ECN

Energy research Centre of the Netherlands

How to compare cost of wind energy

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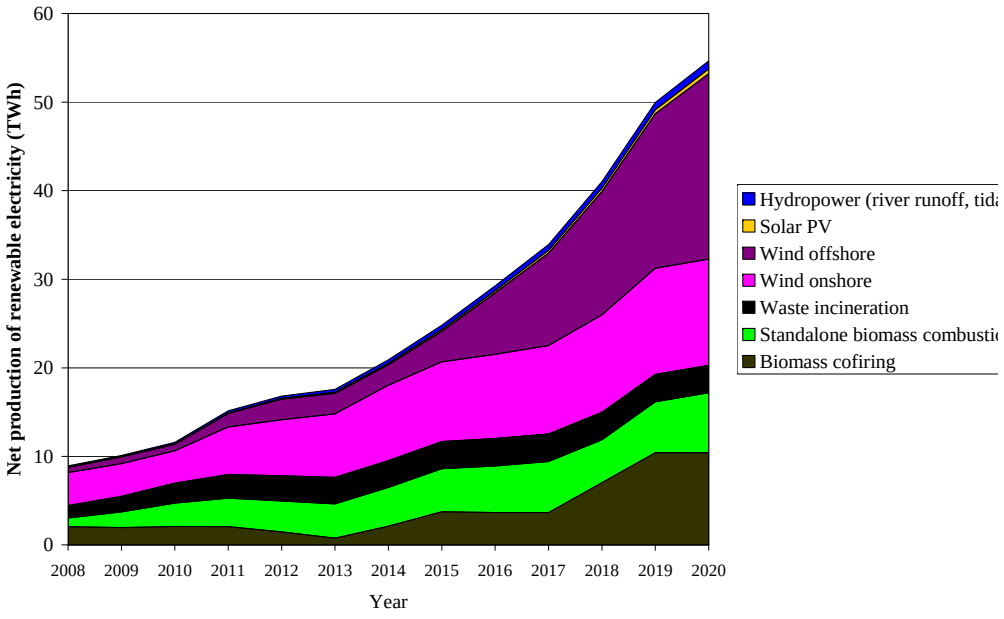
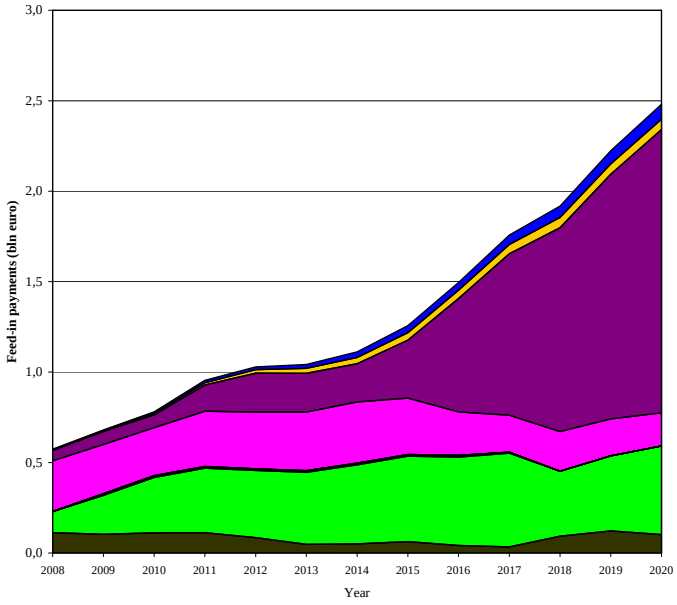
Investments needed for wind energy

- Ambitions for wind energy require huge investments





Why differences between countries

- Feed-in tariffs, premium, certificates are designed to cover the financial gap

Section 29

Wind energy

(1) The tariff paid for electricity from wind-powered installations shall amount to 5.02 cents per kilowatt-hour (basic tariff).

