VGB

Survey 2012

Investment and Operation Cost Figures – Generation Portfolio

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(updated from December 2011)

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Introduction

This survey is based on an extensive enquiry and consultation with our members from generators and suppliers.[1] The ambition is to provide our members, policymakers and academia with a comprehensive and robust set of 'order of magnitude' data.

We are aware of the literature on costs of technologies, which we have carefully crosschecked with our own results. This survey reflects the generators' position based on the past few years experiences with investment. It will be updated on an annual basis.

Objective

The electricity sector is in a state of dynamic and constant change, driven by innovation, learning curves and consequent changes in the generation mix. Any overview of investment, operating and refurbishment costs for the entire set of generation technologies will therefore necessarily be an approximation. The objective of this survey is thus not to present precise numbers, but '**order of magnitude**' data that **reveals the trends and the comparative cost advantages of technologies in a timeline up to 2030.**

Scope

This survey covers the entire generation portfolio: renewables (RES) (on/off-shore wind, photo-voltaic and solar-thermal), hydropower (with pumped storage and run-of-river), and thermal power plants (coal, lignite, gas and nuclear). This overview provides an update of the status in mid-2011.

Principles underlying the data on CAPEX and OPEX

Assumptions on investment cost (CAPEX) and operation cost (OPEX) have been derived from real projects and the corresponding operational data. We are aware that exchange rates, material costs and market interventions are key cost drivers. By making no assumptions on those factors, or on fuel prices and inflation rates, we maintain the comparative element and avoid adding further uncertainties to our assumptions. Our sources are the major players in Europe, on both the generation and the supply side.

[1] The set is partly an update of the data set developed for the EURELECTRIC study "Power Choices" and for the OECD/NEA study "Projected Cost of Generating Electricity."

CAPEX is commonly defined as money spent to acquire or refurbish systems and system components such as machinery. It can be further broken down into costs for predevelopment, engineering construction, all systems ‘within the fence’, and other infrastructure. The only distinction we make is to assume ‘greyfield’ conditions for fossil and nuclear plant sites and ‘greenfield’ conditions for renewables, based on the assumption that meteorological/geological conditions are decisive for the installation of RES plants.

The expenditures for new pumped storage projects are highly depending on geological conditions and infrastructure.

We have singled out refurbishment and lifetime extension costs in our analysis, which are presented in a dedicated row in the table. This facilitates an understanding of the increased costs for nuclear with lifetime extension and increased security standards, but also for the refurbishment of older hydro plants.

OPEX is commonly defined as the expenditure related to the operation and maintenance of power plants; it includes spare parts, auxiliary cost, insurance, labour costs, grid fees, taxes, and maintenance contracts. We have noted these expenditures as a percentage of investment cost per year. Fuel costs or expenditures for carbon certificates are not included.

The given figures are ‘average’ values across different locations and conditions that alleviate specific impacts. In addition one has to take into account that the number of equipment suppliers in Europe – general contractors, system suppliers and material suppliers – is limited and that market conditions tend to converge.

It is obvious that the figures on investment per installed electric power (€/kW_{el}) scatter within a certain range; this is valid for both conventional and renewable equipment suppliers. The scattering range starts in 2011 with ‘reliable’ values that only reflect site-specific differences. However, this range will increase over time due to the growing weight of prognosis uncertainties. Thus, for 2011 variations of +/- 100 €/kW_{el} are possible; beyond 2030 the scattering range rises to about +/- 200 €/kW_{el}.

Learning Curves

The data for the future take learning curve assumptions into account. These are well-known for conventional technologies, but much more difficult to anticipate for RES. Indeed, learning curves depend on various factors such as RDD, mass production, raw material cost, or engineering effort. We did not take impacts driven by market regulation, nor subsidies or priority dispatch into account. Since we excluded assumptions on inflation rates or steel prices, all future figures are based on the 2011 reference figures.

The future development of CAPEX figures depends - beyond other factors - on the technical progress. The manufacturing or physical/chemical or market effects are determining the technical progress. It is evident that the capex figures are the pre-requisite for the OPEX figures.

Therefore the parameters affecting the cost components of any system able to produce electricity are:

- Physical effects
- Chemical effects
- Simplification of the system
- Process technology
- Material consumption
- Quality of material, e.g. rare earth, platinum
- Engineering ´basic´
- Engineering for specific installation
- Technical maturity
- Standardisation of components and concept
- Manufacturing process → mass production Y/N
- Large scale deployment
- Licensing procedure
- Site impact → geology, meteorology etc.
- Installation and commissioning on site
- Life time impact

The long list demonstrates the complexity influencing the cost structure. The decisive point for reducing costs is a competitive environment, i.e. different suppliers acting in a market not dominated by subsidies. In the following it will be shown what one can expect from future developments; in any case we will see at the end a saturation effect.

