Solar Energy Systems

Solutions on global and local level

Dipl.Ing. Arnulf Dinkel

Fraunhofer Institute for
Solar Energy Systems ISE

2011 International Workshop - Noordwijk, The Netherlands
Global Collaboration in Environmental and Alternative Energy Strategies

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Fraunhofer ISE

Who we are

Fraunhofer Establishments worldwide

- Leading organization for applied research in Europe
- 59 research institutes at different locations throughout Germany
- 17,000 employees, the majority of whom are qualified scientists and engineers
- Annual research budget of more than 1.6 billion euros
- 2/3 of the research contracts are from industry and public funds
- International cooperation is supported through affiliate institutes in Europe, USA, Asia and the Middle East

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Who we are

Fraunhofer Institute for Solar Energy Systems ISE

Largest European Solar Energy Institute
Freiburg, Germany
Director: Prof. Eicke R. Weber

Established 1981
Staff: ~1300 (incl. students)

Budget: €55 million
15% basic financing
85% contract research
>10% p.a. growth rate

30th anniversary 2011

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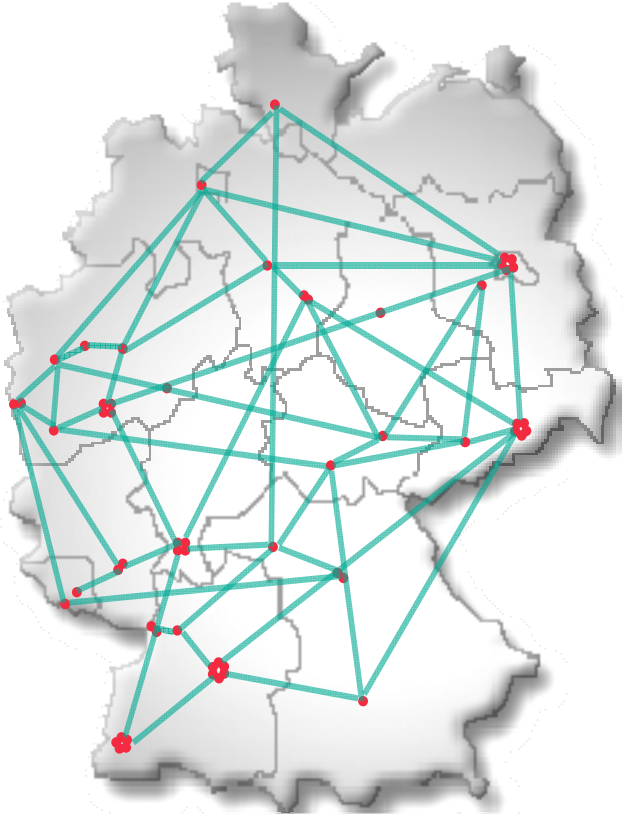
Memberships within the Fraunhofer Gesellschaft

- Fraunhofer Energy Alliance
  (Member-in-Charge, Administrative Office)
- Fraunhofer Building Innovation Alliance
- Fraunhofer Nanotechnology Alliance
- Fraunhofer Optic Surfaces Alliance
- Fraunhofer Photocatalysis Alliance
- Fraunhofer Water Systems Alliance, SysWater
- Fraunhofer Group for Materials and Components - MATERIALS



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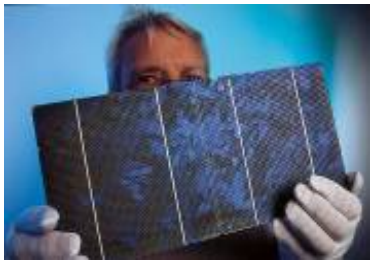
Approach

Research, Development and Services at Fraunhofer ISE

Research
Materials
Modelling
Methods



Development
Components,
Prototypes,
Systems, Procedures

Services
Consulting, Tests
Monitoring
Quality Assurance

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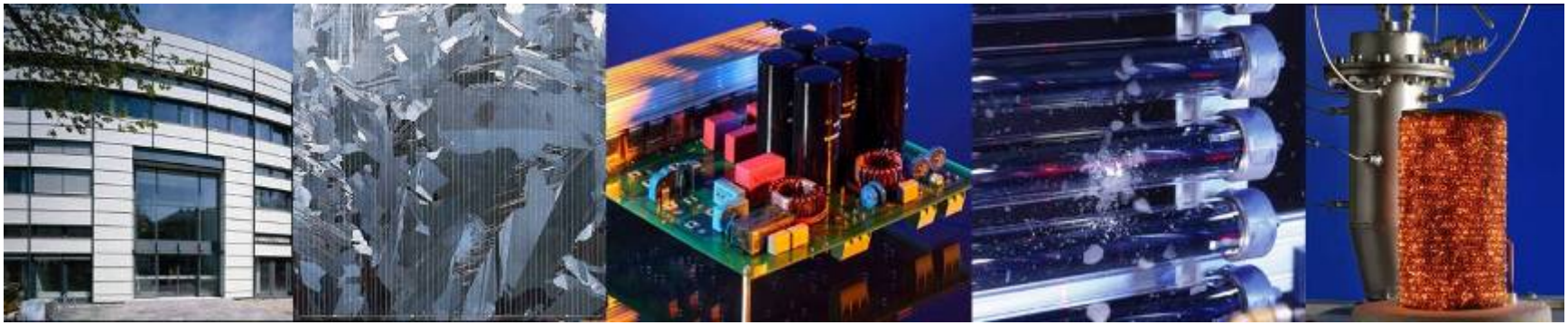
The range

Areas of Business at Fraunhofer ISE

- Energy Efficient Buildings and Technical Building Components
- Applied Optics and Functional Surfaces
- Solar Thermal Technology
- Silicon Photovoltaics
- Alternative Photovoltaic Technologies
- Renewable Power Supply
- Hydrogen Technology



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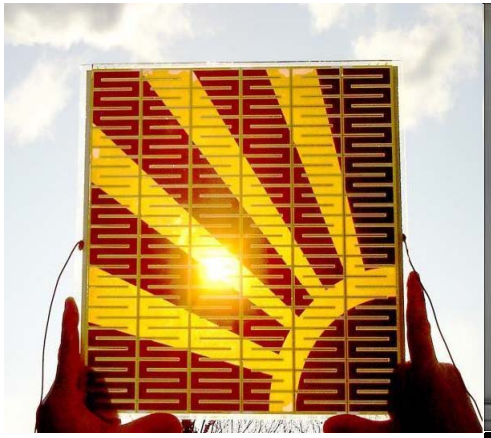
Hydrogen Generation by Solar Energy and Filling Station, e-mobility



Fuel Cell Systems

We will start 2012

Filling station

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Solar Membrane Distillation Systems

- Manufacturing procedure developed at Fraunhofer ISE
- Since 2005, successful long-term operation of compact system (150 l/day) in Morocco, Jordan, Grand Canary and Fraunhofer ISE.
- Since 2006, two-loop system (1000 l/day) in Jordan and Grand Canary

Compact system

Two-loop system with 5 desalination modules, Grand Canary

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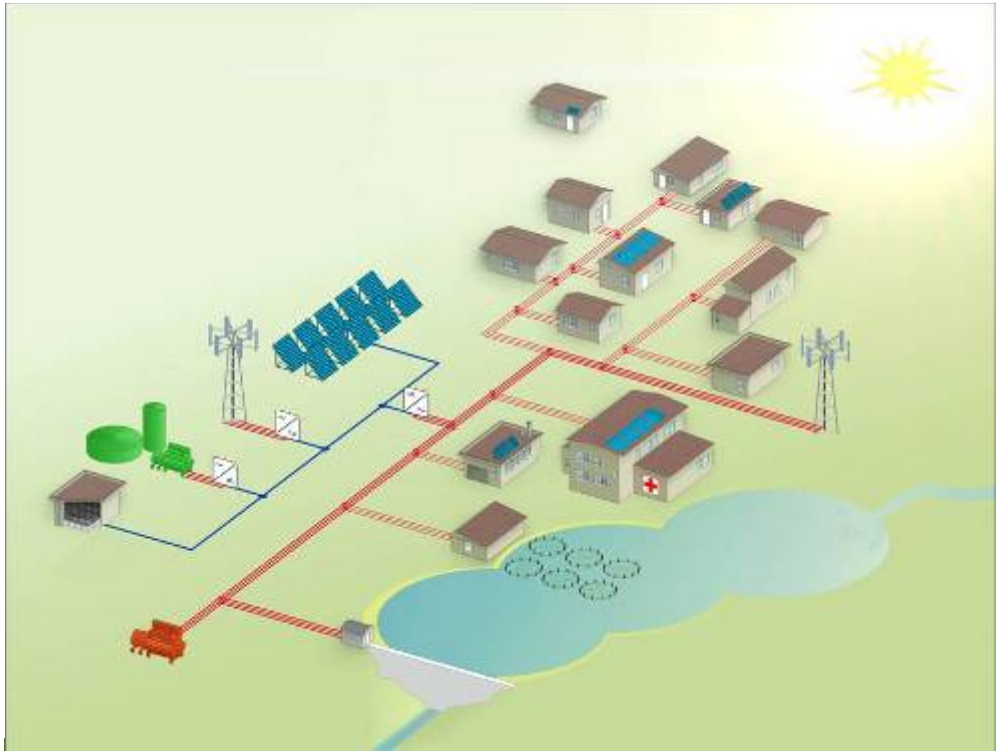
Next Generation of Hybrid PV Mini-Grids

- Integration of different energy sources (PV, wind, hydro, etc.)

  ➡ Least cost option
- Improve quality of energy services
- Promote local infrastructure and economic development
- Complement national electricity network / grid



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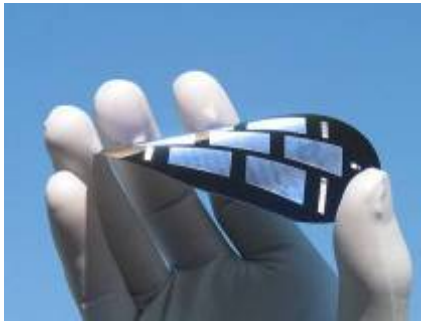
research on whole supply chain

Feedstock

Wafer

Cell



Module

Production

System

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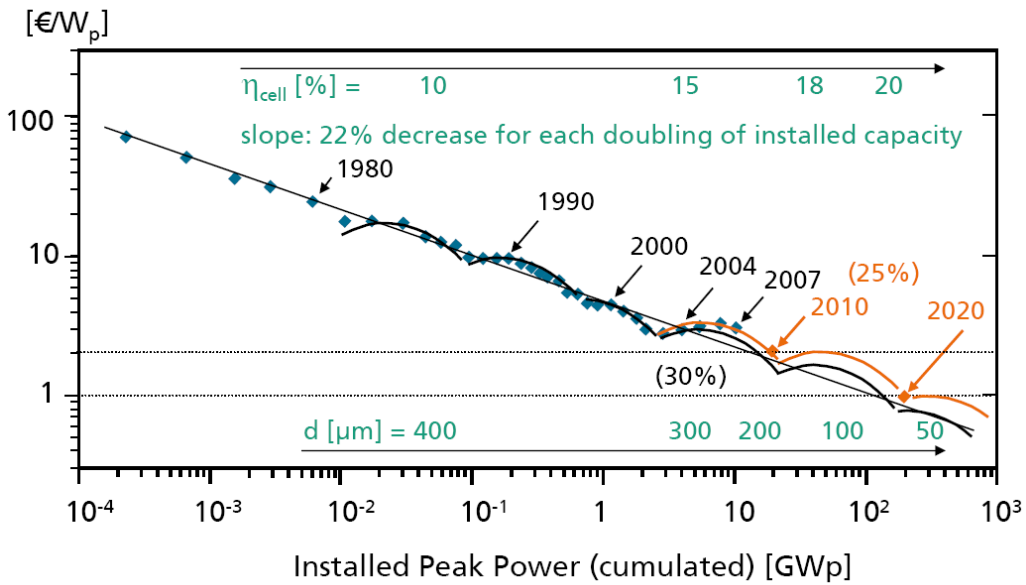
Price learn-curve of crystalline Si PV-modules



Preistrends Oktober 2011

Modultyp, Herkunft	€ / Wp	Trend seit 09/11	Trend seit 01/11
Kristallin Deutschland	1,29	- 3,0 %	- 24,5 %
Kristallin China	0,92	- 6,2 %	- 37,6 %
Kristallin Japan	1,22	- 3,7 %	- 25,3 %
Dünnschicht CdS/CdTe	0,84	- 8,8 %	- 32,8 %
Dünnschicht a-Si	0,74	- 4,5 %	- 31,6 %
Dünnschicht a-Si/µ-Si	0,89	- 3,9 %	- 29,2 %

Prices go down faster as forseen !

