Energy-, Steam- and Fireless Technology

1. The importance of the steam engine
2. Industrial steam is indispensable
3. Advantages of steam technology
4. Current energy policy in Europe
5. Mobile thermal energy storage
6. Combined heat and power CHP
7. Combined heat and mobility CHM

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1. The importance of the steam engine in the history of the world

The steam engine is one of the most important inventions. It enabled industrialization and considerably accelerated land and sea transport:

1. Wheel

2. Book printing

3. Light bulb

4. Steam engine

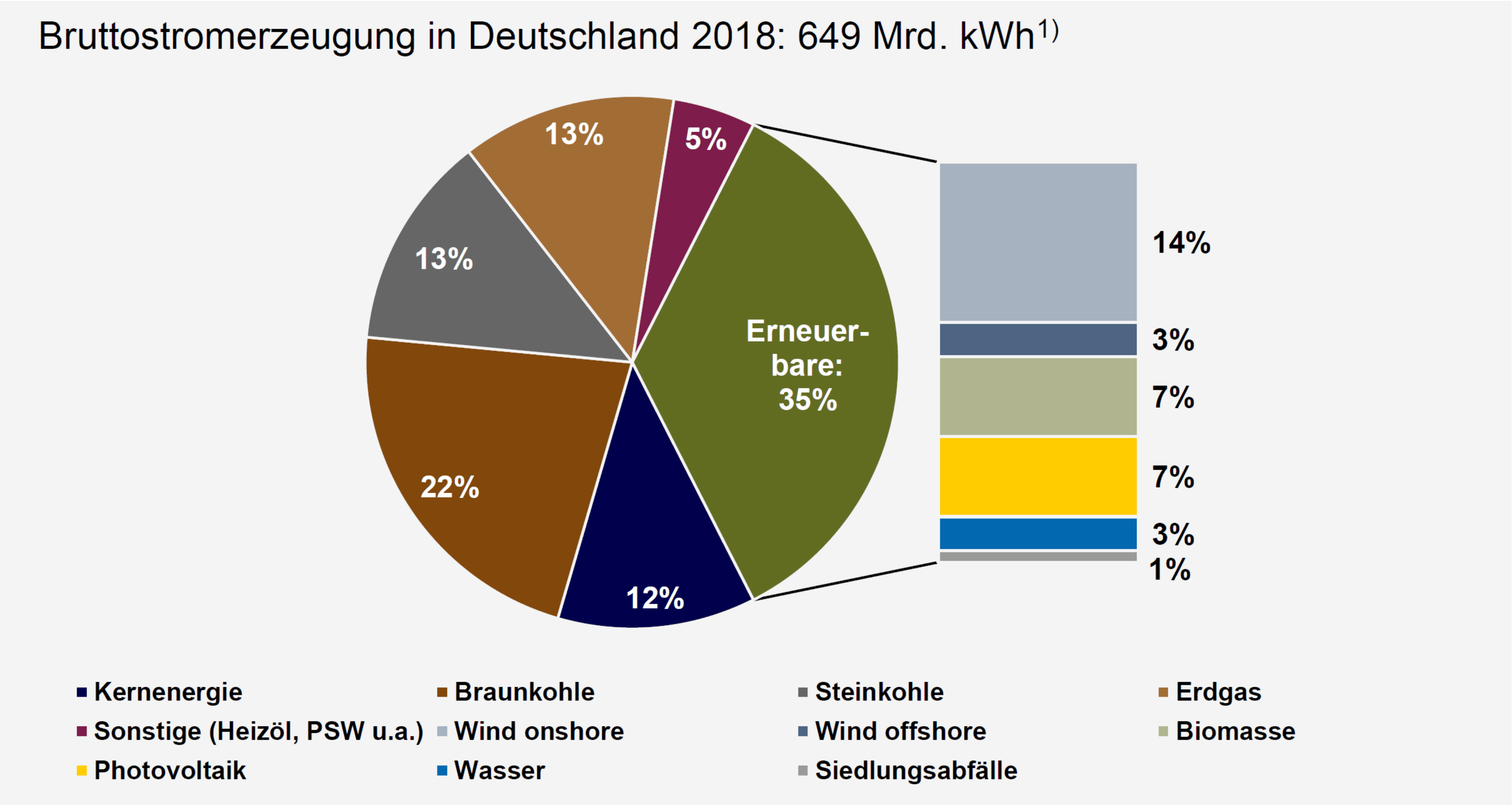
10. Combustion engine …. 12. Internet 13. Car

34. Ship …. 37. Airplane …. 39. Electric motor

40. Mobile phone …. 66. Steam turbine

Developed in 2013 by a team of experts on behalf of *Popular Mechanics* USA

2. Industrial Steam is indispensable



Nuclear energy, coal, biomass and municipal waste produce steam, which in turn generates electricity by means of steam turbines. In Germany, around 70% of the electricity is generated by steam power. Electro-mobility cannot be realized without steam technology.

3. Advantages of Steam Technology

- **„All “ fuels and energies can be used:**
  - **Coal (lump coal, briquettes, dust; hard coal, lignite, anthracite)**
  - **Oil (heavy oil, light oil, waste oil, organic oil)**
  - **Gas (natural gas, CNG, LNG, biogas, Kompogas)**
  - **Biomasse (wood, pellets, bagasse, Chinese reed, peat)**
  - **Waste and waste heat, geothermal, solar thermal, wind energy**
- **Direct drive without clutch and gearbox**
- **Independent of catenery, no system failures**
- **Robust, reliable, no or few electronic devices**
- **Silent if condensation or storage technology is used**
- **Large storage capacity (hot water under pressure)**
- **Huge development potential**

The following six slides show steam locomotives and steam ships with CO_2-neutral biomass firing

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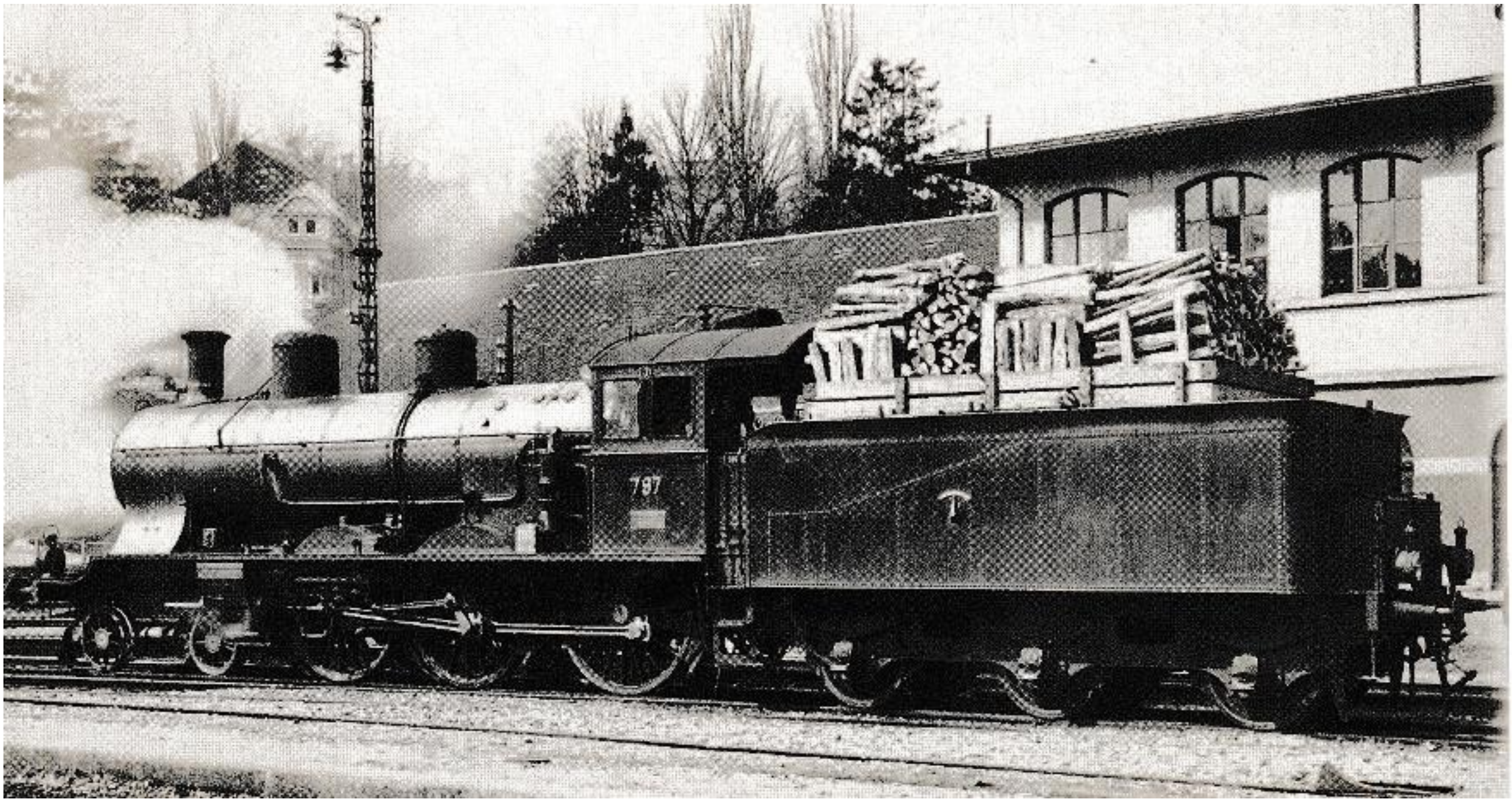
SBB's type A 3/5 with wood firing



