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# Infrastructure made of wood – opportunities for decarbonization of the public sector

*Stefan Zöllig*[1]

## Abstract

The infrastructural construction sector is one of the largest $CO_2$ emitters in Switzerland. The main cause is the use of reinforced concrete. By replacing reinforced concrete with wood, infrastructure construction could significantly reduce its emissions and thus substantially contribute to decarbonization. A corresponding political proposal "Research and innovation of wood as a material for use in infrastructure construction as a decarbonization contribution" was adopted in the Swiss federal parliament in November 2021 and will be implemented in the next few years. For this purpose, Bern University of Applied Sciences (BFH AHB) has developed a strategy together with Timbatec Holzbauingenieure Schweiz AG and TS3 AG. Also, a research project for box-girder heavy duty bridges has been started recently.

## Climate change

We are living in a time of major climate changes. We all know: It's the carbon emission which destroys the world we live in. Because of fossile fuel burning: Gas, oil, coal. Even if we reduce our carbon emissions to a net zero by 2050, temperatures will climb at least 2°C above pre-industrial times, cp. Figures 1 and 2. But this means a complete stop to the burning of fossil fuels.

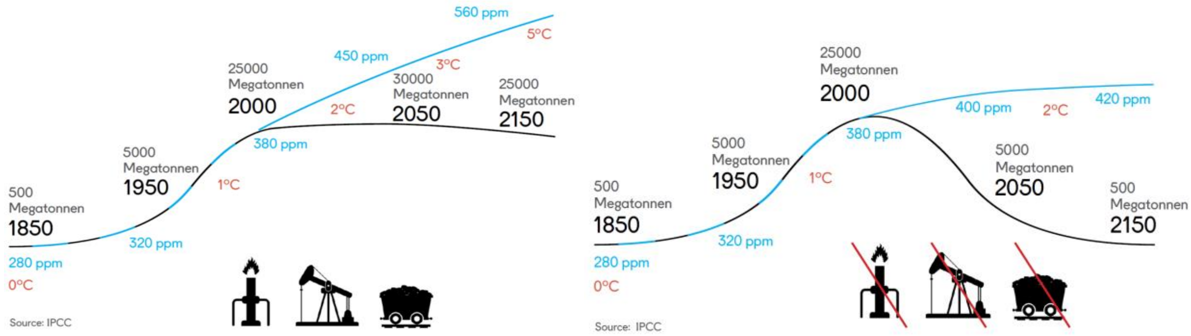


*Figure 1 and 2: $CO_2$ and temperature development over time. Pictures: Timbatec*

People think that air traffic is the main problem. It isn't. Global air traffic only accounts for around 3% of $CO_2$ emissions. Of course, we should not fly excessively. But avoiding flights hardly gains anything measurable. Buildings, on the other hand, contribute around 40% of global $CO_2$ emissions. 20% of the $CO_2$ emissions are caused by the construction of buildings, 20% during operation. Did you know that one of the worst drivers of the climate change is the cement production? 9% of the worldwide carbon emissions is caused by the cement production, the basis of all concrete buildings and infrastructure.

All of us probably have concrete in our portfolios. Industrial investments, real estate, infrastructure. Why? Because concrete is good. It's a fascinating material! It's strong, flexible, cheap, available worldwide. But it has a system error, which cannot be solved. Concrete is destroying our habitat! If cement was a country, it would be the third biggest emitor of carbon: China, USA, Cement. And cement is only one ingredient in reinforced concrete. Other ingredients are: Steel, gravel, sand, aggregates, but also the creation of the formwork, transport, assembly, disassembly and replacement after a few cycles. As mentioned, $CO_2$ emissions during construction add up to about 20% of global $CO_2$ emissions. IPCC Intergovernmental Panel on Climate Change recommends a maximum of only 2% to stay below the 2°C target, see Figures 3 and 4.

The only way to avert this threat is to completely avoid $CO_2$-emitting materials in construction: Concrete, bricks, steel, as shown in Figures 5 to 7.

