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The policy drivers of photovoltaic industry growth in California, Germany, and Japan

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Motivation

Why did I choose photovoltaic industry in California, Germany and Japan?

- Among clean energy technologies, PV is the one that shows a wide spectrum of innovation paths.
- PV shows good opportunities for cost reduction thanks to learning curve effects.
- PV is good even without direct irradiation, for on-grid or off-grid applications, for distributed generation systems, and it is scalable.
- California, Germany and Japan are the first to invent, develop and deploy PV technology and their national PV companies are among the leaders of the photovoltaic market.

Outline

- Objectives and methodology
- Who triggered the PV market growth?
- The reasons for Californian success
- The reasons for German success
- The reasons for Japanese success
- The impact of technology and energy policies on PV companies' performances
- Policy results
- Conclusions
- Acknowledgements
- Sources

Objectives and methodologies

- This thesis aims to investigate the policy drivers to technological change and the good performance of the domestic PV companies

  These policy drivers are of two types:
  - ✓ technology-push (a) &
  - ✓ market or demand-pull (b)
- I proceeded by investigating the performance of analyzed countries' PV enterprises and its correlation with national and international technology-push and market- demand-pull policies.
- I joint assessed different action of policymakers and the relation between energy and technology policies and their good or mismatching with the success and failures of the domestic PV industry (Q-Cells, First Solar, SunPower, Suntech, Sharp).

a) Technology-push policy

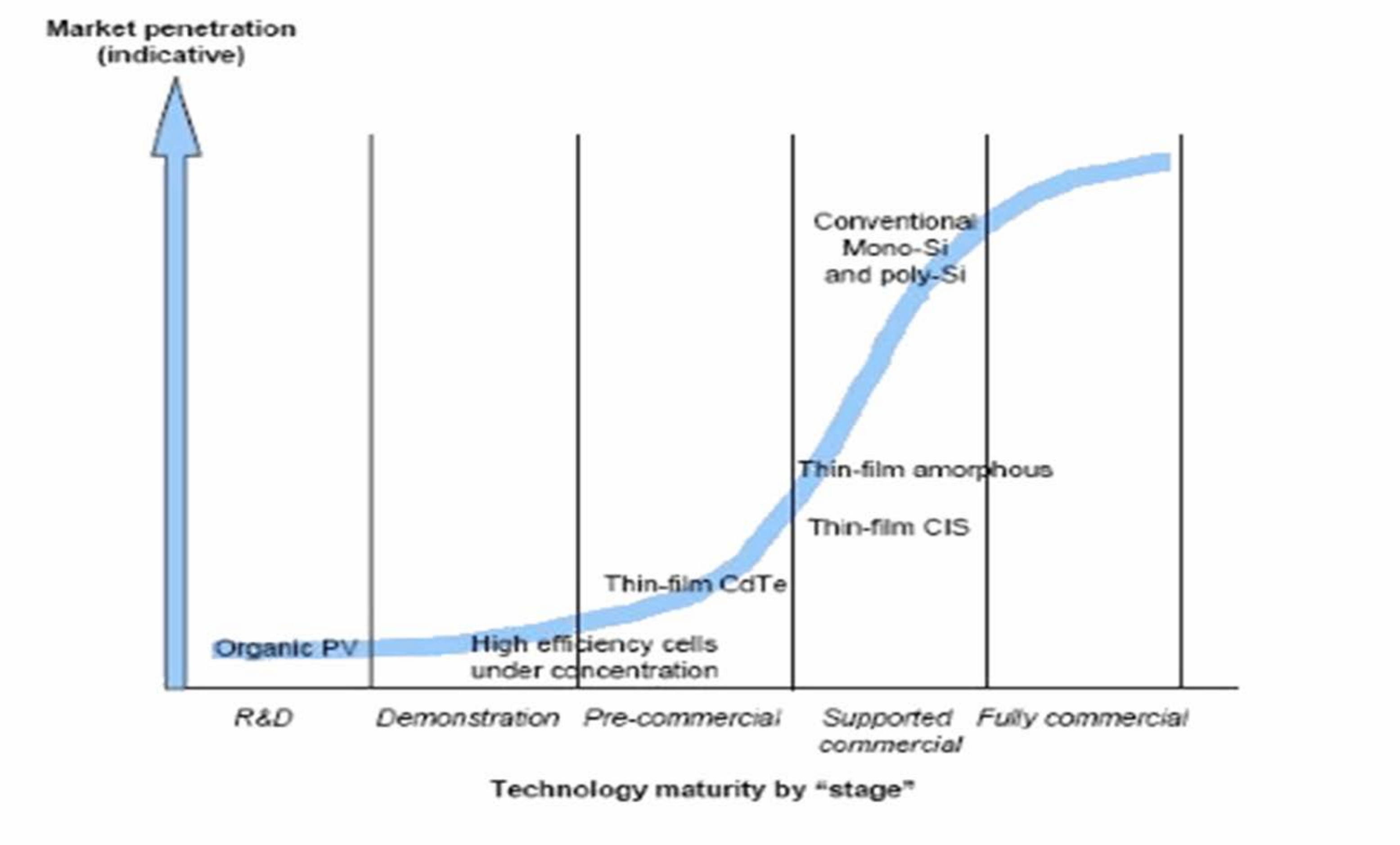
- Stimulates technological innovation and private investments

- It is addressed to research institutions and the *supply side*: PV manufacturers

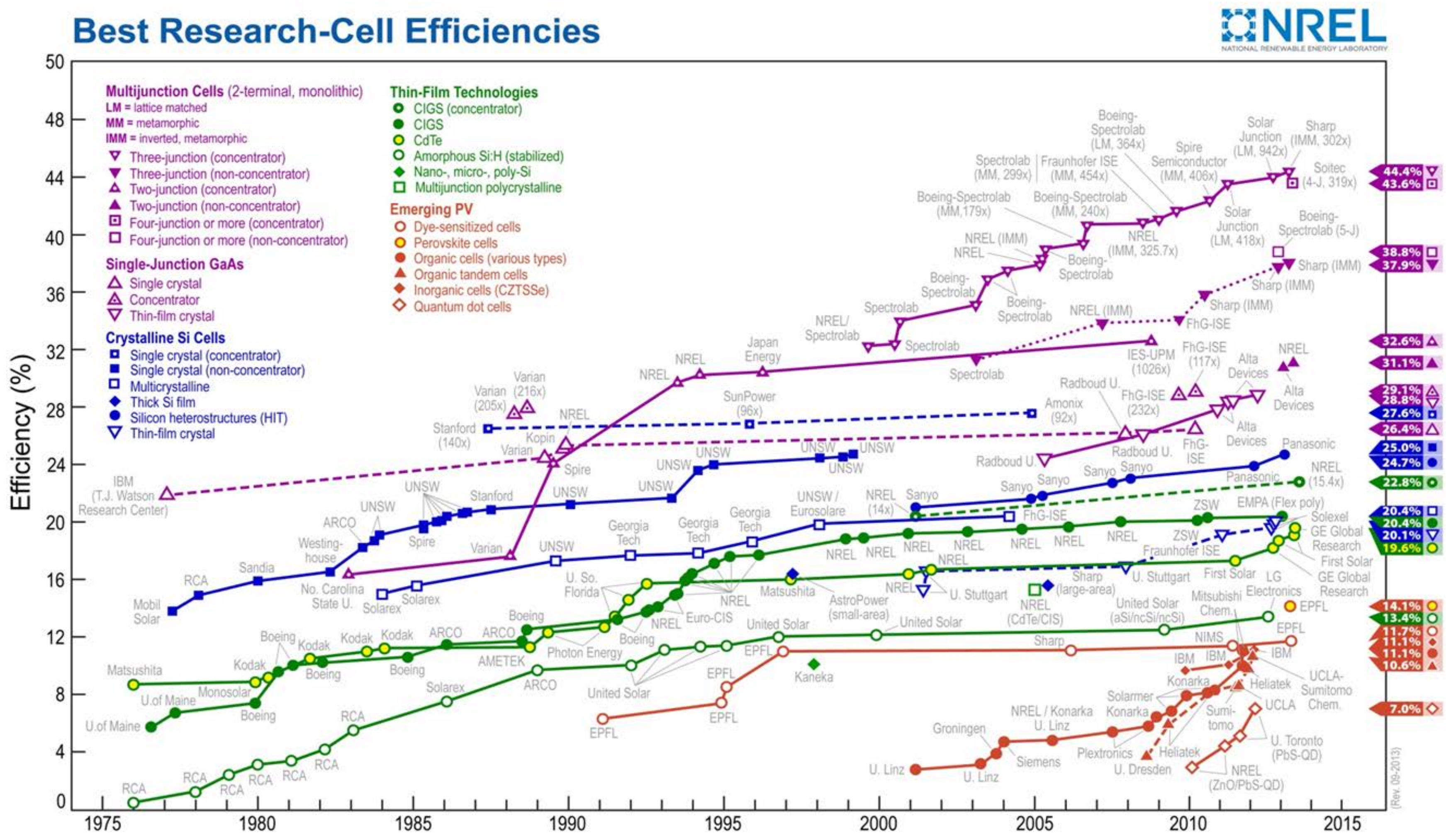
- It is made of direct and indirect policies:

  - ✓ Direct policies are: RD&D funding to universities, research centers, national research laboratories, and private companies (PPPs).
  - ✓ Indirect policies are: RD&D tax credits; demonstration projects, public procurement, patent protection.

