



SERIS  
Solar Energy Research  
Institute of Singapore

# Sustainable energy systems – the role of solar energy

Professor Joachim LUTHER

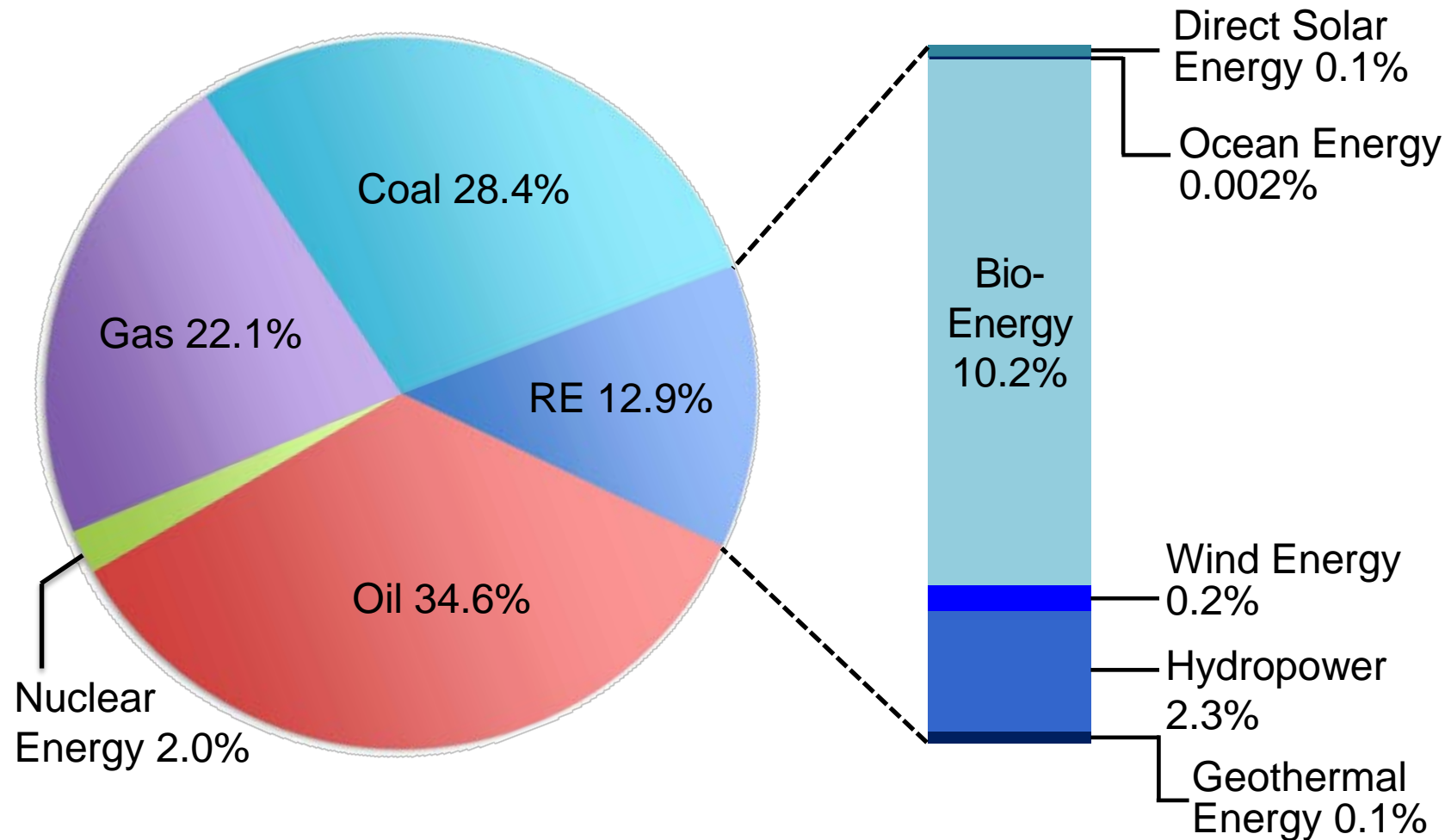
Solar Energy Research Institute of Singapore (SERIS), Singapore

Meeting Our Future Energy Needs: What Role Will Renewables Play?  
Event organised by The Energy Studies Institute (ESI) and Norwegian  
Embassy, Singapore  
24 November 2011

- ❑ **Sustainable energy supply systems**
- ❑ Photovoltaic (PV) technology
- ❑ PV market, cost of solar electricity
- ❑ Leveling out of fluctuations in solar energy generation
- ❑ Smart grids and Photovoltaics
- ❑ Conclusion

# Global energy supply, 2008,

primary energy, total ~ 500 exajoule (EJ)



Source: data IEA 2010

# Benefits of an advanced energy system,

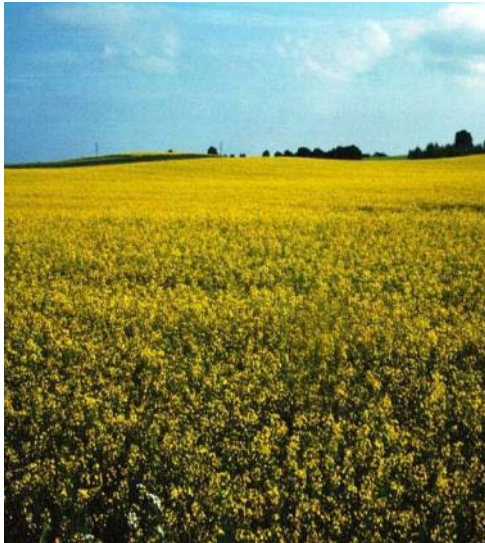
based on the sustainable use of renewable energy sources and energy efficiency

- ❑ Protection of the natural life support system
- ❑ Reduction of energy poverty in developing countries
- ❑ Promotion of peace, by reducing the dependence on regionally concentrated energy resources



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- ❑ Energy security
  - ❑ Promotion of structural changes (future-compliant industries & jobs)

# Sustainable potentials, renewable energy sources



Modern biomass	100 EJ/a
Wind mostly land based*	140 EJ/a
Hydro	15 EJ/a
Solar	effectively unlimited

Today's global demand ~ 500 EJ/a

\* Significantly higher potential for deep water off-shore applications

Source: German advisory panel on global change 2003, [www.wbgu.de](http://www.wbgu.de)

