Railway systems and their transition
Lecture 12

Sustainability & Climate Goals

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Today's agenda

1. Intro
2. Sustainability & Climate Goals

Sustainability and Climate Goals

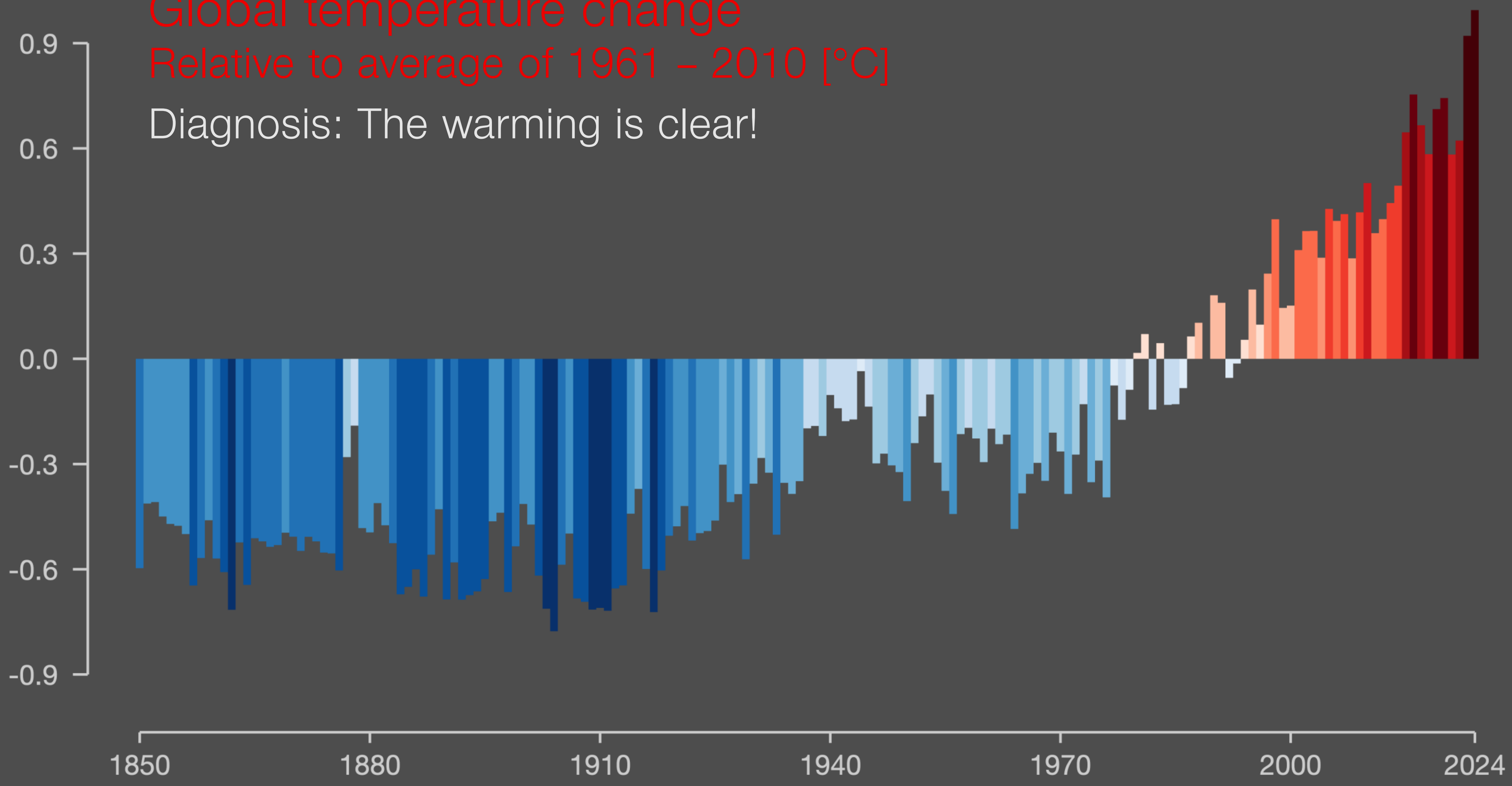
Sustainability and Climate Goals

1. Introduction
2. Indirect Emissions
3. Reducing Emissions
   - Energy Efficiency
   - Renewable Energy
   - Circular Economy
   - Sustainable Procurement
   - Negative Emissions

Global temperature change

Relative to average of 1961 – 2010 [°C]

Diagnosis: The warming is clear!



Source: Ed Hawkins, National Centre for Atmospheric Science, UoR (11.08.2024)

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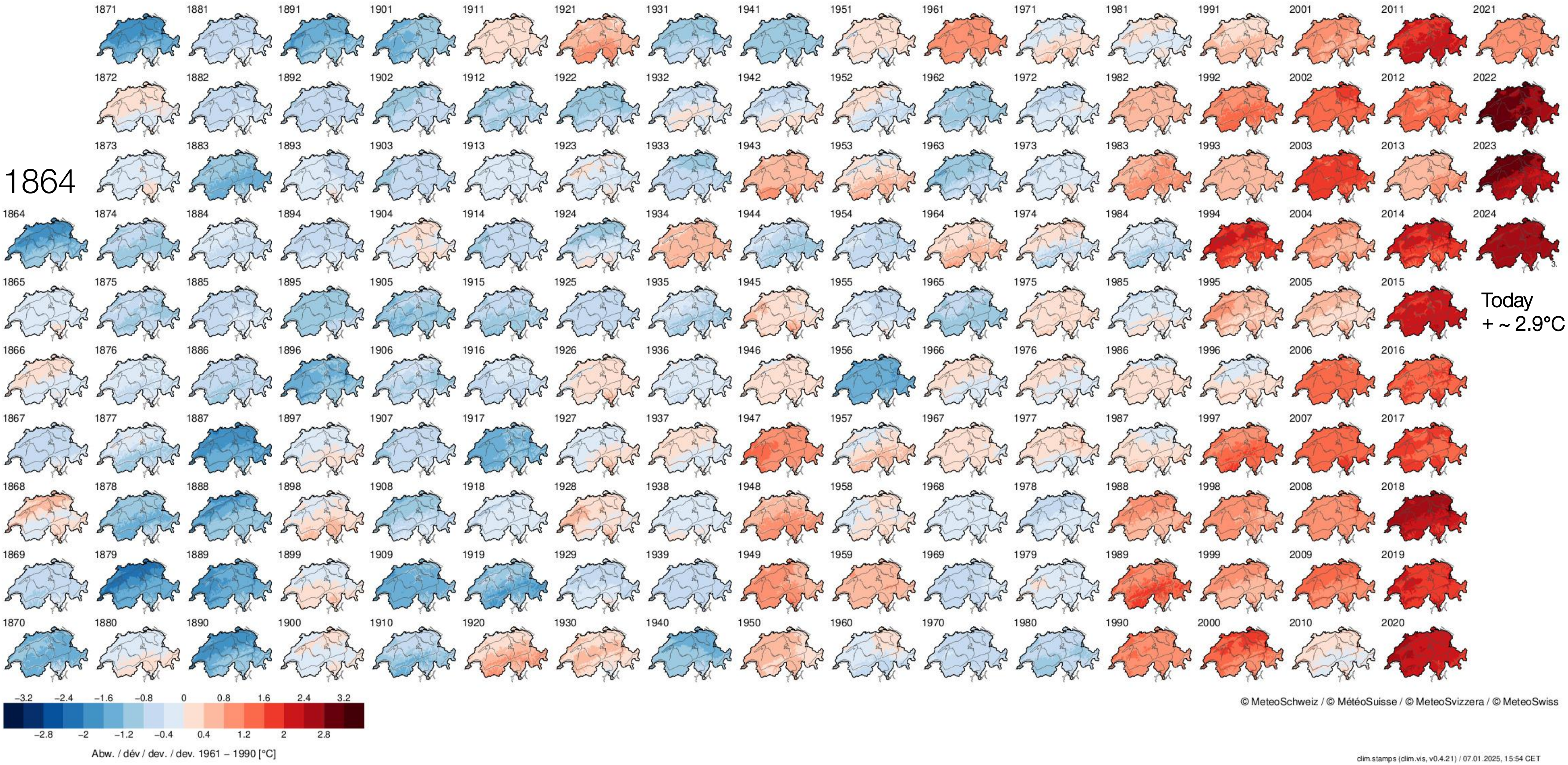
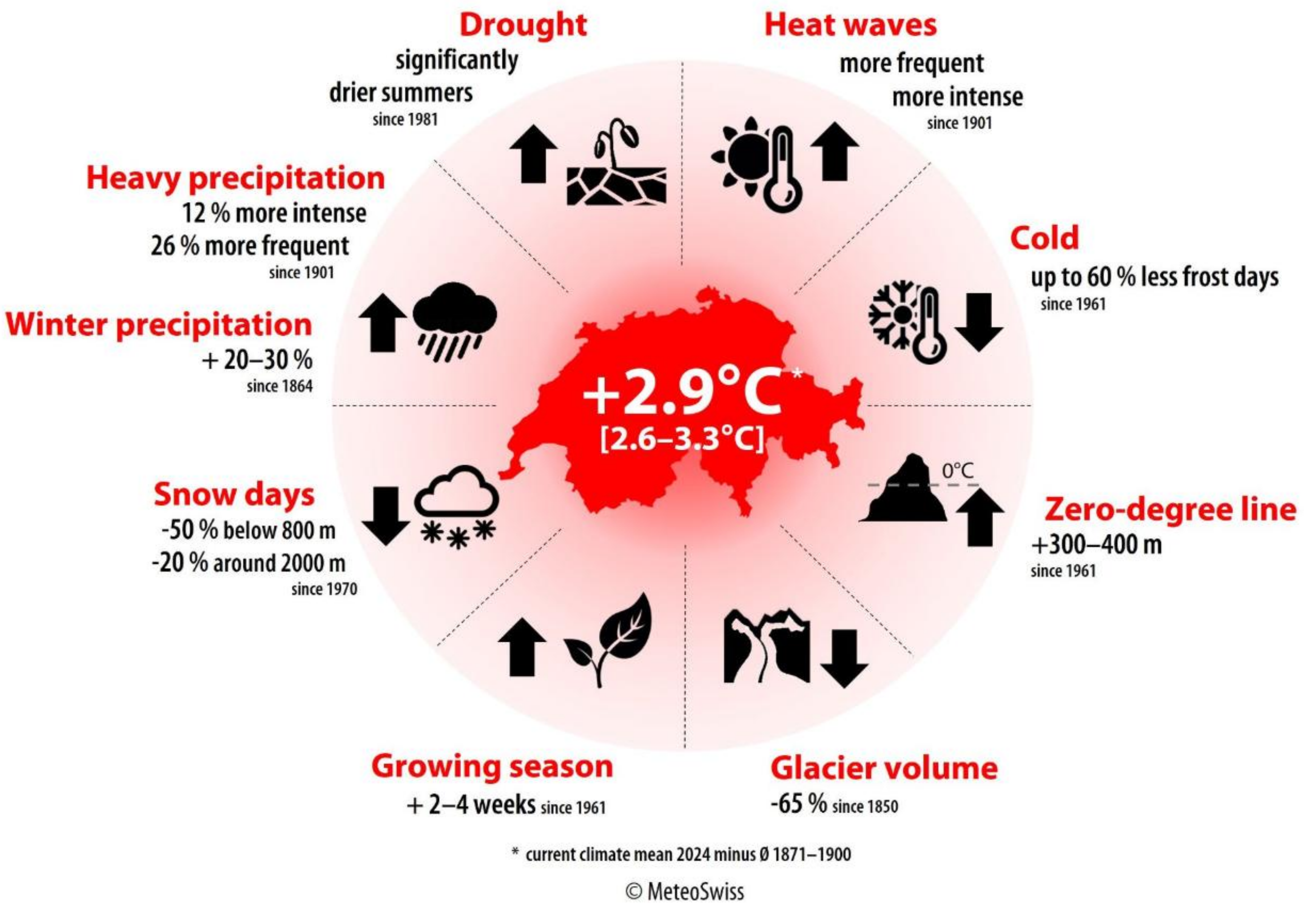


