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Integration of PV Systems in the low voltage grid – experience of the German utility badenova

Klaus Preiser

Experience Klaus Preiser

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- 1983 – 1989 Electrical Engineer at University of Karlsruhe

- 1989 – 2002 Fraunhofer Institut für Solare Energiesysteme, Freiburg

  - Head of department “Electrical Energy Systems”
  - Development of PV Inverter
  - Stand-alone PV systems worldwide

- 2002 – today badenova AG, Freiburg

  - Head of department “Production of Heat and Electricity”
  - CEO badenova Wärmeplus, Freiburg, 100% badenova
  - 45 people installing and operating all kinds of renewable energy systems
  - Installation of 7 MWp PV systems (120 systems)

Worldwide distribution of annual solar irradiance

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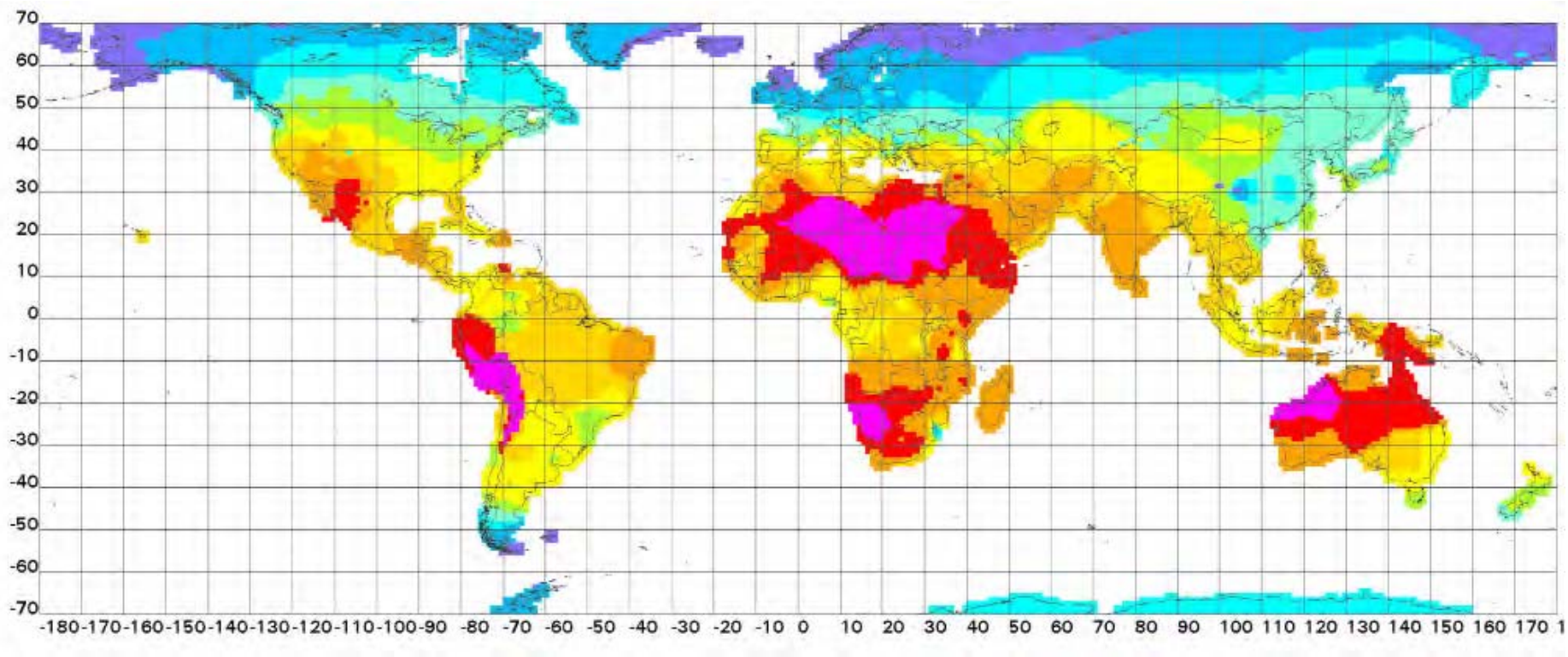

Bild 3

Solar irradiation in Germany

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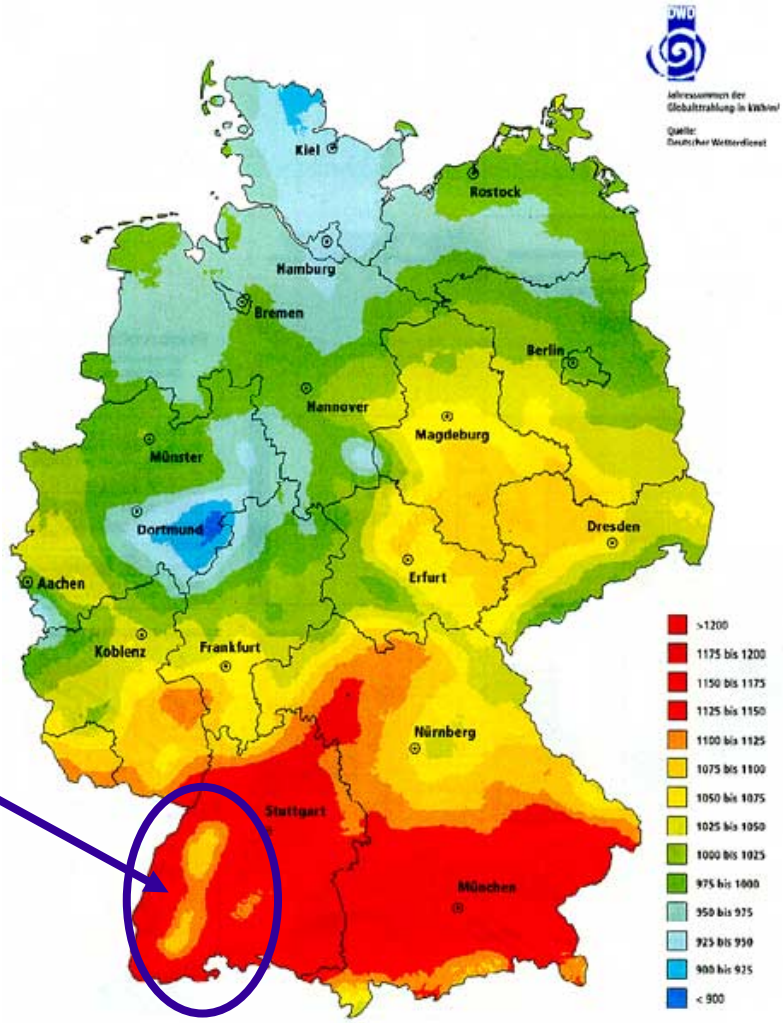
In “badenova-country”:

highest solar irradiation in Germany



Private House nearby Freiburg

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Bild 5

Schlierberg Solar Estate in Freiburg

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Bild 6

The Main Station in Freiburg

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Bild 7

PV Eichelbuck
2,5 MWp on a former landfill site

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Bild 8

regiosonne: 4 MWp of PV installations within a joint ownership project

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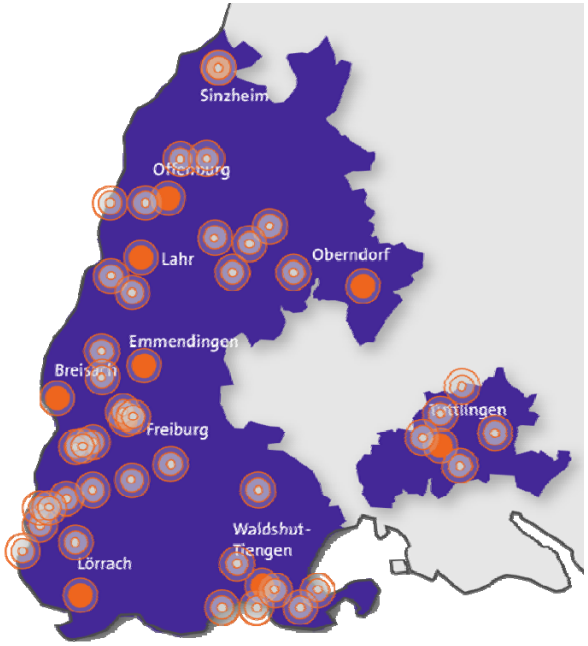
Some Data to badenova



Annual Turnover:	720 Mio €
Employees:	1.200
Natural Gas:	16 TWh, 7575 km, 172.000 clients
Electricity:	1,1 TWh, 4334 km, 152.000 clients
Water:	17 Mio m³, 1340 km, 35.000 clients
Heat:	400 GWh, 120 km, 2.000 clients
Origin:	Merger of seven utilities in 2001
Shareholders:	75 regional municipalities

Installation of photovoltaics by badenova

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- Support schemes for customers who want to install their own system
- Joint ownership systems for investing in municipality owned buildings (schools, town halls, sport buildings, fire brigade, etc.)
- Own investments on own buildings and ground areas
- Green energy is a must in competitive markets
- Municipalities (the share holders of badenova) want more green energy
- Technically seen is PV a proven technology with very low risks
- Financially quite good ROI because of renewable energy act since 2000
- badenova is an ecological oriented utility to promote energy change
- Direct installation of 7 MWp, supporting schemes for about 20 MWp

Reasons for green energy at badenova

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- The badenova region has a long green tradition – fight against nuclear power
- badenova belongs to the regional municipalities
- Lord Mayor of Freiburg is head of our control board belongs to green party
- Our customers strongly ask for green electricity
- Black forest is traditionally a biomass region
- Black forest has very good wind sites
- We are the most sunny region in Germany

  – e.g. the best wine comes from Baden

  - the highest density of restaurants with Michelin stars

People – i.e. our clients – want green energy

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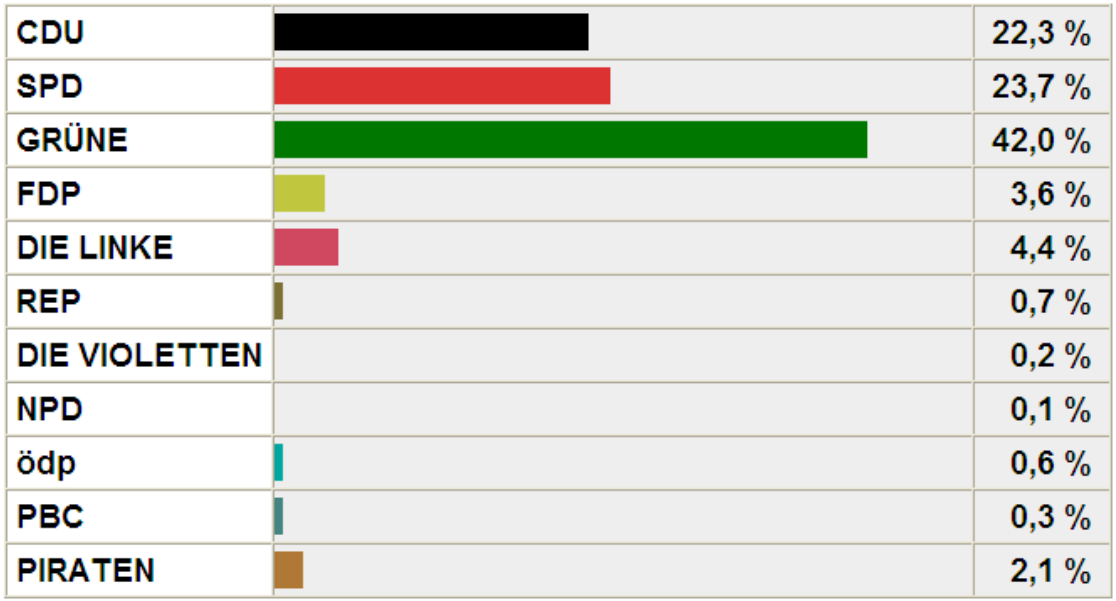
Ergebnis der Landtagswahl am 27. März 2011 im Stadtgebiet Freiburg (Teile der Wahlkreise 46 und 47, kein Wahlkreisergebnis)