(2) In derogation of subsection (1) above, the tariff paid in the first five years after the installation is commissioned shall amount to 9.2 cent per kilowatt-hour (initial tariff). This period shall be extended by two months for each 0.75 per cent of the reference yield by which the yield of the installation falls short of 150 per cent of the reference yield. The reference yield is the calculated yield for the reference installation pursuant to Annex 5 to this Act. The initial tariff shall increase for electricity from wind-powered installations commissioned prior to 1 January 2014 by 0.5 cents per kilowatt-hour (system services bonus) if it demonstrably fulfils the requirements of the Ordinance in accordance with section 64(1) first sentence no. 1 from the date of commissioning.

§ 2. Hernieuwbare elektriciteit

§ 2.1 Windenergie op land

Artikel 2

1. De minister verstrekt op aanvraag subsidie aan producenten van hernieuwbare elektriciteit geproduceerd door een productie-installatie voor de productie van hernieuwbare elektriciteit met behulp van windenergie op land:
   a. met een nominaal vermogen per turbine kleiner dan 6,0 MW;
   b. met een nominaal vermogen per turbine gelijk aan of groter dan 6,0 MW.
2. Aanvragen om subsidie als bedoeld in het eerste lid, worden ontvangen in de periode van 1 maart 2010 tot en met 1 november 2010, 17:00 uur.
3. Een aanvraag om subsidie wordt ingediend met gebruikmaking van het origineel van een ondertekend formulier, dat is opgenomen in de bij deze regeling behorende bijlage 1.

Artikel 3

1. Het subsidieplafond voor het verlenen van subsidie die is aangevraagd in de periode, bedoeld in artikel 2, tweede lid, bedraagt € 937.000.000,-.
2. De minister verdeelt het bedrag, genoemd in het eerste lid, op volgorde van binnenkomst van de aanvragen.

Artikel 4

1. Subsidie als bedoeld in artikel 2, eerste lid, wordt voor een periode van 15 jaar verstrekt.
2. De subsidie-ontvanger neemt de productie-installatie voor de productie van hernieuwbare elektriciteit met behulp van windenergie op land binnen 4 jaar na de datum van de beschikking tot subsidieverlening in gebruik.

Artikel 5

1. Het maximaal aantal vollasturen voor productie-installaties als bedoeld in artikel 2, eerste lid, onderdeel a, bedraagt 1760 uren per jaar.
2. Het maximaal aantal vollasturen voor productie-installaties als bedoeld in artikel 2, eerste lid, onderdeel b, bedraagt 2476 uren per jaar.

