



Energy research Centre of the Netherlands

Transition towards a sustainable energy system: *from fuels to materials*

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Contents

- the transition challenge quantified
- ingredients for the solution
- from fuels to materials: *from the frying pan into the fire?*
- opportunities and challenges for polymers

The challenge quantified

20 ~ 30% emission reduction by 2020...

The challenge quantified

80%+ emission reduction by 2050

The challenge quantified

or: 100% of energy-related emissions

The challenge quantified

10 years left to reverse historic trends

The challenge quantified

2.5 kW primary energy 24/7 p.p.

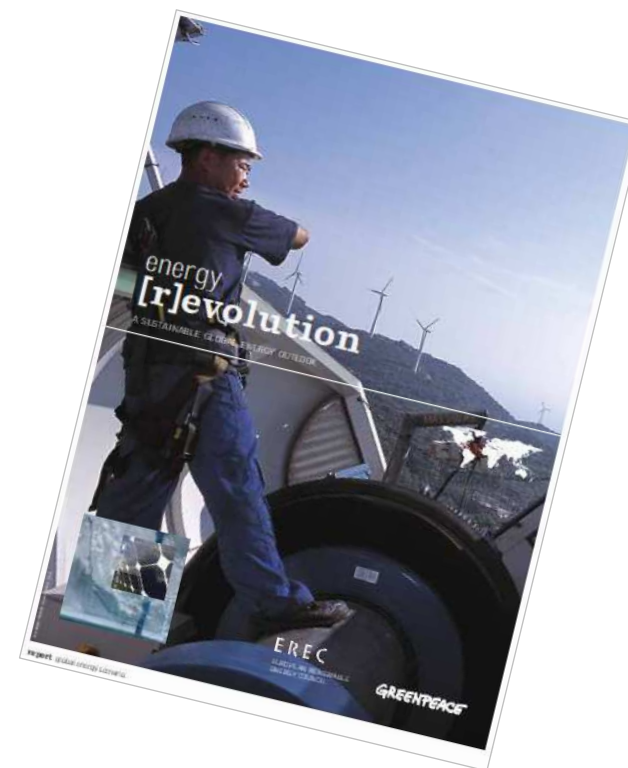
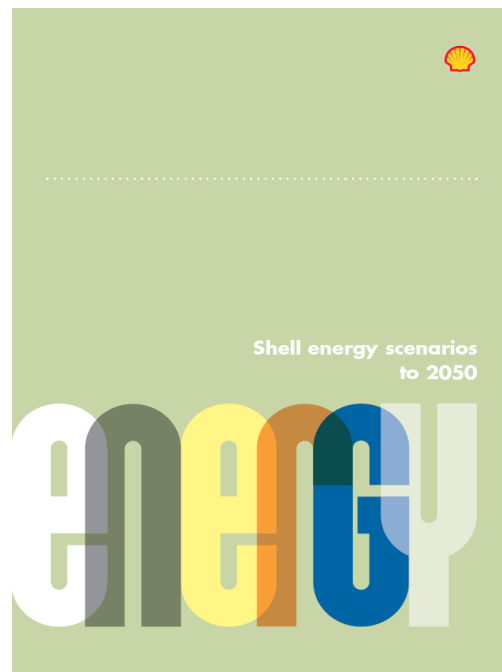
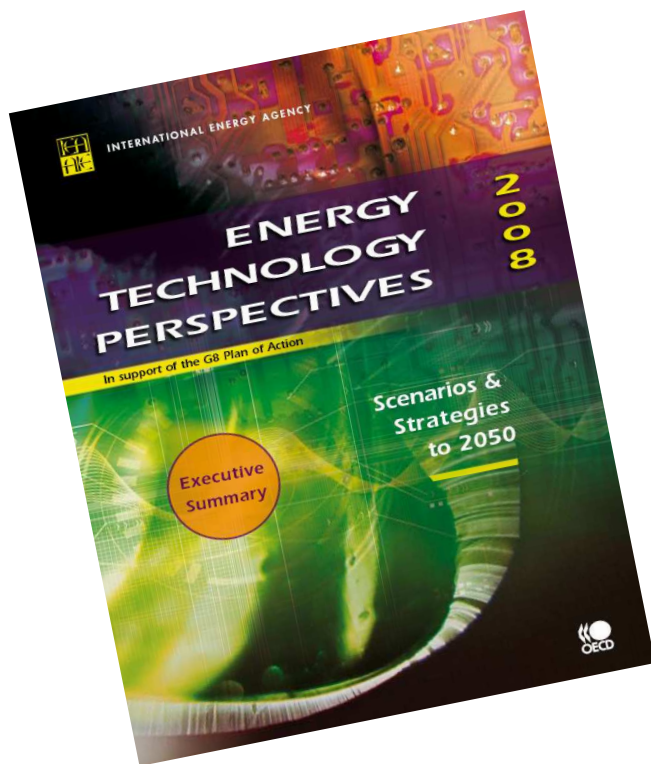
The challenge quantified

6 kW p.p. in NL

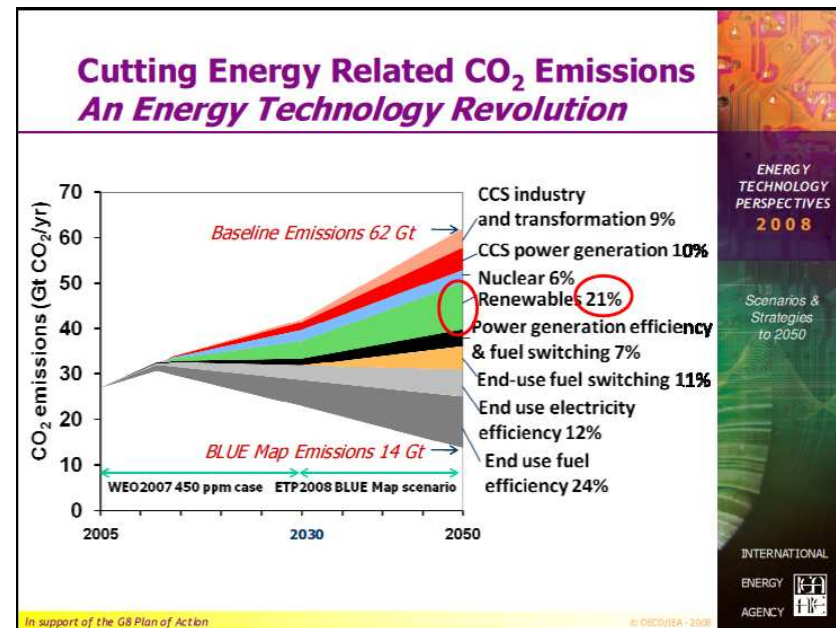
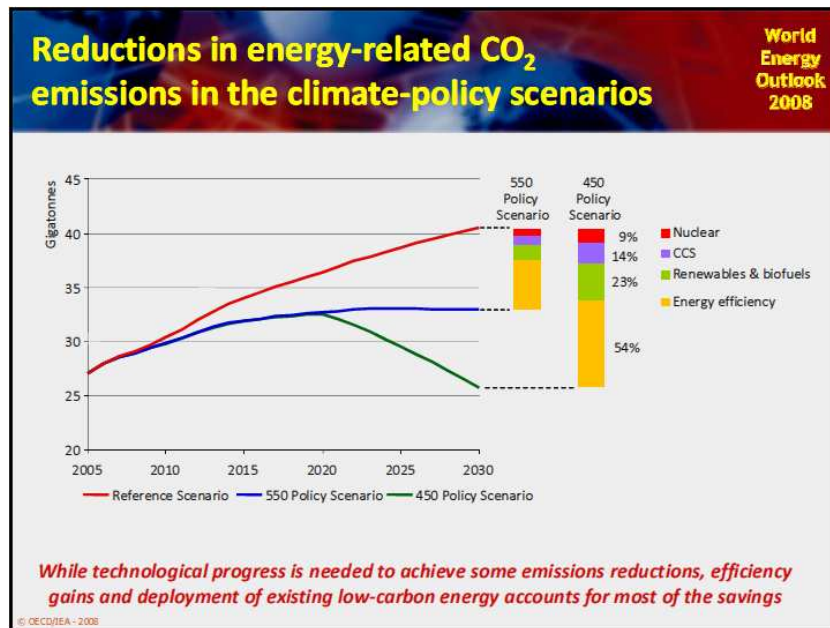
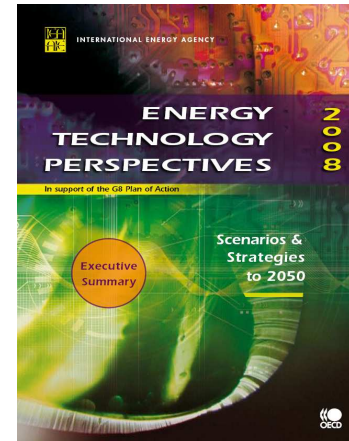
The challenge quantified

