IEA INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

The IEA PVPS Task 14
High penetration PV in Electricity Grids

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Operating Agents IEA PVPS Task 14

IEA-PVPS Task 14 –Workshop

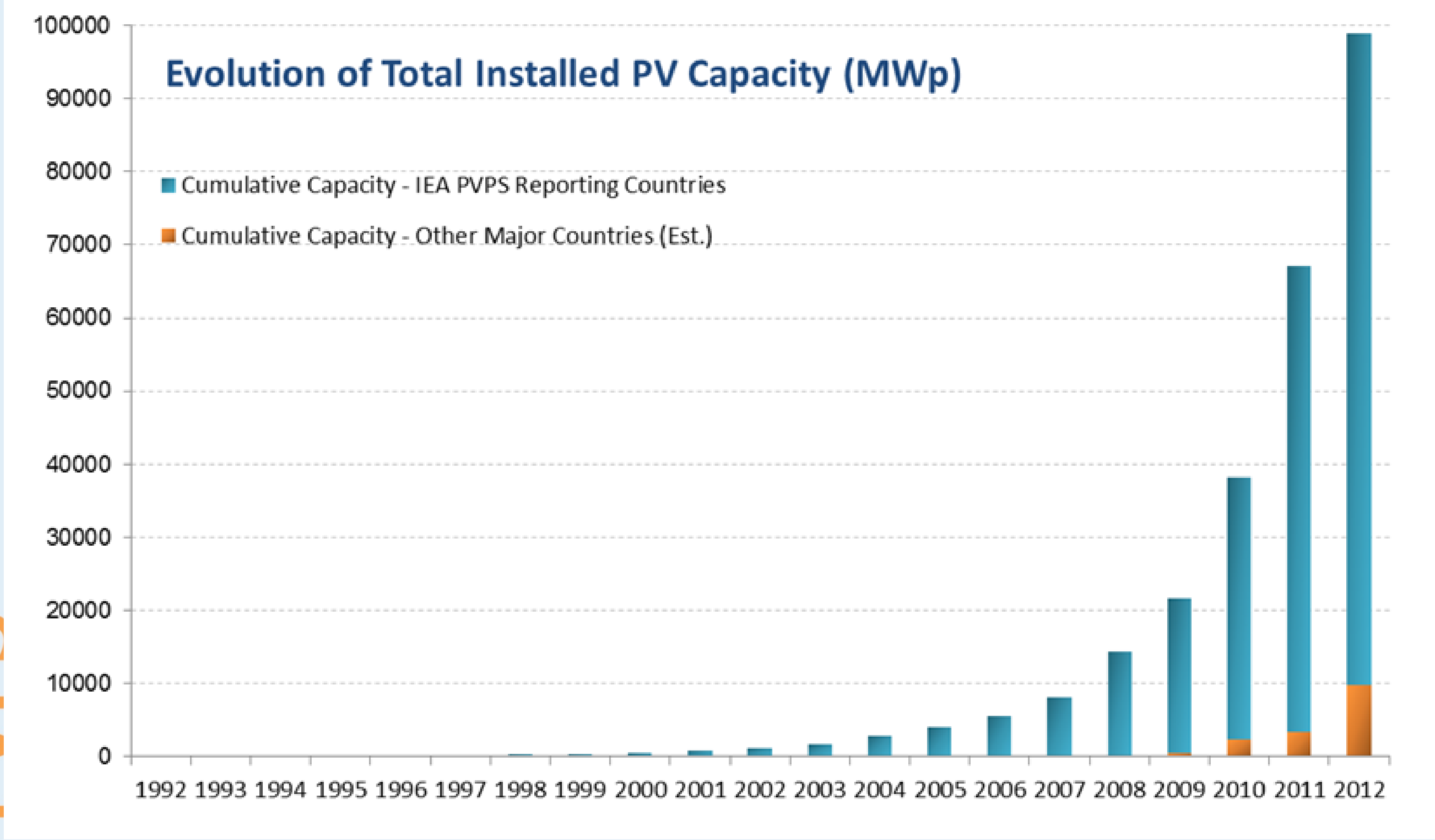
PV and the electricity grid
Sydney, November 26, 2013