During the war, Swiss Federal Railways SBB fired some of its steam locomotives with wood instead of coal, without any major modifications.

Steam Locomotives with Bagasse Firing at Sugar Factories in Indonesia and Cuba

When pressing the sugar cane for sugar production, bagasse is produced as a by-product. Its use as a CO_2-neutral fuel for the sugar mills and for the steam locomotives of the mill railway is ecologically exemplary and sustainable. You get 34 t of bagasse from 100 t of sugar!

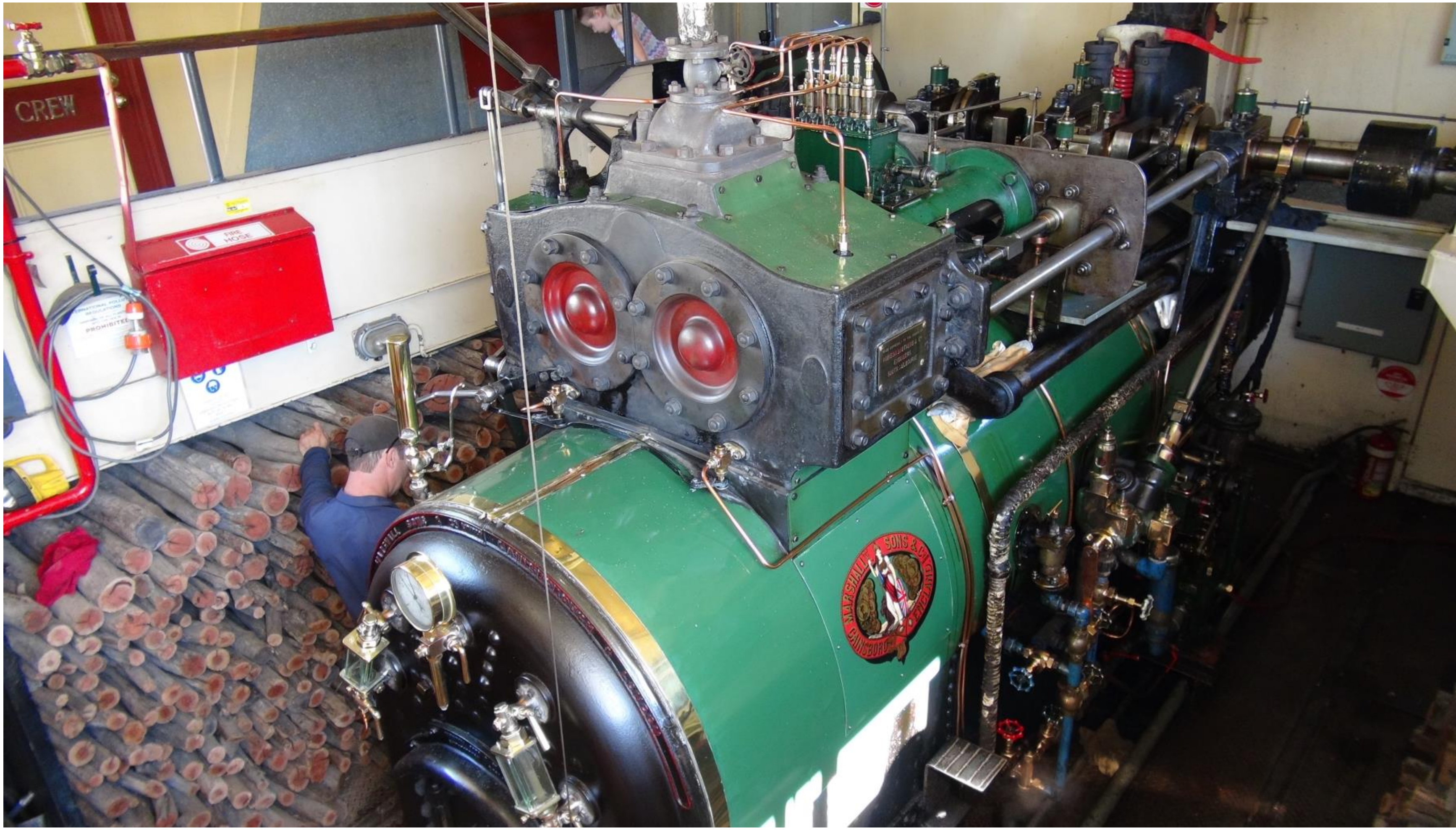
Wood-fired Steam Locomotives of the Benguela Railway in Angola

In Angola even the large, very powerful Garratt steam locomotives were fired with CO_2-neutral eucalyptus wood. The railway's own forests were sustainably managed. Only as much wood was harvested as grew back. The diesel locomotives used today are neither ecological nor sustainable and certainly not CO_2-neutral. Is this progress?

Australian Paddle Steamers…

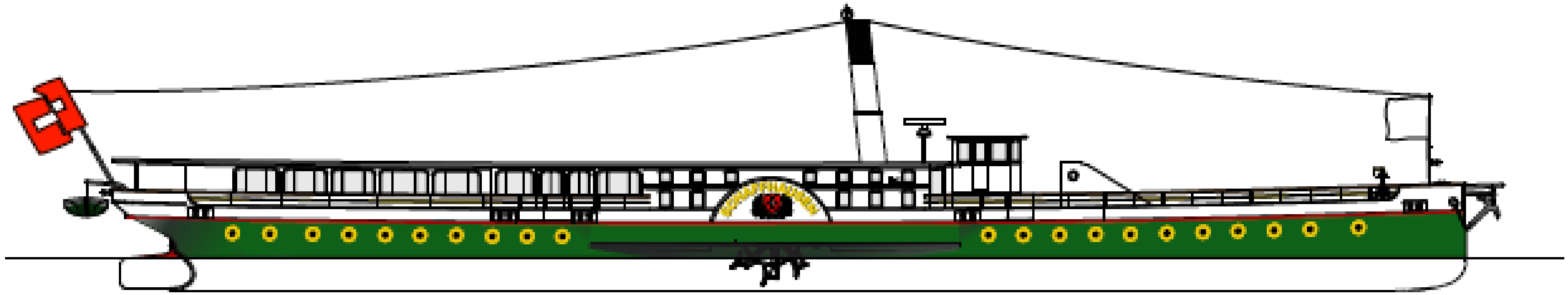
The many paddle steamers that operate on the Murray River are all fired with eucalyptus wood. While the steam engine is operated from the bridge by the captain, the only engineer on board is acting as a fireman.