The PV technology S-curve



PV cells' best efficiency in labs



Source: NREL 2013

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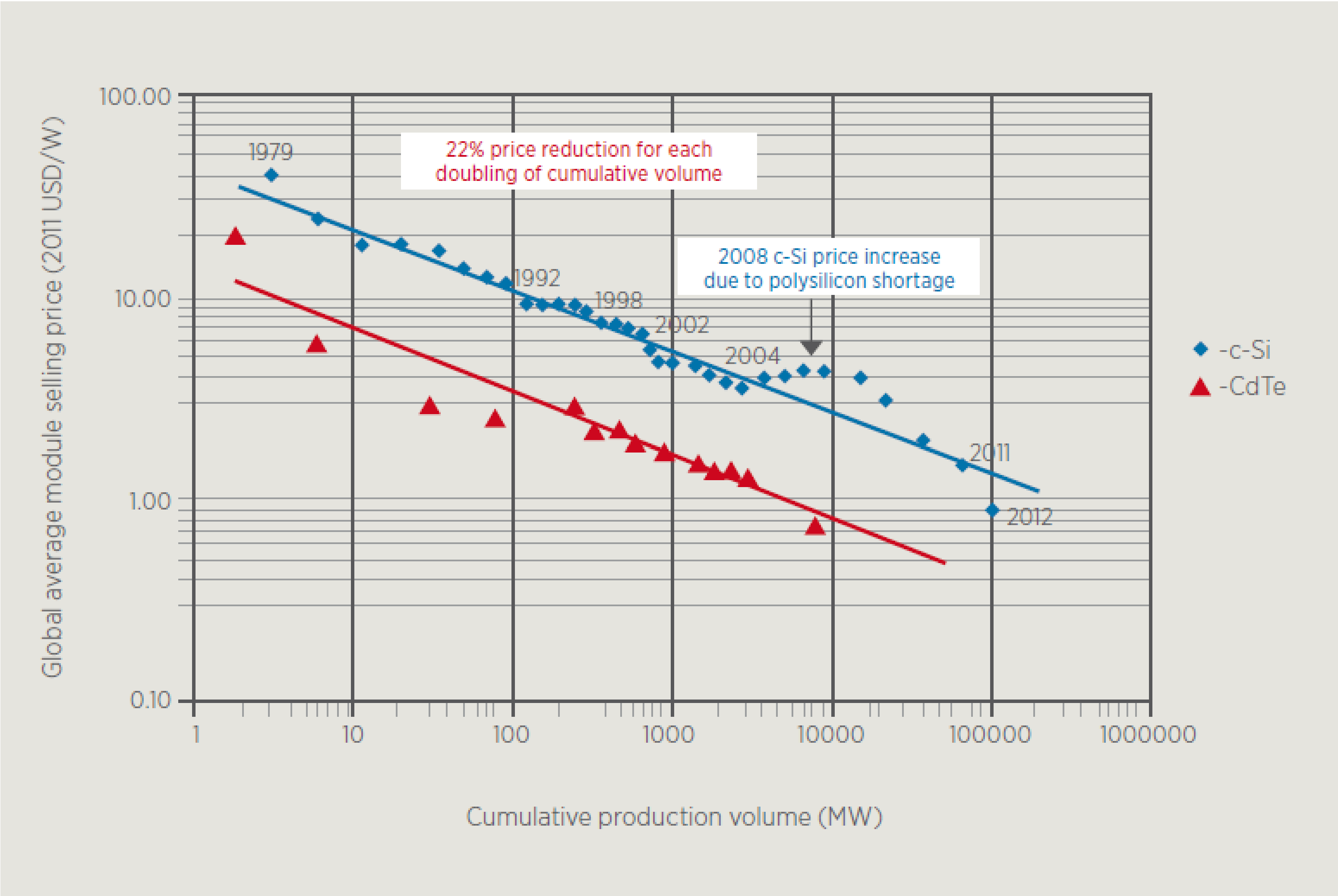
PV modules' learning curve (1)

- The learning curve is an important tool for modeling technical change, informing policy decisions related to energy technology, and guiding firm strategy.
- PV modules have a **learning rate of 22%,** implying that costs will decline by more than a fifth with every doubling of cumulative capacity (IRENA 2013).
- To reduce costs important drivers, other than cumulative capacity, are:
  - ✓ Expected future demand
  - ✓ Knowledge spillovers from other sectors
  - ✓ RD&D
  - ✓ Growing investments

PV modules' learning curve (2)



Source: IRENA 2013

b) Market- or demand-pull policy

- Creates market conditions that are attractive for the exploitation of PV technologies.

- Is addressed to the *demand side*: renewable electricity producers and consumers:

  - ✓ **Renewable Portfolio Standards:** Quota system
  - ✓ **Feed-in Tariffs:** Incentives to solar generation
  - ✓ Renewable Auction Mechanism: Reverse auction
  - ✓ Net Metering Systems: Incentives to solar generation
  - ✓ Roof Programs: Rebates covering up-front costs for distributed generation

Feed-in Tariffs (FiTs)

FiT laws introduce the obligation on utilities to buy renewable electricity from RE producers at a **fixed price.**

- ✓ Pros: 1. they ensure predictable revenues and a stable investment environment.
  2. they ensure non-discriminatory access to the grids.
  3. they can be targeted to specific technologies.
- ✓ Cons: 1. the overall cost may be high, and there is no incentive for cost reduction.
  2. the cost is passed on through the electricity bills to the consumers.
- ➢ In markets where FiT policies were introduced as reliable and predictable market mechanisms, they have proven to develop a sustainable PV industry (Germany). In markets where the price of electricity is high FiT has not proven to be a very popular policy tool (Japan, California).

Renewable Portfolio Standards (RPS)

It is a command-and-control regulation that places an obligation on utilities to include a **fixed amount of RE** in their portfolios (as a share of their retail sale).

✓ Unlike FiTs that guarantee purchase of a specific type of RE regardless of cost (the price is fixed), RPS programs are not targeted to a specific RE technology, thus **favoring mature technologies.**

✓ RPS tend to allow more **price competition** among RE suppliers and **final lower costs.**

- RPS is a common policy instrument in the US where it applies in 29 States. If the quota is not reached utilities will purchase tradable green certificates on the RE electricity market.

Who triggered the PV market growth?

- Japan in the 1990s: thanks to the New Sunshine Program of 1993 and huge private R&DD investments since mid 1990s. Mainly an export PV market and niche residential PV market in Japan triggered by residential subsidy programs.

- Germany in the beginning of 2000s: thanks to the Renewable Energy Sources Act of 2000 and its following amendments (Feed-in Tariffs).

- California since mid-2000s: thanks to the Renewable Portfolio Standard and the California Solar Initiative.

