"Solar Energy" WS 2014/2015

Lecture 17: Environmental Aspects and Costing of PV Systems

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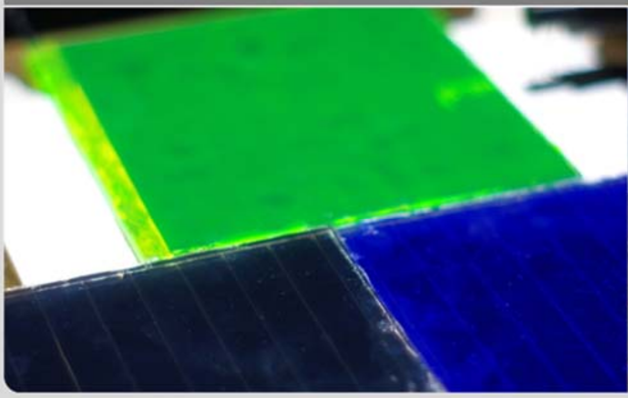
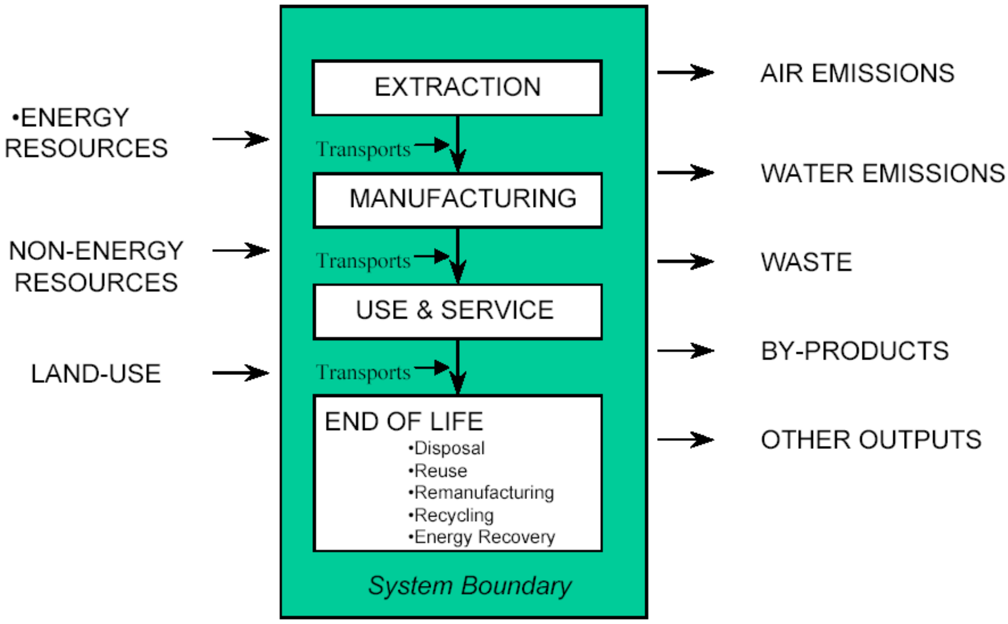
KIT Focus Optics & Photonics



Life Cycle Analysis

- LCA = technique for assessing environ-mental aspects and potential impacts of a product over its whole life cycle (ISO 14040, 1997)



Life Cycle Analysis

- Identify relative environmental impacts of materials use and pollutant loads
- Classify, characterise and value to e magnitude and significance of impacts
- Identify improvement opportunities:
  - cleaner production
  - eco design
  - waste minimisation
- 1980's vicious rumour:
  "PV systems do not pay back the energy used in their production"
- 2000's…
  a few people still think this statement is true…

Life Cycle Analysis

- Embodied Energy E_{in}
- Net Energy $E_{gen} - E_{in}$
- Energy Payback Time $$EPT = \frac{E_{in}}{E_{gen}}$$
- CO_2, SO_x, NO_x Balance $$g_{CO_2-e} = \frac{G_{in}}{E_{gen} \times L_{PV}}$$

Life Cycle Analysis

- Global warming potential of anthropogenic greenhouse gases

Table 3: Global warming potentials of greenhouse gases
Potentials are expressed as a multiple of the global warming potential of carbon dioxide.

Gas	Global warming potential over 100 years
Carbon dioxide	1
Methane	24
Nitrous oxide	360
Chlorofluorocarbon-11	4 600
Chlorofluorocarbon-12	10 600
Hydrofluorocarbons	10–14 800
Sulfur hexafluoride	22 200
Other perfluorocarbons	5 700–11 400

Source: Granier and Shine (1999).

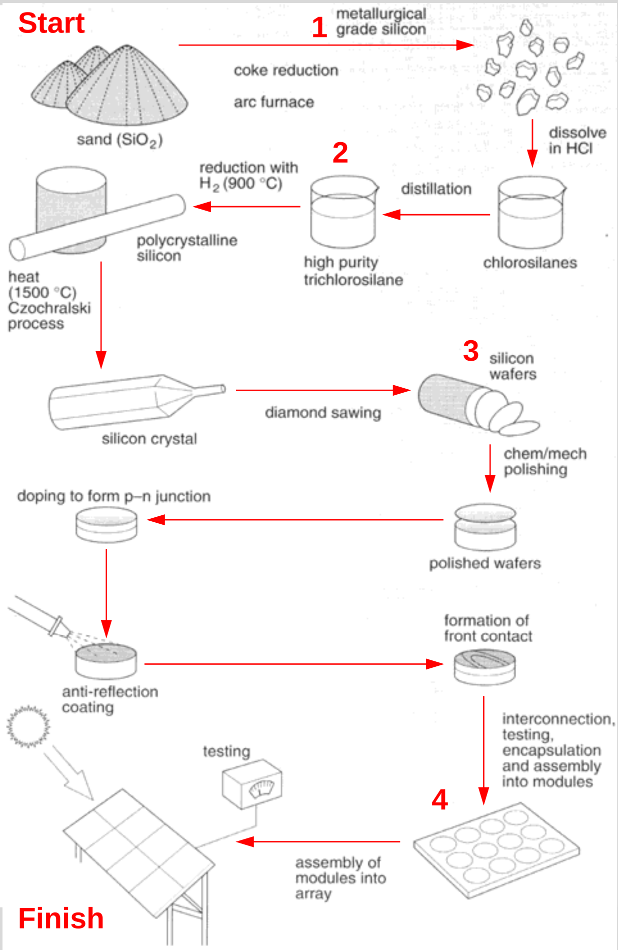
- 1kg of CFC-12 (former refrigerant and aerosol spray propellant) caused damage to ozone layer and very powerful GHG – if released today will cause 10600x as much warming as 1kg of CO_2