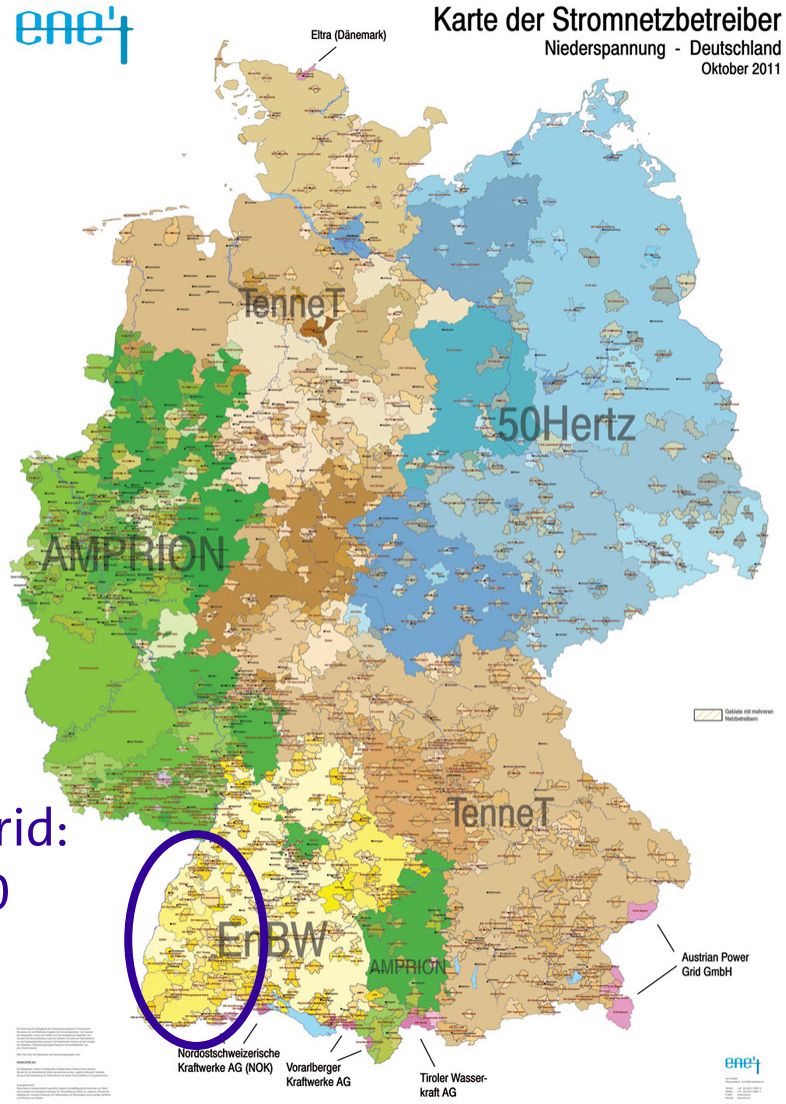
Endergebnis
180 Bezirke



CDU	22,3 %
SPD	23,7 %
GRÜNE	42,0 %
FDP	3,6 %
DIE LINKE	4,4 %
REP	0,7 %
DIE VIOLETTEN	0,2 %
NPD	0,1 %
ödp	0,6 %
PBC	0,3 %
PIRATEN	2,1 %

Wahlbeteiligung: 67,0%

Germany: 854 distribution grid operators



In badenova grid:
more than 100
power dealers

854 distribution grid operators

1015 power supply companies,

4702 different electricity tariffs

Strong competition:
Ecological power supply is an unique selling proposition

Strong competition on the German power market: 100 tariffs for green electricity

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Bild 15

Renewable power generation in Germany

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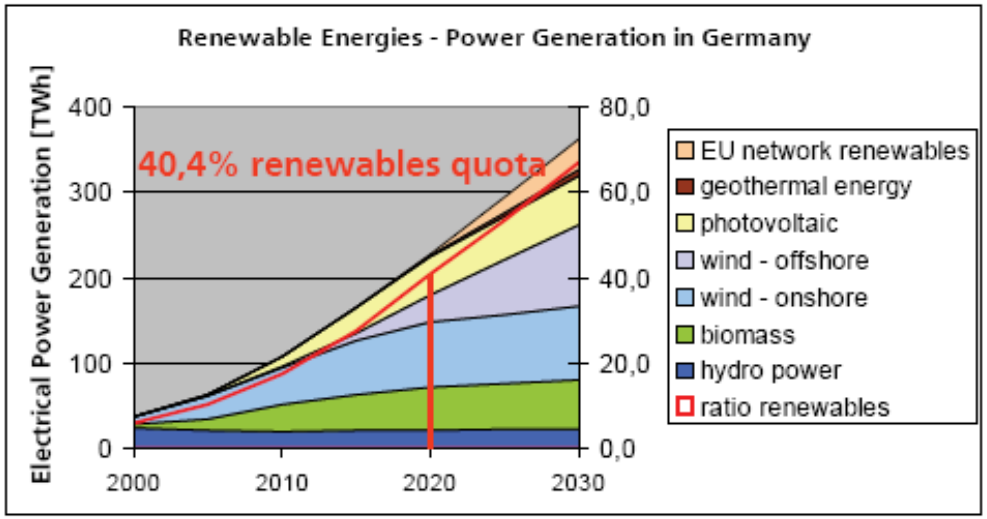

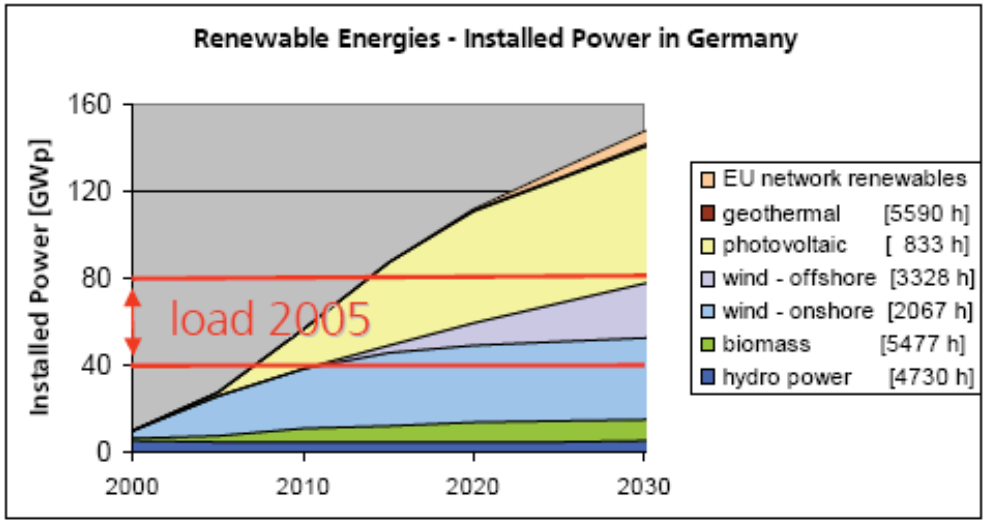

Source: "Leistszenario 2010" – study on behalf of the Federal Ministry for Environment, Nature Conservation and Nuclear Safety

25.000 MW PV in 2011

and the aim of

52.000 MW PV in 2020

means reduction of installation rate from 7.000 MW to 3.000 MW per year

Year 2000 -
The „Renewable Energy Sources Act“

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- Grid operators are obliged to connect PV-plants to their grids
- Priority to Renewable Energies (Wind, Hydro, Biomass, Geothermal PV)
- Fixed feed-in-tariffs – technology specific - over 20 years
- Decreasing tariffs from one year to the next to cope with intended decreasing system prices
- Costs of system connection paid by the operator of the system
- Grid operator disburses the respective fee directly to the plant operator
- A compensation between all transmission grid operators exists
- The costs are burdened to all electricity users

