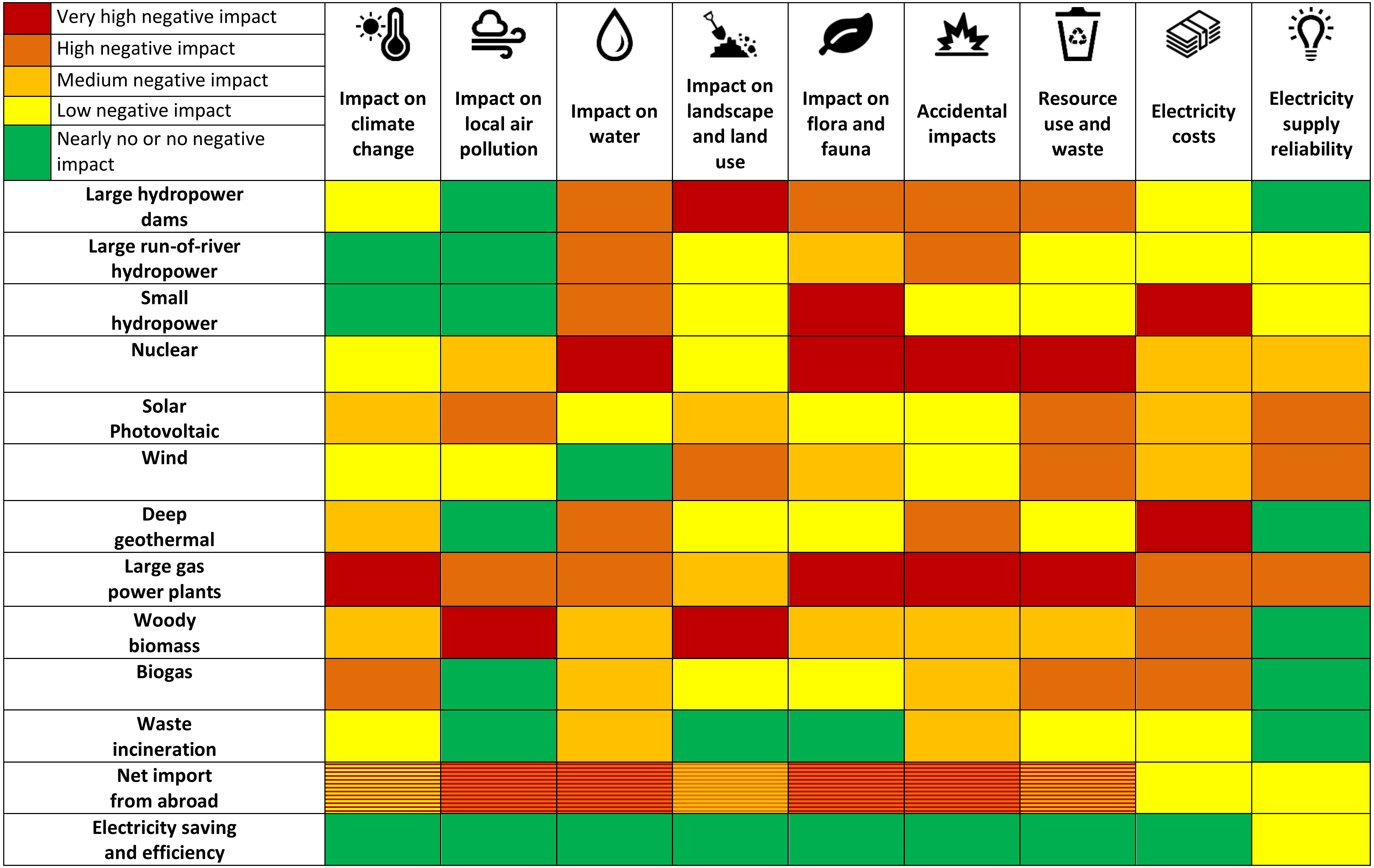

Very high negative impact
High negative impact
Medium negative impact
Low negative impact
Nearly no or no negative impact
Impact on climate change
Impact on local air pollution
Impact on water
Impact on landscape and land use
Impact on flora and fauna
Accidental impacts
Resource use and waste
Electricity costs
Electricity supply reliability
Large hydropower dams
Large run-of-river hydropower
Small hydropower
Nuclear
Solar Photovoltaic
Wind
Deep geothermal
Large gas power plants
Woody biomass
Biogas
Waste incineration
Net import from abroad
Electricity saving and efficiency

Glossary

1 kWh (kilowatt hour) is the amount of electricity that a typical light bulb with 10 Watt consumes during 100 hours. 1 kWh is also the unit for which the electricity price to consumers is defined. For example, the ewz.basis tariff is 26 Rp. per kWh during the day and 15 Rp. per kWh during the night and on Sundays.

A Swiss household with 3 people consumes on average about 7,000 kWh of electricity per year. This amount could be higher than your household's consumption if you do not have electric heating. If all electricity that is consumed in Switzerland by households, industry, businesses, agriculture and transport is added, this would lead to a three times higher electricity consumption per year per household.

In 2035, Switzerland would in total need 70 billion kWh of electricity per year, if the electricity demand would develop as usual.

kW (kilowatt) is the unit that denotes the peak (or maximum) capacity that a power plant can operate at. If the peak capacity of a plant is 1,000 kW, then in its peak hour it could produce 1,000 kWh (1000 kW times 1 hour).

1 gram of CO_{2eq} per kWh is the amount of all types of greenhouse gases (carbon dioxide, methane and others) that are emitted during generation of 1 kWh of electricity. CO_{2eq} stands for so-called carbon dioxide equivalents that combine impact of various greenhouse gases. Every gram of CO_{2eq} contributes equally to climate change, regardless where it is emitted.

1 milligram of PM_{10eq} per kWh is the amount of particulate matter emitted during generation of 1 kWh of electricity. Particulate matter is similar to soot and, once inhaled, increases risk of lung problems. PM_{10eq} stands for so-called particulate matter equivalents that combine impact of various sizes of emitted particulates. PM_{10} refers, for example, to particulates with diameter of 2.5 and 10 micrometers.

Whole supply chain is a term used in environmental impact assessment. It means that not only the environmental impacts caused directly by operation of the power plant are accounted for, but also impacts of other activities related to construction, operation and decommissioning of the power plant. For example, impacts caused by mining of the fuels (e.g. uranium) and resources for the construction of the power plant (e.g. metals for solar cells) or waste disposal are accounted for as well. Even if the power plant is built in Switzerland, a portion of its supply chain is abroad and causes negative environmental impacts there.

(…please turn over)

Electricity costs are the costs of generating 1 kWh of electricity, including costs of investment into the power plant construction, operation, decommissioning and fuel purchase (e.g. natural gas). Electricity costs are lower than the electricity prices that the consumers pay. This is because electricity costs do not yet include electricity grid charges, taxes, administrative expenses of electricity companies, and other costs.

1 billion kWh is a thousand times higher than 1 million kWh. 1 million kWh is a thousand times higher than 1 thousand kWh.

One	1	
1 thousand	1,000	1,000 x 1
1 million	1,000,000	1,000 x 1,000
1 billion	1,000,000,000	1,000 x 1,000,000

Large hydropower dams

Hydropower dams store meltwater from the mountains, spring water, river water and rain water in large reservoirs. As this water flows into another water reservoir or river below the dam, it spins a turbine (a water wheel) that generates electricity. Conventional hydropower dams generate electricity this way. Pumped storage hydropower dams also serve as electricity storage. When there is excess electricity in the grid, they consume electricity to pump the water up to the higher reservoir. When electricity is needed, they generate electricity by letting that water flow down.

Power plants today

Over 80 large hydropower dams generate 18 billion kWh of electricity per year (26% of Swiss electricity production). This is equivalent to the annual consumption of about 2.6 million households. These dams are mostly located in the Alps.

Power plants in the future

The additional amount of electricity that can be produced by building new and renovating existing large hydropower dams is estimated at 700 million to 2.5 billion kWh per year (for 100,000 to 300,000 households). This means that 87-96% of the total potential for large hydropower dams in Switzerland is currently used.

Size of one power plant

An average Swiss dam generates 220 million kWh of electricity per year (for about 30,000 households). For example, the Bieudron dam in the canton of Valais generates 1.8 billion kWh per year, the Tremorgio dam in the canton of Ticino only 7 million kWh.

Impact on climate change

Large hydropower dams do not emit greenhouse gases during operation, which contribute to climate change. If emissions from the whole supply chain are accounted, including emissions that occur during construction of the dams, 12 grams of CO_{2eq} are emitted per kWh of electricity.

Impact on local air pollution

Large hydropower dams do not emit air pollutants during operation, which lead to higher health risks near the plants. If air pollutants from the whole supply chain are accounted, especially from transportation of resources for the construction of the hydropower dams, then 50 milligrams of PM_{10eq} are emitted per kWh of electricity. Air pollution with sulphur dioxide (SO_2) and nitrogen oxides (NO_x) that contribute to smog and acid rain is comparatively low in the whole supply chain.