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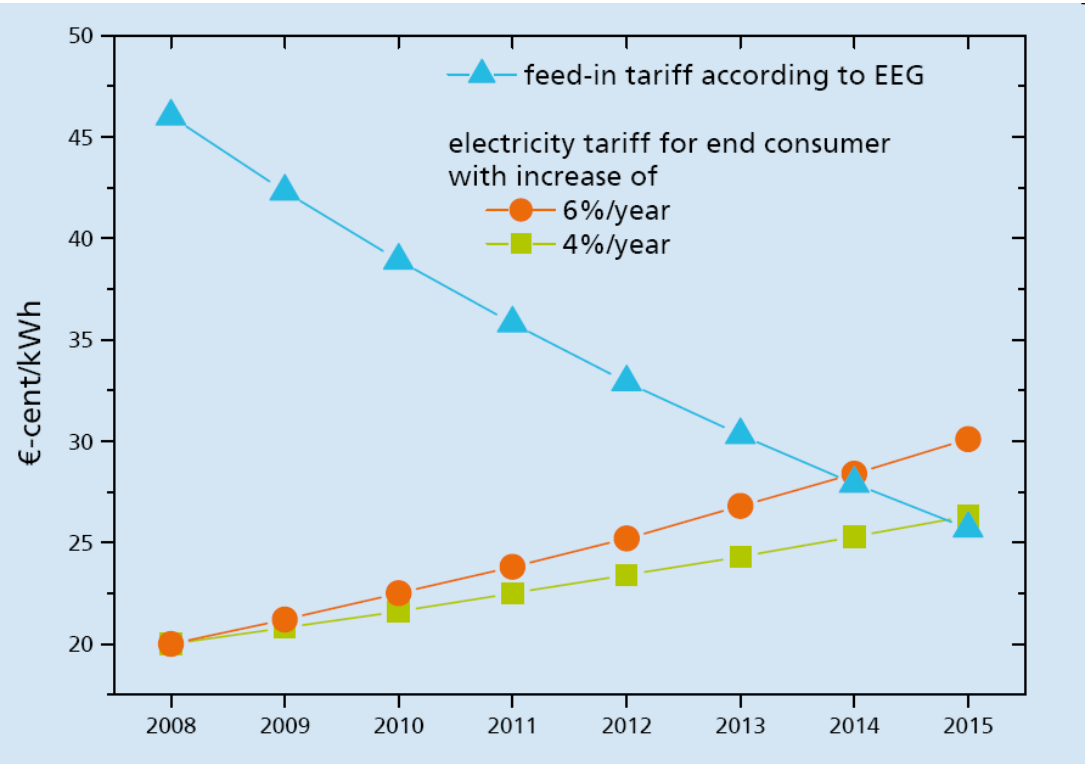
Path to Grid Parity in Germany



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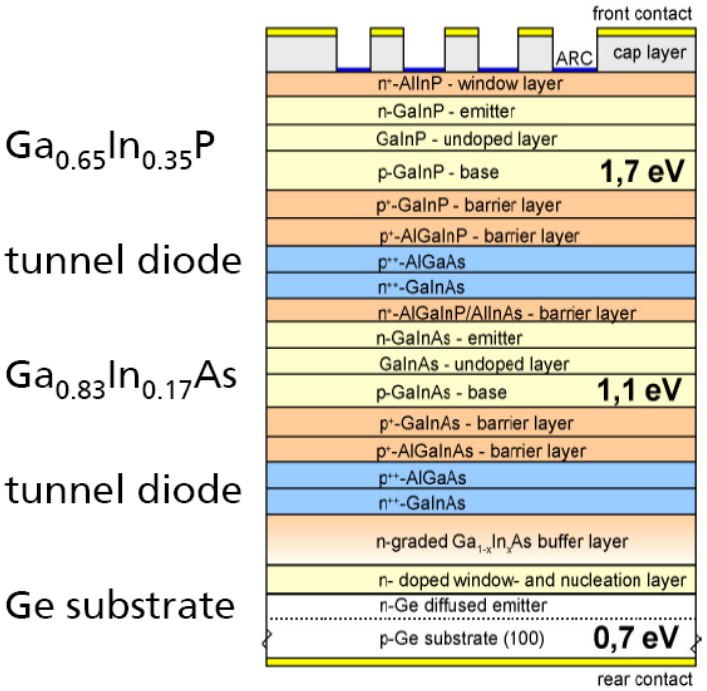
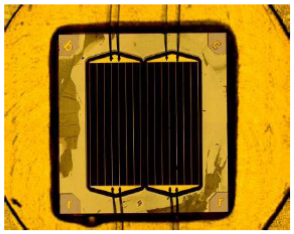
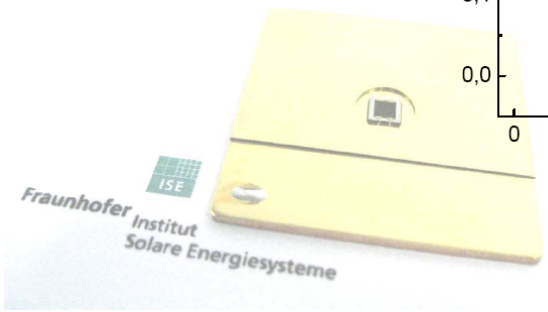
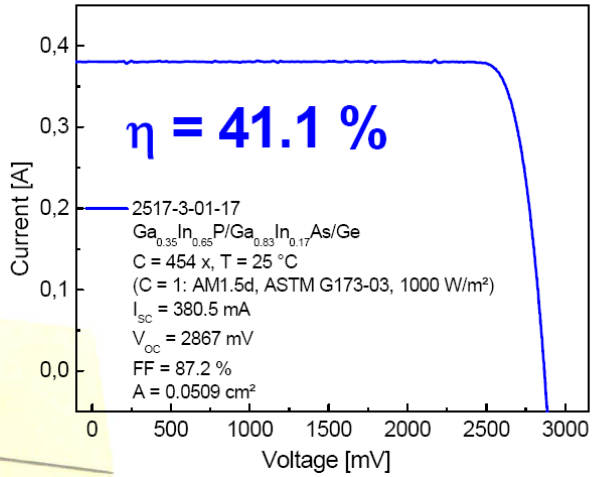
World record metamorphic triple-junction solar cell









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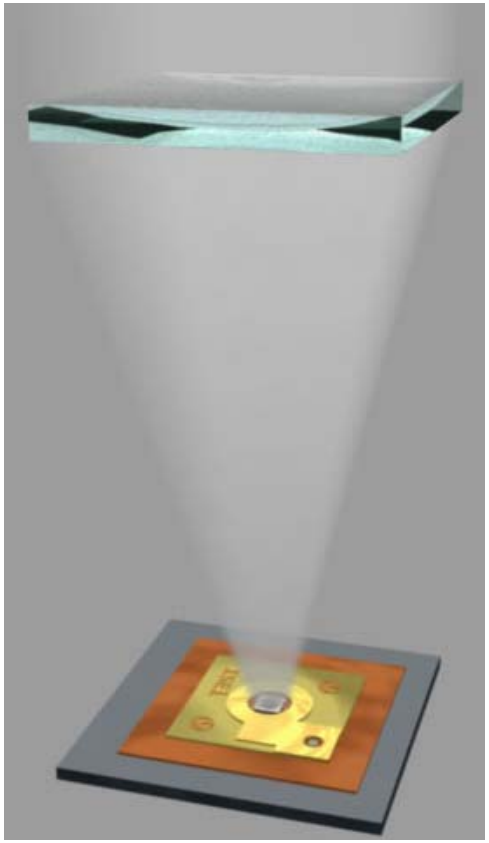
III-V Solar Cells, CPV technology

Concentrix solar



FLATCON™ Module

Fresnel Lens All-Glass
Tandem Cell Concentrator

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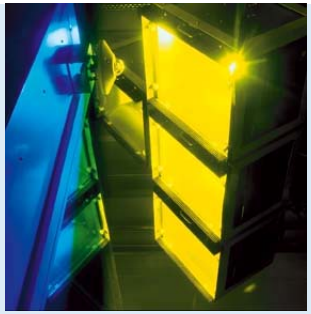
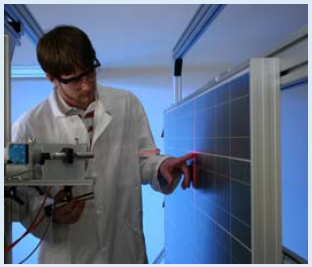
Accredited Test Laboratories and Service Centers

TestLab
Solar Façades

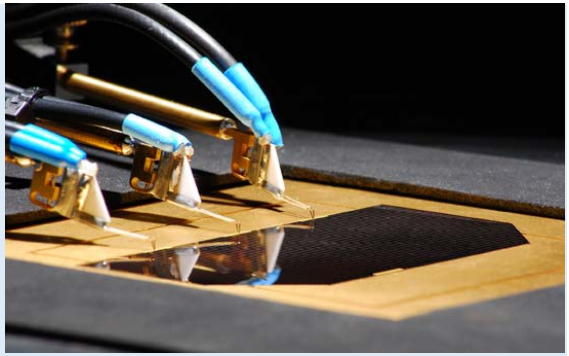


TestLab
PV Modules



TestLab
Solar Thermal
Systems

CalLab
PV Cells



CalLab
PV Modules

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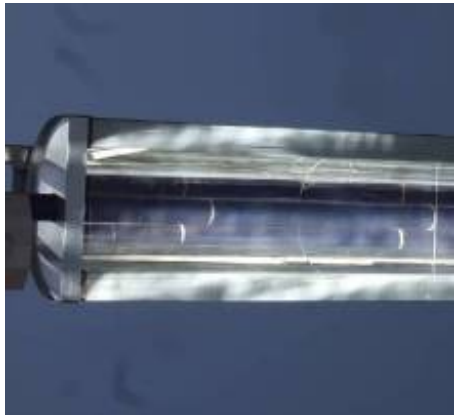
Concentrated Solar Thermal Power – Fresnel concept

- Optimizing Fresnel design
- Coating secondary concentrating mirror
- Optical quality assurance
- Measurement and Analysis
- Partners:
  MAN Ferrostaal,
  Solar Power Group,
  DLR, PSE

Solar thermal demonstration plant in Almería, Spain



Absorber tube with selective coatings developed at Fraunhofer ISE

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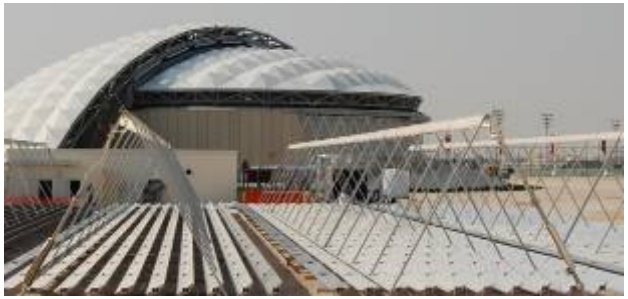
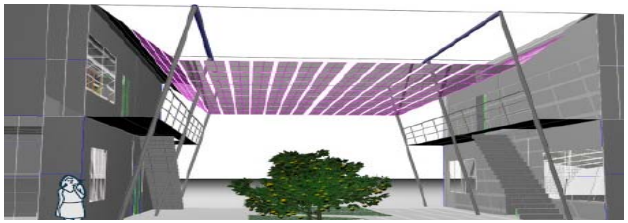
Solar Heat for Industry

- **Applications**
  - Process Heat
  - Direct Steam Generation
  - Refrigeration / Air-conditioning
  - Medium Sized Power Plants
  - Solar Polygeneration
- **Advantages of Fresnel technology**
  - Low wind load
  - Good weight-spread
  - High ground usage factor
  - Precise temperature control
  - Direct steam as sunlight hits absorber tube from below
  - Low O&M



700 kW Solar Cooling with double-effect Absorption Chiller of a Stadium in Qatar

Roof Top Installation References in Italy and Spain



Design-Study Building Integrated Fresnel Collector

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Cities and Building Systems and Façades

Building Systems

- Building Systems analysis and optimization
- Building and User Behaviour
- **Monitoring** of systems

Innovative, transparent façades

- **Solar protection** systems
- Façade concepts
- **Energy generation**
- **TestLab** Solar Facades

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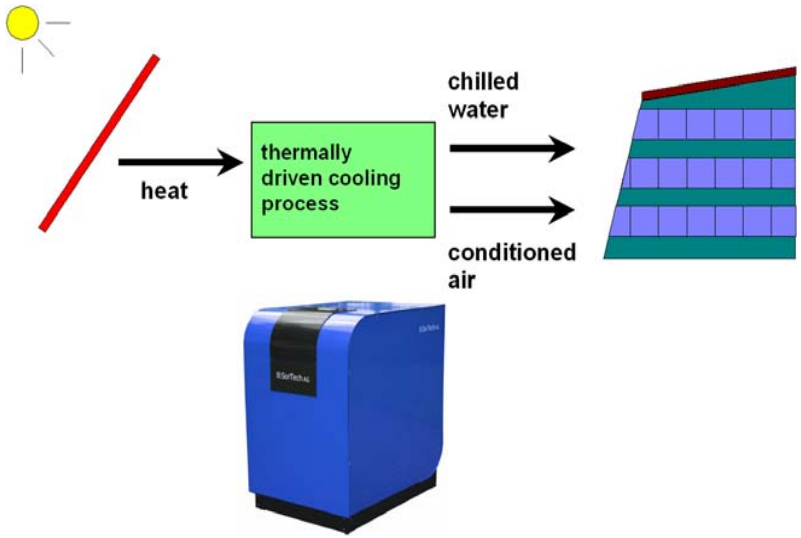
Solar Cooling



Basic systems categories

- Closed cycles (chillers): chilled water
- Open sorption cycles: direct treatment of fresh air (temperature, humidity)

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Smart Energy Lab

- **Real** simulation of thermal and electrical energy flows in buildings
- **Platform** for the analysis, evaluation and development of smart homes and smart grid solutions in the distribution grid
- **Features**: cogeneration, heat storage, PV simulator, PV inverter, island inverter, electrical storage, charging infrastructures for electric vehicles, modern ICT

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Competences in the range of e-mobility

- Renewable energies, energy **concepts and scenarios**
- Energy management of local/mobile consumers
- **Metering**, billing and **communication** solutions
- **Charging stations**
- **Battery** systems techniques
- **Fuel cell** techniques
- **Power electronics**

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More about
Cities, Building Systems and Façades

