THE POTENTIAL OF PV NOISE BARRIER TECHNOLOGY IN EUROPE

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ABSTRACT: Photovoltaics is expanding into new market segments. Photovoltaic noise barriers (PVNB) along motorways and railways permit today one of the most economic applications of grid-connected PV with the additional benefits of large scale plants (typical installed power: more than 100 kWp) and no extra land consumption. The aim of this study is to reveal the large potential that can be exploited for PV on noise barriers with the overall objective of raising the share of renewable energies for the EU´s electricity market. In contrast to many PV-potential studies published before, this proposal is focusing on PVNB only, as one of the cheapest ways to implement large scale grid-connected PV installations.
Keywords**:** PV Market- 1; PV noise barrier technology - 2; Grid-Connected- 3

1. INTRODUCTION

Photovoltaics (PV) is in moderate latitudes the only option to use the sun for electricity production to a larger scale. In the past various investigations have shown that large rated power in the GW range can be integrated in the existing house- and industrial-roof tops. Another area is very attractive due to its easy standardisation and legally clear properties: the transportation lines. These are highways and freeways as well as railway tracks.
Photovoltaic noise barriers (PVNB) along motorways and railways permit today one of the most economic applications of grid-connected PV with the additional benefits of large scale plants (typical installed power: more than 100 kWp) and no extra land consumption. The aim of this study is to reveal the large potential that can be exploited for PV on noise barriers with the overall objective of raising the share of renewable energies for the EU´s electricity market. In contrast to many PV-potential studies published before, this proposal is focusing on PVNB only, as one of the cheapest ways to implement large scale grid-connected PV installations.
Co-financed by the EU Commission DG XVII, TNC GmbH Germany co-ordinated the elaboration of the study together with the following partners:

- Fraunhofer ISE, Germany
- PHEBUS, France
- TNC AG, Switzerland
- NPAC, United Kingdom
- University of Utrecht, the Netherlands
- ENEA, Italy

2. METHODOLOGY

2.1 Data selection and preparation

The analysis of existing and planned noise barriers along rails and roads has been carried out by the national partners together with national authorities, which are experts and responsible for the required data. The methodical approach of this study includes the set-up of a grid with dimensions of 1 by 1 geographical degrees for Germany, Italy, France, United Kingdom and 0.5 by 0.5 degrees for the Netherlands and Switzerland. For each degree the length and orientation of rails and roads, the existing and planned noise barriers are registered and grouped according to their orientations.
The solar radiation is based on data of a METEONORM data set [1]. This includes the solar radiation on horizontal orientation as well as various inclination angles for all possible orientations. Moreover, possible shading has been considered.
The following table 1 gives an overview over existing PVNB projects that have been installed in Europe:

Place Trafficway / Year	**Peak kWp**	**Planner / Investor**
Domat Ems, CH A13/1989	103	TNC AG / Swiss Office for Energy
Gordola, CH Railway/1992	103	TNC AG / Swiss Office for Energy
Seewalchen, A A1/1992	40	Oberösterreichische Kraftwerke
Rellingen, D A23/1992	30	TST (DASA)
Giebenach, CH A2/1995	104	TNC AG / Kanton Basel-Landschaft Swiss Office for Motorways
Saarbrücken, D A6/1995	60	Stadtwerke Saarbrücken
Utrecht, NL A27/1995	55	R&S und others
Ammersee, D A96/1997	30	3 Prototypes, TNC GmbH / Bayernwerk & BMFT
Zürich north, CH A1/1997-99	30	3 Prototypes, TNC AG / Swiss Office for Energy Swiss Office for Roads Zürich Utility EWZ
Ouderkerk, NL A9/1997/98	220	Shell & ENW / EU Commission

Table 1: Realised PVNB in Europe (status end of 1997)

The technical specifications of PVNB are based on the comprehensive knowledge of TNC GmbH and TNC AG with various plants realised [2],[3]. Technologies have been considered for both state-of-the-art and innovative concepts such as bifacial PVNB (see fig. 1). In bifacial PVNB the vertically mounted PV-module is light sensitive on both sides and is used at the same time as noise reflecting element.