Artikel 6

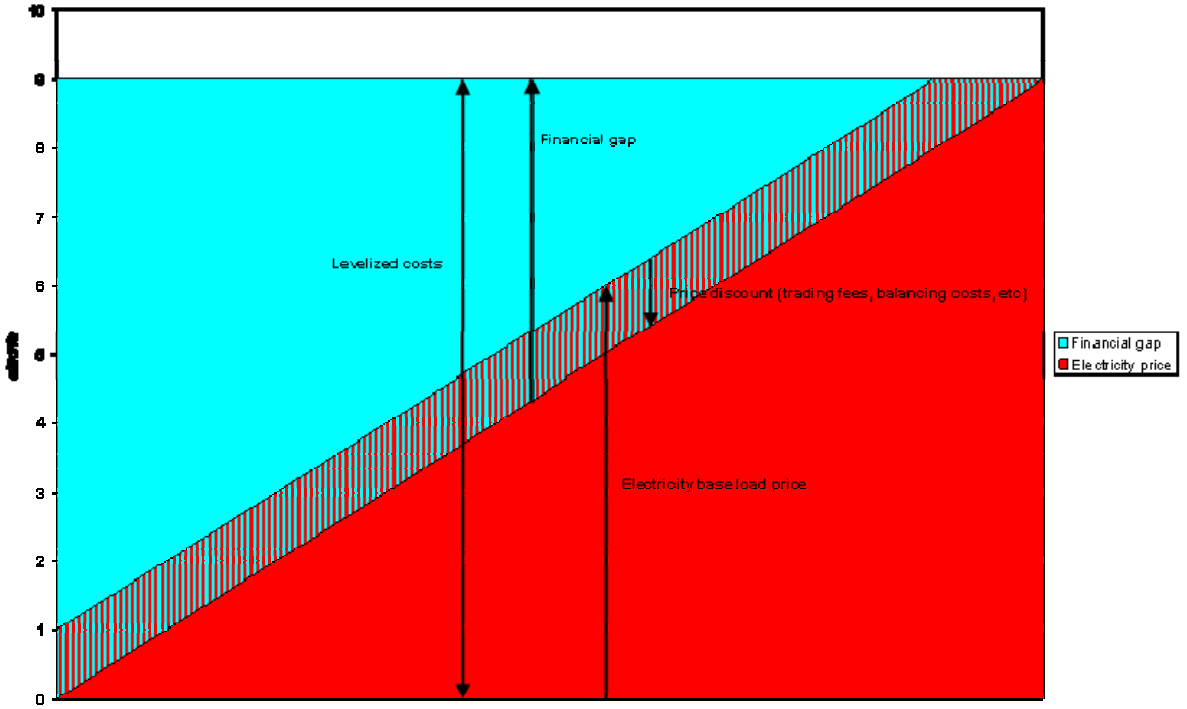
Het basisbedrag, bedoeld in artikel 11 van het besluit, voor subsidie als bedoeld in artikel 2, eerste lid, bedraagt voor productie- installaties als bedoeld in:
a. artikel 2, eerste lid, onderdeel a: € 0,120 per kWh;
b. artikel 2, eerste lid, onderdeel b: € 0,120 per kWh.

Artikel 7

De basiselektriciteitsprijs, bedoeld in artikel 12 van het besluit, voor subsidie als bedoeld in artikel 2, eerste lid, bedraagt voor productie- installaties als bedoeld in:
a. artikel 2, eerste lid, onderdeel a: € 0,049 per kWh;
b. artikel 2, eerste lid, onderdeel b: € 0,050 per kWh.

Methodology to identify differences

- Perspective of developer
- IEA task 26



Development and use of cash flow model (introduction)

- The Netherlands implemented in 2003
  a feed-in premium support scheme for RES-E.
- Feed-in premium compensates for the financial gap.
- ECN advises yearly on the financial gap and production costs.
- Parliament sets the premium levels (€ct/kWh), mostly in line with the ECN advice.

Development and use of cash flow model (introduction)

- Consensus exists between government, stakeholders and ECN on using the ECN cash flow model.
- Cashflow model is publicly available on the Internet

- Discussions are limited to estimating the values of the techno-economic and financial parameters.
- Calculation method for the financial gap is not under major dispute in the Netherlands.

Cost calculation

$$PV = \sum_{t=1}^{T} \frac{IT(t)}{(1+r_e)^t}$$

$$NPV(E) = PV - E \cdot C_{tot} = 0$$

In which:
PV = Present value of the future cash flows (€)
NPV(E) = Net present value of the equity share of the investment (€)
r_e = Return on equity (%)
E = Equity share of the total investment (%)
C_{tot} = Total investment (€)

Now, the financial gap calculation becomes:

$$FG = \frac{E \cdot C_{tot} - \sum_{t=1}^{T} \frac{IT(t)}{(1+r_e)^t}}{\sum_{t=1}^{T_b} \frac{Q(t) \cdot (1-\tau)}{(1+r_e)^t}}$$

Cost characteristics

- Project type
- CAPEX
- OPEX
- Net production
- Cost of capital
- Policy measures