PVPS

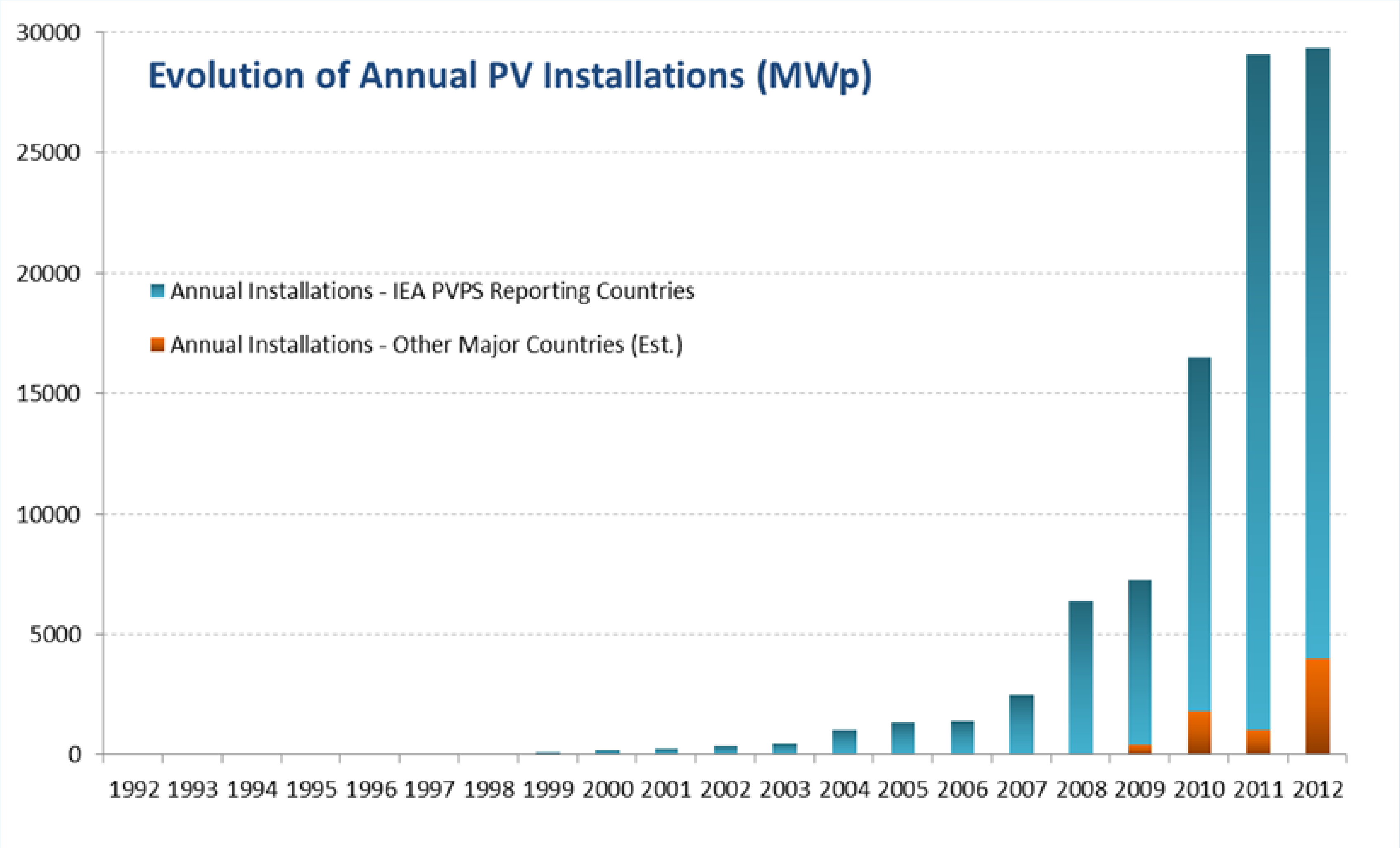
Outline

- Challenges of PV integration
- Overview IEA PVPS Task 14
- Key Methodologies and results
- Summary

High Penetration of PV in Electricity Grids
Global PV development

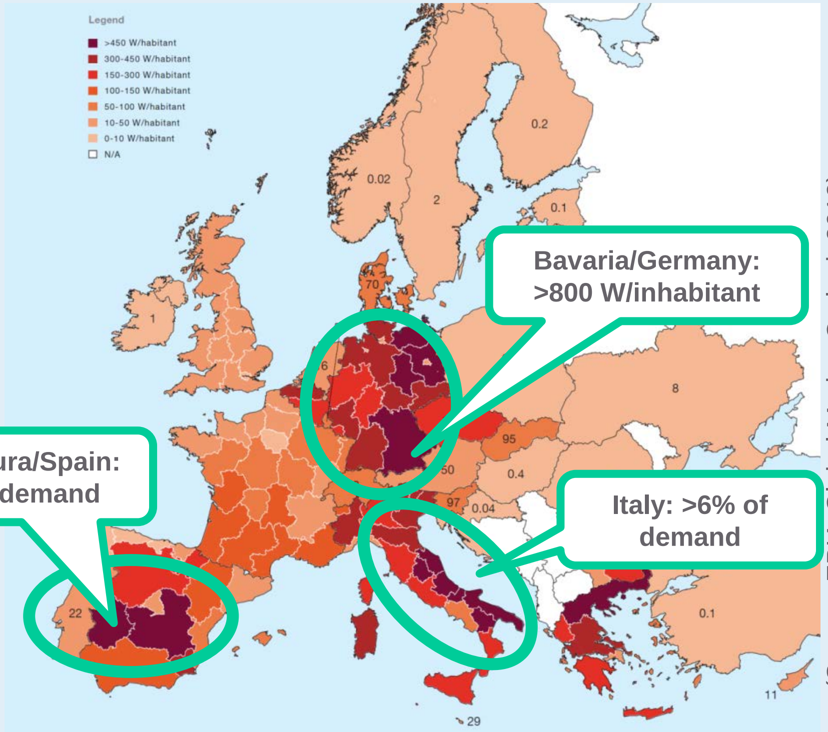


High Penetration of PV in Electricity Grids
Global PV development



High Penetration of PV in Electricity Grids Already reality today

- Feb 2013: World passed 100 GW cumulative installed PV capacity (EPIA)
- Only few countries account for the majority of the global capacity installed *(01/2013)
  - > DEU ~ 32,4 Gigawatt (GW)
  - > ITA ~ 16,4 GW
  - > CHN ~ 8,3 GW
  - > USA ~ 7,8 GW
  - > JAP ~ 6,9 GW
  - > ESP ~ 5,2 GW
- PV penetration levels >100% are already leading to issues in some regions
- With installations growing in the GW range/year grid constraints will become crucial for further deployment of PV.



