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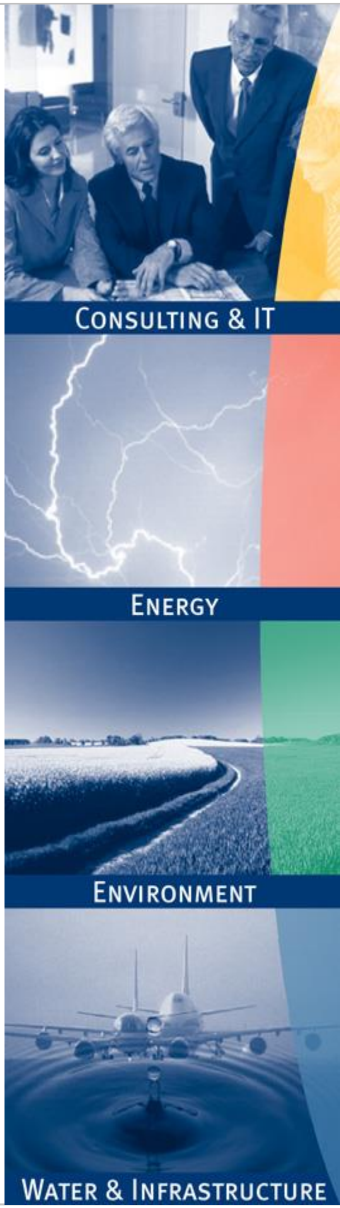
Rooftop PV –
The German Experience & Lessons Learnt
(Technical Perspective)



Hartmut MAURUS, Fichtner
PV Rooftop Workshop, Oman, 13 December 2017

Agenda

Rooftop PV – The German Experience & Lessons Learnt

1. Reasons for the Initial Boom
2. Engineering Really Matters
3. Energy Concept of Buildings
4. Lessons Learnt – The Best Project Approach
5. → Potential Key Drivers for Rooftop PV in Oman

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Reasons for the initial German boom

Technical history

- Photovoltaic effect was discovered by Henry Becquerel back in 1839
- Since 1958 photovoltaic was used mainly in the space industry (i.e. for satellites) or in off-grid systems and
- Consumer appliances such as calculators, watches, etc.

German Policies

- Before year 2000: Feed-in law 1991 (low tariffs), 1,000 and 100,000 Roof Programs to promote PV
- April 2000: **EEG** law into effect ("Renewable Energy Law" to feed RE into grid under a 20-year-fixed tariff) – not only for PV systems, but also for wind, water, biomass
- Update of EEG 2012 introduced intense changes
  → led to big reduction in installed power per year (before up to 7.5 GWp, now 1.3 – 1.5 GWp yearly)
- Still challenging target:
  Till 2025 according to EEG law RE share in electricity production to be 55 - 60% (today 33%)

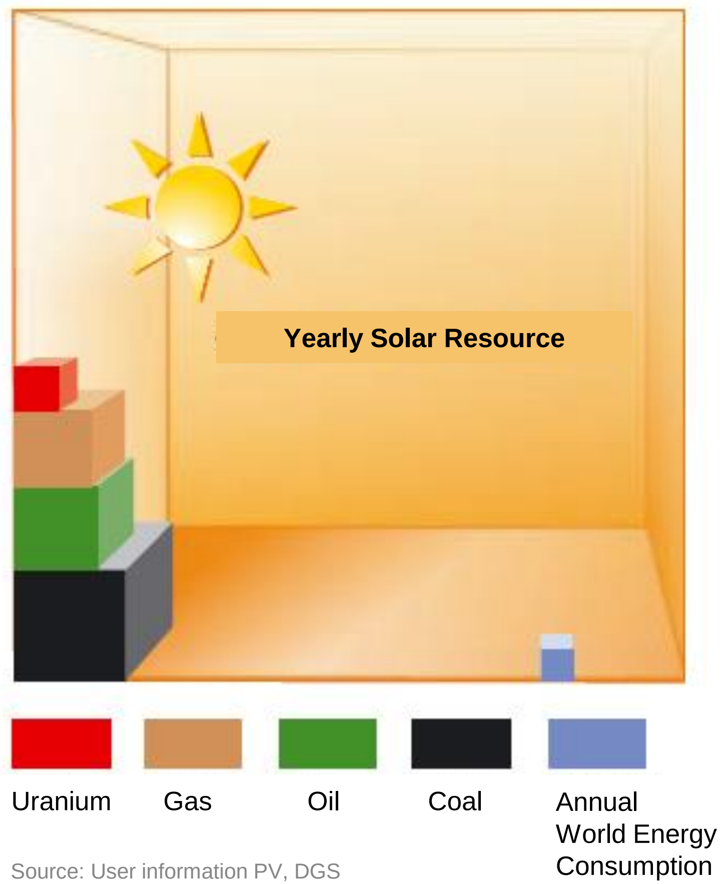
Reasons for the initial German boom

Market Development

- Huge installation boom started in 2000 with each year more installed power till the year 2012 (with 7.5 GWp only for PV)
- Solar Farms and Rooftop installations in all market segments (residential, commercial, utility) System sizes ranging from 1 kWp on a small house up to 10 MWp of a Solar Farm
- **“Gold Digging Atmosphere”** (2003 – 2012, afterwards slowdown)
- Cost reduction (BOS cost) from roughly **7,500 to 1,500 - 900 EUR/kWp** today
  - economies of scale &
  - technological advances
- German boom (“Energiewende” / Energy Transition) influenced many other countries to implement policies with similar schemes and tariffs

→ leads today to e.g. worldwide lowest IPP-offering in KSA, 4 October 2017:
1.79 USc/kWh for 300 MW plant