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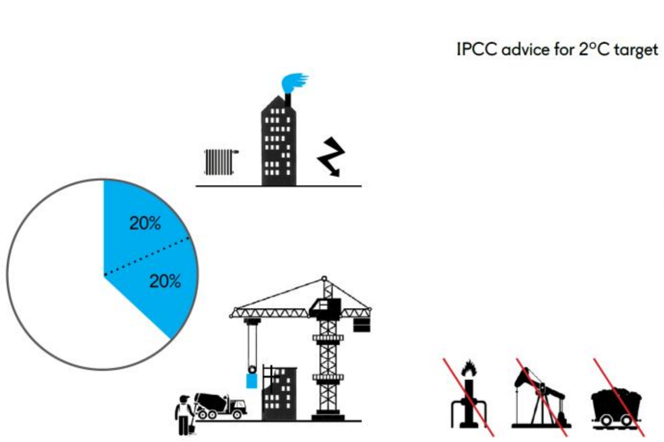
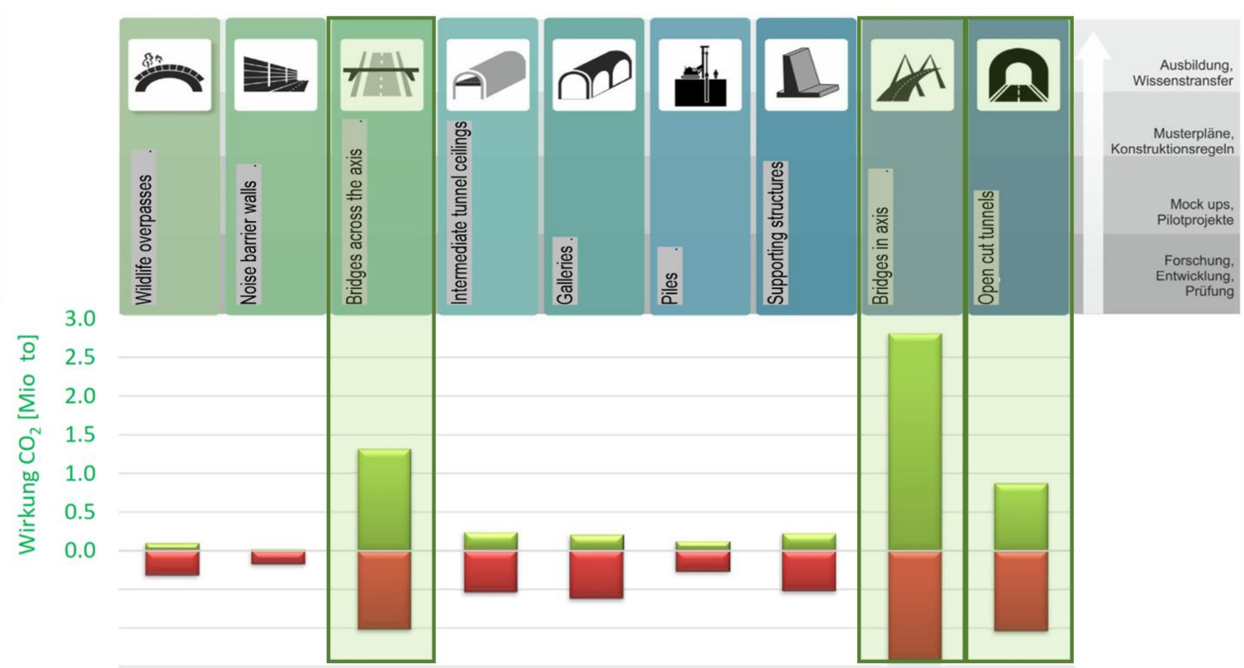



*Figure 3 and 4: $CO_2$ emissions by air traffic and buildings. Pictures: Timbatec*


Source: www.timbatec.com Source: www.colourbox.de Source: www.baudokumentation.ch