(Source: EPIA-Global Market Outlook 2013)

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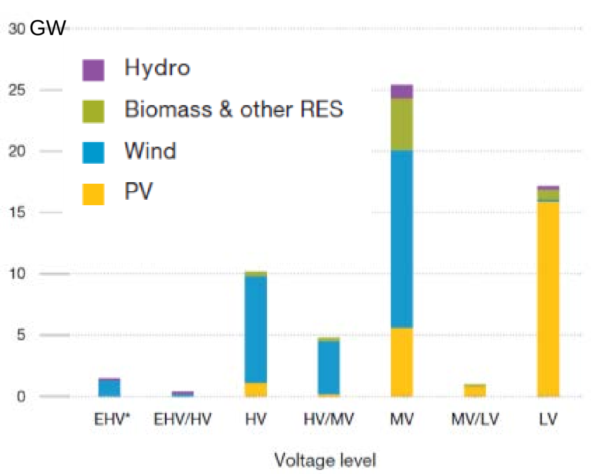
Characteristics of PV power generation
PV specific features

- Variable generation
  - Daily profile
  - Seasonal profile
  - Variability
- Typical system size
  - High number of small scale (residential) installations -> aggregation
  - Also large scale installations in high-irradiation locations
- Connection predominantly at LV grid - Inverter connection
- Frequently linked to buildings

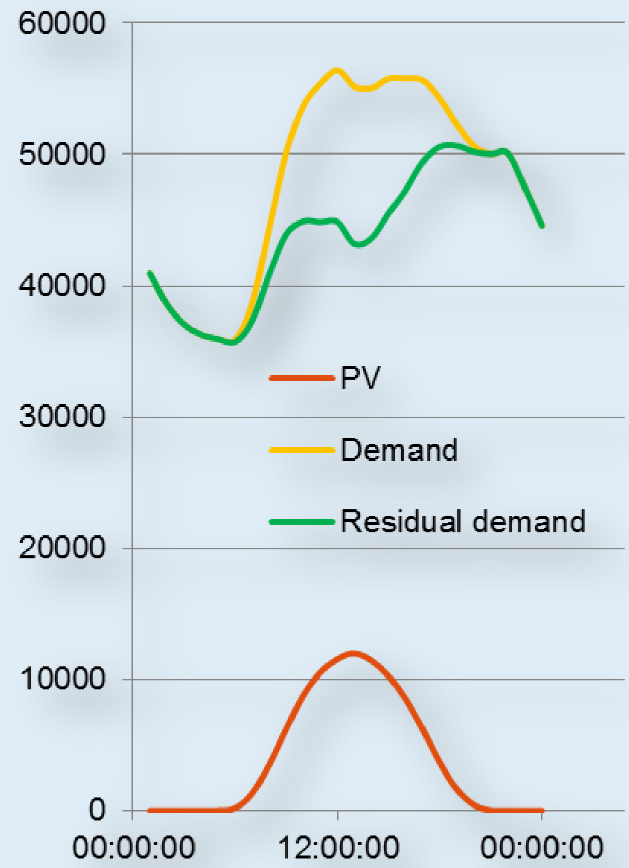


RES capacity in Germany connected to different network levels

Source: EPIA based on DGS figures

Characteristics of PV power generation
PV specific features

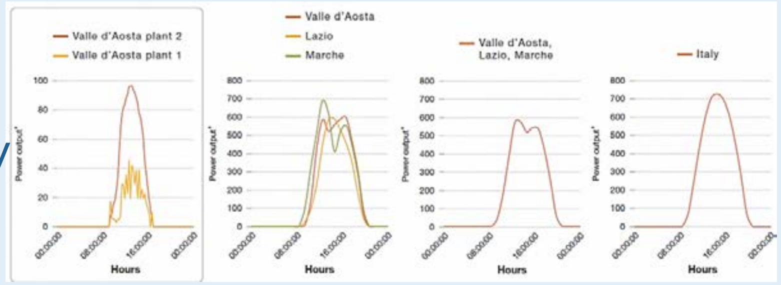
- PV production frequently meets times of high load in networks
- Reduction of network losses due to more local generation and therefore decreased power transmission
- More transmission capacity opens space for other transmission services
- Active network services from multifunctional photovoltaic inverters can support the local network management



Source: EPIA, Task 14 Workshop Kassel, May 2012

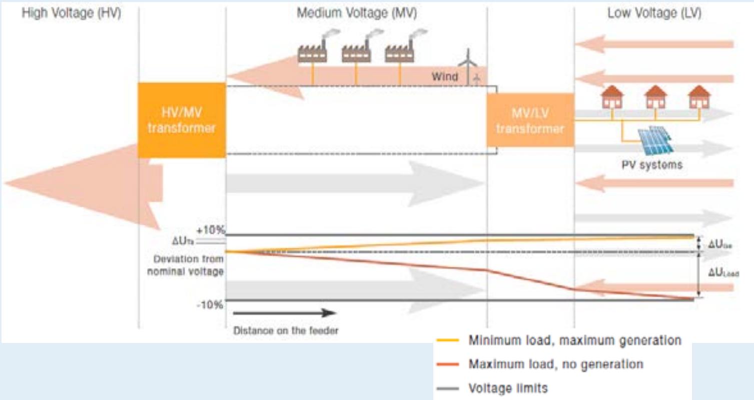
High Penetration of PV in Electricity Grids
Grid integration Challenges

- **PV integration challenges in the overall power system**
  - Managing **variability of supply** with PV
  - Ensuring **security of supply**
  - Matching **supply and demand**
  - Ensuring **frequency stability**



→ **Smart PV integration required !!!**

- **PV integration challenges on the distribution level**
  - **Managing voltage** profiles
  - **Avoiding overloading** of components
  - Transforming **passive to active** grids
  - Integrating **PV in Smart Grids**



Source: EPIA, "Connecting the sun", September 2012

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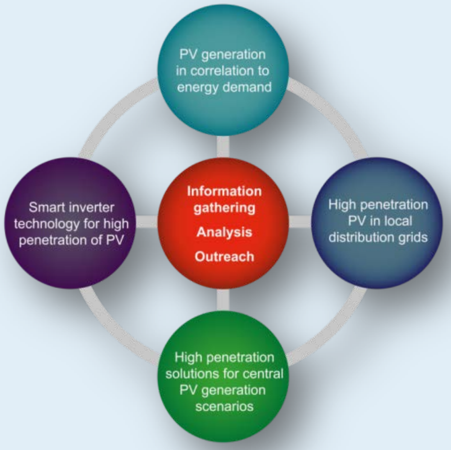
IEA PVPS basics

