

INTRODUCTION

- Brief history of photovoltaics
- PV market
- PV in Portugal
- (Summary of this course)

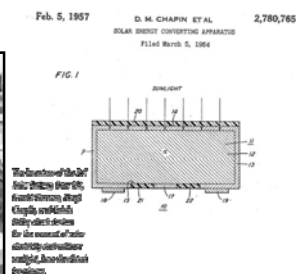
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Brief history of photovoltaics

1839: Edmund Becquerel, a French experimental physicist, discovered the photovoltaic effect.
1873: Willoughby Smith discovered the photoconductivity of selenium.
1876: Adams and Day observed the photovoltaic effect in solid selenium.
1883: Charles Fritts, an American inventor, described the first solar cells made from selenium wafers.
1904: Einstein published his paper on the photoelectric effect.
1916: Millikan provided experimental proof of the photoelectric effect.
1951: A grown p-n junction enabled the production of a single-crystal cell of germanium.
1954: Bell Labs researchers Pearson, Chapin, and Fuller reported their discovery of 4.5% efficient silicon solar cells.

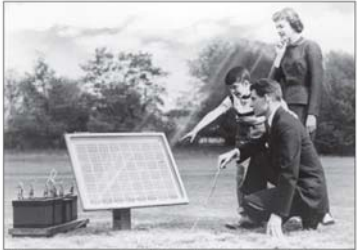
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Brief history of photovoltaics



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Brief history of photovoltaics



Advertisement photos, such as this one that appeared in the 1956 issue of Look Magazine, show off the "Bell Solar Battery" to the American public.


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Brief history of photovoltaics



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PV market – Oil crisis 1970s



Jimmy Carter Library

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PV market - Japanese market in 1990s

- **Incentives:** from 9\$/W (1994) to 2\$/W (2003)
(1G€ from government + 2G€ from companies)
- High grid **electricity prices** (19c\$/kWh)
- Low **interest** rates, low **inflation**, modularity of **construction** industry, large **semiconductor** industry...

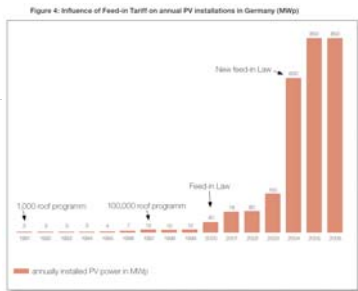
Lead to:

- Rapid decrease in **PV prices**
(70% decrease from 1994 to 2003)
- 22-fold increase **production** capacity
- 32-fold increase **installed** capacity

M.G. Rogol, *Why did the solar power sector develop quickly in Japan?*, MSc Thesis, MIT 2007

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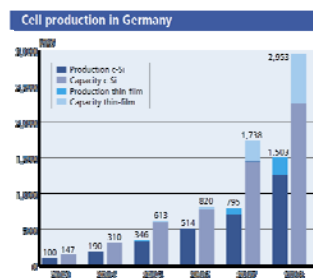
PV market – German market in 2000s



EPIA Brochure: *Supporting Solar Photovoltaic Electricity - An Argument for Feed-in Tariffs*, January 2008

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PV market – German market in 2000s



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PV market – German market in 2000s

- PV electricity production **today** not relevant for German electricity: <0.5% (2007)
- CO₂ abatement cost: 760€/ton
- Massive **invoice** to be paid over 20 years: 63T€
- German PV industry deficit: ~50% **import**
- 205k€/year/new job created

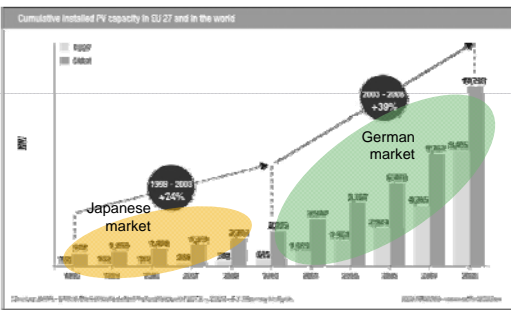
Recommendations:

- Stop feed-in tariff support for PV
- Increase investment into R&D

M. Frondel, et al, Germany's solar cell promotion: Dark clouds on the horizon, Energy Policy 36 (2008) 4198–4204

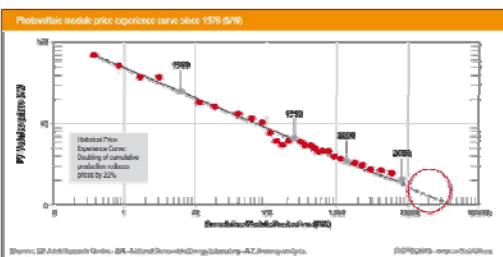
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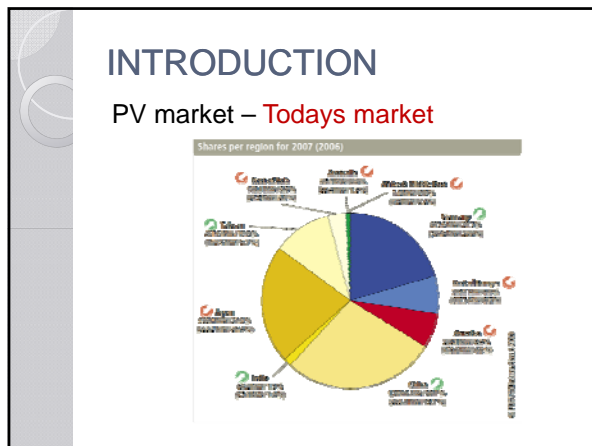
PV market – Today's market

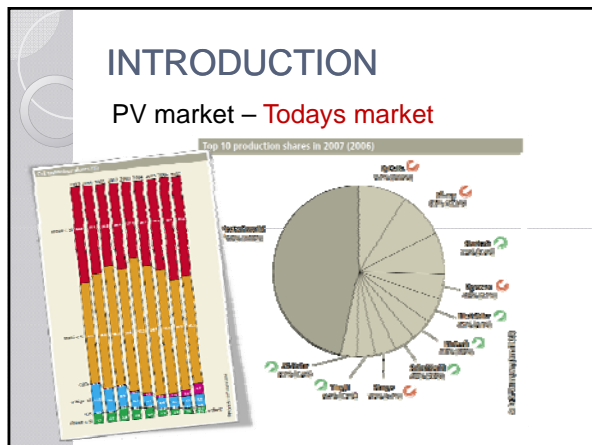


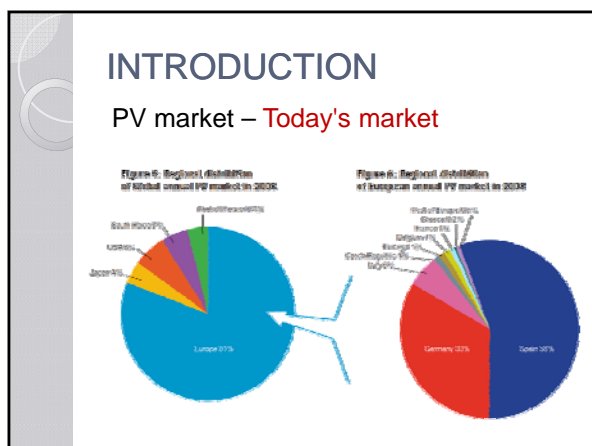
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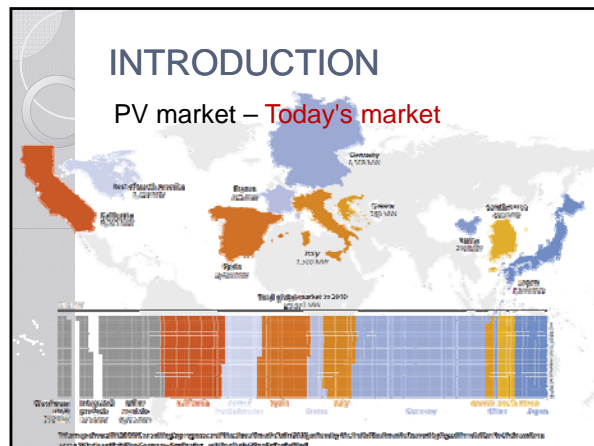
PV market – Today's market