Today
+ ~ 2.9°C

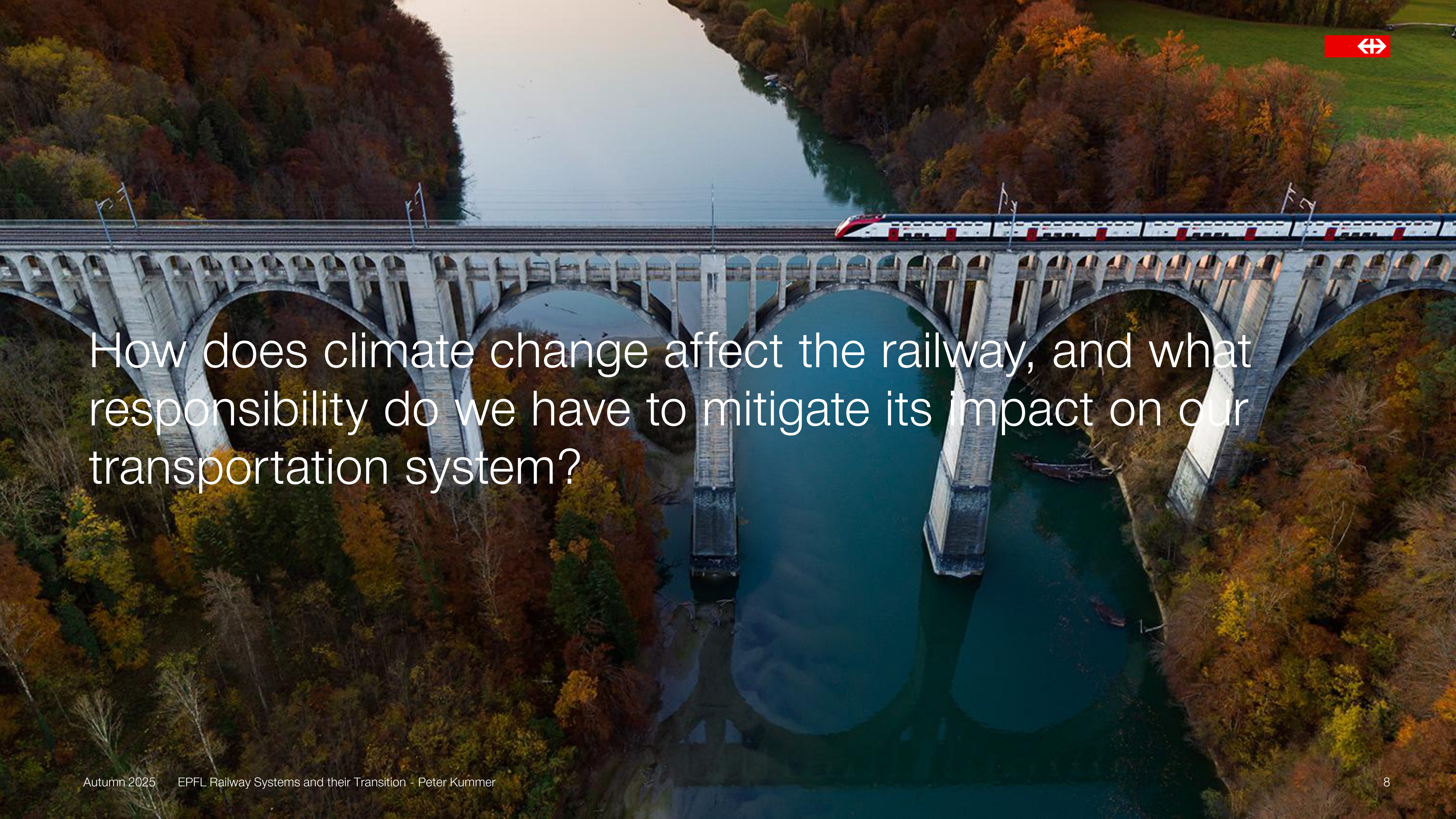
Source: Klimawandel - MeteoSchweiz (11.08.2024)

Consequences of global warming for Switzerland



- GHG emissions drive global warming.
- Switzerland is particularly impacted due to its geography.
- How does climate change affect the railway?

Global Climate Goal - Paris Agreement 2015:
Limit global temperature rise to well below 2°C (Bundesamt für Klimatologie)



How does climate change affect the railway, and what responsibility do we have to mitigate its impact on our transportation system?

Paris Climate Agreement (2015)

According to the Paris Climate Agreement, 2015

Goal:

Limit global temperature rise to well below 2°C, aiming for 1.5°C above pre-industrial levels. (in line with SBTi targets)

Example:

Switzerland's Climate Targets (KIG, 2022):

→ By 2050: Net-zero emissions

→ Federal Companies: Net-zero by 2040 (including railway companies like SBB, BLS …)

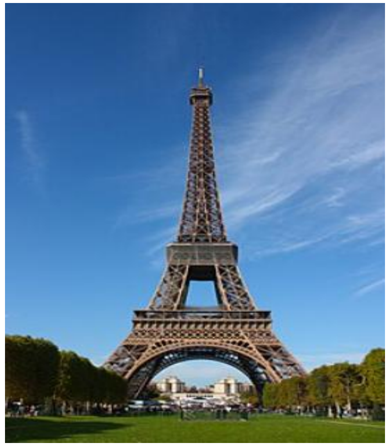
Matterhorn © Zermatt Bergbahnen

Source: Klimaziele - MeteoSchweiz (11.08.2024); BBl 2022 2403 - Bundesgesetz über die Ziele im Klimaschutz, die Innovation und die Stärkung der Energiesicherheit (KlG) | Fedlex (11.08.2024); https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (11.08.2025) Matterhorn – Zermatt Bergbahnen

Question (5'): Train vs. Electric car & aeroplane

- How does the train compare to an electric car or aeroplane in terms of the following:
  - Energy Consumption?
  - Emissions (well to wheel)?

- Journey: Geneva – Paris (540 km)
- Where are the biggest differences?
- Environmental Calculator:

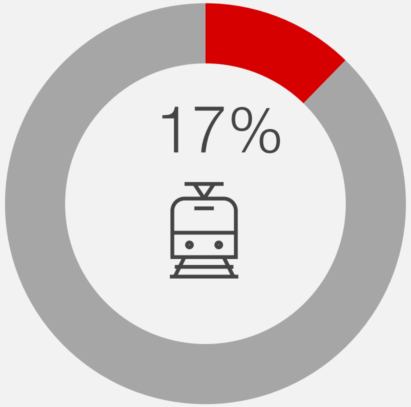


 Source: Mobitool - Umweltrechner Verkehr (06.11.2025)

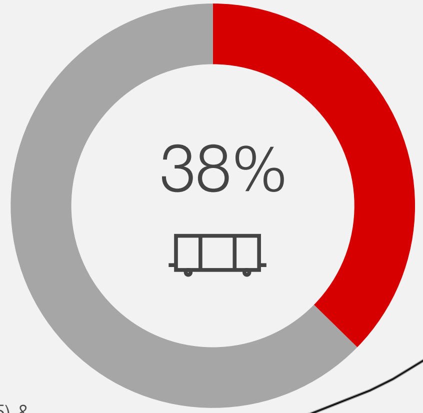
Facts & Figures - Current challenges: Sustainability

Environmental impact of railway systems

- Passengers:



- Goods:



Shares of rail in land transport in Switzerland

Source: Mobility and Transport (FSO, 2025) & Umweltauswirkungen | Bundesamt für Statistik - BFS (2025)

The railways' share of land transport in Switzerland:

5%	Energy consumption
10%	Land use
0.3%*	Emisison production

Railway system compared to battery electric cars:**

- Causes **92% less emissions**
- Requires **24 x less energy**
- Is **8 - 9 x more space-efficient** than the road

Source: Umweltrechner Verkehr – mobitool; Mobility and Transport (FSO, 2025)

*schweizerische Emissionen gemäss Abgrenzung CO2-Verordnung (Absatzprinzip), inkl. Tanktourismus und statistische Differenz

Current challenges: Environmental Impact of railway

The railway is an environmentally friendly means of transport per se, but ...

- The ecological advantage of the rail system over alternative means of transport is undisputed.
- The ecological advantage of rail also remains when compared to the electric car:
  - → Causes 12x less emissions (less than 92%)
  - → Requires 24x less energy
  - → Is 8 – 9 times more space-efficient than the road
- Nevertheless, we cannot rest on our laurels...

Current challenges: Indirect emissions from infrastructure.

Only construct when necessary and apply the principles of circular economy.

Railway causes **15 times more indirect "grey" emissions*** than direct emissions:

- High construction activity
- Steel and concrete are emission-intensive building materials
- A circular economy and sustainable procurement are crucial for reducing Greenhouse Gas (GHG)-Emissions

→ **We cannot afford to rest on our laurels!**

Indirect Emissions

Indirect Emissions

Definition:
The GHG Protocol Corporate Standard classifies a company's GHG emissions into three 'scopes'.

Scope 1 emissions are direct emissions from owned or controlled sources.

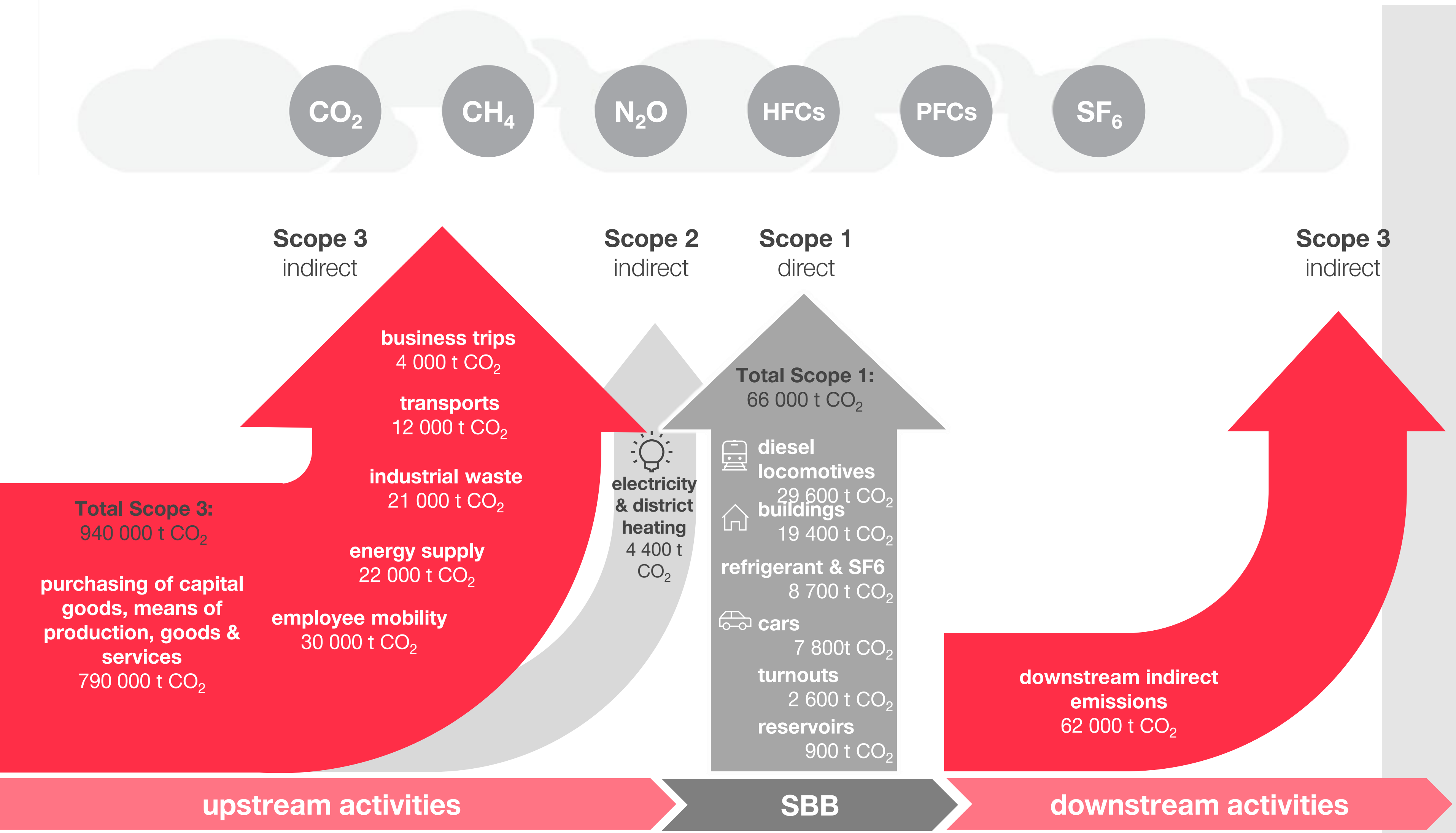
Scope 2 emissions are indirect emissions from the generation of purchased energy.

Scope 3 emissions are all indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions

*Source: Greenhouse Gas Protocol; www.ghgprotocol.org

Scopes of Greenhouse Gas (GHG)-Emissions (Example SBB)

Scope 3 emissions are approximately **15 times higher*** than Scope 1 & 2 emissions.

