Israel Public Utility Authority - Electricity

IEC EMISSION ABATEMENT PROJECT BUDGET OVERRUNS EVALUATION

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1. PROJECT BACKGROUND

The Israeli Electrical Company (herein thereafter "IEC") undertook an Emission Abatement Projects in response to the Israel Clean Air Law that became effective on 01 January 2011 setting the parameters for emissions of industrial plants in Israel to meet international standards. The effect on the processes of IEC's coal fired power plants to meet the emission regulations required a modification to the processes of the combustion and flue gas management to reduce the levels of SOx and NOx being released to the atmosphere.

IEC undertook feasibility studies reviewing the available Flue Gas Desulfurization techniques for the reduction of SOx. The more obvious choice for seawater FGD was discounted by IEC due to environmental restrictions on the seawater discharge. The resulting decision was to retrofit wet FGD processes to both the Orot Rabin Units 5 & 6 Power Plant and to the Rotenberg Units 1 & 2 Power Plant. Rotenberg Units 3 & 4 were constructed with a wet FGD process in place.

The design of the FGD incorporates the use of crushed limestone, thereby eliminating the need for limestone bulk handling and crushing facilities. The design also incorporated modern gypsum handling equipment which prepares the FGD by-product to commercial grade gypsum suitable for use in dry wall manufacture and other related products.

Selective Catalytic Reduction processes were determined by IEC to be the best available technique (BAT) available to meet the NOx reduction limits defined in the Israeli Clean Air Law. Additionally, Low NOx burners were chosen to enhance the combustion performance and reduce the initial NOx content in compliment to the SCR reduction process.

Additional modifications required in the implementation of the emission reduction retrofit of the processes have all been incorporated into the Primary Measure (PM) segments of the IEC Budgets. These modifications include upgrade of the computer control systems, in the cases of Orot Rabin Units 5 & 6, and Rotenberg Units 1 & 2, this also required a change from analogue to digital signal exchange. All modifications required the addition of electrical system expansion to provide power to the new systems. The PM segments of the projects are not part of PUA's benchmark.

WSP have been engaged by the Public Utility Authority of Israel (herein thereafter "PUA"), Electricity Division, to review their (PUA's) international cost benchmark of Flue Gas Desulfurisers (FGD) and Selective Catalytic Reductions (SCR) systems and to review IEC's project cost overruns.

The projects IEC undertook were at the two coal-fired power station sites at the Orot Rabin Coal Fired Power Plant Units 5 and 6 (both 575MW and commissioned 1995 & 6) and

Rotenberg Coal Fired Power Plant Unit 1 and 2 (both 550MW and commissioned 1990), and Units 3 and 4 (both 575MW and commissioned 2000). The plants are similar in process and output.

Compliance with the Israeli Clean Air Law within the allowable period is the driving factor in IEC's emission abatement program. IEC utilized a “Fast Track” approach to the design and construction of the emission abatement modifications. This means that the basic conceptual design was completed sufficient for major equipment procurement.

The major equipment was identified with operational parameters indicating the flow, temperatures and contaminant level derived from the operating plants at the time. Major equipment process to meet the required contaminant reduction levels was chosen by the equipment manufacturers and reviewed by IEC for compliance. Civil works necessary for the installations were initiated based on the manufacturer’s basic design layouts and footprints.

This approach is not the most effective way to execute a project as it introduces later changes in the completion of the design. A more effective approach would normally incorporate a thorough investigation of existing facilities, identify all modifications and rebuild and minimise the amount of re-work and field modifications necessary during the construction thus providing a complete design prior to the start of works. In this instance, the time required for a complete design before the start of works would not satisfy the original project schedule. It should be stated that IEC were not able to finalise the equipment and civil designs for any of the projects within the originally allocated period and so suffered significant delays due to site-based modifications and thus making their Fast Track approach redundant.

The Fast Track concept does provide for an earlier start of the works, to the benefit of the completion, but this concept is prone to construction interference, field modification and re-design of interfaces through the progression of the detailed design of the major equipment which IEC experienced. The completion of the design can also be affected by discovery of unknown existing facilities, and unexpected differences in detailed design requirements from the assumptions made in the concept design.

In the following chapters we will detail our professional opinion on PUA's benchmark and its suitability for estimating FGD and SCR CAPEX and the reasoning to our recommendation to PUA to concede 825 M NIS to IEC over the approved Project budget.

2. REVIEW OF PUA'S BENCHMARK APPROACH

PUA's benchmark estimates the budgetary requirements for typical FGD and SCR plants installed on units ranging from 400 to 700 MW in capacity which utilize the same technology. WSP acknowledges that each FGD and SCR project will be unique and will have specific engineering and environmental constraints that would need to be considered, as done by PUA in their assessment.

PUA's benchmark started with over 350 FGD's and 150 SCR's, all installed in the USA.

PUA filtered out plants installed on coal generating units with an installed capacity lower than 400MW and larger than 700MW to only select plant within this range. Further filtration by boiler types and coal types to those similar to the Israeli stations resulted in 25 FGD and 26 SCR projects which were being considered by PUA in deriving their benchmarks.

WSP notes that if all retrofit or new build SCR and FGD projects were built using identical parameters and location conditions then the CAPEX cost trends would result in a series of graphs which would be easy to plot and analyse but unfortunately, this is not the normal situation. Most power plant are designed and built to suit a specific fuel, unique local terrain, ambient conditions and chosen supplier design/manufacturing/erection experiences.

This means that any matrix from a known database will be influenced by some or most of the following table of factors that can affect the design of individual power station units. Dependent on the factor, the influence may be greater or lesser dependent on where in the world they are built. This is not considered a complete list but is provided to give an indication of some issues that need consideration for each project.

Site factors	**Fuel and reagent factors**	**Supplier technology/manufacturing experiences/preferences**
Terrain: Surrounding countryside or mountainous or coastal area. Underlying ground conditions and stability.	Coal category/type: CV, S content, N content, Ash content	Boiler technology, tangential or wall firing.
Transportation networks and connections for exporting electricity.	Use of Urea or anhydrous ammonia chemicals	SCR technology utilised/preferred.
Availability and proximity of raw materials.	Lime/Limestone characteristics: Reactivity CaOH or CaCO3 purity	FGD technology utilised, packed or open reactor.

2.1 INFORMATION SOURCES

There are a number acknowledged sources available for budgetary costing requirements based on previous projects and these include:

- US EA/EPRI/DOE databases and industry cost price indexes
- EU electricity industry cost price indexes
- UK government industry cost price indexes
- Various international engineering consultancy databases, and
- The International Energy Authority (IEA)

The first of the above listed sources has been used by PUA and is considered to be one of the largest and most extensive sources for information on projects incorporating SCR and/or FGD emissions abatement systems.

PUA used information from the US EA to provide benchmarks from which they can evaluate the Orot Rabin and Rotenberg projects using industry acceptable practices. PUA and IEC reviewed the assumptions made in assessing a benchmark value and the factors to be applied to the benchmark in order to adjust this to the costs appropriate for the IEC projects. These factors included for time of construction, geographic location and process performance parameters of the benchmark projects.

WSP had suggested that PUA eliminate the cheapest and most expensive group of plants within the plant samples in order to give a benchmark value less influenced by high or low extreme values within the databases.

PUA had taken three approaches to benchmarking:

1. Methodology A - Pricing of a "base" project with project specific factors on top of it
2. Methodology B - Database average cost after removing the 'extreme values'
3. Methodology C - Database average cost with project specific factors representative of IEC conditions on top of it

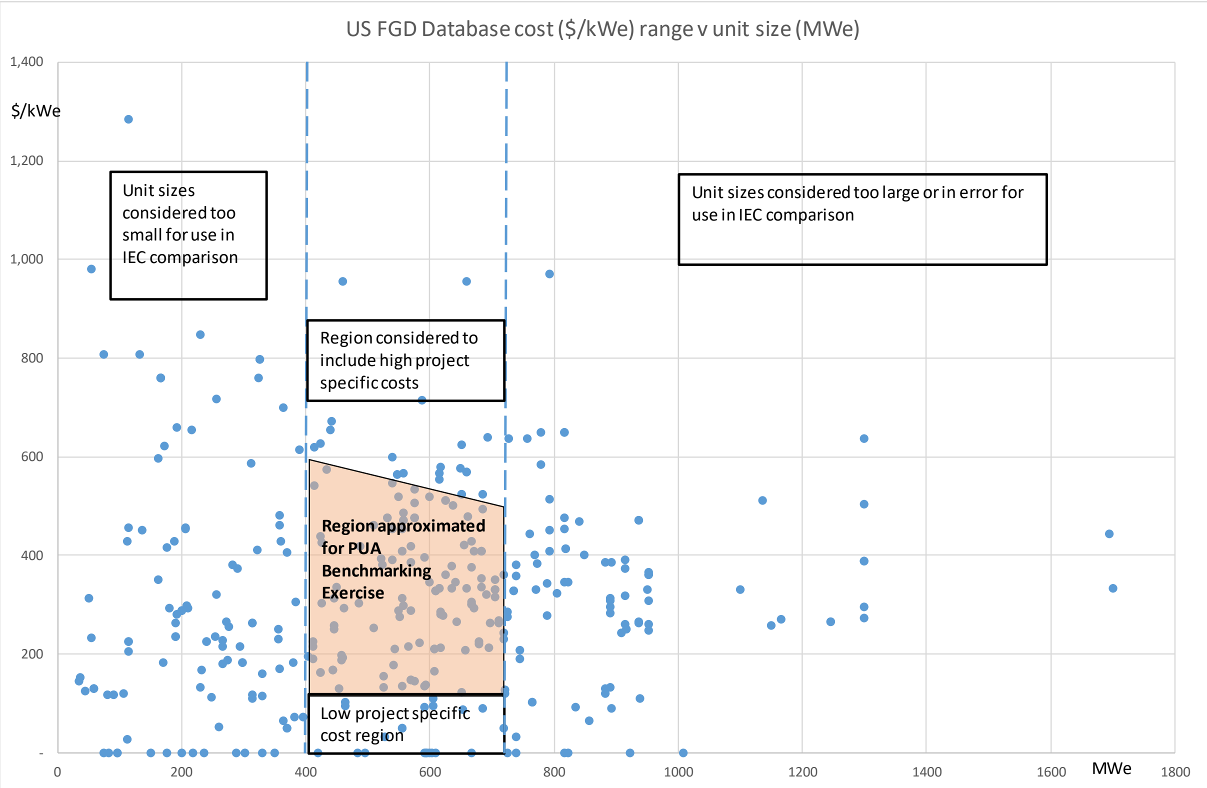
WSP preference may have been to refine the cost values in line with some of the key fuel parameter selections in the spreadsheet such that a benchmark from 3 or 4 projects having similar characteristics to the IEC fuels could have been compared to an average for the full 20 sample databases mentioned previously.

WSP provide explanations on pages 9 & 10 of this document regarding some of the key parameter differences between the database fuels and those relevant to the IEC projects'.

2.2 PUA BENCHMARKING APPROACH TO DATABASE SOURCES

The graph below summarises PUA approach to obtaining a "benchmark data group" from the acknowledged database sources available and the methods for estimating budgetary costs as relevant to the evaluation of the IEC projects at Orot Rabin and Rotenberg.

Figure 2.1



The above reflects the Methodology of approach mentioned above when taken for FGD projects but a similar approach was also adopted for the PUA SCR benchmarking exercise.

3. WSP'S COMMENTS ON PUA'S BENCHMARK

PUA evaluated the full $/kW cost range for the full range of 26 SCR and 25 FGD projects used as the foundation databases and then split the range of costs in to 5 equal portions. The highest and lowest cost groups from this dividing process were ignored so as to remove the extreme upper (most difficult) and lower values (easiest) projects from the benchmarking process. The results of this approach are summarised in the table below:

Parameter $/kWe	Methodology A	Methodology B	Methodology C
SCR			
Min	69	146	170
Ave	119	156	184
Max	188	165	196
FGD			
Min	17	376	314
Ave	256	381	314
Max	273	408	410

METHODOLOGY A

In this approach, rather than taking an average from the remaining 16 SCR and 15 FGD projects, PUA used the benchmark cost for both technologies from the lower of the three remaining cost groups which represents benchmark costs of 115 $/kW for SCR and 253 $/kW for FGD. These two values closely matched the projects at "Cheswick Unit 1" (SCR+FGD) and "Gibson Units 1-3" (SCR+FGD) and "Ghent Units 4-1" (FGD only).

The table below provides a comparison of fuels used on these projects with data available for the IEC projects:

	Table 3.1a Comparison of fuels at benchmark plants with the IEC stations				
Fuel parameter	Units	Cheswick	Gibson	Ghent	IEC
Year		2003	2007	2009	2019+
Cost SCR	$/kW	115	219	N/A	69-196 see above table
Cost FGD	$/kW	426	255	253	256-410 see above table
HHV	BTU/lb	12,348	11,248	11,306	10,814-11,354
Sulphur Des'n	WT %	3.9	3.6	3.8	2.0
Sulpur Op'g	WT %	3.9	3.4	3.1	0.3-1.1
Ash	WT %	10.5	14	N/A	7.5-16.5
NOx removal	%	77	82	N/A	78-92

SOx removal	%	93-99	96-97	92-99	92-98

HHV

This property impact on both SCR and FGD equipment designs. The higher the CV of the fuel the less fuel is needed to provide the heat required by a particular unit size plant and so the size of SCR and FGD equipment should generally reduce with increase CV of the fuel. There is however a counter effect to this appropriate in the design of the SCR plant where higher CV fuel burns at slightly higher temperatures and so creates slightly high NOx concentrations which require larger SCR plant.