Impact on water

Large hydropower dams need water for electricity generation. However, the dams do not directly consume water, although some water is lost when it evaporates from the dams. The primary water impact from large hydropower dams is the change in the natural flow of water from the mountains, springs, rivers and rain.

Large hydropower dams

Impact on landscape and land use

The whole supply chain of large hydropower dams requires up to 4,100 m^2 of land per one million kWh of electricity. Most of this land gets submerged under water after the dam is built. Construction of new dams in Switzerland typically does not require sacrificing useful land or relocating populations. How the dams affect the landscape can be seen in the photo on the other side of this sheet.

Impact on flora and fauna

During construction of large hydro dams, large areas of land are submerged under water, which negatively affects flora and fauna. This can be especially problematic if the dams are built in currently unpopulated areas with a high diversity of flora and fauna. Changes in the natural flow of water upstream and downstream the dams also lead to changes in the habitats and migratory patterns of the aquatic fauna.

Accidental impacts

Large hydropower dams in developed countries like Switzerland have an extremely low risk of a severe accident. One fatality occurs on average for 3,000 billion kWh of electricity generated. A typical accident can lead to a very large number of fatalities and high economic damage. For example, the Vajont dam accident in Italy in 1963 led to 2,600 deaths and about 140 million CHF economic damage.

Resource use and waste

Hydropower is understood as a renewable type of electricity generation. Looking at the whole supply chain, generating 1 kWh of electricity still requires 0.1 kWh of non-renewable energy, for example, for transportation of resources for constructing the dam. Generating 1 kWh of electricity in large hydropower dams also leads to 310 milligrams of solid waste, especially during the stages of constructing and dismantling the dam. This solid waste is mostly not toxic.

Electricity costs

Electricity generation costs in large hydropower dams today range from 3 to 7 Rp. per kWh. In the future, costs can be expected to rise up to at least 8 Rp. per kWh. In the case of newly constructed large hydropower dams, the costs can be much higher than that because high investment is needed to build the new dams.

Electricity supply reliability

Large hydropower dams provide a reliable, flexible and locally available type of electricity generation. In particular, the dams help the electricity system to adapt to seasonal variations because water can be stored in the dams for months until more electricity is needed one day. Pumped storage dams can even serve as an electricity storage. Based on the average temperatures and precipitation in a specific year, the electricity production in hydropower dams fluctuates from year to year.

Large run-of-river hydropower

Run-of-river hydropower plants divert a portion of the river water into a separate stream. This diverted water then spins a turbine (water wheel) and generates electricity. Afterwards, the water is returned to the same river down the stream without changing the river's water level or flow. Run-of-river plants typically do not have a reservoir in order to accumulate water and thus rely on the natural flow of the river. Some run-of-river plants can include a dam that extends to a part or the full width of the river in order to aid water flow regulation. But the dam's effect on the water level in the river is minimal.

Power plants today

Over 100 large run-of-river plants generate 17 billion kWh of electricity per year (24% of Swiss electricity production). This is equivalent to the annual consumption of about 2.4 million households. These plants are located in both the lowlands and the Alps.

Power plants in the future

The additional amount of electricity that can be produced by building new and renovating existing large run-of-river plants is estimated at 700 million to 2.5 billion kWh per year (for 100,000 to 300,000 households respectively). This means that 87-96% of the total potential for large run-of-river hydropower in Switzerland is currently used.

Size of one power plant

An average Swiss run-of-river plant generates 160 million kWh of electricity per year (for about 23,000 households). For example, the Laufenburg plant from Aargau generates 630 million kWh per year, the Wynau dam in Bern only 51 million kWh.

Impact on climate change

Large run-of-river hydropower does not emit greenhouse gases during operation, which contribute to climate change. If emissions from the whole supply chain are accounted, including transportation of resources for the construction of the plants, 4 grams of CO_{2eq} are emitted per kWh of electricity.

Impact on local air pollution

Large run-of-river hydropower does not emit air pollutants during operation, which lead to higher health risks near the plants. If air pollutants from the whole supply chain are accounted, especially transportation of resources for the construction of the hydropower plants, then 50 milligrams of PM_{10eq} are emitted per kWh of electricity. Air pollution with sulphur dioxide (SO_2) and nitrogen oxides (NO_x) that contribute to smog and acid rain is minor in the whole supply chain.

Impact on water

Large run-of-river hydropower plants need water for electricity generation. However, run-of-river hydropower does not directly consume water as the same amount of water that comes to the plant upstream also leaves the plant downstream. The primary water impact from run-of-river hydropower is the change in the natural river flow.

Large run-of-river hydropower

Impact on landscape and land use

The whole supply chain of run-of-river hydropower requires about 150 m^2 of land per one million kWh of electricity. At the location of the run-of-river plant, some land may be required only if the plant includes a dam for regulation of water level and flow. This area of submerged land would be relatively minor. How the run-of-river hydropower affects the landscape can be seen in the photo on the other side of this sheet.

Impact on flora and fauna

Large run-of-river hydropower influence the natural flow of the river and hence the habitat and migratory paths of the aquatic fauna. When fish pass through or around the plant, they can get stressed or injured. The water level and flow speed upstream and downstream also change after the plant is built. In addition, if land is submerged under water, this reduces the habitats for non-aquatic flora and fauna.

Accidental impacts

Large run-of-river hydropower plants in developed countries like Switzerland have an extremely low risk of a severe accident. One fatality occurs on average for 3,000 billion kWh of electricity generated. A typical accident can lead to a large number of fatalities and high economic damage. But the fatalities and economic damage are not as high as in the case of large hydropower dams, which are responsible for most hydropower-related accidents.

Resource use and waste

Hydropower is understood as a renewable type of electricity generation. Looking at the whole supply chain, generating 1 kWh of electricity in run-of-river hydropower plants requires only negligible amounts of non-renewable energy because they do not involve large constructions. No reliable data exist on the amount of solid waste produced at run-of-river plants, but it can be expected to be much less than 310 milligrams per 1 kWh that are applicable to large dams. The solid waste is mostly not toxic.

Electricity costs

Electricity generation costs in large run-of-river hydropower plants today range from 3 to 7 Rp. per kWh. In the future, costs can be expected to rise up to at least 8 Rp. per kWh. In the case of newly constructed large run-of-river hydropower plants, the costs can be much higher than that because investment is needed to build the new plants.

Electricity supply reliability

Large run-of-river hydropower provides a relatively reliable, flexible and locally available type of electricity generation. As run-of-river hydropower does not typically include a reservoir to store water, electricity generation is thus subject to seasonal variations in water flow. Based on the average temperatures and precipitation in a specific year, the electricity production in run-of-river hydropower plants fluctuates from year to year.

Small hydropower

Small hydropower plants include both run-of-river hydropower and dams (see the respective factsheets). Hydropower plants are considered small if their maximum capacity to produce electricity is below 10,000 kW. That is, the plant at its peak produces no more than 10,000 kWh per hour, equal to a little more than what one household consumes per year. This category of small hydropower plants also covers very small plants with the capacity of 300 kW, but these plants are not comprehensively documented in Swiss statistics due to the small size.

Power plants today

450 small hydropower plants, mostly run-of-river, generate over 3 billion kWh of electricity per year (5% of Swiss electricity production). This is equivalent to the annual consumption of about 500,000 households. These plants are located in both the lowlands and the Alps.

Power plants in the future

The additional amount of electricity that can be produced by building new and renovating existing small hydropower plants is estimated at 1 to 2 billion kWh per year (for 140,000 to 280,000 households). This means that 60-75% of the potential for small hydropower in Switzerland is currently used.

Size of one power plant

An average small hydropower plant generates 7 million kWh of electricity per year (for about 1,000 households). For example, the Monthey run-of-river plant from Wallis generates 40 million kWh per year, the Bäch run-of-river plant in Schwyz only 1 million kWh.

Impact on climate change

Small hydropower does not emit greenhouse gases during operation, which contribute to climate change. If emissions from the whole supply chain are accounted, including transportation of resources for the construction of the hydropower plants, 5 grams of CO_{2eq} are emitted per kWh of electricity.

Impact on local air pollution

Small hydropower does not emit air pollutants during operation, which lead to higher health risks near the plants. If air pollutants from the whole supply chain are accounted, especially from transportation of resources for the construction of the hydropower plants, then 50 milligrams of PM_{10eq} are emitted per kWh of electricity. Air pollution with sulphur dioxide (SO_2) and nitrogen oxides (NO_x) that contribute to smog and acid rain is minor in the whole supply chain.

Impact on water

Small hydropower dams and run-of-river hydropower need water for electricity generation. However, neither dams nor run-of-river hydropower directly consume water. In the case of dams, some water is lost when it evaporates from the dam. The primary water impact from small hydropower is the change in the natural flow of water from the mountains, springs, rivers and rain.

