KAPCO

Kot Addu Power Company Limited

5 B/3, Gulberg III
Lahore 54660, Pakistan
UAN +92 42 111 152 726
PABX +92 42 3577 2912-21
Fax +92 42 3577 2922

For information pl.
- Addl. Dir(I)/OR-II
- MF
Copy to:
- DG (Lic)
- ALA (Lic)

24/6/21.
cc: Chairman
- Member/CA
- M(MRE)
- M(Lic)

June 24, 2021
Reference No. KAPCO/CEO/2021/423

The Registrar
National Electrical Power Regulatory Authority
NEPRA Tower, Attaturk Avenue (East)
G-5/1, Islamabad

SUBJECT: **APPLICATION FOR GENERATION LICENSE EXTENSION PROPOSED FOR GENERATION LICENSE NO. IPGL/020/2004 RELATING To 1600MW (GROSS) KAPCO Complex LOCATED AT KOT ADDU DISTRICT MUZAFFARGRAH, PUNJAB, PAKISTAN**

Dear Sir,

1. Pursuant to the applicable laws of Pakistan, including the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997 and the rules and regulations made thereunder (including regulation 10(2) of the National Electric Power Regulatory Authority Licensing (Application Modification Extension and cancellation Procedure) Regulations, 2021) and the National Electric Power Regulatory Authority Licensing (Generation) Rules, 2000) we submit before the National Electric Power Regulatory Authority (the Authority) an Application for Generation License Extension (together with the documents annexed thereto) (the Generation License Extension Application) for the extension of the Licensee's Generation License No. IPGL/020/2004 read with its Extension dated June 24, 2021 (the Generation License).

2. The Application for Generation License Extension (including its annexures) are being submitted in triplicate, together with:

(a) a Bank Draft No. 24765036 dated 22-6-2021 amounting to PKR 1,456,455 (Pakistani Rupees One million four hundred fifty six thousand four hundred Only) drawn in favour of NEPRA, as the application fee for a License Proposed Extension of Generation License (as communicated to us by NEPRA) has been directly sent to NEPRA;

(b) Board resolution of the Company dated June 22, 2021; and

REGISTRAR
Dy. No: 1705
Dated: 24/6/21

KAPCO

(c) Affidavit/Statements of Authorized Representative of Company, Mr. Aftab Mahmood Butt, Chief Executive.

3. In light of the submissions set out in the Application for Generation License Extension and the information attached to the same, the Authority is kindly requested to process the License Proposed Extension of Generation License Application at the earliest.

Thanking you,

Yours faithfully,
For Kot Addu Power Company Limited

Aftab Mahmood Butt
Chief Executive

Enclosures: As stated

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Chief Executive

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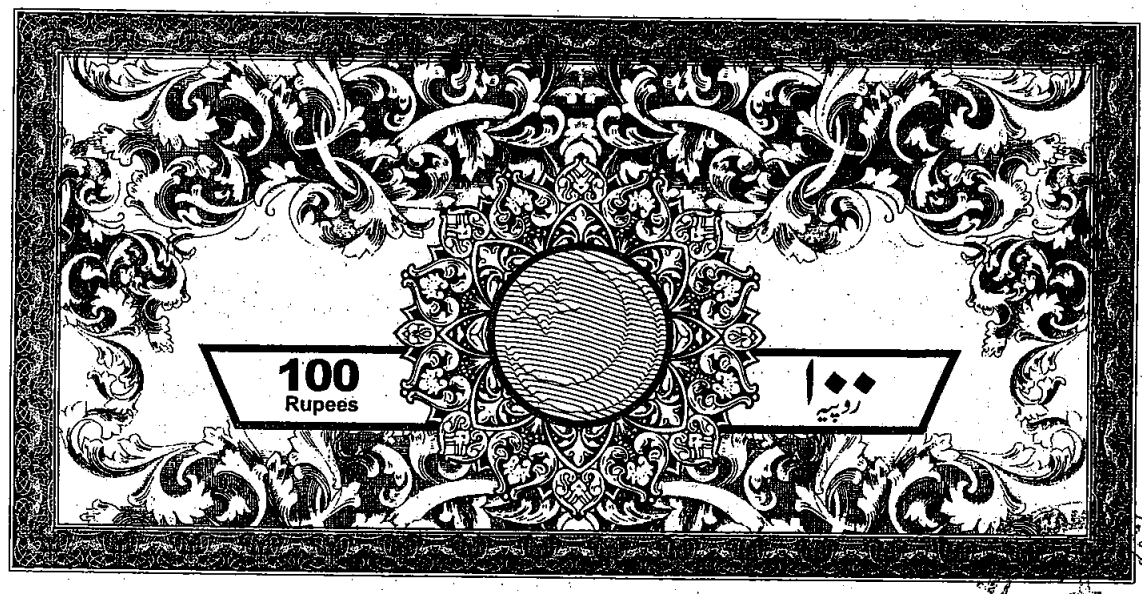


AFFIDAVIT

I, Aftab Mahmood Butt son of Arshad Mahmood Butt (late), adult do hereby solemnly affirm and state as under:

1. That I am the Chief Executive of Kot Addu Power Company Limited, Lahore and I am well conversant with the affairs of the Company.

2. The contents of the application for Extension of Generation Licence of the Company dated June 24, 2021 are true and correct to the best of my knowledge and belief.

DEPONENT

ATTESTED
Notary Public Lahore

KAPCO

Kot Addu Power Company Limited

5 B/3, Gulberg III
Lahore 54660, Pakistan
UAN +92 42 111 152 726
PABX +92 42 3577 2912-21
Fax +92 42 3577 2922

Certified True Copy of the extracts of the Resolutions passed at the 132nd Meeting of the Board of Directors of Kot Addu Power Company held at Lahore on June 9, 2021.

RESOLVED UNANAMOUSLY that Kot Addu Power Company Limited be and is hereby permitted:

(i) to prepare, deliver, file, apply and submit, pursuant to the applicable laws of Pakistan, including the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997 and the Rules and Regulations made thereunder (including regulation 10(2) of the National Electric Power Regulatory Authority Licensing (Application & Modification Procedure) Regulations, 1999' and the 'National Electric Power Regulatory Authority Licensing (Generation) Rules, 2000), an application (together with all documents attached thereto) before the National Electric Power Regulatory Authority (NEPRA) for NEPRA's approval of the extension of the Company's generation license No. IPGL/020/2004 to cater, inter alia, for the remaining useful life and, as a result, the PPA Term Extension, enter into and execute all required documents, make all filings, attend all hearings, provide all required information and pay all applicable fees, in each case, of any nature whatsoever.

(ii) Mr. Aftab Mahmood Butt (Chief Executive); and Mr. Khalid Pervaiz Bajwa (General Manager Engineering) be and are singly and/or jointly authorised as representatives of the Company to address, perform, negotiate, decide, execute, implement and/or undertake all matters of any nature whatsoever in relation to the Generation License Extension Application including, without limitation to review, execute, submit, and deliver the Generation License Extension Application and any related documentation required by the NEPRA for its approval of the Generation License Extension including any contracts, documents, powers of Attorney, affidavits, statements, letters, forms, applications, deeds, guarantees, undertakings, approvals, memorandum, amendments, letters, communications, notices, certificates, request statements and any other instruments of any nature whatsoever.

KAPCO

(iii) affix the Common Seal of the Company including on any document/application for the Generation License Extension subject to the same being done in the presence of the Chief Executive and the Company Secretary.

Certified True Copy

A. Anthony Rath
(Company Secretary)

Dated: June 22, 2021

Account Payee Only

HBL HABIB BANK حبیب بینک

KAPCO MOUZA HALA, KO 0477
KOT ADU DISTT. MUZAFFARGARH

B.C. No. 24765036

Stationary No: **24765036**

2	2	0	6	2	1

NATIONAL ELECTRIC POWER REGULATORY AUTHORITY

Pay to or Order

PKR ******1,456,455.00

Rupees One Million Four Hundred Fifty Six Thousand Four Hundred Fifty Five Only.

Payable at any HBL Branch In Pakistan
Centralised Cheque Payable Account
30019903902586

Please do not write below this line.

Signatory PA No. 2121

ABDUL REHMAN PA No: 10533

Signatory PA No.

⑈ 2476503 6⑈ 054300 1⑆00300 1990390 2586⑈ 010⑈

HBL HABIB BANK حبیب بینک

Banker's Cheque
Customer Advice

KAPCO MOUZA HALA, KO 0477
KOT ADU DISTT. MUZAFFARGARH

24765036

Cheque No. 24765036
Date 22/06/21

WE CONFIRM HAVING ISSUED THE FOLLOWING BANKER'S CHEQUE AT YOUR REQUEST

Favouring NATIONAL ELECTRIC POWER REGULATORY AUTHORITY

The Sum of: Rupee - One Million Four Hundred Fifty Six Thousand Four Hundred Fifty Five Only.

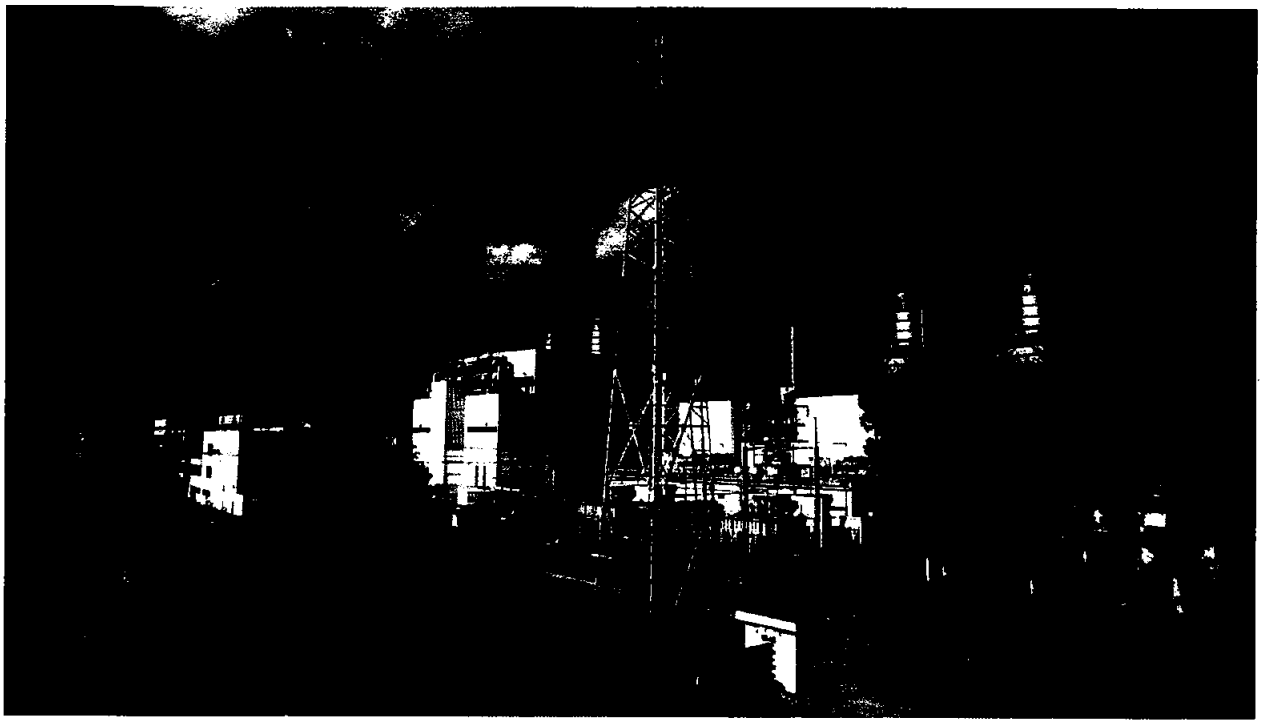
Cheque Amount	PKR ******1,456,455.00
Commission	PKR **********435.00
Total Amount	PKR ******1,456,890.00
Funding Account No	12424011868703
WHT Recovered	**********

THIS IS A SYSTEM GENERATED ADVICE AND DOES NOT REQUIRE A SIGNATURE

BEFORE

THE NATIONAL ELECTRIC POWER REGULATORY AUTHORITY (NEPRA)

APPLICATION
FOR
GENERATION LICENSE EXTENSION



Kot Addu Power Company Limited (KAPCO)

FOR NEPRA's APPROVAL FOR EXTENSION OF KAPCO's GENERATION LICENSE No. IPGL/020/2004

RELATING TO A THERMAL POWER GENERATION FACILITY OF 1600 MW (GROSS) LOCATED AT KOT ADDU DISTRICT MUZAFFARGRAH, PUNJAB, PAKISTAN

June 24, 2021

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SECTION 1
INTRODUCTION TO THE LICENSEE AND THE PROJECT

1.1 INTRODUCTION

Kot Addu Power Company Limited (the "Licensee", "Company" or "KAPCO") having its corporate office at 5B/3, Gulberg III, Lahore 54660 is the applicant for proposed extension to Generation License. The Licensee was incorporated on April 25, 1996 as a public limited company under the Companies Ordinance, 1984 with the object of acquiring the Kot Addu Power Plant from the Pakistan Water and Power Development Authority ("WAPDA"). The principal activities of the Licensee include the ownership, operation and maintenance of the Kot Addu Power Plant.

The Privatization Commission Government of Pakistan following international competitive bidding privatized the Licensee on June 27, 1996. WAPDA in two transactions divested 36% of its shareholding in the Licensee to the strategic investor (National Power (Kot Addu) Limited) along with management control.

In February 2005, the Privatization Commission (on behalf of WAPDA) sold another 18% of WAPDA's shareholding in the Licensee to the general public under An Offer for Sale; and on April 18, 2005 the Licensee was formally listed on the Karachi Stock Exchange, the Lahore Stock Exchange and the Islamabad Stock Exchange, which have since been demutualized in the Pakistan Stock Exchange.

In August 2013, the strategic investor sold its entire shareholding in the Licensee to several local corporate entities and individuals.

The following supporting documents relating to the Licensee are attached herewith:

(a) Annexure A (Shareholding Pattern);

(b) Annexure B (Memorandum and Articles of Association); and

(c) Annexure C (Certificate of Incorporation).

1.2 THE POWER PLANT "COMPLEX"

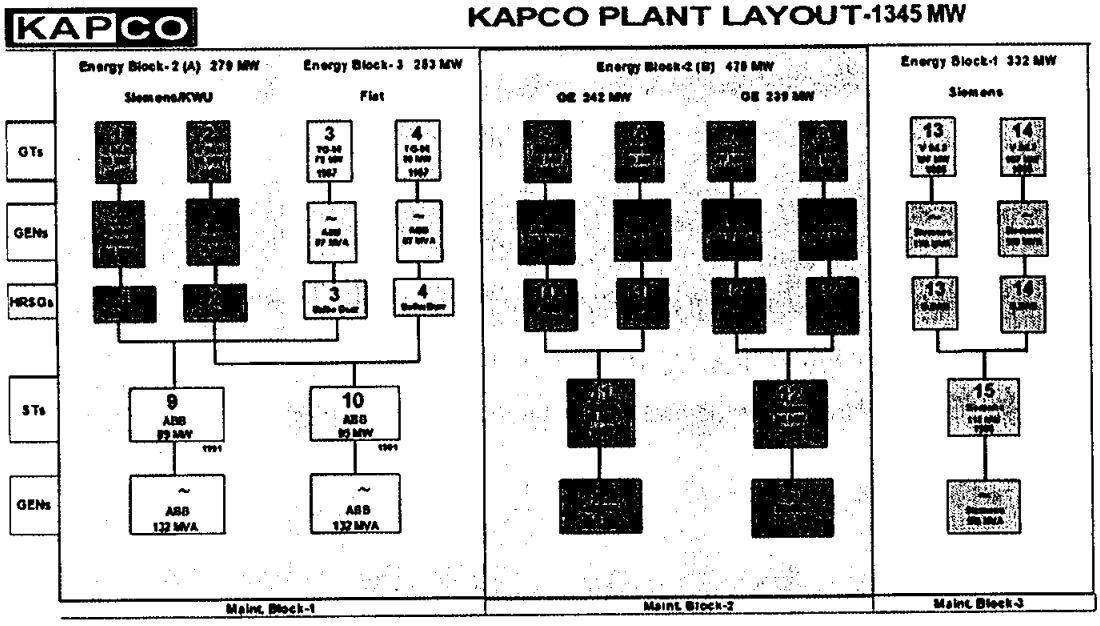
KAPCO Power Plant (the "Complex") was built by WAPDA in five phases between 1985 and 1996 in District Muzaffargarh, Punjab, 90 K.M. north-west of Multan site map attached as Annexure D. The Complex was transferred to the Licensee under the Transfer Agreement between WAPDA and Licensee dated June 27, 1996.

The salient features of the Complex are as under:

- Plant name plate capacity is 1600 MW whereas guaranteed net capacity under IDC is 1345 MW.
- Complex total area is 385 acres. Power Plant Complex is developed on 174 acres and Residential Colony on 211 acres. There are 836 houses of different categories in the Residential Colony with recreation facilities, guest houses and hostels. The Power Plant Complex and Residential Colony lay out is attached as

Annexure-E.

- The Power Plant Complex comprises of 10 Gas Turbines, 5 Steam Turbines and 10 Heat Recovery Steam Generators (HRSG). The Power Plant is n divided into 3 blocks maintenance wise (Blocks 1, 2, & 3) as well as efficiency wise in descending order Energy Block 1, 2 & 3. Power Plant configuration /Lay out is as below.



- The Complex is a multi-fuel gas-turbine power plant with the capability of using three different fuels to generate electricity, namely: Natural Gas/ RLNG (Gas), Low Sulphur Furnace Oil (LSFO) and High Speed Diesel (HSD). Eight (8) of the gas turbines are capable of using all these fuels whereas the remaining two gas turbines GT 3 & 4 can operate only on Gas or HSD.

- All machines and equipment are of European origin OEMs like GE, Siemens, Alstom and Fiat.

- The Licensee has a 220 KV Grid with one and half breaker scheme having 6 transmission lines. 9 units generates power at 11 kV, which is stepped up to 220 kV through nine main transformers and subsequently supplied to the Power Purchaser's grid system.

- 132 KV grid has double bus bar scheme having 6 transmission lines. 6 units generates power at 11 kV, which is stepped up to 132 kV

- Six 220 kV feeders supply power to the following areas:
  - Four feeders to New Multan 220 KV grid.
  - One feeder to Muzaffargarh.
  - One feeder to PakGen.

- Six 132 KV feeders supply power to following areas:
  - One feeder to Industrial estate Multan.
  - One feeder to Shahdan Lund.
  - Two feeders to Kot Addu.
  - One feeder to Muzaffargarh.
  - One feeder to Qasba Gujrat.

- Both 220 KV and 132 KV grid are interconnected with Auto Transformers Auto T-1, T2 & T5 (100 MVA each), 200 MVA Auto T-6 newly installed in April 2021 to replace T3 & T4 and to support the grid system. Single Line Key Diagram is attached as Annexure F.

- The Complex has 3 MW capacity Black Start Diesel Generator set to recover in case of country wide blackout, which has been adequately demonstrated in recent black outs.

- Largest oil storage capacity in the up country area (around 200,000 Tonnes) and also the largest oil storage capacity of any plant. Fuel storage setup consists of 22 LSFO storage tanks having storage capacity of 156 K tonnes and 5 HSD storage tanks can store 40 million litres.

- A 32 km dedicated 10 inch diameter oil pipeline from PSO's Lalpir Depot to the Licensee's premises with capacity of 3,800 Tonnes per day. The pipeline has pig facility which enables it to supply both LSFO and HSD through the same pipeline.

- The Complex has 20 bays decantation facility to take direct LSFO and HSD through tank Lorries. 20 tankers can be decanted at a time.

- Six Fuel oil treatment plants (largest facility in Pakistan) to treat furnace oil for plant operation.

- The Licensee receives gas through three (3) pipelines. Two 16 inch pipelines from main SNGPL network have a capacity of 400 MMSCFD; and one 12 inch pipeline from Dhodak has capacity of 80 MMSCFD.

- Raw water is sourced from two sources:

  (i) Canal water is fed from Muzaffargarh Canal from the River Indus via Taunsa Barrage; and

(ii) Ground water through tube wells.

Water taken from the canal system is treated through clarifiers. In addition to demineralization plants where dissolved salts are removed, RO Plant is also installed to meet the Complex water needs.

- The Complex is equipped with a firefighting system: Two fire water storage tanks each of 700 m3 capacity are supplied from well water. Automatic CO2 system is available for GT enclosure. Automatic water deluge system is available for main transformer.
- The most important factor of the Licensee's twenty-five years excellent performance is its highly skilled, professional and dedicated work force, which is demonstrated year after year through successful Annual Dependability Tests (ADC). The Licensee has maintained the Initial Dependability Test (IDC) capacity. The Authority has allowed degradation for both capacity and heat rate to other IPPs. However, the Licensee with its excellent in-house team has proven their skills by maintaining the IDC parameters without seeking for any degradation.

  The Licensee is one of the few combined cycle plants in the world which operates on LSFO. Two other combined cycle plants in Pakistan tried to burn furnace oil but then had to switch to Gas as primary fuel due to complex and difficult operation on LSFO.

1.3 THE CONTRACTUAL ARRANGEMENTS

For the purposes of the Complex, various contractual arrangements and assurances were put in place, which include the following:

Principal Agreements	Effective Date
Facilitation Agreement and GoP Guarantee	27 June, 1996
Transfer Agreement between the Licensee and WAPDA	27 June, 1996
Power Purchase Agreement ("PPA") with the Power Purchaser	27 June, 1996
Oil Supply Agreement between the Licensee and PSO	27 June, 1996
Gas Supply Agreement (GSA) between the Licensees and SNGPL	27 June, 1996

1.4 THE GENERATION LICENSE

Following promulgation of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997 (the "NEPRA Act") and the rules and regulations made thereunder, the Licensee applied to the National Electric Power Regulatory Authority (the "Authority") for procurement of a generation license

for its Complex and on September 22, 2004, and the Authority granted the Licensee a Generation License No. IPGL/020/2004 (the "Generation License"). A copy of the Generation License is attached as Annexure G for the Authority's reference.

SECTION 2
BACKGROUND TO THIS GENERATION LICENSE EXTENSION APPLICATION

2.1 BACKGROUND

The Generation License was issued on September 22, 2004 and is expiring on September 21, 2021. The Licensee's Power Purchase Agreement ("PPA") was signed on June 27, 1996 was for a term of 25 years.

The Licensee was in arbitration with Power Purchaser on the imposition of unjustified liquidated damages on account of non-availability of Complex due to fuel shortage during the period 2008-2015. The sole cause of non-availability of fuel was the consistent failure of the Power Purchaser to make timely payments to the Licensee. The Government of Pakistan formed a Negotiation Committee notified by the GoP vide notification # F.No.IPPs-1(12)/2019-20 dated June 3, 2020 to discuss with IPPs reduce tariff and resolve major issues like arbitration etc.

The Licensee, in the larger national interest, entered into discussions with the GoP Negotiation Committee following which it agreed to alter some existing contractual arrangements to the extent of, and strictly with respect to, the matters contained in the Memorandum of Understanding dated August 19, 2020 (the "MoU"). Subsequently, GoP constituted the Implementation Committee (the "GoP Implementation Committee") to, inter alia, convert the MoUs singed by the IPPs binding agreements.

Following negotiations with GoP Implementation Committee, and the Power Purchaser, it was agreed to settle the outstanding arbitration dispute (ICC Case No. 23521/PTA/ASB/HTG relating to liquidated damages due to fuel shortage as a result of non-payments by the Power Purchaser, amicably and in good faith in accordance with the Settlement Terms (the "Settlement").

As per the Settlement, it has been agreed to treat the outage period due to non-availability of fuel as an Other Force Majeure Event (OFME) under the PPA. The Master Agreement and Third Amendment to the PPA (the 3rd PPA Amendment") were both signed on February 11, 2021. As per the 3rd PPA Amendment, the Term of the PPA has been extended by another 485 days with effect from June 27, 2021 and will now expire on October 24, 2022.

2.2 THE PPA RENEWAL

The PPA contemplates a mechanism for renewal of the PPA prior to its expiry in terms of Section 4.I (c), which is as follows:

Renewals. Following the end of the twenty-third (23rd) Agreement Year, at the request of either Party, the Company and WAPDA agree to enter into good faith negotiations for a renewal of this Agreement for an additional term or terms of years, on terms and conditions mutually agreed to by the Parties, such term or terms of years to reflect the remaining useful lives of the various Units, and such terms and conditions similarly to reflect the extent to which some Units may have minimal or no remaining useful lives. If the Parties cannot agree to terms and conditions for the renewal of this Agreement, the Company will be permitted to contract with any other party for the sale of dependable capacity and electrical

energy from the Complex and WAPDA shall deliver to the Company any necessary consents for such sale, including any consent required by Section 28 of the Electricity Act, 1910; provided, however, that WAPDA shall have no obligation to assist in such sale (other than, if then permitted by law, the transmission of electrical energy at an appropriate tariff for reasonable compensation acceptable to WAPDA) unless otherwise required by law.

At the commencement of the 24th year of the Term of the PPA, the Licensee wrote to CPPA-G vide letter no KAPCO/CEO/358 dated July 15, 2019 and requested to enter into good faith negotiations for the renewal of the PPA for another term(s) since the expected useful life of the Power Plant is over 10 years. The Licensee also sent reminders on this respect from time to time. Unfortunately, due to busy schedule of CPPA-G impacted by arbitration proceedings and later on negotiation with IPPs, and Covid-19, discussions for the extension of the Term of the PPA were not progressed as hoped. However, the matter did come up before the GoP Negotiation Committee and the GoP Implementation Committee, and was discussed with CPPA-G, WAPDA and the Ministry of Energy (Power Division) during IPPs negotiations. Acknowledging the continued requirement of the Licensee, the Master Agreement (section 3.4) stipulated that the Power Purchaser shall consent to the extension of PPA. The Master Agreement is attached as Annexure H.

A few other organizations also approached the Licensee to acquire power from it after the expiry of the Term of the PPA, however, section 4.1(c) supra states that the first right of refusal is with the Power Purchaser.

SECTION 3
MERITS OF THE PROJECT AND JUSTIFICATION FOR PROPOSED GENERATION LICENSE EXTENSION

3.1 A STATEMENT OF THE REASONS IN SUPPORT OF THE PROPOSED GENERATION LICENSE EXTENSION

Without in any manner limiting the submissions made in other sections of this Generation License Extension Application, which shall mutatis mutandis form part of this Section 3 for the benefit of the Authority, it is re-emphasized that:

The Licensee has successfully operated its Complex; has catered for the Power Purchaser's requirements by generating around 6,427 GWH per annum; and has met its obligations under the PPA for around twenty-five (25) years (commencing from 'Commercial Operations Date' (as defined in the PPA), the Licensee and the Power Purchaser, in pursuance of the provisions of section 4.1 (c) of the PPA, will be engaged in negotiations for the extension of the PPA beyond the 485 days OFME period.

The Licensee's request for the Generation License Extension aims to ensure that the terms of the Generation License caters to:

(a) Extension in the Term of the PPA after completion of its 25th Agreement Year for 485 days under OFME settlement as agreed in 3rd PPA Amendment

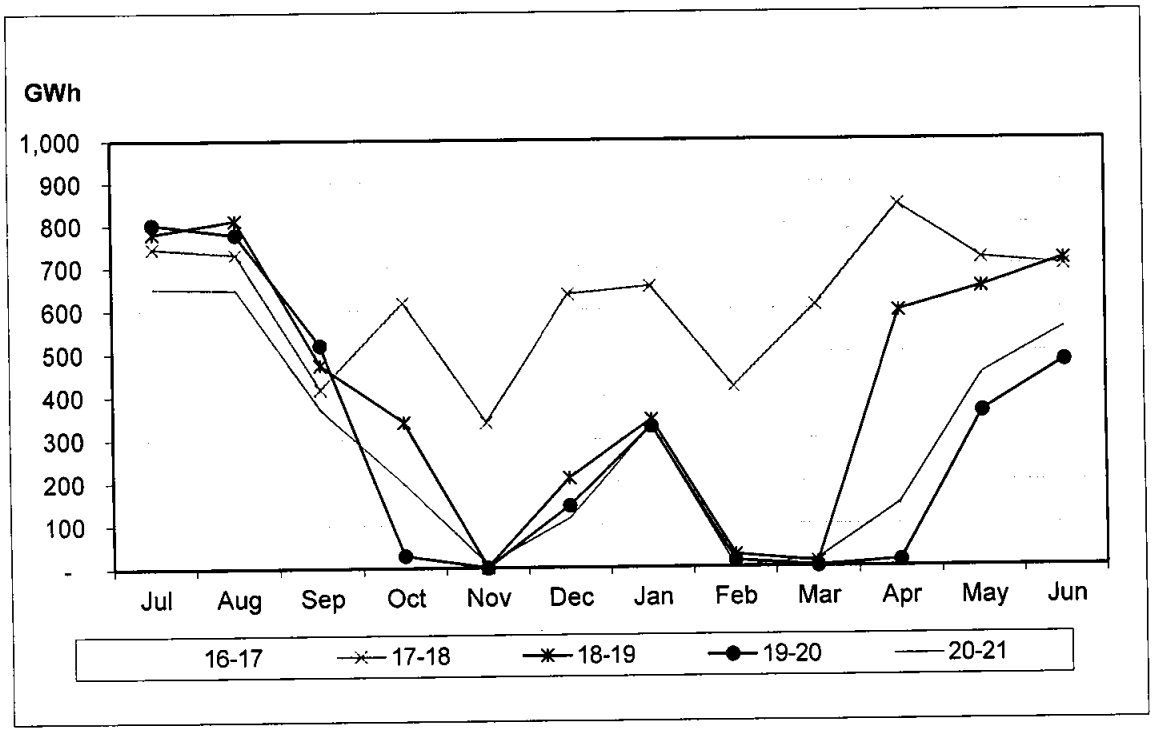
"As a result of the OFME Period the 25th Agreement Year is extended for purposes of the definition of Agreement Year in Section 1.1. of the PPA"

(b) The Remaining Useful Life of the Complex

The Licensee (as part of performance of its obligations under the PPA) has an important, significant and strategic role in the supply of power to the MEPCO local region of Multan, Muzaffargarh, DG Khan, Layyah Districts through the Licensee's 220 KV and 132 KV feeders.

It is highlighted that during the summer months generally and especially in the peak summer months, the Complex runs as a base load plant. The monthly load pattern of dispatch from the Power Plant is set out below for the Authority's reference and the same evidences the Complex's contribution during the peak summer months and again during canal closure and the Licensee's role as part of the embedded generation projects connected to the National Grid:

KAPCO Monthly Net Output for last 5 years



The Licensee strengths are, its location, technology, flexibility of fuel, storage capacity of fuel, gas infrastructure, fuel infrastructure and power supply at different voltage levels.

As stated in Section 1, the Complex is located mid country and is close to major load centers. At times NPCC diverts gas from 9HA based high efficiency projects to the Licensee to meet the demand in this region. In case of gas shortage for the power sector, the Licensee provides support to the system because of its flexibility and huge fuel storage capacity. The Licensee off takes all the surplus LSFO available at Attock Oil Refinery, which enables them to operate their refinery smoothly.

GM (System Operation) NPCC vide their letter no 15373-77/GM (SO)/NPCC/DDPC-1/CPPAG dated November 20, 2020 (attached as Annexure I) to Chief Technical Officer (CPPA-G) emphasized the importance of the Licensee for system reliability. NPCC has placed the Licensee under the category of critically required power plants.

The Licensee's Grid of 132KV and 220KV is very important for NPCC to manage in areas stipulated above. NTDC has to spend huge money to supply areas where 12 feeders are supplying power and it will take time to implement that arrangement.

3.2 USEFUL LIFE OF THE FACILITY

Rule 5(1) of the National Electric Power Regulatory

Authority Licensing (Generation) Rules, 2000 (the "Rules") that states as follows:

"Except where an applicant for a generation license consents to a shorter term, the term of a generation license shall be commensurate with the "maximum expected useful life of the units comprised in a generation facility demonstrated to the satisfaction of the Authority."

To ascertain the remaining useful life of the Complex, a study was awarded by Licensee to a renowned consultant M/s Ramboll of UK/Denmark. Ramboll has a team of around 15000 experts and have 300 offices in 35 countries. Ramboll's brochure is attached as Annexure J.

Ramboll has conducted detailed analysis of overhauling / inspection and test reports by OEMs and other reports based on tests conducted by third party consultants. Based on their worldwide experience on different technologies, Ramboll have carried out a comprehensive analysis and their report on the Remaining Useful Life Assessment (RULA) is attached as Annexure K.

For the Authority's benefit and reference, without in any way limiting the comprehensive analysis presented in the RULA Study Report, part of section 8 (Conclusion & Recommendation) is set out below:

"Operating life before retirement of CCGTs has been observed 40-50 years around the World. This study has assumed a 40-year extended operating life based on a nominal 8,000 operating hours per year, which equates to lifetime operating hours of 320,000. The operating hours of the Units at KAPCO range between 94,000 to 180,000 indicating that the remaining life of the KAPCO units could be in the range 17–28 years, thus demonstrating that a life extension of 10 years being considered by KAPCO should be achievable with resulting good reliability and performance."

It is duly noted that Ramboll has concluded, based on its extensive analysis (as contained in the RULA Study Report), that the overall condition of Complex is 'Good' and the expected remaining life is more than Ten (10) years. In view of the RULA Study Report and the conclusions drawn in the RULA Study Report, the Licensee submits to the Authority that in view of the afore-stated criteria laid out by rule 5(1) of the Rules and for the purposes of conclusively evidencing compliance with the same this Generation License Extension Application primarily aims to extend the term of its Generation License so as to match it with the Remaining Useful Life of the Facility i.e. September 21, 2031 (the "Proposed Generation License Expiry Date").

The Authority's approval of the Proposed Generation License Extension and the subsequent implementation by CPPA-G and the Licensee of the PPA Term Extension will ensure continued supply of reliable electricity to the consumers of

CPPA-G. Alternatively, the Licensee will provide reliable and cheap power to other entities / bulk power consumers under CTBCM Regime.

3.3 MAJOR UPGRADES AND MODIFICATIONS

The Licensee has made significant upgrades and/or modifications as detailed below:

Gas Turbines

- Gas Turbine GT-1 & 2: The third and fourth stage disc and rear hollow shafts were replaced and new, modified, blades and vanes were installed to these rows. Row 4 blades were of the latest free standing blade design.
- Gas Turbine GT-5~8: Stage 1, 2 & 3 buckets, nozzles & shrouds replaced with the latest design having improved material & better rupture strength. Honeycomb seals were installed.
- Gas Turbine GT-13 &14: Si3D upgradation was carried out and Blades and Vanes of Stages 1 & 2 replaced with new design.

Steam Turbines

- On STG-10, Installed upgraded 1st stage rotating blades and Installation of new LP turbine erosion protection rings of last 3 stages.

Generators

- GT-7 and GT8 Replacement of Insulation under Retaining Rings of Generator Rotors during 2015.
- GT-8 Full Stator Rewinding of Generator during 2015.
- STG-11 Full Stator Rewinding of Steam Turbine Generator with new set of bars during 2017.
- STG-12 Full Stator Rewinding of Generators during 2015.

Control Systems

- GT-1 ISKAMATIC obsolete control system replaced with Siemens SPPA T3000 DCS and obsolete analogue type SFC / SEE system replaced with GE (Conver-team) Version D4 during 2016.
- GT-2 ISKAMATIC control system replaced with Siemens SPPA T3000 DCS and obsolete analogue type SFC / SEE system replaced with GE (Conver-team) Version D4 during 2013.
- GT-3 excitation control system was replaced during financial year 2016/17.
- GT-5 and GT-6 Control system upgraded to Mark VIe during the 2015 Hot Gas Path Inspections (GT-7 and GT-8 remains with Mark IV control system).
- GT-13 and GT-14 Replacement of Obsolete Control System with Siemens SPPA T 3000 during 2021.
- STG-9 ABB Procontrol Decontic K obsolete control system replaced with Siemens SPPA T3000 DCS during 2016.

- STG-11 and STG-12 control/protection systems replaced by a new control/ protection system CONTROSTEAM V3.
- ST-15 Steam Turbine Controls system (TELEPERM-ME) and protection system (Iskamatic) replaced by Siemens SPPA-T3000 (Release 7)

Other Modifications

- Fuel Oil Treatment Plant 6 (FOTP-6) was installed / commissioned to enhance Fuel Treatment Capacity during 2015.
- RO plant was installed, commissioned & taken in Operation in order to save the chemical for water treatment.
- Installation of waste water treatment plant

SECTION 4

PROPOSED TEXT FOR GENERATION LICENSE EXTENSION

4.1 THE PROPOSED TEXT

In view of the matters set out in this Generation License Extension Application, including, without limitation, to ensure that the term of the Generation License caters to ensure its term is valid until the Proposed Generation License Expiry Date, the Proposed Generation License Extension amends Article 4 of the Generation License as follows:

"(1) Pursuant to Rule 5 of the Rules, this License is granted for a further term of ten (10) years and the total term of this license is twenty seven (27) years i.e. until September 21, 2031."

SECTION 5

A STATEMENT OF IMPACT ON THE QUALITY OF SERVICE AND PERFORMANCE BY THE LICENSEE OF ITS OBLIGATIONS UNDER THE GENERATION LICENSE

5.1 A STATEMENT OF IMPACT ON THE QUALITY OF SERVICE AND PERFORMANCE BY THE LICENSEE OF ITS OBLIGATIONS UNDER THE GENERATION LICENSE

The Licensee confirms that the Licensee's quality of service and its performance under the Generation License will not be affected during the period relating to the Remaining Useful Life. The Licensee, over almost two and half decades, has been fully diligent and has dedicated itself to providing the highest quality services - setting a benchmark for exceptional performance and excellence in the power generation sector of Pakistan. The Licensee aims to continue with such performance and anticipates to play a continued pivotal role providing reliable energy to the National Grid. Complex Availability, Fuel Mix, Net Output and Load Factor graphs are attached as Annexure-L.

Licensee's Technical Key Performance Indicators are given below;

Year	Net Electrical Output	Plant Load Factor	Plant Availability	Commercial Availability
	GWh	%	%	%
2016-17	7,335	62.4	84.3	96.0
2017-18	7,437	63.3	86.0	96.7
2018-19	4,961	42.2	91.8	95.6
2019-20	3,477	29.5	88.9	96.8
2020-21	3,496	29.7	84.7	95.1
Last 5 Years	26,705	45.4	87.1	96.0

5.2 ANCILLARY SERVICES

200 MVA Auto Transformers #6 has been installed which will increase reliability of 132 KV system and quality of service to DISCOS feeders. (This addition demonstrate the Licensee commitment towards system support that it made investment in the last years of its PPA.)

The Licensee has medium size units and start-up timing is to meet demand for peak hours. The Licensee units have provision of partial loading, therefore, the Complex can provide ancillary support to National Grid in the next 10-15 years. (The importance of such machines will increase after installation of more renewable energy projects.)

Technical Limits & Unit start up times are attached as Annexure-M.

5.3 ENVIRONMENT MANAGEMENT SYSTEM

The Licensee has developed well established Policy Guidelines and Procedures Integrated Management System (IMS certificates attached as Annexure-N for Quality, Health & Safety and Environment.)

The Licensee is accredited and complying with the standards of ISO 14001:2015 Environmental Management System. Environment Performance Monitoring is being conducted on regular basis by EPA Certified Independent Consultant, in compliance with Pakistan Environment Protect Act (1997) and Punjab Environment Protection Agency standards.

Environment Monitoring at the Complex includes, monitoring of air, water and noise emissions generated from Operations of Gas Turbines, Steam Turbines, Boilers, Fuel Oil Treatment Plants etc.

Recent Report submitted to Punjab Environment Protection Agency (PEPA) as per statutory requirement is in compliance to the requirements, and is attached as Annexure –O.

In acknowledgement of accomplishment achieved for Environment Protection, the Licensee received "**Certificate of Appreciation from National Forum for Environment and Health**" in 2020, which is attached as Annexure –P.

5.4 HUMAN RESOURCE

A highly skilled Human Resource is one of its key strengths of the Licensee which gives it a competitive advantage. One of the reasons behind this high skill set is the continuous learning culture, which provides that employees undergo a variety of learning programs throughout the year. These opportunities range from self-paced learning, like book reading from a variety of books available at the OD Book club to online training programs. Class room training ranges from in-house training sessions to experiential learning programmes being conducted in the remote locations to ensure a deeper level of learning associated with such programs.

The Licensee takes keen interest in the development of its Human Resource using a blended learning approach, including face to face as well an online programmes. The training encompasses both functional as well as soft skills training programs to address the developmental needs from a holistic perspective. This approach focuses on the development of the individual as a person. As a result, the individuals experience a transformation in their lives and an up-gradation of their skill set, which positively effects the business results. The Licensee will continue to remain focused in its developmental efforts for its Human Resource for the future, as continuous improvement and development is the only way to thrive in a rapidly changing world.

5.5 IMPACT ON THE OBLIGATIONS OF THE LICENSEE UNDER THE LICENSE

The approval of the Proposed Generation License Extension would enable the Licensee in fulfilling its obligations under the PPA by implementing the PPA Term Extension and, beyond that, until the Proposed Generation License Expiry Date. It is highlighted that the Licensee has to-date ensured strict compliance with the terms of the Generation License and commits to continue to do the same in future.

SECTION 6
CONCLUSION AND SUBMISSION

6.1 CONCLUSION

The study carried out to assess the condition of the gas turbines and steam turbines and critical electrical components covering generator concluded with ratings Good and Satisfactory and power transformer Satisfactory condition. It is pertinent to mention that the qualitative condition assessment and expected life is based on good O&M management practices and condition monitoring, well maintained inspection, maintenance and other monitoring records, timely execution of inspection and maintenance work order, up gradations / replacement of obsolete control system, replacement of component as per preventive spares and follow instructions of troubleshooting as per OEM practices.

6.2 SUBMISSION

PURSUANT TO the applicable laws of Pakistan, including the NEPRA Act and the rules and Regulations made thereunder, including the National Electric Power Regulatory Authority Licensing (Application, Modification, Extension & Cancellation) Procedure Regulations, 2021and the 'National Electric Power Regulatory Authority Licensing {Generation) Rules, 2000 '): the Licensee HEREBY SUBMITS, for the Authority's kind and gracious consideration, this Generation License Extension Application for approval of the Proposed Generation License Extension to ensure that the Generation License is valid until the Proposed Generation License Expiry Date to reasonably utilize the useful life of the Complex.

This Generation License Extension Application is submitted in triplicate.

This Generation License Extension Application is being submitted with the required generation license extension fee banker's cheque has been issued in the amount of 1,456,455 /- (One million four hundred fifty six thousand, four hundred fifty five PKR Only) dated June 23, 2021 in favor of the NEPRA (copy attached), which has been sent directly to NEPRA.

In light of the submissions, the relevant analysis and information contained in this Generation License Extension Application, along with the Annexures attached hereto, this Generation License Extension Application is submitted (pursuant to the applicable laws of Pakistan

PROVISIONS OF NEPRA ACT 1997, READ WITH ENABLING PROVISIONS OF RULES & REGULATIONS MADE THEREUNDER, INCLUDING THE NATIONAL ELECTRIC POWER REGULATORY AUTHORITY LICENSING (APPLICATION, MODIFICATION, EXTENSION & CANCELLATION) PROCEDURE REGULATIONS, 2021 & THE NATIONAL ELECTRIC POWER REGULATORY AUTHORITY LICENSING (GENERATION) RULES 2000

For the Authority's kind consideration and approval of the Proposed Generation License Extension.

