The True Value of Photovoltaics for Germany
– Summary of study findings –

Hand-out for the press conference
3 November 2010, 10.00 a.m.
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Schiffbauerdamm 40, room 1

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Contents

- **Brief summary of study findings**
- Appendix: Basic assumptions and abbreviations used

The key objective of the study is to evaluate the true value of photovoltaics (PV) for Germany

Current situation

- **The surprisingly strong growth of photovoltaics** poses challenges for established subsidy policies, energy systems and market mechanisms
- **The heated political/media debate** around photovoltaics contains both truths and half-truths
- **"PV differential cost"** is used to label PV as a burden on consumers
- **Fundamental decisions** need to be made on the future power generation mix and system integration

Study objectives

- Provide a pragmatic, holistic analysis as input for the debate in response to two main questions:
  - What is the **true value** of photovoltaic electricity for Germany? Is the current differential cost a realistic reflection of the cost of PV?
  - What level of **power generation costs** can PV realistically achieve in Germany?
- The results should provide the foundation for a further **fact-based discussion** of:
  - The continuation of political and societal support for photovoltaics in Germany
  - The increasing responsibility of the PV sector in terms of its growing role in the energy sector

Phoenix Solar and A.T. Kearney want to contribute to a fact-based and solution-orientated debate

The true value of PV for Germany is significantly higher than the current debate indicates

Summary of key findings

The value of PV

The EPEX wholesale market price is not a suitable benchmark for valuing photovoltaic electricity

The full cost of new gas and coal-fired power plants, on the other hand, is an adequate benchmark for valuing photovoltaic electricity

An adequate valuation of photovoltaics would result in up to 18 percent lower PV EEG levies for households in 2011. This can considerably ease the burden on energy consumers!

PV systems installed in Germany reach breakeven for the first time in 2010, which means that the macro-economic benefit will exceed the differential cost

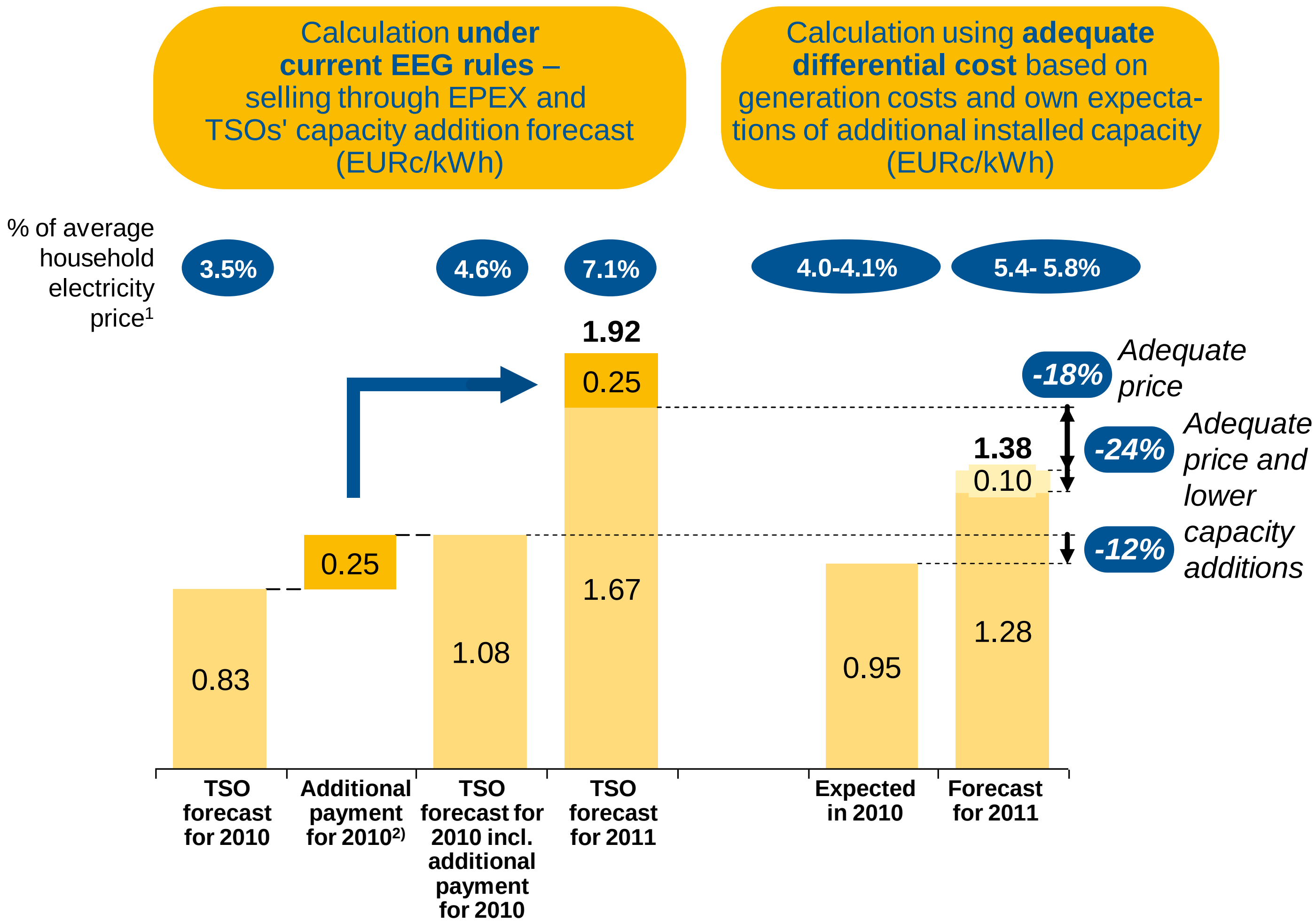
The true value of PV for Germany is significantly higher than the current debate indicates