The Gibson fuel HHV shown in the table above is within the range predicted for the IEC plant and so no HHV correction is considered necessary for this parameter when comparing to IEC SCR and FGD plant design.

As can be seen in the table above the HHV of the Cheswick fuel is approximately 10% higher than the average of range predicted for IEC. The impact of this difference will not be a straight forward linear one because of the counter effects discussed but might suggest that up to a 5% correction increase for the IEC SCR plants might be appropriate.

ASH

The ash contents of both the Cheswick and Gibson fuels come within the 7.5 to 16.5 range predicted for the IEC fuels and so correction for this factor is not considered necessary.

SULPHUR

This is where the largest differences between the fuels occurs. Both the Cheswick and Gibson fuels are identified as relatively high sulphur between 3.6 and 3.9 % S compared to the 0.3 to 1.1 S delivered and 2% S design required for the IEC plants. This represents between a 2x and 3x reduction in fuel S content fed to the boilers and this will have a one to one impact on quantities of limestone used and gypsum produced by these respective plants although the impact on reactor size & design may not be so significant. Therefore, there could be a sound case for reducing the cost of the benchmark when transposed to the IEC fuel for the design of the associated FGD plant.

The database of US plant can be utilised within the PUA spreadsheet to show that up to a 100 $/kW correction might be appropriate for the difference in fuel S% between the IEC fuels and the higher S content of fuels found in the US database of projects. PUA's suggestion to "penalise" IEC by 65 $/kW can be considered generous towards IEC.

PUA and IEC discussions acknowledged that the following general/common factors were reviewed to consider whether they were more onerous on the IEC projects and required adjustment:

Table 3.1b General/common adjustments agreed between PUA and IEC				
ID	Factor	Project impact or concern	PUA consideration	WSP consideration
1.1	*Construction of the facilities in parallel*	Availability/shortage of manpower	Not recognised	Not familiar with Israel employment levels and work force available at the time of work but lack of resources could be solved by outsourcing
1.2	*A large number of subcontractors*	High Density at the site and awkwardness in the areas of the organization.	Not recognised	If true this should result in quicker completion. Concur
1.3	*Poor quality in design and in equipment suppliers*	Repeat of work	Not recognised	Normal risk for fast track projects. Concur.
1.4	*Bankruptcy of suppliers*	Bankruptcy of a metal reactor	Not recognised	Normal commercial risk. Concur
1.5	*Disputes with suppliers*	Lengthening schedules	Not recognised	This is caused by 1.3 but could be considered doubling up.
1.6	*Adjustment of equipment to a variety of coal*	For example sulfur content, caloric value, ash content versus coal PRB Commonly used in the US.	Not recognised	HHV and Ash have influence on both SCR and FGD design. Sulphur content only influences FGD design. See table 3.1a and discussion below it.
1.7	*Adjusting the equipment to a large range of loads*	Increased equipment costs due to the need for longer range coverage	Not recognised	1 into 1 unit design for FGD is identical to database designs. Concur.

SCR DATABASE

PUA's benchmark has three columns of particular interest when trying to determine if projects have a high, medium or low difficulty category related to ash contamination of the catalyst.

- **EK** titled **"higher heating value of fuel"**
- **FZ** titled **"Fuel specification ash coal"**
- **GD** titled "**Specifications of coal ash"**

FZ and GD represent the "design coal" and "operating coal" ash parameters for each reference plant and the fuel CV provides the reason for the need to install "hot ESPs" upstream of some SCR plants in order to avoid excessive fouling of SCR catalyst.

As seen early in this report, if it is assumed all parameters for the design of an SCR system are identical, then the result should be a smooth exponential decay curve for the cost in $/kW with increasing size of unit in MWe,. However, it is rare for power plants to be designed using identical fuels and so actual costs for plants rarely present such a simple profile because of inherent differences between plant design parameters, even if we take a narrow size selection band such as 600-650 MW costs may vary by as much as 50%. An SCR plant designed for a 600MW unit using a high CV fuel @ 13,000 Btu/lb is likely to be smaller than an SCR plant for a similar 600MW unit using a low CV fuel @ 9,000 Btu/lb in a similar manner to the size ratios presented by boiler manufacturer's Combustion Engineering and Babcock and Wilcox in their respective publications on boiler designs. So whilst the coal classification type (bituminous or subbituminous or lignite) may give an initial crude explanation behind cost variations the actual CV should also give a more precise measuring parameter on which to base a difference.

Other columns important in evaluating cost differences at similar unit sizes are columns EX, EY and specifically **EZ** which gives the **"NOx removal efficiency"** for the reference plant. SCR plants with removal % less than 80% should be considered separately.

The SCR projects with upstream ESPs as suggested could be considered as high density dust projects and by acknowledging this someway in the database allows a similar classification of "typical" or "normal" projects compared to "difficult" or "harder" projects. Review of dust concentrations in mg/Nm3 upstream of the new/hot ESP or the ash in the fuel combined with NCV may give a parameter that can be utilised to evaluate a "easy", "typical" or "difficult" category allocation.

The emissions data PUA utilized provide verification of the NOx removal % around the year(s) stated for individual SCR installations. WSP recommended PUA try and identify where these changes are less than 60% reduction because this implies that the SCR has not been designed for the usual 80-95% reduction capable with SCR installation and might be regarded as only a partial installation. This should allow elimination of plants with only partial reductions from the 'benchmarking' process. This is important because as mentioned during our discussions, projects with reductions below 60 or 65% may represent alternate installation of SNCR or LNB technologies. PUA have incorporated this suggestion and the latest spreadsheet has only considered plant providing greater than 75% removal of NOx by SCR.

Other criteria indicated as potential filters within the latest PUA spreadsheet SCR Data page are:

- Column X, Fuel type
- Column Y, Ash content
- Column Z, Sulphur in fuel, and
- Column AC, Heating Value of fuel

The latest PUA benchmarking spreadsheet appears to include for coal types Sub, Bit, and combined. This is probably generous to IEC especially since the fuel classifications for Orot Rabin and Rutenberg are only classed as "Bit". Whilst WSP considered the use of these filters may allow comparison database fuels having fuel specifications closer to the IEC fuels PUA considered this reduces the sample base to very small sample numbers. WSP also raised concern that these types of cost database do not necessarily lend themselves to serious mathematical or simple statistical manipulation since the individual values are unique to each station and the time of execution.

Table 3.2a SCR specific adjustments agreed between PUA and IEC

ID	Factor	Project impact or concern	PUA consideration	WSP consideration
2.1	*Planned removal efficiency*	Planned removal efficiency 91.7% at IEC compared to an average benchmark design between 92 and 95%.	Not recognised	Design ranges are similar so WSP concur.
2.2	*Establishment of connections*	Construction of the connections to the gas channels in the boiler and the air heater only after the construction of the SCR, This led to a very conjested approach in this area.	Not recognised problem was of IEC making	Concur
2.3	*Updating the boiler structure for earthquakes*	The difference between the standards to which IEC is subject and the standards required for	Recognised	Concur

		projects in the United States is a factor that distinguishes the Company's project from the "standard" project and therefore must be taken into consideration.		
2.4	*Steel structure*	The initial design of the steel structure was about 1,000 tons compared to the final design which was about 1850 tons per unit. IEC was forced to undertake the production of the steel structure during the project.	Recognised	Concur
2.5	*Color requirements*	The more stringent color & protection requirements for an industrial marine environment compared to a standard domestic environments of US projects.	recognised	Requires detailed evaluation of US database but on assumption that most US plant are likely to be inland WSP might concur
2.6	*Adjustment of equipment due to replacement of fans*	Changes in NFPA regulations between original design at (22" wg) and current edition requirements of 35" wg)	Recognised	The particular codes mentioned will be applicable to all US retrofits and WSP have similar experiences in UK. Therefore WSP do not concur with recognition as IEC being special.
2.7	*Change Committee U2A*	Mass storage, urea storage and hydraulics versus ammonia solution tank	Recognised since database is not sufficiently detailed & PUA do not have	Most new systems in EU are urea based due to safety issues so WSP do not sufficiently

			resources to check.	familiar withUS experience to concur.
2.8	*System capacity*	IEC's decision to plan the system at Orot Rabin with sufficient capacity for units 1-4 The facilities were installed, SCR so in practice no system was required with an increased capacity.	Recognised	WSP are not convinced. Whilst first 2 units will have proportionally increased CAPEX the second 2 units will have reduced CAPEX.
2.9	*System distance from units*	Replacing the sucking fans required new gas channels at the entrance, including a supporting steel structure that rested partially on the foundations of old fans.The new fans could not be placed on the old foundations.	Recognised	Concur
2.10	*Gas channels and a steel structure for sucking fans*	Replacing the sucking fans required new gas channels at the entrance, including a supporting steel structure that rested partially on the foundations of old fans. The new fans could not be placed on the old foundations.	PUA have been flexible on Recognising this dependent on Methodology A to C used	Replacement of ID fans is standard requirement for retrofit SCR and FGD installations. Flexible approach by PUA appears generous.
2.11	*Special foundations due to soil type*	Special elements were required because of soil saturated with groundwater	Recognised	Concur
2.12	*Length of inlet channels SCR*	Rothenberg 3-4, the entrance channel to - SCRLonger due to the building's location - SCRIn relation to the structure of the boiler and in accordance with the structure of the steel supporting them .	Recognised	Concur
2.13	*Upgrade of airheaters*	A significant addition in the upgrade of air heaters, with the	Recognised	Standard retrofit of SCR requires a

		need to fully upgrade the heater and its sealing due to lack of adaptability of the heater to work with ammonia drift. A standard upgrade project is smaller		degree of boiler economiser and rotary air heater modifications. We would not concur.
2.14	*Difficulty building due to equipment density*	Rutenberg 3-4 : Difficulty in construction due to equipment density - location of cranes and access to required areas- dismantling of bridge beyond units and dense work between bridges and equipment .	Recognised	WSP are not convinced. Based on out experience the sites are not extraordinarily complex or dense.
2.15	*Changes in existing equipment and infrastructure*	Many changes were needed in existing equipment and infrastructure in order to establish the structure of the R- SCR .	Recognised	Most retrofit SCR installations require some of this type of work. We would not concur.
2.16	*Amount of piles*	Brutenberg 3-4 : Unlike the other units , here there was room for only12 pages of the steel structure , due to the many infrastructures . On each of these pages a higher load is applied and therefore there is much more piles And depth 52 meters compared to 30 meters in Rothenberg 1,2. The amount of the - piles Also led to a much larger evacuation of infrastructure.	Recognised	Also related to ground conditions so WSP concur.
2.17	*Stress analysis*	A complete analysis of the boiler, turbine and- mid-bay Since they are connected to local surgery only.	Recognised	Concur. Also related to earth quake modification.
2.18	*Indirect system saves*	Due to demand a wide load range - 30-100%, to install a system indirectly saves the	Recognised	Wider than normal load range may be

		complicated and costly large-diameter piping systems 12 and 16 - inch valves class 2500 Click Design 225 bar and temperature of 400 ° design. The cost of planning + equipment is approximately € 5-6million per production unit (not including construction).		valid but WSP contest need for new HP steam valves and pipes unless necessary in ducting re-routes and catalyst positioning.

FGD DATABASE

Amongst all the columns there are a few having similar useful parameters:

- Column **DA** is titled **"Scrubber Efficiency"**
- Column **DZ** is titled **"Specification of coal ash"**
- Column **EA** is titled **"Specifications of coal Sulphur"**
- Column **ED** is titled **"Removal Efficiency of sulphur"**

Discussions on the impacts of certain fuel characteristics are also mentioned in section 3.1

Subsequent to WSP opine on some of the parameters that PUA should be utilising when benchmarking the database projects for the evaluation of Orot Rabin and Rutenberg power stations PUA correctly focused on the following parameters.

A 2017 Seargent & Lundi evaluation report on FGD suggests the following basis is typical for the parameters they assume during such an evaluation:

- Retrofit Difficulty = 1 (Average retrofit difficulty);
- Gross Heat Rate = 9500 Btu/kWh;
- SO2 Rate = 3.0 lb/MMBtu;
- Type of Coal = Bituminous;
- Project Execution = Multiple lump-sum contracts;
- Recommended SO2 emission floor = 98% removal efficiency or 0.06 lb/MMBtu.
- A wet FGD designed to treat 100% of the flue gas
- Capable of meeting Mercury Air Toxics Standards (MATS) limits for HCl of 0.002 lb/MBtu.
- Capable of removing up to 99% HCl in the flue gas.

Therefore it was considered that PUA should be able to establish some similar evaluation parameters for these benchmark projects in terms of average and maximum/minimum value ranges for fuel CV, fuel S content or mg/Nm3 SO2 at FGD inlet/outlet that can hopefully establish some parameters to compare against the IEC projects in order to establish whether they are within similar ranges and therefore can be classified as "normal" or whether they may warrant an alternative "easy" or "difficult" category for values above or below these ranges.

Although consideration should be given to the area available for installing FGD at each station to develop a "construction difficulty factor", we do not believe that a kW/m2 parameter will be a valid method for these processes. Most FGD plant are located on spare land or the coal stockyard located beyond the stack/chimney of a plant.