Respectfully submitted,

FOR AND ON BEHALF OF:

KOT ADDU POWER COMPANY LIMITED

Aftab Mahmood Butt

CHIEF EXCUTIVE & AUTHORIZED REPRESENTATIVE

ANNEXURE A

SHAREHOLDING PATTERN

ReportID : SH0935MRG (10D09)
UserID : MANAGER

KOT ADDU POWER CO. LIMITED
Category of Shareholders
As On 31/03/2021

Date : 08/04/2021

Particulrs	No of Folio	Balance Share	Percentage
DIRECTORS, CEO, SPOUSE & CHILDREN	8	86005	0.0098
ASSOCIATED COMPANIES	2	402563562	45.7327
BANKS, DFI & NBFI	19	136947047	15.5577
INSURANCE COMPANIES	16	20156706	2.2899
MUTUAL FUNDS	46	22168352	2.5184
GENERAL PUBLIC (LOCAL)	56203	185632678	21.0886
GENERAL PUBLIC (FOREIGN)	2863	25545880	2.9021
OTHERS	201	34988705	3.9748
FOREIGN COMPANIES	25	37013825	4.2049
APPROVED FUND	60	15150468	1.7211
Company Total	59443	880253228	100.0000

Certified True Copy

A. Anthony

A. Anthony Rath
Company Secretary
KOT ADDU POWER COMPANY LTD.

ReportID : SH0930MRG(10D09)
UserID : MANAGER

KOT ADDU POWER CO. LIMITED
Pattern of Shareholding
As On 31/03/2021

Date : 08/04/2021

NO. OF SHAREHOLDERS	<---- HAVING SHARES ----> From	To	SHARES HELD	PERCENTAGE
680	1	100	30655	0.0035
47676	101	500	23712040	2.6938
2965	501	1000	2908041	0.3304
4202	1001	5000	11617955	1.3426
1401	5001	10000	11294188	1.2831
555	10001	15000	7148792	0.8121
383	15001	20000	7072526	0.8035
266	20001	25000	6242885	0.7092
162	25001	30000	4608400	0.5235
99	30001	35000	3275196	0.3721
127	35001	40000	4908484	0.5576
65	40001	45000	2813967	0.3197
124	45001	50000	6103400	0.6934
57	50001	55000	3028268	0.3440
44	55001	60000	2595373	0.2948
25	60001	65000	1588700	0.1805
37	65001	70000	2540612	0.2886
26	70001	75000	1909800	0.2170
24	75001	80000	1884500	0.2141
19	80001	85000	1577400	0.1792
19	85001	90000	1674000	0.1902
12	90001	95000	1118484	0.1271
74	95001	100000	7380000	0.8384
17	100001	105000	1744149	0.1981
11	105001	110000	1195480	0.1358
9	110001	115000	1021000	0.1160
10	115001	120000	1185500	0.1347
9	120001	125000	1114400	0.1266
4	125001	130000	508500	0.0578
8	130001	135000	1060001	0.1204
9	135001	140000	1241400	0.1410
8	140001	145000	1146000	0.1302
17	145001	150000	2542000	0.2888

Certified True Copy

A. Anthony Rath
Company Secretary
KOT ADDU POWER COMPANY LTD.

KOT ADDU POWER CO. LIMITED
Pattern of Shareholding
As On 31/03/2021

NO. OF SHAREHOLDERS	<---- HAVING SHARES ----> From	To	SHARES HELD	PERCENTAGE
3	150001	155000	453750	0.0515
7	155001	160000	1113500	0.1265
5	160001	165000	816000	0.0927
4	165001	170000	675470	0.0767
4	170001	175000	689628	0.0783
6	175001	180000	1076100	0.1222
5	180001	185000	918826	0.1044
1	185001	190000	189500	0.0215
4	190001	195000	773677	0.0879
16	195001	200000	3199761	0.3635
7	200001	205000	1416662	0.1609
4	205001	210000	831500	0.0945
1	210001	215000	214500	0.0244
2	215001	220000	440000	0.0500
5	220001	225000	1111800	0.1263
5	225001	230000	1140500	0.1296
1	230001	235000	232000	0.0264
4	235001	240000	950500	0.1080
3	240001	245000	730000	0.0829
7	245001	250000	1742500	0.1980
1	250001	255000	254519	0.0289
4	255001	260000	1033500	0.1174
2	260001	265000	527000	0.0599
1	265001	270000	268000	0.0304
1	270001	275000	274500	0.0312
3	275001	280000	833000	0.0946
1	280001	285000	280500	0.0319
1	290001	295000	293000	0.0333
9	295001	300000	2696500	0.3063
3	300001	305000	910001	0.1034
3	310001	315000	936500	0.1064
1	315001	320000	320000	0.0364
3	320001	325000	974000	0.1106

KOT ADDU POWER CO. LIMITED
Pattern of Shareholding
As On 31/03/2021

NO. OF SHAREHOLDERS	<---- HAVING SHARES ----> From	To	SHARES HELD	PERCENTAGE
3	325001	330000	984000	0.1118
1	330001	335000	332000	0.0377
1	340001	345000	345000	0.0392
2	345001	350000	700000	0.0795
2	350001	355000	704350	0.0800
1	355001	360000	358333	0.0407
1	360001	365000	364400	0.0414
2	370001	375000	744500	0.0846
2	385001	390000	778500	0.0884
10	395001	400000	4000000	0.4544
2	400001	405000	804500	0.0914
1	405001	410000	406000	0.0461
2	410001	415000	826000	0.0938
1	420001	425000	425000	0.0483
2	425001	430000	860000	0.0977
1	435001	440000	436000	0.0495
1	440001	445000	444000	0.0504
4	445001	450000	1796500	0.2041
2	455001	460000	914444	0.1039
3	460001	465000	1393500	0.1583
1	470001	475000	475000	0.0540
2	475001	480000	956000	0.1086
1	480001	485000	480500	0.0546
2	490001	495000	987500	0.1122
11	495001	500000	5495500	0.6243
2	515001	520000	1033500	0.1174
1	520001	525000	520500	0.0591
2	525001	530000	1051784	0.1195
2	530001	535000	1070000	0.1216
1	535001	540000	539000	0.0612
1	540001	545000	545000	0.0619
2	545001	550000	1098684	0.1248
2	555001	560000	1114000	0.1266

KOT ADDU POWER CO. LIMITED
Pattern of Shareholding
As On 31/03/2021

NO. OF SHAREHOLDERS	<---- HAVING SHARES ----> From	To	SHARES HELD	PERCENTAGE
1	570001	575000	573000	0.0651
2	595001	600000	1200000	0.1363
1	605001	610000	610000	0.0693
1	650001	655000	653000	0.0742
1	660001	665000	665000	0.0755
2	685001	690000	1375500	0.1563
1	705001	710000	710000	0.0807
1	720001	725000	725000	0.0824
1	745001	750000	750000	0.0852
1	750001	755000	753000	0.0855
1	760001	765000	764500	0.0868
2	770001	775000	1542500	0.1752
2	795001	800000	1600000	0.1818
1	810001	815000	812000	0.0922
1	835001	840000	835500	0.0949
1	845001	850000	849000	0.0964
1	860001	865000	865000	0.0983
1	890001	895000	893473	0.1015
2	930001	935000	1865500	0.2119
1	945001	950000	950000	0.1079
2	955001	960000	1916500	0.2177
4	995001	1000000	4000000	0.4544
1	1010001	1015000	1012000	0.1150
1	1020001	1025000	1024500	0.1164
1	1045001	1050000	1050000	0.1193
1	1095001	1100000	1100000	0.1250
1	1105001	1110000	1106000	0.1256
1	1145001	1150000	1146530	0.1302
1	1150001	1155000	1151400	0.1308
1	1165001	1170000	1166500	0.1325
2	1170001	1175000	2349500	0.2669
1	1180001	1185000	1181944	0.1343
2	1245001	1250000	2500000	0.2840

KOT ADDU POWER CO. LIMITED
Pattern of Shareholding
As On 31/03/2021

NO. OF SHAREHOLDERS	<---- HAVING SHARES ----> From	To	SHARES HELD	PERCENTAGE
1	1295001	1300000	1298000	0.1475
1	1325001	1330000	1328108	0.1509
1	1330001	1335000	1333700	0.1515
1	1395001	1400000	1400000	0.1590
1	1445001	1450000	1447000	0.1644
1	1465001	1470000	1465463	0.1665
5	1495001	1500000	7500000	0.8520
1	1500001	1505000	1503000	0.1707
1	1510001	1515000	1515000	0.1721
1	1515001	1520000	1519000	0.1726
1	1595001	1600000	1600000	0.1818
1	1610001	1615000	1610500	0.1830
1	1645001	1650000	1650000	0.1874
1	1730001	1735000	1731000	0.1966
1	1860001	1865000	1863500	0.2117
3	1995001	2000000	6000000	0.6816
1	2000001	2005000	2002500	0.2275
1	2090001	2095000	2093000	0.2378
1	2175001	2180000	2179000	0.2475
1	2260001	2265000	2260139	0.2568
1	2265001	2270000	2269205	0.2578
1	2305001	2310000	2310000	0.2624
1	2320001	2325000	2321295	0.2637
1	2545001	2550000	2550000	0.2897
1	2595001	2600000	2599000	0.2953
1	2675001	2680000	2680000	0.3045
1	2795001	2800000	2797000	0.3177
1	2800001	2805000	2800500	0.3181
1	2935001	2940000	2936000	0.3335
1	2995001	3000000	3000000	0.3408
1	3245001	3250000	3250000	0.3692
1	3370001	3375000	3372500	0.3831
1	4900001	4905000	4901009	0.5568

KOT ADDU POWER CO. LIMITED
Pattern of Shareholding
As On 31/03/2021

NO. OF SHAREHOLDERS	<---- HAVING SHARES ----> From	To		SHARES HELD	PERCENTAGE
1	4940001	4945000		4941500	0.5614
1	5530001	5535000		5531500	0.6284
1	5730001	5735000		5731000	0.6511
1	5800001	5805000		5804000	0.6594
1	5995001	6000000		6000000	0.6816
1	6590001	6595000		6593894	0.7491
1	7045001	7050000		7046000	0.8005
1	7465001	7470000		7469500	0.8486
1	7660001	7665000		7660721	0.8703
1	7695001	7700000		7697500	0.8745
1	15660001	15665000		15662000	1.7793
1	15995001	16000000		16000000	1.8177
1	48250001	48255000		48252429	5.4817
1	69475001	69480000		69476500	7.8928
1	354310001	354315000		354311133	40.2510
59443			Company Total	880253228	100.0000

Certified True Copy

A. Anthony Rath
Company Secretary
KOT ADDU POWER COMPANY LTD.

ANNEXURE B

MEMORANDUM AND ARTICLES OF ASSOCIATION

THE COMPANIES ORDINANCE, 1984

COMPANY LIMITED BY SHARES

KAPCO

Memorandum

and

Articles of Association

of

KOT ADDU POWER COMPANY LIMITED

machinery, equipment and works ancillary thereto and plan, survey, design, supply equipment and carry out the construction of grid stations and transmission lines of all voltages and to do all such acts, deeds and things, without limitation whatsoever as may be necessary or desirable in that connection.

(4) Electrification. To plan, survey, design, supply equipment and carry out the electrification of cities, towns, villages, gas and oil refineries, workshops, building, tube-wells, highways bridges, culverts, airports, air-terminals, sea ports, harbors and tube-well project.

(5) Renovation and Augmentation. To carry out overall planning of electrification, augmentation and renovation of electrical systems and to design and supervise the electrification of all types of buildings and factories.

Schemes. To plan and frame schemes for irrigation, water supply and drainage, recreational use of water resources, inland navigation, flood control, prevention of water logging and reclamation of waterlogged and salted lands and to place wires, poles, wall brackets, stays, apparatus and appliances for the transmission of electricity or for the transmission of telegraphic and telephonic communications necessary for the proper execution of a scheme.

(7) Engineering and Consultancy. To carry on the business of electrical engineers, mechanical engineers, civil engineers, electricians, contractors, consultants, agents and manufacturers of electric plant machinery, equipment and apparatus, and of generating, producing and supplying light, heat, sound and power by electricity, galvanism, magnetism or otherwise, whether for the purpose of light, heat, motive power, telephonic, telegraphic, industrial or other purposes, and generally of installing, executing, providing, working and maintaining all necessary plant, machinery, equipment, cables, wires, accumulators, lamps, exchanges, telephones and apparatus.

(8) Technical Assistance. To render technical assistance to foreign countries in connection with power resource development and utilization and to receive assistance from foreign countries in such matters.

(9) Workshops. To establish all sorts of workshops for manufacture and maintenance of all types of electrical equipments, tools and materials.

(17) Borrowing. To receive money on loan and borrower money in such manner as the Company shall think fit, and in particular by the issue of debentures, or debenture stocks (perpetual or otherwise) and to secure the repayment of any money borrowed, or owing mortgage, charge or lien upon all or any of the property or assets of the Company (both present and future) and also by a similar mortgage, charge or lien to secure and guarantee the performance by the Company or any other person or company of any obligation undertaken by the Company or any other person or company as the case may be, but not to act as a finance or banking company.

(18) Building. To build, construct, alter, maintain, enlarge, pull down, remove or replace, and to work, manage and control any buildings, offices, factories, mills, warehouses, shops, stores, machineries, engines, roads, ways, railways, branches or sidings, bridges, reservoirs, watercourses, wharves, electric works and other works and conveniences which may seem calculated directly or indirectly to advance the interests of the Company, and to join with any other person or company in doing any of these things.

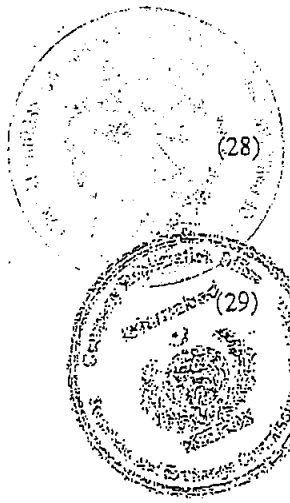
(19) Charity. To subscribe or contribute or otherwise to assist or to guarantee money to charitable, benevolent, religious, literary, scientific, technical, national, public or any other institutions, for its objects or purposes or for any exhibition.

(20) Companies. To promote, constitute, incorporate, form, register and operate any company or companies or other legal entities anywhere for any purpose which may seem directly or indirectly calculated to benefit this Company, and/or to subscribe for, take, or otherwise acquire, and hold shares, debentures or other securities of or amalgamate or merge, into any other company having objects altogether or in part similar to those of this Company or carrying on any business capable of being conducted so as directly or indirectly to benefit this Company, but not to act as an investment company.

(21) Contracts. To enter into agreement with any individual, firm, co-operative or other society, company, corporate body, Government or local authority or other legal entity necessary or expedient for the purpose of carrying on any business of the Company.

(22) Employees' funds. To establish and maintain or procure the establishment and maintenance of any contributory or non-contributory pension or

or for extending any of the powers of the Company or for effecting any modification of the constitution of the Company or for any other purpose which may seem expedient, and to oppose any proceedings or applications which may seem calculated, directly or indirectly to prejudice the interests of the Company, and to enter into arrangements with any Government or authorities, central, provincial, municipal, local or otherwise, public or quasi-public bodies, or with any other persons, in any place where the Company may have interests that may seem conducive to the objects of the Company or any of them and to obtain from any such Government, authorities or persons any rights, privileges and concessions which the Company may think fit to obtain, and to carry out, exercise and comply therewith.



(28) Import and Export. To carry on all or any of the business of importers, exporters, ship owner, shipbuilders, charterer of ships and other vessels, warehousesmen, wharfingers, merchants, ship and insurance brokers, carriers and forwarding agents.

(29) Insurance. To insure the property, assets, and employees of the Company in any manner deemed fit by the Company, and to create any reserve fund, sinking fund, insurance fund or any other special fund whether for depreciation or for repairing, insuring, improving, extending or maintaining any of the property of the Company or for any other purpose conducive to the interests of the Company but not to act as an insurance company.

(30) Investment. To invest the surplus moneys of the Company not immediately required in any manner but not to act as an investment company.

(31) Lending. To advance money or give credit to such persons or companies and on such terms as may seem expedient and in particular to customers and others having dealings with the Company, and to guarantee the performance of any contract or obligation and the payment of money by the Company.

(32) Other Business. To carry on any other business, whether agricultural, industrial, commercial, engineering, consultancy, construction, mining, manufacturing or trading which may seem to the Company capable of being conveniently carried on in connection with the above, calculated directly or indirectly to enhance the value of or render profitable any of the Company's property or rights and to acquire and undertake the whole

Company may think necessary or convenient for the purpose of its business.

(37) Registration/Fees. To file or register any documents required to be filed or registered under law, and to pay any fees, charges, expenses, rents, taxes, duties and other dues payable in connection with the business or operation of the Company.

(38) Regulations. To make rules or regulations not inconsistent with this Memorandum, to provide for all matters for which provision is necessary or expedient for the purpose of giving effect to the provisions of this Memorandum and the efficient conduct of the affairs of the Company.

(39) Research and Development. To improve, manage, develop, grant rights or privileges in respect of, or otherwise deal with, all or any part of the property and rights of the Company and to establish laboratories, research and development centres to perform such research and development as the Company may deem advisable or feasible, and to expend money on experimenting upon and testing and improving or securing any process, or processes, patent or protecting any invention or inventions which the Company may acquire or propose to acquire or deal with.

(40) Sale and Purchase. To accept, buy, sell, market, supply, transfer (including transfer of actionable claims) or deliver any and every kind of moveable property for such price and subject to such terms, conditions and warranties as the Company may think fit.

(41) Sale of Undertaking. To sell, improve, manage, develop, exchange, lease, mortgage, enfranchise, dispose of, turn to account, or otherwise deal with, all or any part of the property, assets or undertaking of the Company for such consideration as the Company may think fit, and in particular for shares, debentures, or other securities of any other company whether or not having objects altogether or in part similar to those of this Company, and to distribute among the members in specie any property of the Company, or any proceeds of sale or disposal of any property of the Company.

(42) Security. To accept or give security, including but not limited to promissory notes, indemnity bonds, guarantees, assignments, receipts, bailments, pledges, hypothecations, liens, mortgages and charges, against the credit extended or moneys borrowed in connection with the business of the Company.

(c) the headings used in each of the paragraphs of this clause are for convenience only and are not intended to affect the construction thereof in any way;

(d) notwithstanding anything contained in the foregoing object clauses of this Memorandum of Association, nothing herein shall be construed as empowering the Company to undertake or indulge in the business of banking, finance, leasing, investment or insurance, directly or indirectly, as restricted under law or any unlawful operations.

IV. LIABILITY:

The liability of the members is limited.

V. SHARE CAPITAL:

The share capital of the Company is Rs. 36,000,000,000.00 (Rupees thirty six billion) divided into 3,600,000,000 (three billion six hundred million) ordinary shares of Rs. 10 (Rupees ten) each with power to increase or reduce the capital and to divide the shares in the capital for the time being into several classes and to attach thereto respectively such rights, privileges or conditions as may be determined by or in accordance with the regulations of the Company, and to vary, modify or abrogate any such rights, privileges or conditions in such manner as may for the time being be provided by the regulations of the Company in accordance with law provided, however, that rights as between various classes of ordinary shares, if any, as to profits, votes and other benefits shall be strictly proportionate to the paid up value of shares.

The Companies Ordinance, 1984

(Company Limited By Shares)

ARTICLES OF ASSOCIATION

OF

KOT ADDU POWER COMPANY LIMITED

I. PRELIMINARY

1. Table 'A' Not to Apply

The regulations in Table 'A' in the First Schedule to the Companies Ordinance, 1984 shall not apply to the Company except as reproduced herein.

2. Interpretation

In these Articles, unless the context or the subject matter otherwise requires:

(a) "Affiliate" means, as to any specified person, any other person owning and controlling, owned and controlled by, or under common ownership and control with such specified person.

(b) "Articles" means these Articles as originally framed and as from time to time altered in accordance with law.

(c) "Board" means a meeting of the Directors duly called and constituted or as the case may be, the Directors assembled at a Board.

(d) "Company" means Kot Addu Power Company Limited.

(e) "Chief Executive" means the chief executive of the Company appointed from time to time by the Directors.

(f) "Debt" means, as to the Company, any obligation for borrowed money (and any notes payable and drafts accepted representing extensions of credit whether or not representing obligations for borrowed money) which

Certified True Copy

A. Anthony Rath
Company Secretary
KOT ADDU POWER COMPANY LTD.

(k) Deleted

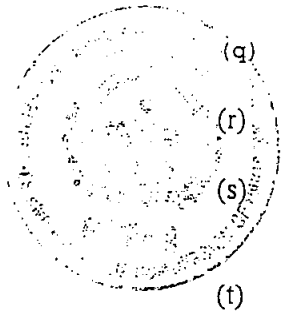
(l) "Lien" means any mortgage, pledge, lien, interest, conditional or instalment sales agreement, option agreement, claim, charge or encumbrance of any kind.

(m) "Member" has the meaning assigned thereto in Section 2(1)(21).

(n) "Month" means a calendar month according to the Gregorian calendar.

(o) "Note" means the Note issued by the Company to WAPDA pursuant to the Note Agreement.

(p) "Note Agreement" means the Note Agreement dated 26 June 1996 between WAPDA and the Company.



(q) Deleted

(r) Deleted

(s) "Office" means the registered office for the time being of the Company.

(t) "Oil Supply Agreement" means the Oil Supply Agreement dated as of 27 June 1996 between Pakistan State Oil Company Limited and the Company.

(u) "Ordinary Resolution" means a resolution passed at a general meeting of the Company when the votes cast (whether on a show of hands or on a poll) in favour of a resolution by Members who, being entitled to vote in person or by proxy, do so vote, exceed the number of votes, if any cast against the resolution by Members so entitled and voting.

(v) "Ordinance" means The Companies Ordinance, 1984 or any modification or re-enactment thereof for the time being in force.

(w) "Power Purchase Agreement" means the Power Purchase Agreement dated 27 June 1996 between WAPDA and the Company.

(x) "Public Offering" means a sale or transfer of shares generally to the public involving a listing of shares on the Karachi Stock Exchange or any other applicable stock

(kk) "WAPDA Nominee Directors" means Directors nominated for election by WAPDA.

(ll) Words importing the masculine gender include all other genders.

(mm) Words importing the singular number include the plural number and vice versa.

(nn) Expressions referring to writing shall unless the contrary intention appears, be construed as including references to printing, lithography, photography and other modes of representing or reproducing words in a visible form.

(oo) Words importing persons shall include individuals, corporations, bodies corporate, partnerships, joint ventures, trusts, unincorporated organisations, governments or governmental authorities or agencies or any other legal entities.

(pp) The head notes are inserted for convenience and shall not affect the construction of these Articles.

(qq) Unless the context otherwise requires words or expressions contained in these Articles shall bear the same meaning as in the Ordinance and, in relation to bodies corporate incorporated outside Pakistan, shall apply so that such terms shall be construed in accordance with the meaning of the nearest equivalent term under the laws of the place of incorporation of such body corporate.

(rr) a reference to any agreement or document is to that agreement or document (and, where applicable, any of its provisions) as amended, novated, restated or replaced from time to time.

II. BUSINESS

3. Public Company

The Directors shall have regard to the restrictions on the commencement of business imposed by Section 146 if, and so far as, those restrictions are binding upon the Company.

the Directors in such manner and form as the Directors may from time to time prescribe. The Seal shall be duly affixed to every share certificate issued by the Company. The signature(s) on the certificate of title to shares may be affixed by any mechanical or electronic method.

9. Issuance of new Certificate

If a share certificate is defaced, lost or destroyed, it may be renewed on payment of such fee, if any, not exceeding Rs. 10/- (Rupees ten), and on such terms, if any, as to evidence, indemnity and payment of expenses incurred by the Company in investigating title as the Directors think fit.

10. Joint Holders

The Company shall not be bound to register more than four persons as the joint holders of any share.

11. Trusts Not Recognized

Except as required by law, no person shall be recognized by the Company as holding any shares upon any trust, and the Company shall not be bound by or be compelled in any way to recognize (even when having notice thereof) any equitable, contingent, future or partial interest in any share or any interest in any fractional part of a share or (except only as by these Articles or by law otherwise provided) any other rights in respect of any share except an absolute right to the entirety thereof in the registered holder.

12. Payment of Commission

The Company may at any time pay a commission to any person for subscribing/agreeing to subscribe (whether absolutely or conditionally) for any shares, debentures or debenture-stock in the Company, but so that if the commission in respect of shares shall be paid or payable out of capital, the statutory requirements and conditions shall be observed and complied with, and the amount or rate of commission shall not exceed such percentage on the shares, debentures, debenture-stock in each case subscribed or to be subscribed, as may be determined by the Board subject to any limits required by law. The commission may be paid or satisfied, either wholly or partly, in cash or in shares, debentures or debenture-stock. The Company may also on any issue of shares pay such brokerage as may be lawful; provided that such brokerage shall not exceed such percentage on the shares, debentures or debenture-stock, as may be determined by the Board subject to any limits required by law.

Witnesses:

Full Name, Father's/
Husband's Name

1. _____
Signature

Nationality

Full Address:

Occupation

_____
_____
_____

Full address of transferee

2. _____
Signature

Full Address:

_____
_____
_____

16. Non-Refusal of Transfer of Shares

The Directors shall not refuse to transfer any fully paid shares unless the transfer deed is defective or invalid. The Directors may decline to recognize any instrument of transfer unless:

(a) a fee not exceeding two rupees as may be determined by the Directors is paid to the Company in respect thereof; and

(b) the duly stamped instrument of transfer is accompanied by the certificate of the share to which it relates, and such other evidence as the Directors may reasonably require to show the right of the transferor to make the transfer.

If the Directors refuse to register a transfer of shares, they shall within thirty (30) days after the date on which the instrument of transfer deed was lodged with the Company, notify the defect or invalidity to the transferee, who shall, after removal of such defect or invalidity be entitled to re-lodge the transfer deed with the Company.

17. Closure of Register

On giving seven (7) days previous notice in the manner provided in the Ordinance, the Register may be closed for such period or periods not exceeding forty-five (45) days in any one (1) year as the Directors may

D. Alteration of Capital

21. Power to Increase Authorized Capital

The Company may, from time to time, by Special Resolution increase the authorized share capital by such sum, to be divided into shares of such amount, as the resolution shall prescribe.

22. Further Issue of Capital

Where the Directors decide to increase the capital of the Company by issue of further shares, such shares shall be offered to the Members in proportion to the existing shares held by each Member unless a Special Resolution is passed.

23. Provisions Applicable to New Shares

The new shares shall be subject to the same provisions with reference to transfer, transmission and otherwise as the shares in the original share capital.

24. Consolidation and Sub-division

The Company may, by Ordinary Resolution:

(a) consolidate and divide its share capital into shares of larger amount than its existing shares;

(b) sub-divide its existing shares or any of them into shares of smaller amount than is fixed by the Company's memorandum of association, subject, nevertheless, to the provisos to Section 92(1)(d);

(c) cancel any shares which, at the date of the passing of resolution, have not been taken or agreed to be taken by any person.

25. Reduction of Share Capital

The Company may, by Special Resolution, reduce its share capital in any manner and with, and subject to, any incident authorized and consent required by law.

give notice to, or the non-receipt of notice by, any Member shall not invalidate the proceedings at any general meeting.

31. Special Business

All business shall be deemed special that is transacted at an extraordinary general meeting, and also all that is transacted at an annual general meeting with the exception of declaring a dividend, the consideration of the accounts, balance sheet and the reports of the Directors and auditors, the election of directors, the appointment of, and the fixing of the remuneration of, the auditors.

32. Quorum

No business shall be transacted at any general meeting unless a quorum of Members is present at that time when the meeting proceeds to business. The quorum for general meetings shall be not less than ten Members present in person or by proxy who between them hold shares representing at least twenty five percent (25%) of the total issued shares; provided that that number must include at least one of WAPDA's representatives or proxies for so long as WAPDA continues to hold not less than twenty five per cent (25%) of the total issued shares.

33. Effect of Quorum Not Being Present

If within half an hour from the time appointed for the meeting a quorum is not present, the meeting, if called upon the requisition of Members, shall be dissolved; in any other case, it shall stand adjourned to the same day in the next week at the same time and place, and, if at the adjourned meeting a quorum is not present within half an hour from the time appointed for the meeting, the Members present, being not less than two, shall be a quorum.

34. Chairman of Meeting

The chairman of the Board of Directors, if any, shall preside as chairman at every general meeting of the Company, but if there is no such chairman, or if at any meeting he is not present within fifteen (15) minutes after the time appointed for the meeting, or is unwilling to act as chairman, any one of the Directors presents may be elected to be chairman, and if none of the Directors is present, or willing to act as chairman, the Members present shall choose one of their number to be chairman.

35. Adjournment

In the case of an equality of votes, whether on a show of hands or on a poll, the Chairman of the meeting at which the show of hands takes place, or at which the poll is demanded, shall not have or exercise a second or casting vote.

38.1 Right Of Directors To Attend General Meetings

Every Director of the Company shall have the right to attend any general meeting of the Company and also to take part in the discussion thereat.

39. Resolutions at General Meetings

Special Resolution Matters will require a Special Resolution at a general meeting.

40. Resolution Passed at Adjourned Meeting.

Where a resolution is passed at an adjourned meeting of:

(a) the Company;

(b) the holders of any class of shares in the Company;

(c) the directors of the Company; or

(d) the creditors of the Company;

the resolution shall, for all purposes, be treated as having been passed on the date on which it was in fact passed, and shall not be deemed to have been passed on any earlier date.

41. Special Resolution Matters

The following matters require a Special Resolution:

(a) any change in the authorised ordinary share capital of the Company, or the issuance of any additional ordinary share capital or of any option or right to subscribe to additional ordinary share capital of the Company; provided, however, that the Company may issue (i) additional shares of ordinary share capital in a pre-emptive rights offering to all Members, (ii) debenture stock and (iii) in the event that the applicable laws of Pakistan authorise the issuance of non-voting ordinary share capital, shares of non-voting ordinary share capital to WAPDA in exchange for its shares of voting ordinary share capital.

(b) sale or issuance of any interest in the Company giving any right to participate in the profits of the Company or in respect of profits relating to any asset of the Company or

Company under any of the Relevant Basic Agreements, or the initiation, conduct, defence, compromise or settlement of any claim by or against the Company under any of the Relevant Basic Agreements;

(i) the removal of any Director, or any other change in the number or composition of the Board of Directors;

(j) any Public Offering ;

(k) fixing the dividend policy or any change to the dividend policy of the Company;

42. The replacement of the Company's auditors shall be a Special Resolution Matter, unless the firm to be appointed to replace the existing firm is either one of the following leading international accountants, namely PriceWaterhouseCoopers, Ernst & Young, Deloittes and KPMG (the "Big 4 Firms"), or the associate firm in Pakistan of one of the Big 4 Firms in which case a Special Resolution will not be required.

C. Votes of Members

43. Right to Vote

Subject to any rights or restrictions for the time being attached to any class or classes of shares, on a show of hands every Member present in person shall have one vote except for election of directors in which case the provisions of Section 178 shall apply. On a poll every Member shall have voting rights as laid down in Section 160.

44. Voting By Joint Holders

In case of joint-holders the vote of the senior who tenders a vote, whether in person or by proxy shall be accepted to the exclusion of the votes of the other joint-holders and for this purpose seniority shall be determined by the order in which the names stand in the Register.

45. Member Of Unsound Mind

A Member of unsound mind or in respect of whom an order has been made by any court having jurisdiction in lunacy, may vote, whether on show of hands or on a poll, by his committee or other legal guardian, and any such committee or guardian may, on a poll, vote by proxy.

49 A E-Voting

Members opting for e-voting shall communicate their intention to opt for e-voting and demand of poll for resolutions through an instrument of e-voting to the Company at least ten (10) days before holding of the general meeting, through regular mail or electronic mail at the registered address/email of the Company provided in the notice of the general meeting. The instrument of e-voting and demand of poll for resolution shall be in the following form or a form as near thereto as may be:

KOT ADDU POWER COMPANY LIMITED

Option 1
Appointing other person as Proxy

I/We, _____ of _____ being member of Kot Addu Power Company Limited, holder of _____share(s) as per Register Folio No. _____ hereby Appoint _____, Folio No. (if member) _____ of _____ or failing him/her _____, Folio No. (if member) _____ of _____ as my / our proxy in my / our absence to attend and vote for me / us, and on my / our behalf at the Annual General Meeting / Extraordinary General Meeting of the Company to be held on _____ and at any adjournment thereof. Signed under my / our hand this _____ date of _____.

_____
Signature should agree with the specimen signature registered with the Company

Signed in the presence of:

_____
Signature of witness
CNIC

_____
Signature of witness
CNIC

V. MANAGEMENT AND ADMINISTRATION

A. Board of Directors

51. Directors

The first Directors of the Company shall be:

(1) Mr. Khalid Jawed
(2) Mr. Bashir Ahmed Abbasi
(3) Mr. Javed Aslam Callea
(4) Mr. Khalid Mohtadullah
(5) Mr. Akbar Khan
(6) Mr. Justice (Retd) Ch. Khalid Mehmood
(7) Mr. Arshad Zaman

and two other persons who shall be nominated by a majority of the Subscribers to the Memorandum within a period ending six months from the date of incorporation and in any case not later than thirty five (35) days prior to the first annual general meeting of the Company (hereinafter collectively referred to as the "First Directors"). The First Directors shall hold office until the first annual general meeting of the Company.

52. Number of Elected Directors

52.1 The number of elected Directors shall be seven (or such other number as may be specified through a Special Resolution) and shall be not less than the minimum number required from time to time by applicable laws of Pakistan for a company of the type which the Company is.

52.2 Deleted

52.3 Directors nominated for election by WAPDA are herein referred to as "WAPDA Nominee Directors".

52.4 The Directors shall be elected in accordance with the provisions of Section 178 (5).

52.5 In addition to the Directors elected or deemed to have been elected under Article 52, the Company may have up to one (1) Director nominated by the Company's creditors or other special interests by virtue of contractual arrangements.

meeting as aforesaid, the appointment of the alternate Director shall be deemed to have been approved by the Board.

56.3 Such an alternate Director shall be entitled to notice of meetings of the Directors and to attend and vote thereat accordingly and generally to exercise all the rights of such absent Director subject to any limitations in the instrument appointing him. For the purposes of the proceedings at such meetings, the provisions of these Articles shall apply as if any alternate Director (instead of his appointer) were a Director.

56.4 An alternate Director shall ipso facto vacate office as and when his appointer (a) vacates office as a Director; (b) removes the appointee from office; or (c) returns to Pakistan. Provided upon each occasion upon which the appointer thereafter leaves Pakistan again, and unless the appointer shall have informed the Company to the contrary, he shall be deemed to have reappointed the appointee as his alternate Director and no further approval of the Board shall be required unless the appointer desires to approve another person not previously approved by the Board as his alternate and takes the necessary steps to do so pursuant to this Article 56.

56.5 If an alternate Director shall be himself a Director, his voting rights shall be cumulative but he shall not be counted more than once for the purposes of quorum.

B Powers and Duties of Directors

57. General Management Powers

The business of the Company shall be managed by the Directors, who may pay all expenses incurred in promoting and registering the Company, and may exercise all such powers of the Company as are not by the Ordinance or by these regulations, required to be exercised by the Company in general meeting, subject nevertheless to the provisions of the Ordinance or to any of these regulations, and such regulations being not inconsistent with the aforesaid provisions, as may be prescribed by the Company in general meeting but no regulation made by the Company in general meeting shall invalidate any prior act of the Directors which would have been valid if that regulation had not been made.

58. Borrowing Powers

(b) if he suffers from any of the other disabilities or disqualifications mentioned in Section 187;

(c) if, in the case of a WAPDA Nominee Director, he is not an officer of WAPDA or any Affiliate of WAPDA.

61.2 A Director shall cease to hold office as a Director:

(a) if he becomes disqualified or disabled from being a Director on any of the grounds mentioned in Section 187; or

(b) if he is removed by a resolution of the Members as hereinafter provided; or

(c) if by notice in writing given to the Company he resigns his office; or

(d) if he fails to acquire his qualification shares within two (2) Months of his appointment; or

(e) if, in the case of a WAPDA Nominee Director, he ceases to be an officer of WAPDA or any Affiliate of WAPDA: or

(f) if he accepts a loan or guarantee from the Company in contravention of Section 195 ;

Provided, however, that no Director shall vacate his office by reason only of his being a Member of any company which has entered into contracts with, or done any work for, the Company but such Director shall not vote in respect of any such contract or work, and if he does so vote, his vote shall not be counted.

D. Proceedings of Directors

62. Meetings of Directors

62.1 The Directors may meet together for the despatch of business, adjourn and otherwise regulate their meetings, as they think fit. A Director may and the secretary on the requisition of a Director shall, at any time, summon a meeting of Directors. Seven (7) days notice at the least (exclusive of the day on which the notice is served or deemed to be served, but inclusive of the day for which notice is given) shall be given for a meeting of Directors provided that, if all the Directors entitled to attend and vote at any such meeting so agree, in writing, a meeting may be held of which less than seven (7) days notice has been

delegated, conform to any restrictions that may be imposed on it by the Directors.

66.2 A committee may elect a chairman of its meetings, but, if no such chairman is elected, or if at any meeting the chairman is not present within ten (10) minutes after the time appointed for holding the same or is unwilling to act as chairman, the members present may choose one of their number to be chairman of the meeting.

66.3 A committee may meet and adjourn as it thinks proper. Questions arising at any meeting shall be determined by a majority of votes of the members present. In case of an equality of votes, the chairman shall have and exercise a second or casting vote.

67. Validity of Directors' Acts

All acts done by any meeting of the Directors or of a committee of Directors, or by any person acting as a Director, shall, notwithstanding that it be afterwards discovered that there was some defect in the appointment of such Directors of persons acting as aforesaid, or that they or any of them were disqualified; be as valid as if every such person had been duly appointed and was qualified to be a Director.

68 Resolution in Writing

Except for the matters specified in Section 196(2), a Resolution in writing signed by all the Directors for the time being in office shall be as valid and effectual as if it had been passed at a meeting of the Board duly called and constituted. For this purpose, it shall be permissible to circulate the text of the proposed resolution duly signed by the Chief Executive and obtain the signatures of all the other Directors thereon separately by fax (the signed original whereof shall be sent in due course by mail or courier to the Company for its record) and such resolution shall be effective as soon as the text of the resolution signed by each of the other Directors shall have been faxed to and received by the Company.

E. Election and Removal of Directors

69. First Election of Directors

At the first annual general meeting of the Company, all the Directors shall stand retired from office, and Directors shall be

75. Official Seal

The Directors may provide for the use in any territory, district or place not situated in Pakistan, of an official seal which shall be a facsimile of the common seal of the Company, with the addition on its face of the name of every territory, district or place where it is to be used. The provisions of Section 213 shall apply to the use of the official seal.

VII. DIVIDENDS AND RESERVE

76. Declaration of Dividends

The Company in general meeting may declare dividends but no dividend shall exceed the amount recommended by the Directors.

77. Interim Dividends

The Directors may from time to time pay to the Members such interim dividends as appear to the Director to be justified by the profits of the Company.

78. Dividends Payable Out of Profits

No dividends shall be paid otherwise than out of profits of the year or any other undistributed profits. No unpaid dividend shall bear interest against the Company.

79. Dividends Payable on Amount Paid on Shares

All dividends shall be declared and paid according to the amounts paid on the shares.

80. Reserve Fund

The Directors may, before recommending any dividend, set aside out of the profits of the Company such sums as they think proper as a reserve or reserves which shall, at the discretion of the Directors, be applicable for meeting contingencies, or for equalizing dividends, or for any other purpose to which the profits of the Company may be properly applied, and pending such application may, at the like discretion, either be employed in the business of the Company or be invested in such investments (other than shares of the Company) as the Directors may, subject to the provisions of the Ordinance, from time to time think fit.

81. Profit Carried Forward

88. Inspection by Members

The Directors shall from time to time determine whether and to what extent and at what time and places and under what conditions or regulations the accounts and books or papers of the Company or any of them shall be open to the inspection of Members not being Directors, and no Member (not being a Director) shall have any right of inspecting of any account and book or papers of the Company except as conferred by law or authorized by the Directors or by the Company in general meeting.

89. Annual Accounts and Balance Sheet

The Directors shall as required by Sections 233 and 236 cause to be prepared and to be laid before the Company in general meeting such profit and loss accounts and balance sheets duly audited and reports as are referred to in those Sections.

90. Compliance with Ordinance

The Directors shall in all respects comply with the provisions of Sections 230 to 247 as may be applicable.

91. Capitalization of Profits

The Company in general meeting may upon the recommendation of the Directors, resolve that it is desirable to capitalize any part of the amount for the time being standing to the credit of any of the Company's reserve accounts or to the credit of the profit and loss account or otherwise available for distribution, and accordingly that such sum be set free for distribution among the Members who would have been entitled thereto if distributed by way of dividend and in the same proportions, on condition that the same be not paid in cash but be applied in or towards paying up in full un-issued shares or debentures of the Company to be allotted and distributed, credited as fully paid up to and amongst such Members in the proportion aforesaid, and the Directors shall give effect to such resolution.

92. Audit

Auditors shall be appointed and their duties regulated in accordance with Sections 252 to 255.

of the property of the Company, and the Directors (if the profits of the Company permit), or the liquidators (in a winding up), may distribute such shares or securities, or any other properties of the Company amongst the Members without realization, or vest the same in trustees for them, and any Special Resolution may provide for the distribution or appropriation of the cash, shares or other securities, benefits or property, otherwise than in accordance with the strict legal rights of the Members or contributories of the Company, and for the valuation of any such securities or property at such price and in such manner as the meeting may approve, and all holders of shares shall be bound to accept and shall be bound by any valuation or distribution so authorized, and waive all rights in relation thereto save only such statutory rights (if any) as are, in case the Company is proposed to be or is in the course of being wound up, incapable of being varied or excluded by these presents.

XII. WINDING UP

97. Division and Distribution of Assets Upon Dissolution

If the Company is wound up, the liquidator may, with the sanction of a Special Resolution of the Company and any other sanction required by law, divide amongst the Members in specie or kind the whole or any part of the assets of the Company (whether they shall consist of property of same kind or not) and may, for such purpose, set such value as he deems fair upon any property to be divided as aforesaid and may determine how such division shall be carried out as between the Members or different classes of Members. The liquidator may, with the like sanction, vest the whole or any part of such assets in trustees upon such trust for the benefit of the contributories, as the liquidator with the like sanction, shall think fit, but so that no Member shall be compelled to accept any shares or other securities whereon there is any liability.

XIII. INDEMNITY

98. Indemnification

Subject to the provisions of Section 194, every Director, Chief Executive and other officer or agent for the time being of the Company shall be indemnified by the Company against (and the Board shall out of funds of the Company pay) all costs, losses and expenses which any officer or servant may incur or become liable to pay by reason of any contract entered into or act or thing done by him as such officer or agent or in any way in the proper discharge of his duties including travel expenses and in particular and so as not to limit the generality of the foregoing provisions against all liabilities incurred by him in defending

ANNEXURE C

CERTIFICATE OF INCORPORATION

(16)

GOVERNMENT OF PAKISTAN

CERTIFICATE OF INCORPORATION

(Under section 32 of the Companies Ordinance, 1984 (XLVII of 1984)

Company Registration No. I-01977

I hereby certify that "KOT ADDU POWER COMPANY LIMITED"

is this day incorporated under the Companies Ordinance, 1984 (XLVII of 1984) and that the company is limited by ~~shares~~

Given under my hand at Islamabad

this 25th day of April

one thousand nine hundred and ~~ninety-six~~

Fee Rs. 2,500,000/- (Rupees Twenty five lac only)

CRO-1.

(BISMILLAH)
Registrar
DEPUTY of Companies
ISLAMABAD

CERTIFIED TO BE TRUE COPY

02/01/2020

Deputy Registrar
Company Registration Office Islamabad

Certified True Copy

PCPPK-Litho/Asia/91-92/DCS&F-12-2-92-12,000 Nos.

No. DRL-1978-dtd 25-4-96

A. Anthony Rath
Company Secretary
KOT ADDU POWER COMPANY LTD.

No. ADL 197

Dated 3/1/20

GOVERNMENT OF PAKISTAN

(34)

CERTIFICATE FOR COMMENCEMENT OF BUSINESS

[Under section 146 (2) of the Companies Ordinance, 1984 (XLVII of 1984)]

COMPANY REGISTRATION NO.I-01977

I hereby certify that the "KOT ADDU POWER COMPANY LIMITED"

which was incorporated under the Companies Ordinance, 1984 (XLVII of 1984), on the 25th day of April 1996 and which has filed a duly verified declaration in the prescribed form that the conditions of clauses (a) to (e) of sub-section (1) of section 146 of the said Ordinance have been complied with, is entitled to commence business.