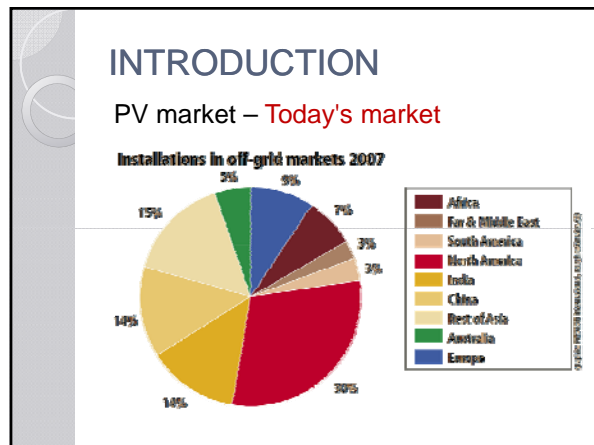


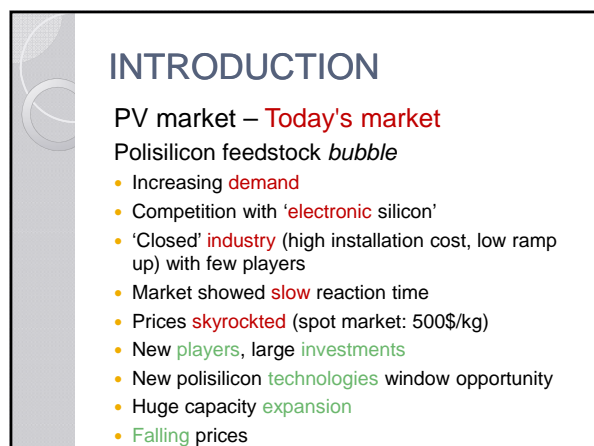


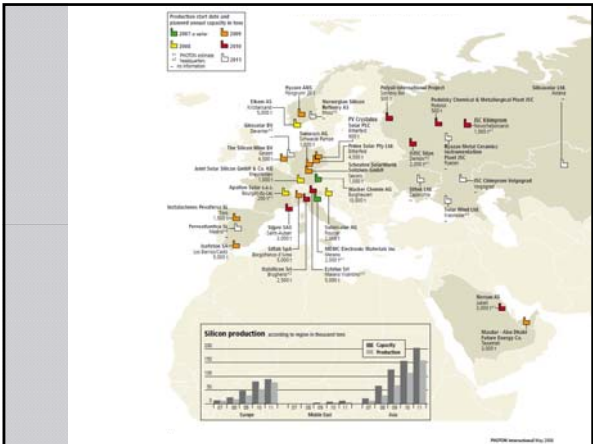


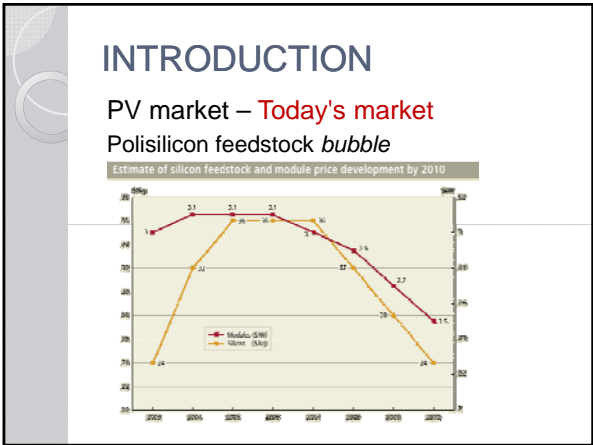


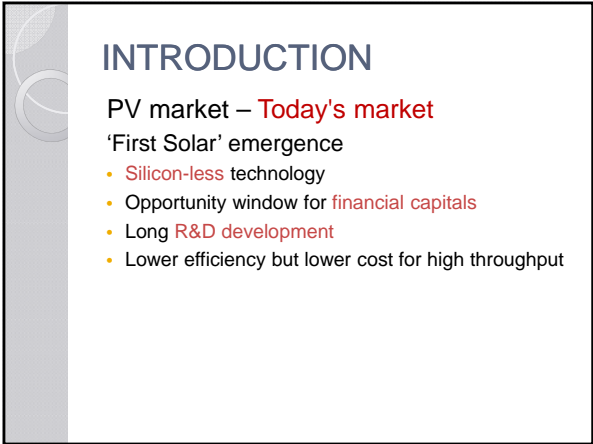












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PV market – **Today's market**

Spanish market *bubble*

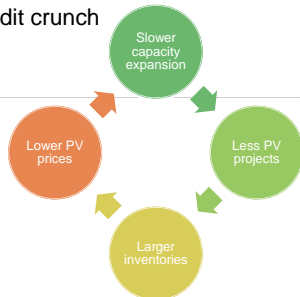
Case study: *what can I do wrong?*

- **Generous** feed-in tariff
- But no maximum **cap**
- **Overwhelming** demand
- **Abrupt** end
- **Fraud**
- Huge **cost** to Spanish government
- **Unbalanced** demand/supply for PV industry

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PV market – **Today's market**