# Electricity from renewables,

## main conversion paths



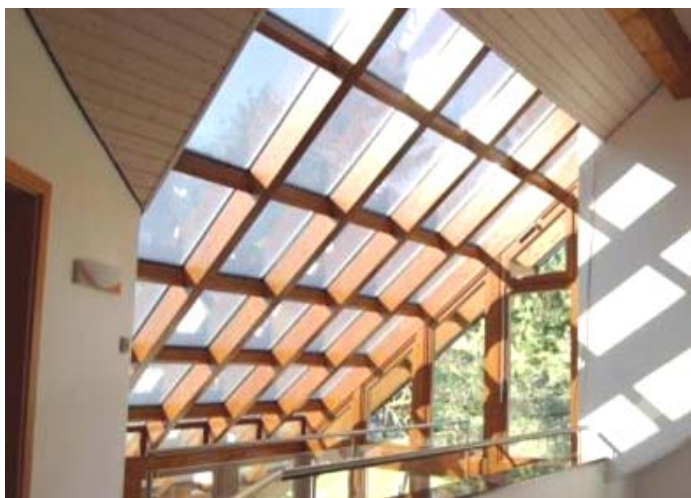
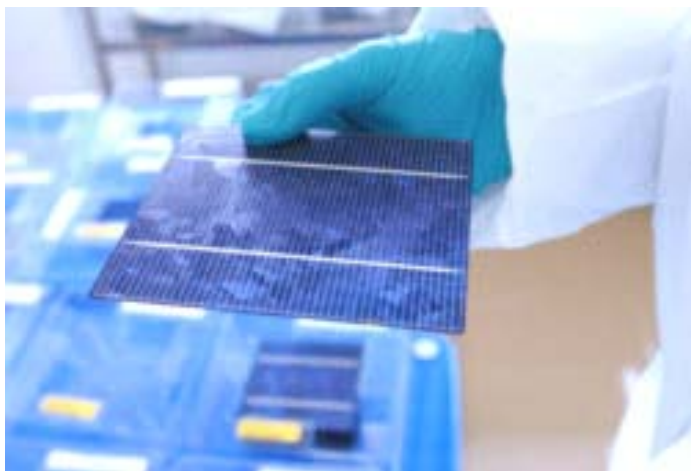
- ❑ Solar energy conversion
  - Flat-plate photovoltaics
  - PV under optical concentration
  - Solar thermal power plants
- ❑ Wind energy
- ❑ Biomass
- ❑ Hydro
- ❑ Ocean (waves, currents,...)
- ❑ Geothermal

# Outline

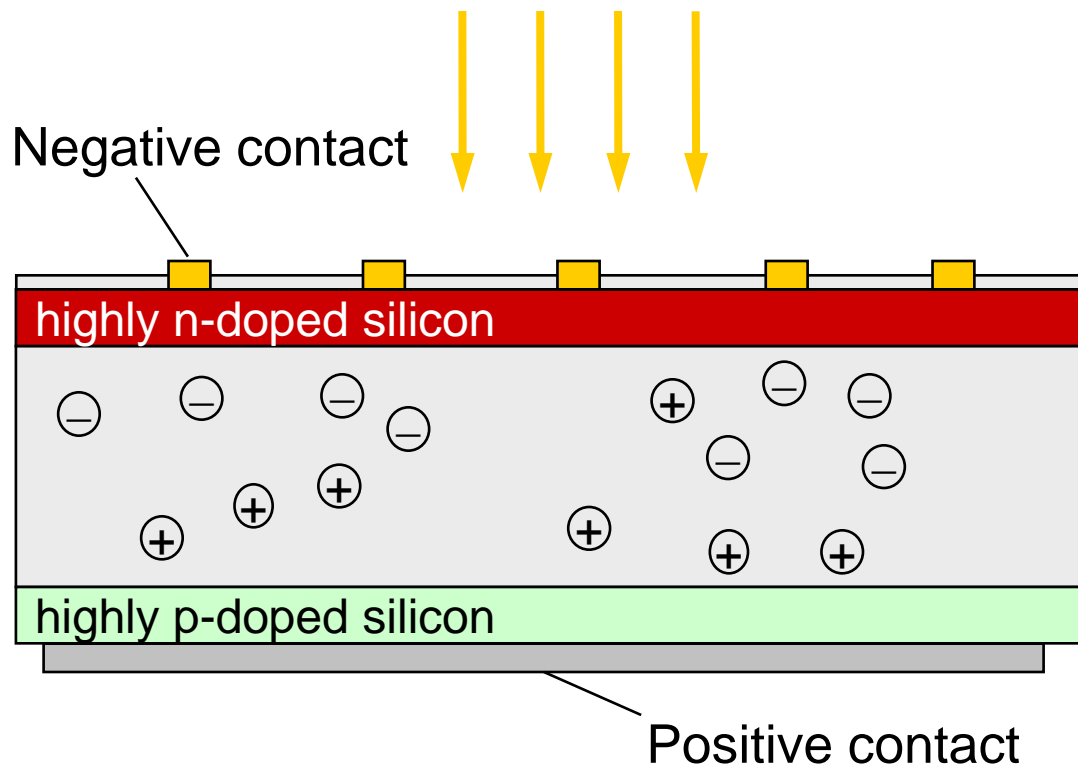
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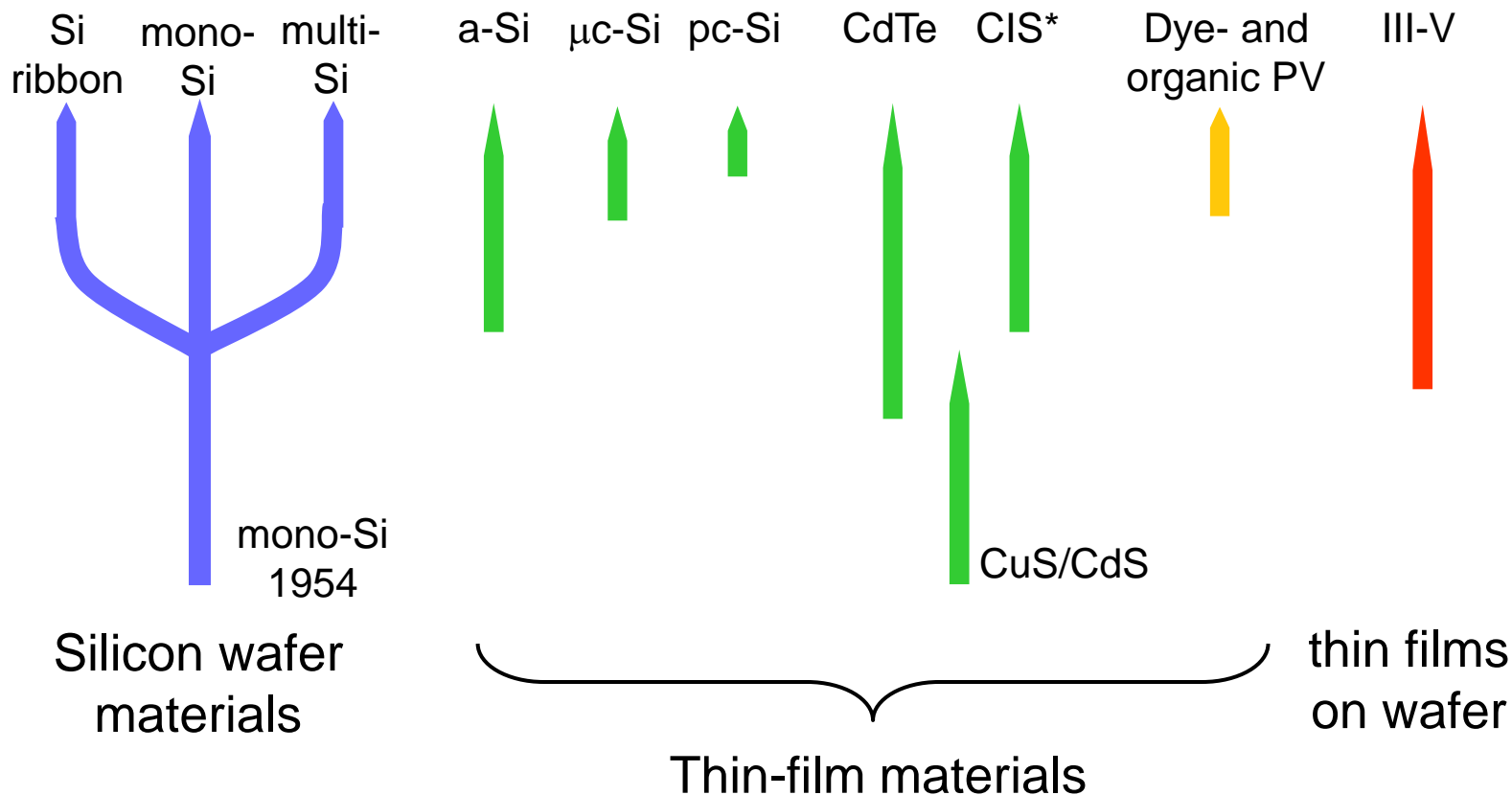
# Photovoltaic energy conversion, power market technologies, examples