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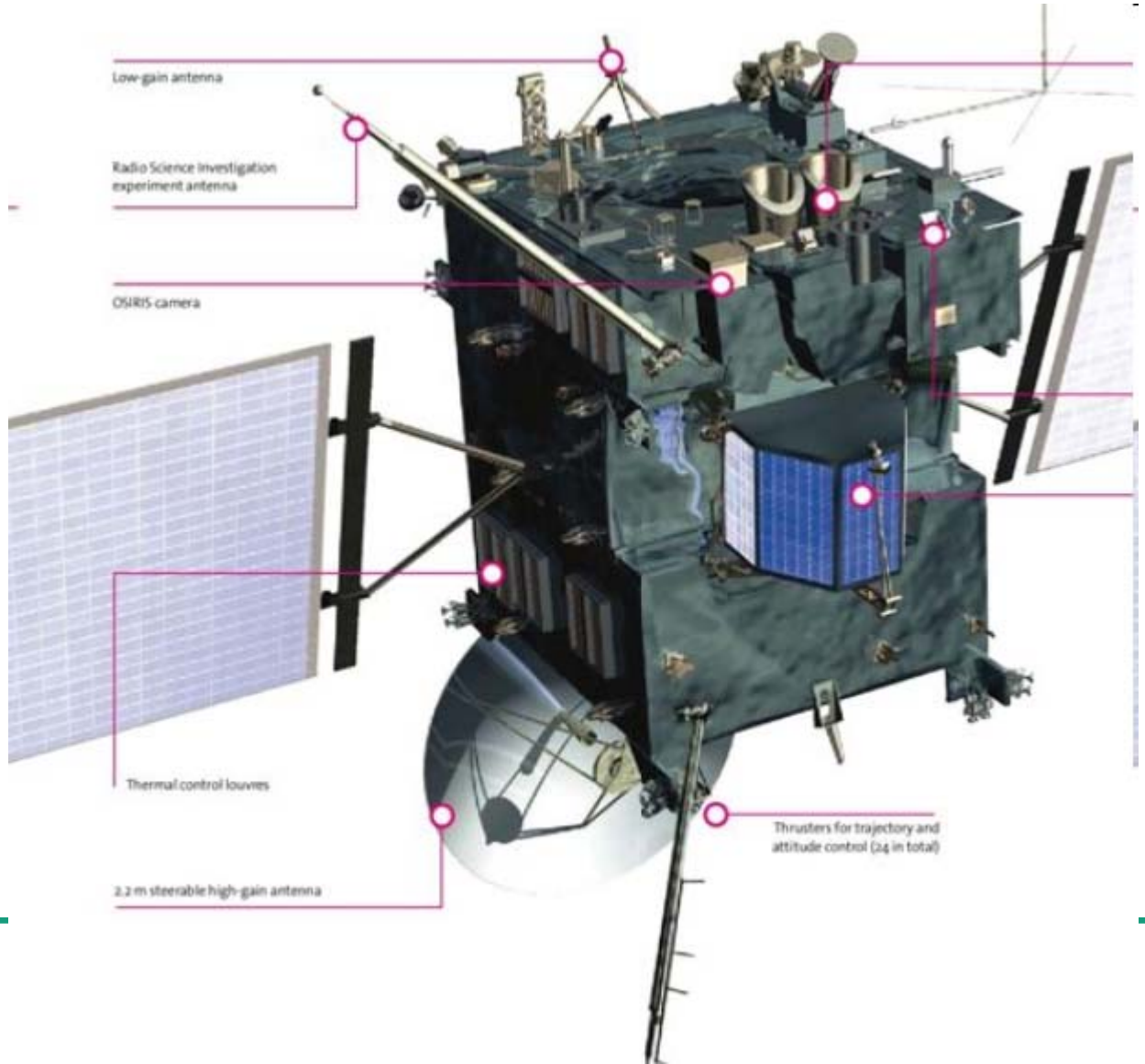
we would like to do this:
- intelligent, efficient, managing extreme conditions



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Or this – smart buildings

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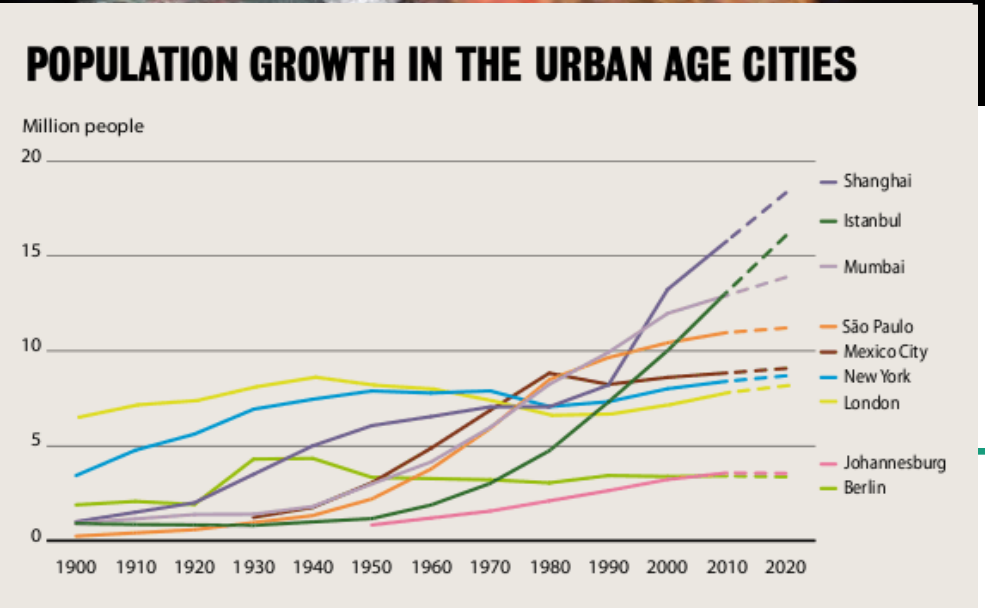
Why buildings and cities ?



- Buildings have a very big carbon footprint
- Cities are growing fast

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Climate Change everywhere! e.g. Middle East

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Or this –

But is it Sustainable ?

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The Building Systems

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Why are Façades important?

Important part of Energy System
New starting point in Europe since 2009

- buildings are responsible for 40% of the CO_2-Emissions in EU
- ➡ higher energy efficiency more renewable energy!
- Net-Zero-Energy buildings as goal (Europe).
- Generate energy, where you need it
- First roof, second façade.
- Energy generation in façades is absolutely necessary in bigger buildings.

Building integrated PV

© Fraunhofer ISE

Façade Type: Passive - Active

- passive solar façades
  - movable solar control & glare protection systems
  - façades for high wintry solar gains
  - switchable glazing
  - nano- and microstructured surfaces
- active solar facades
  - BIPV (Building Integrated Photo-Voltaics)
  - solar thermal façade collectors

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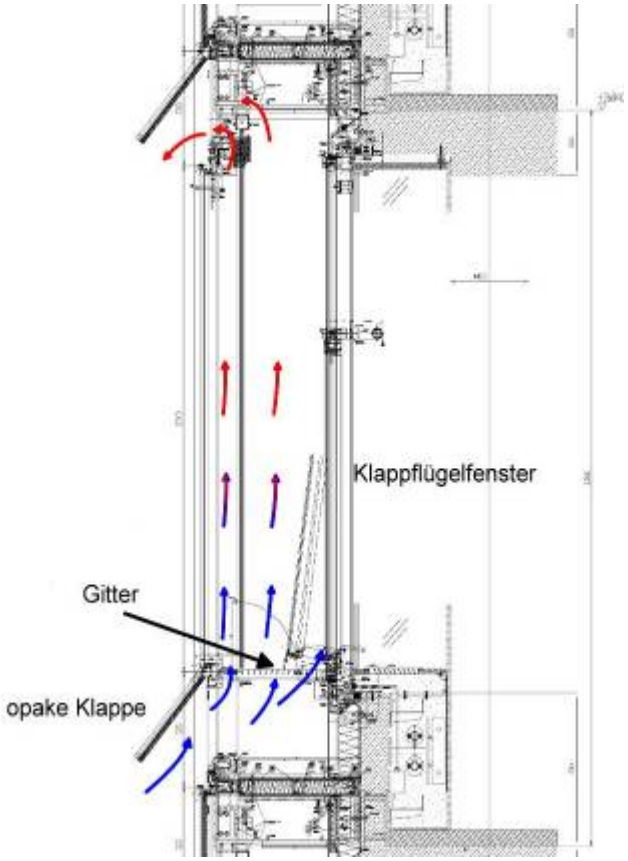
Aeration: Natural air – no air condition

Example: New building of the Fraunhofer headquarters



by order of: Fraunhofer Society

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Energy Generation: Thermal energy/hot air

thermal solar/air collector

1. low-e Absorber Coating
2. piping (transfer of heat to storage or heat pump
3. Air inlet and ventilator
4. Air-heat exchanger at the back surface of the collector

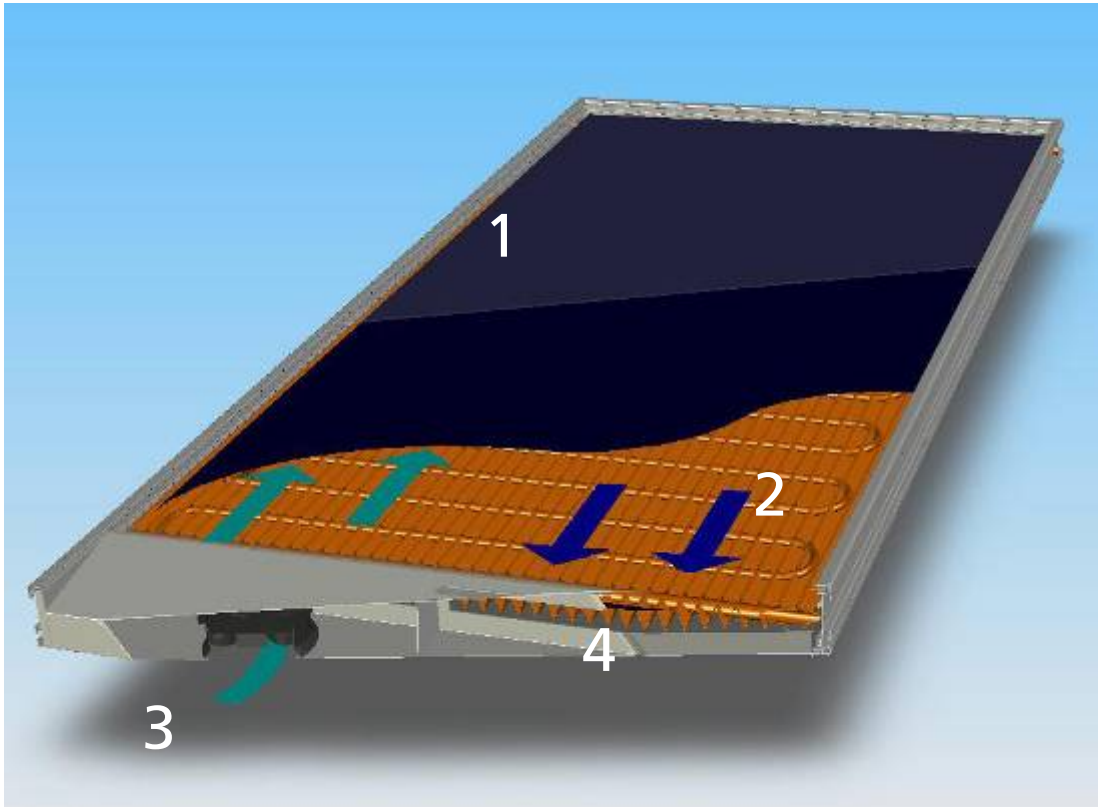

image of Solaera collector © Consolar

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Energy Generation: Thermal energy/hot air

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Shading: Solar Protection

Development of Glazing with seasonal shading & PCM (phase change material)

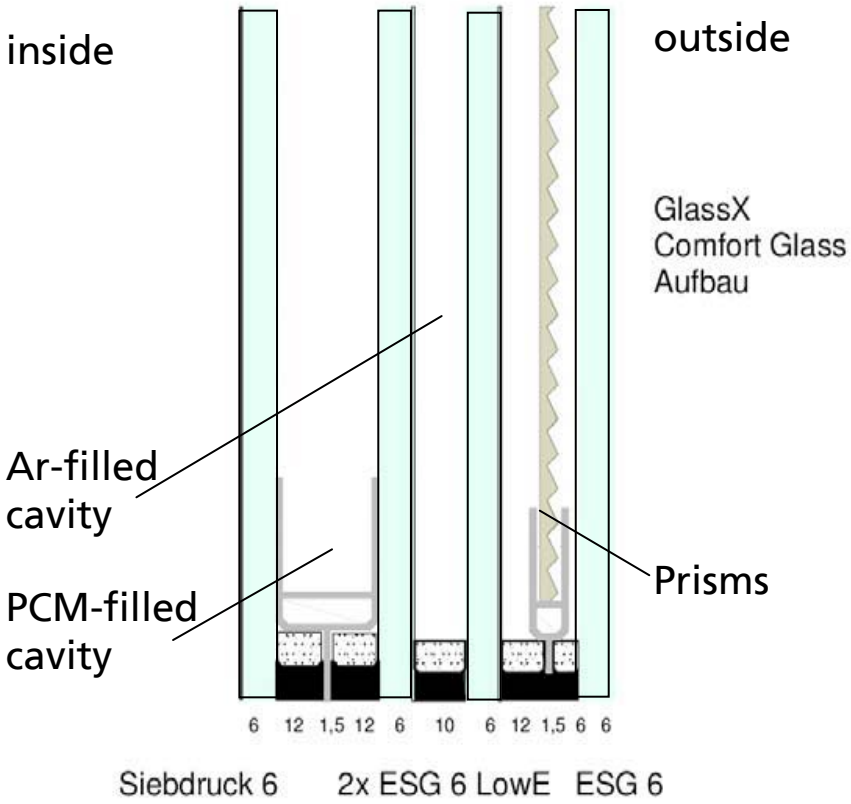
Picture: GlassX, Switzerland

© Fraunhofer ISE

Shading: Solar Protection

Development of Glazing with seasonal shading & PCM (phase change material)

- Transparent prisms provide seasonal shading
- PCM limits peak temperature in summer and allows solar heating in winter



Picture: GlassX, Switzerland

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Shading : Solar Protection

Stainless steel blind s_enn®

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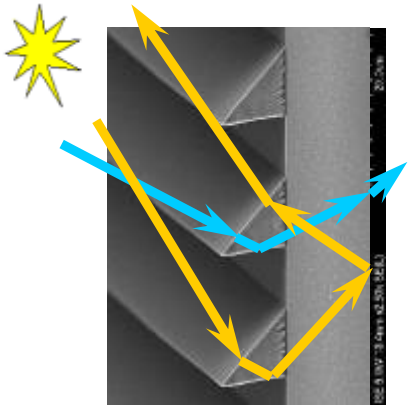
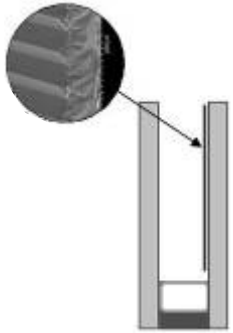
Shading: Solar Protection
Microstructures for solar control and daylight redirection

