Photovoltaic systems and technologies at AIT

Workshop on photovoltaics, grid Integration and funding of the next wave of PV expansion in Cyprus

Nicosia, 13.12.2016

Christoph Mayr

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- Global PV development
- Photovoltaic in Austria
- PV in buildings
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AIT Austrian Institute of Technology

The AIT is **Austria's** largest non-university research institute

Funding

Research and Technology Organisation

Ownership structure

50.46% Republic of Austria

49.54% Federation of Austrian Industries

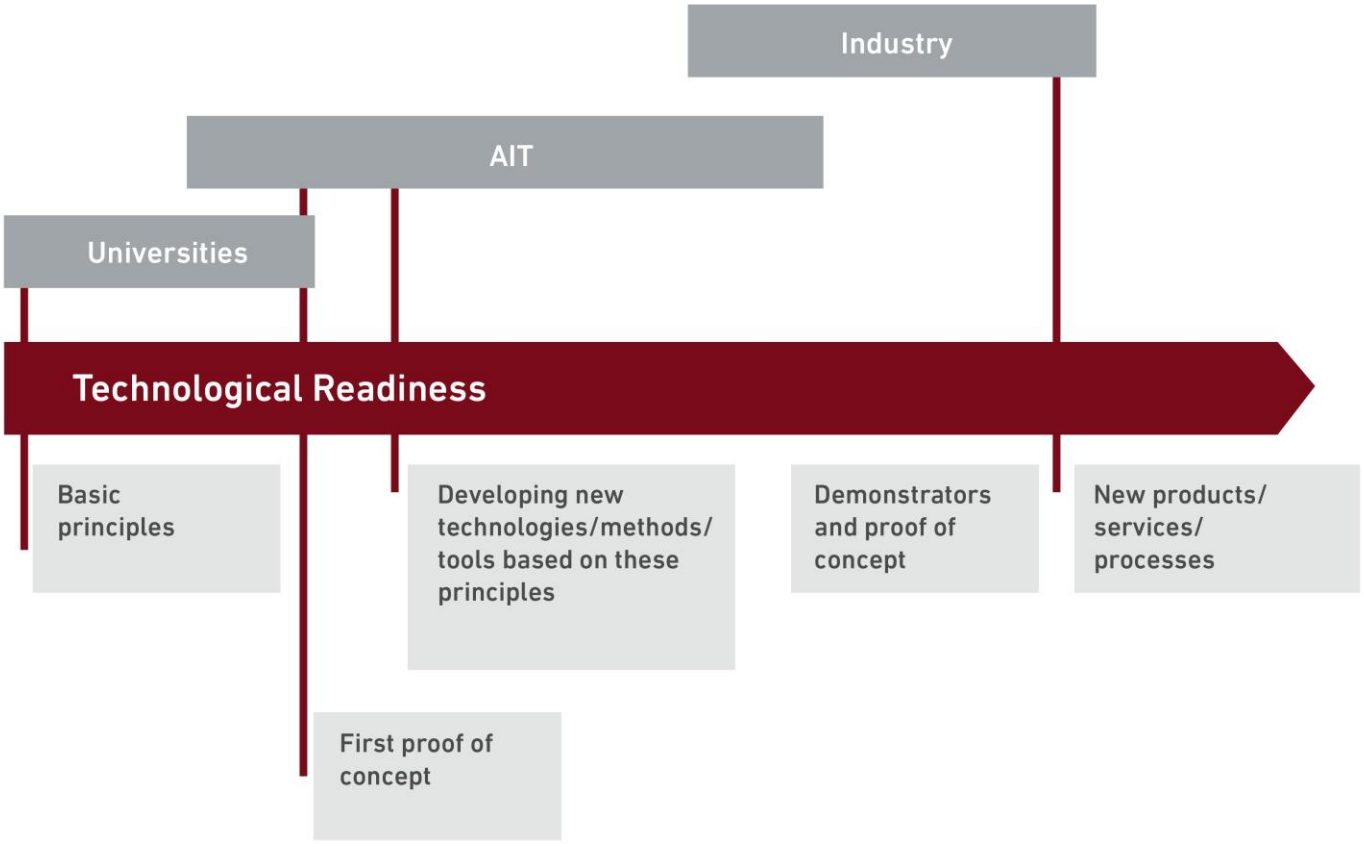
AIT focuses on **Infrastructure-Research**

- Energy
- Mobility
- Digital Safety & Security
- Health & Environment
- Innovation Systems

Employees

1,261

Role of AIT


Industry
AIT
Universities
Technological Readiness
Basic principles
First proof of concept
Developing new technologies/methods/ tools based on these principles
Demonstrators and proof of concept
New products/ services/ processes

AIT Energy Department

The AIT Energy Department develops solutions for a sustainable energy system of tomorrow.

Our Research Fields

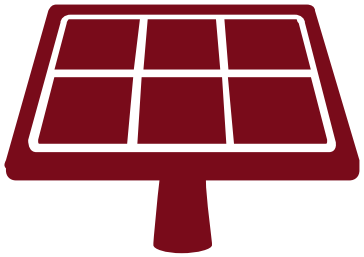
- Energy Infrastructure
  - Smart Grids
  - Photovoltaics
  - Thermal Energy Systems
  - Smart Buildings
- Integrated Energy Systems
  - Smart Cities
  - Complex Energy Systems
  - Green Processes


PHOTOVOLTAICS

Photovoltaics - Challenges

Large-scale implementation
of solar power

use of abundant,
non-toxic raw materials
& recycling



Conversion with
high efficiency

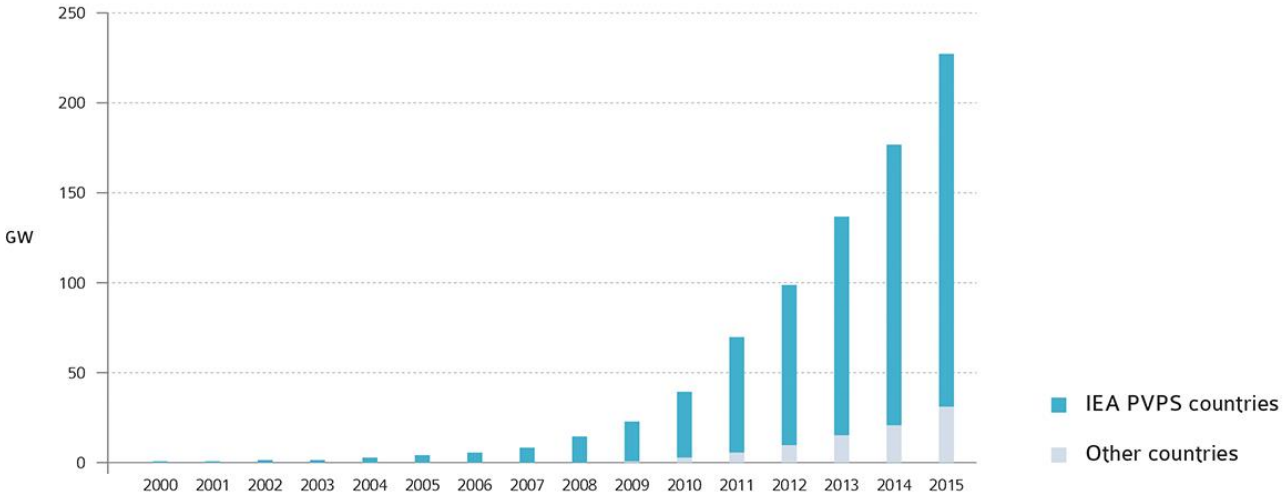
Versatile & multi-
functional applications

Reducing
production costs

Long-term reliable operation

Photovoltaic Development

EVOLUTION OF PV INSTALLATIONS (GW)



SOURCE IEA PVPS & OTHERS.

228 GW
global PV capacity
end of 2015

50,7 GW
commissioned in 2015

With more than 50 GW connected to the grid in 2015, PV continues to prove its ability to significantly contribute to the decarbonization of the power sector. High penetration shares are common and were reached in a few years, at a decreasing cost.

Global PV development 2015

TRENDS IN PHOTOVOLTAIC APPLICATIONS - 2016

Photovoltaic Power Systems Programme - http://www.iea-pvps.org

TOP 5 MARKETS 2015 (MW)

China
15.150

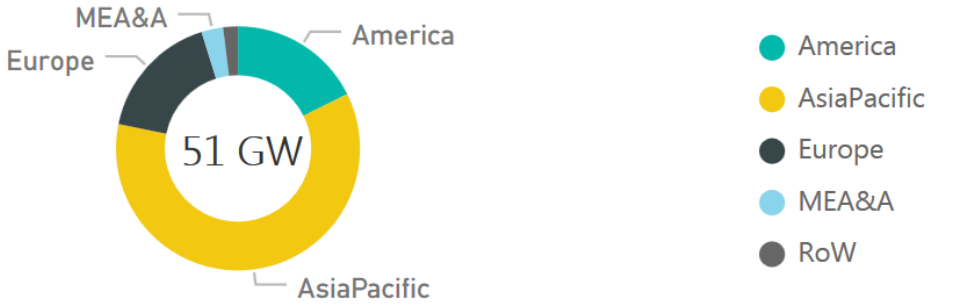
Japan
10.811

USA
7.283

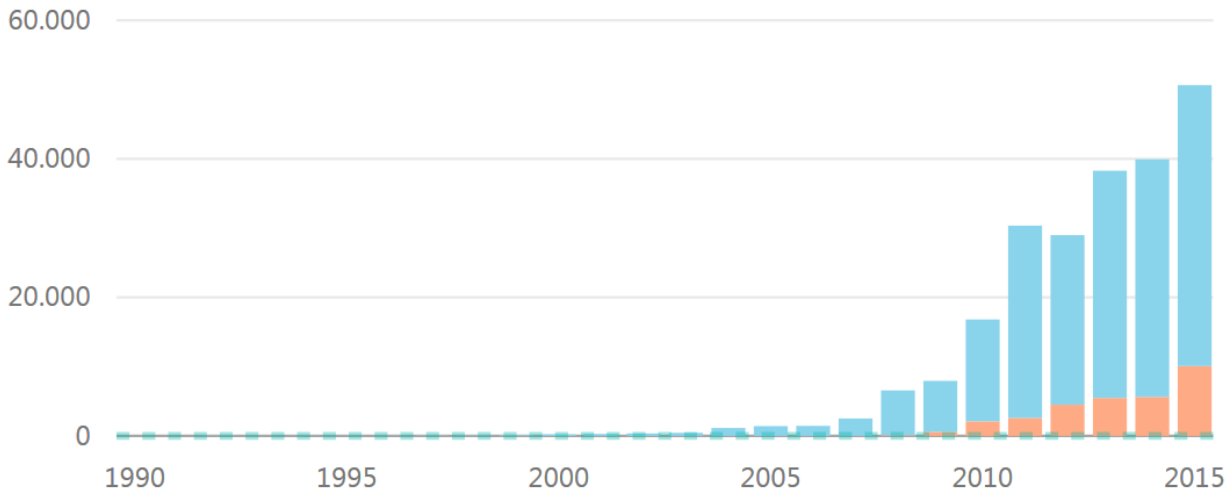
UK
4.105

India
2.100

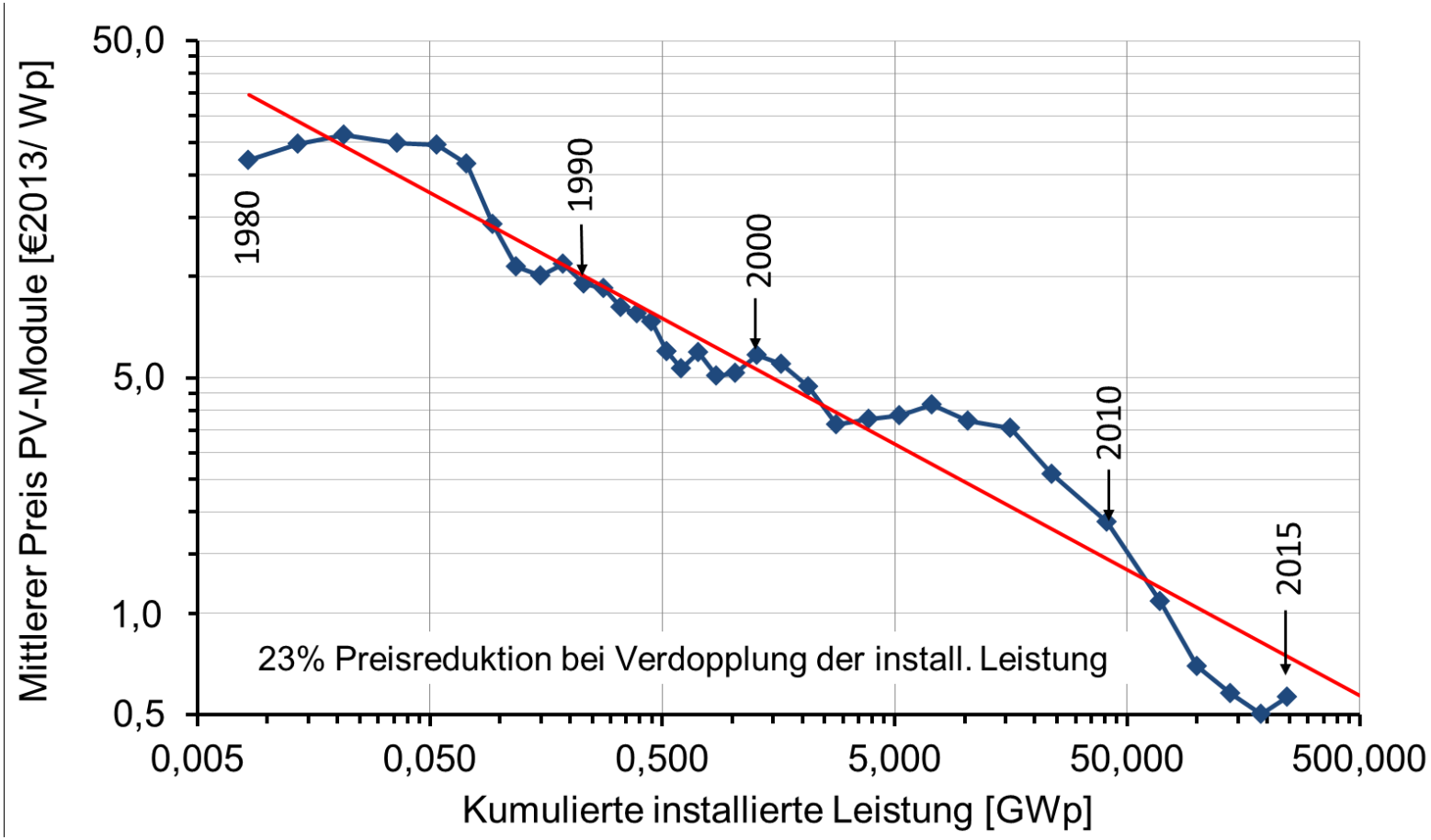
GLOBAL PV MARKET 2015 (MW)