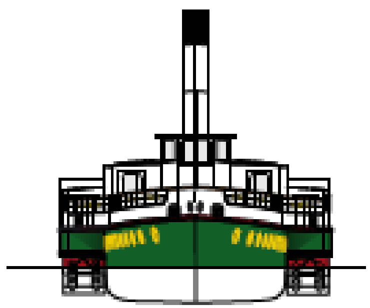
... have Wood-firing



The steam engines of Australian paddle steamers are saddled on the boiler, similar to steam rollers. The wood supply can be seen on the left.

New Paddle Steamers





with CO_2-neutral Pellet firing

DLM is working on the propulsion system for new paddle steamers, which for economic reasons will have an automatic boiler and a new, remote-controlled steam engine (equal manpower requirements compared to a motor vessel). For ecological reasons, pellet firing is planned.

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4. Current Energy Policy in Europe

- Promotion of electrical heat pumps
- Promotion of electric mobility
- Promotion of digital technology
- Promotion of block chain technology, Bitcoins

► Increase in power consumption

- Abandonment of nuclear power plants
- Abandonment of coal power plants
- Resistance to wind power plants
- Resistance to power lines

► Decrease in electricity production

Where will electricity come from in the future?

Volatility of renewable Energy

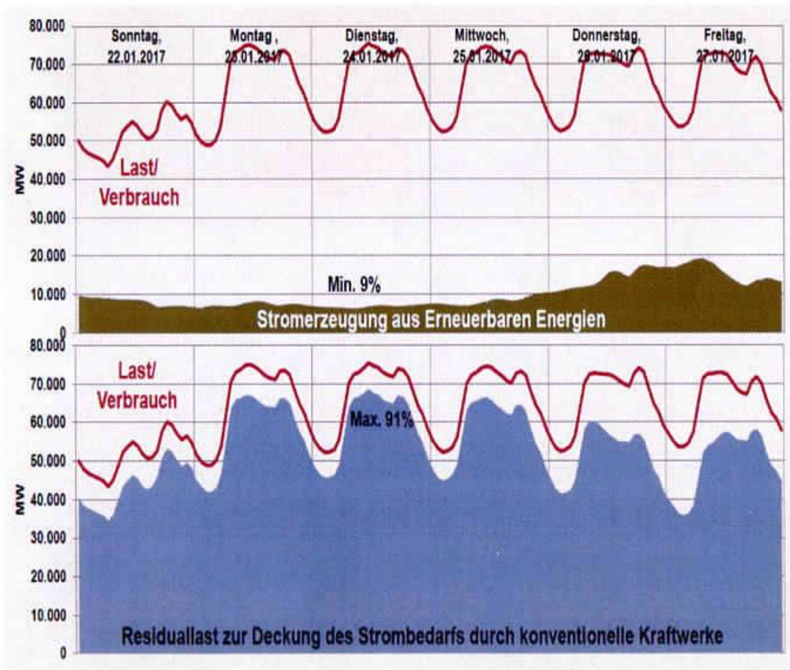

Abb. 3: Volatilität der Einspeisung aus EE – niedrige Einspeisung, Deckung des Strombedarfs 22. Januar – 27. Januar 2017

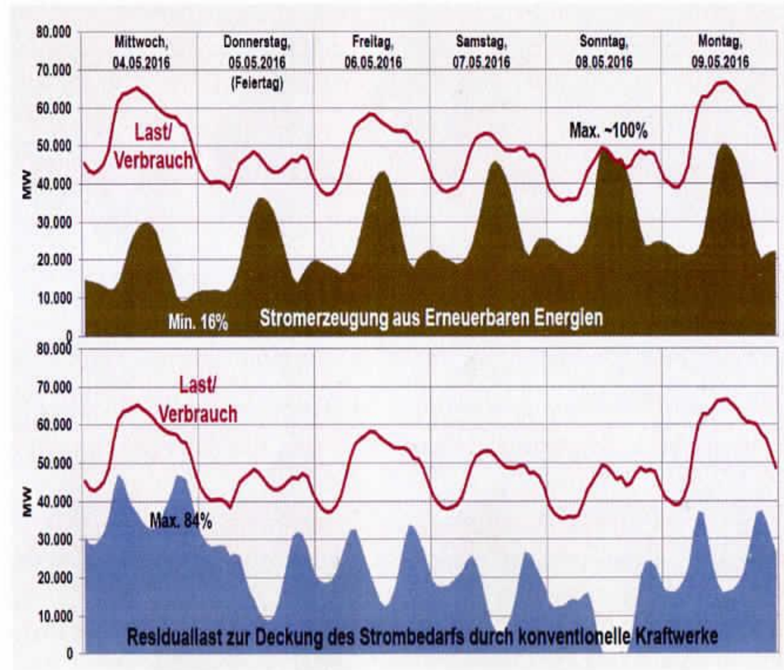

Abb. 4: Volatilität der Einspeisung aus EE – hohe Einspeisung, Deckung des Strombedarfs 04. Mai – 09. Mai 2016 [12]

The steam engine is considered the fourth most important invention because it made industry and transportation independent of the whims of nature. With renewable energy we take a step back. **The red curve shows the electricity demand**, **the brown area the electricity production from renewable energy (in the best case it covers 100% of the demand for a very short time, in the worst case only 9%)**. **The blue area shows the electricity demand that must be covered by conventional power plants**.

Power Plant GKM at Mannheim

Block 9 of the GKM went on line in 2015 as one of the most modern coal-fired power plants in the world. Steam data for steam turbines: 290 bar, 600°C; industrial steam: 20bar; electrical power: 900 MW, thereof 350 MW for the German Railways DB; electrical efficiency: 46.4%, with combined heat and power: 70%. Four fireless locomotives, charged with steam at 20 bar, pull coal trains of up to 4,000 t to the plant.

5. Mobile thermal Energy Storage

The steam storage technology for fireless locomotives uses the ability of water to store large amounts of energy under pressure.

In 1882 the first fireless locomotive was built. By 1986, around 3,500 fireless locomotives were built in Germany alone, some of which remain in service today. With the replacement of the old steam locomotives, the ingeniously simple fireless locomotives also fell into oblivion.

Modernized with today's technology, they are an efficient, economical and environmentally friendly alternative to the polluting diesel traction in local and industrial traffic.

