Life cycle assessment (LCA) of Swiss banknotes

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Under article 1 of the National Bank Law of 1905, the Swiss National Bank (SNB) has the exclusive right to issue banknotes. On 20 June 1907, the day it took up business, the SNB issued its first banknotes, which were largely patterned after the notes of the former issuing banks. During a transition period of three years, these so-called interim notes continued to be in circulation in addition to the older banknotes.

From 20 June 1910 onwards, only the banknotes issued by the SNB were legal tender. A year later, in September 1922, it issued its first banknotes developed independently. Since that time, the SNB has put a new banknote series into circulation every twenty years on average. The notes of the latest series, which was designed by the graphic artist Jörg Zintzmeyer, were put into circulation in progressive steps between 1995 and 1998.

This project aims to analyse the life cycle of the Swiss banknotes, from their development and production, to their destruction and disposal. In the 1st chapter, we shall begin with some facts and figures on banknote circulation in Switzerland and its significance. Chapter 2 describes the development of a banknote series using the example of the latest series. Chapters 3 to 5 provide an outline of the production (chapter 3), the issue and redemption (chapter 4) and the processing, destruction and disposal of banknotes (chapter 5). Chapter 6 contains information on the economic costs that arise during the life cycle of banknotes. In the 7th and final chapter, the cost factor is defined in broader terms so as to include the ecological costs as well. In its ecological charter, the SNB set itself the goal to design, distribute and dispose of banknotes in a way that is as environmentally compatible as possible. Consequently, in 1999, a comprehensive product environmental performance evaluation of Swiss banknotes was compiled. We shall describe the process and provide a summary of results.
1 Banknote circulation in figures

At the end of June 2000, Swiss banknotes to the value of Sfr 31.8 billion were in circulation. The large denominations accounted for a relatively big proportion of the banknotes in circulation, i.e. 53% were 1000-franc notes and 15% were both 500-franc and 200-franc notes. The 100-franc notes added up to 22% of the total, whereas the 50-franc, 20-franc and 10-franc notes amounted to 5%, 3% and 2% respectively. The high proportion of large denominations indicates that banknotes are not only used as a means of payment but to a considerable degree also as a store of value.

The amount of banknote circulation can also be expressed in the number of notes rather than in francs. At the end of June 2000, approximately 250 million banknotes were in circulation. Overall, this breakdown shows a much more even distribution of the different denominations than the one by amount. The proportions vary between 7% for the 1000-franc note and 27% for the 100-franc note.

Banknote circulation has risen drastically in terms of value since the SNB started business in 1907. A part of this increase is due to inflation. Illustration 2 shows the development of the nominal banknote circulation and of the banknote circulation in real terms, deflated with consumer prices (at the price level of 1907).1 After that, from the end of 1907 to the end of 1999, nominal banknote circulation increased by 23,257% or by 6.1% p.a. The growth rates for banknote circulation in real terms are decidedly smaller, but still considerable at 2,148% or 3.4%, respectively.

The increase in banknote circulation is, in part, also a reflection of economic growth. Illustration 3 depicts the course of banknote circulation scaled to the nominal gross domestic product (GDP). This shows that the ratio between banknote circulation and nominal GDP has fallen steadily since the end of the Second World War. In other words, banknote circulation has risen at a slower rate than nominal GDP. This development reflects the progress in the payment technology which has contributed to cashless payment transactions becoming more widespread and allowed companies and households to keep less cash on hand. In contrast to the post-war period, banknote circulation scaled to nominal GDP had still risen during the first four decades of the century, however. Initially, the reason for this development was the increasing replacement of metal coins and drafts by banknotes in the early years of the SNB. Later on, it was especially general uncertainty during the First World War as well as deflation at the beginning of the twenties and again during the Great Depression in the thirties that contributed to the stockpiling of banknotes.

