SWISS GREENHOUSE GAS ABATEMENT COST CURVE

McKinsey&Company

CONTENTS

FOREWORD

To limit global warming in the long term to no more than 2 degrees celsius, the Intergovernmental Panel on Climate Change (IPCC) assesses that greenhouse gas (GHG) emissions must be reduced to approximately 1 tonne per person by the end of the century. This will require a carbon productivity revolution similar in scale to the economic transformation of the Industrial Revolution, and will present a challenge for many nations.

Switzerland has committed to a 10 percent reduction of CO_2 by 2010, compared to emissions for 1990. Reduction targets of at least 20 percent by 2020 have recently been put forward for discussion by the Swiss Federal Government. Similarly, the EU has set as a target that 2020 emission levels should be 20 percent lower than those of 1990, and has stated its intention of aiming for a 30 percent reduction target for 2030.

An intensive debate is now in progress concerning the technical and economic feasibility of different target levels, the emission abatement opportunities that should be pursued (or not), and the costs of different options for meeting the targets.

To provide a quantitative basis for such discussions, McKinsey & Company Switzerland has evaluated abatement measures in terms of their overall potential and their cost for Switzerland. The study is based on the same methodology used in other studies conducted by McKinsey & Company, both globally and in other countries, such as Germany, Sweden, the United States and Australia.

This analysis does not offer any assessment of current policies or implementation programs; nor does it make recommendations to regulators on implementation mechanisms. The aim of this study is to create a fact base and to provide a uniform data set as a starting point for corporate leaders, academics and policy makers when discussing priorities and how best to reduce emissions.

Zurich, January 2009

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EXECUTIVE SUMMARY

While Switzerland already has low domestic GHG emissions compared to other countries (7.2 tonnes per person per year), due to its access to emission-free electricity production and substantial net imports of energy-intensive goods, there are many areas where significant GHG reduction can be achieved economically, notably in the transport sector and in buildings.

In our base case, with a long-term oil price of $52 per barrel and a wide range of measures using available technology, Switzerland has a total reduction potential of 45 percent versus the 2030 baseline, and 43 percent compared with 2005 GHG levels. This potential comes from buildings (45 percent), transport (22 percent), power (16 percent), industry (11 percent) and agriculture (6 percent). The measures involved would cost below €100 per tonne of CO_2e[1] avoided. Measures with an abatement potential of 8.3 megatonnes (Mt) of CO_2e (40 percent of total) have negative costs; that is, they cost less to implement than the amount they save. In a higher energy price scenario (oil price of $100 per barrel, gas and other utilities accordingly), the reduction deriving from measures with negative costs increases from 8.3 Mt to 19.6 Mt of CO_2e.

To realize all reduction measures costing below €100 per tonne of CO_2e avoided, a total investment of €38 billion or approximately 0.7 percent of GDP annually, will be required. In our base case, the total annual cost (excluding transaction and program costs) to finance measures above €0 per tonne of CO_2e amounts to €680 million in 2030. This annual cost represents 0.24 percent of the total Swiss GDP in 2005.

Switzerland has a significant potential to reduce GHG emissions by increasing CO_2 productivity and at the same time save money. We believe this offers an opportunity for many companies to develop further innovative technologies and services.

1 CO_2e: carbon dioxide equivalent

OPPORTUNITIES FOR GHG ABATEMENT IN SWITZERLAND

Switzerland already has low domestic GHG emissions

Compared to other countries, Switzerland has relatively low GHG emissions per capita, due to its access to hydro and nuclear power for electricity production. 95 percent of electricity produced in Switzerland comes from non-fossil energy sources, which makes the CO_2e intensity of all energies consumed in Switzerland among the lowest in Europe (0.22 tonnes of CO_2e per megawatt hour (MWh) equivalent). In addition, due to the absence of energy-intensive heavy industries, Switzerland's industry contributes less to CO_2e emissions compared to other countries, but imports a significant amount of greenhouse gas emissions through imports of energy-intensive goods (e.g., fossil fuels).

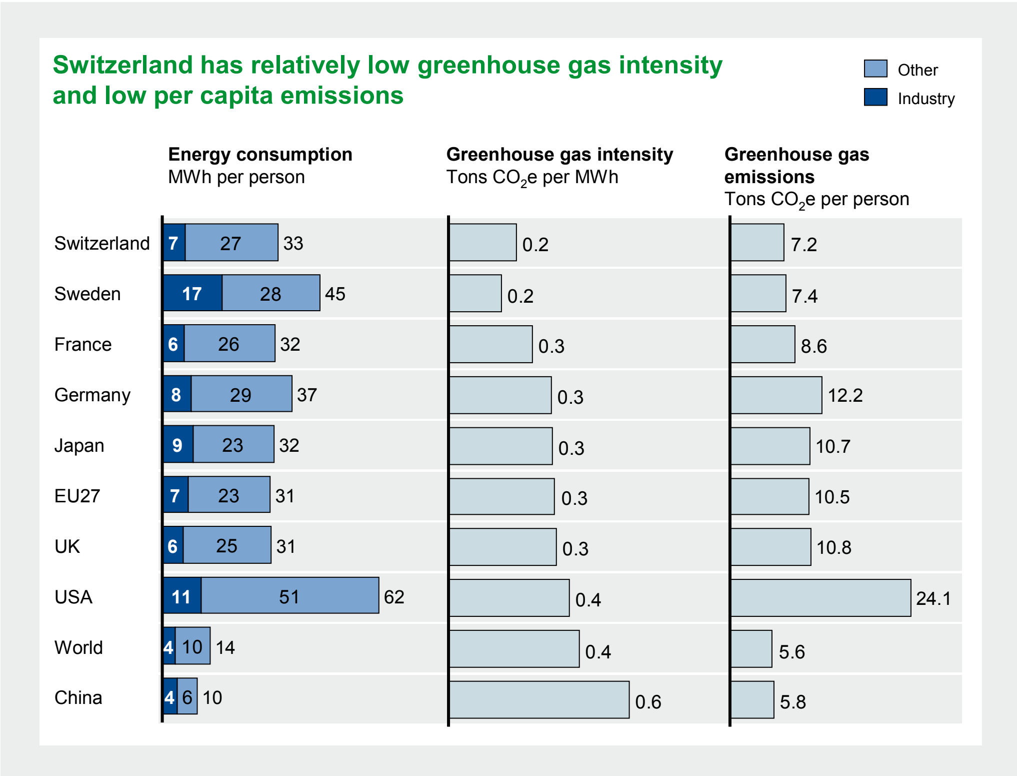


Figure 1

We have chosen to compare direct GHG emissions applying the territorial principle required by the UNFCCC. Calculating overall emissions associated with the goods that a country consumes (principle of national treatment) would lead to higher figures.[2]

2 BAFU (2007): "Graue Treibhausgas-Emissionen der Schweiz 1990-2004"

What is Switzerland currently doing on CO_2?

Switzerland has set a target to reduce its CO_2 emissions by 2010 by 10 percent compared with 1990 levels (CO_2 Act, which entered into effect on 1 May 2000). Measures to support the reduction include a charge on non-transport fossil fuels (SFr 12 per tonne of CO_2 as of 1 January 2008) and a charge on imported transport fuels (1.5 Rp per liter as of 1st October 2005, roughly SFr 100 million per annum). Companies that have committed to reduction targets can ask for exemption from the non-transport fuels charge. The Swiss Government has concluded a number of voluntary agreements with the industry on supporting specific CO_2 projects, which are financed by the charges mentioned above (e.g., Klimarappen Stiftung, Energie-Agentur). There are also a number of support measures by individual cantons, and voluntary efforts by companies and institutions to reduce CO_2 emissions. New legislation will be required to set emission targets beyond 2012. The Swiss Federal Government has recently put forward two options for discussion. Option 1 includes a reduction target of 20 percent by 2020 (with a maximum 1/4 from buying certificates) and the intent to follow a higher target of 30 percent if the EU would agree on the same target. Option 2 proposes a higher reduction target of 50 percent by 2020, with 32 percent reduction achieved through compensation abroad and buying certificates and 18 percent achieved through measures implemented within Switzerland. Similarly, the EU has set a target that 2020 emission levels should be 20 percent lower than those of 1990, and has stated its intention of aiming for a 30 percent reduction target for 2020 if other industrialized countries also commit to large-scale emission reductions.

There is a total reduction potential of 45 percent

In our analysis of the reduction potential we have considered reduction measures costing less than €100 per tonne of CO_2e, as we believe that this represents an acceptable cost level, at which society will consider implementing a reduction measure by 2030. To calculate reduction costs, we have chosen two scenarios: a base case with an oil price of $52 per barrel and a scenario with oil at $100 per barrel.[3] To calculate costs, we apply an interest rate/discount rate of 2.5 percent, and the average actual lifetime of the measure.

In the base case, our analysis indicates a total reduction potential of 20.9 million tonnes of CO_2e at a cost below €100 per tonne of CO_2e, from buildings and the energy and transport sectors. This corresponds to a reduction of 37 percent by 2030 compared with the reference case. In addition, we estimate an additional reduction potential in industry and agriculture of at least 4 million tonnes, which would bring the total reduction potential for Switzerland to 45 percent versus the reference case in 2030. This corresponds to a 43 percent reduction compared with 2005 levels, and would lower the current GHG emission to 3.8 tonnes per person annually.