- Global PV cooperation network
- 28 members: 23 countries, EC, Associations: EPIA, SEPA, SEIA, Copper Alliance
- Activities are carried out collaboratively on a country basis along a number of technical and non-technical subjects
- Currently, 6 Tasks are active
- To enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems
- Task 14 High PV Penetration in Electricity Grids

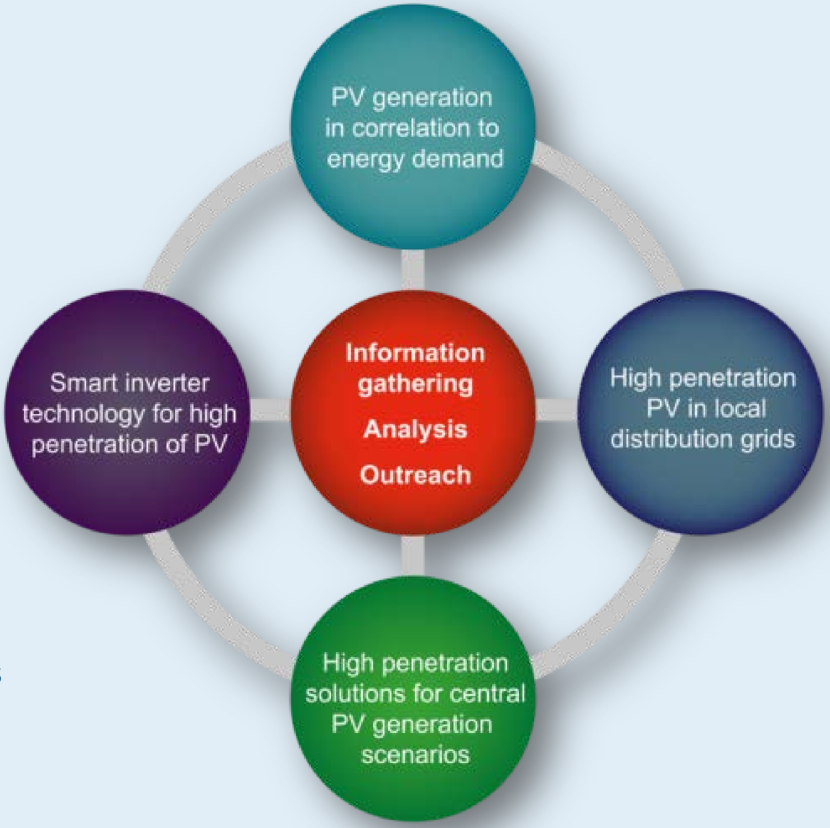
IEA PVPS Task 14: High Penetration of PV in Electricity Grids



- Goals & Objectives
  - Promote the use of grid connected PV as an important source in electric power systems
  - Develop and verify technical requirements for PV and electric power systems to allow for high penetrations of PV systems
  - Discuss the active role of PV systems related to energy management and system control of electricity grids
  - Reduce the technical barriers to achieve high penetration levels of distributed renewable energy systems on the electric power system

IEA PVPS Task 14: Organization and structure

- Subtask 1: PV generation in correlation to energy demand: Switzerland
  Show how with better prediction tools and optimized local energy management, PV penetration can be improved.
- Subtask 2: High penetration in local distribution grids: Germany
  Identify and interpret the role of PV in distribution grids and impact analyses of high PV penetration
- Subtask 3: High penetration solutions for central PV scenarios: Japan
  PV integration from the total power system view point, including forecasting, power system operation and augmentation
- Subtask 4: Smart inverter technology for high penetration of PV: Austria
  Technology, technical requirements and standards as well as system integration aspects for inverters with High Penetration PV
- Cross Cutting Subtask: Information Gathering, Analysis and Outreach:
  Collect and share state of the art information amongst the various tasks.



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IEA PVPS Task 14: Networks

16 Countries

European commission

1 Association

Experts from

- Utilities, DNOs
- Industry, manufacturers, consultancies
- Applied research
- Universities
- Agencies

IEA PVPS Task 14: Outcomes

- **Support PV integration** on high penetration levels by
  - access to more transparent technical analyses
  - guidelines and best practices for industry, network operators, energy planners as well as authorities in the energy business
  - comprehensive international studies for high penetration PV
- **Develop key methodologies** for large scale PV integration
  - PV Power Forecast
  - Active management and control of grid integrated PV
  - Grid interconnection studies and planning
  - Technical standards and interconnection requirements
- **Active dissemination** of objective and neutral high-quality information
  - Task 14 Reports
  - Task 14 Workshops
  - National information networks of Task 14 members

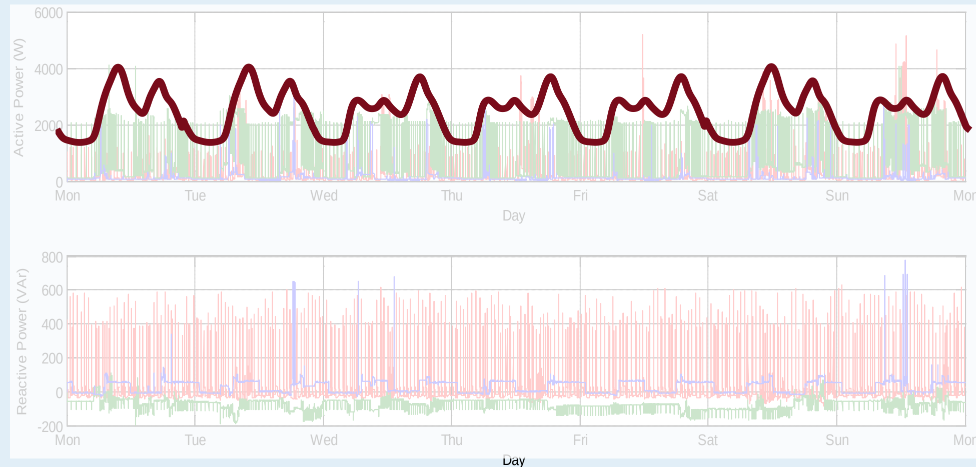
Grid integration of PV
PV power planning tools