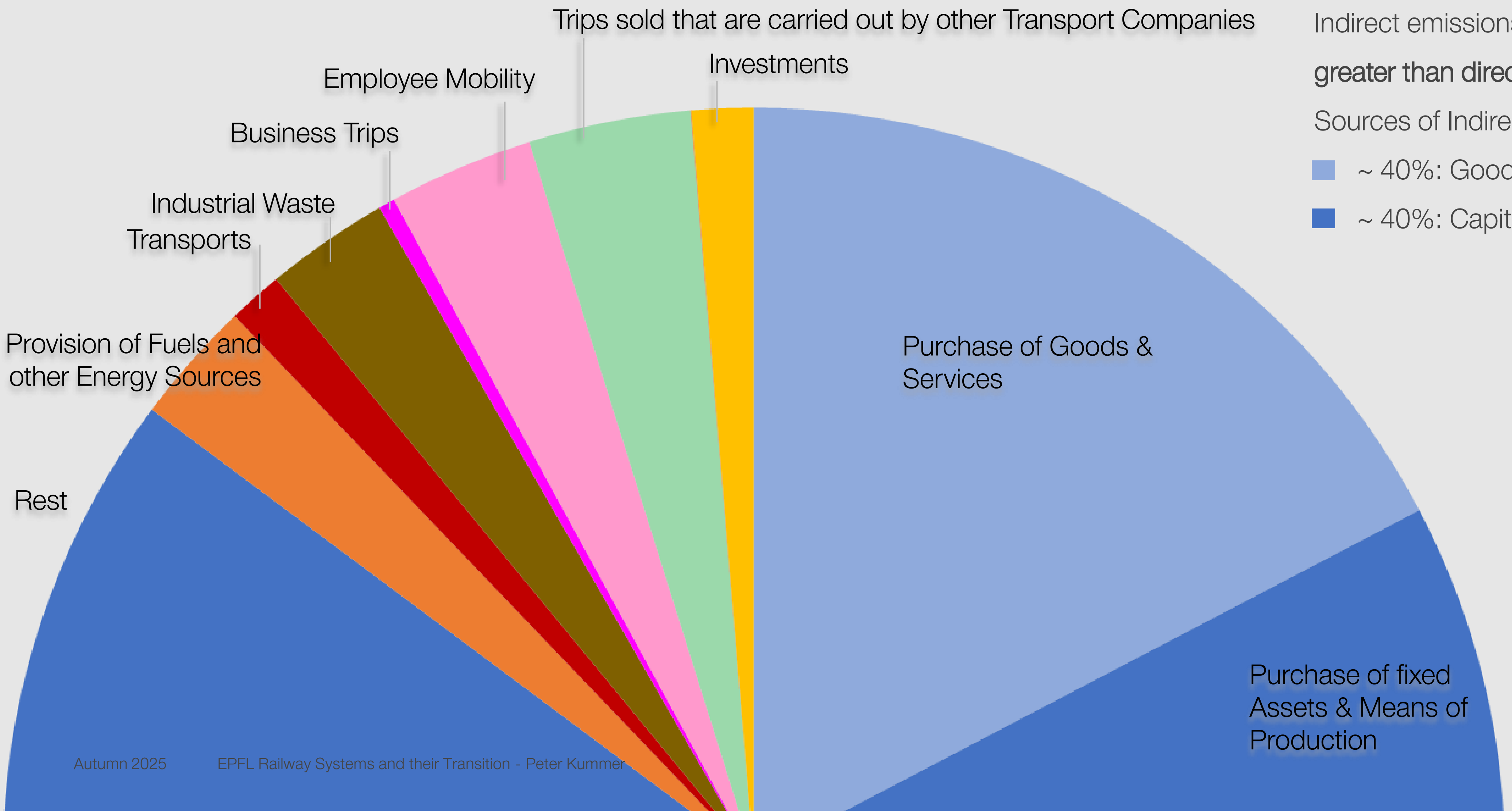


SBTi*-Commitment of SBB
30% reduction in indirect greenhouse gas emissions by 2030 (Scope 3)
(baseline year 2018)

*Source: SBB's own environmental assessment

Example: Total amount of Scope 3 Emissions at SBB for 2024

Indirect Emissions in t CO_{2e}:1‘000‘000 (vs. Direct Emissions in t CO_{2e}: 70‘000)



Indirect emissions are more than **15 times greater than direct emissions** (Source). Main Sources of Indirect Emissions:

- ~ 40%: Goods & Services
- ~ 40%: Capital Goods

Indirect Emissions account for 93% of all emissions at SBB

and ~80% of Scope 3 emissions come from just two categories

SBB Climate Goals

- SBB serves as a role model
- Goals:
  - By 2030:
    - Reducing 50% of its direct emissions (Scope 1 & 2).
    - Reducing 30% of its indirect emissions (Scope 3).
  - By 2040:
    - Reducing 92% of its direct emissions (Scope 1 & 2).
    - Use of negative technologies to reduce the remaining direct emissions (Scope 1 & 2).

Reducing Emissions

Main Levers

How can Emissions be reduced?
The main levers are:

- Increasing **energy efficiency**
- Increase in the share of **renewable energies**
- Promotion of **circular economy**
- **Sustainable procurement**
- Use of **negative emission technologies**

In the Future

How can Emissions be reduced?

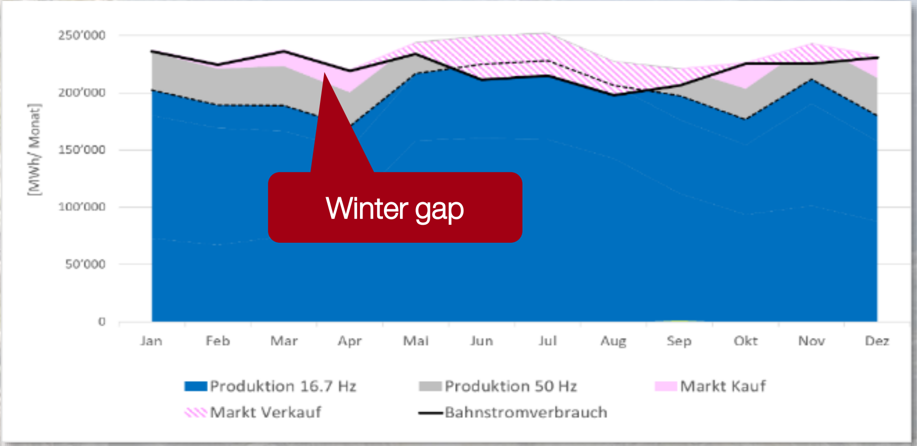
The main levers are:

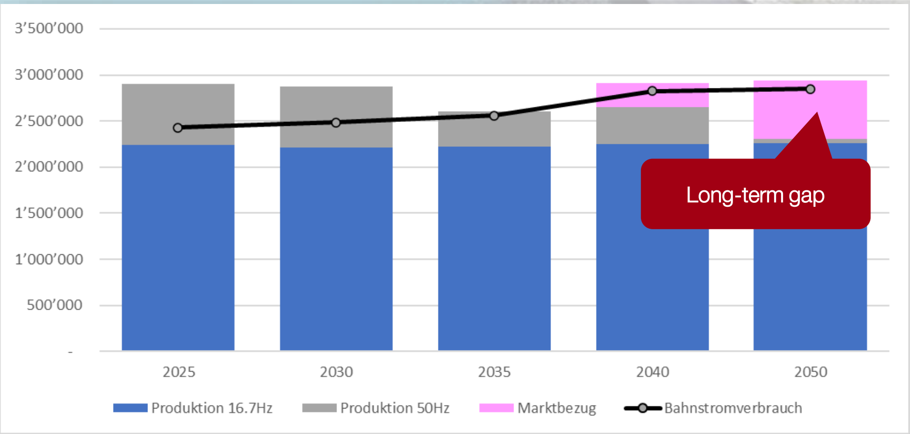
Increasing **energy efficiency**

Increase in the share of **renewable energies**

Energy Efficiency

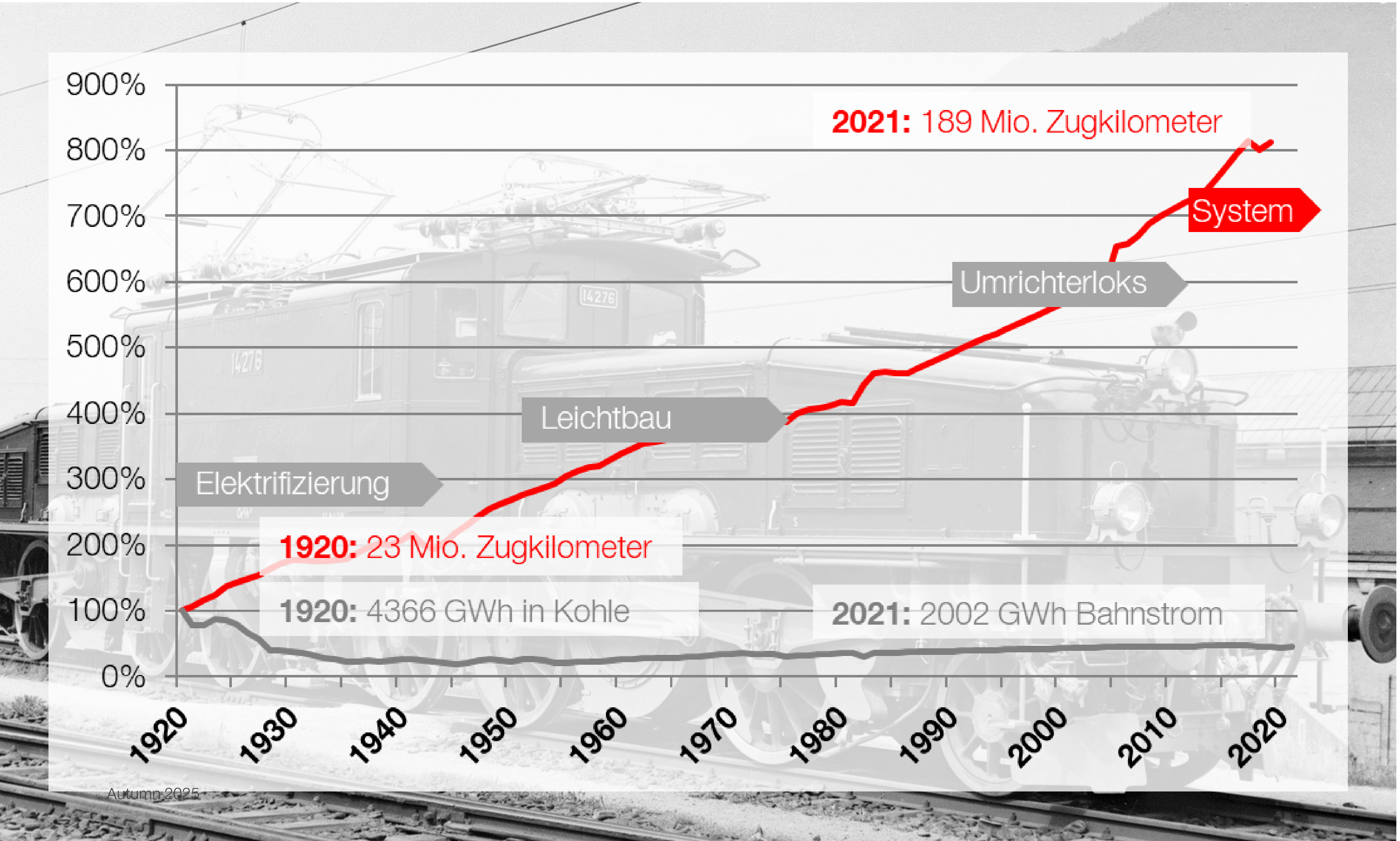
Challenges and solutions.





- Energy demand exceeds in-house production in the medium term
- Two possible solutions:
  1. Save electricity
  2. Produce more

Ten times more trains with half the energy



- Electrification brought massive efficiency gains
- Since then, continuous development to keep the energy requirement at this level

Example: The 3 pillars of the SBB energy strategy

Hydro production, PV production, energy efficiency from the dam wall to the wheel

Production

- Exploiting Hydro's expansion potential
- Maintenance and modernisation of the existing large-scale hydropower plant
- Use of existing expansion potential Hydro.
- Forecast: plus 280 GWh and approx. 100 GWh storage capacity