Who triggered the PV market growth? (continues)

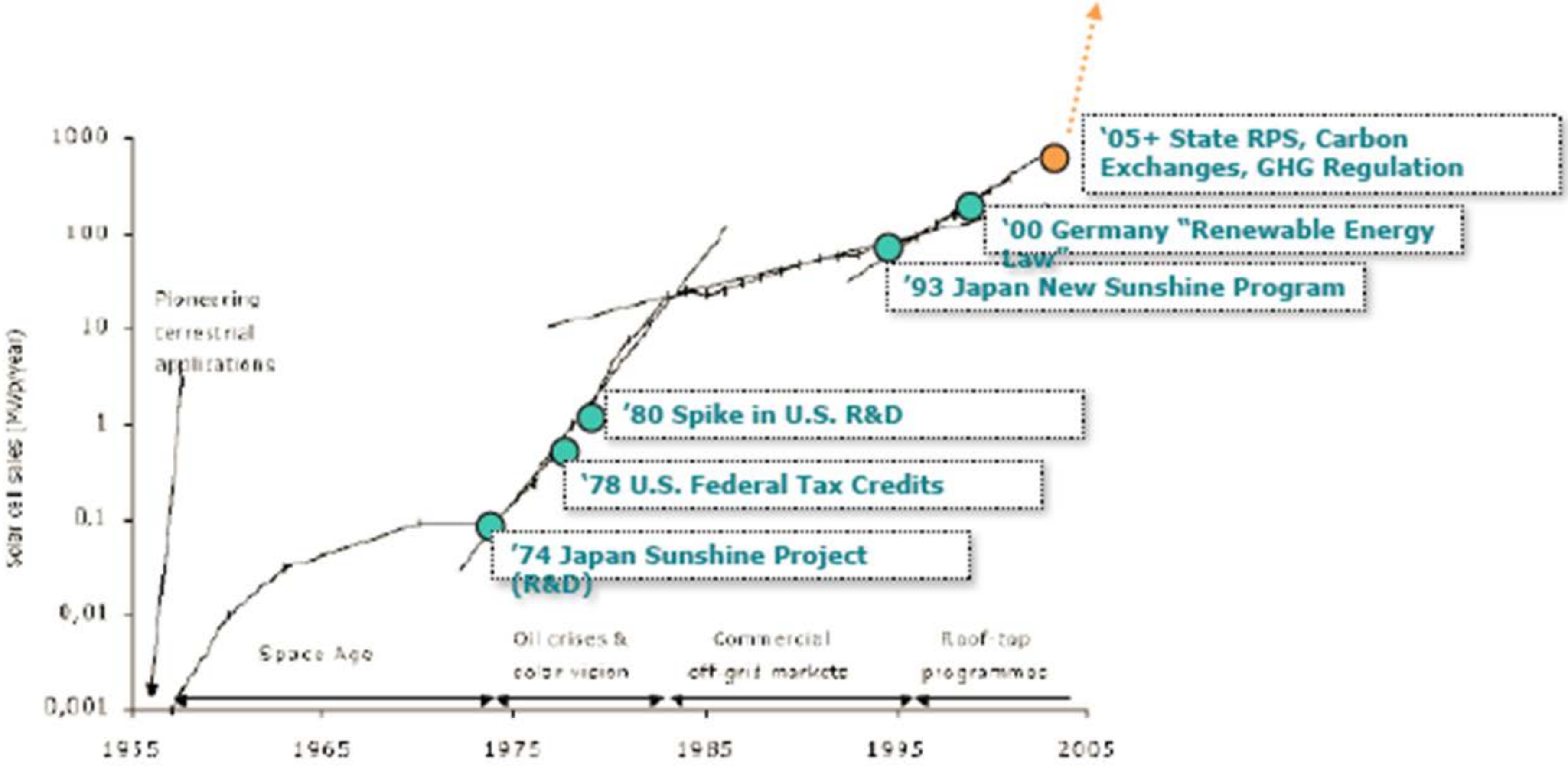


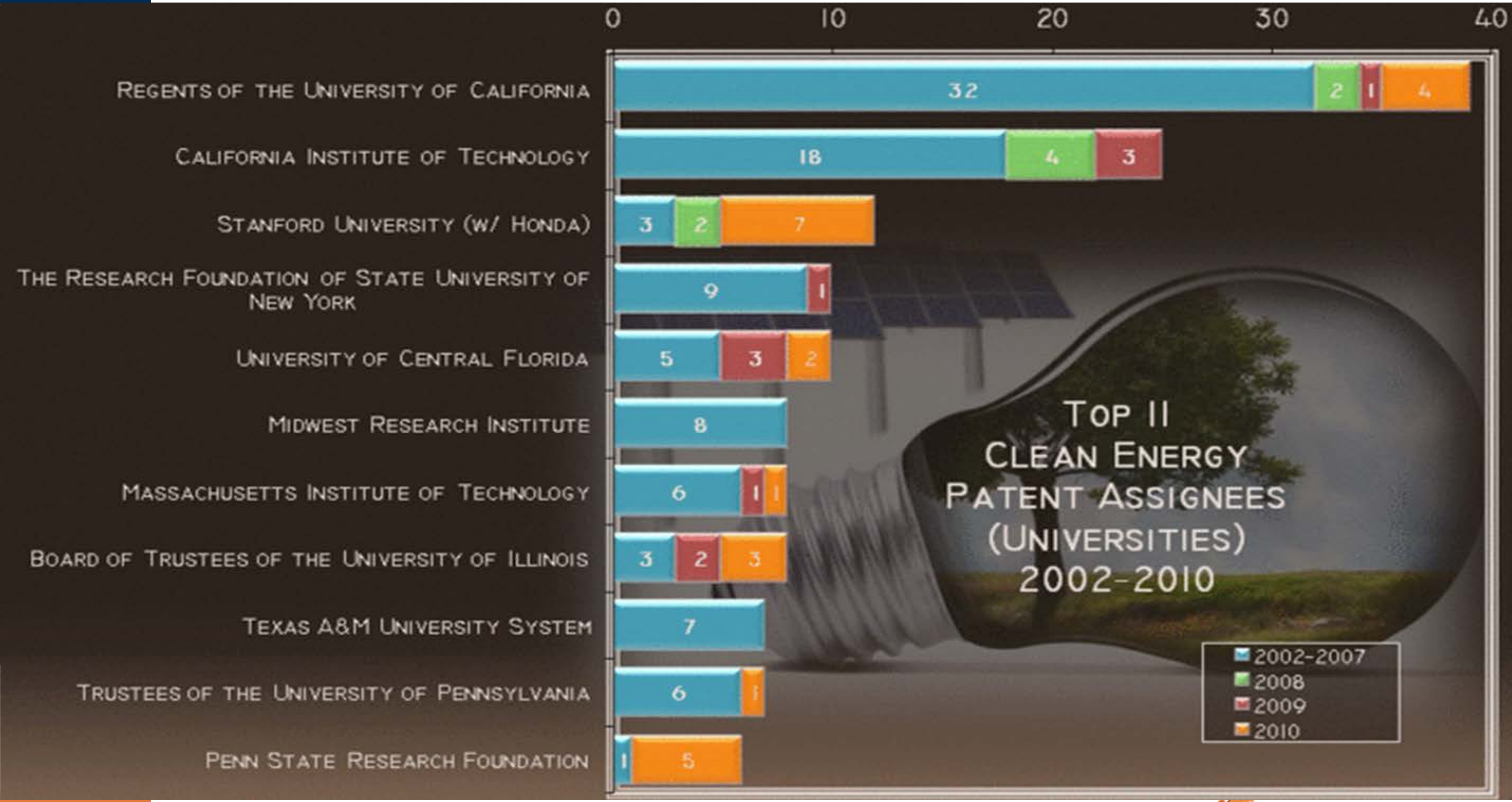
Figure 1. Five phases of solar cell diffusion.

Source: Jacobsson et al., 2004

The reasons for Californian success

- ✓ California receives the **largest amount of federal and private funding** to academic R&D
- ✓ Strong **University-Industry cooperation** (2003-2008 California received 13% of total industry funding)
- ✓ **Top public and private technical universities** (UCBerkeley, Caltech, Stanford)
- ✓ State Laboratories & NREL's PV Incubator Program (3 out of 4 awardees are Californian start-up companies)
- ✓ Business angels & venture capitalists
- ✓ **Stringent RPS targets for all RE: 33% in 2020** (state level)
- ✓ **California Solar Initiative**: state rebate program (2006)
- ✓ Renewable Auction Mechanisms (2010-2012) (utility level)

Top US Clean Energy Patent Assignees Universities (2002-2010)