- **Analysis of hosting capability** of PV in local distribution grids by the means of **Load and PV profiles**

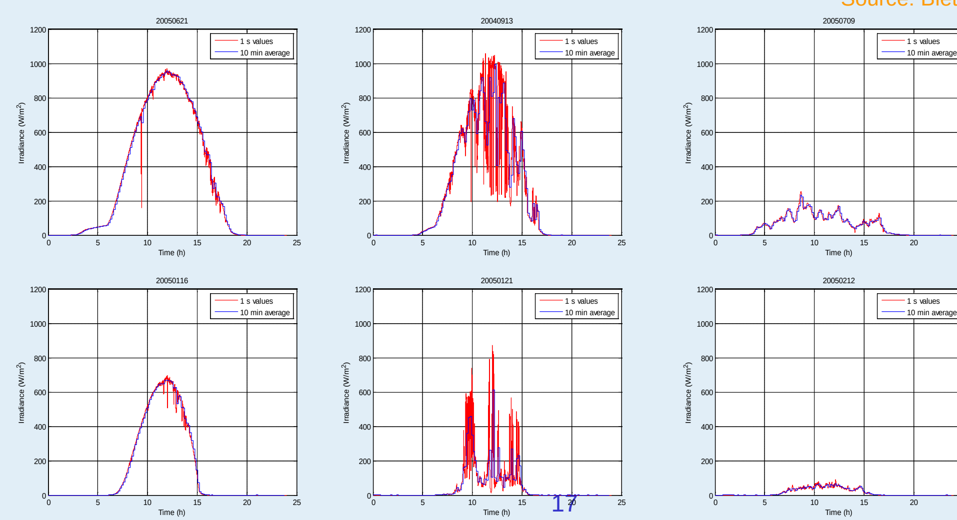
– **real measured profiles** instead of synthetic profiles!

  – Load profiles from 1 sec measurements
  – P and Q of all phases

  – PV profiles from 1 sec {G,T} measurements
  – Six representative days.



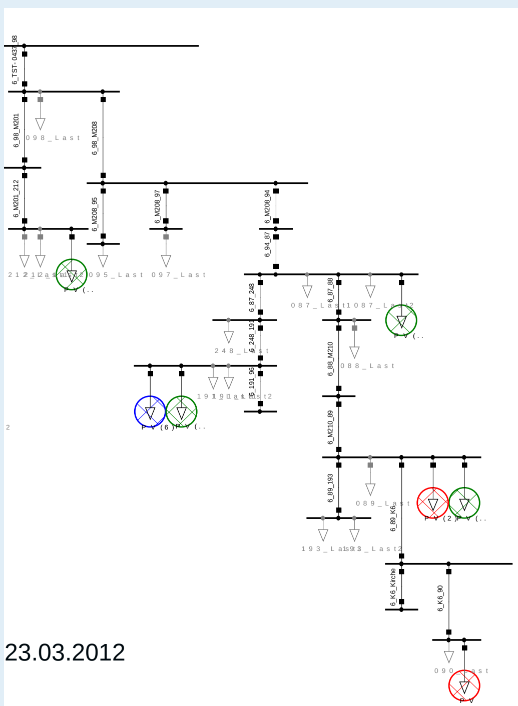
Source: Bletterie

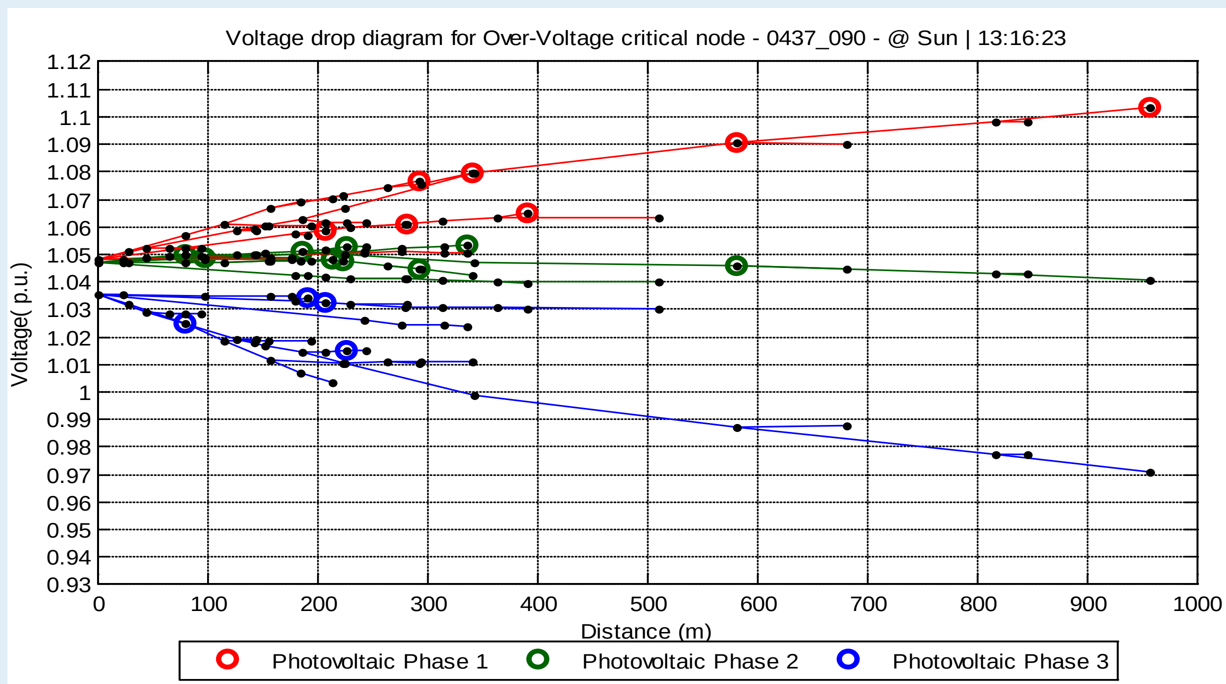


Grid integration of PV
PV power planning tools

- Estimation of Voltage rise caused by
  - a three-phase PV infeed
  - a single-phase PV infeed
  - several single-phase PV infeeds

