# ENERGYLABEL & ECODESIGN FOR AUSTRIAN ROADTUNNEL

Mario Patigler
ASFINAG Bau Management GmbH, AT

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## ABSTRACT

With 94 GWh and a share of approximately 75% of the total electrical energy consumption within ASFINAG, its tunnel facilities are the main energy consumers.
This fact motivates to optimize the analysis of energy consumption in ASFINAG's tunnel facilities. Through standardized equipment we want to develop the comparability of tunnel energy consumption by use of an energy benchmark.
Following the energy classification of electrical devices, the goal is to categorize the tunnels in terms of energy in the future. To achieve this objective, an evaluation system will be developed that focuses on both the quantitative comparability of tunnel facilities and the qualitative assessment based on sustainable or improved equipment.

1. Quantitative quality index

This analysis is based on actual data of energy consumption. The hypothesis is to examine the analogy between equally equipped tunnels by analyzing the energy consumption values of the installed consumers.

2. Qualitative quality index

The quality in terms of sustainable improvements for the consumption of electrical energy is assessed by defining efficiency-enhancing measures in the equipment of technical systems. The hypothesis is based on the fact that higher-quality installations lead to an improvement in the energy balance of the facility.

*Keywords: energy efficiency, sustainability, safety systems, energy supply*

## 1. INTRODUCTION

### 1.1. Sustainability - a means to an end

Austria has a modern, highly technologized and distinctly available transport infrastructure. The establishment of the Autobahnen- Schnellstraßen- Finanzierungs- Aktiengesellschaft (ASFINAG) created the basis for the continuous expansion and modernisation of the high-level transport network. In the heart of Europe, ASFINAG's roads form important connecting routes in the Alpine region due to their partially exposed location.
These routes have 166 road tunnels to enable comfortable passage through the Alpine region. This enables all road users to travel safely at any time of the year and even in poor weather conditions. With Directive 2004/54/EC [1] on minimum safety requirements for tunnels in the trans-European road network and the Austrian Road Tunnel Safety Act [2], these facilities were comprehensively upgraded in terms of safety by 2018 and are among the safest tunnels in Europe [3]. ASFINAG's responsibility throughout Austria and the development of planning premises (ASFINAG planning manuals) have standardised the equipment and functionality of the tunnels. With the expansion, the tunnels were brighter lit and better ventilated. With the additional information systems, information signs, traffic light signalling systems and many sensors and actuators, the facilities have become high-tech systems and guide road users safely

through the tunnels. However, all these safety systems have one thing in common. The components are operated using electrical energy and the safety expansion leads to an increase in the energy consumption of the tunnels. They consume the most electrical energy within ASFINAG. This fact motivates us to optimize our analysis of energy consumption in the tunnel facilities.
In addition to economic aspects, new legal framework conditions such as EU and national requirements and certification measures have led to a sensitisation regarding sustainability and the introduction of regular audits on efficiency and energy consumption within ASFINAG. Due to the rapid development of LED technology, efficiency-enhancing measures with the use of LED tunnel lighting were also considered during refurbishments in parallel with the safety expansion and are now also having an effect as electricity consumption in the tunnels is falling again. In addition, qualitative measures with the expansion of alternative energy generation systems in the tunnel are also leading to a reduction in the purchase of electrical energy.
For the classification we are pursuing the development of an evaluation system that focuses on both the quantitative comparability of tunnel facilities and the qualitative assessment based on sustainable or improved equipment. Electrical energy is one of the most important forms of energy and the best alternative for protecting our environment thanks to the options and chances of sustainable energy generation. *Saving energy is the key to combating climate change and reducing energy dependency* [4]

### 1.2. Objective

Improving energy efficiency naturally covers many areas in the traffic and transport sector. At ASFINAG, the core topics include:

- Conservation of resources
- **Energy an emission during operation**
- Traffic emissions
- Biodiversity
- Landscape
- Noise protection

Not only the shift towards e-mobility, but also the range of construction measures and the maintenance of operations through sustainable solutions and systems is constantly growing.