Even though banknotes have tended to become less significant during the last decades, they remain an important means of payment. This is particularly true also in the case of Switzerland which, by international standards, has a relatively high amount of banknotes in circulation. Table 1 shows currency in circulation scaled to nominal GDP of the seven largest industrial countries and Switzerland as of the end of 1998. In order to facilitate an international comparison, currency in circulation was given preference over banknotes in circulation. It comprises notes and coins which are not held by banks and Swiss Post. The results reveal that the ratio between currency in circulation and nominal GDP ranges from 2.9% (for U.K.) to 11.0% (for Japan). At 9.3%, Switzerland ranks second behind Japan, thus exhibiting an amount of currency in circulation that is above average.

Such international comparisons should be interpreted with a grain of salt, however. Banknotes of different countries are likely to circulate or be stockpiled in varying proportions in foreign countries. It is known, for example, that U.S. dollar notes are used as a parallel means of payment or store of value in large quantities outside the United States. The currency quotas calculated, therefore, are likely to be distorted in part. Unfortunately, there is no precise information on what proportion of banknotes in circulation of a given currency is held outside the borders of the respective country.

1 The banknotes of the former banks of issue mentioned previously, which circulated parallel to the SNB banknotes until 1910 and the "Bundeskassenscheine" (certificates which were redeemable in gold) issued by the Confederation and in circulation between 1914 and 1929 are included in these figures.

2 Data was taken from the IMF International Financial Statistics. The difference in quantity between banknotes in circulation and currency in circulation is negligible so that the results are not influenced significantly by choosing currency in circulation.

SNB 2 Life cycle assessment (LCA) of Swiss banknotes
Banknote circulation 1907–1999

Illustration 2

The ratio between banknote circulation and GDP

Illustration 3

Currency in circulation by international standards
(currency in circulation in % of the nominal GDP, 1998)

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>5.4</td>
</tr>
<tr>
<td>Japan</td>
<td>11.0</td>
</tr>
<tr>
<td>Germany</td>
<td>7.2</td>
</tr>
<tr>
<td>France</td>
<td>3.4</td>
</tr>
<tr>
<td>Italy</td>
<td>6.1</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2.9</td>
</tr>
<tr>
<td>Canada</td>
<td>3.6</td>
</tr>
<tr>
<td>Switzerland</td>
<td>9.3</td>
</tr>
</tbody>
</table>
2 Development of a banknote series

The SNB has produced eight banknote series since its establishment. Table 2 indicates the denominations and the names of the notes’ designers for each series. In addition, the date of the first issue and the date of recall are given.3

Only a part of the eight banknote series was put into circulation. The second and third series also included reserve banknotes which were never put into circulation. The fourth and the seventh series were reserve series only, created in the event a series would have to be replaced immediately for pressing reasons (e.g. a disproportionate number of counterfeits). The reserve series designed by R. and E. Pfund in the 1980s is likely to have been the last one. In future, we will forgo the considerable time and effort spent on such a venture. Instead, banknotes in circulation will continuously be developed further and brought in line with the latest technological standards.4

When designing a new banknote series, there are three different requirements to be considered. First, the banknote must meet the security requirements. With the help of security features, the public should be able to recognise genuine banknotes easily and to identify counterfeits. These security features must be difficult to forge. The rapid development of reproduction technology forces the SNB to ever-new adjustments of security features. Second, the banknote must be user-friendly. Users want banknotes that are easy to handle and to distinguish. They should also be tough and available in practical denominations. Third, banknotes should be aesthetically pleasing. The designer of a banknote, therefore, must try to reconcile the artistic design with the technicalities of user and security requirements. The SNB defines the design elements in the “Technical Directives”. These elements pertain to the colours, the personalities to be featured, the motifs as well as the placement of the security features, the denomination and the SNB lettering in the four official languages.

The development of the latest banknote series began in the eighties when several basic decisions were taken. The first choice was to issue a 200-franc note instead of the 500-franc note. In doing so, the SNB reacted to the sharply declining proportion of the 500-franc note in circulation. In addition, several changes were made to the format of the banknotes. First of all, uniform breadth of 74 mm was set for all banknotes, thus making their handling by machines considerably easier. In addition, the difference in length between two denominations was set at 11 mm. With a length of 126 mm, the 10-franc note is the smallest of the series, whereas the 1000-franc note, measuring 181 mm, is the largest. This should also enable visually impaired users to distinguish the banknotes easily. In addition, to make the 20-franc and the 100-franc note clearly distinguishable from one another, we decided in favour of a red colour for the former (both notes were blue before).