# Silicon solar cell, functional principle



# Materials for PV energy conversion, industry 2011, examples



\*CIS includes CIGS and related materials

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# PV installations,

data 2010

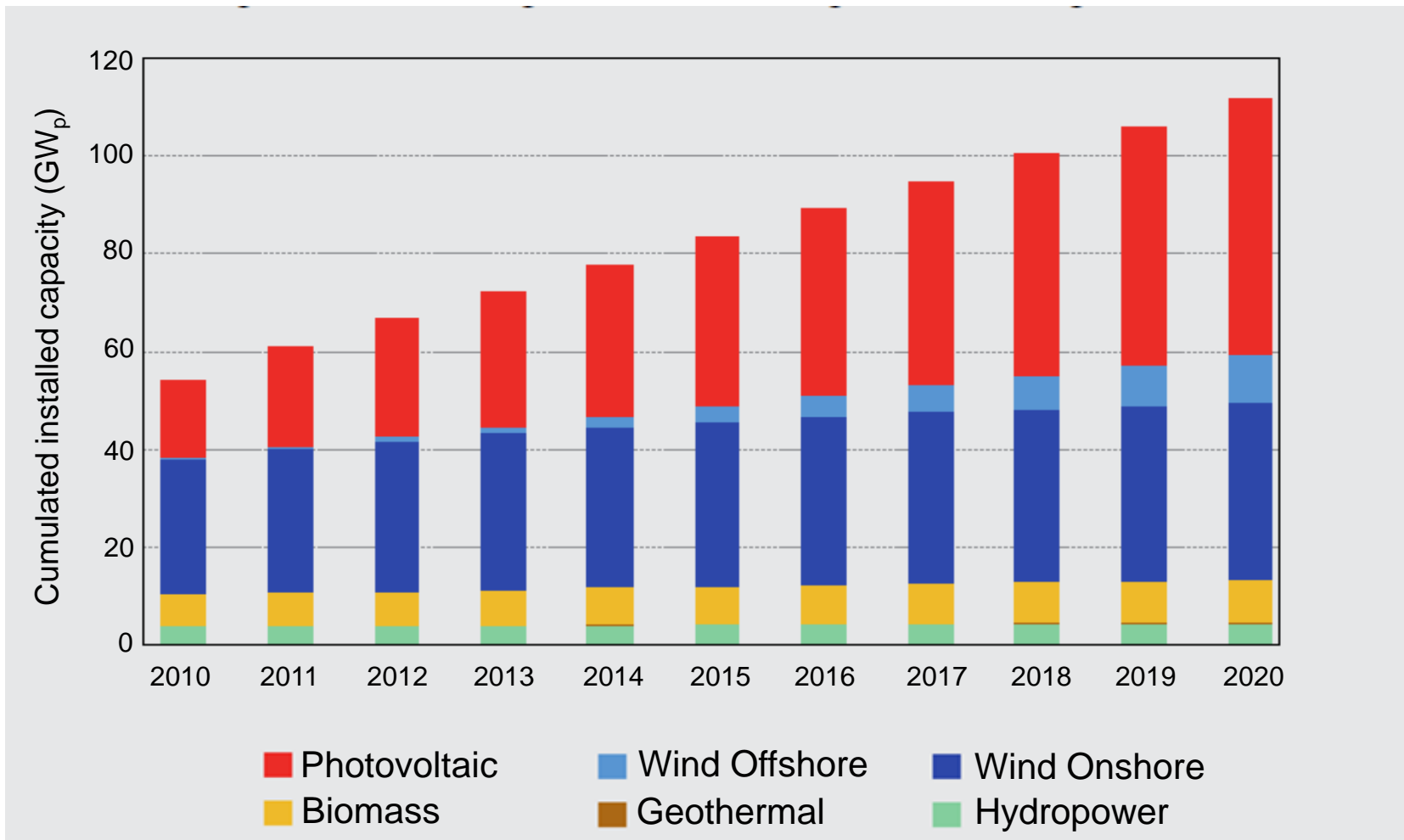
Cumulative PV capacity globally installed	39.5 GW
PV fraction of global electricity generation	~ 0.2 %
Cumulative PV capacity installed in Germany*	17 GW
PV fraction of German electricity generation	3 %
PV capacity globally installed in 2010	16.6 GW
Average market growth rate since 2000	~ 45%
Global market volume, 2010	~ US\$ 45 billion