Microstructured elements integrated in windows and façade systems

- Vertical glazing
- Tilted / roof glazing
- Lamellar systems





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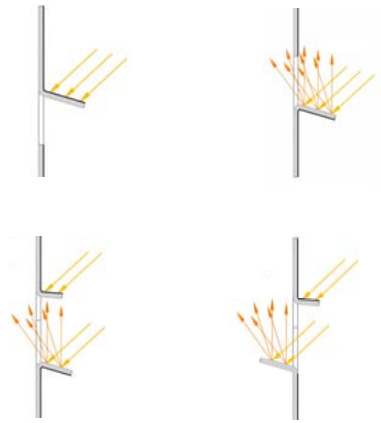
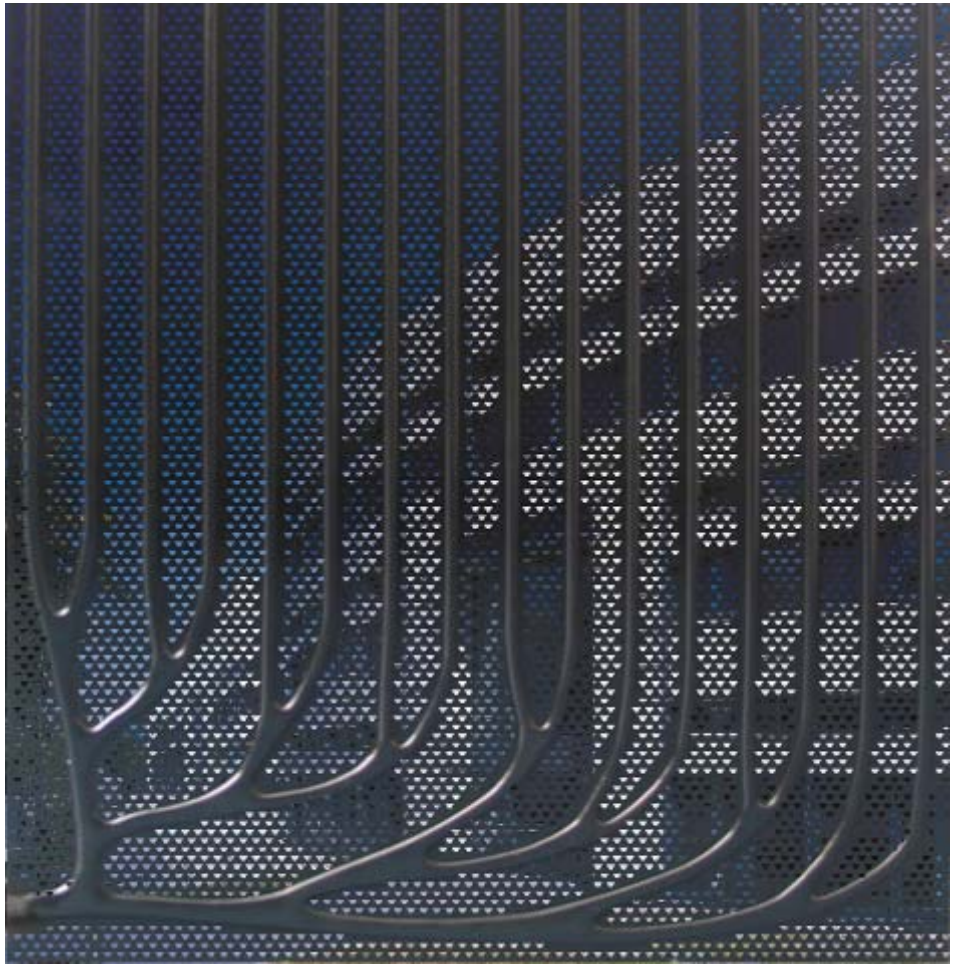
Energy Generation+shading: Thermal energy/hot water

Transparent Solar Thermal Façade Collector (Colombra®)



Multifunctionality

- solar thermal energy
- visual contact
- solar control
- glare control
- daylighting



Virtual image of transparent solar thermal collector
© Fraunhofer ISE

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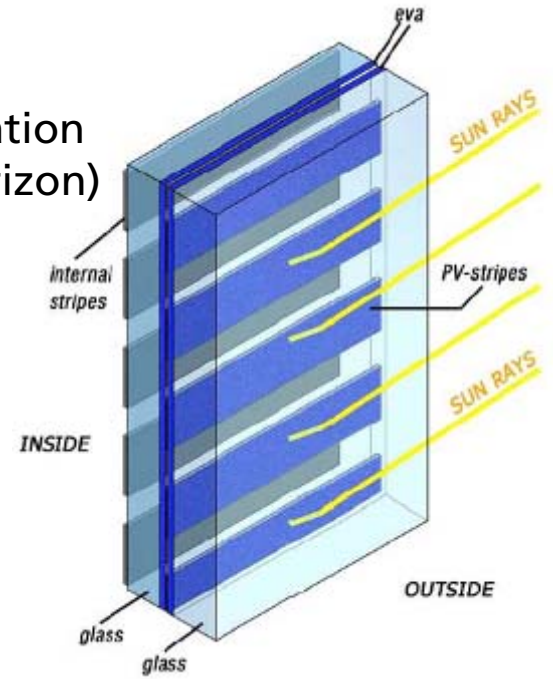
Energy Generation: PV-electricity

Multifunctional BIPV glazing

- **solar electricity**
  (high effieniency for irradiation coming from above the horizon)
- **visual contact**
  (horizontal or downwards)
- **solar control**
  (g-value g < 0.10)
- **glare control**
  (Daylight Glare Probability DGP < 0.30)



Visual mock-up for new BIPV component
Photos © Fraunhofer ISE

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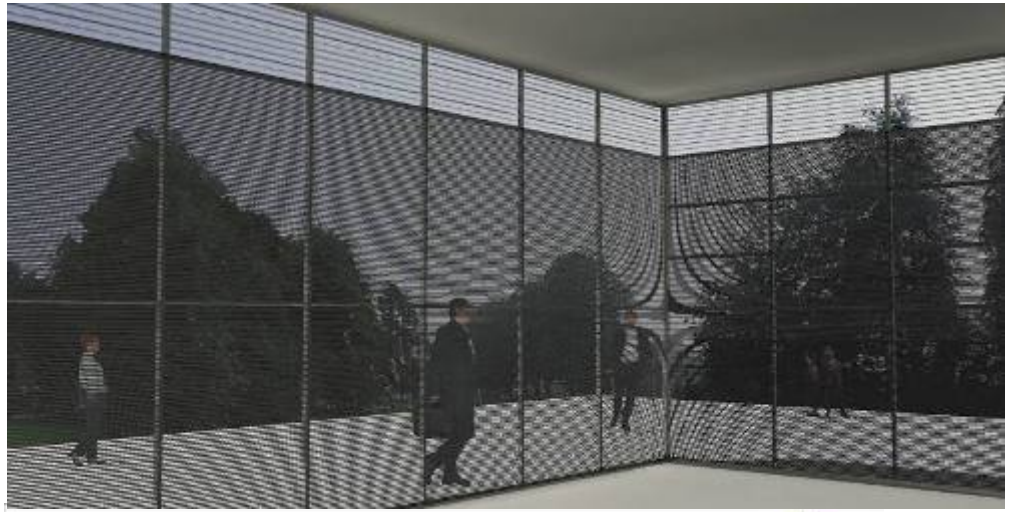
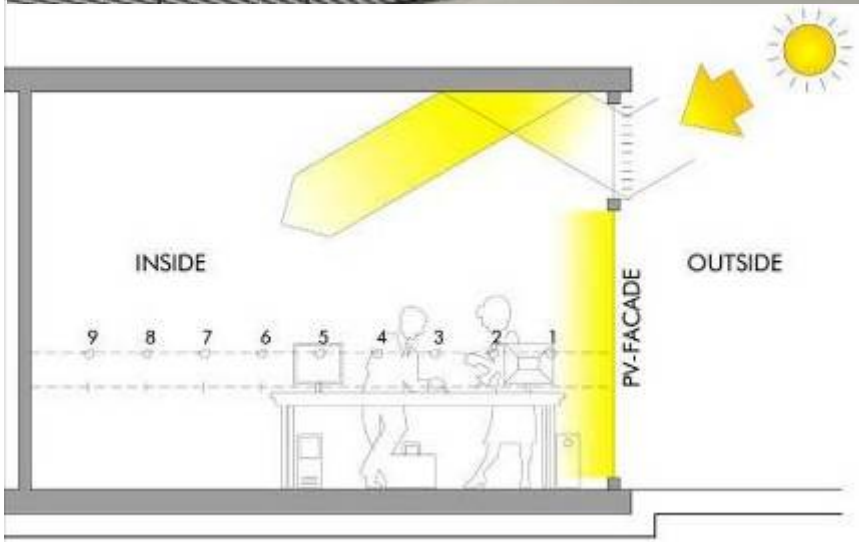
Energy Generation: PV-electricity

Multifunctional BIPV glazing

- **Example for installation**
  the new device is especially useful for large open spaces





virtual images *© Fraunhofer ISE*

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New Office: passive + active systems

- better than energy code

- Approved under realistic conditions. Reliability during planning phase and operation
- Optimal daylight use - no dark glasses

Prime Tower, Zürich, Switzerland

FrankfurtHochVier, Frankfurt, Germany

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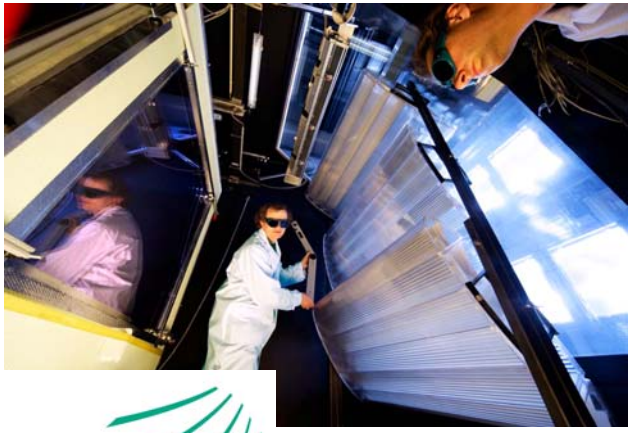
We test and approve new systems in our TestLab

- g-value (solar factor)
- U-value
- Transmittance
- Reflectance
- User response and daylight glare



TestLab
Solar Façades

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Research and partnership

Torre de Cristal Madrid
Source: Emmer Pfenninger Partner

EU-Project "cost-effective":
Converting facades of existing high-rise buildings into energy gaining components

www.cost-effective-renewables.eu

The whole building

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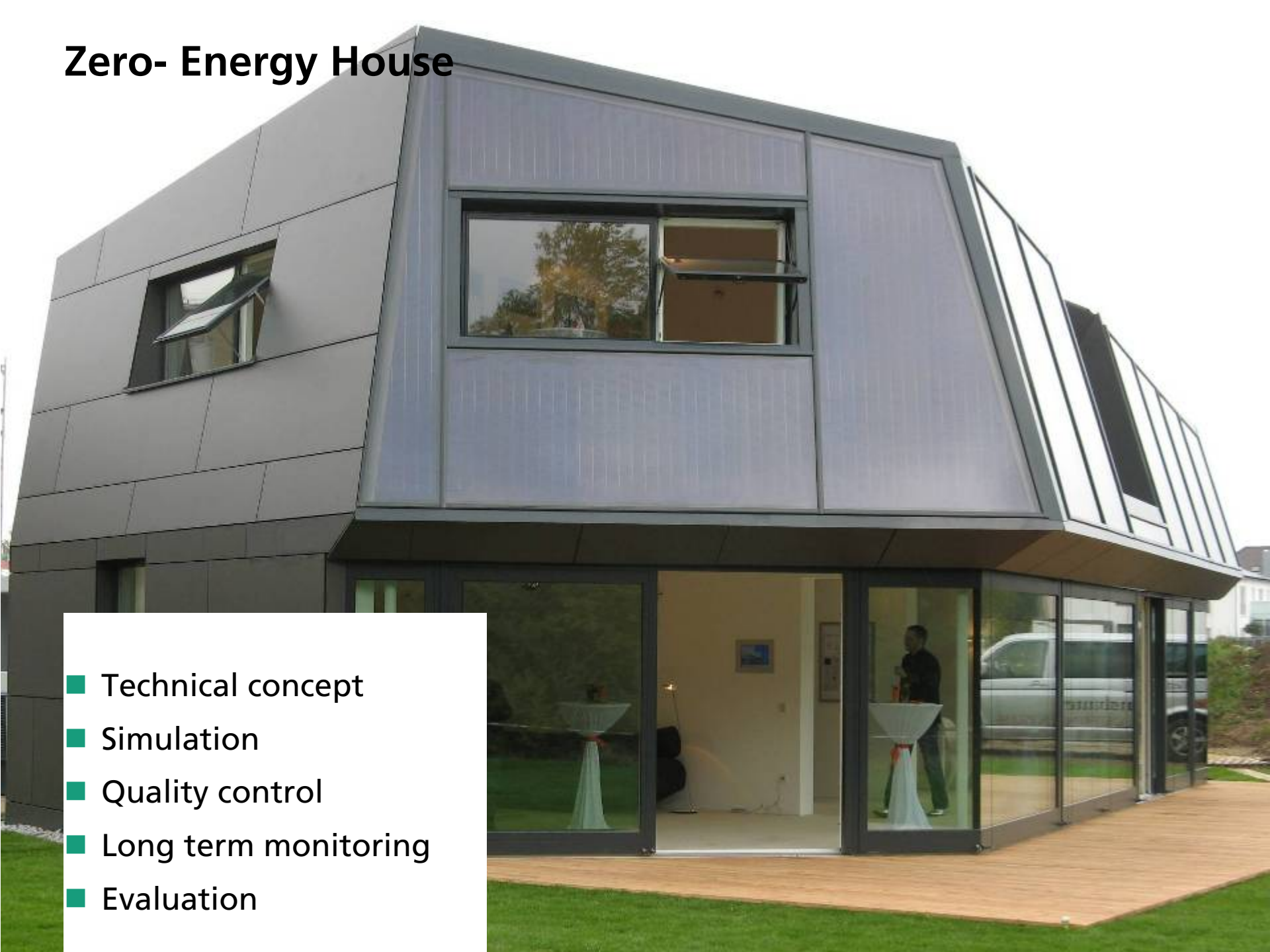
Single Family House: passive + active systems
Zero- Energy House

Form follows function & energy

Sonnenkraft, Germany

Zero- Energy House



- Technical concept
- Simulation
- Quality control
- Long term monitoring
- Evaluation

Zero- Energy Building Seoul, South Korea

- Exhibition
- Education
- Office
- 4000 m²

- Lead of engineers consortium
- Technical concept
- Simulation
- Quality control
- Long term monitoring
- Evaluation