GLOBAL PV ANNUAL MARKET 2000 - 2015 (MW)

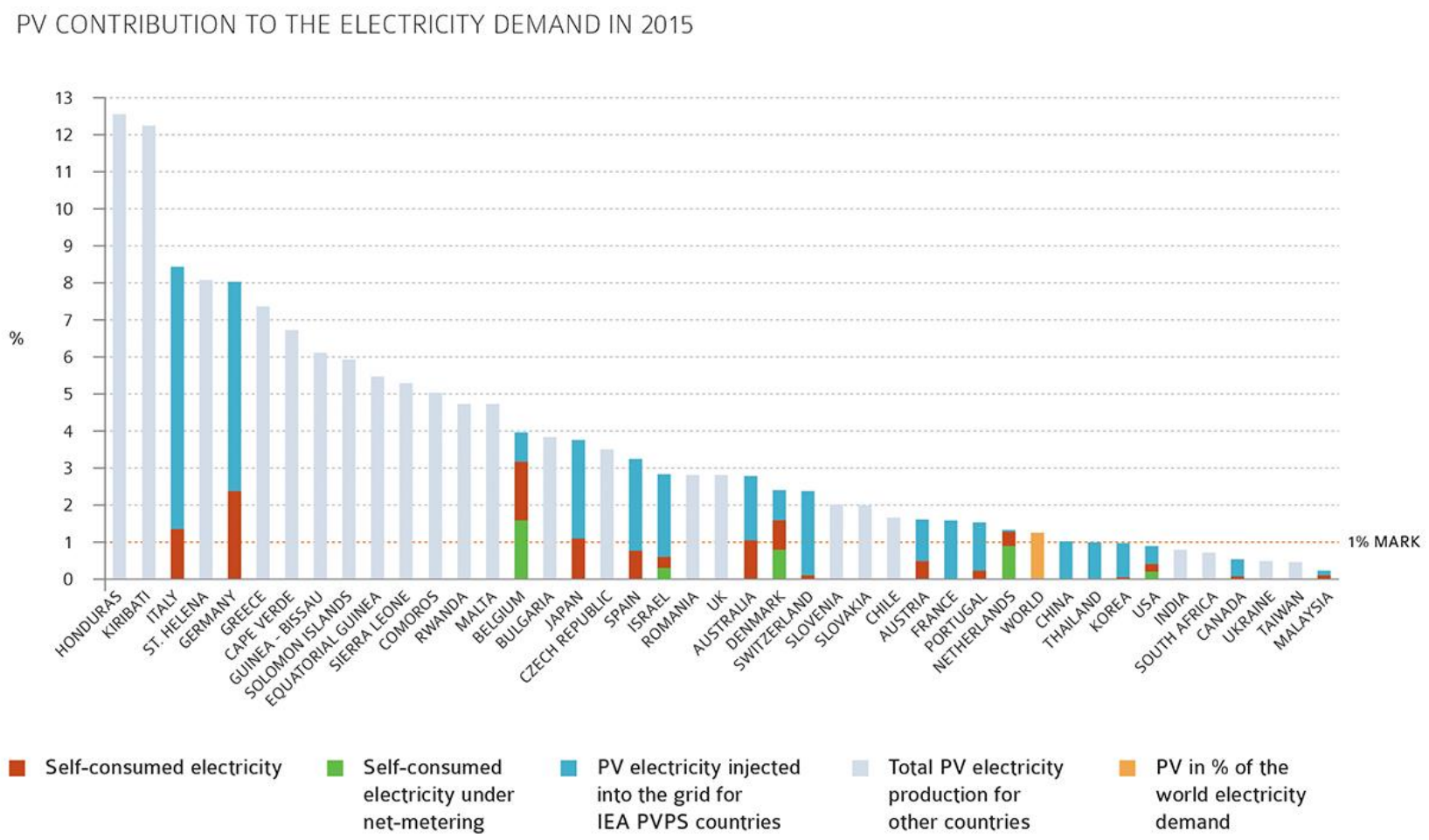


Long term PV learning rate



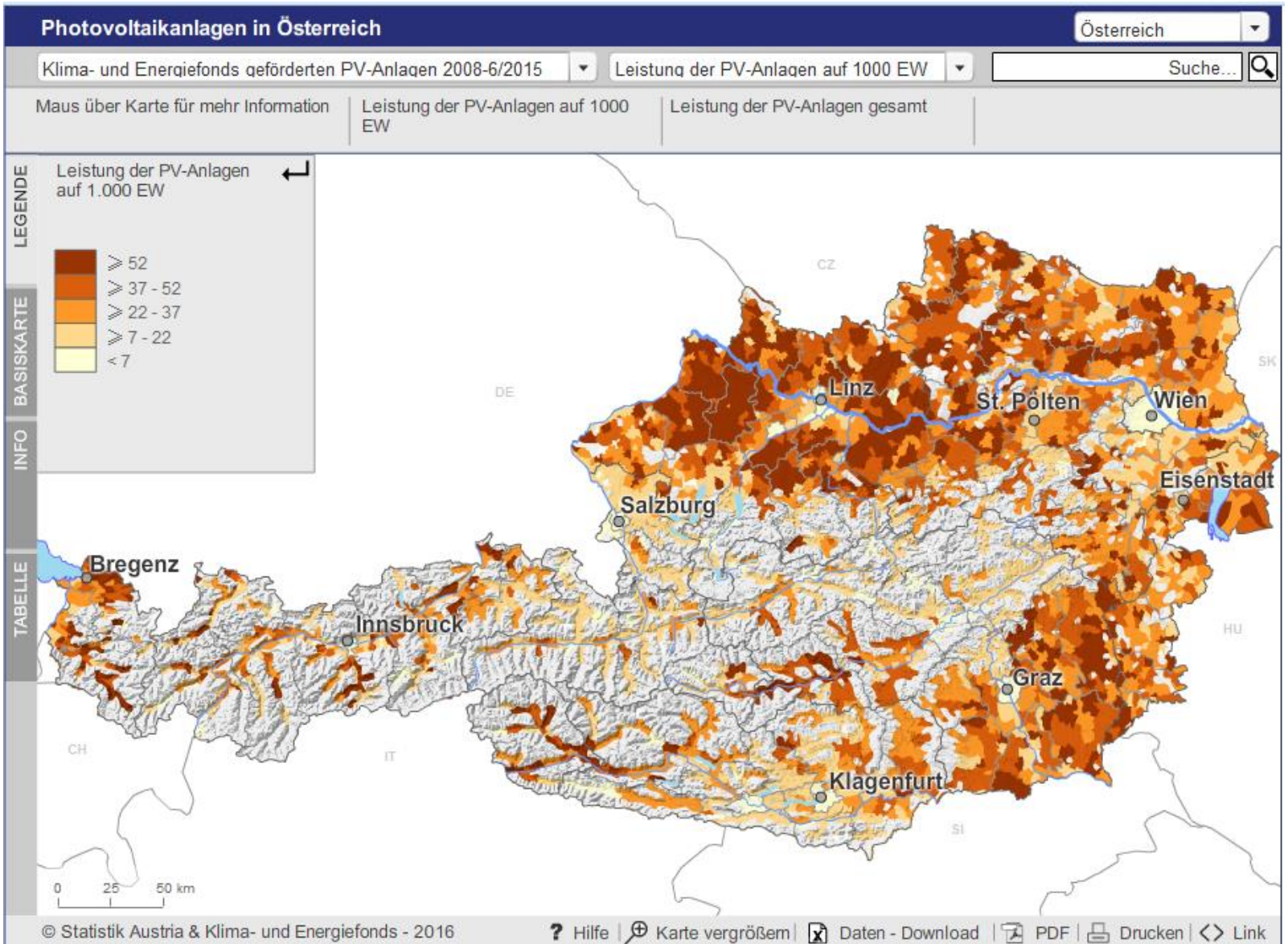
Source: PSE AG/Fraunhofer ISE, data from: Strate-gies Unlimited/Navigant Consulting/EuPD.

Photovoltaic contribution levels

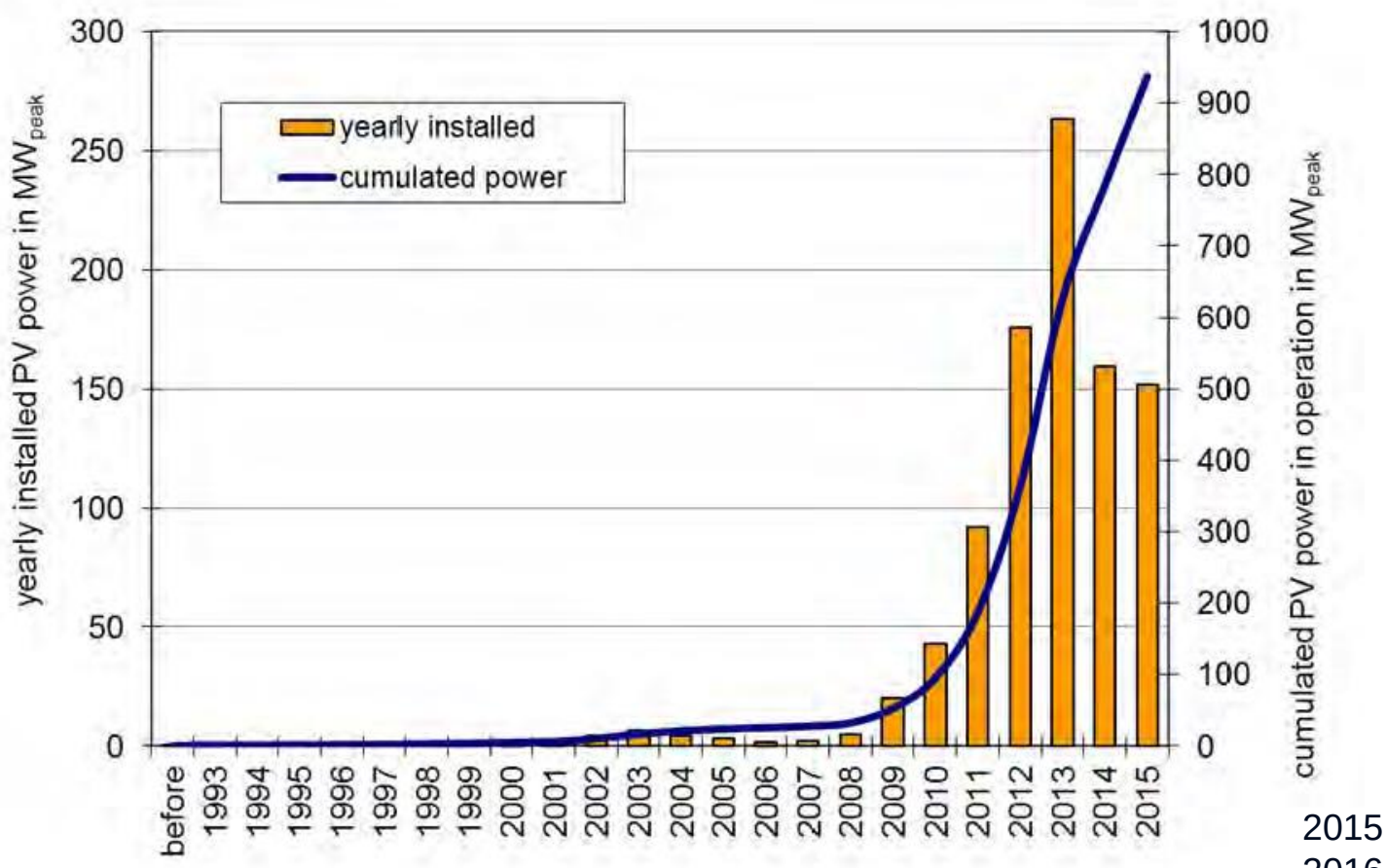


SOURCE SOURCE IEA PVPS & OTHERS.

Photovoltaic in Austria



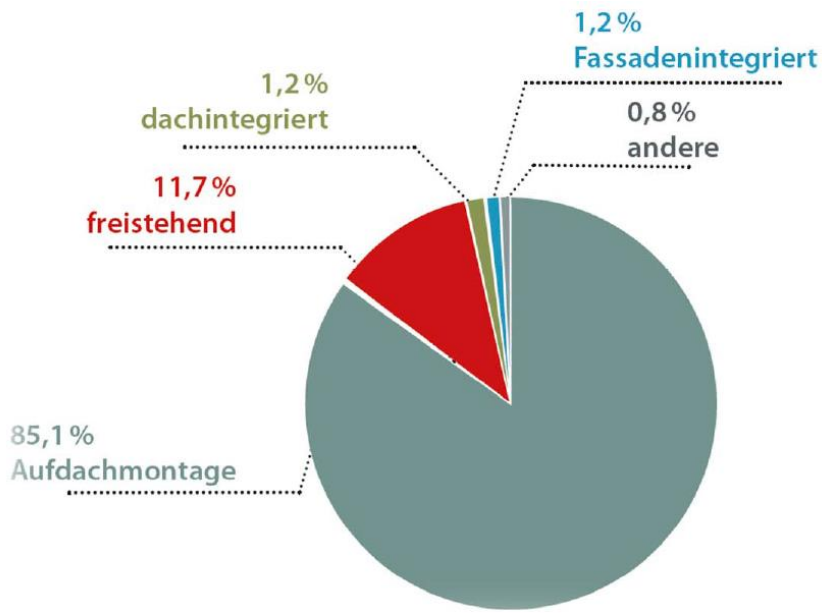
Photovoltaic – development in Austria



2015:	151.8 MW
2016:	~130 MW
Total:	*1070 MW*

Source: **Innovative Energietechnologien in Österreich Marktentwicklung 2015**

PV installations in Austria



PV installation types in Austria
(Source: Innovative Energietechnologien in Österreich Marktentwicklung 2015)