Small hydropower

Impact on landscape and land use

The whole supply chain of small hydropower requires up to 4,100 m^2 of land per one million kWh of electricity produced in dams and about 150 m^2 in run-of-river plants. This land is submerged under water as described in the respective fact sheets on large dams and run-of-river plants. How small hydropower affects the landscape can be seen in the photo on the other side of this sheet.

Impact on flora and fauna

Small hydropower (primarily run-of-river hydropower) influences the natural flow of the river and hence the habitat and migratory paths of the aquatic fauna. When fish pass through or around the plant, they can get stressed or injured. The water level and flow speed upstream and downstream also change after the plant is built. Small hydropower plants produce comparatively little electricity but still lead to substantial changes to the river ecosystem.

Accidental impacts

Small hydropower plants in developed countries like Switzerland have an extremely low risk of a severe accident. One fatality occurs on average for 3,000 billion kWh of electricity generated. A typical accident leads to a relatively low number of fatalities and economic damage due to the small size of the plants. In addition, most small hydropower plants are run-of-river plants, which carry lower risks than hydropower dams.

Resource use and waste

Hydropower is understood as a renewable type of electricity generation. Looking at the whole supply chain, generating 1 kWh of electricity in small hydropower plants (primarily run-of-river) requires only negligible amounts of non-renewable energy because such plants do not involve large constructions. No reliable data exist on the amount of solid waste produced at small hydropower plants, but it can be expected to be much less than 310 milligrams per 1 kWh that are applicable to large hydropower dams. The solid waste is mostly not toxic.

Electricity costs

Electricity generation costs in small hydropower plants today range from 10 to 40 Rp. per kWh. Even if these plants are not necessarily costly overall, they produce comparatively small amounts of electricity. In the future, costs can be expected to rise up to 12 to 50 Rp. per kWh.

Electricity supply reliability

Small hydropower (primarily run-of-river hydropower) provides a relatively reliable, flexible and locally available type of electricity generation. As run-of-river hydropower does not typically include a reservoir to store water, electricity generation is subject to seasonal variations in water flow. Based on the average temperatures and precipitation in a specific year, the electricity production in small hydropower plants fluctuates from year to year.

Nuclear

Nuclear power plants use the processed mineral of uranium as a fuel. During the so-called nuclear fission, the atoms (small components) of uranium are split, which releases large amounts of heat. This heat is used to produce high-temperature and high-pressure steam, which circulates in a closed cycle and spins a steam turbine that generates electricity. The remaining heat from the process can be used to heat buildings of the neighboring area. If there are no heat consumers nearby, the steam cycle is cooled down by using river or lake water or is cooled down in cooling towers, using an additional water cycle.

Power plants today

5 nuclear power plants generate 22 billion kWh of electricity per year (32% of Swiss electricity production). This is equivalent to the annual consumption of about 3.1 million households. They are located in the cantons of Aargau, Berne and Solothurn.

Power plants in the future

No licenses for new nuclear power plants can be currently issued in Switzerland. Therefore, at most only these 5 nuclear power plants can generate electricity in the future. One, several or all of these nuclear power plants can also be phased out in the years to come.

Size of one power plant

The Leibstadt and Gösgen plants generate 9 and 8 billion kWh of electricity per year respectively (for 1.3 and 1.1 million households respectively). The smaller Mühleberg, Beznau I and Beznau II plants generate about 3 billion kWh each (for 400,000 households).

Impact on climate change

Nuclear power plants do not emit greenhouse gases during operation, which contribute to climate change. If emissions from the whole supply chain are accounted, especially from uranium mining and transportation of resources for the construction of the plants, 14 grams of CO_{2eq} are emitted per kWh of electricity.

Impact on local air pollution

Nuclear power plants do not emit air pollutants during operation, which lead to higher health risks near the plants. If air pollutants from the whole supply chain are accounted, especially from uranium mining and transportation of resources for the construction of the plants, then 130 milligrams of PM_{10eq} are emitted per kWh of electricity. Air pollution with sulphur dioxide (SO_2) and nitrogen oxides (NO_x) that contribute to smog and acid rain is minor in the whole supply chain.

Impact on water

Nuclear power plants consume large amounts of water for cooling the steam after it was used to generate electricity. If river or lake water is used to cool the steam, then hot water is returned to the lake and river. This leads to so-called thermal pollution. If the cooling tower is used, then the water evaporates into the atmosphere. In the whole supply chain, large amounts of water are also used during uranium mining, processing, and storage.

Nuclear

Impact on landscape and land use

The whole supply chain of nuclear power plants requires about 130 m^2 of land per one million kWh of electricity produced. The land is needed where uranium is mined and prepared into fuel abroad, as well as for power plants themselves in Switzerland. Uranium mining and long-term waste storage requires digging into the underground. How nuclear power plants affect the landscape can be seen in the photo on the other side of this sheet.

Impact on flora and fauna

Clearing land to the power plants in Switzerland and the uranium mines abroad leads to habitat loss for flora and fauna. This can be especially problematic if currently unpopulated areas with a high diversity of flora and fauna are disturbed, especially for new uranium mines. If river or lake water is used to cool the steam from the plants, the thermal pollution negatively affects the aquatic flora and fauna. In the case of nuclear power plants, this thermal pollution is substantial.

Accidental impacts

Nuclear power plants in developed countries like Switzerland have an extremely low risk of a severe accident. One fatality is estimated to occur on average for over 1,200 billion kWh of electricity generated (directly at the plant or as a result of health effects). A severe accident can lead to a very high economic damage, but the number of direct fatalities is typically low. The Fukushima accident in 2011 in Japan has led to nearly 190 billion CHF loss. Although the number of fatalities is debated, there were no direct fatalities at the power plant itself.

Resource use and waste

Even if very small amounts of uranium are sufficient to generate large amounts of electricity, the global deposits of uranium are finite. Looking at the whole supply chain, generating 1 kWh of electricity in nuclear power plants requires 3.8 kWh of non-renewable energy. Generating 1 kWh of electricity also leads to 3,000 milligrams of solid waste. A small portion of this waste stays radioactive for thousands of years. Switzerland is currently planning its long-term nuclear waste repository.

Electricity costs

Electricity generation costs in nuclear power plants today range from 4 to 5 Rp. per kWh. These plants require a very high upfront investment for the construction, whereas the costs of operating the plants are comparatively low. In the future, costs can be expected to rise up to 5 to 12 Rp. per kWh.

Electricity supply reliability

Nuclear power plants provide a reliable, steady and large electricity source that does not depend on daily or seasonal weather. In very hot and dry summers nuclear power production could be limited if insufficient river or lake water is available for cooling the steam. Nuclear power plants rely on uranium that is imported from abroad. Although global uranium reserves are limited, current analyses indicate that it will last for many decades ahead.

Solar cells (photovoltaic)

Solar cells (photovoltaic) consist of multiple thin plates of a conductive metal or a semiconductor, such as silicon. In a so-called photoelectric effect, the material absorbs sunlight and releases electrons, which are used as electricity. Electricity is generated directly and proportional to the amount of sunlight that is absorbed. Solar cells are scalable in size. They can range from small plants on rooftops or facades of buildings that do not supply electricity to the grid to larger industrial-scale solar 'farms' on unused land.

Power plants today

Over 100,000 solar power plants of the size of a rooftop generate 1.1 billion kWh of electricity per year (1.6% of Swiss electricity production). This is equivalent to the annual consumption of 150,000 households. The cells are primarily located on residential rooftops throughout Switzerland.

Power plants in the future

The additional amount of electricity that can be produced by new solar cells (photovoltaic) is estimated at 5 to 17 billion kWh of electricity per year (for 700,000 to 2.4 million households). This means that 6-18% of the potential for solar cells in Switzerland is currently used.

Size of one power plant

One residential rooftop with a solar installation generates roughly 8,000 kWh of electricity per year (a little more than one household consumes). Larger industrial plants generate on average about 300,000 kWh (for about 50 households).

Impact on climate change

Solar cells (photovoltaic) do not emit greenhouse gases during operation, which contribute to climate change. If emissions from the whole supply chain are accounted, especially resource mining and manufacturing of the solar cells, 81 grams of CO_{2eq} are emitted per kWh of electricity.

Impact on local air pollution

Solar cells (photovoltaic) do not emit air pollutants during operation, which lead to higher health risks near the plants. If air pollutants from the whole supply chain are accounted, especially from resource mining and manufacturing of the solar cells, then 210 milligrams of PM_{10eq} are emitted per kWh of electricity. In the whole supply chain, there is also some low air pollution with sulphur dioxide (SO_2) and nitrogen oxides (NO_x) that contribute to smog and acid rain.