Life Cycle Analysis

- Silicon solar cell manufacturing
- Si: second most abundant element in earth's crust
- SiO_2 reduced in large furnaces by carbon (coke, coal & wood chips)

$$SiO_2 + 2C \rightarrow Si + 2CO$$

- Si poured from furnace → further purified with O/Cl mixtures → >1m tonne MG-Si p.a. → 98-99% pure → used mostly for steel and aluminium industries
- Quite energy efficient → total energy (mining, transport, processing) for MG-Si (16-18 kWh/kg, c.f. Al at 19 kWh/kg)



Life Cycle Analysis

2. Purify 1-2% further to electronic grade Si via Siemens process:

$$Si + 3HCl \rightarrow SiHCl_3 + H_2$$

Gases condensed and multiply distilled

Pure $SiHCl_3$ reacted with H_2 at 1100°C for ~200 – 300 hours to produce a very pure silicon

$$SiHCl_3 + H_2 \rightarrow Si + 3\ HCl$$

Costly, low yield and energy intensive – estimates at energy content of EG-Si as used to be as high as 620 kWh/kg now more like 210 kWh/kg

Life Cycle Analysis

3. CZ process and slicing also low yield (cutting process wastes half) → 0.4 m^2/kg → energy content of Si wafer used to be 1700 kWh/m^2

4. Solar cell processing and encapsulation adds ~250 kWh/m^2

   Assume 90% yield (wafers to modules) → total energy content of 2170 kWh/m^2 → today more like 600 kWh/m^2

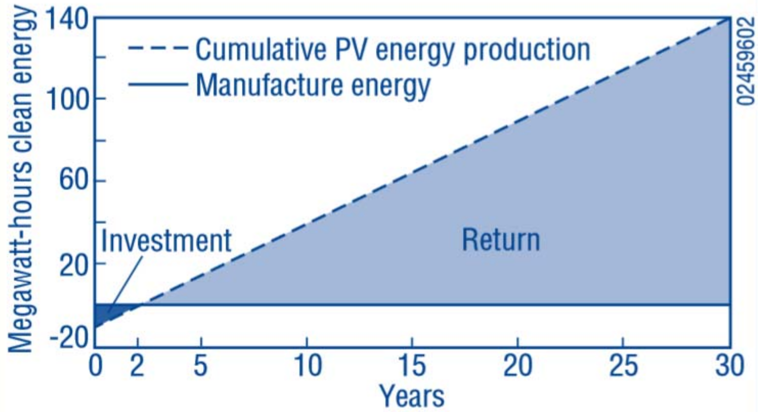
Back of the envelope EPT calculation (η=17%, 3 PSH/day = 3 kWh/m^2):

$$EPT = \frac{E_{in}}{E_{gen}} = \frac{600\ \text{kWh/m}^2}{0.17 \times 3\ \text{kWh/m}^2 \times \#\text{days}}$$

$$\#\text{years} = \frac{1176}{365\ \text{days/year}} = 3.2$$

Life Cycle Analysis

Figure 2. Cumulative Net Clean Energy Payoff



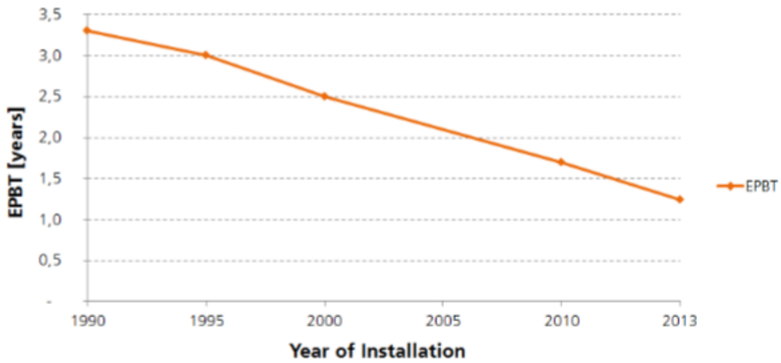
PV systems can repay their energy investment in about 2 years. During its 28 remaining years of assumed operation, a PV system that meets half of an average household's electrical use would eliminate half a ton of sulfur dioxide and one-third of a ton of nitrogen-oxides pollution. The carbon-dioxide emissions avoided would offset the operation of two cars for those 28 years.

Life Cycle Analysis

Depending on the technology and location of the PV system, the EPBT today ranges from 0.7 to 2 years.

Rooftop PV systems produce net clean electricity for approx. 95 % of their lifetime, assuming a life span of 30 years or more.

