around 85% of all commercial energy consumed comes from fossil sources and reserves, and resources of these are very large and, if used, will result in CO_2 emissions which exceed any carbon budget that fulfils proposed climate targets (Kjärstad and Johnsson, 2012). The technologies and measures available to reach the above mentioned target are to use less energy, to shift fuel and technology or to capture and store CO_2.

4 Historically, economic growth (increased wealth) has resulted in increased use of energy and it has proven difficult to decouple growth from increased energy use (Ayres and Warr, 2005, Cleveland, Kaufmann and Stern, 2000, and references therein) and from increased emissions of carbon dioxide (and other GHGs). So far, there has been a strong dependency on fossil fuels for energy. Fossil fuels are highly rich in energy since they are a result of several millions of years of accumulating organic matter, which society now takes out as energy over a very short period. Within the coming decades, society cannot be expected to use less energy but use the amount of energy it finds most economic, given available information and prevailing market conditions. There is also an increase in population, but affluence and increased wealth using the current developed world lifestyle should be a greater threat to climate changed mitigation than population increase in itself. This is double since for poor regions an increase in wealth is a prerequisite for reducing population increase, especially with respect to that increased wealth for the poor resulting in access to education and birth control.

5 Another option to reduce the energy use is to employ different technology, such as replacing an old inefficient power plant with a new one with higher efficiency. Yet, this may only result in increased competitiveness and what is referred to as rebound effect, i.e. more units of energy sold. The concept of rebound effect was first described by Jevons (1865) and is sometimes called the “Jevons paradox.” Jevons found that in spite of significant increases in the efficiency of steam engines, requiring less coal for a certain work output, steam engines were more widely used resulting in an increase of coal consumption. The concept of rebound effect (Saunders, 1992, Berkhout, Muskens, and Velthuijsen, 2000) is complex and has been under debate during recent decades since it has important bearings on environmentally driven energy efficiency policies. It can result in both direct rebound effects (such as observed by Jevons) as well as indirect effects where money saved from increased efficiency in a certain sector (e.g. home heating systems or buying a smaller, cheaper and more fuel efficient car) is spent in another energy consuming (and GHG emitting) sector. It seems that energy-efficiency policies need to include a policy which also influences how the money saved is spent. Lifestyle changes have also proven difficult with respect to “downsizing” the energy use. With increased wealth (including rebound effect) we tend to spend our additional money on carbon intensive activities, such as with low fare airline traveling or long distance charter trips rather than on low carbon alternatives (See Roy and Pal (2009) for an overview of this issue). The issue of lifestyle changes is connected to the concept of rebound effect.

6 Fuel shifting has been applied widely, especially in the stationary energy sector. Notably, Europe and North America have seen a significant shift from coal to natural gas electricity generation (e.g. Kjärstad and Johnsson, 2007). This has lowered the carbon intensity of electricity generation (increased thermal efficiency and less carbon intensive fuel). Yet, as indicated above, this has also made electricity production more competitive implying a rebound effect and at least for Europe, increased dependency on foreign natural gas production (reduced Security of Supply) as opposed to using domestic coal (especially lignite) resources and renewable fuels. The shift to biomass has indeed reduced emissions but the overall effect is still limited and for some types of biomass, the climate benefit is not always obvious (considering direct and indirect land use change, LUC and ILUC). Most bioenergy systems can deliver large greenhouse gas savings, if they replace high emissive fossil-based energy and that the bioenergy production emissions, including emissions due to land use change, are kept low (Berndes, Bird and Cowie, 2010a).

7 In the 1970s and 1980s, there was an increased use of nuclear power which resulted in lower CO_2 emissions compared to if the corresponding electricity (base load) would have been produced from fossil fuels (such as coal). Subsequently, nuclear power has lost public acceptability in many regions and the high upfront costs make it a risky investment on a deregulated market (as opposed to the nuclear programs in the 1970s for which the investment risks were more or less taken by national governments). In recent years, Europe has shown a move back to nuclear power with discussions and decisions on lifetime extensions and upgrading of existing plants. This trend has recently been moderated as a result of the 2011 events in Fukushima, Japan, following the earthquake.

8 At present, there are significant initiatives on increasing the deployment of renewable energy, but renewable technologies (especially wind power, solar PV, solar thermal and biomass) still only account for a small share of the energy mix in most countries. In cases where renewables account for a significant share of the energy mix, it is often in the form of “old” renewable such as large scale hydropower for which further