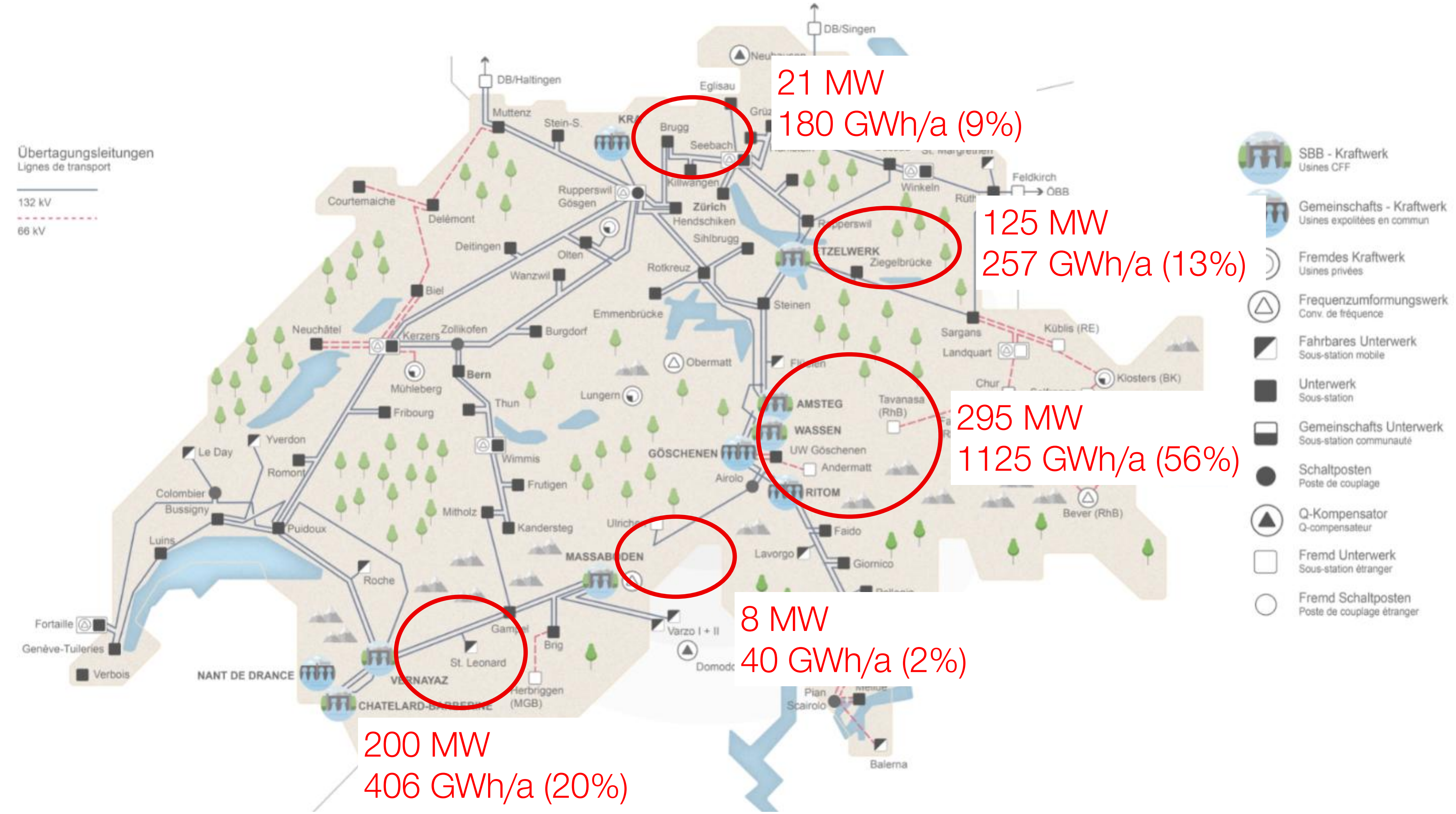
- Expansion of new renewable energies
- Expansion of PV on SBB sites:
  - 100 GWh/a by 2030
  - 160 GWh/a by 2040

Consumer

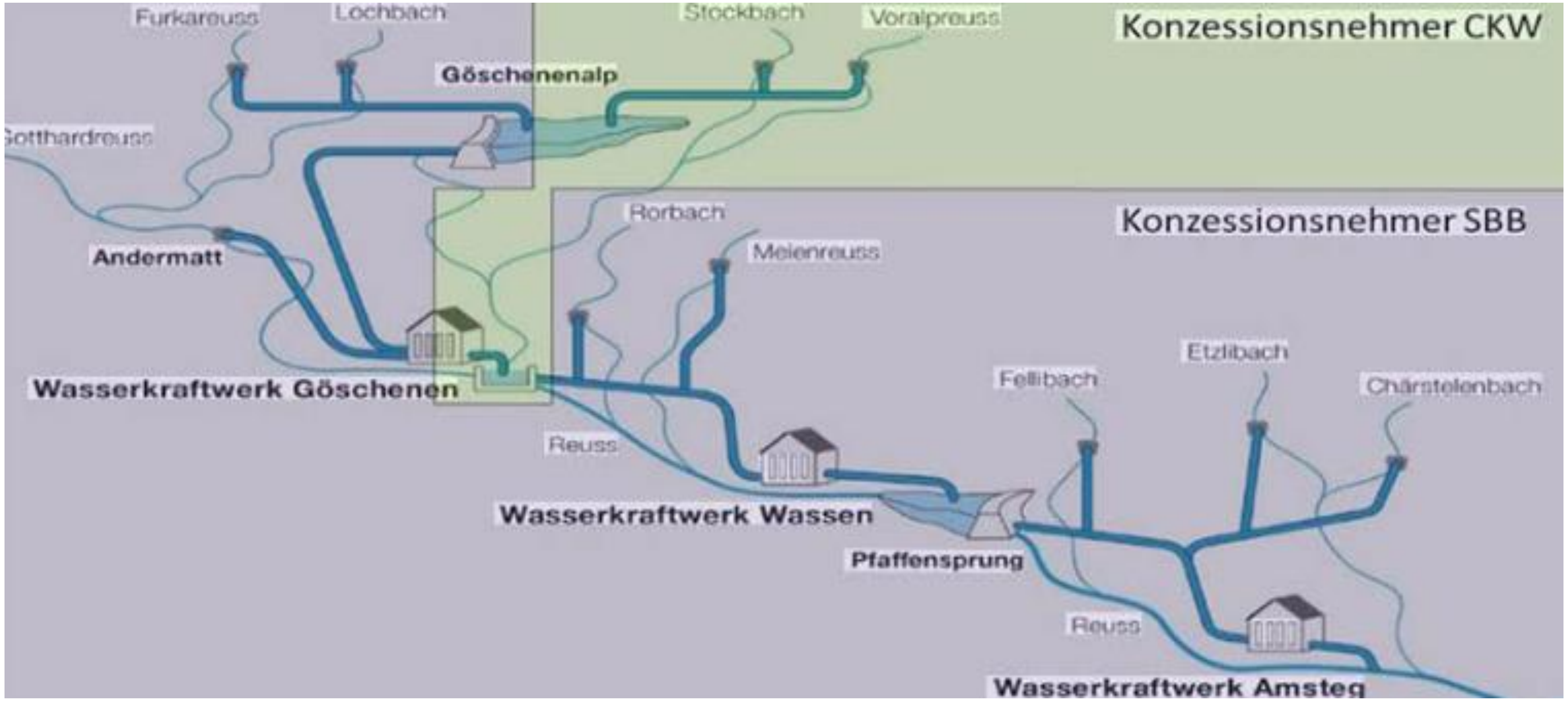
Demand forecast
- 2300 GWh/a in 2030
- 2400 GWh/a in 2040
- 2500 GWh/a in 2050 (total sales of all ISB’s)

Energy saving target:
- 850 GWh by 2030 (- 30% compared to 2010)

Railway traction hydropower plants.



«Reuss river cascade»



- Today, SBB covers around 40% of its traction power requirements with Uri hydropower.
- The associated concessions all end in 2043.
- At the Hydropower Round Table, the federal government prioritised the Göscheneralp dam elevation and the expansion of the Wassen power plant in order to increase winter energy production by 2040.

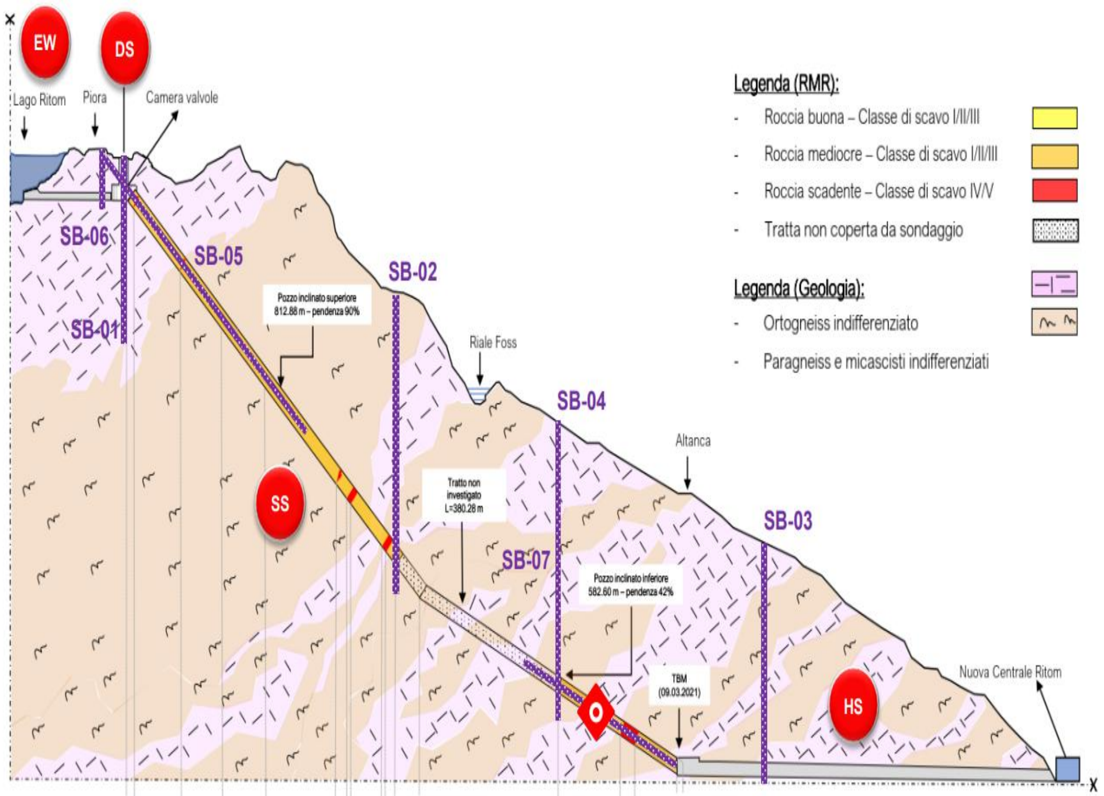
Ritom

1 turbine 16.7 Hz 60 MW with generator
1 turbine 50 Hz 60 MW with generator
1 pump 60 MW
1 frequency converter 50-16.7 Hz
1 equalization basin of 100,000 m3
A pressure pipeline with a length of about 2 km

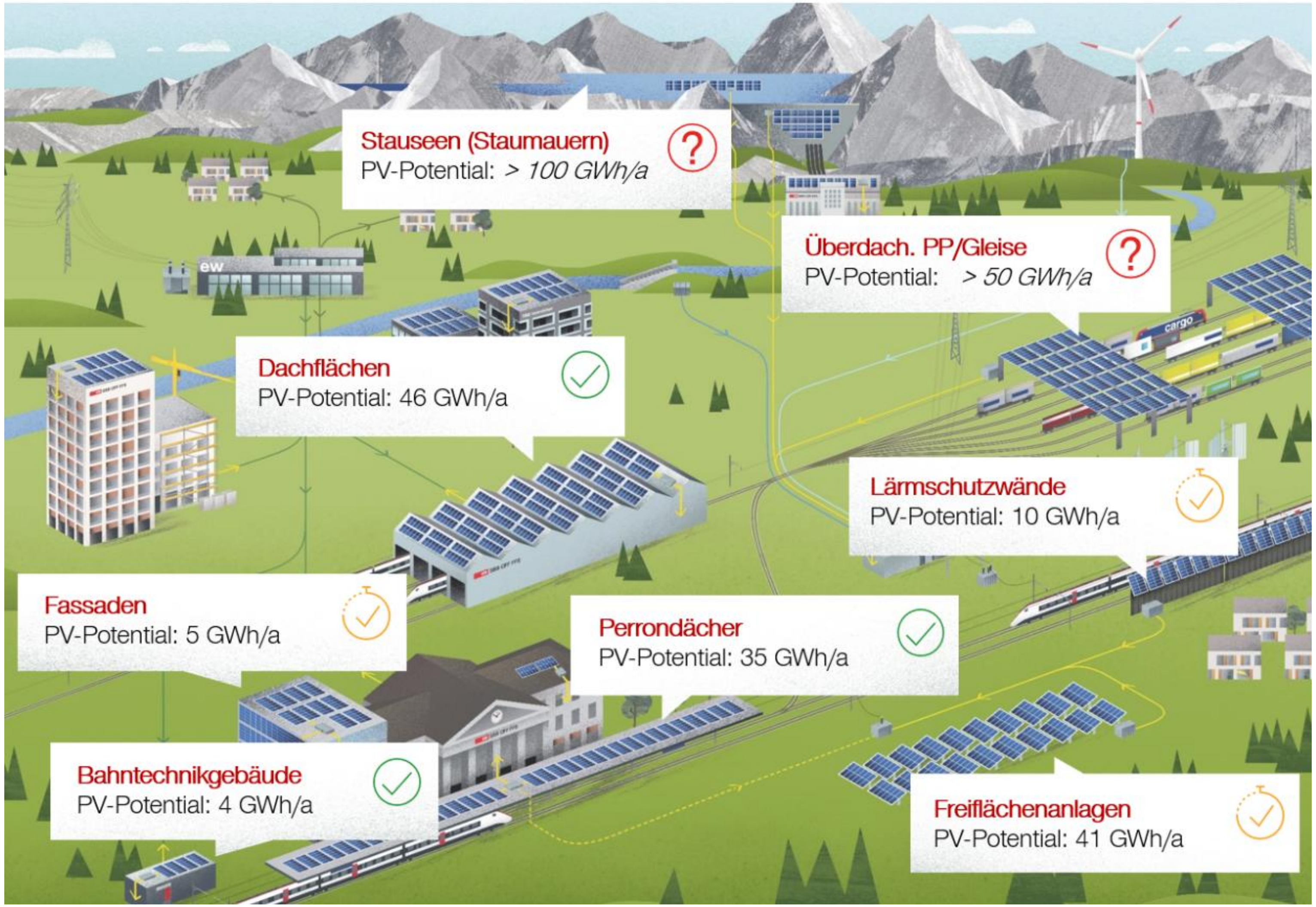
Schedule:
2010 Memorandum of Understanding between AET, Canton and SBB
2012 Submission of the concession application
2015 Approval of the Grand Council of Ticino
2015/2017 Construction project
2018-2027 Realization
2027 Commercial operation

Ritom

pressure shaft, inclined shaft, horizontal tunnel



Potential for photovoltaics.