*Figure 5, 6, 7: $CO_2$ - emitting materials to be avoided*




Source: Dr. Bettina Franke, Prof. Dr. Steffen Franke, BFH AHB, Timbatec

*Figure 8 and 9 wood applications in infrastructure.*

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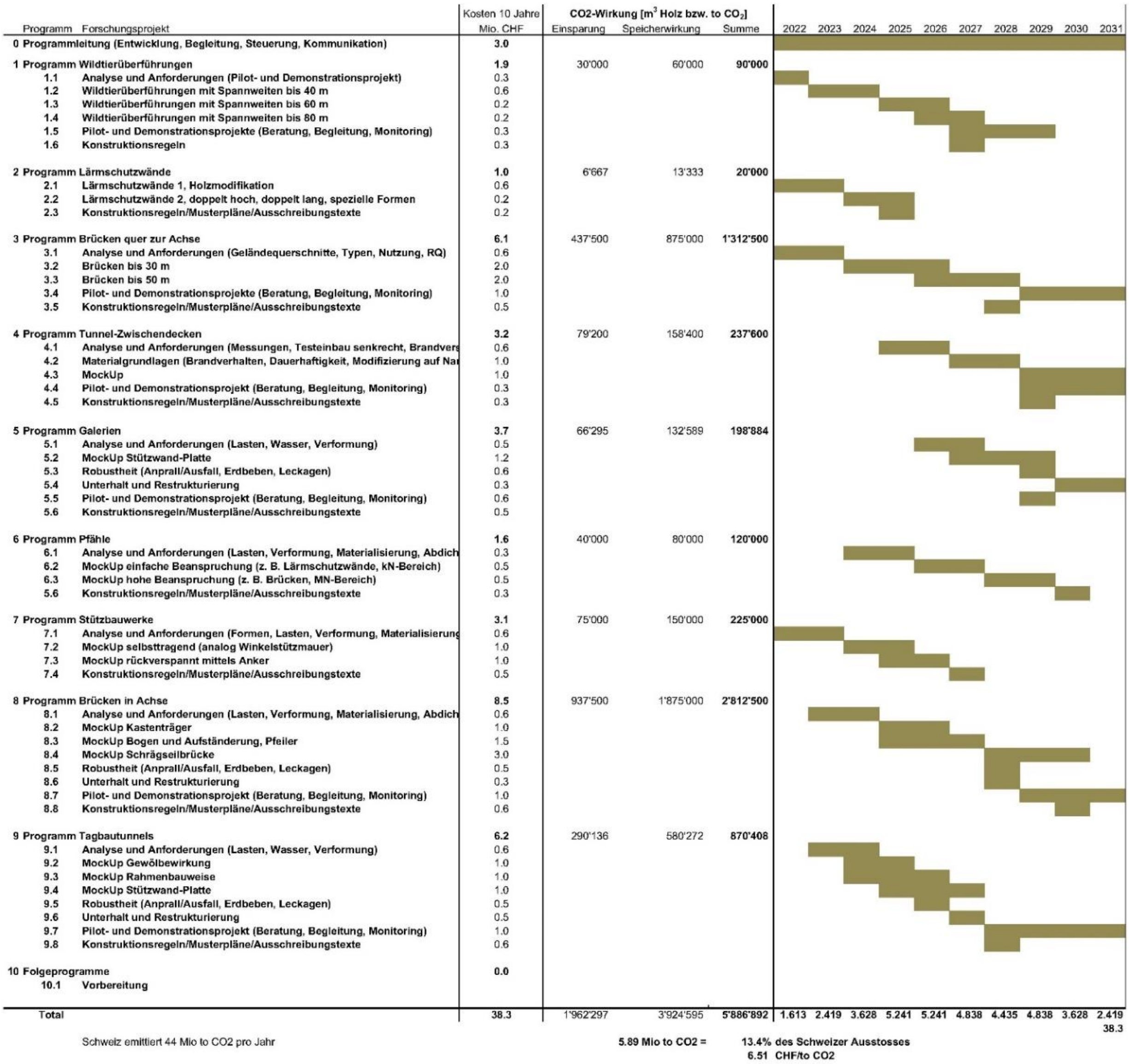
## Strategy for infrastructure in wood

The timber industry is already experiencing an increasing demand for timber buildings. Also, the demand for wood infrastructure is increasing. The task now is to replace reinforced concrete in infrastructure (Figures 9 to 11) with $CO_2$-storing materials such as wood. For this purpose, the Bern University of Applied Sciences AHB has worked out a research and implementation strategy together with Timbatec, Figure 12. Wood could be used in a wide variety of applications in the infrastructure sector.