### 1.3. Energy consumption in the operation of our road infrastructure

As an ISO 50001 certified company, ASFINAG is obliged to take measures:

- to improve the CO2 balance by using resources sparingly and utilising potential for improvement,
- to reduce energy consumption by implementing efficiency-enhancing projects with positive profitability certificates,
- to comply with legal requirements with a positive impact on owners, employees, and customers

To achieve this, the goal of electricity self-sufficiency by 2030 was set. The measures are divided into the qualitative expansion (e.g., to generate 100 MWp of electricity) in the route network and the quantitative analysis of consumption behaviour to reduce energy consumption by 20% per route kilometre. At around 94 GWh, tunnels account for the largest share of total electrical energy consumption within ASFINAG.

### 1.4. Hypotheses

Analysing the consumption characteristics of electrically operated tunnel safety equipment and electrical equipment leads to worthwhile potential savings in the consumption of electrical energy without compromising safety-related functions. By forming consumption groups, system-specific features can be analysed in a structured manner regarding consumption and innovative and sustainable solutions can be developed in a targeted manner. Sustainable and innovative solutions for increasing efficiency can be argued more easily and further developments are promoted.

- The analysis of measurement data on the consumption behaviour of tunnels leads to a comparability of the Austrian tunnel system. The classification can be based on the energy classes of the EU energy label.
- Improving equipment features that lead to a qualitative improvement in the tunnel systems in terms of sustainability or efficiency can be assessed and can be considered in the planning phase for refurbishments, etc.

### 1.5. Methodology for development work

The answers to the questions and the development of the evaluation models should lead to a comparability and recognisability of analogies in the 166 tunnels in the high-level Austrian railway network and are analytically carried out by:

a. Literature research
The general basic approaches to the EU energy label [5] are collected for the basic research. The aim is to derive a comparability like that of electrical appliances in general and to develop an understanding of the approach to categorisation. Existing elaborations, e.g., from the Swiss Federal Roads Office (ASTRA), which deal with the energy efficiency of road tunnels, are considered.

b. Quantitative content analysis
To obtain a practical reference or results under real conditions and to be able to compare these with the calculations and theoretical approaches, measurement data from existing tunnels are collected and analysed. The load profiles (15-minute values) of the electricity supply company for the respective tunnel system are primarily used as measurement data. For the verification of data, the existing documents regarding the equipment of the tunnel systems and, if available, the balance sheet design and energy distribution are primarily used. Technical specifications for function, operating mode, hazard classes and operating behaviour are applied based on technical documentation, safety documents, planning premises and guidelines.

c. Qualitative content analysis
The considerations of sustainability-improving measures and equipment in tunnels are included in a catalogue of measures based on procedures and studies on the respective main topic. Calculation approaches are analysed and described using examples for the applicability and allocation of a points system based on quality characteristics and for the presentation of the savings and improvement potential.

## 2. DEVELOPMENT OF ENERGYLABEL AUSTRIAN ROAD TUNNELS

### 2.1. Data analysis of the consumption values

The 15-minute load profile values per year for all 166 tunnels are standardised using the existing metering points of the energy supply systems. To ensure comparability, the data was verified for plausibility, traceability and usability. A qualitative and quantitative check was carried out and transferred into an editable form. The following key exclusion features were identified when checking the usefulness of the data sets:

- Measurement gabs

Data series that are not representative over a longer period (weeks, months with "0" values)

- Supply of several tunnels of a metering point

Data series that show consumption values that cannot be traced or where the supply of several tunnels or other installations lead to an influence due to the circumstances.

After appropriate verification, the data of 53 tunnels >500m (expansion in accordance with the Road Tunnel Safety Act STSG) and 8 tunnels <500m with usable consumption values are available after the inspection of 166 tunnels. The 15-minute power values are converted with a factor of 0.25 to obtain electrical energy values in kWh. The annual energy consumption is calculated by adding the values.