10 kW p.p. in USA

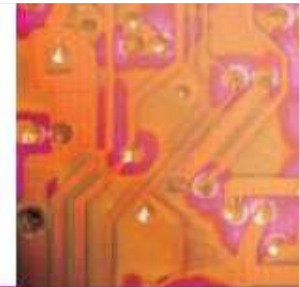
Some views on the future of our energy supply



World CO₂ emissions



Growth of Renewables in BLUE Map

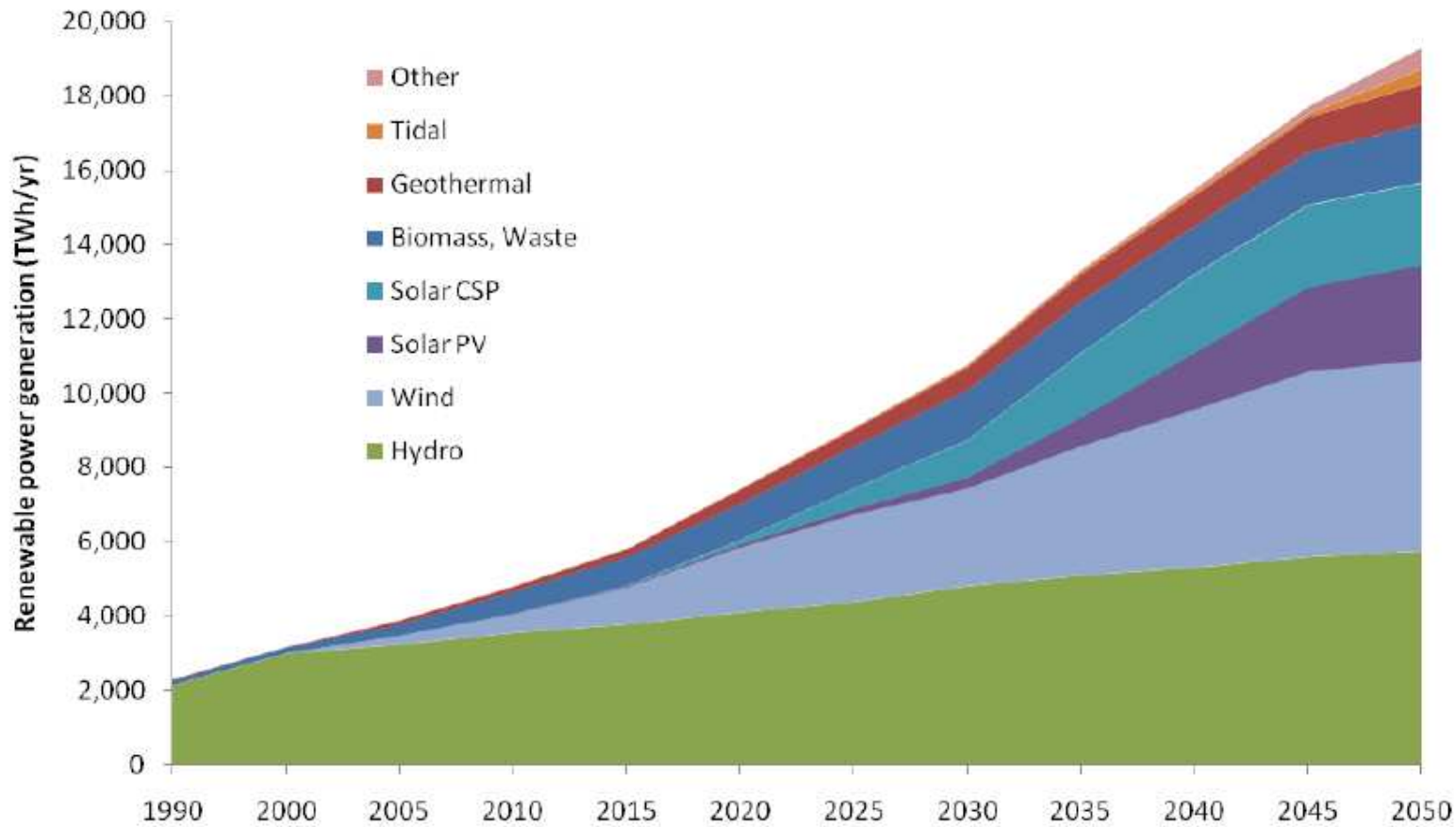


ENERGY
TECHNOLOGY
PERSPECTIVES
2008

Scenarios &
Strategies
to 2050

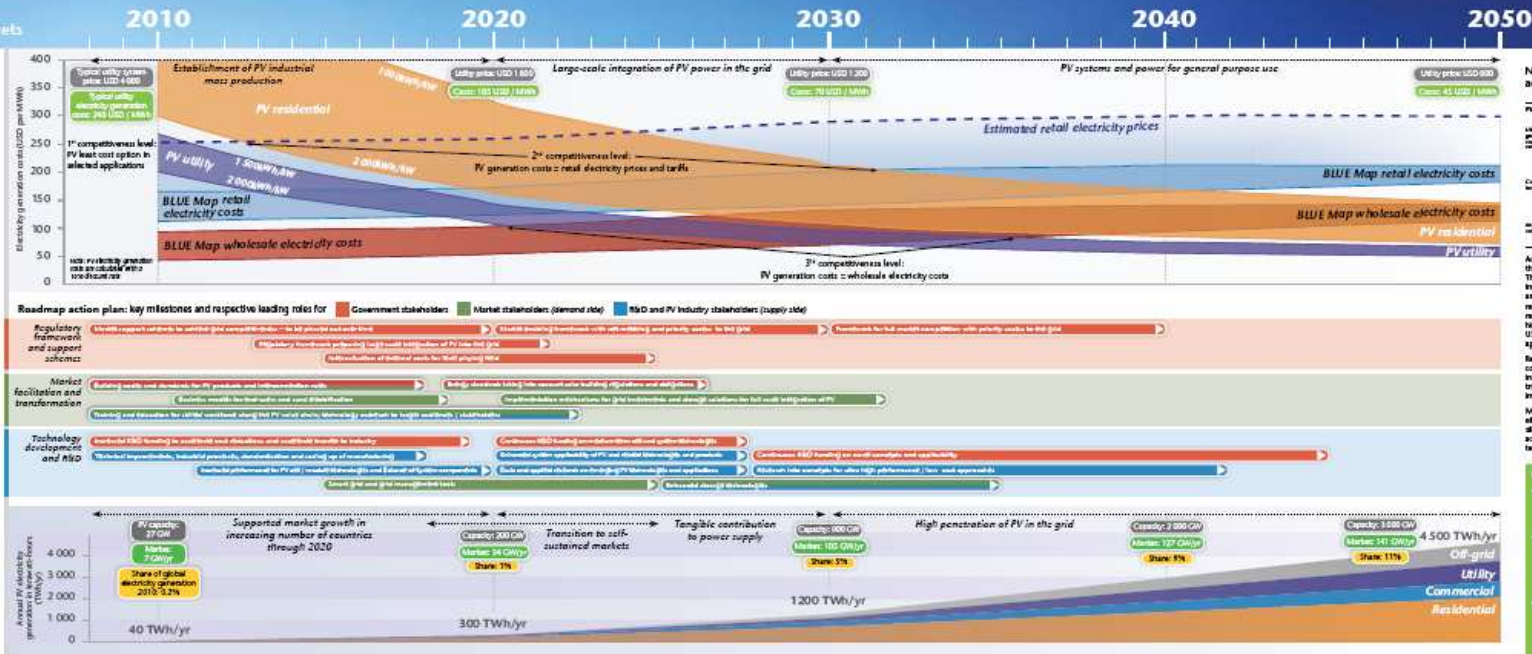
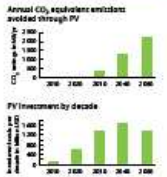
INTERNATIONAL