Bridges across the axis | Bridges in axis | Open-cut tunnels

Source: www.timbatec.com | Source: www.autobahnen.ch | Source: www.timbatec.com

*Figure 9, 10, 11: Rising demand for wood in infrastructure: Bridges across the axis, bridges in axis, open-cut tunnels*



| Programm | Forschungsprojekt | Kosten 10 Jahre Mio. CHF | CO2-Wirkung [m³ Holz bzw. to $CO_2$] Einsparung | Speicherwirkung | Summe | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | Programmleitung (Entwicklung, Begleitung, Steuerung, Kommunikation) | 3.0 | | | | | | | | | | | | | |
| 1 | Programm Wildtierüberführungen | 1.9 | 30'000 | 60'000 | 90'000 | | | | | | | | | | |
| 1.1 | Analyse und Anforderungen (Pilot- und Demonstrationsprojekt) | 0.3 | | | | | | | | | | | | | |
| 1.2 | Wildtierüberführungen mit Spannweiten bis 40 m | 0.6 | | | | | | | | | | | | | |
| 1.3 | Wildtierüberführungen mit Spannweiten bis 60 m | 0.2 | | | | | | | | | | | | | |
| 1.4 | Wildtierüberführungen mit Spannweiten bis 80 m | 0.2 | | | | | | | | | | | | | |
| 1.5 | Pilot- und Demonstrationsprojekte (Beratung, Begleitung, Monitoring) | 0.3 | | | | | | | | | | | | | |
| 1.6 | Konstruktionsregeln | 0.3 | | | | | | | | | | | | | |
| 2 | Programm Lärmschutzwände | 1.0 | 6'667 | 13'333 | 20'000 | | | | | | | | | | |
| 2.1 | Lärmschutzwände 1, Holzmodifikation | 0.6 | | | | | | | | | | | | | |
| 2.2 | Lärmschutzwände 2, doppelt hoch, doppelt lang, spezielle Formen | 0.2 | | | | | | | | | | | | | |
| 2.3 | Konstruktionsregeln/Musterpläne/Ausschreibungstexte | 0.2 | | | | | | | | | | | | | |
| 3 | Programm Brücken quer zur Achse | 6.1 | 437'500 | 875'000 | 1'312'500 | | | | | | | | | | |
| 3.1 | Analyse und Anforderungen (Geländequerschnitte, Typen, Nutzung, RQ) | 0.6 | | | | | | | | | | | | | |
| 3.2 | Brücken bis 30 m | 2.0 | | | | | | | | | | | | | |
| 3.3 | Brücken bis 50 m | 2.0 | | | | | | | | | | | | | |
| 3.4 | Pilot- und Demonstrationsprojekte (Beratung, Begleitung, Monitoring) | 1.0 | | | | | | | | | | | | | |
| 3.5 | Konstruktionsregeln/Musterpläne/Ausschreibungstexte | 0.5 | | | | | | | | | | | | | |
| 4 | Programm Tunnel-Zwischendecken | 3.2 | 79'200 | 158'400 | 237'600 | | | | | | | | | | |
| 4.1 | Analyse und Anforderungen (Messungen, Testeinbau senkrecht, Brandvers | 0.6 | | | | | | | | | | | | | |
| 4.2 | Materialgrundlagen (Brandverhalten, Dauerhaftigkeit, Modifizierung auf Na | 1.0 | | | | | | | | | | | | | |
| 4.3 | MockUp | 1.0 | | | | | | | | | | | | | |
| 4.4 | Pilot- und Demonstrationsprojekt (Beratung, Begleitung, Monitoring) | 0.3 | | | | | | | | | | | | | |
| 4.5 | Konstruktionsregeln/Musterpläne/Ausschreibungstexte | 0.3 | | | | | | | | | | | | | |
| 5 | Programm Galerien | 3.7 | 66'295 | 132'589 | 198'884 | | | | | | | | | | |
| 5.1 | Analyse und Anforderungen (Lasten, Wasser, Verformung) | 0.5 | | | | | | | | | | | | | |
| 5.2 | MockUp Stützwand-Platte | 1.2 | | | | | | | | | | | | | |
| 5.3 | Robustheit (Anprall/Ausfall, Erdbeben, Leckagen) | 0.6 | | | | | | | | | | | | | |