The selection of security features was given particular attention. The decisive factor was that only an optimum combination of features meeting criteria pertaining to availability, effectiveness and cost would provide adequate protection against counterfeiting. The features which had already been used in previous series were supplemented with new ones for the new notes. The magic number, the coloured number, the moving number, the perforated number, the chameleon number and the glittering number should help verify the authenticity of the banknotes.

The personalities to be represented were selected based on the suggestions by external specialists. Six Swiss artists were chosen whose work is internationally renowned.

Fourteen artists were invited to participate in a competition for the artistic design of the banknotes and given the established parameters. A ten-member jury selected three of the designs submitted. The winners were subsequently asked to work out a design concept for one denomination all the way to the printing stage. Based on the results, the SNB Bank Committee, in whom the respective responsibility is vested, appointed Jörg Zintzmeyer to design the new banknotes in 1991.

The banknotes of the current series have been produced by consistently applying computer technology. They are thus a novelty both on a technological level and from a design point of view. The first banknote of the series, the 50-franc note (Sophie Taeuber-Arp), was put into circulation in October 1995. Approximately one year later, the 20-franc note (Arthur Honegger) was issued. At intervals of six months each, this was followed by the 10-franc note (Charles-Edouard Jeanneret, Le Corbusier), the 200-franc note (Charles Ferdinand Ramuz), the 1000-franc note (Jakob Burckhardt) and the 100-franc note (Alberto Giacometti).

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3 When a banknote is recalled, a deadline is given which determines up to what date banknotes may still be accepted by banks, Swiss Post or by the SNB.
### The banknote series of the SNB

<table>
<thead>
<tr>
<th>Series</th>
<th>Denomination</th>
<th>Concept</th>
<th>1st issue</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1000, 500, 100, 50</td>
<td>Interim notes</td>
<td>20.06.1907</td>
<td>01.07.1925</td>
</tr>
<tr>
<td>2.</td>
<td>1000, 500, 100, 50, 20, 5, 40, 10</td>
<td>F. Hodler, E. Burnand, Balzer Reserve notes</td>
<td>16.09.1911 – 03.08.1914</td>
<td>31.12.1935 – 01.05.1980</td>
</tr>
<tr>
<td>4.</td>
<td>1000, 500, 100, 50</td>
<td>Balzer, Orell Füssli</td>
<td>20.06.1907 – 01.07.1925</td>
<td>01.04.1956</td>
</tr>
<tr>
<td>5.</td>
<td>1000, 500, 100, 50, 20, 10</td>
<td>H. Erni, V. Surbek Reserve series</td>
<td>29.03.1956 – 14.06.1957</td>
<td>01.05.1980</td>
</tr>
<tr>
<td>6.</td>
<td>1000, 500, 100, 50, 20, 10</td>
<td>P. Gauchaz, H. Eidenbenz</td>
<td>04.10.1976 – 05.11.1979</td>
<td>01.05.2000</td>
</tr>
<tr>
<td>7.</td>
<td>1000, 500, 100, 50, 20, 10</td>
<td>E. and U. Hiestand Reserve series</td>
<td>04.10.1976 – 05.11.1979</td>
<td>01.05.2000</td>
</tr>
<tr>
<td>8.</td>
<td>1000, 200, 100, 50, 20, 10</td>
<td>J. Zintzmeyer</td>
<td>03.10.1995 – 01.10.1998</td>
<td></td>
</tr>
</tbody>
</table>

The current banknote series (designed by J. Zintzmeyer) ![Illustration 4](image)

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1 After recall, banknotes can still be exchanged at the SNB at their nominal value for another 20 years.
3 The production of banknotes