85% rooftop installations

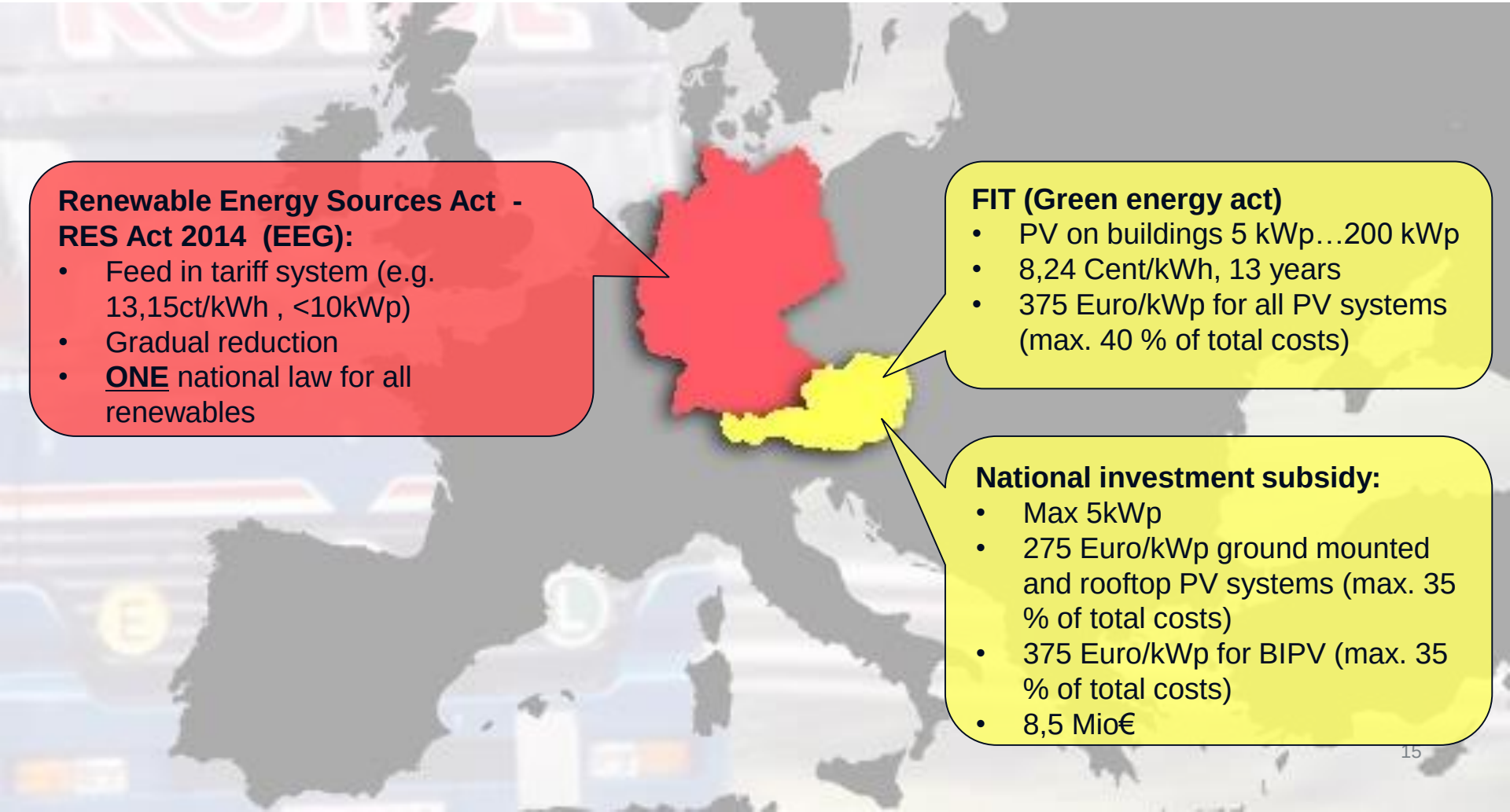
Potential surfaces for solar generation:
230 km² total potential surface (approx. 70 km² facades)


PV Anlage Semriach


Wien Energie

TU Wien

National Policy framework for the promotion of PV



Renewable Energy Sources Act - RES Act 2014 (EEG):

- Feed in tariff system (e.g. 13,15ct/kWh , <10kWp)
- Gradual reduction
- **ONE** national law for all renewables

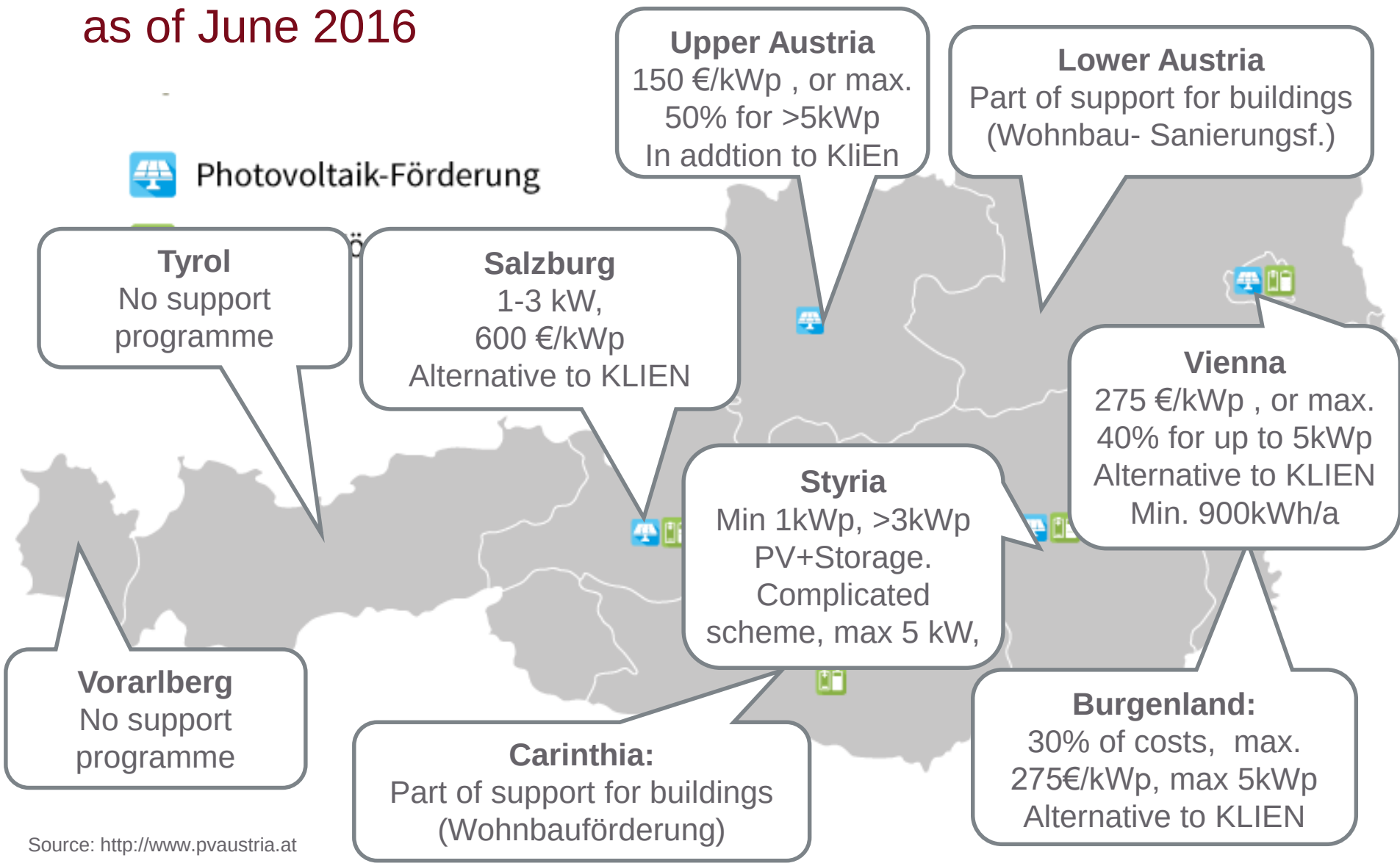
FIT (Green energy act)

- PV on buildings 5 kWp…200 kWp
- 8,24 Cent/kWh, 13 years
- 375 Euro/kWp for all PV systems (max. 40 % of total costs)

National investment subsidy:

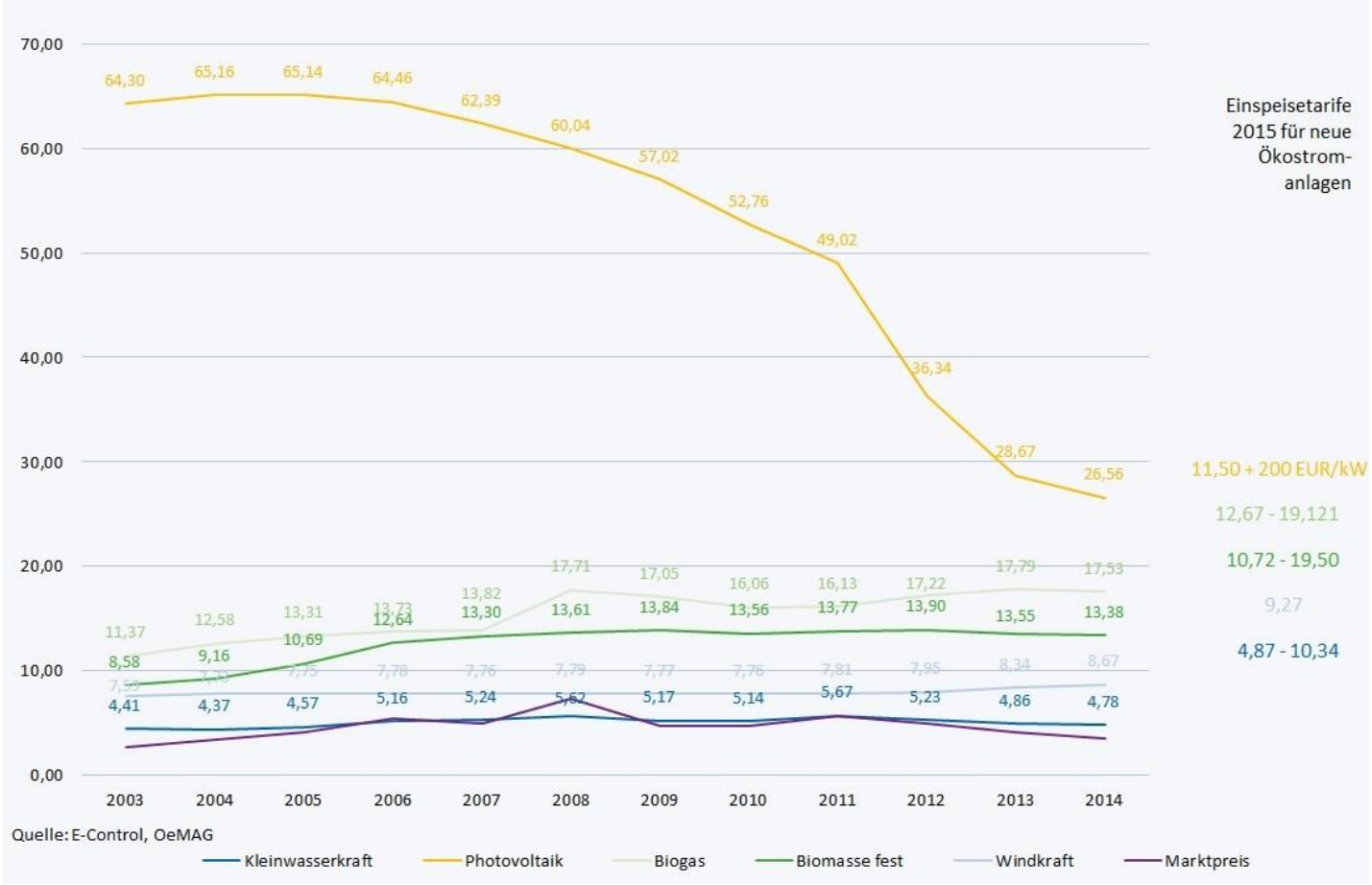
- Max 5kWp
- 275 Euro/kWp ground mounted and rooftop PV systems (max. 35 % of total costs)
- 375 Euro/kWp for BIPV (max. 35 % of total costs)
- 8,5 Mio€

PV programmes of federal states as of June 2016



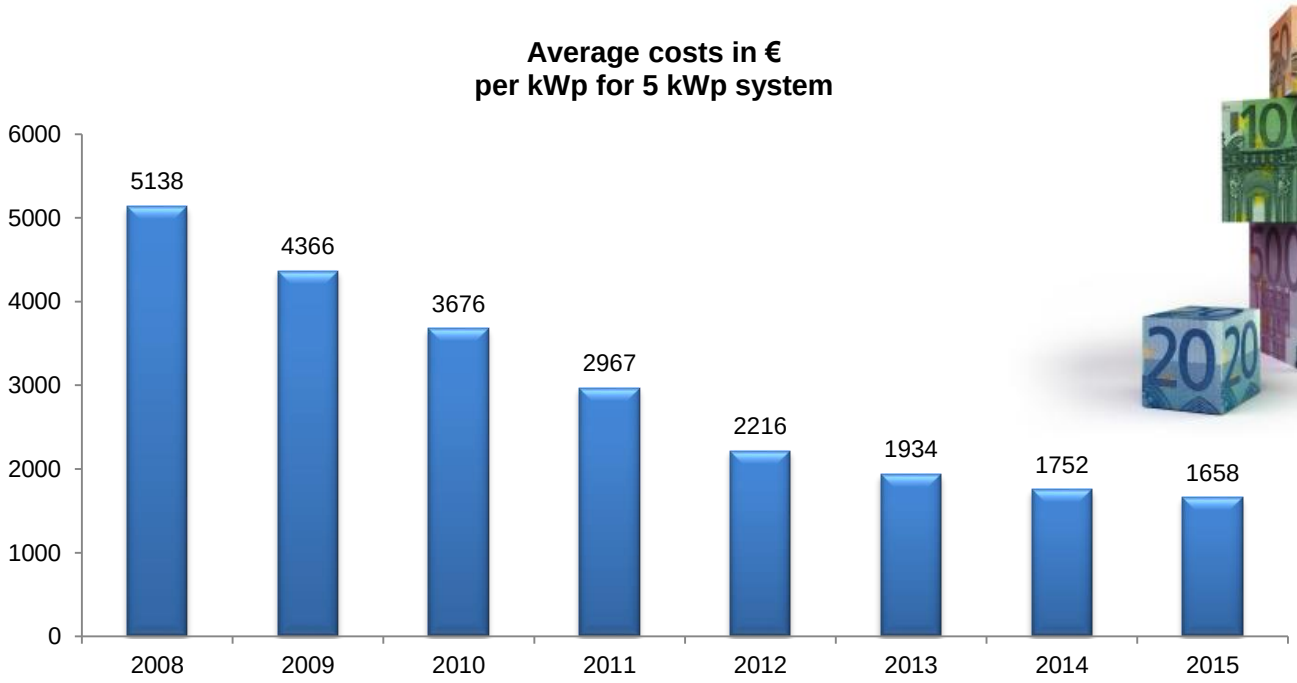
Source: http://www.pvaustria.at

National Policy framework for the promotion of PV: development



Source: e-control

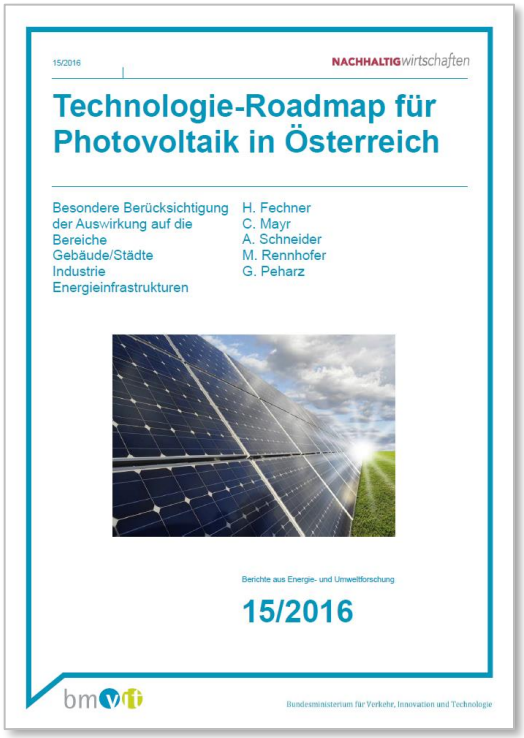
Cost reduction of PV systems: -68% since 2008 in Austria