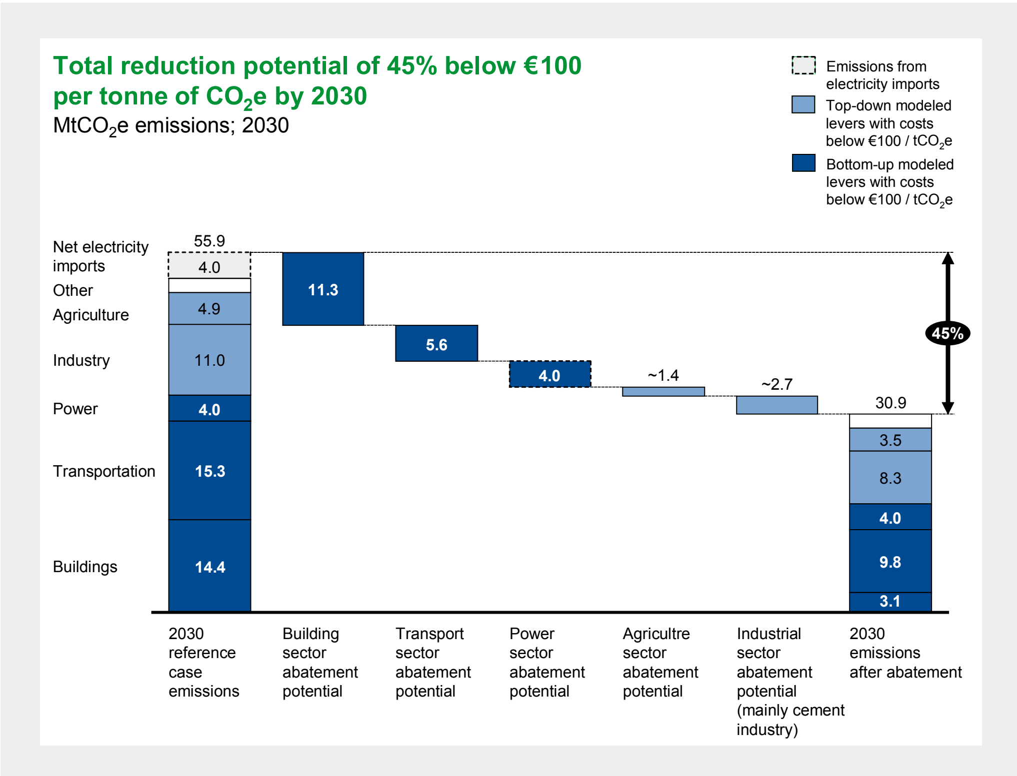
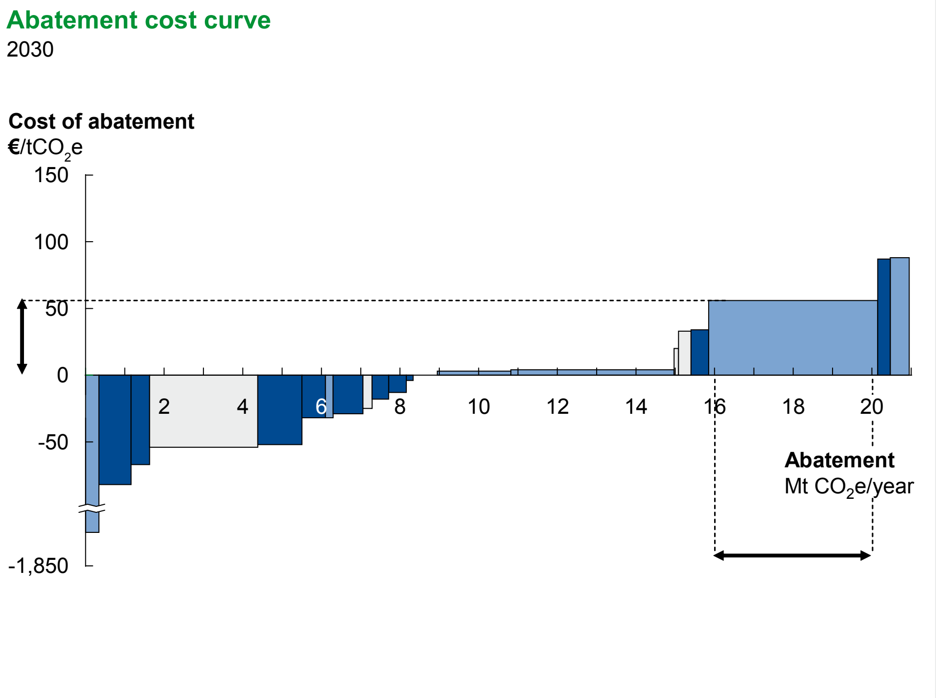


Figure 2

3 We have assumed two scenarios: one with an oil price in 2030 of $52 per barrel (base case) and one with $100 per barrel, to show a potential range of energy prices and the impact of higher oil prices on the abatement cost curve. IEA assumptions in the World Energy Outlook were $62 per barrel in 2007 and $122 per barrel in 2008.

How to read the abatement cost curve



Each bar represents one opportunity to reduce greenhouse gas emissions. There are 2 dimensions:

- Volume dimension: The width represents the amount of CO_2e (in million tonnes) that can be reduced in a specific year by this lever, irrespective of the year when the opportunity was implemented.
- Cost dimension: The height indicates the average cost of reducing 1 tonne of CO_2e with this opportunity, relative to the activities that would otherwise occur in the reference case. Cost is averaged across sub-opportunities and years (as opportunities are created in different years and at different cost). It excludes taxes, subsidies, transaction and program costs, and uses a "societal" interest rate equivalent to the rate of long-term government bonds (2.5 percent p.a.).

Important aspects of the GHG reduction cost curve:

- The curve focuses on the potential volume and cost levels deemed feasible. It is not a forecast of what will actually happen in the future.
- There can be considerable uncertainty about both the volume and the costs involved.

How to read the abatement cost curve

- Negative costs (those below the horizontal axis) indicate a net financial benefit to society over the lifecycle of the reduction opportunity; positive costs (above the axis) imply that capturing the opportunity would incur incremental lifecycle costs compared to the reference case.
- The average cost of an opportunity does not necessarily correspond to the price signal needed to stimulate the capture of that opportunity.
- For some measures the curve only includes the incremental reduction potential to avoid double-counting, i.e., the reduction potential for hybrids and electric vehicles also includes the potential of the other transport measures.
- The curve includes packages of measures with total potential and average cost of all measures included. The individual measures in the package, however, may have different costs while they do not ensure equivalent efficiency gains; e.g., certain insulation measures for retrofitting buildings.

The reduction cost curve is a useful tool for:

- Creating an integrated perspective on reduction potential and opportunities.
- Evaluating orders of magnitude and prioritizing reduction measures within and across sectors.
- Providing a fact base to support the assessment of possible regulatory arrangements.

It does not give indications for:

- Defining a target CO_2e concentration level to solve climate change issues.
- Forecasting CO_2 prices or potential climate regulation.
- Predicting the development of individual technologies.

40 percent of the GHG abatement measures would save significant amounts of money

The cost curve represents the economical potential of measures under €100 per tonne of CO_2e to abate GHG emissions relative to our reference case. Each bar on the cost curve represents one reduction action (or a group of actions) that could be taken, with the width representing the annual emission reduction impact in 2030 relative to the reference case (i.e. if no reduction actions were taken), and the height representing the cost per tonne of annually avoided CO_2e emissions. To develop the curve, we have looked only at technical measures, and did not consider potential reductions from lower demand or changes of lifestyle. For example, we have included reduction measures to improve the fuel efficiency of a car that would reduce emissions, but we have not included measures such as driving fewer kilometers.

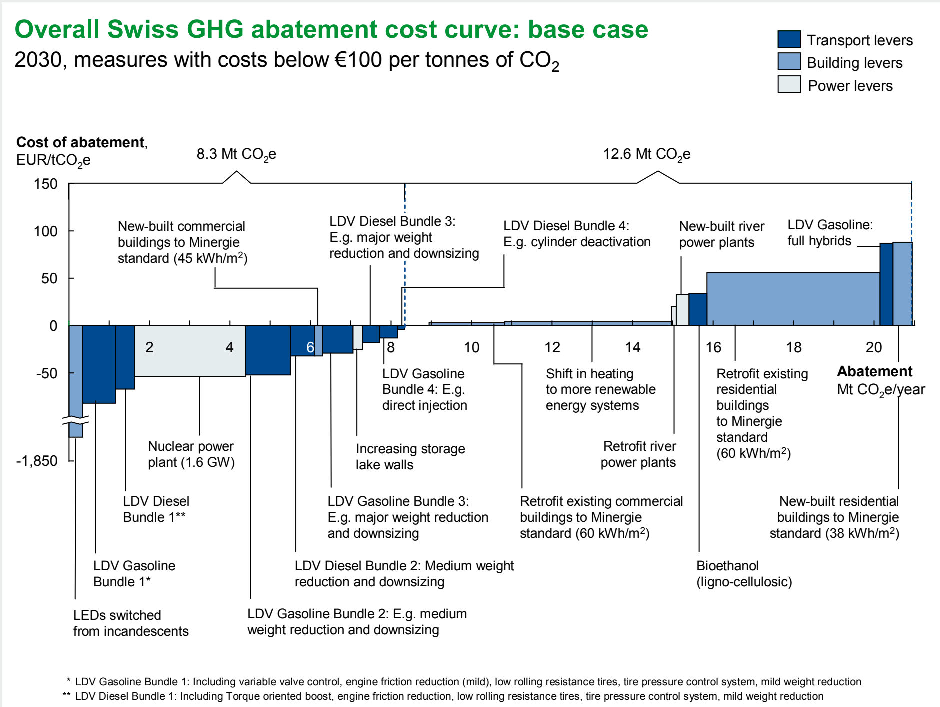


Figure 3

In our base case calculations with an oil price of $52, measures with a reduction potential of 8.3 million tonnes have negative costs; that is, the savings from reduced energy consumption more than compensate for the additional initial investment over the average lifetime of the investment.

More than 50 percent of the measures with negative abatement costs are in the transport sector, where there are significant technical opportunities to increase energy efficiency (e.g., better aerodynamics, low-friction tires, lighter materials, better engines, hybrids) without compromising lifestyle or reducing demand.

While buildings represent the greatest overall reduction potential (11.3 Mt), the total cost of reduction is higher than for transport measures. The cost is slightly above €0 per tonne of CO_2e for retrofitting commercial buildings or changing heating systems, and around €50 per tonne of CO_2e for renovating or retrofitting existing residential buildings to low energy standards.

