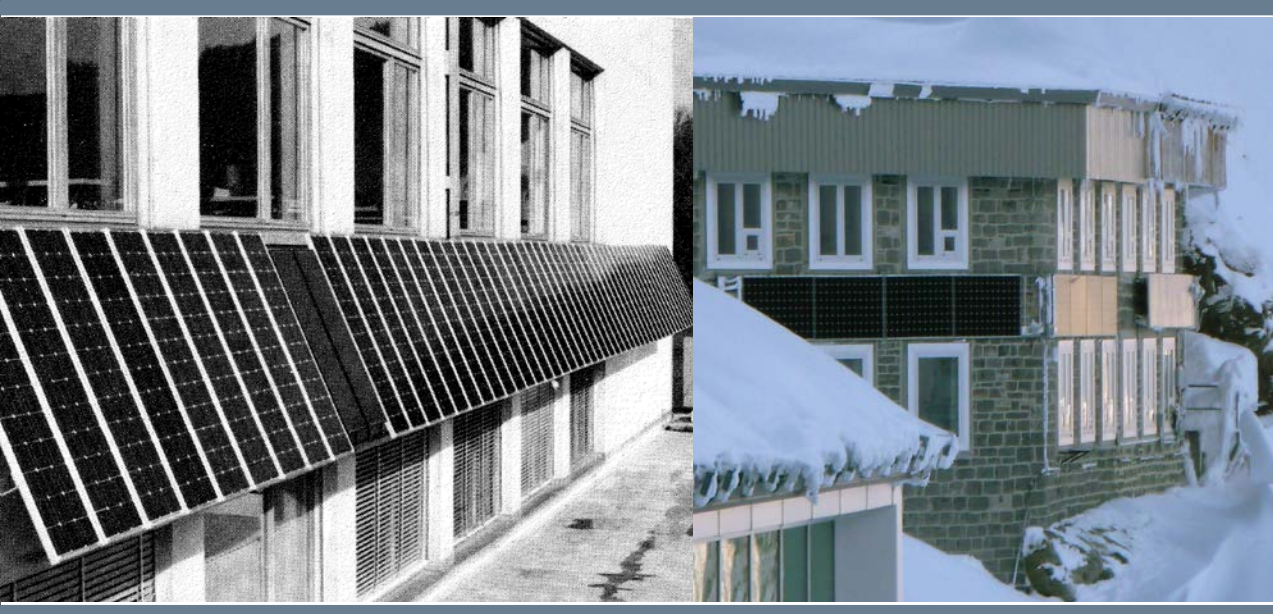




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# Long-term Measurements of PV Installations

Laboratory for Photovoltaic Systems (PV LAB)