What drives us? – The potential of the sun



Source: User information PV, DGS

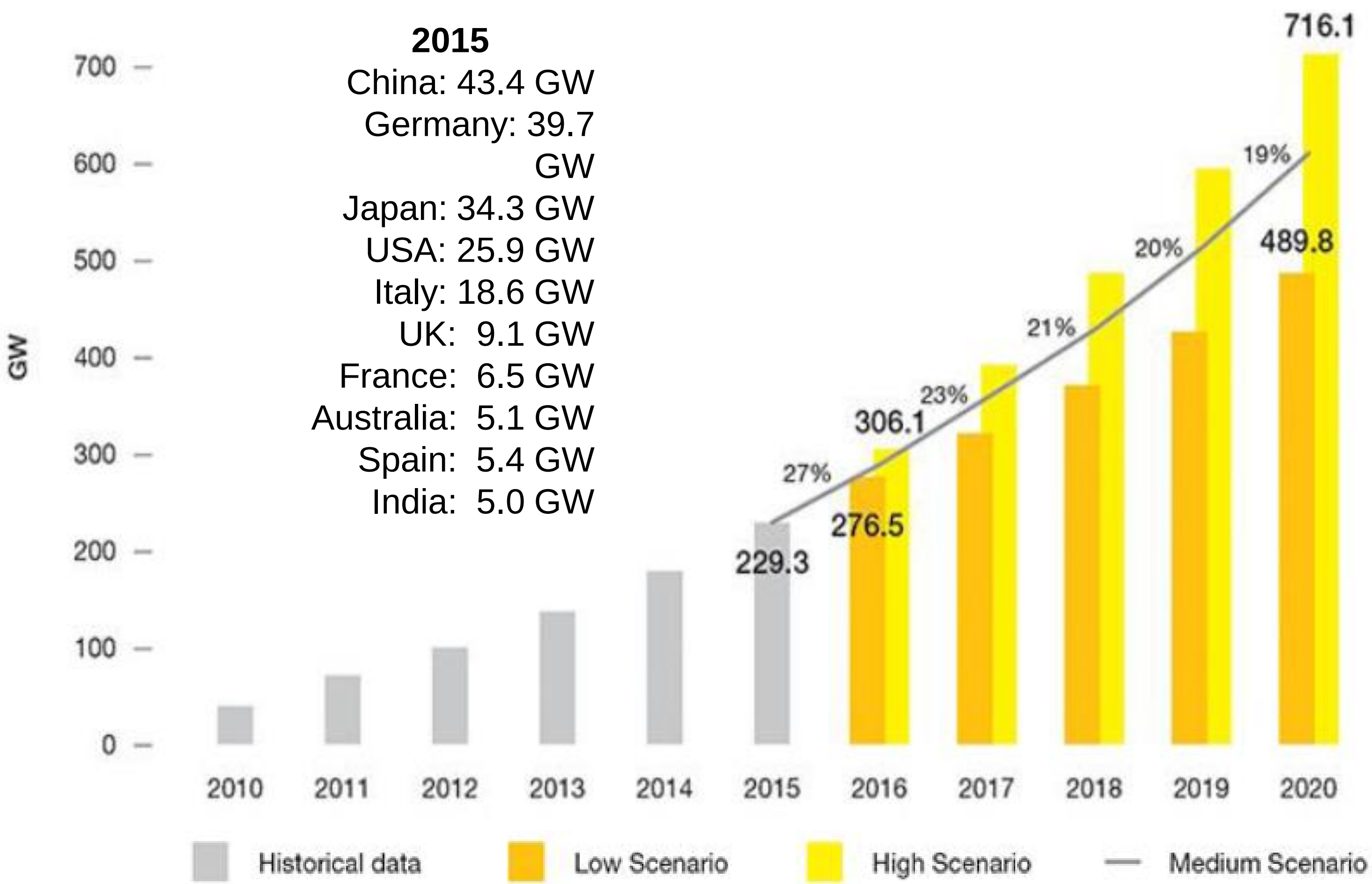
- Only in Germany yearly solar irradiation supersedes demand by around 80 times.
- This energy source during the next 5 billion years will be limitless, for free and eco-friendly.
- Fossils like uranium, coal, gas and petroleum get expensive and have limits.

→ Sun does not send any invoice!

PV power – worldwide development

Global **total** PV installation – scenario until 2020

2015
China: 43.4 GW
Germany: 39.7 GW
Japan: 34.3 GW
USA: 25.9 GW
Italy: 18.6 GW
UK: 9.1 GW
France: 6.5 GW
Australia: 5.1 GW
Spain: 5.4 GW
India: 5.0 GW



Source: Solarpower Europe 2016

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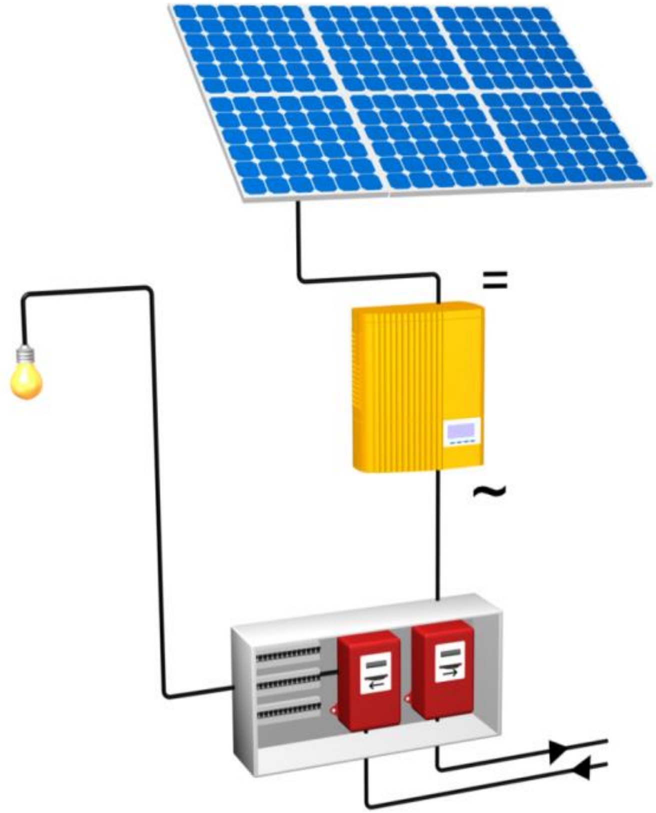
Introduction in PV power systems

Basic components of Photovoltaic System



Photovoltaic modules connected in series (strings)

Mounting structure (or tracking system)

Inverter (DC/AC) + monitoring systems

Electricity meter / grid connection

Typical rooftop systems – pitched roofs

Normally in parallel to slope of roof

- Mounted with metal systems as simple as possible
- Perforating roofing system with hooks and/or screws
- Allocation depending on area of roof to one or more separated sub-generators (→ O&M needs)

Source: SW-Heidelberg

Typical rooftop systems – pitched roofs

In-roof PV systems

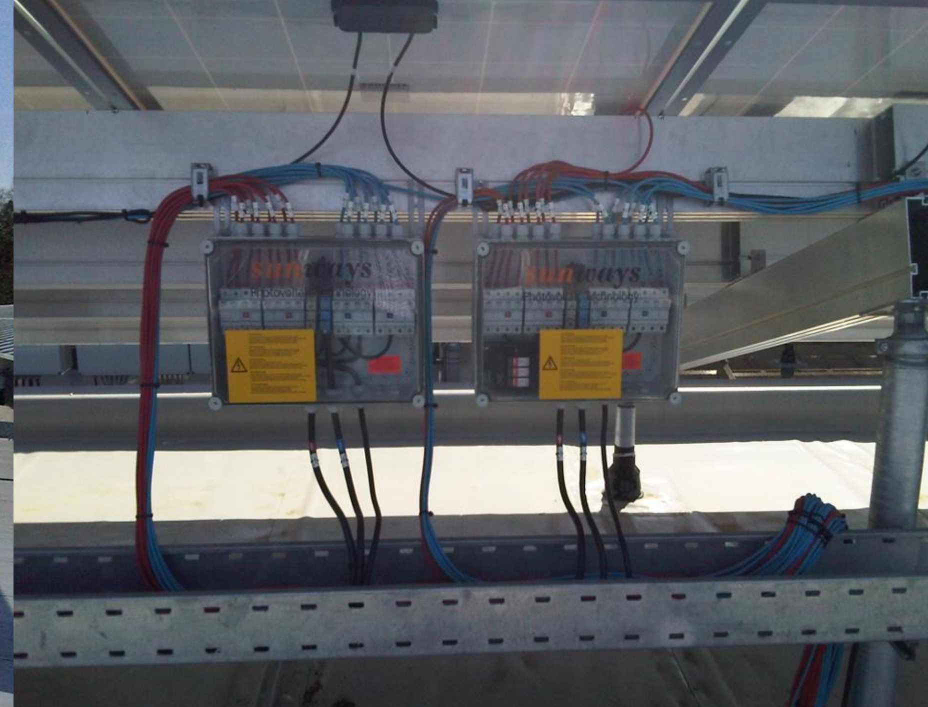
- Glass-glass or glass-foil laminates
- Different framing options or without frame
- Mainly in black color, but different color options
- The PV system replaces on pitched roofs the conventional roofing system