Advantages of Steam Storage Technology

- **External energy production:**
  - ► **Waste heat, all fuels, geothermal and solar thermal energy, …**
- **Emission-free, no exhaust gases**
- **Silent in operation, noiseless at standstill**
- **No energy consumption at standstill, no idling**
- **Explosion-protected, important in chemical industry**
- **No oxygen demand, ideal for tunnel rescue**
- **Fast reload (5 - 20 minutes)**
- **Maximum torque (tractive force) from start**
- **Overloadable, unlimited energy extraction**
- **Simple, robust, reliable, low maintenance costs**
- **Long-life cycle (Battery: 5-10 years, Storage technology: 60-100 years)**

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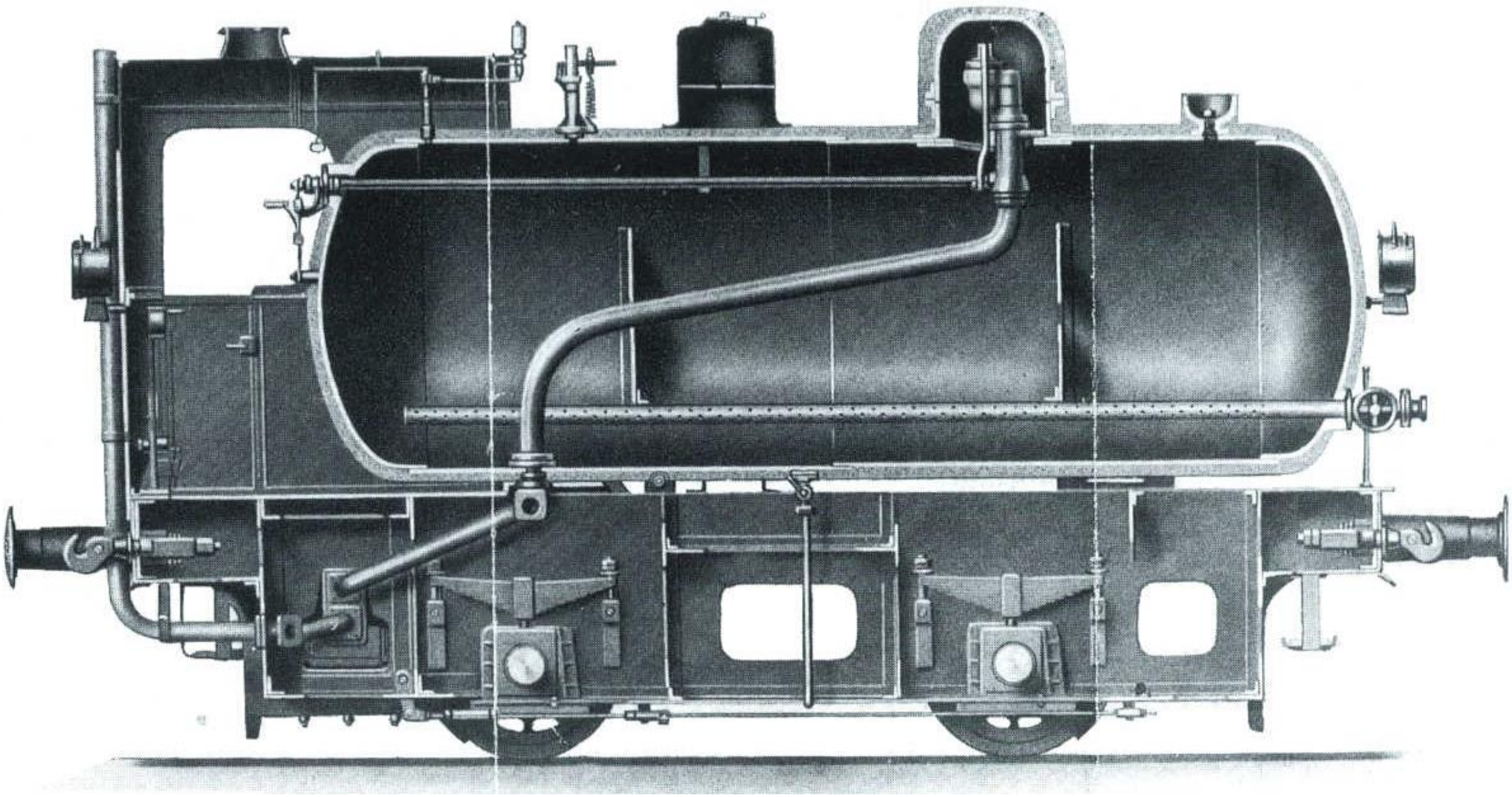
Fireless Locomotives

economical - clean - quiet - environmentally friendly - CO2-neutral

Schematic of a fireless Locomotive



Low pressure fireless locomotives have storage pressures of up to 20 bar. The steam cylinders work with saturated steam, from 20 to 8 bar with full tractive effort, from 8 down to 2 bar with reduced tractive effort.

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Refilling a fireless Locomotive

One of the two four-axle fireless locomotives of GKM (Grosskraftwerk Mannheim) at the charging station. Reloading is carried out with the power plant's own steam of 20 bar in only 15 to 25 minutes. These locomotives pull 4'000 t trains.

Disadvantages of Diesel Locomotives

Diesel locomotives used in works transport have considerable disadvantages, as the following slides show:

- **No direct drive from motor to wheel**
  - diesel-electric, -hydraulic or -hydrostatic

  ► Complex drive ► High maintenance costs

  ► 75% Idling ► Waste of energy, noise
- **Very poor emission values**

  ► Soot particle filters and catalysts necessary

  ► increases complexity, capital + maintenance costs
- **High noise level when driving and at standstill**
- **Dependance on (Diesel) oil**

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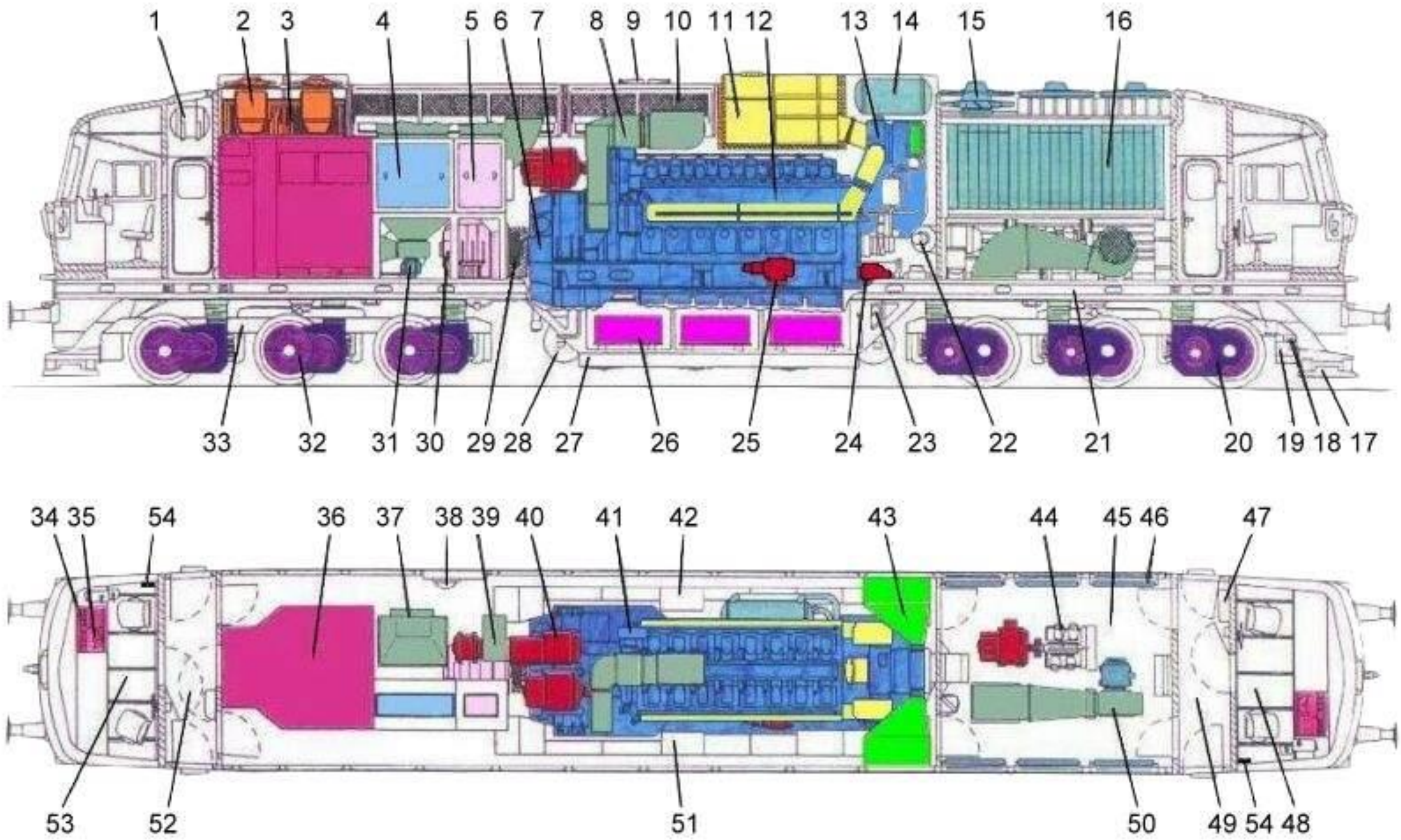
Schematic of a Diesel Locomotive