Average costs of complete installed PV plants based on 5kWp grid connected systems

(source: Biermayr et al. 2009-2015

Study: Photovoltaic Roadmap for Austria

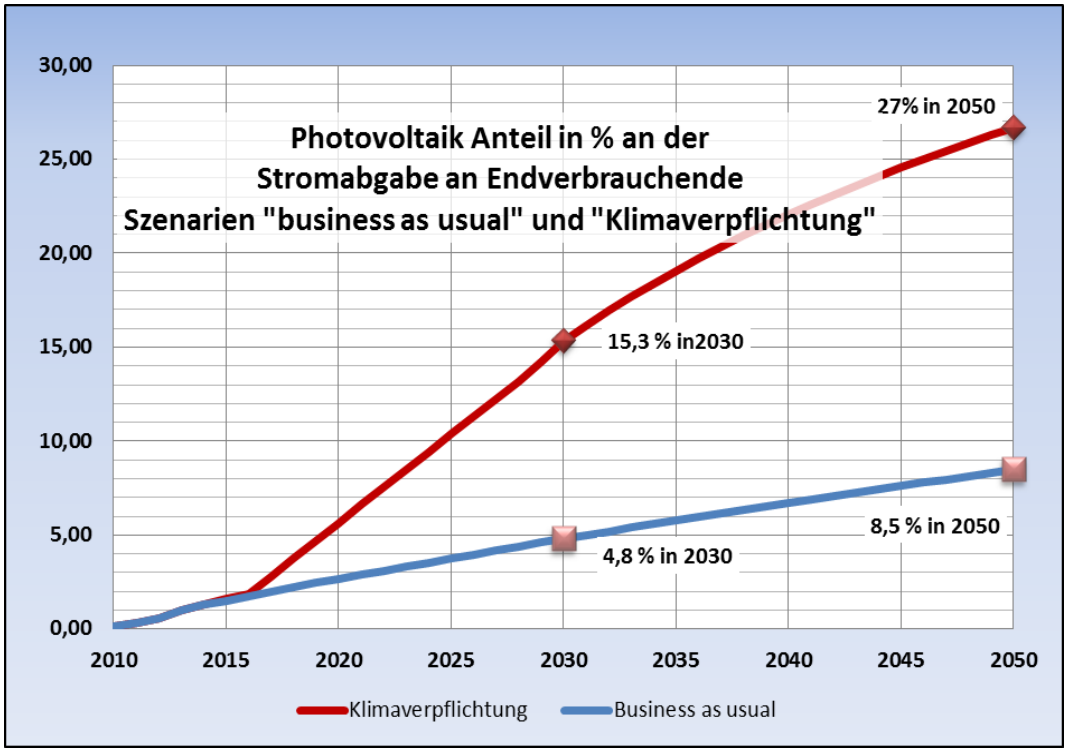


In collaboration of AIT with FH-Technikum Wien and Joanneum Research

Study for the Austrian Ministry of Transportation, Innovation and Technology:

- "Technology-Roadmap for Photovoltaic in Austria"
- Basis: EU CO2 targets
- In accordance with recognized analyses for 100% renewables in Austria until 2050

Study: Photovoltaic Roadmap for Austria



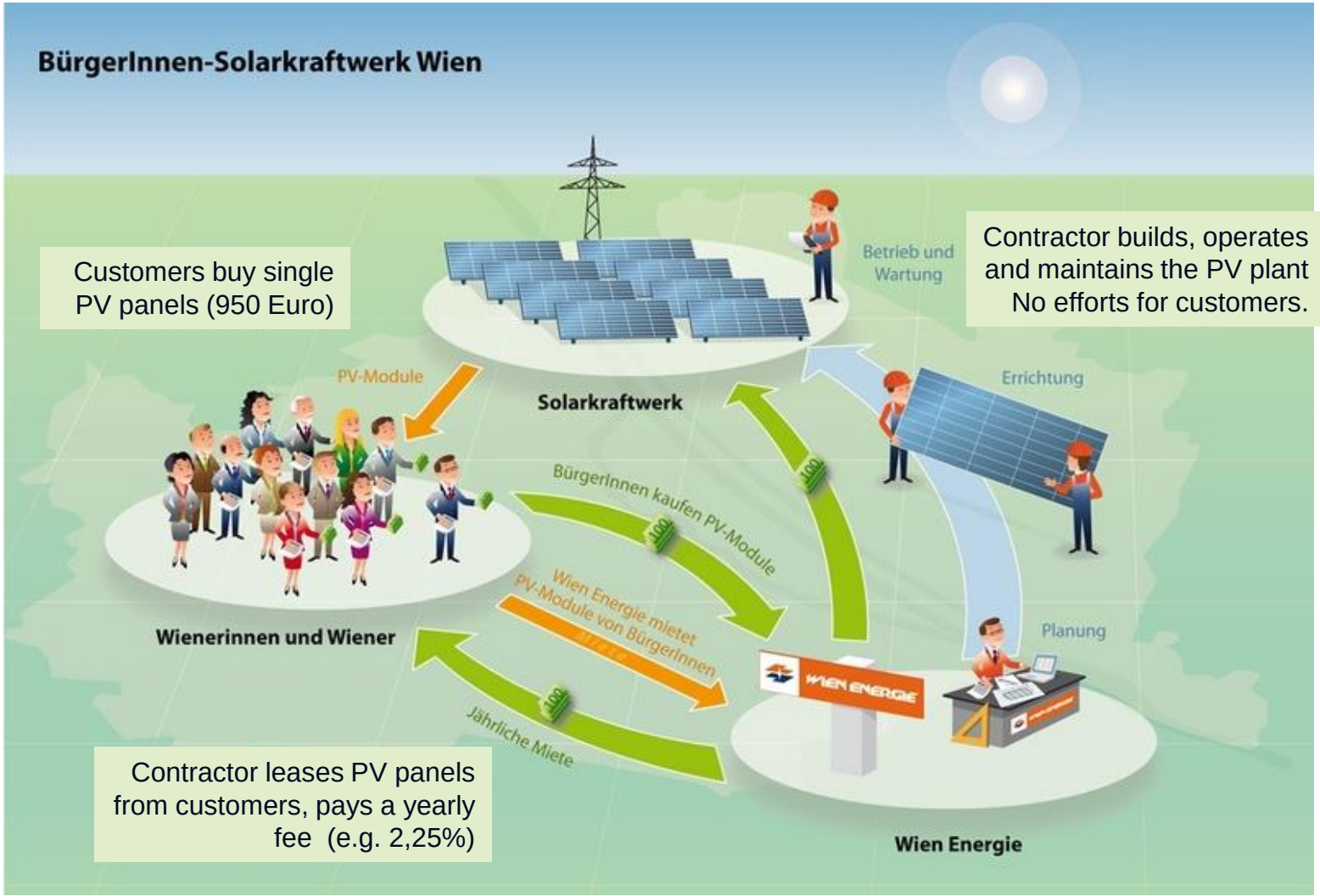
2050

- +25,6 GW until 2050,
- 27% of the electricity supply
- 12,4% of total energy supply

Building Integrated Photovoltaic will play a major role:

- 140 km2 roof area
- 50 km2 façade area

Crowd funding: „Sale-and-Lease-Back“



Crowd funding: „Voucher“

- 950 investment
- 60 Euro/a voucher for the supermarket
- 5,1% revenue
- After 25 years 400 Euro back

Contracting: 12ct power plant

- Contractor builds PV plant >20kWp
- No investment,
- 12ct/kWh for the produced energy
- Self-consumption and feed-in of additional energy
- Costs only for 15 years maximum 980 kWh/kWp per year
- Every kWh in addition is for free

Ihre Ersparnis bei einer 20 kWp Anlage (Beispielrechnung)**

angenommener Strombedarf	übliche Stromkosten	installierte Leistung	erzeugter PV Strom	verrechneter PV Strom*	PV Strompreis	angenommener Eigenverbrauch	üblicher Überschusstarif	angenommene Strompreis-erhöhung
50.000 kWh	14 Cent/kWh	20 kWp	20.000 kWh	19.600 kWh	12 Cent/kWh	70%	6 Cent/kWh	2% pa.

	Stromkosten ohne Photovoltaikanlage	Stromkosten mit Photovoltaikanlage	Ihre Gesamtersparnis
nach 15 Jahren	€ 121.054,-	€ 116.213,-	**€ 4.841,-**
nach 25 Jahren	€ 224.212,-	€ 185.182,-	**€ 39.030,-**

* Deckelung des verrechneten PV Stroms bei 980 kWh/kWp
** Alle Beträge exkl. MwSt.

Source: www.Mea-solar.at

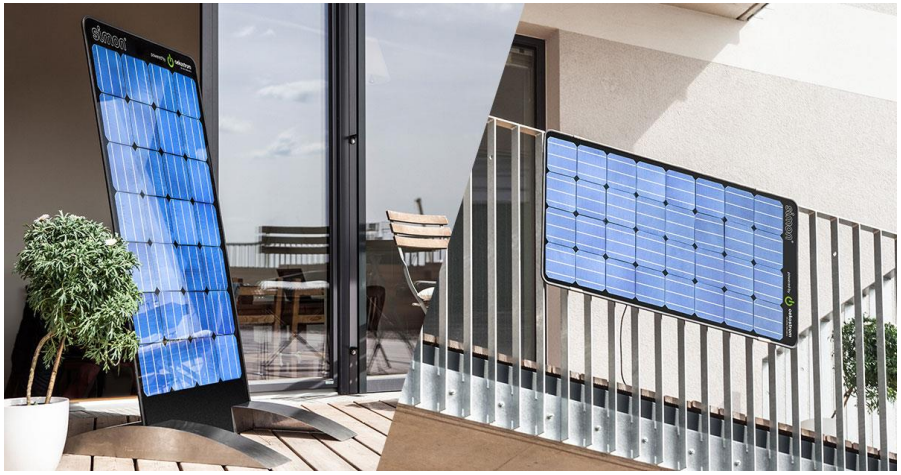
Contracting: various models

- Provision of roof for contractor
- FIT
  - 5% of FIT for customer for 13 years
  - After contracting time (13 years) customer get PV plant for free
- Self consumption
  - Direct consumption
  - 5% cheaper than from other utilities
  - After contracting time (negotiable) customer get PV plant for free

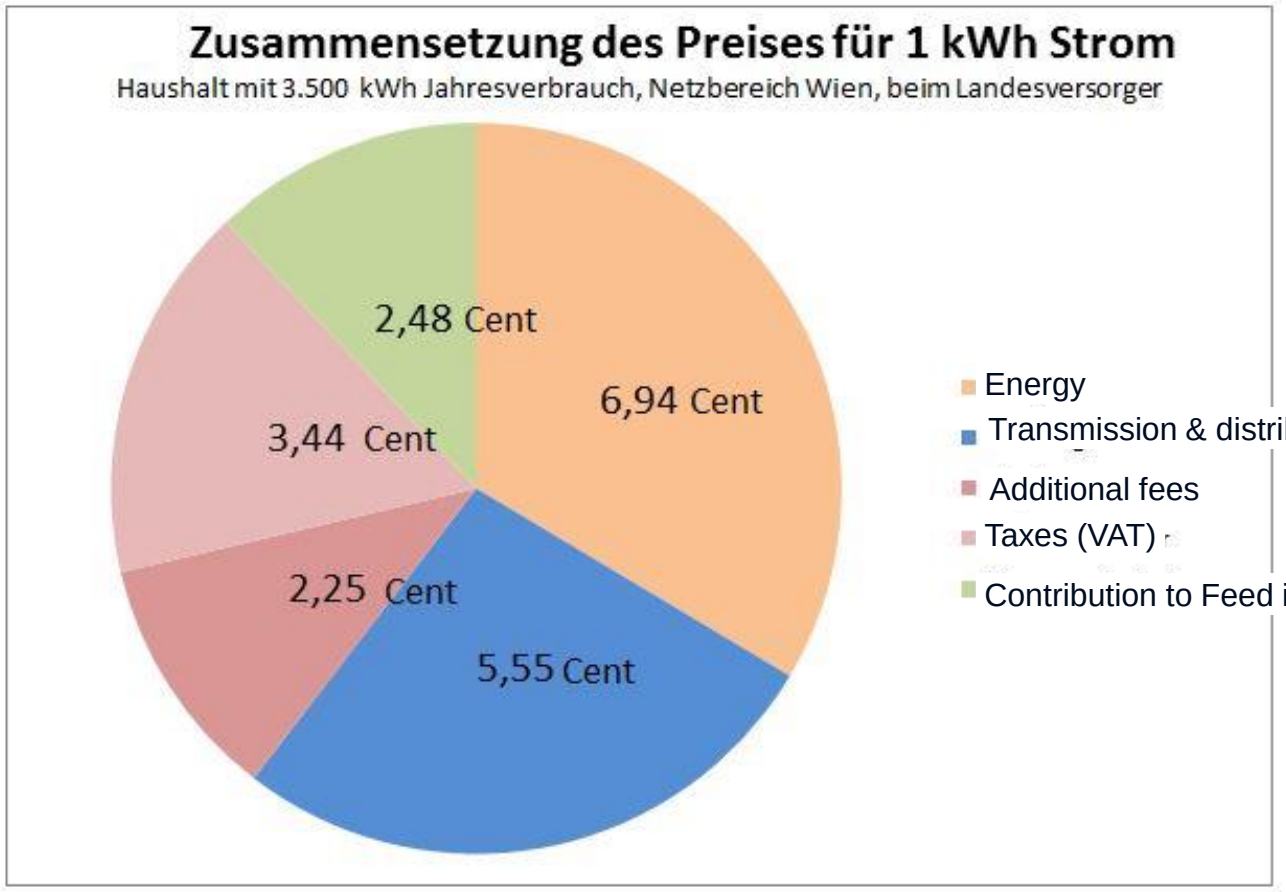
Source: http://www.mair-solarpower.at/pv-contracting.html