Impact on water

Solar cells (photovoltaic) consume practically no water during operation. Only some water is used for cleaning. Looking at the whole supply chain, the manufacturing process of solar cells consumes considerable amounts of water. This water consumption, however, can be expected to decrease in the future.

Solar cells (photovoltaic)

Impact on landscape and land use

The whole supply chain of solar cells (photovoltaic) requires about 300 m^2 of area per one million kWh of electricity produced. If building rooftops and facades are used, then only very little land needs to be dedicated to mining of resources and manufacturing of the cells. Larger industrial-scale solar 'farms' may be built on land that could also be used for other purposes. How solar cells affect the landscape can be seen in the photo on the other side of this sheet.

Impact on flora and fauna

If building rooftops and facades are used for solar cells, then there is no direct loss of habitat for flora and fauna. Larger industrial-scale solar 'farms' that are built on land would in parts lead to loss of habitat for flora and fauna. Additional land is sacrificed at the sites where resources for solar cells are mined and cells are manufactures. Local air pollution near manufacturing sites abroad negatively affects flora and fauna too, including particulate matter and acid rain.

Accidental impacts

Solar cells in developed countries like Switzerland have an extremely low risk of a severe accident. One fatality is estimated to occur on average for 36,000 billion kWh of electricity generated. A typical accident leads to a comparatively low number of fatalities and limited economic damage due to the small size of the plants. For example, an explosion in the silicon manufacturing plant for solar cells in Japan in 2014 led to 2 fatalities.

Resource use and waste

Solar energy is understood as a renewable type of electricity generation. Looking at the whole supply chain, generating 1 kWh of electricity in solar cells still requires 0.3 kWh of non-renewable energy for resource mining and manufacturing of cells. Solar cells also require rare metals that are finite worldwide. Little reliable data exists on how much solid waste is produced. The solid waste, however, includes toxic materials that can be problematic, especially if the solar cells are not disposed properly after the end of their lifetime.

Electricity costs

Electricity generation costs of solar cells (photovoltaic) today range from 15 to 37 Rp. per kWh. These plants require a relatively high upfront investment for the construction, whereas the costs of operating the plants are minor. The electricity costs have been dropping dramatically in the last decade. In the future, costs can be expected to decrease to 7 to 12 Rp. per kWh.

Electricity supply reliability

Solar cells (photovoltaic) provide a locally available, but unsteady and inflexible electricity source. As they are dependent on sunshine, these plants are subject to day-to-night as well as to seasonal fluctuations in electricity generation. Some of the day-to-night fluctuations can be smoothened if electric batteries are coupled to the solar cells. Otherwise, the rest of the electricity system needs to adapt the operation of other power plants to be able to smoothen the impact of fluctuating solar electricity.

Wind

A wind power plant typically includes a rotor with three blades, similar to the airplane wings. The rotor is positioned on a tower that is as tall as a 20-40 story building. At this height, the wind is faster and less turbulent than on the ground. The wind turns the blades, which in turn spin the generator inside the plant and produce electricity. The plant's rotor can shift direction in order to generate most electricity at every direction and speed of the wind. In case of storms, the plant automatically stops and twists its blades not to catch wind. Wind power plants can be built as stand-alone plants or as parks with multiple plants.

Power plants today

57 wind power plants in 37 locations generate 110 million kWh of electricity per year (0.2% of Swiss electricity production). This is equivalent to the annual consumption of 15,000 households. The plants are primarily located in the lowlands of Switzerland.

Power plants in the future

The additional amount of electricity that can be produced by building new wind power plants is estimated at 1.3 to 4 billion kWh per year (for 190,000 to 600,000 households). This means that 3-8% of the potential for wind power plants in Switzerland is currently used.

Size of one power plant

An industrial wind power plant generates 3 million kWh of electricity per year (for about 450 households). For example, the Mt. Crosin wind park in the canton of Berne generates 57 million kWh, the Chürstein (Gäbris) plant in Appenzell Ausserrhoden only 4,000 kWh.

Impact on climate change

Wind power plants do not emit greenhouse gases during operation, which contribute to climate change. If emissions from the whole supply chain are accounted, including manufacturing of the plants abroad, 17 grams of CO_{2eq} are emitted per kWh of electricity.

Impact on local air pollution

Wind power plants do not emit air pollutants during operation, which lead to higher health risks near the plants. If air pollutants from the whole supply chain are accounted, including manufacturing of the plants abroad, then 90 milligrams of PM_{10eq} are emitted per kWh of electricity. Air pollution with sulphur dioxide (SO_2) and nitrogen oxides (NO_x) that contribute to smog and acid rain is minor in the whole supply chain.

Impact on water

Wind power plants consume practically no water during operation. Only some water is used for cleaning. Looking at the whole supply chain, the manufacturing process of wind power plants consumes also comparatively minor amounts of water.

Wind

Impact on landscape and land use

The whole supply chain of wind power plants requires up to 2,100 m^2 of area per one million kWh of electricity produced. Most of this land is needed directly at the site where the power plants are built. This land around the plants, however, can be simultaneously used for other purposes too, such as agriculture. How wind power plants affect the landscape can be seen in the photo on the other side of this sheet.

Impact on flora and fauna

Although wind power plants require relatively lots of land, this land can still remain inhabited by the native flora and fauna. Wind power plants can injure and kill birds and bats, but the known migratory paths of birds are typically avoided. Local air pollution near the sites of manufacturing wind power plants abroad negatively affects flora and fauna too, including particulate matter and acid rain.

Accidental impacts

Wind power plants in developed countries like Switzerland have an extremely low risk of a severe accident. One fatality is estimated to occur on average for 5,000 billion kWh of electricity generated. A typical accident leads to a comparatively low number of fatalities and low economic damage due to the small size of the plants. For example, a helicopter crash into a wind power plant in Noxen in the United States in 2013 led to 5 fatalities.

Resource use and waste

Wind energy is understood as a renewable type of electricity generation. Looking at the whole supply chain, generating 1 kWh of electricity in wind power plants still requires 0.1 kWh of non-renewable energy, for example, for manufacturing of the power plants. Wind power plants also require rare metals that are finite worldwide. Generating 1 kWh in wind power plants also leads up to 1,600 milligrams of solid waste, especially during the stages of constructing and dismantling the plant. A small portion of this solid waste is toxic.

Electricity costs

Electricity generation costs of wind power plants today range from 15 to 35 Rp. per kWh. These plants require a relatively high upfront investment for the construction, whereas the costs of operating the plants are minor. The electricity costs have been dropping in the last decade. In the future, the costs can be expected to decrease to 8 to 18 Rp. per kWh.

Electricity supply reliability

Wind power plants provide a locally available, but unsteady electricity source. As they are depending on wind speed, these plants are subject to daily as well as to seasonal fluctuations in electricity generation. The rest of the electricity system thus needs to adapt the operation of other power plants to be able to smoothen the impact of fluctuating wind electricity. If there is too much electricity generation for the demand at a specific time, wind power plants can be flexibly stopped not to feed electricity into the grid.

Deep geothermal

Deep geothermal plants rely on wells that reach 3-5 kilometer deep into the underground, where temperatures naturally are above 100°C. If there is a natural aquifer with hot groundwater at that depth, this water is extracted, used to produce steam, and reinjected back. The steam spins a steam turbine and generates electricity. If the rock underground is dry, it is fractured to create a reservoir and to enable water circulation. Cold water is then injected from over the ground and extracted after it heats up. The remaining heat in both cases can be used to heat buildings of the neighboring area.

Power plants today
No deep geothermal plants operate in Switzerland today. The previous projects in the cities of Basel and St. Gallen have been stopped due to earthquakes (Basel and St.Gallen) and insufficient amounts of underground water found (St. Gallen).

Power plants in the future
The amount of electricity that can be produced in Switzerland by deep geothermal plants is estimated at 2.5 to 4.4 billion kWh per year (for 350,000 to 630,000 households). This means that the current potential for electricity production in Switzerland is not used at all.

Size of one power plant
An average deep geothermal plant could produce 46 million kWh of electricity per year (for about 7,000 households). Larger plants could produce 122 million kWh per year, smaller ones only 24 million kWh.

Impact on climate change
Deep geothermal plants do not emit greenhouse gases during operation, which contribute to climate change. If emissions from the whole supply chain are accounted, including emissions that occur during mining of resources for the construction of the plants, 59 grams of CO_{2eq} are emitted per kWh of electricity.

Impact on local air pollution
Deep geothermal plants do not emit air pollutants during operation, which lead to higher health risks near the plants. If air pollutants from the whole supply chain are accounted, including during manufacturing of the plants, then 50 milligrams of PM_{10eq} are emitted per kWh of electricity. Air pollution with sulphur dioxide (SO_2) and nitrogen oxides (NO_x) that contribute to smog and acid rain is minor in the whole supply chain.