Feed-in tariffs decreased each year

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													derzeitiges Gesetz (* zubauabhängig)		geplante Änderung (keine Vergütung über 10 MW)					
Anlagentyp		2004	2005	2006	2007	2008	2009	2010	Juli 2010	Okt. 2010	2011	2012	Juli 2012 (−15 %) *	2013 (−24 %) *	April 2012	Mai 2012	Juni 2012	Juli 2012	...	Januar 2013
auf einem Gebäude oder einer Lärmschutzwand	bis 10 kW	57,4	54,53	51,80	49,21	46,75	43,01	39,14	34,05	33,03	28,74	24,43	20,77	18,57	19,50	19,35	19,20	19,05		18,15
	ab 10 kW														16,50	16,35	16,20	16,05		
	ab 30 kW		51,87	49,28	46,82	44,48	40,91	37,23	32,39	31,42	27,33	23,23	19,75	17,65						
	ab 100 kW	54,0	51,30	48,74	46,30	43,99	39,58	35,23	30,65	29,73	25,86	21,98	18,68	16,70					monatl. -0,15 ct	
	ab 1000 kW						33,00	29,37	25,55	24,79	21,56	18,33	15,58	13,93	13,50	13,35	13,20	13,05		12,15
Freiflächenanlagen (leistungsunabhängig)	vorbelastete Flächen	45,7	43,4	40,6	37,96	35,49	31,94	28,43	26,16	25,37	22,07	18,76	15,95	14,26						
	Sonstige Freiflächen								25,02	24,26	21,11	17,94	15,25	13,63						
	Ackerflächen								-	-	-	-	-	-	-	-	-	-	-	-

Costs and remuneration of PV since 2006

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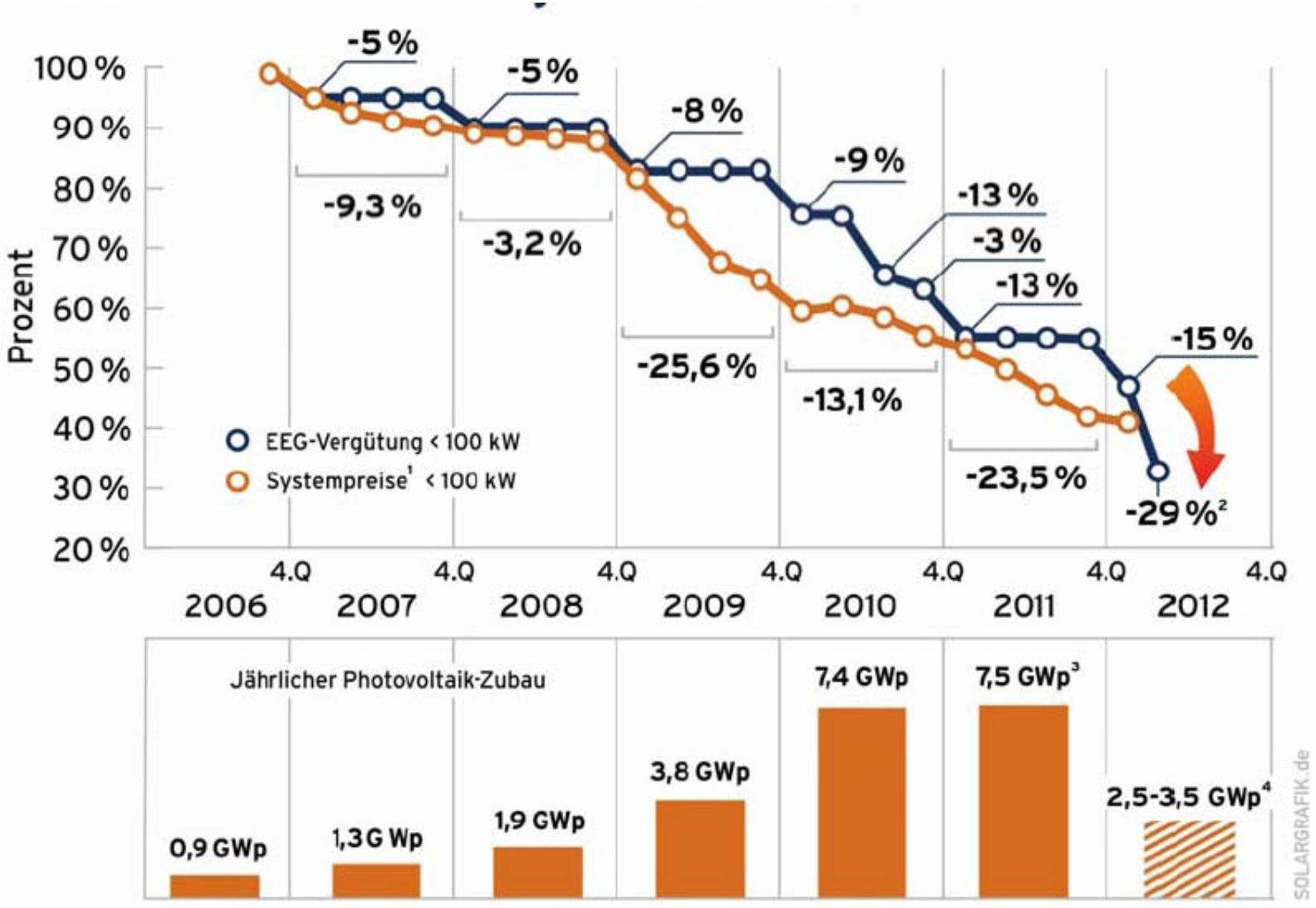

¹ Systempreise: Durchschnittliche Endkundenpreise fertig installierter Aufdach-Anlagen ohne USt.
² geplant zum 9.3.2012
³ Bundesnetzagentur, vorläufig
⁴ Zielkorridor BMU/BMWi

Quelle: BSW-Solar, **www.solarwirtschaft.de**

Technology - lessons learnt

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- Module Quality is unique and (nearly) uniform
- Inverter quality is decisive, meanwhile wide variety available
- Installation quality is crucial for long-term performance
- Grid problems negligible (up to now)
- Installation Guidelines developed
- Connection and Safety Guidelines
  - DIN, VDE, CENELEC and IEC standards
  - conditions and guidelines of the local or regional utility
  - building regulations and authorization
  - technical rules for constructions with glass
  - lightning and surge protection
- conservation laws applying to historic buildings
- regulations for safety at work

Connection to the low voltage grid

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1 PV generator
2 connection box
3 DC cabling
4 DC-AC inverter
5 meters