Given under my hand at Islamabad this 24th day of June one thousand nine hundred and ninety-six

Fee Rs. 100/-

C.R.O.-4

(BISMILLAH)
DEPUTY REGISTRAR
OF
COMPANIES
ISLAMABAD

CERTIFIED TO BE TRUE COPY

02/01/202

Deputy Registrar
Company Registration Office Islamabad

No. OR-I/285 dt 24/6/96

Certified True Copy

PCPPK—Litho/2064/91-92/DCS&F—8-2-92—2,000 loose.

A. Anthony Rath
Company Secretary
KOT ADDU POWER COMPANY LTD.

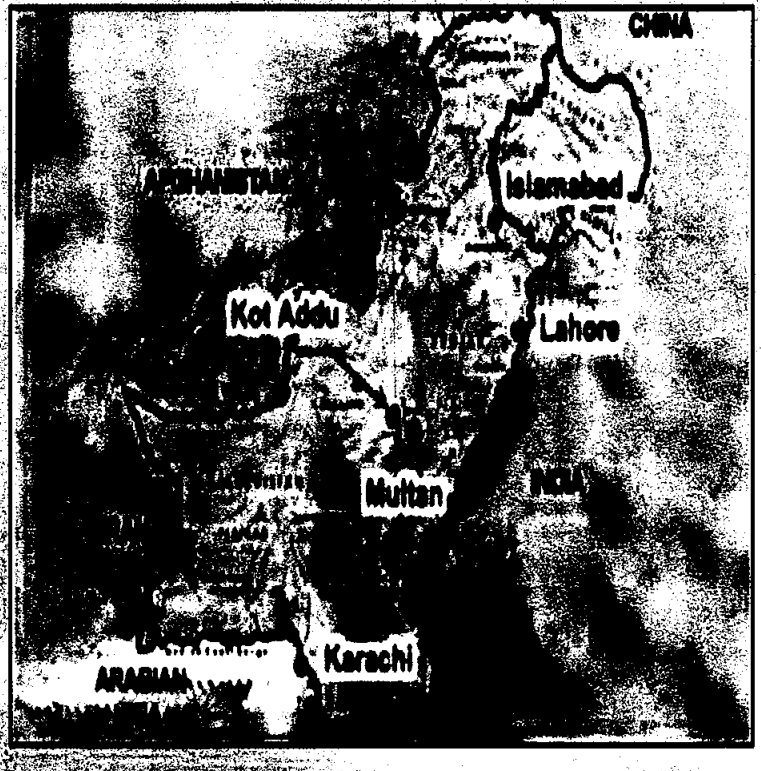
No. ADI 197

Dated 3/1/20

ANNEXURE D

SITE MAP

KAPCO Plant Site Location



ANNEXURE E

PLANT AND COLONY LAY -OUT

COVERED AREA DETAIL		
CATEGORY	TYPE	COVERED AREA
I	A	3000 sft
II	B	2100 sft
III	C	1560 sft
III	C+	2000 sft
III	C NEW	1953.50 sft
IV	D	1000 sft
V	E	606 sft
VI	F	570 sft

Sr. No.	DATE	MODIFICATIONS
4	15-09-2017	12 NOS. C-TYPE NEW RESIDENCES ADDED.
3	19-07-2013	30 NOS. F TYPE HOUSES DEMOLISHED
2	19-07-2013	60 NOS. E TYPE HOUSES DEMOLISHED
1	18-12-2012	4 NOS. C+ TYPE HOUSES ADDED

KOT ADDU POWER COMPANY LIMITED (KAPCO)

LAYOUT PLAN OF RESIDENTIAL COLONY

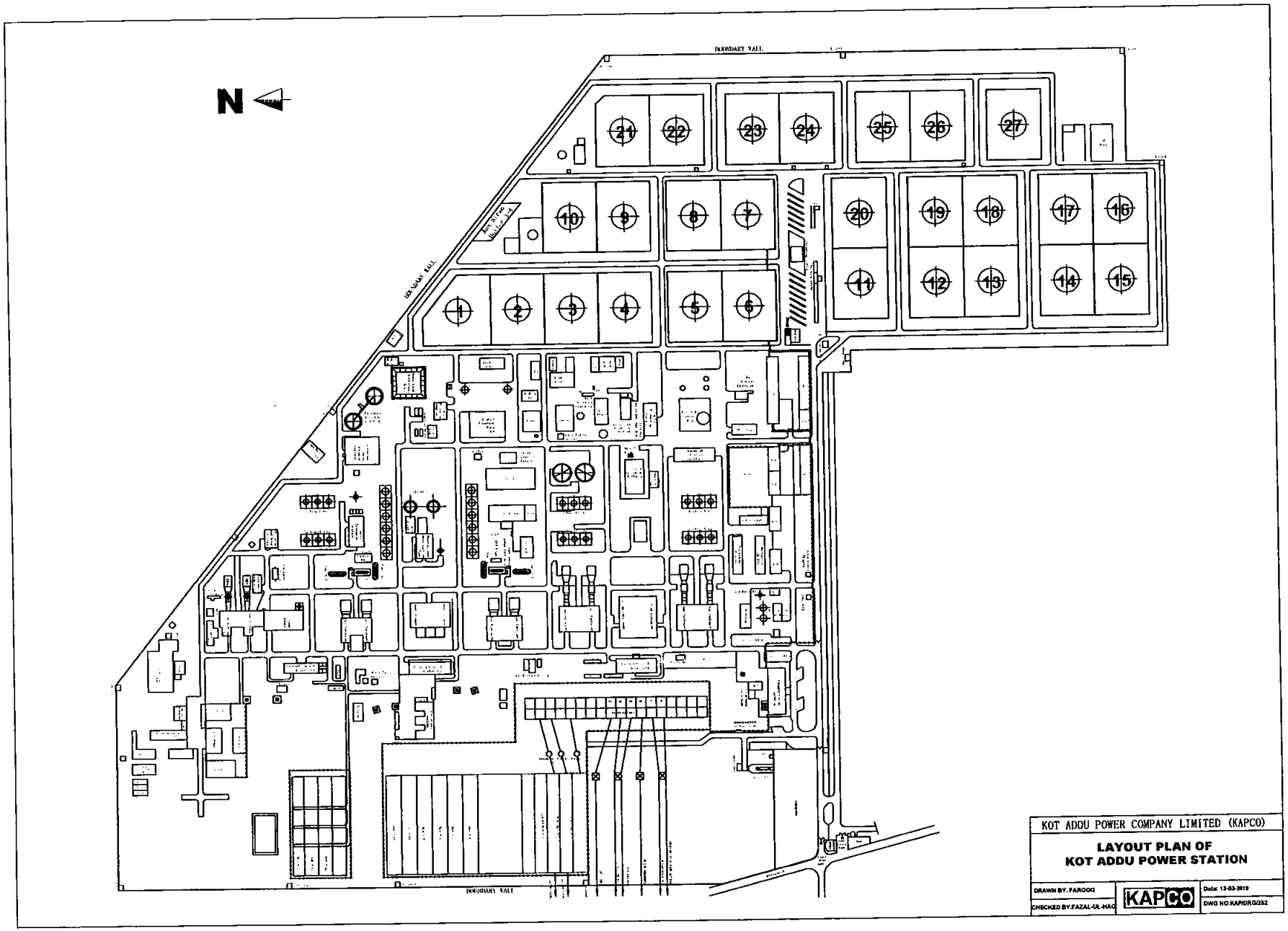
DRAWN: FAROOQ

CHECKED: FAZAL SB.

KAPCO

DATED: 04-06-2010

NO.KAP/DRG/254


N
BOUNDARY WALL
21
22
23
24
25
26
27
10
9
8
7
20
19
18
17
16
1
2
3
4
5
6
11
12
13
14
15
KOT ADDU POWER COMPANY LIMITED (KAPCO)
LAYOUT PLAN OF
KOT ADDU POWER STATION
DRAWN BY: FAROOQ
CHECKED BY:FAZAL-UL-HAQ
KAPCO
Date: 13-03-2019
DWG NO:KAP/DRG/252

ANNEXURE-F

SINGLE LINE KEY DIAGRAM

National Transmission & Despatch CompanyLtd

Phone # : 051 - 4939217
PLC # : 4903
Fax # : 051 – 9250532/4939227

Office of the
General Manager (S.O)
National Power Control Centre
NTDC, H – 8/1, Islamabad.

No. 4119-25/GM(SO)/Addl.C.E (NRCC)/(Drawing). Dated: 26/03/2021.

General Manager Engineering,
KAPCO ,Kot Addu.

Subject **Single Line Key Diagram Of 220/132 kV Kot Addu Switchyard**

Reference: : Office letter No. KCW/2510/11 dated 24-03-2021

Enclosed please find herewith '**final single line diagram**' of subject Power Plant as per information provided/verified vide above referred letter. Kindly ensure that the designated operational code numbers have been properly marked on the respective equipment in Control room, Relay room and Switch yard. Any discrepancy observed in final drawing, be conveyed to the undersigned at the earliest.

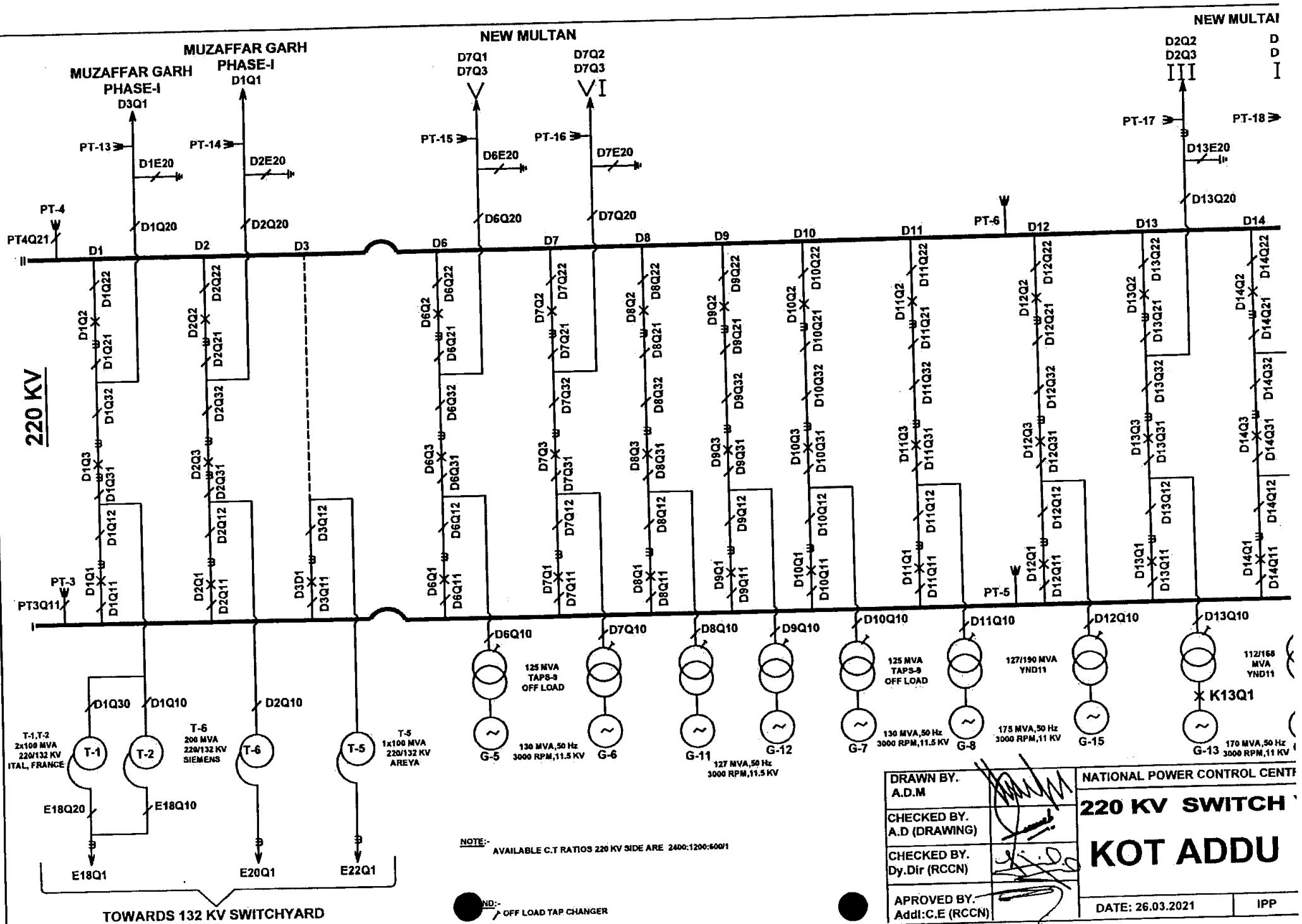
PURPOSE: ***Proposed replacement of 220/132kV, Auto-Transformers T-3&4(2*100MVA) with 220/132kV, Auto-Transformer T-6(200MVA).***
(As per up gradation work due to aging of existing auto-transformers)

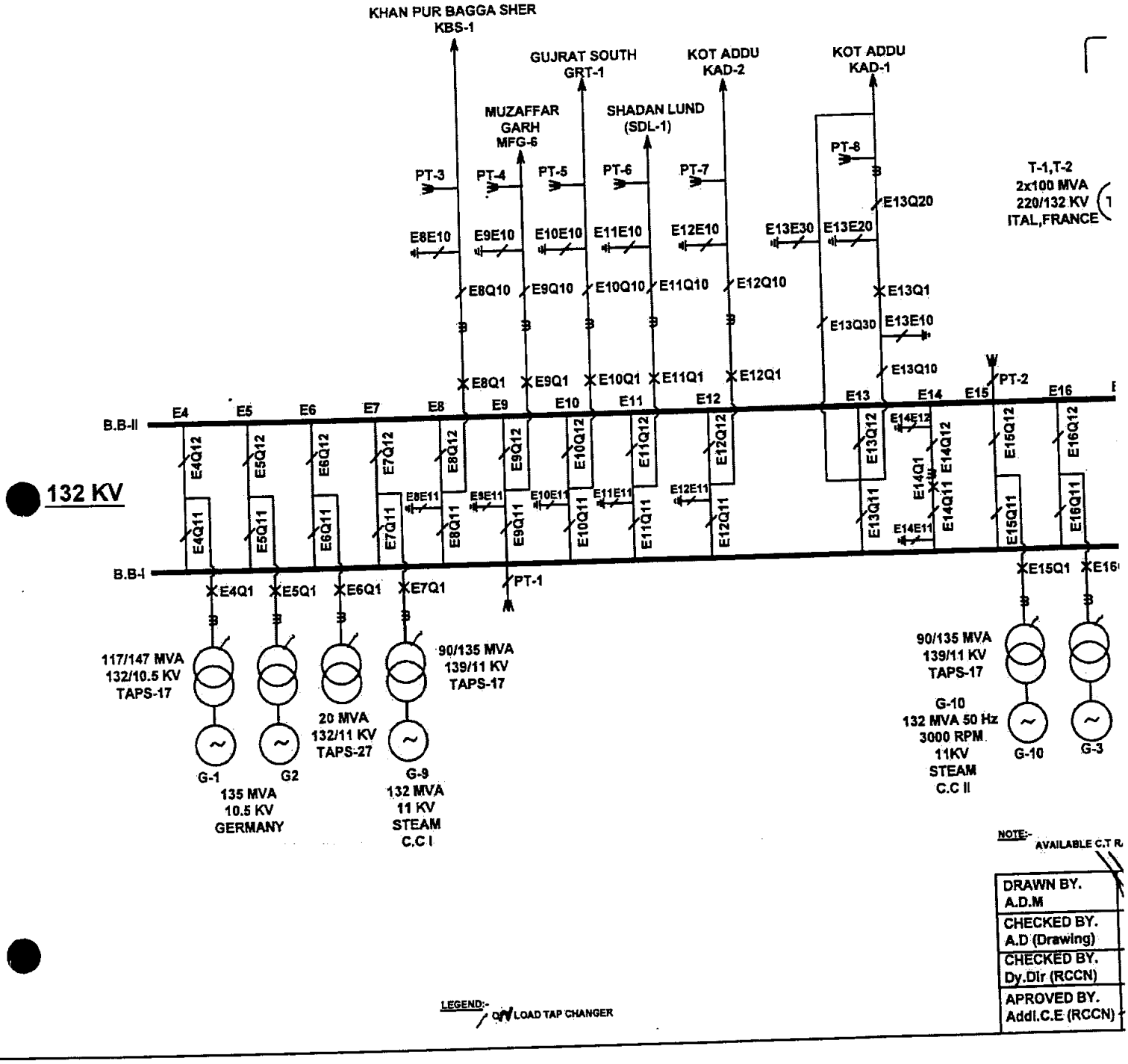
NOTE: This verified updated drawing of the station(s) will be implemented after completion of modification work during the shutdown at the station(s). The **ISOLATION** and **RESTORATION** switching for the shutdown will be carried out according to **EXISTING** and **VERIFIED UPDATED** NEW drawing respectively.

Addl: Chief Engineer (RCC(N),
NPCC/NTDC, Islamabad.

Copy for information:

- General Manager (Power Planning), NTDC, Lahore.
- CTO, CPPA-G, Islamabad
- Chief Engineer substation Design, NTDC, 143-WAPDA house Lahore.
- Chief Engineer (System Protection), NTDC, Lahore
- Director RCC (South), Jamshoro.
- Deputy Director (S/D) ,NCC, Islamabad
- Deputy Director (SCADA) NPCC, Islamabad.


MUZAFFAR GARH PHASE-I
D3Q1
MUZAFFAR GARH PHASE-I
D1Q1
NEW MULTAN
D7Q1
D7Q3
D7Q2
D7Q3
NEW MULTAI
D2Q2
D2Q3
III
D
D
I
PT-13
PT-14
PT-15
PT-16
PT-17
PT-18
D1E20
D2E20
D6E20
D7E20
D13E20
D13Q20
D1Q20
D2Q20
D6Q20
D7Q20
PT-4
PT4Q21
PT-6
D1
D2
D3
D6
D7
D8
D9
D10
D11
D12
D13
D14
220 KV
PT-3
PT3Q11
PT-5
D6Q10
D7Q10
D8Q10
D9Q10
D10Q10
D11Q10
D12Q10
D13Q10
K13Q1
125 MVA TAPS-9 OFF LOAD
125 MVA TAPS-9 OFF LOAD
127/190 MVA YND11
112/168 MVA YND11
D1Q30
D1Q10
D2Q10
T-1,T-2 2x100 MVA 220/132 KV ITAL, FRANCE
T-6 200 MVA 220/132 KV SIEMENS
T-5 1x100 MVA 220/132 KV AREVA
T-1
T-2
T-6
T-5
G-5
G-6
G-11
G-12
G-7
G-8
G-15
G-13
130 MVA,50 Hz 3000 RPM,11.5 KV
127 MVA,50 Hz 3000 RPM,11.5 KV
130 MVA,50 Hz 3000 RPM,11.5 KV
175 MVA,50 Hz 3000 RPM,11 KV
170 MVA,50 Hz 3000 RPM,11 KV
E18Q20
E18Q10
E18Q1
E20Q1
E22Q1
TOWARDS 132 KV SWITCHYARD
NOTE:-
AVAILABLE C.T RATIOS 220 KV SIDE ARE 2400:1200:600/1
OFF LOAD TAP CHANGER
DRAWN BY. A.D.M
CHECKED BY. A.D (DRAWING)
CHECKED BY. Dy.Dir (RCCN)
APROVED BY. Addl:C.E (RCCN)
NATIONAL POWER CONTROL CENTR
220 KV SWITCH
KOT ADDU
DATE: 26.03.2021
IPP


KHAN PUR BAGGA SHER
KBS-1
GUJRAT SOUTH
GRT-1
KOT ADDU
KAD-2
KOT ADDU
KAD-1
MUZAFFAR
GARH
MFG-6
SHADAN LUND
(SDL-1)
T-1,T-2
2x100 MVA
220/132 KV
ITAL,FRANCE
132 KV
B.B-II
B.B-I
PT-1
PT-2
PT-3
PT-4
PT-5
PT-6
PT-7
PT-8
E4
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E16
E8E10
E9E10
E10E10
E11E10
E12E10
E13E30
E13E20
E13Q20
E8Q10
E9Q10
E10Q10
E11Q10
E12Q10
E13Q1
E13Q30
E13E10
E13Q10
E8Q1
E9Q1
E10Q1
E11Q1
E12Q1
E4Q12
E5Q12
E6Q12
E7Q12
E8Q12
E9Q12
E10Q12
E11Q12
E12Q12
E13Q12
E14E12
E14Q1
E14Q11
E14Q12
E15Q12
E16Q12
E4Q11
E5Q11
E6Q11
E7Q11
E8Q11
E9Q11
E10Q11
E11Q11
E12Q11
E13Q11
E14E11
E15Q11
E16Q11
E8E11
E9E11
E10E11
E11E11
E12E11
E4Q1
E5Q1
E6Q1
E7Q1
E15Q1
E16
117/147 MVA
132/10.5 KV
TAPS-17
G-1
G2
135 MVA
10.5 KV
GERMANY
20 MVA
132/11 KV
TAPS-27
90/135 MVA
139/11 KV
TAPS-17
G-9
132 MVA
11 KV
STEAM
C.C I
90/135 MVA
139/11 KV
TAPS-17
G-10
132 MVA 50 Hz
3000 RPM
11KV
STEAM
C.C II
G-10
G-3
NOTE:-
AVAILABLE C.T R
DRAWN BY.
A.D.M
CHECKED BY.
A.D (Drawing)
CHECKED BY.
Dy.Dir (RCCN)
APROVED BY.
Addl.C.E (RCCN)
LEGEND:-
ON LOAD TAP CHANGER

ANNEXURE G

GENERATION LICENSE

National Electric Power Regulatory Authority

Islamic Republic of Pakistan

2nd Floor, OPF Building, G-5/2, Islamabad.
Ph : 9207200 Ext : 330 —— Fax : 9210215
E-mail : office@nepra.org.pk
Direct Phone : (051) 9206500

Registrar

No. NEPRA/R/LAG-18/11670-71

22-9-2004

Chief Executive Officer,
M/s. Kot Addu Power Company Ltd.
Kot Addu Gas Turbine Power Station,
District Muzaffargarh (PC 34060),

Subject: **Grant of Generation Licence IPGL/020/2004**
Licence Application No. LAG - 18
M/s. Kot Addu Power Company Ltd.

Please refer to your application No. nil, dated 17.06.2002 for a Generation Licence.

2. Enclosed here is Generation Licence No. IPGL/020/2004 granted by the Authority to M/s. Kot Addu Power Company Ltd. The Licence is granted to you pursuant to Section 15 of the Regulation of Generation, Transmission and Distribution of Electric Power Act (XL of 1997).

3. Please quote above mentioned Generation Licence No. in your future correspondence with the Authority.

DA/As above.

NATIONAL ELECTRIC POWER REGULATORY AUTHORITY
REGISTRAR
(NEPRA)

22.09.04.
(Mahjoob Ahmad Mirza)

Copy for information to Director General, Pakistan Environmental Protection Agency, 44-E, Office Tower, Blue Area, Islamabad.

National Electric Power Regulatory Authority
(NEPRA)
Islamabad – Pakistan

GENERATION LICENCE

No. IPGL/020/2004

In exercise of the Powers conferred upon the National Electric Power Regulatory Authority (NEPRA) under Section 15 of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997 (XL of 1997), the Authority hereby grants a Generation Licence to:

Kot Addu Power Company Limited

Incorporated under the Companies Ordinance, 1984
Under Certificate of Incorporation

No. I-01977 Dated 25th April 1996

to engage in generation business subject to and in accordance with the Articles of this Licence.

Given under my hand this 22nd day of September, Two Thousand & Four, and expires on 21st day of September, Two Thousand & Twenty One.

22.09.04

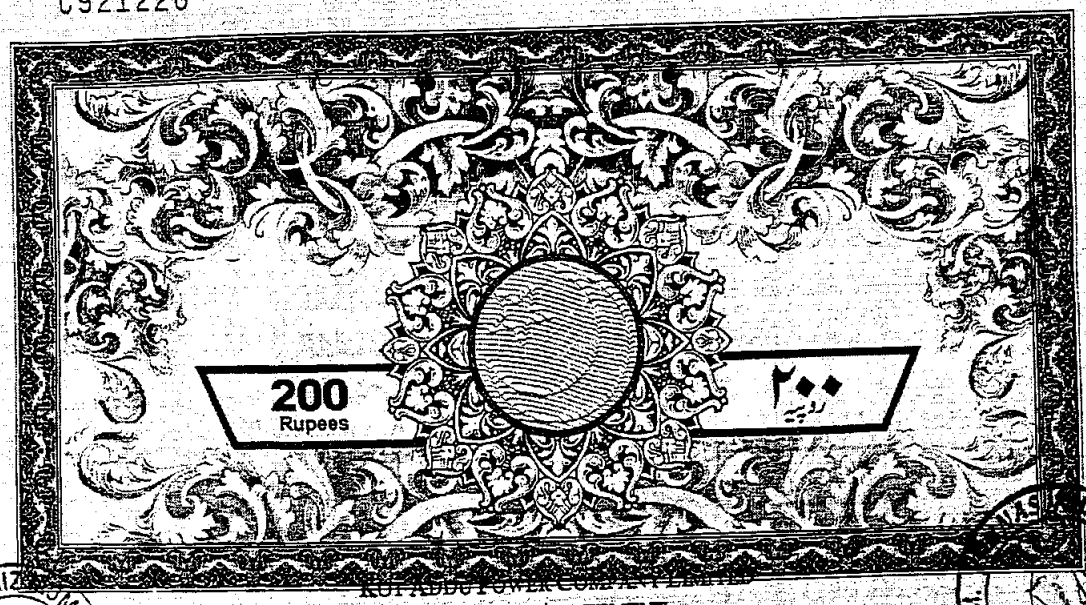
Registrar

NATIONAL ELECTRIC POWER REGULATORY AUTHORITY
REGISTRAR
(NEPRA)

ANNEXURE H

MASTER AGREEMENT

C921220



KOT ADDU POWER COMPANY LIMITED

MASTER AGREEMENT

This Agreement is made and entered into as of this day of 11th February 2021 by and between:

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY a statutory corporation established pursuant to Pakistan Water and Power Development Authority Act of 1958, with its principal office located at Lahore (the "**Power Purchaser**").

KOT ADDU POWER COMPANY LIMITED, a company incorporated under the laws of Pakistan whose corporate office is located at 5B/3, Gulberg III, Lahore Pakistan (the "**Company**").

(Each of the Power Purchaser and the Company are hereinafter referred to, individually as a "**Party**" and collectively as the "**Parties**".)

RECITALS:

A. Whereas, the Committee for negotiations with Independent Private Power Producers ("**IPPs**"), notified by the Government of Pakistan through notification number F.No.IPPs-1(12)/2019-20 dated 03.06.2020, and the IPPs including the Company representing the 1994 Power Policy projects, had several rounds of discussions and agreed to alter their existing contractual arrangements to the extent of, and strictly with respect to, the matters contained in the Memorandum of Understanding dated 12.08.2020 (the "**MoU**");

B. Whereas, the Company has, at the request of the GOP, in the larger national interest, voluntarily agreed to alter its contractual rights for the sustainability of the power sector;

ATTESTED
SULTAN PERVAIZ MUMTAZ
Advocate High Court Lahore

ATTESTED
M. Younas Khan ADVOCATE
Notary Public
High Court Lahore

(1392)
0304-4323...

200 5539 10-02-2021

President of Islamic Republic of Pakistan

M. Asif

Kapco Master Agreement

C. Whereas the Government of Pakistan through notification number F.No.IPPs-1(12)/2020 (Vol-II) dated 7th October 2020 constituted the Implementation Committee to, *inter-alia*, convert the MOU into a binding agreement between the Parties;

D. Whereas the Parties agree that payment of receivables, remains an integral consideration for the Parties to enter into this Agreement; and

E. Whereas the Power Purchase Agreement was entered into between WAPDA and the Company on 27th Jun 1996 as amended up-to-date (the "**PPA**"); the Parties along with Central Power Purchasing Agency (Guarantee) Limited (CPPA-G), have on the date hereof entered into a novation agreement.

NOW THEREFORE, with the intention to be legally bound for due consideration, the Parties agree as follows.

1. Definitions

Unless otherwise defined herein or if the context so requires, all capitalized terms used in this Agreement shall have the meaning ascribed to them in the PPA.

2. Competitive Trading Arrangement

The Parties acknowledge that the Company's project predates the creation of the NEPRA (National Electric Power Regulatory Authority) regime. The Government of Pakistan intends to create a competitive power market. Without prejudice to the terms of its generation license, the Company shall actively support and participate in the competitive trading arrangement when it is implemented and becomes fully operational. Article 6 of the Company's generation license relating to the competitive trading arrangement is reproduced herein below:

"(1) During the subsistence of the Agreements entered into by the Licensee prior to the enactment of the Act, the Licensee shall have the option to participate in such measures as may be directed by the Authority from time to time for development of a Competitive Trading Arrangement.

(2) Any variation or modification in the Agreements under the foregoing sub-article (1), for allowing the Licensee to participate wholly or partially in the Competitive Trading Arrangement shall be subject to mutual agreement of the parties thereto and such terms and conditions as may be approved by the Authority.

(3) In the event that the Licensee exercises its option to participate wholly or partially in development of the Competitive Trading Arrangement under the fore-going sub-article (1), the Licensee shall in good faith work towards implementation and operation of the aforesaid Competitive Trading Arrangement in the manner and time period specified by the Authority and in doing so, the Licensee shall not by any act or omission impede the development, implementation or operation of the Competitive Trading Arrangement."

3. Facilitation

3.1 The Power Purchaser shall assist and support the Company in Tax issues with Federal Board of Revenue for early and positive resolution of all ongoing cases including apportionment of input tax on Capacity Purchase Price invoice.

3.2 The Power Purchaser shall assist and support the Company in getting tax exemption similar to other IPPs, after the initial Term of the PPA or any extension thereof.

3.3 The Power Purchaser shall assist and support the Company in removing the requirement of 'Approval of GOP for Additional Debt' and bar on 'Creation of Security' by the Company for making any investment under clauses 7.2 and 7.3 of the Facilitation Agreement.

3.4 Subject to agreement on the terms and conditions and completion of legal and corporate formalities, the Power Purchaser shall consent to the extension of the PPA for an additional term following the expiry of the Term of the PPA.

4. Governing Law

The rights and obligations of the Parties under or pursuant to this Agreement shall be governed and construed according to the Laws of Pakistan.

5. Miscellaneous

The Parties agree that nothing contained in this Agreement shall be deemed or be construed as an admission of liability, wrongdoing or improper action on the part of the Company.

Nothing contained herein shall prejudice any other rights of and remedies available to the Parties under the PPA.

6. Conditions Precedent

Notwithstanding anything to the contrary in this Agreement, the Power Purchaser agrees to the following conditions precedent to the effectiveness of this Agreement:

(i) the Company's shareholder approval at general meeting in accordance with the Articles of Association of the Company and the Company shall promptly notify the Power Purchaser once approval has been obtained or refused by its shareholders.; and

(ii) the execution of the amendment to the Facilitation Agreement and the execution of the amendment to the GoP Guarantee in form and substance annexed to this Agreement. The effectiveness and validity of this Agreement is subject to fulfilment of this condition to the satisfaction or waiver by the Company.

IN PRESENCE OF THE WITNESSES BELOW, the Parties have executed this Agreement on the date first written above.

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY	KOT ADDU POWER COMPANY LIMITED
By: JAVED AKHTAR	By:
Member Power	Chief Executive Officer
Witnesses:	
Name: WAQEEM MUKHTAR	Name: NAVEED ASGHAR CH
CNIC: 61101-8935122-5	CNIC: 36302-0341134-7

Cha CHA-6

ANNEXURE I

GM NPCC LETTER NO 15373-77/GM (SO)

National Transmission & Despatch Company Ltd.

General Manager (System Operation) NPCC

No: 15373-77/GM (SO)/NPCC/DDPC-1/CPPAG/ Dated: 20-11-2020

CTO (CPPA-G)
Dy 1654 23/11

Chief Technical Officer
CPPA-G, Blue Area,
Islamabad

Subject: **Impact of Early Retirement of Power Projects Under 1994 Power Policy on System Operations.**

Reference: (i) CPPA-G Letter No. CPPA-G/2020/CTO/22275-80 Dated: 17-11-2020.
(ii) CPPA-G Letter No. CPPA-G/2020/CTO/22281-86 Dated: 17-11-2020.

It is apprised that NTDC power system planning department in coordination of this office and other relevant NTDC offices has worked on the subject matter as desired by the 'Committee for Negotiation with IPPs' formed pursuant to CCoE decision of 20th May 2020. The preliminary assessment of the future requirements of the existing IPPS of 1994 policy is based on the following aspects:

a. Existing system performance and available future grid system expansion plan for the next 5 years.

b. Consideration of IPPs fulfilling the following grid system operational requirements:
   - Grid constraint management and voltage stability support, especially during high demand scenario in summer
   - Economical power dispatch
   - Peaking capability, and load following capability especially considering increased share of variable renewable energy (VRE) in future

1. Considering the grid system operational requirements as defined in Item a & b, IPPs have been prioritized, into the following three categories:
   - Critically required
   - Semi-critically required
   - Not required

CTO (CPPA-G)
Diary No: 550
Date: 23-11-2020

CTO CPPAG	
D# 5783	Dt 23/11
DGM(C)	DGM(MO)
DGM(NC)	DGM(R)
DGM(F-I)	DGM(F-II)
Dir. I&A	DGIT

C.F.O
C.T.O
MT-CgR-II
To discuss
may forward to the Ministry.
23/11/2020
MTCgR-II
Please coordinate with Mr. Zubair for the meeting.

2. It is important to highlight that this preliminary assessment has been prepared based on the professional knowledge, experience and system understanding on the part of NTDC engineers coupled with in-house deliberations. Consequently, in the absence of detailed studies, recommendations made through this report are indicative.

3. This report gives an insight of IPP requirements in consideration of grid system operational requirements for the next 5 years only and does not include generation capacity analysis. It is reiterated that for more accurate future need assessment of IPPs, detailed analyses would be required in medium to long term perspectives; such analyses would be based on hourly production simulation (generation capacity analysis) and grid system operational support studies. The detailed assessment would also include (i) technical examination/inspection/test of the generation facilities to ascertain their current health, emissions, efficiency and longevity; and (ii) assessment of potential capacity and/or energy to DISCOs in the bilateral contract market envisaged under the CTBCM.

4. The results of the preliminary assessment by NTDC regarding IPP requirements under 1994 Policy is provided in the attached table.

Submitted for your information and further analysis.

(Engr. Muhammad Ayub)
General Manager (System Operation)
NPCC, NTDC, Islamabad

C.C.

1. Managing Director NTDC, 414-Wapda House Lahore.
2. Dy: Managing Director (P&E), NTDC, WAPDA House Lahore.
3. Dy: Managing Director (AD&M), NTDC, 413-WAPDA House Lahore.
4. General Manager (Power System Planning) NTDC, PIA Tower Lahore

Name of Plant	Dependable Capacity (MW)	Fuel Type	Retirement Year	Priority			Remarks
				Critically Required	Semi-Critically Required	Not Required	
KEL	124	RFO	2027	✓			• Required till the completion of Lahore North 500/220/132 kV grid station (expected in 2023) • This plant is candidate for consideration as merchant plant after expiry of its PPA, in view of system operational support capability when needed.
HCPC	129	GAS	2030	✓			• Provides grid system operational support to feed QESCO • Plant is unavailable since October 2019 due to expiry of gas contract between the complex & SSGC. RLNG contract between the parties has not yet finalized.
UCH	549	GAS	2030	✓			• Low cost dedicated gas plant.
FKPCL	151	RLNG	2030	✓			• Required for grid constraint management during summer season in future, especially in case of reduction in dispatch of Trimmu power plant (expected COD in Dec. 2020) which may be either due to generator outages or unavailability of RLNG.
AES LALPIR	350	RFO	2028		✓		• Wide operating range of generation. • May be considered as a merchant plant after expiry of PPA. • Its dependable capacity may also help to evacuate additional ARE generation in the NTDC system which needs further exploration.

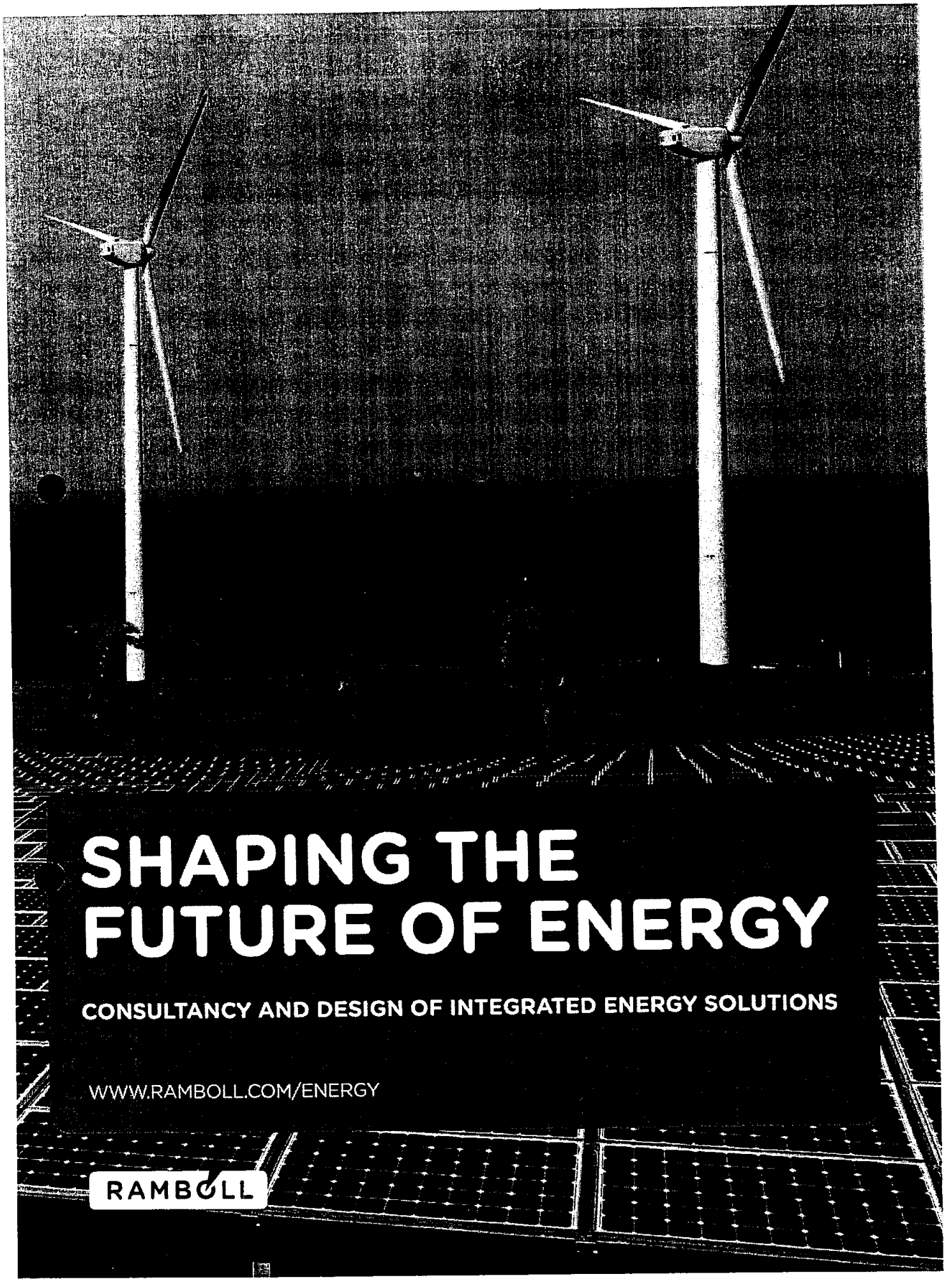
Priority Proposed for the Power Generation Projects Under 1994 Policy

Name of Plant	Dependable Capacity (MW)	Fuel Type	Retirement Year	Proposed Priority			Remarks
				Critically Required	Semi-Critically Required	Not Required	
A. IPPs under 1994 Policy							
KAPCO	1345	RFO, HSD & RLNG	2021	✓			• Its generators are connected at two voltage levels (220 & 132 kV). • It has two components: (i) Generators; and (ii) 220/132 kV grid station with 500 MVA capacity feeding MEPCO. • Its 220/132 kV grid station is required for system operational support. • May be considered as merchant plant after expiry of its PPA • Detailed feasibility study from independent consultant is required to determine the quantum of generation capacity required in future as well as to assess the potential benefits of its utilization for peaking duty.
HUBCO	1207	RFO	2027			✓	• Not required for system operational support. • M/s HUBCO is considering to sell its 600 MW power to KE by converting 2 out of 4 units from oil to coal.

Name of Plant	Dependable Capacity (MW)	Fuel Type	Retirement Year	Proposed Priority			Remarks
				Critically Required	Semi-Critically Required	Not Required	
AES PAKGEN	350	RFO	2028		✓		• Same remarks as for AES LALPIR
ROUSCH	395	RLNG	2030		✓		• Grid operational support is not so significant, especially in view of large sized RLNG plant in its vicinity. • Generation cost is lower.
SABA	126	RFO	2030		✓		• Required for system operational support till the completion of Lahore North 500/220/132kV grid station (expected in 2023)
LIBERTY POWER	213	RLNG	2027	✓			• Low cost on Raw gas.
AEL	28	RLNG	2032			✓	• Grid operational support is not so significant, especially in view of large sized RLNG plant. • Generation cost is lower than RFO.
DAVIS	10	RLNG	2044			✓	• Grid operational support is not so significant, especially in view of large sized RLNG plant in its vicinity. • Generation cost is lower than RFO.

ANNEXURE J

RAMBOLL BROCHURE


SHAPING THE
FUTURE OF ENERGY
CONSULTANCY AND DESIGN OF INTEGRATED ENERGY SOLUTIONS
WWW.RAMBOLL.COM/ENERGY
RAMBOLL

RAMBOLL AT A GLANCE

15,000 EXPERTS
300 OFFICES
35 COUNTRIES

ENERGY

With security of supplies, climate change, energy efficiency and resource scarcity as top priorities on the global agenda, there is a general push towards renewables, although conventional energy will continue to play a significant role in the energy mix in the coming years. As a consultancy, Ramboll is at the forefront of addressing the green transition and offers a holistic approach to energy that supports the sector on the journey towards more sustainable solutions. Read more at: http://ramboll.com/energy

BUILDINGS

Buildings form a fundamental part of our lives by shaping our communities and daily activities.

For these reasons, Ramboll's design philosophy is always to make room for the human experience. As one of Europe's top 3 buildings designers with decades of experience in the global market, we create visionary, sustainable, and award-winning buildings that improve life for users and enhance the surrounding landscape.
Read more at:
http://ramboll.com/buildings

TRANSPORT

Mobility fuels economic and social development and with 50% of the world's population now living in urban areas, efficient and reliable transport systems are essential.

To meet this need, Ramboll has been working on some of the world's largest, most innovative infrastructure projects and is the leading consultancy in the Nordic market.

We create value for transport authorities, contractors and local authorities by providing multidisciplinary technical excellence and minimising resource usage.
Read more at:
http://ramboll.com/transport

PLANNING & URBAN DESIGN

Ramboll's holistic approach to urban development encompasses strategy, planning and world class technical design services and is based on an integrated multidisciplinary skills base.