The measured removal capability of individual FGD systems can be evaluated in a similar manner to that used for SCR systems i.e. by comparing inlet and outlet SO2 concentrations before and after the years of supposed FGD installation. This can then be used to more accurately define "benchmark" project values for FGD systems where removals are above a minimum value, say 88%. However, when we review some of the removal efficiencies declared in the spreadsheet these show values at greater than 97%. This is not possible because the chemical reaction coefficients and kinetics are known to limit the equilibriums to less than 97% and maximum values demonstrated in the field are between 95 and 96%.

PUA have included the following parameters that WSP considered could be used within the spreadsheet to filter the plant database:

- Column K, unit size MWe
- Column Y, fuel sulphur content
- Column AB, fuel CV
- Column AD, fuel ash content
- Column AD, fuel ash content
- Columns AI & AJ, sulphur removal % duty
- Column AL, reagent type, lime or limestone
- Column AM, whether product is used for gypsum or not

The 20 cases used for benchmarking include one case where the product is not used for the local gypsum market.

At present, the full benchmarking range includes fuels having sulphur ranges between 0.2 and 4.4% whereas the Israel plants are only expected to see between 0.4 and 1.1% sulphur in fuel. Whilst WSP suggested the reduction of this fuel sulphur filter in line with the Israel plants using columns Y and AE reduces the sample base for benchmarking down to 3 or 4, PUA preferred the statistical approach of splitting the cost value range in to 5 groups as discussed previously and in separate documents.

Table 3.3a FGD specific adjustments agreed between PUA and IEC

ID	Factor	Project impact or concern	PUA consideration	WSP consideration
3.1	*Level of difficulty*	In Orot Rabin: Difficulty building due to the density of equipment adjacent to chimney. Utilised an area of - 9 acres reserved for future development of the combined cycle units. -Rotenberg : Difficulty during construction due to equipment density -location of cranes and access to required areas and necessary changes to pipeline routes and underground services.	Recognised	The sites did not seem overly congested. WSP does not concur.
3.2	*Pipe bridges and long ducts at the entrance to the FGD*	Orot Rabin : Need for pipe bridges and especially long ducts . The length of new ducting required is about 300 meters compared to 100 meters in a standard project. BOP About 600 meters away from the units compared to 150 meters in a standard project. Rotenberg : Pipe bridges extra long and overcrowding meant that it took a lot of bends. The length of new ducting required is about 200 meters compared to 100 meters in a standard project. - BOP About 1100 meters from the units compared to about 150meters in a standard project.	Recognised	WSP would partially concur.
3.3	*Indirect burrows and gases to an old chimney*	Indirect burrows gases into an old chimney compared to a standard project in which there is no indirect.	Recognised	Concur

3.4	*Special elements due to type the soil*	Special elements were required because of soil saturated with groundwater	Recognised	Previous Ground surveys or new study by IEC (specialist surveyor) prior to tendering should have alerted IEC's specs. WSP would not concur.
3.5	*Changes In existing equipment and infrastructure*	<u>*Rottenberg 1-2*</u>: It took many changes in existing equipment and infrastructure for FGD. Example, waste pond location had to move twice including pipelines (temporary and final). The temporary solution included a small pool combined with settling systems connection speed +additional pools on site to create an interim solution sufficient capacity.	Recognised	There is always some of this type of work necessary with retrofit works. Difficulty is getting IEC to justify above benchmark allowance. WSP would partially concur.
3.6	*Receptor material*	Receptor design was subject to economic study of 4 options. IEC preferred selection of C-276 rather than contractors standard carbon-steel rubber coated. Change in the standard of earthquakes and wind after tender award caused supplier to demand replacement of item as original was unsuitable and thicken the building material.	Part recognised	Issue arose from IEC actions. Concur.
3.7	*Sewage facility for large flow*	It was designed for a large chloride range of 15,000-40,000 to save water (compared to planning for only 15,000 in a standard project in the US), leading to the design of a relatively large effluent facility suitable for the lower limit of the chloride concentration (15) K(While the receptor and pump structure materials	Not recognised	Concur. [Sewage treatment is normally related to number of permanent staff on site. This appears more related to WWT design basis adopted.]

		were adapted to the upper limit) K).		
3.8	*Wastewater capacity facility - double capacity*	<u>In Orot Rabin</u> : The wastewater treatment facility was designed with a double capacity that was also supposed to serve units 1-4. <u>Brutenberg</u> : Capacity of wastewater treatment facility WWTP Adapted to the project D .	Recognised	Some increased capacity is expected as part of FGD installation. IEC should justify as above normal included in benchmark.
3.9	*Color requirements*	The most stringent color requirements for an industrial marine environment compared to a standard domestic project	Recognised	Requires detailed evaluation of US database but on assumption that most US plant are likely to be located inland. WSP might concur
3.10	*Integration of the control system*	Integrating the control system for FGD 1-2 in the existing control system of units 3-4	Recognised saving potential.	Concur
3.11	*Saving the cost of subsystems per unit 1-2*	At Rutenberg significant savings in construction costs for all subsystems for the treatment and storage of the limestone and gypsum since they catered for all 4 units, Accordingly, the cost of adapting the existing equipment was recognized to 3-4 for the system.FGD Of 1-2 units, offset by the sum of approximately NIS 58 million, which constitutes the cost savings of the establishment of separate sub-systems for 1-2 units.	Recognised saving potential.	Concur
3.12	*Upgrading the existing subsystems in Section 3-4*	Upgrade to existing sub-systems is required FGD Rothenberg 3, 4 was 18 years old, so he could serve the new units and ensure availability in the future.	Not recognised	Concur

3.13	*Changes at the front of the station*	Changes in front of station: Transformers, electrical layout		Changes in this area is not uncommon for retrofit FGD installations to accommodate new or bigger fans and pumps. Should not be accepted without IEC justification as special.
3.14	*Auxiliary cooling systems and new make-up systems*	Auxiliary cooling systems and new makeup systems		Needs justification as being above normal benchmark requirements.
3.15	*Upgrading to a control system DCS*	Upgrading to a control system DCS Modern including command rooms. A system at a age of over 15 years that demanded that it be replaced and that it should be connected to the new systems.		This is common for retrofit FGD installations and so should be challenged as included in benchmark price.
3.16	*A variety of water sources*	A variety of sources of water - sources, boronwater, recycled water from the station to save water.		Can be an issue with none coastal sites but all IEC stations are coastal so should be able to use sea water.

4. PUA BENCHMARK CONCLUSIONS

4.1 PUA's 3-way approach of using a "base" project with factors, an average value and the average value with factors yields similar total values for FGD and SCR combined.

4.2 The PUA spreadsheet includes databases for over 260 SCR projects and 360 FGD projects as well as a considerable amount of background information related the fuel and project specific characteristics that make it one of the best tools available globally for predicting costs and potential variations in costs for SCR, FGD or PM projects and it is the WSP opinion that tweaking it further using the abovementioned energy density and fuel type factors will give an even higher level of certainty when comparing IEC and industry costs.

4.3 WSP discussions with PUA have also suggested the use of fuel parameters such as: type of coal, CV, N content, S content, and ash content may also provide a more quantitative method for explaining some of the cost differences between different projects. However, PUA have not been able to discern cost trends using these technical filters and prefer to remain with the statistical based method developed using a larger database sample which introduces inherent inaccuracies to the benchmarking process.

4.4 The start of construction of these projects when only 20% of design was completed rather than a typical 75-80% completed has contributed to considerable additional costs for design and re-works during construction and erection.

4.5 In the preceding section WSP have provided some opines on some of the IEC correction factors discussed between IEC and PUA for the common, SCR specific and FGD specific areas of these projects. WSP consider that some of these factors represent events arising from a rushed and incomplete project managing strategy. An example is the lack of reference to previous ground investigations related to the original plant build or the proceeding without reinvestigating the new areas of land identified for locating retrofit works. Also in some instances the activities suggested as specific to the IEC projects, such as changes in NFPA regulations, will have been addressed on the US plants within the database and WSP have addressed them on similar UK projects.

5. WSP'S REVIEW OF SEARGENT & LUNDY 2016 REPORT ON RUTENBERG AND OROT RABIN EMISSIONS ABATEMENT PROJECTS

5.1 GENERAL SUMMARY

The above review was conducted in 2016 and these projects remain ongoing.

Unit sizes at the three stations are between 550 and 575 MW and so can be considered similar size to each other from this comparison.

All six units were being retrofit converted in accordance with same version of Israel Emissions Legislation / Clean Air Regulations dated 01 January 2011.

Construction phase of all projects was approved after only 20% completion of design in order to meet 'fast track' requirements. This factor has been acknowledged by Sargent & Lundys experience in their report on page 10/78 where they make a recommendation *"that, in order to lower cost overruns during construction, the design should be at least 80% complete before the general works contractor (GWC) is allowed to proceed with construction"*.

A summary of planned abatement technology improvements at the three stations are given in the table below:

Project	Rotenberg 1 & 2	Rotenberg 3 & 4	Orot Rabin 5 & 6
LNB + OFA + SCR	Yes, all	Only SCR, others exist	Yes, all
Wet limestone FGD	Yes	Existed	Yes
PM measures	Yes	No	Yes
Special features			SCR ducting arrangements into and out of SCR catalyst block were onerous. Use of C-276 FGD absorber, cold ducts and stack to enable use of high Cl scrubbing

5.2 S&L BENCHMARKING APPROACH

5.2.1 SCR

The benchmarked units identified in the U.S. were similar to Orot Rabin and Rutenberg. These units had the following similarities:

- Same size units
- New ID fans on one unit
- Economizer modifications to lower temperature
- No air heater modifications (IEC has included this scope in PM)
- Similar SO2 removal efficiencies

The scope adjustment had to be made for the following:

- New ID fan on second units
- Additional cost for U2A system
- Construction strategy employed by IEC
- Remove allowance for funds used during construction (AFUDC)
- Higher retrofit difficulty

Financial costs were based on 2016 exchange rates.

An adjustment factor of 0.8 was also made for the differences between Israel "engineering manhour costs" and those for a similar activity in the US.

Similarly, an adjustment factor of 0.59 was made for site labour cost differences between Israel and the US.

Figure A-1 from the report shows how the costs for individual plants can be so unique and provide a considerable scatter from the simple/ideal basis suggested in section 1 of this report. This same graph also suggests that only six US plants were available in the 550 to 650 MW sample range from which to derive the so called benchmark costs.

5.2.2 FGD

The benchmarked units identified in the USA were as close as possible to Orot Rabin and Rutenberg. These units had the following similarities:

- Same size units (~600 MW)

- Single absorber per unit
- Wet chimney
- Similar SO2 removal efficiencies

Scope adjustment were made for the following aspects at Orot Rabin and Rutenberg:

- C-276 alloy absorber
- Reagent preparation and handling to accommodate compressed air conveying and Euro silo
- Adjustment for low-sulfur coal
- Construction strategy employed by IEC
- Long inlet ductwork
- Long pipe bridges

Site specific adjustments for Orot Rabin were:

- higher degree of difficulty in constructing the chimney
- reagent preparation and storage facilities, and
- gypsum dewatering and storage

Site specific adjustments for Rutenberg were:

- extremely congested site,
- relocation of ponds, cable trays, multiple concrete electrical buildings, and,
- potentially high construction costs for all areas of the FGD.

The adjustment factors between Israel and US costs for Engineering and Construction manhour rates were also applied to the FGD projects as those adopted for the SCR projects.

No similar figure to A-1 is given for the US database plants used to provide the benchmark costs for FGD and so this remain unknown.

5.2.3 PRIMARY MEASURES

The primary measures include the following sub-systems:

- LNBs/OFA
- Coal mills upgrade with dynamic classifier
- Air heater modifications

- Auxiliary power system upgrade
- Control upgrades – DCS replacement

The benchmarked units identified in the U.S. were as close to Orot Rabin and Rotenberg as possible. These units had the following similarities:

- Same size units (~600 MW)
- Recently installed LNBs with OFA
- Upgraded coal mills
- Upgraded controls

Scope adjustments had to be made for the following:

- New air heater
- Construction of DCS and air heater during outage

The adjustment factors between Israel and US costs for Engineering and Construction manhour rates were also applied to the PM projects as those adopted for the SCR & FGD projects.

No similar figure to A-1 is given for the US database plants used to provide the benchmark costs for PM and so this remains unknown.

5.3 S&L CONCLUSIONS ON RUTENBERG 1 & 2 PROJECT

The SCR conversion had only cost 95% of the equivalent US benchmark project in equivalent 2016 $/kW but the manhour expenditure for both engineering and construction had consumed between 20% and 30% more hours than the equivalent benchmark project.

Similarly, the FGD installation had only cost 86% of the equivalent US benchmark project in equivalent 2016 $/kW but the manhour expenditure for both engineering and construction had consumed between 40% and 50% more hours than the equivalent US benchmark project.

Unlike the previous SCR & FGD projects, the costs for these PM modifications exceeded the equivalent benchmark assessment by 121% in 2016 $/kW equivalents and it was also estimated that between 40% and 50% additional hours had been consumed compared to that expected in the equivalent US benchmark project.

5.4 S&L CONCLUSIONS RUTENBERG 3 & 4 PROJECT

Summary table ES-1 suggests that on a 2016 $/kW basis the SCR for these units has over spent by 112% of its equivalent US benchmark project. However, this does suggest a considerable overspend on manhours for this project.

5.5 S&L CONCLUSIONS OROT RABIN 5 & 6 PROJECT

The SCR conversion had cost approximately the same as an equivalent US benchmark project in equivalent 2016 $/kW. No information the additional manhours consumed is given but with the labour cost differences this is assumed to be between 30% and 40% additional hours than the equivalent benchmark project.