\*peak electricity demand 2010: 78 GW

Source: European Photovoltaic Industry Association (EPIA), SERIS market research 2011

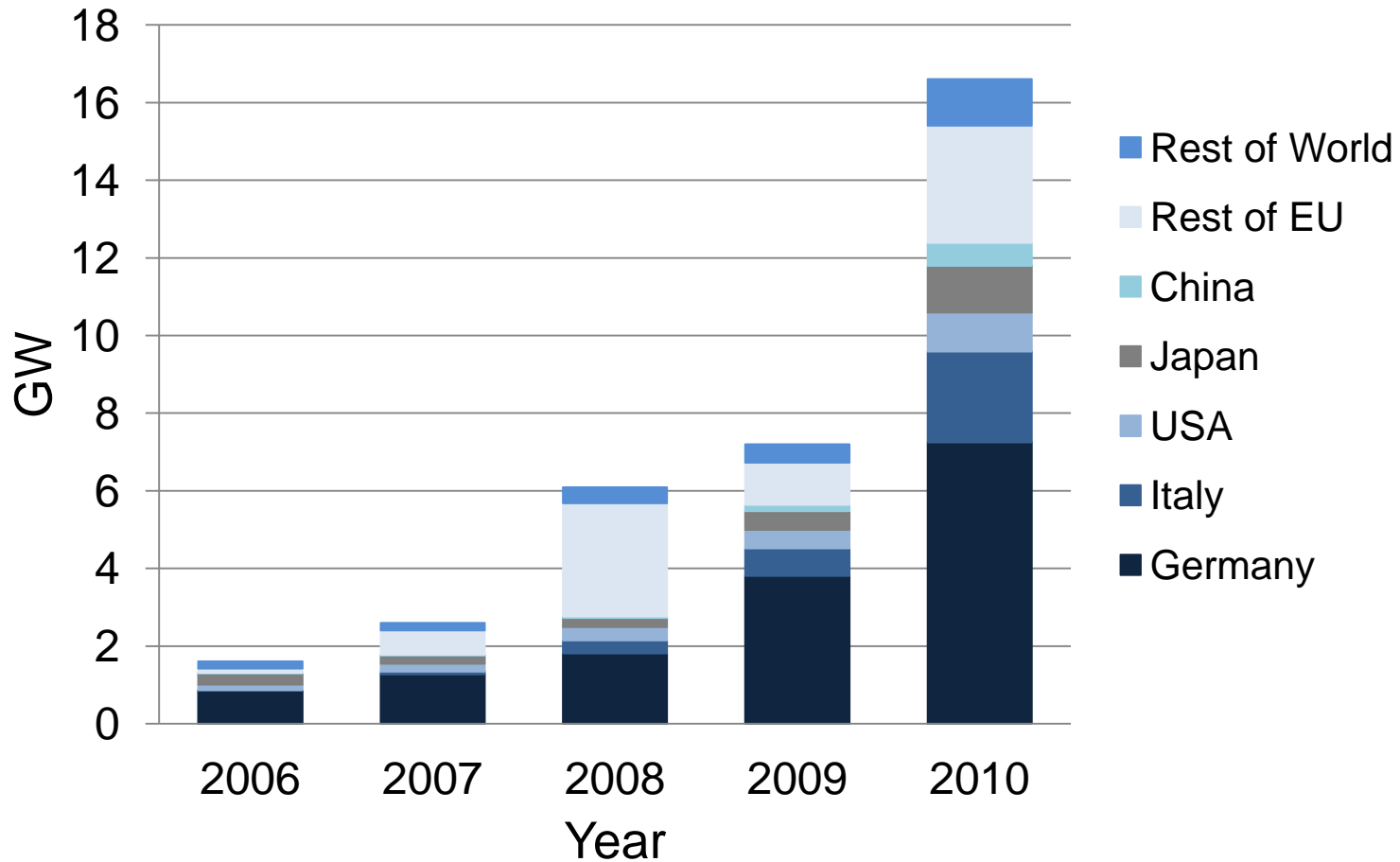
# Evolution of renewable energies

## Germany



Source: National