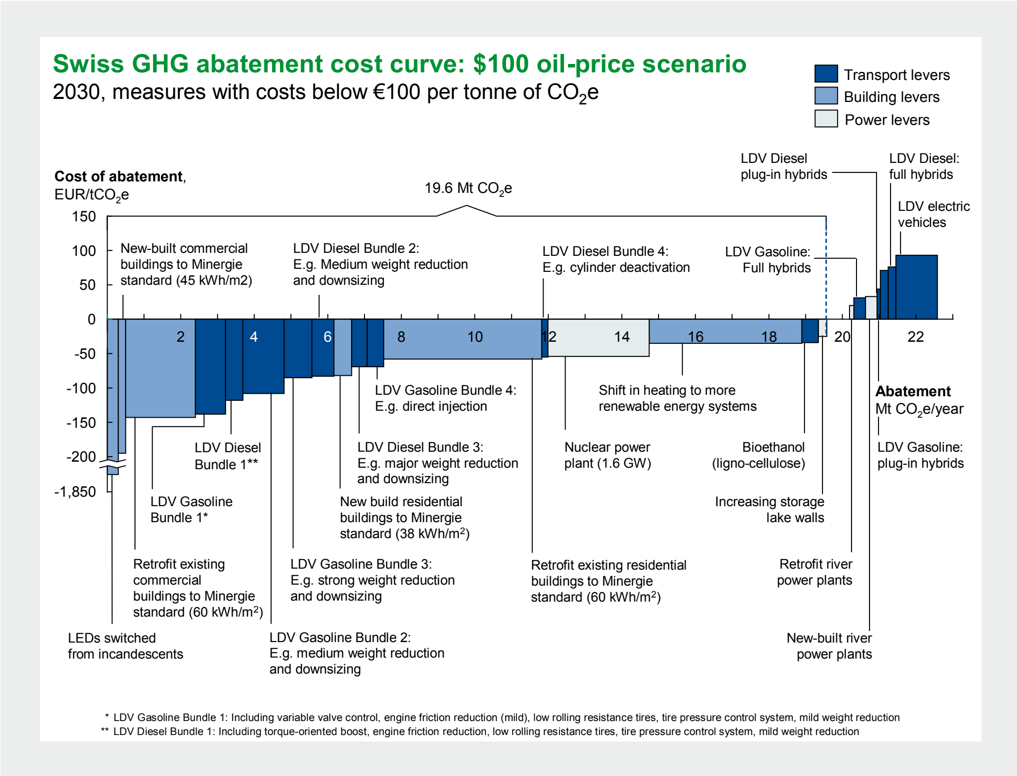


Figure 4

In a high energy price scenario (oil price of $100 per barrel, gas and other utilities accordingly), the contribution of measures with negative costs increases from 8.3 Mt to 19.6 Mt of CO_2e. The overall reduction potential with costs below €100 per tonne of CO_2e from buildings and the transport and power sectors increases only slightly from 20.9 to 22.6 Mt of CO_2e. This is because few of the additional levers, most notably hybrid and electric vehicles, are below the €100 per tonne threshold.

Realizing all reduction measures would require investments of €38 billion

To realize the 45 percent reduction by 2030, additional investments of about €38 billion will be required from 2010 to 2030, with an average annual investment of about €1.9 billion or approximately 0.7 percent of GDP (this comparison simply shows the order of magnitude, and does not indicate any impact on GDP). However, this estimate should be treated with caution, for two reasons. First, the assumption that all opportunities would be effectively addressed is highly optimistic. Second, in reality there would be significant dynamic effects in the economy from a program of this magnitude – effects that could either increase or decrease the cost.

A more detailed look into the investments required reveals potential financing challenges. Some 76 percent of additional investment is in the consumer-related transport and building sectors.

The net additional cost of investing in fuel-efficient vehicles and energy-efficient buildings is typically low (at least in the high energy price scenario), as much of the investment is regained through energy savings. Nevertheless, finding effective ways to finance the additional cost may not be easy. The investment in buildings amounts to about €17 billion, including costs for retrofitting residential and commercial buildings of more than €13 billion. The measures in the transport sector require investments of about €12 billion, with full hybrid gasoline cars demanding the highest incremental investment costs. Finally, a new nuclear power plant would represent the main up-front cost of the measures in the power sector, which in total amount to about €9 billion.

In the higher energy price scenario – including plug-in hybrids and electric vehicles – investment costs in the transport sector would increase to more than €22 billion, thus expanding overall investment costs to more than €48 billion (or about 0.9 percent of GDP).

Overall investment cost of €38 billions over the period from 2010 to 2030

€ billions, measures with costs below € 100 per tonnes of CO_2, 2010 - 2030

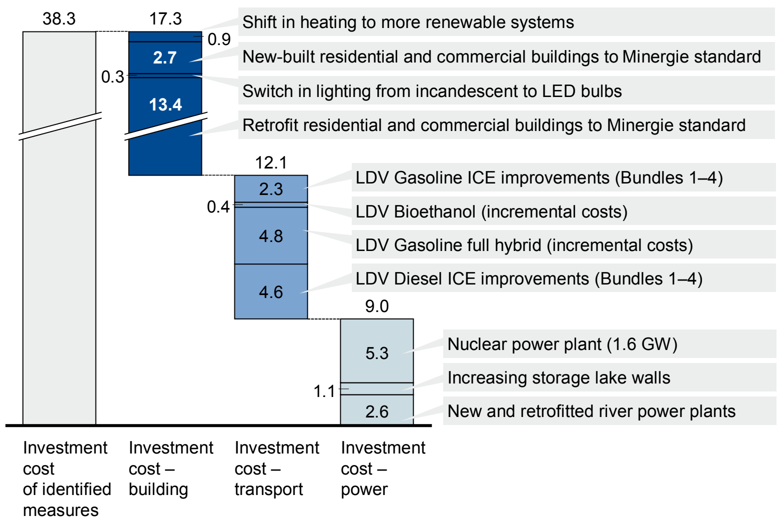


Figure 5

On a per capita basis this investment translates into €250 per person per year in the base case. However, cost savings from energy efficiency and other measures would offset these additional investments. Furthermore, according to current climate science, inaction represents a huge cost to society. Adaptation and damage costs are notoriously hard to gauge, but they have been estimated at 5 to 20 percent of global GDP in 2100 if "business as usual" growth of GHG emissions continues.[4]

4 Range shows estimates from Stern Review 2006; DIW Berlin 2005 using WIAGEM model; Cambridge Hope 2003 using PAGE 2002 model

In terms of net additional annual costs, the total annual cost of all positive-cost measures in the base case scenario is about €680 million in 2030. This sum represents 0.24 percent of total Swiss GDP in 2005. The total net savings of all measures with negative cost to society – where energy savings outweigh the additional investment – amounts to about €790 million (0.28 percent of Swiss GDP in 2005). Overall, more than €110 million could be saved in the base case by applying all measures whose cost is below €100 per tonne of CO_2e in 2030.

In a scenario with higher energy costs, the total net savings would amount to about €900 million in 2030 or about 0.3 percent of Swiss GDP, as higher energy prices make energy efficiency measures more profitable. While the total cost of all positive-cost measures remains about constant (about €650 million in 2030, mainly due to the cost of electric vehicles), the total net savings of all negative-cost measures increases substantially, to more than €1.5 billion in 2030 (mainly from measures related to buildings).

The costs shown in the cost curve reflect "project costs" only – including all elements involved in planning, implementing, and operating the reduction project over its lifetime. They exclude typical transaction and program costs, such as building national capacity to create, monitor and monetize such projects.

Going beyond 2030

In our calculations, current new technologies (solar panels, carbon capture storage, etc.) remain too expensive up to 2030 to come below the €100 per tonne threshold. However, it is likely that these technologies could play an important role in achieving long-term reduction objectives beyond 2030. New technologies such as carbon capture and storage, and potentially nuclear power, and other alternative energies, will need to play a more substantial role beyond 2030.[5] The development of new, and the improvement of existing alternative energies, as well as other GHG-efficient technologies represents a significant opportunity for many companies.

In our calculations, we have excluded potential GHG reductions arising from behavioral change. Reducing car driving by 10 percent (compared to the reference case) would reduce emissions by more than 1 Mt of CO_2e. A shift to smaller cars with lower CO_2e emissions would have a similarly substantial impact.

5 International Energy Agency (IEA) (2008); Energy Technology Perspectives 2008 and McKinsey (2009): Global Greenhouse Gases Reduction Cost Curve; Version 2

Societal vs. decision-maker perspective

The overall economic perspective of this effort is a societal one. It applies much lower interest rates than those that might be incurred by the private investor, and assumes the actual lifetime of the assets, while the decision-maker's timeframe is often much shorter. This has significant implications for the cost of the measures, particularly in the sectors most affected by consumer behavior, such as transport and buildings.

While the societal approach gives a good indication of the burden or benefit that accrues to society, it does not necessarily reflect the economic investment decision an individual decision-maker faces. Decision-makers face different interest rates, different expected time horizons for repayment, and different taxes, tariffs and subsidies, depending on whether they are institutional, corporate or private consumers. The cost to the decision-maker might therefore be quite different from the cost to society shown in our cost curve.

Reduction levers can be divided into several categories, which incur different directional cost changes when viewed from a decision-maker's perspective. Levers related to buildings, industry, and agriculture tend to involve higher costs for decision-makers, mainly due to the higher interest rates involved. Levers related to the energy efficiency of transport tend to involve a lower cost per tonne for decision-makers, due to the additional savings on fuel taxes which are not included in our calculations. Levers included under emerging technologies may benefit substantially from subsidies and appear economical to a decision-maker.

With its societal perspective, the cost curve is a good tool for comparing the cost of different reduction options from a social-welfare perspective. It is also helpful in comparing the volume of different options. The decision-maker's perspective is better suited to assessing switching costs or estimating CO_2 prices needed to provide an incentive for certain technology investments.

Negative cost opportunities – what are they, and do they exist?

An important aspect of our study is that some CO_2 savings can also represent substantial financial savings. By our definition, an emission reduction opportunity has a negative cost when the operational savings over the lifetime of the measure exceed the annualized investment. This definition excludes the transaction and program costs required to realize the opportunities. Most negative cost opportunities are energy efficiency measures, where the operational cost savings from reduced energy consumption outweigh the annualized upfront investment.

As these opportunities have a positive business case, the question arises as to why they are not captured automatically, and thus form part of in the reference case. There are several explanations, most of which relate to market imperfections of different kinds.

