Factsheet: Water and energy

This information sheet – without making any claims to completeness – brings together various facts on the subject of water and energy, focusing on Switzerland but also covering the international perspective.

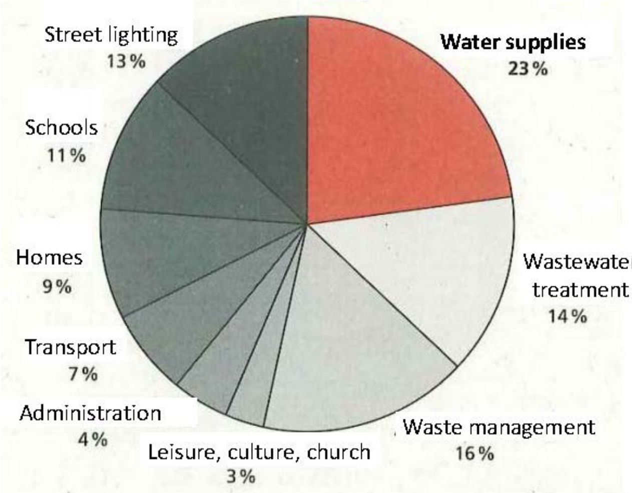
Hydropower

- Hydropower accounts for around 20% of global electricity production; in Switzerland, the proportion is 56%[1] (2010: 37.5 TWh of a total of 66.3 TWh domestic production, representing a 12% share of gross final energy consumption).
- 43% of hydropower in Switzerland comes from run-of-the-river plants, 57% from reservoir plants.
- The impacts of hydropower exploitation on surface waters are manifold – e.g. disruption of longitudinal river continuity, alteration of solids dynamics or natural discharge regimes (residual flow situation, hydropeaking, etc.). For more information on the ecological impacts of hydropower use, see:

>>>separate factsheet on "Hydropower and ecology": http://www.eawag.ch/en/consulting/consulting-knowledge-transfer/publikationen-fuer-die-praxis/

Drinking water

- Switzerland's 3,000 public water utilities supply a total of 1 billion cubic metres of drinking water a year, or 355 litres per inhabitant per day (including industry, commerce, etc.); this is equivalent to around 2% of total annual precipitation, or roughly the contents of Lake Biel.[2,3,4]
- In households, per capita consumption is 162 litres per day, of which around 30% is for toilet flushing.[5]
- For the abstraction, treatment and distribution of drinking water, water utilities consumed around 0.4 TWh of electricity per year (1995) or approx. 0.4 kWh/m^3, with pumping accounting for easily the largest proportion.[4]
- This is equivalent to per capita consumption of at least 50 kWh per year, or a required output of around 6 watts per inhabitant (around 3 watts, based on household consumption).



Electricity consumption in the public municipal sector (rough estimates, 1995)[4]

- In the public municipal sector, water supplies account for around a fifth of total electricity consumption (see chart); thus, water utilities alongside wastewater treatment plants and waste management facilities are among the largest municipal electricity consumers.
- Potential for savings lies in increased efficiency, optimal plant management and internal electricity production (see: Opportunities). A certain potential lies in the reduction of consumption (especially peak demand) and in the prevention of – still sometimes substantial – water losses through leakage in the network. If the latter could be reduced by 50% across Switzerland, savings of around 20 GWh per year could be achieved.
- In some other countries, energy requirements for drinking water treatment (e.g. by membrane filtration) are much higher. This is because almost half (47%) of the groundwater used in Switzerland is of sufficiently high quality to be supplied without treatment. 40% of groundwater is treated by simple methods (usually sand filtration), and only 13% undergoes two or more stages of treatment.

Wastewater

- In Switzerland, around 750 centralized and 3,500 small plants treat some 1,450 million cubic metres of wastewater per year – i.e. about 200 m^3 per inhabitant per year (or about half of this figure, based on household requirements).[6,7]
- The total electricity consumption of Switzerland's WWTPs is around 0.5 TWh per year; in addition, fossil fuel consumption amounts to 0.1 TWh.[8]

- Per capita (97% connection rate), this is equivalent to 66 kWh per year, or a required output of 7.5 watts (electric power); the WWTPs' net consumption is lower because many also generate electricity themselves from sludge gas (over 0.1 TWh in total). The untapped potential is considerable; according to experts, current electricity production could be doubled or trebled.[9]
- With an additional treatment step to eliminate micropollutants by ozonation, WWTPs' energy requirements are increased by about 15% (an increase from 7.5 to 9 watts per capita)[10] – unless this consumption can be reduced by technological developments or efficiency-increasing measures.

