An Analysis of the National Nuclear Power Programme

The implementation of the National Nuclear Power Programme should be analysed on several levels:

1. Economic aspects
    - 1.1 Investment costs,
    - 1.2 Market offer,
    - 1.3 Operating costs,
    - 1.4 Decommissioning costs,
    - 1.5 Total cost level;
2. Social aspects
    - 2.1 Effect on employment:
    - ◙ During construction,
    - ◙ During operation;
    - 2.2 Effect on the economic development of the country:
    - ◙ Directly,
    - ◙ Indirectly (possible multiplier effects);
3. Logistics
    - 3.1 Obtaining a site,
    - 3.2 Development of grid connections,
    - 3.3 Construction timetable (deadlines),
    - 3.4 Internal programme organisation;
4. Political aspect
    - 4.1 Level of public acceptance,
    - 4.2 Level of voters' acceptance,
    - 4.3 Feasibility of the programme and associated timetable,
    - 4.4 Impact on energy security of the country;
5. Environmental aspect
    - 5.1 Reducing greenhouse gas emissions,
    - 5.2 Security,
    - 5.3 Management of:
    - ◙ Nuclear fuel,
    - ◙ Spent nuclear fuel;
6. Conclusion

Confining such a multi-dimensional, complicated analysis to a short publication using layman's rather than technical and economic terms does not seem possible. It is worthwhile, however, to try and provide a discussion of the above-mentioned issues in a manner that makes them accessible to the general public, so that it can be used as a sort of "terms of reference" for the project currently being developed by the government, or rather by the Government Commissioner for Nuclear Power. In particular, this analysis concerns the economic aspects of introducing nuclear power to Poland.

The issue of the environmental security of nuclear power raises the most controversy. Past experiences of nuclear power stations malfunctioning are not very positive, but it must be admitted that the power station being built in Poland is to use a completely different technology (EPR – a pressurised reactor of the III+ generation) to that employed at the Chernobyl power station (a second generation graphite reactor). The only problem is the fact that no such reactor is as yet operational (a few installations of this type are under construction, including the famous Olkiluoto 3 reactor).

1. Economic aspects

1.1. Investment costs

Much information can be found on the internet regarding the investments necessary for nuclear power development. Unfortunately, most of it is not reliable, as it does not reflect transaction (contract) prices, and is really just advertising. Information on the level of investment can be found in source materials, rather than in media reports based on the declarations of parties with a vested interests in the issue. Back in 2007, the Moody's credit ratings agency already estimated the unitary cost of a nuclear power station at $5 million per MW. Current estimates are much higher and reach $9 million per MW, that is €6 million per MW. The transcript of a hearing before the Public Service Commission of Maryland state concerning the financial situation of the Baltimore Gas and Electric Company[1] is an interesting source of information in this respect. This hearing is based on data from the Calvert Cliffs 3 investment. Interesting data regarding current nuclear power station costs in the US is also provided by the testimony of David A. Schlisse[2] before the same Public Service Commission. Schlisse points to a dramatic rise in the investment price of nuclear power stations in the US. It should be pointed out that the Calvert Cliffs 3 is an EPR III+ power station produced by AREVA.

An interesting analysis of the costs of energy production by nuclear power stations is provided in a publication[3] by François Lévêque entitled "Nuclear generation costs – revisiting estimates" (Ecole

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[1] http://webapp.psc.state.md.us/Intranet/Casenum/NewIndex3_VOpenFile.cfm?ServerFilePath=C:%5CCasenum%5C9100-9199%5C9173%5C%5C210.pdf

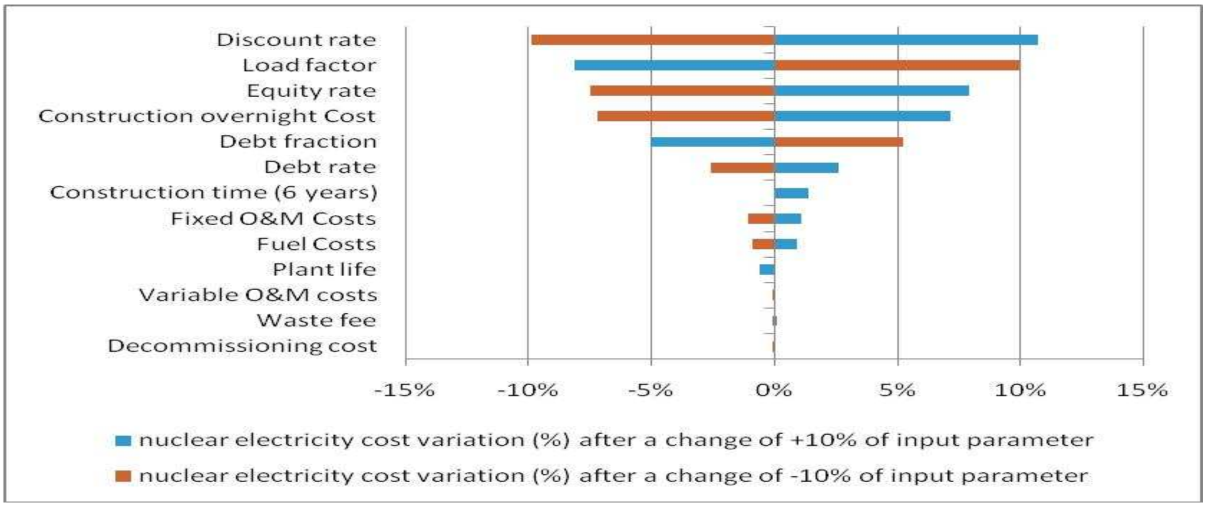
[2] www.nirs.org/nukerelapse/calvert/schlisse_cc_testimony071608.pdf

[3] http://www.energypolicyblog.com/2009/10/23/nuclear-generation-costs-%E2%80%93-revisiting-estimates-once-again/

des Mines de Paris, October 2009).The results of individual analyses differ significantly: the estimate of the cost varies between 18 €$_{2007}$/MWh and 80 €$_{2007}$/MWh. Furthermore, newer reports point to higher costs: analyses published in 2003-2005 give a mean of around 43 €$_{2007}$/MWh, that is much lower than the 2007-2009 average of around 63 €$_{2007}$/MWh.

Sensitivity of energy costs to the value of parameters is shown in Fig. 1.

Figure 1. Sensitivity of decomposed generation costs to changes in key parameters.



Source: François Lévêque

As it can clearly be seen in Fig.1, the strongest influence on generation costs is exerted by: the discount rate, the load factor, the equity rate, the construction overnight cost and the fraction and rate of debt (credit). Changes in the construction time, fixed costs and fuel, variable costs, waste fees and decommissioning costs only have a weak impact. The analysis took changes of +/- 10% into account. A significant lengthening of construction work causes financial costs to rise dramatically. The example of Olkiluoto 3 shows that overnight costs also rise.

An interesting analysis is presented by Cambridge Energy Research Associated (CERA) looking at the escalation of capital costs. Over the 2002-2007 period, the rate of escalation stood roughly at an annual 8%, then at 14%. Some sources give even higher rates of investment cost increase[4].

Table 1. Capital investment in the US

Investment	Investor	Data	Overnight million $/MW	Total million $/MW	All included million $/MW

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[4] Du Yangbo and John E. Parsons, 2009, Update on the Cost of Nuclear Power, Center for Energy and Environmental Policy Research, May 2009, http://web.mit.edu/ceepr/www/publications/workingpapers/2009-004.pdf

Turkey Point 2xAP 1000	Florida P&L	II 2008	2,444	3,582	3,108	4,540	5,780	8,071
2xAP 1000	Florida Progress Energy	III 2008	3,376	5,144	6,636		No data	No data
Virgil C. Summer 2xAP 1000	South Carolina E&G Co	V 2008	No data	No data	4,05		No data	No data
Lee 2xAP 1000	Duke Energy Carolinas	XI 2008	No data	No data	5,00		No data	No data
Bellefonte 2xAP 1000	TVA	XI 2008	2,516	4,649			4,500	7,955
Vogtle 2xAP1000	Georgia Power Co	IV 2009					7,366	

Source: Wikipedia[5]

Much fuller data can be found in an exhaustive analysis by Cooper (see Table 2), which includes 35 estimates of individual capital costs, from 1175 $/kW to 10383 $/kW – a truly mind-boggling range, the only possible explanation being that the low prices come from a time when the US did not yet build nuclear power stations, and so these are 'paper,' rather than contract amounts. The last column of Table 2, showing the busbar cost of electricity, is also worrying. These figures warn against excessive optimism as to the low prices of energy from nuclear power stations.