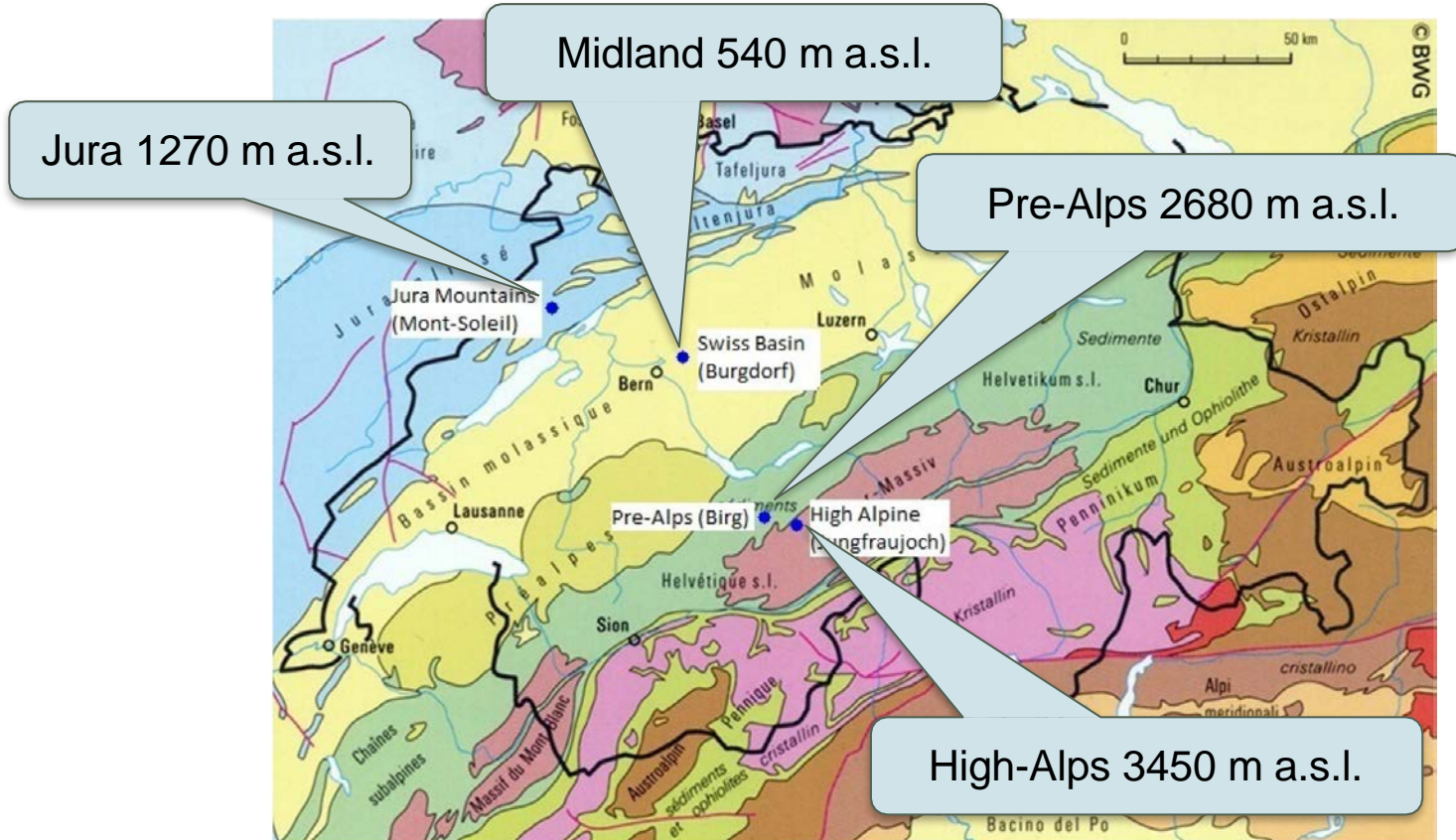
Competence Group on Long-term Measurements

Thomas Schott, Prof. Urs Muntwyler, PD Dr. Eva Schüpbach

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# Long-term Measurements of PV Installations

## PV installations monitored by the PV LAB at BFH



Located in four climate regions in Switzerland



# Long-term Measurements of PV Installations



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## ► **Robustness and degradation**

Regarding long-term measurements:

### **Focus 20 years ago**

- *What is the technical serviceability of an installation?*
- *What is the failure frequency of an installation?*
- *How many components need to be replaced and how often (e.g., converters)?*
- *What is the decrease in energy yield due to dirt and module ageing?*
- *What is the lifetime of the PV modules?*

# Long-term Measurements of PV Installations

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- ▶ *What is the lifetime of the PV modules?*

### **Focus today**

- ▶ *Long-term data records of high quality*
- ▶ *Used for model calibration (e.g., [www.sonnendach.ch](http://www.sonnendach.ch))*