Similarly, the FGD installation had only cost 86% of the equivalent US benchmark project in equivalent 2016 $/kW so it is assumed the manhour expenditure for both engineering and construction had consumed between 40% and 50% more hours similar to Rutenberg 1&2 project.

Unlike the previous SCR & FGD projects the costs for these PM modifications exceeded the equivalent benchmark assessment by 115% in 2016 $/kW equivalents and it was also estimated that between 40% and 50% additional hours had been consumed compared to that expected in the equivalent US benchmark project.

5.6 OVERLYING EXPLANATIONS OFFERED FOR PROJECT OVERSPENDS

1. Early start of construction at 20% design complete rather than normal recommendations of 80% design complete.
2. The occurrence of a considerable number of "unforeseen construction difficulties".
3. The "fast track" nature of these projects prevented sufficient time to consider all the construction elements of each project

5.7 WSP POINTS OF CONCERN IN S&L REVIEW REPORT

1. The apparent disregard for, or explanation of, the potential spread of costs for similar size plants as demonstrated by figure A-1 on page 66 of the report which shows US plant SCR costs to deviate between 250 and 580 2016 $/kW.
2. The greater than 2x variation in US SCR database project costs might suggest a greater spread or variation in SCR costs for the Israel SCR predicted costs than just between 180 and 250 $/kW

3. Lack of definition of US plants considered in defining the benchmarks for the Israel projects, particularly with regard to the number of FGD and PM database projects available.
4. There appears to be no investigation of any differences in fuel characteristics for either the US reference/database projects used and those associated with the three Israel projects.

6. IEC BUDGET OVERRUNS REVIEW

PUA has requested IEC to detail its expenditure in excess of the 2013 Approved Project Budget for the different packages with the specific reasons for these overruns and in the typical project breakdown of Engineering, Equipment, Construction and Project Management and Commissioning.

IEC have provided PUA with a summary of the over expenditures on main packages and items in Excel format along with written explanations and a 2016 PowerPoint slide.

Below are the items that IEC reported budget overruns to PUA and the respective IEC reason as to why these were required. These tables below include IEC man hour overruns in most instances and expenditure in millions of NIS when discussing direct costs.

WSP would stress that its findings below are solely based on the site visits carried out, meetings with the IEC and the evidence information provided by IEC in the tables below. No additional reasoning further to this information was made available to us for review.

WSP's findings in this work have resulted in a recommendation to PUA to concede 825 M NIS to IEC out of a total over-expenditure of roughly 1.5 B NIS.

Table 2: Boiler Building Reinforcement:

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommended % to be conceded by PUA of the Budget Overrun	Mill NIS conceded
Reinforcing Steel Structure Boiler Unit 5,6 (2 units)	X		0	381,250	**381,250**	Based on an estimate by Mr. Aviram Inbar to Unit 5 (140,000 man hours) (each unit is 140,000 man hours + 25 Mil NIS for shared parts), including travel 25%	200000	The reinforcing of the steel mechanical structures were as a consequence of the change in legislation pertaining to seismic conditions and standards. This change in legislation was imposed on IEC and the implementation was coincided with the SCR and FGD projects. Although there was no initial budget for Orot Rabin, fair and reasonable to concede some effort. The initial estimates for the material volumes were underestimated, hence the extent of manhours due to engineering and construction management. Not sure why no budget was then not carried forward to Rutenberg. Each unit could be constructed using 30 staff fulltime on site for 3 years (200k manhours per site) appears reasonable and acceptable and not the 360k-420k hours spent per project.
Reinforcing steel structure Boiler No. 1,2 (2 units)	X		0	360,000	**360,000**	Based on the estimate of the Hadera cost with reduction because of the amount of steel is smaller	200000	
Reinforcing Steel Structure Boiler Unit 3,4 (2 units)	X		0	421,200	**421,200**	Based on the estimate of the Hadera cost with reduction because of the amount of steel is smaller	200000	
Total work hours	**1,162,450**		**0**	**1,162,450**	**1,162,450**			
Total in Millions of NIS	**244**	**0**	**0**	**244**	**244**			

Table 3: Under-evaluation of the construction of the urea plants

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommened % to be conceded by PUA of the Budget Overrun	Mill NIS conceded	WSP Observation/Comments
Urea facility (5-6)		X	7,650	56,250	**48,600**	The original design was designed to lay skids and once the project started IEC understood that they need to build an ammonia production plant including a 2-storey steel structure, containers, pipes and rotating equipment. Based on an up-to-date and detailed estimate according to the sketches, plus 6 items that were actually carried out in the installation of storage containers.	100	10.21	IEC acknowledged that their initial design considerations were not for a comprehensive/full-scale U2A plant, they were considering modular type assemblies. This design philosophy changed soon into their project execution and therefore needed to consider the comprehensive Urea facilities. The initial budget estimates were insufficient, however, the application of the full scale Urea systems is beneficial to the plant's effective operation and is reasonable to conceed the additional effort. 56250 and 74256 manhours equates to approximately 8 and 12 persons fulltime on site respectfully for 3 years, appears reasonable.
Urea facility (1-4)		X	14,688	74,256	**59,568**	The original design was designed to lay skids and once the project started IEC understood that they need to build an ammonia production plant including a 2-storey steel structure, containers, pipes and rotating equipment. According to a calculation of 52 employees on average for 7 months compared with 12 employees for 3 months in the original planning or	100	12.51	

						based on the estimate in 5,6 (an increase of about 40% compared to units 5,6 due to the size of the facility).			
Total work hours		**108,168**	**22,338**	**130,506**	**108,168**				
Total in Mil NIS	**0**	**23**	**5**	**27**	**23**				

Table 4: Infrastructure Relocation

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommened % to be conceded by PUA of the Budget Overrun	Mill NIS conceded	WSP Observation/Comments
R & D infrastructure 5,6 (diesel generator + sulfur tank + steel structure + piping + electricity + hydraulic unit copying + piping and cable identification etc.)	X		0	165,000	**165,000**	During the drillings for the foundations, a clash between the cable route and the element location was created, which required the copying of the cables (SCR). Also, for the installation of the SCR facility it is necessary to transfer diesel generators to the substation. The work includes the installation of a temporary diesel generator (IMC) and an existing diesel generator transmission including the construction of new control panels and eventually diesel generator and temporary generator.) In FGD opening trenches and identifying cables, copying gates and weight trucks.	50	82500	Although it is extremely difficult to estimate for these types of activities before the site is accessed, it is puzzling why IEC did make any provision for this initially. However, the extent and challenge of having to relocate existing infrastructure is an engineering feat. Due consideration has to given for the effort particularly with respect to clearing infrastructure for the purposes of foundation piling and preparation. The piling is a significant exercise, also the routing, assembly and construction of the service bridges, cable runs and other underground services. The replacement surface tanks as well as the re-routing of systems associated required additional engineering effort. Furthermore, IEC have not sufficiently motivated the expenditure nor provided

Transferring the infrastructure of units 1,2 (diesel generator + sulfur tank + steel structure + piping + electricity + hydraulic unit copying + piping and cable identification + waste water and more)		X	84,240	293,424	**209,184**	The SCR facility is required to transport diesel and modular generators to an alternate work place and includes the installation of a temporary diesel generator (MICH) and an existing diesel generator transmission including The construction of new control panels and the dismantling of the temporary diesel generator.In order to construct the SCR facility, the sulfur facility must be moved to a new location, based on an average of 35 employees for 10 months (5 months per column)) .GGD has a general infrastructure relocation that includes temporary and permanent waste water + as fire + air + compressors + water cooling Embodied + + Power + dismantling old bridges to future projects.) In PM required the evacuation of infrastructure in the boiler, electrical liquidation, dissolution surfaces for mills + SOFA. About 13 employees for one year.	50	104592	sufficient evidence to substantiate the cost and schedule overruns, therefore only 50 % of the claimed man-hours conceded.

Infrastructure relocation 3,4 (steel structure + piping + electricity + hydraulic unit relocation + piping and cable identification)	X		0	42,840	**42,840**	For the purpose of assembling the SCR facility, diesel generators should be transferred to an alternative location. The work includes the installation of a temporary diesel generator (IMC) .The existing diesel generator transmission includes the construction of new control panels and eventually diesel generator and temporary generator.According to the calculation of about 20 employees for 10 months.	50	21420	
Total work hours	**207,840**	**209,184**	**84,240**	**501,264**	**417,024**				
Total in NIS	**0**	**0**	**0**	**0**	**0**				

Table 5: Flue gas ducts and steel structure between ID Fans and ash sediment and boiler

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommened % to be conceded by PUA of the Budget Overrun	Mill NIS conceded	WSP Observation/Comments
Gas trenches + steel structure 5-6	X		0	85,000	**85,000**	Between ID Fans and the Bypass to the old chimney. The source of the chimney was designed for threading between the units +	100	18	Difficult to appreciate why zero initial budget, however, the difficulty in the design arrangement of the new stack and maintaining the original stack as the bypass, and then having to incorporate the duplicate gas ducting arrangement within an already congested area is extremely challenging. The flue gas ducting is very large components of infrastructure and would have been very challenging in the design process but also challenging in the assembly and construction activities. 85000 manhours equates to approximately 12 persons fulltime for 3 years, remains within reasonable limits.
Gas channels + steel structure 1-2, 3-4	X		0	85,000	**85,000**	Between ID Fans the Bypass to the old chimney. The source of the chimney was designed for threading between the units +	100	18	
Strengthening of gas channels between the boiler and the outlet. 1-2 Rotenberg	X		0	58,000	**58,000**	New content according to the BBS provider findings	100	12	
Total work hours		**228,000**	**0**	**228,000**	**228,000**				
Total in NIS	**0**	**48**	**0**	**48**	**48**				

Table 6: Wastewater Treatment Plant

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommened % to be conceded by PUA of the Budget Overrun	Mill NIS conceded	WSP Observation/Comments
Wastewater Treatment Plant		X	23,000	53,563	**30,563**	Update of the estimate due to the increase in steel structure, containers, equipment pumps and piping.	50	3	IEC have acknowledged that these water packages were designed by 3rd party contractors but assembled and constructed by IEC, clearly a significant under-estimation on the effort required for the construction but the 55k-53k manhours would equate to 11-12 persons full time on site for 24 months, which appears to be excessive. These facilities should be constructed in 12 - 15 months using the same number of personnel (12) which would equete to roughly 36k manhours per site. The 50% of the overspend agreed to herein would yeild a total man hours spend of 77k.
Wastewater Treatment Plant		X	22,000	55,416	**33,416**	Update of the estimate due to the increase in steel structure, containers, equipment pumps and piping.	50	4	
Total work hours		**63,979**	**45,000**	**108,979**	**63,979**				
Total in NIS	**0**	**13**	**9**	**23**	**13**				

Table No. 7: Piping Systems (cooling water, Instrument Air and Piping in Bridges) and Steel Structure Pipe Bridges

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommened % to be conceded by PUA of the Budget Overrun	Mill NIS conceded	WSP Observation/Comments
Piping systems (cooling water, Air Instruments and Piping in Bridges)		X	14,825	59,375	**44,550**	Additions to estimates after receiving data, drawings and updated quantities.	50	5	The initial budget estimates were significantly underestimated. The pipe and sytems bridges required between the Urea facilities and the SCR plants were cmplex in nature to design and implement within the existing site facilities. The distances were longer than initially anticipated and the routing was challenging having to thread the systems between the existing infrastructure , plant and equipment. The electrical services as well as coolimg systems required for the FGD plants were similarly challenging to design and integrate. The 60k-70k manhours would equate to 12-14 persons full time on site for 24 months, which appears to be excessive. These facilities should be constructed in 12 - 15 months using the same number of personnel (14) which would equate to roughly 42k manhours. The 50% of the overspend agreed to herein would yeild a total man hours spend of 80k.
Steel Structure Pipe Bridges		X	15,984	71,040	**55,056**	Update of the estimate due to the increase in the structure steel pipe bridges PB17, PB28, PB40-PB54 (from 360 tons to 1600 tons).	50	6	
Total work hours		**99,606**	**30,809**	**130,415**	**99,606**				
Total in NIS		**21**	**6**	**27**	**21**				

Table 8: Assembling actuators for boiler burners

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommened % to be conceded by PUA of the Budget Overrun	Mill NIS conceded	WSP Observation/Comments
Assembling actuators for burners in boilers in No. 5,6 units	X		0	68,000	**68,000**	New content. Approximately 8 employees work for one month for each burner (there are 20 burners per unit).	50	7	No initial budget for these engineering activities. The retro-fiiting of the new low Nox burners, including all the associated sytems and equipment is always an engineering challenge due the the very constrained and restricted area around the burner assemblies. The 'night' gates and requisite additional actautors were not initially taken into account and therefore required some additional engineering, assembly and construction activities. Acknowledge that these engineering activities are absolutely necessary but the 8 employees per burner required for this job will use up 30,000 manhours and that's assuming no parallel work takes place.
Assembling actuators for burners in boilers No. 1,2	X		0	65,280	**65,280**	New content. Approximately 8 employees work for one month for each burner (there are 20 burners per unit).	50	7	
Total work hours	**133,280**		**0**	**133,280**	**133,280**				
Total in NIS	**28**	**0**	**0**	**28**	**28**				