Implementation

Piloting

Analysis

Production: SBB's PV strategy

By 2040 SBB will produce 160 GWh of PV per year on its sites — 100 GWh/year already by 2030..

Photovoltaics on buildings (50Hz household electricity)
- On-roof and roof-integrated PV systems on SBB buildings (railway stations, industrial plants,...)
- Household electricity (50Hz) for self-consumption

Buildings account for around 1/3 of SBB's PV potential

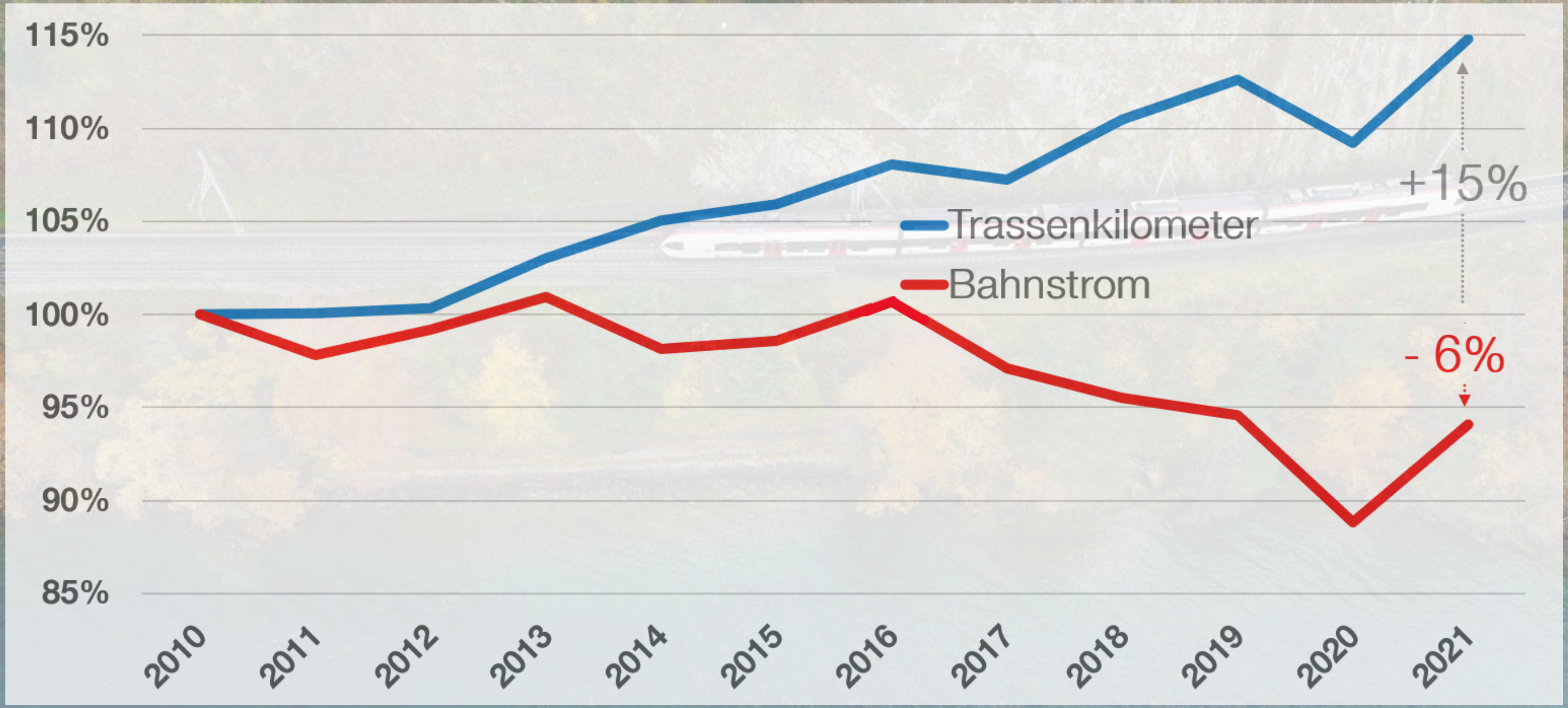
PV-LSW in Holland (ProRail)

Photovoltaics on infrastructure (50Hz and 16.7Hz)
- PV systems on platform roofs, noise barriers, parking lots/railway tracks or as ground-mounted systems, among other things
- Household electricity (50Hz) or as a direct feed into the 16.7Hz traction power network for railway operation

Infrastructures account for around 2/3 of SBB's PV potential

Consumer: Energy Efficiency

Saving energy through increased efficiency

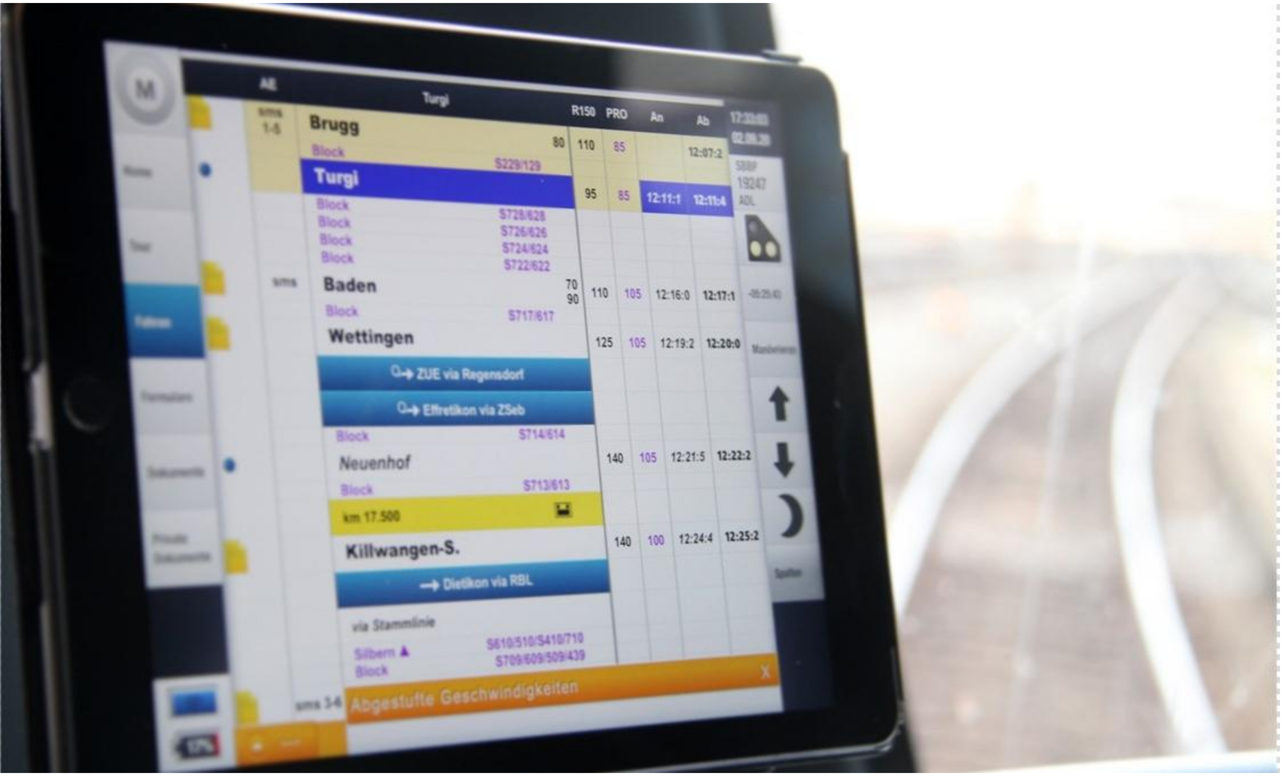


- Goal:
  - 850 GWh by 2030 (- 30% compared to 2010)
- 200+ measures already implemented, impact approx. 540 GWh by 2023
- A further 90 measures identified and evaluated
- Savings from 2030 currently expected to be around 811 GWh per year

Driver assistance: An intelligent dispatching layer provides speed recommendations to the train drivers.

Examples of promoting energy efficiency in railway operations:

Assistance systems for train drivers



- Adaptive steering

  (prevent deviations from plan, stops before red signals)

  → -70 GWh/year
- Optimized driving profile vPRO (based on daily updated information)

  → -50 GWh/year
- Train driver Cargo sees live information from the dispatch department (Timetable situation)

  → -10 GWh/year

IT project "Green wave for the locomotive driver":

With ADL, SBB IT is making a significant contribution to SBB's energy-saving targets.

Without ADL:

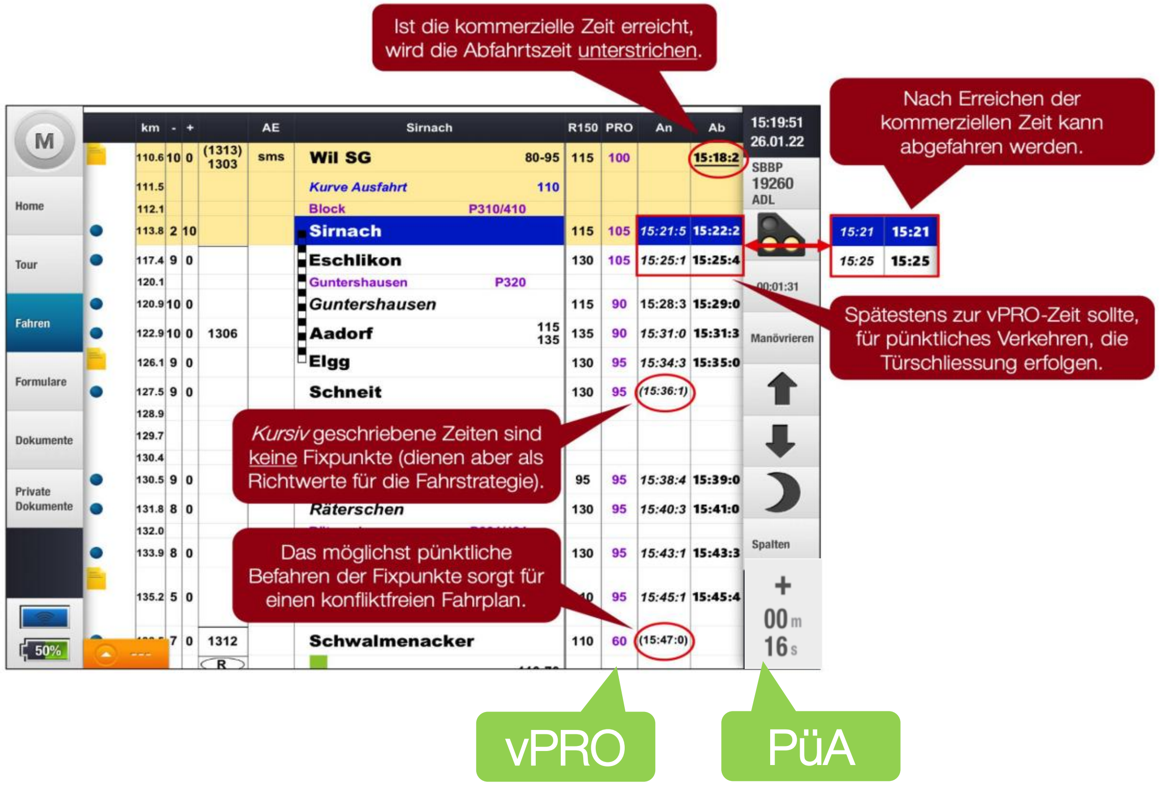
Energy consumption: 350 kWh,
Travel time 651 s

With ADL:

Energy consumption: 204 kWh, -40%!
Travel time 626 s

Driver assistance.

The production plan from the dispatching layer is transmitted to the driver's cab as a driving recommendation.



Gradual further development
from **ADL** (adaptive guidance, from 2016),
via **vPRO** (time/speed based on plan information, 2021),
to **PüA** (punctuality display at transit points, 2023).