Typical rooftop systems – flat roofs

4 methods of mounting on flat roofs

- Staggered single row allocation with low tilt (5 – 10°) using the wind loads and ballast as shelter (south orientation) – (1)
- Double row allocation with low tilt (5 – 10°) using wind loads and ballast (east/west orientation) - (2)
- Using filled trays/tanks as base for modules (see next page) - (3)
- Perforating roofing system to connect to structure (page after next page) – (4)

Edeka Supermarket, Bad Dürrheim,
Germany by Sunways AG - 290 kWp


sunways
sunways


sunways

Typical rooftop systems – solar carports

Objectives

- Energy production
  (plus e-mobility solution → battery charging??)
- Weather protection (against heat and hail)
- Management of Parking Lots (ROI)
- Special mounting systems in series
- Architecture / appearance / corporate identity

Source: BlueOak

Source: Schletter

Engineering really matters

Critical issues for a PV rooftop project *(more in tomorrow's session)*

- Orientation and yield:
  → Shadings
  → Energy demand of the building
  → Land-use plans in the neighborhood

- Structural loads:
  → wind, snow, dead + additional PV system weight

- Integrity of existing roof / building structure:
  → sealing material / roofing system
  → refurbish before PV installation?

- Cost influence
  →early integrative planning approach brings best solutions

- Architecture / appearance

The move forward

Rooftop PV on the first glance may be and is an opportunity to earn money by means of tailor-made business models for harvesting optimum RE using feed-in tariffs / agreements and thus maximizing return on investment (ROI).

Rooftop PV allows for much higher benefits!

Price decrease through mass production, technological advances and learning from projects develops awareness of all stakeholders. The focus is then less on ROI, but more on the interdependencies between building itself and its function and the entire energy concept of such building ("green building approach").

An integrated approach allows for high self-consumption, lower OPEX of the building and releases partly the public grid.

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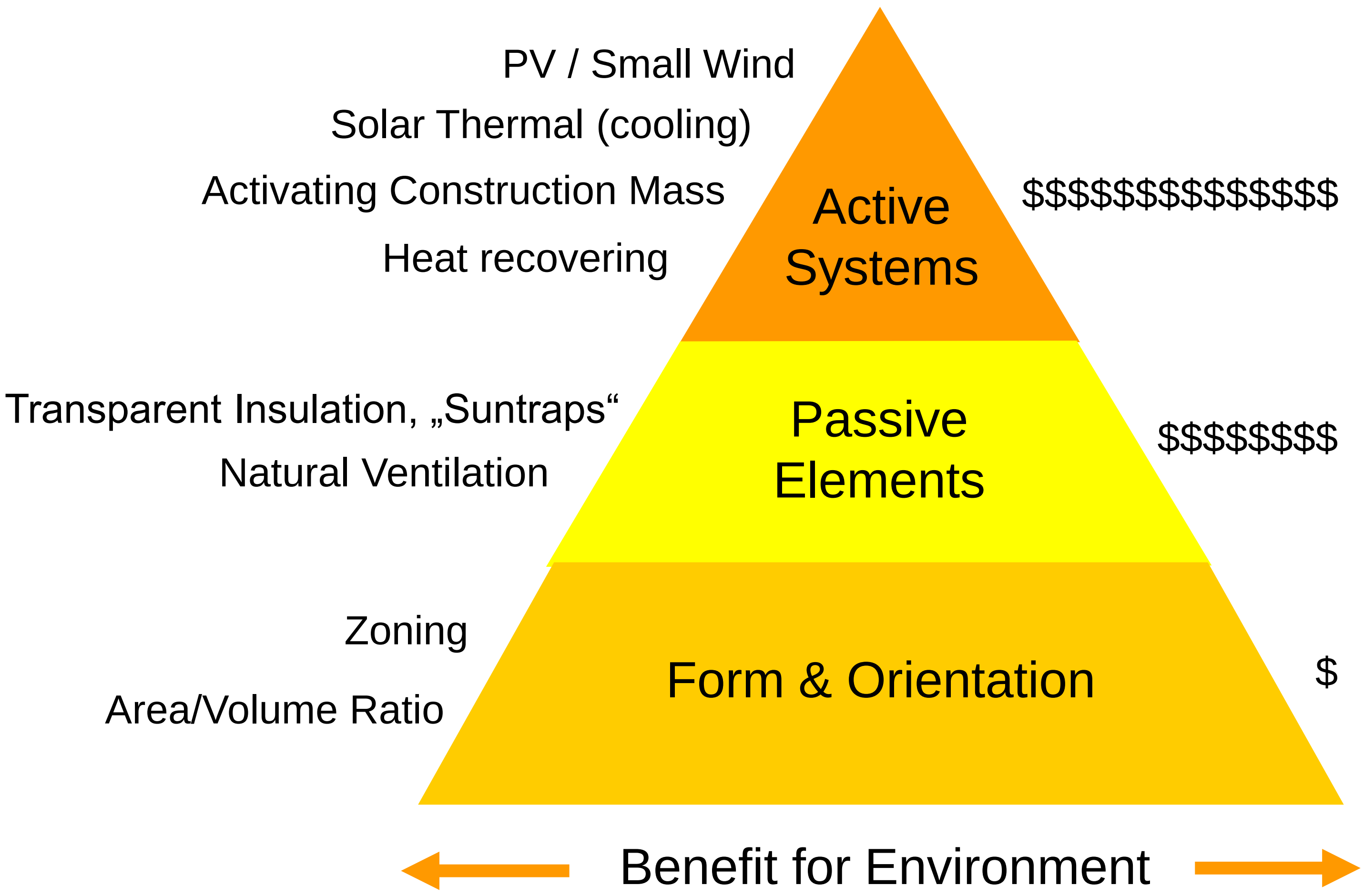
Adaptability worldwide