Table 10: Upgrade of air heaters 3 and 4

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommened % to be conceded by PUA of the Budget Overrun	Mill NIS conceded	WSP Observation/Comments
Upgrade of air heaters 3,4	X		0	85,350	**85,350**	It was unknown. Based on an estimate in the PM project.	0	0	Covered in Table 19
Upgrade to an early heater 3,4	X		0	23,460	**23,460**	It was unknown. According to a calculation of 17 employees for 3 months per unit.	0	0	
Total work hours	**108,810**		**0**	**108,810**	**108,810**				
Total in NIS	**23**		**0**	**23**	**23**				

Table 11: Increase in the use of mobile cranes

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommened % to be conceded by PUA of the Budget Overrun	Mill NIS conceded	WSP Observation/Comments
Use of power plants 5,6		X	40	86	**46**	An increase resulting from additions and changes in the project	0	0	The budget overrun requested herein is for mobile crane hire cost beyond the approved schedule of 60 months. The consequence for the additional charges are directly related to the project delays, schedule overruns and the various factors of complexity within the FGD, SCR and PM associated projects. Typical retrofit projects will normally complete within 35-45 months and IEC's projects went a long way over the approved schdule and thus the costs associated with crane hire beyond the project schedule are not conceeded. IEC's project were initiated and constructed in a 'Fast-Track' approach which should yeild a short completion schedule especially when IEC's projects were agreed with a lengthy schedule of 60 months per site. Any expenditure beyond the approved schedule should not be conceeded under these circumstances."
Use of power units 1,2		X	41	93	**52**	An increase resulting from additions and changes in the project	0	0	
Use of power plants 3,4		X	15	55	**40**	An increase resulting from additions and changes in the project	0	0	
Total in NIS		**139**	**96**	**234**	**139**				

Table 12: Increase in employee transportation activity

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommened % to be conceded by PUA of the Budget Overrun	Mill NIS conceded	WSP Observation/Comments
Transportation of employees		X	32	50.8	**18.6**	An increase resulting from additions and changes in the project			"WSP would have assumed that the transportation of employees is inlcuded in IEC's hourly rate and this does not constitue as a 'package' in its own rights a typical project. Typical retrofit projects will normally complete within 35-45 months and IEC's projects went a long way over the approved schdule. IEC's project were initiated and constructed in a 'Fast-Track' approach which should yeild a short completion schedule especially when IEC's projects were agreed with a lengthy schedule of 60 months per site. Any expenditure beyond the approved schedule should not be conceeded under these circumstances."
TRANSPORTATION OF EMPLOYEES		X	34	50	**16**	An increase resulting from additions and changes in the project			
TRANSPORTATION OF EMPLOYEES		X	10	29	**19**	An increase resulting from additions and changes in the project			
Total in NIS		**54**	**75**	**130**	**54.2**				

Table No. 13: FGD Orot Rabin Units 5-6

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommened % to be conceded by PUA of the Budget Overrun	Mill NIS conceded	WSP Observation/Comments
Increase site management team		x	27,000	57,563	**30,563**	Addition of 2 employees (as opposed to combined cycle unit) + Project engineer for the core team for two years + Worker to monitor equipment supply for two years + Employee responsible for setting up the chimney and its components.	0	0.00	"Typical retrofit projects will normally complete within 35-45 months and IEC's projects went a long way over the approved schdule. IEC's project were initiated and constructed in a 'Fast-Track' approach which should yeild a short completion schedule especially when IEC's projects were agreed with a lengthy schedule of 60 months per site. Any expenditure beyond the approved schedule should not be conceeded under these circumstances."
Extending the project	x		0	93,750	**93,750**	The duration of the construction is extended by one year - an increase in the hours of site management, temporary electricity services, administration, plumbing. Supervision hours - The duration of construction of the chimney and FGD facilities in 3.5 years.	0	0.00	

RECEPTORS + CHANGE ORDER FOR LOAD DISTRIBUTORS AND FLUID CHANGES		X	150,000	300,000	**150,000**	Updating the estimate of the receptors according to the drawings received, similar to the Orot Rabin. Material change to C276 + welding certification	70	105000.00	Conceed that additional engineering, construction and supervision activities were required as a consequence of the design consideration and changes for the receptor material and associated welding procedure mofifications and certifications. The actual hours spent on these seems out of the ordinary as the IEC manhours spent on construction, supervision and design are around 71% of the total FGD project cost while the typical value for such activities in a typical retrofit project is 55-60% which IEC were able to meet in their PM and SCR projects. This effort might be rewquired in a fast track approach but the projects have all gone beyond schedule.
SW - SW	X		0	15,625	**15,625**	A new system in the project, the main cooling water	70	209562.50	
Steel structure (pipe bridges, auxiliary facilities)		x	75,350	81,250	**5,900**	Additions to estimates after receiving data, drawings and quantities.	70	3500.00	
Infrastructure relocation	x		0	180,740	**180,740**	Opening trenches and identifying cables, copying gates and weight of trucks.	100	15625.00	Required scope with reasonble expenditure
Electricity and communications services during construction - update		x	55,625	355,000	**299,375**	The estimate was updated as a result of the increase in work hours / manpower mainly during the last quarter of 2014 and in 2015.			These activities are covered under Table 7.
House compactors	x		0	5,000	**5,000**	New content			
Total	**295,115**	**485,838**	**307,975**	**1,088,928**	**780,953**				

Table No. 14: SCR Orot Rabin (Hadera) Units 5-6

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommened % to be conceded by PUA of the Budget Overrun	Mill NIS conceded	WSP Observation/Comments
Increase site management team		x	18,000	23,875	**5,875**	The addition of 2 employees (compared to combined cycle units) + the addition of a project engineer to the core team for two years + works to monitor the supply of the equipment for two years.	0	0.00	"Typical retrofit projects will normally complete within 35-45 months and IEC's projects went a long way over the approved schdule. IEC's project were initiated and constructed in a 'Fast-Track' approach which should yeild a short completion schedule especially when IEC's projects were agreed with a lengthy schedule of 60 months per site. Any expenditure beyond the approved schedule should not be conceeded under these circumstances.on."
Extending the project	x		0	12,000	**12,000**	The duration of the construction is extended by one year - an increase in the hours of site management, temporary electricity services, administration, plumbing. Supervision hours - The length of the consolidation and assembly of the SCR is one year.	0	0.00	

The railway facility SCR 6 unit (steel structure, reactor, catalyst and piping facility)		x	70,475	156,575	**86,100**	Sub-assessment due to lack of familiarity with the facility. According to the calculation of 2,200 tons of steel structure * 46 NIS per ton + 20 employees on average for 12 months. + 4,000 NIS for sorting and identifying parts of a steel structure in the warehouse (3 employees for 6 months), compared to 1,000 tons and 10 workers for 12 months.	100	86100.00	A typical retrofit breakdown of 40-45% equipment and 55-60% construction, engineering and commissioning and these sub categories appear to be aligned with engineering international 'best practices'.
Reinforcing Steel Structure David Unit 5,6 (2 units)	x		0	381,250	**381,250**	Based on an estimate by Mr. Aviram Inbar to Unit 5 (140 ISR) (each unit is 140 PAU + 25 ISU for shared parts).	0	0.00	Costs considered in Table 2
Urea device		x	7,650	56,250	**48,600**	Table 3	0	0.00	Additional expenditure recognised in Table 3
Assembling steam pipes in bridges, ammonia pipes, salt-free water pipes DW, CCW cooling water pipes, industrial wastewater pipelines WM, eco steam cleaners		x	8,750	34,750	**26,000**	Additions to estimates after receiving data, drawings and quantities.	100	26000.00	This particular engineering actvity was grossly under-estimated and the costs spent seem reasonble.
Modification of air and gas permeability in SCR 6	x		0	31,875	**31,875**	According to 60 modules each module will work 5 days and 5 employees on shift	100	31875.00	Zero initial budget, these systems were imperitive to the effective operation of

									the SCR, hence required and additional expenditure was unavoidablebudget
Sub-evaluation general technical offices		X	0	52,000	**52,000**	Including supervision of the construction contractor SCR	100	52000.00	We would agree that this is required and in line with typical project expenditure
IDF fans (for 2 units)		x	52,700	70,550	**17,850**	Under-estimate for the size of the fans. The location of the fans on a new foundation near the supply, the supply of the fans in parts and not on Skid as a single unit.	100	17850.00	Acknowledge that the ID fans were under capacity for the new implememted technology, fans needed to be upgraded, expenditure unavoidable however IEC could provide clearer motivation for the extent of the over-expenditure
Total	**425,125**	**184,425**	**157,575**	**819,125**	**661,550**				

Table No. 15: PM Orot Rabin Units 5-6

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	IEC Reasoning provided	Recommened % to be conceded by PUA of the Budget Overrun	Mill NIS conceded	WSP Observation/Comments
Increase site management team		x	15,000	20,563	**5,563**	The addition of 2 employees (compared to combined cycle units) + the addition of a project engineer to the core team for two years + works to monitor the supply of the equipment for two years.	0	0.00	"Typical retrofit projects will normally complete within 35-45 months and IEC's projects went a long way over the approved schdule. IEC's project were initiated and constructed in a 'Fast-Track' approach which should yeild a short completion schedule especially when IEC's projects were agreed with a lengthy schedule of 60 months per site. Any expenditure beyond the approved schedule should not be conceeded under these circumstances."
Extending the project	x		0	69,000	**69,000**	Duration of construction in 3 years - Increase in site management hours, temporary electricity services, administration, plumbing. Supervision hours - lengthening the duration of the construction of an electricity structure in one year, the performance of a grout works instead of a contractor.	0	0.00	
Additional work to back up the electricity grid at the station's front	x		0	52,775	**52,775**	Piping and cable bridges PB - 5,6,12,13,14, dismantling and assembling fire extinguishing systems	100	52775.00	A typical retrofit breakdown of 40-45% equipment and 55-60% construction, engineering and commissioning and these sub-categories are aligned with international norms.

						Electrical structure and transformer, adding 4 cells to the RB divisions for electrical building and assembly lines.		
Replacement of primary air fans		x	12,875	21,250	**8,375**	Update according to the OCHA estimate.	100	8375.00
Additional Upgrade to PAF Fans - Initial Air	x		0	11,900	**11,900**	For further disassembly and assembly. According to a calculation of 56 employees (shifts) per month. Additive to strengthen primary air channels	100	11900.00
Upgrading the control room, expanding SCS	x		0	11,000	**11,000**	Changes Committee	100	11000.00
Assembling a bridge to cable channels near the transformers	x		0	10,000	**10,000**	Manual assembly with no strength of 100 NIS per ton of steel structure. Power reinforcement at the front of the station	100	10000.00
x		0	4,680	**4,680**			100	4680.00
x		0	7,500	**7,500**		Additional work to allow upgrading grinders	100	7500.00
	x	99,750	131,000	**31,250**		Adjustments and changes in the process (adding VSD rooms, according to the supplier's demand for first-time operation)	100	31250.00
x		0	11,250	**11,250**		For testing and checking the upgrade of the first	100	11250.00

						mill.According to actual investment.			
	x	40,800	81,250	**40,450**		Addition in respect of the supply of the heater in small and non-large modules as required in the following sections. Addition of welds and assembly	100	40450.00	
x		0	10,000	**10,000**		No other system was known	100	10000.00	
x		0	5,000	**5,000**		Construction of a temporary control system in the turbine hall and transfer to a new control room above the midbay control room	100	5000.00	
x		0	20,000	**20,000**		Addition of electricity columns for low voltage electricity supply, connection 16 Control cabinets for temporary rooms instead of new electronics room (changes 13-4), civilian inspection of boiler reinforcement 5,6	100	20000.00	
213,105	**85,638**	**168,425**	**467,168**	**298,743**					

Table 16: FGD Rothenberg Units 1-2

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	Remarks	Recommened % to be conceded by PUA of the Budget Overrun	Man-hours conceded	WSP Observation/Comments
Extending the project	X		0	48,960	**48,960**	Duration of establishment in two years - management of the site, administration, plumbing, communications, monitoring and supply of equipment. 10 employees for four years	0	0.00	Typical retrofit projects will normally complete within 35-45 months and IEC's projects went a long way over the approved schdule. IEC's project were initiated and constructed in a 'Fast-Track' approach which should yeild a short completion schedule especially when IEC's projects were agreed with a lengthy schedule of 60 months per site. Any expenditure beyond the approved schedule should not be conceeded under these circumstances.
Increase site management team		X	17,280	38,333	**21,053**	At the request of the project manager for 6 years.	0	0.00	
Increasing amounts of steel structure and pipe bridges PB17-PB28, PB40-PB54		X	15,984	71,040	**55,056**	Increasing quantities from 360 tons to 1600 tons (1.2 * 37 * 1240).	70	38539.20	Conceed that additional engineering, construction and supervision activities were required as a consequence of the design consideration and changes for the receptor material and associated welding procedure mofifications and certifications. The actual hours spent on these seems out of the ordinary as the IEC manhours spent on construction, supervision and design are
RECEPTORS + CHANGE ORDER FOR LOAD DISTRIBUTORS AND FLUID CHANGES		X	144,000	300,000	**156,000**	Updating the estimate of the receptors according to the drawings received, similar to the Orot Rabin. Material change to C276 + welding certification	70	109200.00	

Transferring general infrastructure (temporary and permanent sewage + fire + air conditioning + cooling compressors + raw water + electricity + dismantling old bridges + future work)		X	84,240	400,000	**315,760**	In accordance with the actual expenditure of about 135 ISR + forecast.	70	19992.00	around 70% of the total FGD project cost while the typical value for such activities in a typical retrofit project is 55-60% which IEC were able to meet in their PM and SCR projects. This effort might be rewquired in a fast track approach but the projects have all gone beyond schedule.
Building a temporary sewage system Stage 2 (for words)	X		0	15,912	**15,912**	It was unknown. Actual performance - new content	70	9853.20	
Addition to the early assembly of gas tunnels from the chimney of ash to the chimney		X	104,400	520,000	**415,600**	Supply of gas pipe parts as plates rather than three-dimensional parts	70	28980.00	
Gas channels A subdivision between the IDF and the receptors		X	24,480	46,512	**22,032**	Only walls were accepted. According to a calculation of 20 employees for 6 months per unit (compared with 10 employees originally).	70	98056.00	
Adding bypass	X		0	28,560	**28,560**	Bypass to the old chimney (not known). According to a calculation of 14 employees for 5 months per unit. The source of the chimney was designed for concatenation	100	29376.00	Having to reposition the stacks as a consequence of wind modelling resulted in longer lengths of ducting to the new stack positions. This cost is unavoidable.
Longer ducts due to changing chimney position + pants + trenches and ladders	X		0	29,376	**29,376**	It was unknown. According to a calculation of 12 employees for 6 months per unit. Change of location of chimney after analysis in wind tunnel	100	19200.00	If these costs are a consequence of a change in legislation, then additional costs are unavoidable.