With vPRO, locomotive crews receive **more precise planning information** on time and speed, which **they** can use to **drive more precisely.**

With the **experience of the driving staff** and these **precise details**, **unnecessary conflicts** are **avoided.**

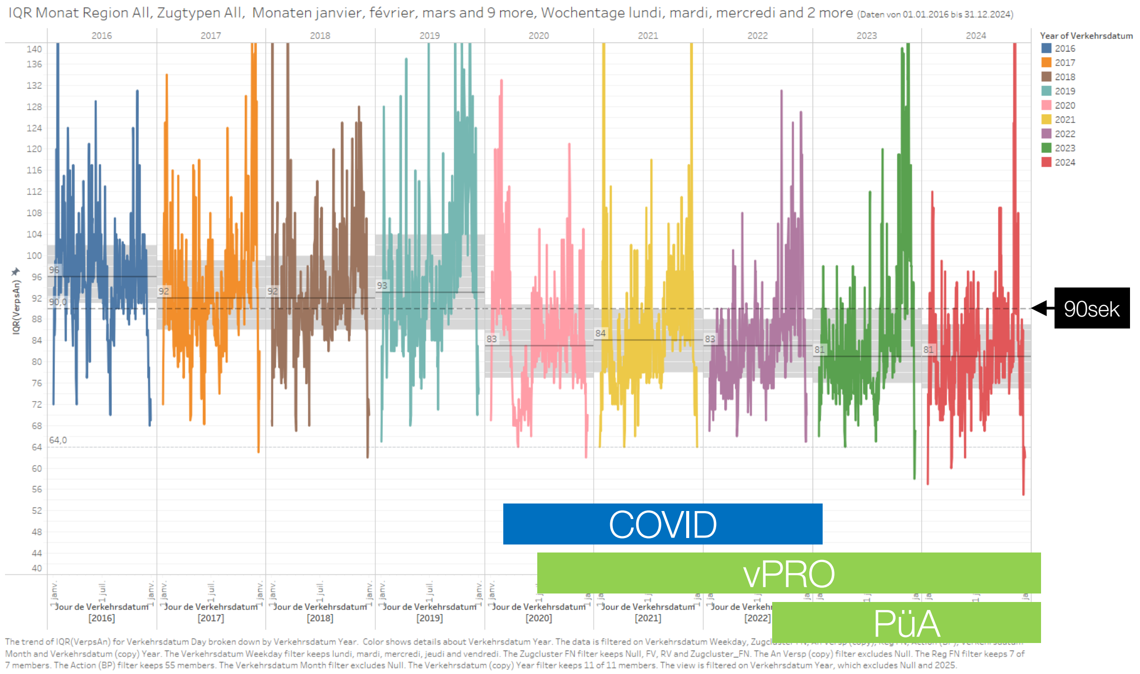
This leads to a mostly green wave, a more relaxed journey, more **punctuality in relevant junctions** and ultimately **less wear and tear and energy consumption.**

Driver assistance.

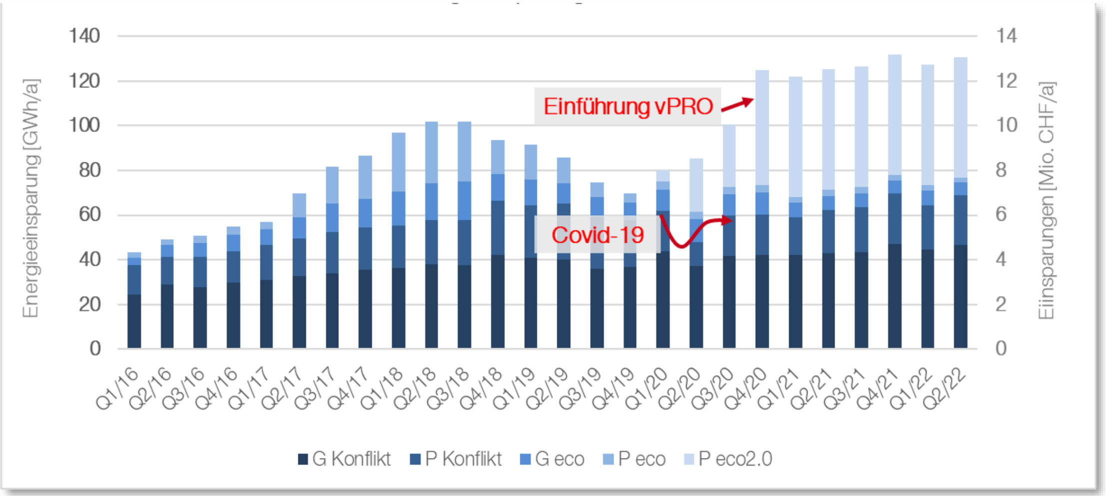
The more precise execution of the production plan has a positive effect on stability (punctuality) and energy consumption.

Stability: **Dispersion of** train arrivals (Monday-Friday) in the months Jan - Apr at an **all-time low**.

vPRO = time/speed based on plan information
PüA = Punctuality displayed (Pünktlichkeitsanzeige)



Depending on the route and rolling stock, the energy requirement will fall by 2 per cent to 4 per cent in the RV and between 1 per cent and 3 per cent in the FV. **Reduction in annual energy requirements by a good 50 GWh.**



Train driver feedback on punctuality display

- ...the tool is excellent for orientation. Good overview and not distracting. Good for everyday use.
- The feedback has been very positive. Most Lf find it very supportive. Few wish that PüA could be switched off.

Examples of promoting energy efficiency in railway operations:

Load management: Smarter control

- Smart control for more efficient energy use
- Load peaks occur only for a short time and are steep
- Short-term shutdown of wagon heating and point heating

Examples of promoting energy efficiency in railway operations:

Snooze operation and energy-optimised shutdown

- Saves heating energy when the trains are not in use
  → -61 GWh/year)
- Passenger trains run 8-12 hours per day
- Train detects shutdown automatically (standstill and lights off)
  → -50 GWh/year
- Or receives operating times directly from the vehicle planning (remote control)
  → -11 GWh/year

Renewable Energy

SBB passenger transport is 100% electrified, but around 1000 special vehicles are still powered by fossil fuels.

9 %

Firefighting and rescue trains

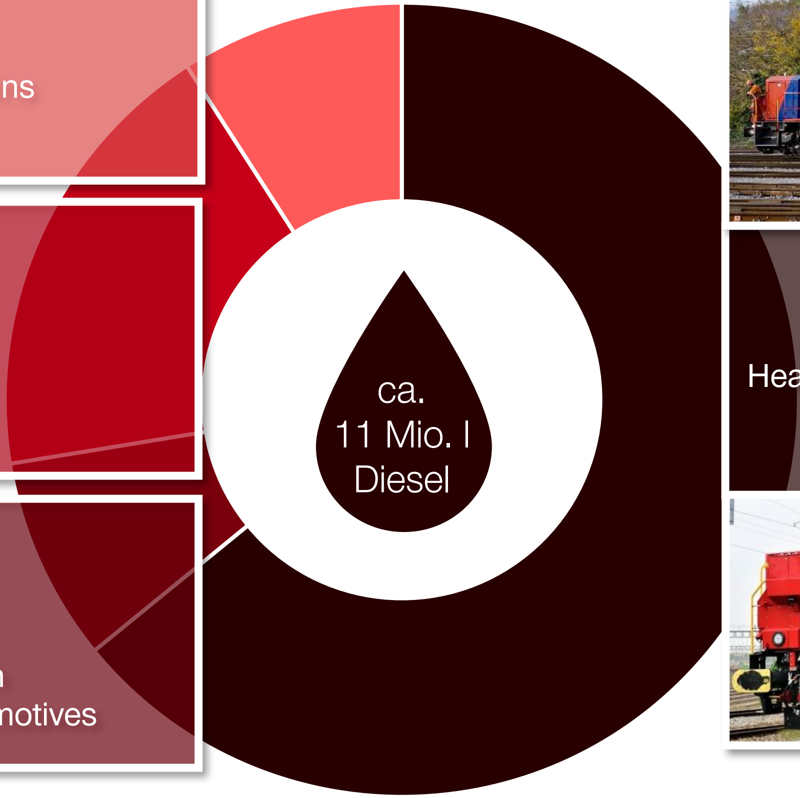
14 %

Construction site and maintenance vehicles e.g. Tm 234-x

9 %

Other

e.g. service vehicles with generators, light shunting locomotives

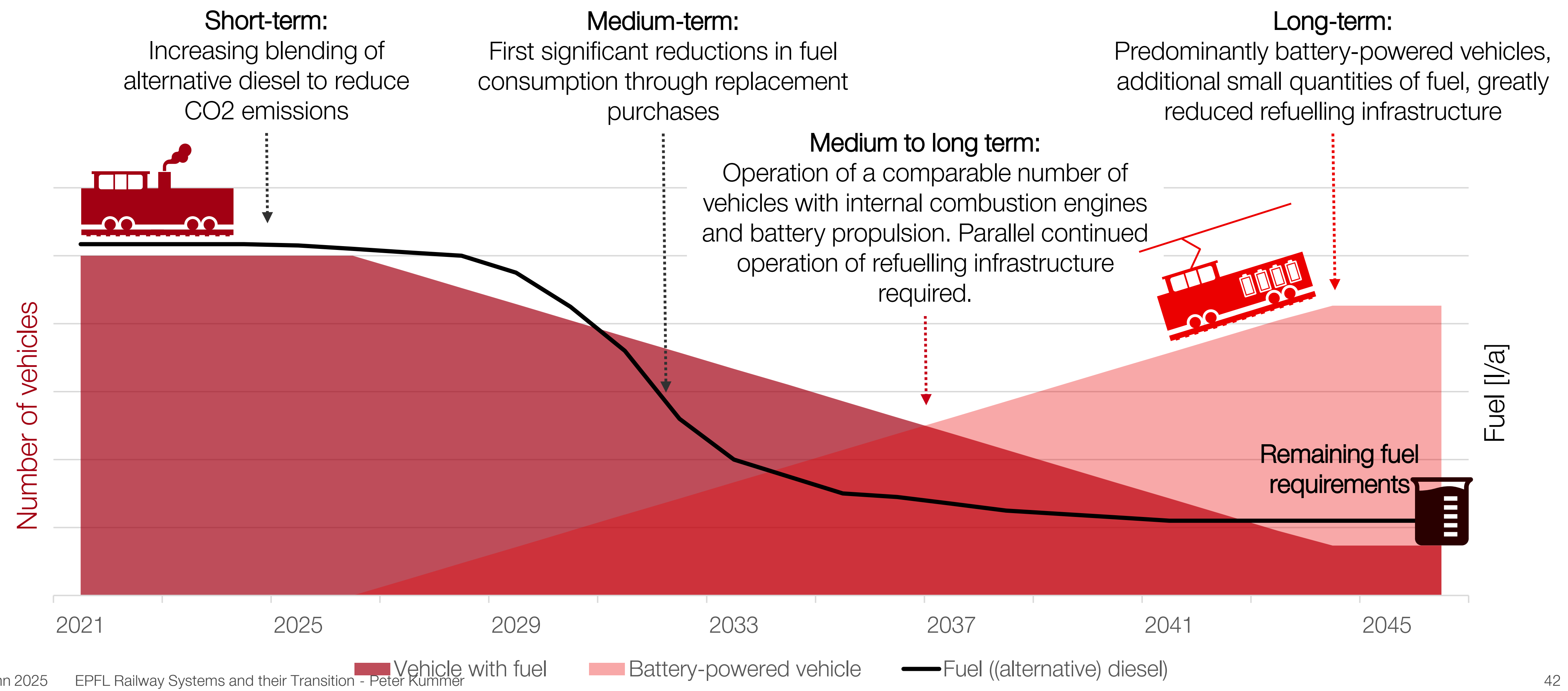


68 %

Heavy shunting locomotives e.g. Am 843

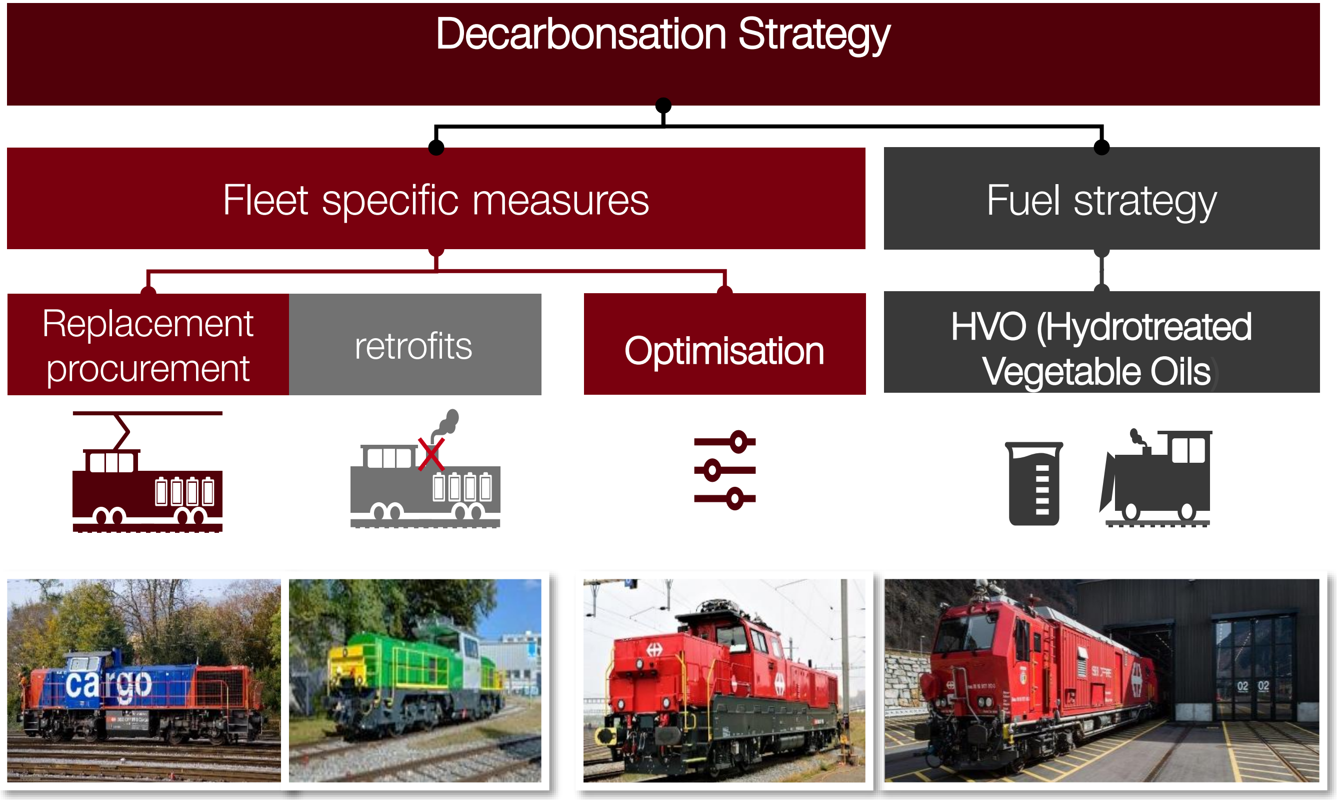
Challenge: Transition phase

Electrification of diesel-powered rail vehicles



Decarbonisation Strategy.