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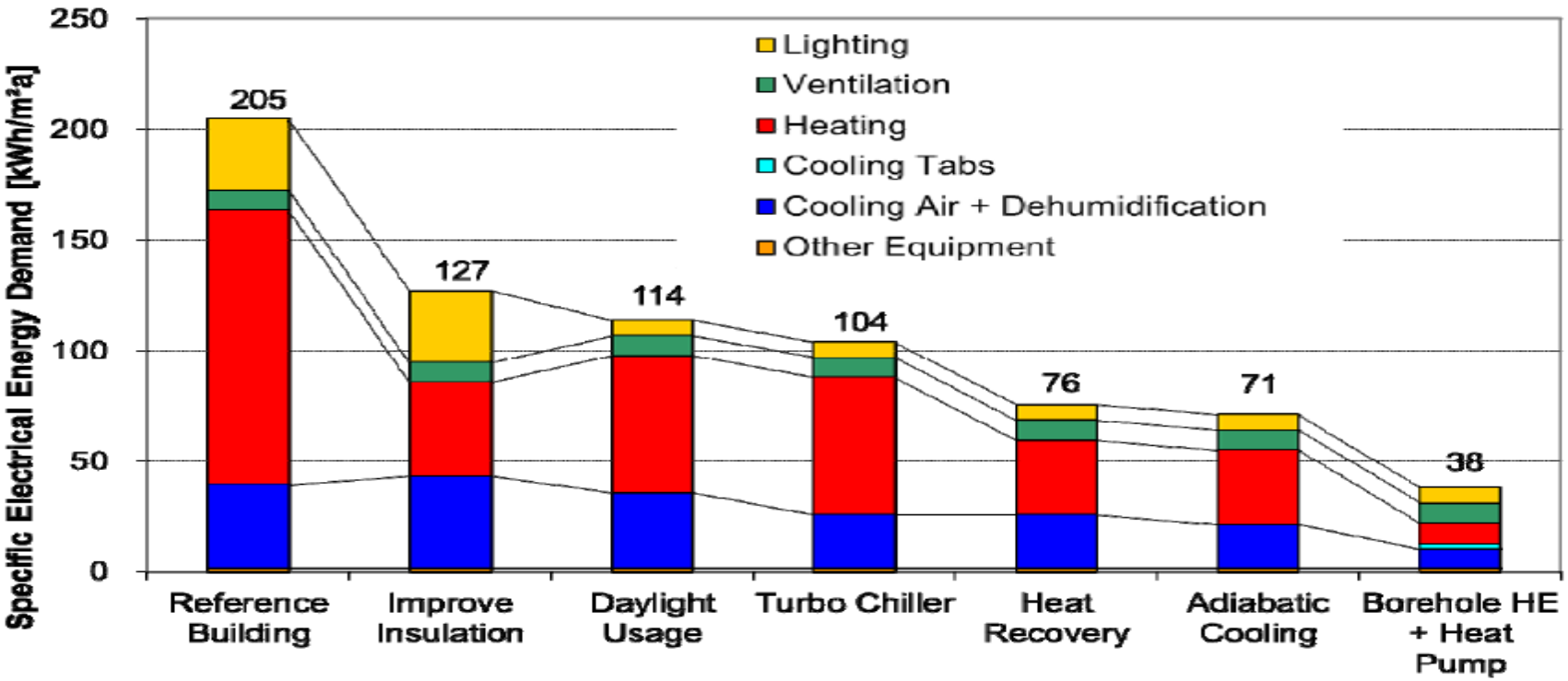
Zero- Energy Building, Seoul, South Korea



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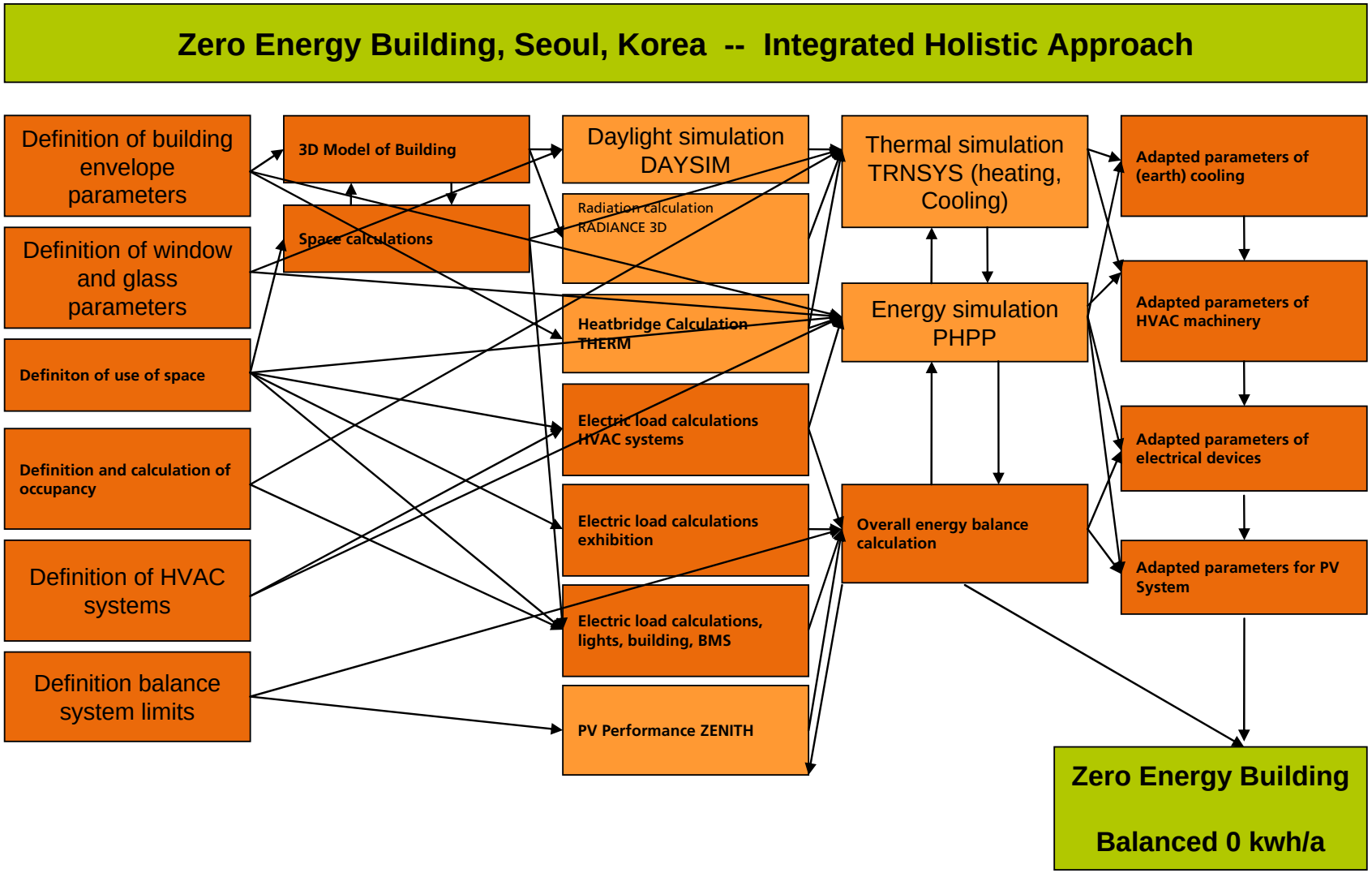
Zero- Energy Building, Seoul, South Korea



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Energy Balance

Category	Energy Usage (kWh/a)
HVAC	99,439
Lighting	25,000
Other Equipment	64,088
Exhibition and Offices	62,000
Contingency (9.6%)	24,465
Total	274,992

Per Area:

- 52.8 kWh/m^{2}a
- 69.2 kWh/m^{2}a inclusive Exhibition and Office

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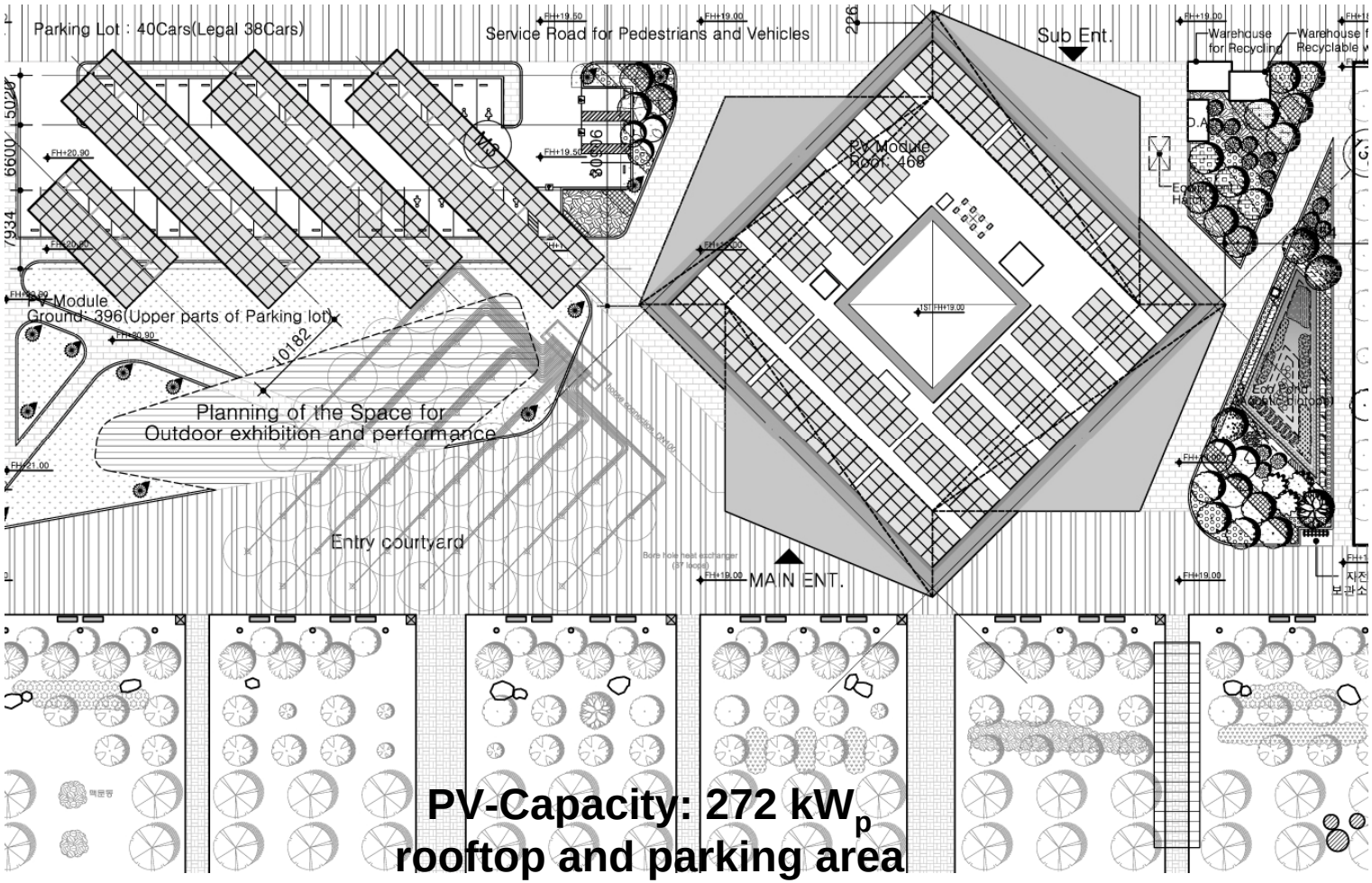
PV covers electric loads



PV-Capacity: 272 kW_p
rooftop and parking area

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Zero- Energy Building, Seoul, South Korea

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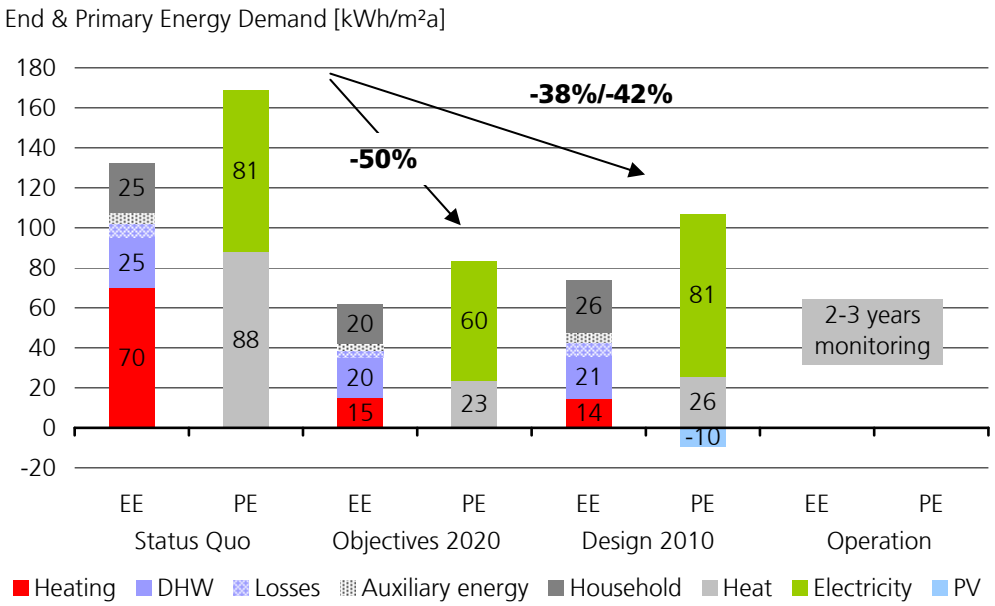
ISE

Retrofit high-rise appartment building, Freiburg, Germany

Built 1968

Today



Retrofit

- Passive House standard
- Replication for the whole district
- Next steps more cost effective
- No higher rental cost

Approach will be multiplied

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Making new districts energy-neutral