## 2.2. Development of reference figure for the energy label

In most cases, the key figure in kilowatt hours per year (kWh/a) is used to compare the consumption characteristics of the electrical appliances. Due to different system characteristics, e.g., the length of the tunnel and the number of lanes, considerations were considered during development to obtain as homogeneous a basis as possible for all tunnels and to eliminate their influences. In the initial analysis, the benchmark

$$\frac{kWh}{a * FSm}$$

to quantify comparative approaches, attempts were made to derive analogies based on the analysis of annual energy data by grouping various tunnel characteristics, such as operating mode, hazard classes, geographical evaluation, ventilation system and traffic volume. However, the analysis of this basic data did not lead to a useful result. During further investigations, a reconsideration of the connection with

$$\frac{MWh/a}{FSm}$$

The benchmark used is therefore made up of the annual energy consumption per year (MWh/a) and the sum of all lane lengths in metres or the lane metre (FSm). This correlation enables a more homogeneous categorisation. Here too, the influencing factor of tunnel length and number of lanes is eliminated by referencing the FSm.

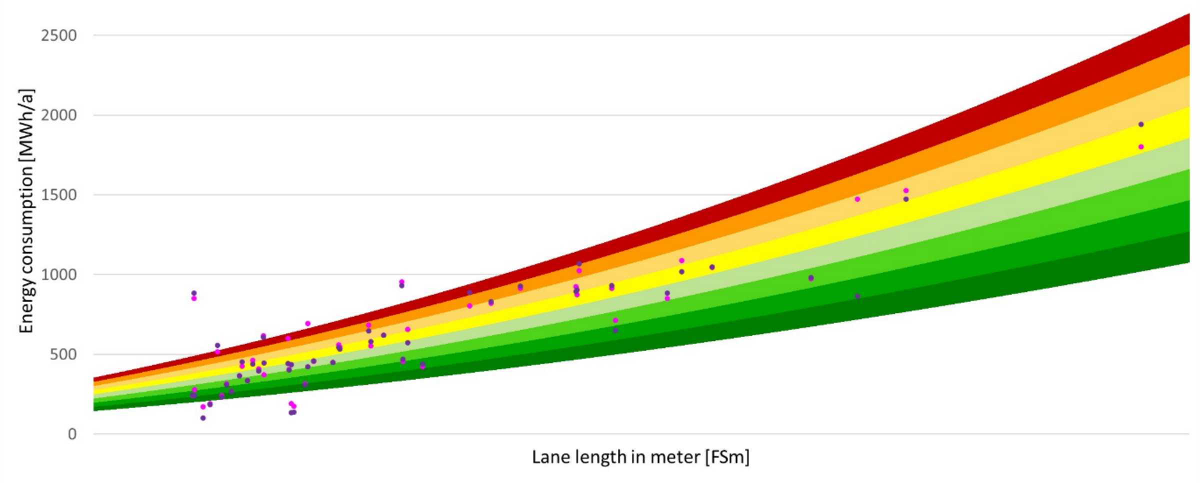


Figure 1: Evaluation of the energy values (MWh/a) in relation to FSm for example longitudinally ventilated directional traffic tunnels

To assign the tunnels to the label classes, the percentage shift in 10% increments was used for the naturally or longitudinally ventilated tunnels selected in Figure 1. For cross-ventilated tunnels, the transition is made in 5% steps. As shown in Figure 1, the result is a largely linear progression and erratic transition areas are eliminated. It is easier to read in consumption data by analysing the annual curve. Further analyses are therefore based on these findings and the use of the representative data sets defined in section 2.5.