Impact on water
Deep geothermal plants consume medium amounts of water for cooling the steam after it was used to generate electricity. If river or lake water is used to cool the steam, then hot water is returned to the lake and river. This leads to so-called thermal pollution. However, usually remaining heat from the steam is used to heat buildings in the neighborhood. If there is a natural aquifer with hot ground water at the geothermal plant, then this water is pumped up to the ground. If the rock underground is dry, then additional water from above the ground needs to be used and this leads to some water loss.

Deep geothermal

Impact on landscape and land use

The whole supply chain of deep geothermal systems requires about 160 m^2 of area per one million kWh of electricity produced. The land is primarily needed at the site where the plant is built. Deep geothermal systems also require drilling into the deep underground, although little soil is removed from the underground. How deep geothermal systems affect the landscape can be seen in the photo on the other side of this sheet.

Impact on flora and fauna

The construction of deep geothermal power plants in Switzerland leads to some habitat loss for flora and fauna, although the land requirement for these plants is relatively low. In the case that river or lake water is used to cool the steam from the plants, the thermal pollution negatively affects the aquatic flora and fauna.

Accidental impacts

Deep geothermal plants in developed countries like Switzerland have an extremely low risk of a severe industrial accident. One fatality is estimated to occur on average for 4,700 billion kWh of electricity generated. These plants, however, can also induce potentially damaging seismicity. For example, the Basel geothermal project in 2006 caused an earthquake of a magnitude 3.4 (slightly felt by a few people) and over 7 million CHF damage to insured property. Experts believe that a similar earthquake could occur in 1 out of 10 plants per year. Larger-magnitude and potentially fatal events are extremely unlikely, but cannot be completely ruled out with confidence.

Resource use and waste

Geothermal energy is understood as a renewable type of electricity generation, even if after decades of operation the temperature at the bottom of the geothermal well slightly decreases. Looking at the whole supply chain, generating 1 kWh of electricity in deep geothermal plants requires negligible amounts of non-renewable energy. Generating 1 kWh of electricity leads to up to 60 milligrams of solid waste, especially during the stages of constructing and dismantling the plant. The solid waste is mostly not toxic.

Electricity costs

There are no deep geothermal plants in Switzerland today and only several of them exist worldwide. The technology is relatively new and thus costly, especially when an artificial reservoir needs to be created in the deep underground. Therefore, there are little electricity cost estimates that are based on data from actual plants. In the future, costs can be expected to range from 10 to 60 Rp. per kWh.

Electricity supply reliability

Deep geothermal plants provide a reliable and steady electricity source that does not depend on daily or seasonal weather. These power plants typically work on their full capacity and are not fully flexible to quickly adapt to the changes in electricity demand. They rely on a locally available energy source and are thus not dependent on imported fuel.

Large gas power plants

Large gas power plants use natural gas as a fuel. The gas is burnt to release large amounts of high-temperature exhaust fumes that spin a turbine and hence generates electricity. Additional heat can be recovered from this stream of exhaust fumes to produce steam to spin another steam turbine and generate more electricity. The remaining heat from the process can be used to heat buildings of the neighboring area. If there are no heat consumers nearby, the heat is cooled down by using river water or by producing water vapor in the cooling towers and releasing this vapor into the atmosphere.

Power plants today

Nearly 40 natural gas power plants in various industrial sites throughout Switzerland generate 1 billion kWh of electricity per year (1.5% of Swiss electricity production). This is equivalent to the annual consumption of about 140,000 households. However, these are currently mainly relatively small power plants.

Power plants in the future

Deployment of large gas power plants in Switzerland is limited only by the capacity of gas import infrastructure and availability of sites. Energy analyses have estimated that up to 28 billion kWh of electricity per year could be produced (for 4 million households). Existing plants could also be closed if the aim is to reduce climate change impacts.

Size of one power plant

Currently, an average gas power plant in Switzerland produces 25 million kWh of electricity per year (for about 3,600 households). Yet, the size of one large plant can reach a capacity of up to 7 billion kWh per year (1.1 million households) or even more.

Impact on climate change

Burning natural gas in large power plants directly emits greenhouse gases that contribute to climate change. If the whole supply chain is accounted, including emissions that occur during extraction and transportation of natural gas, 600 grams of CO_{2eq} are emitted per kWh of electricity.

Impact on local air pollution

Burning natural gas emits various gases into the atmosphere, such as carbon dioxide (CO_2) and water vapor. The emissions of particulate matter near the plants are minor. If air pollutants from the whole supply chain are accounted, especially from extraction of gas and resources for the construction of the plants, then 150 milligrams of PM_{10eq} are emitted per kWh of electricity. Gas power plants also contribute to some extent to smog and acid rain by emitting sulphur dioxide (SO_2) and nitrogen oxides (NO_x).

Impact on water

Gas power plants consume medium amounts of water for cooling the steam after it was used to generate electricity. If river or lake water is used to cool the steam, then hot water is returned to the lake or river. This leads to so-called thermal pollution. However, usually remaining heat from the steam is used to heat buildings in the neighborhood. If the cooling tower is used, then the water evaporates into the atmosphere. Looking at the whole supply chain, large amounts of water are also used for gas extraction.

Large gas power plants

Impact on landscape and land use

The whole supply chain of large gas power plants requires about 340 m^2 of area per one million kWh of electricity produced. The land is needed where gas is extracted abroad, as well as in Switzerland for power plants themselves. Natural gas extraction also requires digging into the underground on land or in the ocean. How large gas power plants affect the landscape can be seen in the photo on the other side of this sheet.

Impact on flora and fauna

The construction of power plants in Switzerland and the natural gas extraction abroad leads to habitat losses for flora and fauna. This can be problematic if currently unpopulated areas with a high diversity of flora and fauna are disturbed, especially at the gas extraction sites at land or offshore. In the case that river or lake water is used to cool the steam from the plants, the thermal pollution negatively affects the aquatic flora and fauna. Contribution of these plants to air pollution also affects flora and fauna.

Accidental impacts

Large gas power plants in developed countries like Switzerland have a low risk of a severe accident. One fatality is estimated to occur on average for 120 billion kWh of electricity generated. Most of the accidents occur during gas extraction. The accidents at the power plant itself are rarer. When an accident occurs, its impacts in terms of fatalities and economic damage can vary significantly. For example, an explosion in a large gas power plant in Connecticut, United States, in 2010 led to 5 deaths.

Resource use and waste

The global deposits of natural gas are finite. Looking at the whole supply chain, generating 1 kWh of electricity in gas power plants requires 2.6 kWh of non-renewable energy, including the natural gas as a fuel as well as energy for manufacturing of the plants. Generating 1 kWh of electricity also leads to 4,700 milligrams of solid waste, especially during the stages of constructing and dismantling the plant. The solid waste is mostly not toxic.

Electricity costs

Electricity generation costs of large gas power plants today range from 8 to 14 Rp. per kWh. Construction costs of these plants are relatively low. The large portion of the electricity generation costs consists of expenses that are required for purchasing natural gas during operation. In the future, costs can be expected to be from 10 to 22 Rp. per kWh and will primarily depend on the natural gas prices.

Electricity supply reliability

Large gas power plants provide a reliable and steady electricity source that does not depend on daily or seasonal weather. These power plants are also flexible and can quickly adapt to the changes in electricity demand. These plants rely on natural gas that is imported from abroad. Although global natural gas reserves are limited, current analyses indicate that they will last for many decades ahead. Natural gas trade is, however, subject to geopolitical tensions and risks.

Woody biomass

Woody biomass plants use various kinds of low-quality wood as a fuel, such as wood chips, wood pellets, waste wood, saw dust, residues from mature forests or bark. Often such plants are built next to wood-processing industries. The wood is either burnt directly or first used to produce biogas and then this biogas is burnt. The heat from the burning process is used to produce steam that spins a turbine (a steam wheel) and hence generates electricity. The remaining heat from the process can be used to heat buildings of the neighboring area. In many cases, the primary goal is to produce heat rather than electricity.

Power plants today

70 larger and thousands of small plants generate 200 million kWh of electricity per year (0.3% of Swiss electricity production). This is equivalent to the annual consumption of about 26,000 households. They are located throughout the country.

Power plants in the future

The additional amount of electricity that can be produced in Switzerland by woody biomass plants reach up to 1 billion kWh of additional electricity per year (for 140,000 households). This means that 16% of the potential for woody biomass plants in Switzerland is currently used.

Size of one power plant

An average Swiss woody biomass plant generates 800,000 kWh of electricity per year (for about over 100 households). For example, the Basel woody biomass plant generates 18 million kWh per year, small plants can generate as little as 80,000 kWh.

Impact on climate change

Burning woody biomass emits greenhouse gases (CO_2), but they contribute to climate change only little because wood, when it grows, consumes greenhouse gases (CO_2) too. If the whole supply chain is accounted, including emissions during collection and transportation of biomass, 46 grams of CO_{2eq} are emitted per kWh of electricity.