Source: Clean Energy Patent Growth Index, 2010

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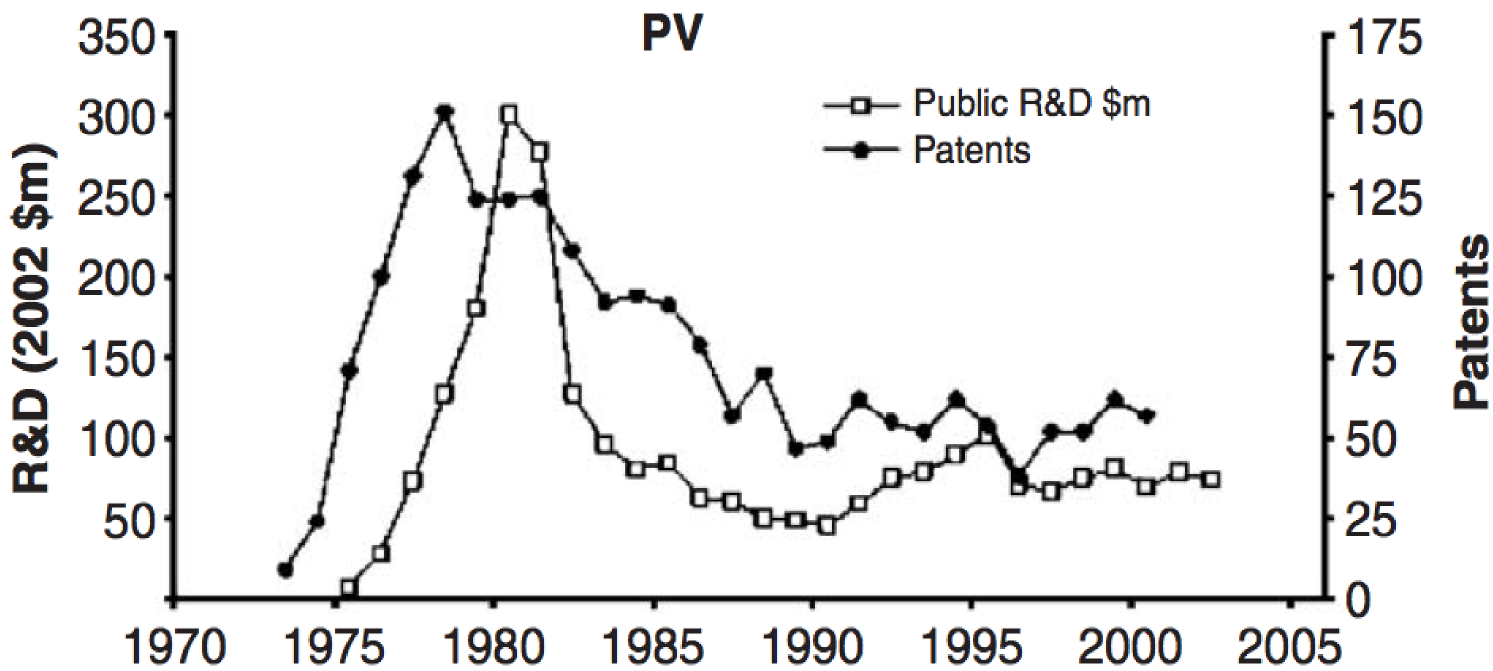
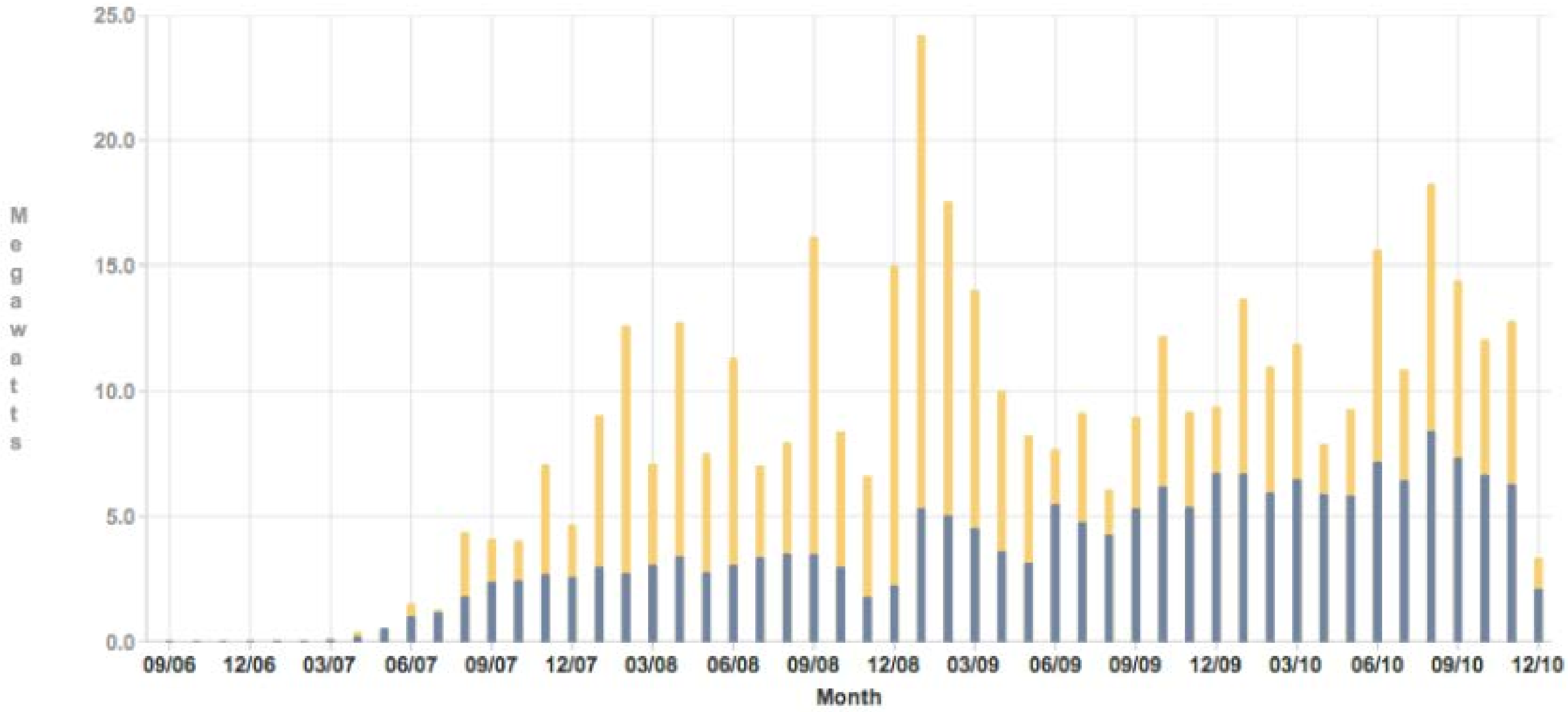
PV patents granted for public R&D investments in the US



Source: Nemet, Kammen, 2007

California Solar Initiative's installed applications (2006-2010)