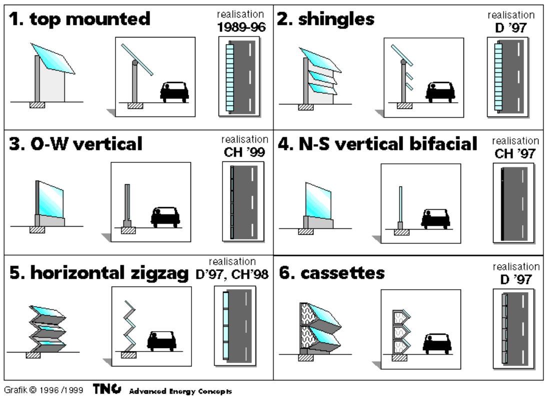

Figure 1: Schematic sketch of different photovoltaic noise barrier (PVNB) structures including integrated PVNB [4]

2.2 Definition of potentials

Installed PV power and produced electricity have been calculated for the following potentials:

Theoretical: Assessment of the maximal possible PVNB. All existing rails and roads (R&R) will be equipped with PV. PV is mounted on the support structure (which is not necessarily a NB) with the optimal tilt angle. A further development of the technology used is assumed. As shading is not considered all R&R will be equipped with PVNB.

Technical: All NB along R&R, planned today, will be equipped with PV. Moreover, the already installed NB will be upgraded with PV. A classification of the NB into all possible orientations is done for each 1 by 1 degree. The technology used is state-of-the-art. Shading is considered.

Short term: All NB planned today will be equipped with PV. A classification of the NB into all 1 by 1 degrees is done. The used technology is state-of-the-art. Shading is considered.

European extrapolated: In the progress of this study it became evident that France, Italy and United Kingdom have poor short-term potentials due to the lack of NB-planning. Consequently, a European extrapolated potential was defined: Length density within each degree was correlated with the average short-term potentials of the other countries investigated.

EU-member: For the EU-members not considered in this study an EU-member potential was defined: The average ratio of potential of electricity resp. power to the length of roads/rails installed was extrapolated to the other EU-members. Sweden and Finland have not been considered due to their low population density.

Anticipated: The anticipated potential is based on the analyses on the national basis according to the economic and political boundary conditions. This means the calculation of the economic competitiveness of PVNB in comparison with its alternatives. The relevant financial parameters for costs and revenues were considered. Moreover, the political willingness for a reinforced introduction of PV on NB were analysed.

2.3 Calculation and visualisation procedure

The calculation of potential is done in Excel 7.0. Special emphasis had been put on the visualisation of the results

Output data are used to produce maps, which are divided in coloured pixels of 1 x 1 degrees or 0.5 x 0.5 degrees. All colour levels represent the potential of PV power installed or PV electricity production "per pixel".

White pixels denote a zero potential or lie outside the area under consideration. The coloured pixels follow a near-logarithmic scale with 5 colour levels. These colour levels are identical for all maps, nevertheless, the same colour may denote different ranges for different maps.

In fact, the ranges change with the different types of potential (theoretical, technical, and short term). Moreover, colours are different for maps of installed power (green) and electricity production (red), but, the colour ranges remain constant for all countries. So, a map showing the theoretical potential for Italy will be comparable to the same type of map for Germany. On the other hand, two maps for France, showing the theoretical and the short term potential, will use different scales.

2.4 Technical process of map production

The maps are created from ASCII tables by the software package GMT. The output of GMT is one PostScript file per map.

The slides, consisting of a map on the right, the headline and the caption on the left, and several logos are formatted using LaTeX.