Impact on local air pollution

Burning woody biomass or biogas emits various gases into the atmosphere, such as carbon dioxide (CO_2) and water vapor. The emissions of particulate matter near the plants, especially smaller ones, are high. If pollutants from the whole supply chain are accounted, including collection and transportation of wood, then 2,970 milligrams of PM_{10eq} are emitted per kWh of electricity. These plants also contribute to some extent to smog and acid rain by emitting sulphur dioxide (SO_2) and nitrogen oxides (NO_x).

Impact on water

Woody biomass power plants consume medium amounts of water for cooling the steam after it was used to generate electricity. If river or lake water is used to cool the steam, then hot water is returned to the lake or river and leads to so-called thermal pollution. However, usually remaining heat from the steam is used to heat buildings in the neighborhood. In the whole supply chain, large amounts of water are in principle consumed by the biomass growth. As woody biomass plants in Switzerland primarily rely on low-quality wood that would not be used for other purposes, this water impact is negligible.

Woody biomass

Impact on landscape and land use

The whole supply chain of woody biomass plants requires up to 12,600 m^2 of land per one million kWh of electricity. This primarily refers to the land for growing wood. As the plants in Switzerland rely on low-quality wood, such as residues from mature forests, the land use due to electricity generation only is in fact lower. How these plants affect the landscape can be seen in the photo on the other side of this sheet.

Impact on flora and fauna

As the woody biomass plants in Switzerland rely on low-quality wood, they do not directly affect the forest as habitats for flora and fauna. In the case that river or lake water is used to cool the steam from the plants, the thermal pollution negatively affects the aquatic flora and fauna. Contribution of these plants to air pollution also affects flora and fauna.

Accidental impacts

Woody biomass plants in developed countries like Switzerland have a low risk of a severe accident. Although comprehensive data do not exist, one fatality could be expected to occur on average for 6,000 billion to 9,000 billion kWh of electricity generated. A typical accident leads to a comparatively low number of fatalities and low economic damage due to the small size of the plants. For example, an explosion at a biomass plant in North Rhine-Westfalia, Germany, in 2010 lead to 3 deaths.

Resource use and waste

Woody biomass is understood as a renewable type of electricity production. Looking at the whole supply chain, generating 1 kWh of electricity in woody biomass plants still requires 0.2 kWh of non-renewable energy, especially for collection and transportation of wood. Little reliable data exists on how much solid waste is produced. Some waste, especially the ash from wood burning, can have toxic properties.

Electricity costs

Electricity generation costs in woody biomass power plants today range from 24 to 30 Rp. per kWh. Both the investment needed to build these power plants as well as to operate them and to pay for the wood contribute significantly to these costs. In the future, the costs can be expected to be from 16 to 32 Rp. per kWh.

Electricity supply reliability

Woody biomass power plants provide a reliable and steady electricity source that does not depend on daily or seasonal weather. As woody biomass can be stored as a fuel, the plants can adapt to seasonal changes in electricity demand. Some plants are yet less flexible to rapid changes if they rely on wood burning in furnaces. As far as the wood originates in Switzerland, these plants rely on a locally available energy source and thus are not dependent on imported fuel.

Biogas

The biogas power plants use biogenic waste as a fuel, such as slurry and dung from agriculture, green waste from households and food industry, and sludge from wastewater treatment plants. The waste is collected, grinded and kept in a so-called digester until it is decomposed by microorganisms into biogas (comparable to natural gas) and waste products. The biogas is then burnt and the resulting heat is used to produce steam that spins a turbine (a steam wheel) and hence generates electricity. The remaining heat from the process can be used to heat buildings of the neighboring area.

Power plants today

Over 400 biogas plants altogether generate 300 million kWh of electricity per year (0.4% of Swiss electricity production). This corresponds to the annual consumption of about 40,000 households. They are located in rural areas throughout Switzerland.

Power plants in the future

The additional amount of electricity that can be produced by biogas plants is estimated at over 1 billion kWh (for 160,000 households). That is, 20% of the potential for biogas plants in Switzerland is currently used.

Size of one power plant

An average Swiss biogas plant generates 700,000 kWh of electricity per year (for about 100 households). Larger plants generate over 1 million kWh per year, the smaller ones only 300,000 kWh.

Impact on climate change

Burning biogas emits greenhouse gases (CO_2), but they contribute to climate change little because biogenic waste, if left to decompose naturally, would emit greenhouse gases too. If the whole supply chain is accounted, including emissions during collection and transportation of waste, 347 grams of CO_{2eq} are emitted per kWh of electricity.

Impact on local air pollution

Burning biogas emits various gases into the atmosphere, such as carbon dioxide (CO_2) and water vapor. The emissions of particulate matter near the plants are minor. If pollutants from the whole supply chain are accounted, including collection and transportation of waste, then 50 milligrams of PM_{10eq} are emitted per kWh of electricity. Biogas plants also add to some low air pollution with sulphur dioxide (SO_2) and nitrogen oxides (NO_x) that contribute to smog and acid rain.

Impact on water

Biogas power plants consume medium amounts of water for cooling the steam after it was used to generate electricity. If river or lake water is used to cool the steam, then hot water is returned to the lake or river and leads to so-called thermal pollution. However, usually remaining heat from the steam is used to heat buildings in the neighborhood. In the whole supply chain, materials that are used to produce biogas, such as slurry or food waste, contain lots of water. But as this water would not be used for other purposes, this water impact is negligible.

Biogas

Impact on landscape and land use

The whole supply chain of biogas plants requires about 160 m^2 of land per one million kWh of electricity. This primarily refers to the land for the digester and the power plant. As biogas is produced from biogenic waste, slurry or wastewater sludge, land use for agriculture and other activities that produce this waste is not accounted. How biogas plants affect the landscape can be seen in the photo on the other side of this sheet.

Impact on flora and fauna

Construction of biogas plants leads to some land losses. However, these plants are usually located near existing farms, wastewater treatment facilities, and industries. The habitat loss is thus minor. In the case that river or lake water is used to cool the steam from the plants, the thermal pollution negatively affects the aquatic flora and fauna. Contribution of these plants to air pollution also negatively affects flora and fauna.

Accidental impacts

Biogas power plants in developed countries like Switzerland have a low risk of a severe accident. One fatality is estimated to occur on average for 6,000 billion kWh of electricity generated. A typical accident leads to a comparatively low number of fatalities and low economic damage due to the small size of the plants. For example, an explosion at a biogas plant in Zeven, Germany, in 2005 lead to 4 deaths.

Resource use and waste

Slurry, wastewater sludge, and other biogenic waste are understood as renewable resources. Looking at the whole supply chain, generating 1 kWh of electricity in biogas plants still requires 0.7 kWh of non-renewable energy, especially for the construction of the plant as well as for collecting and transporting waste to the plant. Little reliable data exists on the amount of solid waste produced. Some waste can have toxic properties.

Electricity costs

Electricity generation costs in biogas power plants today range from 16 to 26 Rp. per kWh. These costs include the investment needed to build these power plants as well as to operate them and to pay for collection or purchase of biogenic material. In the future, costs can be expected to remain at a similar level.

Electricity supply reliability

Biogas plants provide a reliable, steady and flexible electricity source that does not depend on daily or seasonal weather. As biogas can be stored as a fuel, the plants can in parts flexibly adapt to the changing electricity demand. As far as the biogenic material for biogas originates in Switzerland, these plants rely on a locally available energy source and thus are not dependent on imported fuel.

Waste incineration

Waste incineration plants use municipal and some industrial waste as a fuel. The waste is burnt in large furnaces and the resulting heat from the burning process is used to produce steam. The steam spins a turbine (a steam wheel) and hence generates electricity. The remaining heat from the process can be used to heat buildings of the neighboring area. In many cases, the primary goal of the waste incineration plants is to reduce the amount of waste that reaches the landfills as well as to produce heat rather than electricity.

Power plants today

30 larger and 70 smaller waste incineration plants generate 2 billion kWh of electricity per year (3.2% of Swiss electricity production). This is equivalent to the annual consumption of about 300,000 households. They are primarily located in larger cities.

Power plants in the future

The additional amount of electricity that can be produced by extending and building new waste incineration plants and accounting for changes in waste volumes is estimated as 1 billion kWh per year (180,000 households). This means that over 60% of the potential of waste incinerators in Switzerland is currently used.

Size of one power plant

An average Swiss incinerator produces 60 million kWh of electricity per year (for about 8,000 households). For example, the Zuchwil plant in Solothurn generates 130 million kWh per year, the Gamsen plant in Wallis generates less than 1 million kWh.

Impact on climate change

Burning waste emits greenhouse gases (CO_2), but they contribute to climate change less because waste, if left to decompose naturally, would emit greenhouse gases (CO_2) too. If the whole supply chain is accounted, including emissions during collection and transportation of waste, 7 grams of CO_{2eq} are emitted per kWh of electricity.