INTEGRATION ERGONOMY COMFORT FUTURE REDUCTION **UNIVERSALITY** ECOLOGY PARTNER

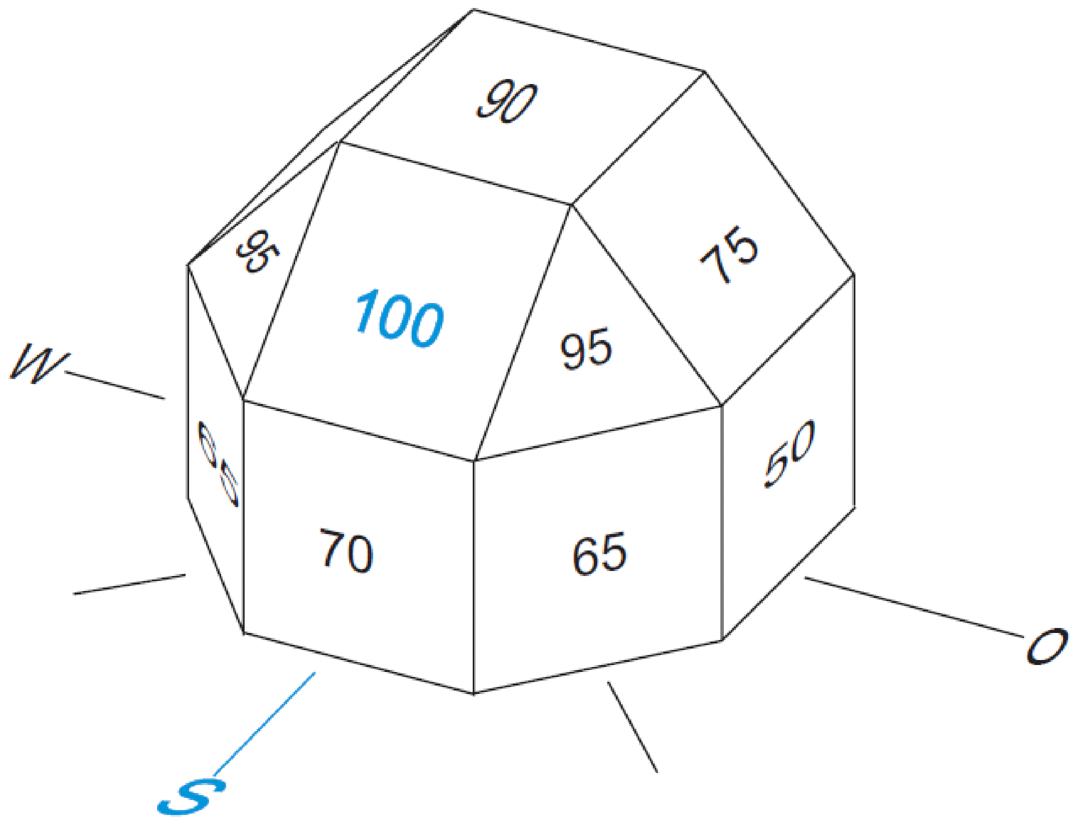
Source: C. Bender, Behnisch Architekten

Basics of planning – holistic approach as optimum



Source: SolArchiCon

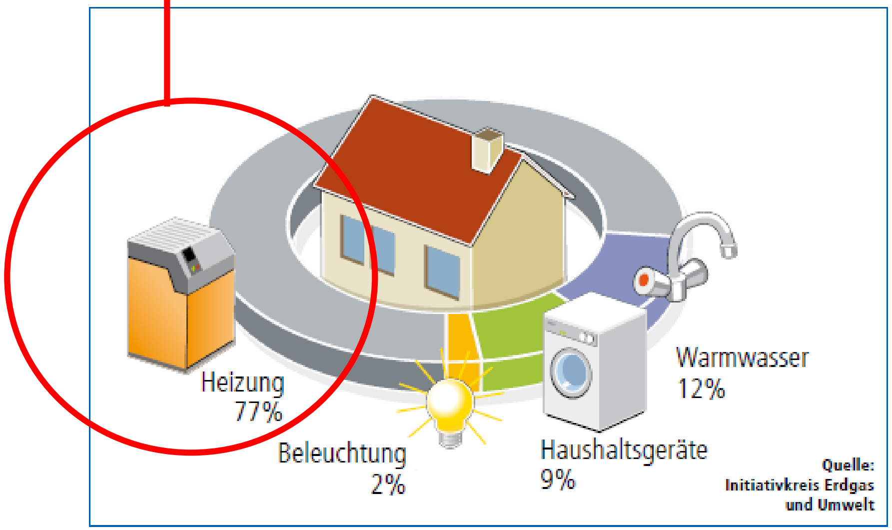
Orientation - Yield

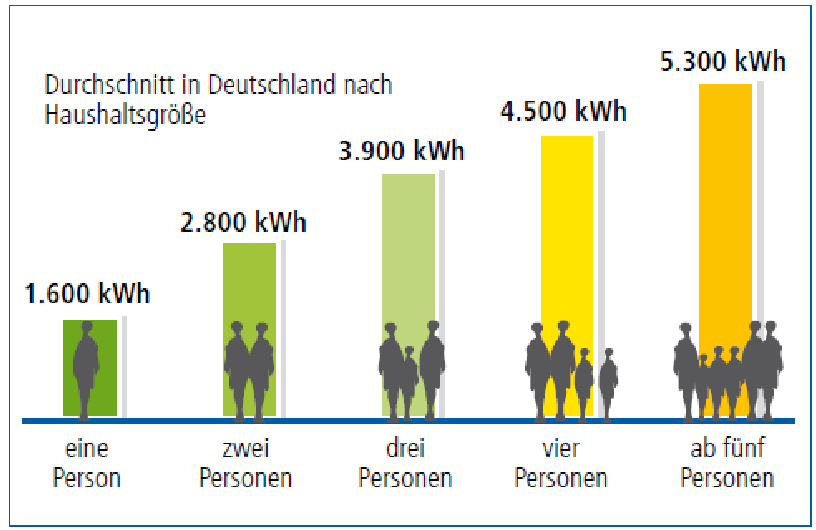


Source: DGS

Operational cost of a building

Cooling in Oman





Source: DGS

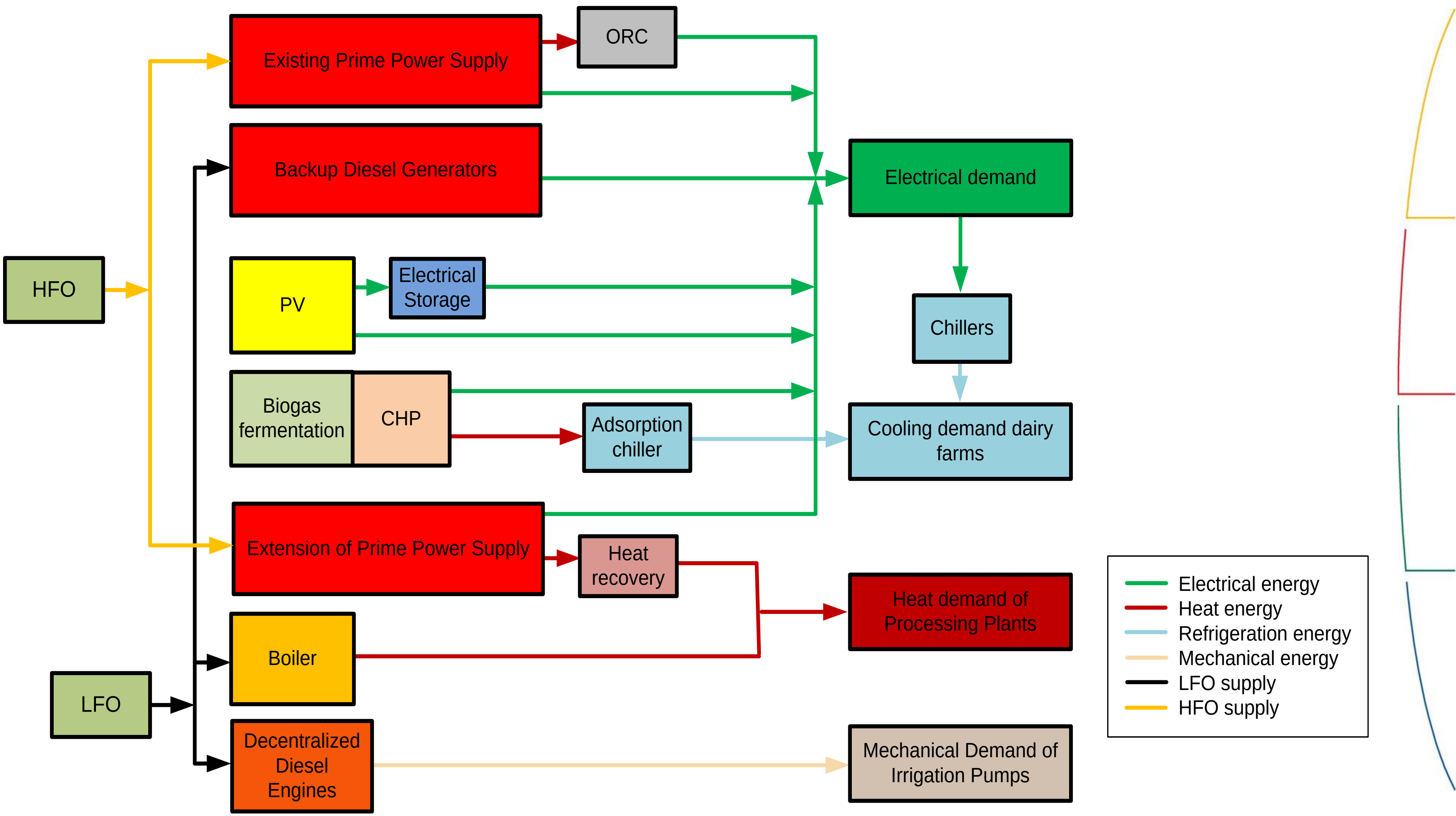
Consumption in residential households in Germany