Diesel locomotives are hard to beat in terms of complexity. In practical use the "good efficiency" is not as good as advertised.

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Efficient Diesel Locomotives?

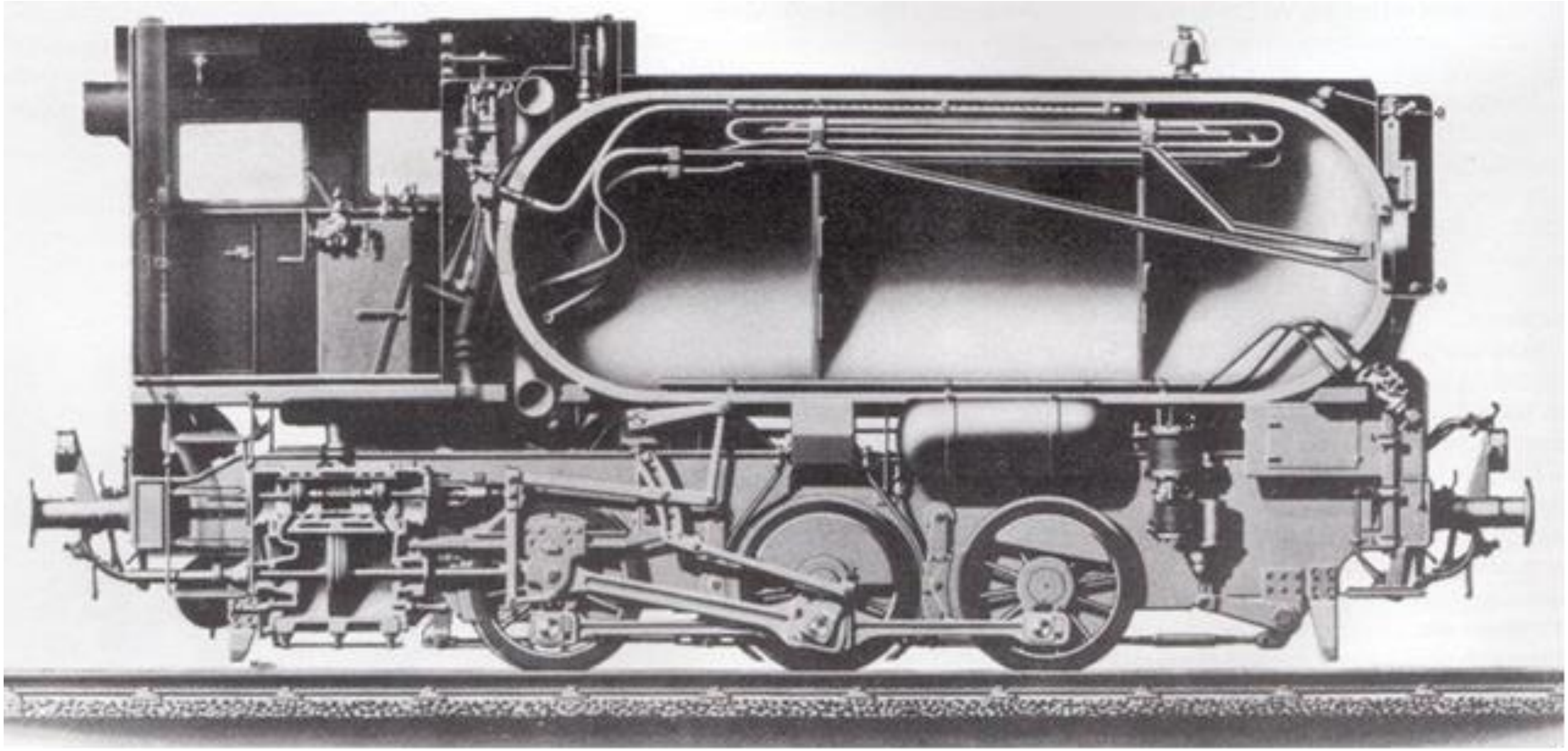
Unloading of alumina trains at Martinswerk Bergheim

- Time to unload the train: 4 Hours
- Running time of diesel engine: 4 Hours =► **thereof idling: 95%**
- Fuel consumption: 64 l = 640 kWh Cost: approx. 90.- Euro
- Lubrication oil consumption: 7 l Cost: approx. 20.- Euro
- Shunting work approx. 10 kWh =► **Efficiency: 1.6% !!**
- **Fireless locomotives do this more efficiently and for a fraction of the costs**