EPBT of multicrystalline PV rooftop systems installed in Southern Europe*

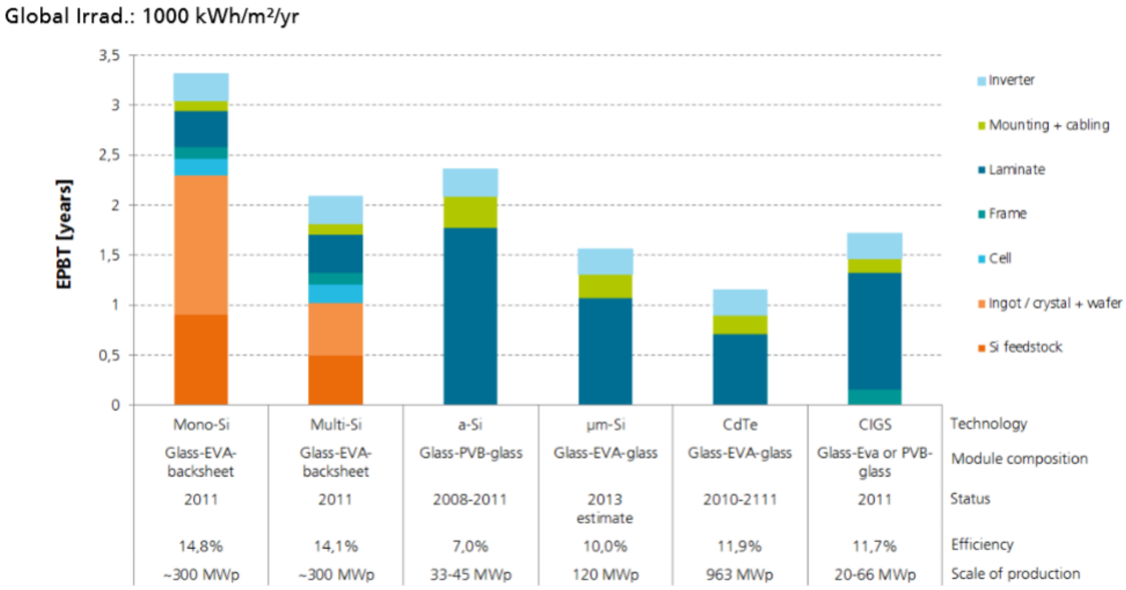


*Irradiation: 1700 kWh/m²/a at an optimized tilt angle

Source: http://www.ise.fraunhofer.de/de/downloads/pdf-files/aktuelles/photovoltaics-report-in-englischer-sprache.pdf

Life Cycle Analysis

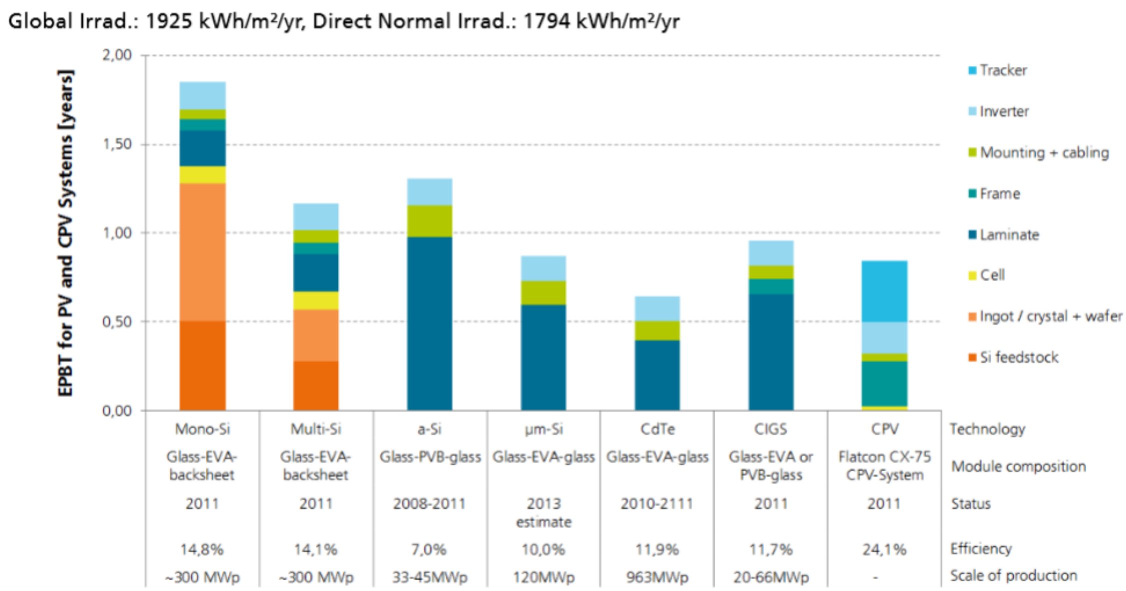
Energy Pay-Back Time of Rooftop PV Systems from different Technologies in Germany



Source: http://www.ise.fraunhofer.de/de/downloads/pdf-files/aktuelles/photovoltaics-report-in-englischer-sprache.pdf

Life Cycle Analysis

Energy Pay-Back Time for PV and CPV Systems from different Technologies in Catania, Sicily, Italy



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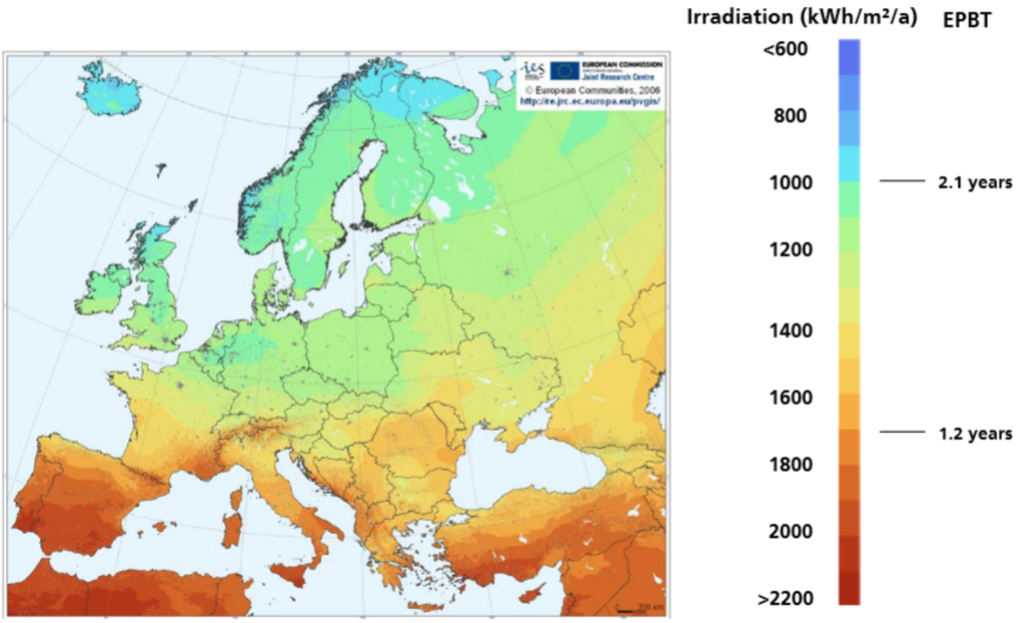
Life Cycle Analysis