| 5.4 | Unterhalt und Restrukturierung | 0.3 | | | | | | | | | | | | | |
| 5.5 | Pilot- und Demonstrationsprojekt (Beratung, Begleitung, Monitoring) | 0.6 | | | | | | | | | | | | | |
| 5.6 | Konstruktionsregeln/Musterpläne/Ausschreibungstexte | 0.5 | | | | | | | | | | | | | |
| 6 | Programm Pfähle | 1.6 | 40'000 | 80'000 | 120'000 | | | | | | | | | | |
| 6.1 | Analyse und Anforderungen (Lasten, Verformung, Materialisierung, Abdich | 0.3 | | | | | | | | | | | | | |
| 6.2 | MockUp einfache Beanspruchung (z. B. Lärmschutzwände, kN-Bereich) | 0.5 | | | | | | | | | | | | | |
| 6.3 | MockUp hohe Beanspruchung (z. B. Brücken, MN-Bereich) | 0.5 | | | | | | | | | | | | | |
| 5.6 | Konstruktionsregeln/Musterpläne/Ausschreibungstexte | 0.3 | | | | | | | | | | | | | |
| 7 | Programm Stützbauwerke | 3.1 | 75'000 | 150'000 | 225'000 | | | | | | | | | | |
| 7.1 | Analyse und Anforderungen (Formen, Lasten, Verformung, Materialisierung | 0.6 | | | | | | | | | | | | | |
| 7.2 | MockUp selbsttragend (analog Winkelstützmauer) | 1.0 | | | | | | | | | | | | | |
| 7.3 | MockUp rückverspannt mittels Anker | 1.0 | | | | | | | | | | | | | |
| 7.4 | Konstruktionsregeln/Musterpläne/Ausschreibungstexte | 0.5 | | | | | | | | | | | | | |
| 8 | Programm Brücken in Achse | 8.5 | 937'500 | 1'875'000 | 2'812'500 | | | | | | | | | | |
| 8.1 | Analyse und Anforderungen (Lasten, Verformung, Materialisierung, Abdich | 0.6 | | | | | | | | | | | | | |
| 8.2 | MockUp Kastenträger | 1.0 | | | | | | | | | | | | | |
| 8.3 | MockUp Bogen und Aufständerung, Pfeiler | 1.5 | | | | | | | | | | | | | |
| 8.4 | MockUp Schrägseilbrücke | 3.0 | | | | | | | | | | | | | |
| 8.5 | Robustheit (Anprall/Ausfall, Erdbeben, Leckagen) | 0.5 | | | | | | | | | | | | | |
| 8.6 | Unterhalt und Restrukturierung | 0.3 | | | | | | | | | | | | | |
| 8.7 | Pilot- und Demonstrationsprojekt (Beratung, Begleitung, Monitoring) | 1.0 | | | | | | | | | | | | | |
| 8.8 | Konstruktionsregeln/Musterpläne/Ausschreibungstexte | 0.6 | | | | | | | | | | | | | |
| 9 | Programm Tagbautunnels | 6.2 | 290'136 | 580'272 | 870'408 | | | | | | | | | | |
| 9.1 | Analyse und Anforderungen (Lasten, Wasser, Verformung) | 0.6 | | | | | | | | | | | | | |
| 9.2 | MockUp Gewölbewirkung | 1.0 | | | | | | | | | | | | | |
| 9.3 | MockUp Rahmenbauweise | 1.0 | | | | | | | | | | | | | |
| 9.4 | MockUp Stützwand-Platte | 1.0 | | | | | | | | | | | | | |
| 9.5 | Robustheit (Anprall/Ausfall, Erdbeben, Leckagen) | 0.5 | | | | | | | | | | | | | |
| 9.6 | Unterhalt und Restrukturierung | 0.5 | | | | | | | | | | | | | |
| 9.7 | Pilot- und Demonstrationsprojekt (Beratung, Begleitung, Monitoring) | 1.0 | | | | | | | | | | | | | |
| 9.8 | Konstruktionsregeln/Musterpläne/Ausschreibungstexte | 0.6 | | | | | | | | | | | | | |
| 10 | Folgeprogramme | 0.0 | | | | | | | | | | | | | |
| 10.1 | Vorbereitung | | | | | | | | | | | | | | |
| Total | | 38.3 | 1'962'297 | 3'924'595 | 5'886'892 | 1.613 | 2.419 | 3.628 | 5.241 | 5.241 | 4.838 | 4.435 | 4.838 | 3.628 | 2.419 |