The current Swiss banknotes are printed on special paper supplied by the firm landQart®. This paper is made of linters and combings (short cotton fibres) which are by-products of the processing of cotton. Cotton products are used because their special fibre structure gives banknotes their resistance and durability. The cotton fibres are divided into small sections, shortened and crushed before they are mixed with filling material, glue and colouring matter. The paper machine forms the watermark, integrates the silver thread and drains the paper. After the drying process, printability and surface sizing is enhanced by applying a coat of starch. Afterwards, the paper is smoothed and rolled up. In the finishing area, the paper rolls are cut to size and piled up sheet by sheet on pallets ready for delivery to the printer.

In addition to special paper, the production of banknotes also requires special security colour which must meet the strictest requirements: it must be resistant to 18 different chemicals as well as to light, and it must even be machine-washable at high temperatures without being damaged! The supplier for security colours for the printing of Swiss banknotes and many foreign ones is Sicpa SA in Prilly-Lausanne.

The latest banknotes series, as the previous ones, is printed by Orell Füssli Security Printing Ltd. The company uses printing machines manufactured by a company in western Switzerland, De La Rue Giori S.A. in Lausanne. The current banknotes are manufactured in a process comprising a total of four different printing procedures, two application procedures and a perforation procedure.

The printing process begins with the processing of the electronic data delivered by the artist. The original printing plates are generated via CAD (Computer Aided Design). With a Supersimultan offset printer, the sheets of paper are then printed on both sides with different multicoloured lines. The printing is so precise that, because the lines match up, there is a transparent register. The application machine applies the moving number (Kinegram®) and the glittering number (metal-coated number). The chameleon number (optically variable ink) and the magic number (iriodin® digits) are two additional security features that are subsequently applied onto the sheets by means of silkscreen printing. Intaglio or siderographic printing creates a relief which is recognisable by touch and presents itself to the eye in a different way depending on the angle. Unlike many foreign banknotes, Swiss banknotes are printed by intaglio printing both on the front and on the back. What’s more, by applying a perforation procedure, banknotes are then equipped with the perforated number (a feature known as microperf®). They are the first notes in the world to have this feature.

In the next production step, by means of a numbering machine and in letterpress printing, the banknotes are turned into individual pieces and coated with a varnish. A cutting machine divides the finished sheets into single banknotes. A computer-guided device then checks the printing quality of the banknotes and eliminates faulty ones. In a final step, bundles of a hundred notes are packed, loaded into crates and prepared for transport to the Cash Division of the SNB in Berne.

A quality control takes places in the Cash Division in Berne by means of a spot check of 5% of the banknotes that come off the press. Specially trained personnel verifies the general appearance of the banknotes and two security features that change daily. In addition, the machine-readable authenticity features are checked with a banknote-testing device. Faulty banknotes are rejected and destroyed. Once the banknotes have successfully passed the quality control, they are stored in the SNB vaults. The remaining 95% of the banknotes delivered fresh from the press are weighed for control purposes and also stored.

Illustration 5
4 Issuance and redemption of banknotes via the SNB’s network of cash distribution services

Issuance and redemption of banknotes is carried out via the SNB’s network of cash distribution services. This network comprises the SNB’s four own bank offices with cash distribution services (head offices in Berne and Zurich, branches in Geneva and Lugano), 18 agencies and almost 700 domestic correspondents.

The SNB’s four own bank offices are the largest units of Switzerland’s network for the provision of currency. These offices have processing and storage capacities and are responsible for the provision of currency in their respective regions. They are also in charge of servicing the agencies they are responsible for.

The agencies are cash distribution services operated by cantonal banks on behalf of the SNB. These agencies are responsible for the issuance and redemption of cash at their place of business and – unlike the four SNB bank offices – only have limited processing and storage facilities for cash.

The so-called domestic correspondents are banks entrusted with a mandate by the SNB and operate mostly in rural areas. They cover most of their cash needs directly at the local post offices. Since cash typically accumulates at the post offices during the course of the month, as postal customers make payments, this is compensated for on a local level, thereby helping post offices to unload their surplus cash and supplying banks with cash.