The following maps have been designed:

- 6 countries plus Europe as a whole,
- 3 types of potential (theoretical, technical, and short term/extrapolated potential),
- 2 quantities (installed power and electricity production),
- and all this for rails and roads

3. RESULTS

3.1 Theoretical Potential

Theoretical		Countries						All six	Average of
Potential		CH	D	NL	UK	I	F	countries	all countries
Relevant roads	[km]	1868	11013	2701	10791	6830	12255	45458	7576
rails	[km]	1663	6652	3065	9967	4820	7850	34017	5669
roads	[MW_p]	2236	13183	3233	12917	8176	14669	54414	9069
rails	[MW_p]	1422	5687	2620	8522	4121	6712	29084	4847
rails&roads	[MW_p]	3658	18870	5854	21439	12297	21381	83498	13916

Table 2: Total of theoretical potential of expected installed power for each country

3.1 Theoretical Potential

The theoretical potential assesses the upper boundary of installable PV along traffic ways All existing R&R will be equipped with NB. The main potential is located in the European metropolitan areas London, Paris. Approx. 65% of the 75TWh/a annual production are related to roads, the remaining 35% to rails.

3.2 Technical Potential

The technical potential for the six countries investigated is encouraging: approx. 584 MWp PV along roads and 217 MWp PV along rails (see figure 2).

D and NL have 74% of the total technical potential, whereas UK and I have only 9% of the existing European NB which could be upgraded to PVNB.

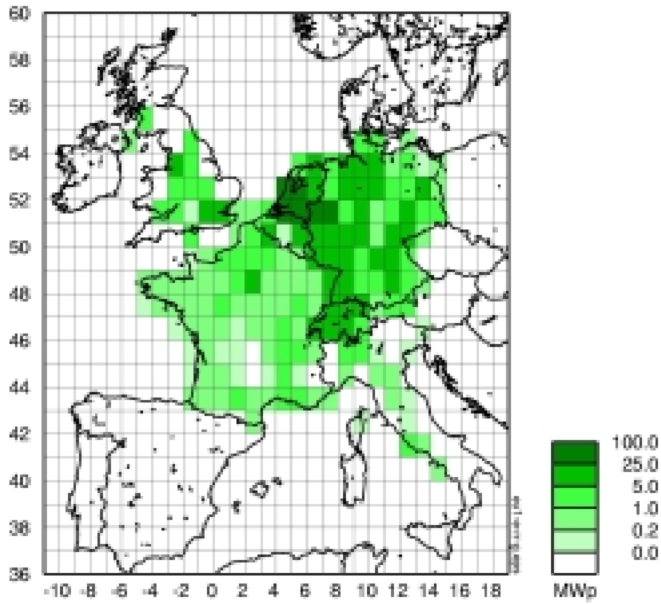

Figure 2: Technical potential of installed power of PV along rails & roads in all six countries

3.3 Short term/extrapolated potential

The short-term potential for Switzerland, Germany and NL is approx. 140 MWp PV along roads and 145 MWp PV along rails (see figure 3).

This results for all EU members to an extrapolated potential of 1145 MWp PV along roads and rails.

If the national policy changes in France, Italy and United Kingdom to a European extrapolation, the expected potential in France is 96 MWp, in Italy 170 MWp resp. in United Kingdom 385 MWp.

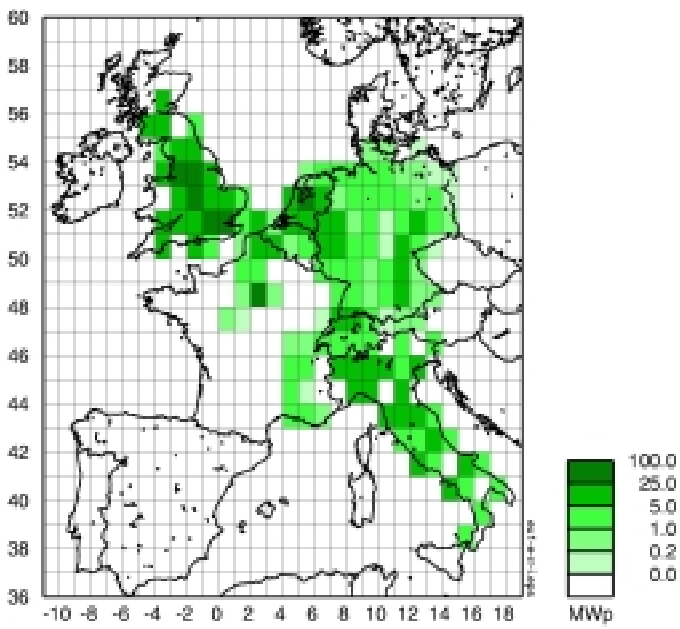

Figure 3: Extrapolated potential of installed power of PV along rails & roads in all six countries

3.4 The potentials for all EU-member countries

Not all countries of the European Union could be investigated in detail within the scope of this study. The following countries were not considered in this study: Belgium, Denmark, Finland, Greece, Ireland, Luxembourg, Portugal, Spain and Sweden

Consequently, an EU-member potential was defined: The existing road resp. rail lengths in these countries have been multiplied with the average ratio of the potential of electricity/power and road/rails in the six countries investigated.