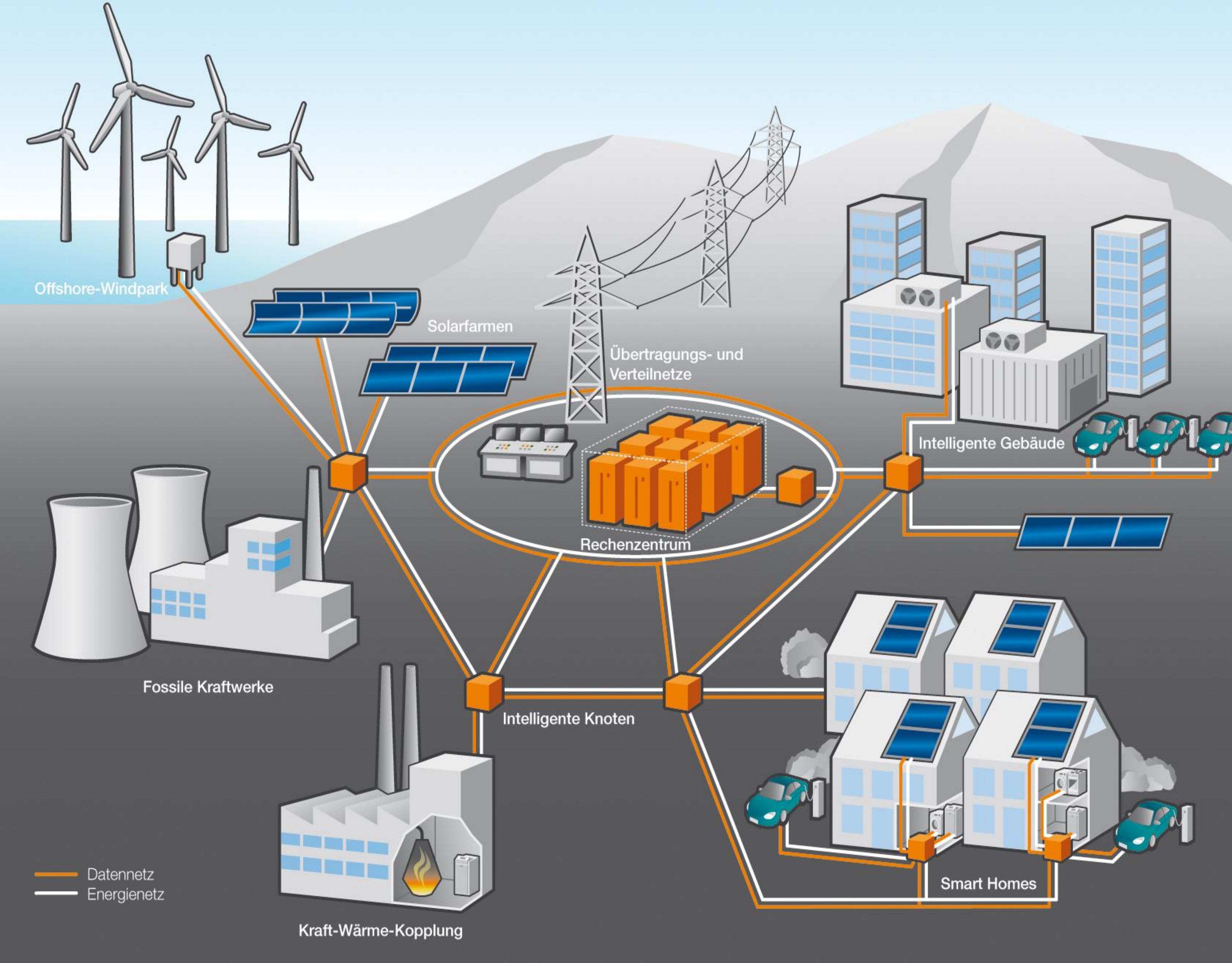
Decision makers in a PV project

Stakeholders with big influence on PV applications:

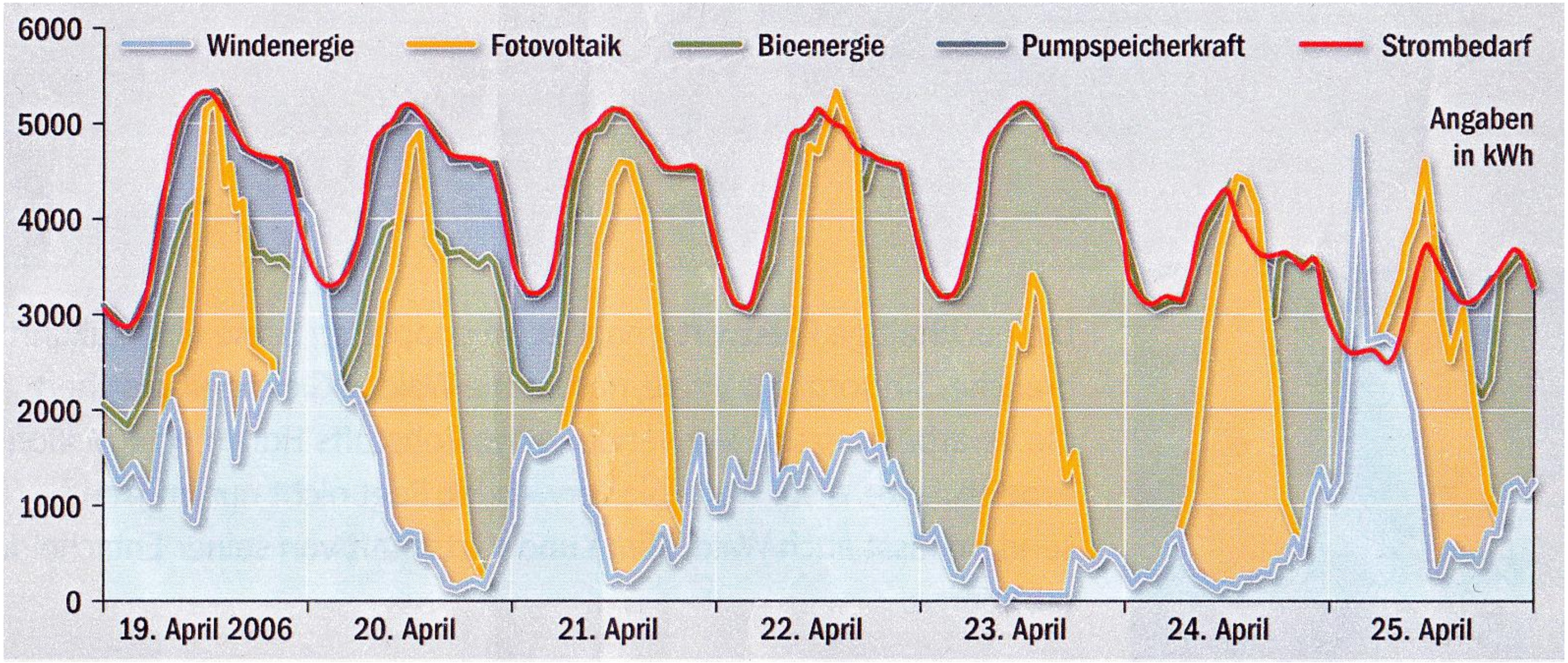
- • • • • Engineers → Decision Makers
  + Climate engineer
  + Roof / Façade planner
- • • • Architect
- • • Investor
- • Owner
- Approval entities (municipalities)
- Further public entities being part of permitting process (environmental authorities – EIA)