Focus on replacement procurement – Fuel strategy only for vehicles with very low operating hours



Decarbonisation as an overarching goal

1. **HVO (Hydrotreated Vegetable Oils):** As a transitional technology and for consumers with very low operating hours such as snow blowers or applications that are difficult/expensive to electrify (powered by paraffinic diesel)
2. **Optimisation** as a cornerstone for all existing vehicles that will remain in service for longer.
3. Conversions or **retrofits** are not a priority due to project risks and changing requirements.
4. **Replacement** procurement as the most effective long-term decarbonisation measure.

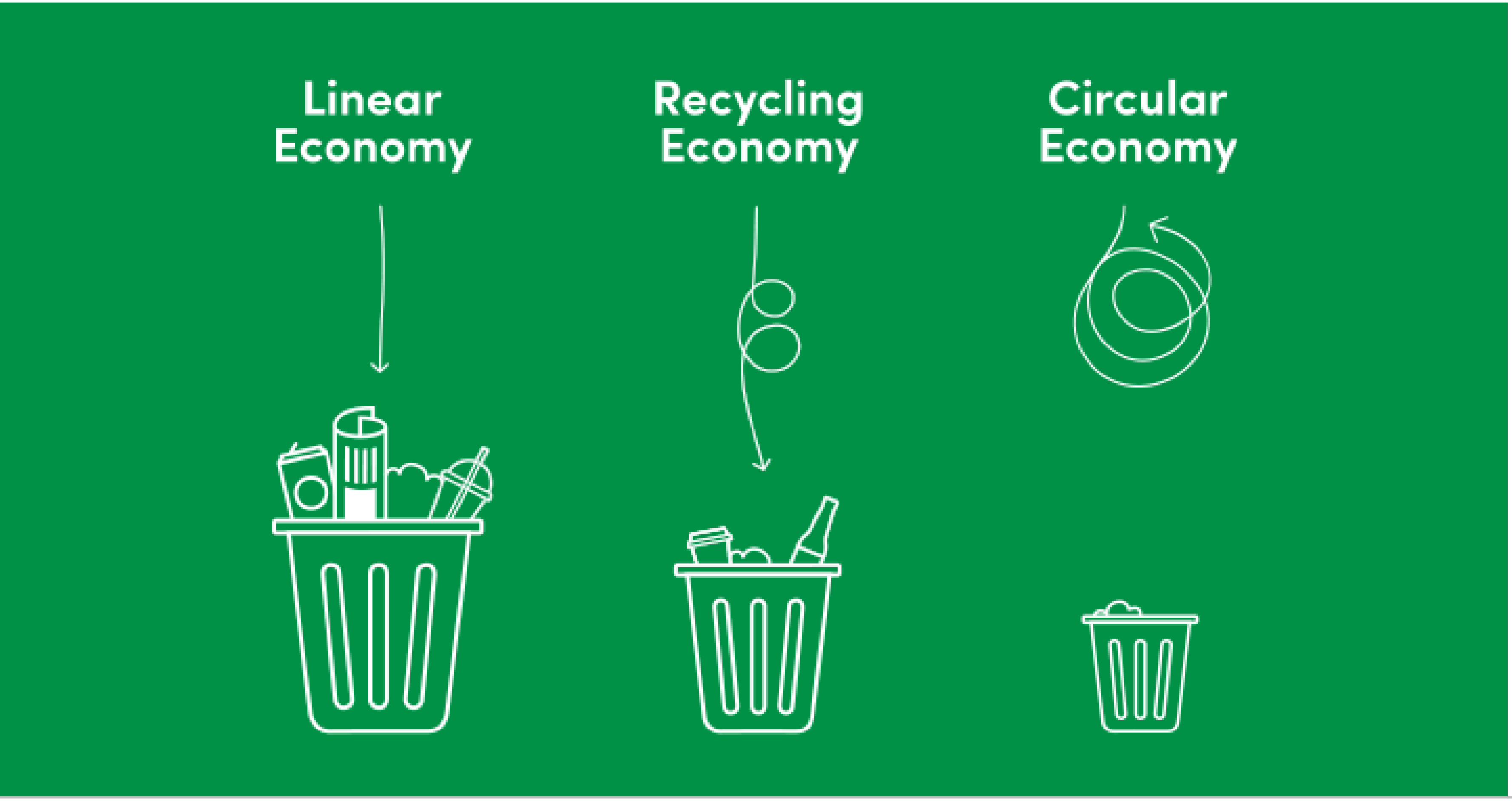
How does SBB reduce its emissions?

The main levers are:

- Promotion of **circular economy**
- **Sustainable procurement**

Circular Economy

Circular instead of linear—conserves resources and avoids emissions!



The 10 R Model:

1. Refuse
2. Rethink
3. Reduce
4. Reuse
5. Repair
6. Refurbish
7. Remanufacure
8. Repurpose
9. Recycle
10. Recover

Efficiency & Circularity

How do we actually reduce indirect CO2 emissions?

By implementing a circular economy in the rail system. Specifically, as follows:

Efficiency & Circularity

The Circular Economy Model:
Less Raw Material → less Waste → less Emissions

The earlier measures are taken in the cycle, the greater the leverage effect throughout the entire cycle:

1) **Promote sufficiency:**
   - Rethink design & reduce Raw Material
   - Ensure modularity
   - Enable reparability
2) **Promote the use of secondary materials:**
   - Increase the proportion of recycled materials in the product
3) Exploit the life cycle
   - Keep products in use for as long as possible
   - Reuse products
4) Recycle materials in a circular manner
   - Dispose of correctly and break down into their components
   - Return materials to the cycle

The circular economy is also a business case: In the rail system, for example, more ballast has already been laid than can ever be extracted.

Source: European Parliament Research Service (2023)

Examples Circular Economy

Several measures exist, but there is still a lot of potential.

Gravel cleaning, in-situ or with mobile cleaning system. Share of ballast cleaning must increase due to scarce availability.

Refurbishment of catenary material – "as good as new". High savings potential for standardised parts. Scale to all assets.

Breaking "old" SBB concrete sleepers with 40% **recycled concrete content** in new production. Improved environmental balance and resource conservation.

Standards adapted to **recycled asphalt** for platform construction. Reduce environmental impact by a quarter, business case neutral.

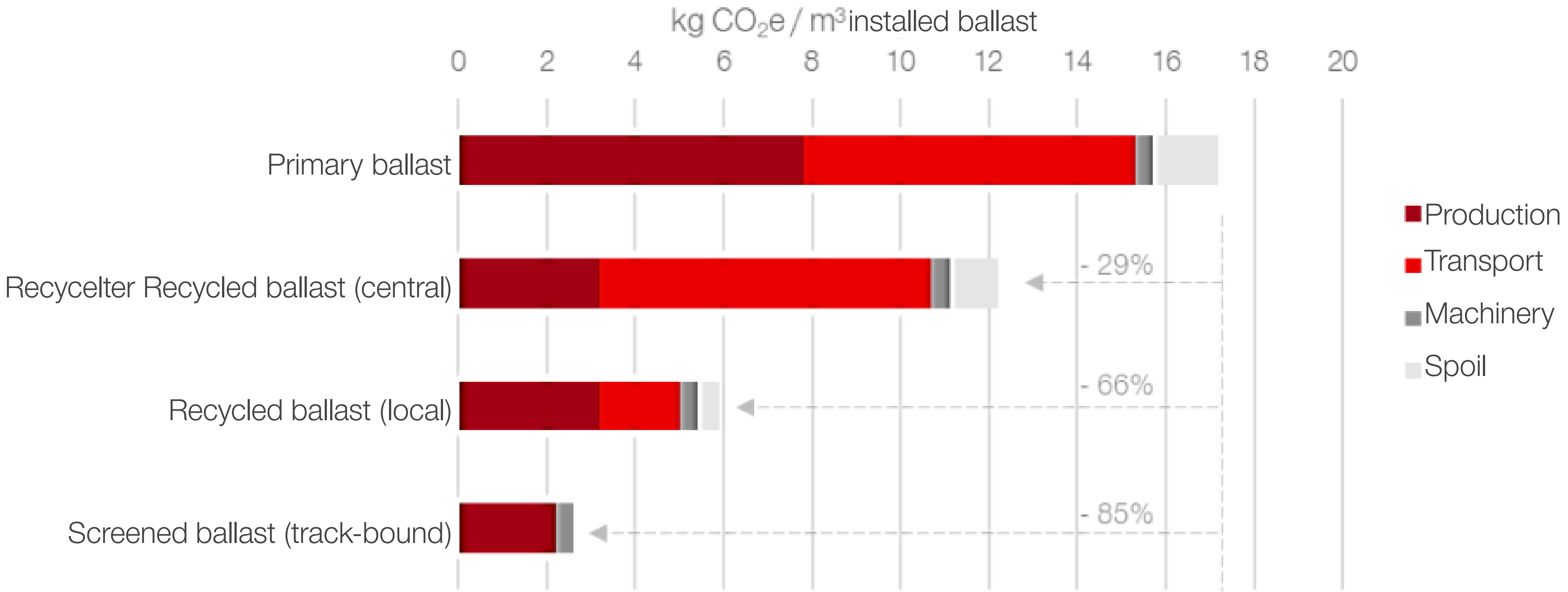
CO2-reduced rails: CO2 footprint integrated as an award criterion in the 2024 tender. Saarstahl supplies rails made of secondary steel.

Refurbishment of rails: Reusing used rails when changing rails or in side tracks is also financially worthwhile.

Example: Ballast cycle

- **More ballast in place than can be quarried** — inventory classification needed.
- **Reuse** of ballast = business case.
- Quality: May be **inferior** to new ballast → define application zones (ballast classification).
- Must be **chemically clean** according to regulations.
- Permissible fractions: rounded/unsuitable grains limited.
- Processing: **mobile on site** or at the ballast plant.
- Recovery mobile on site = first choice (efficient, ecological, sustainable).
- **Logistics: rail first.**
- **Supplier: product qualification required**

Example: Ballast cycle - greenhouse gas emissions.



Sustainable Procurement

Sustainable Procurement for the rail system

Railway companies are subject to public procurement law

Public procurement law summarized:

Above a certain procurement volume — and depending on the object of procurement — companies must carry out a public tender.

1) Non-discriminatory
2) Anyone may apply, provided they can meet the mandatory (MUST) criteria.
3) The contract is awarded to the most advantageous offer" (BöB/VöB)
4) Quality is therefore also evaluated, not just the price.
5) Tenders will be published on Simap

Components of a Tender

Award Criteria (Optional)
- Competition according to the evaluation system
- Sustainability is a quality criterion

Technical specification (mandatory)
- Technically mandatory to fulfill;
- otherwise exclusion from the tender

Minimum Criterion (mandatory)
- Mandatory to meet at minimum;
- otherwise exclusion from the tender

Suitability Criteria (mandatory)
- Mandatory to fulfil;
- otherwise not admitted to the tender

Contracts (mandatory)
- Not procurement-relevant,
- contains service agreements such as disclosure of diesel consumption data

Example of Award Criteria.