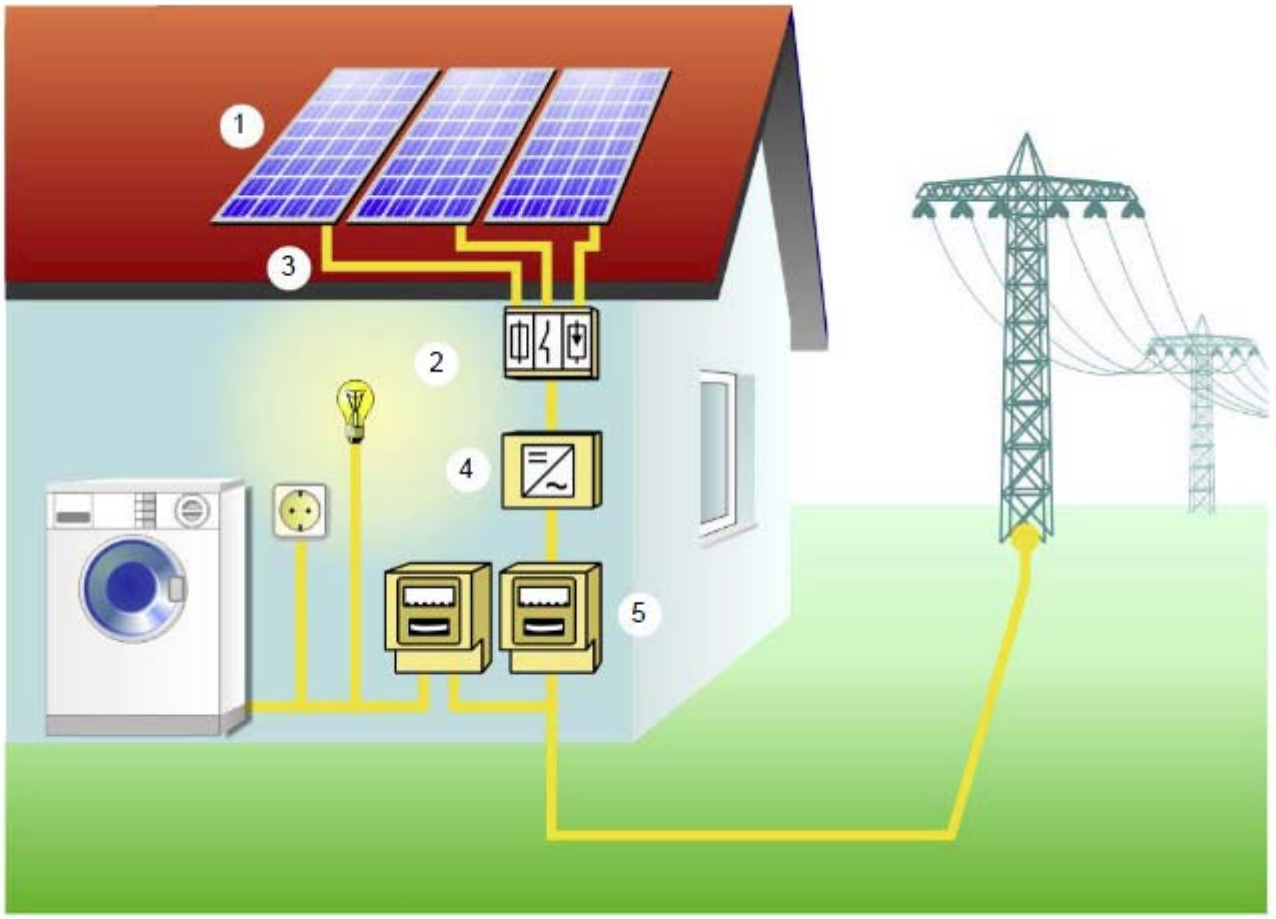

Image: Solarpraxis AG, Berlin, Germany

PV plant as grid manager

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- For long time PV plants considered “negative consumers”
- Quality requirements of inverter: Efficiency, MPP-Tracking, anti-islanding
- Today PV plants provide system services like:
  - remote power limitation by grid operator
  - active power reduction in case of overfrequency
  - option of reactive power provision
  - option of riding through short-term grid voltage drops with simultaneous feed-in of reactive current
- Factor governing its applicability is not the grid level but the installed power, i.e. 100 kWp

Technical Guideline by German association of energy and water industries BDEW

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Technical Guideline

Generating Plants Connected to the Medium-Voltage Network

Guideline for generating plants' connection to and parallel operation with the medium-voltage network

June 2008 issue

bdew
Energie. Wasser. Leben.

The relevant codes – low voltage

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	E VDE-AR-N 4105	VDE
	Dies ist eine VDE-Anwendungsregel im Sinne von VDE 0022 unter gleichzeitiger Einhaltung des in der VDE-AR-N 100 beschriebenen Verfahrens. Sie ist nach der Durchführung des vom VDE-Präsidium beschlossenen Genehmigungsverfahrens unter der oben angeführten Nummer in das VDE-Vorschriftenwerk aufgenommen und in der „etz Elektrotechnik + Automation" bekannt gegeben worden.	FNN

ICS

Einsprüche bis 2010-09-30

Erzeugungsanlagen am Niederspannungsnetz –
Technische Mindestanforderungen für Anschluss und Parallelbetrieb von Erzeugungsanlagen am Niederspannungsnetz

Generators connected to the low-voltage distribution network -
Technical requirements for the connection to and parallel operation with low-voltage distribution networks

Anwendungswarnvermerk

Dieser VDE-Anwendungsregel-Entwurf wird der Öffentlichkeit zur Prüfung und Stellungnahme vorgelegt.

Weil die beabsichtigte VDE-Anwendungsregel von der vorliegenden Fassung abweichen kann, ist die Anwendung dieses Entwurfes besonders zu vereinbaren.

Stellungnahmen werden erbeten

- vorzugsweise als Datei per E-Mail an **fnn-stellungnahme@vde.com** in Form einer Tabelle. Die Vorlage dieser Tabelle kann im Internet unter **www.vde.com/fnn/stellungnahme** abgerufen werden
- oder in Papierform an den VDE Verband Der Elektrotechnik Elektronik Informationstechnik e.V., FNN, Bismarckstr. 33, 10625 Berlin.

Die Empfänger dieses Entwurfs werden gebeten, mit ihren Kommentaren jegliche relevante Patentrechte, die sie kennen, mitzuteilen und unterstützende Dokumentationen zur Verfügung zu stellen.

Gesamtumfang 68 Seiten

VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V.