ENERGY
AGENCY



IEA
Solar PV roadmap targets

- Key findings**
- Solar photovoltaic (PV) power is a cost-competitive and scalable technology with a significant potential for long-term growth in nearly all world regions. This roadmap estimates that by 2050, PV will provide around 11% of global electricity production and reduce 3.2 gigatonnes (Gt) of CO₂ emissions per year.
 - PV will achieve competitive parity with the power grid by 2020 in many regions. Achieving this will require a strong and balanced policy effort in the next decade to allow for optimal technology progress, cost reduction and ramp-up of industrial manufacturing for mass deployment.
 - As grid competitiveness is achieved, the policy framework should evolve towards fostering self-sustained markets, with the progressive phasing out of economic incentives and access guarantees, and sustained R&D support.
 - As PV reaches full-scale industrial production, grid integration and management will become key issues. The PV industry, grid operators and utilities will need to develop new technologies and standards to increase the range of PV into flexible, efficient and smart grids.



Next 10 years: achieving grid parity for PV

Achieving this roadmap's targets will require the rapid expansion of the PV industry by 2020. This will imply a steady increase of annual industrial production up to 34 GW/yr by 2020, and reducing system and generation costs by more than 50% to achieve grid parity in many markets. Typical generation costs in residential markets require will range from 10 - 21 USD cents/kWh depending on the type of application and irradiance level.

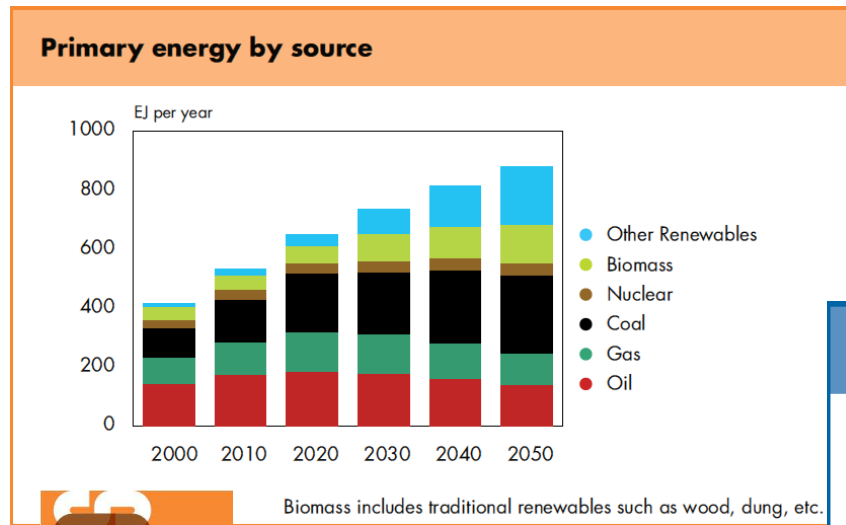
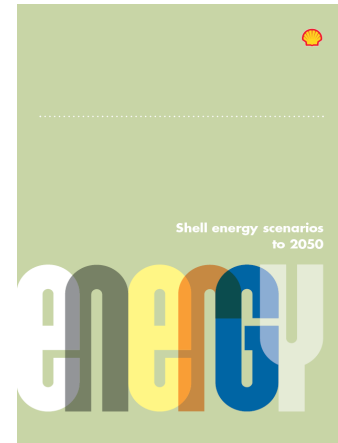
Reaching these goals will require sustained and consistent policy frameworks and incentives in more of countries in order to access markets, trigger investments and foster industrial improvements worldwide.

Moreover, it will be important to sustain R&D efforts. This will allow to improve system integration and the PV system, as well as to accelerate the development of emerging technologies and novel devices.

Key actions 2010-2020

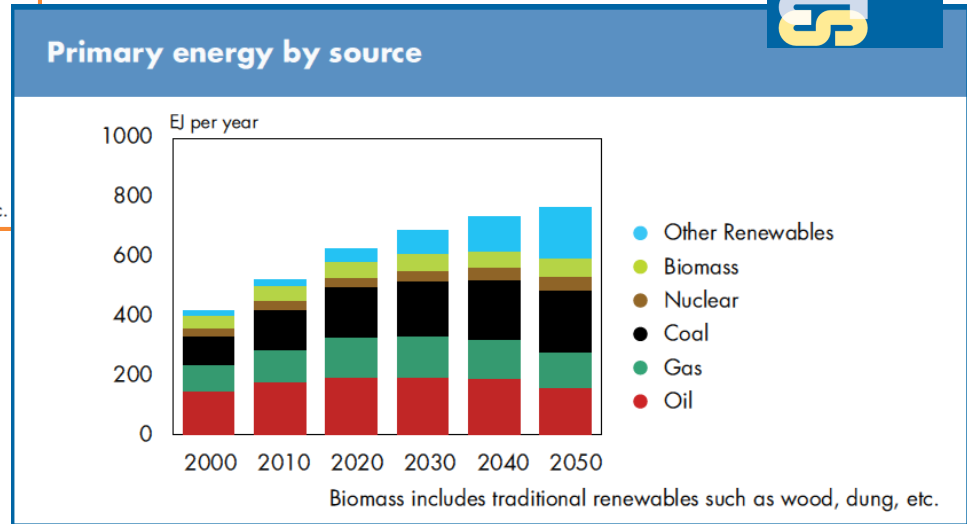
- Provide long-term targets and supporting policies to build confidence for investors in mass electricity capacity and deployment of photovoltaic systems.
- Implement effective and cost-efficient PV incentives schemes and financing mechanisms, respective schemes will be transitional and decrease over time to foster innovation and technological improvement.
- Increase R&D efforts by nation states and ensure PV remains a capital-intensive, while also supporting long-term breakthroughs.

World energy consumption



Biomass includes traditional renewables such as wood, dung, etc.