Bleu: residential installations

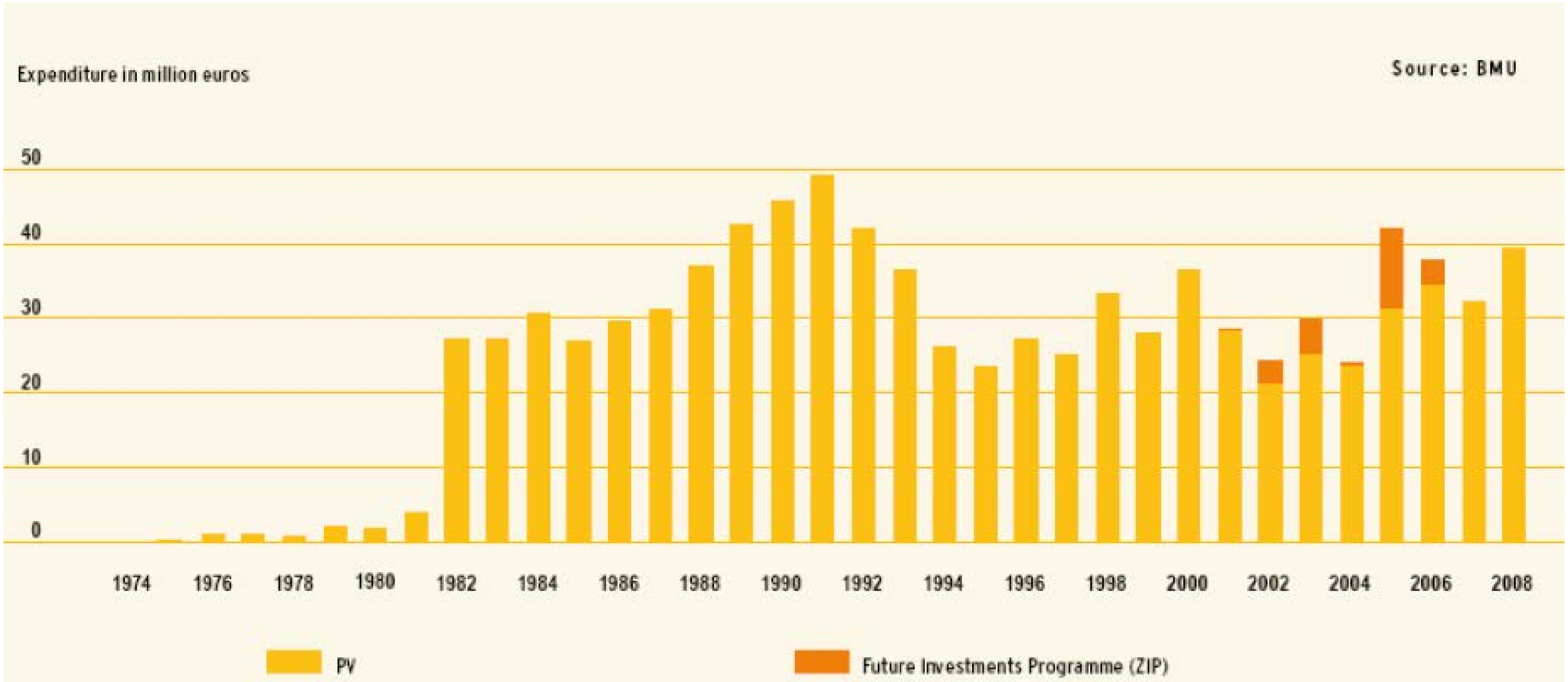
Yellow: non-residential installations

www.CaliforniasolarStatistics.ca.gov

The reasons for German success

- ✓ **Successful policy framework**: **Renewable Energy Sources Act** (EEG)
- ✓ High private and public RD&D investments
- ✓ Favorable political environment
- ✓ Industry-academia-government cooperation
- ✓ National research centers (e.g. Frauenhofer-ISE Institute)
- ✓ **Skilled labour** & developed universities' network (240 university degrees with a focus on PV)
- ✓ Green jobs: the German PV industry currently employs 100 thousand people
- ✓ Highly developed **supply industries** and most innovative **industrial PV cluster.**

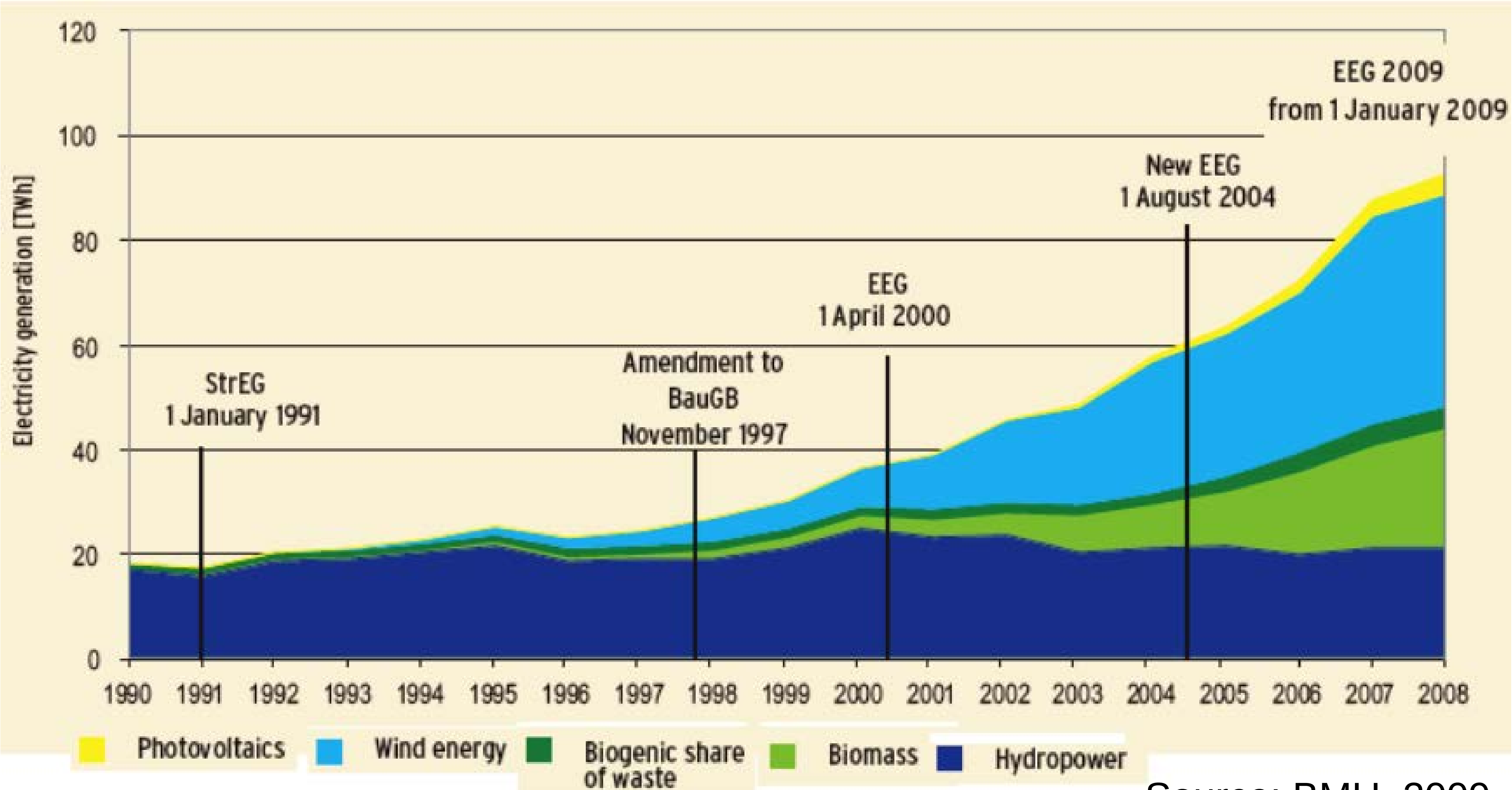
R&D Expenditure in PV Projects (1974-2008)



(ZIP: Solar Thermal, geothermal, off shore wind, fuel cells, biomass projects)

Source: BMU, 2008

Electricity Generation from RES since FiT law introduction



Source: BMU, 2009

StrEG: Electricity Feed Act (same tariff for PV and wind energy)