Summary of key findings

Competitiveness of PV	**If the true value of photovoltaics is taken into account, photovoltaics will be a competitive alternative to electricity provided by gas and coal-fired power plants in 5 to 8 years** **From that point in time, photovoltaic electricity can be taxed and have grid costs added similar to conventional electricity**
Contribution to structural change	**PV is an enabler of the structural transition to an efficient and distributed energy world**

Adequate valuation of PV and our installed capacity assumptions result in 18-24% lower levies for PV

Value of PV: Calculating the EEG levy on photovoltaics for end consumers



- Due to major forecast variation in 2010, an additional payment of 0.25 EURc/kWh is necessary for photovoltaic power in 2010
- TSOs forecast the EEG levy for 2011 at 3.53 EURc/kWh, of which around 1.67 EURc/kWh is implicitly for PV. This is based on 9.5 GWp additional installed capacity in both 2010 and 2011
- If the adequate electricity prices for 2010 and 2011 as calculated in the course of the study were applied instead of the EPEX prices, the PV EEG levy would be 12% and 18% lower, respectively
- Moreover, if the additional installed capacity in 2010/2011 totals 8 and 6 GWp respectively, the 2011 levy would be 24% lower than that forecast by the TSOs

1) Based on a household electricity price of 23.7 EURc/kWh and assuming a generation mix excluding base load and higher IEA scenario
2) Additional payment for the period 01/01/2010 – 30/09/2010 to make up the difference between forecast and tariff payments
Note: TSO = Transmission System Operator Source: TSOs; A.T. Kearney analysis