We have an extensive track record working with a number of the world's largest cities to create liveable, sustainable, and implementable urban development solutions that are fully adapted to the local context.
Read more at:
http://ramboll.com/planning-and-urban-design

COUNTRIES WITH PERMANENT OFFICES **NORDIC REGION:** Denmark - Copenhagen, company head office, Finland, Greenland, Norway, Sweden **EUROPE:** Belgium, Cyprus, France, Germany, Italy, Netherlands, Poland, Romania, Russia, Spain, Switzerland, United Kingdom **MIDDLE EAST:** Kingdom of Saudi Arabia, Qatar, United Arab Emirates **ASIA-PACIFIC:** Australia, China, India, Indonesia, Malaysia, Myanmar, New Zealand, Singapore **THE AMERICAS:** Brazil, Canada, Mexico, USA **AFRICA:** South Africa

WATER

Water is essential to life and one of our most precious resources. Working with municipalities, utilities, and industrial clients, Ramboll draws on proven multidisciplinary expertise to manage the most challenging water resources, wastewater, and storm water issues.

We integrate treatment process selection and engineering, operational services, and regulatory management and planning to deliver innovative solutions that benefit both industries and society.
Read more at:
http://ramboll.com/water

ENVIRONMENT & HEALTH

As a globally recognised environmental and health consultancy, we have earned a reputation for technical and scientific excellence, innovation and client service.

Advances in science and technology and evolving regulatory, legal and social pressures create increasingly complex challenges for our clients. We evolve to keep pace with these changes - by adding new services, contributing to scientific advances or expanding geographically.
Read more at:
http://ramboll.com/environment-and-health

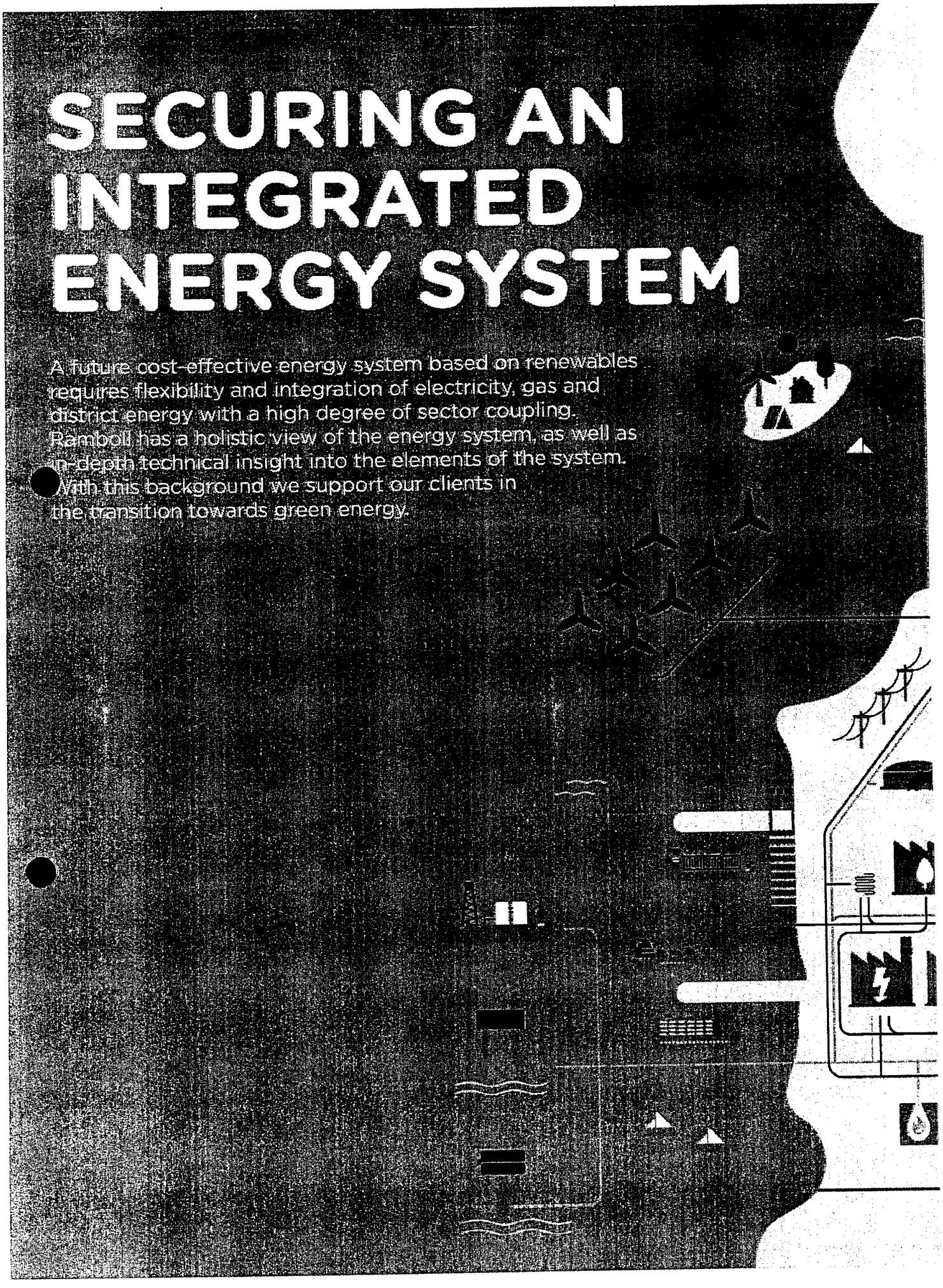
MANAGEMENT CONSULTING

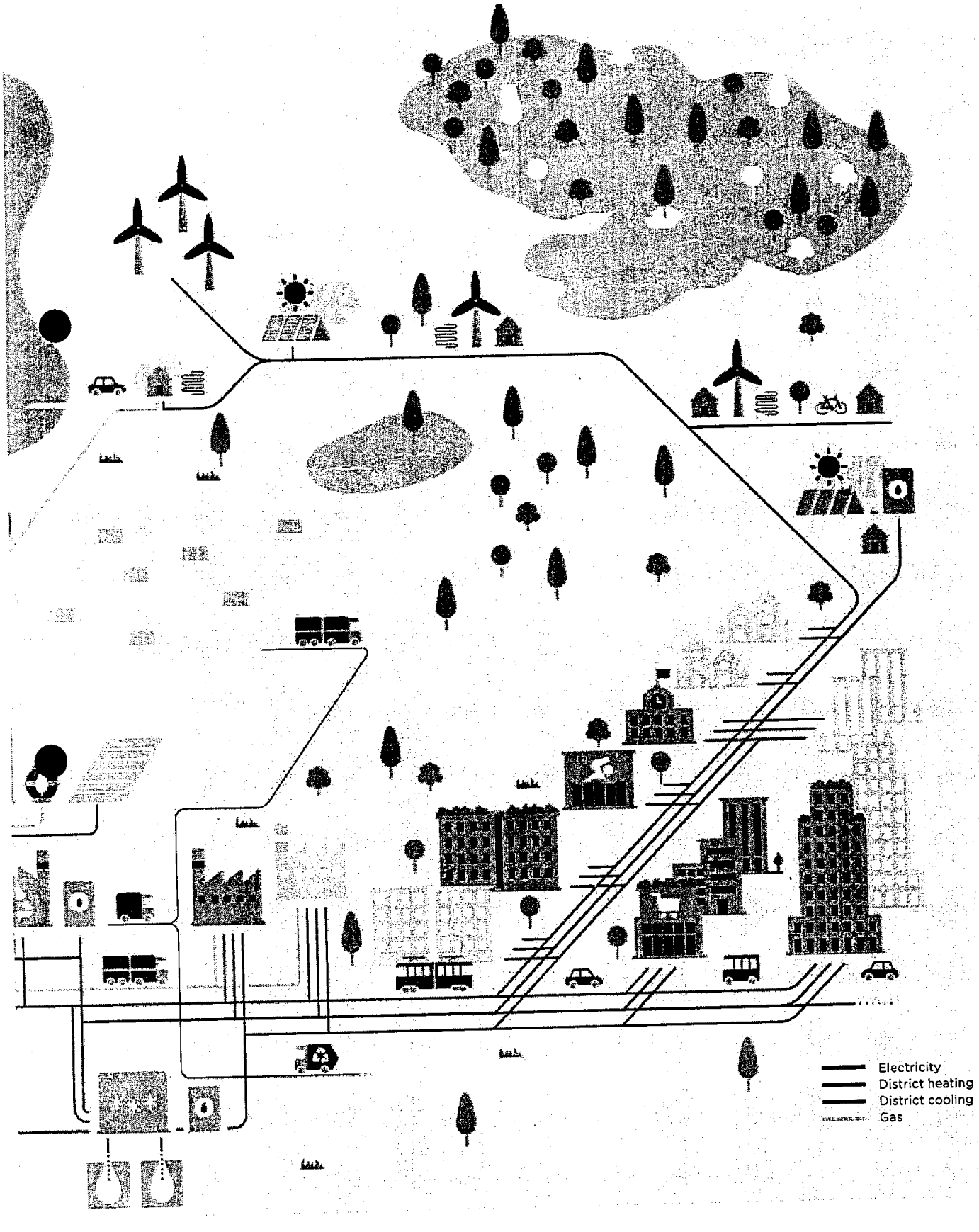
National, regional and local authorities are responsible for issues that affect us all; from healthcare, education and day care to strategic planning of infrastructure and climate initiatives. Drawing on 500 management experts, Ramboll acts as a trusted partner to public administrations, creating the insights needed to make informed strategic decisions that promote stronger societies.

With unprecedented levels of competition in the global economy, Ramboll focuses on empowering private sector customers with expertise and powerful management tools.
Read more at:
http://ramboll.com/management-consulting

SECURING AN INTEGRATED ENERGY SYSTEM

A future cost-effective energy system based on renewables requires flexibility and integration of electricity, gas and district energy with a high degree of sector coupling. Ramboll has a holistic view of the energy system, as well as in-depth technical insight into the elements of the system. With this background we support our clients in the transition towards green energy.




Electricity
District heating
District cooling
Gas

ENERGY ABOUT US

REVENUE IN 2018
EUR 163 MILLION

NUMBER OF EMPLOYEES
Ramboll Energy has approx. 1,800 specialists working dedicatedly with renewable and conventional energy.

GEOGRAPHICAL SPREAD
Ramboll has 55 energy offices in 14 countries, including Denmark, Sweden, Norway, UK, Germany, Poland, Switzerland, USA, Canada, Qatar, UAE, India, Singapore and China.

RANKINGS
Ramboll is ranked no. 1 in Cogeneration, no. 1 in Towers & antennae, no. 2 in Hazardous waste, no. 3 in Wind generation and no. 8 in Offshore and underwater facilities in the ENR survey of top international design firms (Dec. 2018 rankings).

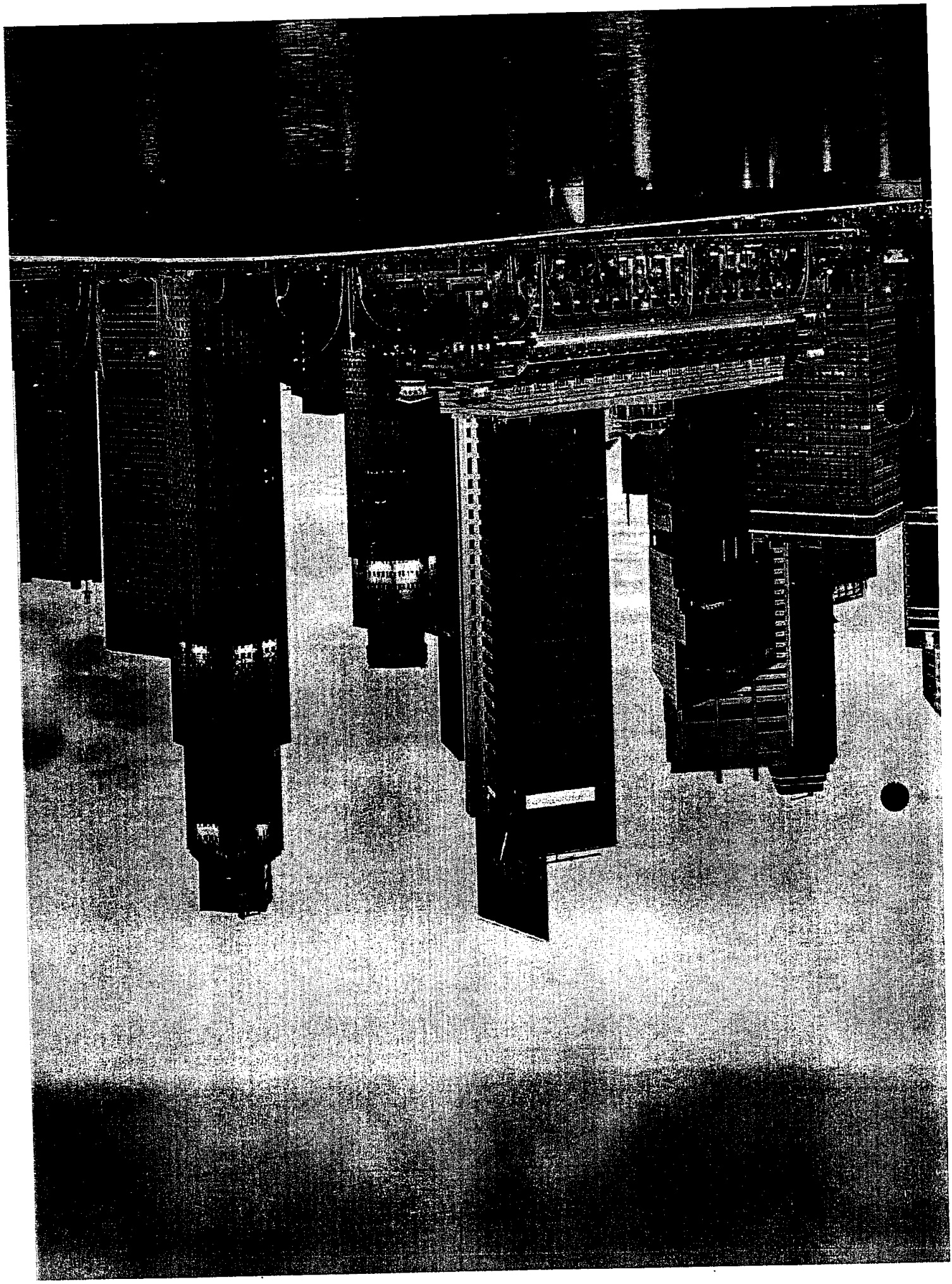
ONE OF THE LARGEST WASTE-TO-ENERGY FACILITIES ON EARTH IN ONE OF THE WORLD'S SMALLEST COUNTRIES
Ramboll is part of a multidisciplinary consultancy technical team for the planning, design and construction management of one of the world's largest waste-to-energy facilities, which will enable Singapore to reap the benefits of energy and resource recovery maximisation for years to come (image p. 7).

Ramboll has more than 50 years of experience in the planning, design and implementation of energy solutions and is among the ten leading energy consultancies in Europe. We focus on adding maximum value both to our clients and society at large through an integrated and multidisciplinary offering that cuts across the whole value chain.

The projects that we carry out for our clients typically provide the overall society benefits of securing the supply of energy, reducing climate impact, improving energy efficiency and countering resource scarcity. In this way, we contribute to a sustainable development of the energy sector.

As a people-based company, we believe that the key to our success lies in the motivation, persistence, skills and commitment of our employees. With offices around the world, we combine global knowledge with local presence. Being an international company enables us to mobilise large project teams across geographies and disciplines.

Our services are based on integrity, deep specialist insights and absolute independence of third party providers.



OUR APPROACH

A PARTNER FOR CHANGE

WHAT OUR CLIENTS GET

- A change partner who helps our clients think, design and implement their green energy transition
- A committed partner who takes end-to-end responsibility of our clients' projects
- A partner who listens to our clients' needs and challenges before designing the best solutions
- Proactive out-of-the-box and innovative thinking, translating ideas into pragmatic solutions
- A partner of integrity, offering independent expert consultancy
- Integrated energy solutions based on an understanding of the interaction between the different sectors and technologies, technical insight and multidisciplinary competencies
- Access to strong technical capabilities and best practice

The energy sector is shifting from a system based on fossil fuels to one exploiting renewable energy. As sustainable society consultants, we bring our clients one or more steps closer to a renewable energy system, and we optimise energy efficiency, systems, technologies and processes.

We enable people and organisations to design and implement sustainable change with a lasting impact – for both business and society.

Driving green energy transition should always be built on a holistic understanding as well as in-depth expertise and experience. And it should be built on close engagement between us and our clients because no change encounter is the same, and each initiative, challenge and dialogue therefore calls for depth, creativity and perspective.

We seek long-term relationships with our clients and have worked for many of them for more than 30 years.

We are committed to guiding our clients and their organisations into a better state and to always delivering sustainable energy solutions that are innovative, integrated and flexible to suit the unique challenge at hand.

HOW WE WORK

DELIVERING TECHNICAL EXCELLENCE

PROJECT EXECUTION MODEL

Ramboll's ambition is to be known as the consultancy and engineering partner that sets the industry benchmark for excellence within project management. We are committed to exceeding client expectations and creating successful partnerships by consistently delivering optimised solutions, on time and within budget.

To achieve this, we have a common approach to project management across the Ramboll Group. This includes a stage gate model covering all project phases and practical tools that are based on internationally recognised standards and best practices developed by Ramboll specialists.

From idea to operation

We assist our clients on all aspects of a project, ranging from planning and engineering design, to long-term operation & maintenance and lifetime extension. We strive to have a close, proactive dialogue and engagement through the entire project life-cycle.

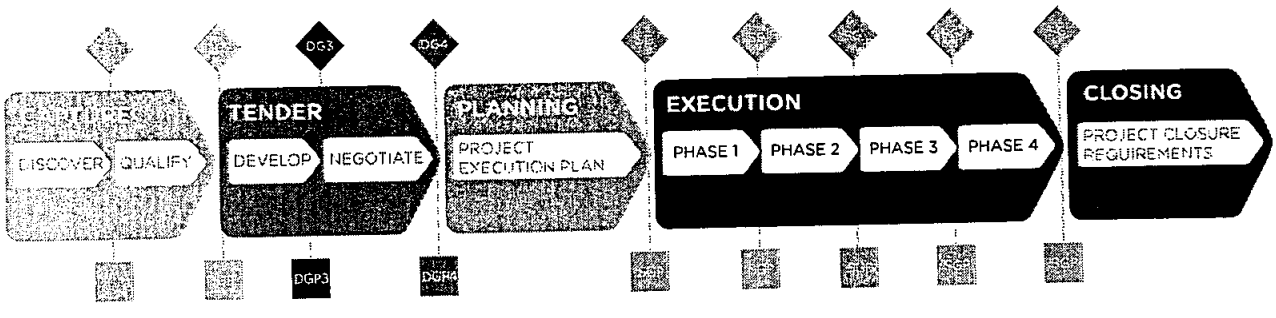
Owner's Engineers

We typically act as the Owner's/ Developer's Engineer or Lead Advisor on multi-million EUR energy investment projects, assisting our clients with project management, technical expertise and engineering, while securing a solid contractual basis (commercially and technically) for the client vis-à-vis contractors/ suppliers.

Unlike most other consultancies, we work both as strategic advisors and are deeply involved in the implementation phase of our projects, drawing on our hands-on experience of the operation and maintenance of energy facilities.

Strong focus on risk management

Risk management lies at the centre of our project management model and is conducted in order to anticipate possible challenges in relation to time, cost and quality. It involves the identification of risks and the proactive initiation of risk control and risk mitigation measures.



WORLD CLASS PROJECTS

WE EXECUTE PROJECTS OF PARAMOUNT IMPORTANCE TO OUR CLIENTS

AVEDØRE POWER PLANT, DENMARK - ONE OF THE WORLD'S MOST EFFICIENT MULTIFUEL POWER PLANTS

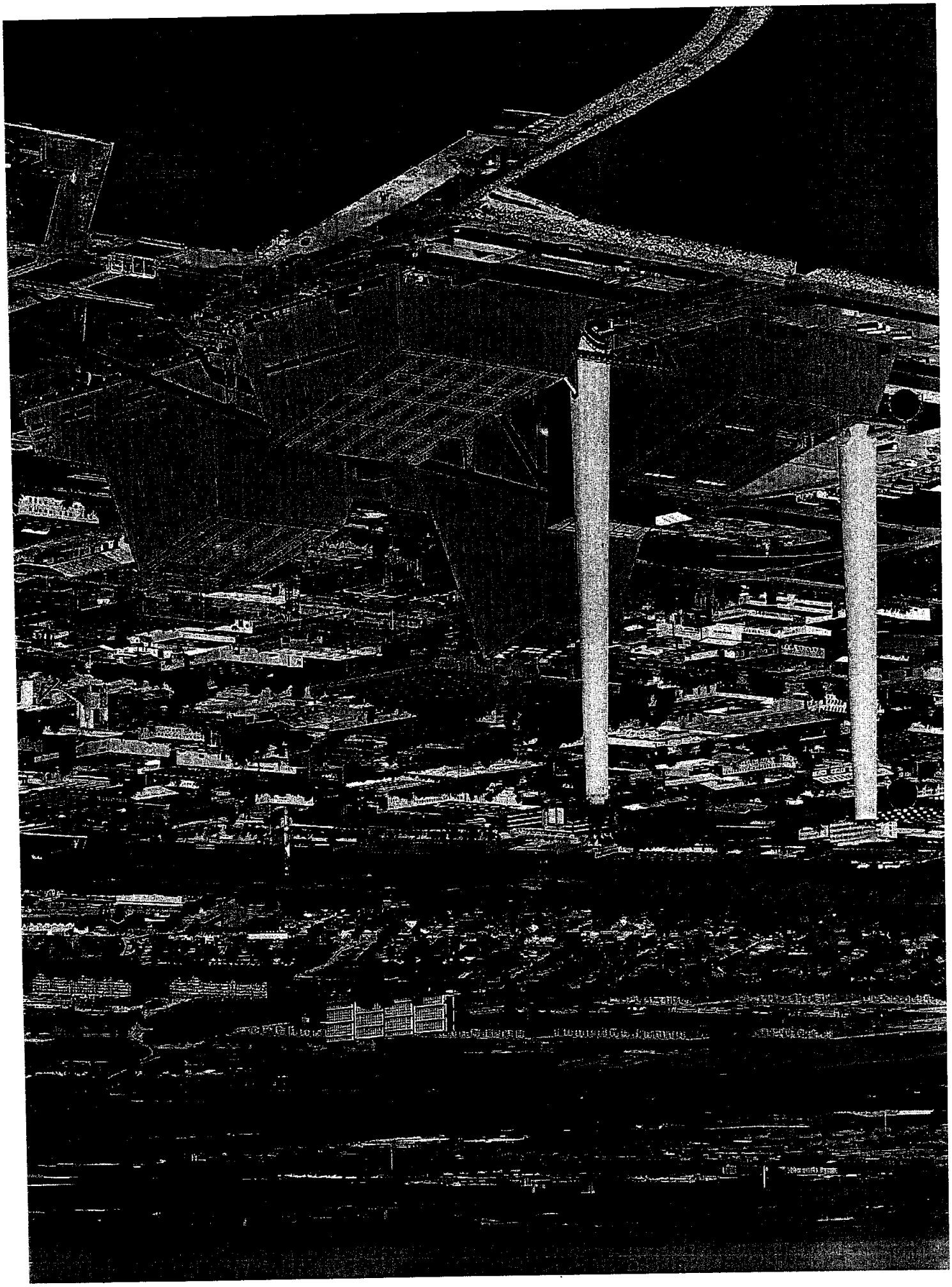
Since the conception of Avedøre Power Plant's Unit 1 in the 1980s, Ramboll has been a regular advisor to the owner Ørsted on a wide range of specialist issues. We have contributed to the development of the plant's continuous and flexible adaptations to new fuel types, leading up to today's state-of-the art multifuel production of power and heat for Copenhagen's district heating system (image p. 13).

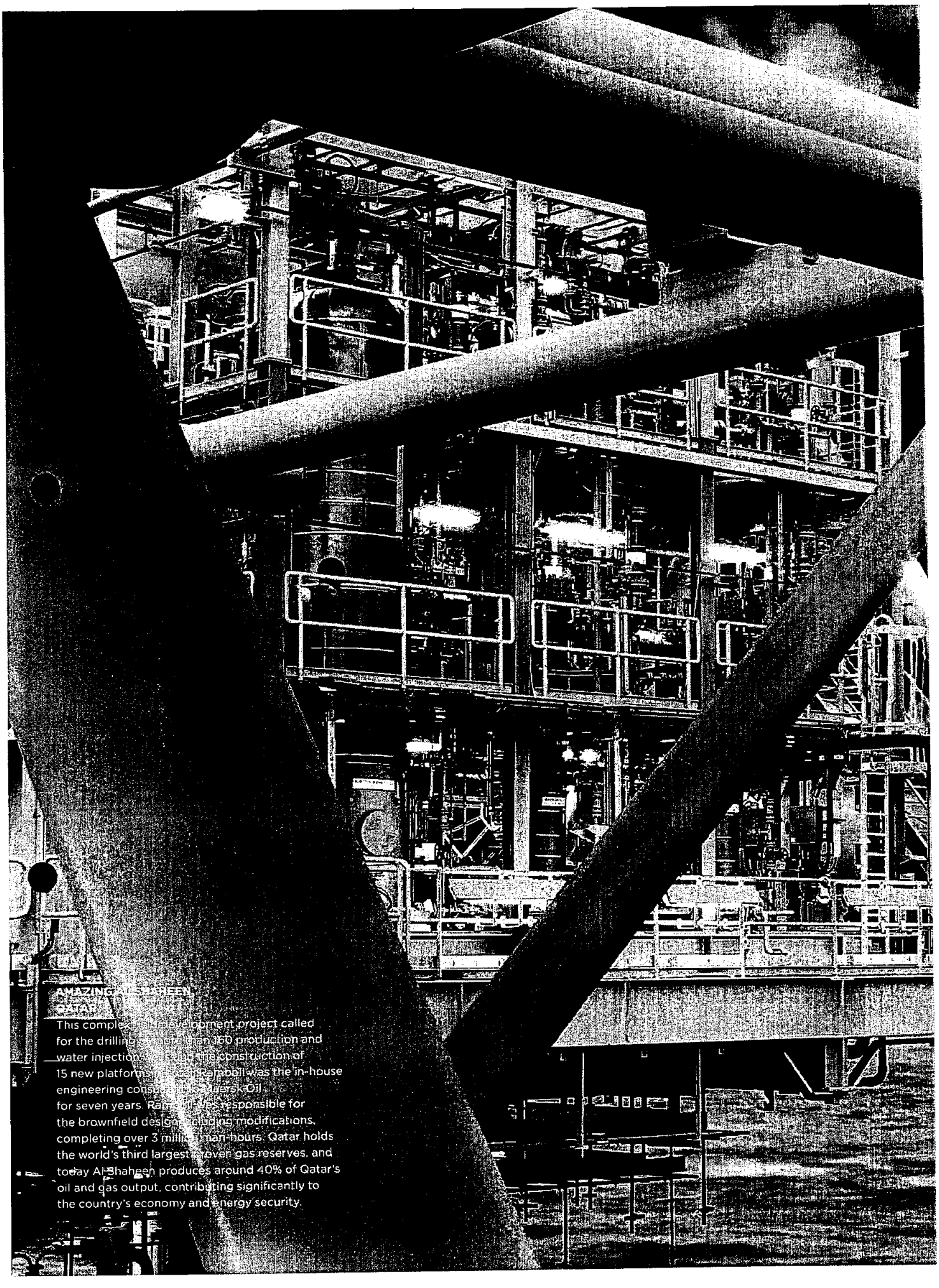
Our portfolio is unmatched by other consultancies and includes a wide range of projects developed across geographies. Each project represents a different challenge and a unique endeavour with specific requirements which demanded multidisciplinary competencies and knowledgeable management for its successful implementation.

Technology is our passion, and we maintain an unwavering engineering focus in everything we do. We are passionate about delivering world-class, high-quality solutions to our clients.

Through Ramboll's Project Excellence Platform, we bring together all aspects of project delivery and the associated enablers of continuous people development, clearly defined processes and governance, as well as effective knowledge sharing. This serves to maximise benefits for our clients by creating high value solutions, delivering project certainty, and nurturing strong and enduring relationships.

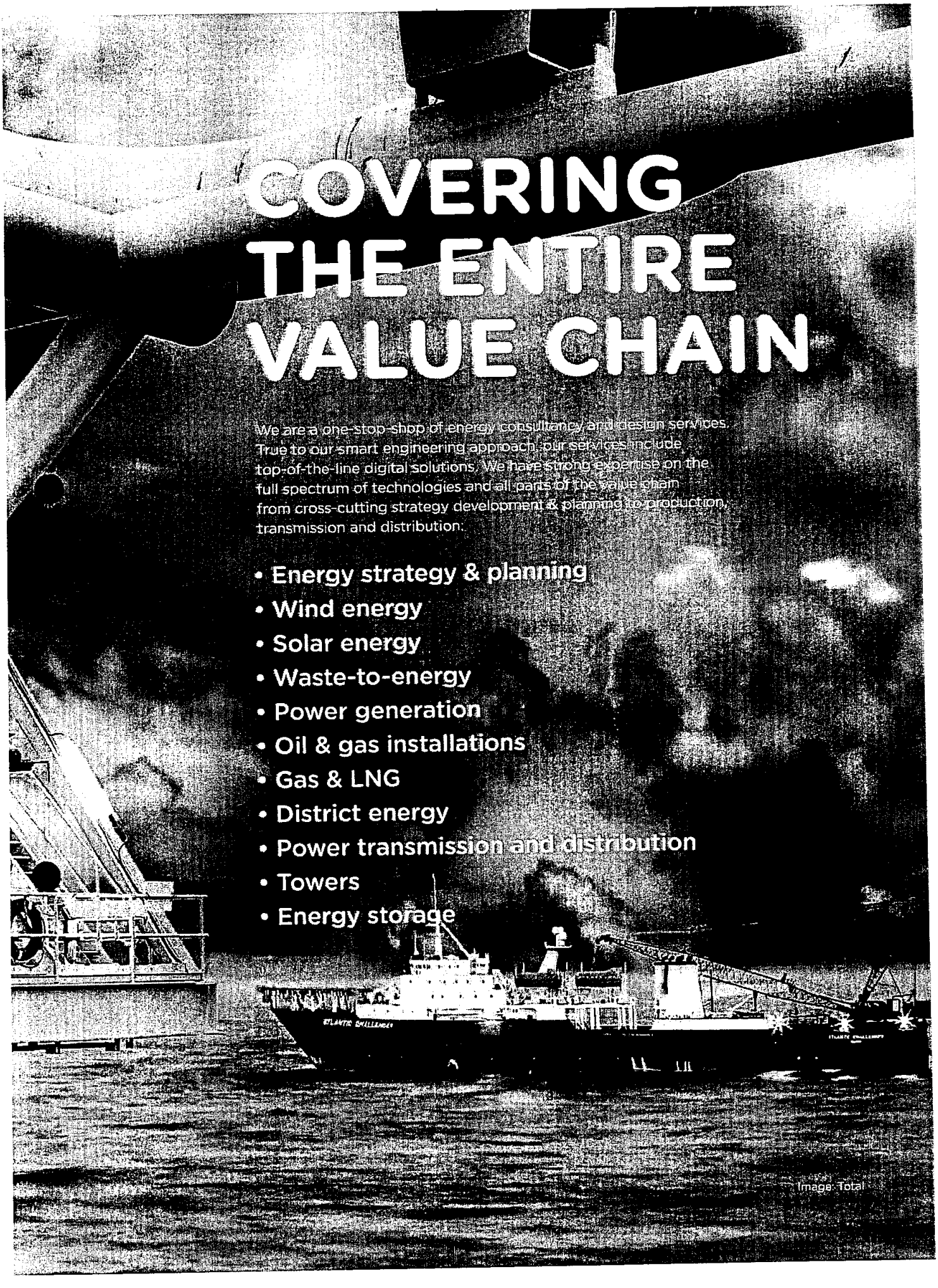
We enjoy a high client satisfaction rate as we are able to meet key success criteria such as deep technical insight and solutions tailored to our clients' requirements.





AMAZING [illegible]
QATAR

This comple[illegible] development project called for the drilling [illegible]en 160 production and water injection [illegible]e construction of 15 new platforms [illegible] Rampell was the in-house engineering cons[illegible] Maersk Oil for seven years. Ra[illegible] was responsible for the brownfield design, including modifications, completing over 3 millio[illegible] man-hours. Qatar holds the world's third largest proven gas reserves, and today Al Shaheen produces around 40% of Qatar's oil and gas output, contributing significantly to the country's economy and energy security.



COVERING THE ENTIRE VALUE CHAIN

We are a one-stop-shop of energy consultancy and design services. True to our smart engineering approach, our services include top-of-the-line digital solutions. We have strong expertise on the full spectrum of technologies and all parts of the value chain from cross-cutting strategy development & planning to production, transmission and distribution.

- Energy strategy & planning
- Wind energy
- Solar energy
- Waste-to-energy
- Power generation
- Oil & gas installations
- Gas & LNG
- District energy
- Power transmission and distribution
- Towers
- Energy storage

Image: Total

ENERGY STRATEGY & PLANNING

DRAWING ON CROSS-SECTOR AND MULTIDISCIPLINARY CAPABILITIES

STRATEGY DOCUMENTS

- Energy supply & demand forecast
- Energy supply strategies
- Energy delivery planning and design
- Storage solutions
- Smart energy
- Energy efficiency & demand side management

BUSINESS CASES

- Investment planning
- Circular economy
- CAPEX, OPEX & ABEX assessments
- Lifecyle assessment ISO55000
- CBA - international best practice

POLICY

- Regulatory analysis & compliance
- Security of supply
- Market models
- Subsidies and frameworks

DUE DILIGENCE

- Commercial & financial
- Technical & operational
- Environmental assessment
- Risk assessment

Ramboll is a strategic partner to international and domestic clients offering proven commercial, financial and engineering consulting capabilities to assist our clients with the development of strategy documents, business cases, policy and due diligence studies.

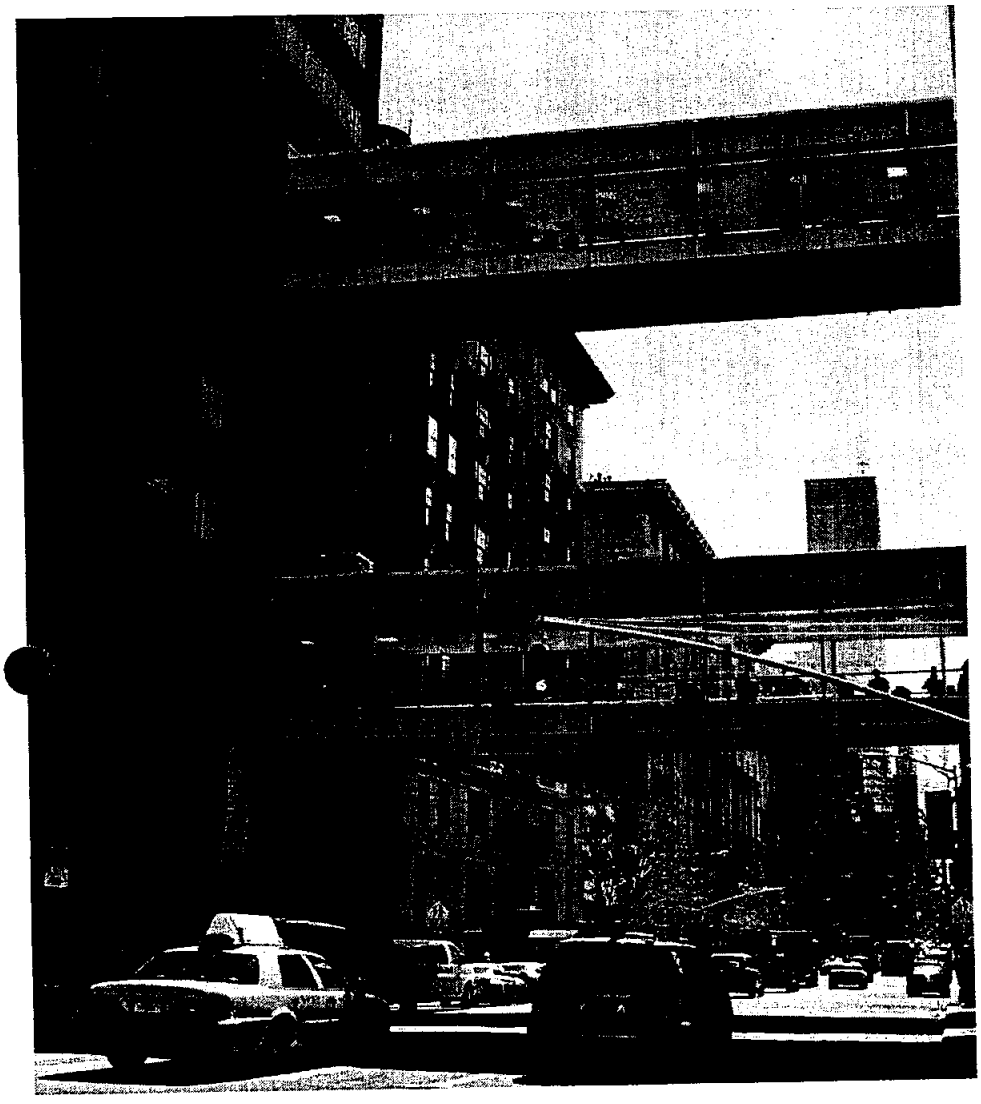
We add value to projects by having full local knowledge across Europe, North America, Middle East and Asia to provide understanding of the energy lifecycle and the interaction of the different elements in the energy system.

We provide solutions to the challenges of our client: cities, universities, governments and the EU; investors; generators; transmission system operators; distribution system operators; and large consumers.

We offer a core energy strategy and planning team as the single point of contact within Ramboll for the development, execution and implementation of projects globally.

The core team draws on Ramboll expertise in 300 offices in 35 countries to offer our clients the advantage of a global platform with leading energy sector experts and local knowledge across Europe, North America, Middle East and Asia to provide the right knowledge for the right geography.

The team draws on Ramboll's multidisciplinary capabilities, e.g. within buildings, environment & health, management consulting and transport.



ENERGY MASTER PLANNING AT THE CITY UNIVERSITY OF NEW YORK, US

The City University of New York (CUNY) is the nation's leading urban public university. It serves over 500,000 students from 25 campuses, 300 buildings and almost 2.5 million square metres of building space, and it has an annual energy spend of nearly USD90 million. OBG, now Ramboll, has been assisting CUNY with their New York City Carbon Challenge since 2007, having developed climate action plans that identify CUNY's strategy to reduce carbon intensity by 40% by 2030.

CARLSBERG – NEW URBAN DISTRICT IN COPENHAGEN

In 2009, Carlsberg's production moved to a new site in Denmark, leaving a 330,000 m² industrial site in Copenhagen open for development. It was the vision to create a new sustainable district in Copenhagen with housing, shops and office buildings in harmony with the historical old buildings and the neighbouring districts. Ramboll planned the infrastructure with a focus on sustainable energy supply.

WIND ENERGY

WORKING WITH WIND ENERGY SINCE 1986

OFFSHORE
Over 60% of the world's offshore wind turbines rise from foundations engineered by Ramboll.

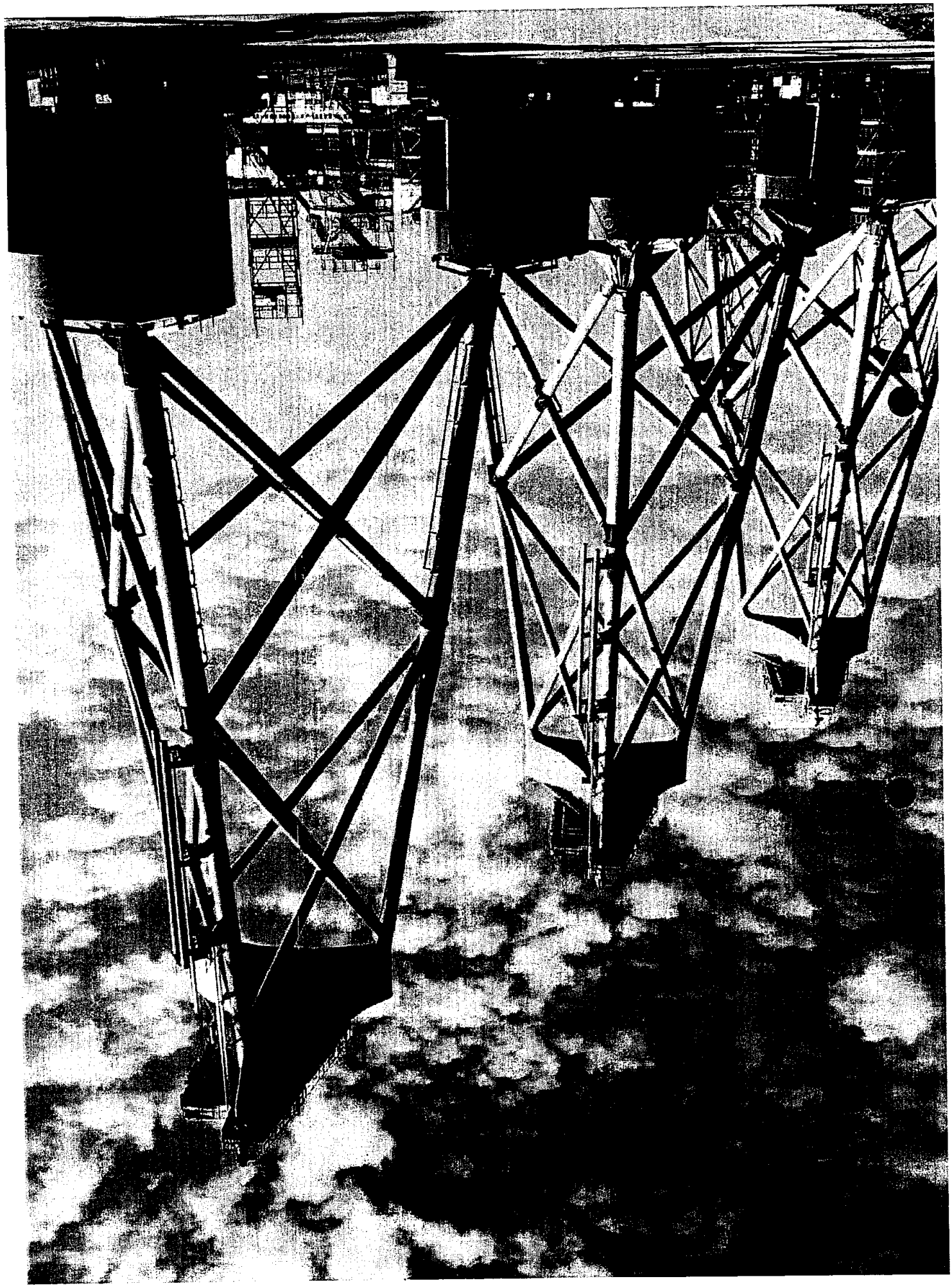
ONSHORE
We have provided expert input to onshore wind farms with a nominal output of more than 60 GW in +60 countries.

ONSHORE WIND FARM RASKIFTET, NORWAY
The public utility of Munich in Germany, Stadtwerke München GmbH (SWM), intends to generate sufficient green energy [illegible]ts plants to cover all energy consumption in Munich by 2025. As part of this endeavour, SWM has invested in several onshore and offshore wind farms in recent years, including Raskiftet Onshore Wind Farm in Norway. On behalf of SWM, Ramboll provided technical due diligence services including yield calculations and was subsequently commissioned for the supervision of the construction process as the Owner's Engineer.

OFFSHORE WIND FARM BORKUM RIFFGRUND I
Ramboll contributed to Ørsted's successful installation of the world's first offshore wind turbine foundation based on the Suction Bucket Jacket (SBJ) technology. The scope of our work included the design of the SBJ for the offshore wind farm Borkum Riffgrund I, 37 km off the German island of Borkum. The SBJ was designed with three cup foundations that are slipped into the seabed through suction. It can be installed in a single lifting and assembly process, which reduces installation time and its associated costs. It also has a quieter installation, meeting the new noise restrictions set to protect local ecosystems (image p. 19).