CHANGE



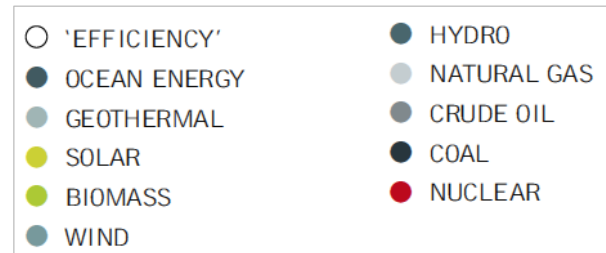
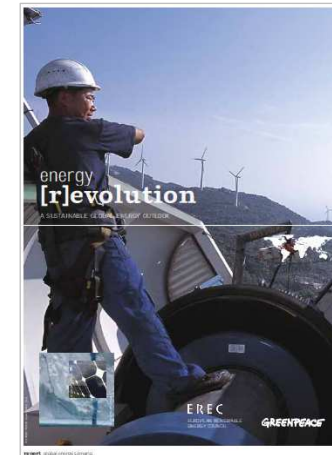
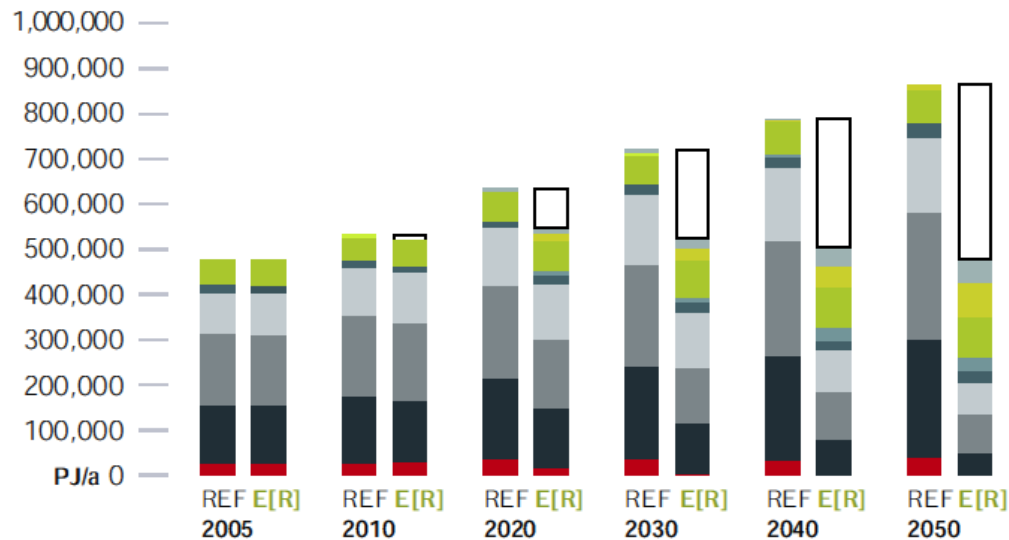
Biomass includes traditional renewables such as wood, dung, etc.

REPORTS

World energy consumption

figure 0.1: global: development of primary energy consumption under the two scenarios

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



World energy consumption

figure 0.2: global: primary energy demand in energy [r]evolution scenario until 2100

FOSSIL FUEL PHASED OUT BY 2095

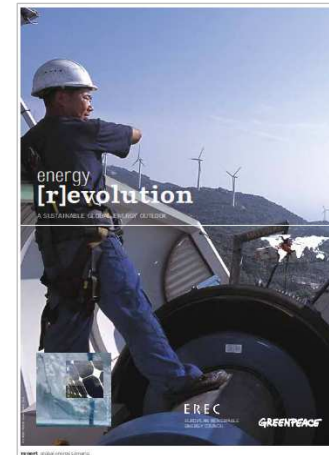
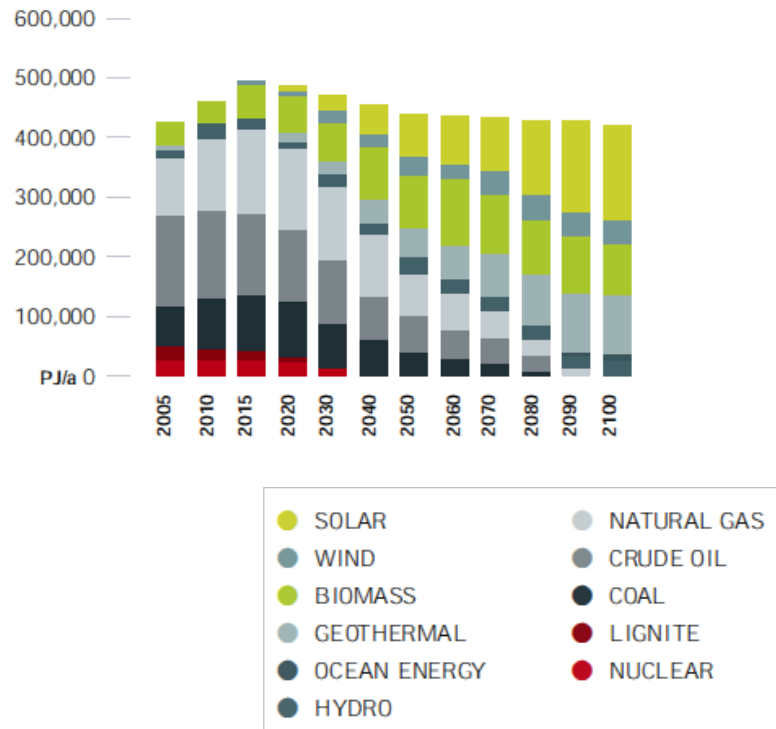
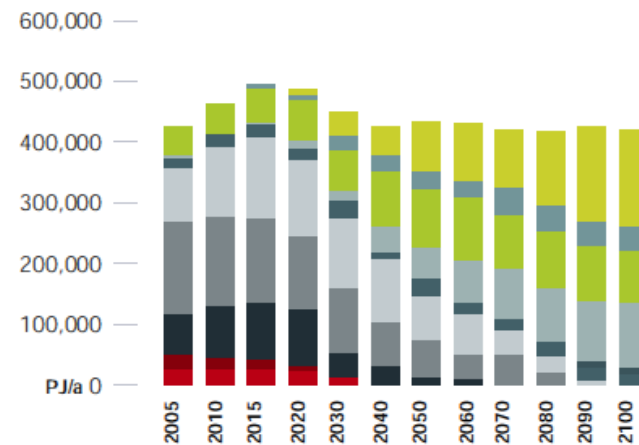


figure 0.3: global: primary energy demand in the advanced energy [r]evolution scenario until 2100

COAL POWER PLANTS PHASED OUT BY 2050



EU Strategic Energy Technology (SET) Plan

- **Technology development in support of 2020 (and 2050) targets**
- **Large-scale, industry-led initiatives per technology area:**
 - e.g. Solar Europe Industry Initiative (PV + CSP)
 - vision: 12% + 3% = 15% contribution to EU electricity by 2020
- **To be financed by industry, member states and EC**