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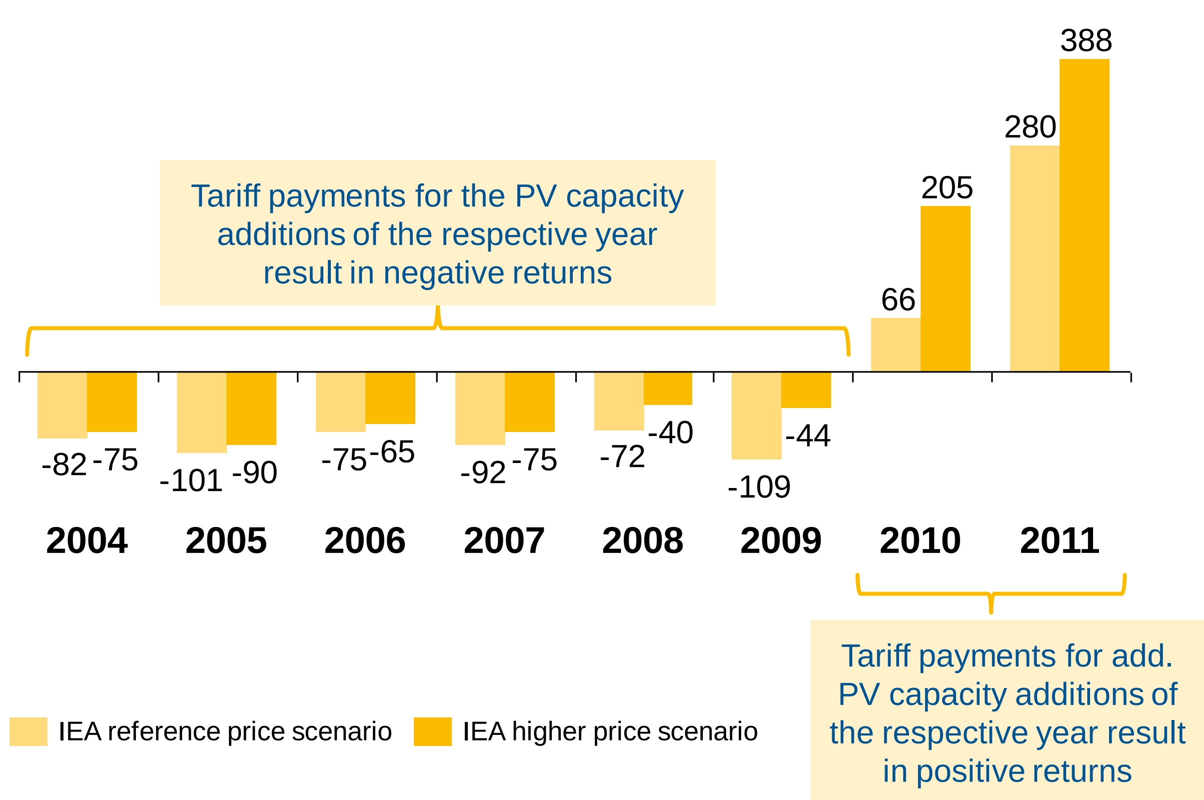
Additional PV installed capacity in Germany will reach macroeconomic breakeven in 2010

Value of PV: Investment case for installed PV capacity in a single year

Benefit of EEG tariff investment in photovoltaics in a specific year in EUR m (annuity)



Comments

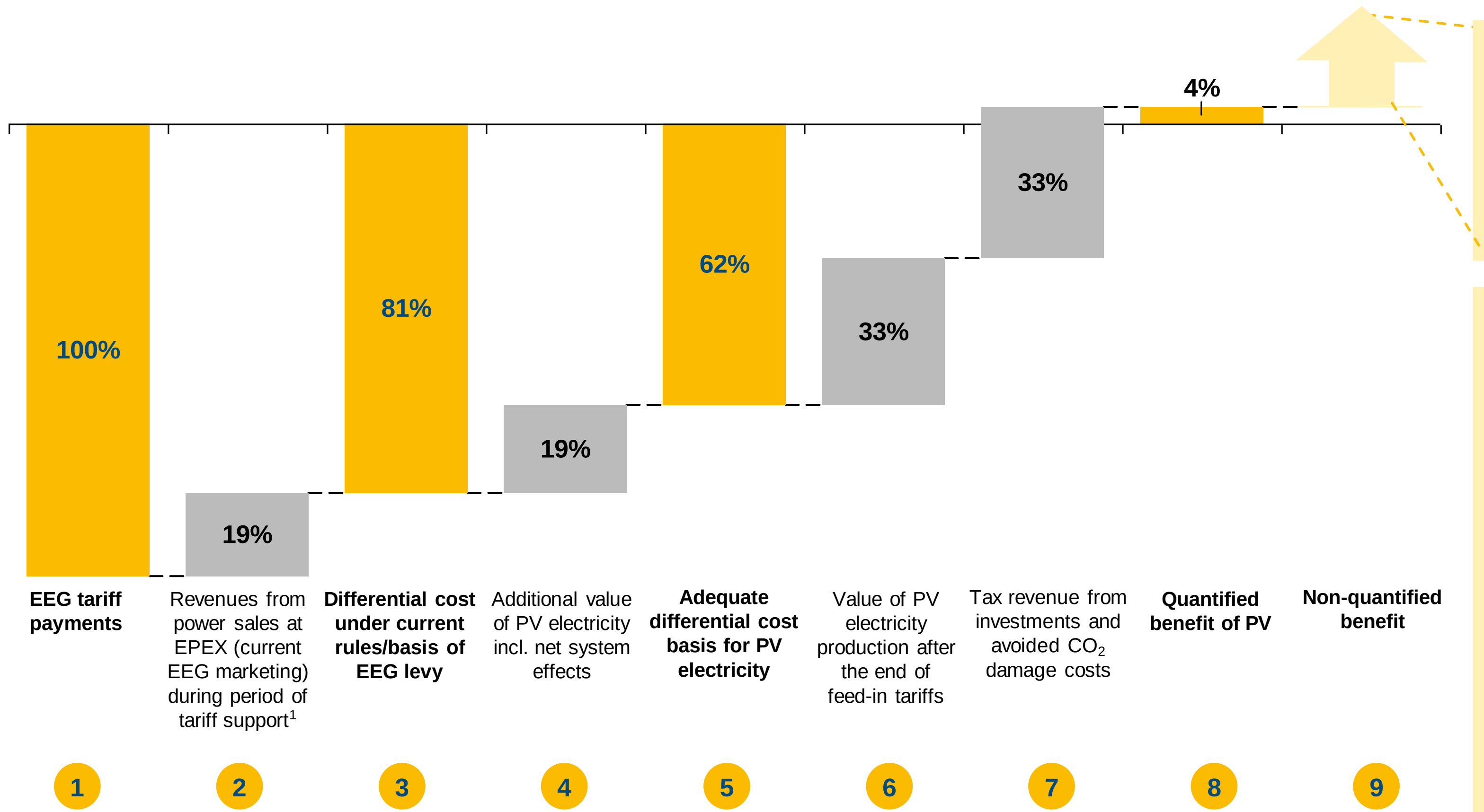
- The PV capacities installed in 2010 generate a positive return for the first time. This result is obtained for both of the assumed gas/coal price scenarios
- With an expected 6 GW of capacity additions and 13% tariff reduction, the result is significantly more positive in 2011 than in 2010
- Continuing capacity additions beyond 2011 as tariffs continue to fall make investing in PV increasingly profitable