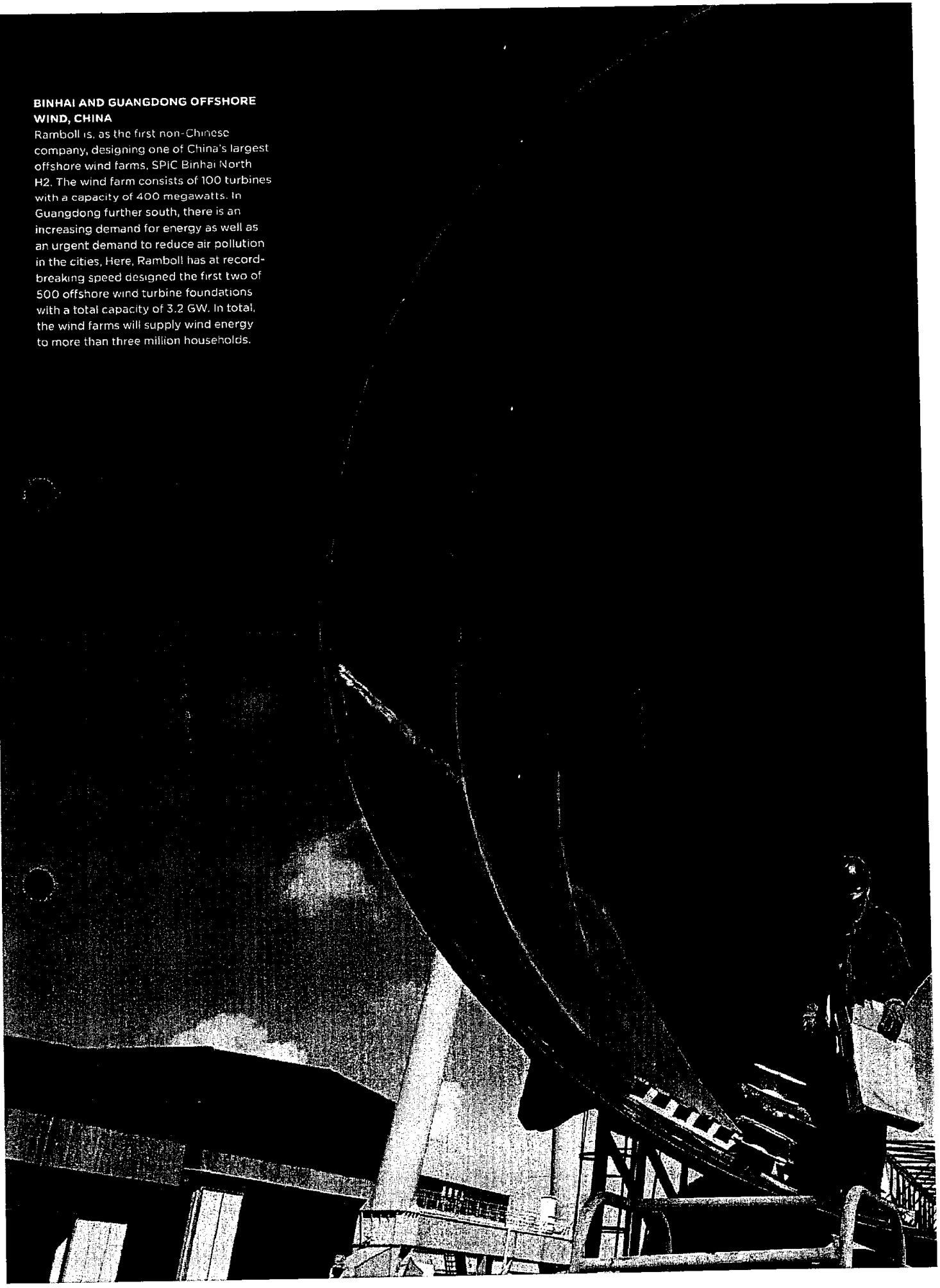
With the rapid growth of wind energy production worldwide, Ramboll offers our clients international, multidisciplinary and wind specific competencies. We offer expert services for the different project phases from early feasibility, business case and impact assessment studies to planning, engineering, implementation, commissioning and the subsequent operation & maintenance and eventually life-time extension or decommissioning.

We can effectively manage the entire project or contribute with our expertise in different sub-projects according to our client's needs. Ramboll is a full-service consultancy and wind energy leader with global knowledge and a network of offices and resources that serve clients locally.

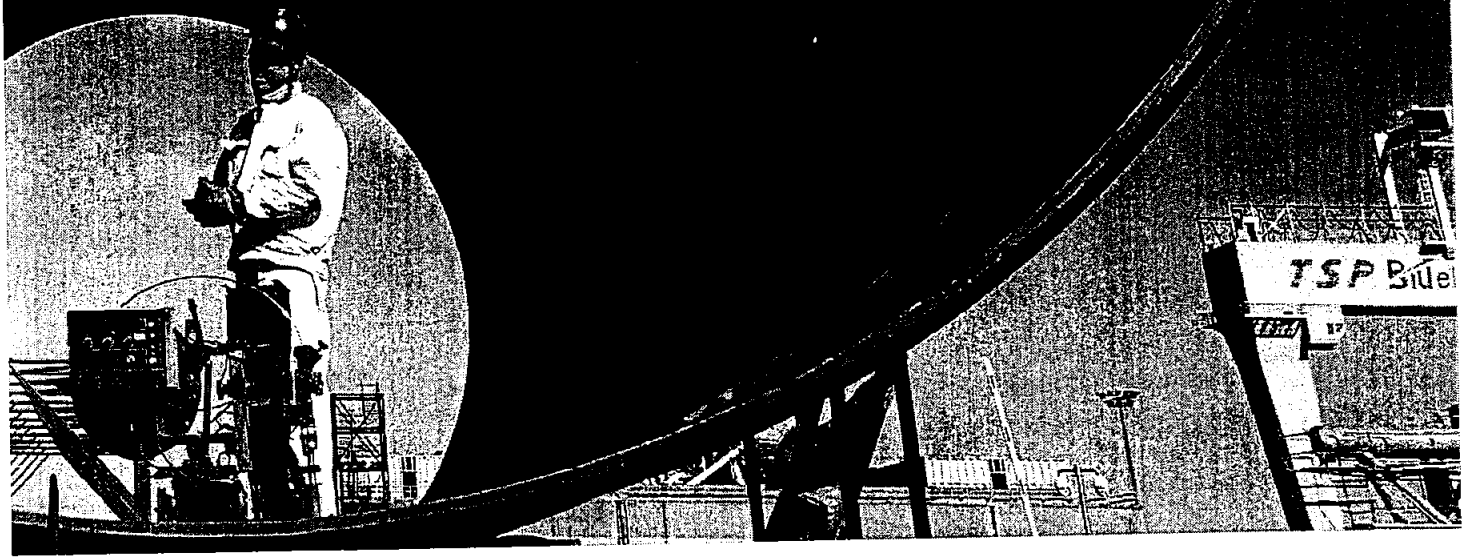


BINHAI AND GUANGDONG OFFSHORE WIND, CHINA

Ramboll is, as the first non-Chinese company, designing one of China's largest offshore wind farms, SPIC Binhai North H2. The wind farm consists of 100 turbines with a capacity of 400 megawatts. In Guangdong further south, there is an increasing demand for energy as well as an urgent demand to reduce air pollution in the cities, Here, Ramboll has at record-breaking speed designed the first two of 500 offshore wind turbine foundations with a total capacity of 3.2 GW. In total, the wind farms will supply wind energy to more than three million households.



MAKING CLEAN WIND ENERGY AVAILABLE TO 3 MILLION HOUSEHOLDS IN CHINA



SOLAR ENERGY

SOLAR HEATING
The best managed and optimised solar heating facility can utilise more than 45% of the annual solar radiation and convert this to district heating. Our experience includes consultancy services provided to both large-scale and small-scale solar heating plants, ranging from 200m² to more than 75,000 m².

SOLAR PV
Ramboll has over 15 years of experience working with solar energy. We have contributed to the success of more than 500 small to utility scale solar PV power projects, carried out in more than 25 countries around the world.

CAPITALISING ON THE LARGEST SOURCE OF ENERGY ON EARTH

With smart engineering at the core of our work, Ramboll is a world leading consultant and auditor, providing a full range of solar services. We assist our clients with comprehensive advice and future-proof solutions based on expert knowledge and state-of-the-art technology.

Solar PV

Our multidisciplinary structure enables us to offer holistic services covering every aspect of a solar PV project worldwide. Specialised teams are assembled from across the entire Ramboll group to ensure that the strongest expertise is applied to each individual project. Our services within solar PV range from expert planning, engineering and project management to resource and financial assessments, as well as other specialist studies including ESIA, grid impact studies, and performance monitoring.

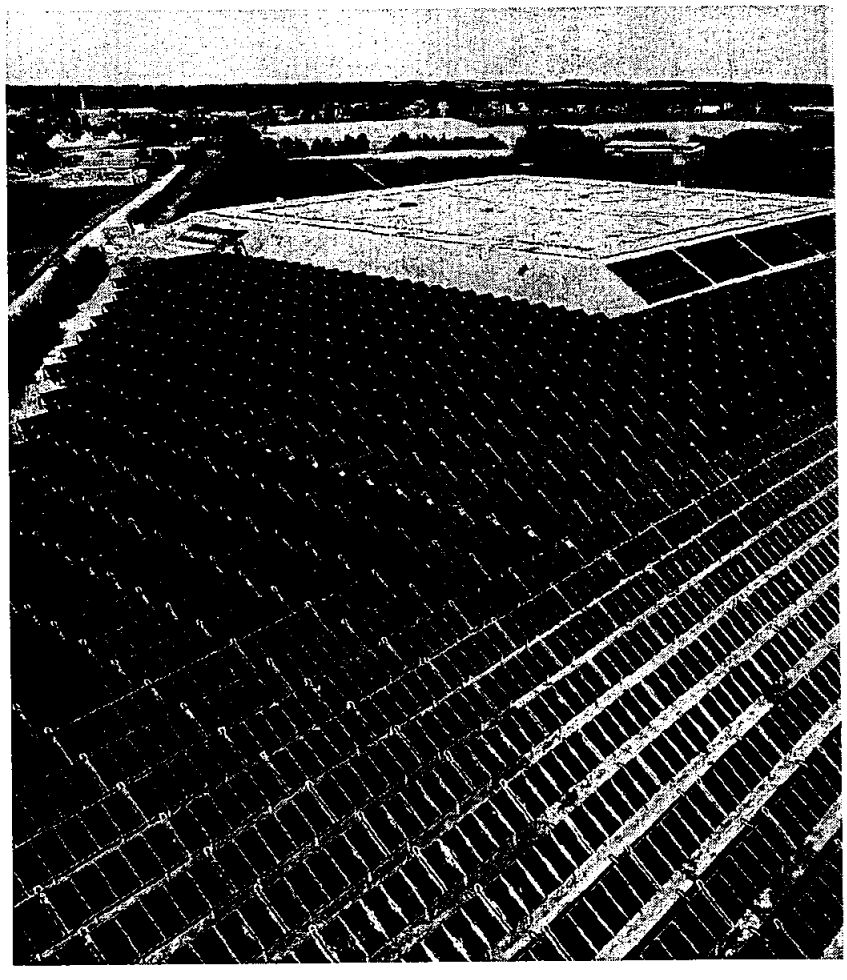
As a one-stop-shop of energy services, we offer singular, modular and tailor-made solutions for individual project requirements throughout the entire project life. With our multidisciplinary approach we provide innovative, efficient and cost-effective solutions for all kinds of solar PV projects, including solar PV power plants for IPPs and utilities, solar PV for commercial clients with self-consumption and solar PV as a substantial part of hybrid energy systems. For every project, we always strive for sustainability and with that in mind, we place the focus on designing long-lasting solutions.

Solar heating

Large-scale plants are a special Scandinavian concept for solar heating, supplying energy to the local district heating network through a heat accumulator. Ramboll has participated actively in the development of these solar heating plants and performed research into the latest technologies and underground storage systems. We also provide consultancy services relating to their integration into existing heating and combined heat and power plants.

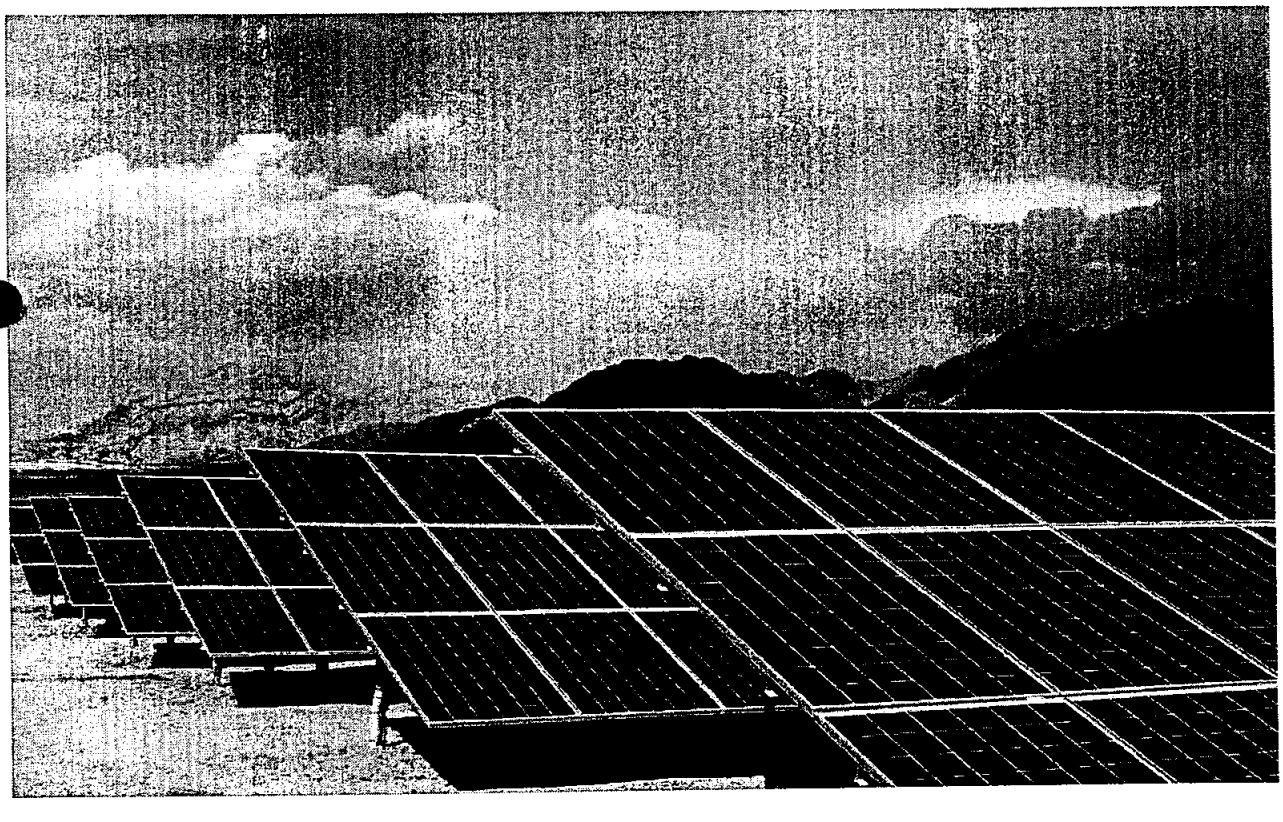
BOOSTING SOLAR HEATING IN DENMARK

In cooperation with Ramboll, three Danish municipalities in southern Jutland - Logumkloster, Vojens and Gram - converted to new flexible district heating solutions. For Logumkloster, Ramboll devised a strategic master plan for heat production that considered a series of heat production technologies, including different types of electric heat pumps, absorption heat pumps, solar heating and thermal storage of various sizes, biomass boilers, electric boilers as well as optimisation of existing gas. In Gram, Ramboll assisted our client in tripling the size of its solar heating facility.



SHAMSUNA SOLAR PV, JORDAN

Acting as the Owner's Engineer for the first utility scale (10 MW) solar PV plant in Jordan, Ramboll provided technical support throughout the whole project including feasibility, development, planning & design, EPC tendering process, construction supervision and commissioning.



WASTE-TO-ENERGY

EXPERIENCE
Ramboll has worked on waste-to-energy projects in 45 countries, providing consulting services for 155 new units and retrofits.

LEADING WASTE-TO-ENERGY CONSULTANT

As the world population and energy consumption increase there is a pressing need for the reduction of waste generation, high-quality recycling and the use of residual waste for efficient and clean energy generation.

Recovering energy from waste
Ramboll is the world's leading waste-to-energy consultant with unmatched technical insight.

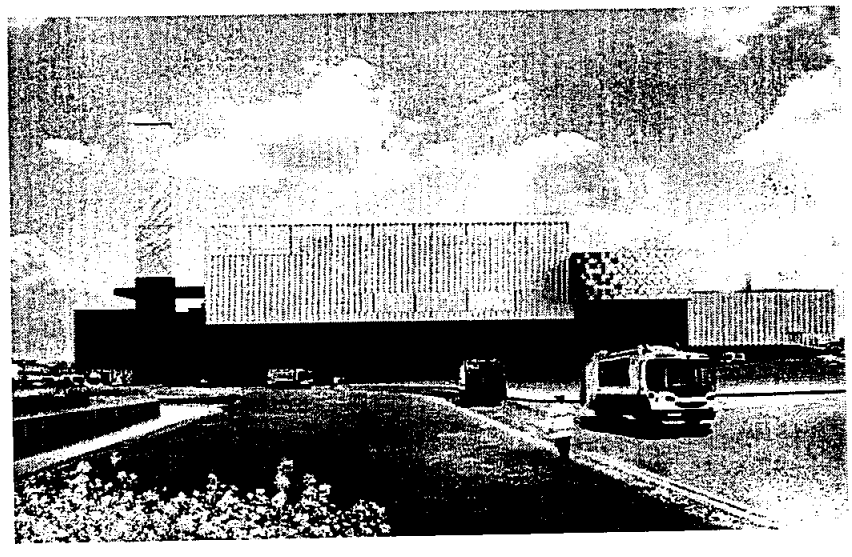
We have an extensive portfolio of successfully completed projects that involved the planning, engineering, procurement and contract management of waste management facilities. We assist our clients through all phases of the project – from idea to operation – and the combination of our experience and expertise means that we can provide no-learning-curve client support.

Our holistic specialist knowledge covers all aspects of asset management, including upgrades and retrofits, and always with a focus on cost and process optimisation.

Biogas from waste
Organic waste has become an important raw material for boosting biogas production from both manure and sewage sludge. Biogas can be used locally for the generation of electricity and heat or it can be upgraded for injection into the natural gas network or utilised as a transport fuel. Ramboll has many years of experience in the successful implementation of biogas projects. Our technical expertise enables us to handle the specific challenges that arise when using organic waste for the production of biogas.

WASTE-TO-ENERGY FACILITY IN LONDON, UK
Ramboll is acting as Technical Advisor to North London Waste Authority (NLWA) on the delivery of its North London Heat & Power Project. Ramboll is leading the design development of a new state-of-the-art 700ktpa waste-to-energy facility with combined semi-dry/wet flue gas treatment to meet Best Environmental Practice. We have also conducted thorough technical assessments of the existing waste-to-energy facility to establish its condition and future expected performance, preparing recommendations for investment requirements and costs over short-term and medium-term horizons.

ICONIC AMAGER BAKKE, DENMARK
Amager Bakke is one of the most efficient waste-to-energy facilities in the world. As the Owner's Engineer, Ramboll has assisted in the planning and implementation of the 560,000 tpa facility, which produces 20% more energy per tonne of waste compared to the plant that it replaces and has emission levels far below limit values. The facility is fully integrated into the urban setting, surrounded by high-end flats, and features a ski slope and other recreational facilities on the roof (image p. 25).



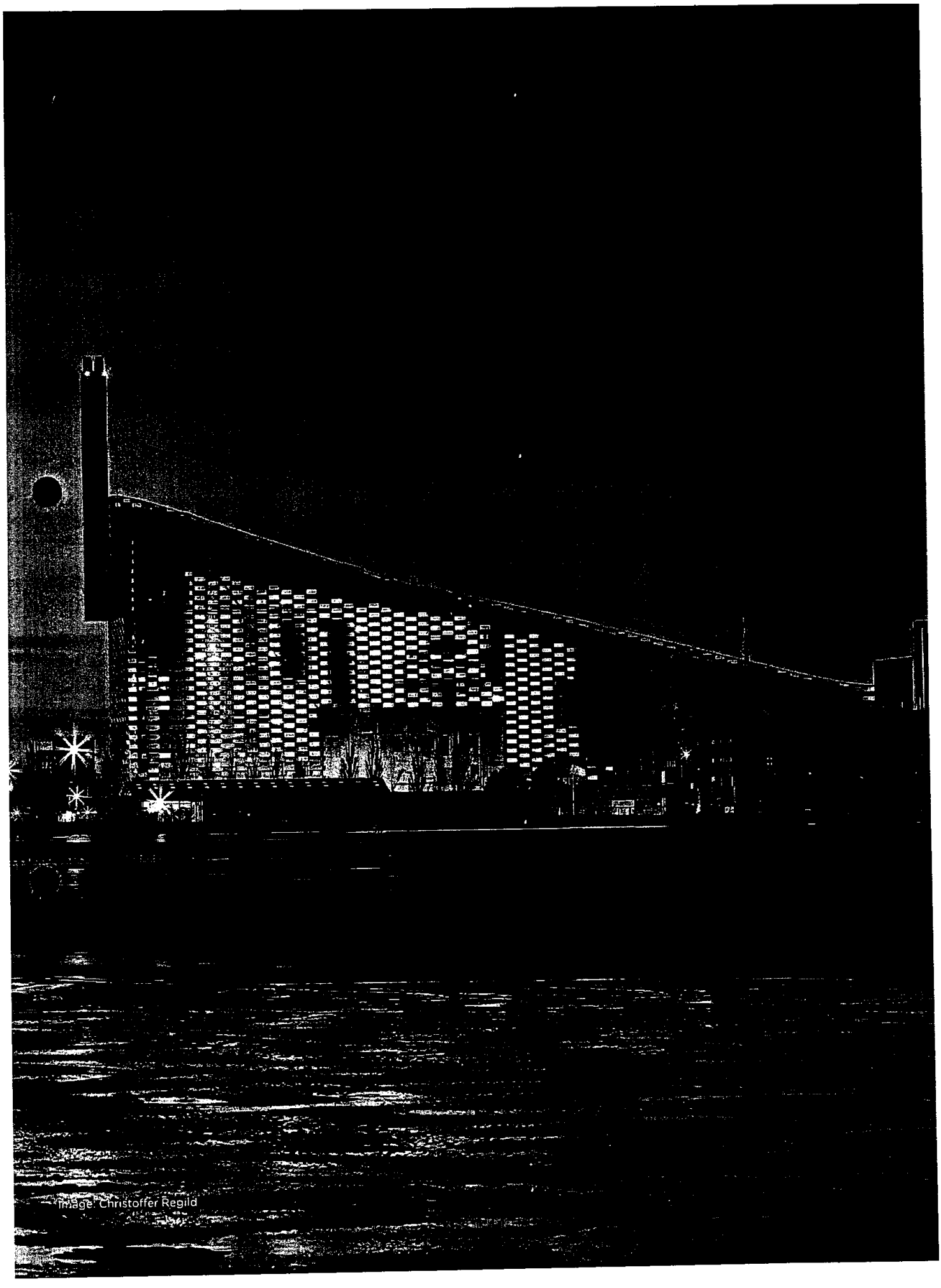


Image: Christoffer Regild

POWER GENERATION

EXPERIENCE
Ramboll has designed and constructed more than 100 major power plants, including some of the most energy efficient plants in the world and has been instrumental in the ongoing conversion from fossil fuels to biomass.

INCREASING ENERGY EFFICIENCY WHILE REDUCING CLIMATE IMPACTS

As the world shifts towards a sustainable energy mix, there is a need for thermal power generation plants to reduce emissions, by maximising efficiency or alternatively by switching to the use of renewable fuels such as biomass. Similarly, there is a need for plants to operate more flexibly as the level of intermittent energy sources increases.

Ramboll has pioneered the development of innovative power plants worldwide, having particular expertise in high efficiency power plants, biomass and bioconversions, and cogeneration (CHP).

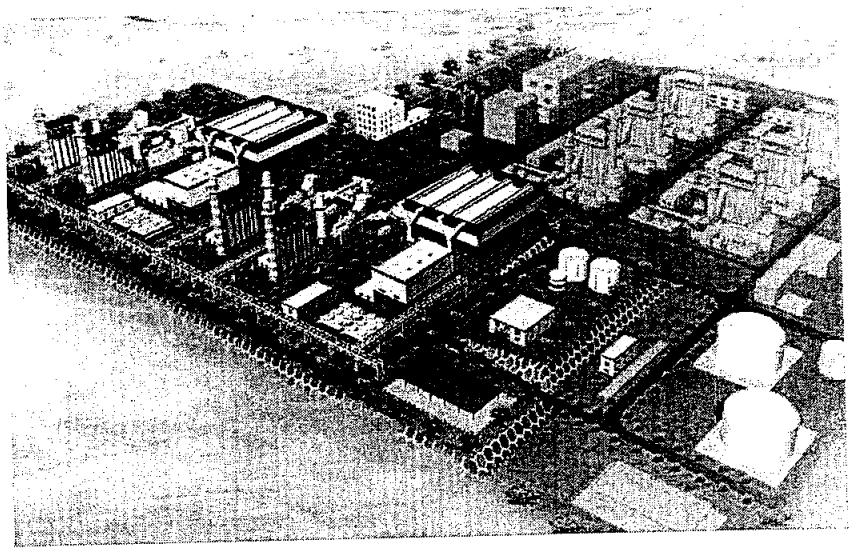
We have extensive experience in the design and implementation of flexible, fuel efficient combined cycle and major thermal power plants, including expertise in supercritical and ultra-supercritical boiler plants.

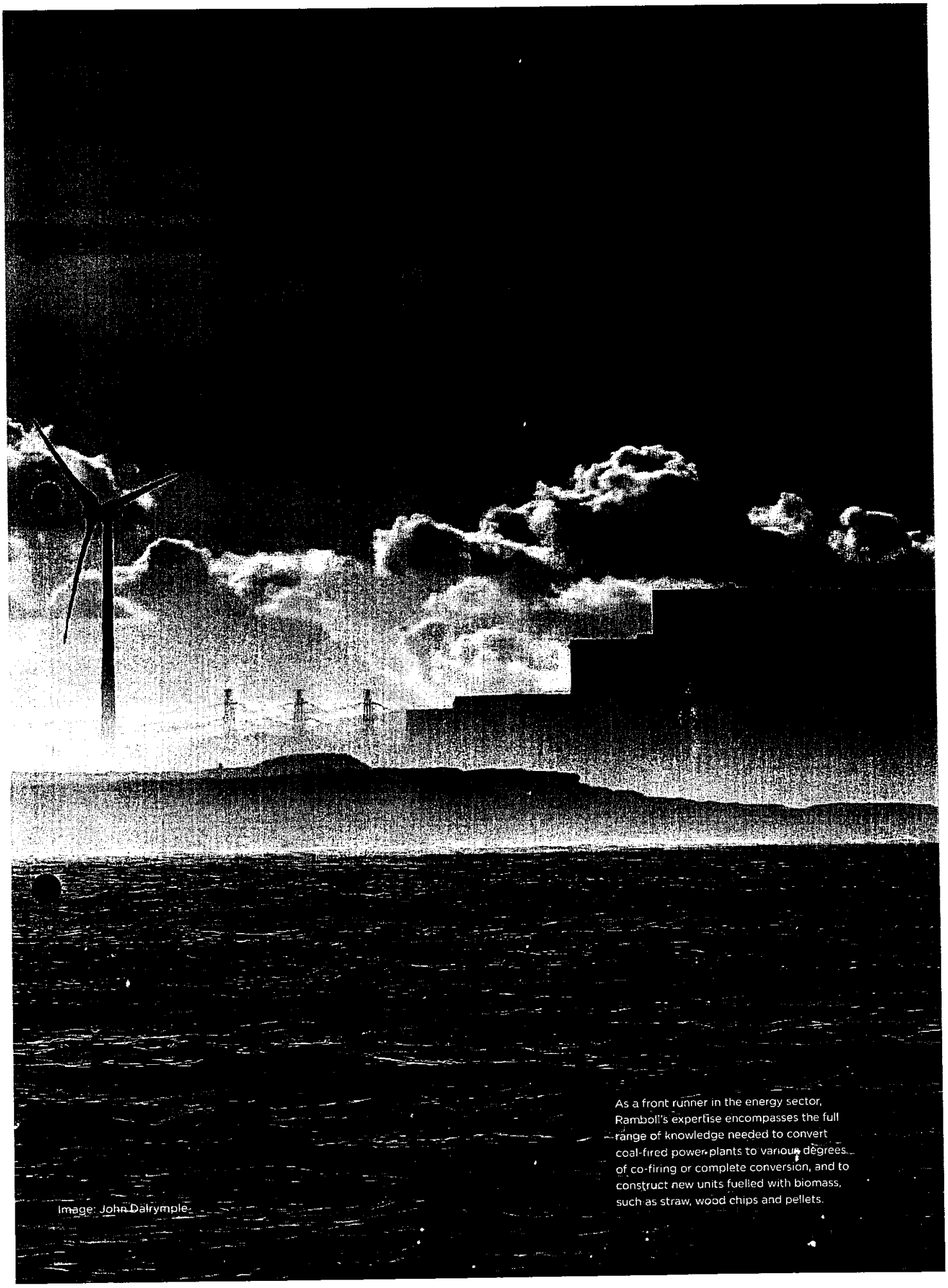
Our unique position has been acquired through our contribution to the detailed development and implementation processes of some of the world's most efficient power plants.

Our specialist knowledge covers the full project life-cycle, from early feasibility study stages through to implementation and subsequent operations and maintenance support, failure investigation, and power plant rehabilitation and upgrades. Throughout all phases we always strive to set and achieve the highest standards of health and safety of a project and subsequent plant operation.

TECHNICAL ADVISOR FOR POWER PLANT IN SALALAH, OMAN
Ramboll was selected by Oman Power and Water Procurement Company SAOC to be the technical advisor to the electricity off-taker of the Salalah II IPP Power Plant. The project resulted in a highly efficient plant with an energy conversion that went from 32% in the existing plant to 54% in the new plant. The new plant has a lower fuel consumption and reduced emissions.

LYNEMOUTH POWER PLANT CONVERSION TO BIOMASS, UK
Ramboll provided engineering consultancy services to the conversion of Lynemouth Power Plant from coal to biomass. The converted plant exports around 390MW of low-carbon electricity to the national grid. Wood pellets are imported to the plant from global fuel supply markets, via a newly constructed biomass import terminal at the Port of Tyne (Newcastle UK), which along with the power plant and site fuel storage and handling, also fell within the scope of Ramboll's work (image p. 27).





As a front runner in the energy sector, Ramboll's expertise encompasses the full range of knowledge needed to convert coal-fired power plants to various degrees of co-firing or complete conversion, and to construct new units fuelled with biomass, such as straw, wood chips and pellets.

Image: John Dalrymple

OIL & GAS INSTALLATIONS

RAMBOLL IS INTERNATIONALLY KNOWN FOR OUR OPTIMISED OIL & GAS DESIGN SOLUTIONS

RECORD BREAKER
Ramboll broke the world record for deep water installation of a 36" pipeline.

As global energy consumption continues to grow, oil and gas will continue to play an important role in the world's energy mix for many years to come.

To make it in today's fast-paced and competitive oil and gas market, companies depend on advanced technical solutions that combine economic efficiency with stringent health, safety and environmental standards in the production and distribution processes. These elements form an integral part of Ramboll's independent and multidisciplinary consultancy service, which covers the entire asset life cycle - from early phase studies, FEED, detailed engineering, modifications, maintenance and lifetime extension to decommissioning.

We excel in consultancy and have designed offshore structures for industry giants such as Total, ConocoPhillips, INEOS and Equinor since the 1970s.

Ramboll works across the oil and gas sector, covering engineering services within energy & infrastructure consulting, offshore production facilities, onshore production & refining, pipelines, and Gas & LNG.

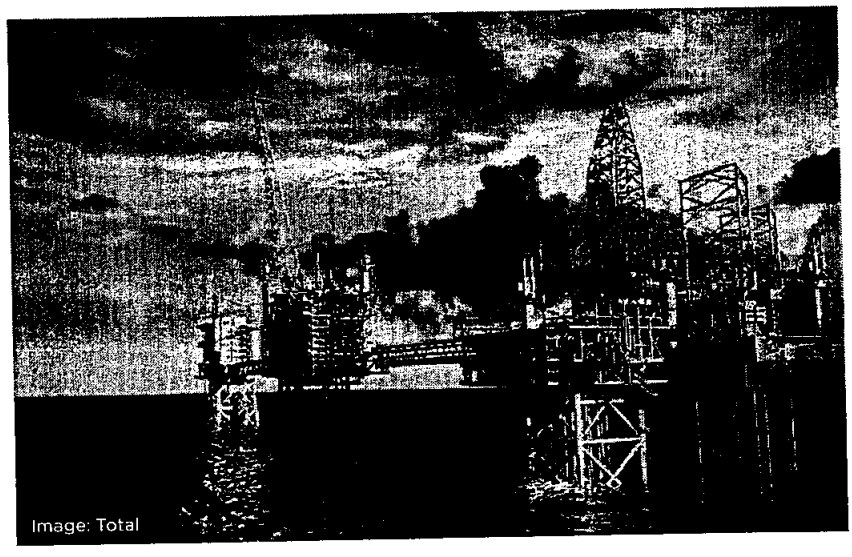
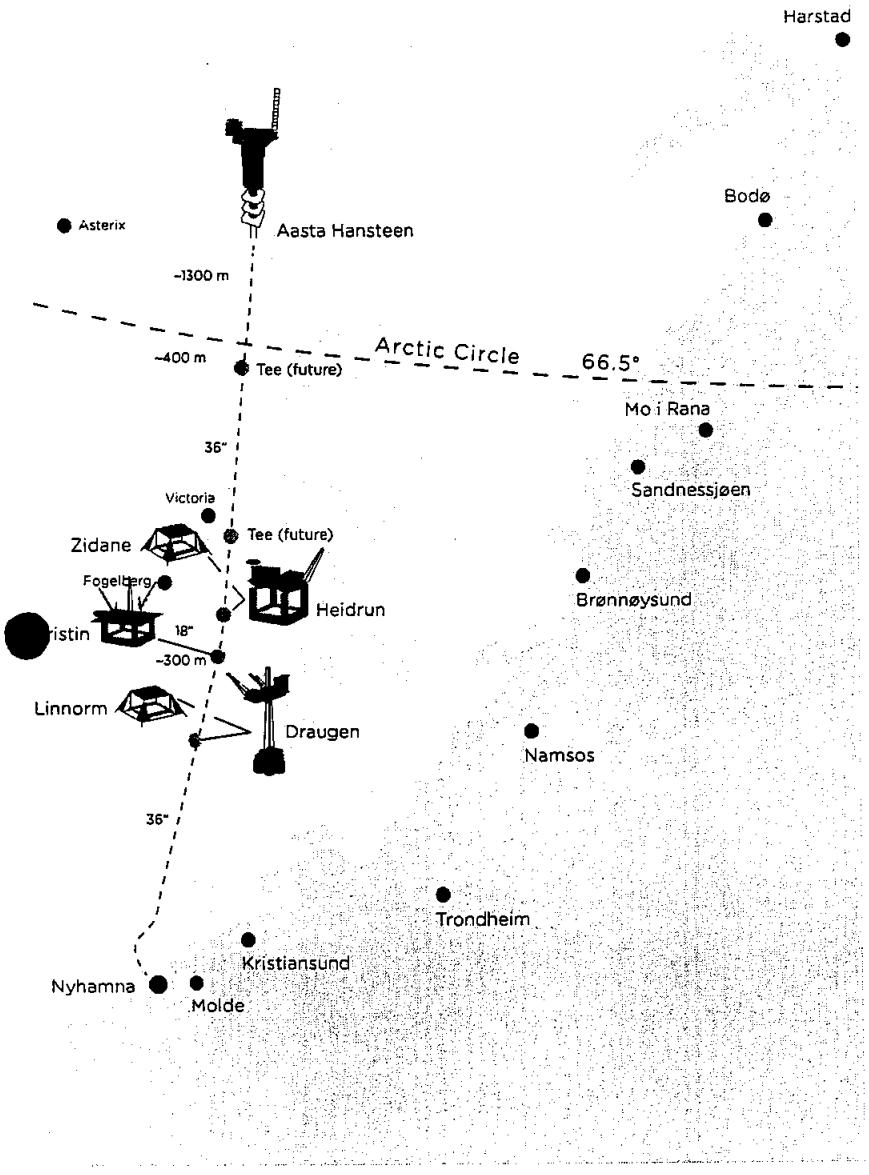


Image: Total

EMARKABLE CULZEAN
The Culzean field was discovered in 2008 and is one of the largest fields in the British North Sea. With temperatures reaching 170 degrees C and the pressure being three times higher than average fields, a platform optimised for these conditions is paramount. Ramboll carried out the detailed design of three jackets for Maersk Oil (now Total).

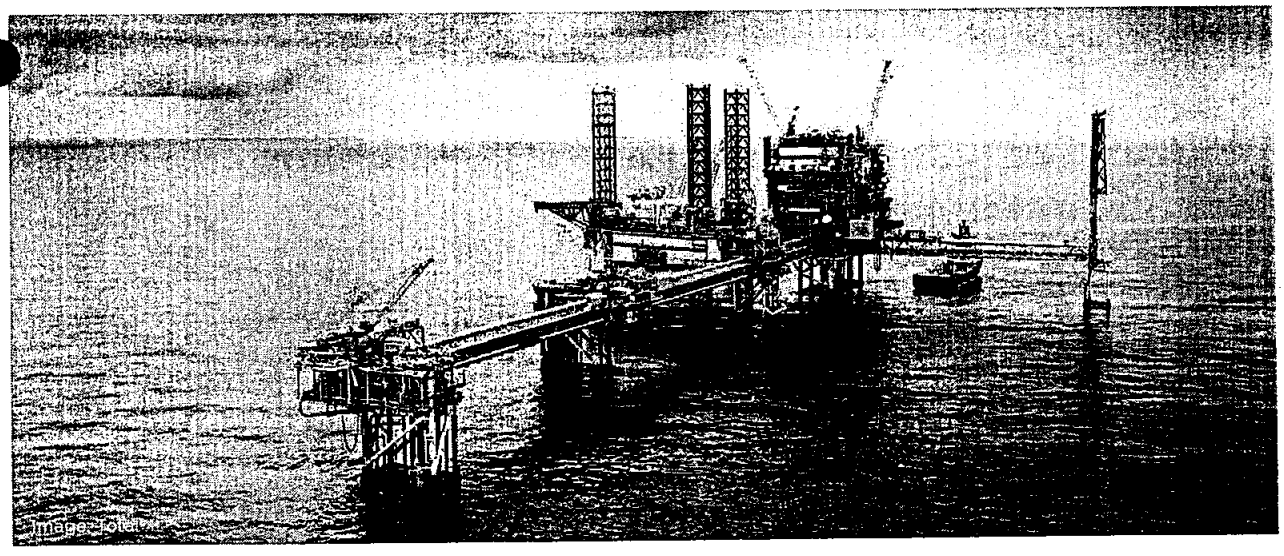


RECORD-BREAKING POLARLED PIPELINE

This unprecedented 482 km pipeline crossing the Arctic Circle on an extremely uneven seabed connects new fields in the Norwegian Sea with existing infrastructures to secure future energy supply in Europe. The pipeline was installed at water depths reaching 1,265 m, setting a world record for deep water installation of a 36" pipeline. Ramboll was instrumental in designing the pioneering technical solution for the pipeline, incl. FEED, detailed design, route optimisation, pipeline tie-in, geotechnical foundation design, risk and safety, EIA, and interface coordination.

INVESTIGATING TWO CONCEPTS FOR THE TYRA FIELD, NORTH SEA

The Tyra Field in the North Sea has been in production for thirty years, and the facilities are suffering from seabed subsidence, old age and increasing operating expense. Maersk Oil (now Total) was assessing several lifetime extension options to make continued operation feasible. For the Tyra Future redevelopment project, TFU, Ramboll carried out two pre-FEED (conceptual) studies. Concept 1 focused on examining the rebuild of Tyra East into an unmanned satellite producer, while concept 2 investigated an option to rebuild Tyra East as a field centre with new topsides for several of the existing wellhead and riser platforms.



GAS & LNG

GLOBAL FOOTPRINT
Ramboll's gas & LNG portfolio includes a worldwide geographical footprint, from Europe to Morocco, Uganda, Iraq, Qatar, Yemen and Venezuela.

BRIDGING THE GREEN TRANSITION

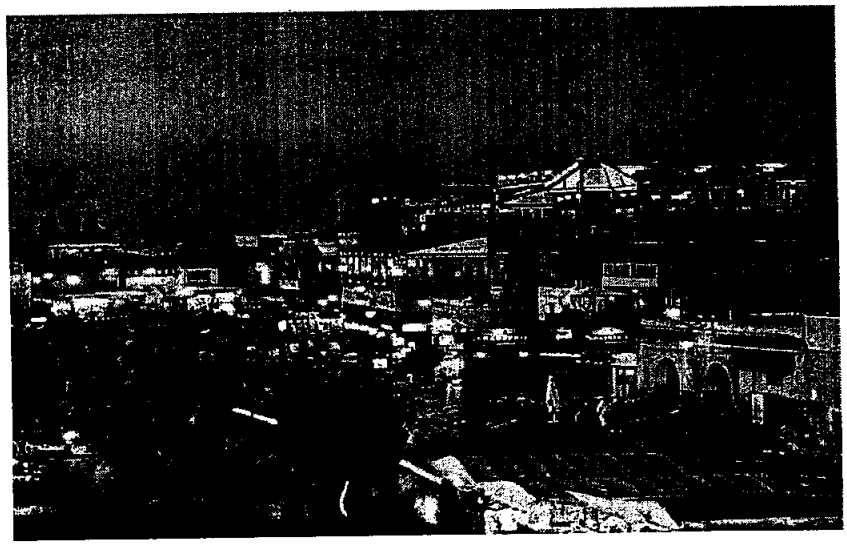
With modern society relying heavily on energy for its continuance and development, governments and energy companies alike are concerned with finding the right energy mix that will meet the demand while allowing the integration of renewable energy. As a future-driven consultancy, our expertise within energy and renewables can successfully be applied to gas projects, bridging the transition to cleaner energy forms.

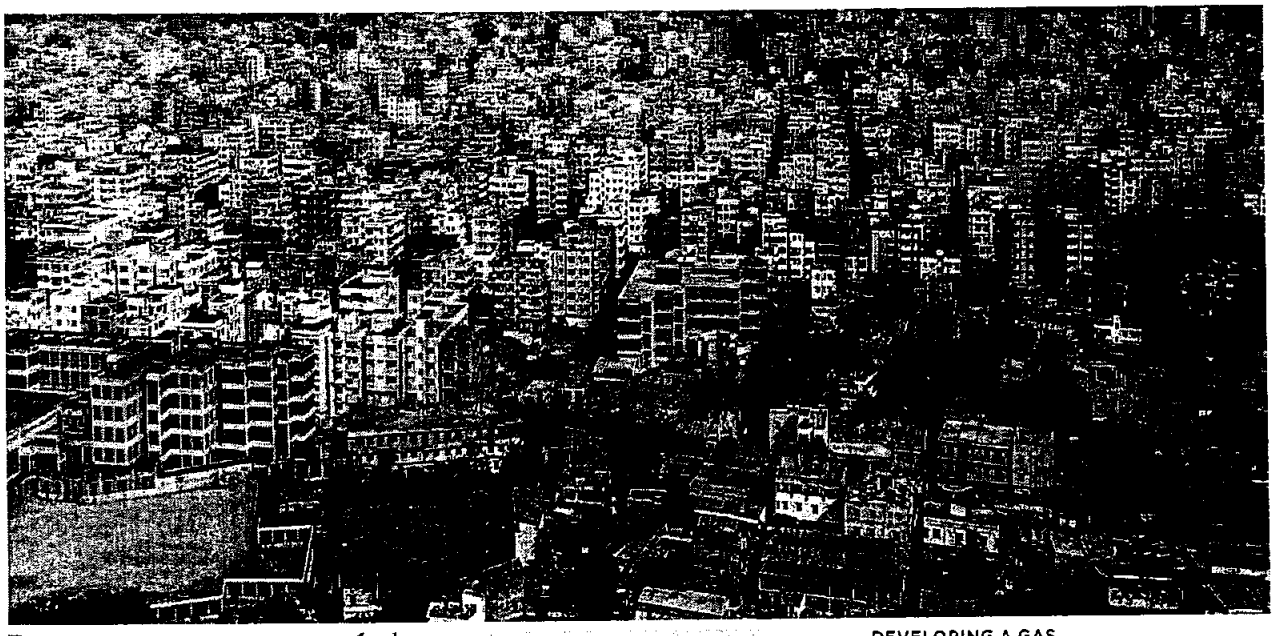
Gas forms a substantial part of the energy mix that keeps modern society running today, and will continue to do so in the future.