Table 2: Juxtaposition of investment costs and busbar energy costs

Original Estimate	**Date of Estimate**	**Source of Estimate**	**Overnight Cost 2008$/kW**			**All-in Cost 2008$/kW**			**Busbar Costs 2008$/MWh)**		
			Low	Mid	High	Low	Mid	High	Low	Mid	High
SAIC	2001	U of C	2300	2300	2300	—	—	—	75	81	89
SAIC	2001	U of C	1840	1840	1840	—	—	—	69	61	63
SAIC	2001	U of C	1570	1570	1570	—	—	—	53	56	63

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[5] http://en.wikipedia.org/wiki/Economics_of_new_nuclear_power_plants

Original Estimate	Date of Estimate	Source of Estimate	Overnight Cost 2008$/kW			All-in Cost 2008$/kW			Busbar Costs 2008$/MWh)		
			Low	Mid	High	Low	Mid	High	Low	Mid	High
SAIC	2001	U of C	1295	1295	1295	—	—	—	45	52	74
Scully	2002	U of C	1434	1434	1674	—	—	—	41	46	51
Sandia	2002	U of C	2131	2131	2131	—	—	—	68	—	95
EIA	2003	U of C	2015	2015	2217	—	—	—	72	—	78
EIA	2003	U of C	1241	1563	1784	—	—	—	49	—	61
MIT	2003	MIT	1175	2350	—	—	—	—	65	79	—
U of C	2004	U of C	1380	1725	2070	—	—	—	61	71	82
TVA	2005	TVA	—	1853	—	—	—	—	—	—	—
CEC	2007	CEC	—	3021	—	—	3840	—	—	106	—
Keystone	2007	Keystone	3018	—	3018	3653	—	4092	85	—	114
Harding	2007	Harding	—	3329	—	4349	—	4655	96	—	125
South Texas 3&4	2007	CRS	2931	3214	3754	—	—	—	—	—	—
Turkey Point 3&4	2007	CRS	3179	3179	4644	—	—	—	—	—	—
Calvert 3	2007	CRS	—	5778	—	—	—	—	—	—	—
Levy 1&2	2008	CRS	—	4260	—	—	—	—	—	—	—
Summer 2&3	2008	CRS	—	4387	—	—	—	—	—	—	—
Vogtle	2008	GA PUC	—	4381	—	—	6447	—	—	—	—
Callaway 1	2008		—	4250	—	—	6125	—	—	—	—
Duke	2008	Lovins	—	4800	—	—	—	—	—	—	—
S&P	2008	S&P	—	4100	—	—	—	—	—	—	—
DOE Loans	2008	DOE	—	—	—	—	6528		—	—	—
EIA	2008	EIA	—	3400	—	—	—	—	—	—	—
CRS	2008	CRS	—	3900	—	—	—	—	—	83	—
CBO	2008	CBO	—	2358	—	—	—	—	—	74	—
Lazard	2008	Lazard	3750	—	5250	5750	—	7550	100	—	126

Original Estimate	**Date of Estimate**	**Source of Estimate**	**Overnight Cost 2008$/kW**			**All-in Cost 2008$/kW**			**Busbar Costs 2008$/MWh)**		
			Low	Mid	High	Low	Mid	High	Low	Mid	High
Moody's	2008	Moody's	—	6250	—	—	7500	—	—	151	—
Severance	2008	Severance	6233	7440	—	8858	0553	—	250	300	—
MIT II	2009	MIT II	—	4092	—	—	—	—	—	86	—
Bell Bend	2009	PPL	—	—	9375	—	—	—	—	—	—
Harding - Medium	2009	Harding 09	5524	7263	9217	—	—	—	137	173	212
Harding - High	2009	Harding 09	6189	8184	10383	—	—	—	150	190	235

Source: Cooper (2009)

As can be seen from Table 2: Juxtaposition of investment costs and busbar energy costs] estimates of investment costs are clearly rising, and have almost tripled over the 2001-2009 period – the investment cost increase factor, calculated using mean values, exceeds 3,7.

1.2. Market offer

Table 3: Advanced nuclear reactors of generation III and III+

Type of reactor	**Generation**	**Power MWe**	**Number in project stage**	**Number under construction**	**Number in operation**
EPR AREVA	III+	1600	4	2	0
AP1000 Westinghouse/ Toshiba	III+	1154	14	4	0
ESBWR General Electric/Hitachi	III+	1550	4	0	0
ACR Atomic Energy of Canada Ltd	III+	1165	2	0	0
ABWR General Electric/Hitachi	III	1350	2 (+3)	3	4
US APWR	III	1700	2	0	0

Mitsubishi					
APR 1400 KHNP (KOPEC/Doosan)	III	1400	6	2	0
VVER 1200/491 Rosenergoatom	III (?)	1170	4	4	0
Total	III i III+		41	15	4

Source: Internet analysis, Wikipedia, DoE, NEAC

In practice, only the French EPR and the American AP1000 are being constructed, while the other III+ generation reactors, i.e. those with passive security systems, are still in the design phase. Wikipedia quotes an analysis[6] indicating the improved competitiveness of nuclear power brought on by the need to use CCS technologies:

Table 4: Capital investment and electricity generation costs in the US

	Overnight capital cost (2008 $/kW)	**Electricity cost (c/kWh)**
Nuclear	4038	8.34
Supercritical coal	2214	8.65
Supercritical coal +CCS	4037	14.19
IGCC	2567	9.22
IGCC + CCS	3387	12.45
Gas combined cycle	869	7.60
Gas combined cycle + CCS	1558	10.31

Source: Connecticut Integrated Resource Plan study quoted in **World Nuclear Association**[7]

However, M. Cooper's wide-ranging analysis (op. cit.) conveys a very different message. Cooper indicates that nuclear power is competitive only when compared with coal power stations equipped with CCS.

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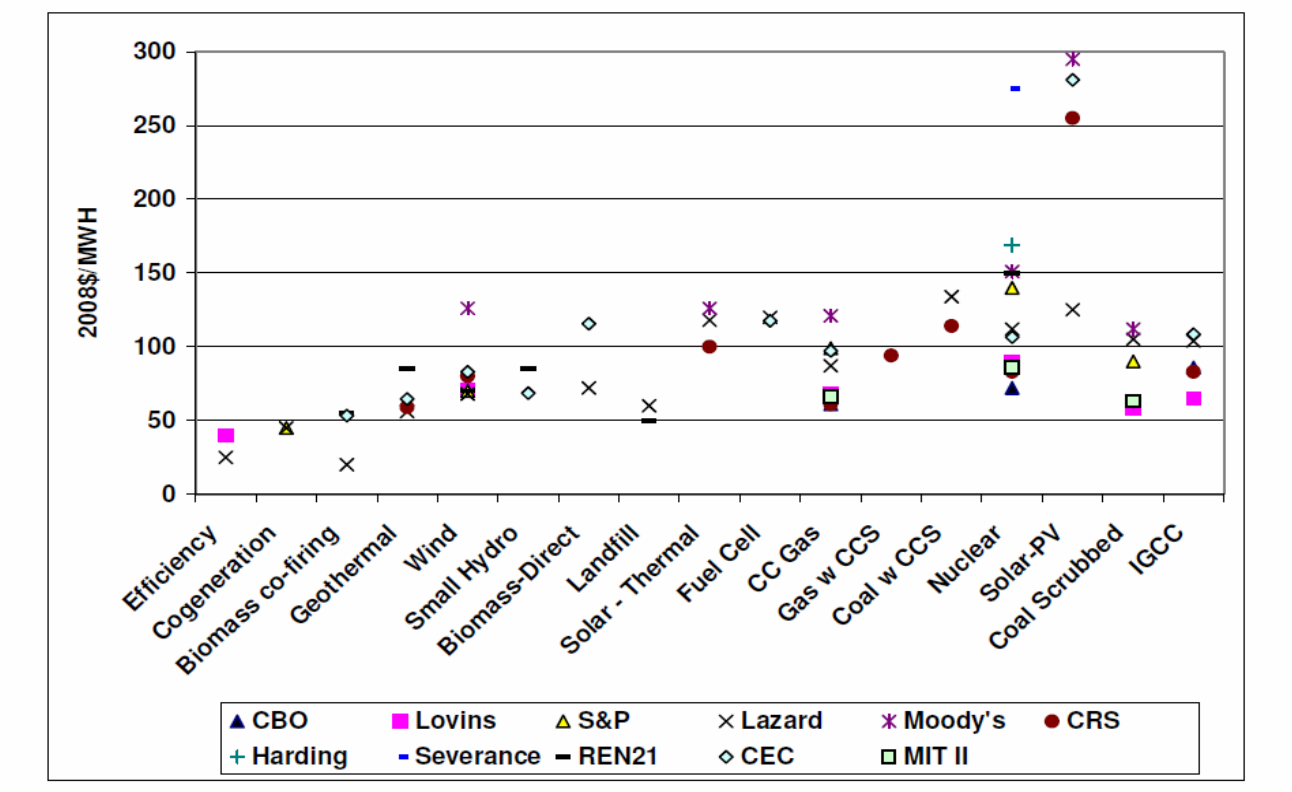
[6] The Economics of Nuclear Power, *Information and Issue Briefs*, World Nuclear Association, 2009, http://www.world-nuclear.org/info/inf02.html, Retrieved 2009-04-01.