# Long-term Measurements of PV Installations

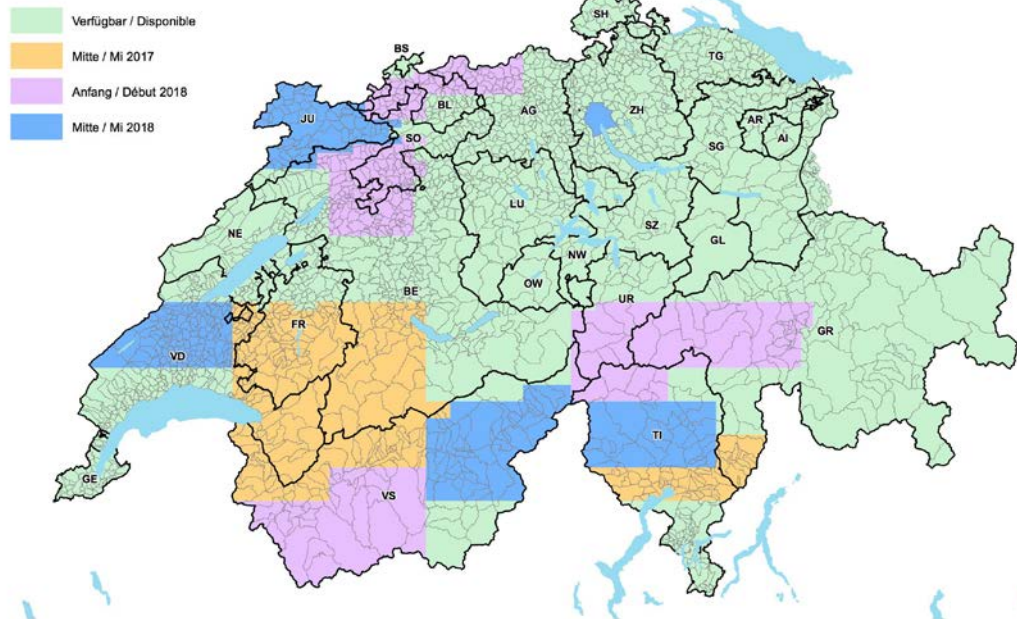
## Example 1: Modelling of solar energy earnings on roofs in Switzerland

[www.sonnendach.ch](http://www.sonnendach.ch)

- ▶ Freely available web application to calculate how much electricity / warm water can be produced on each individual building roof in Switzerland.
- ▶ The work will be completed in May 2018, when calculations can be done on all roofs in Switzerland.
- ▶ [www.sonnendach.ch](http://www.sonnendach.ch) is a project financed by the Swiss Federal Office of Energy (SFOE).

Sonnendach.ch: Geplante Publikationsdaten  
Toitsolaire.ch: Date de publication prévue

Stand 31.03.2017, Änderungen sind vorbehalten.  
Etat au 31.03.2017, droit de modification réservé.



# Long-term Measurements of PV Installations

Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK  
Bundesamt für Energie BFE  
Dienst Geoinformation

Solarpotentialanalyse für Sonnendach.ch

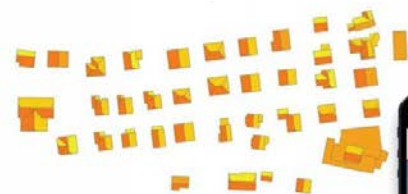
Daniel Klausner, 19.02.2016

## Solarpotentialanalyse für Sonnendach.ch

### Schlussbericht



3D Gebäude  
zu  
2D Dachflächen (Vogelperspektive)



Datum: 19.02.2016

Ort: Bern

Auftraggeber: Bundesamt für Energie BFE, 3003 Bern

Auftragnehmerin:  
Genossenschaft Meteotest, Fabrikstrasse 14, 3012 Bern

Autor:  
Daniel Klausner (Meteotest)

Begleitgruppe: Martin Hertach (BFE), Dominique Kröppli (BFE), Aebi (swisstopo)

BFE-Bereichsleitung: Martin Hertach (Dienst Geoinformation)  
BFE-Vertrags- und Projektnummer: SI/300186-01

Model results are validated with measured data from the long-term monitoring network operated by the PV LAB at BFH. The PV installation sites used for the model validation (in total 10 systems) all display a 10-year record (from 2004-2014). Three sites are located in the Bernese Oberland, one in the Jura Mountains (Mont Soleil), five in Burgdorf (Swiss Basin) and one in Basel.

### 9.2.1. Validierung mit langjährigen Messreihen der BFH Burgdorf

Die Langzeitmessungen des Labors für Photovoltaik der BFH Burgdorf umfassen 14 PV-Anlagen, die teilweise mehrere Teilanlagen aufweisen. Davon wurden 7 Anlagen mit insgesamt 10 Teilanlagen für die Validierung ausgewählt. Die Daten wurden von der BFH Burgdorf für die vorliegende Validierung aufbereitet. Ausgewählt wurden jene Anlagen, für die mindestens für 10 Jahre der Periode 2004 – 2014 Messwerte vorliegen. Umfangreiche Informationen zu den Anlagen sind auf der Webseite des Labors für Photovoltaik (<http://www.pvtest.ch>) zu finden. Von den 10 Teilanlagen liegen 5 in Burgdorf (Gfeller, NewTech1-3, Schlossmat), eine im Jura (Mont-Soleil), eine im Baselbiet (Liestal) und drei im Berner Oberland (Birg, Jungfrauoch).