Note: Based on an annuity of EEG payments and benefits in EUR m. Discount rate: 2.0%. PV investments from 2000 to end of 2011, module lifetime vintage 2000-2007: 30 years, module lifetime in 2008-2011: 35 years. Reference price: Average LV/MV generation price at consumer level assuming a conventional generation mix excluding base load capacity.
Capacity additions in 2010: 8 GW, capacity additions in 2011: 6 GW

Source: A.T. Kearney analysis

The return on all PV installations built between 2000 and 2011e is slightly positive for Germany

Value of PV: Investment case for capacities installed in 2000-2011e



IEA: "higher" fuel prices

Non-quantified benefits

- Reduced import dependency
- Contribution to structural change

Key assumptions:

- Capacity additions in 2010: 8 GWp, in 2011: 6 GWp
- Tariff reduction on 01/01/2011: 13%
- Rise in fuel costs per year:
  Gas: +3.5%
  Coal: +2.2%
- Assuming the "IEA reference price scenario": a 5% investment on the part of society remains

Note: Based on an annuity of EEG payments and benefits in EUR m. Discount rate: 2.0%. PV investments from 2000 to 2011, module lifetime from 2000-2007: 30 years, module lifetime in 2008-2011: 35 years. Reference price: Average LV/MV generation price at consumer level assuming a conventional generation mix excluding base load capacity; based on the IEA's "higher price sensitivity" scenario

1) Including value of peak load generation, taking into account the marketing costs for PV under EEG