Circulating Water Cycle (CCW)	X		0	14,076	**14,076**	Additional VAT for pre-planned FGD - including pumps, panels and instrumentation. According to a calculation of 23 employees for 3 months.	100	10000.00	Unavoidable as this requirement was not in the original design consideration.
Eurosilu (Bridges + Piping + Utilities)	X		0	41,400	**41,400**	Additional VAT for pre-planned FGD - including pumps, panels and piping equipment. According to a calculation of 15 employees on average for 12 months.	100	2200.00	Unavoidable as this requirement was not in the original design consideration.
Electricity and communications services during construction - extension of the project		X	49,920	190,000	**140,080**	In accordance with the actual expenditure of about 45 NIS + forecast.	100	2500.00	Unavoidable as this requirement was not in the original design consideration.
Fire detection complex project execution department	X		0	19,200	**19,200**	Was not known according to the requirements of fire-fighting organization	0	0.00	Covered in Table 4
Identification of cables + marking + cutting in the sewage complex and area of FGD facilities	X		0	203,000	**203,000**	It was unknown. According to a calculation of 8 employees on average for 20 months.	0	0.00	Covered in Table 4
Reloacting cables	X		0	47,142	**47,142**	Replacement of about 500 cables including expenses from the the contingency and tests before returning to the reserve. According to a calculation of 10 employees on average for 18 months.	100	15912.00	These costs appear unavoidable and the expendiute is reasonable

Building a Western Gate (piping + electricity)	X		0	10,000	**10,000**	It was unknown.	0	0.00	Covered in Table 4
Add gypsum pumps near gypsum tanks 3 + 4 units	X		0	2,200	**2,200**	It was unknown.	0	0.00	Covered in Table 5
The new warehouse house	X		0	2,500	**2,500**	It was unknown.	0	0.00	
Total	**462,326**	**1,125,581**	**440,304**	**2,028,211**	**1,587,907**				

Table No. 17: SCR Rotenberg Units 1-2

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	Remarks	Recommened % to be conceded by PUA of the Budget Overrun	Man-hours conceded	WSP Observation/Comments
Extending the project	X		0	12,271	**12,271**	Duration of establishment in two years - management of the site, administration, plumbing, communications, monitoring and supply of equipment. 10 employees for two years.	0	0.00	Typical retrofit projects will normally complete within 35-45 months and IEC's projects went a long way over the approved schdule. IEC's project were initiated and constructed in a 'Fast-Track' approach which should yeild a short completion schedule especially when IEC's projects were agreed with a lengthy schedule of 60 months per site. Any expenditure beyond the approved schedule should not be conceeded under these circumstances.
Increase site management team		X	11,520	27,187	**15,667**	At the request of the project manager for 4 years.	0	0.00	
Modification of the modularization of air and gases in SCR		X	0	61,200	**61,200**	According to 60 modules each module will work 5 days and 5 employees on shift	100	61200.00	A typical retrofit breakdown of 40-45% equipment and 55-60% construction, engineering and commissioning and

Assembling the SCR facility, unit 1,2 (steel structure, reactor, catalyst and piping facility)		X	268,512	384,672	**116,160**	Sub-assessment due to lack of familiarity with the facility. According to the calculation of 2,200 tons of steel structure * 46 NIS per ton + 10 employees on average for 12 months. + 4,000 NIS for sorting and identifying parts of a steel structure in the warehouse (3 employees for 6 months), compared to 1,000 tons and 10 workers for 12 months.	100	116160.00	these sub categories appear to be aligned with engineering international norm.
Reinforcing steel structure David No. 1,2 (2 units)	X		0	360,000	**360,000**	Based on estimate of Orot Rabin (without detailed planning)	0	0.00	Costs considered in Table 2
Urea facility (1-4)		X	14,688	74,256	**59,568**	Table 3	0	0.00	Additional expenditure recognised in Table 3
IDF fans (for 2 units)		X	50,592	67,728	**17,136**	Sub-estimate for the size of the fans. The location of the fans on a new foundation near the maintenance of the fans in parts rather than on Skid as a single unit.	100	17136.00	Unfortunately no initial budget but the cost is unavoidable and reasonable

Steam pipes and eco steam drain	X		0	11,424	**11,424**	It was unknown. 8 employees for 7 months.	100	11424.00	
Command room	X		0	10,000	**10,000**	Another work that was not priced at first	100	10000.00	
Control rooms above the control room	X		0	4,000	**4,000**	It was unknown.	100	4000.00	
Equipment conservation	X		0	10,000	**10,000**	Was unknown, due to the extension of the project	0	0.00	Please see row 7 and 8.
Sub-evaluation general technical offices		X	0	85,000	**85,000**	Including supervision of the construction contractor SCR	0	0.00	This is covered under the site management expenses
Total	**407,695**	**354,731**	**345,312**	**1,107,738**	**762,426**				

Table No. 18: PM Rutenberg 1-2

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	Remarks	Recommened % to be conceded by PUA of the Budget Overrun	Man-hours conceded	WSP Observation/Comments
Extending the project	X		0	69,000	**69,000**	Duration of establishment in two years - management of the site, administration, plumbing, communications, monitoring and supply of equipment. 10 employees for 4 years	0	0.00	Typical retrofit projects will normally complete within 35-45 months and IEC's projects went a long way over the approved schdule. IEC's project were initiated and constructed in a 'Fast-Track' approach which should yeild a short completion schedule especially when IEC's projects were agreed with a lengthy schedule of 60 months per site. Any expenditure beyond the approved schedule should not be conceeded under these circumstances.
Increase site management team		X	9,600	40,000	**30,400**	At the request of the project manager for 4 years.	0	0.00	
Strengthening the gas channels between the boiler and the outlet	X		0	96,000	**96,000**	New content according to the BBS provider findings	100	96000.00	A typical retrofit breakdown of 40-45% equipment and 55-60% construction, engineering and commissioning and these sub categories appear to be aligned with engineering international norm.
Upgrading Grinders - Update		X	96,000	144,000	**48,000**	Updating an estimate of 8 items per mill to 12 items.	100	48000.00	
Electric reinforcement at the front of the station FOS (bridges + electricity works + fire pipe + transformers + electrical structure + tracks)	X		0	36,720	**36,720**	It was unknown. According to a calculation of about 18 employees for 10 months.	100	36720.00	

Infrastructure relocation includes clearing for SOFA	X		0	34,500	**34,500**	Evacuation in the boiler hall, dismantling of electricity, dismantling of surfaces for grinders + SOFA. Approximately 15 employees for one year.	100	34500.00	
Air and sealing system + Inert steam	X		0	23,460	**23,460**	Including the dismantling and assembly of new air-sealing systems. Approximately 23 employees for 5 months.	100	23460.00	
The assembly is cut off by coal pipes	X		0	18,360	**18,360**	It was unknown. According to a calculation of 10 employees for 5 months per unit.	100	18360.00	
Refrigeration system and flame testers	X		0	7,600	**7,600**	It was unknown.	100	7600.00	
Production and assembly PLC for 10 grinders	X		0	7,000	**7,000**	When upgrading the coal grinders, PLC cabinets should be installed in a temporary place.	100	7000.00	
Add 2 VSD cabinets and 2 control rooms including steel structure	X		0	7,400	**7,400**	Late planning including the installation of a temporary VDS closet including the production of frames for the boards, construction of infrastructure, laying of cables and wiring.	100	7400.00	
Early air heaters	X		0	55,200	**55,200**	It was unknown. According to a calculation of 12 employees for 10 months per unit.	100	55200.00	
Boiler Booster + Preheat air	X		0	4,800	**4,800**	Mainly contractor supervision.	100	4800.00	
Total	**360,040**	**78,400**	**105,600**	**544,040**	**438,440**				

Table No. 19: SCR Rotenberg Units 3,4

Work content	New content	Updating an estimate as a result of the additions and updating of the plans	Original design	Current planning	Total additions and changes	Remarks	Recommended % to be conceded by PUA of the Budget Overrun	Man-hours conceded	WSP Observation/Comments
Increase site management team		X	22,080	66,240	44,160	At the request of the project manager for 6 years.	0	0	Typical retrofit projects will normally complete within 35-45 months and IEC's projects went a long way over the approved schdule. IEC's project were initiated and constructed in a 'Fast-Track' approach which should yeild a short completion schedule especially when IEC's projects were agreed with a lengthy schedule of 60 months per site. Any expenditure beyond the approved schedule should not be conceeded under these circumstances.
Assembling facility SCR 3,4 (steel structure, reactor, catalyst and piping facility)		X	268,512	891,552	623,040	Sub-assessment due to lack of familiarity with the facility. According to the calculation of 2,200 tons of steel structure * 46 NIS per ton + 40 employees on average for 24 months. + 4,000 NIS for sorting and identifying parts of a steel structure in the warehouse (3 employees for 6 months), compared to 1,000 tons and 10 workers for 12 months.	100	623040	
Reinforcing steel structure boiler No. 1,2 (2 units)	X		0	421,200	421,200	Based on estimate of Orot Rabin (without detailed planning)	0	0	Refer to Table 2

Modification of air and gas permeability in SCR units 3,4		X	0	61,200	61,200	According to 60 modules each module will work 5 days and 5 employees on shift	100	61200	5 persons for 5 days per 60 modules equals approximately 60000, figure IEC is claiming appears reasonable
SCR steel structure addition - dismantling and assembly	X		0	63,648	63,648	The dismantling of an old structure for each unit and changes in the steel structure of the boiler to connect to the gas chambers of the SCR - about 40 employees for a period of 4 months for each unit.	100	63648	Unfortunately no initial budget, unavoidable cost
Transferring infrastructure 3 + 4 units (steel structure + plumbing + electricity + hydraulic units + piping and cable identification)	X		0	42,840	42,840	Table 4	0	0	Covered in Table 4
Upgrading of air fans	X		0	36,648	36,648	It was unknown. 60% of the PM project.	100	36648	Unfortunately no initial budget, unavoidable cost
Upgrade air heaters 3 and 4	X		0	85,350	85,350	Table 10	100	85350	
Upgrade an early heater 3 and 4	X		0	23,460	23,460	Table 10	100	23460	
Steam pipes and eco steam drain	X		0	12,880	12,880	It was unknown. 8 employees for 7 months.	100	12880	
Command room	X		0	30,300	30,300	Another work that was not priced at first	100	30300	
Total	716,326	728,400	290,592	1,735,318	1,444,726				

	IEC's Claim			Rocommended PUA Concession			
Item	**Hadera 5-6**	**Ashkelon 1-2**	**Ashkelon 3-4**	**Hadera 5-6**	**Ashkelon 1-2**	**Ashkelon 3-4**	**Remarks**
SCR facilities							
Boiler Reinforcement	**80.1**	**76**	**88.5**	***42.00***	***42.00***	***42.00***	Details in Table 2
under-estimation of the construction of the urea plant	**10.2**	**13**		***10.21***	***12.51***		Details in Table 3
SCR Hadera	**48.7**			***44.90***			Details in Table No. 14
SCR Ashkelon 1-2	**-**	**71.1**			***46.18***		Details in Table 17
SCR Ashkelon Units 3-4			**214.9**			***196.67***	Details in Table 19
Mobile Cranes	**5**	**10**	**40**				Details in Table No. 11
Transportation of employees	**2.8**	**5**	**19**				Details in Table 12
Total SCR	**146.7**	**175.1**	**362.4**	***97.11***	***100.69***	***238.67***	-247.73
FGD facilities							
Flue gas channels and steel structure between ID fans and ash sedimentor and boiler	**17.9**	**30**		***18***	***30.03***		Details in Table 5
Wastewater Treatment Plant	**6.4**	**7**		***3***	***4***		Details in Table 6 are included in Table 13 or 16
Infrastructure relocation (diesel generator + sulfur tank + steel structure + plumbing + electricity + hydraulic unit copying + piping and cable identification and more)	**-**	**-**					Included in PM
Piping systems and steel structure and pipe bridges	**9.4**	**11.6**		***5***	***6***		Details in Table 7
Assembling FDG receptors	**31.5**	**32.8**					
Mobile Cranes	**30**	**30**		***0***	***0***		Details in Table No. 11
Transportation of employees	**8**	**10**					Details in Table 12
Hadera FGD	**132.5**			***70.07***			Details in Table No. 13
FGD Rothenberg 1-2	**-**	**300.7**			***77.26***		Details in Table No. 16
Total FGD	**235.6**	**422.1**		***95.81***	***116.58***		**-445.31**
PM facilities							
Assembly of actuators to the boiler burners	**14.3**	**13.7**	**-**	***7***	***7***		Details in Table 8
Mobile Cranes	**11**	**12**	**-**	***0***	***0***		Details in Table No. 11
Infrastructure relocation (diesel generator + sulfur tank + steel structure + plumbing + electricity + hydraulic unit copying + piping and cable identification and more)	**34.7**	**43.9**		***19.33***	***24.46***		Details in Table No. 4
Transportation of employees	**3**	**7**	**-**				Details in Table 12
PM Hadera	**62.7**		**-**	***47.08***			Details in Table No. 15
PM Ashkelon	**-**	**92.1**	**-**		***71.20***		Details in Table 18
Total PM	**125.7**	**168.7**		***73.55***	***102.51***	***0.00***	-118.34
Total additions in NIS millions	**508**	**765.9**	**362.4**	***266.47***	***319.78***	***238.67***	
Total additions throughout the project		**1,636.30**					
Credits in equipment items and contractors throughout the project		**141.9**		**These credits already considered in WSP's analysis within the respective tables.**			
Total increase in total investment		**1,494.40**			***824.92***		-811.38

6.1 GENERAL OBSERVATIONS AND COMMENTS ON IEC OVER-EXPENDITURE

WSP's general comments and observations noted during the various engagements with IEC and PUA as well as all the analysis undertaken on this assignment are highlighted below.