The SNB organises the transport of cash between its bank offices and the agencies. All other transports are the responsibility of its customers. They are often handled by specialised private security transport companies.

Customers cannot simultaneously offer and demand notes of the same denomination. For example, they cannot return 100-franc notes and get new ones at the same time. The SNB thus forces the customer to pre-sort the banknotes. Banknotes received by the customer should again be spent in the same denomination and only the excess delivered to the SNB. This rule keeps customers from passing on to the SNB the sorting necessary for their own purposes. Some customers have outsourced this pre-sorting to cash handling companies.

The SNB issues and receives a large volume of banknotes each year. In 1999, approx. 490 million notes were issued and 470 million received. With an average banknote circulation of 250 million, a banknote is therefore returned to the SNB 1.9 times on average. As a result of the replacement of the sixth series with the eighth banknote series, this figure is slightly above the long-term average of approximately one-and-a-half times a year. In other words, in a two-year period, the banknotes are returned to the SNB roughly three times. Illustration 6 shows that the annual return is different for each denomination. Overall, the big denominations return to the SNB more frequently than the small ones.

<table>
<thead>
<tr>
<th>Banknote return to the SNB</th>
<th>Illustration 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of returns per year</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>20</td>
<td>50</td>
<td>100</td>
<td>200</td>
<td>500</td>
<td>1000</td>
</tr>
</tbody>
</table>

The diagram shows the annual return for each denomination. It is clear that the big denominations return more frequently to the SNB.
5 Processing and destruction of banknotes

Banknotes that are routed to an SNB bank office directly or via the network of cash distribution services are sorted and checked for authenticity in special sorting machines. Authentic banknotes in good condition are put into circulation again. Genuine banknotes that are damaged and dirty are destroyed immediately. Notes that the sorting machine does not clearly recognise as authentic are rejected and must be checked manually. Counterfeit banknotes are handed over to the police.

Notes that are fragmented, burnt, worn, or – due to improper opening of a security case – have been mixed with colour or are otherwise severely damaged are sent to the cash division in Berne for a verification of their authenticity. Genuine banknotes of which more than half is intact and whose series and number are recognisable are redeemed at their nominal value. If exactly half of a banknote is given to the SNB, the customer will be credited with half of the note’s nominal value.

In principle, the SNB uses two methods to destroy banknotes: destruction via the sorting machine or manual destruction. The sorting machines used for the processing of banknotes have an integrated shredder which – in one and the same process – destroys banknotes that have been recognised as authentic but are no longer useable. Notes that cannot be processed by the sorting machine because they are part of an old series or are in very bad condition and are thus rejected must be destroyed in a shredder under tight security conditions. What remains after using both methods of destruction are banknote scraps, which are pressed and subsequently brought to a public waste incineration plant.

The life span of a banknote varies depending on the denomination (see Illustration 9). Large denominations tend to have a longer life expectancy than small ones. The 1000-franc, 200-franc and 100-franc notes are in circulation for four years on average, whereas the 50-franc, 20-franc and 10-franc notes must be destroyed already after two to three years. In 1999, destroyed notes accounted for just under 20% of the notes processed. It was thus every fifth note processed that had to be taken out of circulation. The SNB has approximately 100 million notes printed per year to replace the ones that were destroyed.
6 The costs of the cash distribution system

The good quality of the Swiss banknotes has its price. The costs of producing a banknote (conception and design, paper, printing, information) average approximately 30 centimes per new note. Assuming that the average life span of a banknote is three years, the yearly production cost comes to 10 centimes per note in circulation.

The yearly processing costs the SNB incurs amount to about 20 centimes per note in circulation. If you add up the yearly production and processing cost per banknote, the yearly overall cost amounts to roughly 30 centimes per note in circulation.

The cost of the cash distribution system is a prominent item in the SNB’s income statement. Overall, roughly half of the SNB’s total costs of approximately Sfr 190 million are accounted for by expenses relating to the cash distribution system.