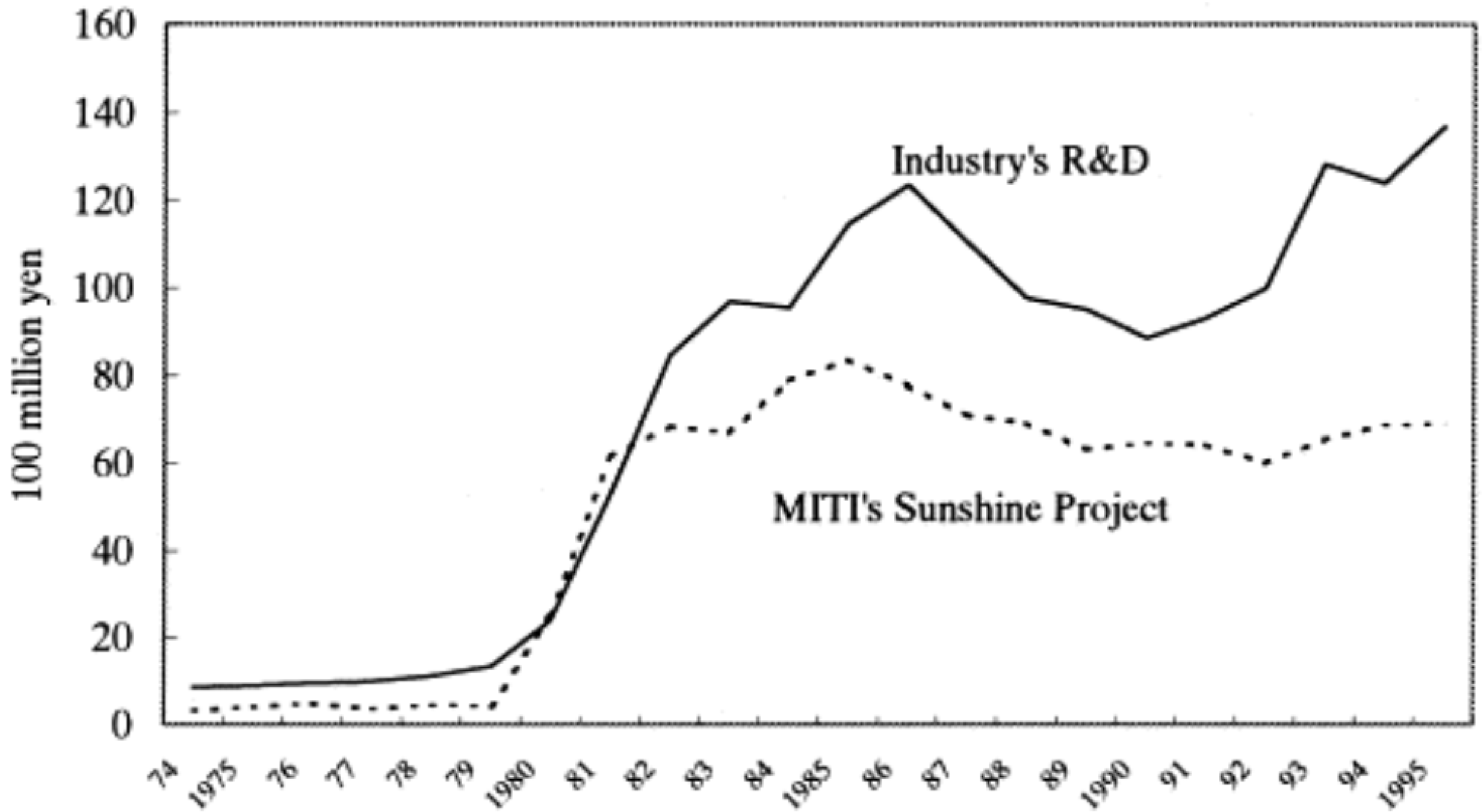
BauGB: Construction Code

EEG: Renewable Energy Sources Act: (technology-specific tariff)

The reasons for Japanese success

- ✓ Public RD&D (**2 Sunshine Programs 1974 and 1993)**
- ✓ **Inducing vigorous industry investment in PV RD&D**
- ✓ **Inter-firm cooperation** (PVTEC consortium) and cross-sectoral technology spillovers
- ✓ Engineering departments and university cooperation
- ✓ **Flourishing IP activities**
- ✓ The role of Ministry of Economy, Trade and Industry (METI): until 1980's **protection policy** in favor of domestic industry
- ✓ Residential PV program (1994)
- ✓ FiT increased residential PV power generation (80% residential vs. 20% non-residential - opposite than US & EU)

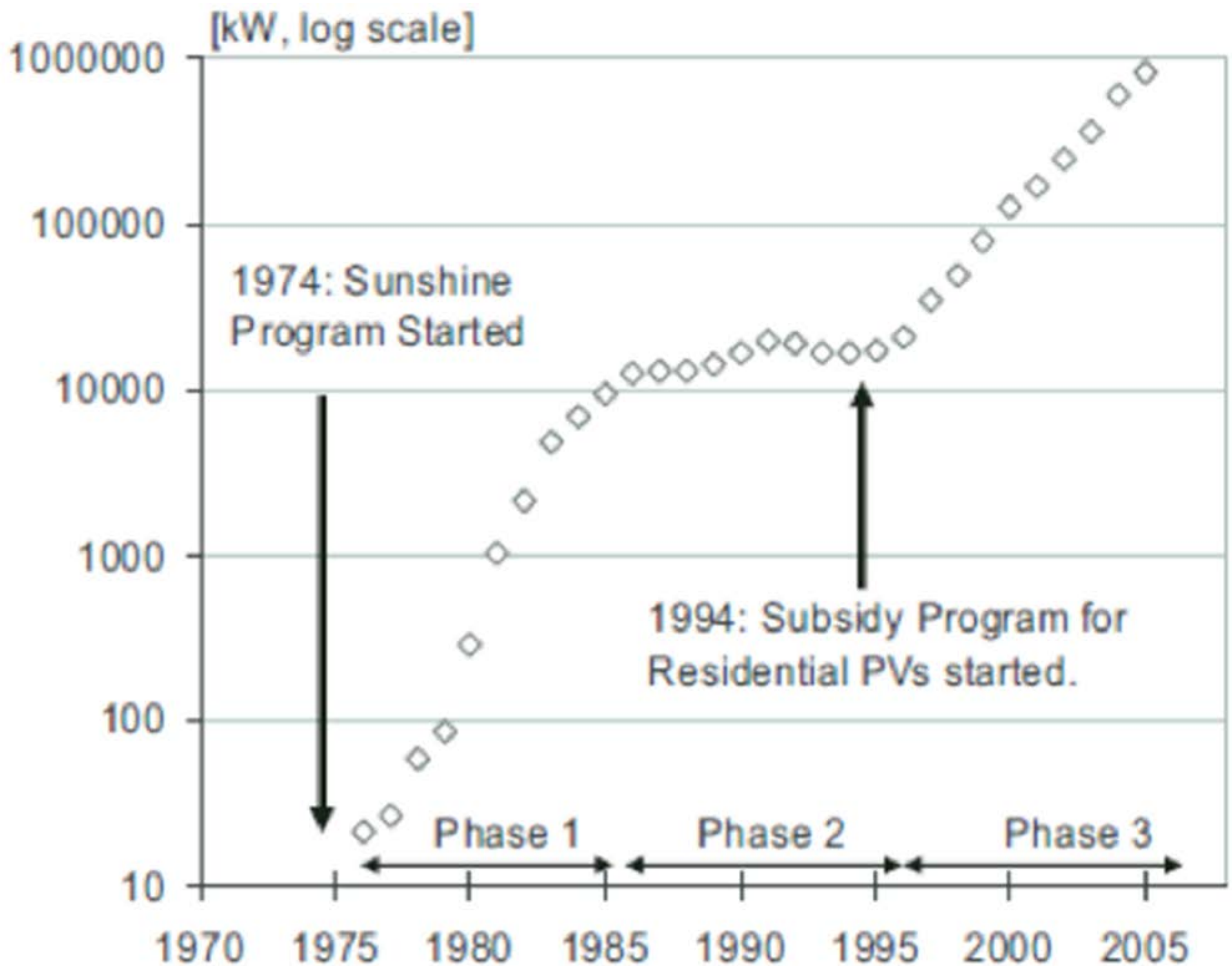
Trends in PV R&D expenditures (1974-1995)*



*At 1985 fixed prices

Source: Watanabe et al, 2000

Trend of solar cells production in Japan (1976-2005)



Source: Kimura, Suzuki, 2006

Top Solar Energy Patent Assignees at USPTO (2002-2010)

Source: Clean Energy Patent Growth Index, 2010

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Patent Protection vs. Trade Secret

- The stronger the patent protection, the weaker the incentives for diffusion because of fear of spill-over effects.
- European and US companies tend to favor trade secret to patent protection.
- Japan tend to favor patent protection and it is the top patent applicant at EPO and at USPTO (2002-2010). Japanese patent law is designed to encourage industrial dissemination and small incremental modifications are patented generally.
- Frauenhofer is at 5th place worldwide for nr. of PV patents in 2010.
- SunPower is the US PV company with more PV patents in 2010.
- Many of the top ten PV manufactures are not patent holders.

Linear or non linear innovation?

“Everyone knows that the **linear model of innovation is dead**”, claimed Rosenberg (Rosenberg 1994).

Mowery and Rosenberg believe that **demand-pull and technology-push must exist simultaneously** (Mowery and Rosenberg, 1979), they are not substitutes, but they are **complementary.**

Also, **incremental and non-incremental innovations** are not two unrelated entities, but they need to be developed **along the entire innovation chain**.

The impact of technology and energy policies on PV companies' performances

Top ten global PV manufacturers (2009)

Ranking	*Company*	*Technology*	*MWp*
1.	First Solar (US)	Thin film (CdTe)	1,112
2.	Suntech (China-US)	Crystalline/Thin film	704
3.	Sharp (Japan)	Crystalline/Thin film	595
4.	Q-Cells (Germany)	Crystalline/Thin film	586
5.	Yingli Green (China)	Crystalline	525
6.	JA Solar (China)	Crystalline	520
7.	Kyocera (Japan)	Crystalline	400
8.	Trina Solar (China)	Crystalline	399
9.	SunPower (US)	Crystalline	397
10.	Gintech (Taiwan)	Crystalline	368

Source: EurObserv'ER, 2010

R&D as percentage of revenue (2002-2009)

Company/Year	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
First Solar (USA)	1230%	119.7%	9.17%	4.94%	4.71%	3%	2.69%	3.74%
SunPower (USA)	62.44%	196.12%	124.35%	7.65%	4.09%	1.75%	1.49%	2.07%
Suntech Power (China)	2.03%	1.06%	0.55%	1.49%	1.4%	1.11%	0.8%	1.71%
Q-Cells (Germany)	0.41%	0.95%	0.62%	0.75%	0.86%	1.25%	2.13%	2.48%
Sharp (Japan)	6.98%	6.7%	6.15%	5.83%	5.52%	6.07%	5.74%	6.87%

Source: own calculations on Datastream Thomson Reuters Data

R&D intensity is taken as a proxy for good indirect and direct technology-push measures and for patent creation.