Source: A.T. Kearney analysis

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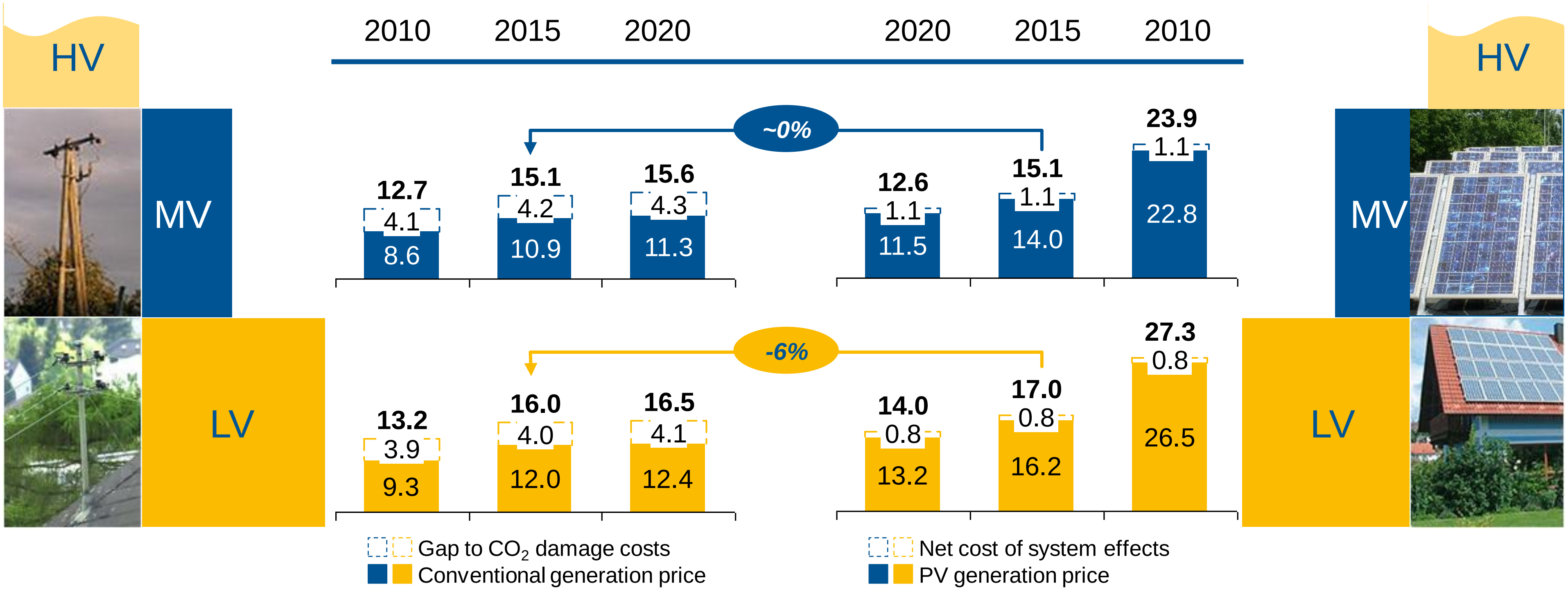
Taking into account environmental costs and system effects, PV becomes competitive in 5 to 8 years

Competitiveness: Conventional vs PV generation prices in Germany
(real prices, in 2010 EURc/kWh)

Conventional generation prices plus complete CO_2 avoidance costs[1]

PV generation prices[2] for LV and MV plus net cost of system effects[3]



1) Difference between CO_2 damage costs (EUR 70/t) and the CO_2 certificate prices that are already factored into conventional power generation. Fuel costs for coal and gas in line with higher IEA scenario
2) Calculated on the basis of CIGS technology for installation in southern Germany. Low-voltage level (LV): 3kW rooftop installation with 4.4% WACC, medium-voltage level (MV): 2.5 MW ground-mounted installation with 6.5% WACC
3) Net cost of system effects: Avoided grid losses, avoided O&M costs at HV level plus contribution to grid stabilisation through provision of reactive power less cost of back-up power plant and balancing power to balance out variable PV feed-in

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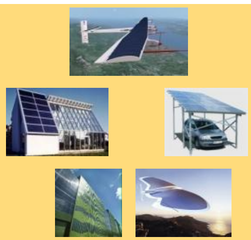
Source: A.T. Kearney analysis

PV is a key enabler of the structural transition to an efficient and distributed energy world

Structural change: PV's contribution to structural change

PV's contribution to structural change

Area of change	PV's contribution to structural change
National power generation mix 	Reduces degree of concentration in the oligopolistic power generation market Reduces Germany's dependency on gas and coal imports Safeguards power generation at known, low variable costs for up to 35 years
Distributed element of the smart grid 	Accelerates the deployment of smart grids Delivers grid services through smart inverters Reduces grid losses if feed-in is aligned with consumption
Key element in integrated, innovative applications 	Cuts material and grid costs in urban applications integrated within buildings Delivers electricity-generating components for stand-alone and e-mobility applications, e.g. charging stations Enables innovative and integrated system approaches with export potential