Credit crunch



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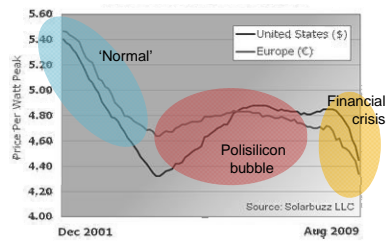
PV market – **Today's market**

Summary

- Polysilicon feedstock *bubble*
- Emergence of 'First Solar'
- Spanish market *bubble*
- Emergence of a chinese PV industry
- Credit crunch and the financial crisis

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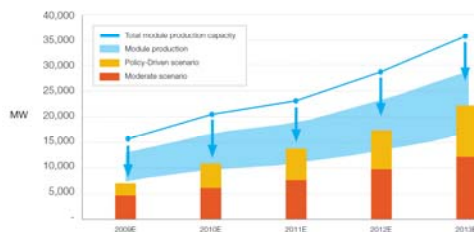
PV market – Today's market



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PV market – Today's market

Figure 10: Global Outlook – Production Capacity vs. Market



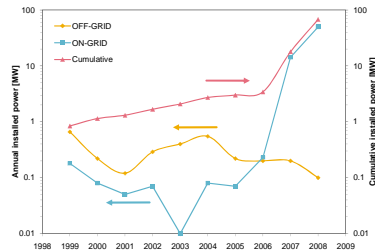
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PV in Portugal – flagship projects

- Selvagem Grande, Madeira (1983, 660W)
- Solar XXI, Lisbon (1989; 2.2kW)+ (2005; 12+6kW)
- Brinches, Serpa (2007; 11MW)
- Amareleja, Moura (2008; 46MW)

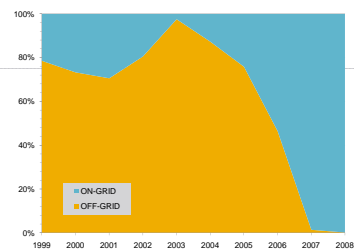
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PV in Portugal



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PV in Portugal



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PV in Portugal – legal framework

- Roadmap: 2010: 150MW
- Feed-in tariff: ~30c€/kWh [2005]
- Microgeneration: Renewables-on-demand (renovaveisnagora.pt) [2008]
- Demonstration R&D projects:
 - PV concentration (29c€/kWh) [2009]

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PV in Portugal – microgeneration

- Renewables-on-Demand, Law Decree 363/2007
- Annual cap: 10MW (annually increased by 20%)

Tariffs

- the **general regime** applicable to any type of micro-generation (or co-generation) source, limited to 5.75kW (25A single-phase) interconnection power; the feed-in tariff is the regulated tariff (true net metering) defined annually by the national Energy Regulator;
- the **special regime** exclusively for renewable sources: solar PV, wind, hydro, biomass, fuel cells (provided the hydrogen is produced from renewable energy sources), limited to 3.68kW (16 A single-phase) interconnection power.

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PV in Portugal – microgeneration

- Renewables-on-Demand, Law Decree 363/2007
- Annual cap: 10MW (annually increased by 20%)

Tariffs: special regime

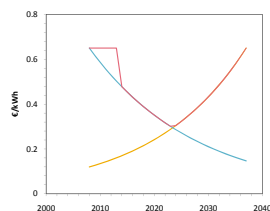
- 65c€/kWh** for PV (less for other renewable sources)
- Decreases 5%/10MW installed

Requirements

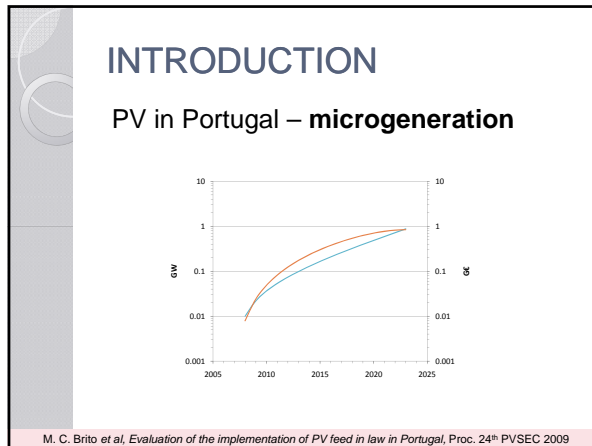
- All electricity produced sold to the grid
- solar water** heating system (min: 2m²) is mandatory
- condominiums: **energy audit** and fulfillment of all identified energy saving measures with payback time below 2 years