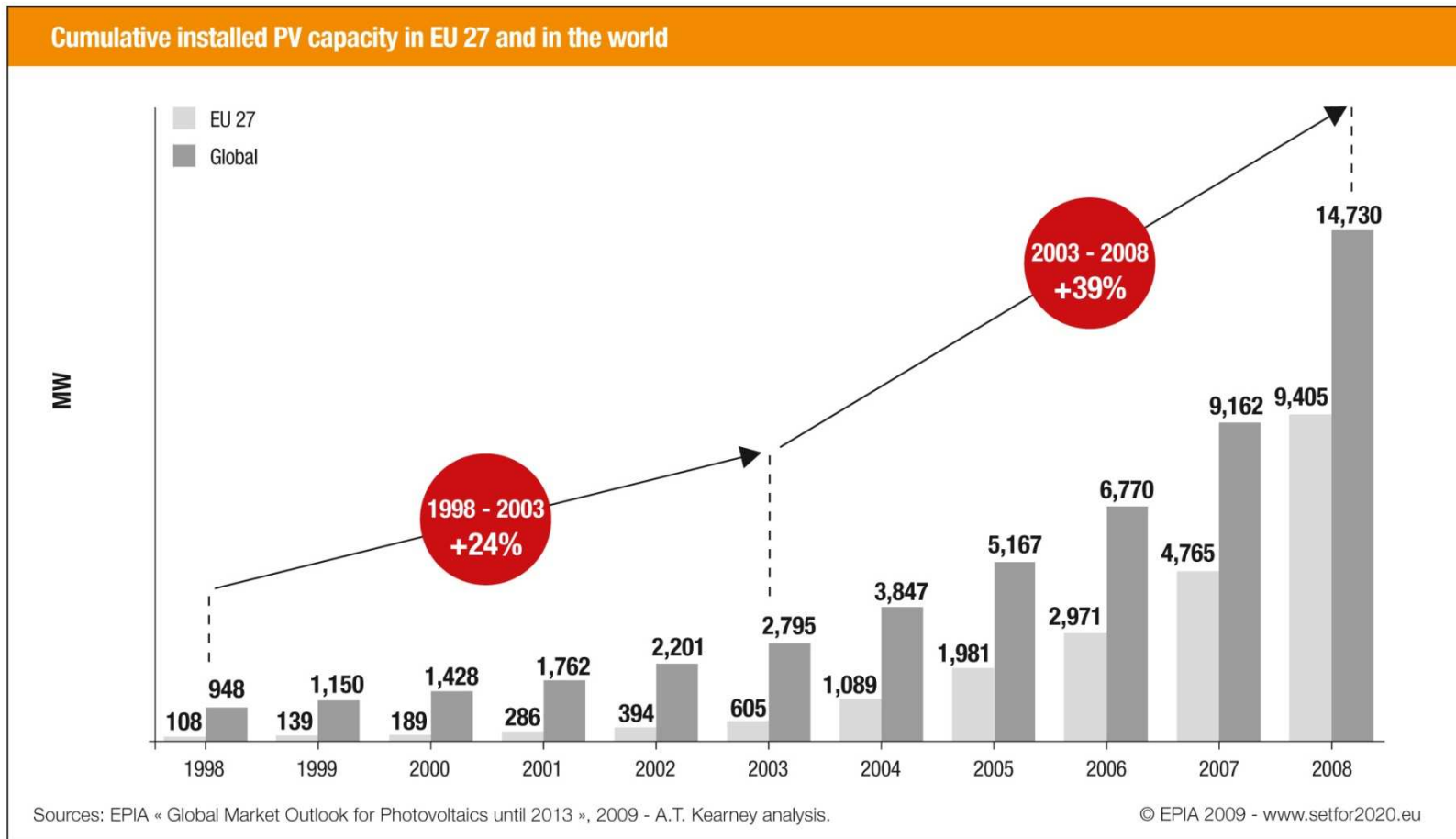


SOLAR EUROPE INDUSTRY INITIATIVE

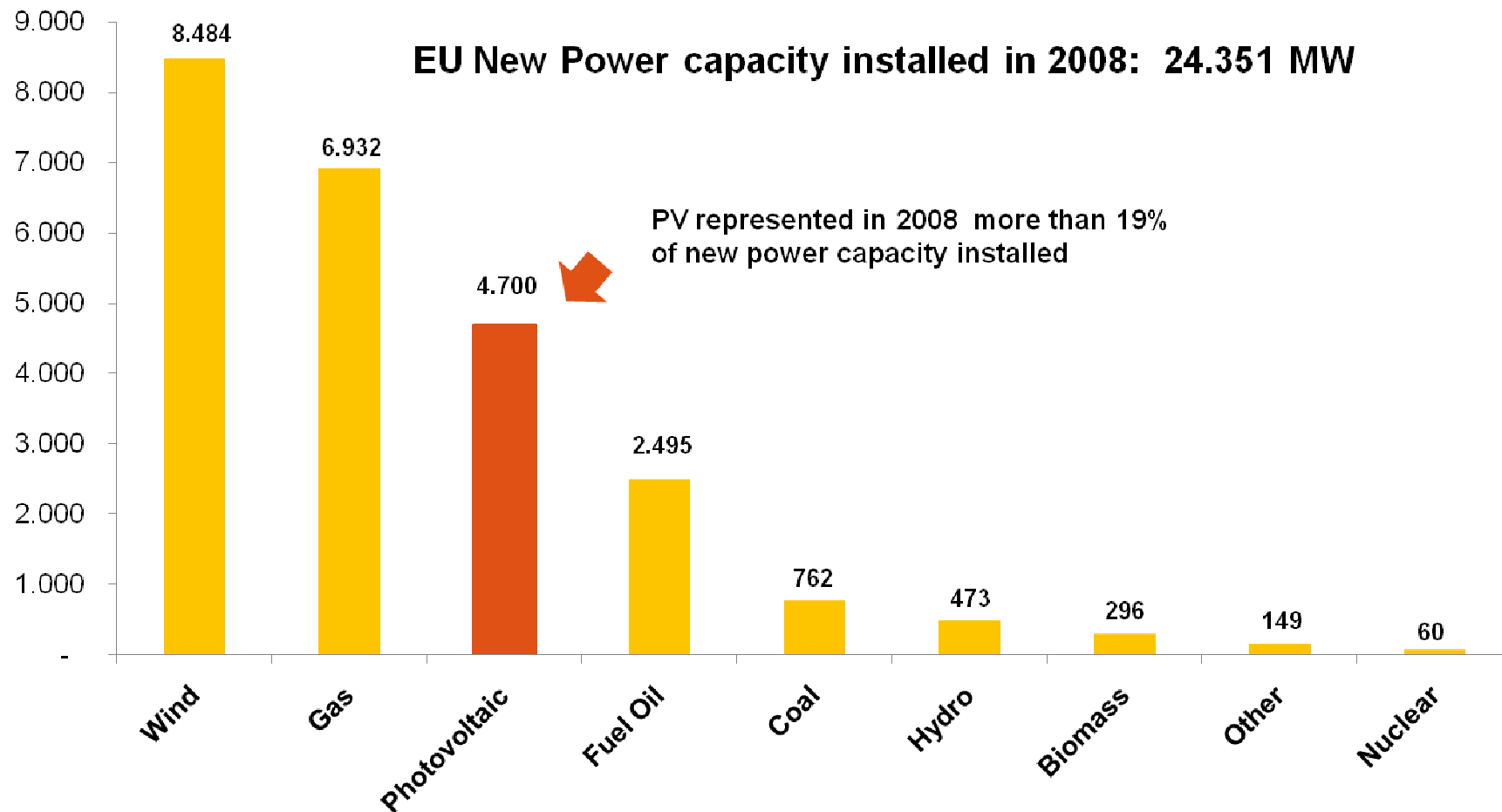
SETTING THE PACE OF THE SOLAR AGE



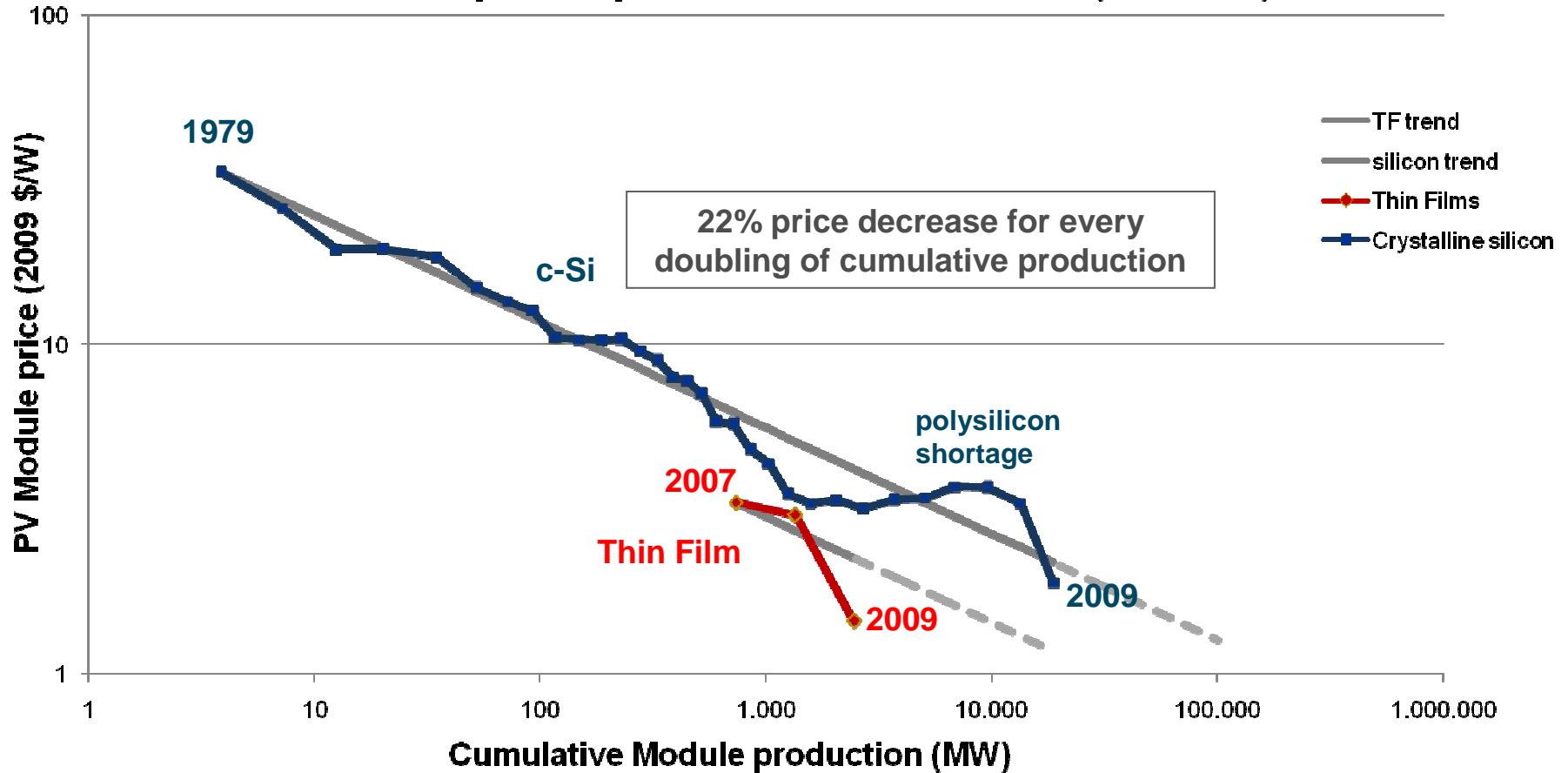