Connection process roof tops

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- roof mounted PV systems:
  - no need of any permission except a proof of the static ability of the roof
  - application for grid connection to DSO responsible for connection
  - determination of the next feed-in connection point by the DSO
  - designation of maximum allowed apparent power and cosphi by the DSO
  - >30 kWp DSO may charge connection costs to the PV system operator
  - >30 kWp electronic switch for disconnecting by the DSO must be installed
  - design and installation by system operator according to the agreed rules
  - approval by the representative of the DSO
  - own energy counting device for billing with the DSO
  - installation of an appropriate lightning protection systems
  - assurance within the building assurance contract

Connection process ground mounted systems

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- ground mounted systems (in addition to rooftop systems):
  - construction authorisation by the community, legal construction plan
  - partly: authorisation by flight authority (reflection of solar rays)
  - next grid connection point under respect of lowest connection costs
  - anti-theft protection (important, PV is sexy!)

„Power flow is turned upside down“

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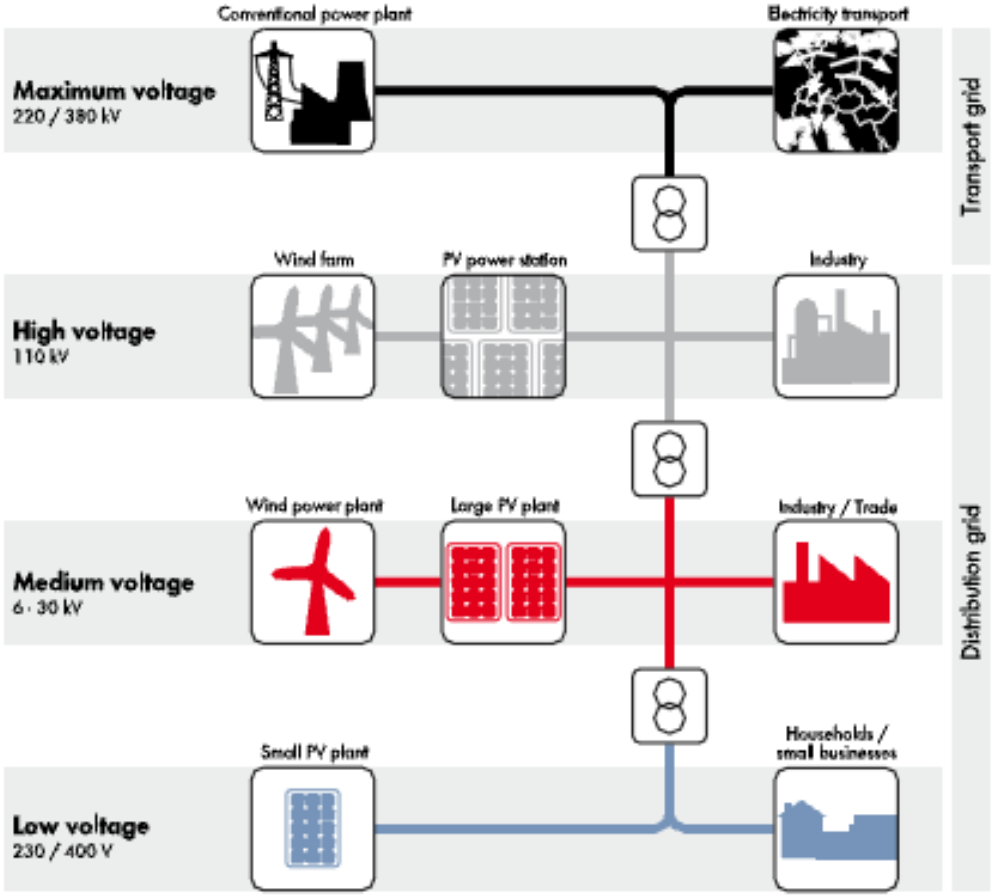
- From top-down structure to fluctuating bi-directional power flow
- Distribution grid is “collector” grid
- Renewables also have to fulfil system services

- Only a few on high voltage 110 kV
- 15 % medium voltage level 6 -30 kV
- 85 % low voltage level 230 V/400 V



Typical load curve in Freiburg

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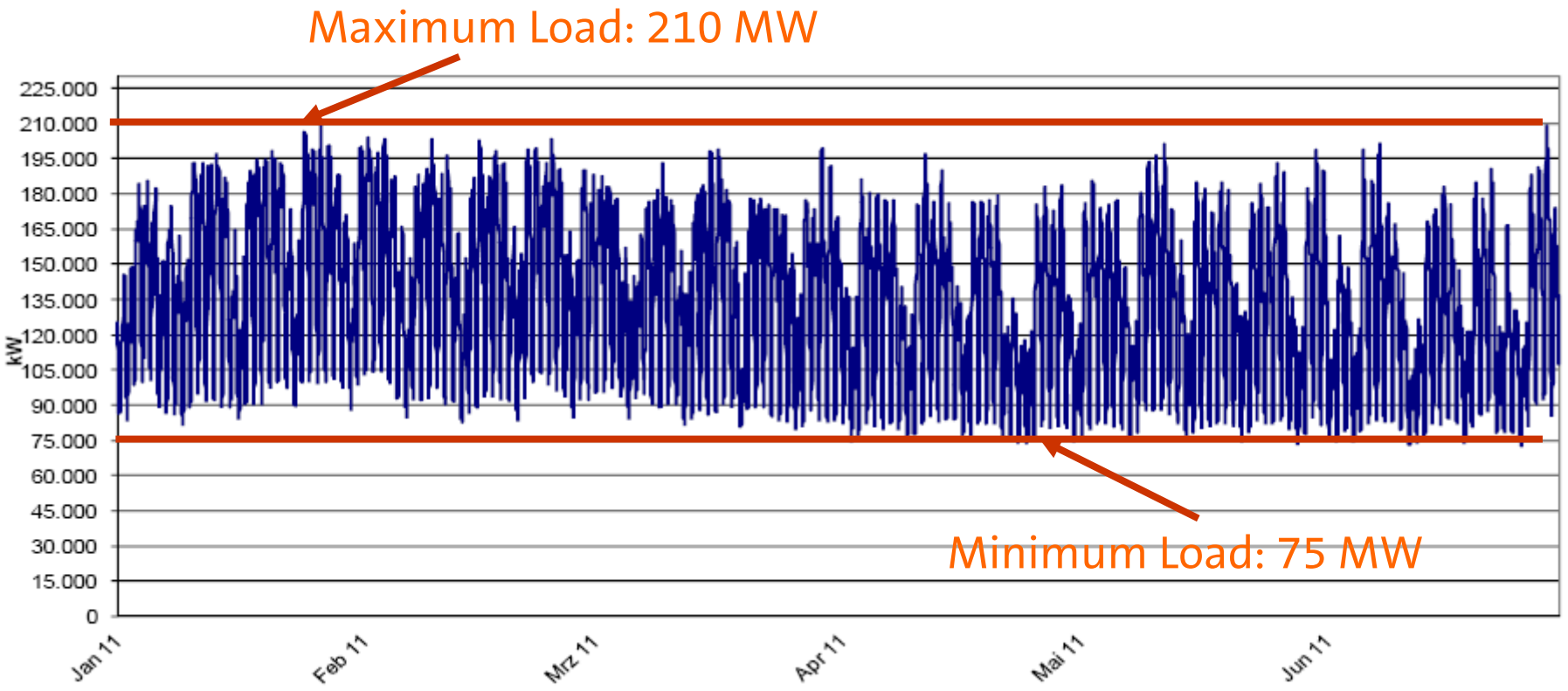