Table 1: Evaluation examples for length ranges <7000m lanes with benchmark and category (Energy data base 2022)

| FSm Bereich | <2000m | | <3000m | | <4000m | | <5000m | | <6000m | | <7000m | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tunnel | Tretting | Bergisl | St. Georgen | Kreuzer-gegend | Wolfs-berg | Flirsch | Nieder-hart | Falken-berg | Zeder-haus | Noitz-mühle | Kalcher-kogel | Herzog-berg |
| FSm | 1800 | 1914 | 2400 | 2440 | 3250 | 3252 | 4520 | 4554 | 6180 | 6532 | 7948 | 7980 |
| MWh/a (22) | 101,7 | 184,3 | 364,3 | 453,5 | 437,4 | 134,5 | 534,2 | 647 | 886,9 | 832 | 893,9 | 905,2 |
| Kategorie | A+ | A+ | E | C | C | A+ | D | E | G | E | E | E |

As can be seen from the selection in Table 1, comparable consumption characteristics can be derived using the annual key figure in MWh/a (based on 2022) and the allocation of lane meters. The significant deviation in the consumption value, for example in the area <4000m from the Flirsch tunnel, is due to the influence of the internal consumption of a small hydroelectric power plant. The consumption behaviour is correspondingly higher but cannot be determined due to the lack of measurement data. In the length range <6000m, the tunnels are very close to the border areas and therefore fall into category E or G.

## 2.3. Labelling of the tunnel systems based on annual energy values

The energyload profiles and the data from the years 2021 and 2022 were used to derive the data, which was then presented with the category classes based on the EU label. For the 2022 data set, this results in the classification reading to Figure2 for the individual tunnels on the high-ranking Austrian road network.

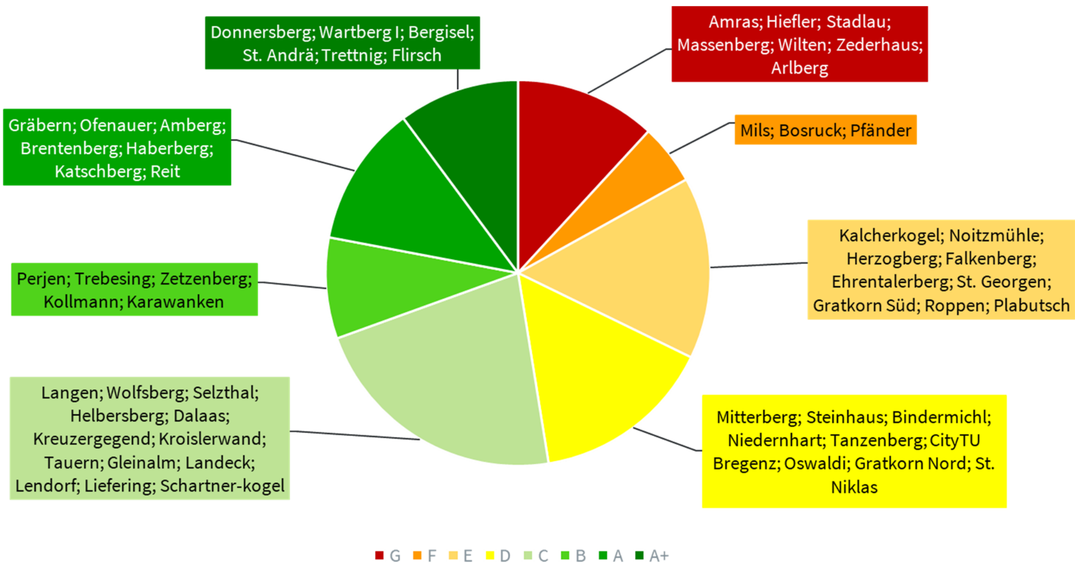


Figure 2: Categorisation and labelling with energy data from 2022

## 3. „ECODESIGN“ AND EVALUATION OF QUALITATIVE MEASURES

### 3.1. Quality features of the Austrian tunnelling system for a continuous improvement

The energyload profiles of some tunnel systems could not be used for the quantitative analysis. As described in chapter 2.1, the data was implausible. The causes influencing the measurement results and metering values of the feed-ins were sought by means of questionnaires on the existing plants, checking energy balances or meticulously searching through existing documents. A comparison of the annual energy data revealed striking changes. The supply and self-consumption of alternative energy supply systems can be mentioned here as an example. The unambiguous allocation of consumption, but also of the supply of individual systems, cannot be made due to the lack of consistent individual measured values within a system.