AC modules for the people

- Idea: „Plug and Safe“ module
- Design approach
- 150W
- 599 Euro + mounting kit
- TOR D4 allows AC modules up to 600W only for permanently connected generators (no plugs)
- Administrative burden and weak support by grid operators

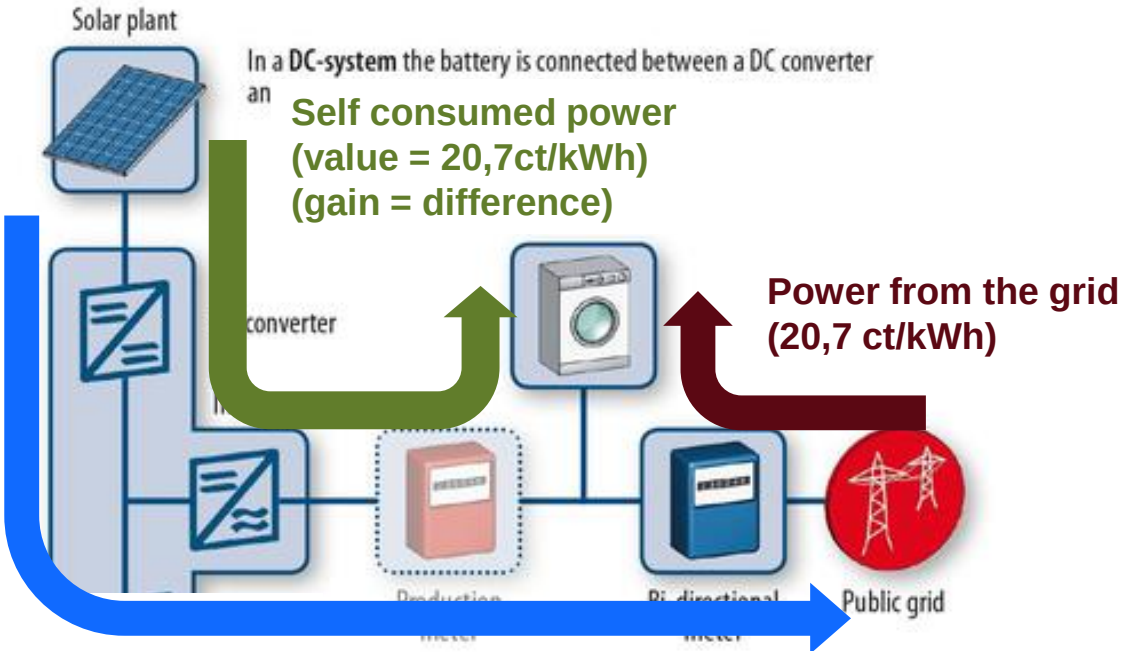


Price for electricity (1kWh)



Source: www.e-control.at

Business case PV



Source:www.pv-magazine.com

PV generation in correlation with energy demand in household

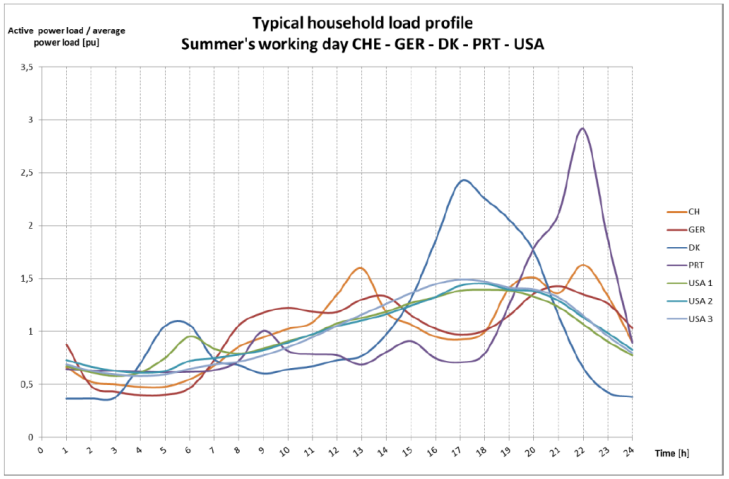
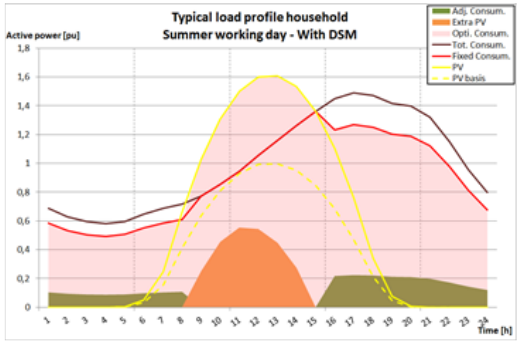
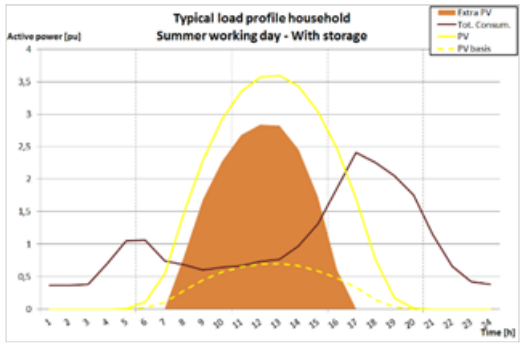
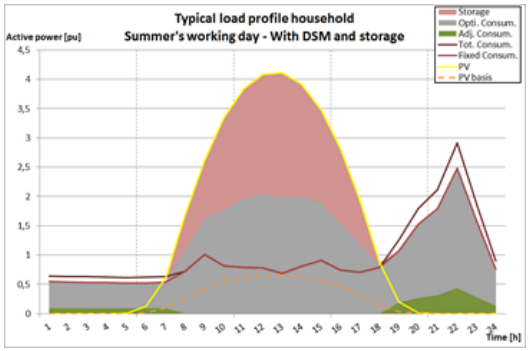


Figure 14 : Typical load profiles on summer's working day, normalized.

- How much PV I can integrate into the grid without reverse flow ?
- Case studies for PV integration (DK, PRG, USA, CH, DE)
  - Base case
  - Integration with DSM
  - Integration with Storage system (6 kWh)
  - Integration with DSM and Storage



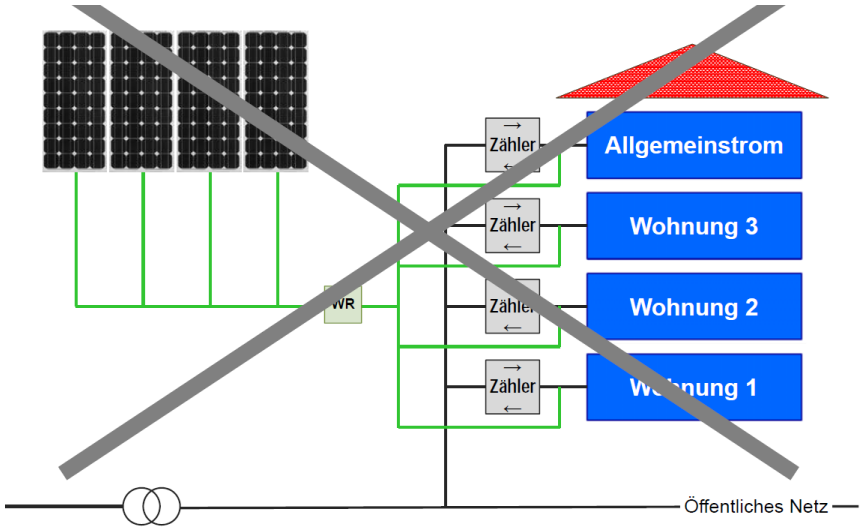


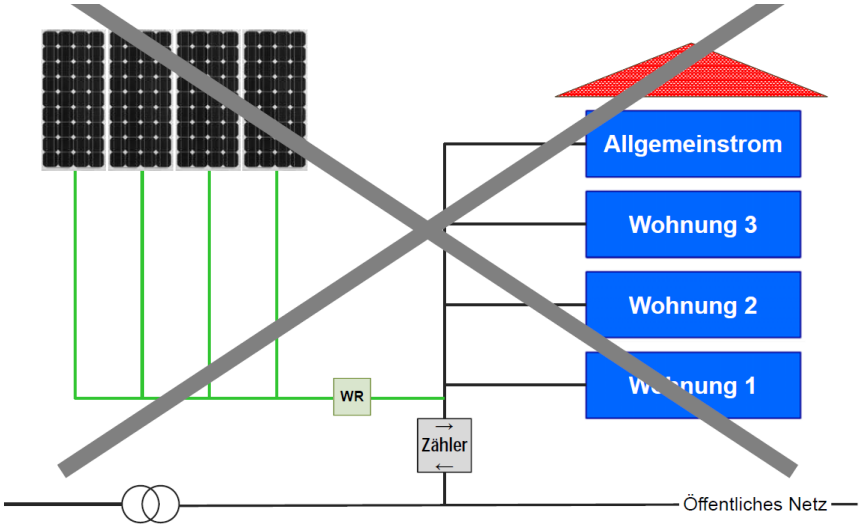


Source: IEA PVPS Task 14

Concepts for multi-family houses [1]

- Not allowed

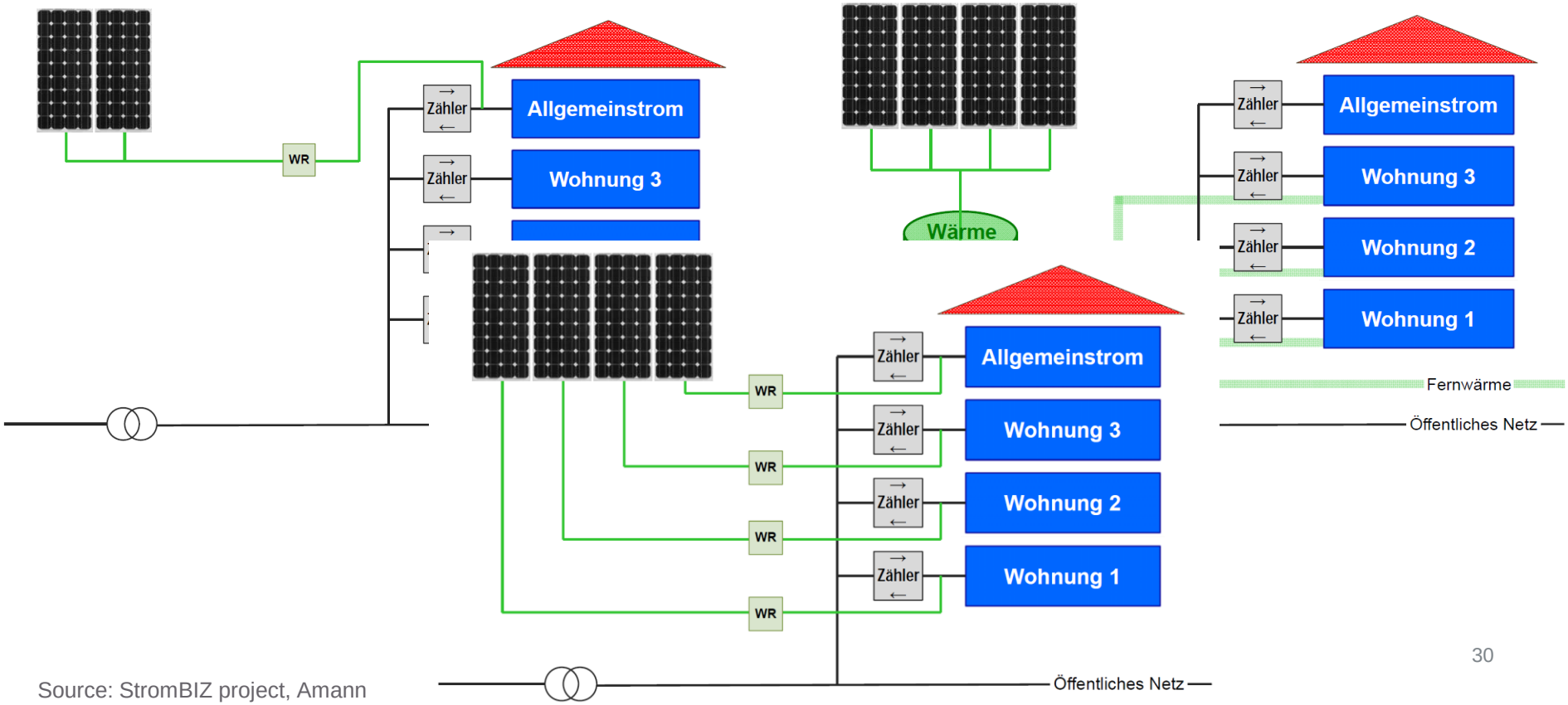




Source: StromBIZ project, Amann

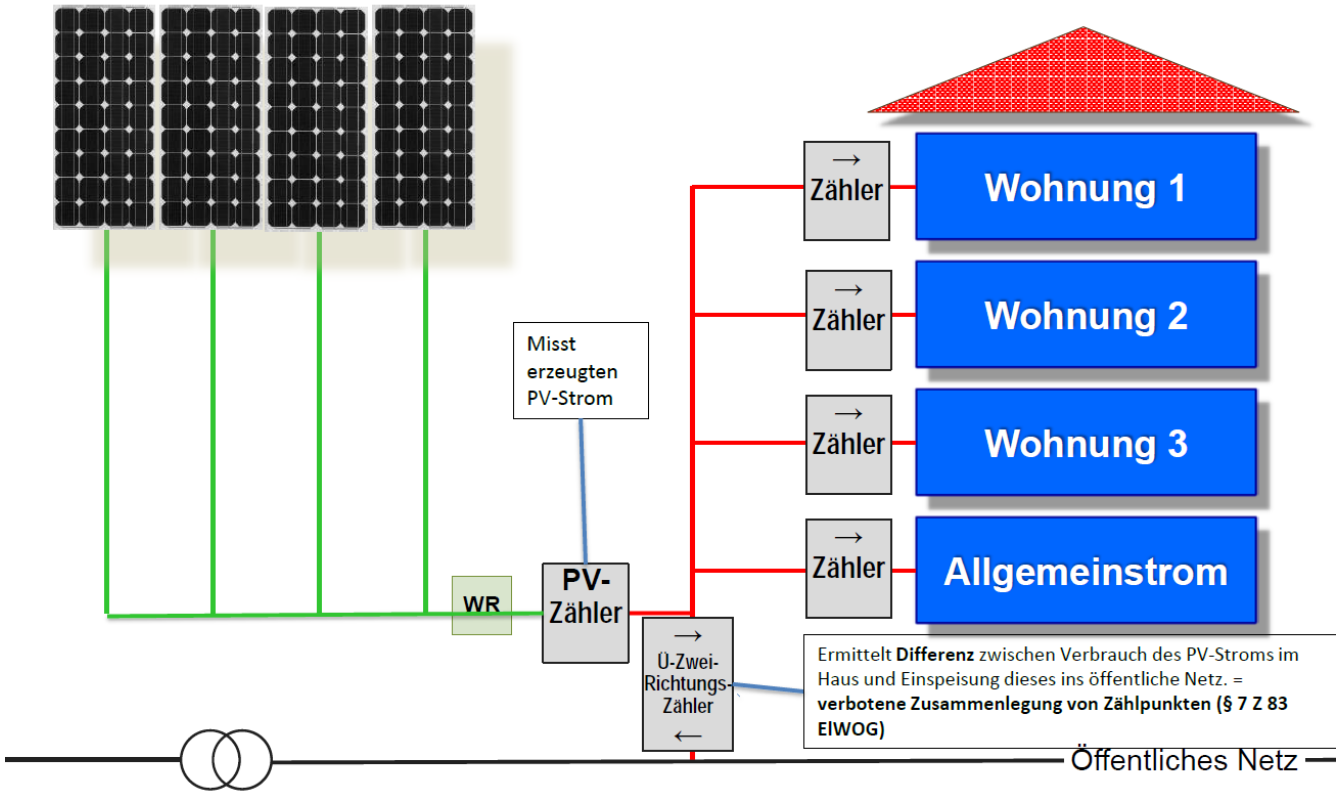
Concepts for multi-family houses [2]