Water heating

- In the water sector, by far the most energy is used for heating service water – 12.5 TWh per year in Switzerland (of which 2.5 TWh is electricity consumption, excluding devices such as dishwashers, washing machines, etc.).[11] This is equivalent to a per capita output of 180 watts, including 37 watts for electricity. Accordingly, saving and efficiency measures are particularly welcome here, as well as the replacement of electricity and fossil fuels by solar or geothermal heat, or other renewable sources of energy.

Seawater desalination/water recycling

- Energy consumption for seawater desalination: the process generally used today (reverse osmosis) requires around 4 kWh per cubic metre of desalinated water. New methods (electrodialysis) require only 1.5 kWh/m^3; the theoretical minimum is 0.86 kWh/m^3.[12] Compared with seawater desalination, the recycling of wastewater to produce drinking water requires about 60% less energy, since the osmotic pressure of treated wastewater is much lower.

Impacts on water and aquatic ecosystems in the energy sector

Apart from the direct use of hydropower, water resources and waterbodies are also affected by other forms of energy production.

- Gas extraction: In the extraction of shale gas, large quantities of water are injected into the ground under high pressure to open fissures in rock (hydraulic fracturing). The waste water, laden with chemicals, can contaminate surface waters and groundwater. The same applies to coalbed methane extraction; what is particularly problematic here is the salt content of the waste water.[13][14]
- Cooling: River or lake water is widely used in building cooling systems and for generator or nuclear plant cooling. This can lead to unnatural warming of surface waters and to changes in aquatic fauna. The Swiss Water Protection Ordinance (GSchV) specifies that cooling water discharges must not raise the temperature of rivers (after complete mixing) by more than 3°C (or more than 1.5°C in trout waters) and that the water temperature must not exceed 25°C.[15] During hot summers or prolonged low water periods – both scenarios which are likely to become more frequent as a result of climate change – power plants have to be shut down.
- Biofuels: If fuels (ethanol, biodiesel) are obtained from maize or rapeseed, for example, the main issues are the water requirements for crop irrigation (the ratio of water to fuel produced is around 500:1) and any fertilizer or pesticide inputs.[16,17] The additional global freshwater requirement for biofuels by 2030 is estimated at 1000–1900 km^3[18], or around 2000 times Switzerland's annual water consumption.

Grey energy

Embodied in water supply and wastewater treatment infrastructure is the energy consumed in construction and in the acquisition of raw materials. A rough indication is given by the following estimates for 34 OECD countries (total population approx. 1.2 billion):

- Average annual investment in water and wastewater services by 2025: USD 1040 billion; current expenditure on water infrastructure USD 580 billion[19];

In Switzerland:

- The estimated replacement value of Switzerland's water supply and wastewater management infrastructure is CHF 218 billion. The wastewater sector alone comprises a sewer network with a total length of 87,000 kilometres, 750 centralized and over 3,000 small treatment plants.[20] Taking a rough, conservative estimate of 400 MWh grey primary energy per million Swiss francs and a service life of 50 years, the annual figure for grey (primary) energy would be 1.7 TWh or 220 kWh per capita (= 25 watts output). This grey primary energy cannot be directly compared with the electricity consumption for operation of plants. Nonetheless, there is doubtless potential for savings in improved planning and dimensioning of future infrastructure.

Opportunities

Energy recovery

- Wastewater heat: higher-than-ambient-temperature wastewater, groundwater or lake water is also used for heating purposes, via heat pumps. In Switzerland, the potential for energy recovery from wastewater is estimated at 300 megawatts (40 watts primary energy per capita). This would meet the heating energy requirements of 200,000 single-family houses[21] or replace around 3% of the fossil fuels consumed in Switzerland. A small proportion of this potential is already being used today at over 80 plants where heat is recovered from treated wastewater – mainly at the WWTP outlet – and heat pumps are used to produce heating energy. In Schlieren (Canton Zurich), heat recovered from wastewater supplies the Zurich-Mülligen Letter Centre, for example; when it is completed, the Schlieren district heating system will replace 5 million litres of heating oil per year, supplying the equivalent of 9,000 "Minergie" standard homes[22]. Eawag has investigated how the performance of heat exchangers in wastewater can be maintained despite biofilm development ("biofouling").
- Drinking water power plants: In water supply networks, pressure reduction turbines can be used to generate electricity. Around 100 drinking water power plants are currently operating in Switzerland. The Swiss Federal Office of Energy estimates the untapped potential nationwide at 0.06 TWh (which could supply around 20,000 households).
- Methane recovery from Lake Kivu (a special case): With the roughly 60 km^3 of methane stored in Lake Kivu (Rwanda/Democratic Republic of the Congo), it would be possible to generate 300 MW of power for a period of 50 years. Pilot plants are already operating. Eawag is involved in monitoring methane extraction and the stability of lake stratification, as the consequences of an uncontrolled eruption of gases (as well as methane, around 300 km^3 of carbon dioxide are stored in the lake) could be catastrophic.