	Award Criteria	Proof	Weighting	Max. Credits
AC1	Price	P: Completed price sheet	60%	300
AC2	Quality assurance in production	P: Verification in accordance with section 3of the QSV through documents, processes, etc.	25%	125
AC3	Transparent supply chain	P: : Legally valid signed form. Disclosure of the supply chain using the“ Transparent Supply Chain” table; only fully completed forms will be considered in the assessment.	10%	50
AC4	Share of renewable energy in the production of XXXX	P : Confirmation/certificate from third parties (e.g., energy supplier)or proof of own production (e.g., when using waste heat from the manufacturing process or own photovoltaic system)	5%	25
Total Credits			100%	500

Example: Sustainable Procurement of Rails

How we reduce emissions from rails by 50% by 2030.

When procuring products, there are two levers that can be used to reduce emissions:

Purchased material *(t / Jahr)* × **CO2 - Intensity** *(CO2-eq / t)*

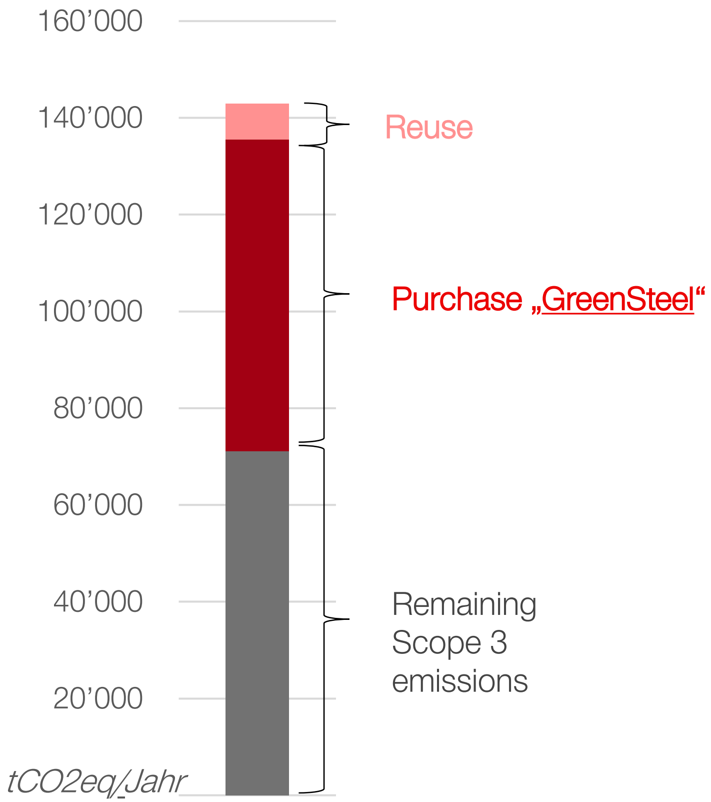
Purchased material

- Check the reusability of materials within the system before purchasing new goods (recycling, reuse).
- Avoid excess: Create quantity structure based on actual material used

CO2 - Intensity

- Increase the proportion of recycled material
- Ensure reusability
- In this case: "Green Steel" label as a requirement

Example: Rails: Reduction potential by 2030



Example: Sustainable Procurement of «signal box»

Repairability as a Business Case:

- Must-have: **Modularity** of key components (maintenance*)
- Award criterion in tenders:
    - Share of **repairable** parts (including price details for replacement and repair)
    - Description of the **repair process**
- Scoring: Supplier offering the highest repairability rate receives the highest score

*reduce lifecycle costs, increase availability, enhance sustainability.

Impact on Procurement

- Repairability* proved cheaper than replacement in all cases and, following the specified repair processes, ensured better and faster maintenance compared with product replacement.
- Prices for "repairable" vs. "replace" were integrated into life-cycle cost planning.
- Circular economy thus became a viable business case.

*Enables cost savings, faster turnaround, and supports sustainability goals.

Result

- The supplier offering the highest repairability rate won the contract.
- That offer was also the most cost-effective.
- Economic performance, climate targets and business outcomes were optimized by requiring circularity of the system.

Sustainable procurement, as shown by circular-economy requirements, can deliver long-term cost and emission savings.

Source SBB: SBB: Neue digitale Stellwerke ab 2029 | SBB News

How can Emissions be reduced?

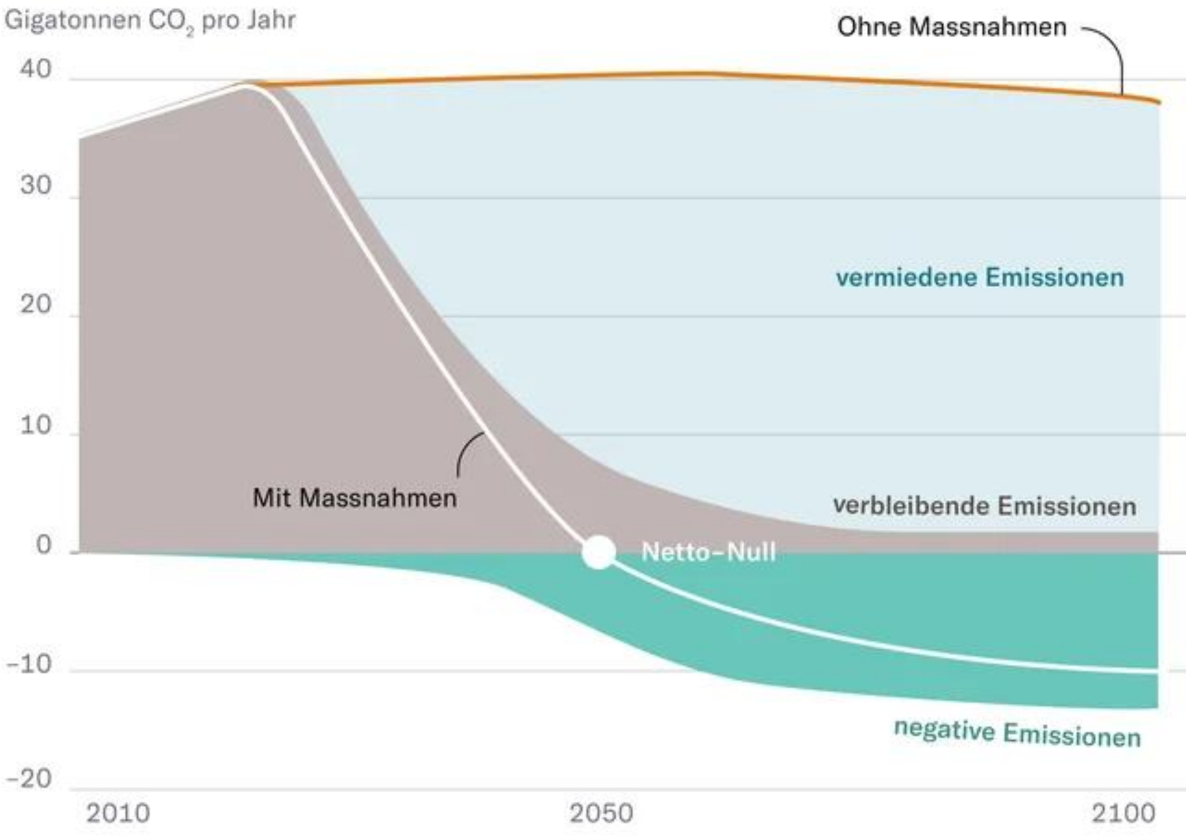
The main levers are:

Use of **negative emission technologies**

Negative Emission Technologies (NET)

What role do NET play in the decarbonization strategy of the railway system?

Net zero definition



Quelle: NZZ, 2021.

Net zero = CO2 concentration remains constant

3 processes for net zero:

1. Emission reduction
2. Emission prevention
3. Emission offsetting with CO2 removal

How CO_2 removal works

1. Step
   - Remove CO_2 from the air and turn it into a stable, transportable form.
2. Step
   - Permanently store CO_2 removed from the air.

Step 1: CO_2 removal – three ways

Grow plants (afforestation), weathering, direct air capture technology

Direct Air Capture & Carbon Storage DACCS

Most negative emissions come from biochar and Bio-Energy with Carbon Capture & Storage (BECCS), but some technical approaches also exist — price matters

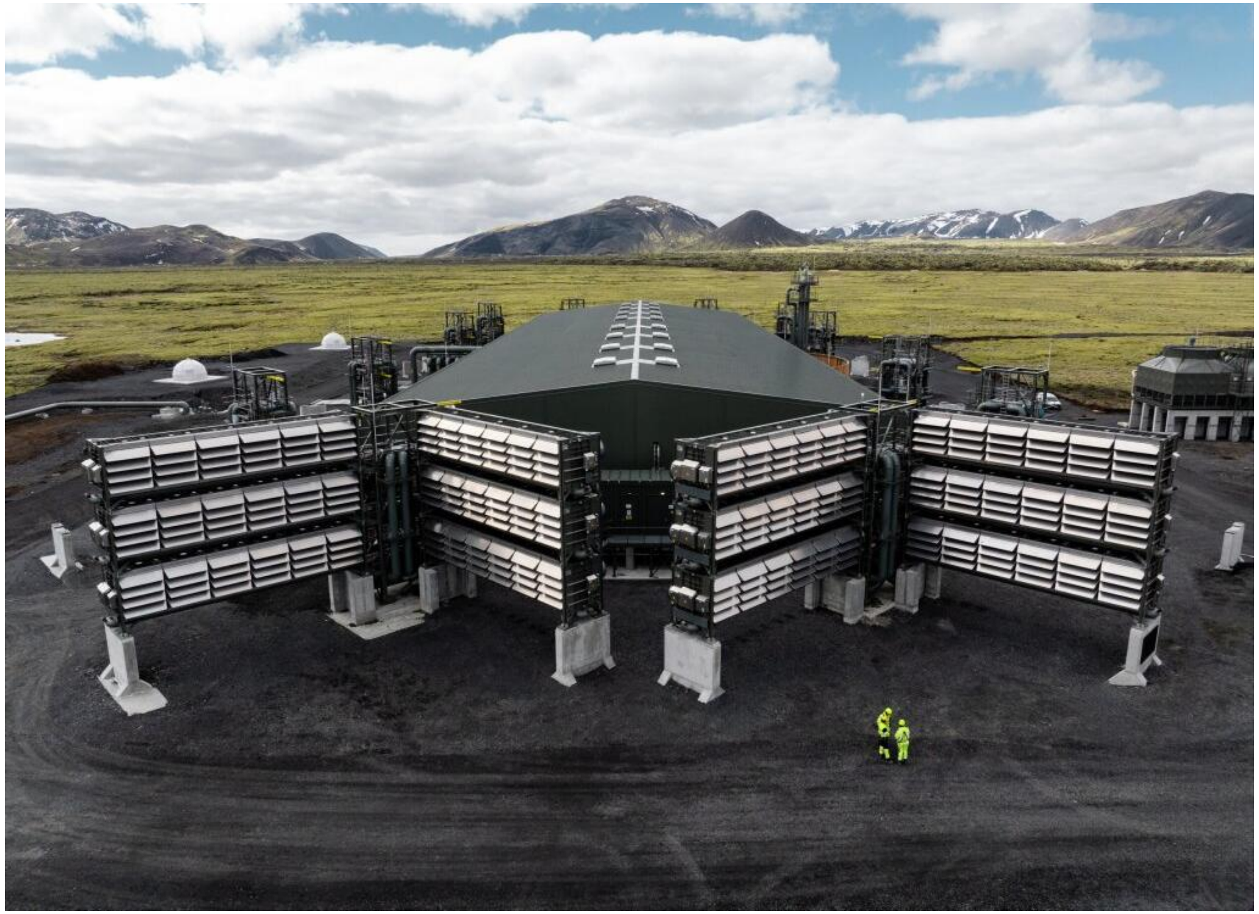


Image: Mammoth, climeworks.com

How it works :

- DACCS = Direct Air Capture & Carbon Storage Chemical filters remove CO_2 from the air. This process is very time-consuming, as the concentration of CO_2 in the air is only 0.0421%. The CO_2 is then stored in geological reservoirs or similar.

Step 2: CO_2 storage – Example Biochar

- Biochar = plant charcoal
- Plants remove CO_2 from the atmosphere for growth
- Pyrolysis of biomass (thermal decomposition in the absence of oxygen)
- CO_2 is stably stored in biochar.
- Storage of biochar:
  - agricultural soils
  - concrete (as an additive)

Possible use of biochar @ SBB

Advantageous cost per storage capacity

- Storing 200kg of CO_2 per tonne of concrete
- 30,000t of concrete per year for building construction stores 6000t of CO_2

Numbers based on estimation by klark.swiss

Conclusion: How does SBB reduce its emissions?

The main levers are:

- Increasing **energy efficiency**
- Increase in the share of **renewable energies**
- Promotion of **circular economy**
- **Sustainable procurement**
- Use of **negative emission technologies**

In the Future

Conclusion

Conclusion

- Train causes **20x less emissions** than an electric car
- Nevertheless, we must not rest on our laurels:
  - **Indirect emissions** from construction activities and material consumption **are 15x higher than direct emissions**
- Levers are:

1) Increasing energy efficiency
2) Increasing the share of renewable energies
3) Circular economy
4) Sustainable procurement