Impact on local air pollution

Burning waste emits various gases into the atmosphere, such as carbon dioxide (CO_2) and water vapor. The emissions of particulate matter near the plants are minor. If pollutants from the whole supply chain are accounted, including construction of the plant as well as collection and transportation of waste, then 40 milligrams of PM_{10eq} are emitted per kWh of electricity. Waste incineration plants add to some low air pollution with sulphur dioxide (SO_2) and nitrogen oxides (NO_x) that contribute to smog and acid rain.

Impact on water

Waste incineration plants consume medium amounts of water for cooling the steam after it was used to generate electricity. If river or lake water is used to cool the steam, then hot water is returned to the lake or river and leads to so-called thermal pollution. However, usually remaining heat from the steam is used to heat buildings in the neighborhood. In the whole supply chain, waste and especially their biogenic share contain lots of water. But as this water would not be used for other purposes, this water impact is negligible.

Waste incineration

Impact on landscape and land use

Waste incineration requires land for the plants themselves, collection and transportation of waste, as well as for the final disposal of waste that remains after incineration. At the same time, when waste is burnt, even larger areas of land for landfills are avoided. Thus, waste incineration reduces land use. How waste incineration plants affect the landscape can be seen in the photo on the other side of this sheet.

Impact on flora and fauna

Some land is needed for waste incinerators and associated infrastructures. But even more land is saved for flora and fauna by avoiding land loss for landfills. In the case that river or lake water is used to cool the steam from the plants, the thermal pollution negatively affects the aquatic flora and fauna. Contribution of these plants to air pollution also negatively affects flora and fauna.

Accidental impacts

Waste incinerations plants in developed countries like Switzerland have a low risk of a severe accident. Although comprehensive data do not exist, one fatality could be expected to occur on average for 6,000 billion to 9,000 billion kWh of electricity generated. A typical accident leads to a comparatively low number of fatalities and limited economic damage due to the small size of the plants.

Resource use and waste

Municipal waste is in principle understood as a renewable resource. Looking at the whole supply chain, generating 1 kWh of electricity in waste incineration plants requires 0.02 kWh of non-renewable energy, especially for construction of the plant as well as collection and transportation of waste. Small amounts of toxic ash remain after the waste has been incinerated, which to be disposed in special sites.

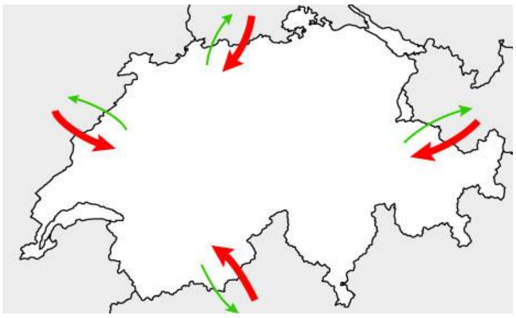
Electricity costs

Electricity generation costs in waste incineration plants today range from 5 to 13 Rp. per kWh. Both the investment needed to build these power plants as well as to operate them and to pay for collection of waste contribute to the costs. Waste incineration plants, however, help to reduce other costs of society, such as extension and maintenance of landfills. In the future, the costs can be expected to remain in the similar range.

Electricity supply reliability

Waste incineration plants provide a reliable and steady electricity source that in principle does not depend on daily or seasonal weather. These power plants typically work on their full capacity and are less flexible to quickly adapt to the changes in electricity demand. They rely on a locally available energy source and thus are not dependent on imported fuel.

Net import from abroad



Swiss electricity grid is connected with the grids of France, Germany, Austria, Italy, and Lichtenstein. Electricity is being imported to and exported from Switzerland every day based on the differences between countries in terms of electricity price, demand, and amounts of generated electricity. Looking throughout one year, Switzerland could import more electricity from abroad than it exports. This would lead to so-called net import. If Switzerland decides to cover parts of its electricity demand with net import for the longer term, less power plants would be built in Switzerland.

Situation today

42 billion kWh of electricity per year are imported and 43 billion kWh are exported, leading to 1 billion kWh of net export during the year and no net import. These amounts, however, change from year to year.

Situation in the future

The estimates of how much more electricity could be imported to and exported from Switzerland in principle depend on future decisions to maintain or extend the capacity of grid connections. Energy analysis have so far considered net import of 22 billion kWh per year as the maximum (for over 3 million households).

Capacity of grid connections

Electricity exchange with the other countries can be flexibly increased or decreased. Currently, 60% of imports come from France, 26% from Germany, 12 % from Austria, and 2% from Italy. How much electricity is actually imported can vary.

Impact on climate change

Impact on climate change by imported electricity depends on where this electricity comes from. If the whole supply chain is accounted, the average unit of electricity from France emits 60 grams of CO_{2eq} (mainly nuclear), from Germany 610 grams (coal and gas power), from Austria 170 grams (mainly hydro power), and from Italy 500 grams (gas and coal power).

Impact on local air pollution

Impact on local air pollution by imported electricity depends on where this electricity comes from. This impact would not occur in Switzerland. If the whole supply chain is accounted, the average unit of electricity from France emits 310 milligrams of PM_{10eq} per kWh, from Germany over 4,000 milligrams, from Austria 700 milligrams, and from Italy 1,900 milligrams. Electricity from Germany and France contributes to some extent to smog and acid rain with sulphur dioxide (SO_2) and nitrogen oxides (NO_x) emissions.

Impact on water

Impact on water by imported electricity depends on where this electricity comes from. This impact would not occur in Switzerland. In all the four countries that Switzerland imports from, electricity generation has large to very large negative impact on water. In France, large portions of electricity are produced by nuclear power plant, in Germany and Italy by coal and gas power plants, and in Austria by hydropower.

Net import from abroad

Impact on landscape and land use

Impact on land use by imported electricity depends on where this electricity comes from. This impact would not occur in Switzerland. The land use is comparatively low in France due to nuclear power. The land use is moderate in Germany and Italy because dominating coal and gas plants require only medium amounts of land. The land use for electricity production is relatively high in Austria due to high share of hydropower.

Impact on flora and fauna

Impact on flora and fauna by imported electricity depends on where this electricity comes from. This impact would not occur in Switzerland. All neighboring countries rely to a large share on power plants that have significant effects on flora and fauna, such as nuclear power in France (land loss, thermal water pollution), coal and gas plants in Germany and Italy (leading to land loss, thermal water pollution, air pollution), and hydropower in Austria (land loss, aquatic flora and fauna).

Accidental impacts

Accidental impacts by imported electricity depend on where this electricity comes from. France relies on nuclear power with one fatality at every 1,200 billion kWh. Both Germany and Italy rely on coal and gas power plants, for which one fatality is estimated to occur on average for every 70 billion kWh (coal) or 120 billion kWh (gas) of electricity generated. Austria has a large share of hydropower plants with one fatality at 3,000 billion kWh. When a typical accident occurs in these plants, it can lead to a very large number of fatalities and high economic damage though. This impact would not occur in Switzerland.

Resource use and waste

Impact on resource use and waste by imported electricity depends on where this electricity comes from. Primarily nuclear electricity from France requires non-renewable uranium and contributes to the stock of radioactive waste. Electricity from Germany and Italy require significant amounts of non-renewable resources of coal and natural gas that both also leave significant amounts of waste. The impact of electricity from Austria is moderate due to a large share of hydropower.

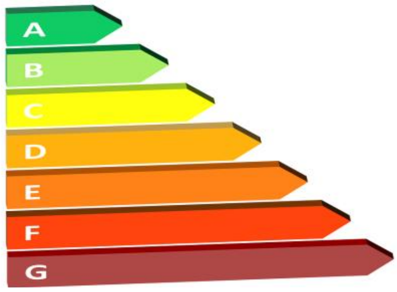
Electricity costs

The costs of imported electricity depend on the country from which the electricity is imported. Currently, the electricity from France on average costs about 5 Rp. Per kWh, from Germany about 4 Rp. per kWh, from Austria about 4 Rp. per kWh, and from Italy about 6 Rp. per kWh. The future costs will depend on strategic decisions about the electricity generation mix in these countries.

Electricity supply reliability

Electricity import from abroad is a reliable and steady electricity source that can be used flexibly to contribute to the Swiss electricity needs and to benefit from difference in electricity generation costs. As electricity generation in the neighboring countries is subject to the strategic decisions of every individual country, relying to a larger extent on electricity imports in Switzerland also means relying on strategic decisions elsewhere too.

Electricity saving and efficiency



If less electricity is consumed in Switzerland, less electricity needs to be generated or imported into the country too. The reduction in consumption can be achieved by saving electricity or by improving its use efficiency. Saving electricity requires a change in behavior, for example, switching off the lights or appliances that are not used, or avoiding stand-by mode that still consumes electricity. Another option is to buy less electricity-consuming devices in the first place. Electricity use efficiency can be improved by buying appliances, such as light bulbs or fridges, that are more energy-efficient. Typically, there is an energy label on the appliance.