- Current practice



Source: StromBIZ project, Amann

Concepts for multi-family houses [3]: new approach



Source: StromBIZ project, Amann

Legal feasibility of business models

Electricity Industry and Organisation Act

ElWOG 2010

- Erzeuger/Lieferant
- Endverbraucher
- Netz
- Zähler
- Lieferantenwahl

Right of abode

Wohnrecht

- MRG
- WEG
- ABGB

Consumer Protection Act

Konsumentenschutzrecht

- KSchG
- ABGB
- Spez. ElWOG 2010
- FAGG

Taxes

Tax fees apply on energy

- Provision (distribution) of electricity
- Consumption of electricity by energy suppliers
- Consumption of self produced electric energy (1,5ct/kWh)

- Up to 25 000 kWh/a no tax fees for PV plant operators

Regulatory framework recently revised

- Interconnection requirement TOR D4 revised 02/2016
  - Treshold level for single phase interconnetion reduced
  - Introduction of voltage control: Q(U), P(U)
  - Idea: increased hosting capacity by local measures on the generator target ~+50%
  - Consideration of energy storage: Same requirements as for DG
  - Definition of „micro generators“ <0,6 kW per installation with fit-and-inform approach

- Green Energy Act
  - Under revision

- ELWOG:
  - solutions for use of PV in multi-family homes under implementation

EU-Directive for ‚Nearly Zero Energy Buildings‘

New Driver for BIPV in EU -> Directive 2010/31/EU:

of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings:

> *„Nearly zero-energy building: a building that has a very high energy performance. The nearly zero or very low amount of energy required* ***should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.“***
>
> http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32010L0031

‚Efficient House Plus

Source: BMUB –Effizienzhaus Plus, Sobek Architect

Active Town House

Source: HHS - Hegger Architects, ABG Frankfurt Holding GmbH

Nearly Zero Energy Building

Source: AIT, POS-Architects

Solar Refurbishment

Source: Astrid Schneider, Solar Architecture

Tradition of Construction - Innovation

Source: Astrid Schneider, Solar Architecture

Historic Building before and after renovation with BIPV in Solar Village Nechlin, crystalline and amorphous PV

Traditional procedures:

- materials known for centuries
- well known constructions
- DIN ‚Buidling Codes' and standard construction rules
- Industries for decades in ‚construction' (brick industry, wood, roof tiles ..)
- traditional education of installers and craftsman which need to be certified
- Engineers and Architects learning about the subject at university

Building Integrated Photovoltaics: the Challenge

Consumer Electronics

- Industry
  - Semiconductors / Coating / Wafers
- Technology
  - Solar Cells: Thin Film, Crystalline
- Standards
  - IEC

BIPV-Component:

Electronic & Construction properties and purposes from global to local markets, rules conditions

Construction Material

- Industry
  - Stone, Steel, Concrete, Wood
- Technology
  - Stonewall,
  - Roof Structure
- Standards
  - ISO

Building integrated Solar Modules need to fulfill electric and construction standards – at national, European and international level

BIPV-Standards – Actual Status

- **NEW: EU – European Standard CENELEC - BIPV**

  Status: EN Standard on BIPV published and in force since 1/2016:

  - EN 50583-1 – „Photovoltaics in buildings - Part 1: BIPV modules"
  - EN 50583-2 – „Photovoltaics in buildings - Part 2: BIPV systems"

- **ISO – PV Glass:**

  ISO/TC 160/SC 01/WG 09 "Glass in building - Building integrated photovoltaics"

  Status: DRAFT INTERNATIONAL STANDARD: ISO/DIS 18178

  "Glass in building — Laminated solar PV glass"

- **IEC – International Standard on: Photovoltaics (PV) on roof**
  „Photovoltaics (PV) on roof": IEC 82/1055/NP

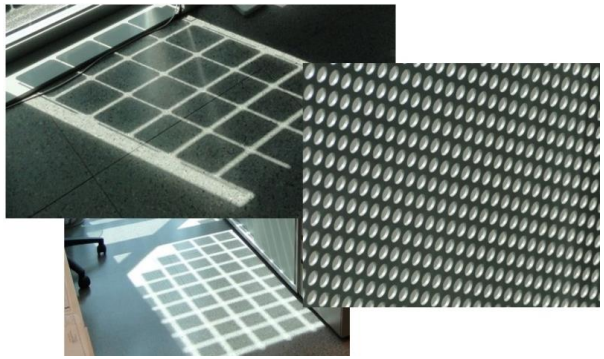
  Status: NEW WORK ITEM PROPOSAL – Proposed by South Korea

- **IEC – International Standard on: Photovoltaics on Curtain Wall**
  „Photovoltaic modules for building curtain wall applications**": IEC 82/888/NP**

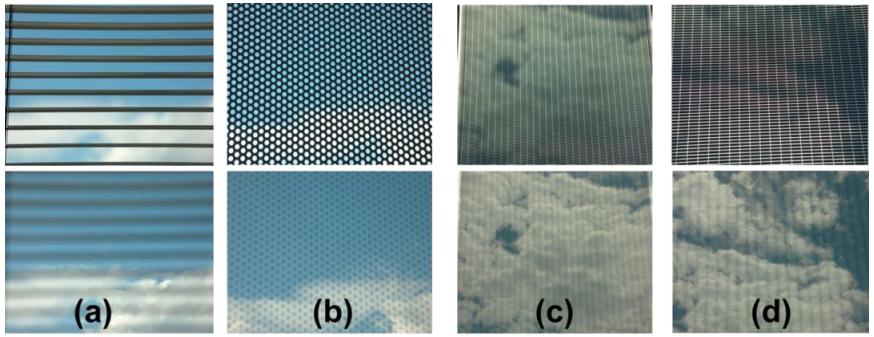
  Status: NEW WORK ITEM PROPOSAL – Proposed by South Korea

Integrated solutions for PV in buildings (BIPV)

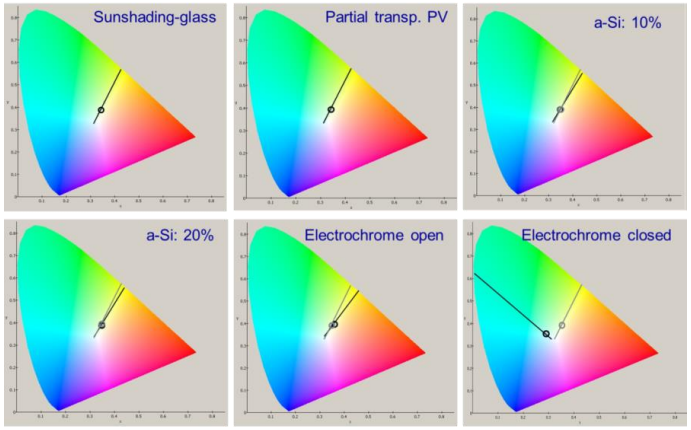
Visual comfort



Shading



Architecture (Enzian-Tower / Bozen)

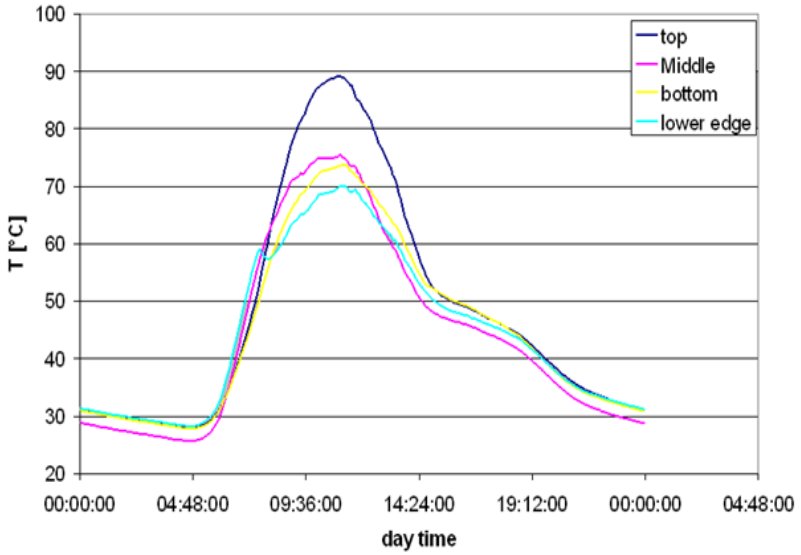


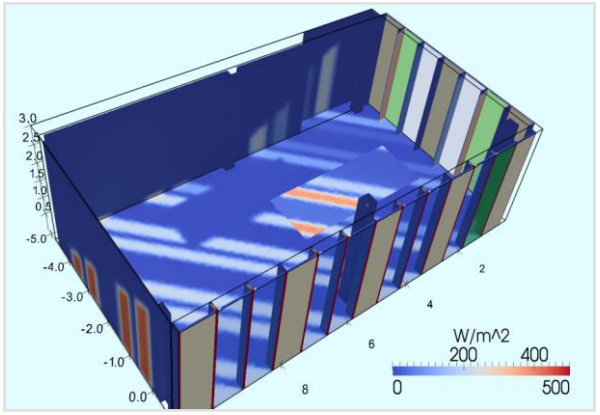
Color reproduction

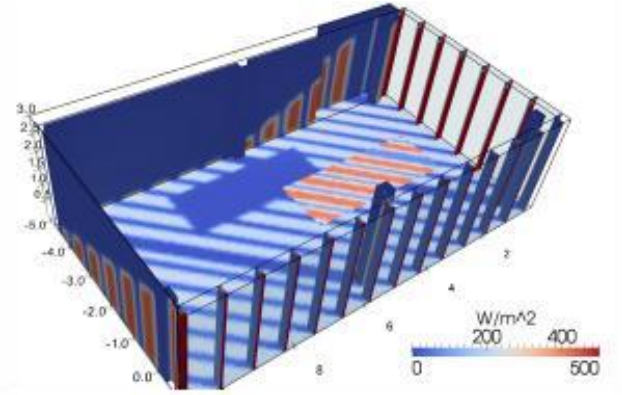
Integrated solutions for PV in buildings (BIPV)

Thermal comfort

- Computational Fluid Dynamic Simulation (CFD)
- Calculation of surface temperatures



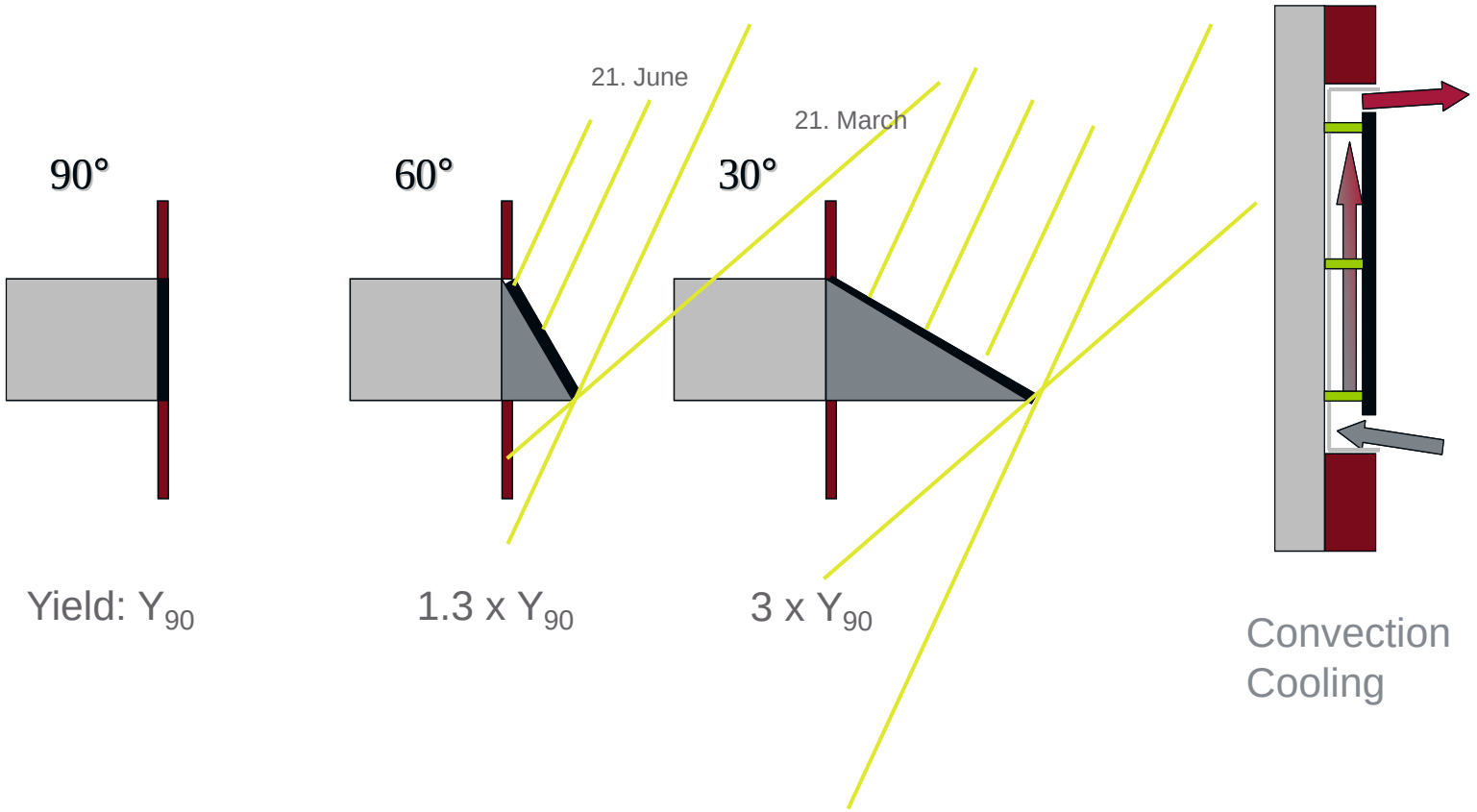




Integrated solutions for PV in buildings (BIPV)