These include:

Agency issues

Buildings contractors, for instance, have limited incentives to insulate homes beyond the level required in building codes, since home-owners and tenants are largely unwilling to pay for higher-grade insulation, even if it would reduce their energy bills. Appliance-makers compete on low shelf price rather than on energy consumption, and so do not focus on providing additional energy-saving features, even if such features would pay for themselves over the lifetime of an appliance.

Lack of awareness

Consumers and businesses are often unaware of energy efficiency alternatives and potential savings, perhaps because opportunities are too small individually to be a priority, even though they yield significant energy savings in aggregate. Low-energy light bulbs, for instance, have a good business case, with payback times of only a few months. However, the overall saving is very limited in relation to the average household budget in many countries.

Financing hurdles

The initial investment, specifically in buildings and transport, can be a significant barrier. Many consumers cannot or will not borrow or save to pay for it, even if the long-term payback is positive. Also, houses and cars are often re-sold several times, and it can be difficult to gain compensation for energy efficiency in these secondary markets.

Consumers' need for quick pay-back

This has been demonstrated in many surveys. For example, a recent study showed that only 27 percent of consumers are willing to consider energy efficiency investments with payback periods greater than two years.

Capturing these energy efficiency measures is far from easy. We have not investigated which regulations would be most effective in achieving energy efficiency goals, but solutions will probably include stricter technical standards for buildings, vehicles, and appliances, as well as incentives for efficiency measures in cars and especially buildings, which often require large initial investments.

SECTOR DETAILS

The five sectors offering the greatest scope for GHG reduction in Switzerland are buildings, transport, power, and agriculture and industry. The measures and their potential savings are set out below in more detail for each of the sectors.

1. BUILDINGS

Buildings are the largest single source of GHG emissions in Switzerland. In 2005 they emitted 19.7 Mt of CO_2e (including indirect emissions from the consumption of electricity). Sources of emissions include heating, ventilation, and air conditioning (HVAC), water heating, lighting, and appliances. Residential buildings, which include single-family homes and apartment buildings, form 69 percent of overall sector emissions. Commercial and public buildings, are responsible for 31 percent of emissions.

Direct emissions from primary energy usage in buildings accounted for 17.6 Mt of CO_2e in 2005, which is 89 percent of building emissions. Indirect emissions from power usage total only 2.1 Mt of CO_2e, or 11 percent of total emissions, as power generation in Switzerland is almost entirely carbon-free.

Residential buildings have an assumed average lifespan of 65 years if newly built and about 49 years if extensively retrofitted. The average life of commercial buildings ranges between 56 years for comprehensive retrofits and 70 years for new buildings. Thus, decisions made during a building's construction (such as heating equipment and insulation) have a strong lock-in effect for future emissions.

Though population and total floor space are predicted to increase in Switzerland up to 2030, in the reference case emissions from buildings will decline by 14 percent, to 16.6 Mt of CO_2e in 2030. This is mainly due to the continuing shift from oil to gas, electricity and renewable energies.[6] For example, the share of oil consumption in residential buildings is expected to decrease from 50 percent in 2005 to 37 percent in 2030 while, at the same time, the share of alternative energies consumed is expected to increase from 11 percent to 14 percent in 2030.

The potential reduction of 11.3 Mt of CO_2e in buildings is broken down below into its most significant components: retrofitting residential and commercial buildings, newly built residential and commercial buildings, a shift to alternative heating systems, and a switch from incandescent to LED lighting.

6 This reference case is based on scenario 1 of the reports of Prognos (2007) "Der Energieverbrauch der privaten Haushalte, 1990-2035" and of the Centre for Energy Policy and Economics (CEPE) (2007): "Der Energieverbrauch der Dienstleistungen und der Landwirtschaft, 1990-2035" commissioned by the Bundesamt für Energie.

Retrofitting residential and commercial buildings (reduction potential: 6.1 Mt of CO_2e)

Retrofitting buildings has the largest potential with regard to buildings, assuming that 90 percent of all existing buildings are retrofitted to Minergie standards by 2030 (60 kilowatt hour (KWh) per square meter of floor space). Retrofitting includes improving the insulation of walls, roofs, and floors, as well as replacing the ventilation system.[7] While the overall reduction potential is greater for existing residential buildings at about 4.2 Mt of CO_2e (compared with 1.9 Mt of CO_2e for commercial buildings), the reduction costs are significantly higher for retrofitting residential buildings compared to commercial buildings. This can be explained by the greater reduction in energy consumption needed in commercial and public buildings compared to residential buildings, assuming that the reduction can be achieved at the same cost per square meter of floor space.

In the base case scenario, the abatement costs for retrofitted buildings are mostly positive, as the investment costs exceed the energy savings over the full lifetime of a retrofitted building. Abatement costs in the building sector are highly sensitive to the price of energy. Thus, in a scenario with an oil price of $100, costs become negative due to greater energy savings, i.e. the cost of retrofitting residential buildings decreases from about €55 with low energy prices to about −€60 per tonne of CO_2e. Costs are also largely dependent not only on the energy price, but also on whether an insulated building is equipped with a ventilation system or not. If an owner abstains from the comfort of a ventilation system, the reduction cost falls significantly, to about €10 per tonne of CO_2e with low energy prices.

It is important to note that the reduction costs for retrofitted buildings are the average costs of the individual measures required to conform to the Minergie standard. Individual measures have different costs and may not achieve equivalent efficiency gains. Thus, it may be advisable to apply extensive insulation to the ground floor and roof only (about €20 per square meter), instead of applying the whole Minergie package, including the more expensive insulation of the walls (about €50 per square meter). To calculate the appropriate measures for efficiently retrofitting a building, an individual analysis of the building is needed. We have assumed the adoption of the Minergie standard as an appropriate simplification for our level of analysis.

Newly built residential and commercial buildings (reduction potential: 0.7 Mt of CO_2e)

Our analysis assumes that overall floor space will increase from about 443 million square meters in 2005 to 561 million square meters in 2030.[8] Assuming that 95 percent of all new buildings conform to the Minergie standard, the reduction potential is 0.7 Mt of CO_2e in 2030 (0.5 Mt of CO_2e of which for residential buildings). This is substantially less than for retrofitted buildings, as a smaller number of houses will be newly built compared with the retrofitting of almost all existing houses. Our analysis shows that the cost difference between commercial

7 Double-glazed windows featuring high-efficiency glazing are included in the reference case scenario as nowadays they can be considered as standard.

8 Wüest & Partner, 2004 (Wüest & Partner: “Fortschreibung der Energiebezugsflächen: Modellrevision, Ergänzung um Bauteile, Perspektiven bis 2035, Schlussbericht” Commissioned by the BfE.

and residential buildings is even more pronounced for new buildings than for existing ones, despite the fact that Minergie standards "require" a maximum consumption of 38 KWh per square meter floor space for residential buildings, compared to a less restrictive average target of 45 kWh per square meter for commercial and public buildings.

Shift to alternative heating systems (reduction potential: 4.2 Mt of CO_2e)

In addition to measures to improve energy efficiency in buildings, we also analyzed the potential of replacing heating systems that consume fossil fuels with more carbon-efficient fuels such as wood pellets, with solar systems, and by installing heat exchange pumps. While in the reference case the proportion of heating systems using oil falls from 60 percent in 2005 to 48 percent in 2030, we assume a further reduction to 13 percent in 2030 in our abatement scenario. At the same time, we see the maximum potential of renewable heating systems increasing from 13 percent in 2005 to 58 percent (compared with 18 percent in the reference case). This is mainly due to a substantial technical potential for heat pumps, which could make up 41 percent of capacity, compared to 6 percent in the reference case. Realizing this potential would lead to a total reduction of 4.2 Mt of CO_2e. Heat pumps would consume about an additional 3.7 TWh of electricity, and the realization of the full reduction potential is highly dependent on the CO_2 intensity of the electricity. This is discussed in more detail in the section on power. Reduction costs are sensitive to whether thermal insulation is first substantially improved. A newly built or retrofitted house with good insulation consumes less energy and thus requires a smaller heating installation. The slightly positive reduction cost for the shift to alternative heating systems already largely includes the improved insulation of buildings in 2030.

Switch from incandescent to LED lighting (reduction potential: 0.3 Mt of CO_2e)

Lastly, we calculated the reduction potential of replacing existing incandescent bulbs in residential, commercial, and public buildings with energy-efficient light-emitting diode (LED) bulbs. Assuming that 30 percent of all lighting were provided by LEDs, 5.6 TWh of electricity could be saved, reducing the amount of electricity imported by about 30 percent in 2030. Interestingly, the cost of the reduction opportunity from retrofitting LED bulbs is highly negative, with a payback time of only a few months. However, the reduction potential of LEDs is only about 0.3 Mt of CO_2e, as electricity produced in Switzerland is relatively carbon-free. If it were not possible to replace the electricity imports in the reference case by substantial savings in electricity and/or new power capacity (see the section on power), the reduction potential of efficiency measures to reduce electricity consumption would increase substantially, e.g., for LED bulbs from 0.3 to 1.3 Mt of CO_2e, assuming that we would save CO_2 from reduced net electricity imports.

2. TRANSPORT

The transport sector is the second largest sector for GHG emissions in Switzerland (29 percent). In 2005 it emitted 15.7 Mt of CO_2e.[9] Our analysis covers only road transport, excluding emissions from motorcycles, tank tourism (visitors filling up their vehicle with cheaper gasoline in Switzerland) and off-road vehicles (construction machines, vehicles used for agriculture and forestry, etc.). It comprises fuel combustion emissions ("tank-to-wheel") only, and excludes emissions related to the production of the fuel. Total emissions in 2005 were 13.5 Mt of CO_2e.

The analysis segments road vehicles into three types:

- Light-duty vehicles (LDVs), i.e., passenger cars and commercial vehicles up to 3.5 tonnes – some 4.15 million vehicles, emitting 84 percent of the total, or about 230 g of CO_2 per km in 2005.
- Medium-duty vehicles (MDVs), like trucks and buses with 3.5–16 tonnes in weight (e.g., delivery trucks) – some 41,440 vehicles emitting about 5 percent of the total in 2005.
- Heavy-duty vehicles (HDVs), defined as trucks greater than 16 tonnes in weight (e.g., long-haul freight trucks) – some 18,055 vehicles emitting about 11 percent of the total in 2005.