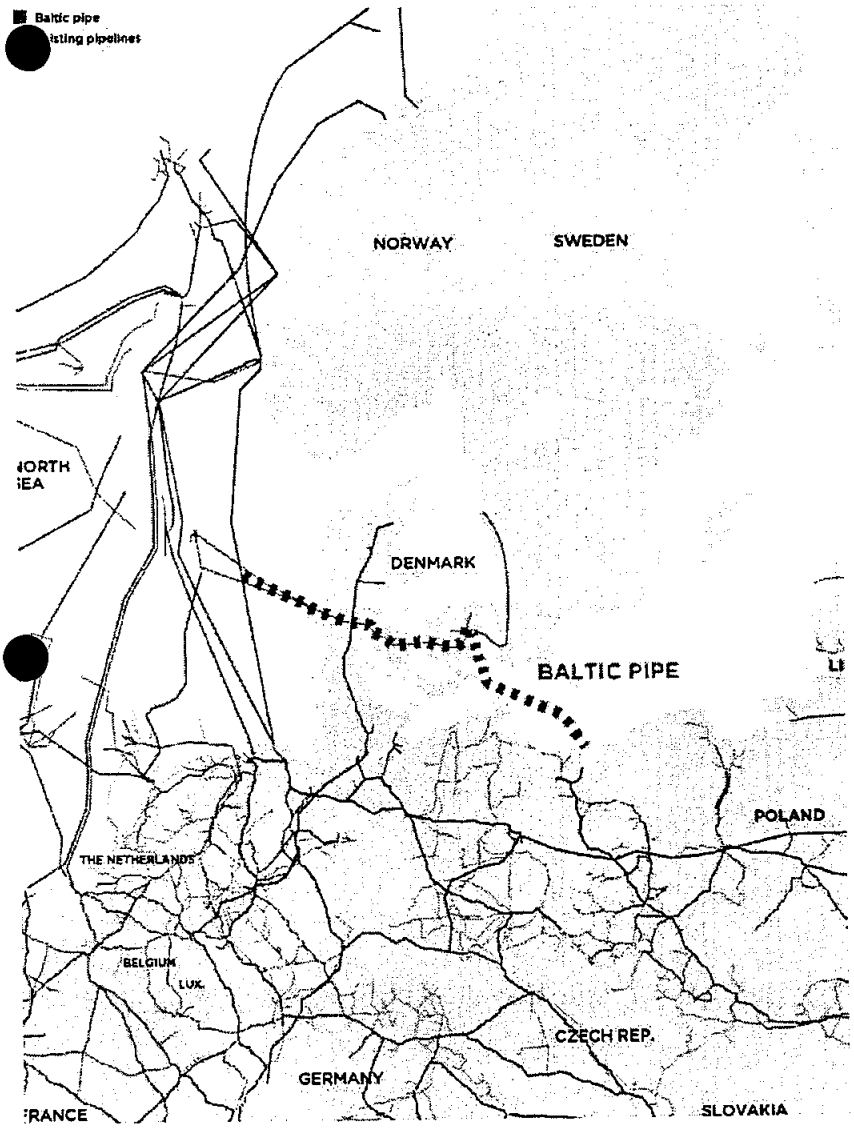
With origins in a gas-producing country, Ramboll perfectly understands energy providers' challenges and opportunities. Our holistic approach to gas & LNG solutions considers the socioeconomic, the environmental and the public and political factors that influence the market in order to provide the most profitable and efficient energy solutions in all the projects we are involved in.

Ramboll has provided the gas sector with multidisciplinary engineering solutions for the past four decades. Our expert know-how and unique experience range from onshore and offshore gas production to infrastructure projects.

TECHNICAL ADVISOR FOR GAS-TO-POWER PROJECT, MOROCCO
Ramboll was selected by Morocco's state power and water utility ONEE to act as the technical advisor to a gas-to-power project, in a joint venture with French partner Sofregaz. The gas-to-power project is part of a programme of ONEE to add 6 GW of flexible, largely gas-fired, power generation capacity, 4 GW of interconnectors with neighbouring countries, and 2 GW of pumped hydro, all by 2030. The planned LNG infrastructure and gas-fired power plants will enable Morocco to manage intermittency as it expands renewable capacity to over half of the installed mix in 2030.







DEVELOPING A GAS SECTOR MASTERPLAN FOR BANGLADESH

Ramboll was awarded the World Bank sponsored project for the development of the Bangladesh Gas Sector Master Plan, aimed at providing Bangladeshi authorities and state companies with a strategic and technical plan for the long-term development of the gas sector in the country.

TECHNICAL ADVISOR FOR THE BALTIC PIPE

Since finalising a feasibility study in 2016 and the EPII terminal feasibility study in 2017, Ramboll has been the technical advisor for the Baltic Pipe project. The Baltic Pipe is recognised as one of EU's projects of common interest (PCI) and aims to further strengthen the European internal energy market. The Baltic Pipe will provide affordable, secure and sustainable reliable energy not only in Denmark, Poland and Sweden, but also in Central and Eastern European countries and Baltic countries.

DISTRICT ENERGY

EXPERIENCE
Based on 40 years of experience, Ramboll has provided consultancy services to more than 200 district heating systems worldwide, ranging from small village schemes to city-wide transmission networks.

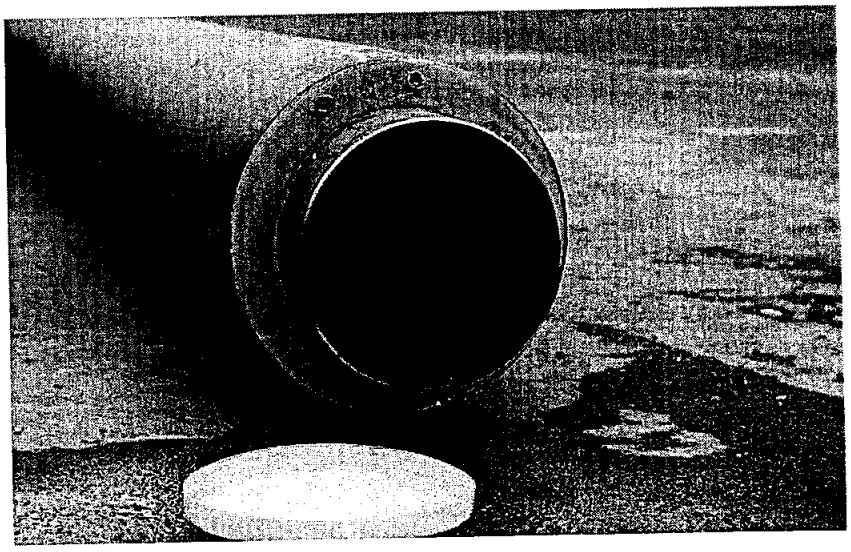
DELIVERING OPTIMAL SOLUTIONS FOR DISTRICT HEATING AND COOLING SYSTEMS

District energy systems have several benefits including improved energy efficiency, enhanced environmental protection, ease of operation and maintenance, as well as reliability, comfort and superior convenience for consumers.

With our decades of experience, Ramboll is globally regarded as one of the most experienced district energy consultants in the world. We are also one of the very few consultants that offer our clients a full range of services on district energy projects from feasibility studies and planning to follow-up on operation and maintenance.

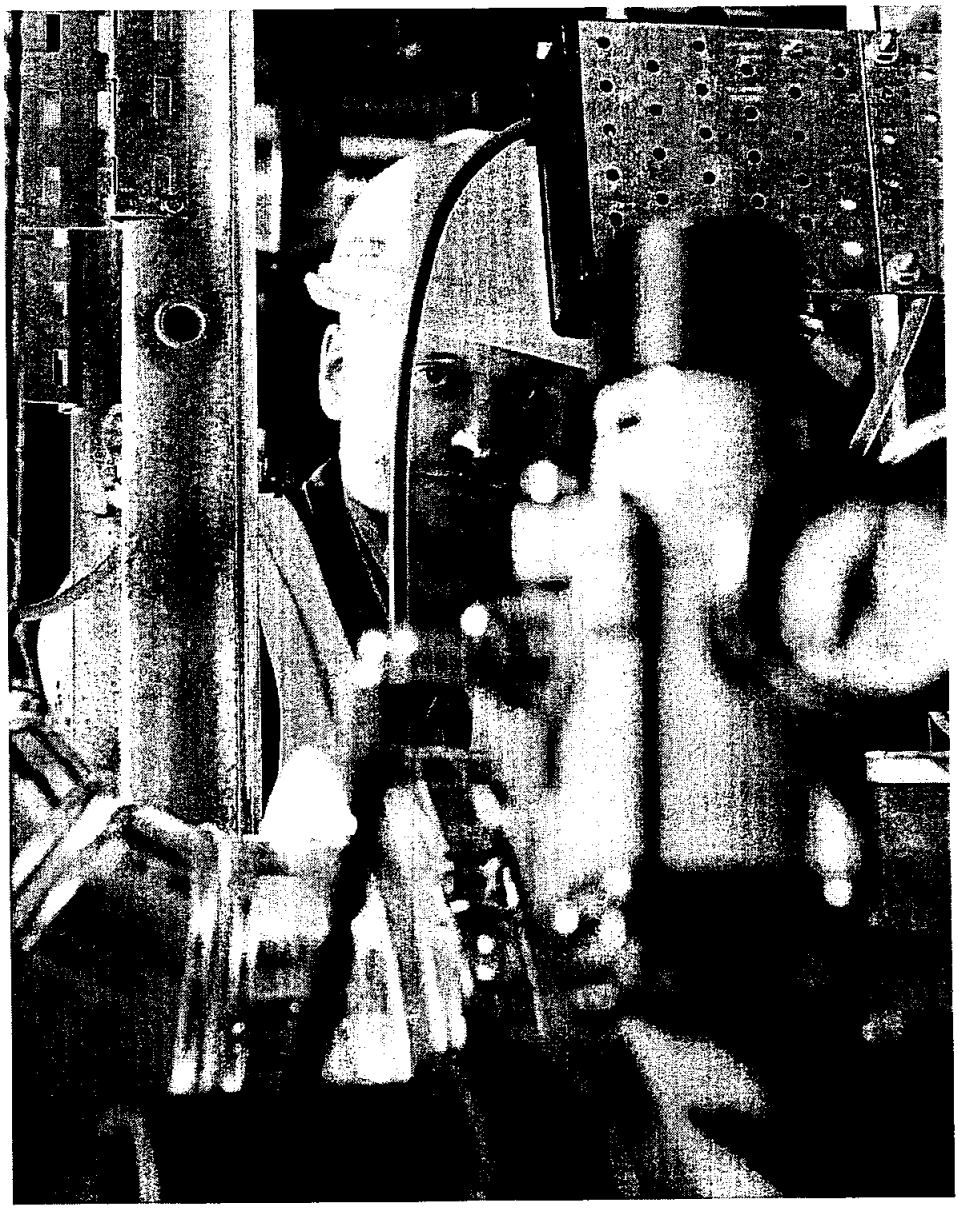
Based on our interdisciplinary approach, our district energy, waste-to-energy, CHP, renewable energy and building installation teams work closely together to provide optimal use of heating and cooling sources.

We use our expertise to offer our clients more sustainable solutions based on the most advanced renewable technologies including biomass plants, geothermal and solar thermal. By use of large heat pumps - which enable the co-production of heating and cooling by reusing surplus heat from facilities like data centres - we also work with electricity integration in the district energy systems.

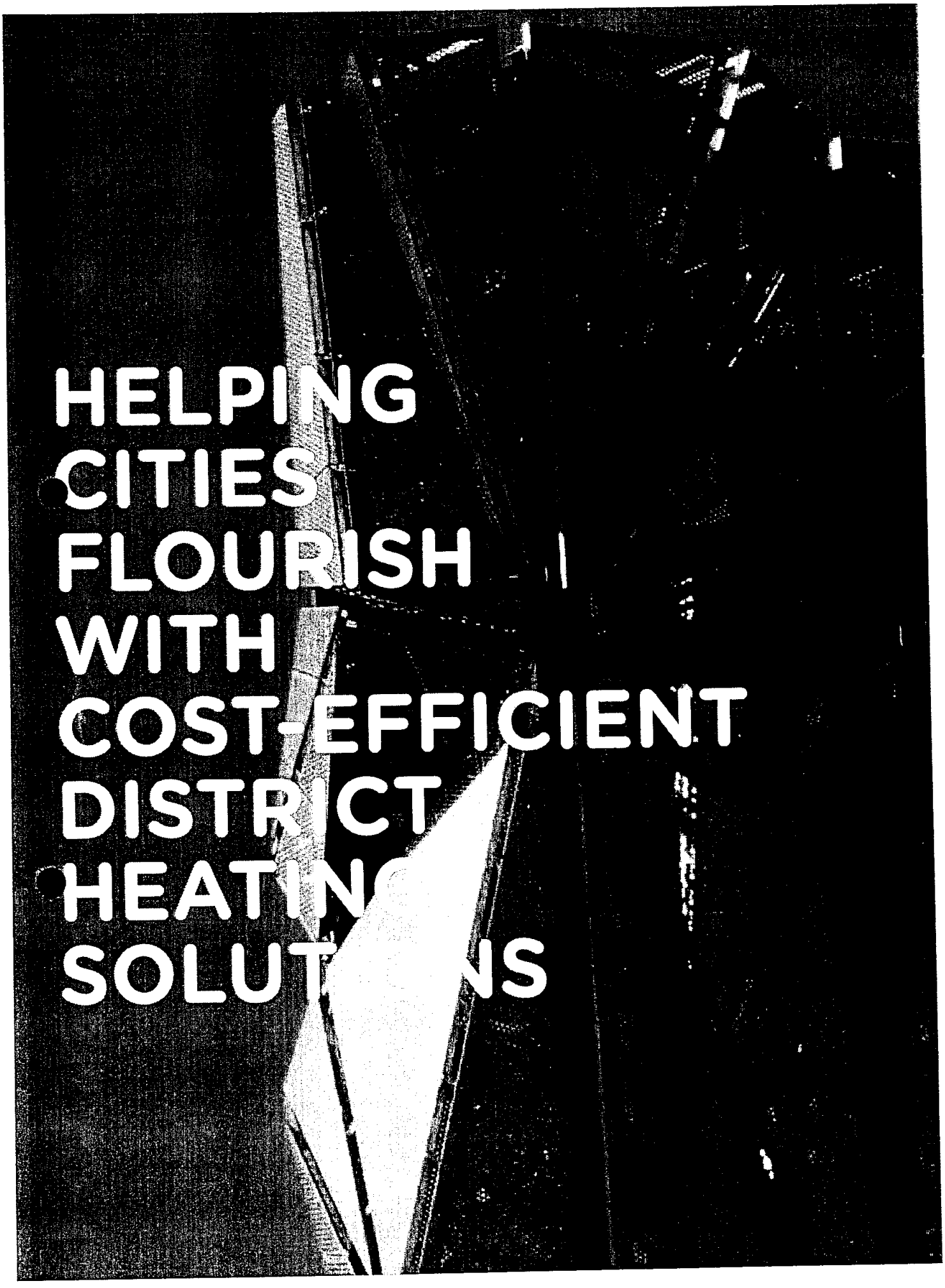


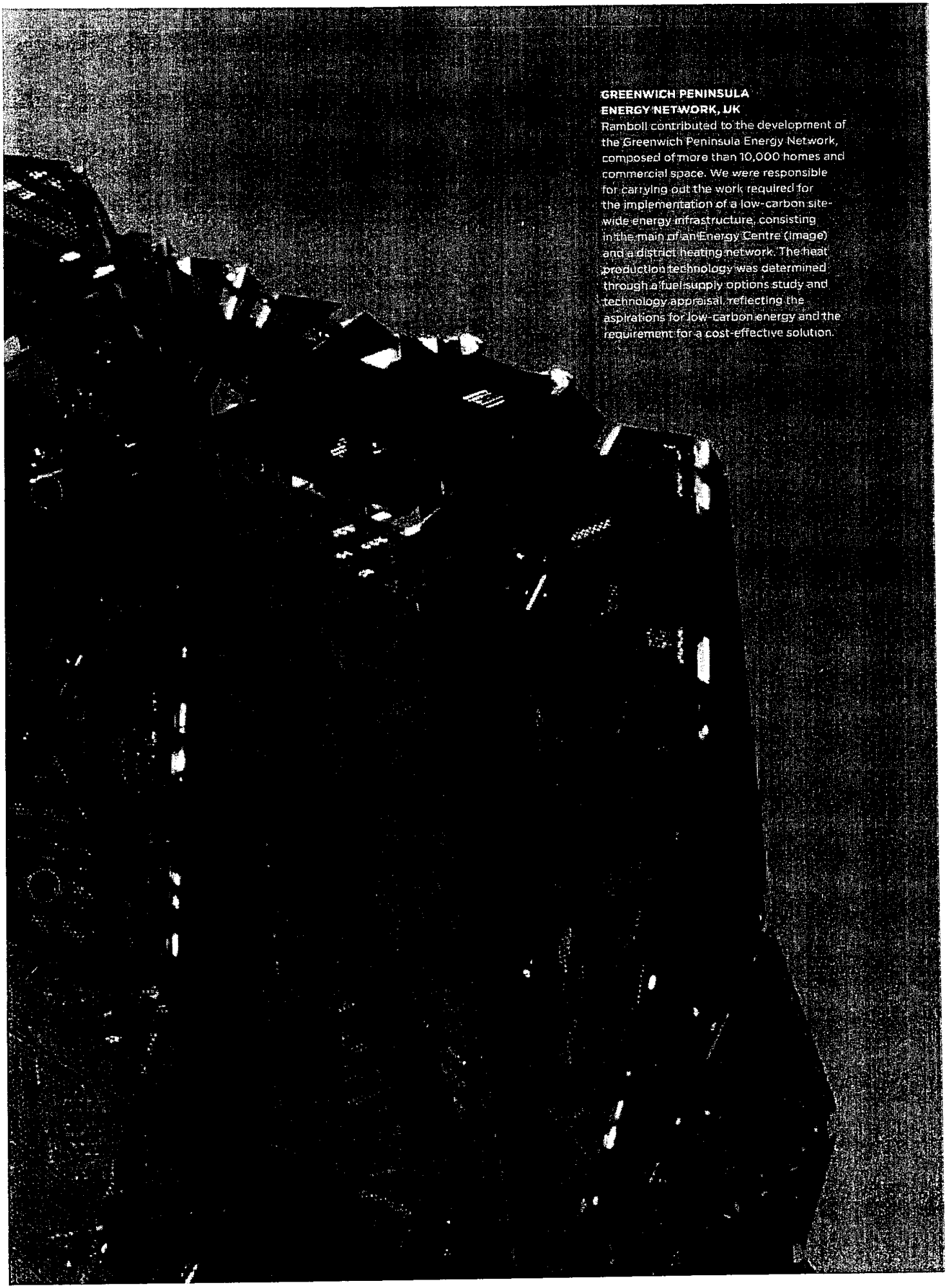
COPENHAGEN DISTRICT HEATING SYSTEM, DENMARK
Copenhagen's district heating system is one of the largest in the world, and the associated networks supply low-carbon heat to a city of one million people. For more than 30 years, Ramboll has been the Metropolitan Copenhagen Heating Transmission Company's main consultant, providing consultancy assistance during all stages of the project from planning and design to operation and maintenance of the city-wide system.

REPLACEMENT OF DISTRICT ENERGY SYSTEM AT STONY BROOK UNIVERSITY, US
The new district energy system supports all the thermal needs of Stony Brook University, which is the largest research University in the State University of New York system. The work was performed on an active university campus and phased to minimise interruptions of academic work and to avoid the use of temporary systems.



DATA CENTRE SURPLUS HEAT RECOVERY, DENMARK
Ramboll has provided consultancy services for the district heating company Fjernvarme Fyn on an energy centre with large heat pumps, utilising excess heat from the servers of a mega data centre in Odense. The heat pumps increase the temperature of the waste heat, so that it can be used in the local district heating network. It will be Denmark's largest heat pump to date, and utilisation of data centre excess heat has not been done in this scale before anywhere in the world.


HELPING
CITIES
FLOURISH
WITH
COST-EFFICIENT
DISTRICT
HEATING
SOLUTIONS



GREENWICH PENINSULA ENERGY NETWORK, UK

Ramboll contributed to the development of the Greenwich Peninsula Energy Network, composed of more than 10,000 homes and commercial space. We were responsible for carrying out the work required for the implementation of a low-carbon site-wide energy infrastructure, consisting in the main of an Energy Centre (image) and a district heating network. The heat production technology was determined through a fuel supply options study and technology appraisal, reflecting the aspirations for low-carbon energy and the requirement for a cost-effective solution.

POWER TRANSMISSION AND DISTRIBUTION

PEOPLE
Ramboll has 125 specialists in power transmission and distribution providing services that range from specialised technical advice to full engineering design solutions and project management.

UPGRADE OF POWER TRANSMISSION SYSTEM IN NORWAY, STATNETT
Due to the age and technical condition of existing power lines, the electricity demand growth in cities and the push for integration of renewables, the transmission grid capacity in Norway needed reinforcement. Ramboll acted as the project manager for this reinforcement, including a new 420kV transmission line and the upgrading of existing lines. This has made it possible to connect new wind power to the main grid and provide a secure supply of energy in Central Norway (image p. 37 bottom left).

ELECTRIC DISTRIBUTION UPGRADES AT ITHACA COLLEGE, NY, USA
Over the past 25 years, OBG, now Ramboll, has performed electrical studies, design and construction administration for new and upgraded medium voltage electrical distribution projects throughout the campus of Ithaca College. The purpose of these projects was to provide power reliability to 58 buildings on campus, working closely with the campus administration to minimise disruption of daily operations (image p. 37 bottom right).

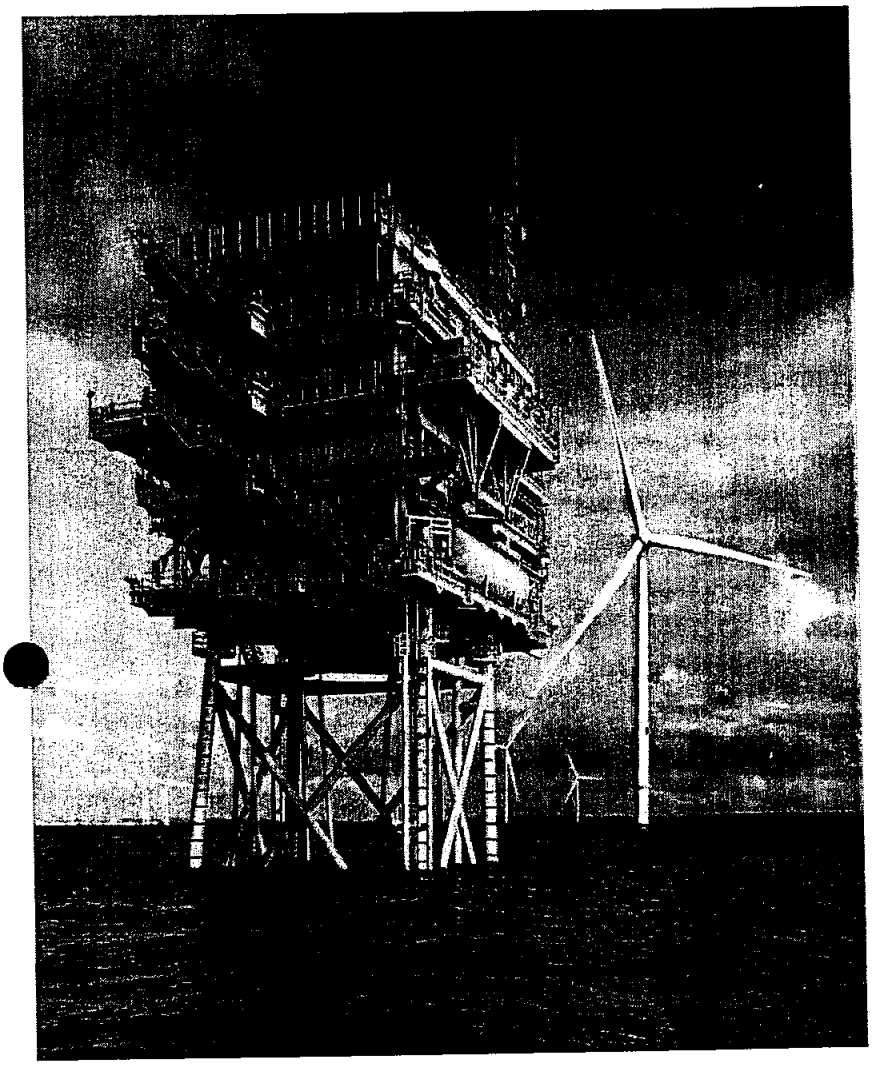
ENABLING THE INTEGRATION OF RENEWABLE ENERGY INTO THE ELECTRICITY GRID

In a world where energy and power demands are rapidly changing, and where the power generation mix is moving from thermal to renewable sources, Ramboll's holistic approach enables us to identify the changing demands on the power transmission and distribution networks, while our in-depth knowledge of such networks enables us to provide effective long-term solutions for the networks of the future. The power networks of the future will need to provide security and reliability with changing generation profiles and higher levels of intermittency. With its knowledge and expertise Ramboll is well placed to advise clients on the impact of new generation connections and the needs of future networks.

We tailor our services to meet our clients' needs. Our services range from specialised technical advice and power system studies (steady state and transient studies) to techno-economic feasibility studies, technical due diligence, front end engineering design and project management. We offer full Owner's Engineer services for project delivery as well as detailed engineering design when appropriate.

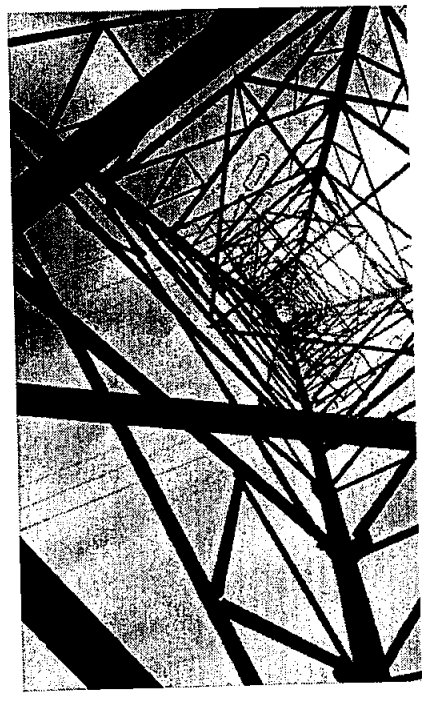
We have a wealth of expertise and experience in power system studies, grid connections for thermal and renewable generation and large industrial loads, offshore transmission systems, transmission lines and towers, cables, AIS and GIS substations, switchgear, transformers and reactors, protection, control and automation and HVDC interconnections. Our capability is at voltages up to and including 500kV.

Our power transmission and distribution skills are complemented by Ramboll's expertise in thermal and renewable power generation, offshore substation platform design, civil and structural engineering and environmental impact studies.



TECHNICAL DUE DILIGENCE FOR OFFSHORE TRANSMISSION (OFTO) ACQUISITION, UK

Ramboll provided technical due diligence services to Diamond Transmission Corporation (part of the Mitsubishi Group) in connection with the acquisition process for the UK offshore transmission (OFTO) schemes. These schemes provide the transmission link between the offshore wind farms and the onshore grid system.



TOWERS

RANKING
Ramboll is ranked the no. 1 design company globally by ENR within 'Towers & Antennae'.

FOOTPRINT
More than 130,000 masts and towers around the world bear the Ramboll stamp.

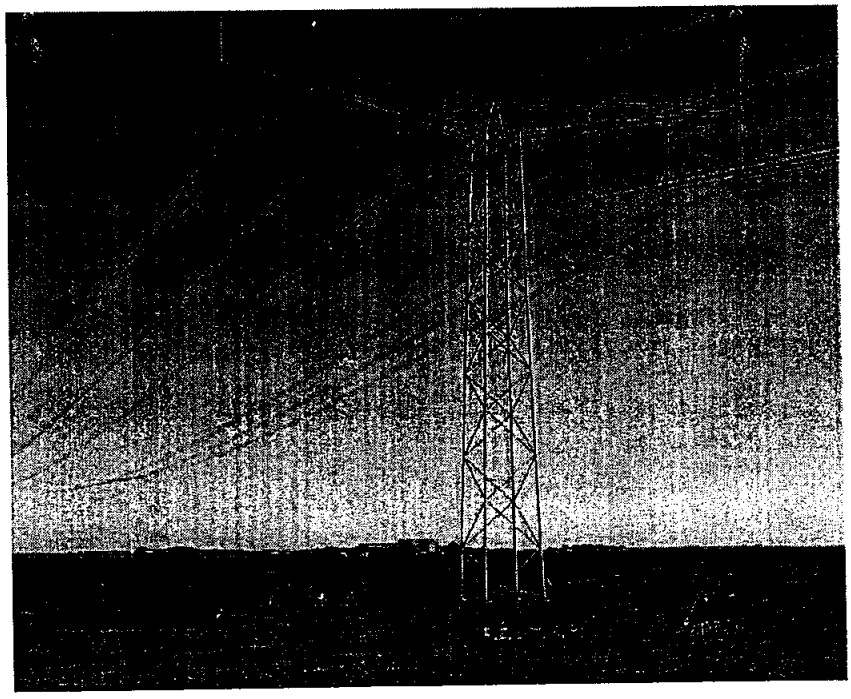
COST-EFFICIENT DESIGN PHILOSOPHY

Ramboll has been working with towers since the company was founded in 1945. We offer our clients a broad spectrum of consultancy services from analysis, technical due diligence, measurement and design to construction of masts and towers.

Ramboll focuses on reducing the total site costs for our clients, without compromising on sustainability and high quality. Our global presence and extensive engagement in international standardisation and R&D ensures that we can continue to provide world class solutions to our clients.

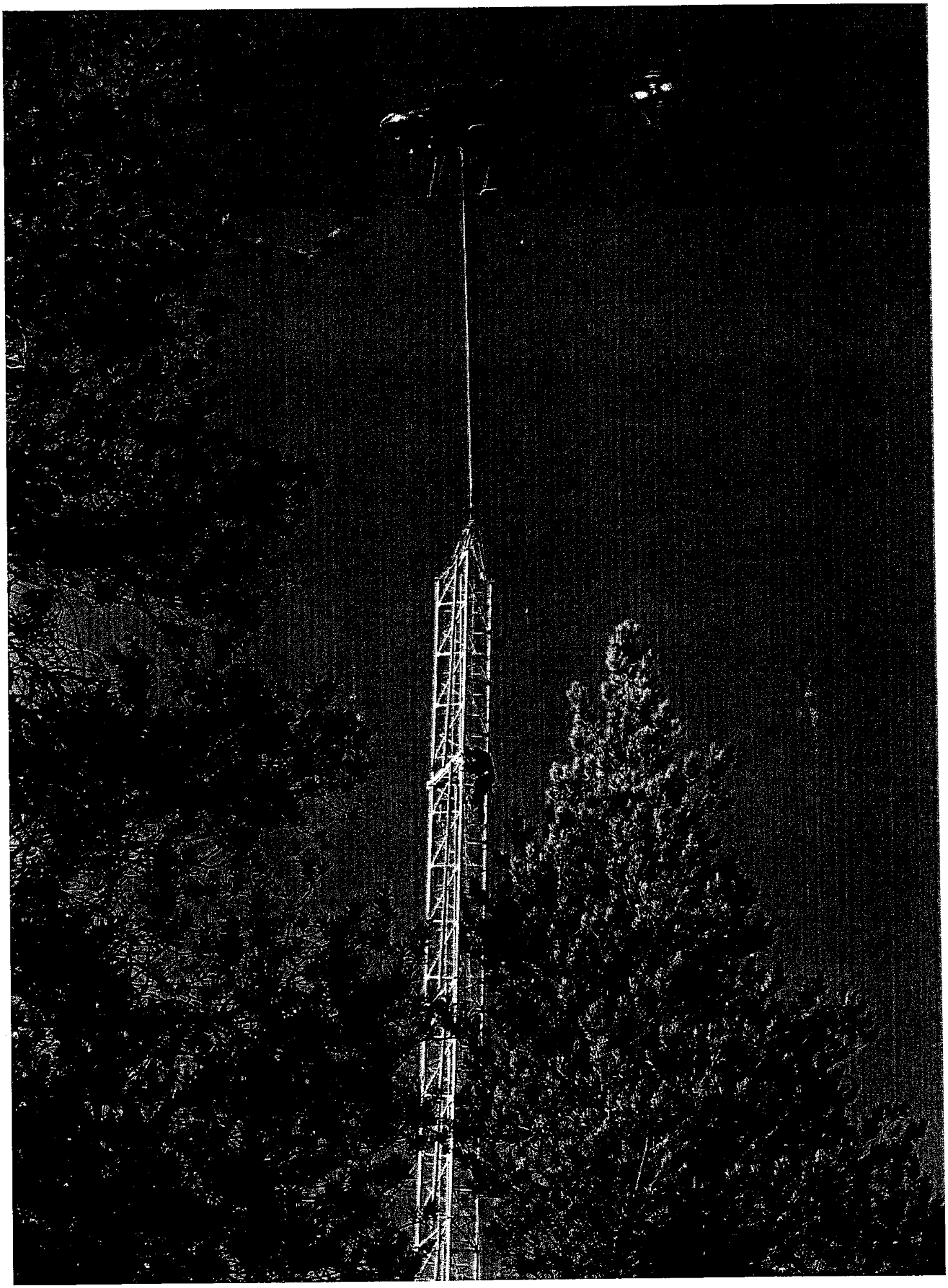
Based on our cost-efficient philosophy, our masts and towers are optimised by minimising wind load, foundations, logistics and installation time.

Supply and installation
In selected business segments Ramboll offers a full turn-key towers solution to our clients, from engineering, and procurement to construction (EPC).



AN INNOVATIVE SOLUTION FOR OVERHEAD TRANSMISSION LINE TOWERS TO ENERGINET
Together with the architect Dissing+Weitling, Ramboll was appointed to design the innovative Thor towers for the 2x400 kV grid for Energinet. The transmission line will establish high voltage connection in the southern and western part of Jutland, Denmark. Compared to traditional transmission line towers made of steel angle bars, the new tower is made of steel tube elements to obtain an elegant design, which is installed and maintained with less effort, compared to existing power pylons.

150M MAST FOR LUND UNIVERSITY, SWEDEN
Ramboll entered into a full turnkey-contract with Lund's University for the engineering, procurement and construction (EPC) of a 150m guyed met-mast. After completion of the detailed design, Ramboll handled the manufacturing and delivery of mast and accessories before completing the installation of mast and foundations. Installation of the mast-sections was performed by helicopter (image p. 39).



ENERGY STORAGE

WORLD RECORD BREAKER
Ramboll broke the world record for largest heat storage pit with the design and construction of a 200,000m³ heat storage facility.

USING SURPLUS ENERGY
The challenge for energy storage facilities is not only to increase the market share of surplus energy from wind, solar and hydro, but rather to use it cost-effectively.

KEY TO LOW-CARBON COMMUNITIES

Ramboll offers our clients the smartest solutions for their projects and society based on expertise in analysing the energy infrastructure and its energy carriers for electricity, gas and thermal energy. We take into account quality and time – ranging from seasonal storage to frequency stabilisation. Our solutions cover electricity, gas, district heating (hot water) and district cooling (cold water), and encompass a wide range of storage solutions including heat storage tanks and pits, cold storage tanks, natural gas storage, compressed air in caverns, electric batteries, frequency stabilisation, hydro power and pump stores, and steam storage tanks.

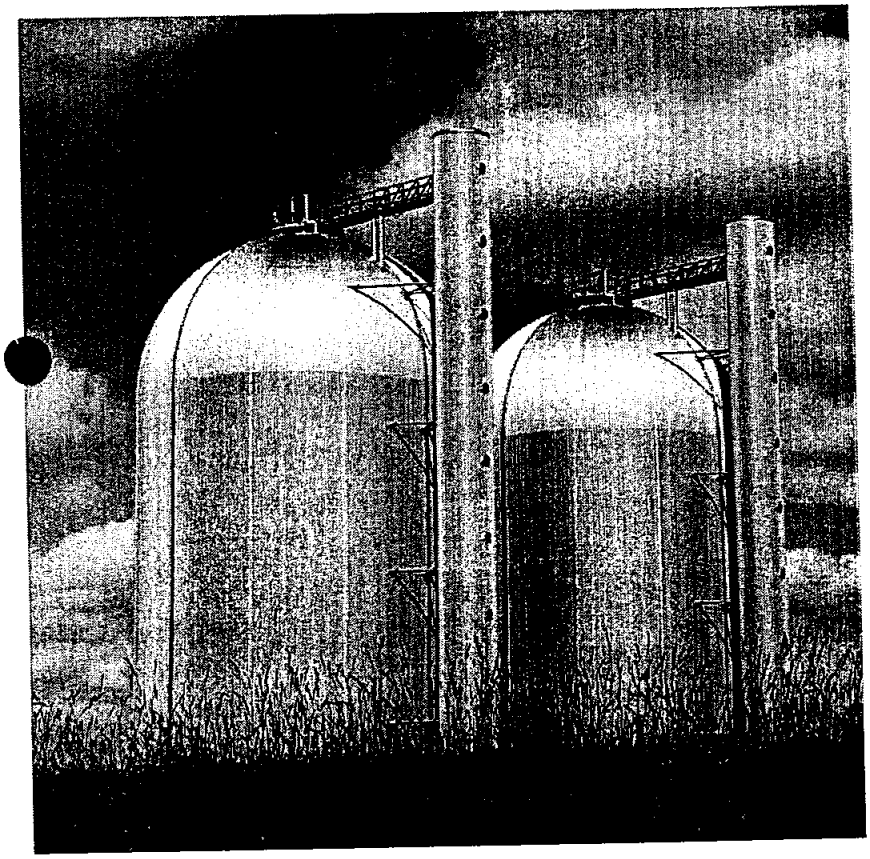
Cities acting as a virtual battery
A smart energy system that relies on fluctuating energy sources such as wind and solar power requires new, flexible energy usage and storage solutions. The water-based integrated energy system in the cities can be exploited as a cost-effective means of using and storing electricity.

With its large thermal storage facilities for hot and cold water in combination with large heat pumps, compressor chillers and electric boilers, the system can use a lot of electricity while the prices are low and avoid electricity consumption in times of high prices. Compared to individual solutions without storage capacity, i.e. small heat pumps and compressor units that need electricity every day or even every hour, the water-based energy system is equivalent to a virtual battery.

Ramboll has been involved in a wide range of projects for planning and designing all components of the integrated energy system in cities, e.g. the district heating system in Greater Copenhagen.

Electrical storage
As emerging technologies, chemistries, and platforms (mobile, EV & stationary) mature, the future for electrical storage is very promising. These assets allow for great potential to dynamically act as a load or a resource, balancing in real time the many requirements of our critical infrastructure.

With our simulation tools, we support and design all kinds of battery storage and assist our clients in the implementation phase. Our services include both the electrotechnical design and the economic optimisation of the capacity and power. Depending on the application, battery storage today has several different functions and business models. They enable peak shaving, equalise the fluctuating feed-in of electricity from renewable energy plants and save the energy in times with excess renewable generation.



HEAT STORAGE PIT RECORD IN VOJENS, DENMARK

As a consultant for Vojens District Heating in Jutland, Denmark, Ramboll designed and constructed a 200,000 m^3 heat storage facility in an old gravel pit. It was driven by an extension of the existing solar heating plant from 17,500 m^2 to 70,000 m^2 - breaking the world record in the process. The entire project was carried out without subsidy and has reduced the cost of heat production substantially.

CHP ACCUMULATOR TANKS, AVEDØRE PLANT, DENMARK

Ramboll designed large-scale heat accumulators, allowing the Avedøre CHP plant - one of the world's most efficient multi-fuel power plants - to decouple heat and power production, optimise demand economics and support a system with high wind power generation.

DIGITAL INNOVATION

DRIVING INNOVATIVE THINKING THROUGH SMART ENGINEERING

Innovation is at the heart of Ramboll's approach. We see creative thinking and innovation as key drivers for success and with that in mind, we continuously invest in the development of new engineering methods and techniques that harvest the full potential of new and existing technologies to create and offer more efficient and cost-effective services to our clients. Below are some examples of how we use the latest technologies to help our clients solve their problems and advance their projects.

True Digital Twin
Offshore structures such as platforms and wind turbines are billion dollar investments. With the True Digital Twin technology the operation and maintenance costs can be reduced and decisions on lifetime extension can be made on the basis of a genuine understanding of the structures.

Ramboll's True Digital Twin continuously monitors the structure via a digital model updated with real-time information about the loads affecting the structure, using an innovative structural health monitoring system combined with digitalisation. This intelligent asset management technology can be used for assets in other parts of the energy sector where structural behaviour can be monitored.

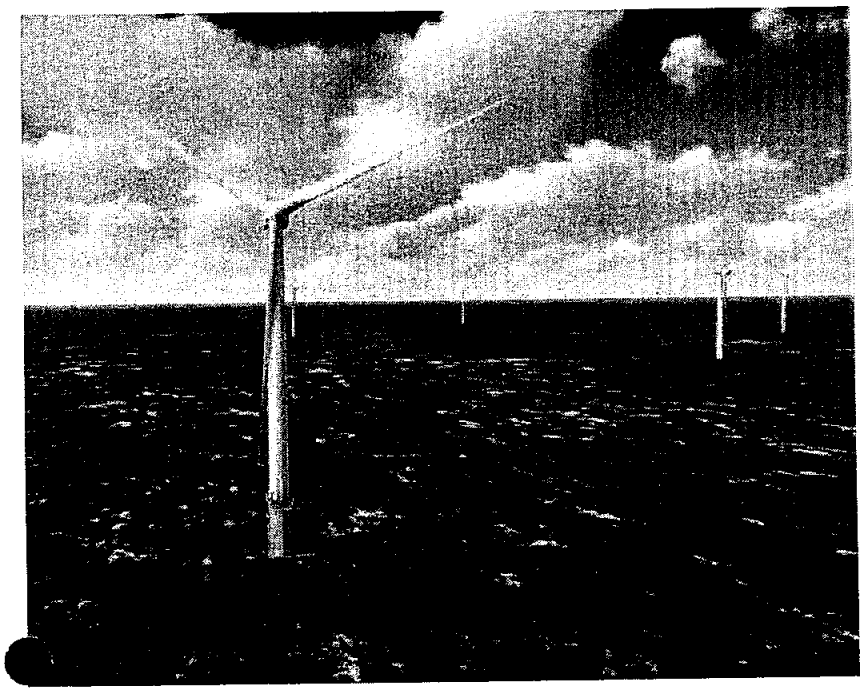
ROSAP/cloud computing
The Ramboll Offshore Structural Analysis Program - ROSAP - has been developed over the past 30+ years to meet the ever-increasing demands for structural design, optimisation and lifetime extension of offshore structures. ROSAP provides indispensable tools for new design, modification work and lifetime extension assessments of onshore and offshore steel structures, covering all phases from transport and lifting to in-service.

To further optimise the design, Ramboll has worked with several cloud vendors to improve its in-house software in this area through cloud computing, providing our engineers with a platform with faster, more robust and cloud-based storage and execution.