Shading & PV-Cooling

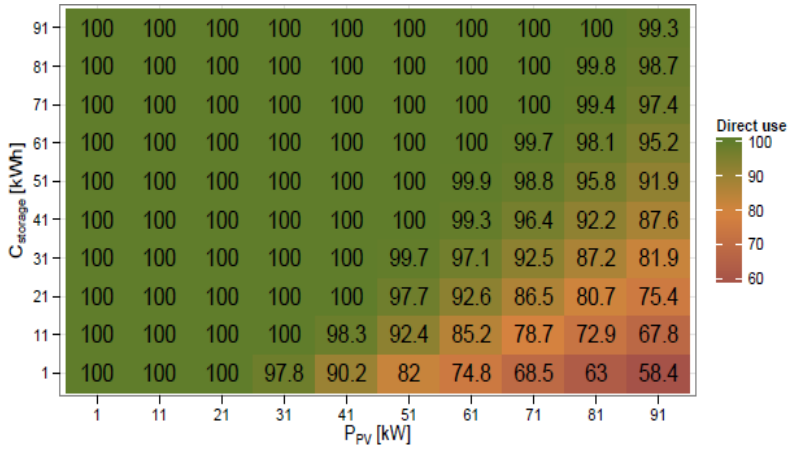
- Precise energy yield calculation



Integrated solutions for PV in buildings (BIPV)

Evaluation of state-of-the-art buildings with PV

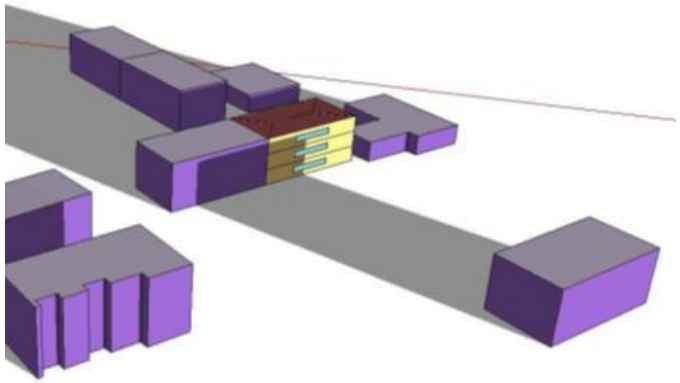
- Evaluation of potential for high self consumption with or without storage
- At once marketable
- Low supplementary costs
- Fast ROI
- Increase rating of building energy labeling



Integrated solutions for PV in buildings (BIPV)

Energy in buildings

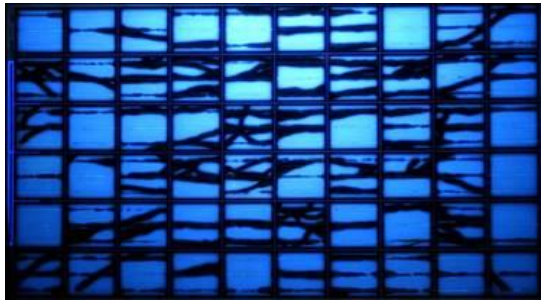
- **Rapid decision support** for planners, architects and developers using rapid building modelling tools to fasten and ease pre-conceptual studies and certification of energy performance
- **Data driven optimization of building performance** including fault detection to optimize energy efficiency, indoor comfort and aspects of health
- **Consultancy services** on how to fulfill legislative requirements (energy efficiency and resources) at minimum cost

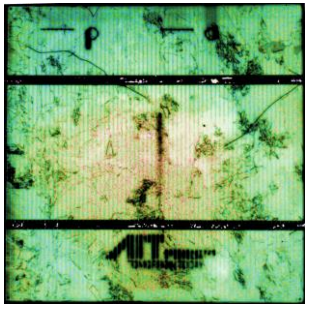


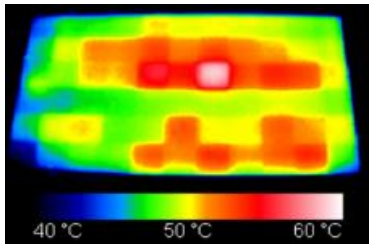
Integrated solutions for PV in buildings (BIPV)

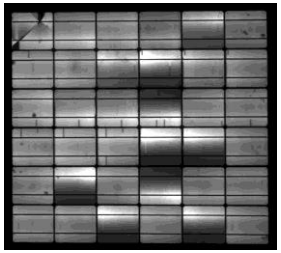
Reliability and performance

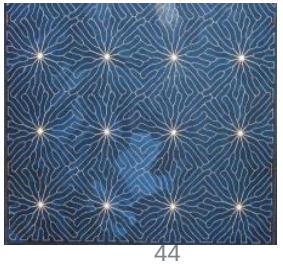
- Multifunctionability of BIPV
- Module performance
- System behavior
- yield optimization (partial shading)



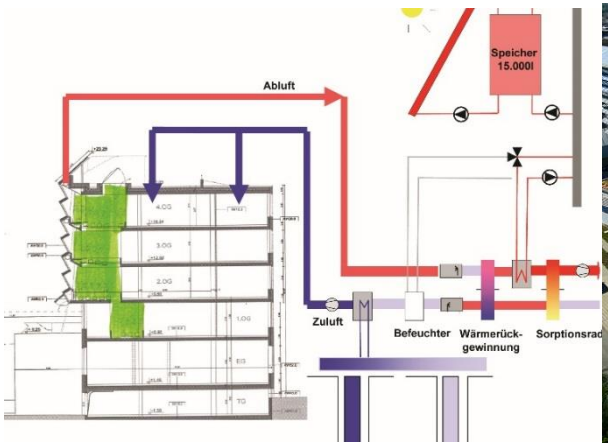








Democase
ENERGYbase



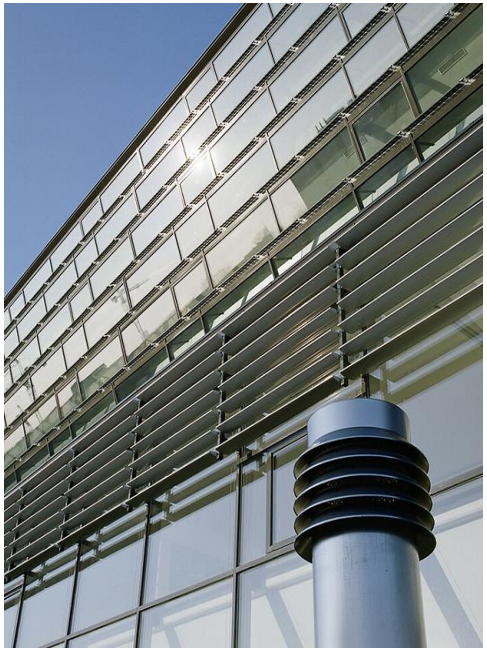
Solar Buildings like the 'ENERGYbase' are becoming the new standard with Europe's 'Energy Performance of Buildings Directive' **Directive 2010/31/EU:**

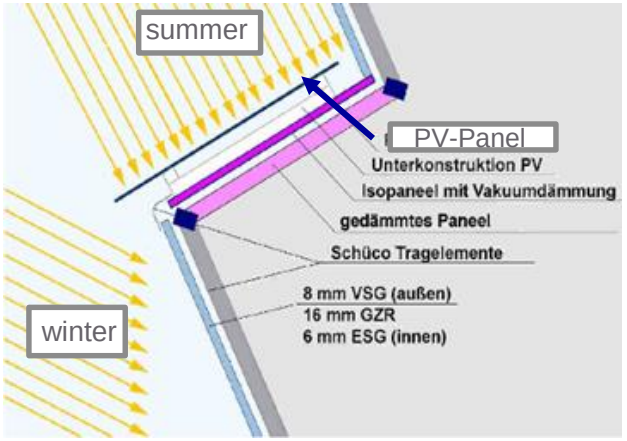
Energy System:

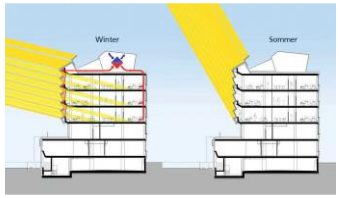
- Photovoltaic system with folded fascade
- Solar thermal collectors: Solar cooling by sorption chilling process
- Heat pumps coupled with ground water for passive cooling
- Concrete core activation
- Indore plants for humidification

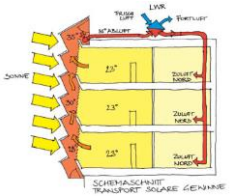
Total annual demand for heating, cooling and ventilation: **20 kWh/m2a**

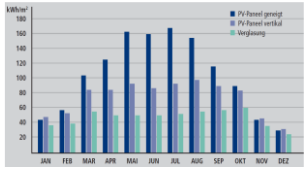
AIT ‘ENERGYbase’- Solar Optimized BIPV-Façade











The folded façade allows:

- Optimized solar power generation, shading, and daylighting
- +30% more Solar PV-Electricity Generation than vertical façade
- Building Integrated Photovoltaics generate ca. 30% of annual electricity consumption for heating, cooling and ventilation of the building

Democase

Sheikh Zayed Desert Learning Center –Al Ain - UAE

Scientific Planning Support

- Building and HVAC simulation
- Optimisation by parameter study
- Passive cooling and Concrete core activation
- Measures for peak load reduction
- Photovoltaic system design

ENERGY MODELLING (LEED / ESTIDAMA Certification)

- Modeling and Simulation
- Energy Assessment by simulation ‘Baseline’ versus ‘As Designed’

Cooperative Research: PV@Fassade Project

Project

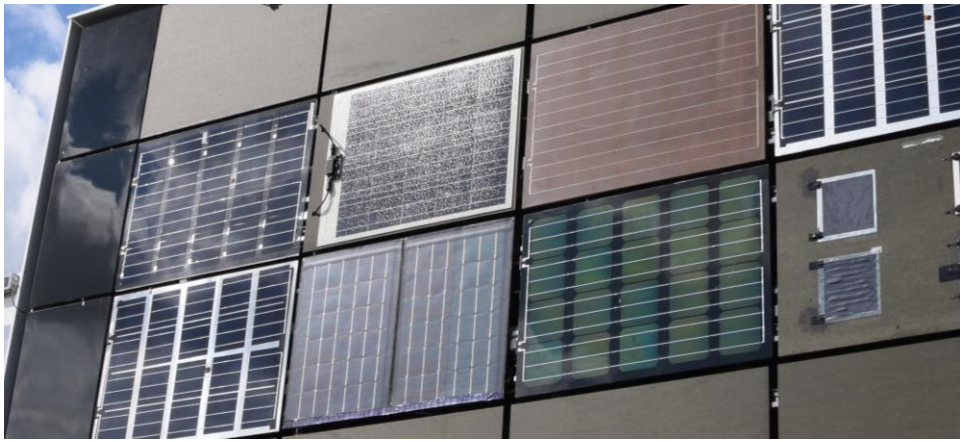
- e!MISSION project „PV@Fassade – façade modules with PV-active layers“

Key data

- Coordination: OFI Technology & Innovation
- Duration: 1 April 2014 – 31 March 2017
- Budget: EUR 2,200,000
- AIT share: EUR 290,000

Results

- Solutions for reliable, cost-effective and aesthetically pleasing building-integrated photovoltaics
- Façade integrated PV-solutions as an outcome of an intense cooperation of innovative Austrian thin-film-PV start-ups, with companies from the structural-facings sector and research
- Exploitation of the needs of planners, architects, installers and residents



Shape-PV – The shape of BIPV to come: Concept for R&D

Project

- National funded project, Energieforschung (e!MISSION) 2014

Key data

- Coordination: AIT
- Duration: 1 September 2015– 31 August 2016
- Budget: EUR 237,529
- Consortium: University of Applied Sciences, Technikum Wien; ATB-Becker; Architecture office of Reinberg

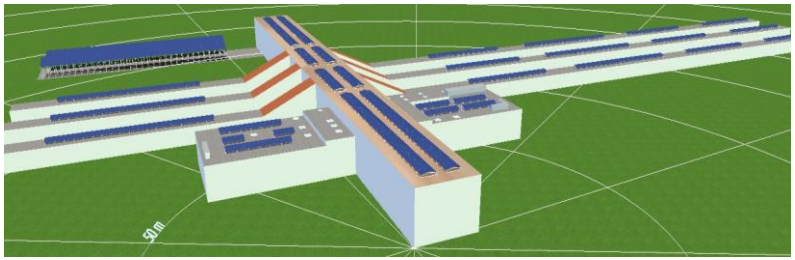
Results

- defines the requirements and future targets for BIPV for Austrian Market
- develops a research and implementation roadmap
- drafts a concept for a first implementation phase

Ertex Solar – BIPV-Facade with LED, Fondation Pierre Arnault, Architect: Jean Pierre Emery

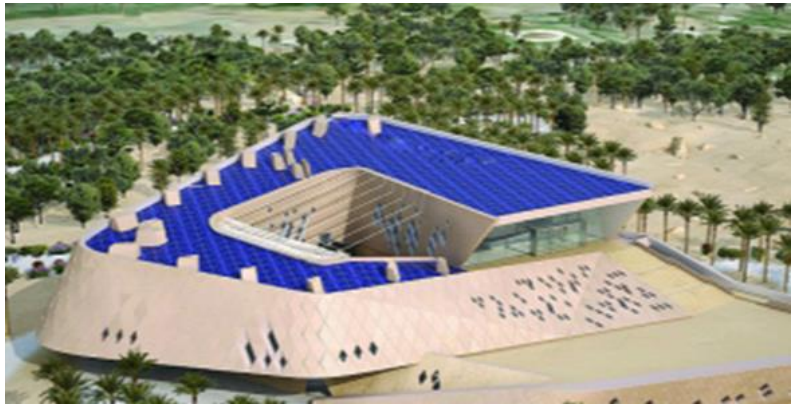
Project:: Reinberg Architects, Vienna

Consultancy's for Building Integration of Photovoltaics



PV-roof-integration for Railwaystation
ÖBB Railwway operator

PV-facade-integration for Office Building
Research Centre Jülich, Photovoltaic Institute