Improved water management

- Energy required for pumping and treatment steps can be saved if (drinking) water and especially hot water is used economically, and if water losses from the distribution network are prevented. For example, thanks to a project in which scientific support was provided by Eawag, the commune of Gordola (Canton Ticino) was able to save around 120,000 kWh per year in pumping energy and shelve a planned reservoir expansion scheme.[23] In addition, Gordola promoted water conservation by measures such as progressive charges or restricted-use periods and coordinated planning for water-intensive applications (e.g. filling of swimming pools).
- Substantial savings are possible in the area of irrigation, where massive reductions in water consumption can be achieved e.g. with drip irrigation systems, since evaporation losses are lower than with spray irrigation. (Comparison: In the US, this "smart irrigation" method is used on less than 7% of all agricultural land, while in Israel the proportion is already over 60%.[24])
- Water-intensive facilities (horticultural production, wet storage of timber, etc.) can be supplied with river or lake water or locally harvested rainwater, rather than drinking water, if it is of adequate quality for the purposes in question.

Improved energy efficiency

- Thanks to new methods, energy requirements for seawater desalination have been reduced from around 8 kWh/m^3 (1980) to less than 2 kWh/m^3.
- Gravity-driven membrane filtration processes studied at Eawag could represent a low-energy option for preparing drinking water from contaminated raw water (lake or river water) in the home.
- Recent years have seen substantial improvements in the energy efficiency of WWTPs, particularly in energy requirements for aeration – e.g. use of the anammox process in nitrogen removal from digester liquid[25]; nutrient recycling and fertilizer production via air stripping[26]; and reduction of greenhouse gas emissions – especially nitrous oxide (N_2O) – in wastewater treatment.[27] Despite higher demand, WWTPs have reduced their electricity consumption by about a quarter over the last 10 years.
- Solar water heating and solar air conditioning. Thermal insulation of hot-water tanks and pipes.

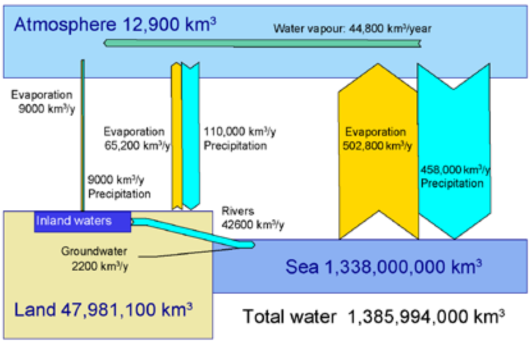
October 2011
Contact: Andri Bryner, Eawag Media Officer, medien@eawag.ch; +41 (0)58 765 5104

"SwissEnergy for infrastructure plants" campaign on the SFOE website:
http://www.bfe.admin.ch/infrastrukturanlagen/

Appendix:

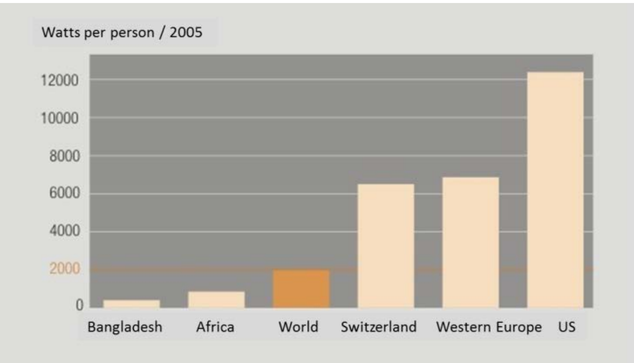
Global water cycle

The evaporation of 577,000 km^3 water per year requires around 422 million TWh of energy. By way of comparison, the total energy consumption of all humankind is approx. 130,000 TWh per year. Apart from evaporation (and transport) in the atmosphere, water is involved in ocean circulation. This gigantic mass and heat exchange is driven by the warming and cooling, evaporation and condensation of near-surface water. The crucial factors here are its temperature- and salinity-dependent density. How much energy could be obtained from marine currents, waves and tides worldwide (without causing significant systemic disturbances) has yet to be estimated. Prototype plants are in operation, but they are not yet commercially viable. [28]