In the reference case, we assume continued growth in vehicle numbers of 0.7 percent annually for LDVs and 0.1–0.2 percent annually for MDVs and HDVs. The distance travelled per vehicle also increases, for MDVs and HDVs at least, by 0.7–0.8 percent annually, with stable development for LDVs. Nevertheless, the reference case shows emissions decreasing by more than 2 percent, reaching 13.2 Mt of CO_2e in 2030. This is due to the ongoing shift to more efficient diesel-powered vehicles, whose share of all LDVs is expected to peak in 2015, stabilizing afterwards at 40 percent, and to ongoing improvements in fuel economy until 2010.[10]

We identified four groups of technical reduction levers in road transport – 1) Improvements to the conventional internal combustion engine (ICE); 2) Hybrid vehicles; 3) Electric vehicles; 4) Biofuels. The overall reduction potential is 5.6 Mt of CO_2e (42 percent compared to the reference case) at costs below €100 per tonne of CO_2e. In a scenario with higher energy prices (oil price about $100 per barrel), transport emissions could even be reduced by 55 percent compared to the reference case. The detailed analysis of the reduction measures focuses on LDVs only, as they generate 84% of all transport emissions.

9 International emissions from air transport and shipping are not included in national calculations.

10 This reference case is based on scenario 1 of the Infras (2007) report: "Der Energieverbrauch des Verkehrs, 1990–2035" commissioned by the Bundesamt für Energie (BFE).

Improvements to the conventional internal combustion engine (ICE) (reduction potential: 4.9 Mt of CO_2e)

Vehicles powered by conventional internal combustion engines (ICEs) using gasoline or diesel can be made more fuel-efficient by power-train and non-power-train technical improvements that come at an additional initial cost. These improvements are grouped into four bundles of efficiency measures for vehicles of all sizes, ranked by increasing aggressiveness from Bundle 1 to Bundle 4. For example, Gasoline Bundle 1 for LDVs includes power-train improvements such as variable valve control and engine-friction reduction, as well as non-power-train improvements such as tires with low rolling resistance, tire pressure control systems, and some weight reduction.

Additional efficiency packages always include previous packages plus further improvements. All LDV efficiency packages are at a negative cost for society, with the costs for the different packages increasing with the level of aggressiveness involved. A scenario in which all vehicles in 2030 are equipped with the highest efficiency bundle to reduce fuel consumption offers a maximum potential of 3.2 Mt of CO_2e for gasoline LDVs and 1.7 Mt of CO_2e for diesel LDVs.

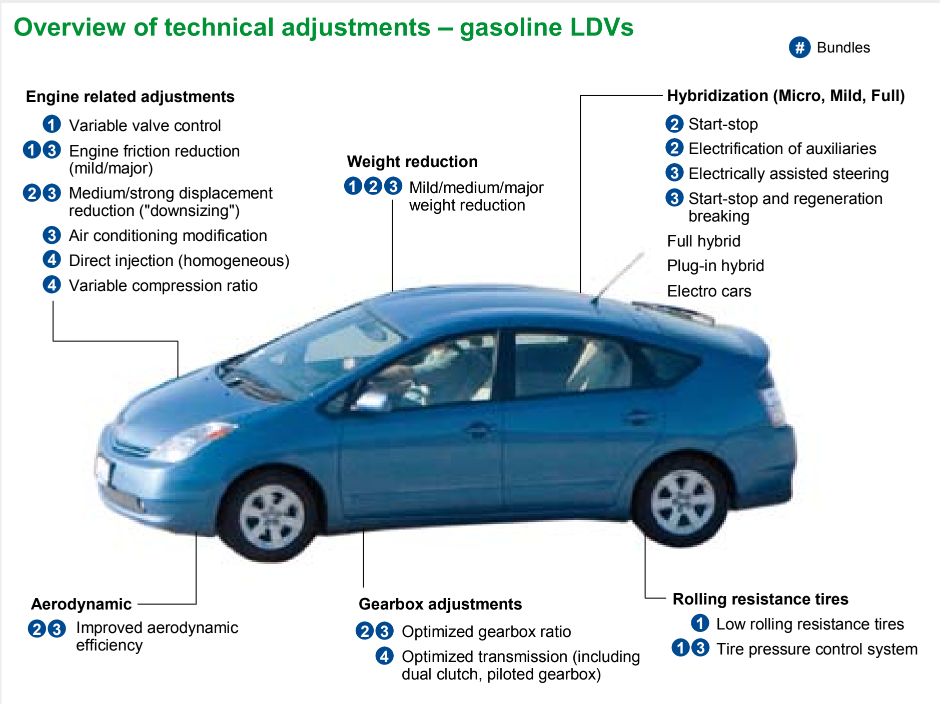


Figure 6

Hybrid vehicles (reduction potential: additional 0.6 Mt of CO_2e; 0.2 Mt below €100 per tonne of CO_2e)

The second group includes two types of hybrid vehicles: full hybrid and plug-in. Full hybrid vehicles, which are already gaining importance in today's new car sales, have a conventional ICE plus a battery-powered electric motor. The battery is charged by the drive cycle of the car (e.g., by braking), not externally. Full hybrids also benefit from non-power-train fuel efficiency measures such as weight reduction. Plug-in hybrids have a conventional ICE plus a battery-powered electric motor. The battery is charged externally through a connection to the power grid, which means that emission reduction depends on the CO_2e intensity of the electricity. Plug-in hybrids thus have relatively high potential emission reductions in Switzerland compared to other countries, as electricity consumed (and produced) in Switzerland is almost carbon-free.

In the scenario of a hybrid/electric world in 2030, our analysis assumes that 100 percent of LDV vehicles would be full hybrid cars in 2030. Compared to the scenario with ICE vehicles, the additional reduction potential of full hybrids replacing gasoline cars is about 0.2 Mt of CO_2e for, at a cost only slightly below €100 per tonne of CO_2e, while the reduction potential (about 0.2 Mt of CO_2e) of replacing diesel-powered cars with full hybrids comes at a cost above €100 per tonne of CO_2e. The additional reduction potential of 0.2 Mt of CO_2e in a scenario where 30 percent of the full hybrids are replaced by plug-in hybrids (consuming 80 percent electricity and 20 percent gasoline or diesel) would come, however, at higher cost from a societal perspective, at above €100 per tonne of CO_2e.

Electric vehicles (reduction potential: additional 1.1 Mt of CO_2e above €100 per tonne of CO_2e)

Electric vehicles without a conventional ICE require significant battery capacity. As with plug-in hybrid vehicles, the actual reduction potential from electric vehicles is relatively high in Switzerland, given the low CO_2e intensity of electricity. In a scenario where 50 percent of full hybrid vehicles are replaced by electric vehicles, an additional 1.1 Mt of CO_2e could be reduced in 2030. Extensive technological development is expected to result in a sharp drop in the cost of electric vehicles, rendering them more economic. However, in our calculations abatement costs in 2030 are still expected to be above €100 per tonne in the base case, and at around €100 per tonne in a scenario with high energy prices ($100 oil).

Biofuels (reduction potential: additional 0.5 Mt of CO_2e)

The fourth group is biofuels that replace gasoline and diesel. While the reduction potential varies globally according to the feedstock used for biofuel production and the emissions associated with the increased production of the fuel, this group is less important in Switzerland. Lowest-cost first-generation bioethanol is derived from sugarcane, which is unlikely to be imported in larger amounts. Other first-generation biofuels from sugar beet, wheat, and rape seed have costs above €100 per tonne of CO_2e. Second-generation biofuels (from cellulose biomass or algae) are still in early development phase. Assuming that up to 10 percent of fuel consumed in Switzerland is generated from second-generation biofuel, this would result in an reduction potential of an additional 0.5 Mt of CO_2e at about €30 per tonne of CO_2e.

Fuel efficiency improvements: a decision-maker's perspective

Fankhauser AG, a road transport contractor, plans to equip 115 heavy-duty vehicles with spoilers to reduce fuel consumption by about 2.5 liters per 100 kilometers. The annual distance travelled by these HDVs is about 100,000 km, leading to overall fuel savings of about 290,000 liters per year. Fankhauser states that the total cost of equipping the HDVs is about SFr 365,000, with the "Klimarappen" foundation contributing one-third of the capital expenditure. The fuel saving over the expected lifetime of the spoilers (about 10 years) is expected to amount to about SFr 3.2 million. As energy savings over the full lifetime are much higher than the initial investment, which is amortized after about one year, the spoilers have a negative cost not only to society but also to the truck owner. Our calculations show that 850 tonnes of emissions can be avoided annually, at a negative cost of SFr 345 per tonne of CO_2e.

3. POWER

Swiss power supply has been almost carbon-neutral for a long time. Accordingly, emissions from domestically produced power accounted for just 3.5 Mt of CO_2e (about 6 percent of overall emissions) in 2005. This is relatively small compared to other countries. In 2005, 57 percent of electricity was produced by hydro-electric plants and 38 percent by nuclear power stations. The emission sources are mainly waste incineration plants, with about 2.1 Mt of CO_2e (3 percent of power supply in Switzerland) and fossil-fuel combined heat and power (CHP) plants partly used for district heating, with about 0.4 Mt of CO_2e. Emissions from petroleum refining in Switzerland, at about 1 Mt of CO_2e, are included in the power sector.

In the reference case, we assume that emissions from waste incineration plants remain roughly stable, while emissions from CHP plants are expected to increase by 2.3 percent annually. While petroleum refining emissions may decrease by 2030 due to reduced demand for oil and gas in buildings and transport, our analysis does not quantify the abatement potential of expected further efficiency gains in waste incineration plants. We also assume no substantial improvements in combined heat and power plants until 2030.