6.1.1 The extent of IEC's claim for project over-runs, schedule delays and increased costs amount to over NIS 1.5 Billion NIS.

6.1.2 IEC have stated that this additional expenditure is all related to IEC man-hours associated with engineering design, construction supervision, project management and commissioning activities. We note the following concern;

An average hourly rate of NIS 210 would see an additional 7,500,000 man-hours over the project's combined life cycle of implementation. Assuming the 7-year period quoted, this would imply an additional 1,000,000 man-hours per year, equal to 500 'additional staff on site each year. This appears extra-ordinary. The use of an additional 500 site workers over each year of this period is considered excessive/unrealistic and with the congestion claimed by IEC in its sites will be also physically impossible and/or not effective due to interference.

6.1.3 There appears to be very little milestone acceptance/approval between IEC and PUA through the duration and implementation of these projects across the two power sites. One would expect to see project budget variations and associated motivations tabled with PUA for consideration and approval as these variations are realised, rather than attempting to resolve the differences post the events.

6.1.4 IEC have submitted very little information to substantiate the variances to the initial budget figure. It would be sensible for IEC to provide thorough and well-motivated reasons and explanations for the project delays and coinciding additional expenditure rather than providing the external parties with very general rhetoric information and leaving the commentators having to make a tremendous amount of assumptions in their analysis.

The task of evaluating the causes and consequences of project delays would and should be a simple exercise with the claimant providing thorough and compelling justifications for project over-expenditure but this was not done thoroughly by IEC. Based on the material provided by IEC we would recommend that PUA concede 825 M NIS.

Appendix A - IEC's Budget Overrun Presentation

Total investments are updated

Division by components

Percent change	Change required (M NIS)	Cumulative execution 12/2015	The estimated cost includes updated (M NIS)	Total Investment Budget 2013 (M NIS)	Project component
9%	40.3	408.1	507.7	467.4	Design*
6%	135.9	1,923.90	2,520.60	2,384.70	equipment
52%	1278.4	1,524.50	3,387.20	2,108.80	Construction and assembly **
80%	74.4	64.3	167.6	93.2	Revenue per action
85%	51.1	63.9	111.2	60.1	difference
-15%	-69.6	--	413.9	483.5	Unexpected Expenses
27%	1,510.50	3,984.70	7,108.20	5,597.70	total

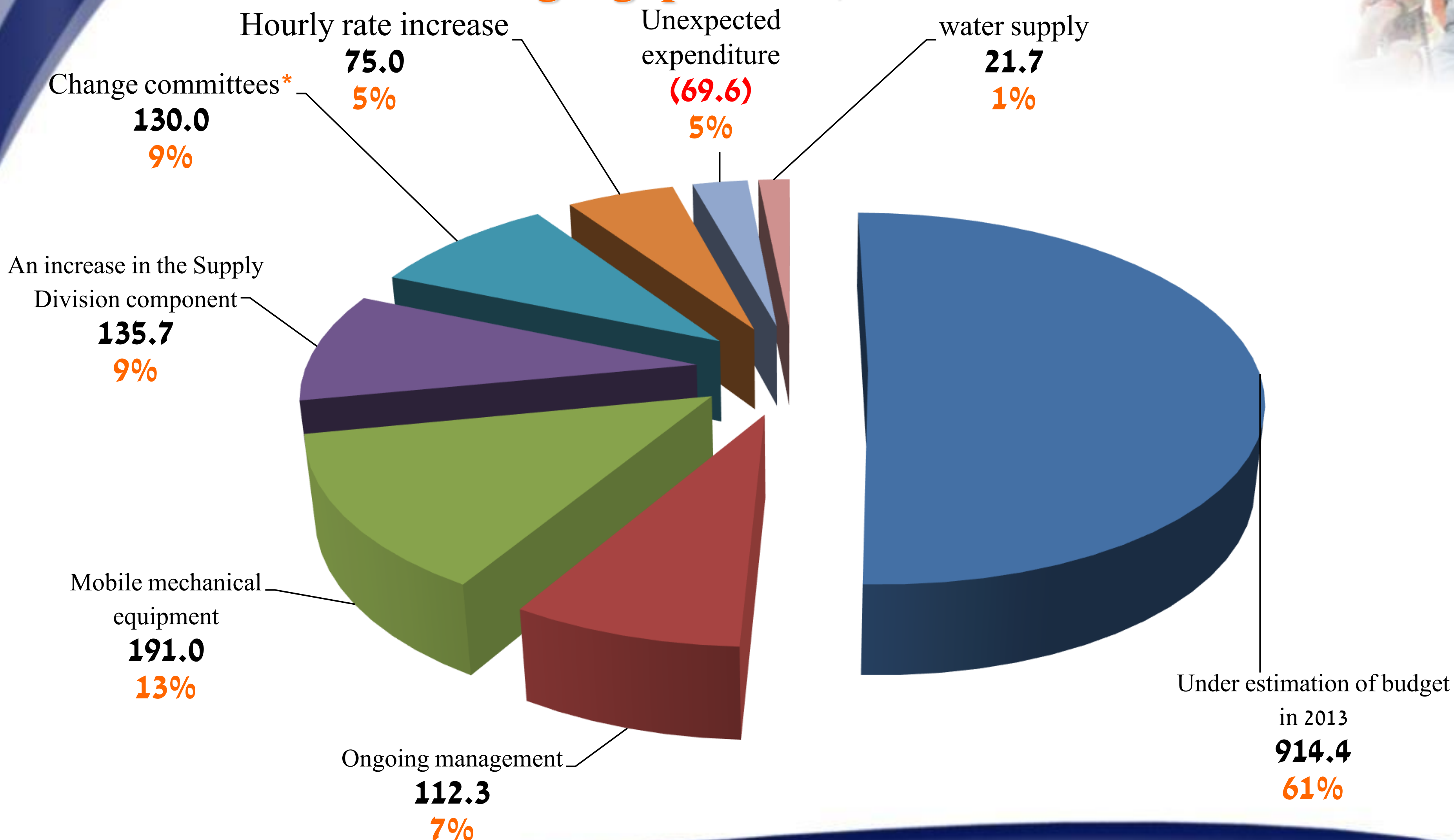
* Including pre-project and infrastructure evacuation planning

**Incl. Expenses for mobile cranes and transportation

- Including work of a sum of approx. NIS 100 million.
- The project includes the aircraft's antiaircraft unit, which stood at NIS 172 million in 2013 and NIS 64 million in the requested budget.

Increase in total investments

Budget gaps NIS 1,510.5 million



The approved budget does not reflect the project's scopes

Example 1 – FGD Receptors

- In the 2013 budget, the assembly of an FGD receptor totalled 54,000 Man hours was allocated (NIS 10.6 million)
- This budget is based on historical data from the Rutenberg site
- In 2012, the first of the four receptors, whose actual expenditure until then was 78,000 man hours (NIS 15 million)

- Actual installation cost was NIS 20.3 million per unit.
- And a total of NIS 81 million compared to NIS 42 million.

The approved budget does not reflect the project's contents

Example 2 - Front of station

- In the 2013 budget, the front of station activity was budgeted at NIS 0 (!)
- Compared to an investment in equipment required for installation in the amount of NIS 28 million
- The actual assembly cost is NIS 48 million
- The contents of this work include the following components:
  - Pipe bridges
  - Structures
  - Protections
  - Cables

The approved budget does not reflect the project's contents

Example 3 - Infrastructure relocation

- In the 2013 budget, infrastructure relocation activity at the two sites was budgeted based on 151,000 man hours (NIS 30 million).
- This activity is characterized by uncertainty and requires a change in the location of cable systems and piping systems of all types on a large scale: water, sewage, fuel, oil, etc.
- In practice, IEC utilized 530,000 man hours (NIS 103 million)

The approved budget does not reflect the project's contents

(U2A)Example 4 - Urea device

- In the 2013 budget, the installation activity was allocated to the urea plant at a negligible scale of NIS 5 million.
- The budget for the construction of the urea plant was budgeted on an assumption that the plant is small and comes pre-assembled.
- The cost of the equipment is NIS 65 million
- The actual installation cost is NIS 36 million

The approved budget does not reflect the project's contents

Example 5 - Establishment of facilities SCR

- In the 2013 budget, SCR facilities installation was budgeted at 604,000 man hours (NIS 123 million).
- This budget was determined on the basis of the SCR facility at Rothenberg built about ten years earlier.
- The facility that was planned in the past was significantly different from the new facility, as follows:
  - Size of the facility: previously designed 200 tons new plant 1,000 tons
  - Area of the facility: Previously designed 500 sq.m. new plant 1,800 sq.m.
- Actual expenditure NIS 309 million

The approved budget does not reflect the project's contents

Example 6 - Reinforcing steel structure

- In the 2013 budget, activity was allocated to strengthen the steel structure in the amount of 16,000 man hours (NIS 3 million).
- The budget was based on an estimate of a steel structure of 500 tons and a low estimate for each reinforcement point.
- In practice, the required reinforcement is 800 tons, rather than the required 5,700 reinforcement points.
- In practice, NIS 183 million

The approved budget does not reflect the project's contents

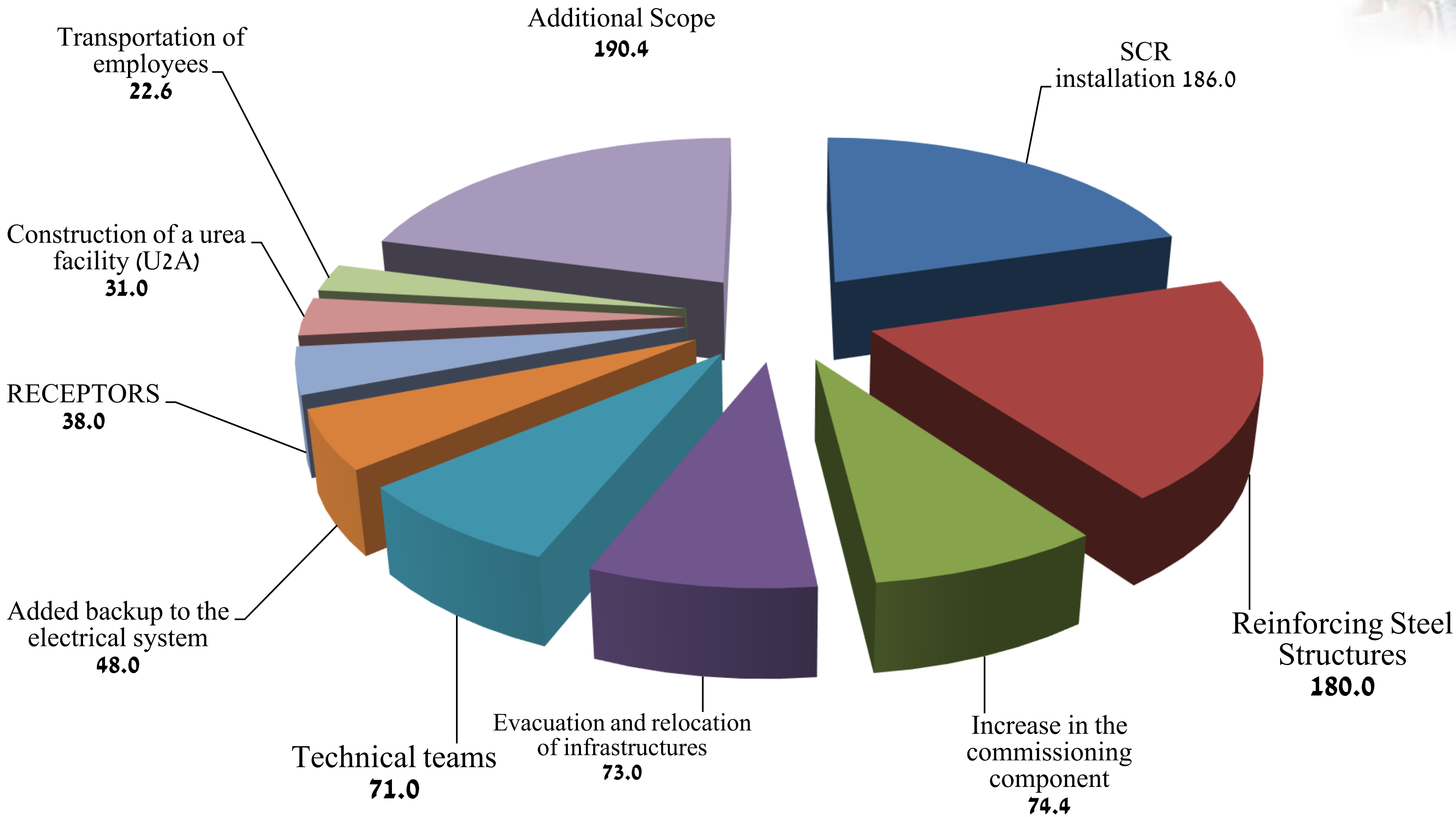
Concentration of the cost of construction and assembly