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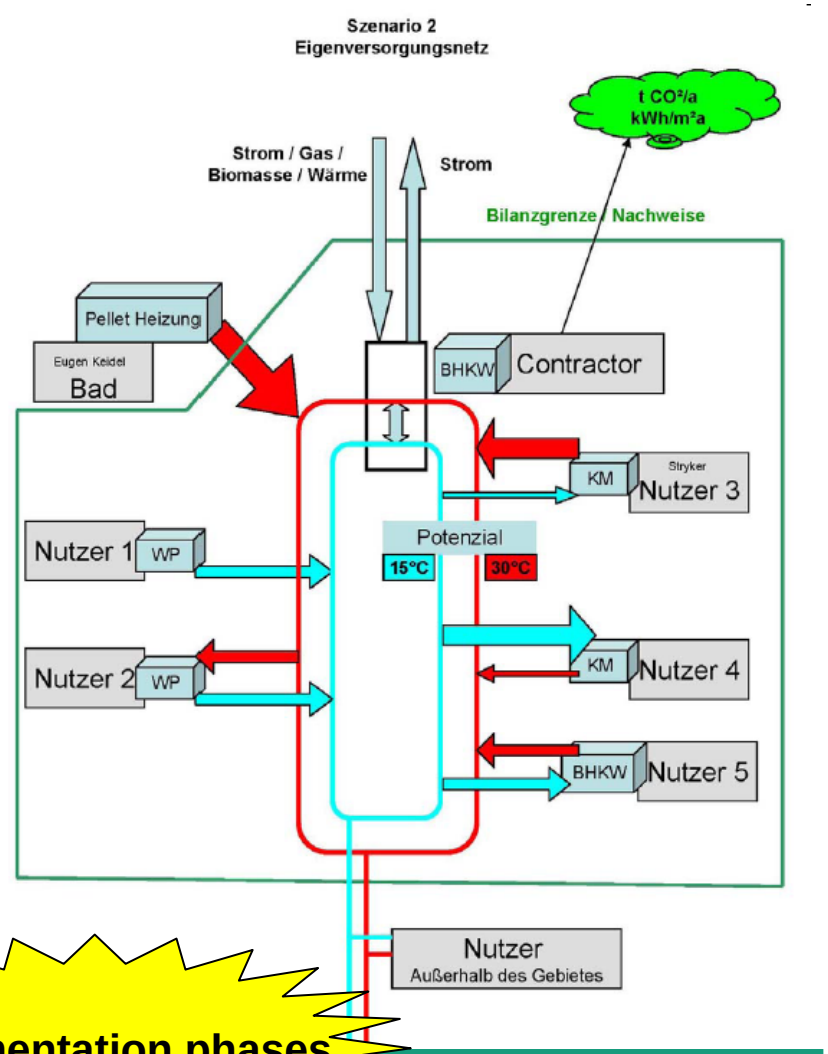
Zero energy industry park, Freiburg, Germany



- High standards for industry buildings
- District heating and cooling with net reactive building systems
- New planning standards for regulations
- Feed-in renewables

Implementation phases

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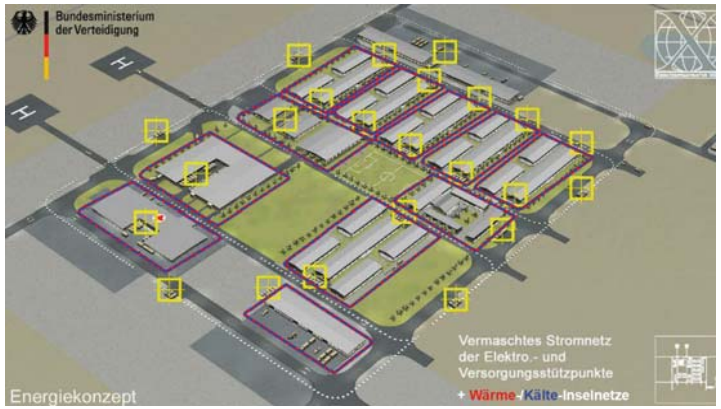
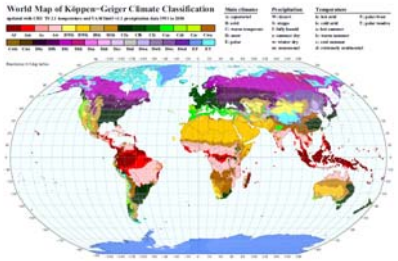
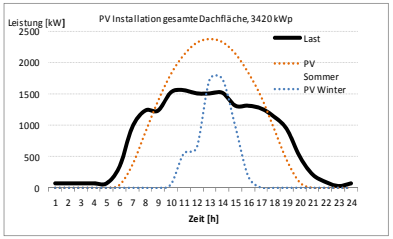
1000X: an energy autonomous city for 1000 people for armys exterritorial activities

Planing phases



- Modular equipment
- Maximum use of renewables, Sun PV, biogas, wind
- Adaption for different climate zones
- Linked and redundant energy systems





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Improving the existing City

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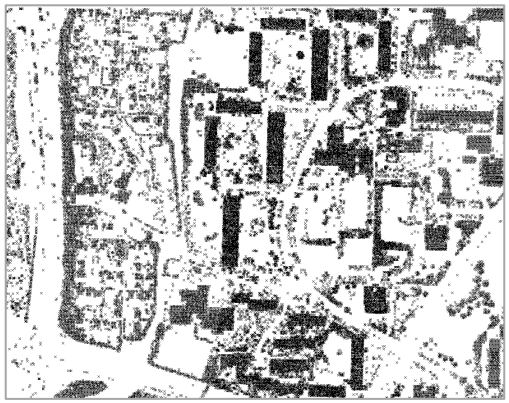
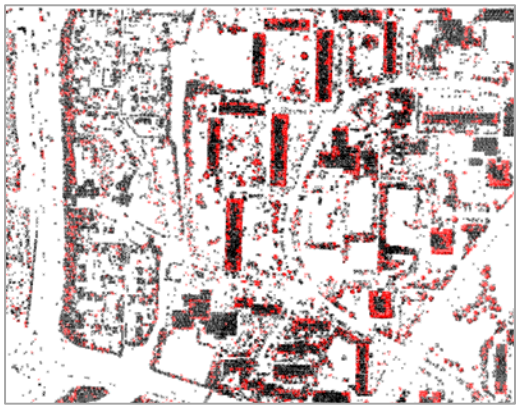
LiDAR – Extracting building hight

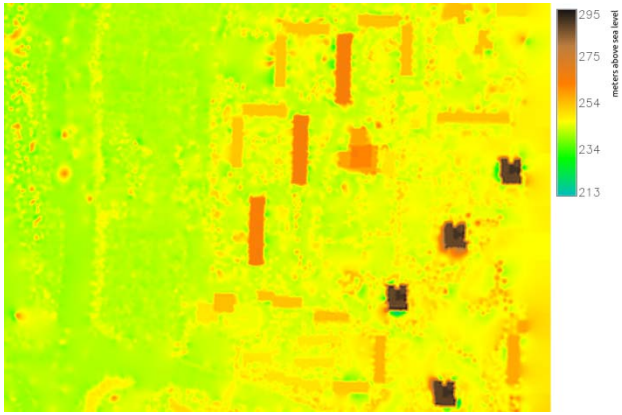


Points cloud (x,y,z)



Edge detection

Colored building hight



Contour building hight

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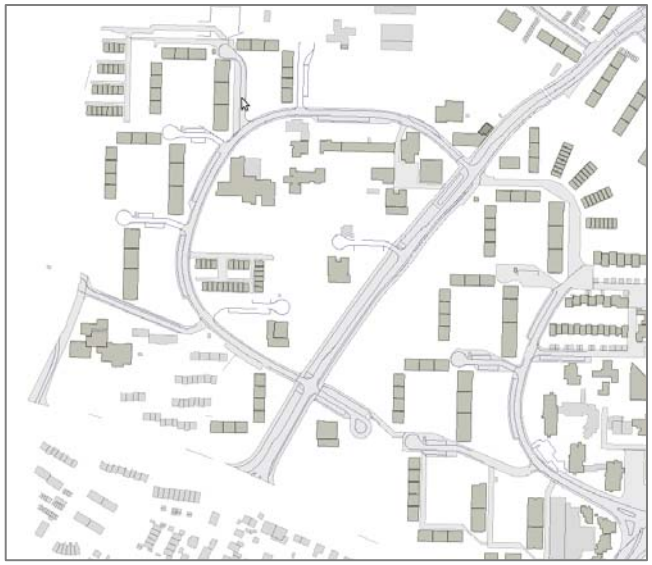
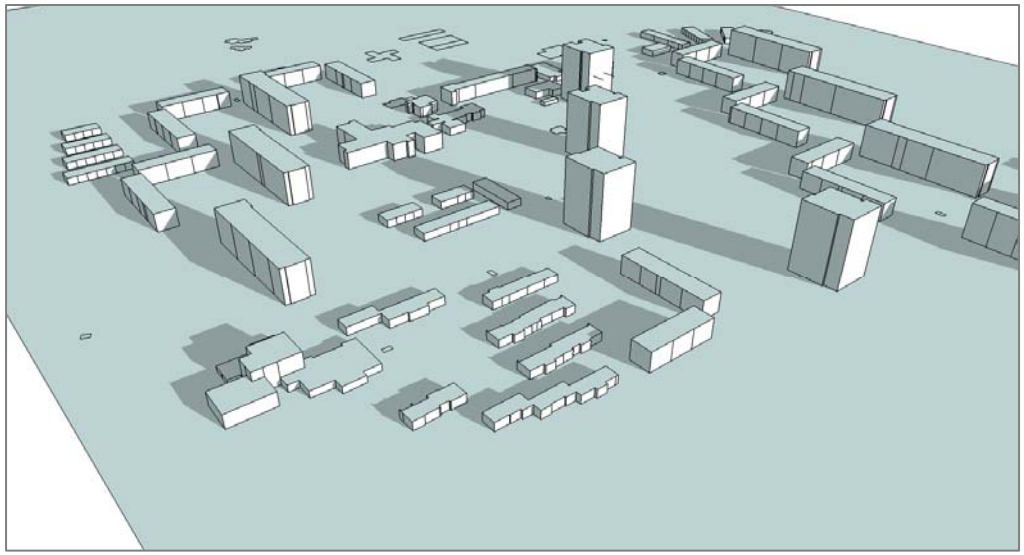
3D Model of District



Building footprint from GIS



3D Model of buildings by combining Information from LiDAR and GIS

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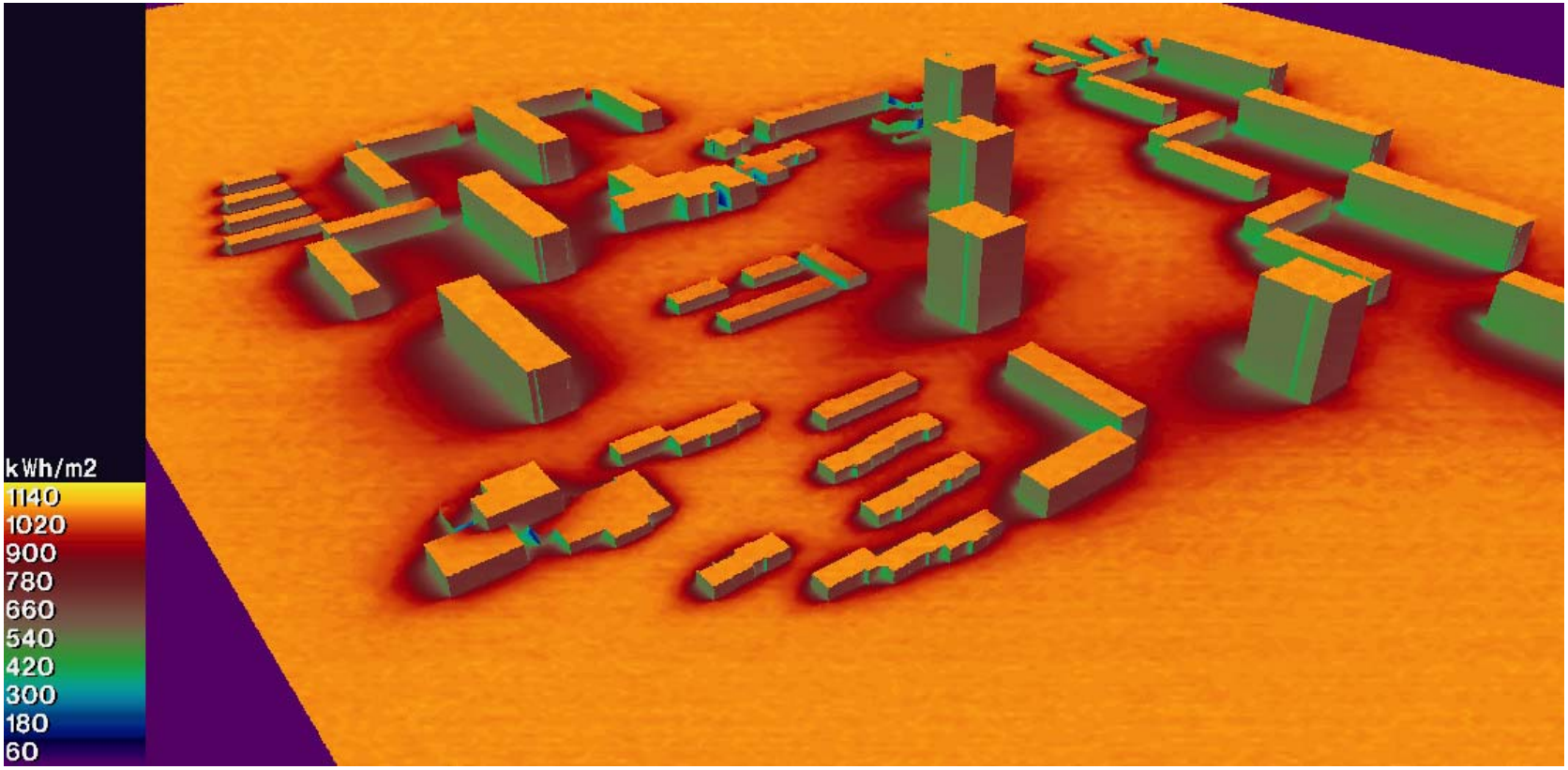
Solar Map