action plan for renewable energies, German government 2011

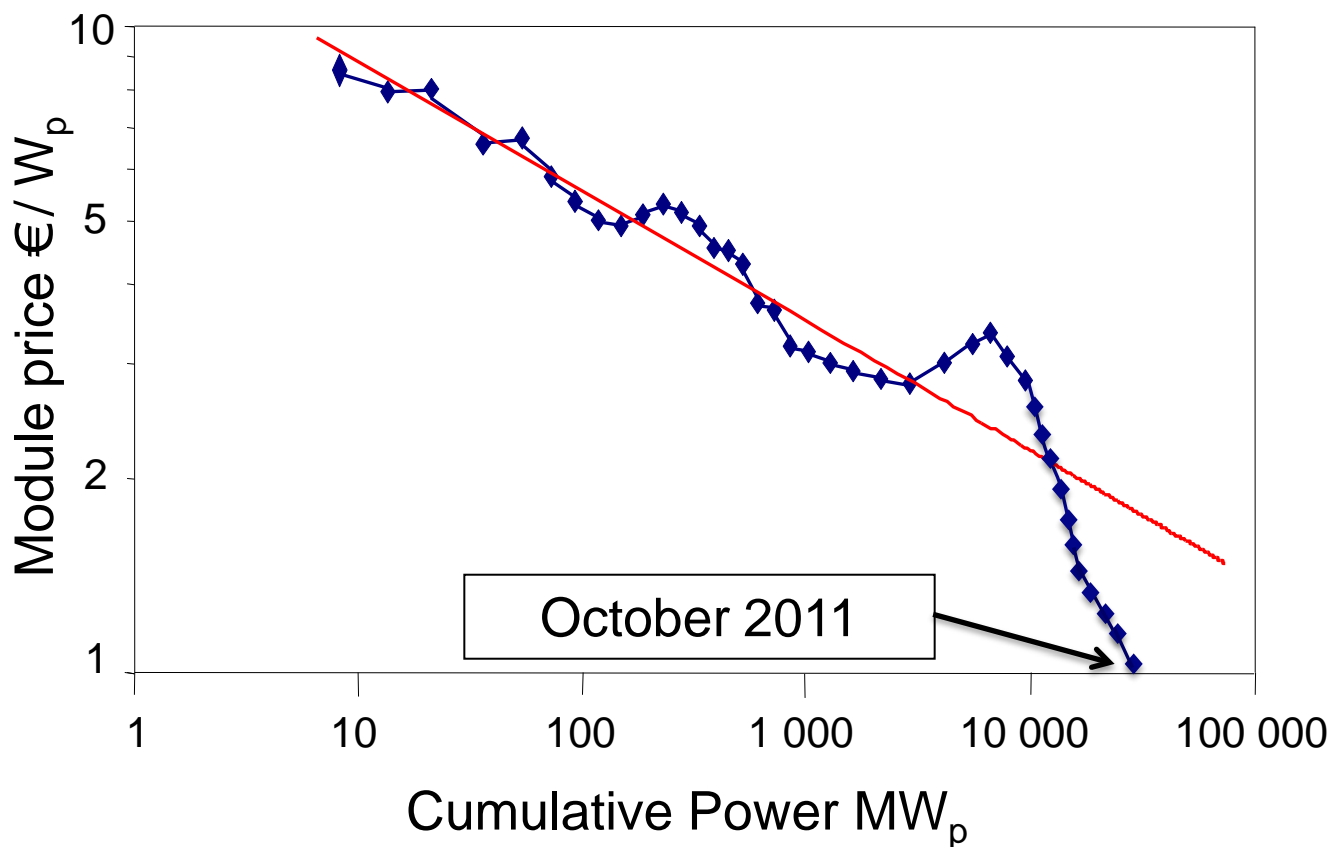
# Annual global PV installations



Source: EPIA, SERIS market research 2011

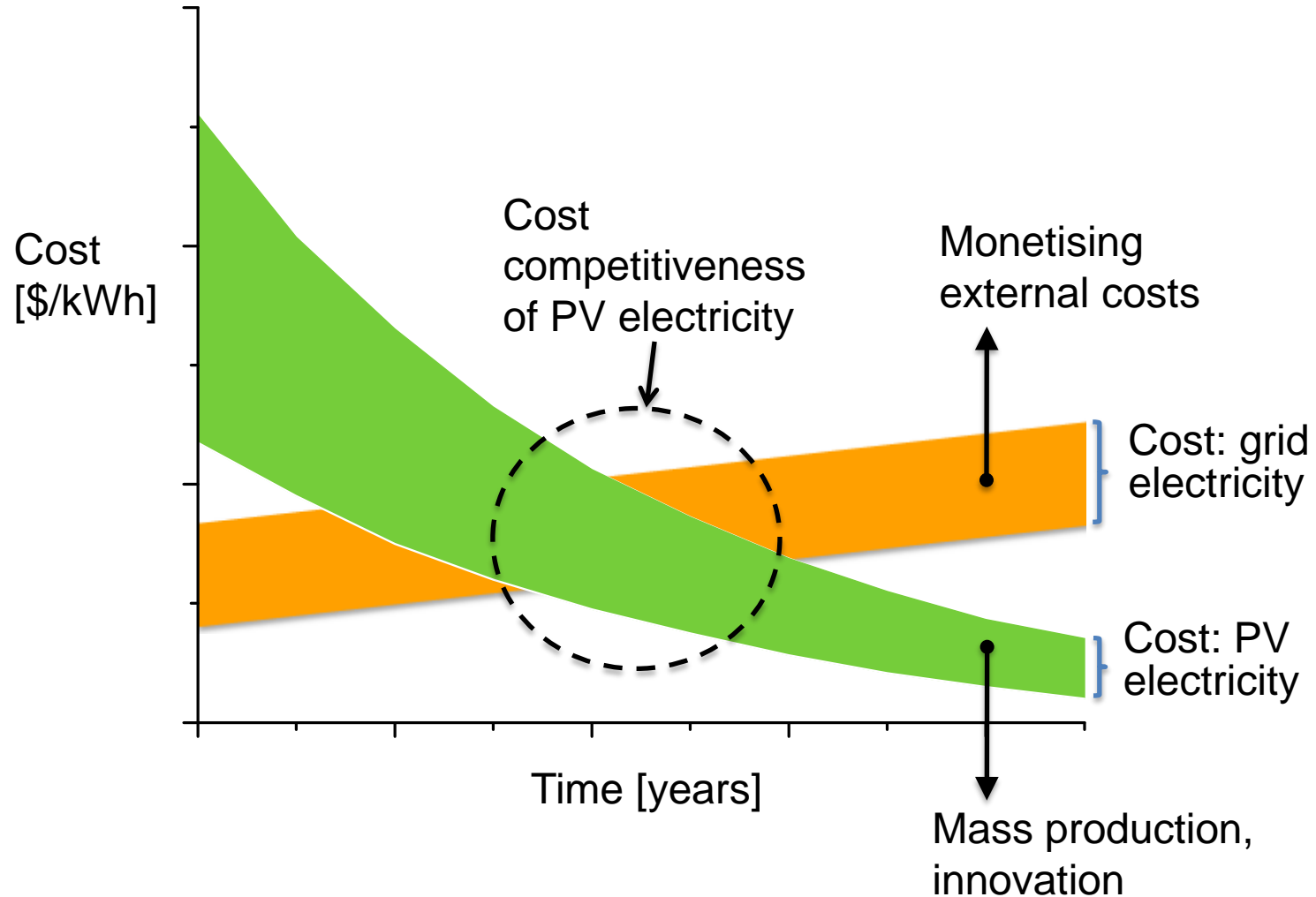