Cumulative PV installations 1998 - 2008



Total global 2008 investments in renewables bigger than in conventional power generation

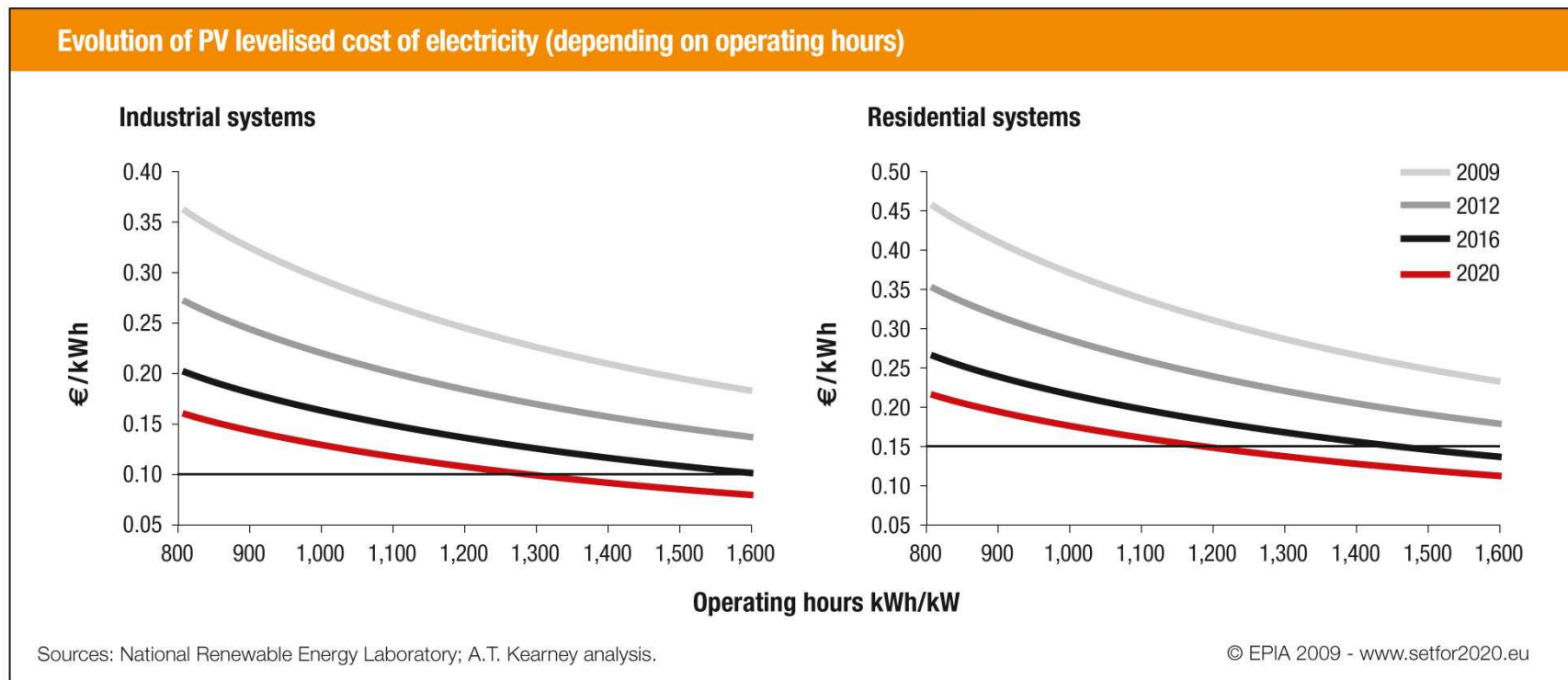


PV Module price experience Curve since 1979 (2009 \$/W)