Netherlands 2008, onshore

	INPUT PARAMETERS	Unit	Input value	Value used	Formula
Total investment cost	Wind turbine	€/kW		value overruled	a
	Wind turbine transportation	€/kW		value overruled	b
	Wind turbine Installation	€/kW		value overruled	c
	Subtotal: wind turbine cost	€/kW	1045	1045	D=a+b+c
	Foundations	€/kW	115	115	E
	Internal grid	€/kW	35	35	f
	Grid connection, grid code compliance	€/kW	70	70	g
	Grid reinforcement	€/kW		0	h
	Substations and transformer station	€/kW		applies to offshore only	i
	Subtotal: elektrical net / grid	€/kW		105	J=f+g+h+i
	Certification	€/kW		0	k1
	Environmental surveys	€/kW		0	k2
	Non-infrastructure development subtotal	€/kW		0	k=k1+k2
	Access roads	€/kW	35	35	l
	Miscellaneous	€/kW	10	10	m
	Interest payment before operation	€/kW	15	15	n
	Subtotal other project development costs	€/kW		60	O=k+l+m+n
	Total project investment costs	€/kW		1325	P=D+E+J+O
Total decommissiong costs	Decommisioning, excluding scrap value	€/kW		value overruled	q
	Returning the land to the natural state	€/kW		value overruled	r
	Scrap value	€/kW		value overruled	s
	Net decommissioning costs	€/kW	0	0	T=q+r-s
Project Operation	Operational time / full load hours, excluding derate	h/yr	2200	2200	DD=cc/(aa+bb)
	Derate of full load hours	h/yr		0	ee
	Net operational time / full load hours	h/yr		2200	FF=DD-ee
	Economic life	yr	20	20	
	Time horizon for cost calculations	yr	20	20	
Financial variables	Loan duration	yr	15	15	
	Loan - market interest rate		6,0%	6,0%	hh
	Soft loan advantage		Modify input	1,0%	ii
	Return on debt			5,0%	GG=hh-ii
	Required return on equity, excluding market volatility risk adder		15,0%	15,0%	u
	Market volatility risk adder			0,0%	v
	Net required return on investment equity			15,0%	W=u+v
	Local equity ownership		Modify input	0%	x
	Equity share, excluding local equity ownership		20%	20%	y
	Total equity share			20%	Z=x+y
	Debt share			80%	1-Z
	Corporate tax rate (national or federal)		Modify input	25,5%	α
	Corporate tax rate (municipal of state)		Modify input	0,0%	β
	Net tax rate			25,5%	Γ=α+β
	Depreciation period	yr	Modify input	15	

Support/subsidy for wind energy

- Support is needed to attract investments

Cash flow model for financial gap calculations
Wind: Netherlands 2007

	Symbol	INPUT PARAMETERS	Unit	Fixed or average value
Project features	U	Unit size	kW_e	1000
	H	Operational time / full load hours	h/yr	2000
	T_b	Economic life	yr	20
Costs	C_{tot}/U	Investment costs	€/kW	1122
		Decommisioning costs	€/kW	0
	c_f	Maintenance costs fixed	€/kW	48,32746853
	c_v	Maintenance costs variable	€/kWh	0
Market	p_e	Other revenues	€/kWh	0,082
		Other costs	€/kWh	0,0101
Policy support		Upfront tax-based investment subsidy		37%
		Upfront cash investment subsidy		0%
		Feed-in tariff	€/kWh	0,066
		Production-based tax credit	€/kWh	0,000
		Production-based tax deduction	€/kWh	0,000
Project financing features	R_d	Return on debt		5,0%
	R_e	Required return on equity		15,0%
	e	Equity share (excluding EIA benefit)		20%
	d	Debt share (including EIA benefit)		80%
		Corporate tax rate (Municipal/state)		0%
	τ	Corporate tax rate (National/federal)		25,5%
Time horizons	T_r	Loan duration	yr	10
	T_d	Depreciation period	yr	10
	T_p	Economic life	yr	20
Output	FG	Financial gap	€/MWh	-36
	LC	Levelized electricity generation cost	€/MWh	91