# Price experience (learning) curve

Silicon-wafer based modules

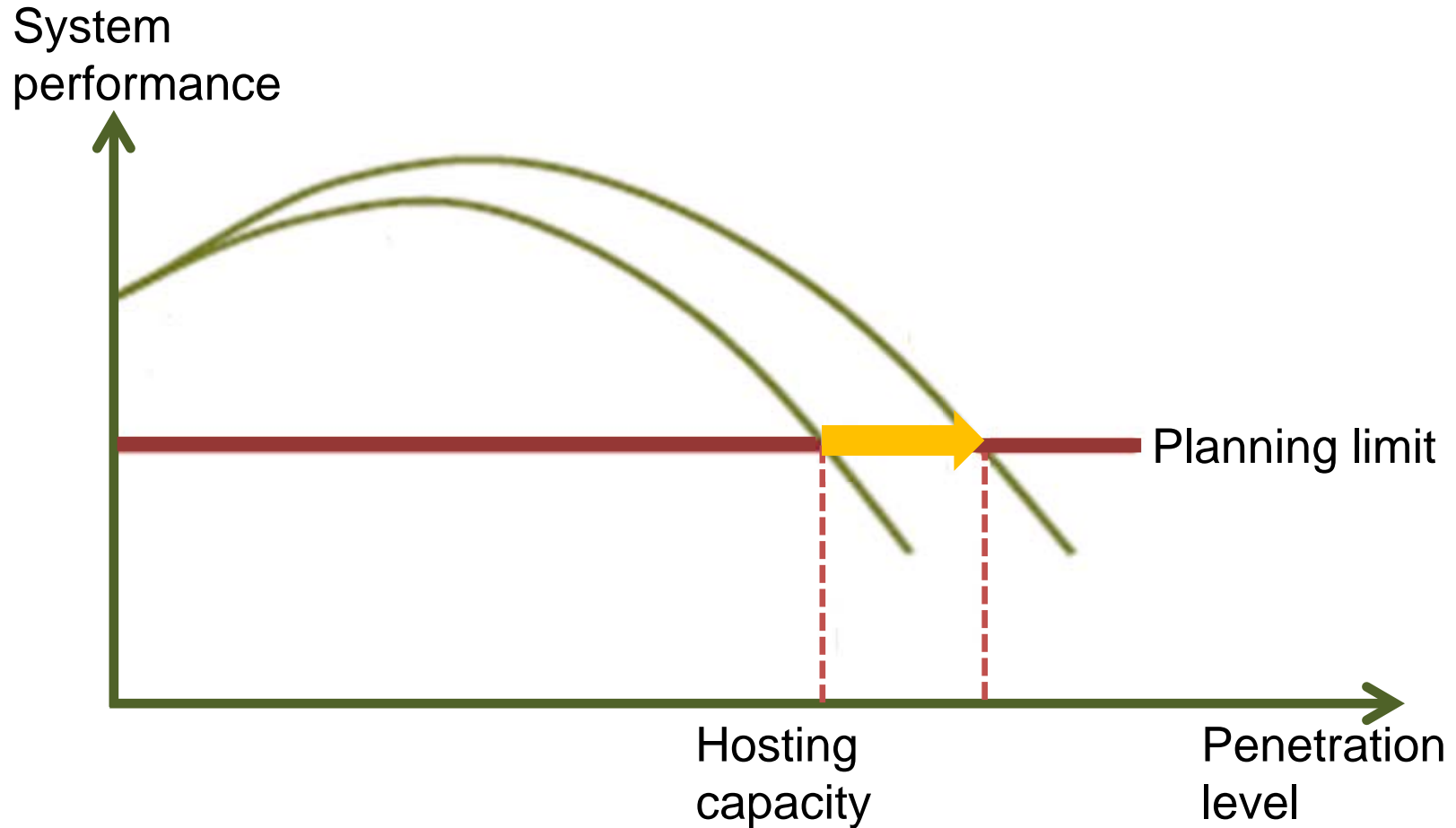


Source: Solar Generation, IEA-PVPS 2006; Deutsche Bank, SERIS 2011

# Cost, solar electricity



# The concept of hosting capacity