The short-term – including the European extrapolated - potential of installed PV–capacities for roads will increase by 15%, for rails by 28% by including these EU countries. Spain is according to this assessment the most important country for a more detailed analysis

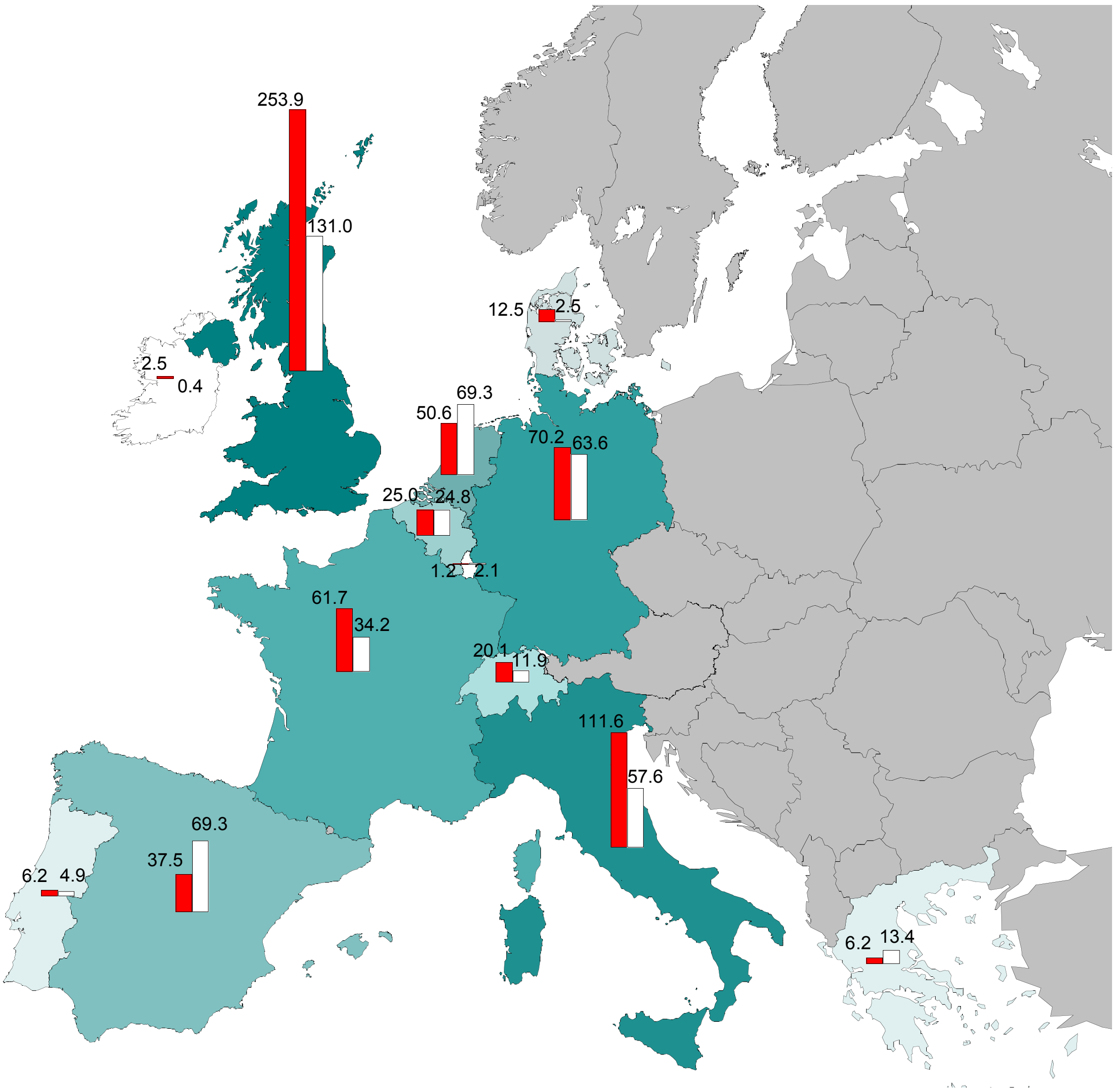

Figure 4: European extrapolation of the short term potential of installed power for PV in all EU-member countries. Data for CH, D, NL, UK, I and F have been calculated in detail; the potential is based on all noise barriers planned today (left bar: roads, right bar: rails)

3.5 Anticipated Potential

Switzerland is still the country with the highest installed PV power capacity in the world. The technology profits from a big interest and goodwill by many people. The idea of using PV on NB was lanced in Switzerland. NB are a fixed part of Swiss highways. A national plan for the construction of more than 105 km of NB along roads and 76 km along rails of NB in the next five years has been set up. The interest for the construction of PVNB has grown very much during the past few years. Especially pressure groups of concerned people show interest, also communities and private persons.

Summarising, the boundary conditions in Switzerland are very favourable to realise a large share of the existing potential.

Germany has very favourable conditions for the realisation of further PVNB [5]:

- A high density of rails and roads
- An ongoing demand for a further construction of NB
- Reasonable to excellent tariffs for PV-electricity fed into the interconnected grid
- Favourable acceptance of PVNB by the public opinion

Consequently Germany is one of the key countries for a reinforced introduction of PVNB.

In **the Netherlands** attitudes of the parties involved in the erection of PVNB are neutral to positive. Obstacles to implementation are the large number of parties involved in the erection of noise barriers, the economic feasibility and the accessibility of noise barriers in urban areas.
The large rail projects offer the best perspective for short-term large-scale introduction of PVNB in the Netherlands.

In **United Kingdom**, the actual potential for the use of PVNB is rather low as a result of the low usage of noise barriers on roads and railways, the lack of formal incentives for PV electricity fed into the grid and the reduced programme of road building expected in the next few years. The attitude to the use of PV as a future source of electricity in the UK is generally quite positive, but demonstration of actual PV noise barriers would be required to make this application acceptable.