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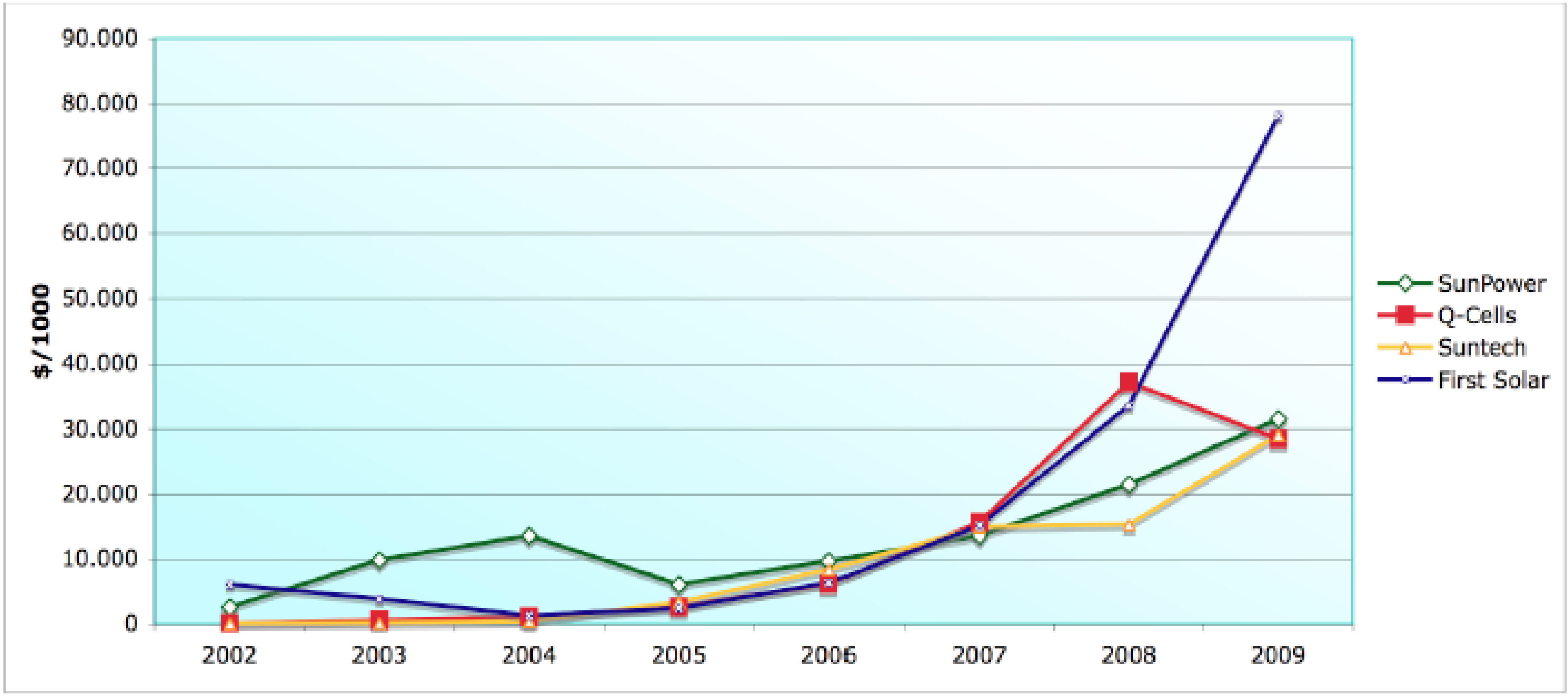
R&D in-house expenditures (2002-2009)



Source: Datastream Thomson Reuters (own calculation)

Higher R&D expenditures are associated with lower average expected costs, and are a proxy for higher competiveness of PV companies.

Annual PV installed capacity in MWp (2000-2009)

Country /Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Germany	40*	78	80	150	600	850	850	1,271	1,809	3,806
Japan	112	135	185	223	272	290	287	210	230	484
California (US)	2** (22 US)	8 (29 US)	18 (44 US)	32 (63 US)	44 (90 US)	55 (114 US)	70 (145 US)	95 (207 US)	179 (342 (US)	220 (477 US)***

Source: EPIA (2010a), SEIA (2010); for California data from 2000 to 2004 data see Wiser *et al.*, LBNL-59282 NREL/TP-620-39300.

* In Germany in the period from 1991 to 1999 the cumulated PV installed capacity was 57 MW.

** From 1981 to 1998, California had a total of 6,263 kW of cumulated installed capacity.

*** The figure includes MW installed in California that are almost half of total US installation.

PV installed capacity is a proxy for good national energy policies.

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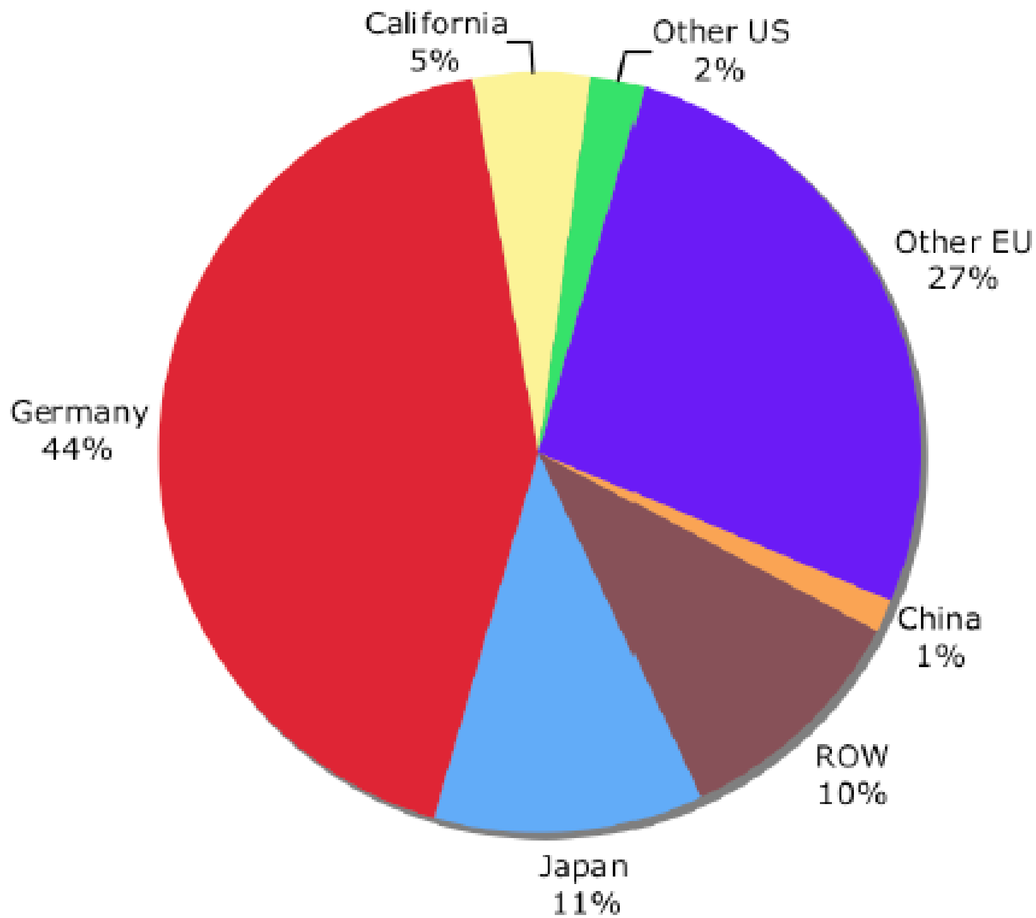
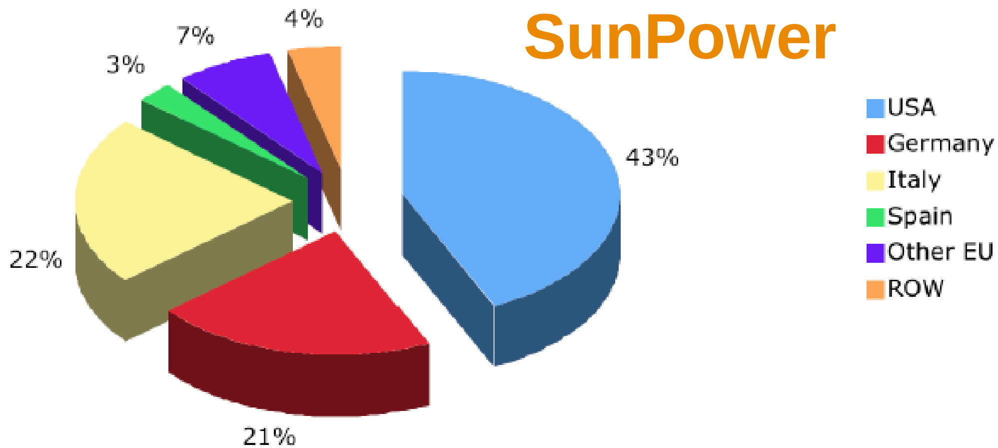
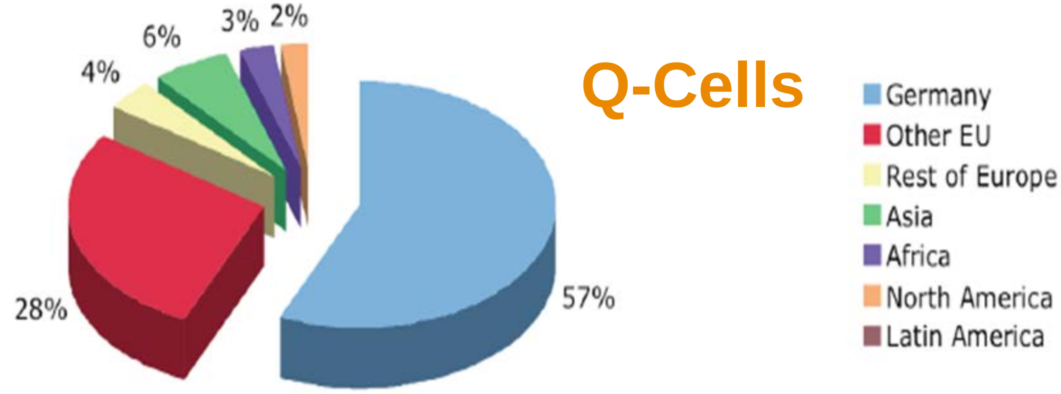
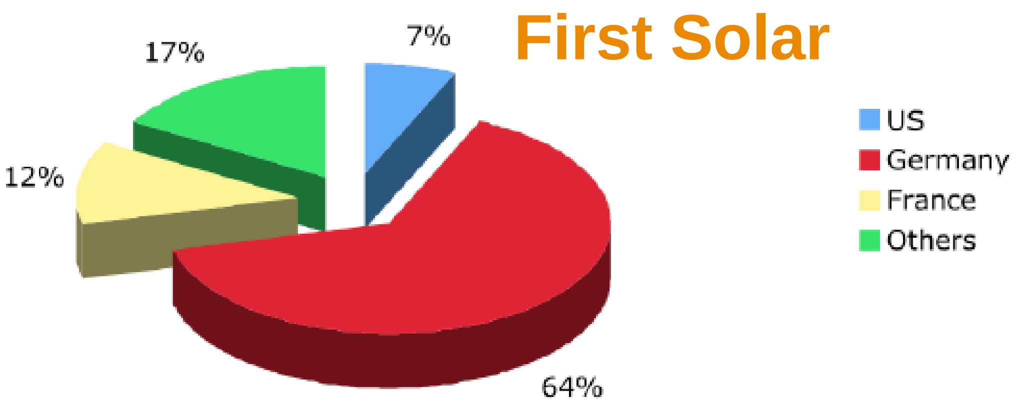
Share of cumulative PV installed capacity (end 2009)