Source: A.T. Kearney

There is need for action by all stakeholders to ensure further development of PV in Germany

Summary of needed actions

	Political / legal framework	Energy market	PV industry
Value of PV	• Adjust marketing mechanism to reflect adequate valuation in differential cost • Continued support to warrant significant capacity additions	• Ensure flexibility of conventional power generation portfolio to balance/ backup PV	• Further develop PV systems to become intelligent nodes for energy management and grid service
Competitiveness of PV	• Decrease feed-in tariffs in line with cost reduction of total system cost • Adjust incentives to foster improved geographic and temporal distribution of feed-in	• Reflect actual cost inflicted by conventional power (CO2 damage) as well as PV (system integration cost)	• Focus all efforts on PV system cost reduction
Contribution to structural change	• Switch to time-of-use tariffs • Support market introduction of integrated PV applications	• Accelerate systematic smart grid introduction incl. e-mobility applications	• Improve cross-industry sector collaboration for integrating PV in innovative system applications

Contents

Description of PV- value components

BACK-UP

	Component		Subcomponent	Explanation
1	EEG tariff payments			▪ Includes all tariff payments for capacities installed between 2000 and 2011
2	Revenues from power sales at EPEX (current EEG marketing) during the period of tariff support			▪ Revenues from power sales at EPEX, including peak load generation (20%) and accounting for cost of EEG marketing
3	Differential cost under current rules, basis of EEG levy			▪ Difference between EEG tariff payments and revenues from power sales at EPEX
4	Additional value of PV electricity, incl. net system effects	4a	Additional value of PV-generated medium/low-voltage electricity during period of tariff payments	▪ Value of the difference between marginal cost valuation (EPEX) and costs for medium and low-voltage customers (which reflects the widely distributed generation of PV electricity)
		4b	Avoided grid losses and costs	▪ Value of avoided grid losses and costs at high and medium-voltage level
		4c	Balancing and back-up costs	▪ Cost of balancing power (variable generation profile of PV) and back-up capacity
5	Adequate differential cost basis for PV electricity			▪ Value of PV benefit and costs reflected in the energy system
6	Value of PV electricity production after the end of feed-in tariffs			▪ Value of electricity generated after the end of EEG tariff payments
7	Tax revenue from investments and avoided CO_2 damage costs	7a	CO_2 avoidance costs are not reflected in CO_2 certificate prices	▪ Difference between the (fixed) CO_2 avoidance costs and the (rising) CO_2 certificate prices
		7b	Rise in volume of tax	▪ Value of the higher tax revenues resulting from the additional PV capacities
8	Quantified benefit of PV			▪ Total value of quantified costs and benefits
9	Non-quantified benefits			▪ The value of the reduced import dependency and contribution to structural change represent benefits to society that have not been quantified in this study

Assumptions (1/6)

Assumptions on the price of generating power from conventional energy sources

Model components	Description	Sources
Fuel costs	▪ Coal: Reference case (2010: USD/t 65.9, 2050: 119.0), higher price sensitivity case (2010: USD/t 65.9, 2050: 156.2) ▪ Gas: Reference case (2010: USD/Mbtu 6.0, 2050: 18.5); higher price sensitivity case (2010: USD/Mbtu 6.0, 2050: 24.1)	▪ International Energy Agency (World Energy Outlook 2009)
Cost of capital	▪ Investment costs in EURc/kWh: hydro (5.1), lignite (1.3), nuclear (2.0), hard coal (1.4), gas (1.68), pumped storage (3.6) ▪ All kept constant over time (2010 to 2050)	▪ A.T. Kearney analysis based on EWI, IER
Generation margin	▪ The assumption is that as renewable energies' share in electricity generation rises margins for conventional generation will decline over time ▪ Low voltage (2010: 35%; 2050: 15%), medium voltage (2010: 25%; 2050: 15%)	▪ A.T. Kearney estimate based on annual reports
CO_2 certificate prices	▪ CO_2 certificate price: EUR/t 22.0 (2010), 18.2 (2020), 38.4 (2030), 58.5 (2040), 75.2 (2050)	▪ Energy scenarios for an energy concept by the German government, 2010 (ewi/gew/Prognos)
	▪ CO_2 damage costs: EUR/t 70.0 (2010-2050)	▪ DLR/ISI "External costs of electricity generation from renewable energies compared with electricity generation from fossil fuels", 2006
	▪ CO_2 emissions: lignite (1,150 g/kWh), hard coal (950 g/kWh), gas (400 g/kWh). Lifetime emissions from photovoltaics (48.5 g/kWh) were subtracted in each case	▪ IEA – System's Values Beyond Energy, 2008
Base, medium, peak load share	▪ Low voltage: 35% (base), 50% (medium), 15% (peak) ▪ Medium voltage: 70% (base), 25% (medium), 5% (peak) ▪ Percentages kept constant over time (2010 to 2050)	▪ Standard load profile, BDEW low voltage ▪ Assumptions based on client examples, medium voltage