Three technologies will be considered in its principle features:

<u>Photovoltaic</u>
Referring to the mass production effect photovoltaic is the most feasible one because the cell production requires a big scale production line; consequently the development cost and engineering cost can be spread on a huge amount of cells. The physical/chemical effect is limited; therefore the process technology is struggling with lower cost per cell but also with lower efficiency and/or shorter life time. System simplification is focused on the classical part as instrumentation & control system, electric equipment, civil engineering and site specific improvements.

<u>Concentrated Solar thermal Plant</u>
Referring to ´Solar thermal´ one has to distinguish the solar part and the conventional steam turbine part and the storage facility part. At the end the solar part is conventional - except new concepts as Fresnel-type collector. The cost for

the steam turbine part is well known, no surprises will occur. The big unknown is the storage part due to the fact that there is the biggest potential for improvements.

Wind power plants

Referring to wind turbines there is achieved at a high degree of technical maturity. Standardised processes are in use. But the mass production effect is reduced on the instrumentation & control system, the electric equipment and the pylon components; the turbine blades itself are a top sophisticated manufacturing process with very limited mass productivity factor. In addition the site impact is becoming more and more important as the experience with the off-shore projects show. The connection to decentralised grids with its specific challenges has not been considered.

As a conclusion one can quote that the biggest effect will come from the photovoltaic side. But what we need is a more realistic view as we learned from the off-shore wind power plants, but also from the photovoltaics.

Data Table and Graphs

Table 1 consists of the following columns: technology, lifetime, operation hours, CAPEX (balance of plant, mean regional impact), efficiency (net efficiency in terms of heat value), refurbishment (major upgrade in replacing turbine blades, pulveriser or I&C systems) and the scattering range from 2011 to 2050 as well as annual OPEX (personnel, insurance, taxes, auxiliaries, etc.) in % of invest costs.

The graphs 1 and 2 show the levelised costs of electricity LCOE splitted in invest costs, O&M costs, fuel costs and CO_2 costs. The invest costs have been calculated based on the equivalent annual cost method at 10% discount rate.

CO_2 costs have been calculated based on a certificate price of 30 €/tCO_2. A difference of 10 €/tCO_2 changes the LCOE by 6% for gas, 11-13% for hard coal and 13-17% for lignite.

Levelised Costs of Electricity EURELECTRIC / VGB 2011 Edition

Technology		Life time (years)	Typical Plant Size (MW)	Operation hours (h)[1] (baseload)	CAPEX (EUR/kW) and Efficiency (%)						OPEX per year as % of invest
					2011		*2030*		*2050*		
					CAPEX	**Efficiency**	*CAPEX*	*Efficiency*	*CAPEX*	*Efficiency*	
Fossil Fuels											
Gas open cycle		25	~ 250	6000	650	45	*650*	*45*	*650*	*45*	3.0%
Gas CCGT		25	> 400	6000	800	60	*800*	*62*	*800*	*62*	2.5%
Hard coal 600		35	~ 800	7500	1300	> 45	*1300*	*47*	*1300*	*49*	2.0%
Lignite 600		35	~ 800	7500	1400	> 43	*1400*	*47*	*1400*	*49*	2.0%
Hard coal / Lignite 700		35	~ 800	7500			*2100*	*50*	*1800*	*52*	2.0%
Hard coal 700 + CCS		35	~ 800	7500			*3000*	*40*	*2700*	*41*	2.0%
HC 600 + Biomass-co-firing		30	~800	7500	1390	>45	*1300*	*47*	*1300*	*49*	2.0%
Nuclear											
EPR1600		40[2]	1600	7900	3000[3]	36	*2600*	*37*	*2600*	*37*	2.0%
Storage											
Pumped storage		50-60	~250	2500[4]	1100-2400[5]	80	*1100-2400* [5]	*80*	*1100-2400* [5]	*80*	1.0%
Renewables											
Run-of-river		50-60	20-250	6000	1800-2200[5),6]	90	*1800-2200* [5),6]	*90*	*1800-2200* [5),6]	*90*	1.0%
Wind onshore		25	2-3	1800	1100-1300		*1100*		*1100*		3.3%
Wind off-shore	near	25	5	3200	2000-2200		*1800*		*1800*		4.3%
	far	25	5	3800	2600-3000		*2200*		*2200*		5.0%
Solar PV		25	0.005-0.5	2000	1800-2800		*1700* [7]		*1700* [7]		1.0%
Solarthermal CSP		30	2-50	2800	3000-3500		*2000*		*2000*		2.0%
Biomass		30	< 25	7500	2500	~ 40	*2500*	*~ 40*	*2500*	*~ 40*	2.5%