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# Long-term Measurements of PV Installations

## ▶ **Robustness and degradation**

Regarding long-term measurements:

### **Focus 20 years ago**

- ▶ *What is the technical serviceability of an installation?*
- ▶ *What is the frequency of failure of an installation?*
- ▶ *How many components need to be replaced and how often (e.g., converters)?*
- ▶ *What is the decrease in energy yield due to dirt and module ageing?*
- ▶ *What is the lifetime of the PV modules?*

### **Focus today - Addendum:**

- ▶ *What is the realistic duration of a PV module's exposition to the sun?*
  - *Life time of a roof is 40 years (SIA norm)*
  - *profitability (BKW pays 4 Rp. / kWh)*



# Long-term Measurements of PV Installations

## Example 2: Lifetime and degradation of PV modules

- ▶ Analysis of the time variation curves of the PV installation sites at Mont Soleil (Jura Mountains) and Jungfrauoch (Swiss Alps) by Breitinger & Moser (2017)\*:

- Siemens M55 modules on all PV installations included in the analysis
- Age of PV modules included in the analysis: 25 years (+/- 2 years)

-> **Results:** Lifetime & degradation are linked to climate (mean temperature, temperature differences (min./max.), (solar radiation intensity))

- \* Bachelor Thesis, Spring Semester 2017:  
“Auswertung 25 Jahre PV-Anlage Mont-Soleil”  
Authors: Dominik Breitinger, Jürg Moser





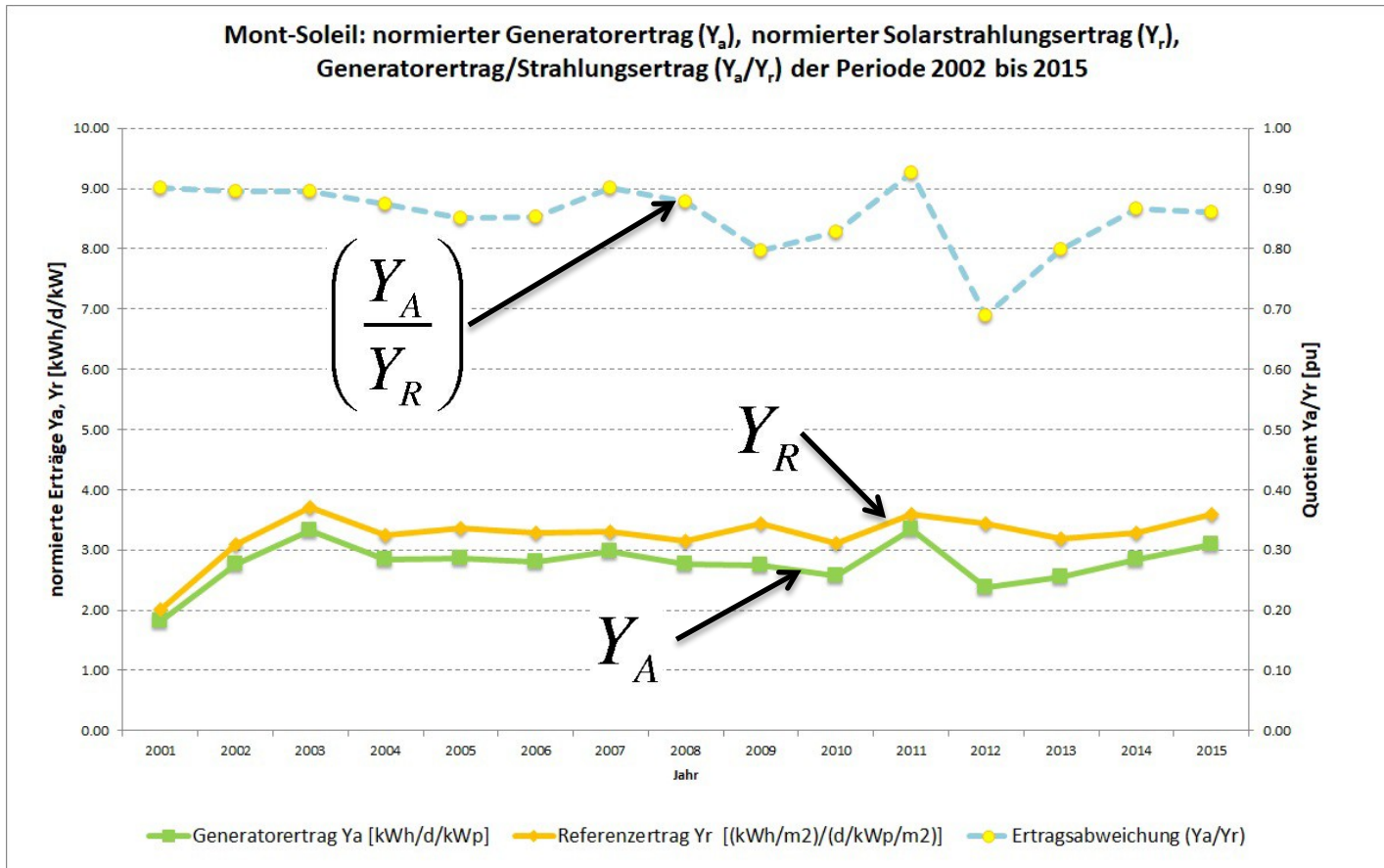
# Long-term Measurements of PV Installations