Assumptions (2/6)

Power plant mix and cost assumptions

Model components	Description	Sources
Development of the conventional power plant mix and costs	▪ Current power plant mix: hydro (3.5%), lignite (27.7%), nuclear (28.8%), hard coal (21.6%), gas (13.7%), pumped storage (1.2%) (data from 2008) ▪ As PV is being compared with an alternative conventional reference technology, the model is not dependent on the developed power generation mix	▪ BNetzA 2009 monitoring report ▪ Assumption
Efficiency	▪ Development of efficiency of hard coal and gas-fired power plants ▪ Gas efficiency rises to 62% by 2019, up from 57.4 in 2010 ▪ Coal efficiency rises to 50% by 2038, up from 44.6 in 2010	▪ A.T. Kearney estimate

Financial assumptions

Model components	Description	Sources
Inflation	▪ Inflation (2%) drives the nominal development of electricity prices	▪ Assumption based on historical inflation figures (Economist Intelligence Unit) ▪ DLR/IWES/IFNE "Long-term scenarios and strategies for the expansion of renewable energies in Germany, taking account of developments in Europe and across the world", 2010
Discount rate	▪ To calculate the net present value and the annuity, a discount rate equal to the assumed inflation (2%) has been chosen	▪ Assumption

Assumptions (3/6)

Assumptions on PV systems installed in Germany in 2000-2011e

Model components	Description	Sources
Revenue	▪ 900 kWh/kWp as an average figure	▪ I-suppli 2010, ISET "Value of PV energy in Germany", 2008
Degradation	• Average degradation of 0.5 % p.a. is assumed for the systems already installed, across all technologies	▪ Osterwald et al. (2006) "Comparison of degradation rates of individual modules held at maximum power" ▪ Phoenix Solar
Lifetime	▪ Installations between 2000 and 2007: 30 years ▪ Installations between 2008 and 2011: 35 years	▪ Phoenix Solar estimate ▪ Expert interviews
Capacity additions	▪ 8 GW capacity additions in 2010 ▪ 6 GW capacity additions in 2011	▪ 2010: Figure expected by Phoenix Solar and A.T. Kearney ▪ DLR/IWES/IFNE "Long-term scenarios and strategies for the expansion of renewable energies in Germany, taking account of developments in Europe and across the world", 2010
Tariff degression	▪ 13% degression on 1 January 2011	▪ BNetzA report according to EEG para. 20

Assumptions (4/6)

PV value model assumption

Model components	Description	Sources
Grid losses	▪ Avoided grid losses, medium voltage (2.2%) ▪ Avoided grid losses, low voltage (4.4%) ▪	▪ A.T. Kearney analysis based on destatis (German Federal Statistical Office)
Balancing costs	▪ 0.1 EURc/kWh until 2015, then 0.2 EURc/kWh	▪ ISET "Value of PV energy in Germany", 2008
Back-up costs	▪ 1.0 EURc/kWh	▪ Based on IER (2010) calculation, A.T. Kearney analysis
Tax effects	▪ Total tax effects of EUR 4.4 bn for capacity additions in 2010 (indirect tax volume: EUR 2.1 bn)	▪ EuPD Research (2010)

Assumptions (5/6)