Energy Pay-Back Time of Multicrystalline Silicon PV Rooftop Systems - Geographical Comparison



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Environmental Impacts

Manufacturing

Toxicity and explosive nature of some gases. Problems with

- Accidental release
- Explosions or inhalations
- Exposures to low levels of toxic materials over long periods

Use/Operation

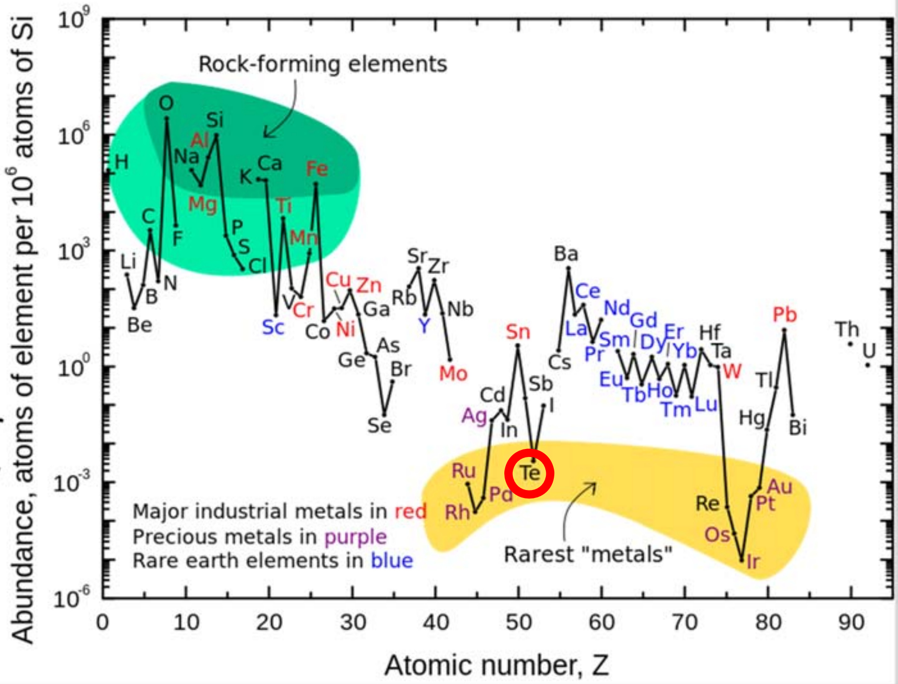
- Leaching of heavy metals (cadmium, selenium)
- Accidental fires could release toxic fumes

Environmental Impacts

- Cadmium - a heavy metal classes as a hazardous substance ⇒ toxic and carcinogenic
- Waste by-product of zinc refining therefore its production does not depend on PV market demand
- cadmium chloride ($CdCl_2$) used to increase the CdTe device overall efficiency ⇒ but is both toxic and highly soluble in water ⇒ possibly replace with harmless magnesium chloride
- N.B. large growth in the CdTe PV sector actually has the potential to reduce global cadmium emissions! How?! Well, burning coal releases about 140 g of Cd for every GWh of electricity produced (as well as about 1000 tons of CO_2, 8 tons of SO_2, 3 tons of NO_x, and 0.4 tons particulates)

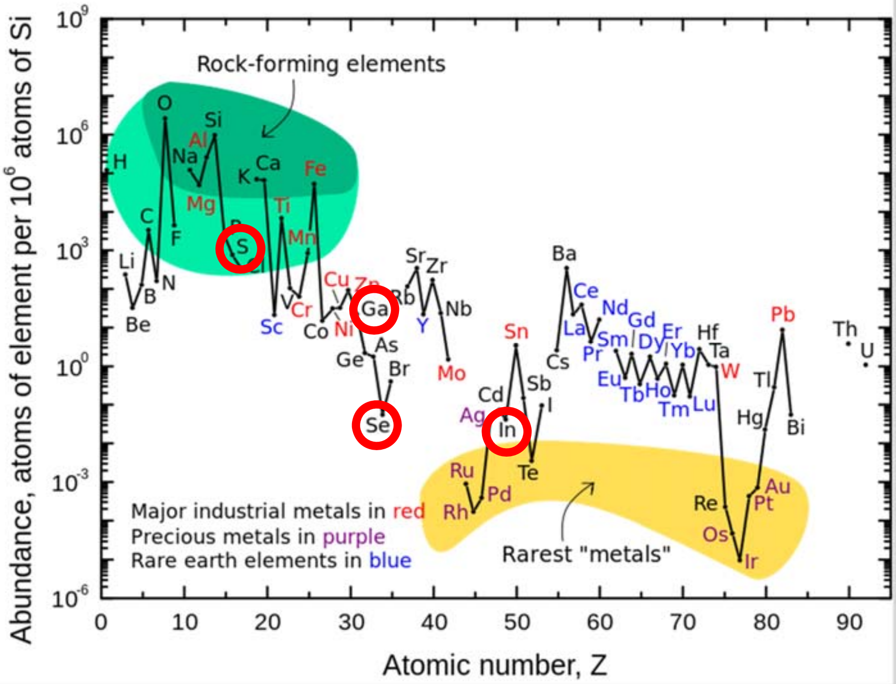
Environmental Impacts

- Tellurium - metal mostly obtained as by-product from copper refining
- According to USGS, global production in 2007 was 135 metric tons ⇒ 1 GW of CdTe PV modules would require about 93 metric tons (c.f. First Solar production capacity in 2014 ~ 2GW) ⇒ recycling?