38.3

Schweiz emittiert 44 Mio to CO2 pro Jahr

5.89 Mio to CO2 = 13.4% des Schweizer Ausstosses

6.51 CHF/to CO2

*Figure 12: Strategy, Research programs and projects for decarbonization of infrastructure. Graphic BFH AHB, Timbatec.*

9 main application areas were evaluated, assessed, and quantified. In estimating the volumes of wood to be used, it was found that there are three predominant areas of high impact: Bridges across the axis, bridges in axis, and open-cut tunnels. In comparison, the other areas are almost negligible.

This strategy does not need to fear the cost-benefit comparison either. In Switzerland alone, 1.96 million tons of $CO_2$ can be saved and 3.92 million tons of $CO_2$ can be substituted by replacing concrete. In total, an effect of 5.89 million tons of $CO_2$ is achievable. This corresponds to 13.4% of Switzerland's annual $CO_2$ emissions. The costs of the entire strategy amount to CHF 38.3 million, or CHF 6.51/to $CO_2$.

Taking into account that it takes roughly 5 years from order to execution, there are 25 years left for achieving to net-zero, cp. Figure 13. Therefore 4% of $CO_2$ emissions will have to be reduced annually over the next 25 years - while construction activity remains unchanged. This will not be possible even with emission-reduced concrete. But if every possible application is ordered in wood, the storage of $CO_2$ in the wood gives a certain head start, so that the goal remains achievable.


*Figure 13: Time lag from order to execution 5 years. Graphic: BFH, Timbatec.*

## Political homework

It is understandable that the authorities were not waiting for this task. The main task of the road authorities is to create and operate the traffic routes, and to do so as safely and cost-effectively as possible. Sustainable infrastructure in wood is not. If we want the sustainability of the constructions to become the task of the authorities as well, we also have to do the political homework. Jakob Stark, member of the Council of States, and Erich von Siebenthal, member of the National Council, have submitted a motion that has been adopted in both federal chambers by the end of 2021, Figure 14. Not only the road authorities, but all authorities concerned with the construction and operation of infrastructure buildings must now fulfill this task. This also includes, for example, the railroads or the army’s buildings.

To enable the widespread use of wood in infrastructure buildings, the legal basis must be established first. So if you want to play a decisive role in your country or state, find a parliamentarian to submit this proposal. Politicians are grateful for well-researched and ready-made proposals. This saves them a lot of work, strengthens their political effectiveness, and raises their sustainability profile in the society.

**21.3293 Motion**

Submitted by Stark Jakob, Ständerat, Fraktion der Schweizerischen Volkspartei

**Research and innovation of wood as a material for use in infrastructure construction as a decarbonization contribution**

Text submitted:

The Federal Council is instructed to research the possibilities for decarbonizing infrastructure construction in cooperation with universities and the relevant standards commissions. In particular, it should be examined, and efforts made to supplement or replace reinforced concrete with $CO_2$-absorbing materials. The focus should be on researching and innovating wood as a material for widespread use in infrastructure construction. A corresponding research and implementation strategy is to be developed.

Explanation:

Infrastructure construction is one of the largest $CO_2$ emitters in Switzerland. The main cause is the use of reinforced concrete. Cement production (2020: 4 214 785 tons, source cemsuisse.ch), with annual $CO_2$ emissions of about 2.5 million tons, contributes more than 5 percent to national $CO_2$ emissions (46.4 million tons).

For the construction of infrastructures, in the building sector, but also in other sectors such as the road sector, various solutions are already available today with materials that do not produce $CO_2$ during production but store it, such as wood. One cubic meter of wood stores about 1 ton of $CO_2$ in the long term. When used properly, wood is a very long-term and also cost-effective $CO_2$ store for infrastructure buildings in all sectors. The advantages over the currently discussed CCS (Carbon Capture and Storage) are obvious: with CCS, one pays a high amount per ton of $CO_2$ for the pure storage function, whereas this is included in the price when using wood for infrastructure construction, i.e. it is free of charge, so to speak.