Normalised yields ( $Y_R$  and  $Y_A$ ) are used to compare the PV installation sites:

Symbol / Term	Meaning / Definition	Unit
<p>▶ <math>Y_R</math> = Reference Yield = theoretical yield measured by the pyranometer</p>	<p><math>Y_R</math> is equal to the time that the sun has to shine with <math>G_0 = 1 \text{ kW/m}^2</math> to irradiate the energy <math>H_G</math> onto the solar generator</p>	$\left[ \frac{\text{kWh} / \text{m}^2}{d \cdot 1 \text{ kW} / \text{m}^2} \right] = \left[ \frac{h}{d} \right]$
<p>▶ <math>Y_A</math> = Array Yield = Generator (DC-) performance</p>	<p><math>Y_A</math> is equal to the time that the <math>P_V</math> plant has to operate with its nominal power <math>P_0</math> to generate array (DC-) energy <math>E_A</math></p>	$\left[ \frac{\text{kWh}}{d \cdot 1 \text{ kW}} \right] = \left[ \frac{h}{d} \right]$

# Long-term Measurements of PV Installations

Because  $Y_R$  represents the effectively captured energy yield, while  $Y_A$  represents the finally converted energy, we can put  $Y_A$  in relation to  $Y_R$  and receive a quotient that represents a measure of the degradation.