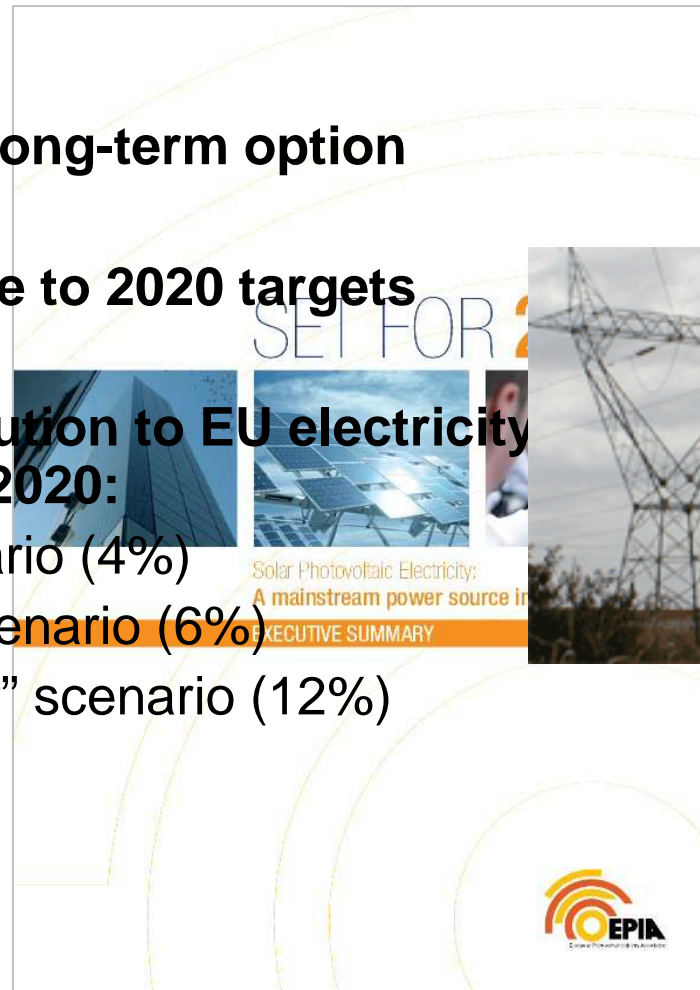
Courtesy: EPIA, October 2009

Generation cost solar electricity to reach grid parity soon



Solar Europe Industry Initiative / SET for 2020

- PV is not *only* a long-term option
- PV *can* contribute to 2020 targets
- potential contribution to EU electricity consumption in 2020:
 - baseline scenario (4%)
 - accelerated scenario (6%)
 - “paradigm shift” scenario (12%)



M. Lippert, SAFT



50

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page 74



January 2008

www.SciAm.com

A GRAND PLAN FOR **SOLAR ENERGY**

By 2050 it could free the U.S. from foreign oil and slash greenhouse emissions. Here's how ...

Nanotech Power

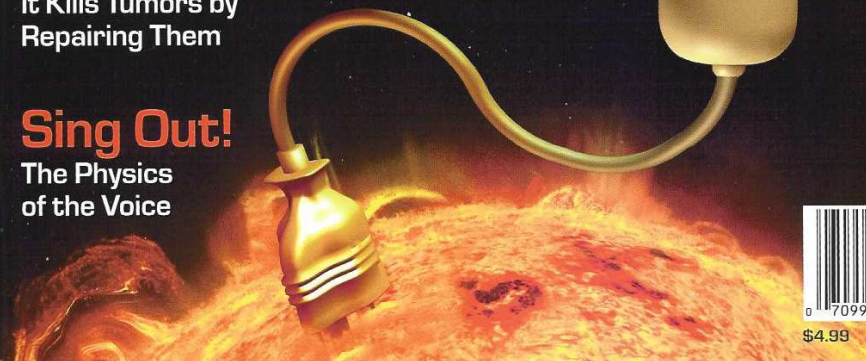
Tiny Devices
Reclaim Wasted Energy

Cancer Drug Paradox

It Kills Tumors by Repairing Them

Sing Out!

The Physics of the Voice



\$4.99



U.S. Plan for 2050

Solar Power Provides ...

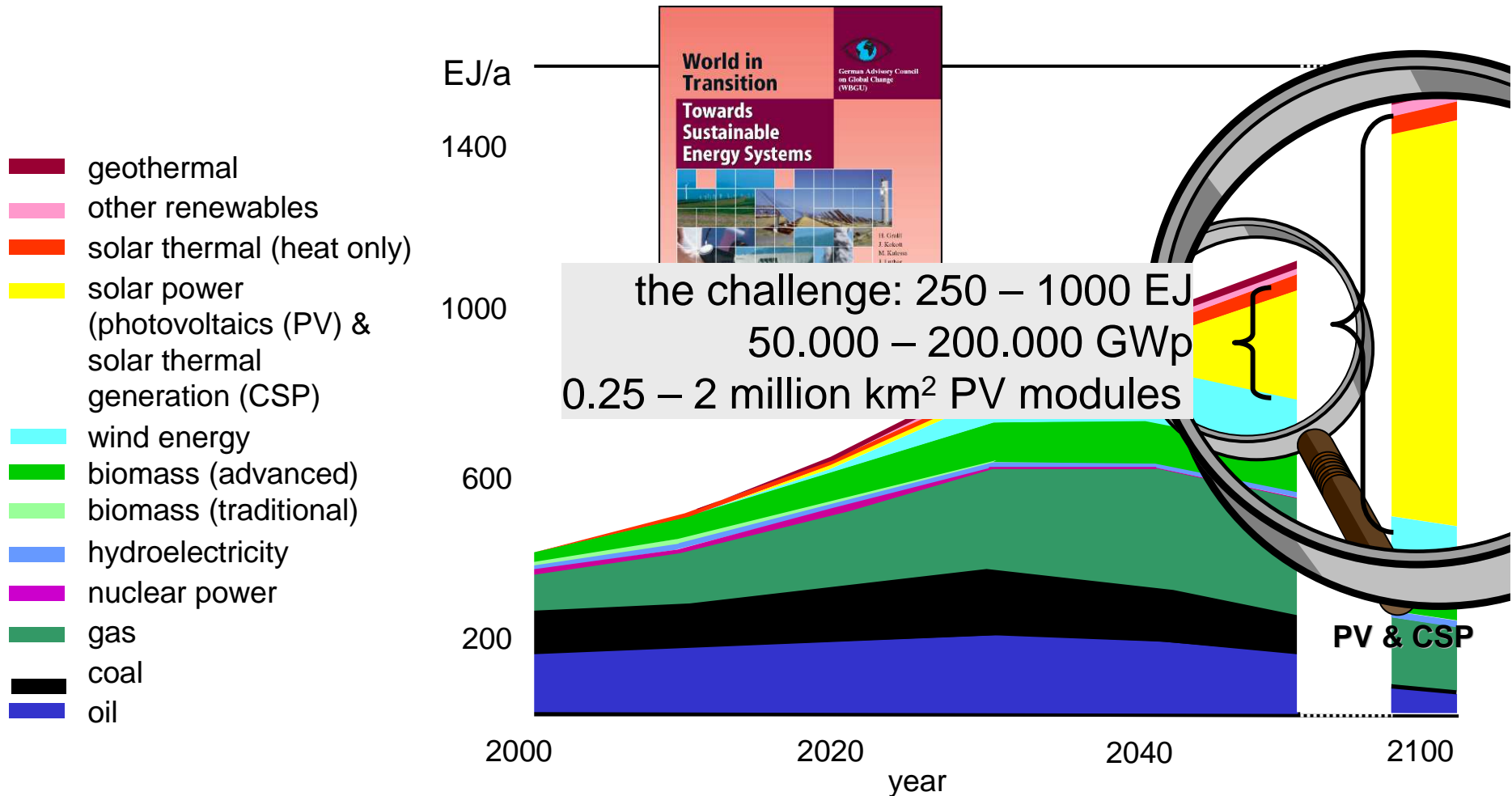
69%
of electricity

35%
of total energy



**Ken Zweibel, James Mason
and Vasilis Fthenakis**

Solar energy in the energy transition



Source: German Advisory Council on Global Change, 2003, www.wbgu.de (example scenario)

**From fuels to materials:
materials consumption for VLSPV (TW scale)**

100,000 km² PV systems (minimum for any impact):

- **0.1 ~ 10 μm conversion layers:** $10^4 \sim 10^6 \text{ m}^3$ (>>10⁴ tons)
- **1 ~ 10 μm conductive layers:** $10^5 \sim 10^6 \text{ m}^3$

(concentrators: $\times 1/_{100} \sim 1/_{1000}$; add optics & trackers)

- **0.3 ~ 3 mm encapsulation layers:** $3 \cdot 10^7 - 3 \cdot 10^8 \text{ m}^3$

+ cabling (Cu, Al ?)