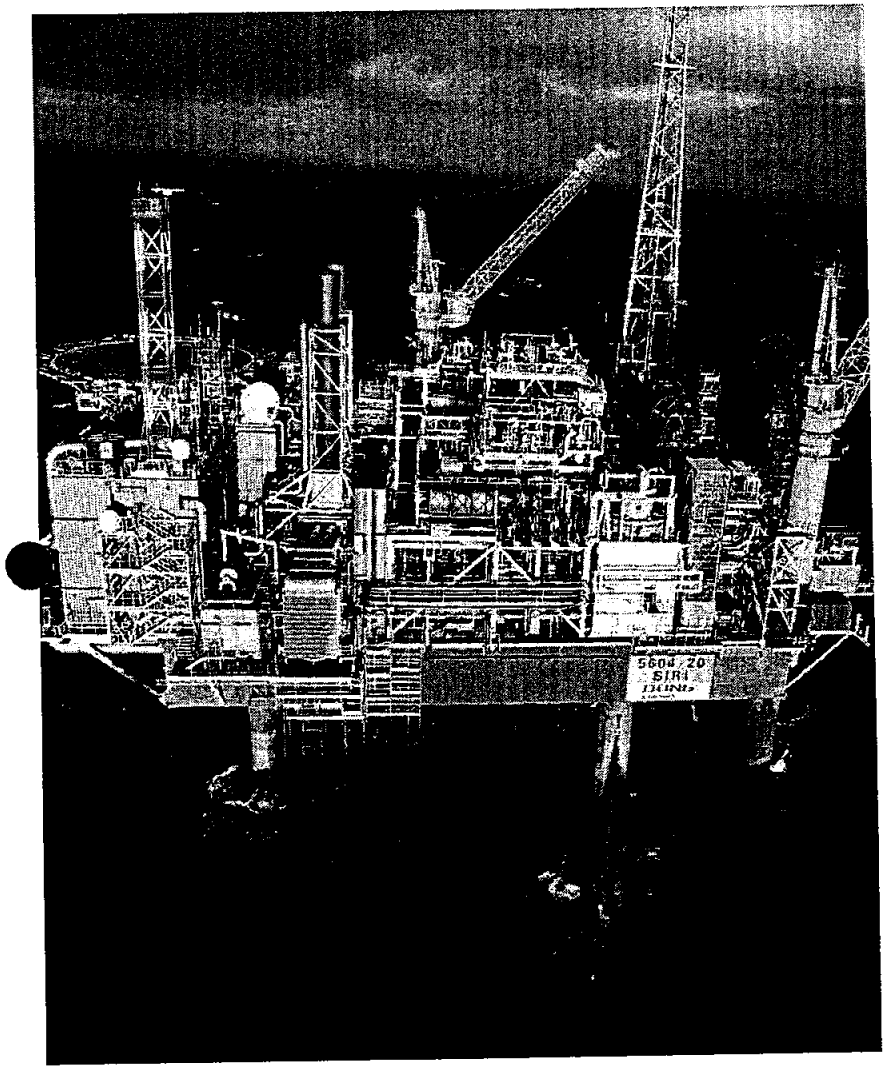
VR/AR visualisation
As our energy projects and designs become increasingly more complex, new solutions are required to visualise our projects, both in the design phase and during operation. Virtual Reality (VR) presents itself as a powerful technology that delivers more realistic and interactive visualisations of our engineering designs and models, while simultaneously enhancing the communication process with project stakeholders. Unlike VR, which requires an entirely virtual environment, Augmented Reality (AR) simply adds computer-generated images to the existing natural environment to enhance the current perception of reality. This is a strong project planning and implementation tool.

3D laser scanning and survey
Ramboll has worked with 3D laser scanning and surveying since the late 1990s. 3D laser technology facilitates the capture of physical objects such as structures, pipe work and mechanical components. Through survey analysis this is converted to a virtual but true to life as-built 3D model. With the 3D laser technology, errors can be prevented and new designs can be precisely tailored to fit existing layouts.

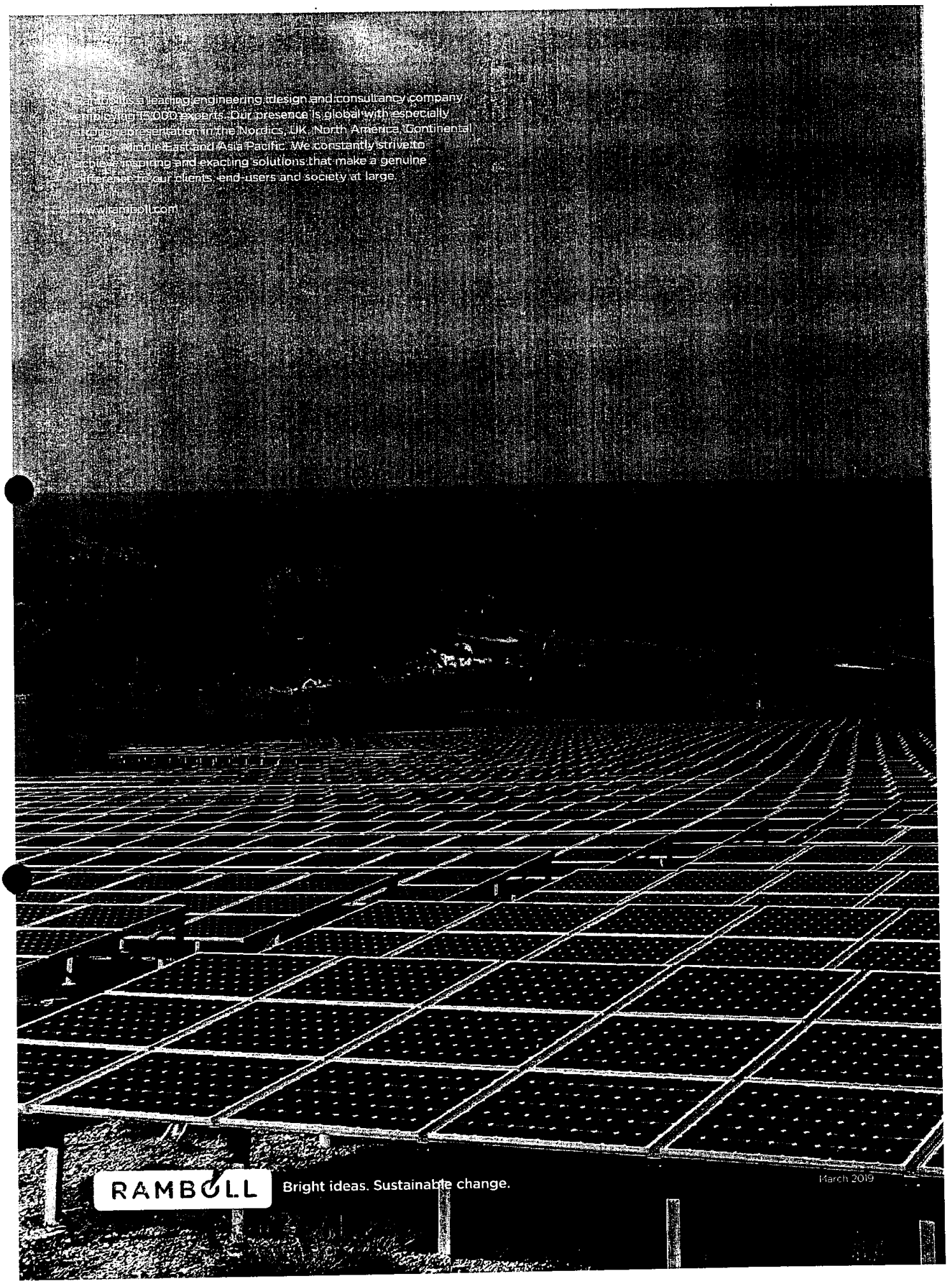
INVALUABLE SOFTWARE
Ramboll Offshore Structural Analysis Program (ROSAP) has been used for more than 3,100 individual foundation designs for wind turbines for 62 offshore wind farms around the world, accounting for a total nameplate capacity of 13,800MW.



MONO BUCKET CONCEPT FOR OFFSHORE WIND TURBINE FOUNDATIONS
Ramboll has established a close collaboration with Universal Foundation on an on-going joint development project concerning the design and certification of the Mono Bucket concept, including load iterations with MHI Vestas Offshore Wind. We assisted our client with the design basis, design briefs, collision analysis, load calculations and structural verifications of the structures. The designs were subsequently turned into real-scale 3D models able to be visualised and interacted with using VR technology.



SIRI A TRUE DIGITAL TWIN (SHMS), NORTH SEA
For the Siri Offshore Platform located in the North Sea, cracks were observed in the structure. This required extensive repair and reinforcement, and analysis and re-certification for keeping the facility in production. Ramboll assisted the client by creating a True Digital Twin of the platform based on real-life measurement data from an installed Structural Health Monitoring System (SHMS). The purpose of the True Digital Twin was to improve and control the structural safety of the platform during all phases of the project from the time of observation of the crack development, during the re-assessment analysis and to final repair of the platform. The project resulted in the minimisation of costly shut-downs and platform evacuations, while maintaining a high safety level.

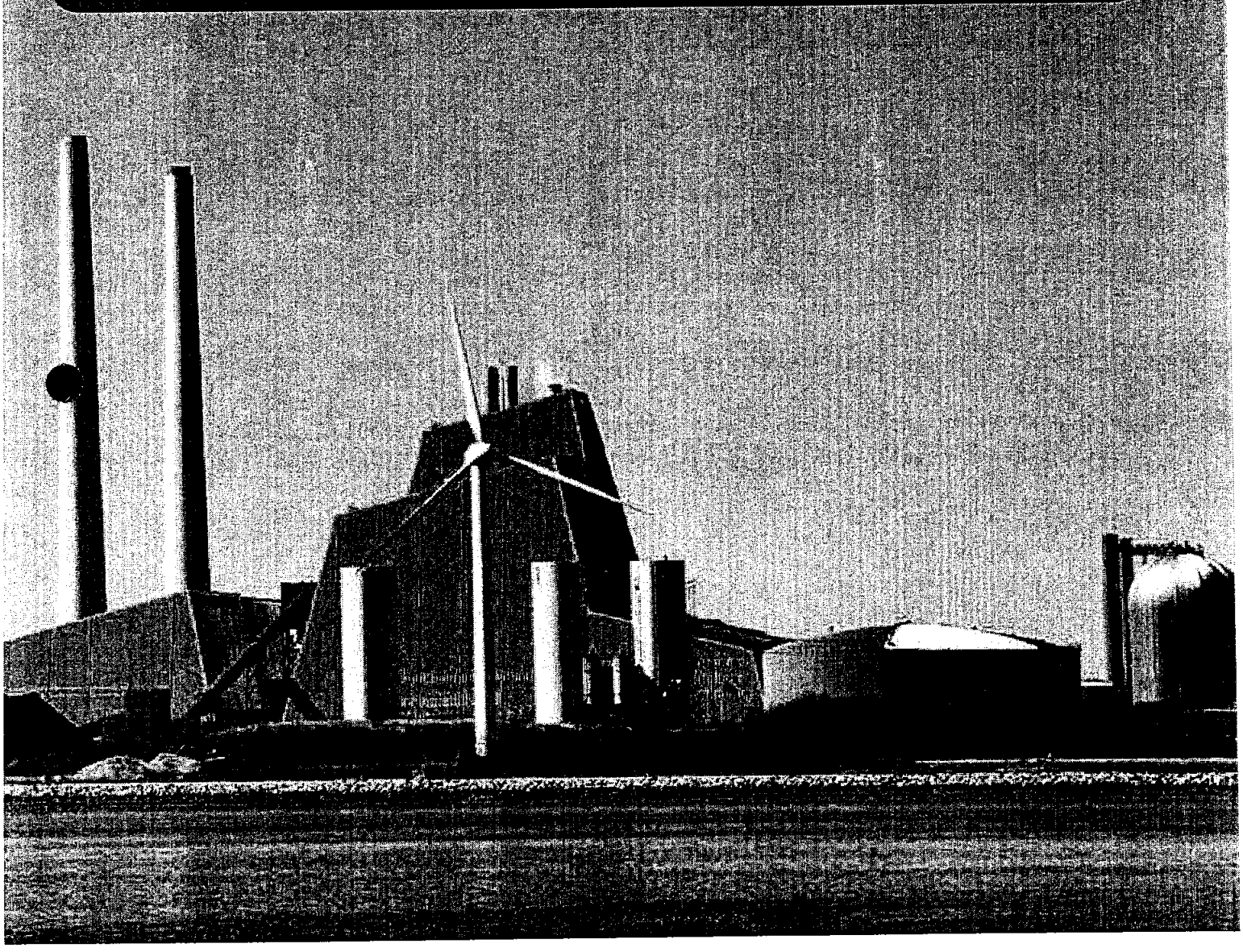

Ramboll is a leading engineering, design and consultancy company employing 15,000 experts. Our presence is global with especially strong representation in the Nordics, UK, North America, Continental Europe, Middle East and Asia Pacific. We constantly strive to achieve inspiring and exacting solutions that make a genuine difference to our clients, end-users and society at large.
www.ramboll.com
RAMBOLL
Bright ideas. Sustainable change.
March 2019

APPENDIX C: RAMBOLL POWER GENERATION BROCHURE

RAMBØLL

POWERING THE FUTURE

CONSULTANCY ON FLEXIBLE, EFFICIENT AND RELIABLE THERMAL POWER PLANTS



CONTENTS

RAMBOLL ENERGY

Ramboll has more than 45 years of experience in the planning, design and implementation of energy solutions.

Our energy team provides expertise on the full spectrum of technologies and all parts of the value chain from production through to transmission and distribution.

Our special competencies lie within thermal power, wind energy, waste-to-energy and district energy. Within these four areas, we provide a one-stop shop of services based on know-how and experience gained from a large number of projects, unmatched by other

WHAT WE CAN DO FOR YOU

Modern energy systems face increasingly complex challenges. Global power demand is rising as societies develop, whilst we must also reduce climate change impacts. Growth in wind, solar and other renewable generation, along with the development of higher efficiency and flexible fossil fuel plants are increasingly seen as the key to delivering these reliable lower carbon solutions.

Sustainable solutions
The projects that we carry out for our clients typically provide the overall societal benefits of securing the supply of energy, reducing climate impact, improving energy efficiency and countering resource scarcity.

We assist our clients in all project phases, ranging from planning and engineering design, to long-term operation and maintenance.

Special energy competency areas
Besides thermal power, we offer world leading competencies within offshore wind, waste-to-energy and district energy.

More than 65% of the world's offshore wind turbines rise from foundations engineered by Ramboll, and we have provided expert services to onshore wind farms with a nominal output of +60,000 MW in more than 60 countries.

We have worked on waste-to-energy projects in 45 countries, providing consulting services for 145 new units and retrofits.

We have provided consulting services to more than 200 district heating and cooling systems worldwide, ranging from small village schemes to city-wide transmission networks.

Thermal power services
Ramboll offers a 'one-stop shop' of services based on a multidisciplinary approach to power generation.

Our unique strength stems from the acquisition in 2011 of DONG Energy's in-house thermal engineering team, responsible for the project development and implementation stages of world leading high efficiency power plant projects right through to operations and maintenance support, failure investigation and power plant rehabilitation and upgrades.

Unlike many other consultants we are able to bring expert plant operational insight into new power project developments. Our power group has continued to strengthen with strategic recruitment of staff with extensive international power generation engineering consulting experience.

Thermal power experience
On behalf of our clients, we have designed and constructed more than 90 major power plants, including some of the most energy-efficient plants in the world, and are instrumental in the ongoing conversion from fossil fuels to biomass.

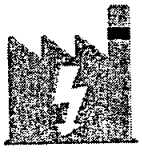
For our clients, working with Ramboll means that they will benefit from our long-term experience and know-how, and together we can transform complex challenges into solutions that are future proof, energy efficient, cost effective and practical.

INDEPENDENT ADVICE
- Owner's Engineer
- Lender's Engineer
- Project and programme manager
- Environmental advisor

LARGE RESOURCES
- Group 13,000 staff
- Energy 1,500 staff
- Power experts >240 staff

FULL SCOPE SUPPORT
- Feasibility & costing
- Specification, tendering & contracting
- Construction
- Commissioning
- O&M
- Life extension & upgrade
- Decommissioning & redevelopment

KEY EXPERTISE
- High efficiency power plants
- Biomass and bioconversions



>90

Number of major power plants designed

OUR ROLE IN THERMAL POWER PROJECTS

Ramboll has pioneered the development of innovative power plants with worldwide highest efficiencies and have particular expertise in:

- High efficiency power plants
- Biomass and bioconversions
- Cogeneration (CHP)

The Ramboll mind-set is to set and achieve the highest standards for health and safety throughout all stages of a project and subsequent plant operation.

Full project lifecycle services
We provide a comprehensive range of project lifecycle services ranging from strategic level to highly expert engineering specialisms.

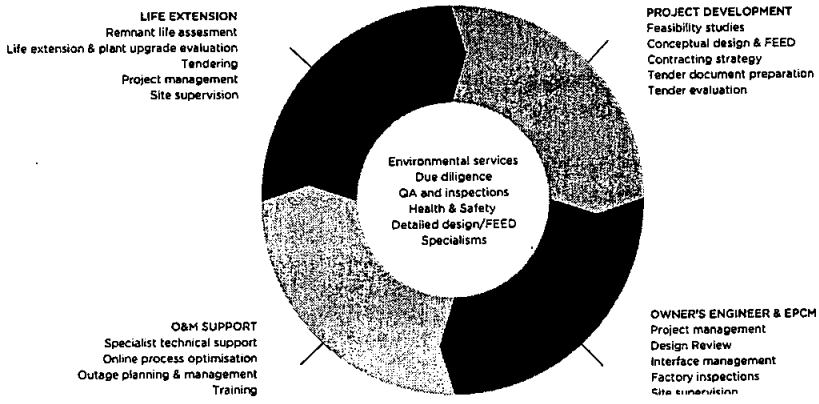
Where projects involve wider infrastructure such as LNG facilities, ports etc. Ramboll is also able to deliver and integrate a complete range of project services.

Project development
The project development stage is of vital importance. It is at this time when key decisions are made on a project; this is the time to optimise to ensure the site selection, fuel type, technology and subsequent contracting methods considered are best aligned with the overall project objectives. If not addressed fully at the outset, subsequent optimisation and changes in later stages of a project can have significant cost and programme implications.

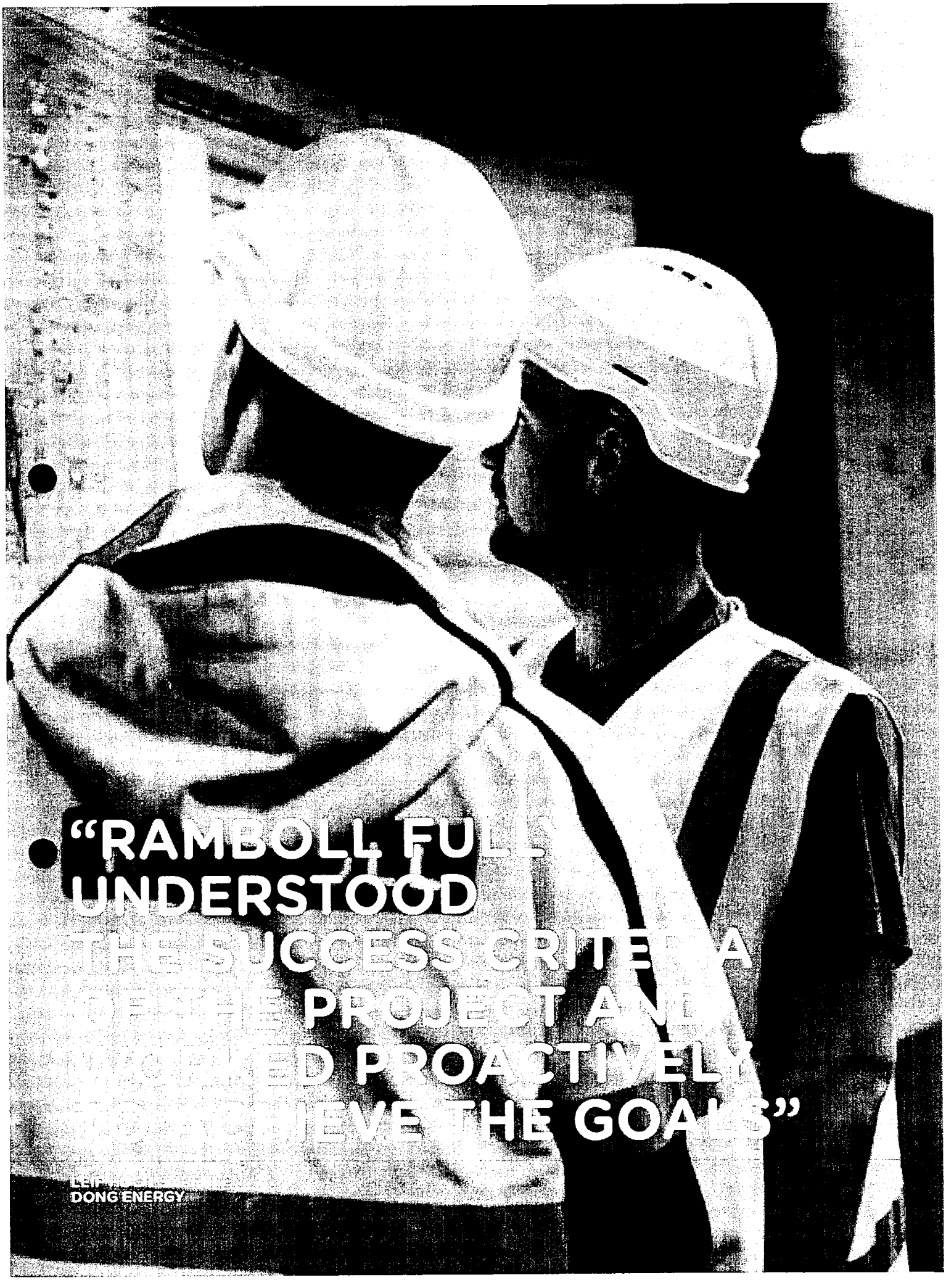
Owner's Engineer & EPCM
During project execution Ramboll provide Owner's Engineer and EPCM services to make sure the client's interests are best served. We ensure the appointed contractor(s) progress the plant design, manufacturing and subsequent construction and commissioning stages in line with the contract specification, programme and budget with the highest regard for health and safety.

O&M support
Ramboll has strong competencies within operation and maintenance, which enables our clients to make their operations more efficient and hence optimise the operating economy of their plant. Ramboll can assist with trouble-shooting on the entire power plant, from the inlet of the fuel through the delivery of power, steam and heating as well as the handling of residual products and flue gas.

Life extension
Lifetime extension of existing power plants can present an efficient way of meeting power generation needs whilst keeping investments at a manageable level. Ramboll's highly experienced experts identify how to extend the lifetime of power plants and seek out all possible improvements leading to increased plant efficiency, flexibility and availability and reduction of operational costs.



Full project lifecycle services offered by Ramboll.


"RAMBOLL FU
UNDERSTOOD
THE SUCCESS CRITE
THE PROJECT AND
PROACTIVELY
ACHIEVE THE GOALS"
LEIF
DONG ENERGY

BIOMASS

Sustainable biomass offers a renewable low carbon alternative to fossil fuels for thermal power and heat generation.

Common fuels include manufactured wood pellets, grown crops, recovered residues, straw and various wastes.

Global leading experience
Ramboll has delivered biomass plants of all types and is a global leader in this area.

As well as developing multiple new biomass power and CHP plants, Ramboll staff pioneered the conversion of coal plants to biomass firing - at a time when there was no experience in the contracting supply chain.

Our experience of coal to biomass conversion is unparalleled. Our references are famous world-wide, and we continue to take a leading role globally.

Services
Ramboll offers all engineering services with respect to the planning, design, tendering, construction and operational phases for new build or upgraded power or CHP plants, fuelled by all types of biomass.

Optimising combustion
Biomass combustion can lead to fouling and corrosion of boiler heating surfaces as well as placing new demands on flue gas treatment systems and the disposal of the ash. Ramboll's expertise can help our clients to optimise the fuels and power generation systems that are critical for good efficiency and availability.

Delivering fire safety
Fuel system changes require consideration of fire safety (ATEX) and other health and safety issues.

Ramboll provides advice, risk management support and design solutions for all challenges arising.

Storage facilities
The main challenges in storage facilities stem from fire and explosion hazards.

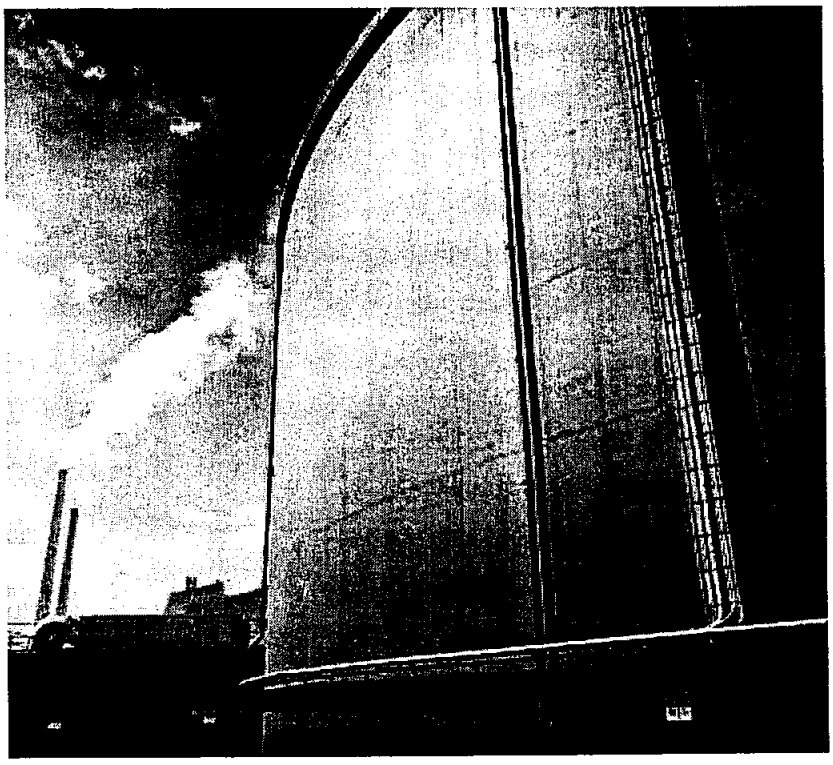
Ramboll is internationally recognised as the leading expert in the area of biomass related fire safety. We have invented and have a patent pending on a fire fighting concept which is highly suited for large wood pellets inventories.

Designing innovative solutions
Ramboll has designed highly automated bio fuelled power plants comprising automated straw reception and transport systems that only require man-power during receipt of straw.

01

01. Manufactured wood pellets are globally traded and used for power and heat generation

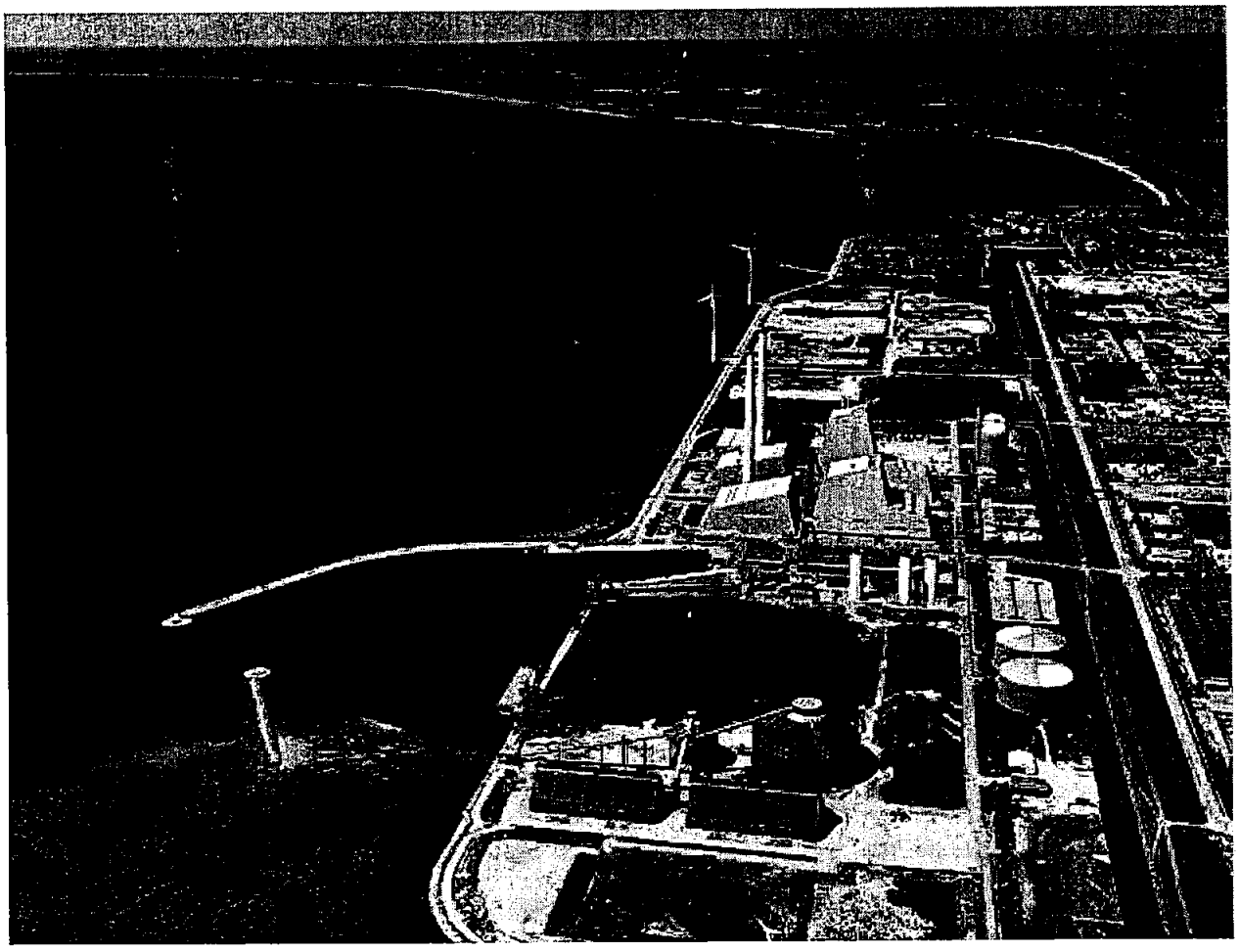
02. Straw handling at a



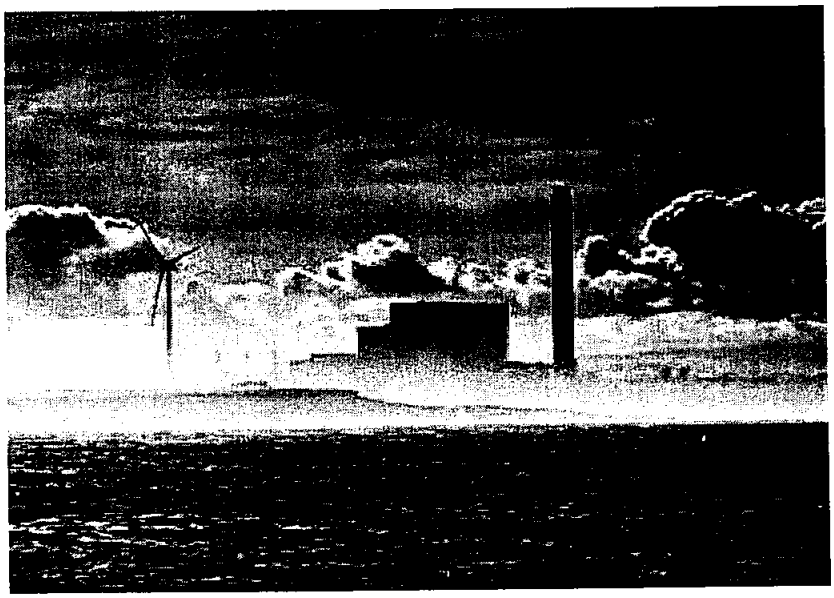
03

03. AVEDORE UNIT 2, DENMARK
575 MW
New biomass fuel storage silos. The fire detection and response system specifications were developed by Ramboll.

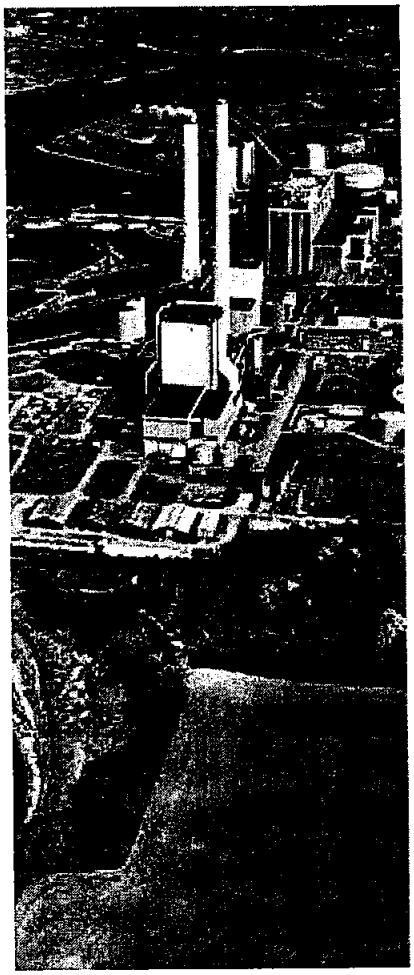
04. Avedore Unit 2 is one of the world's most efficient multi-fuel power plants and has undergone 100% biomass conversion. Ramboll supplied development, design and expert engineering support to the Owner (DONG Energy) from concept to operation, covering all aspects from fuel handling & storage, to combustion & turbines, CHP systems, emission controls and residue management. Similar services are provided for the conversion of Unit 1.



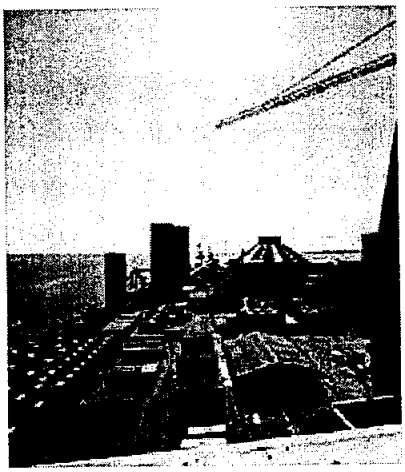
FEATURED BIOMASS REFERENCES



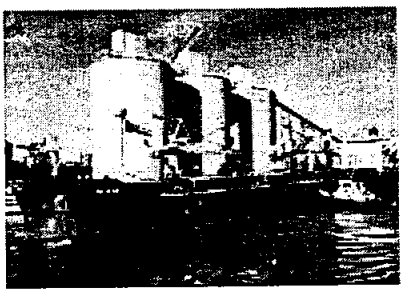
LYNEMOUTH, UK
420 MW full biomass conversion. Having supported the Owner at the development stage, Ramboll was appointed to provide support for the implementation of the project. In total the project comprises nine engineering packages, including an import terminal, site fuel handling and storage as well as the power plant conversion (Image: John Dalrymple).



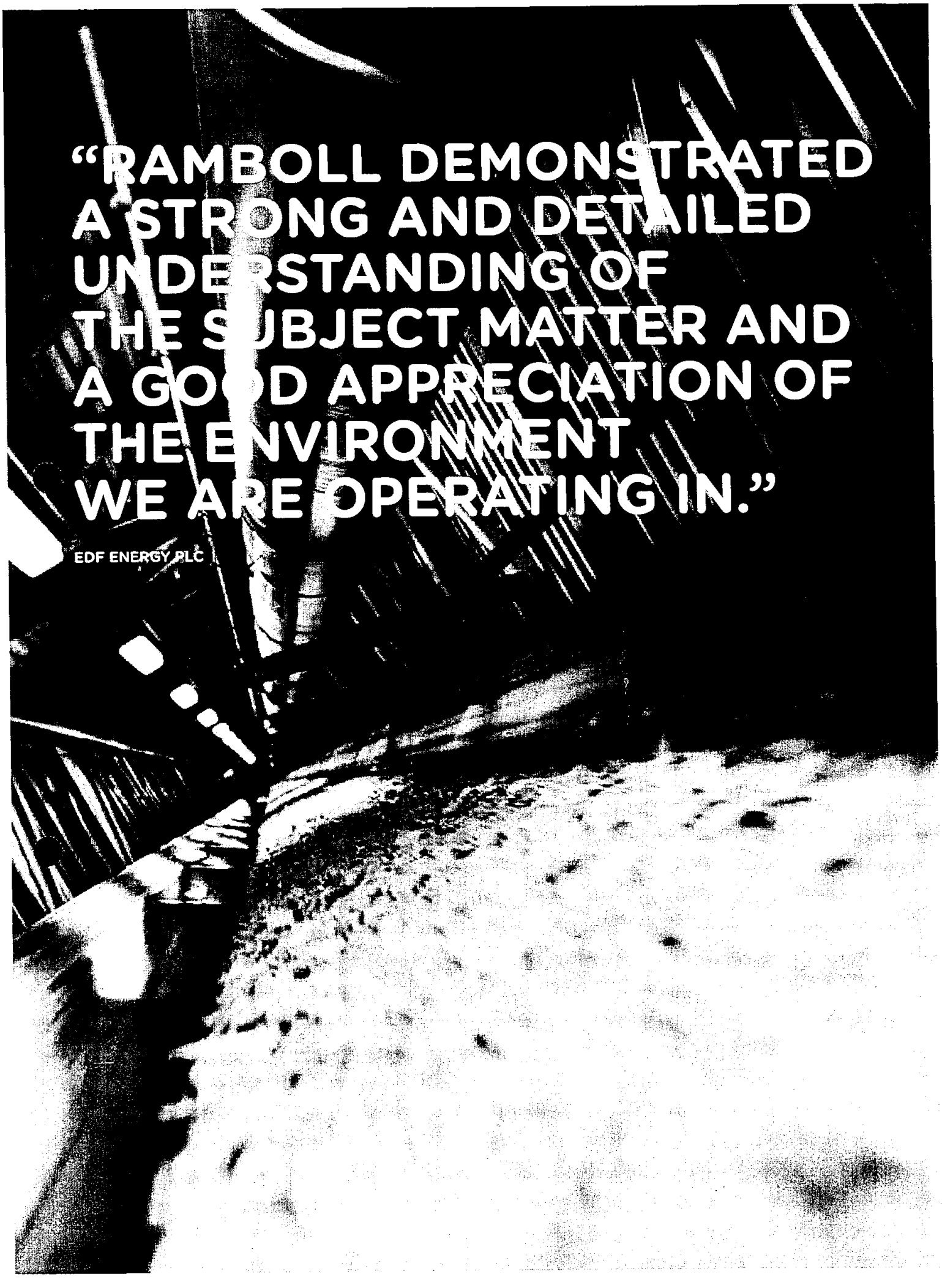
ASNÆS, DENMARK
Full biomass conversion of existing units and development of a 180 MW dedicated biomass fired power plant integrated into the existing power plant site.



STUDSTRUP UNIT 3, DENMARK
Full biomass conversion. Supplies 350 MW electricity and heat to the surrounding district heating system. Ramboll supported the plant's owner in all project phases from analysis through to commissioning.



GLADSTONE DOCK, LIVERPOOL, UK
Wood pellet import terminal with 100,000 tonne storage capacity. The plant is rail connected for fuel distribution. Ramboll was expert adviser to the construction contractor (Image: Drax).


"RAMBOLL DEMONSTRATED A STRONG AND DETAILED UNDERSTANDING OF THE SUBJECT MATTER AND A GOOD APPRECIATION OF THE ENVIRONMENT WE ARE OPERATING IN."
EDF ENERGY PLC

HIGH-EFFICIENCY POWER PLANTS

RAMBOLL OFFERS EXPERTISE IN:

- Ultra super critical plants
- Combined cycle and open cycle gas turbine plants
- Integrated solar thermal
- Multi-fuel applications
- Carbon capture and storage
- Advanced technologies such as gasification and oxyfuel

Thermal efficiency
Fossil fuel fired power plants continue to play a significant role in providing secure and affordable energy. Ramboll has specialist expertise which can reduce the carbon impact of fossil fuel power plants through the optimisation of thermal efficiency and deployment of state-of-the-art emissions abatement technology.

Efficient coal utilisation
The Nordjylland 3 Ultra Super Critical (USC) Power Plant, engineered by Ramboll, indeed holds the world record for most efficient coal utilisation, with an efficiency of over 47%. Ramboll achieved this through extensive insight and optimisation of the steam cycle and overall plant design.

Plant flexibility
Equally important for modern thermal plants is to operate highly flexibly, with a need to rapidly balance energy demands resulting from an increase in intermittent renewable energy sources. Ramboll has successfully engineered plant modifications which enable faster start-up times and greater cyclic operation.

USC plants
Ramboll has designed and realised some of the most efficient and fuel flexible thermal power plants in the world, applying the most advanced USC steam parameters and steam cycles. The plants are typically designed for coal, heavy fuel oil and/or natural gas.

Combined cycle plants
Our knowledge of Combined Cycle Gas Turbine (CCGT) plant concepts is extensive. Ramboll has realised some of the most efficient and flexible CCGT power plants in the world to date.

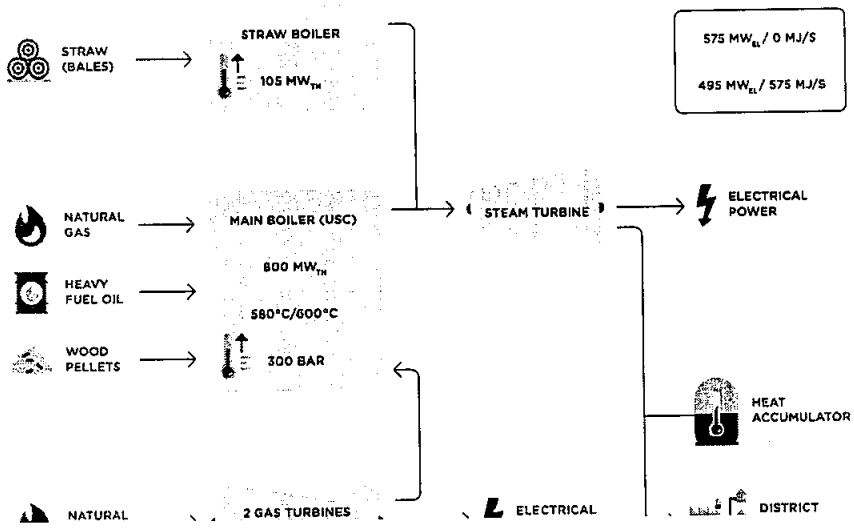
We can handle both relatively standardised CCGT projects and highly advanced CCGT projects involving customisation to fit specific requirements such as process steam supply for an industry, district heating supply or integration of a CCGT into an industrial process plant.