Imported electricity

Several factors are expected to change the situation in the Swiss power sector by 2030. While demand for electricity is expected to increase by 0.6 percent annually, from about 62 TWh in 2005 to about 72 TWh in 2030,[11] supply is expected to remain stable, as the reduction in electricity production capacity by nuclear power stations (due to the expiry of operating licenses for the plants in Beznau I by 2020 and Beznau II and Mühleberg by 2025) can be offset only approximately by additional capacity from hydro-electric and renewable-energy power plants. As no decision has yet been taken on how to fill this gap, the reference case assumes that an increasing amount of electricity will have to be imported. In doing so, Switzerland would also import the corresponding emissions, as the CO_2 intensity of neighboring countries' electricity is higher, particularly in Germany, with its high share of coal-fueled power plants (see also the reference case 2030 section in the appendix).

According to the UNFCCC guidelines, emissions from imported electricity do not have to be accounted for by the importing country. However, we think it is important from Switzerland's perspective to assess the potential and cost of opportunities to avoid electricity imports, as it is difficult to forecast under what conditions such large-scale electricity imports will be possible in 2030.

Our analysis thus includes the potential of electricity savings and new power plant capacity in Switzerland to replace the emissions of imported electricity from neighboring countries. It identifies a potential of at least 4 Mt of CO_2e at a cost below €100 per tonne of CO_2e. Forecast net electricity imports of about 17 TWh in 2030 could thus be fully replaced and the corresponding GHG emissions of about 4 Mt of CO_2e associated with the imports avoided entirely. First, we evaluate the reduction potential from electricity savings in the buildings and transport

11 This reference case is based on scenario 1 (Variante G) of the Prognos-report (2007) "Die Energieperspektiven 2035", commissioned by the Bundesamt für Energie (BFE).

sector, which will reduce the amount of electricity imports needed in 2030. Additional savings would further reduce imports – for example, more energy-efficient electronics and appliances, or a reduction of demand.

Electricity savings in buildings reveal a net potential of about 2.4 TWh, corresponding to a reduction potential of about 0.6 Mt of CO_2e in 2030. This mainly comes from savings in lighting (about 5.6 TWh) and in retrofitting buildings (about 0.5 TWh), offset by a net increase of 3.7 TWh from heating systems. The decrease in electricity demand due to the replacement of electric heating systems (from 9 percent to 0 percent in 2030) is more than compensated by the increased electricity demand due to electric heat pumps (from 2 percent to 41 percent in 2030), resulting in a net additional demand for electricity of about 3.7 TWh.

Additional electricity savings potential

Additional reduction potential from further electricity savings was not evaluated in detail. The Swiss agency for efficient energy use (SAFE)[12] summarizes this additional technical electricity savings potential as follows:

- About 25 percent for appliances (corresponding to about 2 TWh)
- About 35 percent for electronics (corresponding to about 1 TWh)
- About 40 percent for ventilation/air conditioning (corresponding to about 2 TWh)
- About 50 percent for water heating (corresponding to about 1.5 TWh)
- About 25 percent in the industrial sector (more efficient drive systems as well as mechanical system optimization, see also industrial section and corresponding to about 5 TWh)
- About 10 percent in the public transportation system (0.5 TWh)

Compared to our reference-case electricity consumption in 2030, an additional savings potential of up to 12 TWh would be possible on the basis of these assumptions, reducing the net imports of electricity required from 17.3 TWh to about 3 TWh (corresponding to less than 1 Mt of CO_2e).

New power capacity

Besides measures to reduce the demand for electricity, a detailed analysis was made of newly built and retrofitted power plants generating more carbon-efficient power. Newly built capacity was ranked by lowest cost in 2030, assuming that the identified maximum potential was realized. New capacity is then included to match demand. Reduction is achieved by replacing the emissions of the remaining required net electricity imports of the reference case. Abatement costs were evaluated by comparing the investment and operational cost of new (or retrofitted) power plants with the reference-case cost of imported electricity (at producers' costs).

12 http://www.energieeffizienz.ch/files/SAFE_Sparpotential_Strom_2005_JN.pdf

The lowest abatement cost of about –€50 per tonne of CO_2e comes with nuclear power stations. A new-generation nuclear power station with a capacity of 1.6 GW (producing about 12 TWh annually) has a full reduction potential of about 2.8 Mt of CO_2e in 2030. While the construction of a new nuclear power station by 2030 involves political factors, the reduction potential would come at a negative cost to society even at a relatively high investment cost of SFr 5,000 per KW (including retrofitting and decommissioning costs). Our calculations of costs do not include potential additional technology risks, e.g., the cost of the state guarantee to cover accidental risks.

Increasing the height of existing dams and storage areas would help to increase the power supply during winter when electricity demand peaks. The maximum reduction potential of about 0.2 Mt of CO_2e in 2030 would come at a negative cost (–€25 per tonne of CO_2e). Moreover there is also a technical reduction potential from retrofitted and newly built river-run power plants of 0.6 Mt of CO_2e at a slight positive cost (€20–€30 per tonne of CO_2e) adding about 2 TWh electricity capacity in 2030.

Scenario without additional nuclear capacity

With an overall potential of 4.1 Mt of CO_2e at costs below €100 per tonne of CO_2e, the reduction measures identified (including new nuclear power capacity) avoid the need for net imports of electricity in 2030. In a scenario of potential additional electricity savings of about 12 TWh, no additional power generation would be required.

We have therefore calculated an abatement cost curve without adding new nuclear capacity. In a scenario with high energy prices (oil price of $100), additional electricity consumption due to plug-in hybrid and mainly electric vehicles has been taken into account – as their costs then fall below the barrier of €100 per tonne of CO_2e – resulting in about 3 TWh of additional electricity demand. Without newly built nuclear capacity, a gap between power demand and supply of about 4 TWh would result in 2030. As the imported electricity (e.g. from Germany) would be less carbon-efficient, a higher CO_2 intensity of electricity must be applied to evaluate the electricity efficiency measures.

In doing so, the reduction potential of electricity-efficiency measures increases, e.g., the switch in lighting to LEDs, as does the potential of measures replacing the consumption of fossil fuels by electricity-related decreases, e.g. plug-in hybrids and electric vehicles. Overall, if we do not include new nuclear power capacity, or the above-mentioned additional electricity savings potential evaluated by SAFE, the overall reduction potential decreases from 22.6 to about 21 Mt of CO_2e in 2030. The reduction potential at negative cost to society also shrinks slightly from 19.6 to 18.4 Mt of CO_2e in 2030.

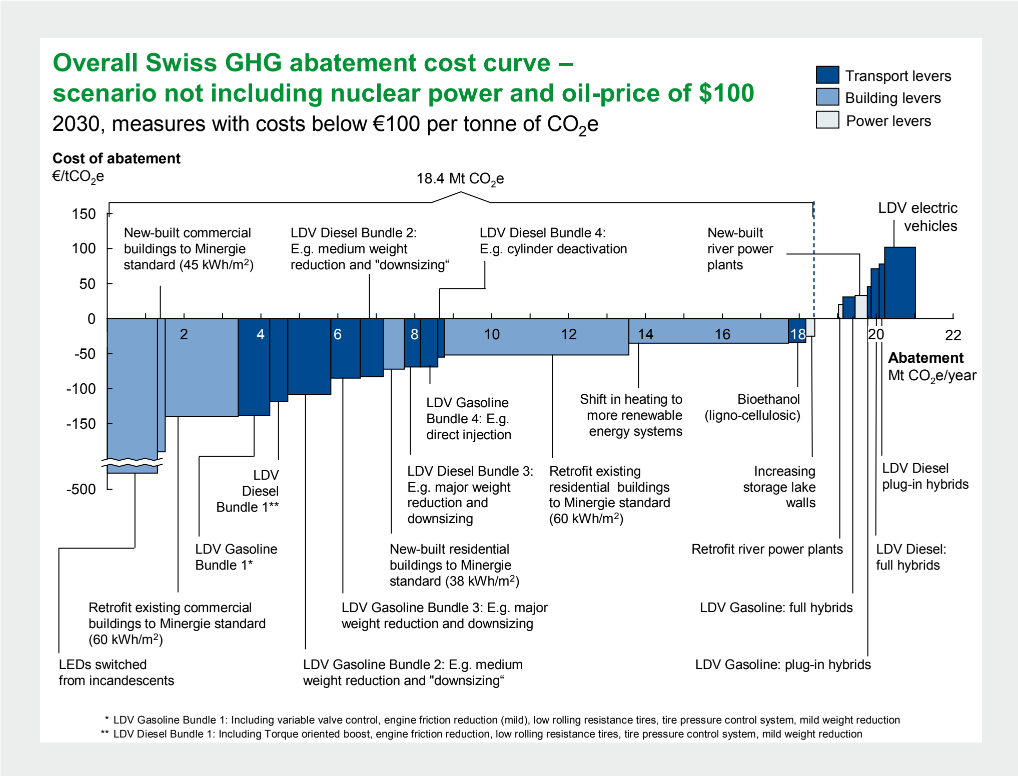


Figure 7

New renewable-power plants

The reduction potential of other new renewable-power plants comes at a cost to society substantially above €100 per tonne of CO_2e.[13] While the potential is fairly small for new hydro power (storage power plants with 0.3 Mt of CO_2e), wind (0.3 Mt of CO_2e) and biogas power plants (0.5 Mt of CO_2e), there is considerable reduction potential from natural-gas combined-cycle plants equipped with carbon capture and storage (CCS, 0.6 Mt per plant) and solar photovoltaic (PV) plants on rooftops (2.7 Mt of CO_2e if every other rooftop were equipped by 2030). We have assumed that the costs of these technologies will fall at current linear rates. If such measures are to be economic by 2030, more rapid development is required. Especially for solar PV, there is great uncertainty about future developments. If the investment cost fell significantly, to less than €1,300 per kW, the abatement cost would fall below €100 per tonne of CO_2e. The capture and storage of carbon emissions from power and heavy-industry plants (CCS), in particular, is seen as a potential key technology of the future from a global perspective. However, the potential of CCS is insignificant in Switzerland, as there is little heavy industry, no fossil-fuel power plants are used or planned, and long-distance transport to place the carbon in storage remains very expensive for relatively small amounts of carbon dioxide.

13 Cost assumptions mainly based on Prognos report (2007) "Die Energieperspektiven 2035" commissioned by the Bundesamt für Energie (BFE).