[7] http://www.world-nuclear.org/info/inf02.html

Figure 2: Cost of alternative means of energy supply (busbar)



Source: Cooper (2009)

Only one conclusion can be drawn from this: a layman's analysis of the construction and operation costs of nuclear power stations, thus also of the end cost of energy from such power stations, is not a sufficient basis for making a decision on an issue of such importance to the Polish economy. The potential error will greatly affect it, but the social and political consequences may be even greater. If nuclear power does not supply us with so called "cheap electricity," and this is not entirely certain, then public trust in state institutions and leaders will be seriously shaken. Those responsible for such a decision will pay for it politically, and the price may be very high. This is why the issue of costs must be subjected to professional analysis based on data from reliable sources, such as: contract prices, government programmes (e.g. DoE) and similar documents citing definite commitments. Interviews, advertising and over-simplistic presentations must be excluded from the decision process.

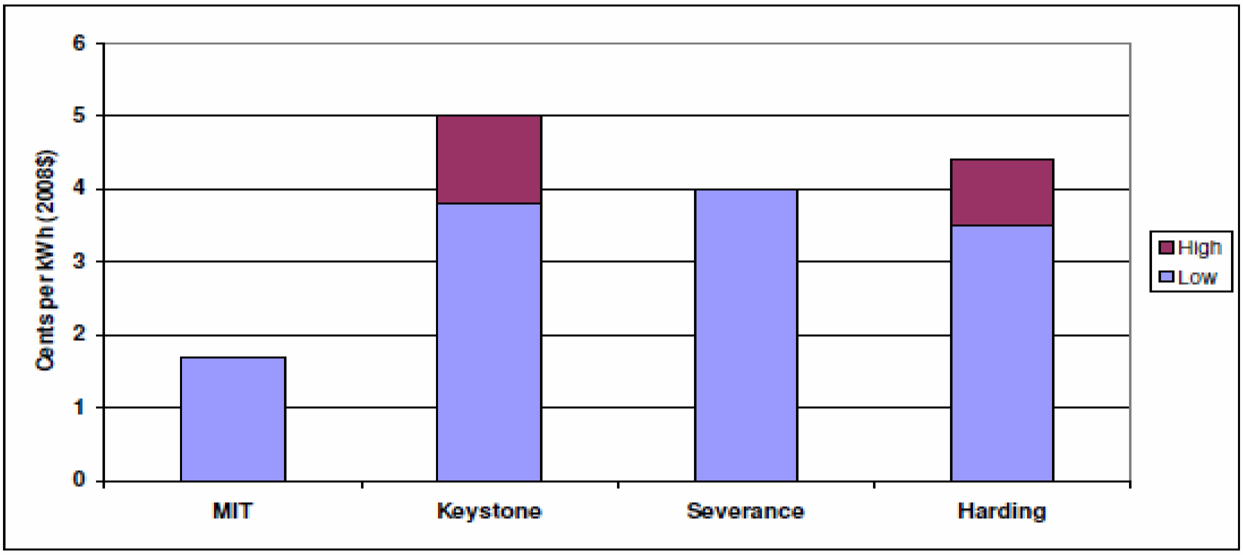
Figure 1 reminds us, that out of the six most important factors affecting the price, as many as four have an economic basis, independent of technology. It must also be noted that a 10% rise in load level is no longer possible, because new installations report loading of above 90% (above 8000 h/year), and some time must be devoted to refuelling and reparations. This means that the end cost of energy will be determined by financial engineering, rather than technology. According to

Polish investment experts, whom I agree with, the cost will be influenced by the real time of project implementation, which translates into the capital cost of the investment period (IDC – interest during construction, and return on equity – ROE).

1.3. Operating costs

In nuclear power operating costs are usually less significant, but it must be noted that also in this respect there are great differences between various calculations.

Figure 3: Operating costs in American nuclear power stations

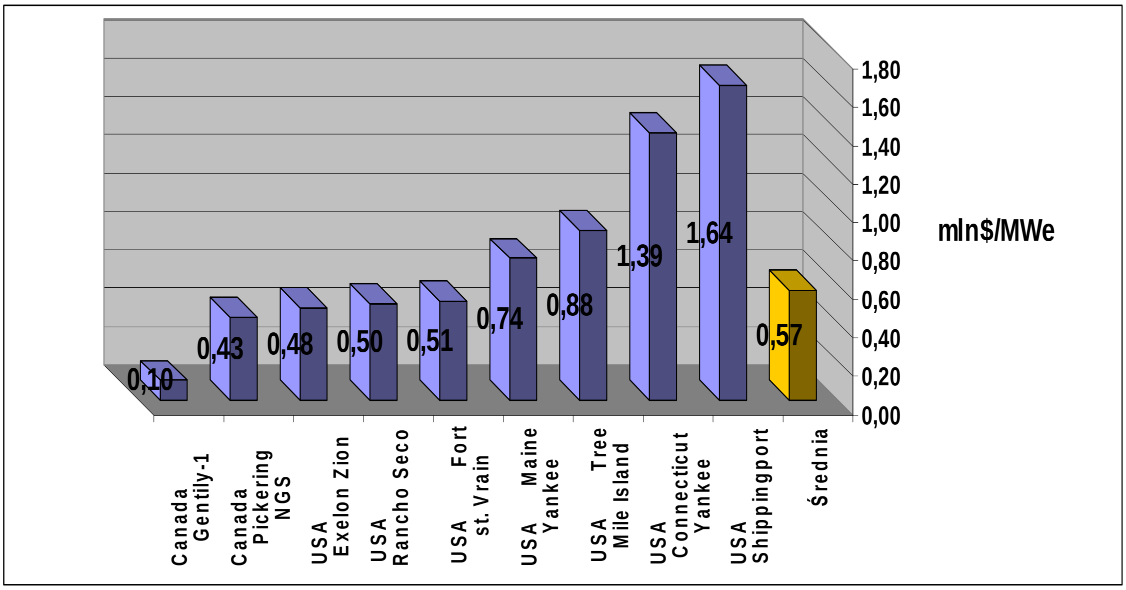


Source: M. Cooper (2009)

1.4. Decommissioning costs

The level of expenses related to decommissioning a nuclear power plant is very difficult to determine. This cost should be taken into account when calculating the price, and funds collected from buyers should be saved in a special decommissioning trust, which should enable not only the disassembling of the power plant, but also the full decontamination of the land on which it functioned. According to American data, the cost of decommissioning is currently estimated at 325 million $ per reactor, which in the case of an AP 1000 reactor would give 0.28 million $ per MWe – this value is clearly an underestimate. Historic data can be seen in Figure 4. In Europe, the costs of decontamination are higher: in the UK they amount to 2.6 million $ per MWe, and in France – 4 million $ per MWe.

Figure 4: Historic costs of decommissioning in Canada and the US



Source: Own calculations based on information from Wikipedia[8]; Średnia = mean value

1.5. Total cost level

An interesting analysis of electric energy costs can be found in a report of the Nuclear Energy Advisory Committee (November 2008)[9] – the committee, which advises the US Department of Energy. Below is an estimate of the costs:

Table 5: An estimate of total costs

Cost category	**Minimum estimate $/MWh**	**Maximum estimate $/MWh**
Cost of capital	46	62
Fuel	13	17
Fixed operating cost (O&M)	19	27
Variable operating cost (O&M)	5	5
Total	**83**	**111**

Source: Nuclear Energy Advisory Committee

The cost presented in Table 5 is the so-called decomposed cost, which includes the cost of closing the power station and full land clean-up. It can clearly be seen that with the current dollar exchange rate this cost is not particularly attractive, as it amounts to a value between 236 and 315

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[8] http://en.wikipedia.org/wiki/Nuclear_decommissioning
[9] http://www.ne.doe.gov/neac/neacPDFs/NEAC_Final_Report_Web%20Version.pdf

zl per MWh. The attractiveness of this cost will of course rise after 2013, which is when the obligation to buy CO2 emission permits comes into force, and especially after 2019, when the derogation period will end. This example clearly shows that introducing the cap & trade system with a high price for CO2 emissions has opened the way for nuclear energy development – independently of the intentions of the system's creators.