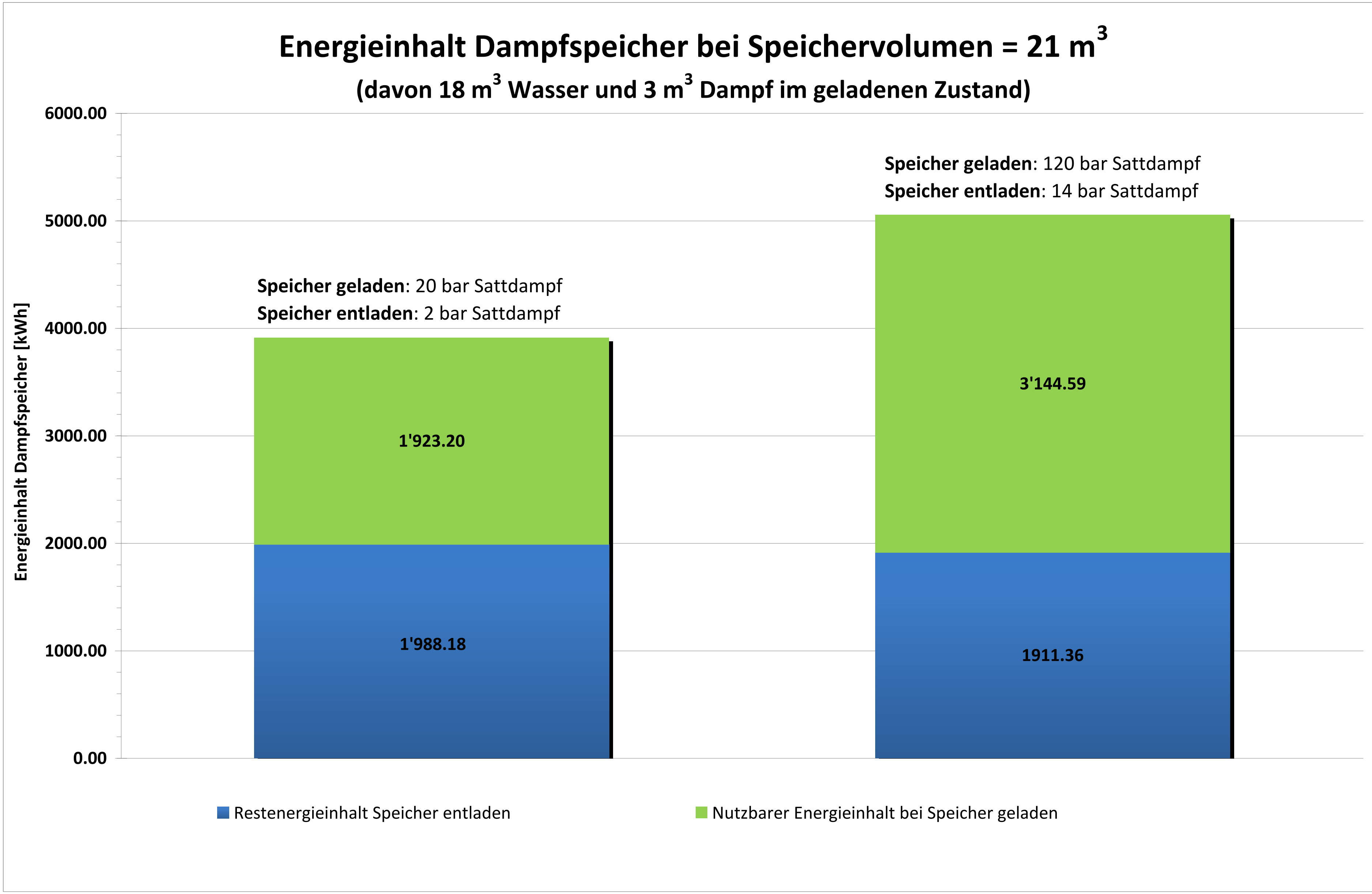
High-pressure fireless Locomotives

High-pressure fireless locomotives are built for storage pressures of up to 120 bar. After throttling the steam to the working pressure of 16 bar, the steam is superheated resulting in a much improved operating range.