Cash flow model for financial gap calculations
Wind: Netherlands 2008

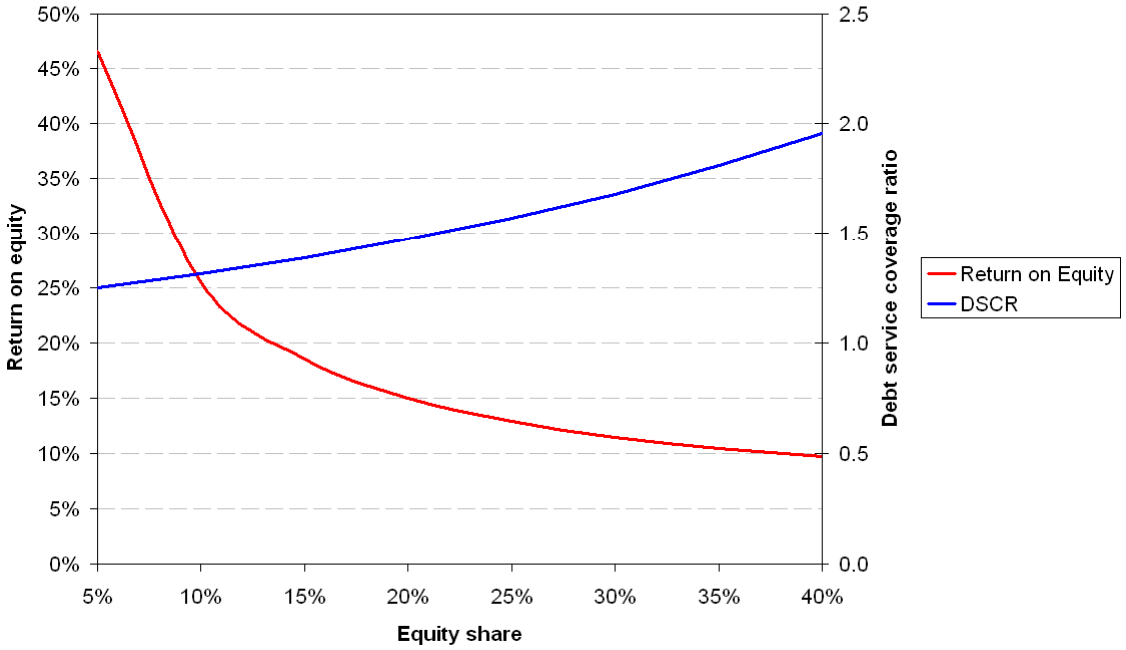
	Symbol	INPUT PARAMETERS	Unit	Fixed or average value
Project features	U	Unit size	kW_e	15000
	H	Operational time / full load hours	h/yr	2200
	T_b	Economic life	yr	20
Costs	C_{tot}/U	Investment costs	€/kW	1325
		Decommisioning costs	€/kW	0
	c_f	Maintenance costs fixed	€/kW	31,39238321
	c_v	Maintenance costs variable	€/kWh	0,013363553
Market	p_e	Other revenues	€/kWh	0,080
		Other costs	€/kWh	0,0097
Policy support		Upfront tax-based investment subsidy		20%
		Upfront cash investment subsidy		0%
		Feed-in tariff	€/kWh	0,028
		Production-based tax credit	€/kWh	0,000
		Production-based tax deduction	€/kWh	0,000
Project financing features	R_d	Return on debt		5,0%
	R_e	Required return on equity		15,0%
	e	Equity share (excluding EIA benefit)		20%
	d	Debt share (including EIA benefit)		80%
		Corporate tax rate (Municipal/state)		0%
	τ	Corporate tax rate (National/federal)		25,5%
Time horizons	T_r	Loan duration	yr	15
	T_d	Depreciation period	yr	15
	T_p	Economic life	yr	20
Output	FG	Financial gap	€/MWh	-3
	LC	Levelized electricity generation cost	€/MWh	94