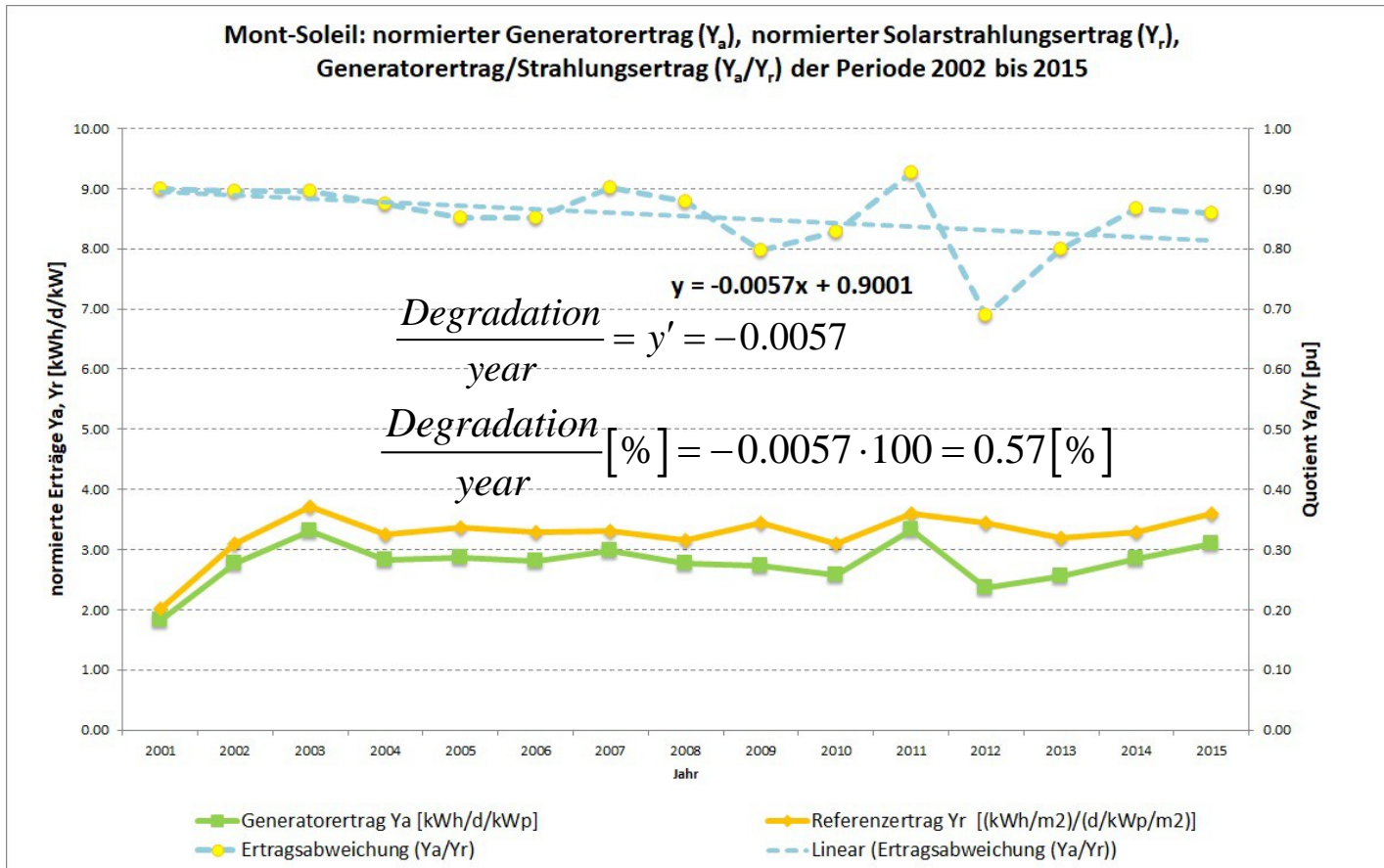


# Long-term Measurements of PV Installations



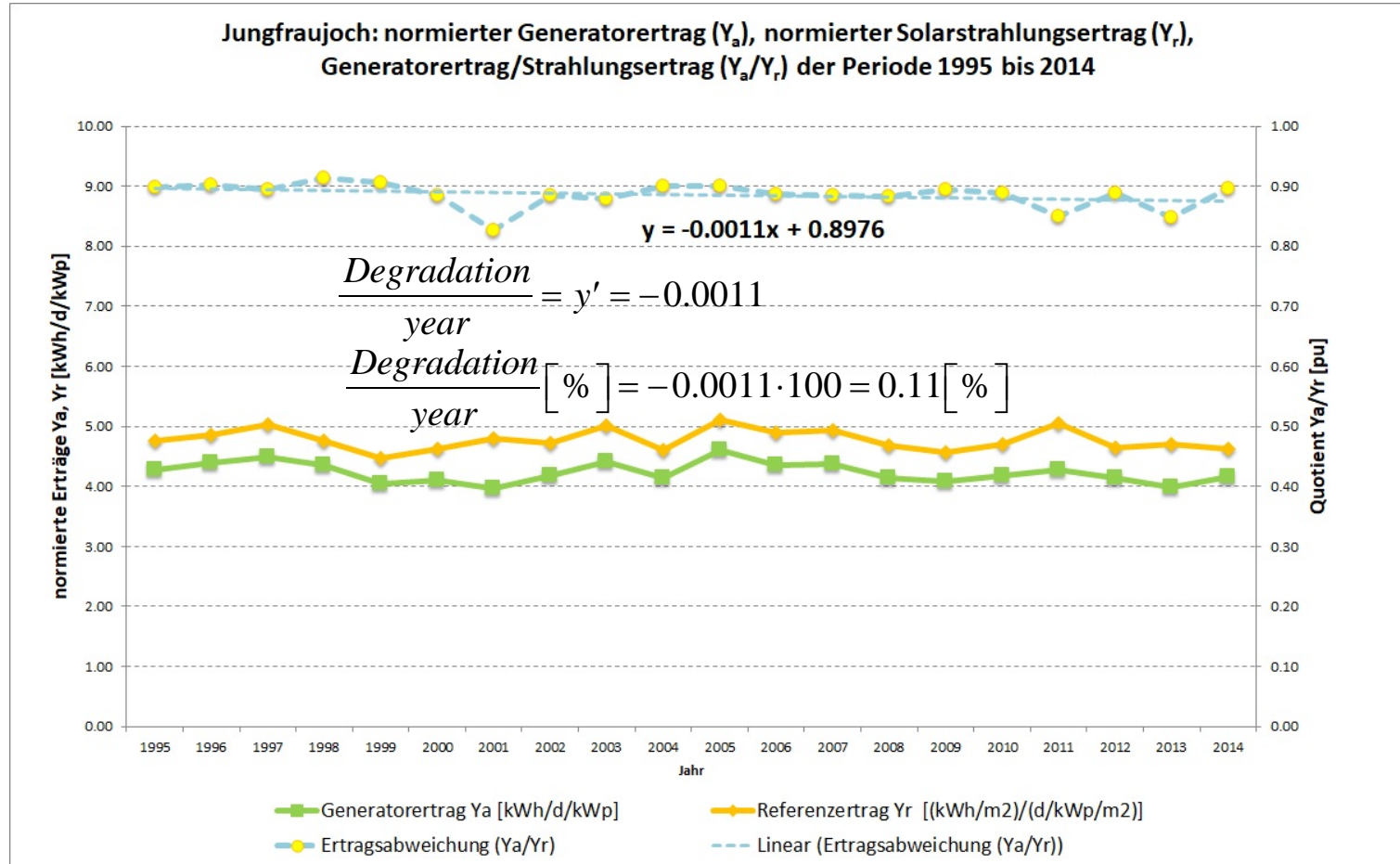
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A linear curve fitting to the time variation curve provides the well known function:  
 $y = ax + b$ , where the factor  $a$  represents the gradient that corresponds in our case to the degradation per year in per-units [pu].