7 A product environmental performance evaluation for banknotes

7.1 Objective and method

Within the framework of its environmental charter, the SNB has set itself the goal of organising the cash distribution system as environmentally compatible as possible. To serve as a basis, a product environmental performance evaluation of Swiss banknotes was compiled in 1999. A product environmental performance evaluation (or life cycle assessment = LCA) is concerned with the environmental impact of a product, encompassing its entire life cycle from raw material extraction, all major processing, transport and treatment stages up to waste disposal. For all the processes under review, raw materials used and emissions in air, water and soil are analysed and evaluated. In our case, the life cycle assessment should enable us to assess whether the banknotes are problematic from an ecological (and/or health) perspective, whether certain processes during their life cycle pose particular risks to the environment and to identify potential areas for improvement.

The SNB followed an internationally recognised procedure, i.e. ISO norm 14040 for the compilation of the life cycle assessment. Evaluating and weighting the input and output factors that are ecologically relevant was accomplished on the basis of a point system widely used in Switzerland (UBP 97). This system classifies the impact factors that are detrimental to the environment. In addition, certain environmental effects were analysed specifically, i.e. the impact of the life cycle of banknotes on the greenhouse effect, acid rain and summer smog.

7.2 System and process parameters

In principle, all processes affecting the environment, i.e. input and output factors, should be considered in the life cycle assessment of a product. In a first step, it must be determined which areas are to be included in the life cycle assessment. Subsequently, system boundaries must be defined. The impact of certain processes is not so significant as to merit their compilation.

5 ISO = International Standardisation Organisation
6 The basis for this system is public perception of environmental impact which was defined in the objectives of Swiss environmental policy and in the 1997 legal system. In this connection, also refer to BUWAL 1997 (Swiss Agency for the Environment, Forests and Landscape), publication on the environment no. 297. An alternative concept to the UBP 97 point system is the eco-indicator 95 used in many European countries that was also considered for comparison purposes.
The life cycle assessment for the Swiss banknotes is based on the data of the eighth banknote series of 1998, extrapolated based on a median yearly requirement of the sixth series. Illustration 10 shows the six main processes which were included in the analysis: Cotton production, fibre production, paper production, note printing, banknote distribution (internal transport, storage, processing) and waste disposal. What was not included were security transports on behalf of the commercial banks and other agencies (i.e. the distribution of banknotes from the SNB bank office or agencies) as well as the public’s use of banknotes.

In accordance with the breakdown shown in illustration 10, the ecological relevance of material and energy flows was measured roughly on the basis of an estimated annual production of about 100 tonnes or 100 million banknotes, respectively. Materials used in quantities in excess of 2 tonnes were included in the life cycle assessment. However, materials with smaller yearly quantities were only considered if there was evidence of toxic material or ecological relevance. This especially refers to colours and varnishes as well as auxiliary materials used in the production of paper.

7.3 Data

The input and output data of the individual processes was compiled on the basis of the 93.4 tonnes of banknotes of the sixth series the SNB received from Orell Füssli on average per year. In the case of processing processes within the SNB, this figure was multiplied with the median annual circulation frequency and the average life span of the banknotes. As a rule, standard published data were generally used to calculate electricity consumption, heating, transport, infrastructure, materials and auxiliary materials as well as waste management processes.

Data on cotton production – in part only approximate figures – was taken from the literature. For example, only the total energy use per kilogram of harvested cotton is known. Since relatively inferior cotton parts are used for the production of paper, the damage to the environment of cotton production was measured relative to the economic value of the fibres. Transport of cotton into Switzerland was not taken into consideration since the country of origin cannot be determined. Furthermore data whose quality is rated as medium to good is also available from companies producing linters and combings (short cotton fibres).

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7 During circulation, banknotes absorb very small quantities of many different toxic substances which cannot be estimated with reasonable effort.

8 After the new banknote series was issued, only a little under 78 tonnes had to be procured in 1998. The production process, therefore, had to be converted or indexed by a factor of 1.2.