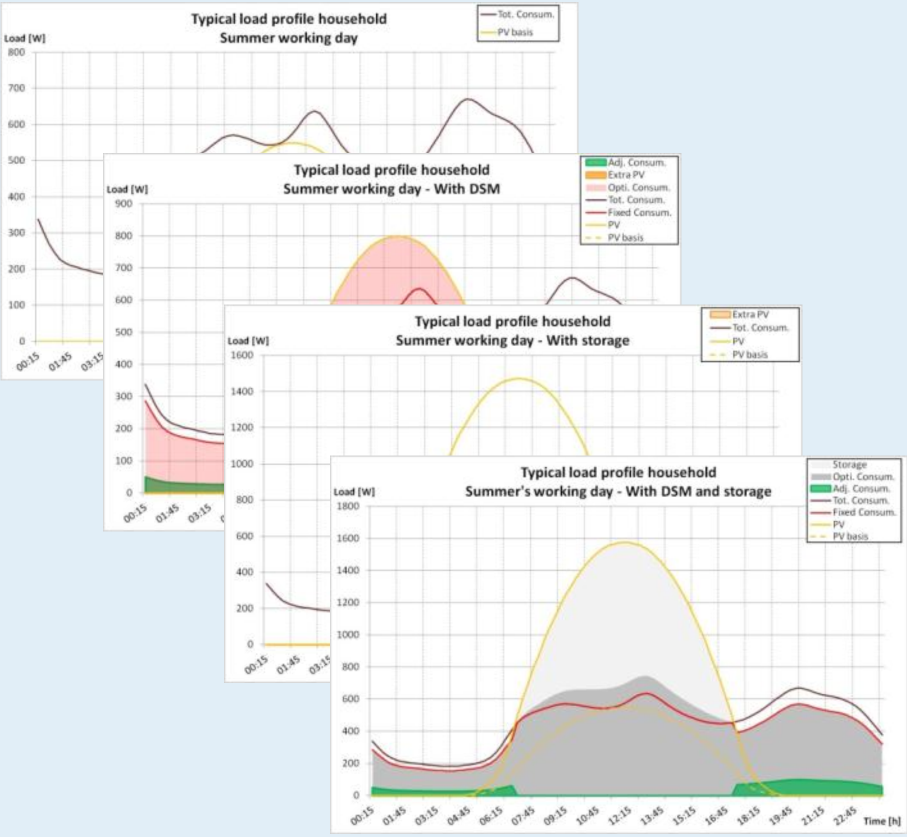
- Scenarios for planning
  - Worst case: all on e.g. L1
  - Best case: ideal distribution over phases
  - “Worst-best case” or “residual unbalance concept”





Grid integration of PV
Local energy management

- **Case studies for PV grid integration**
  - Base case
    PV 4.5kWh/d
  - Integration with DSM
    PV 6.5kWh/d (+45%)
  - Integration with storage system
    PV 12kWh/d (+165%)
  - Integration with DSM and storage system PV 12.9kWh/d (+185%)



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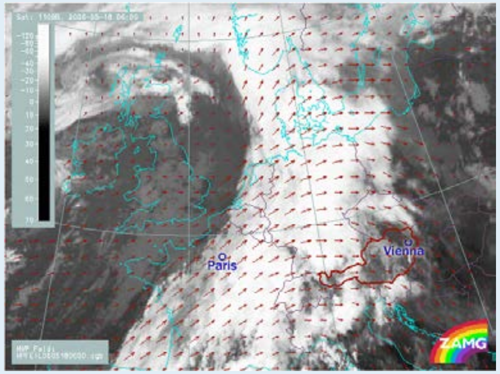
Grid integration of PV
PV power prediction tools

- Parameter:
  - horizontal global irradiation
  - PV-Power
- Forecast Timeframe :
  - Very short-term （0-6h）
  - Short-term （6h-72h）
  - Medium and Long-term (seasonal)
- Forecast Area :
  - Point
  - Area (regional weighting)

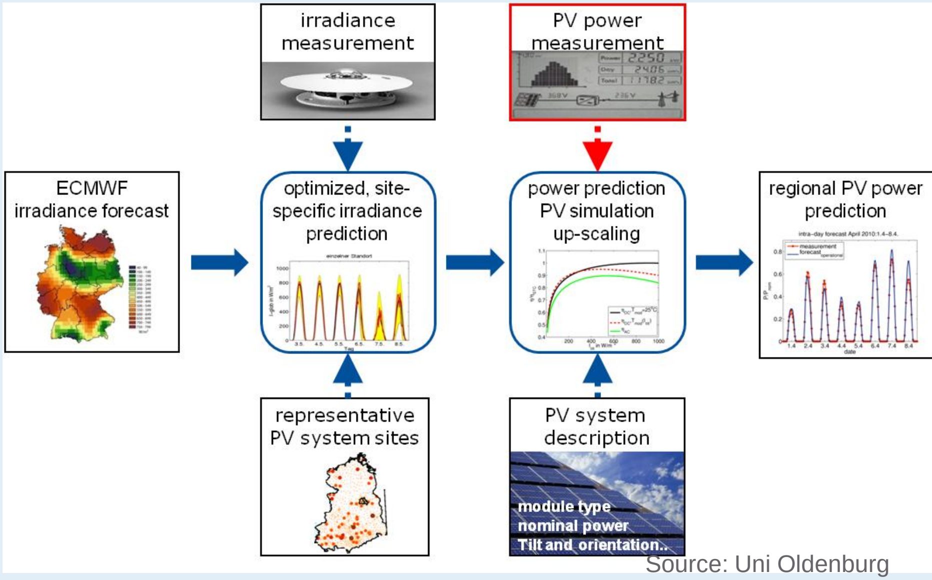
➔ Handling short-term variability is a challenge