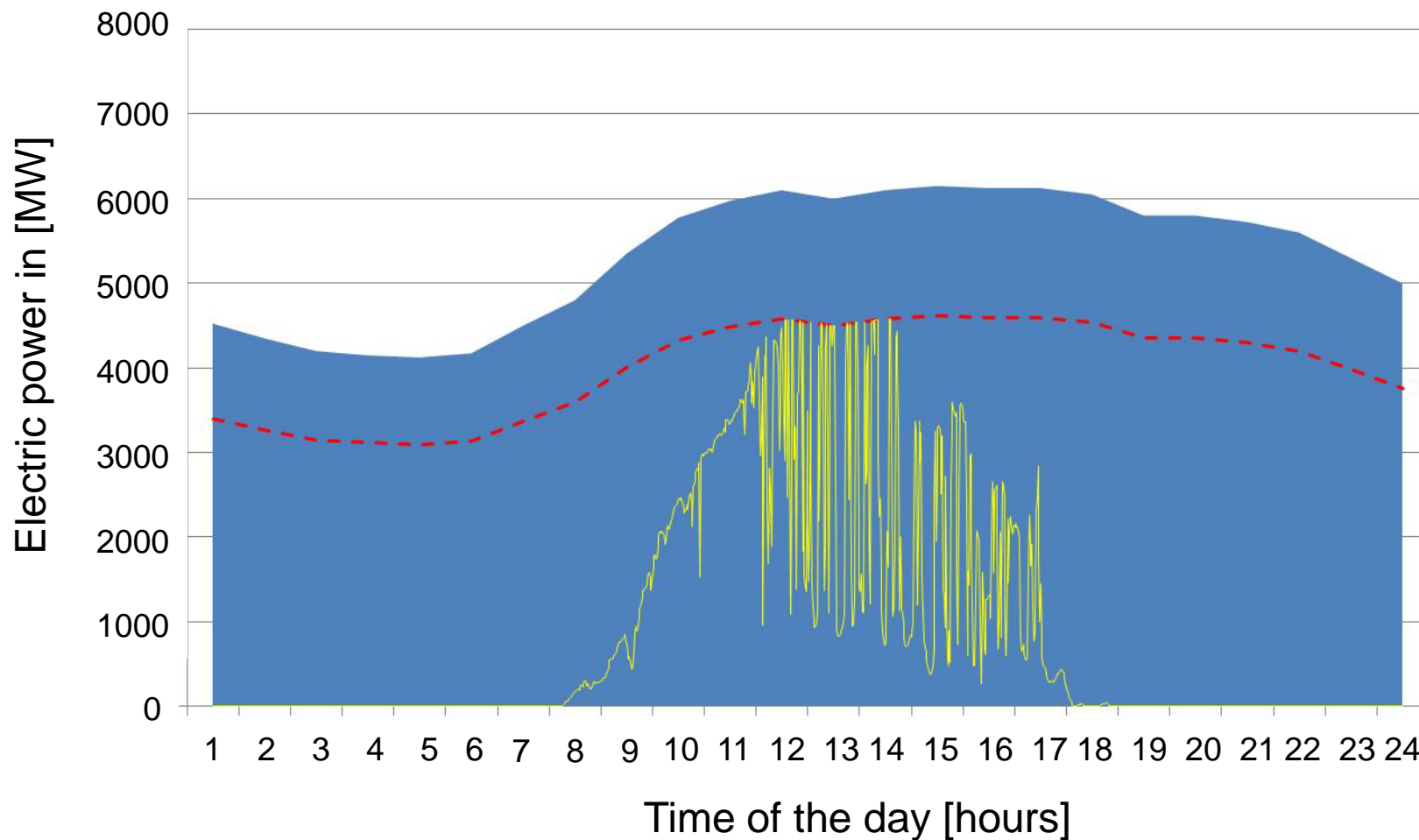


Source: DTMC consulting 2011

# Outline

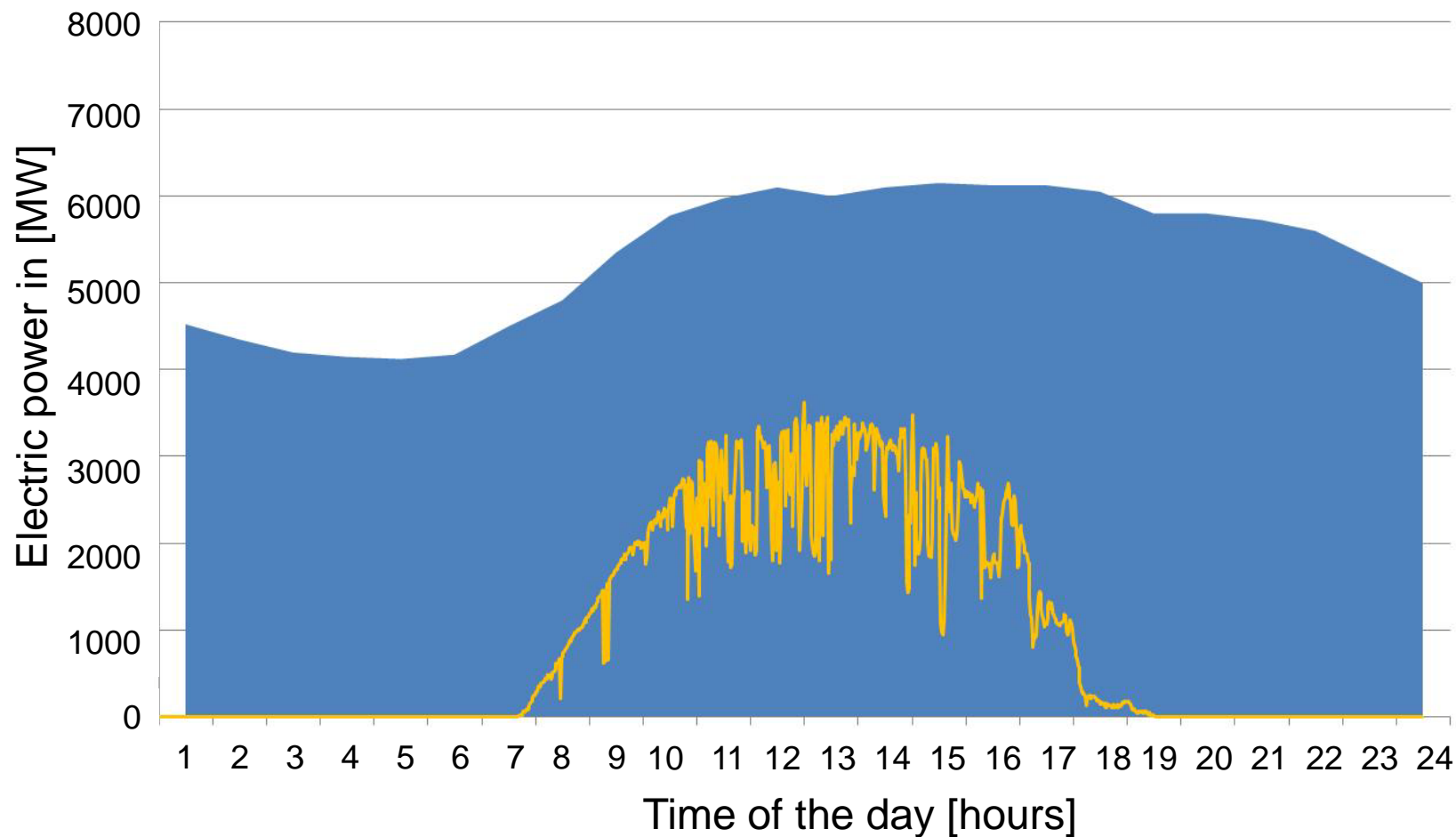
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# Curtailing of PV generation, shaving at 75% of the demand