In the case of Poland, the costs will depend on the situation on the capital market, i.e. on the price of debt capital – probably 8% – and on the price of equity – not below 12%. Banks can be expected to request a share of at least 30%. Given that the longest credit period is currently 30 years, based on this data we can expect the capital cost in the first year of operation to reach 103,5 to 141 $ per MWh, depending on the way the debt is paid off – fixed payment or fixed rate. This figure is the result of financial analysis, i.e. liquidity, rather than accounting analysis, so called "amortisation." It goes without saying that for the debtor, and especially for the bank, the former is more important.

2. Social aspects

2.1. Effect on employment

Modern power stations do not require many employees. An estimate of ¼ person per MW can currently be made, which gives a workforce of 750 for a 3000 MW power station. Such a power station will initially need 4000 people to be employed over 5 - 7 years during the construction period. If two blocks are being built, the construction period will total around 9 years – assuming a two-year time delay in the building of the second block. It must be assumed that around 50% of employees running the power station will have to come from abroad – due to a lack of local professionals. During construction, the proportions may be more favourable – Polish workers are currently employed in the construction of Olkiluoto 3 in Finland.

Case study – Indian Point power station[10]

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[10] http://www.atom.edu.pl/index.php?option=com_content&view=article&id=76, http://www.flickr.com/photos/tonythemisfit/2755502911/;

Table 6: Parameters of the Indian Point power plant

Unit	Net Capacity MW(e)	Generation (Million Kilowatt Hours)	Capacity Factor (Percent)	Type	On Line Date	License Expiration Date
2	1,020	8,212	92	PWR	8/1/1974	9/28/2013
3	1,025	9,176	102	PWR	8/30/1976	12/15/2015
	2,045	**17,388**	**97**			
PWR =pressurized light water reactors.						

Source: http://www.eia.doe.gov/cneaf/nuclear/page/at_a_glance/reactors/in_point.html

The Indian Point nuclear power plant in Buchanan, New York state, employs[11] 1683 workers on two blocks (2 and 3) built in 1974 and 1975. With a total power of 2090 MWe, this means an employment factor of 0,81 persons per MW – such a high factor results from the outdated construction of the PWR reactors. This power plant is the subject of an interesting analysis of the effects on employment in the area around the plant – i.e. in the neighbouring five counties where 81% of the workers live.

Table 7: Turnover and employment generated by a nuclear power station (2002)

Sector of economy	**Expenses for power plant**	**Employees' total income***	**Number of employees***
Value of electric power generated	650 931 840 $ (Income for power plant)	126 764 472 $	1 357
Real estate tax	9 180 758 $	N.A.	N.A.
Bulk trade	5 997 007 $	2 528 002 $	39
Private health service	5 638 043 $	3 317 516 $	57
Upkeep, conservation and repairs of buildings	4 704 194 $	1 969 959 $	99
Trade in real estate	4 536 372 $	615 432 $	19
Public health service	4 324 430 $	2 614 840 $	61
Banking	4 087 369 $	789 038 $	16
Catering	3 367 526 $	1 366 463 $	79
Insurance	3 083 332 $	1 117 537 $	17

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[11] http://en.wikipedia.org/wiki/Indian_Point_Energy_Center

Other	67 437 028 $	30 355 410 $	809
Total	**763 287 899 $**	**171 438 669 $**	**2 553**

Source: **http://www.atom.edu.pl/index.php?option=com_content&view=article&id=76**

The issue of employment generation in the area around the power plant is presented in Table 8

Table 8: Direct, indirect and induced employment (2002)

	Direct†	**Indirect***	**Induced****	**Total**
Value of electric energy generated	$ 650,000 million	$ 26,523 million	$ 86,765 million	$ 763, 288 Million
Cost of employment	$ 126,583 million	$10,913 million	$ 33,943 million	$ 171,439 million
Number of jobs created	1 355	280	918	2 553

Source: **http://www.atom.edu.pl/index.php?option=com_content&view=article&id=76**

† “Direct” means the inhabitants of neighbouring counties employed directly in the power plant;

* “Indirect” means income for local companies, and the use of their services for the plant;

** “Induced” employment results from increased income for local households, caused by a flow of cash from the Indian Point nuclear plant.

Higher income leads to a local increase in demand, which brings an increase in production by local companies and the creation of new work places.

The total income of the workers (the power station’s own employees and those of associated companies) amounts to $171.4 million, and other local expenses stand at $16.7 million. As the above data suggests, this so-called “multiplier effect” should not be overestimated – in the case of Indian Point, the direct increase in employment is 0,65 persons per MW, and the indirect and induced increase is 0,57 persons per MW, which gives a total 1,22 persons per MW. As can be seen from this analysis, the value of the “multiplier effect” as applied to employment does not exceed 2, and when it comes to revenue – 1⅔. This is why it seems that talk of the employment of an additional 20 000 people locally is somewhat exaggerated. Such a significant rise in employment can only be temporary and can only concern the construction period.

2.2. Effect on the economic development of the country

It is difficult to state unequivocally whether Poland produces, or can produce, materials (cement, steel, turbines, generators) of the high quality required for the safe functioning of a nuclear power station. Much will depend on the form of the construction contract, and above all on the existence, size and type of offset. In the absence of an offset, most materials and all hi-tech products will be imported from the country of the supplier.

The influence of heightened energy security cannot be easily translated into higher GDP, revenue and competitiveness of the economy, but it is undoubtedly positive.

3. Logistics

3.1. Obtaining a site

It must be kept in mind that to obtain a site in Poland, and in particular to obtain conditions for construction and land use (e.g. planning permission), an Environmental Impact Assessment (EIA) is required by law. This is a detailed assessment needing prior information from a relatively advanced stage of the design process. A detailed final design is not yet required here, but there is a need for more than an outline concept of the building layout, in itself insufficient to determine the channels of environmental effects. It is the latter that the EIA requires. It can thus be concluded that the political declarations of local leaders are far from sufficient for an analysis of site location possibilities.

3.2. Development of grid connections

When building a nuclear power station it must be kept in mind that the energy generated in it must be conveyed to a grid. The planned power (ultimately two or three blocks of 1000 or 1600 MW) and amount of energy produced indicate that this will have to be a grid of the highest voltage – 400 kV. This grid must be appropriately expanded and strengthened. Polish law does not facilitate making grid investments. Take for example a segment of the 400 kV Ostrów-Plewiska line near Kórnik[12], which has been under construction for 12 years due to permanent protests by local inhabitants. It is worth noting that the new line is basically just a renovated version of the old 220 kV line.

Here it is pertinent to quote the opinion of an expert in electric power grid construction strategy[13]: “To ensure security for the functioning of the national electric power system in northern Poland, the modernisation of existing high voltage power lines and the construction of new ones will be essential. This concerns lines between: Poznań – Gorzów – Szczecin, Poznań – Piła – Żydowo – Koszalin, Żydowo – Gdańsk, Pątnów – Bydgoszcz – Gdańsk, as well as probably the construction of new lines: Gorzów – Piła, Żydowo – Słupsk, Płock – Olsztyn, Bydgoszcz – Grudziądz, as well as lines needed in view of the siting and power of the nuclear plant. The necessity of modernising

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[12] http://orka2.sejm.gov.pl/IZ5.nsf/main/3EA0377B

[13] http://www.proinwestycje.pl/konferencje/powerring2009/ppt/maciejewskizygmunt.pdf