Environmental Impacts

- Indium – soft metal, not so toxic ⇒ does not occur alone as an element, but together with zinc, iron, lead, and copper ores
- Worldwide reserves estimated at ~6,000 tonnes of economically viable In
- Other elements used for CIGS/Se PV: not so much Se in the world, but S and Ga better



Environmental Impacts

POST BUSINESS | Japan tsunami spares major economic zones

Solar Energy Firms Leave Waste Behind in China

By Ariana Eunjung Cha
Washington Post Foreign Service
Sunday, March 9, 2008

GAOLONG, China -- The first time Li Gengxuan saw the dump trucks from the nearby factory pull into his village, he couldn't believe what happened. Stopping between the cornfields and the primary school playground, the workers dumped buckets of bubbling white liquid onto the ground. Then they turned around and drove right back through the gates of their compound without a word.

This ritual has been going on almost every day for nine months, Li and other villagers said.

PHOTOS

"It's poison air. Sometimes i… to close all the doors and wi… front of a dumping site in his… son's health. (Zhang Quanfe…

China quells village solar pollution protests

BY ROYSTON CHAN
HAINING, China | Sun Sep 18, 2011 6:58am EDT

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Riot policemen remove protesters outside the entrance of a factory of Zhejiang Jinko Solar Co. Ltd. in Haining, Zhejiang province September 17, 2011.
CREDIT: REUTERS/STRINGER

Environmental Impacts

Decommissioning

Disposal of large quantities of modules to a single landfill presents potential risks for humans, communities and the environment as the leaching of chemicals can contaminate local ground and surface water.

Fthenakis (2003) indicates that the main concern during this life cycle phase will be associated with the presence of cadmium.

> **At First Solar, we believe that powering the future with renewable solar energy** requires a commitment to responsible product life cycle and end-of-life (EOL) management. As PV solar scales globally, we need to ensure that solutions to clean energy don't pose a waste management burden for future generations. First Solar leads the industry with proven recycling solutions that fulfill solar's promise as a clean and sustainable renewable energy.

The long life of PV cells and the fact that it is a young industry makes data from landfills not yet available

Environmental Impacts

Decommissioning

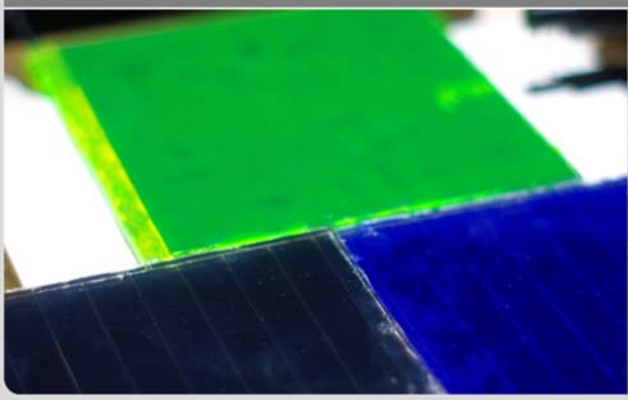
Many of the chemicals found in electronic waste (e-waste) are also found in solar PV, including lead, brominated flame retardants, cadmium, and chromium.

The disposal of e-waste is becoming and escalating environmental and health problem in countries in West Africa, Asia and Latin America. This should be prevented in the case of PV systems!

Karlsruher Institut für Technologie

Life Cycle Costing for Renewable Energy Systems: The Off-Grid Scenario

KIT Focus Optics & Photonics



LCC for Stand-Alone (Off-Grid) RE Systems

- For 24 hr power a generator is least expensive capital cost
- When you begin to look at operational and maintenance (O&M) costs: batteries and inverters will be cost effective.
- But a complete renewable system can have high capital costs, low maintenance costs

$\Rightarrow$ WHAT IS THE OPTIMUM SOLUTION?

LCC Analysis

- Determine all the installed capital costs of the equipment.
- Determine all the operating and maintenance costs associated with each piece of equipment.
- Determine component life and replacement cost.
- Use present value or present cost analysis to compare different systems.

Net Present Value (NPV)

- NPV is an economic evaluation tool which can be used to compare different system options.
- The total cost of the alternatives are evaluated over the expected operating life of the system.
- These costs are totalled up for each year, but each year's costs are discounted according to when those costs will be incurred.
- Any money spent on the system in the future is best understood if it is converted into a *present value*,

  ⇒ *what would be the cost, using the value of money as it is today, to purchase components for the system in the future?*

Discount Rate

- If you were owed €10,000 now, BUT were not paid for 5 years you would want the "interest" that the money would have earned.
- In RE, the discount rate is the reverse of this:
- i.e. if you had to spend €10,000 in 5 years, how much do you put away now to have €10,000 in 5 years time.
- How much is the future cost "discounted" to today's value?

"Generally a measure of the cost of funds to the investor, e.g. the interest paid on borrowed funds, forgone on own funds expended, or the potential income in the form of interest and/or dividends if the funds were to be invested in the best possible alternative to the project under consideration".

(Source: Australian Standard AS3595)

Present Value

- Thus, in effect, the present value evaluates the total sum of money which would need to be put-aside now, and invested at the appropriate discount rate, in order to cover each year's costs as they came up for the whole life of the system.

Treatment of Capital

- Renewable energy projects tend to have high up-front capital costs and zero on-going fuel costs
- Conventional alternative like a generator is likely to have lower first-year capital costs but on-going fuel costs
- If NPV is used to evaluate a renewable energy project against a conventional project the result will be dependent on the discount rate
- When a high discount rate is used, the renewable energy project will be disadvantaged

Treatment of Capital

- However, if money for the project is borrowed, then repayment is by principle and interest
- These can then be treated as on-going costs to the project
- Treating capital in this way results in more favourable outcomes for capital intensive renewable energy projects
- (of course this approach should only be used if it truly reflects the way in which capital is being accessed for the project)

Price Escalation (Inflation)

- Any realistic analysis of energy alternatives must take inflation and the effect of "oil crises" into account.
- That is, energy price rises are often higher than general inflation
- **All inflation rates and discount rates used in the analysis remain fixed for the duration of the project (despite the fact that this will, in practice, be unlikely to happen)**
- Inflation rates can be determined by the consumer price index (CPI), or generally easier just using the general rate

Discount Rates

- <u>Real Discount Rate</u> is the return the investor wants <u>after inflation</u>

Discount Rate = Real Discount Rate + Inflation Rate

- Example real discount rates:
  - private business sector: 8%
  - public (government) sector: 4%
  - private residential sector: 2%

Present Value Calculations

In general a principle sum of money, P, today will have a value (X) after n years according to the formula:

$$X = P \times \frac{(1+d)^n}{(1+g)^n} \quad , \text{ where}$$

d = inflation rate,

g = discount rate (interest rate)

This can be re-arranged to calculate the present value of a future sum of money:

$$PV = X \times \frac{(1+g)^n}{(1+d)^n}$$

Present Worth Calculations

- In an off-grid power system if there is a diesel generator (genset) that is used regularly there will be regular maintenance costs associated with of the system, e.g. the cost of fuel and maintenance of the genset.

