technologies.

- Behaviour change: simple measures such as switching off equipment that is not in use, and following best practice in terms of operating procedures can in some cases lead to considerable energy savings at little or no cost.

- Fuel switching: this can also be applied across multiple industrial subsectors and technologies. There may not be energy efficiency benefits (although these may exist when switching to an easily controlled fuel, such as natural gas) but there may be considerable emissions savings, especially if switching to a biomass fuel. Switching to electricity may also offer emissions savings, depending on the generation technology.

An additional energy efficiency opportunity that finds application throughout industrial subsectors is the use of combined heat and power (CHP) systems. By producing both heat and electricity, where there is sufficient demand, energy efficiency is improved over separate generation. A study by the World Bank (2009) highlighted the considerable potential for CHP in the Lebanese industrial sector due to the large proportion of self-generation of electricity within the sector (see Figure 2). CHP is most successfully employed where there is a constant demand for heat at a relatively low temperature. CHP is often used in the Food and beverages, Chemicals and Pulp and Paper subsectors of industry. As an alternative to conventional steam systems heat pumps and renewable fuelled heating technology can also be considered.

The largest two sectors of Lebanese industry by energy expenditure, the Other non-metallic mineral products sector and the Food products and beverages sector are examined further here as an example of energy use and efficiency opportunities. The split of economic output within these sectors is shown within Figure 5 and Figure 6.

Cement, lime and plaster manufacture accounts for almost half of economic output within the Other non-metallic mineral products sector (see Figure 5). As Cement has a high energy and carbon intensity in terms of economic output it would be expected to dominate energy and emissions within this sector. Cement output in Lebanon has also grown significantly in recent years, increasing from 3348kt in 2006 to 5227kt in 2010 (Taib 2012). The cement sector manufactures a very homogenous product for which there are a small number of processing routes, with variations on the same basic technique. The subsector is also responsible for significant amounts of process emissions, linked to the chemical reactions that occur as part of production. Large energy savings are possible in cement manufacture if out of date processes are being employed, for example by switching from the "wet" to the "dry" process. However if best practice in terms of kiln technology is already employed potential savings through energy efficiency measures are relatively small. Emissions savings can also come from fuel switching or "clinker substitution" (where alternative materials are used to partially substitute for clinker, whose production dominates energy use and emissions). Carbon capture and storage and low carbon alternative cements offer possible future, but uncertain, opportunities for reduced energy use and/or emissions (Griffin et al. Forthcoming).

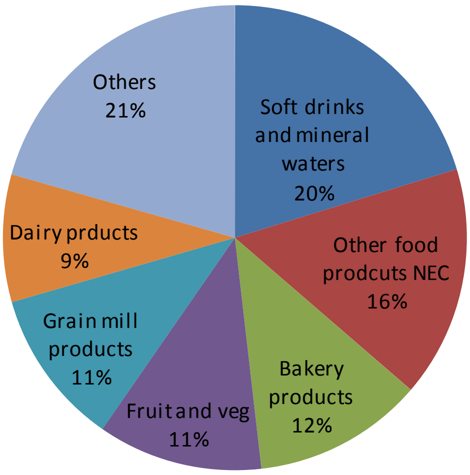

Figure 5: Split of economic output in the Lebanese Other non-metallic mineral products sector. Source: Republic of Lebanon Ministry of Industry (2010).

The Food products and beverages sector shows a diverse number of subsectors contributing to economic output (see Figure 6), the energy using processes within the sector would also be expected to vary considerably. This diversity makes an assessment of energy efficiency within this sector difficult. Whilst there are likely energy efficiency opportunities in process specific uses of energy, for example in pasteurising within the dairy subsector, the greatest opportunities may come from the cross-cutting technologies described above. Heat, supplied in the form of steam systems, is a relatively common carrier of energy within the Food and beverages sector, supplying a variety of end uses. In supplying this steam opportunities in improving the efficiency of the boiler and steam distribution system, or utilising CHP systems or heat pumps, can have applications across the Food and beverages sector (Norman 2013). The Lebanese climate may also make the use of solar powered heating systems attractive. Cooling systems are also used throughout the sector and opportunities may be found here.

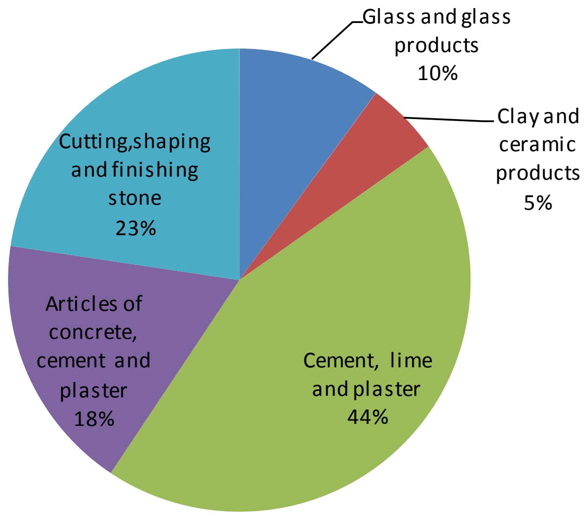

Figure 6: Split of economic output in the Lebanese Food products and beverages sector. Source: Republic of Lebanon Ministry of Industry (2010).