PV-Roof as major energy source
Sheik Desert Centre

Consultancy on Solar cell and module Technologies, Colours and Shapes

Cooperative Research: Print.PV

Project

- National funded Flagship project (Energy Research)

Objectives

- Development of a printing technology for flexible CZTS monograin foils, with max. web-speed of 40 m/min
- All process steps are addressed: polymer development, grain embedding, back contact, front transparent contact (FC),…
- AIT develops an all solution-processed composite front transparent contact, compatible with high web-speed processing

Results

- Solutions for highly transparent, highly conductive and stable front cover with high deposition rate
- Innovative chemical bath-deposited ZnO/AZO with high performance and low cost

Key data

- Coordination: Joanneum Research
- Duration: 1 April 2014 – 31 March 2017
- Budget: EUR 4,000,000

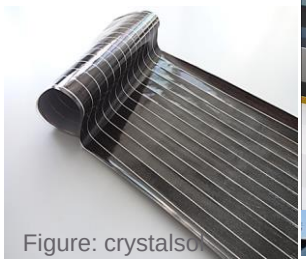
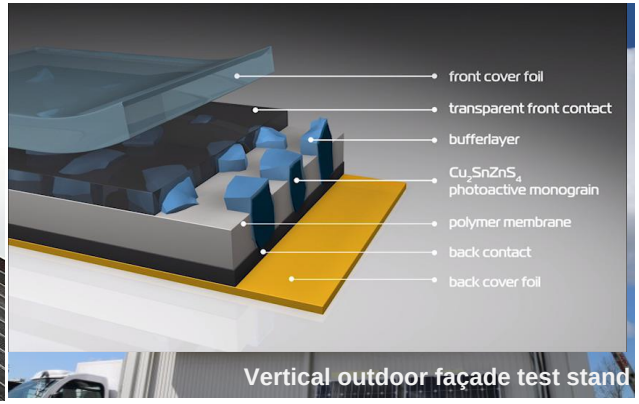


Figure: crystalsol



Climate Adaptation of Photovoltaic Modules: INFINITY Project

Project

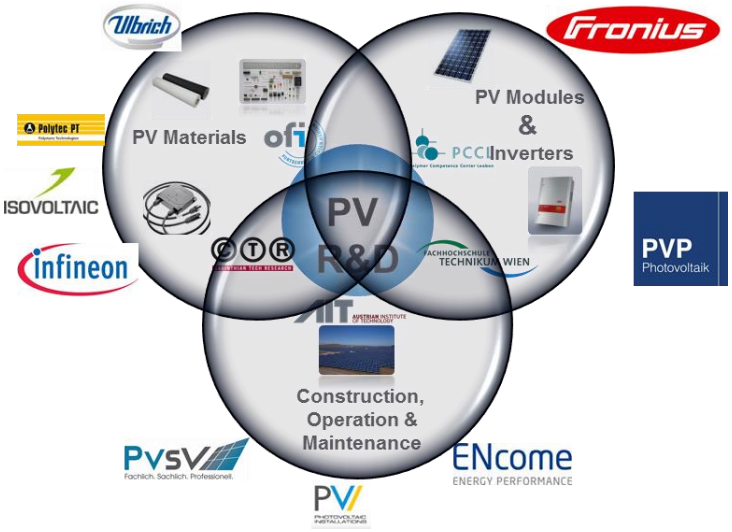
- National funded Flagship project: **INFINITY** „Climate-sensitive long-term reliability of PV“
- State funded research project together with main industry partners

Objectives

- Adapt photovoltaic systems for different climate zones like desert, (sub)tropical or alpine regions
- Error analysis of materials, modules and inverters in extreme climates
- Improvement of climate protection and making companies more competitive at an international level

Key data

- Coordination: CTR Carinthian Tech Research AG
- Scientific lead: AIT, Energy Department, PVS
- Duration: 1 November 2015 – 31 October 2018
- Budget: EUR 5,481,000
- AIT share: EUR 600,000



European Research Collaboration with Industry: CHEETAH

Project

- Funded by European Union
- EU FP7 project aimed at combining Europe's research and development efforts in support of the European PV industry

Objectives

- Solve specific R&D issues in the EERA-PV Joint Programme
- Overcome fragmentation of European PV R&D in Europe
- Intensify collaboration between R&D providers and industry to accelerate the uptake of innovations in the European PV industry

Key data

- Coordination: ECN, Netherlands
- Duration: 1 January 2014 – 31 December 2017
- Budget: EUR 13,282,470

- Developing new concepts and technologies for wafer-based crystalline silicon PV (modules with ultrathin cells), thin-film PV (advanced light management) and organic PV (very low-cost barriers)
- Accelerating the implementation of innovative technologies in the PV industry

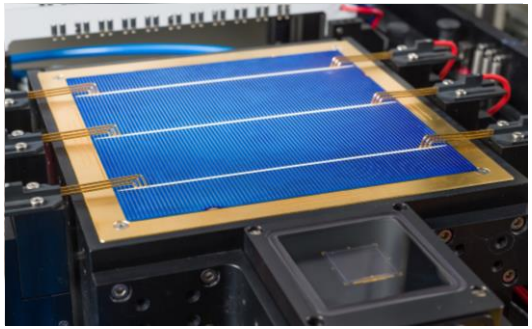
CHEETAH

CHEETAH: Cost Reduction through Material Optimisation and Higher Energy Output of Solar Photovoltaic Modules

Photovoltaic: collaboration and services by AIT

Component manufacturers

- Accredited PV module test laboratory
- Development support and validation of photovoltaic components
- Development of new material combinations and cell concepts
- Design of manufacturing processes

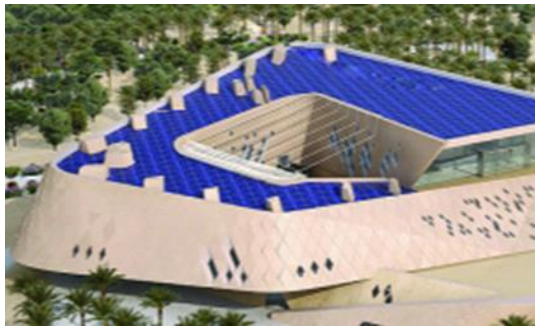


System Developers and operators

- Planning and evaluation support
- Due diligence for PV parks
- Tendering support
- Quality assurance for high PV plant performance

Building and Public Sector

- Planning support for BIPV facilities
- Quality assurance of BIPV components
- Consulting for technical integration issues and technology selection
- Studies for PV deployment



Accredited PV Laboratory

Services and expertise

- Development support for cell and module manufacturers
- Testing of photovoltaic components
- Precise characterization of PV technologies
- Electro-optical methods for Solar Cell and module analysis
- Independent performance measurements
- Quality assessment and life time testing

Accreditation and standardisation activities

- Accredited test lab according to EN ISO/IEC 17025
- Member of IECEE CB Scheme
- Member of national and international standardisation committees (IEC/CLC TC82, TC64)

Product certification

- In cooperation with the Austrian Electro-technical Association (OVE)

Independent accredited testing

- IEC 61215 (new ed.)
- IEC 61646
- IEC 61730 (new ed.)
- IEC 60904 series

Component manufacturers → System Developers and operators → Building and Public Sector

Quality Assurance of PV Systems

Services and expertise

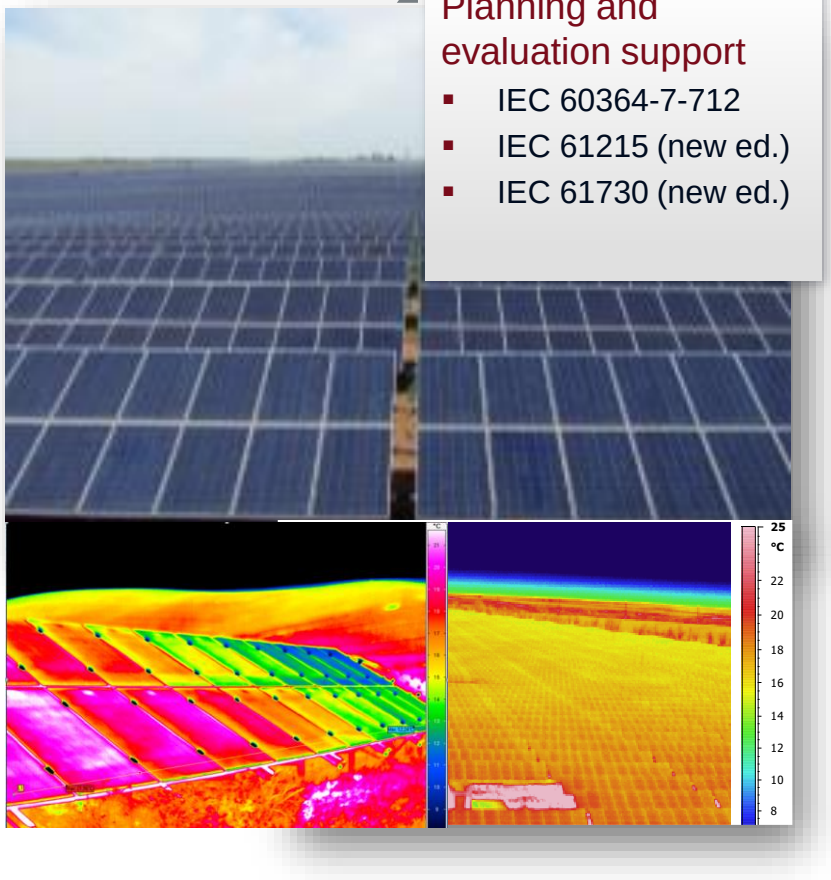
- High quality technical support for PV plants owners, investors, insurance companies and financial service providers
- Consulting for EPC providers
- Assessment of the quality, planning and operation of PV facilities
- Technical due diligence
- Yield prediction and site analysis
- Scientific analysis of high-resolution monitoring data for optimizing inverter and system performance

Infrastructure

- Mobile outdoor test equipment
- Analysis tools for automated monitoring data evaluation

Planning and evaluation support

- IEC 60364-7-712
- IEC 61215 (new ed.)
- IEC 61730 (new ed.)



Component manufacturers | System Developers and operators | Building and Public Sector

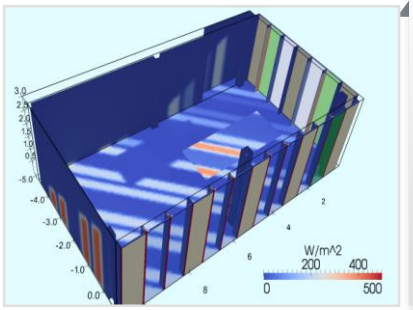
Integrated solutions for PV in buildings (BIPV)

Services and expertise

- Analysis of electric performance, visual- and thermal comfort
- Combined simulation of BIPV components and buildings for integrated planning
- Feasibility studies and evaluation of innovative BIPV concepts in accordance with relevant standards and guidelines
- PV system behavior and yield optimization in the built environment

Infrastructure

- Advanced integrated performance measurement
- Software framework (CFD-simulation, MC-Ray tracer, 1D thermal modeling, PV-Sol, PV-SYST, SAM, SAPM)



Services for industry

- R&D support for BIPV products
- PV building integration solutions
- Advanced simulation services

Component manufacturers | System Developers and operators | Building and Public Sector

Technologies for next-generation solar cells

Services and expertise

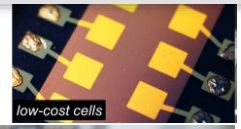
- Development of new material combinations and cell concepts
- Design of high-yield, cost-efficient fabrication processes for thin-film solar cells and modules
- Abundant, non-toxic and stable materials
- Nanostructures for advanced optical management

Infrastructure

- Vacuum-based techniques
- Patterning techniques
- Solution-based techniques

Services for Industry

- Functional coatings and material processing
- Process development
- Innovative solar cell prototypes



Component manufacturers | System Developers and operators | Building and Public Sector

Networks and Partners

Networks

PhotoVoltaic EUROPEAN TECHNOLOGY & INNOVATION PLATFORM

SolarPower Europe

EUREC

EERA European Energy Research Alliance

iea International Energy Agency

International Energy Agency Photovoltaic Power Systems Programme

TECHNOLOGIE PLATTFORM PHOTOVOLTAIK

CENELEC

Partners

EURAC research

EMPA

JÜLICH FORSCHUNGSZENTRUM

TU WIEN

TU Graz

tecnalia Inspiring Business

Fraunhofer ISE

CHEETAH

FOSS Research Centre for Sustainable Energy

ECN

cea

ines INSTITUT NATIONAL DE L'ENERGIE SOLAIRE

HUMBOLDT-UNIVERSITÄT ZU BERLIN

ENEA

DTU Danmarks Tekniske Universitet

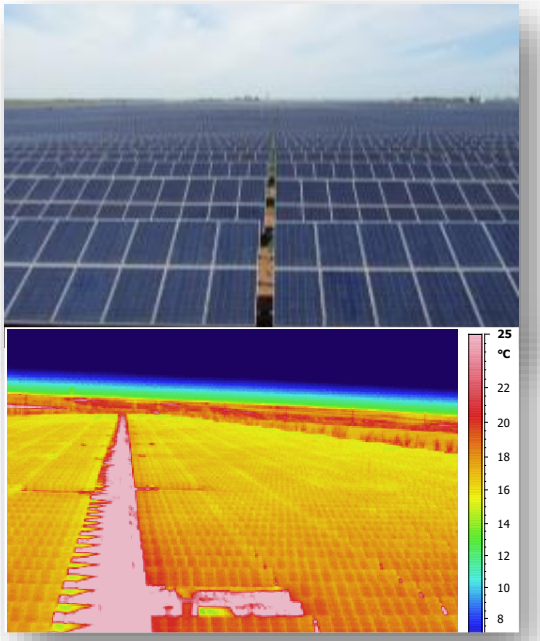
Training and Education

- 7 days basic **training** for
  - installers, electricians, roofer, planners, architects, engineering offices and distributors
- Additional specialization modules
- Ensuring **quality** of
  - planning,
  - installation,
  - operation and
  - maintainance

- http://www.ait.ac.at/departments/energy/photovoltaics/?L=1

Summary

- PV integration in building skins to reach 100% renewable scenarios (urban areas)
- BIPV create technical and organizational challenges
- PV generation now significant in the power system
- High PV penetration situation create technical challenges:
  - At the local level: quality of supply, infrastructure stress
  - At the system level: system stability, need of flexibility
- Adequate technology, standards and grid codes for successful PV building and PV grid integration
- PV becomes mainstream, this also means to take over responsibility
- PV as reliable source of energy



TwinPV

Stimulating scientific excellence through twinning in the quest for sustainable energy

European Commission
Horizon 2020
European Union funding
for Research & Innovation

Grant Agreement: 692031-TwinPV

AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

AIT Austrian Institute of Technology

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