- We can work out the present value of all of the yearly fuel payments using a factor called the present worth factor (PWF). This again depends on *g*, *d*, & *n*

Present Worth Calculations

$$PWF\,(g,d,n) = \frac{1 - \dfrac{(1+g)^n}{(1+d)^n}}{\dfrac{(1+d)^n}{(1+g)^n} - 1}$$

Years

Inflation rate

Discount rate

Present Worth Calculations

- Example #1:
- The battery bank has a cost of €5000.
- Batteries have a life of 10 years (*very* optimistic).
- What would be the present value of the replacement costs of the batteries if the interest rate is 12% and inflation is 10%?


Interest rates are so low that Germans are paying to keep money in banks

Deutsche Skatbank has become the first EU bank to introduce negative savings rates for retail clients, months after the European Central Bank introduced interest rates below zero

The negative rate means Germans' euros are being taken away in banks Photo: AP

Present Worth Calculations

- Example #1:

$$PV = 5000 \times \frac{(1 + 0.10)^{10}}{(1 + 0.12)^{10}}$$

$$= €4175.58$$

Present Worth Calculations

- Example #1:
- If one invests the above some of money for 10 years then the amount of money will be:

  $= 4175.58 \times (1 + 0.12)^{10}$

  = €12698.72

- At the same time the batteries which cost €5000 today will cost in 10 years :

  $= 5000 \times (1 + 0.10)^{10}$

  = €12698.72

⇒ the same!

Present Worth Calculations

- Example #2:
- The annual fuel cost for operating a diesel generator is €1400. The inflation rate is 3%, while the discount rate is 6%.

  a) Calculate the net present value of the fuel costs for each year for the next five years.

  b) What is the net present worth of the fuel cost over the next 5 years?

Present Worth Calculations

- Example #2:

a) Apply factor for each year

$$f = \frac{(1 + d)^n}{(1 + g)^n} = 0.972$$

Year 1 = €1360.38

Year 2 = €1321.88

Year 3 = €1284.46

Year 4 = €1248.11

Year 5 = €1212.79

Present Worth Calculations

- Example #2:

b) Add the five years:

Year 1	= € 1360.38
Year 2	= € 1321.88
Year 3	= € 1284.46
Year 4	= € 1248.11
Year 5	= € 1212.79

Present Worth = € 6427.62

Costs for Off-Grid RE Systems

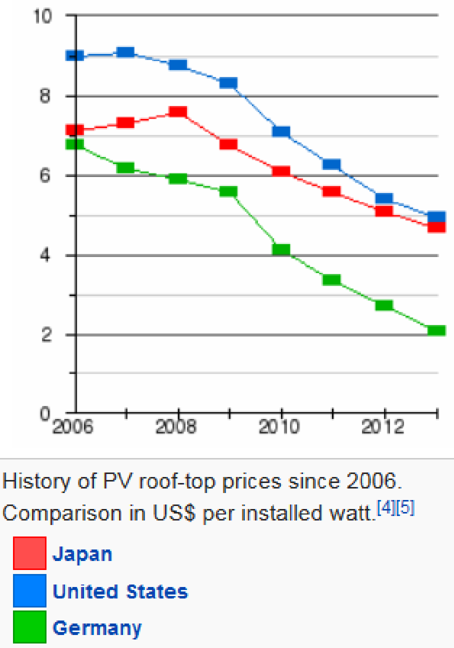
- Different costs associated with each component of a off-grid power system
- The capital costs of the equipment.
- The ongoing costs associated with each piece of equipment.
- Replacement cost at end of component life.

Photovoltaic Modules

Capital costs:

- A PV array installed will cost about US$1630 / kWp installed in Germany (mid 2014 data) – other countries significantly higher
- This depends mainly on the price of modules, but is also affected by the BOS costs such as support structures, foundations, cabling etc, and labour

Median installed system prices for residential PV Systems in Japan, Germany and the United States ($/W)



History of PV roof-top prices since 2006. Comparison in US$ per installed watt.[4][5]

Source: http://en.wikipedia.org/wiki/Photovoltaic_system

Photovoltaic Modules

Maintenance costs:

- In general, the maintenance associated with solar modules is small, and undertaken at 6 and 12 month intervals.
- It is recommended that for the life cycle analysis a minimum of 2 hours per kW installed per year is costed in undertaking maintenance at a typical site.
- Alternatively, if a detailed calculation is not required, a figure of less than 1% of the capital cost (say 0.5%) is usually sufficient as an approximate figure.

Photovoltaic Modules

Replacement costs:

- Nearly all solar modules will last longer than 20-30 years.
- It is very unusual to perform a life cycle analysis for a life cycle period greater than 20 years, therefore don't need to consider replacement cost.