➔ Seasonal variability can be well handled and does not challenge system operation



Cloudvectors and motionvectors (ZAMG)

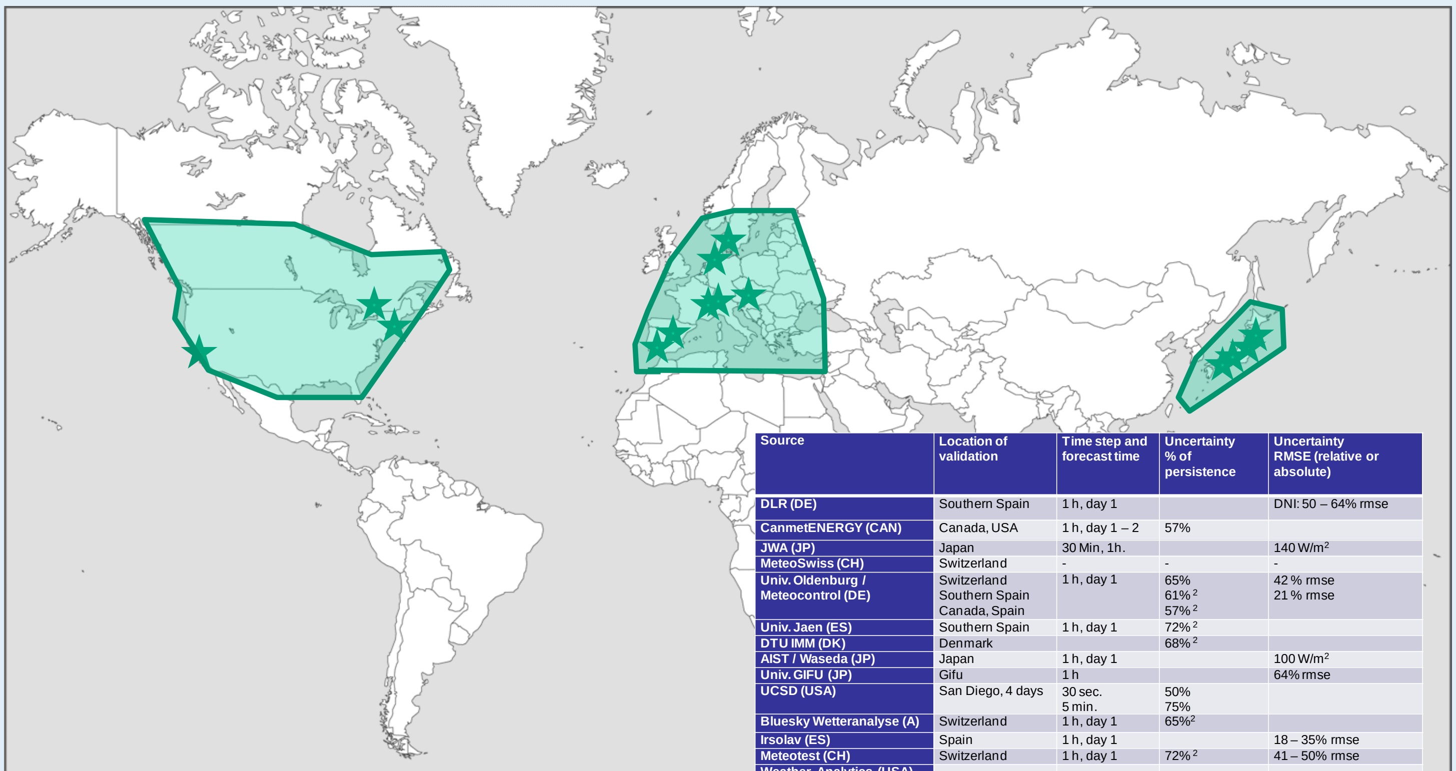
Source: [REMUND]



Source: Uni Oldenburg

Grid integration of PV
PV forecast: state of the art

- **3 regions: USA, Europe and Japan**



Source	Location of validation	Time step and forecast time	Uncertainty % of persistence	Uncertainty RMSE (relative or absolute)
DLR (DE)	Southern Spain	1 h, day 1		DNI: 50 – 64% rmse
CanmetENERGY (CAN)	Canada, USA	1 h, day 1 – 2	57%	
JWA (JP)	Japan	30 Min, 1h.		140 W/m^2
MeteoSwiss (CH)	Switzerland	-	-	-
Univ. Oldenburg / Meteocontrol (DE)	Switzerland Southern Spain Canada, Spain	1 h, day 1	65% 61% [2] 57% [2]	42 % rmse 21 % rmse
Univ. Jaen (ES)	Southern Spain	1 h, day 1	72% [2]	
DTU IMM (DK)	Denmark		68% [2]	
AIST / Waseda (JP)	Japan	1 h, day 1		100 W/m^2
Univ. GIFU (JP)	Gifu	1 h		64% rmse
UCSD (USA)	San Diego, 4 days	30 sec. 5 min.	50% 75%	
Bluesky Wetteranalyse (A)	Switzerland	1 h, day 1	65%[2]	
Irsolav (ES)	Spain	1 h, day 1		18 – 35% rmse
Meteotest (CH)	Switzerland	1 h, day 1	72% [2]	41 – 50% rmse
Weather Analytics (USA)	-	-	-	

Source: Jan Remund, Meteotest

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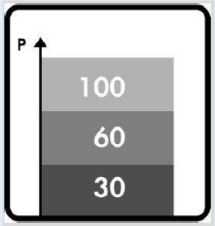
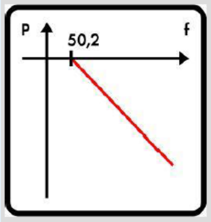
Grid integration of PV
PV power active management and control

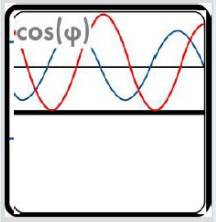


Remote dispatch
control PV generation to a specified % of nominal power rating (Remote Dispatch for security actions)

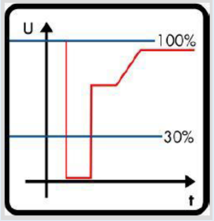
→ Standardized control and communication interfaces required



Support Frequency Control
automatically reduce active power with frequency deviations (Over Frequency Response)
→ Integrate harmonized frequency stabilization functions!