Energy Concept - Example




Offshore-Windpark
Solarfarmen
Übertragungs- und
Verteilnetze
Intelligente Gebäude
Rechenzentrum
Fossile Kraftwerke
Intelligente Knoten
Smart Homes
Kraft-Wärme-Kopplung
Datennetz
Energienetz

Vision of safe supply with combined renewables



Source: Focus 39/2007

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Lessons learned – The best project approach

Regulations

- Policy maker view:
  Policies can hinder, promote, heat up and even overheat a market ("Gold Digging")
- Grid parity in most markets reached: It drives self-consumption concepts.
  → feed-in tariffs become less important
- Developer view: Early check of national laws and regulations
  → tariffs, grid code, building code
- Assess land use plan for the neighbourhood
  → future shadings?

Lessons learned – The best project approach

PV technology

- Yield and losses? Orientation to sun?
  → Possible shadings on modules to be assessed
  → South orientation gets less important – in residential projects East/West is appropriate
- Mounting on a roofing systems is critical
  → wind, dead and snow loads?
  → free reserves for PV installation?
- Sealing systems condition to be thoroughly assessed:
  → refurbish a roof before installing PV?
  → how is long-term integrity of sealing in conjunction with PV installation
- OPEX and O&M
  → targeting long-lasting quality of 30+ years

Lessons learned – The best planning approach

Planning / construction

- The function of the building?
  → Its energy demand and expected load profile depend from it.

- How efficient / eco-friendly is the building?
  → Is it a new construction or is it a refurbishment project?

- Passive building systems to be preferred:
  → if passive measure taken, then active systems to be used
  → mostly cheaper than active systems such as PV, chillers, pumps, storage systems

- Early integrative planning approaches and energy concepts are crucial for technical & economical benefits.

Lessons learned

→ Maximizing profit (ROI) as a sole objective becomes less important!

→ Integrative energy concepts are very important!

Trend in all market segments:

- Residential → "plus energy homes" / smart homes
- Commercial → shopping malls, factories
- Utility-scale → grid integration, smart grids

Key words are: Storage, Self-Consumption, Green-Building, Low Impact – High Comfort, etc.

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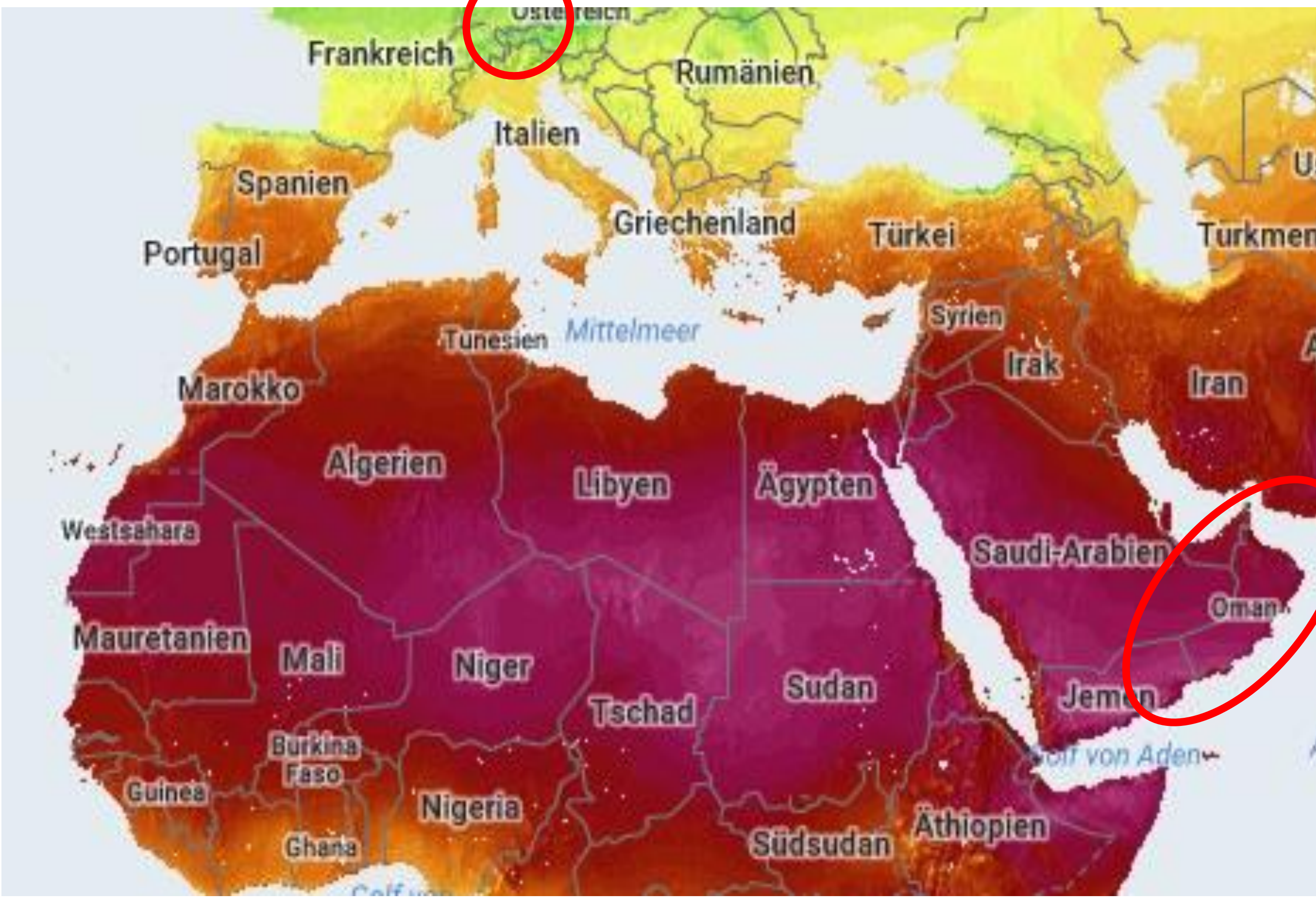
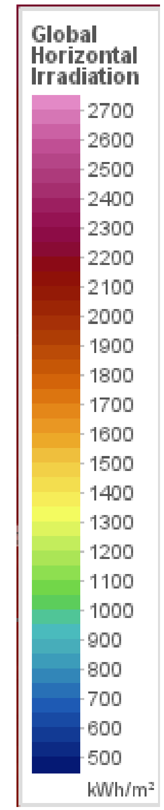
Potential key drivers for rooftop PV in Oman