Solar rooftop plants: a decision-maker's perspective

From a societal perspective, the reduction cost of solar rooftop plants on every other building in Switzerland is about €250 per tonne of CO_2e (assuming a linear rate of cost efficiency improvements until 2030). Adjusting the assumptions of the lifetime of such plants (from 30 years in the societal perspective to 25 years in the decision-maker's perspective) and increasing the discount rate (from 2.5 percent to 6 percent) makes solar photovoltaic plants more expensive (about €480 per tonne of CO_2e).

When the compensation for the electricity fed into the grid – regulated in Switzerland by the "Stromversorgungsverordnung" (www.admin.ch/ch/d/as/2008/1223.pdf) – is taken into account, solar photovoltaic rooftop plants finally become financially attractive for decision-makers (the owners of the buildings). For example, for integrated plants with a capacity below 10 kW, the compensation amounts to SFr 0.90 per kWh, falling by 8 percent annually, resulting in SFr 0.17 per kWh in 2030 and reduction costs of about – €5 per tonne of CO_2e from a decision-maker's perspective. As the reduction in the compensation for electricity fed into the grid will probably be adjusted by the regulator, the resulting solar power generation cost are subject to change, as is the abatement cost in 2030.

4. AGRICULTURE AND INDUSTRY

While our bottom-up analysis focused on buildings, and the transport and power sectors, we have also estimated the total abatement potential in two other major sectors: agriculture and industry. The costs for the individual measures in these sectors have not been calculated.

Agriculture

Agriculture is the fourth largest sector for GHG emissions in Switzerland, and accounted for about 10 percent of Swiss GHG emissions in 2005. About 38 percent of total emissions come from agricultural soil practices, about 46 percent from enteric fermentation, and about 15 percent from manure. Agricultural emissions are in the form of methane (54 percent of sector emissions) and nitrous oxide (46 percent) rather than CO_2. In the absence of reduction measures, agricultural emissions in Switzerland are projected to decline by approximately 0.4 percent annually,[14] from 5.4 to about 4.9 Mt of CO_2e in 2030. Our analysis identified two main reduction measures with an overall potential of at least 30 percent of the emissions in the reference case. About 80 percent of the reduction potential is through carbon sequestration in soils. We assume that one-third of the overall organic soil could be technically restored in Switzerland by 2030. The other 20 percent of reduction potential would come from the vaccination of all ruminants in Switzerland by 2030, assuming a reduction potential of 12 percent of overall emissions from enteric fermentation. Our analysis has not evaluated measures to reduce the emissions from livestock manure, on account of their relatively small potential. One opportunity might be the reutilization of manure for the production of biogas. However, as shown in the section on power, the generation of electricity from biogas will not become economical by 2030 without substantial subsidies for the collection of agricultural waste.

Industry

The industrial sector emits 9 Mt of CO_2e, corresponding to approximately 17 percent of overall GHG emissions. While 35 percent of the emissions is due to industrial processes, the remaining 65 percent comes from the combustion of fossil fuels in industrial facilities. The cement industry is the largest source of emissions in the industrial sector, accounting for about one-third of overall emissions. The chemical industry – the second largest source of emissions at about 12 percent – is followed by the pulp, paper and print, and the iron and steel industries, each at about 6 percent. In the reference case industrial emissions are forecast to increase from 9 Mt to about 11 Mt of CO_2e in 2030. The estimated growth in emissions of about 0.8 percent per annum is based on an average GDP growth forecast for the Swiss industrial sector of about 2.5 percent, while continuing improvements in energy efficiency are expected to amount to about 1.7 percent annually. A reduction potential of at least 2.7 Mt of CO_2e (25 percent) has been identified for the Swiss industrial sector.

Two main measures are expected to come at negative cost: 1 Mt of CO_2e could be reduced by 2030 due to more efficient drive systems and mechanical system optimization.

14 US Environmental protection agency (EPA): "Global Anthropogenic Emissions of Non-CO_2 Greenhouse Gases 1990-2020 (EPA Report 430-R-06-003)"

Energy efficiency improvements in industrial buildings (e.g., retrofits) would result in an additional reduction potential of about 0.3 Mt of CO_2e. Cemsuisse has already committed itself to reducing the emissions in the cement industry to about 2.3 Mt CO_2e in 2010, which represents a 44 percent reduction compared to the 1990 level. We assume a technical reduction potential in the combustion of fossil fuels of around 50 percent, or about 0.7 Mt of CO_2e in 2030 compared to the reference case. Our analysis also indicates that the amount of CO_2 emitted per ton of clinker could be further reduced by 2030 with increased use of clinker substitutes, resulting in an additional reduction potential of about 0.7 Mt of CO_2e. Other national studies show that such measures in the cement industry cost less than €20 per tonne of CO_2 emitted. Finally, additional measures in other industrial sectors (e.g. chemicals) were not evaluated in this analysis as their expected additional contribution is only marginal.

The purpose of this research was to provide an objective, consistent data set on the opportunities and costs to reduce the emissions of greenhouse gases in Switzerland. This analysis shows that there is substantial technical potential for Switzerland to achieve a major reduction in GHG emissions by 2030.

We hope that this research will serve as a useful starting point for discussions by companies, policy makers and academics on how to further reduce Swiss greenhouse gas emissions.

APPENDIX: THE METHODOLOGY

This study shows the relative importance of different sectors and measures, and provides input for the discussion about the potential and actual costs of reducing GHG emissions. For this perspective we have made similar assumptions as for our global GHG reduction cost curve (a new version of that report will be published in January 2009) and have assessed the potential for the key sectors in Switzerland in more detail. This will also enable a comparison of the situation in Switzerland with that in other countries.

The study provides a fact-based economic model as a basis for discussions about greenhouse gas (GHG) emissions. Our analysis models only domestic emissions in line with UNFCCC guidelines, but includes GHG emissions associated with direct net electricity imports. The baseline reference case assumes that total GHG emissions would increase slightly from 54.6 mega tonnes (Mt) of CO_2e in 2005 to 55.9 Mt of CO_2e in 2030.

Our model takes a "societal perspective" and looks for the GHG reduction potential and costs over the lifetime of a measure (e.g., 65 years for newly built residential houses, the average lifetime of a building) even if an individual investor might apply different investment criteria and have other incentives. We have measured the reduction potential against the figure for 2005 and against a reference case for 2030 in which we assume that the economy continues to grow at its past average rates, and that no additional GHG measures are applied to the ones already in place today. We have used IEA and BFE forecasts to construct this reference case 2030 for Switzerland.

We have taken 2030 as our reference point in line with the timeline in our global report.
This is because:

- A societal perspective requires a long-term view on measures to reduce GHG
- Reduction costs and volumes can only be measured with reasonable certainty up to 2030
- Global emissions need to be reduced significantly by 2030 to achieve a GHG concentration level of 450 ppm, the IPCC scenario given a global temperature increase of 2 degrees celsius.

The study considers the maximum technical GHG reduction potential of an opportunity – measured in carbon dioxide equivalent (CO_2e)[15] – if it were fully implemented by 2030 (e.g., how much CO_2 would theoretically be reduced if all technically suitable buildings were retrofitted by 2030). It does not consider the market potential (i.e., how much potential is likely to be captured by retrofitting buildings by 2030). The different penetration rates of various technologies in the scenarios are used solely to illustrate the maximum range of technical reduction potential, and should not be considered as a forecast or an endorsement of a specific technology.

15 Carbon dioxide equivalent is the unit for emissions that, for a given mixture and amount of greenhouse gas, represents the amount of CO_2 that would have the same global warming potential (GWP) when measured over a specific timescale (generally 100 years). Greenhouse gases are mainly composed of CO_2 (carbon dioxide), CH_4 (methane), N_2O (nitrous oxide), CFCs (chlorofluorocarbons), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons), and SF_6 (sulfur hexafluoride).

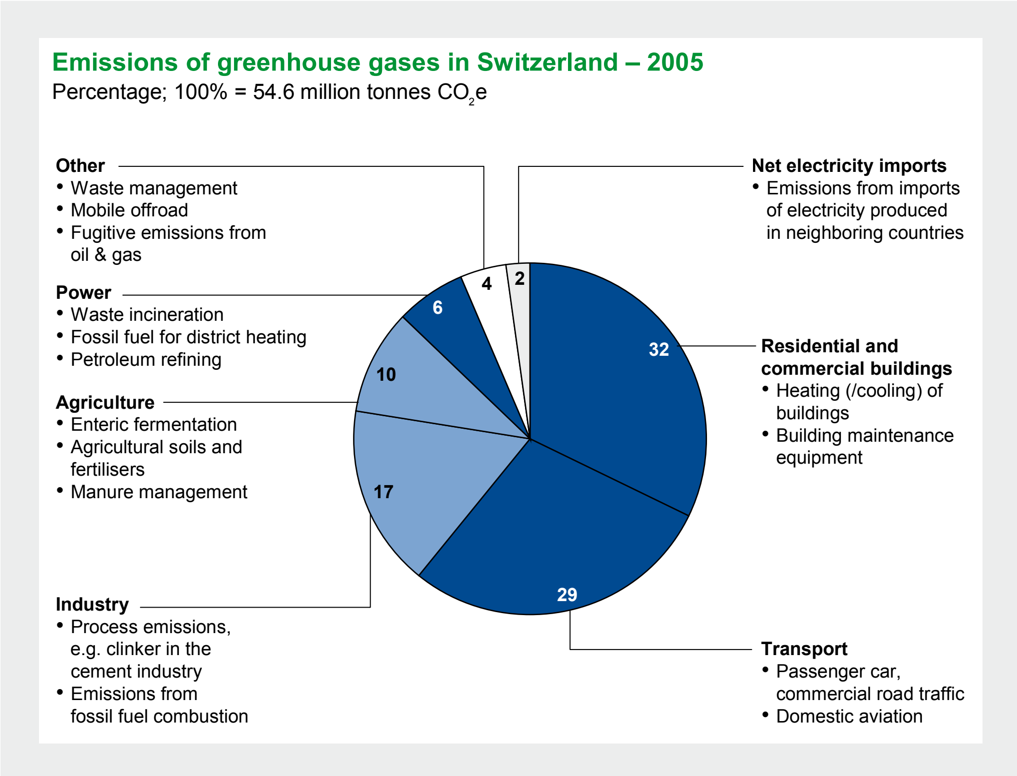


Figure 8

We have not taken into account any behavioral changes that would be required to reduce demand. Thus we have not, for example, assumed that people would drive less kilometers. Such changes present significant additional reduction potential.