# Leveling out of fluctuations in PV,

lumped minute averages of 10 PV installations in Singapore

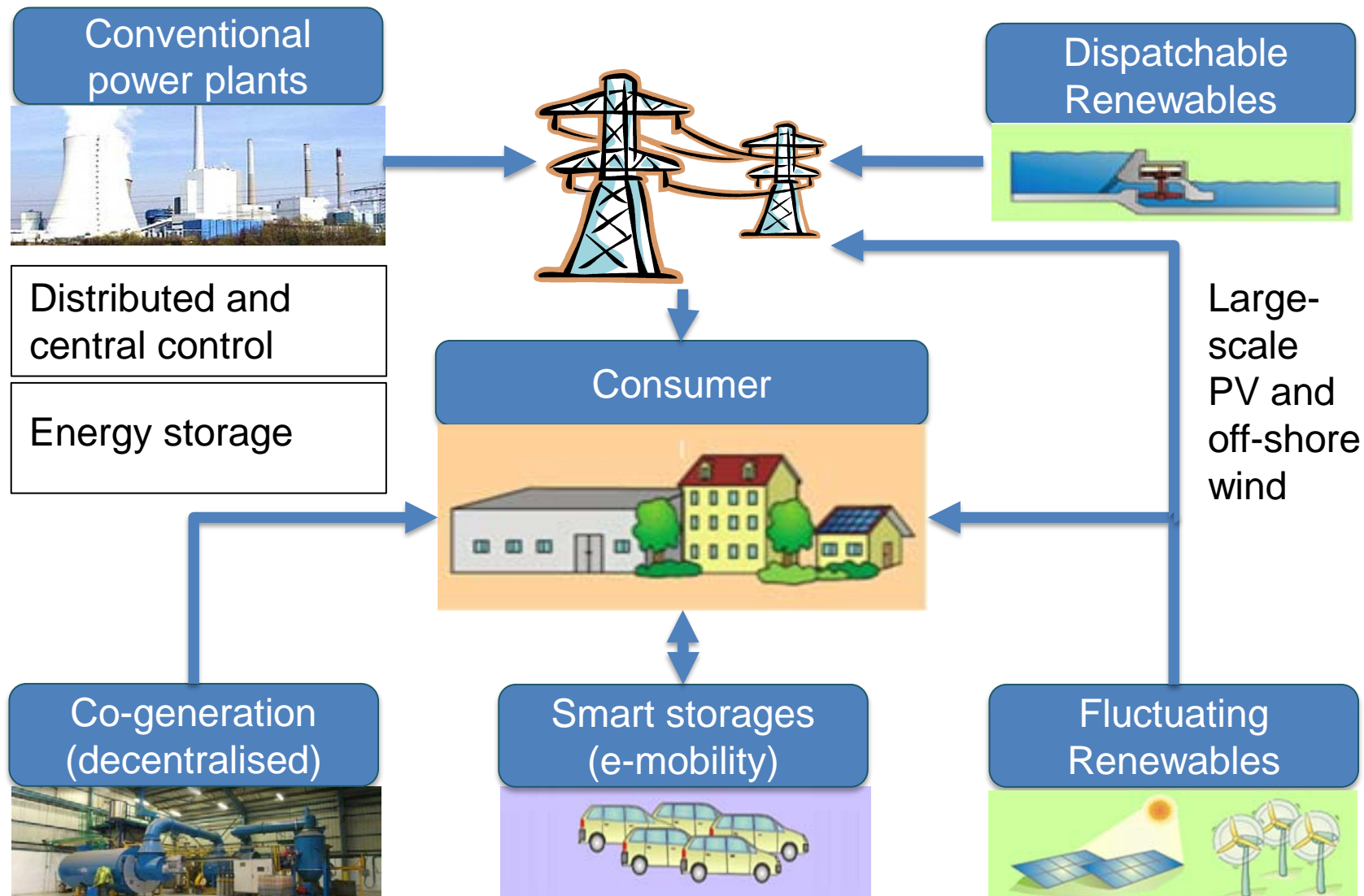


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# New grid architecture and control



# Smart grids, merging of power and information networks



- ❑ Matching demand and generation on a centralised and decentralised level (“smart energy centres”):
  - Control of less time-sensitive loads
  - Temporary storage (e.g. in EV’s)
  - Smart tariffs



- ❑ Large-area grids and inter-woven decentralised “smart energy centres”

# Smart grids

merging of power and information networks (cont'd)



- ❑ “Intelligent” power electronics, i.e. PV inverters to become active part of the power grid:
  - Power output control
  - Active / reactive grid support
  - Fault ride through capabilities

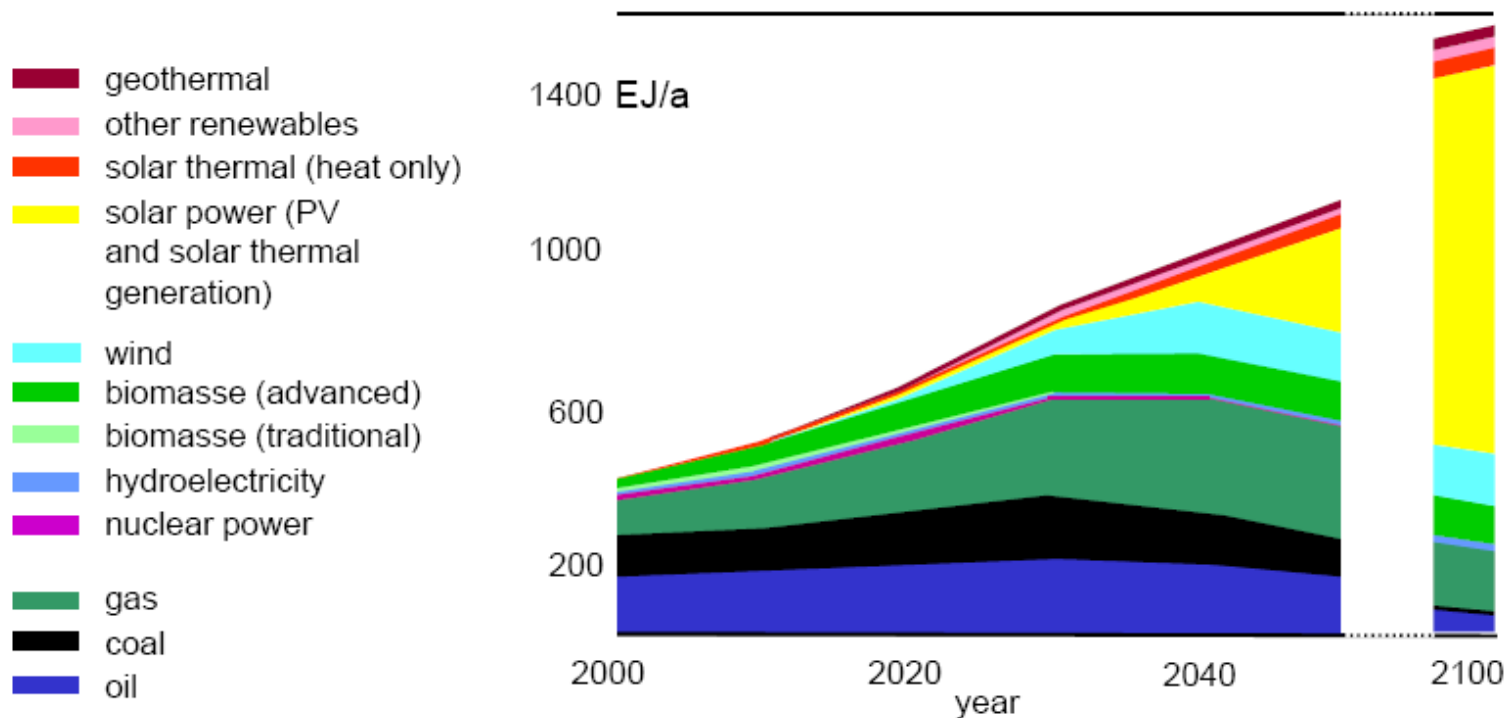
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# Future energy mix

Scenario, 2 °C



Source: German advisory panel on global change, 2003, [www.wbgu.de](http://www.wbgu.de)

# Thank you for your attention!

[www.seris.sg](http://www.seris.sg)