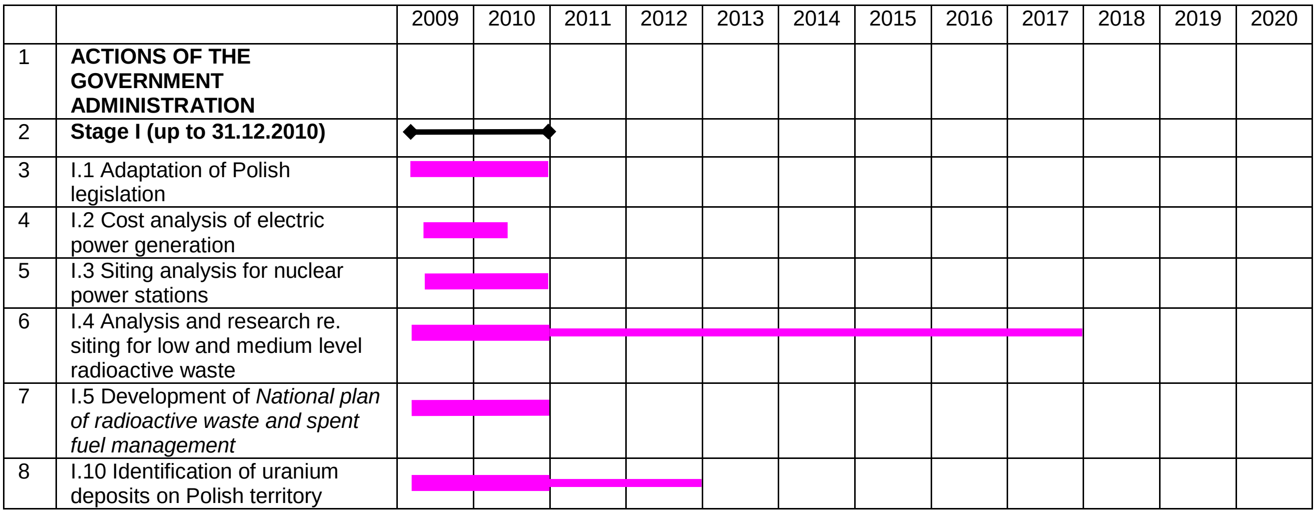
and building around 2000 km of modern 400 kV lines by 2020, as well as building around ten new high voltage substations, needs to be taken into account. The average cost of building 1 km of a new 400kV power line is estimated at between 2.5 and 3.5 million zl, and the cost of a high voltage substation at 20 to around 50 million zl." According to these data, the total investment cost will amount to between 5 200 and 7 500 million zl – the equivalent of 5 - 7 years' of PSE-Operator SA's current investment effort. These means should be incorporated into the company's transmission prices.

3.3. Project schedule (deadlines)

The time needed to construct a reactor is well illustrated by a detailed description of the experiences from the construction of the relatively common ABWR reactor[14]. From first entering the construction site, 72 months (7 years) are needed on average, and from when cementing work begins – 54 months (4 ½ years). These are the deadlines for a well understood type of construction. "First of a kind" (FOAK) constructions usually take 20-25% longer to complete, and cost up to 35% more[15].

The state schedule, accessible on the Ministry of Economy website[16], is relatively general. It is shown graphically in Figure 5. A simplified version of this schedule is represented in Figure 6. The shaded (grey) regions correspond to tasks which, according to the author, do not fit into the schedule.

Figure 5: Graphic representation of the state schedule for nuclear power



		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	**ACTIONS OF THE GOVERNMENT ADMINISTRATION**												
2	**Stage I (up to 31.12.2010)**	◆—	—◆										
3	I.1 Adaptation of Polish legislation	■	■										
4	I.2 Cost analysis of electric power generation	■	■										
5	I.3 Siting analysis for nuclear power stations	■	■										
6	I.4 Analysis and research re. siting for low and medium level radioactive waste	■	■	■	■	■	■	■	■	■			
7	I.5 Development of *National plan of radioactive waste and spent fuel management*	■	■										
8	I.10 Identification of uranium deposits on Polish territory	■	■	■	■								

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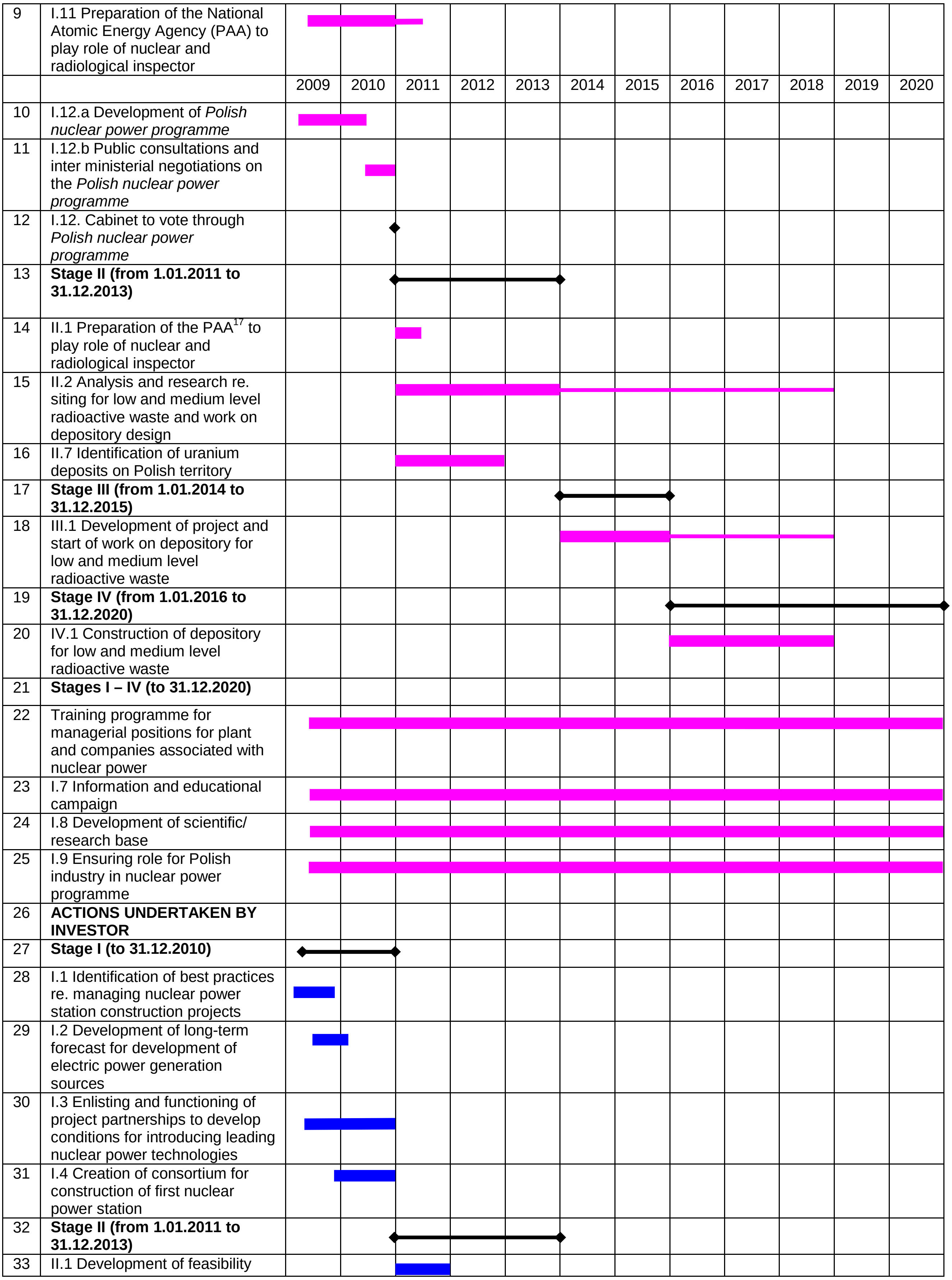
[14] http://www.ftj.agh.edu.pl/~cetnar/ABWR/Chapter12.pdf

[15] Summary: http://www.ne.doe.gov/np2010/reports/NuclIndustryStudy-Summary.pdf
http://www.eusustel.be/public/documents_publ/links_to_docs/cost/uoc-study.pdf

[16] Schedule: http://www.mg.gov.pl/NR/rdonlyres/553ECCA6-72AD-4CFA-8769-186E6539B1B4/56195/Ramowyharmonogramwykres2.pdf