### 3.2. Evaluation model for the representation of qualitative characteristics in equipment and the operating and safety facilities as consumers of electrical energy

The operational and safety systems must be installed and operated in the tunnels in accordance with the regulations and guidelines. The large number of electrical consumers fulfil a wide variety of tasks. There are systems that are largely only installed in the event of an accident and others that have to be operated permanently during operation. There are also measures that are indirectly related to the electrical consumers. In this respect, the energy requirement due to the large number of safety measures is not necessarily related to the efficiency of the tunnels. The operation of alternative energy sources does not lead to an improvement in efficiency either. A catalogue of points was therefore chosen for the evaluation methodology to assess quality. A selection of criteria can be made for the tunnels and the energy requirement category can be determined using the points model. A standard ASFINAG tunnel is defined as follows:

Table 2: Definition of a standard tunnel in ASFINAG

| | |
|---|---|
| Control speed | 100km/h |
| Hazard class | III |
| Ventilation system | Longitudinal |
| Anual running time ventilation system | 10-50h |
| Fire-fighting system | none |
| Pressure generation system | Elevated tank |
| Pumps for water protection systems | < 5kW / < 200h |
| Other consumer | < 5kW / < 200h |

By referencing the characteristics, systems with a high energy requirement defined by criteria such as laws, guidelines, environmental conditions, etc. can be identified. This energy requirement can be improved by operating alternative energy sources. Result categories are:

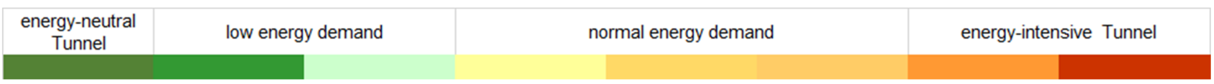


Figure 3: Result categories

Efficiency-enhancing measures relate to the appropriate optimisation of electrical energy consumption. The improvement is achieved through technical solutions and has a positive and sustainable influence on the efficiency of the generated benefit. Criteria can be determined in advance using a model calculation and efficiency can be influenced as a result. The following criteria are currently planned:

Table 3: Criteria for increasing efficiency

| | |
|---|---|
| Transformer losses | Night-time lowering of traffic equipment |
| Typ of uninterruptible power supply | Coolingtype of the electrical operating room |
| Light source of the lightning system | Frost portection fot the extingueshing water system |
| Type of luminous flux adjustment | Improvement of the reflexion coefficent of the covering |
| Condition of the wall coating | Light well glazing in the entrance area |
| Complete tunnel wash | |

Additional criteria to increase efficiency can be added at any time.

### 3.3. Definition of standardised consumption classes with simulation of consumption values as a planning tool

The analyses of consumption and potential savings make one fact very clear. The derivations can only be made primarily through interpretation, manual allocation of data, analyses of existing documents and raw data. For better comparability, the tunnel consumers were divided into eight consumption groups.

Table 4: Definition of consumption group and manual allocation using energy balances

| 1<br>Entrance lightning | 2<br>Lightning for IS / PB / Portal | 3<br>Ventilation | 4<br>Heating, ac, ventilation, plumbing | 5<br>Control system | 6<br>Safety systems | 7<br>Traffic systems | 8<br>others |
|---|---|---|---|---|---|---|---|
| Entrance | Indor track | Driving area | Ventilation system | Control system | Emergency call | Traffic light | Trace heating |
| | Brakedown bay | Cross conections | Air conditioning | Network system | Danger detection | Information sys. | Extinguishing water |
| | Outside portals | Auxiliary drive | Heating system | | Video system | Var. traffic signs | Water protection |
| | Cross conections | Flap drive | | | Sound system | Guiding system | House installation |
| | Escape routes | | | | Doors and gates | Height control | Cellular system |
| | | | | | Opening assistan. | Barriers | System lighting |
| | | | | | Radio system | | Heater electrical cabinet |
| | | | | | Emergency light | | Crane system |
| | | | | | Air quality | | Shaft inspection |
| | | | | | Sensors | | |

By analysing and entering the performance data, it is possible to calculate the energy requirements for the tunnel systems. The analytical and interative approximation of the operating factors and annual seasonality is used to simulate the calculated energy curve over a year. The measured consumption data was then compared for verification and can be plausibly presented as in the example show in Figure 4.