Solar Irradiation in Oman





Source: SolarGIS

Solar irradiation GHI

2200 - 2600 kWh/m²

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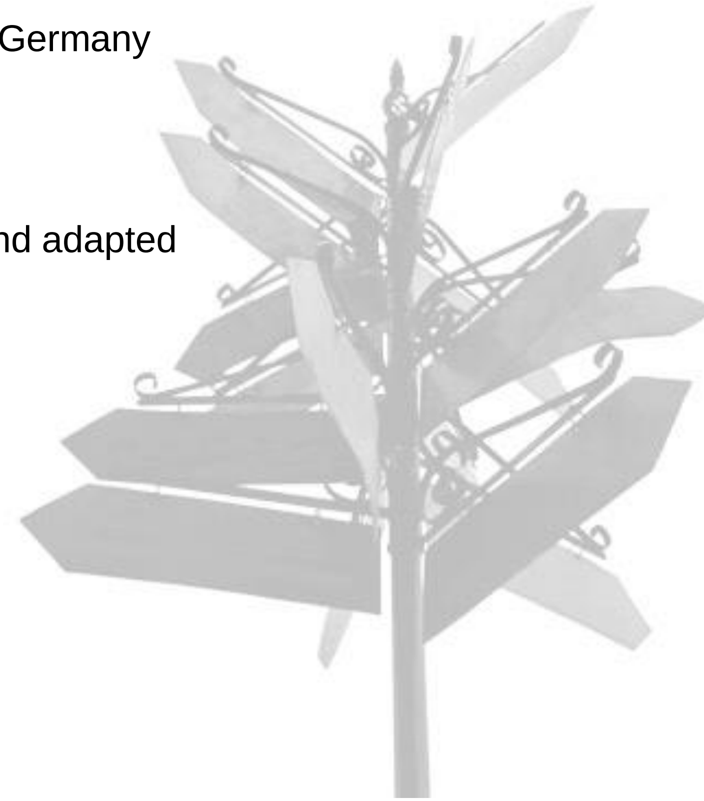
Potential key drivers for rooftop PV in Oman

Solar Resources

- Double the solar irradiance figures as in central Europe/Germany

Regulations

- Long experience in other markets, which can be used and adapted
  → simple and stable policies to create confidence
- Grid parity easily reached
  → self consumption concepts are at reach



PV technology

- Technology is easily available
- BOS cost still decreasing
- Proven technology with 30+ years of experience

Maturity of market

→ To be discussed with all of you during the two days.

Apple is inaugurating these days its new central...

Thank you very much for your attention!

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Backup Slides

PV projects – Development guideline

Fichtner prepared a PV development guideline for IRENA. The report can be used by developers to minimize the risks during the single steps of project development. It can be downloaded under:

https://navigator.irena.org/inside/pn/learn/SiteAssets/IRENA_Project_Navigator_TCG_Utility-Scale_Solar_Photovoltaic_web.pdf

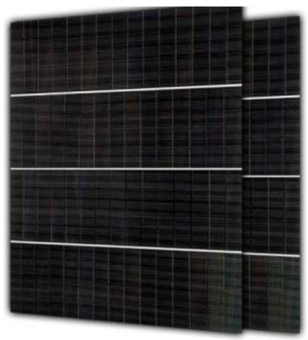
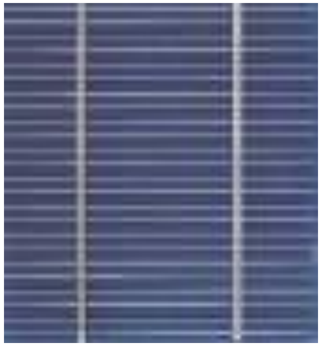
Photovoltaic

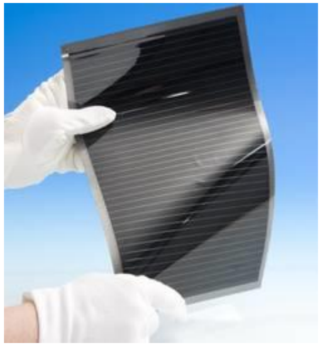
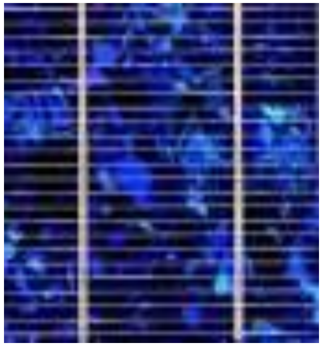
Types of solar cells - Overview

There are basically two different technologies to manufacture PV solar cells:

- Wafer based crystalline silicon solar cells (represent the bulk of the market)
  - Mono-crystalline cells
  - Poly-crystalline cells

- Thin-film technology
  - Different materials and deposition processes

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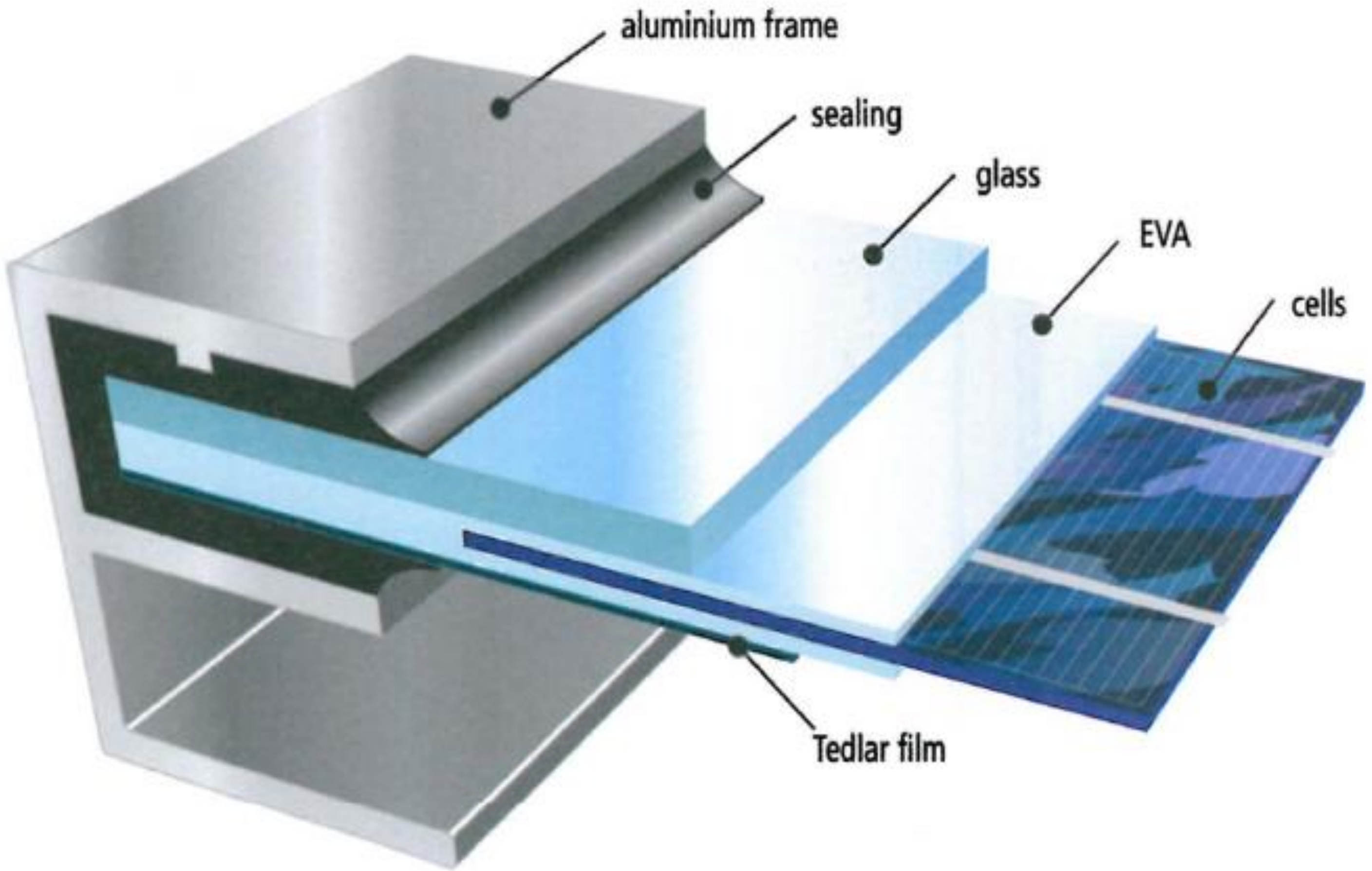
Photovoltaic