Support Voltage Control
Reactive power supply/absorbtion for voltage support
→ reduces grid extension costs significantly



LVRT Fault Ride Through

supply reactive current during fault ride-through period,

→ No disconnection during grid faults

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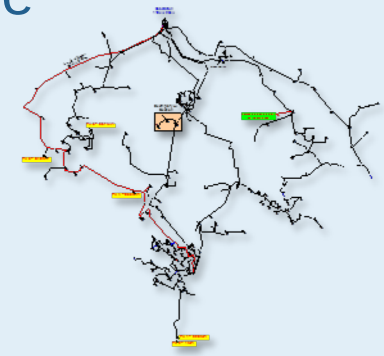
Source: [BRAUN], BDEW, SMA

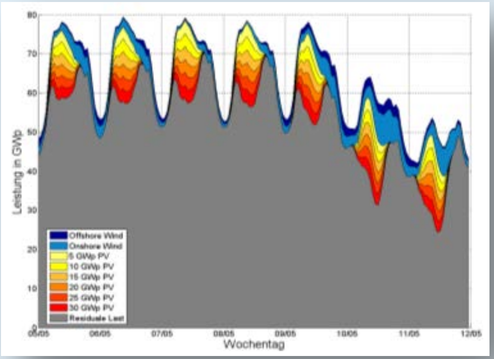
Grid integration of PV
High Penetration Case Studies

- Distribution grid case studies
  - Germany
  - USA
  - Belgium
  - ...
- Overall power system studies
  - Japan
  - USA
  - Italy
  - ...



Source: E.on Bayern/Fraunhofer IWES

Source: SMUD/NREL

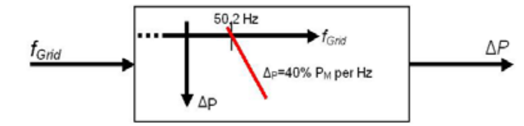


Source: Y.M. Saint Drenan/Fraunhofer IWES

Source: NREL

Grid integration of PV
Technical standards and interconnection requirements

- **Adaption of technical requirements**
  - according to changing general conditions
  - e.g. 50,2 Hz (VDE0126-1-1) -> frequency control (AR N4105)
  - Harmonizing testing procedures



$$\Delta P = 20\ P_M \frac{50{,}2\ Hz - f_{Grid}}{50\ Hz} \text{ at } 50{,}2\ Hz \le f_{Grid} \le 51{,}5\ Hz$$

P_M Currently available active power
ΔP Power reduction
f_{Grid} Grid frequency

In the range 47,5 Hz ≤ f_{Grid} ≤ 50,2 Hz no reduction

At f_{Grid} ≤ 47,5 Hz and f_{Grid} ≥ 51,2 Hz disconnection from the grid

Source: VDN 2007 , translation SMA

- **Consistency of requirements**
  - Growing complexity and diversity of requirements may create an increasing barrier to effectively apply the potential of new inverter functionalities in practice

- **International exchange of experiences and harmonized standards**

Increasing the hosting capacity of distribution grids

Level of PV penetration	Grid measures	Intelligent solutions	Participation of DG in system operation
Low	Adjustment of voltage settings of MV/LV transformer	Application of intelligent planning and monitoring tools in distribution grids	Active/reactive power control
			Using balanced 3-phase feed-in
	Extension and/or reinforcement of power lines	Self-regulated or controlled transformers	Remote control of DG in case of emergency situations
High	Exchange of MV/LV transformer	Decentralised storage and DSM	Active support to system operation

Based on eon Bavaria 2011, EPIA 2012 and AIT analysis

High Penetration of PV in Electricity Grids Summary and key conclusions

- Increasing penetration level of PV (and RES) present challenges on the overall system as well as on the local levels
- Today in Europe the role of PV has changed from a marginal technology to a visible player in the electricity market
- Solutions for integrating PV on high penetration levels are available but they need to be implemented in an appropriate way
  - PV Power Planning tools
  - PV Power Prediction tools
  - PV power active management and control
  - Grid interconnection assessment
  - Technical standards and interconnection requirements
- By improving the knowledge of LV networks, additional reserves can be made available for PV.

High Penetration of PV in Electricity Grids
Summary and key conclusions

- PVPS Task 14 will act as a collaboration platform for international experts on the subject of high penetration PV
- Task 14 supports PV integration on high penetration levels
  - access to more transparent technical analyses
  - guidelines and best practices for industry, network operators, energy planners as well as authorities in the energy business
  - comprehensive international studies for high penetration PV
- Task 14 aims at reducing the technical barriers to achieve high penetration levels of PV on the electric power system.

References

- IEA PVPS Task 14 expert group
- metaPV (European) www.metapv.eu
- ECOGRID EU (European) www.eu-ecogrid.net
- PV Grid (European) www.pvgrid.eu
- IEA GIVAR project (global)
- Sunshot Initiative (US) http://www1.eere.energy.gov/solar/sunshot/index.html
- PV integrated (Germany) www.pv-integrated.de
- e-energy Demo Regions (Germany) www.e-energy.de
- DG DemoNet projects (Austria)
- morePV2grid (Austria)

Thank you for your attention!

http://www.iea-pvps.org

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