1) operation hours are determined by market conditions
2) 60 years with additional measures
3) for new plants after 2015, taking learning effects from first projects into account
4) perspective value for coming requirements due to bridging the intermittency of RES
5) large spread, depending on local conditions
6) net investment (without specific measures)
7) target figure, open to be achieved

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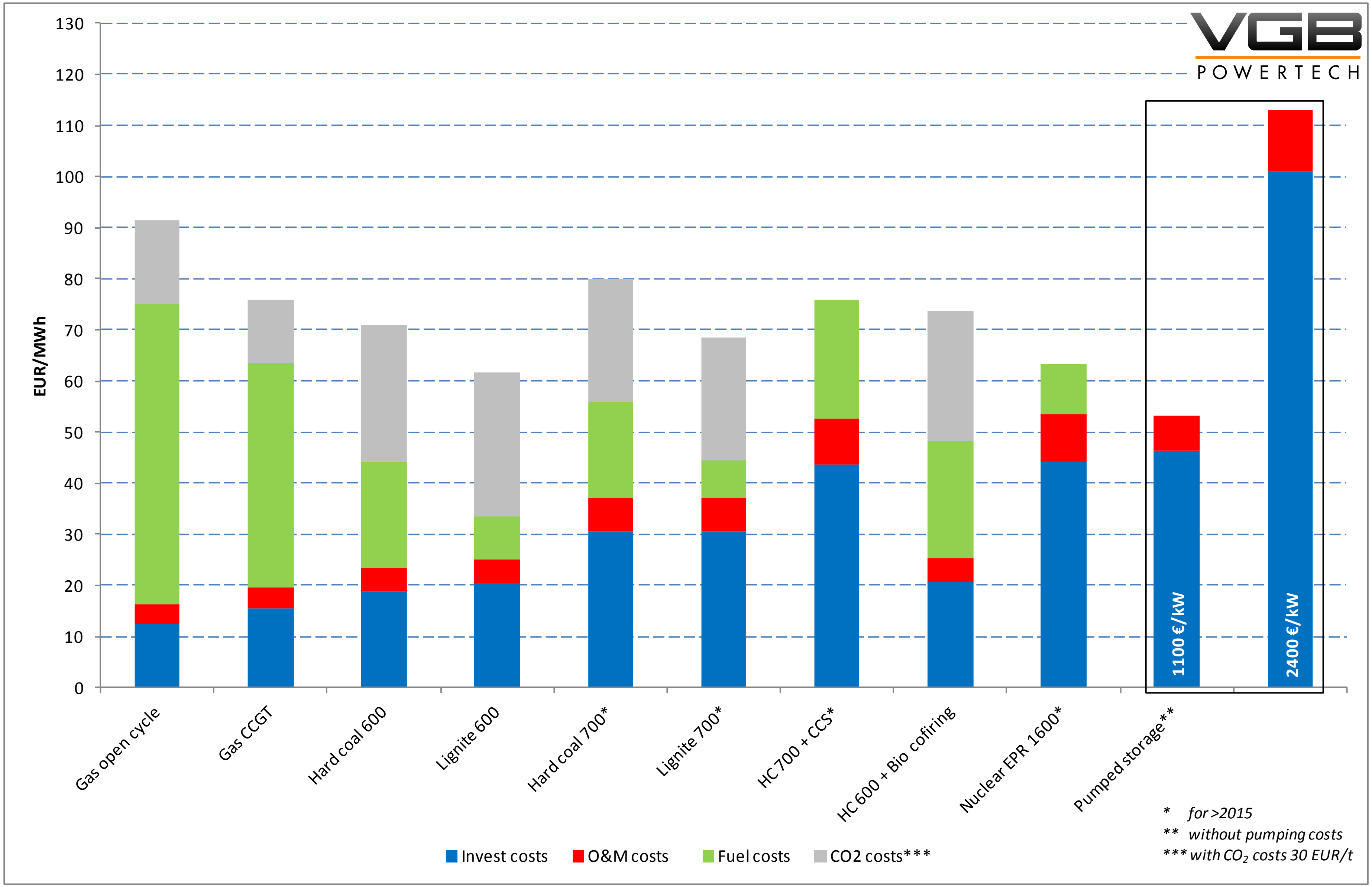
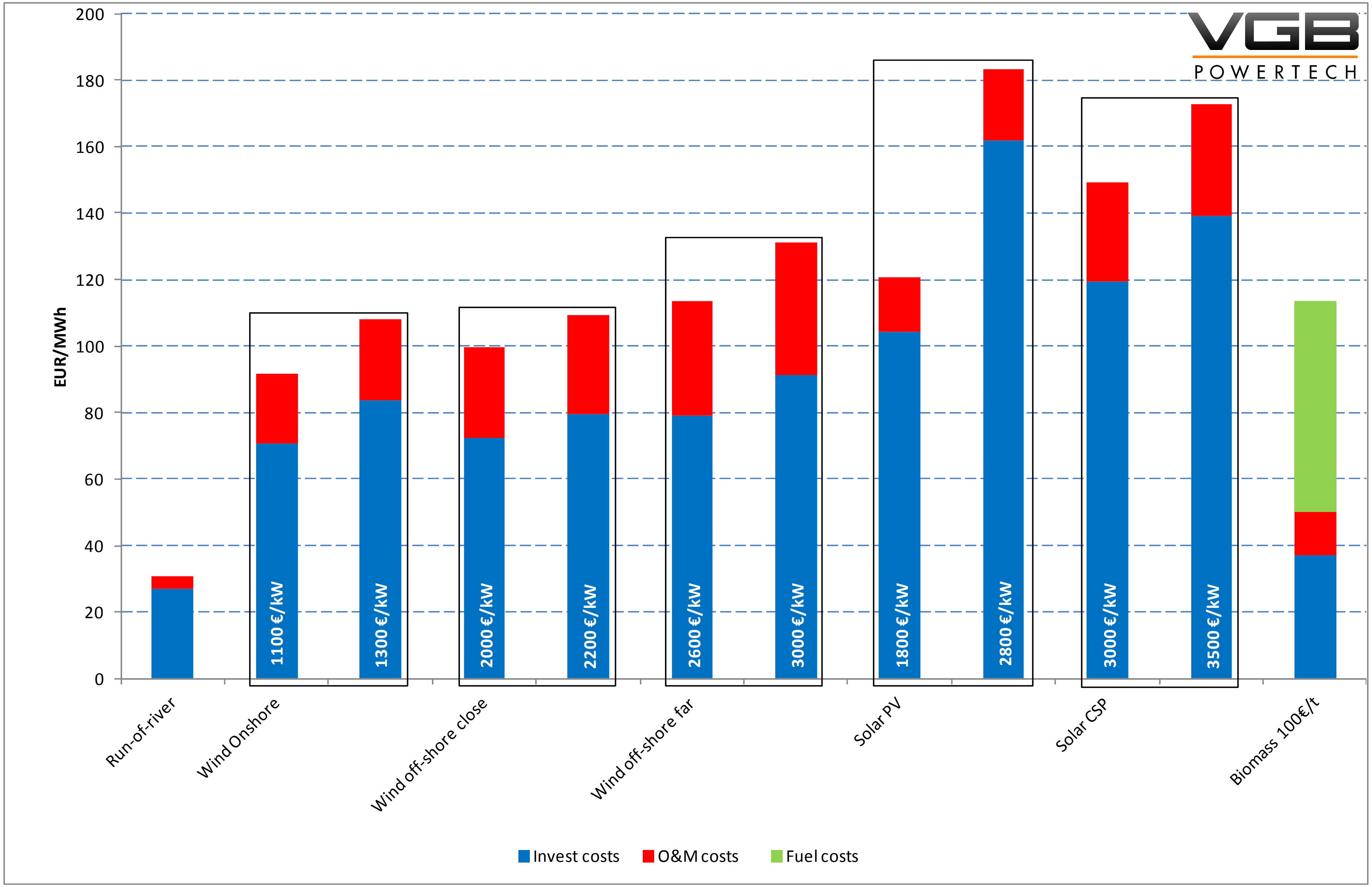
Table 1: CAPEX and OPEX of different technologies



Graph 1: Levelised Costs of Electricity 2011 – Conventional technologies



Graph 2: Levelised Costs of Electricity 2011 – Renewables