In addition, there is the reduction in $CO_2$ emissions due to the substitution of reinforced concrete with wood; one cubic meter of wood replaces approximately one cubic meter of reinforced concrete. In addition, the energy input per cubic meter of material is significantly lower for wood components than for reinforced concrete.

Although the first promising applications of wood in infrastructure construction are available, increased support for research and innovation is needed so that a significant contribution can be made in time to the storage of $CO_2$ and the reduction of $CO_2$ production. Together with universities and standardization associations, a research and implementation strategy should be developed that provides a general basis but also focuses specifically on the various areas and types of structures. The offices involved in the construction of infrastructure buildings, such as ARMASUISSE, ASTRA, BAFU, BAV (SBB), BBL, BFE, BWO OR PUBLICA are to be involved accordingly.

https://www.parlament.ch/de/ratsbetrieb/suche-curia-vista/geschaeft?AffairId=20213293

*Figure 14: Full text of the submitted proposal 21.3293 of Ständerat Jakob Stark and Nationalrat Erich Von Siebenthal*

## Wooden wildlife overpasses in Switzerland

Stefan Zöllig wrote the first study on wildlife bridges made of wood in 1998. Afterwards, it took 22 years until the first wooden wildlife overpasses could be built. So, the first wooden wildlife overpasses of Switzerland were built in 2020 in Rynetel AG (Figure 15) and 2021 in Neuenkirch LU (Figure 16). The wildlife overpass in Rynetel AG is a double arch with 17.5 m span each. The wildlife overpass in Neuenkirch LU is designed as a double single span girder with 17.5 m span each and a center support.

Further wildlife bridges are planned in Ziegelbrücke GL (Figure 17) and in Tenniken BL. The wildlife bridge in Ziegelbrücke GL will be designed as an arch with a span of 57 m.

*Figure 15: Built wildlife overpass Rynetel AG, Switzerland. Picture: Nils Sandmeier, Timbatec*

*Figure 16: Built wildlife overpass Neuenkirch LU, Switzerland. Picture: Nils Sandmeier, Timbatec*

*Figure 17: Planned wildlife overpass Biberlikopf Ziegelbrücke GL, Switzerland. Picture: Nightnurse Images, Zürich*

## Research: Heavy duty box girder bridges

To be successful in infrastructure made of wood, it is not enough to criticize reinforced concrete. Nor is the experience gained so far sufficient to be successful in the three determined areas. On the contrary, we must very quickly develop the necessary methods to be able to realize long-span heavy-duty bridges in wood. Previous reinforced concrete bridges were designed as box girders. Can this construction method be transferred to timber construction? To answer this question, Dr.-Ing. Bettina Franke and Prof. Dr. Steffen Franke from the Bern University of Applied Sciences AHB have started a research project together with Stefan Zöllig from Timbatec and TS3 as well as with other business partners. Here, the feasibility of prestressed hollow box girders in wood is evaluated and developed. The TS3 technology, in which CLT cross laminated timber panels are joined together by butt joint bonding, is making an important contribution to this. The joint edges of the CLT panels are CNC-machined and pre-treated in the factory. On site, the CLT panels are arranged in the correct geometry, sealed and grouted with a high-performance casting-resin without applying pressure. This is done in panel plane, but also with miter joints.

This feasibility study is, so to speak, the "entry debate" until the implementation of the Stark motion starts.

Two box-girder modules in the courtyard of the Bern University of Applied Sciences in Biel, as shown in Figures 18 to 20, will be used as working models where the envisaged static models, but also practical exercises can be carried out. It is to be expected that, in the course of the research project, new findings will emerge that will require adjustments to the model. This is desired and planned in order to be ready for the realization of the first prestressed box girder bridges as soon as possible.

*Figure 18: Manufacturing box-girder modules at the factory. Picture: Flück AG, Wangen b. Dübendorf*

*Figure 19: Installation of the box-girder modules. Picture: Steffen Franke*

*Figure 20: Box-girder modules in the courtyard of the Bern University of Applied Sciences Biel. Picture: Steffen Franke*