9	I.11 Preparation of the National Atomic Energy Agency (PAA) to play role of nuclear and radiological inspector												
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
10	I.12.a Development of *Polish nuclear power programme*												
11	I.12.b Public consultations and inter ministerial negotiations on the *Polish nuclear power programme*												
12	I.12. Cabinet to vote through *Polish nuclear power programme*												
13	**Stage II (from 1.01.2011 to 31.12.2013)**												
14	II.1 Preparation of the PAA[17] to play role of nuclear and radiological inspector												
15	II.2 Analysis and research re. siting for low and medium level radioactive waste and work on depository design												
16	II.7 Identification of uranium deposits on Polish territory												
17	**Stage III (from 1.01.2014 to 31.12.2015)**												
18	III.1 Development of project and start of work on depository for low and medium level radioactive waste												
19	**Stage IV (from 1.01.2016 to 31.12.2020)**												
20	IV.1 Construction of depository for low and medium level radioactive waste												
21	**Stages I – IV (to 31.12.2020)**												
22	Training programme for managerial positions for plant and companies associated with nuclear power												
23	I.7 Information and educational campaign												
24	I.8 Development of scientific/ research base												
25	I.9 Ensuring role for Polish industry in nuclear power programme												
26	**ACTIONS UNDERTAKEN BY INVESTOR**												
27	**Stage I (to 31.12.2010)**												
28	I.1 Identification of best practices re. managing nuclear power station construction projects												
29	I.2 Development of long-term forecast for development of electric power generation sources												
30	I.3 Enlisting and functioning of project partnerships to develop conditions for introducing leading nuclear power technologies												
31	I.4 Creation of consortium for construction of first nuclear power station												
32	**Stage II (from 1.01.2011 to 31.12.2013)**												
33	II.1 Development of feasibility												

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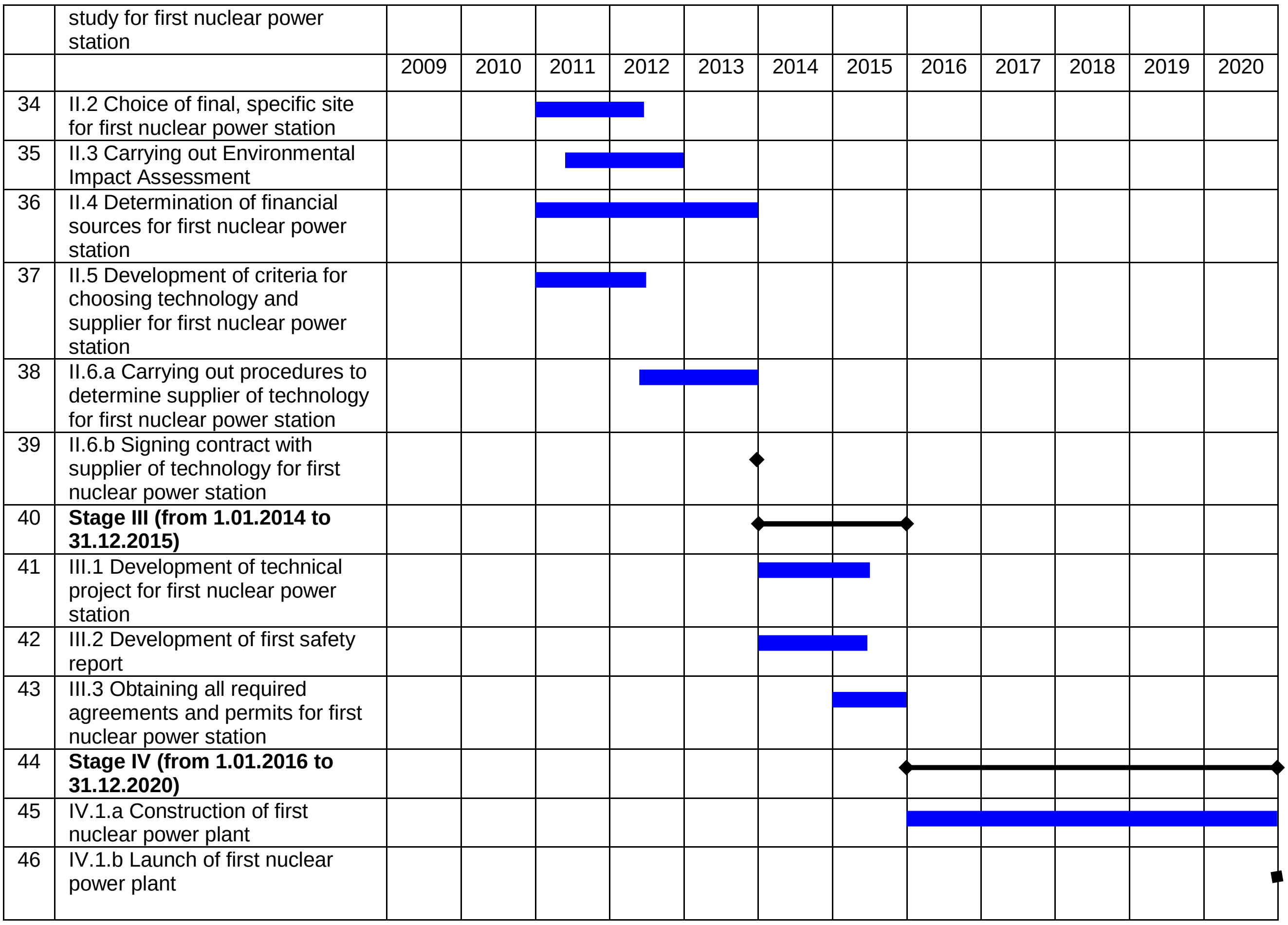
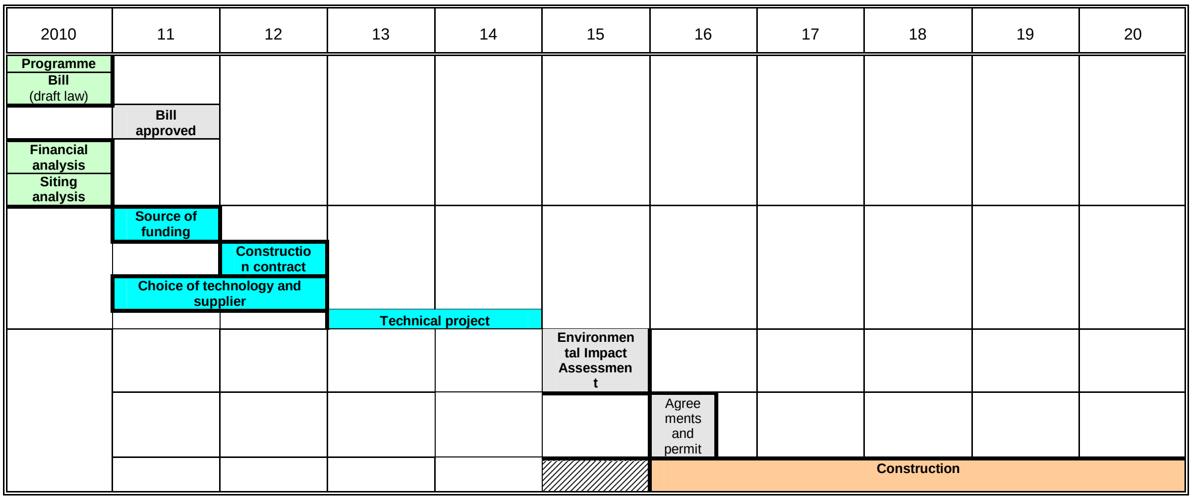
[17] National Atomic Energy Agency



	study for first nuclear power station												
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
34	II.2 Choice of final, specific site for first nuclear power station			■	■								
35	II.3 Carrying out Environmental Impact Assessment			■	■								
36	II.4 Determination of financial sources for first nuclear power station			■	■	■							
37	II.5 Development of criteria for choosing technology and supplier for first nuclear power station			■	■								
38	II.6.a Carrying out procedures to determine supplier of technology for first nuclear power station				■	■							
39	II.6.b Signing contract with supplier of technology for first nuclear power station					◆							
40	**Stage III (from 1.01.2014 to 31.12.2015)**						◆━	━◆					
41	III.1 Development of technical project for first nuclear power station						■	■					
42	III.2 Development of first safety report						■	■					
43	III.3 Obtaining all required agreements and permits for first nuclear power station							■					
44	**Stage IV (from 1.01.2016 to 31.12.2020)**								◆━	━	━	━	━◆
45	IV.1.a Construction of first nuclear power plant								■	■	■	■	■
46	IV.1.b Launch of first nuclear power plant												◆

Source: Ministry of Economy, http://www.mg.gov.pl/NR/rdonlyres/553ECCA6-72AD-4CFA-8769-186E6539B1B4/56195/Ramowyharmonogramwykres2.pdf

Figure 6: Doubts as to the government nuclear power schedule



Source: author

3.4. Internal programme organisation

I urge those interested in the logistics of the nuclear plant design and licensing process to consult a figure from the Nuclear Regulatory Commission[18] website, showing the time actually needed to obtain the necessary Construction and Operation License (COL).