Discounting

- Developer's perspective
  - Focus on developer's equity
  - Equity as input
  - Return on equity as discount rate

- Societal perspective
  - Focus on total capital that is needed
  - Total investment as input
  - WACC as discount rate

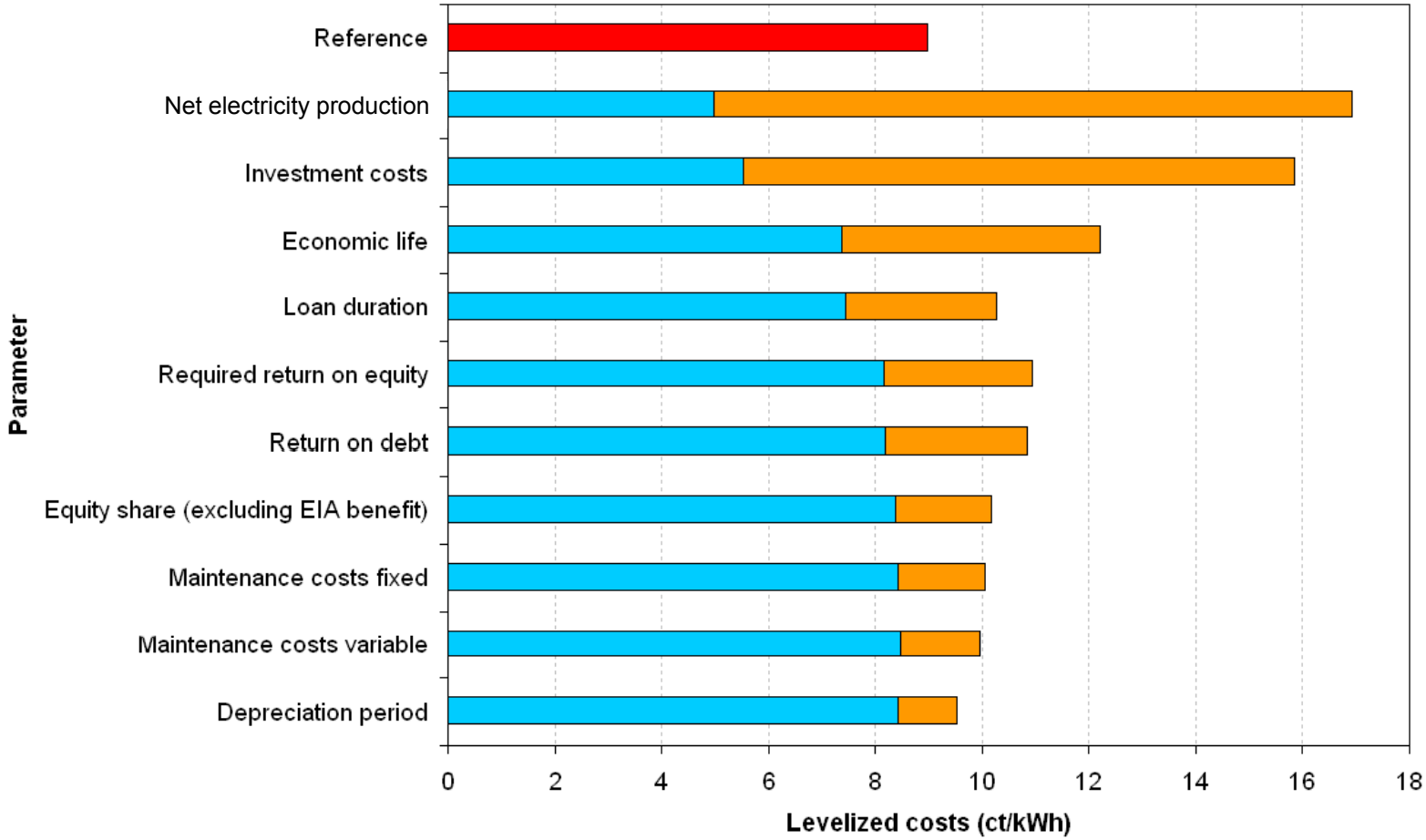
Equity share vs Return on Equity (illustration)