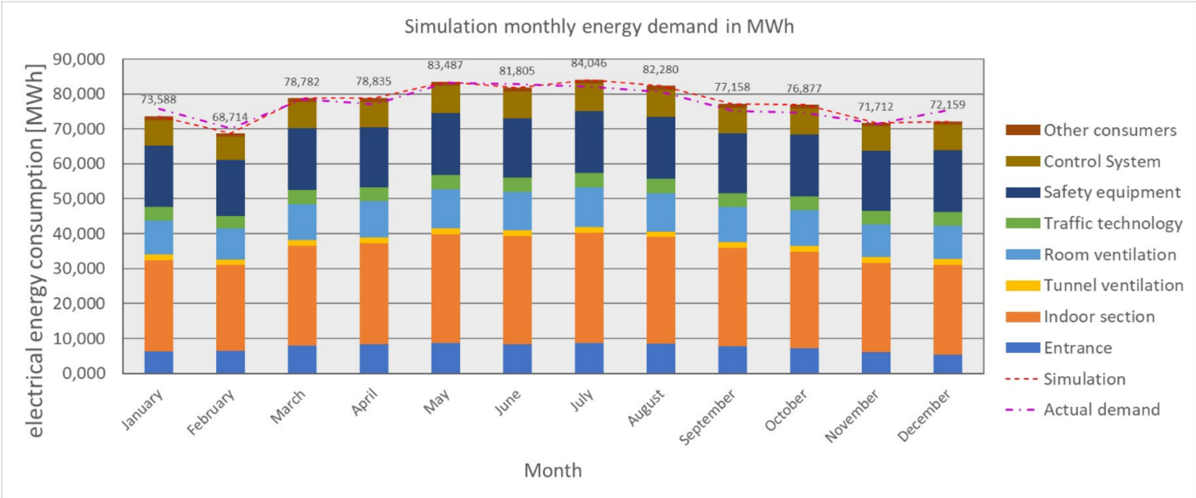


Figure 4: Simulation result of the monthly energy demand in MWh using the example of the Milser Tunnel

## 4. SUMMERY AND CONCLUSION

The comparability of tunnels via benchmarks and the energy label enabel to evaluate and monitor the consumption characteristics of tunnels. In combination with this, the quantitative analysis is expected to further sensitise people to the consumption of electrical energy. The motivation to better record the consumption behaviour of systems in order to make targeted investments in more sustainable systems will be increased. The knowledge gained will also support the goal of establishing an appropriate energy management system. With the planning tools and observation models of the simulation, efficiency-enhancing system features can be taken into account in the run-up to refurbishments and extensions in the future. With the longer lead times, innovative approaches can be better analysed and thus promoted.

### 4.1. Findings from the studies

For both quantitative and qualitative analyses, there is a need to increase the quality of the input parameters and reduce the theoretical assumptions. This can be done by further checking detailed information, carrying out and expanding measurements and analysing existing data to verify the approaches taken. The quality of the data is particularly important here. Data collection is currently very time-consuming and resource-intensive. Possible solutions are offered by the plans for the expansion of energy management systems and an energy control centre within ASFINAG in order to handle both the expansion of renewable energy and the main consumers. Detailed evaluations of the consumption groups, e.g. by implementing measurement concepts and thus improving monitoring, can lead to functional and operational improvements in addition to energy optimisation. The knowledge gained from this closes the cycle of the continuous improvement process and can in turn be incorporated into planning assumptions.

## 5. REFERENCES

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