In **Italy**, the actual potential for the use of PV on noise barriers is rather low as a result of the low usage of noise barriers on roads and railways and the lack of formal incentives for PV electricity fed into the grid.
On the other hand the attitude to the use of PV as a future source of electricity is generally quite positive, but demonstration of actual PV noise barriers would be required to make this application acceptable.

In **France** the potential of PV noise barriers is rather low for the moment. The principal obstacles to their development are the very low price that the grid operator is disposed to pay for PV electricity and the lack of information about this new kind of noise barriers among specialised professionals and decision-makers.
The work to be done in order to overcome these obstacles is at first to bring higher pressure for increasing the feed-in tariff paid for PV electricity as a sustainable energy, free of greenhouse effect gas emission as well as of contaminated waste.
The second task is to inform and to convince decision makers of PVNB possibilities. For that purpose, we expect much from the achievement of SUNWATT's PVNB, as it will be the best demonstrative example in real size of this technology.

4. OUTLOOK

The result of this study confirms the current activities to implement PV on noise barriers as an important share in the PV market.
It is anticipated by the partners that the chances to realise large shares of the potentials are good in Germany, the Netherlands and Switzerland. In France, United Kingdom and Italy the realisation of larger PVNB is rather unlikely.
There are recent changes in the revenue rate for electricity of PV feed-into the inter-connected grid: In Germany 0.506 EURO/kWh for 20 years has been decided, in Spain 0.40 EURO/kWh are currently under discussion. In both cases (in Germany together with the soft-loan of the 100,000 Roof-Programme) the profitability of PVNB is strongly improved and reinforced actions to install further PVNB are envisaged.

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The full report can be found in the internet:
www.tnc.ch

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