Potential in the future

Behavior change and efficiency improvements, related to electricity consumption in all sectors (e.g. housing, agriculture, transport), could reduce the electricity consumption by nearly 7 billion kWh per year (equivalent to today's consumption of up to 1 million households).

Impact on climate change, local air pollution, water, landscape and land use, flora and fauna, accidental impacts, and resource use and waste

If less electricity is consumed due to behavior change or efficiency improvements, then less electricity needs to be generated. This helps to prevent negative impacts that are unavoidably related to electricity generation, be it on climate change, local air pollution, water, landscape and land use, flora and fauna, accidents, and resource use and waste. If in general less appliances are bought, this even helps to avoid negative impacts related to the manufacturing of these appliances. The manufacturing of energy-efficient appliances typically has comparable negative impacts to those of manufacturing standard devises.

Electricity costs

If less electricity is consumed and needs to be generated in Switzerland, in principle, cheaper types of power plants can be prioritized and the most expensive ones can be avoided. This would decrease the overall electricity price in the country. Although some energy-efficient appliances can cost more than the standard appliances, in many cases the expenses that are saved because less electricity is needed compensate the higher expenses of purchasing the appliance.

Electricity supply reliability

The less electricity needs to be generated, the more power plants are available to guarantee the overall electricity supply reliability. However, a lower demand could lead to a higher relative proportion of weather-dependent wind and solar power in the electricity mix and the electricity system would need to be able to react more flexibly.

Acknowledgements and data sources

These factsheets have been prepared by the team of the project "RIsk GOveRnance of electricity pOrtfolioS (RIGOROuS): Cross-technology and spatial tradeoffs of multiple risks" at ETH Zurich. This project is funded by the Swiss National Science Foundation (Grant No. 160563).

Statistics and data on technology potentials

Information on current electricity generation (year 2015) in Switzerland and its future potentials have been taken from these sources:

- – . 2013. Trialog Neue Energiepolitik. Energiestrategie 2050 aus Sicht des Energie Trialogs. Schlussbericht der Lenkungsgruppe. Energie Trialog: Zurich.
- Bundesamt für Energie. 2012. Das Potenzial der erneuerbaren Energien bei der Elektrizitätsproduktion. Bundesamt für Energie: Bern.
- Bundesamt für Energie. 2012. Wasserkraftpotenzial der Schweiz. Abschätzung des Ausbaupotenzials der Wasserkraftnutzung im Rahmen der Energiestrategie 2050. Bundesamt für Energie: Bern.
- Bundesamt für Energie. 2015. Schweizerische Elektrizitätsstatistik 2015. Bundesamt für Energie: Bern.
- Bundesamt für Energie. 2016. Schweizerische Statistik der erneuerbaren Energien. Bundesamt für Energie: Bern.
- Bundesamt für Energie. 2016. Statistik der Wasserkraftanlagen der Schweiz. Bundesamt für Energie: Bern.
- Bundesamt für Energie. 2016. Thermische Stromproduktion inklusive Wärmekraftkopplung (WKK) in der Schweiz. Ausgabe 2015. Bundesamt für Energie: Bern.
- Bundesamt für Energie. 2017. Aussenhandel der Schweiz mit Elektrizität nach Ländern. Bundesamt für Energie: Bern.
- Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation. 2017. Faktenblatt «Abstimmung Energiegesetz - Überblick». Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation: Bern.
- Hirschberg S., Bauer C., Bäuerle Y., Biollaz S., Burgherr P., Cox B., et al. 2016. Perspectives for Swiss electricity supply: Potentials, costs and environmental assessment. Poster at the Swiss Competence Center for Energy Research-Supply of Electricity conference, 12 - 13 September 2016, Sion.
- Hirschberg S., Wiemer, S., Burgherr, P. 2014. Energy from the Earth: Deep geothermal as a resource for the future? TA Swiss Geothermal Project Final Report. TA Swiss: Bern.
- Hüsser P. 2015. National Survey Report of PV Power Applications in Switzerland 2014. International Energy Agency: Paris.
- Pöyry. 2012. Angebot und Nachfrage nach flexiblen Erzeugungskapazitäten in der Schweiz. Pöyry Management Consulting: Zurich.
- Schweizerische Eidgenossenschaft. 2017. Geokatalog. Available at: https://map.geo.admin.ch/.
- Verband der Betreiber Schweizerischer Abfallverwertungsanlagen. 2015. Einheitliche Heizwert- und Energiekennzahlenberechnung der Schweizer KVA nach europäischem Standardverfahren. Bundesamt für Umwelt, Bundesamt für Energie: Bern.
- Verband Schweizerischer Elektrizitätsunternehmen. 2012. Wege in die neue Stromzukunft. Gesamtbericht. Verband Schweizerischer Elektrizitätsunternehmen: Aarau.
- Volkart K., Bauer C., Burgherr P., Hirschberg S., Schenler W., Spada M. 2016. Interdisciplinary assessment of renewable, nuclear and fossil power generation with and without carbon capture and storage in view of the new Swiss energy policy. International Journal of Greenhouse Gas Control 54, 1-14.

Data on impacts

Data on electricity generation impacts have been taken from these sources:

- Arup. 2016. Review of Renewable Electricity Generation Cost and Technical Assumptions. UK Department of Energy and Climate Change: London.
- Bauer C., Frischknecht R., Eckle P., Flury K., Neal T., Papp K., et al. 2012. Umweltauswirkungen der Stromerzeugung in der Schweiz. ESU-services GmbH and Paul Scherrer Institut: Uster and Villigen.
- Burgherr P., Hirschberg S. 2014. Comparative risk assessment of severe accidents in the energy sector. Energy Policy 74 (S1), S45-S56.
- Bundesamt für Bevölkerungsschutz. Katastrophen und Notlagen Schweiz 2015. Bundesamt für Bevölkerungsschutz: Bern.
- Bundesamt für Energie. 2017. Aussenhandel der Schweiz mit Elektrizität nach Ländern. Bundesamt für Energie: Bern.
- Bundesamt für Umwelt, Naturschutz und Reaktorsicherheit. 2011. Erneuerbare EnergienInnovationen für eine nachhaltige Energiezukunft. Bundesamt für Umwelt, Naturschutz und Reaktorsicherheit: Berlin.

- Department for Business, Energy and Industrial Strategy. 2016. Electricity generation costs. Department for Business, Energy and industrial Strategy: London.
- Fleishman L. A., De Bruin W. B., Morgan, M. G. 2010. Informed public preferences for electricity portfolios with CCS and other low-carbon technologies. Risk Analysis 30 (9), 1399-1410.
- Fraunhofer ISE. 2013. Levelized cost of electricity. Renewable energy technologies. Fraunhofer ISE: Freiburg, Germany.
- Fthenakis V., Kim H. C. 2009. Land use and electricity generation: A life-cycle analysis. Renewable and Sustainable Energy Reviews 13 1465-1474.
- Hertwich E. G., Gibon T., Bouman E. A., Arvesen A., Suh S., Heath G. A. et al. 2015. Integrated life-cycle assessment of electricity-supply scenarios confirms global environmental benefit of low-carbon technologies. Proceedings of the National Academy of Sciences of the United States of America 12(20): 6277–6282.
- Hirschberg S., Bauer C., Bäuerle Y., Biollaz S., Burgherr P., Cox B., et al. 2016. Perspectives for Swiss electricity supply: Potentials, costs and environmental assessment. Poster at the Swiss Competence Center for Energy Research-Supply of Electricity conference, 12 - 13 September 2016, Sion.
- Hirschberg S., Wiemer, S., Burgherr, P. 2014. Energy from the Earth: Deep geothermal as a resource for the future? TA Swiss Geothermal Project Final Report. TA Swiss: Berne.
- Masanet E., Chang Y., Gopal A. R., Larsen P., Morrow W.R., Sathre R. et al. 2013. Life-Cycle Assessment of Electric Power Systems. Annual Review of Environment and Resources 38:107–36.
- Meldrum J., Nettles-Anderson S., Heath G., Macknick J. 2013. Life cycle water use for electricity generation: a review and harmonization of literature estimates. Environmental Research Letters 8 (015031), 1-18.
- Messmer A., Frischknecht R. 2016. Umweltbilanz Strommix Schweiz. Treeze Ltd., fair life cycle thinking: Uster.
- Sovacool B. K., Andersen R., Sorensen S., Sorensen K., Tienda V., Vainorius A., Schirach O.M., Bjørn-Thygesen F. 2016. Balancing safety with sustainability: assessing the risk of accidents for modern low-carbon energy systems. Journal of Cleaner Production 112, 3952-3965.
- Trutnevyte E., Azevedo I.L. 20147. Induced seismicity hazard and risk by Enhanced Geothermal Systems: An expert elicitation approach. Environmental Research Letters 13(3): 03400.

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