Cost of Solar Power

Cost of generated kilowatt-hour by a PV-System (US¢/kWh) [hide]

depending on solar radiation and installation cost during 20 years of operation

Installation cost in $ per watt	Insolation annually generated kilowatt-hours per installed kW-capacity (kWh/kWp•y)								
	2400	2200	2000	1800	1600	1400	1200	1000	800
$0.20	0.8	0.9	1.0	1.1	1.3	1.4	1.7	2.0	2.5
$0.60	2.5	2.7	3.0	3.3	3.8	4.3	5.0	6.0	7.5
$1.00	4.2	4.5	5.0	5.6	6.3	7.1	8.3	10.0	12.5
$1.40	5.8	6.4	7.0	7.8	8.8	10.0	11.7	14.0	17.5
$1.80	7.5	8.2	9.0	10.0	11.3	12.9	15.0	18.0	22.5
$2.20	9.2	10.0	11.0	12.2	13.8	15.7	18.3	22.0	27.5
$2.60	10.8	11.8	13.0	14.4	16.3	18.6	21.7	26.0	32.5
$3.00	12.5	13.6	15.0	16.7	18.8	21.4	25.0	30.0	37.5
$3.40	14.2	15.5	17.0	18.9	21.3	24.3	28.3	34.0	42.5
$3.80	15.8	17.3	19.0	21.1	23.8	27.1	31.7	38.0	47.5
$4.20	17.5	19.1	21.0	23.3	26.3	30.0	35.0	42.0	52.5
$4.60	19.2	20.9	23.0	25.6	28.8	32.9	38.3	46.0	57.5
$5.00	20.8	22.7	25.0	27.8	31.3	35.7	41.7	50.0	62.5

USA | Japan | Germany — Small rooftop system cost and avg. insolation applied to data table, in 2013

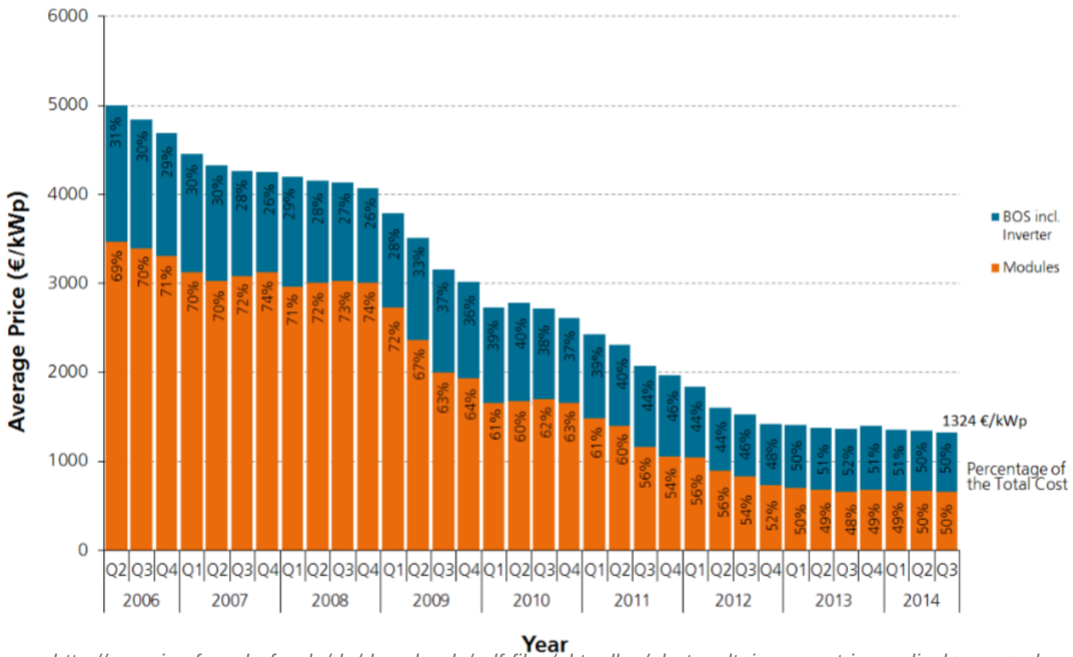
Notes:

1. Cost per watt for rooftop system in 2013: Japan $4.64,[4] United States $4.92,[4] and Germany $2.05[5]
2. Generated kilowatt-hour per installed watt-peak, based on average insolation for Japan (1500 kWh/m²/year), United States (5.0 to 5.5 kWh/m²/day),[115] and Germany (1000 to 1200 kWh/m² /year).
3. A 2013 study by the Fraunhofer ISE concludes LCOE cost for a small PV system to be $0.16 (€0.12) rather than $0.22 per kilowatt-hour as shown in table (Germany).

Source: http://en.wikipedia.org/wiki/Photovoltaic_system

Cost of Solar Power

Average Price for PV Rooftop Systems in Germany (10kWp - 100kWp)



Source: http://www.ise.fraunhofer.de/de/downloads/pdf-files/aktuelles/photovoltaics-report-in-englischer-sprache.pdf

Small Wind Turbines

Capital costs: Installed cost for a wind generator can vary greatly, depending on size and manufacturer

- Costs based on the actual unit selected
- Costs should include tower, footings, cabling, conduit, etc., and labour.
- In USA, installed cost estimates of top ten small wind turbine models in 2011 ranged between $2300 / kW and $10000 / kW (average was $6000 / kW). Average in China much lower at $1500 / kW

Maintenance required:

- Lubrication of joints; checking & retightening bolted connections; changing of bearings

Small Wind Turbines

Maintenance costs:

- Bearing replacements every 5 years (or more frequently if recommended by manufacturer)
- Labour costs for annual maintenance including checking bolted connections, blade maintenance, inspection of slip-rings, brushes and electrical connections
- Annual material costs for lubricants, blade tape.
- If a detailed calculation is not required, a figure of 1% – 2% of the capital cost is usually sufficient as an approximate figure.

Replacement costs:

- with proper maintenance a wind turbine should last >20 years (designers should confirm with the manufacturer what is the expected life of the unit)

Micro Hydro Generator

Capital costs:

- Purchase price of the generator by itself can costs as much as €2000 per kW (small unit) down to €800 per kW (for 20 kW unit)
- The actual costs of the hydro unit should be used, along with an estimate of ancillary and installation costs
- Ancillary costs include penstock and supports, civil works, cabling, conduit etc, and labour.
- The installation costs for micro hydro unit can vary from as little as a ~€2000k up to € 20000

Micro Hydro Generator

Maintenance costs:

- Bearing replacements every 5 years (or more if ecommended by manufacturer)
- Labour costs in cleaning intake pipe, filters, trash racks etc.
- A labour cost for vegetation clearing may be incurred if an aerial cable run is used
- If a detailed calculation is not required, a figure of 1% – 2% of the capital cost is usually sufficient as approximate figure

Replacement costs:

- micro-hydro generators should have a life greater than 20 years but it is dependent on the quality of the unit that is installed. No replacement is usually necessary in the life cycle costing

Battery Bank

Capital costs:

- A battery bank can vary in cost from €100 to €300 per kW installed.
- Actual battery costs should be used,
- Include costs for stands, trays, signage, cabling, fusing etc., and labour.