2016 M NIS	2013 M NIS	activity
81	43	RECEPTORS
48	0	Front of station
103	30	Infrastructure relocation
36	5	Urea device (U2A)
309	123	Facilities SCR
183	3	Reinforcing steel structure
760	204	Total

A gap of NIS 556 million is 74% of the item (Only increase in content)

Budget gaps

Low estimate - NIS 914.4 million



Budget gaps

hourly rate increase

- Due to changes in the Company, such as the approved personnel frameworks, the dismissal of temporary employees, the non-absorption of workers and a change in the mix of temporary and permanent employees, there was an increase in the price of work hours, which led to an increase in the cost of the projects.
- **The price of the increase in hourly rates is NIS 75 million**

Budget gaps

Water supply to sites

- In preparing of the 2013 budget, it was decided to treat the water supply as a separate parallel project
- Since the water supply to the sites will serve the emission reduction projects and given the scope of the work to be performed, it was decided to assign the activity to the project's scope when preparing a total investment budget 2016
- **Water supply to sites cost is NIS 21.7 million**

The story of the project

delay is Schedule

	Predicted/Actual completion dates	Completion dates 2013	Unit
21 months	15.01.2016	15.04.2014	unit 5 SCR+PM
27 months	31.07.2016	15.04.2014	unit 5 FGD
28 months	15.02.2017	15.10.2014	unit 6 SCR+PM
30 months	01.10.2017	15.04.2015	unit 1
31 months	01.05.2018	15.10.2015	unit 2
30 months	01.10.2018	15.04.2016	unit 4
29months	01.03.2019	15.10.2016	unit 3

Rabin Power plant

Rutenberg Power plant

The project in terms of schedule

Delays by suppliers / contractors

- BNG Company (SCR system supply)
- Failure of the supplier to meet contractual obligations for the timely supply of planning and equipment, including non-compliance with the required quality
- Significant delays in the supply of planning
- Many problems with the quality of the design provided

<u>The project in terms of schedule</u>

Delays by suppliers / contractors

- CDI Company (Construction of the chimney and plaster factory)
- Failure to comply with the contractual schedule
- Insufficient administrative organization to carry out the site works
- Many labor disputes with the local subcontractors, including Solel Boneh, when the chimney envelope was poured

The project in terms of schedule

Delays by suppliers / contractors

- ABB (Provider of the integrative control system)
  - Poor design quality of the integrated control system caused the duration of the planning to continue
  - The failure of the Factory Acceptance Test also caused a delay of many months in the supply of the system
  - The immaturity of the system at the time of the income into operation led to the extension of the duration of the income to the action

The project in terms of schedule

Delays by suppliers / contractors

- A.P.I.D Company (Supply of steel structure to the plumbing bridges)
  - The equipment supplier did not meet the dates and quality of the supply of the production drawings and the dates of the supply itself
  - Due to the poor quality of planning and manufacturing, many inconsistencies were discovered in the area, which led to the dismantling of several bridges and their return to the plant for repairs

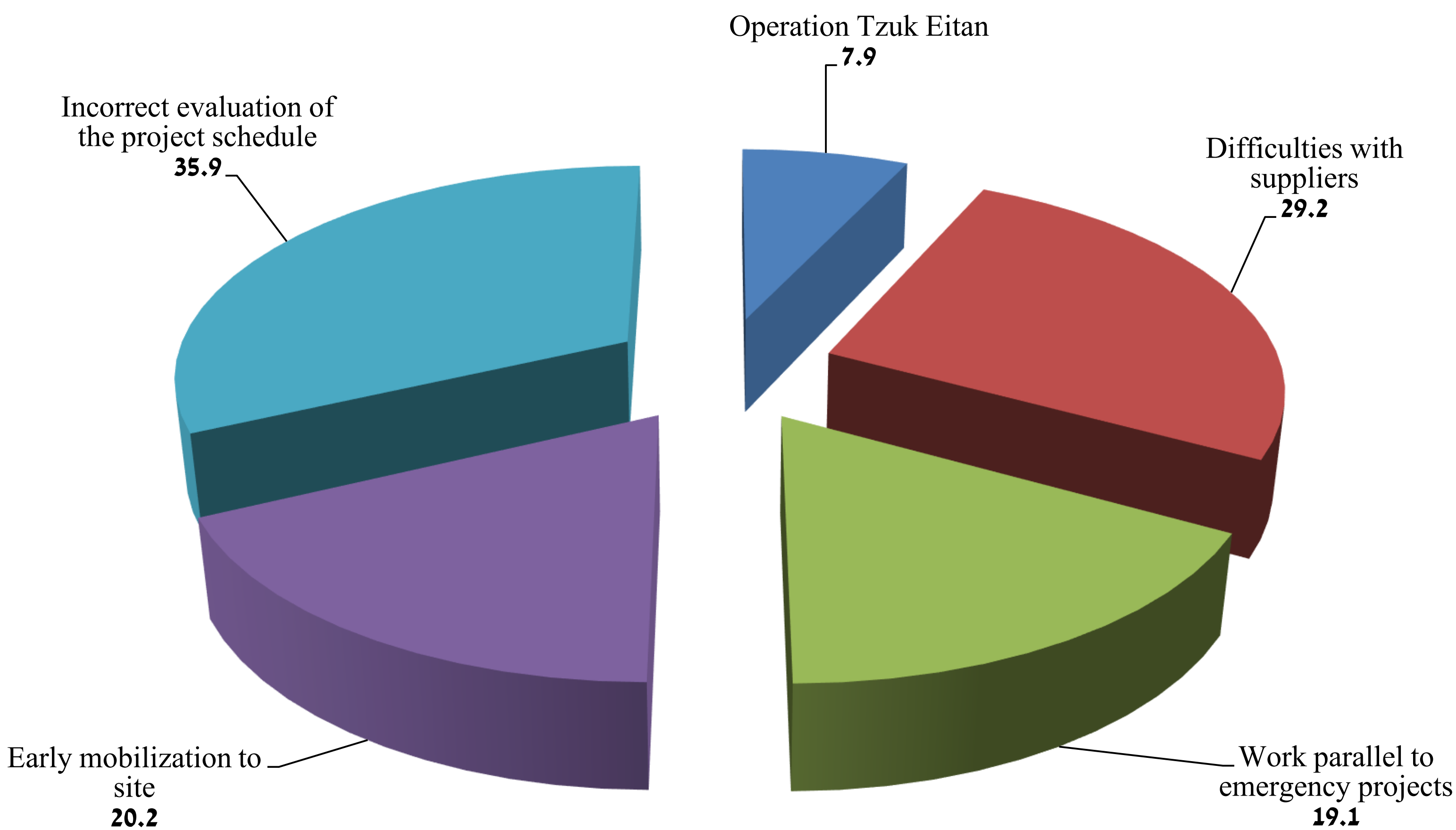
The project in terms of schedule

Security difficulties

- Following Operation Tzuk Eitan (Gaza Skirmish), there were several difficulties in managing the projects:
  - The company "Hagiva" was forced to slow the pace of production of parts to the SCR structure
  - The companies "Inchiko" and "Doosan" delayed the arrival of experts to Israel
  - Work performed by the Company's employees at the Rotenberg site was halted for two months
  - At the end of the operation, it was difficult to return the contractors to the site, which caused further delays
  - The contracting companies found it difficult to absorb workers due to the deterioration in security checks

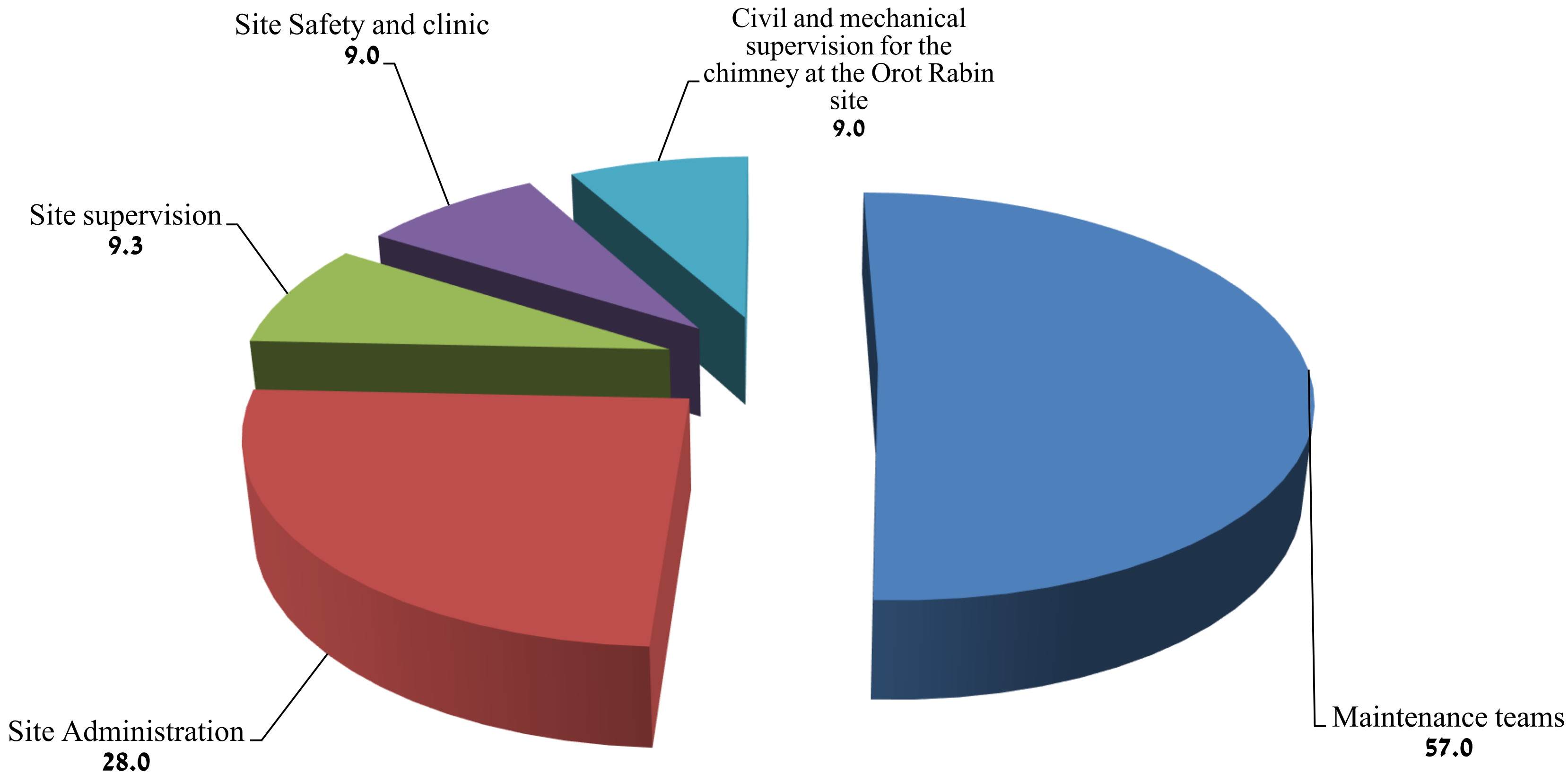
Budget gaps

Costs associated with delayed schedulres 112.3 M NIS



Budget gaps

Ongoing management- 112.3 M NIS



Budget gaps

Change in the Supply and Storage Division

- **Change in costs, mainly for the Supply Division, for storage and handling of purchases, in scope of 135.7M NIS**

- **The longer the duration of the projects, the higher the equipment storage and retention costs than those planned for 2013**

- **According to the budgeting method used at the time, in the last approved 2013 total investment, the costs of storage were budgeted until 2013 (inclusive) and the allocation for this activity for the years 2014 and thereafter**

As of the preparation of the Company's budgets for 2014, the budgeting method was improved

Budget gaps

Mobile Cranes

- **Component of mobile mechanical equipment (cranes) cost around 191 M NIS**

The nature of the emissions reduction project requires
A large amount of major cranes including additions to the reinforcing elements of the steel structure, pipe bridges, the relocation of infrastructures and civil works.
Variance including prolongation of project duration and handling
In equipment malfunctions, more work was required in the crane component.