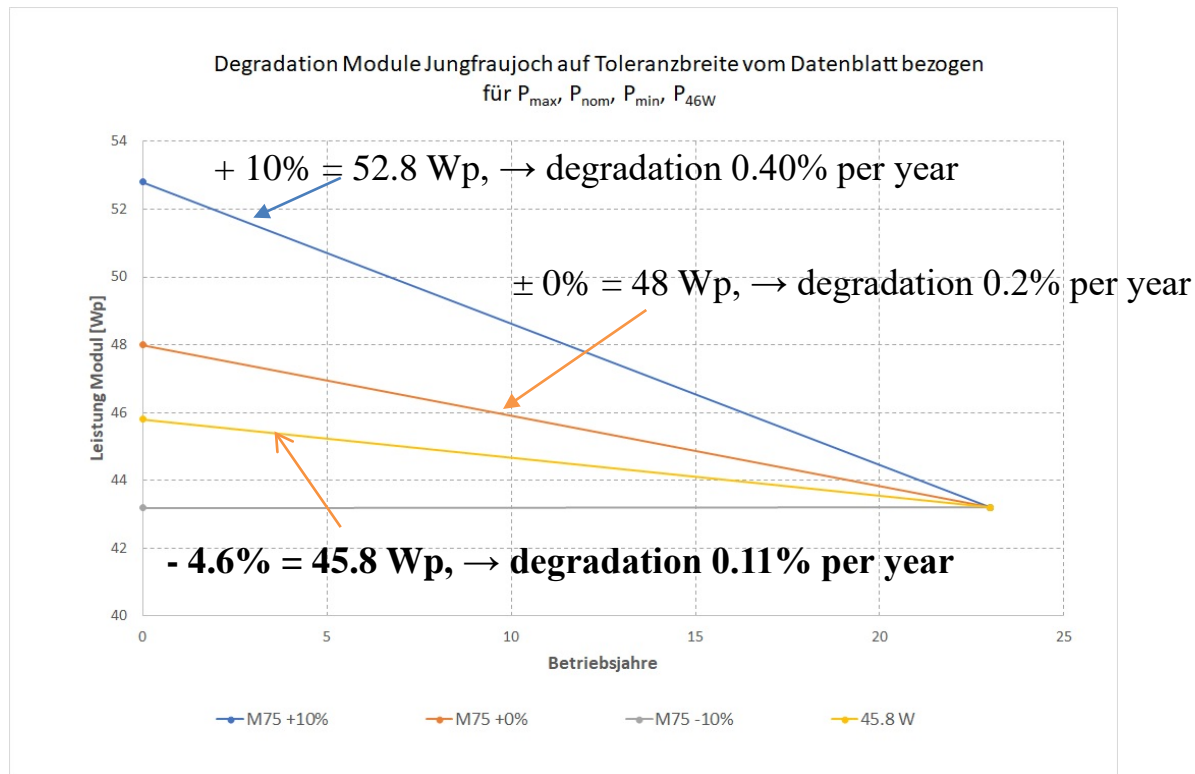
# Long-term Measurements of PV Installations