The variation within the Other non-metallic mineral products sector and the Food and beverages sector, in terms of the outputs, and energy using processes, gives an indication of the importance of the level of disaggregation of data collection. If data on energy use and output was only reported for two digit ISIC codes (i.e. at the level of Other non-metallic mineral products, and Food and beverages) it would be very difficult to make comparisons with best practice as the relative size of the disaggregated subsectors within these groupings will have a considerable influence on energy use and output.

Wider systems considerations

The Lebanese industrial sector exists within a global system that produces the inputs to the sector and utilises its outputs. Whilst a tightly defined system boundary is often necessary for the study of energy efficiency opportunities the widening of the boundary can offer additional insights. The adoption of radical or novel technologies could considerably change the inputs and outputs of the industry under consideration. To compare the level of savings due, not just to changes in the energy use of the process industry, but also changes in these inputs and outputs, a tool such as Life Cycle Assessment (LCA) can offer insights.

The discussion above has focussed on the industrial activity that occurs within Lebanon's borders. However Lebanon will consume products and materials that are manufactured in other nations. The energy use and emissions of Lebanon could be measured on a consumption basis, which will include the impact of imports, and exclude those of exports [see for example Scott et al. (2013)]. This gives an important perspective when examining energy use and emissions. As an example of the importance of this approach, the Lebanese basic metals sector (ISIC 27) uses a relatively small amount of energy within the industrial sector (it is included within the Other sectors in Figure 1). However, in many nations this subsector is among the highest energy users of the industrial sector. Lebanon has not produced any steel since the closing of the country's only rolling mill in 2003 (Taib 2012). Lebanon obviously still consumes steel but the impacts of production take place outside its borders. A full account of the impact of Lebanese consumption should include such impacts. Techniques to measure the consumption based emissions, as opposed to the territorial emissions, include multi-regional input-output (MRIO) analysis (Minx et al. 2009) or carbon footprinting (Cranston and Hammond 2012), for the whole economy, or material flow analysis (MFA) for a given material or subsector (Allwood, Cullen and Milford 2010). Data may have to be collected to allow these techniques to be applied.

The report has focused on energy efficiency in production processes. Savings can also be made by considering material efficiency, both in the production process and in the consumption of products (Allwood and Cullen 2011). For example reducing the steel use in an automobile through a lightweight design would reduce the embodied energy use and emissions through a reduction in the demand for steel (this example of material efficiency would also lead to less energy demand in the use phase, as a lighter car will generally require less fuel). Material efficiency can be particularly important for energy-intensive sectors of industry, where the remaining opportunities for energy efficiency are limited without the adoption of radical technologies.

Energy efficiency opportunities can have impacts beyond the obvious implications for energy demand and greenhouse gas emissions discussed here. The wider environmental , social and economic impacts that an efficiency measure could have should also be considered. These are more likely to be significant when large radical changes are made to existing processes and equipment rather than through evolutionary improvements to efficiency.

The rebound effect (Sorrell 2009) can influence the effectiveness of energy efficiency improvements. The rebound effect is the mechanism through which improvements in efficiency do not lead to the full savings potential being realised, and can be either direct or indirect. An example of a direct rebound effect in the manufacturing sector would be that improved efficiency (and hence lower energy costs) encourage the substitution of energy for labour, or other inputs, in production (Greening et al. 2000). An indirect effect example is that the cost savings from efficiency gains may be reinvested in additional equipment, which itself will have an energy requirement to produce. Whilst the rebound effect should not discourage efficiency improvements to be pursued it is important to consider, although difficult to quantify.

Concluding remarks

The current lack of data on energy use in the Lebanese industrial sector is a major barrier to assessing levels of energy efficiency and improvement potential. Information on energy use (in thermodynamic terms) and output, both in economic and physical terms should be collected at an appropriate level of subsector disaggregation. This would allow a comparison of energy efficiency, both to best practices and internationally, which can give an indication of the scale of improvements that could be made and so the priorities for action. The collection of such data would also allow efficiency indicators to be tracked over time to quantify the improvements made. Detailed information on energy flows within each subsector are also important, especially for those subsectors that are large users of energy. Energy audits of representative sites are one method of collecting this data. This more detailed information would be required to make more precise recommendations on the changes that could lead to increased efficiency.

Some insights into the likely efficiency opportunities within Lebanese industry can be gained from experiences in other nations. Energy-intensive industries may have limited efficiency opportunities without the application of more radical technologies (although this requires confirmation through better information). Non-energy-intensive industries may find there are easily realised efficiency opportunities through the application of cross-cutting technologies. Energy efficiency has been the focus of this report, although it is absolute energy use and the associated impacts that are important when considering the challenges of climate change and energy security. The energy use of Lebanon’s industrial sector may grow as output increases. This can have obvious positive effects on the development of the country and should not be discouraged. Efficiency in using energy, and other resources, can contribute to this development occurring in a sustainable manner. Opportunities for energy efficiency should be assessed with a view to wider impacts, and against other opportunities for resource efficiency. Many efficiency improvements can be made immediately, in an economic manner. A significant contribution from bioenergy, electricity decarbonisation and industrial CCS would require considerable research and development and turnover of capital stock. There is an inertia to this form of change (Jollands et al. 2010) and whilst in the long term these options will likely be important, efficiency measures can often have a more immediate impact. Additionally a reduction in energy demand through efficiency reduces the challenge of meeting this demand through alternative means.

[1]: The definition of industry here excludes: Mining and quarrying; Coke and refined petroleum products; Electricity, gas, steam and hot water supply; and Collection, purification and distribution of water. The energy use and efficiency opportunities in these excluded industries will be significantly different to those within the remainder of industry, which is focussed on here.

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