Battery Bank

Maintenance:

- Keeping the battery terminals clean and tight. Cleaning might only be once a year with checking on connections as often as one month but at least every 6 months.
- Topping up with distilled water (if using wet LA batteries). Could vary from monthly to yearly Depending on brand
- Checking the specific gravity of cells (flooded cells only) - at least every three months

Battery Bank

Maintenance costs:

- Labour costs in checking and cleaning battery terminals
- Labour costs in adding distilled water.
- Material costs in purchasing distilled water.
- If a detailed calculation is not required, a figure of 2% of the capital cost is usually sufficient as an approximate figure.

Battery Bank

Replacement costs:

- Batteries can have a design life as little as 3 years and as long as 12 years.
- It is recommended that the designer uses manufacturers data (cycle life data) in predicting the life of the batteries in the system, in conjunction with the daily depth of discharge.
- The replacement costs of the batteries are then shown accordingly in any life cycle analysis.
- But what to do about residual value?

Inverters, Charge Controllers, etc.

Capital costs:

- Inverters cost as little as €150 per kW, up to €500 per kW
- Regulators vary in price from €100 to €500.
- Battery chargers can vary from €200 to €1000
- Actual equipment costs should be used, along with costs for mountings, cabling and labour.
- Labour costs for the installation of the electronics should include the physical installation, as well as programming & set-up time.

Inverters, Charge Controllers, etc.

Capital costs:

Inverter / Converter	Power	Efficiency	Market Share (Estimated)	Remarks
String Inverters	Up to 100 kWp	98%	~ 50%	• ~ 15 €-cents /Wp • Easy to replace
Central Inverters	More than 100 kWp	Up to 98.5%	~ 48 %	• ~ 10 €-cents /Wp • High reliability • Often sold only together with service contract
Micro-Inverters	Module Power Range	90%-95%	~ 1.5 %	• ~ 40 €-cents /Wp • Ease-of-replacement concerns
DC / DC Converters (Power Optimizer)	Module Power Range	Up to 98.8%	n.a.	• ~ 40 €-cents /Wp • Ease-of-replacement concerns • Output is DC with optimized current • Still a DC / AC inverter is needed • ~ 0.75 GWp installed in 2013

Source: http://www.ise.fraunhofer.de/de/downloads/pdf-files/aktuelles/photovoltaics-report-in-englischer-sprache.pdf

Inverters, Charge Controllers, etc.

Maintenance costs:

- Checking of the terminal (cable) connections to ensure they have not become loose , labour costs can be included in battery costs
- Most electronic equipment can require repair during their lifetime and possibly some token charge should be included every 10 years.
- If a detailed calculation is not required, a figure of 1% of the capital cost is usually sufficient as an approximate figure.

Inverters, Charge Controllers, etc.

Replacement costs:

- Electronics products can last 10+ years (possibly longer) but can also in general be repaired.
- The designer should ask the manufacturer what is the expected life of the inverter they are installing in the system.
- If it is less than the length of the life cycle analysis then a replacement should be included in the analysis, e.g. budget in a replacement inverter after 10 years.

Generators

Capital costs:

- Diesel gensets can range from €300 – €600 per kW, depending on size, quality and features.
- The capital cost should also include the genset controller, fuel tanks, pipework, drip trays, start battery etc, and the cost of mounting and accommodation.
- Labour covers physical installation as well as testing and commissioning.

Generators

Fuel and Maintenance requirements:

- Every generator has a manufacturer's specification for fuel usage per hour at full load and at other % loads.
- Use the 60% loaded figure determine the amount of fuel used each day and therefore the cost required to be used in the life cycle analysis.
- Alternatively, the fuel quantity can be calculated on the basis of the daily energy required to meet the loads and recharge batteries, divided by an efficiency figure for the genset
- Other maintenance includes: changing oil, changing oil filters, fuel filters and air filters, replacing spark plugs (petrol), starter battery maintenance

Generators

Maintenance costs:

- Labour in undertaking service of the genset
- Material costs for oil, air filters oil filters and any other component that needs replacing.

Run Time	Maintenance Rate (%)	
(h per wk)	Diesel Generator	Petrol Generator
0 to 1	2	2.0
1 to 7	2.5	6.0
8 to 28	5.0	12.0
29 to 112	10.0	Do not use
113 to 168	18.0	Do not use

Generators

Replacement costs:

- Gensets have a rated life before they require engine overhaul or replacing.
- This is specified by the manufacturer and is generally given in operating hours, e.g. 10 000 h.
- Generator running hours will therefore determine the time for engine replacement or major overhauls.

Other Costs

- AC cable and conduit to loads
- AC distribution boards, transfer boxes, circuit breakers etc
- DC control board, metering, fusing, isolation switches, breakers etc
- Travel time for installation visit
- Travel costs for maintenance or any other call-out related costs depending on the number of visits to the site per year
- Any other costs incurred
- Contingencies

Life Cycle Costing Summary

- It is essential that when comparing different power supply options, the same discount and inflation rates are used for each option
- The comparison between different system options can be simplified if all common costs are left out
- When analysing a number of different options, e.g. different sizes of PV array in a PV-diesel hybrid, care should be taken to ensure that the changes to all costs are accounted for.
- In general LCC of any power system is often related to the price of electricity: €/kWh.

Announcement!

- We have 30 bookings for trip ISE – bus holds 30 – so full!

- Please be ready at the CS bus stop (where KIT Shuttle stops) at 7:45am!!