Assumptions on PV cost development – new installations between 2010 and 2020

Model components	Description	Sources
Module efficiency	▪ Continuous increase in solar conversion efficiency; rising to 18.4% for c-Si modules (multi-crystalline); rising to 17.4% for CIGS modules	▪ EU PhotoVoltaic Technology Platform, 2010 ▪ Photovoltaics ▪ A.T. Kearney & Phoenix Solar analysis
Module price	▪ Reduction in processing costs due to economies of scale and learning curve effects ▪ Continuous but levelling improvements in polysilicon consumption ▪ Polysilicon price to stabilise at USD 35-40/kg ▪ Price rises for other raw materials (glass, aluminium, etc.) of between 3% and 5% p.a ▪ Declining gross margins (down to 7-15% in some cases); however, to isolate the margin effects, a constant standard margin of 20% was assumed for a cost-plus scenario	▪ A.T. Kearney cost model ▪ Various analyst forecasts ▪ EU PhotoVoltaic Technology Platform, Solar Europe industry initiative – implementation plan 2010-2012, 2010
Balance of system costs (non-module costs)	▪ Rising unit prices for mounting systems, cables, etc. (caused by the rise in raw material prices) are offset by reduced material needs per W_p ▪ Significant reduction in the price of inverters is assumed	▪ A.T. Kearney cost model ▪ Company data ▪ Expert interviews
Installation costs	▪ Labour cost increases of 2.2-2.6% p.a. (depending on the job) will be almost completely balanced out by process efficiencies ▪ Margins are expected to fall significantly	▪ A.T. Kearney cost model ▪ Company data ▪ Federal Statistical Office
Operation & maintenance costs	▪ Labour cost increases of 2.2-2.6% p.a. (depending on the job) will be almost completely balanced out by process efficiencies ▪ Margins are expected to fall	▪ A.T. Kearney cost model ▪ Company data ▪ Expert interviews ▪ Federal Statistical Office

Assumptions on PV cost development – new installations between 2010 and 2020

Model components	Description	Sources

Financing costs & discount rate	▪ The model incorporates financing costs by discounting future cash flows with a WACC
	▪ The following WACC were assumed (constant until 2020):
	  ▪ **Residential rooftop systems: 4.4%**
	  ▪ **Ground-mounted systems: 6.5%**
		▪ Based on cost model assumptions regarding the share of borrowed capital and actual expected interest rates and returns

Solar irradiation/ insolation	▪ The model assumes mean irradiation for southern Germany of **1,200 kWh/m²** ▪ For the whole of Germany the assumed average is: **1,087 kWh/m²** ▪ Irradiation is assumed to be constant. Note, however, that some scientists consider an increase of 4 kWh/m² per decade to be a realistic scenario for Germany	▪ German Meteorological Service (DWD) ▪ Remund, J., 2009, Development of global irradiation over time in the period 1950-2099

Performance ratio	▪ PV system's initial performance ratio (before degradation):
	  ▪ Ground-mounted system: c-Si/CIGS: 80%
	  ▪ Rooftop system: c-Si/CIGS: 75%
		▪ Expert interviews with companies that install large numbers of systems

Lifetime	▪ Economic lifetime of 35 years for the complete PV system, with replacement of the inverter in year 20	▪ King et al., 2000, Photovoltaic Module Performance and Durability Following Long-Term Field Exposure

Degradation	▪ Degradation assumptions for new installations:
	  ▪ c-Si: initial degradation 2%, annual degradation: 0.25%
	  ▪ CIGS: initial degradation 1%, annual degradation: 0.20%
		▪ DGS Compendium

Abbreviations used in the document

Abbreviations used in the study

AR = Anti-reflecting
BNetzA = Bundesnetzagentur, the German regulatory office
BOS = Balance of systems
CAGR = Compound average growth rate
CdTe = Cadmium telluride
CIGS = Copper-indium/gallium-diselenide/ disulphide
EEG = German Renewable Energies Act
EPEX = European Power Exchange (Leipzig)
FiT = Feed-in tariff
HV = High voltage
IEA = International Energy Agency
kVArh = Kilovolt ampere reactive hour
KWKG = German Heat and Power Co-generation Act
LCOE = Levelised cost of energy
LID = Light-induced degradation
LV = Low voltage
MT = Megaton
MTBF = Mean time between failure
MV = Medium voltage
O&M = Operation & maintenance
PD&I = Project development & installation
PV = Photovoltaics
SG&A = Sales, general management and administration expenses
TCO = Transparent conductive oxide
TSO = Transmission System Operator
WACC = Weighted average cost of capital
W_p = Watt peak