+ support structures (concrete, Fe, wood ?)

Polymers & energy: why polymers?

- **functionality**
- **sustainability**
- **cost**

Polymers & energy (examples)

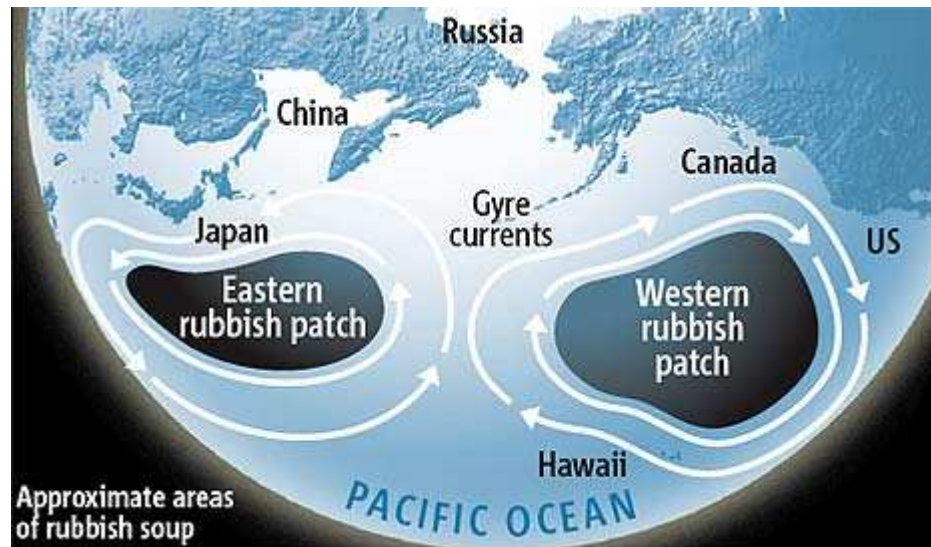
functionality

- *opto-electronic / optical*
 - solar cells & solid state lighting (semiconductors)
 - concentrators (light management)
- *electrochemical*
 - fuel cells & H₂ production (membranes)
 - blue energy (membranes)
- *“physical”*
 - solar energy (encapsulation)
 - blue energy (membranes)
- *mechanical*
 - wind energy (composites for blades)
 - solar energy (framing, support structures)

Polymers & energy

sustainability

- low energy input
- recyclability



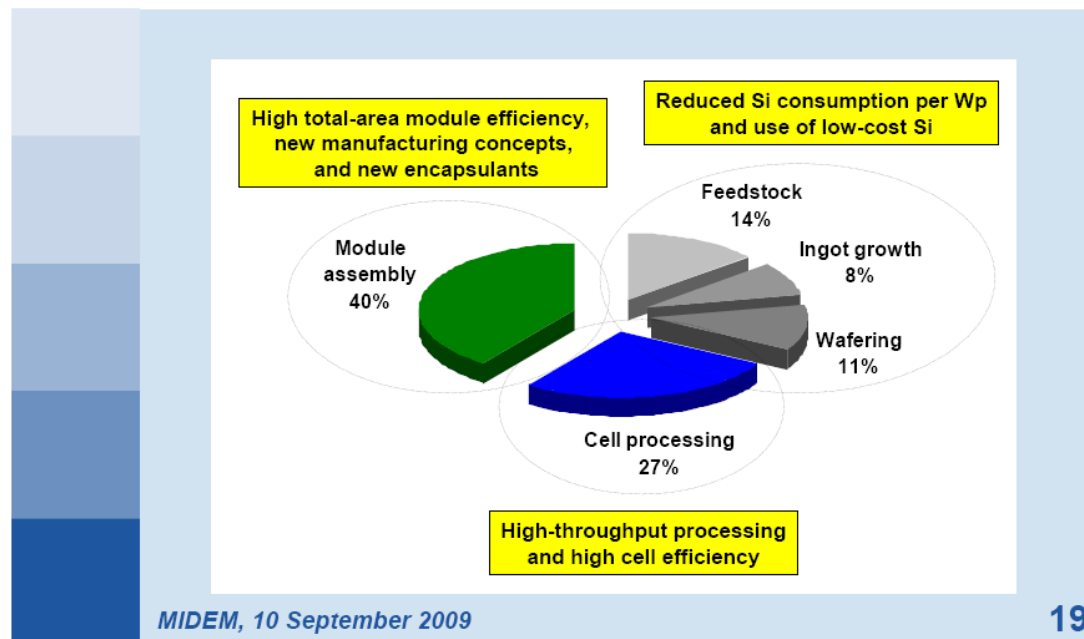
Polymers & energy

cost

- not per kg, but per unit of service delivered

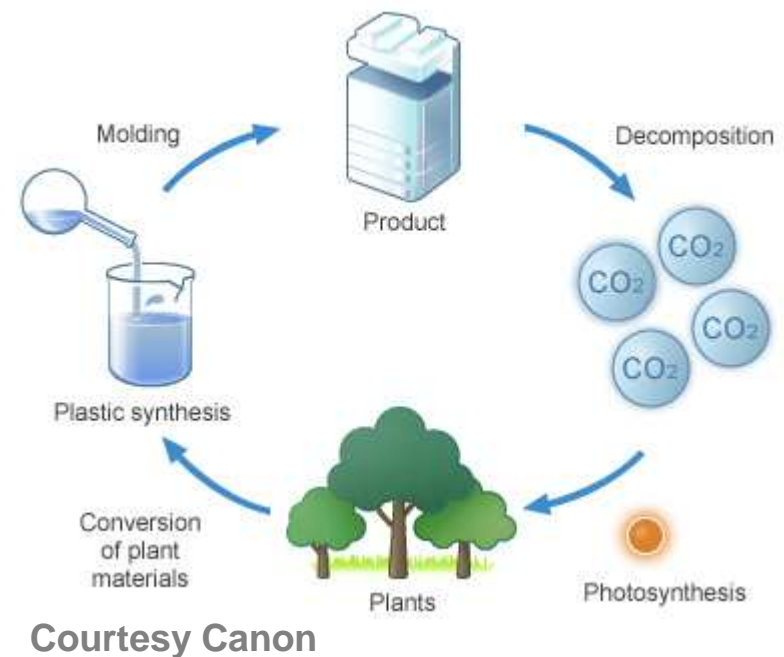


Approaches towards cost reduction wafer-based silicon PV modules



Polymers & energy: challenges

- high performance at low cost
- long lifetime / small degradation of functionality
- alternatives for fossil-fuel-based feedstock
- recyclability of composites and mixed materials



In conclusion

Polymers are indispensable for the energy transition

Major challenges remain to be addressed

Opportunities for science, technology and application are huge

THANDBERG

THERE MUST BE
A SOURCE OF ENERGY
DOWN THERE

thank you for your attention!

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