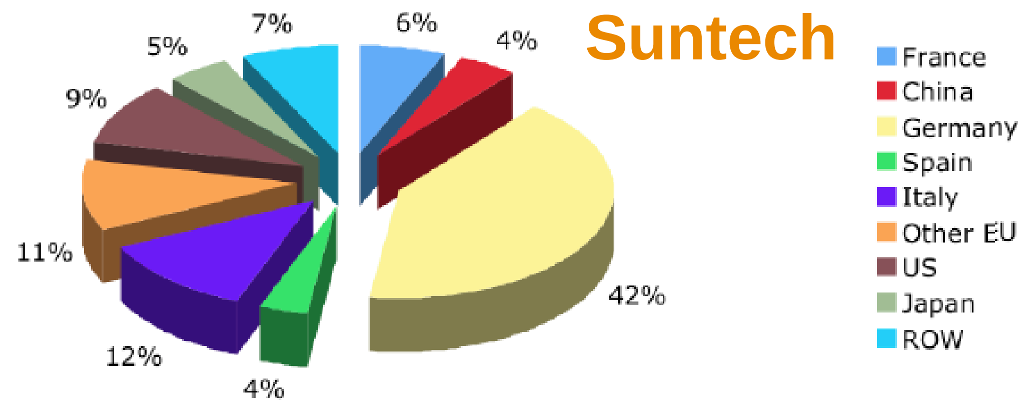


Companies geographical sales distribution (2009)









Geographical sales distribution is a proxy for good energy policies that have an impact both on national and foreign PV companies' performance in terms of production rate.

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Policy results

1) Main drivers to PV growth

- Trade benefits (Japan)
- Domestic solar use (Germany)
- Green jobs creation (Germany, California)
- GHG emissions concerns (California, Germany, Japan)
- IP creation (California, Japan)

Policy results (continues)

2) Some observed trends

- Countries with market-oriented culture adopt RPS programs that allow for price competition (California).
- Countries with poor domestic fossil fuel resources, or opting out from nuclear energy, are strong promoter for solar RD&D and adopt technology-push measures (Japan, California).
- Countries more concerned about GHG emissions tend to encourage the installation of more solar power through market-pull measures like FiTs (Germany).

Policy results (final)

3) Final policy results

- Strong positive correlation between technology policies and successful performance of PV enterprises in the long term.
  - Measures designed to overcome typical barriers in intensive R&D sectors are critical in determining structural competitive advantages in a time frame consistent with the life cycle of technology.
- Short-term correlation of market-pull policies with the business success of PV enterprises.
  - Measures aimed at promoting the diffusion of technology can help enhance the benefits of PV enterprises but are not sufficient in addressing the evolutionary path of new technological systems and in this way in guaranteeing a long-term business success.

Conclusions

1. A synergy between long-term RD&D policy and progressively decreasing economic support schemes is the key to self-sustained growth of PV industry.
2. Policy stability avoiding retroactive measures to support schemes is fundamental for triggering PV industry growth.
3. PV energy positive externality (avoid cost of pollution) should be internalized in order to make PV costs closer to grid parity and counteract subsidies.
4. Fossil fuels' negative externality should be priced and subsidies to fossil fuels should be reshaped.

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Managers at SunPower Corp., First Solar, Suntech, Sharp, Q-Cells

Sources

DSIRE (Database of State Incentives for Renewables and Efficiency), North Carolina Solar Center and the Interstate RE Council (IREC)

EPIA (European Photovoltaic Industry Association)

IRENA (International Renewable Energy Agency)

SEIA (Solar Energy Industries Association)

DOE - EERE (US Department of Energy, Energy Efficiency Renewable Energy Program)

NREL (National Renewable Energy Lab)

LBNL (Lawrence Berkeley National Lab)

CPUC (California Public Utility Commission)

CEC (California Energy Commission)

NSF (National Science Foundation)

BMU (German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety)

BMBF (German Federal Ministry of Education and Research)

METI (Japanese Ministry of Economy, Trade and Industry)

Sources (continues)

European Commission JRC - Annual PV Status Report

REN21

EurObserv'ER (2010). "Photovoltaic Barometer"

Clean Energy Patent Growth Index, 2010

Jacobsson S. et al. (2004), "Transforming the energy sector: teh evolution of technological systems in renewable energy technology". Industrial and Corporate Change, 13 (5)

Kimura O., Suzuki T. (2006). "30 years of solar energy development in Japan: co-evoluton process of technology policies and the market".

Nemet G.F., Kammen D.M. (2007). "Us energy research and development", *Energy Policy* 35 (1)

Mowery D., Rosenberg N. (1979). "The influence of market demand upon innovation: a critical review of some recent empirical studies", *Research Policy* 8 (2)

Rosenberg N. (1994). "Exploring the Black Box: Technology, Economics and History". Cambridge: Cambridge University Press.

Watanabe *et al.* (2000). *Technovation* 20 (6)

Thank you for your attention

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