9 Linking the data in the material balance sheet (input and output data) as well as the calculation was carried out with the EMIS software (version 2.2) which already contains standard data by ESU-ETH (Federal Institute of Technology), Infras and other sources that are used frequently.

10 Laursen/Hansen/Baghl/Jensen/Werther (1997) on worldwide cotton cultivation: Spaar (ETH Zurich, without date) on cotton cultivation in the U.S.
There is new data of good quality on the banknote paper production process as a whole. 40% of landQuart’s power supply is generated from its own river power plant. Since it can run independently from the paper company, the entire electricity used was reported as mains power supply.\footnote{This is a sensible assumption. In Switzerland, power from a mains supply generated from predominantly nuclear and water power plants is in addition to some proportion coming from imported electricity. If landQuart’s own production were included as “electricity from water power plant”, pollution resulting from paper production in the environmental performance evaluation in illustration 11 would be reduced by one quarter.}

There is also reliable data on the individual processing steps of printing banknotes. General processes, such as lighting, administration, and labour are not included. 1–5% of the substances in colours and varnishes belong to the toxic class 3 or 4 (approx. 400 kg per year). 50% of the substances in screen printing colour belong to toxic class 4 or 5. After they are dry, colours and varnishes are no longer toxic. No data is available on the metal foil (kinegram). Since the synthetic carrier foil makes up most of the weight of the banknote, standard data for polyethylene was used as a substitute.

Data for the various processing steps within the SNB were taken from the annual SNB environmental performance evaluation. While adding the use of resources to the cost of banknotes worked well in the case of smaller bank offices, the corresponding figures for the two head offices had to be projected based on the empirical values from the branch offices.

With regard to waste management, shredded banknotes destined for the waste incineration plant were reported as fresh fibre paper, since no detailed information on the substances in the dried colour was available. This assumption appears unproblematic since – according to the information available – printing colours and varnishes do not contain any critical substances. In connection with the incineration of paper, the energy generated in the waste incineration plant as well as the useful heat was added to the banknote’s credit column.

7.4 Results

The results of the life cycle assessment for banknotes are first discussed in view of the overall damage to the environment, which is measured on the basis of UBP 97 (a point system to measure environmental impact predominantly used in Switzerland). Afterwards, the impact of banknote circulation on the greenhouse effect, acid rain and summer smog is examined.

Environmental pollution

Illustration 11 shows the environmental pollution caused by the different processing steps. Storing and processing banknotes at the SNB are the most significant factors, accounting for approx. 1,300 million points (UBP 97), i.e. just under half of the overall environmental pollution. Printing and paper production contribute to pollution to a considerably lesser degree. Together, these processes make up roughly a third of the UBP 97 points. The high valuation of storage and processing is, among other factors, due to the fact that the banknote sorting machines, air-conditioning and lighting of the rooms are in operation throughout the entire year at the SNB. One must bear in mind that each banknote is processed five to six times on average during its life span. The annual requirement for new banknotes, by contrast, is printed within a few months, while paper production takes even less time, only a little over three weeks per year.

At just under 10%, environmental pollution connected with the raw material cotton is not negligible, while unreliable data must duly be taken into consideration. What is negligible, however, is the pollution caused by the disposal of banknotes.

In general, it is evident that in most processing systems, particularly the storing and processing of banknotes, the use of electricity (or more accurately the provision thereof) is the least eco-efficient. Besides these factors, however, transport, heating, pollutive waste (from the printing of banknotes) and emissions (fertilisers and pesticides from the cultivation of cotton) have a significant impact on the environment as well.

If the infrastructure (machines, vaults, vehicles, etc.) is included in the calculation, environmental pollution increases by 13% overall,\footnote{For purposes of the sensitivity analysis “with infrastructure”, the estimated life expectancy (vaults 100 years, machines 10–60 years, vehicles 5–10 years) was added to the corresponding processes across the board.} with the additional burden being attributable to the SNB. Environmental pollution is even greater if – instead of the mix of electricity sources in Switzerland – the European one is used which has a greater proportion of coal and oil power plants.
Certain shifts in emphasis occur if, instead of the UBP 97, the eco-indicator ‘95\(^{13}\) is applied. The latter is widely used in the countries of the European Union. Consequently, by using the eco-indicator 95, a little less than a third of the environmental pollution caused by banknotes is attributable to cotton. This is because the pesticides used for this crop are weighted more than with the UBP 97 method. The ratios for the other processes remain roughly the same.