Today about 3.000 PV system with about 30 MW of PV systems feed-in their power in the low voltage grid of badenova, up to now no real problems occured

Power fed in to the different voltage levels

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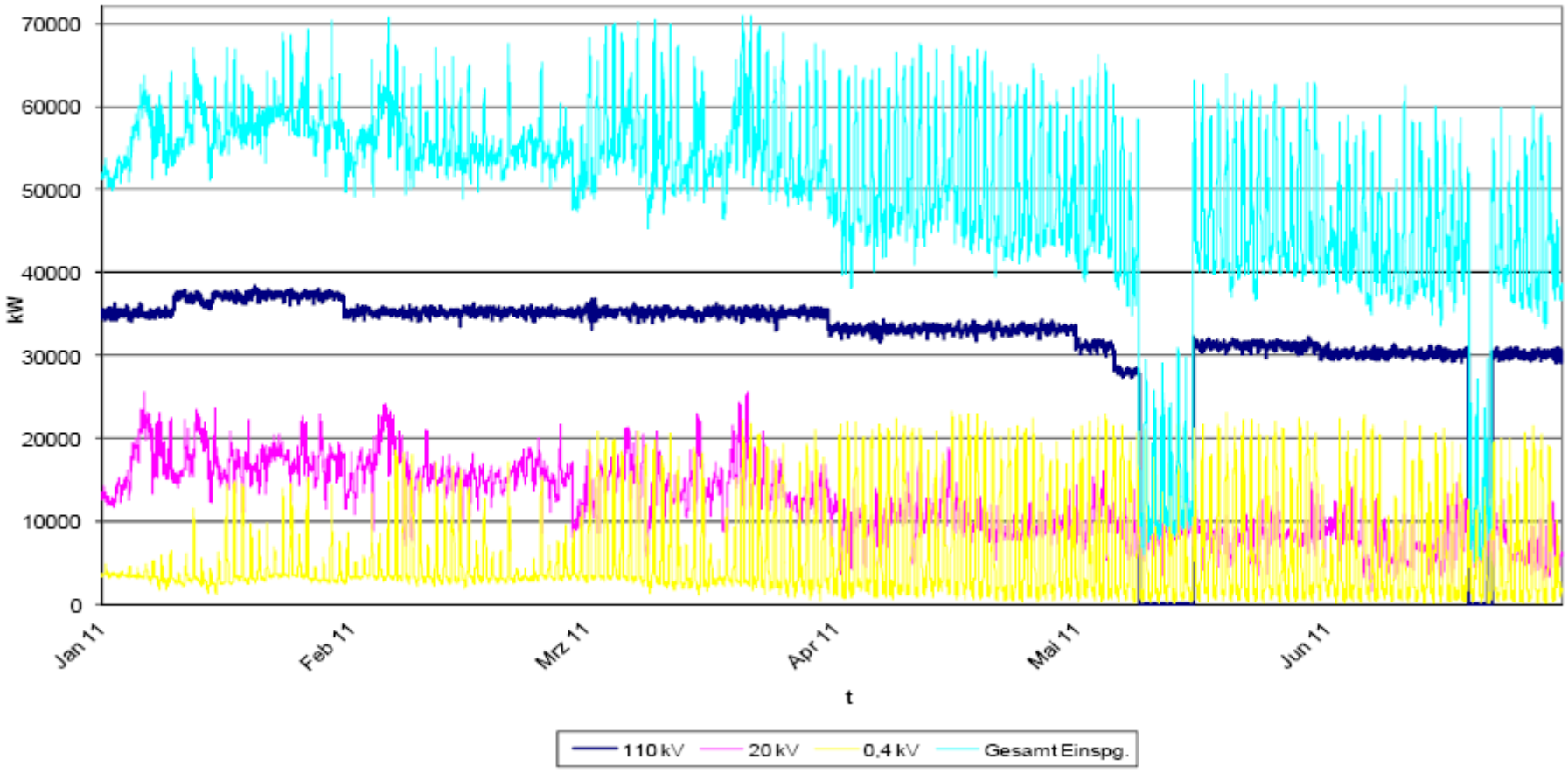

In 2011 no power reverse flow did occur in the badenova grid

Germany: What‘s up with PV today?

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- Technically proven sytems and components available
- Installation guidelines developed and continously adapted
- High quality installation process (short planning and authorisation phase)
- High qualification of thousands of installers
- Grid problems negligible
- Reduction of installation velocity due to missing planning process:
  - PV and wind are fluctuating sources
  - CO_2 abatement strategy restricts use of coal fired power plants
  - Nuclear power to be shut down completely until 2022
  - The „big four“ (RWE, eon, Vattenfall, EnBW) must find new businesses
  - Electricity prices on stock market currently to low to install gas turbines