Simulation of annual solar radiation with RADIANCE

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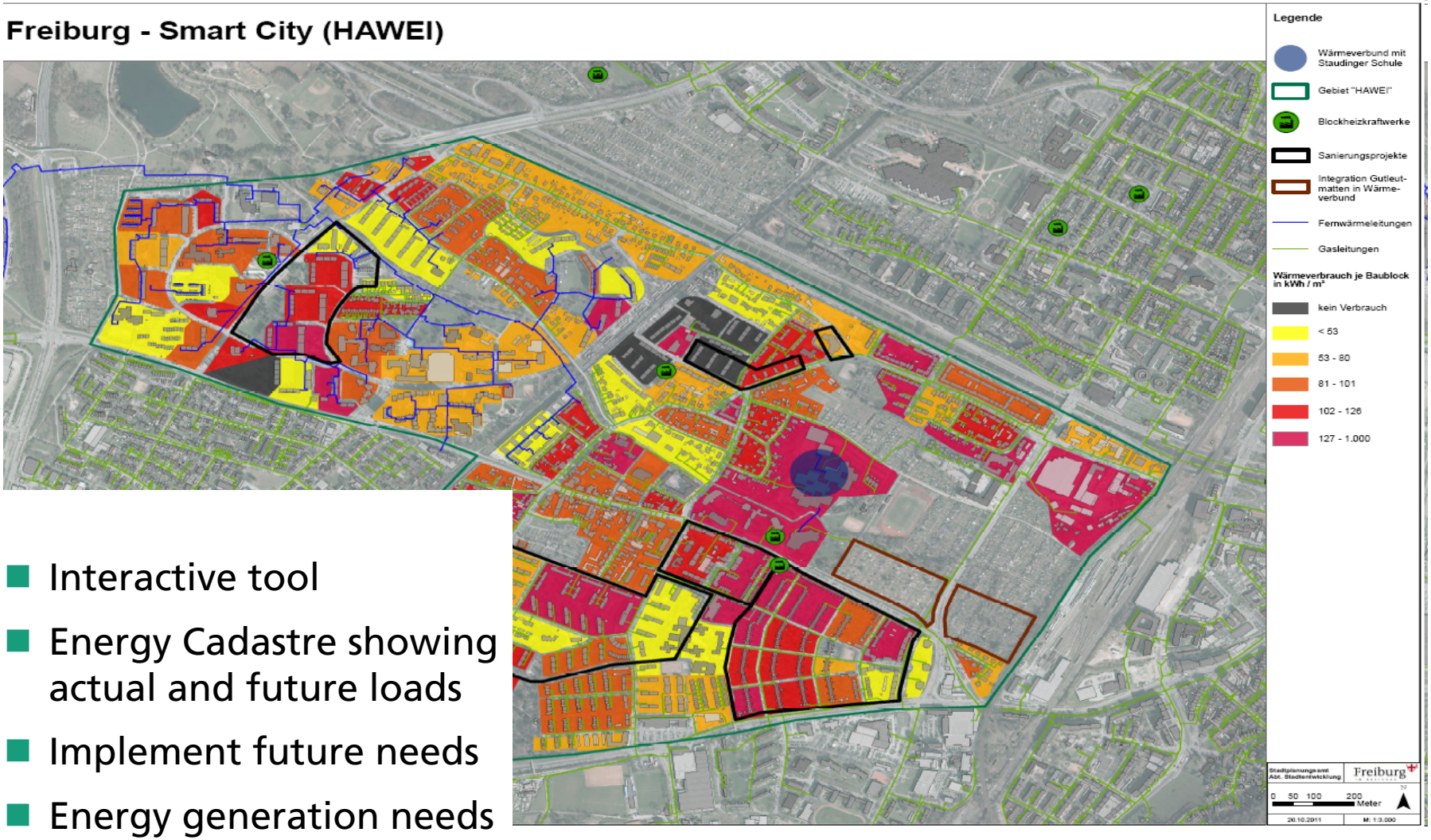
Integrated energy plans for cities and districts



- Interactive tool
- Energy Cadastre showing actual and future loads
- Implement future needs
- Energy generation needs

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Masdar City, Abu Dhabi

© Fraunhofer ISE

Fast growing region

1960

1990

2010

© Fraunhofer ISE

Energy consumption is high

- Water Use 500l /day/ per capita
- Electricity 10000 kwh/ year/ per capita

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Build a new City: Masdar City

- A sustainable City providing the highest quality of life
- with the lowest environmental footprint

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Masdar City – Fast Facts

Masdar City Fast Facts	
Total Site Area:	700 ha
Large Square: Small Square: Supporting Infrastructure: Landscape:	225 ha 55 ha 45 ha 375 ha
Resident Population:	40,000
Commuters:	50,000
Residential Density:	140 People/Hectare
Peak Daily Density:	245 People/Hectare

- Cleantech Cluster - Powered by 100% Renewable Energy
- Zero Waste - Carbon Neutral - Fossil Fuel Free Zone

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Build a new City: Masdar City

Masdar City

Noordwijk

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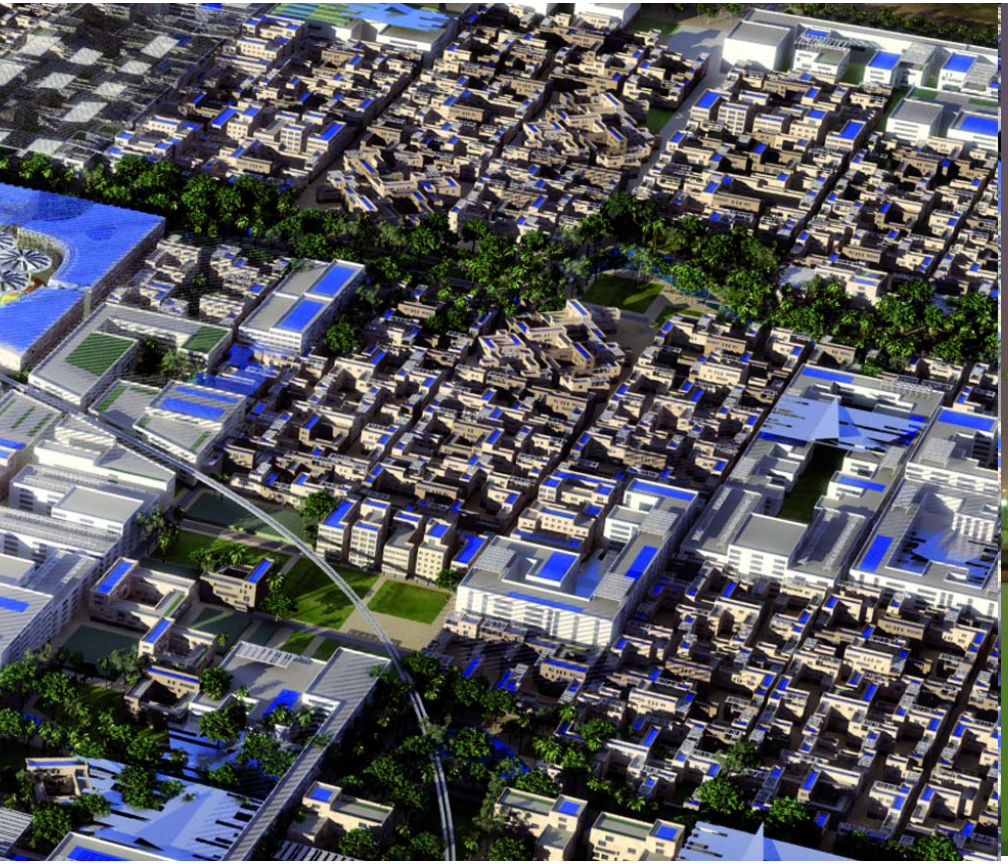
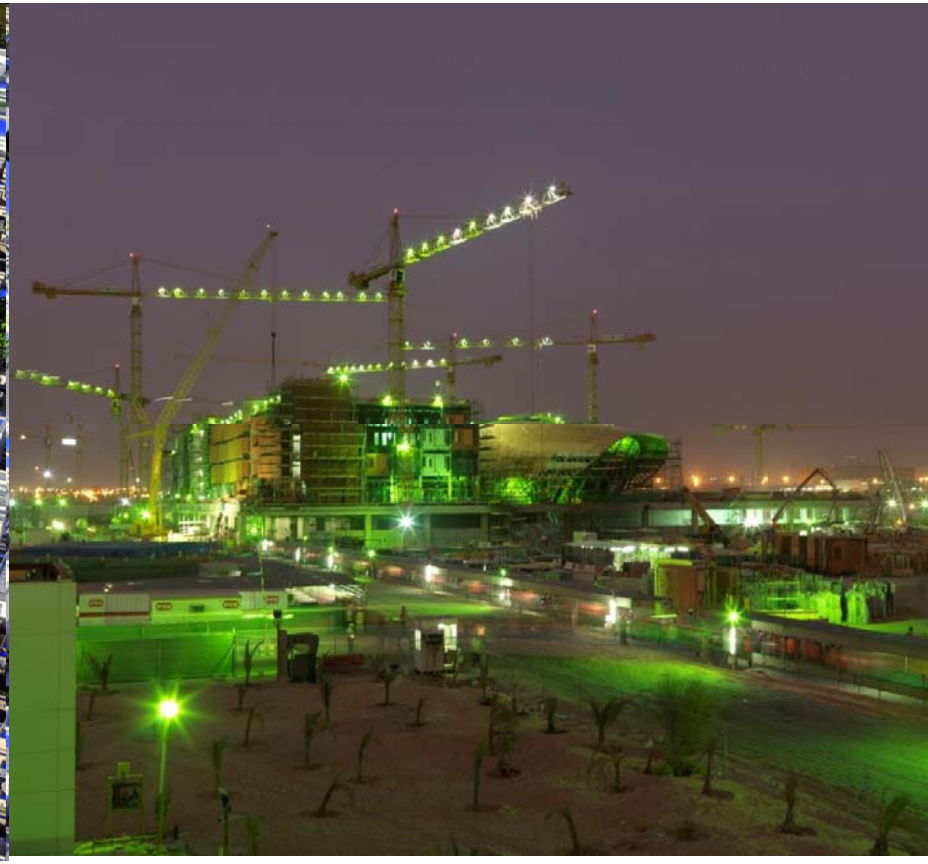
From Vision to Reality

Masdar CITY مدينة مصدر





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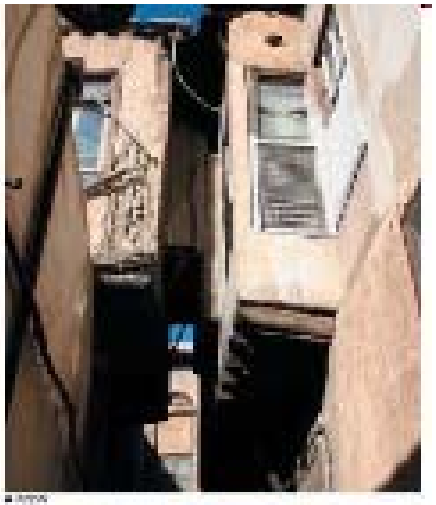
Town planning

- Narrow streets
- Natural shading
- High Density/Low Rise Living
- Public spaces
- Mixed Use
- Walkable



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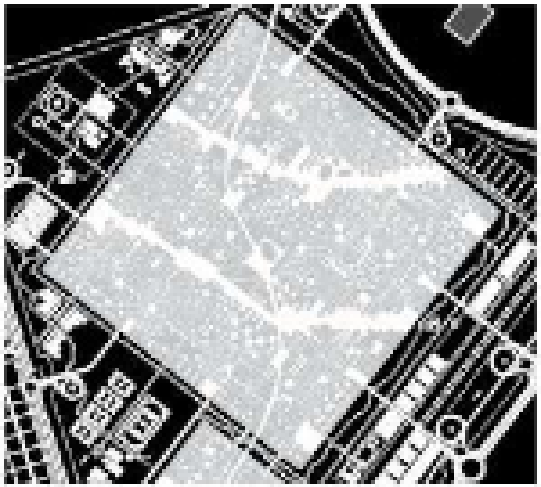
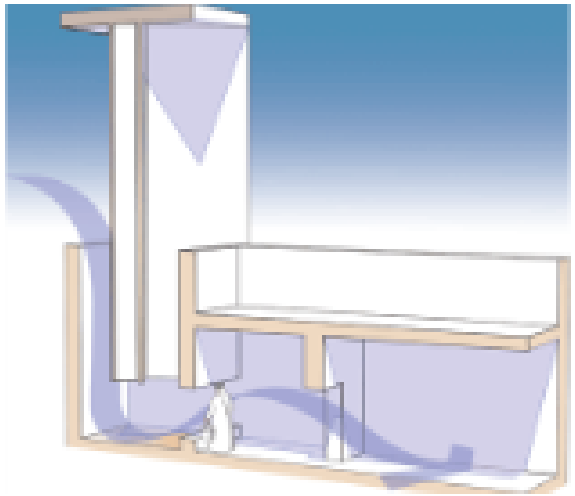
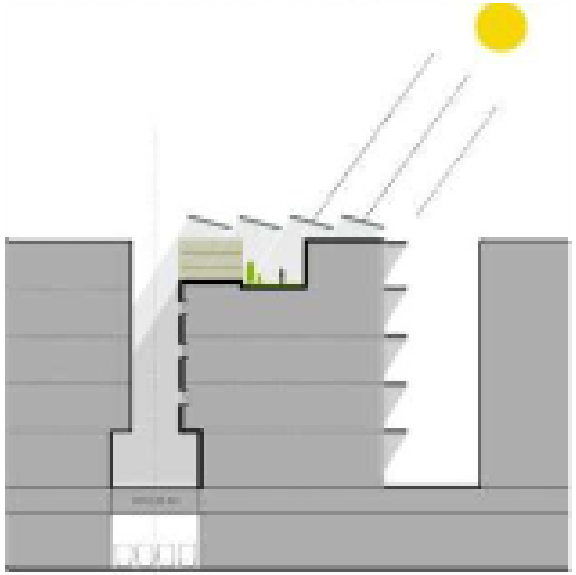
Passive Design



Northeast/Southwest Orientation

Natural Wind Towers





Roof – Day Shading

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Mobility Grid

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Personal Rapid Transport System

- Walking, electric vehicles, cycling, PRT and LRT are the modes of transportation within Masdar City

PRT Fast Facts	
PRT Vehicles:	3,000
PRT Stations:	85-100
FRT Vehicles	810
PRT Trips per day:	135,000
Max. Walking Distance to PRT Station:	150m
LRT Trips per hour:	5,000 people

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Carbon Neutral

MASDAR CITY

Building Design Energy efficient	Energy Generation Renewable	Transportation Electric/Solar	Recycling/ Waste to energy	Carbon offsetting/ Carbon Sequestration
-56%	-24%	-7%	-12%	-1%

= Carbon Neutrality

CONVENTIONAL CITY

Building Design Conventional	Energy Generation Oil and Gas	Waste Landfill	Transportation Fossil Fuel
80%		13%	7%