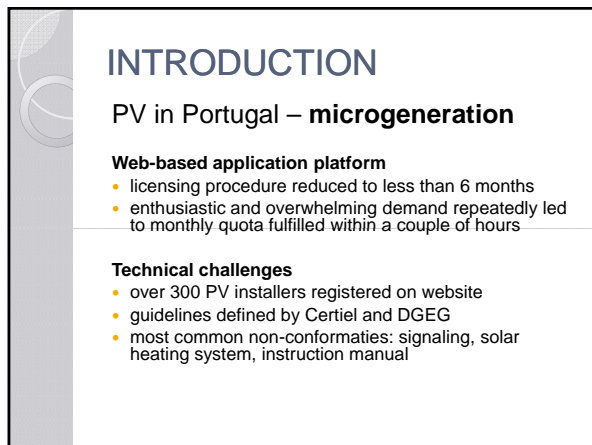
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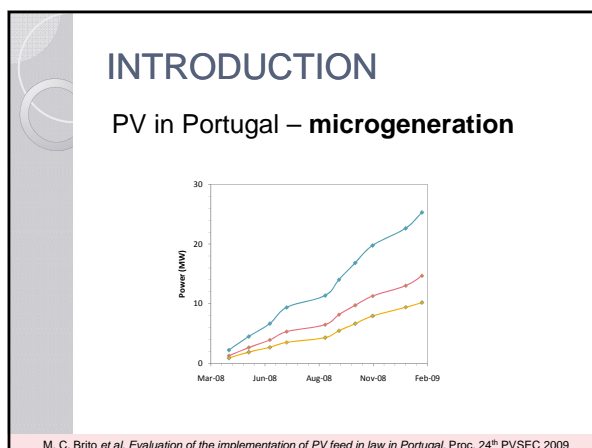
PV in Portugal – microgeneration



M. C. Brito et al. Evaluation of the implementation of PV feed in law in Portugal, Proc. 24th PVSEC 2009







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PV in Portugal - **players**

- Open renewables (Évora; Si; 45MW; 1994)
- Solar Plus (Oliveira Bairro; a-Si; 5MW; 2008)
- Martifer Solar (Oliveira Frades; Si; 50MW; 2008)
- WS Energia (Oeiras; concentration; 2006)
- RPP Solar (Abrantes; Si; 800MW; 2010)
- Quimonda Solar (Vila do Conde; Si; ?; ?)

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PV in Portugal - **research**

- ISEL – a-Si
- LNEG (ex-ineti) – PV systems, DSSC
- FCUL– Si
- FEUC– DSSC
- FEUP– DSSC, III-V
- UA – DSSC, CIGS
- UM – a-Si
- UNL/FCT– a-Si
- UTL/IST – characterization

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This course - contents

- Solar **resource**
- **Physics** of solar cells
- PV **technologies**
- **Characterization**
- PV **systems**
- **Stand alone** systems

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This course - grading

- **Test:** (25%)
- **In class:** problem solving (10%)
- **Lab work:** characterization (15%)
- **Field work:** system monitoring (10%)
- **Home work:** system design (15%)
- **Presentation:** Advanced topics (25%)
and/or
- **Final exam:** everything (100%)

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This course – references

- T. Markvart, *Solar electricity*, 2nd edition, John Wiley & Sons, 2000
- M. Green, *Solar cells – operating principles, technology and system applications*, USW 1986
- R. Messenger, *Photovoltaics system engineering*, 2nd ed., 2003
- A. Luque *et al*, *Handbook of PV Science and Engineering*, 2003
- S. Bowden *et al*, PV CD ROM [pvcdrom.pveducation.org]
- Photon international magazine [www.photon-magazine.com]

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This course

- **Classes**
 - Tuesday, 9-10:30am (T): 8.1.67
 - Tuesday, 11am-1pm (TP/Lab): 8.1.67/8.5.1
 - Friday, 2-4pm (C): 8.3.29
- **Special occasions**
 - SMA presentation (tbd)
 - Visit to INETI (tbd)
 - Departmental seminars: Mondays 12am



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Next week

- **Portal**
 - You need to subscribe: <https://portal.fc.ul.pt/>
- **Classes**
 - Tuesday, 9-10:30am (T): 8.1.67
 - ~~Tuesday, 11am-1pm (TP/Lab): 8.1.67/8.5.1~~
 - Friday, 2-4pm (C): 8.3.29
- **Further reading**
 - S. Hegedus, *Handbook PV Sc&Eng*, Chap 1: Status...
 - S. Bowen, PV CD ROM (browse)