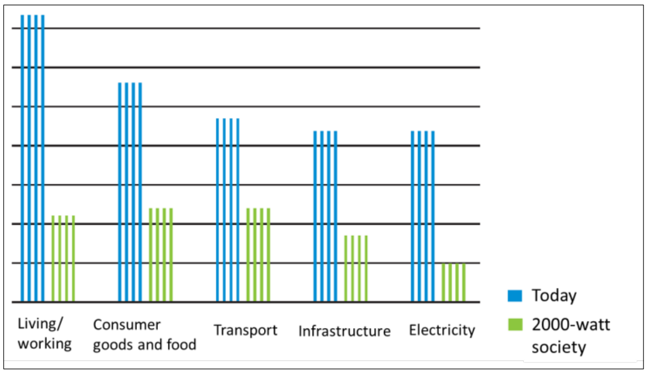


For comparison: 2000-watt society energy statistics

(primary energy, excluding imports via products and services)



www.novatlantis.ch/ >> 2000-Watt Society



Approximate breakdown of requirements in CH / Environmental and Health Protection (UGZ), City of Zurich; 2007;

References

1 Gesamtenergiestatistik 2010, BFE: http://www.bfe.admin.ch/themen/00526/00541/00542/00631/index.html?lang=de&dossier_id=00763
2Statistische Erhebungen der Wasserversorgungen in der Schweiz, Ausgabe 2010, SVGW
3 Wasserversorgung 2025 – Vorprojekt, Eawag (Ed.) 2009
4Energie in der Wasserversorgung; Ratgeber zur Energiekosten und Betriebsoptimierung. Bundesamt für Energie und SVGW, 2004
5 Wasserverbrauch im Haushalt, SVGW, Bafu Infoblatt 2001
6Zustand, Kosten und Investitionsbedarf der schweizerischen Abwasserentsorgung. Maurer M. Herlyn A., Eawag, Bafu (2006)
7 FOEN: http://www.bafu.admin.ch/gewaesserschutz/01295/index.html?lang=en
8 Energie in ARA, Leitfaden zur Energieoptimierung auf Abwasserreinigungsanlagen, VSA, 2008
9Erneuerbare Energien in der Schweiz – Potential (ARA, KVA, WV) und politische Weichenstellungen, Kernen M., Müller E.A.; gwa 3/2006
10Ozonung von gereinigtem Abwasser, Schlussbericht Pilotversuch Regensdorf, Eawag/Bafu 2009
11 BFE 2010: Analyse des schweizerischen Energieverbrauchs 2000-2009, nach Verwendungszwecken
12http://www.desware.net/desa4.aspx
13http://www.elementsmagazine.org/toc/toc_v7n3.pdf (article by Gregory et al.)
14http://waterquality.montana.edu/docs/methane/cbmfaq.shtml
15 Annex 3.3, GSchV, SR 814.201
16 Energy Demands on Water Resources; Report to Congress; US Department of Energy; December 2006
17 http://www.nap.edu/catalog.php?record_id=12039
18 CAOBISCO Brussels 2007
19 Infrastructure to 2030, OECD 2006
20 Zustand, Kosten und Investitionsbedarf der schweizerischen Abwasserentsorgung. Maurer M. Herlyn A., Eawag, Bafu (2006).
21 Eawag 2009: Wärmerückgewinnung aus Abwasser (Wanner et.al.)
22Heizen und Kühlen mit Abwasser, Ratgeber für die Planung, Bewilligung und Realisierung von Anlagen zur Abwasserenergienutzung, Awel/ZH 2010
23http://www.eawag.ch/medien/bulletin/20100107/index_EN
24http://ga.water.usgs.gov/edu/irdrip.html and http://www.businessweek.com/technology/content/dec2005/tc20051230_495029.htm
25 http://www.eawag.ch/forschung/eng/schwerpunkte/abwasser/nitrations_anammoxprozess/index_EN
26 http://www.eawag.ch/forschung/eng/schwerpunkte/abwasser/luftstrippung/index_EN
27 http://www.eawag.ch/forschung/eng/schwerpunkte/abwasser/dynamik_lachgasemissionen/index_EN
28 Data: UNEP, 2008; Vital Water Graphics (flow rates) and Unesco (2009); World Water Assessment Programme (volumes)