= 1,100,000 Tonnes CO2

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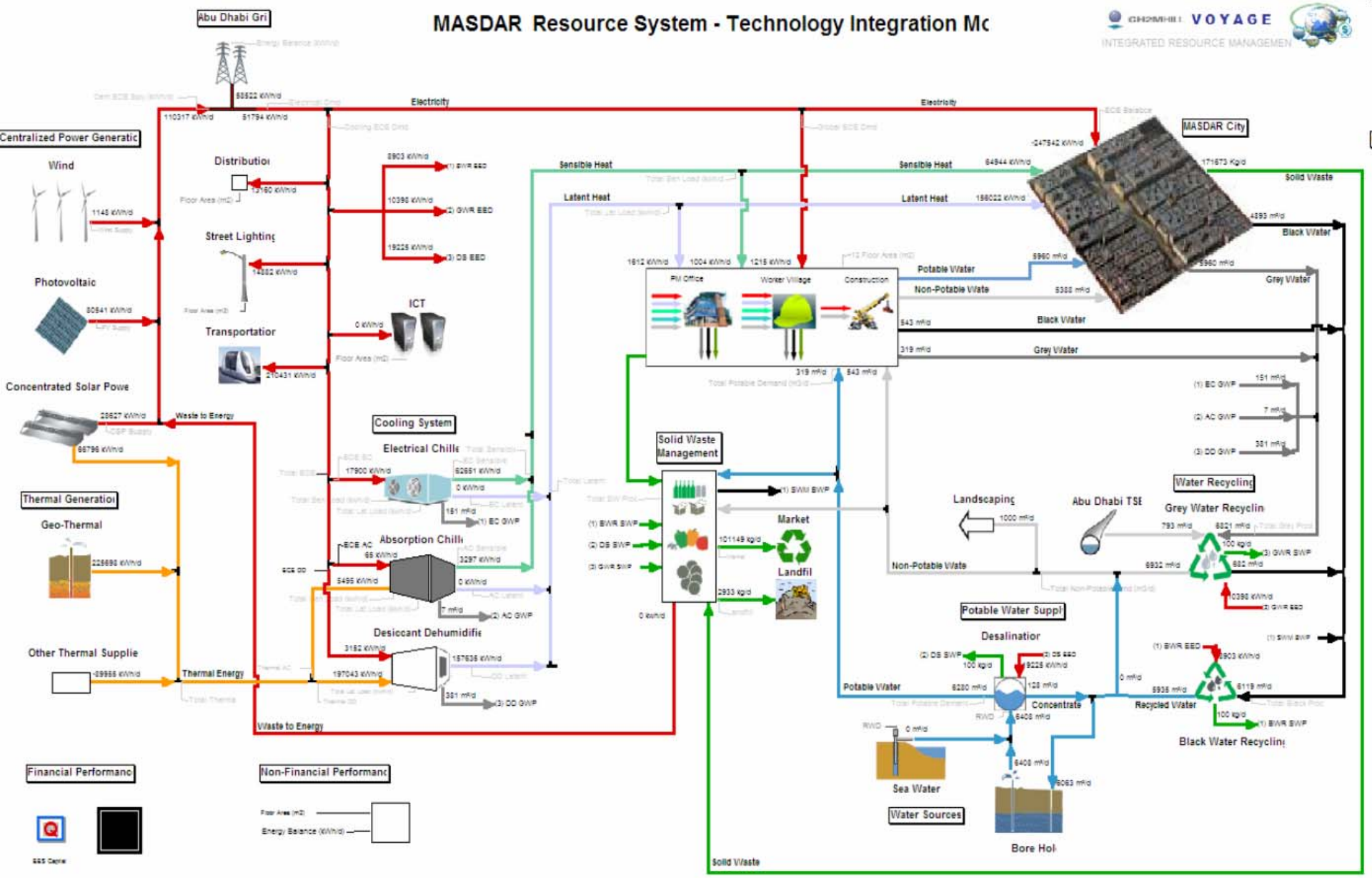
MASDAR Resource System - Technology Integration Mc



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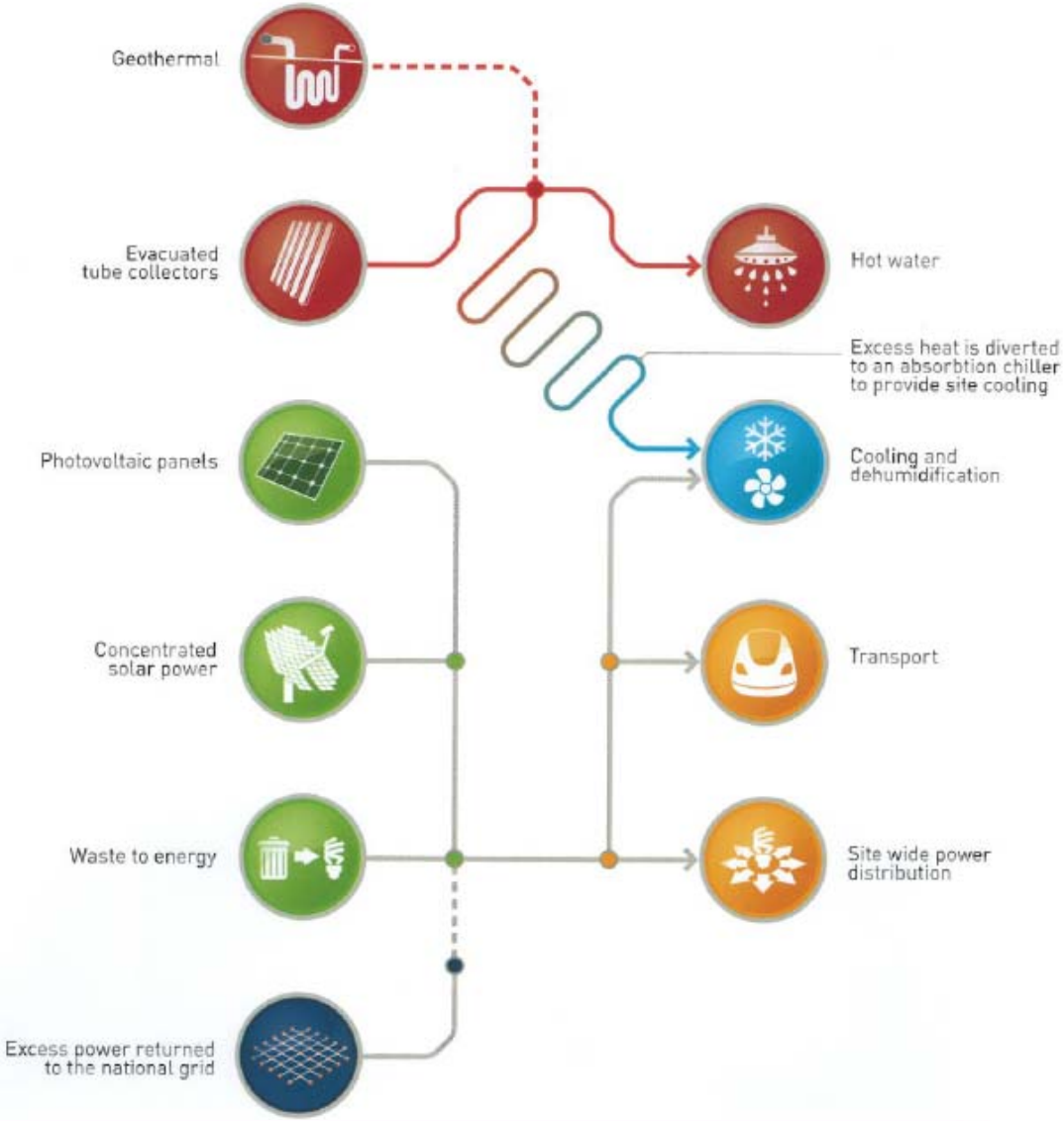
Energy supply



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Under Construction

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The reality

Efficient buildings difficult to realize

Site too small – off site grounds needed

Not efficient- not enough waste

No upscaling experience in solar cooling

But energy price Abu Dhabi: 3ct/kWh !!

No recooling with drinking water

PRT not running

Complete change of system – and city plans

No feed-in regulations

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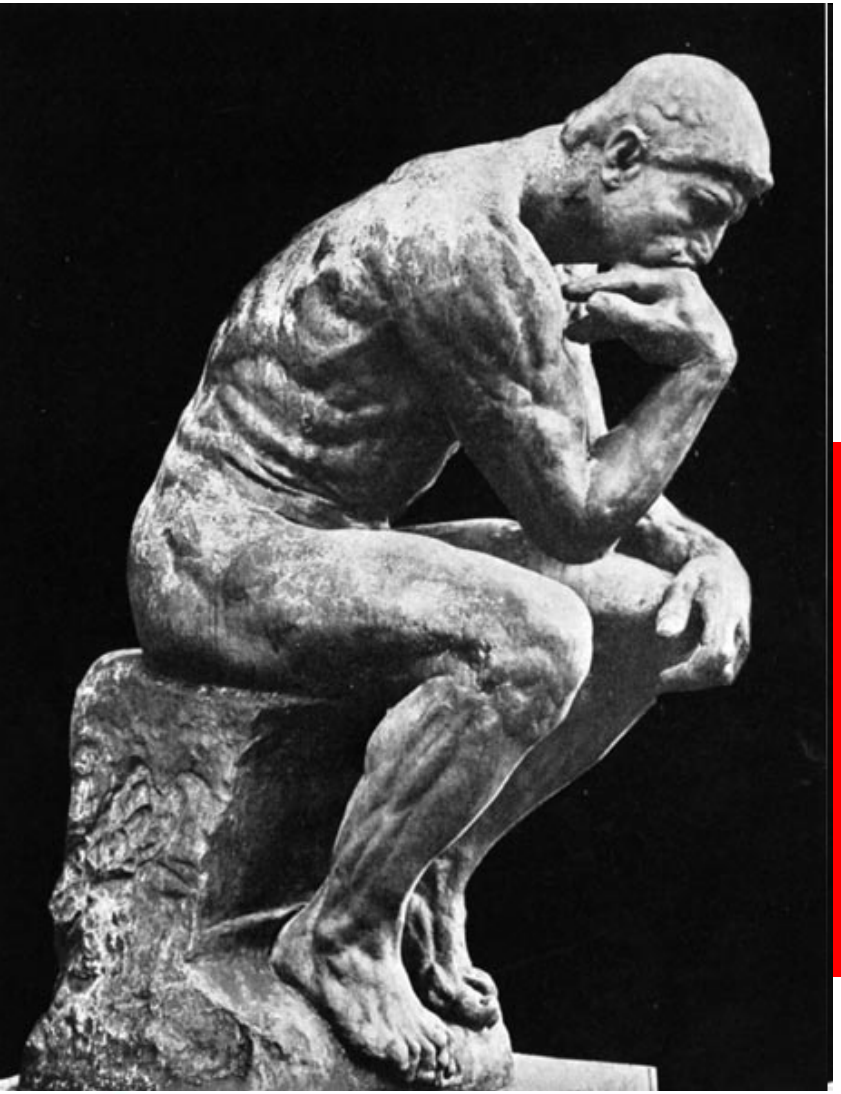

STOP!
Rethink!

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Masdar City learnings

- Revised plans, more realism
- Revised approach – strategic partnerships (e.g. with Fraunhofer)
- Integration of learnings
- Cost effectiveness, smarter constructions
- Better local and regional integration –Masdar is not an island
- Longer development: 10-20 years
- Money does not always help

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Partnership with Fraunhofer

ISE Inside

10MW PHOTOVOLTAIK KRAFTWERK

Masdar
A MUBADALA COMPANY

10MW Photovoltaik Kraftwerk in Betrieb seit Mai 2009
Erzeugter Strom versogt die Masdar Büros und das Masdar Institut
FirstSolar und Suntech PV Module
Registriertes Projekt des „Clean Development Mechanism“

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PV Test field

ISE Inside

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Solar Cooling

PILOTPROJEKT – SOLARE KÜHLUNG MIT EINSTUFIGER ABSORBTIONSKÄLTEMASCHINE

Masdar
A MUBADALA COMPANY

ISE Inside

Lieferant der Komponenten: Yazaki, Japan

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Solar cooling demonstrator monitoring

PILOTPROJEKT – SOLARE KÜHLUNG MIT ZWEISTUFIGER ABSORBTIONSKÄLTEMASCHINE

Masdar
A MUBADALA COMPANY

ISE Inside

Kältemaschine: Broad, China
Parabolrinnenkollektor: Sopogy, USA
Linear Fresnel Kollektor: Mirroxx, Deutschland

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Masdar Institute

Sustainability Goal	Achievements to date
Energy Demand Reduction	• 51% less energy in residential units • 55% reduction in building external heat gain
Renewable Energy	• Up to 30% of electricity provided by 1MW rooftop solar PV • Remaining electricity provided by 10MW solar PV farm • 75% of hot water provided by rooftop solar thermal collectors
Water Demand Reduction	54% less water consumption in residential units
Waste Diverted from Landfill	96% of construction waste reused or recycled
Reduction in Embodied Carbon in Materials	Used low-carbon aluminum and concrete mixes in buildings, infrastructure

IBP+ISE Inside Building Code

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Strategic Partnership with Fraunhofer and Fraunhofer Masdar Technology Center

A Fraunhofer Masdar Living Lab

Research Platform for Future Cities Innovations

Experimental Test Platform for Sustain-Tech

Business Center and Contact Office

Showcase for Innovations from Germany

Visitor and Meeting Center

Hands-on Edutainment for Technicians

A Plattform for Research and Development for Sustainability in City and Building Systems

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Impressions

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Masdar Institute

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Windtower

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Central Plaza Day/Night

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ISE

Masdar Phase 1

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Summary

- Fraunhofer ISE provides you with cutting edge research and development of solar energy systems
- Bring the maximum renewables into the system
- We should give priority to high efficiency measures
- Cost effectiveness is a must
- Many options to generate energy at the building and facades
- Zero enregy buildings and plus energy buildings are possible
- Energy neutral districts and city systems are the next steps

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We will have a soft landing !

If we work for a smaller CO2 footprint

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Thank You for Your Attention!

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International Cooperation, Energy Efficient Buildings and Urban Development
Fraunhofer-Institute for Solar Energy Systems ISE
arnulf.dinkel@ise.fraunhofer.de, www.ise.fraunhofer.de

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