In our analysis, we have assumed ongoing cost improvements by 2030 for already existing technology, but we have not assumed the development of new cost-efficient (i.e., below €100 per tonne of CO_2e) technologies by 2030. While this may happen, the time required to market such technologies on a large scale is typically over 10 years.

Our analysis models domestic emissions in line with UNFCCC guidelines, but includes GHG emissions associated with direct net electricity imports. The reference case assumes that total GHG emissions would increase slightly from 54.6 Mt of CO_2e in 2005 to 55.9 Mt of CO_2e in 2030.

Total GHG emissions in Switzerland for 2005

In 2005, total emissions of greenhouse gases amounted to 54.6 Mt of CO_2e (0.1 percent of the world's total emissions). 45 Mt of CO_2e (83 percent) result from burning fossil fuels, for example in buildings and in the transport and power sectors. The remaining 17 percent is emitted as a direct consequence of industrial and biological processes.

The two largest areas are buildings and transport, with GHG emissions of 17.6 Mt (32 percent) and 15.7 Mt of CO_2e (29 percent) respectively. The third largest source of emissions is the industrial sector, with 9.0 Mt of CO_2e (17 percent), followed by agriculture with 5.4 Mt of CO_2e (10 percent, mainly methane and nitrous oxide emissions).

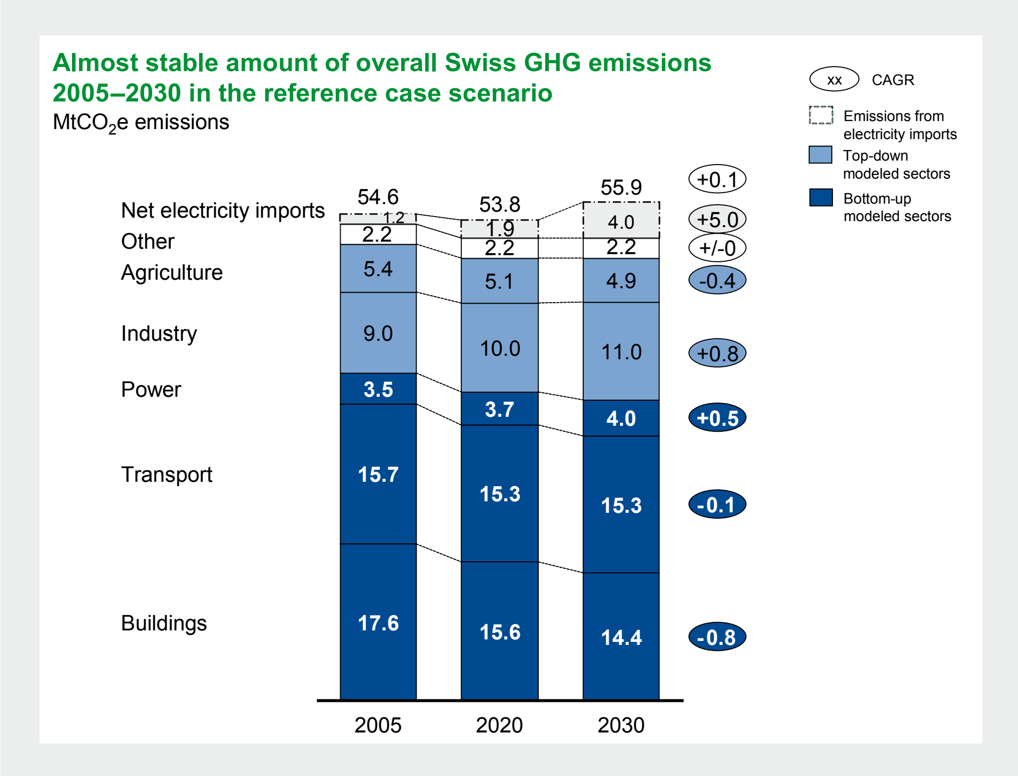


Figure 9

The reference case 2030

To assess the effect of future additional reduction measures, a reference case has been constructed, that shows how emissions would develop up to 2030 without any additional reduction measures. It assumes that no special measures are taken beyond the regulations already decided today. The emission scenarios for buildings and the transport and power sectors correspond to Scenario 1 of the reports from the Bundesamt für Energie (BFE) with outlooks up to 2035. In this reference case, emissions in Switzerland would increase by 0.1 percent annually to 55.9 Mt of CO_2e in 2030.

Emissions from buildings are declining by 0.8 percent annually, mainly due to a shift in consumption from oil (–1 percent p.a.) to gas (+1 percent p.a.) and higher building standards for newly built homes.

Transport emissions remain constant, as the greater number of vehicles and the greater distance travelled by heavy vehicles are compensated for by the increased fuel efficiency of new cars and the continuing shift to more diesel vehicles (from 12.9 percent in 2005 to an expected 40 percent share in 2030). Industrial emissions increase slightly (0.8 percent p.a.). While industrial output grows in line with GDP (average of 2.5 percent p.a. as forecast for 2005–2027), this increase is partially compensated for by continuing energy efficiency measures. Agriculture emissions are expected to decrease slightly to 2030, by 0.4 percent annually.

The energy sector requires special consideration, as demand for electricity increases in the refere-nce case from 61.6 to 72.1 TWh in the absence of additional specific electricity efficiency measures.

We assume that under current regulations three nuclear power stations would be shut down by 2030 (Beznau I before 2020, and Beznau II and Mühleberg before 2025) and the remaining electricity gap of 17.3 TWh in 2030 would be filled with imported electricity.[16] In the reference case, emissions of domestically produced electricity increase slightly, by 0.5%, annually, to 4.0 Mt of CO_2e in 2030. Emissions from net electricity imports corresponding to 17.3 TWh would add another 4Mt of CO_2e in 2030.

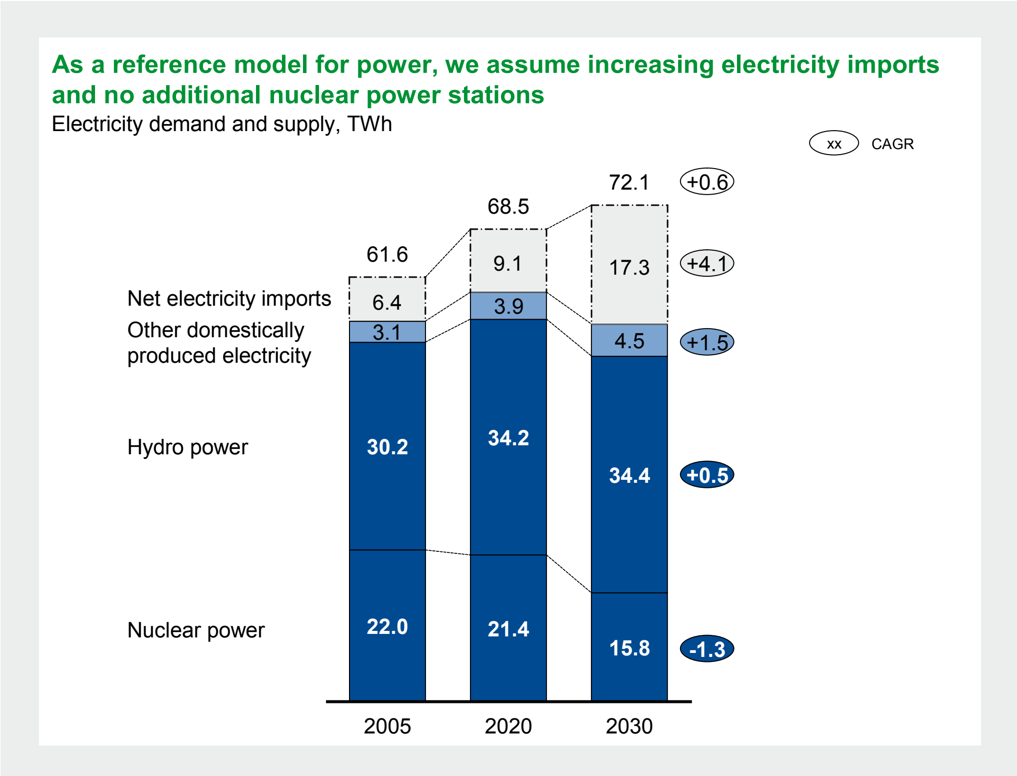


Figure 10

As it is still difficult to estimate the absolute amount and source of electricity imports and exports in 2030, we applied a simplified approach, assessing only the emissions from the necessary net imports of electricity in 2030. Assuming that most electricity will be imported from France, Germany and Austria as today, we expect overall "imported" emissions to increase from 1.2 Mt of CO_2e in 2005 to about 4 Mt of CO_2e in 2030. Our analysis thus compares the cost of potential reduction opportunities in Switzerland with those of net imported electricity in the reference case at the economic cost of production.

We have not included any further CO_2e emissions associated with the trade of goods or services ("grey emissions"). Those emissions are primarily associated with the production and transportation of imported fuels, and would thus increase the total reduction potential of all measures with significant fuel reduction, mainly in the transport sector.

16 We include net electricity imports in the 2005 baseline and the reference case to account for the potentially significant portion of imported net electricity. The UNFCCC guidelines do not include electricity imports but consider GHG emissions from primary energies only.

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BFE and Prognos (2007): “Die Energieperspektiven 2035”

BFE and Infras (2007): “Der Energieverbrauch des Verkehrs, 1990–2035”

BFE and Prognos (2007): “Der Energieverbrauch der privaten Haushalte, 1990–2035”

BFE and CEPE (2007): “Der Energieverbrauch der Dienstleistungen und der Landwirtschaft, 1990–2035”

PSI (2005): “Neue erneuerbare Energien und neue Nuklearanlagen: Potenziale und Kosten”

CEPE (2002): “Grenzkosten bei forcierten Energie-Effizienzmassnahmen in Wohngebäuden”

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