Types of solar cells - Efficiencies

Type	Cell efficiency, laboratory	Module efficiency, market
Mono-crystalline Si	25.6 %	15 – 22 %
Multi-crystalline Si	21.3 %	15 – 17.5 %
a-Si/c-Si (HIT[1])	25.6 %	Up to 19.5%
CdTe	22.1%	Up to 16.4%
CIGS	22.3%	Up to 13.8%

Photovoltaic

Types of solar cells - Cross section of crystalline solar cells



EVA = Etyhlen-Venyl-Acetat encapsulation

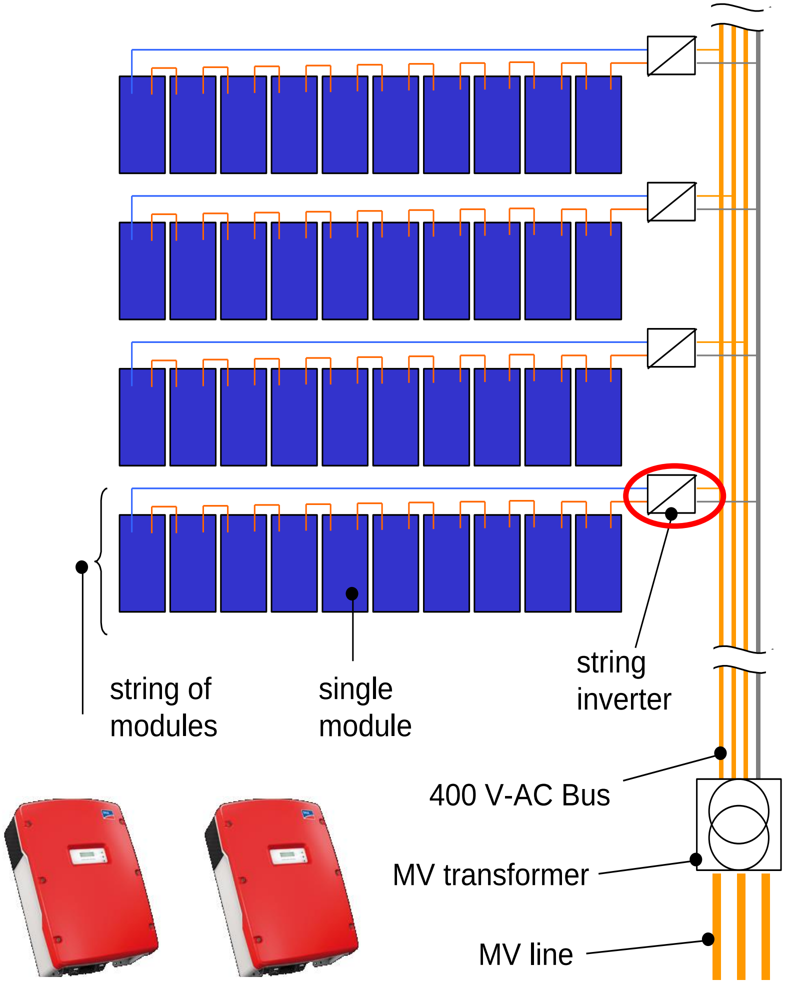
Photovoltaic

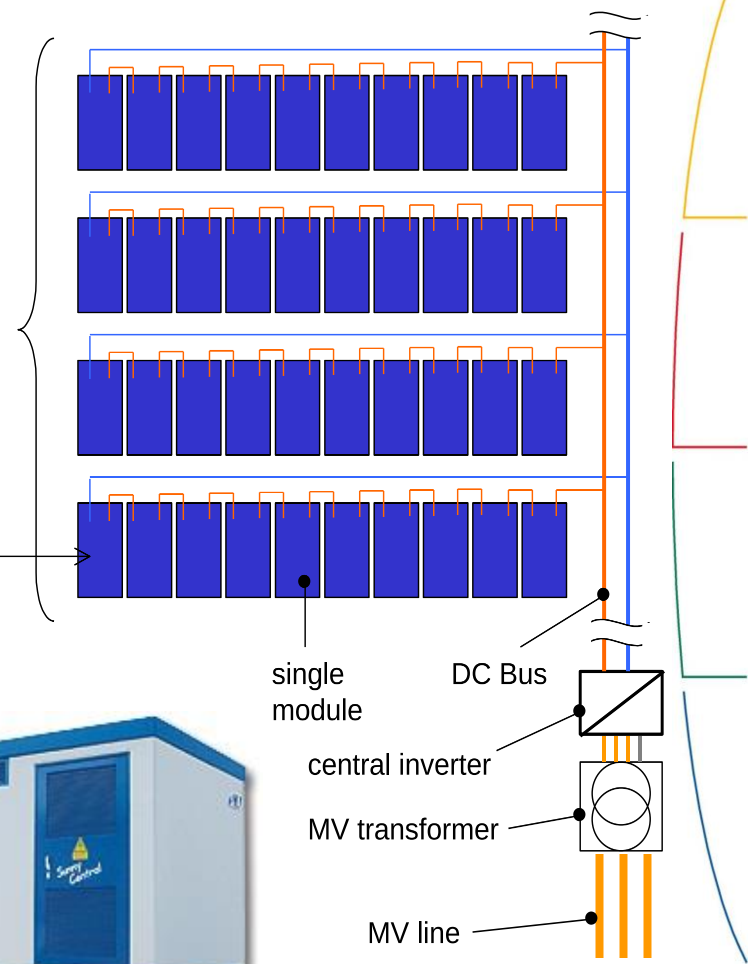
- Inverter Concepts
  - Conversion of direct-current (DC) to alternating current (AC)
  - Maximum efficiency up to more than 98%
  - Central Inverters
    - Large, utility scale (up to 1-5 MW)
    - Increased efficiency and lower inverter costs
  - String Inverters
    - Usually applied in lower to mid power range
    - 15 kW up to 1 MW
    - Higher modularity, system outage less probal
  - inverters should provide
    - monitoring
    - control and
    - protection functions

Source: SMA

Photovoltaic

Inverter Concepts: string vs. central inverter





Source: SMA