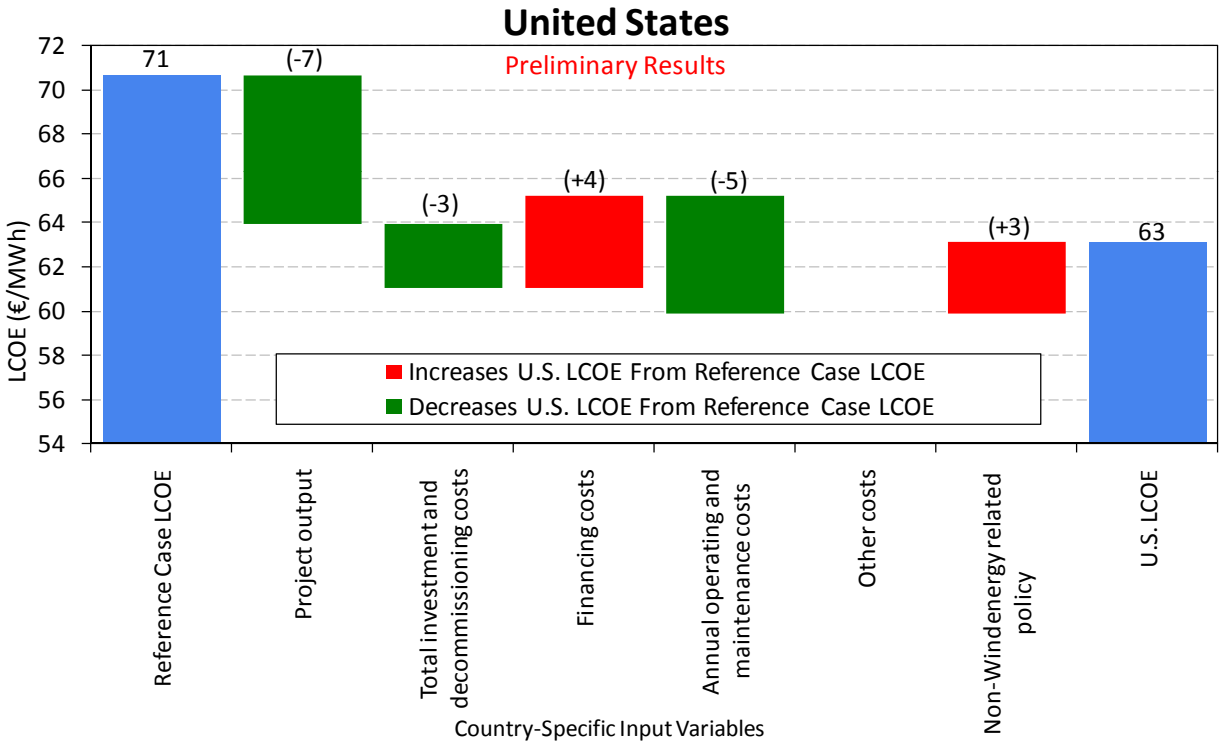
Weighted Average Costs of Capital constant (6.5%)

→ Levelized costs constant (9.0 ct/kWh)

Effects of ±50% parameter value (summary)



Example results, importance of financing



Source: Paul Schwabe (NREL) / IEA task 26

Discussion: general LCOE approach

- Good to estimate wind energy cost for society
- Informative for societal preferences for technology
- Not representative for subsidy needs

Discussion: developer's perspective

- Less informative on societal (system) costs
- Representative for subsidy needs
- Indication for additional funds to lure investments
- For other technologies: indications for autonomous direction of investments