Schematic of a high-pressure fireless Locomotive

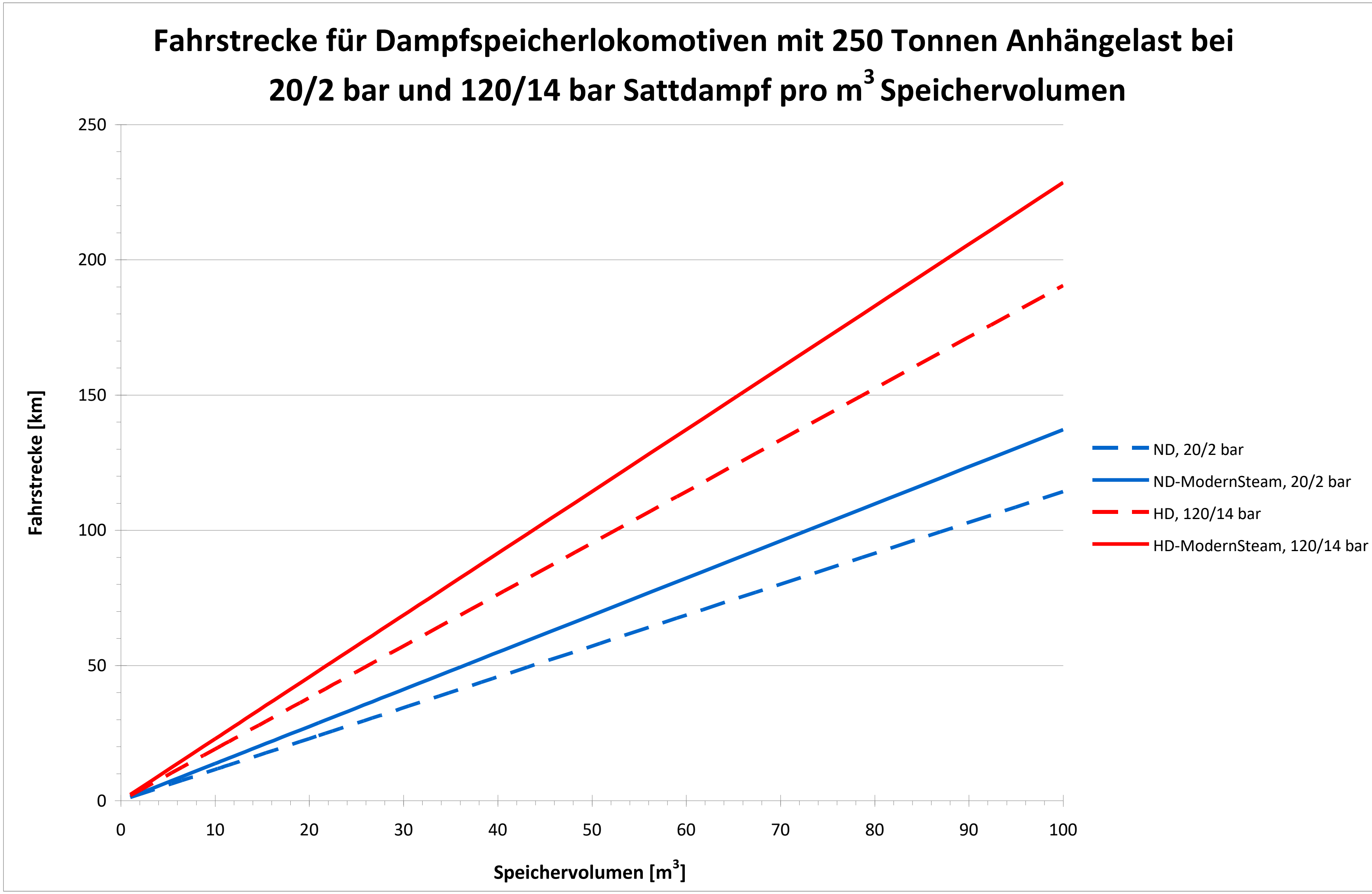


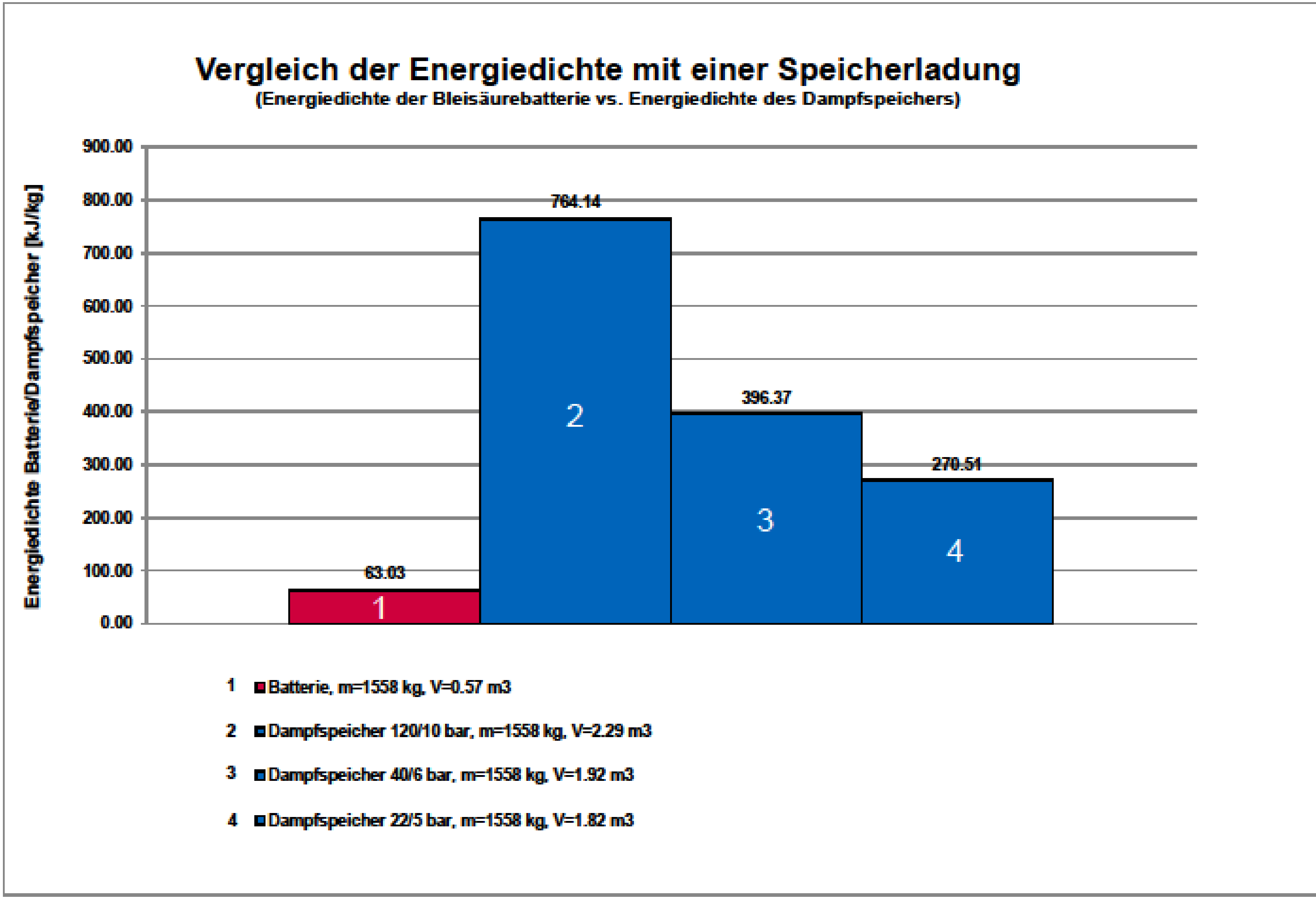
The functional diagram of high-pressure fireless locomotives differs only slightly from that of low-pressure fireless locomotives. The superheater can be seen in the upper part of the pressure vessel.



Comparison of the storage capacity of low- and high-pressure fireless locomotives for a three-axle shunting locomotive. Martin Schneider ZHAW

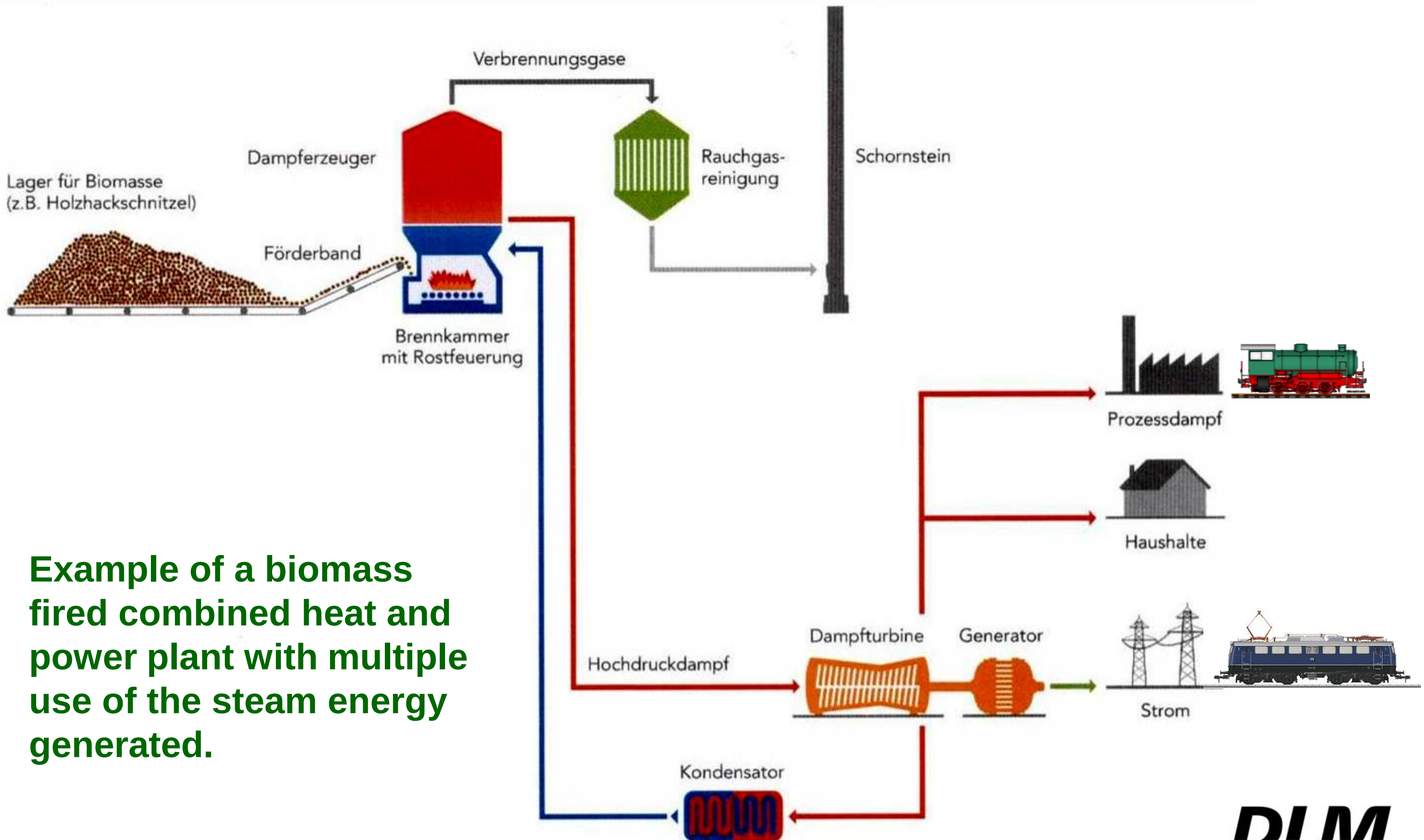
Operating range of modern fireless Locomotives





Comparison of the usable energy of a lead battery with that of hot water storage pressure vessels of the same weight. Martin Schneider ZHAW

6. Combined Heat and Power CHP



Example of a biomass fired combined heat and power plant with multiple use of the steam energy generated.