4. Political aspect

4.1. Level of public acceptance

An overwhelming majority of experts, including those for as well as those against nuclear power, realises that its ultimate success will largely depend on the level of public acceptance, which itself may be partly determined by the information-propaganda campaign. However, in a democratic society, propaganda is a technique that is not only short-sighted, but also lethal for its user. Polish society is particularly sensitive to any signs of propaganda, and independent civil society organisations are extremely skilled at organising protest actions, which are difficult to control and suppress.

Both the government, and any potential nuclear investor, must take this fact into account. The best and most effective information policy in this domain is a policy of full transparency and acceptance of society's control of the investment process. It must be kept in mind that in practice the acceptance of the local community, and not only that of local politicians, is essential for the investment. The example of a 400 kV line near Kórnik should serve as an important reminder.

4.2. Level of voters' acceptance

The level of voters' acceptance and the level of public acceptance are not the same thing. In elections the size of the so-called negative electorate, i.e. those voters who will not back a given party or politician, is extremely important.

Politicians' stands on so-called “hot topics” play a very significant role in forming the negative electorate. These topics have not only a rational, but most importantly an emotional dimension. The voter whose party introduces a hot topic into the political debate either agrees with his party's stand, in which case his electoral motivation increases, or he/she does not agree with it – in which case he/she usually abandons the election altogether, adding to electoral absenteeism. This is why in Poland, with few decided voters and weak “party patriotism,” any hot topic becomes extremely dangerous for its advocate.

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[18] http://www.nrc.gov/reactors/new-reactors/new-licensing-files/new-rx-licensing-app-legend.pdf

4.3. Feasibility and punctuality of programme implementation

The current government schedule for the project of constructing the first energy-producing nuclear reactor together with the first stream turbine generator is impossible to carry out in the time frame given, that is by the end of 2020. The critical stage is the 2013-2015 period, over which the government plans for the power station design to be completed (min. 18 months) as well as an assessment of its environmental impact (min. 12 months), and the construction permit to be obtained (as the result of 16 previous agreements and permits, min. 6 months).

4.4. Impact on the energy security of the country

In the direct (technical) sense, the construction of a nuclear power station will have little impact on improving Polish energy security. The only serious (external) risk to Poland's energy security is currently a break in natural gas supplies from the East – from Russia or through Russia. The construction of a nuclear power station does not provide a solution to this problem in any way.

It is true that, in Poland's current situation, nuclear could be considered safer than gas power (in terms of security of supply), but the latter will also have to be expanded – as regulatory or peak sources, for example. Nuclear power should not be fulfilling these roles.

A real alternative to gas from the East can be provided either by external diversification (LNG from Qatar), or by internal diversification (biogas and underground coal gasification). Another option is the use of the biomass pulverisation process together with dust burners for firing the ground-up biomass.

It seems obvious and indisputable that replacing coal power by nuclear does not increase Poland's level of energy security in the technical sense. The only justification for nuclear power in Poland remains the forecast for high CO_2 emission permit prices.

5. Environmental aspect

5.1. GHG emission reduction

The main argument brought forward by the proponents of nuclear power is its lack of emissions. In comparison with old-fashioned coal power, this means an emission cut from a 1.1 – 0.95 tCO_2/MW level to zero. We are, of course, talking about a direct reduction here, not about the carbon footprint, which does not go down to zero – because this could only happen in the event of an entirely non-carbon economy.

5.2. Safety

As it is generally known, the construction of a modern EPR generator in Olkiluoto 3 has been seriously delayed. This delay is connected with errors in concreting the foundations (cracks are appearing), as well as welding errors. There are also doubts as to the control and safety systems. The above problems have caused a serious overrun of the construction costs, from 3 bn € to over 4.5 bn €.

Safety-related problems have also cropped up in France, during the construction of the Flamanville nuclear power station[19]. This issue is less known in Poland, probably because Polish workers are not employed there, in contrast to Olkiluoto 3. On 4 November 2009, nuclear power regulators from France, Finland and the UK wrote an unprecedented letter to the AREVA company, the producer of the EPR reactor. The letter points to serious problems connected with the basic digital instrumentation and control (I&C) systems. It states: “The issue is primarily around ensuring the adequacy of the safety systems (those used to maintain control of the plant if it goes outside normal conditions), and their independence from the control systems (those used to operate the plant under normal conditions); independence is important because, if a safety system provides protection against the failure of a control system, then they should not fail together. The EPR design, as originally proposed by the licensees and the manufacturer, AREVA, doesn’t comply with the independence principle, as there is a very high degree of complex interconnectivity between the control and safety systems.”

In April 2008, the French Nuclear Safety Authority (*Autorité de Sûreté Nucléaire*, ASN) reported that a quarter of the welds in secondary steel coverings controlled does not comply with the regulations and that cracks were found in the concrete foundations. EDF stated that progress had been made on these issues, raised very early on in the construction process[20], but on 24 April 2009 the ASN ordered a stop to cementing work on the site[21]. A month later cementing work resumed, after the ASN accepted a plan of corrective actions including external review of the work[22].

5.3. Fuel management

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[19] http://en.wikipedia.org/wiki/European_Pressurized_Reactor#cite_note-0

[20] Geoffrey Lean and Jonathan Owen (2008-04-13), Defects found in nuclear reactor the French want to build in Britain, The Independent, http://www.independent.co.uk/news/uk/home-news/defects-found-in-nuclear-reactor-the-french-want-to-build-in-britain-808461.html, Retrieved 2004-04-19

[21] French nuke body partly halts work on new reactor, Reuters, 2008-05-27, http://www.reuters.com/article/rbssIndustryMaterialsUtilitiesNews/idUSL2762459720080527, Retrieved 2008-05-27.

[22] EdF allowed to continue concreting, World Nuclear News, 2008-06-20, http://www.world-nuclear-news.org/RS_EdF_allowed_to_continue_concreting_2006081.html, Retrieved 2008-06-21.

Nuclear fuel management has become a fundamental issue in terms of the impact of the power station on the environment. This regards the question of transport as well as that of storing primary fuel. If fuel is sourced locally within the country, the issue of enriching the uranium ore to the level required by the reactor also arises (and the management of waste created in the enrichment process).

However, the most serious issue is that of storing and transport of spent fuel or, alternatively, the reprocessing of that fuel. Spent fuel still contains around 96% of usable fuel and a certain amount of highly dangerous transuranic elements. The reprocessing process is not simple, nor is it cheap. From a purely economic point of view it remains cheaper to produce new fuel than to reprocess spent fuel. But the reprocessing process reduces a train wagon load of radioactive waste to the volume of a barrel.

The storage of spent fuel must be considered within three time frames:

- Short (3-5 years) – storage until cooled inside the power station,
- Medium (~10 years) – most commonly also within the power plant or nearby,
- Long (100 000 years) – storage adapted to this time frame still does not exist.

Long-term storage is a real problem. Unfortunately, among the 50 countries possessing nuclear waste, none has long-term storage facilities with sufficient capacity to serve all of the country's reactors so far. Experts agree that such a repository should take a geological form at a depth of at least 500m below the surface of the earth. Available data[23] suggests that only two countries have taken decisions to construct such depositories. These are Finland (Olkiluoto, 500m, completion deadline 2020), and the US (Yucca Mountain, provisional completion deadline 2020)[24]. In China, Canada, Argentina, Germany, the UK and Japan discussions are being held in this matter. In Sweden a decision has been taken, but no date for implementation set so far. In France laboratory tests are under way – probable completion date for the repository is the year 2025. Research into this issue is also being conducted by Russia, Spain and Belgium.

It is considered that dangerous transuranic elements and actinides could be safely burnt out in high energy neutron reactors. The problem is that such reactors do not as yet exist.

The water reactor creates around 4 tonnes of spent fuel (2.52 tonnes uranium) for every TWh of energy produced. Multiplying 1500MW x 8000h gives 12TWh, that is 48 tonnes with a volume of 18 m^3 (one train wagon, three big or six medium dumper trucks). This spent fuel must first be

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[23] http://en.Wikipedia.org/Wiki/deep_geological_repository

[24] In March 2009, the Secretary for Energy halted works at Yucca Mountain.

stored, and, after it cools, deposited deep underground or exported to other countries offering repository services.