Development of peak and off-peak electricity prices in the last years due to PV

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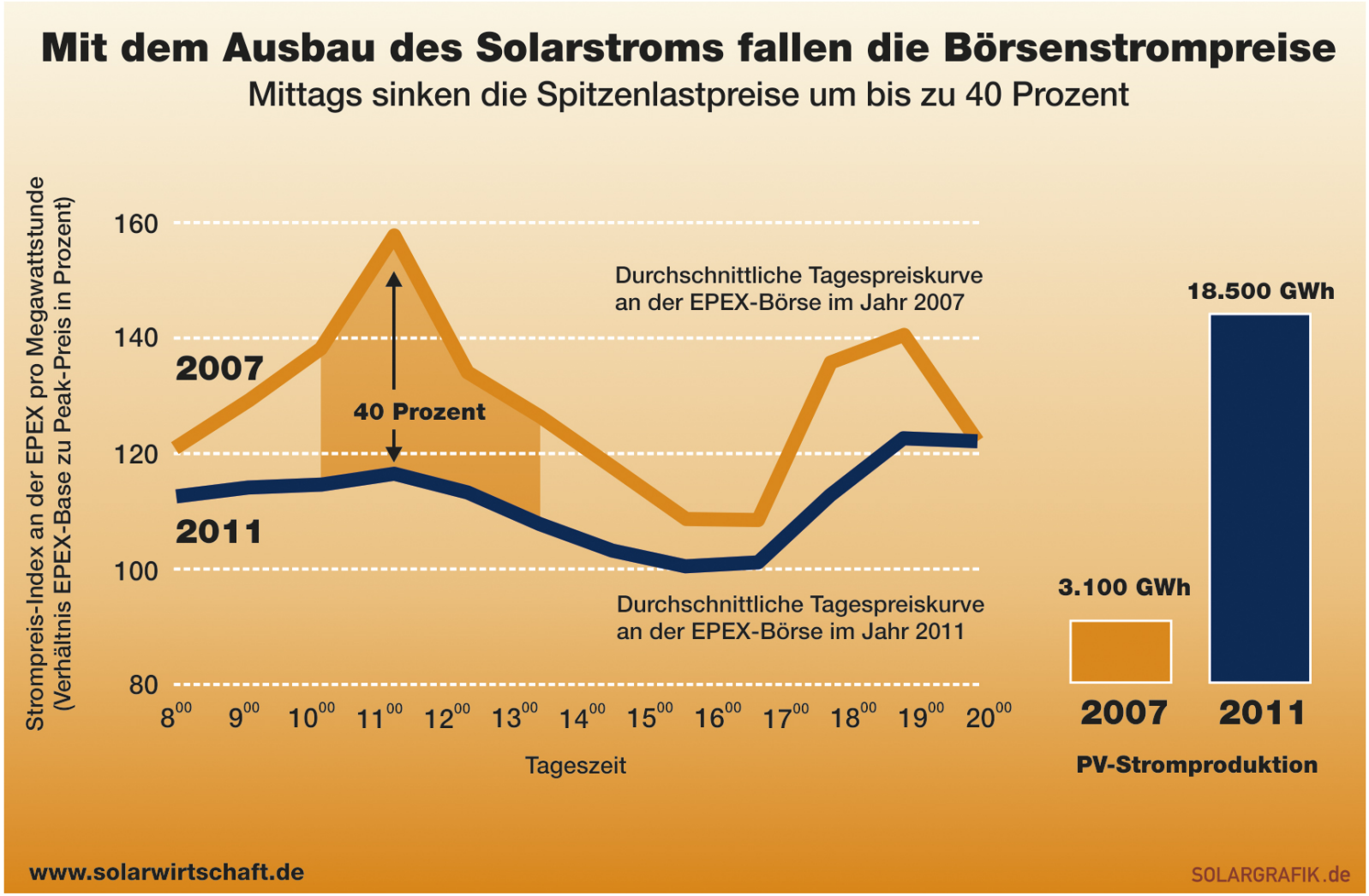

Germany: What‘s up with PV in the future?

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- Installations will be reduced from 7.500 MW_p to about 3.000 MW_p per year
- System prices have to drop again 10 to 20% to give adequate return on investment rates
- Due to very quick drop in system prices (China!) German manufacturers will get more and more in economic troubles – first companies already bancrupt
- Large installations over 10 MW_p will not be supported any more
- Grid extension on the low voltage grid and new operation schemes have to be established
- Electricity storage will become an issue (e-mobility, power to gas...)
- Net metering will be come an issue for private households and business facilities

Solar Energy is the only solution

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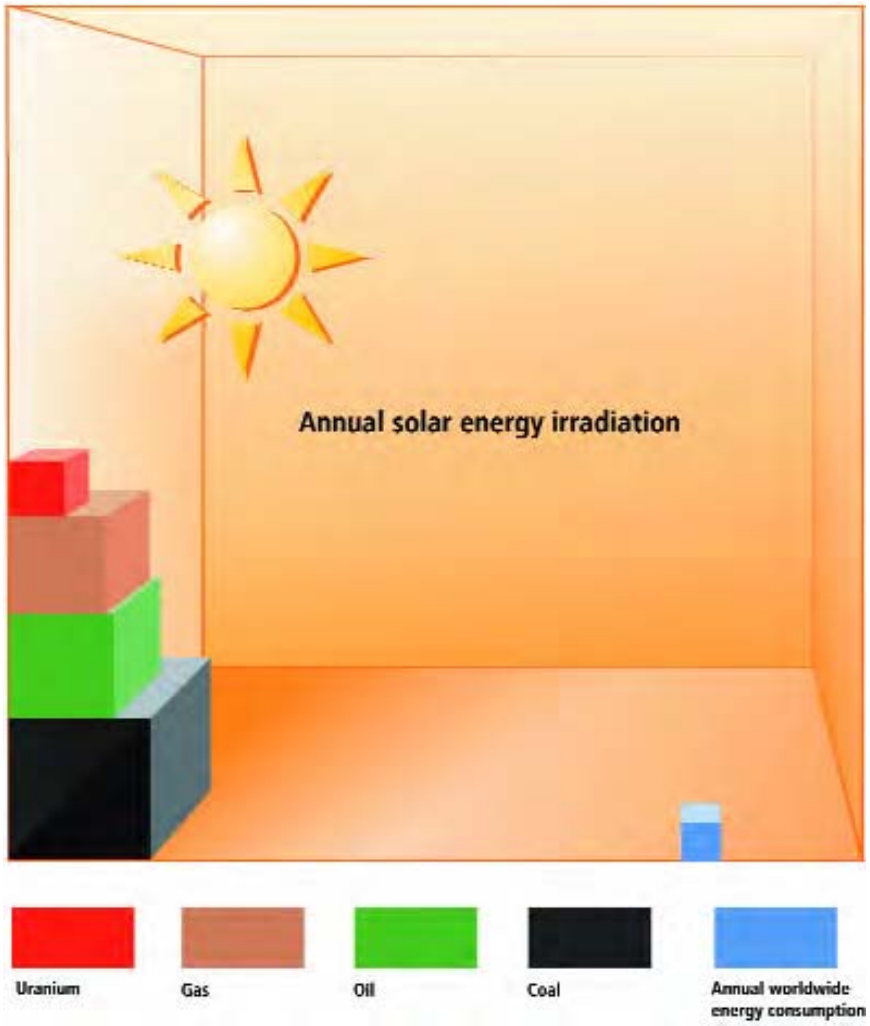

Energy content of annual solar radiation reaching the Earth's surface in comparison to worldwide energy consumption and fossil and nuclear energy resources:

"Each hour the sun delivers the amount of energy that whole mankind consumes for power, heat and transport over the whole year!"

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Thank you very much for your attention