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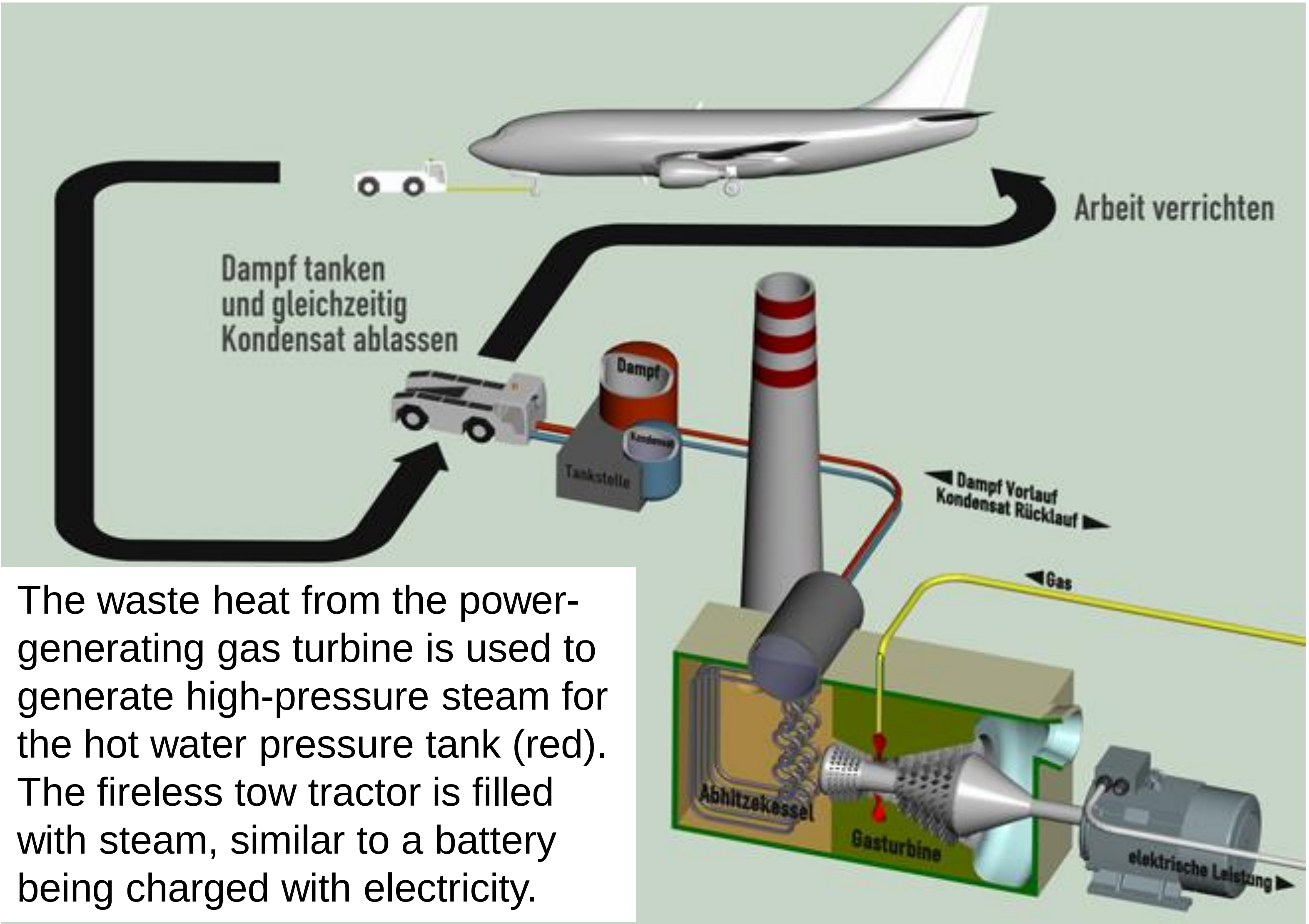
7. Combined Heat and Mobility CHM

Combined Heat and Power CHP uses the waste heat for seasonal heating purposes. Due to climate change and more efficient building technology, the demand for heating energy is constantly decreasing.

Combined Heat and Mobility CHM uses the waste heat all year round for mobility. The waste heat generates pressurized hot water in a waste heat boiler, the steam of which drives modern fireless storage vehicles. As the examples show, all vehicles used in the local area are suitable for storage technology.

Combined Heat and Mobility



The waste heat from the power-generating gas turbine is used to generate high-pressure steam for the hot water pressure tank (red). The fireless tow tractor is filled with steam, similar to a battery being charged with electricity.

Airport Tow Tractors and Busses

The fireless hot water storage technology is suitable for all local commercial vehicles. CHM can save a lot of CO_2 at airports

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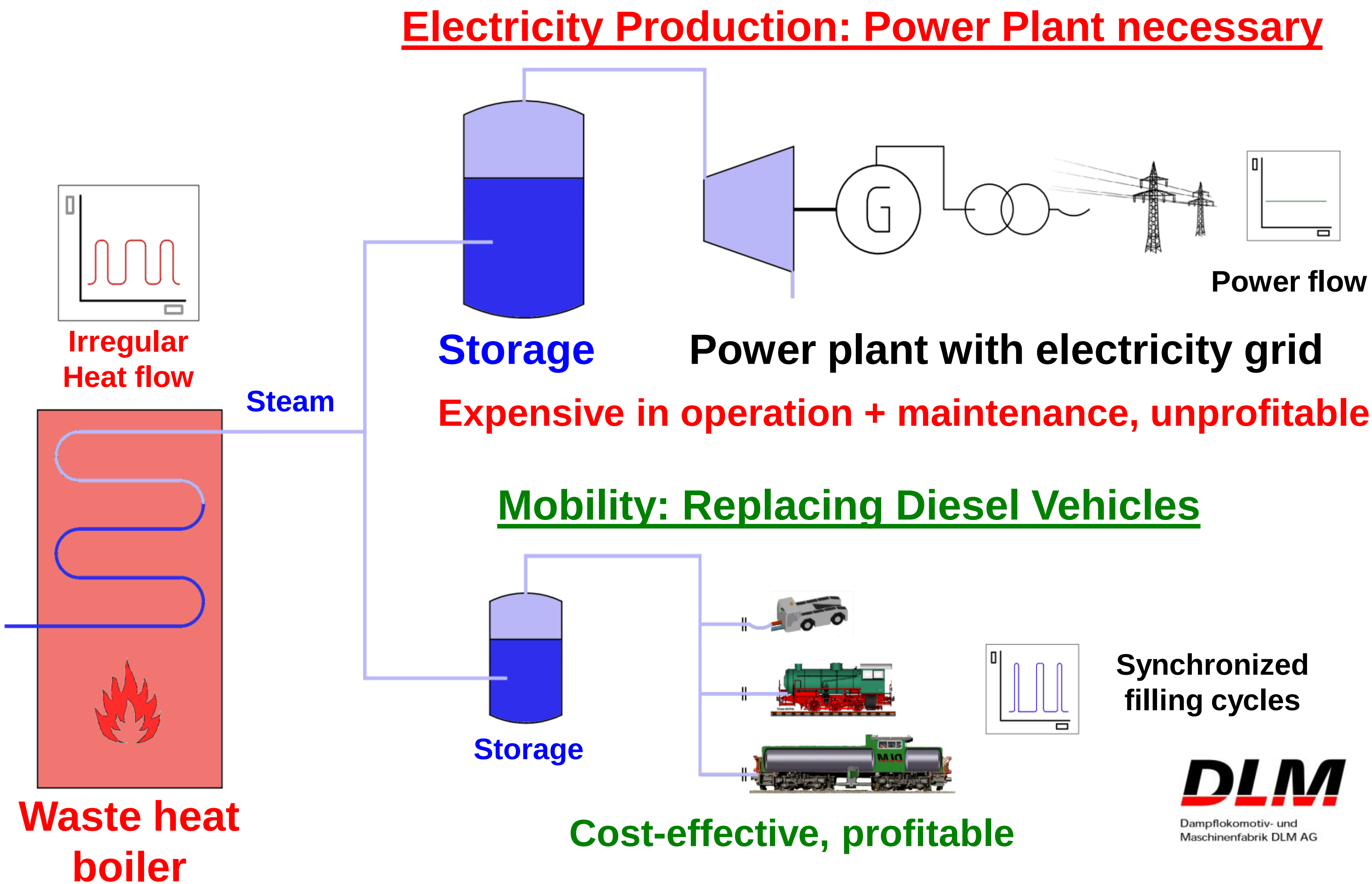
Waste Heat utilization in Steel Works



Modern fireless Locomotives

Am 843 diesel locomotives could serve as the basis for modern high-pressure storage fireless locomotives. Photo: Georg Trüb / Sectional view: design DLM

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Dampflokomotiv- und Maschinenfabrik DLM AG
Lagerhausstrasse 3 CH-8400 Winterthur
www.dlm-ag.ch