The PV installation at Jungfrauoch has been operational for 25 years. The diminution of the effective yield - over the analysed 20 years - is only 0.11% per year.



# Long-term Measurements of PV Installations

Two PV modules at the Jungfrauoch installation were detached (after 25 years of operation) and flashed at the PV LAB at BFH in Burgdorf.



A degradation of 0.11% per year (resulting from the measurement analysis) suggests a performance of the new panel of 45.8 Wp. As compared to the nominal 48 Wp of the data sheet, this is within the tolerance band of  $\pm 10\%$

# Long-term Measurements of PV Installations



3450 m a.s.l.

$\frac{0.11\%}{\text{year}}$



1270 m a.s.l.

$\frac{0.57\%}{\text{year}}$

The degradation analysis by Breitingner & Moser (2017) reveals that PV modules from the 1990s are ageing less dramatically than was anticipated 20 years ago.

# Long-term Measurements of PV Installations

With new technologies, new questions are coming up!

## Technology in 2014

Sunpower X21-345

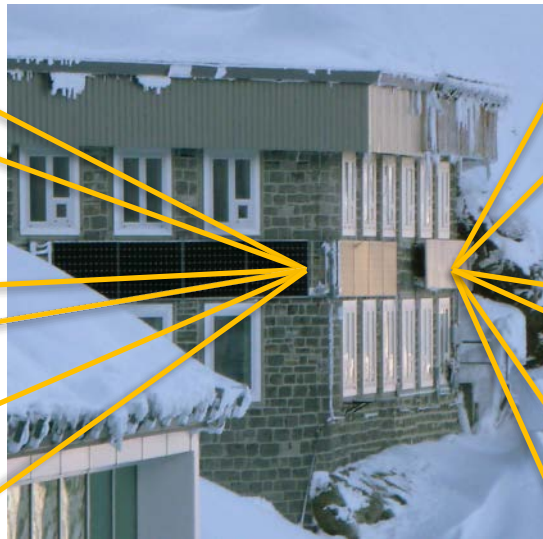
$\eta_{\text{module}}$  : 21 %

tolerance: +5% / -0%

size: 8 x 354Wp  
= 2832Wp  
area: 13.05m<sup>2</sup>

$\eta_{\text{inverter}}$  : 97 %

life time:  
« already » 3 years



## Technology in 1995

Siemens M75

$\eta_{\text{module}}$  : 12 %

tolerance: +10% / -10%

size: 24 x 48Wp  
= 1152Wp  
area: 9.65m<sup>2</sup>

$\eta_{\text{inverter}}$  : 93 %

life time:  
already 21 years



# Long-term Measurements of PV Installations

## Summary

The important question of long-term measurements today is:

- ▶ *What is the realistic duration of a PV module, when exposed to the sun for work?*
- ▶ *Need of long-term data records of high quality for:*
  - *model calibration*
  - *verifications of extrapolations regarding life time forecasts of PV-modules*





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## Acknowledgements

*Swiss Commission for Technology and Innovation (CTI - SCCER program),*

*SCCER-FURIES*

*International Foundation High Altitude Research Stations Jungfrauoch and  
Gornergrat*

*Bern University of Applied Sciences BFH*

*Dominik Breitingner & Jürg Moser (Bachelor Thesis BFH 2017)*

*Prof. Urs Muntwyler (Leader PV LAB at BFH)*

*PD Dr. Eva Schüpbach (PV LAB at BFH)*

**HFSJG** High Altitude Research Stations  
**Jungfrauoch & Gornergrat**



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# Long-term Measurements of PV Installations

Thank you for your attention!



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