6. Summary

When it comes to nuclear power, a whole range of questions is debatable. The author believes some issues not to be debatable, however. These are:

1. Debate is absolutely essential and must be conducted publicly, with all its participants given the same right of expression.
2. No-one is allowed to knowingly use false arguments, and those who do resort to falsifying the facts should be disqualified by all other parties to the discussion.
3. A particularly serious treatment should be given to security issues relating to:

a. The reactor's operation,
b. Transport and storage of nuclear fuel,
c. Transport and storage of spent fuel,
d. Fuel utilisation and reprocessing.

4. The State Commissioner for Nuclear Power should have adequate financial means, as well as a full Department for Nuclear Energy under her disposition – these are not costs to be making savings on.
5. The most important task of the Commissioner for 2010 is to prepare and obtain approval for a fitting Nuclear Law and corresponding regulations. This law must determine the rules to be followed by future investors with precision, to ensure us an adequate level of safety. I think that, within technological limitations, this is similarly not an issue to be saving money on.

Prof. Krzysztof Żmijewski[25]

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[25] PhD Krzysztof Żmijewski, Warsaw University of Technology - Manager with exceptional experience in the area of strategic management and infrastructure. In the years 1990-2001 he held highly responsible positions in the Polish government (vice-minister of construction), governmental agency (founder and first president of the Polish National Energy Conservation Agency), one of the largest Polish governmental companies (President of the Polish Power Grid Company) as well as international telecommunication company (member of the management board of Polkomtel SA). Professor and Manager of Institute of Building Engineering at the Warsaw University of Technology, independent consultant, expert in the field of energy market development, columnist, lecturer (Warsaw University of Technology, KSAP, PJWSTK) and author of numerous publications on the subject of energy. Currently Advisor to the Deputy Prime-Minister and Minister of Economy, Waldemar Pawlak, and Secretary -General of the Public Board for the National Programme for Reduction of Emissions, Member of the National Development Council at the President of the Republic of Poland, Lech Kaczyński. Initiator and merit coordinator of the ElaStan Project – Promotion of Flexible Forms of Employment and Protection of Companies' Intellectual Capital.

Glossary

Busbar cost – total cost of producing electricity, including the cost of capital, debt service, fuel, operation and maintenance costs – in $/MWh (€/MWh). It is the basis for determining the power station's base wholesale price.

Levelized[26] **cost** – decomposed cost, a statistical value, resulting from the division of the discounted sum of "all included" costs by the estimated total discounted production of the power plant, on the assumption of equal annual payments and eliminating the effects of inflation; reduces with the increase of expected years of service; in $/MWh (€/MWh). Has very little to do with the price guaranteeing the liquidity of the power station.

Busbar cost > Levelized cost

Marginal cost – the cost of producing an additional unit of a product over and above the base amount (by definition does not include fixed costs) – in $/MWh (€/MWh).

EPC cost (*Engineering-Procurement-Construction*) – the cost of buying the reactor-turbine-generator system excluding the owner cost, that is the land, framework, installation, infrastructure, cooling towers etc. - in $/MW (€/MW).

Overnight cost – cost of the investment excluding capital costs (debt service etc.), as if the investment had appeared "overnight" - in $/MW (€/MW).

Total cost – including the cost of financing such investments – also sometimes called the *turn-key* cost; in $/MW (€/MW).

All included – total cost including credit repayment and interest as well as returns on the capital for the investor; in $/MW (€/MW).

EPC cost > Overnight cost > Total cost (turn-key) > All included

The above concepts overlap partially – there are no clear boundaries. They are also often confused.

Decommissioning cost – the cost of removing the installation including total land decontamination.

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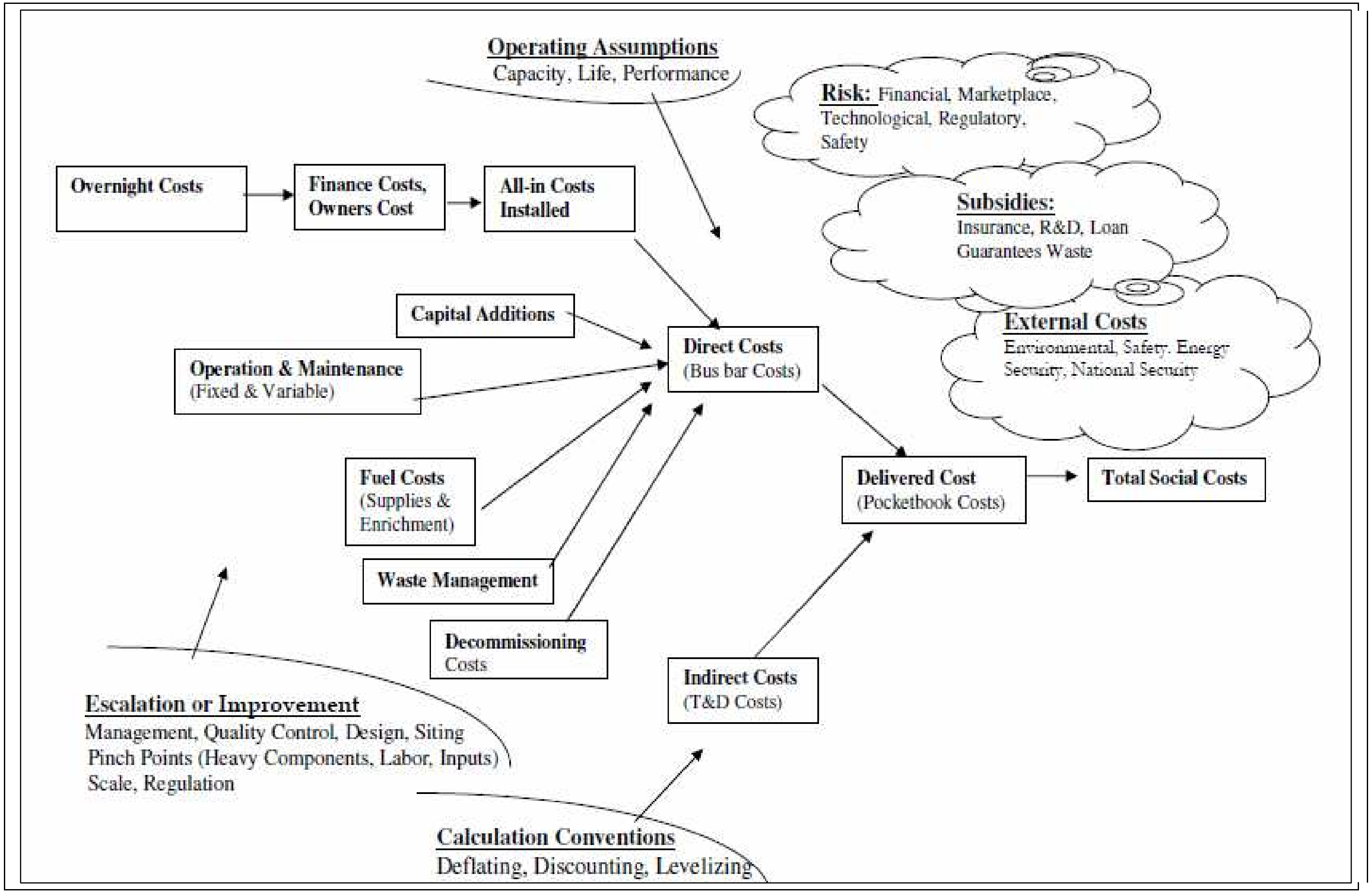
[26] http://www.teachmefinance.com/Scientific_Terms/Levelized_cost.html, http://en.wikipedia.org/wiki/Levelised_energy_cost


Operating Assumptions
Capacity, Life, Performance
Risk: Financial, Marketplace, Technological, Regulatory, Safety
Overnight Costs
Finance Costs, Owners Cost
All-in Costs Installed
Subsidies:
Insurance, R&D, Loan Guarantees Waste
Capital Additions
External Costs
Environmental, Safety, Energy Security, National Security
Direct Costs
(Bus bar Costs)
Operation & Maintenance
(Fixed & Variable)
Fuel Costs
(Supplies & Enrichment)
Delivered Cost
(Pocketbook Costs)
Total Social Costs
Waste Management
Decommissioning Costs
Indirect Costs
(T&D Costs)
Escalation or Improvement
Management, Quality Control, Design, Siting
Pinch Points (Heavy Components, Labor, Inputs)
Scale, Regulation
Calculation Conventions
Deflating, Discounting, Levelizing