**Greenhouse effect**

The greenhouse effect is the warming of the atmosphere caused by the emission of excess carbon dioxide, methane and other gases. Illustration 12 shows the greenhouse gases generated by the different processes in tonnes of CO\(_2\) equivalents. With an average requirement of 93.4 tonnes of banknotes, the emission volume is approximately 1.6 million tonnes of CO\(_2\) equivalents. This corresponds to the greenhouse effect resulting from the combustion of approximately 650,000 litres of extra light heating or diesel oil, or the annual heating oil consumption of about 200 single family homes.

As is the case in the assessment of overall damage, the storing and processing of banknotes at the SNB matters most because its energy consumption is relatively high. The other three processes together account for less then half of the CO\(_2\) emission.

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13 Eco-indicator ‘95: Environmental impact on air and water is weighted using eco-indicator points (1995 level), based on damage to health and to European eco systems. Source: eco-indicator ‘95, NL-Amersfoort 1995.
Acid rain

The release of acid ("acid rain") attacks plants and changes the pH balance of the soil resulting in the mobilisation of heavy metals. Illustration 13 shows the acid rain measured in kilograms of sulphur dioxide equivalents. The total emission volume is just under 10 tonnes of SO₂ equivalents. This approximately corresponds to the effect of burning 3 million litres of fuel oil or 400,000 litres of diesel oil in a truck. If emissions are allocated to the individual processes a result similar to the greenhouse effect emerges.

<table>
<thead>
<tr>
<th>kg SO₂ equivalents</th>
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<tbody>
<tr>
<td>6000</td>
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<td>4000</td>
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<td>3000</td>
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<tr>
<td>2000</td>
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<td>1000</td>
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</tbody>
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Summer smog

The picture is strikingly different in the case of summer smog (ground-level ozone), measured in kilograms of ethylene equivalents, which is created when hydrocarbons (e.g. solvents) and nitrogen oxides react chemically in the presence of sunlight. The total emission amounts to one tonne of ethylene equivalents, which corresponds to the creation of smog from burning approximately 15 million litres of heating oil or the consumption of 500,000 litres of diesel oil in a truck. Screen-printing and varnishing of banknotes account for a particularly significant proportion of this effect.

<table>
<thead>
<tr>
<th>kg ethylene equivalents</th>
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<tr>
<td>600</td>
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<tr>
<td>500</td>
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<td>400</td>
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<td>200</td>
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<td>100</td>
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7.5 Conclusions

Environmental pollution in connection with the Swiss banknotes accounts for a significant part of the SNB’s environmental performance evaluation, with banknote processing alone responsible for one third. Compared with other products, however, Swiss banknotes are not particularly critical for the environment, even with regard to their composition. The biggest environmental pollution is caused by power consumption; it would make sense to take effective measures in this area. Contrary to what one might expect, waste management is not a very significant factor, however. Whether banknotes are disposed of in a waste incineration plant, recycled or composted is not significant ecologically.

By increasing the life span of banknotes environmental pollution could be reduced. A 10% increase of the average life span would reduce environmental pollution by roughly 5%. Any such measures would, however, have a negative impact on the quality of banknotes in circulation. It would also be conceivable to replace cotton, which is not unproblematic, with other carrier materials such has hemp or synthetic materials. Very little is known, however, as to the ecology, printability and security of these materials.

The ecological life cycle assessment of the banknotes is a valuable decision-making tool for two reasons. On the one hand – on the basis of the production and processing processes for the eighth series – the most practical starting points for making ecological improvements can be identified. On the other hand, the study is also a useful tool in view of any new concept for the next generation of banknotes.