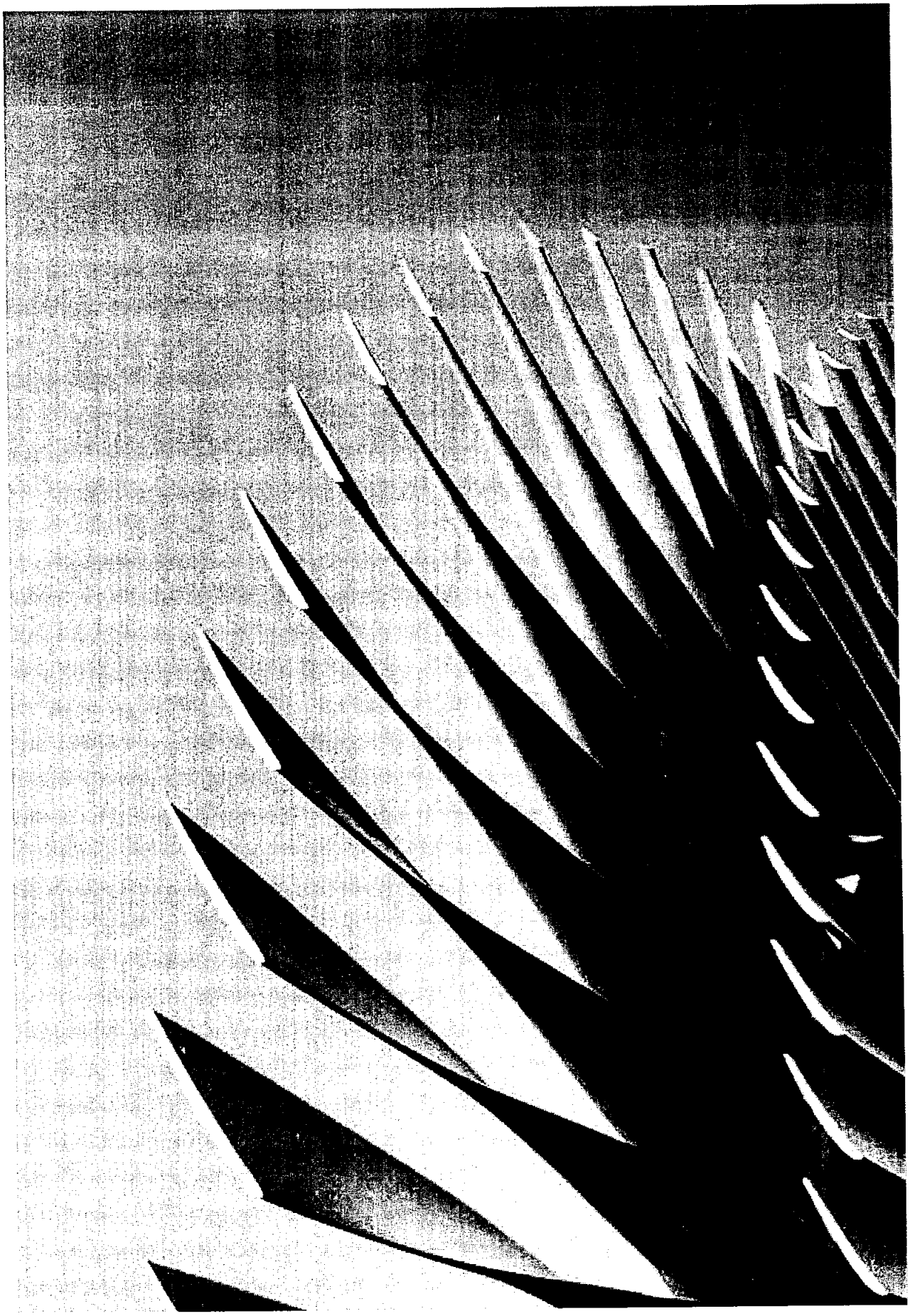
Our specialists have a combined working experience of realising more than 25,000 MW of CCGT plant capacities worldwide.

Multi fuel applications
Our ability to develop innovative power generation projects is ably demonstrated by our role in engineering and implementing the Avedore Unit 2 project which incorporates within an optimised thermal cycle:

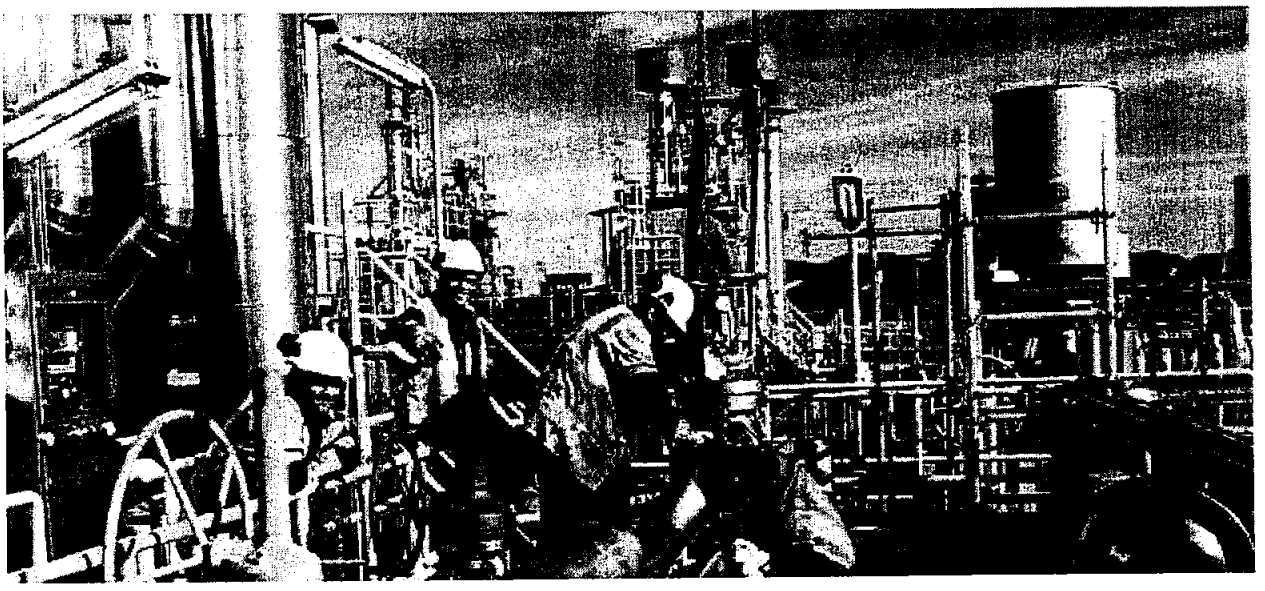
- USC multi fuel fired boiler
- Straw boiler
- Gas fired turbines in feed water cycle
- Energy storage heat accumulators

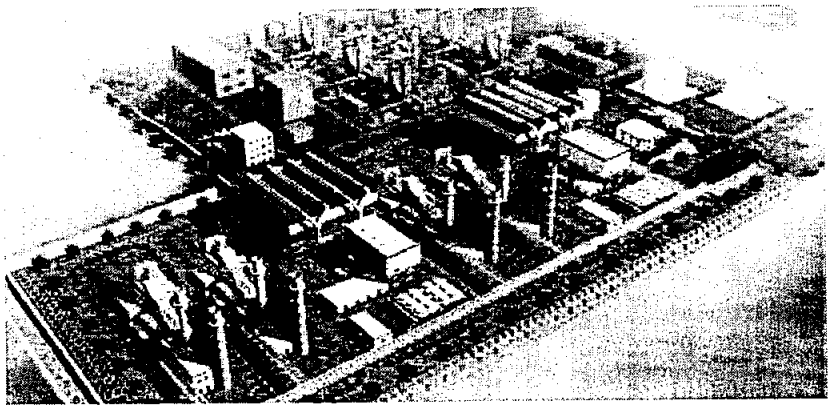
AVEDORE 2 - MULTI FUEL CONCEPT





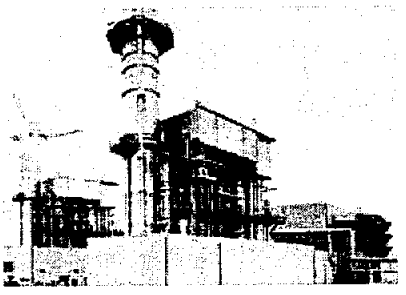
HIGH-EFFICIENCY POWER PLANT REFERENCES



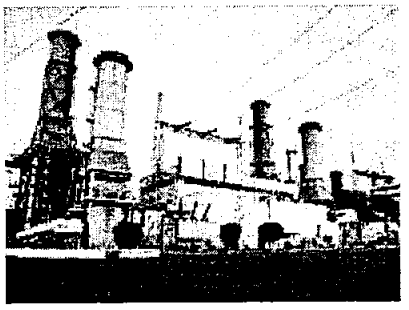


MONGSTAD CCGT CHP PLANT, NORWAY
280 MWe + 350 MWth heat. Refinery integrated high efficiency CHP plant supplying high pressure steam and power. Ramboll staff acted as EPC Manager for the Owner during the plant development and construction.

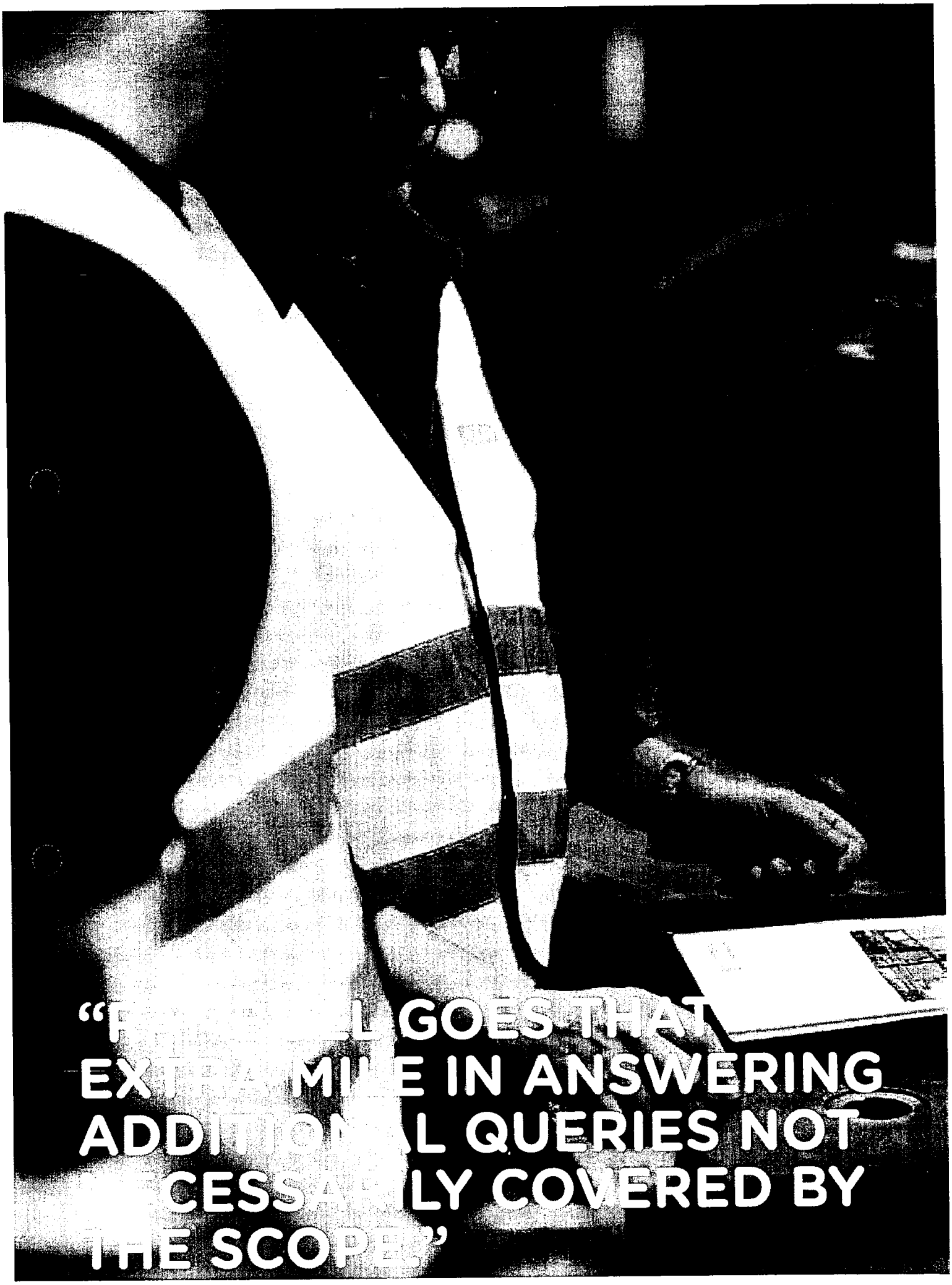
SALALAH II, OMAN
440 MW dual fuel CCGT natural gas/fuel oil. Ramboll was appointed to monitor construction and commissioning and to provide project co-ordination services.



KAPCO, PAKISTAN
Muzaffagarh 660 MW coal fired power plant. Ramboll was appointed to deliver the plant feasibility study, ESIA and EPC Contractor tender evaluation.



ENECOGEN, ROTTERDAM, NL
870 MW high efficiency gas CCGT. Ramboll's Owner's Engineer services included engineering design review, HAZOP, witness of testing, and review of O&M.


"
EXTRA MILE IN ANSWERING
ADDITIONAL QUERIES NOT
NECESSARILY COVERED BY
THE SCOPE."

CO-GENERATION

Co-generation - also known as Combined Heat and Power (CHP) generation - increases the efficient use of fuel by supplying heat as well as power.

With power-only generation, low value energy is lost, but with CHP most of it is captured for use.

CHP can offer the advantage of reliable energy supply as well as lower-carbon or renewable power and heat.

CHP systems also offer the possibility of district scale cooling systems, and can support the intermittency issues experienced with other renewables through energy storage.

KEY COMPETENCIES:
Energy system planning:
- Strategic studies
- Options appraisal
- Systems design
- Demand & supply capacity mapping
- Resource efficiency
- Carbon reduction

POWER PLANTS:
- Fuel handling
- Boiler design
- Process control
- Emissions control systems
- O&M
- Turbine design
- Heat exchangers & pumps
- Energy storage & heat accumulators

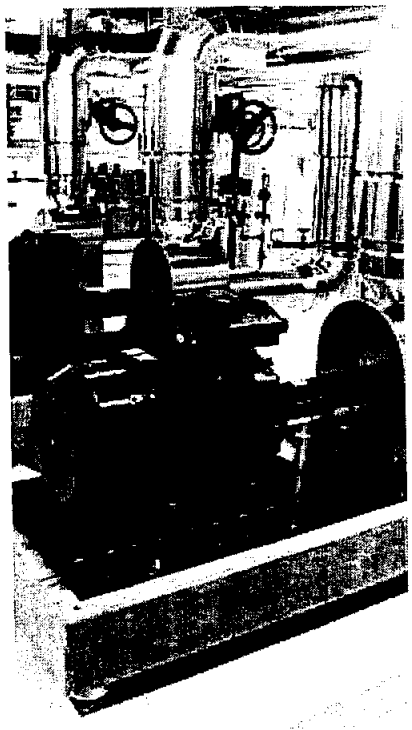
DISTRICT HEATING & COOLING:
- Transmission lines
- Distribution systems

Services
For both new and retrofit CHP projects Ramboll offers all services necessary for establishing optimised:
- CHP plants
- Energy storage
- Heat accumulators
- District & local heating systems
- District & local cooling systems

Our services range from planning, design and procurement to implementation and O&M support:
- Thermal modelling and optimisation
- Turbine design
- Heat accumulator design
- District heating systems design
- Plant generation and heat distribution system interface optimisations

Experience
Ramboll has been a leading consultancy in the development of both district heating, CHP conversion and new plant construction projects for more than 40 years.

Our vast experience with energy production facilities based on a variety of fuels combined with our experience of district heating transmission systems help us maximise the benefits for both investors and consumers.



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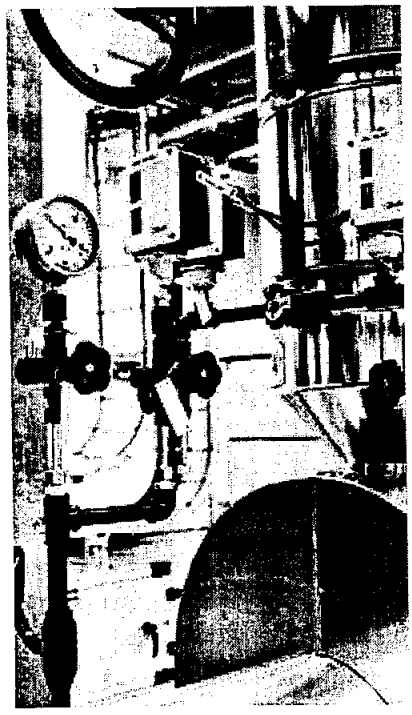
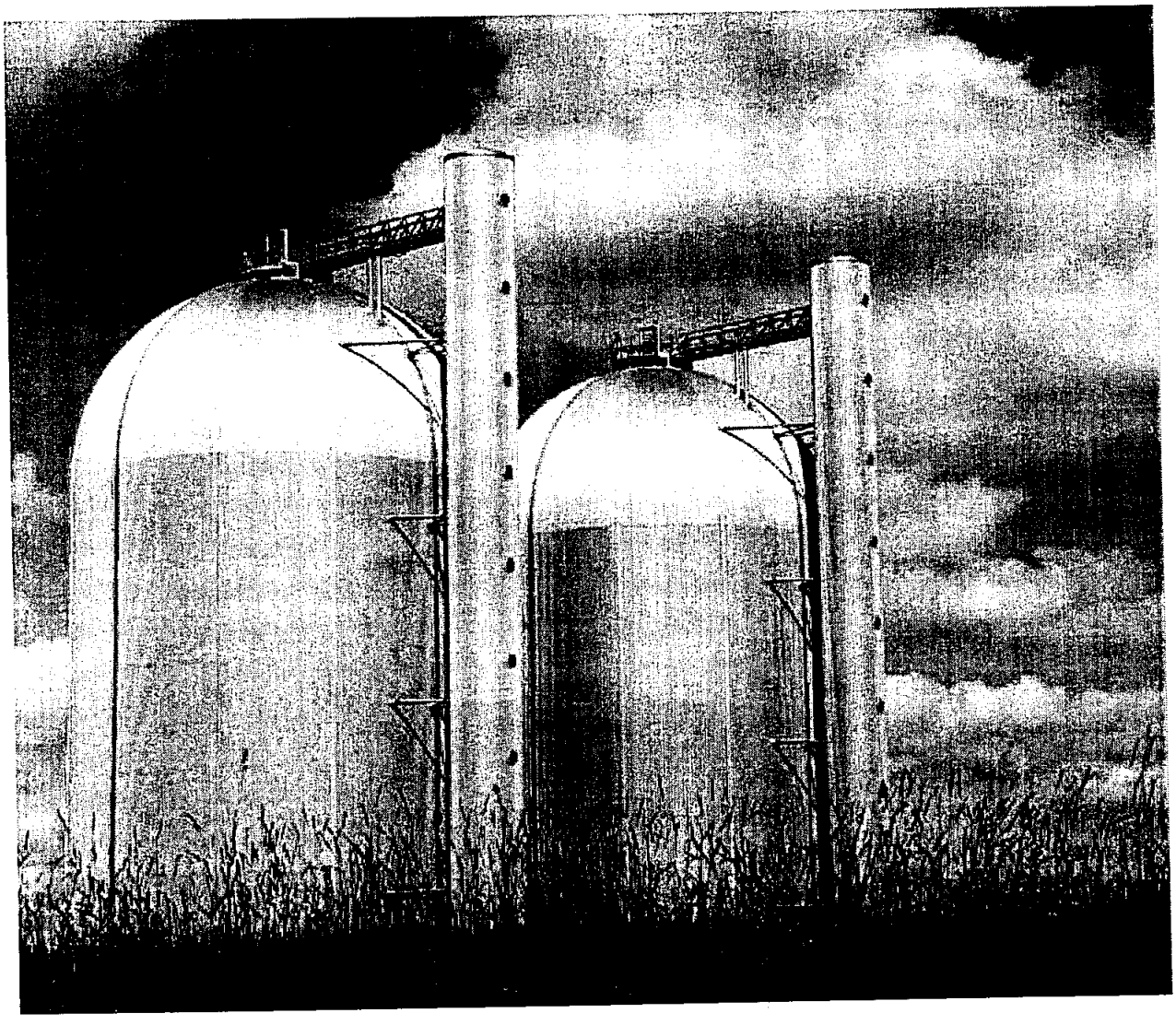


01 and 02. Gladsaxe, Denmark
Natural gas fired district heating peak load facility. Ramboll was lead consultant.

03. CHP accumulator tanks
Ramboll designed large-scale heat accumulators allowing the Avedore CHP plant to decouple heat and power production to optimise demand



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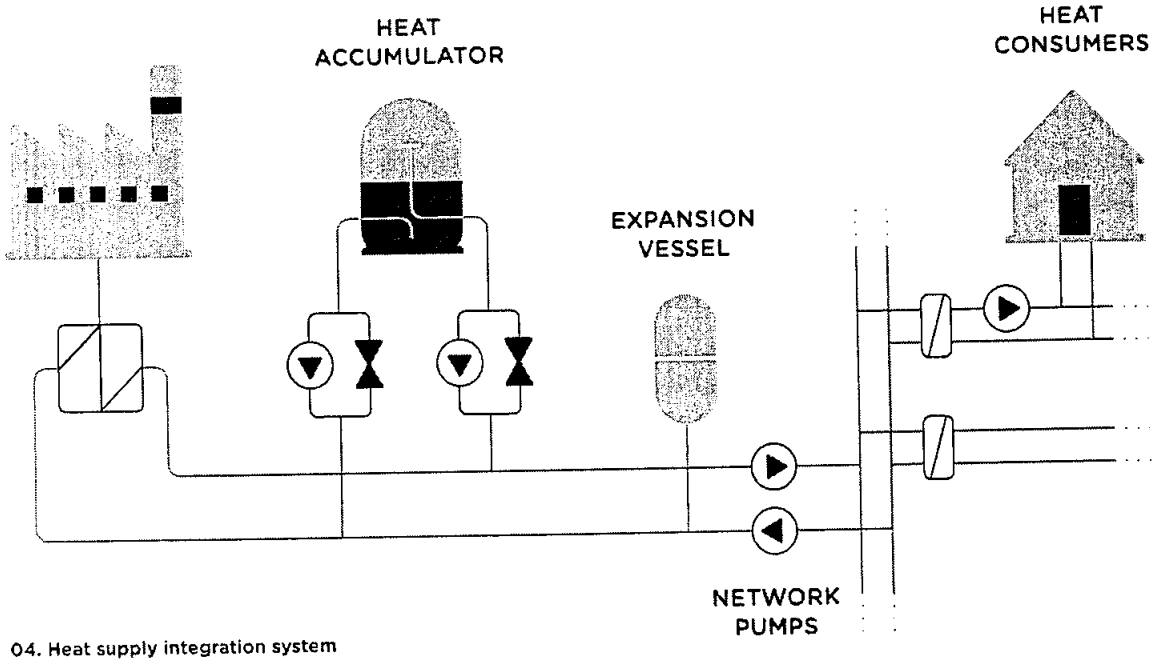


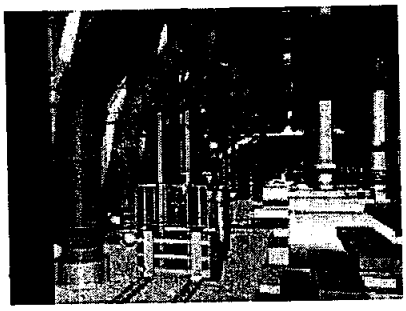
04. Heat supply integration system

SPECIAL COMPETENCIES

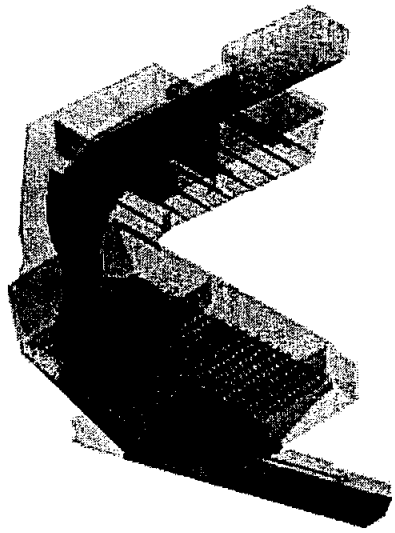
Ramboll is unique amongst independent international power generation consultants, possessing highly expert competencies covering every aspect of power generation facilities and being able to offer clients a truly comprehensive range of specialist services.

Alongside our project lifecycle services we provide specialist services at a detailed design and Front-End Engineering Design (FEED) level including a complete range of services to support plant operation, maintenance and lifetime extension.

Ramboll has developed an Online Process Optimisation system to enable plant operators to continuously identify areas impacting upon plant performance with remote specialist support on hand to assess significant performance deviations.



Using 3D scans, Ramboll provides designers with hundreds of thousands of coordinates in retrofit projects to optimise design and co-ordination.



With solid flow distribution modelling Ramboll can advise on detailed design modifications.

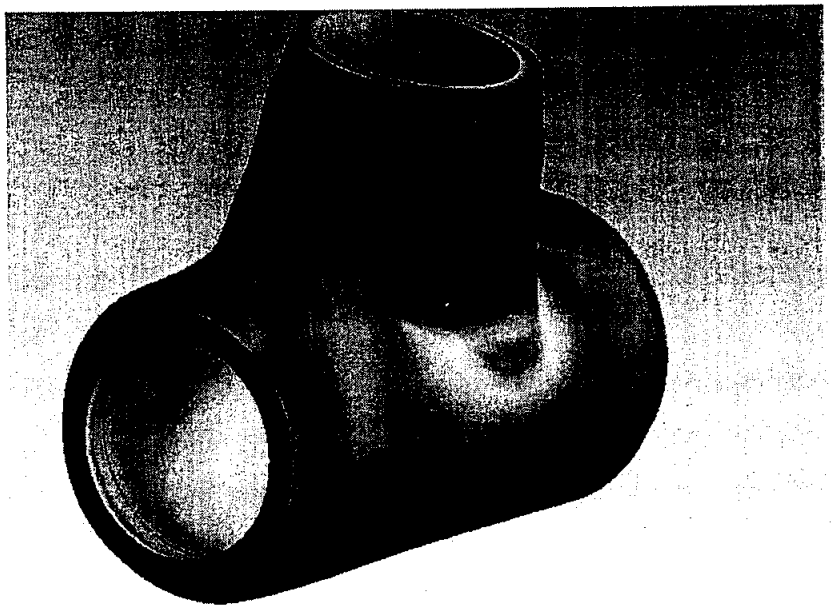
EXPERT COMPETENCIES

- Project Management
- Boiler, combustion and fuel logistics
- Turbine, process, balance of plant and cooling systems
- Power piping
- Environmental and emissions control
- Electrical power systems
- Instrumentation and control
- Civil engineering
- Site supervision
- QHSE & inspection services

Enabling delivery of

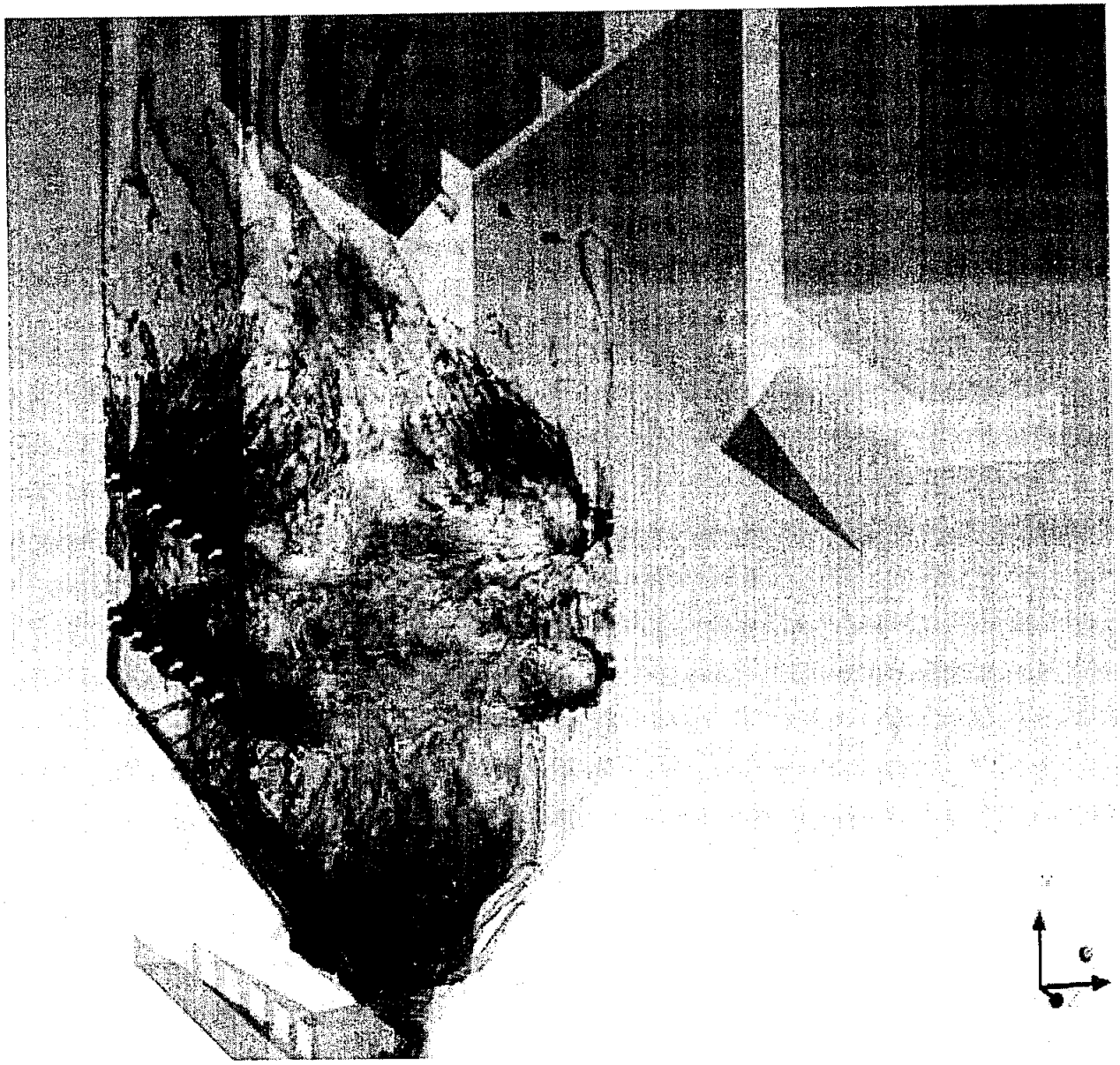
SPECIALIST SERVICES

- Risk and process safety
- Boiler CFD modelling
- Creep damage and low cycle fatigue calculations
- Performance modelling and online process optimisation
- Root cause analysis
- Fire safety & ATEX
- Noise control engineering
- Vibration analysis and vibration protection
- Combustion and emissions performance optimisation
- Condition monitoring
- 3D modelling and laser scanning

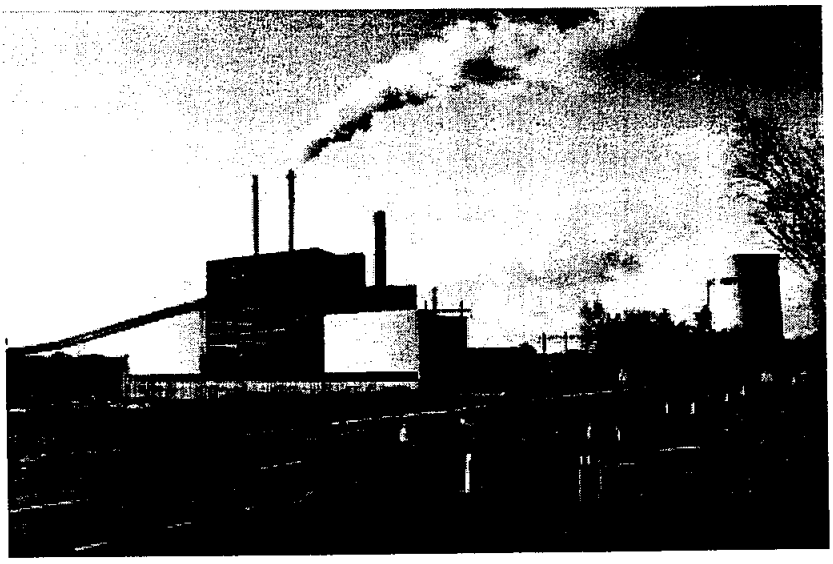


CREEP & FATIGUE CALCULATIONS
For many years, Ramboll specialists have been leading the way in refining fatigue and creep calculations in order to establish knowledge on the remaining lifetime of power plants. We have developed the unique software called Lifetex to perform exact calculations.

CFD BOILER MODELLING
Using our in-house CFD modelling expertise, Ramboll can assess the performance of new and existing boilers as well as develop designs and specifications for fuel and plant modifications.

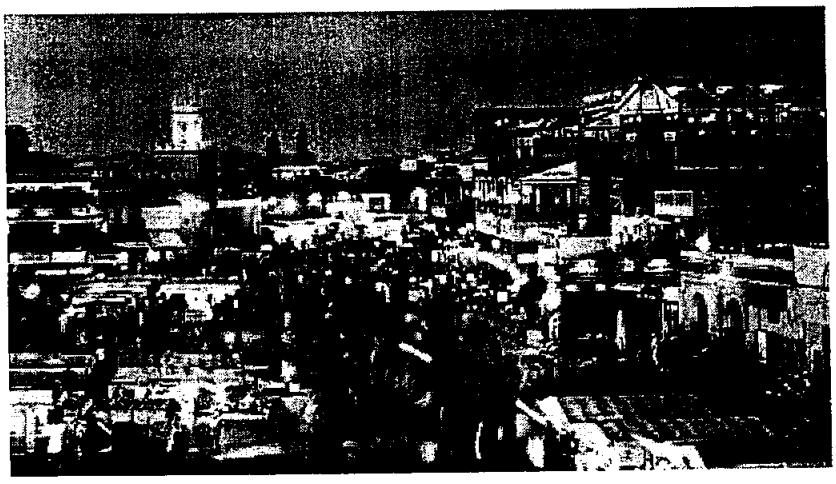


FURTHER REFERENCES



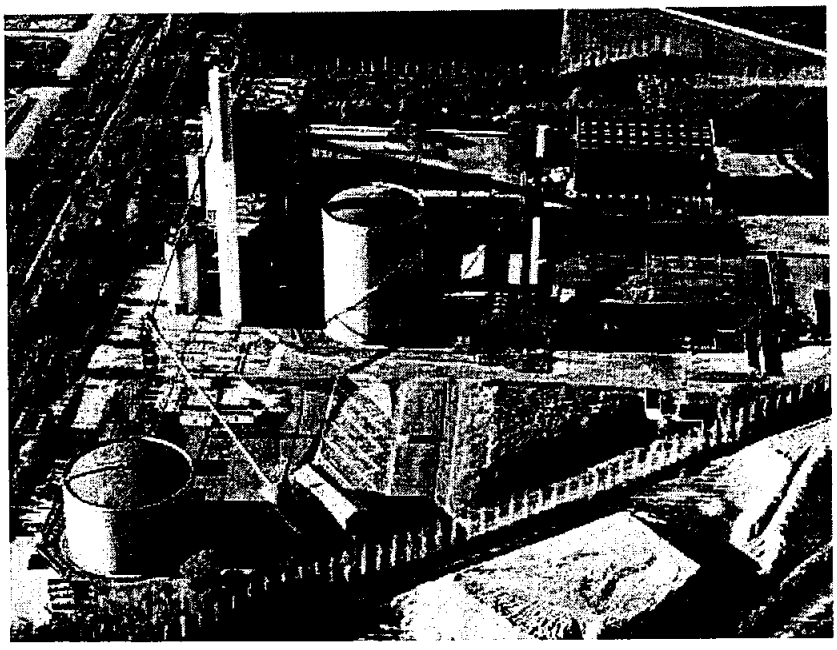
SANDVIK, VÄXJÖ, SWEDEN
40MWe + 60MWth biomass CHP plant. Fuels include wood chips, bark, saw dust and branches and roots.

Ramboll was the Owner's Engineer for the design and construction phase of a new biomass fired unit with technical responsibility for the boiler, turbine, flue gas cleaning and balance of plant. Our role commenced with the procurement of the major components, and then included monitoring of manufacturing, erection and commissioning as well as supervision of initial commercial operation and guarantee tests.



GAS-TO-POWER PROJECT, MOROCCO
LNG import terminal including storage and maritime jetty, 2400 MW CCGT and connecting gas pipelines.

Ramboll is the Technical Adviser to ONEE, working alongside legal and commercial advisers, with the responsibility to develop the project involving the definition of the institutional structuring of the project, preparation of feasibility studies and tender documents, evaluation of the offers, negotiation and contracting leading to the appointment of the company (ies) who will finance, construct and operate the Gas-to-Power project.



HERNING, DENMARK
97MWe 180MWth multi-fuel CHP plant. This plant has been progressively adapted over more than two decades and now combines high efficiency with the capacity for flexible firing of a full range of fossil and biomass fuels, including wood pellets, wood chips, oil, coal and natural gas.

Ramboll was the Owner's Engineer for all project phases from project analysis, design and planning to commissioning. Our technical input was provided across all parts of the plant from fuel delivery, storage and handling, to boiler and controls modifications, fire strategy and emissions control systems.

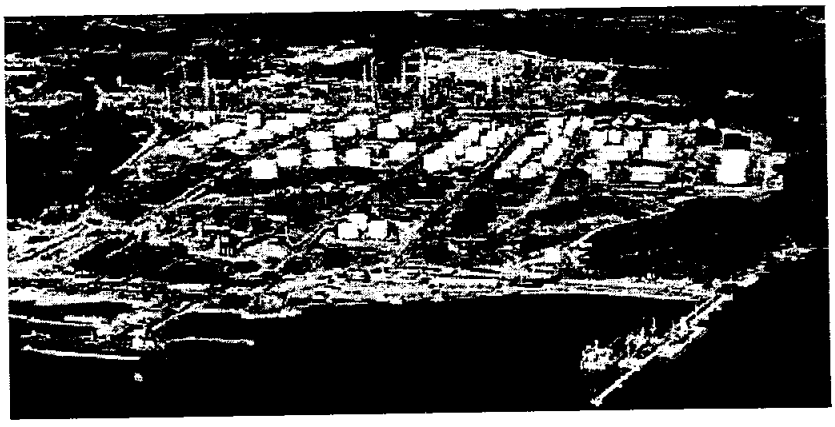
ORION, DHAKA AND KHULNA, BANGLADESH
2 x 630 MW high efficiency coal.

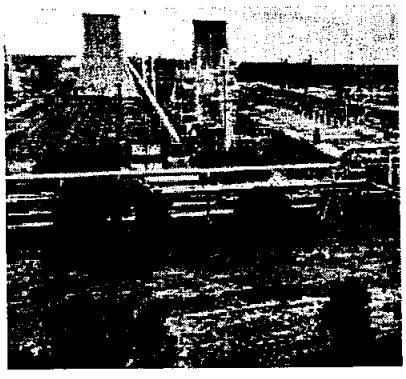
Large increases in power demand in developing countries result in the need for high efficiency solutions to permit development whilst limiting impacts.

Ramboll was chosen as the Owner's Engineer to ensure technical coherence and an optimised plant design comprising the highest possible overall efficiency of the plants.

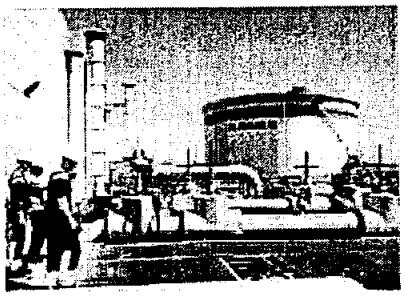
Phases include input from pre-FEED and FEED to tendering and eventual construction and commissioning.

KILPILAHTI POWER PLANT, FINLAND
The project involves the re-planting of thermal facilities at the largest refinery in the Nordic region. Ramboll was appointed as the Lender's Technical Adviser (LTA) covering technical, commercial and environmental aspects up to financial close. We continue as LTA during the construction and operational phases of the project.





PUŁAWY, POLAND
400 MW CCGT. A turn-key EPC project where Ramboll was appointed to provide Owner's Engineer technical support during procurement through to construction and commissioning stages. Services included review of tender specification, tender evaluation and Owner's Engineer services during project implementation.

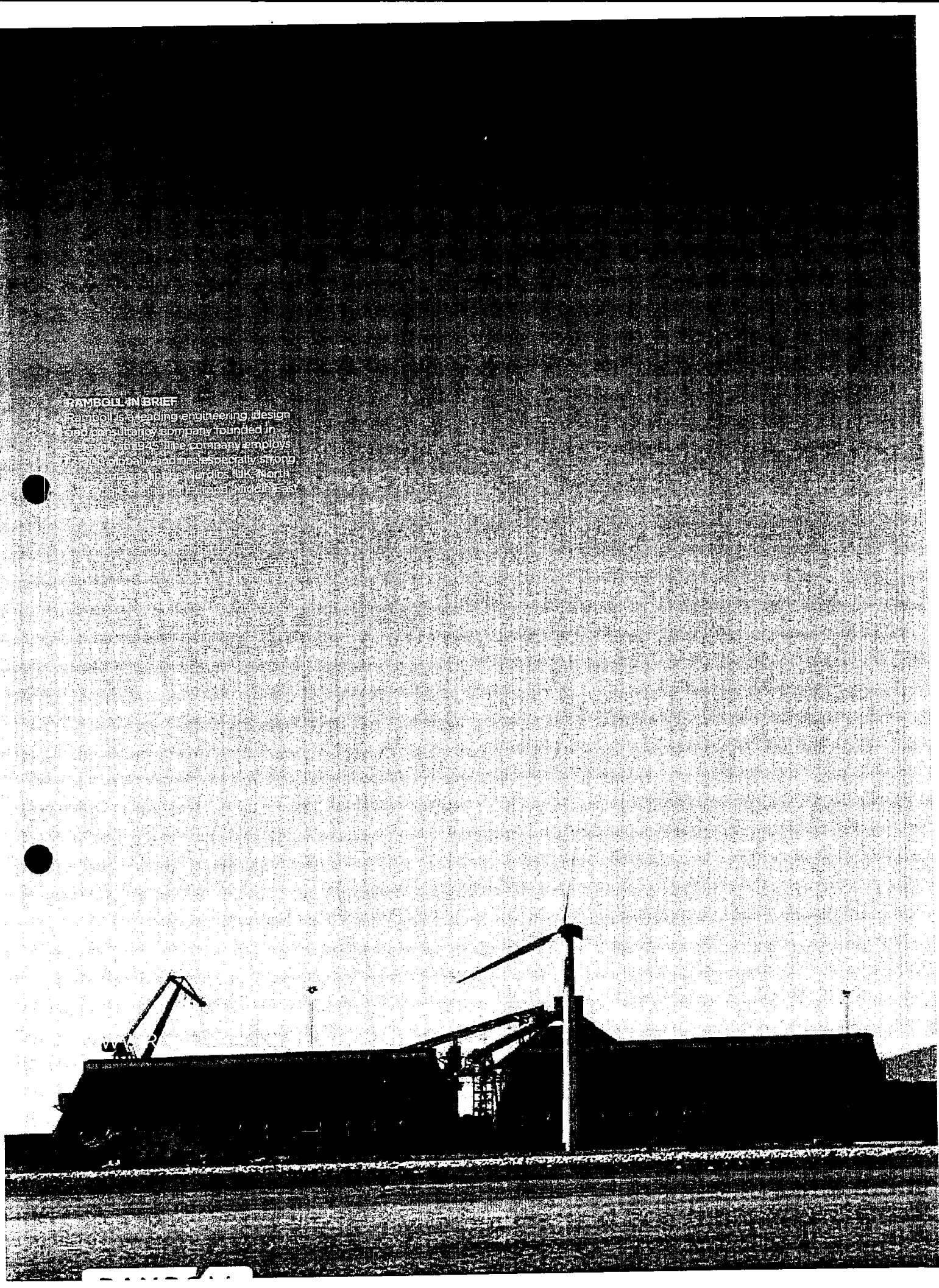


SAUDI ARABIA, RABEC
1200 MW heavy-oil fired power plant. Ramboll executed root cause analysis (RCA) following tube failures and boiler CFD analysis to help select appropriate mitigation. Ramboll acted as independent adviser to the client.

GUELPH, ONTARIO, CANADA
2 x 20MW new biomass CHP plus 1 x 7MW expansion.
Ramboll was appointed by the project developer to provide engineering support to determine the facilities' requirements, options and preliminary engineering design and cost for all three projects, including all mechanical and electrical

RAMBØLL IN BRIEF

Rambøll is a leading engineering, design and consultancy company founded in Denmark in 1945. The company employs [illegible] globally and is especially strong [illegible] in the Nordics, UK, North [illegible] Europe, Middle East, [illegible]



ANNEXURE K

REMAINING USEFUL LIFE ASSESMENT (RULA) REPORT

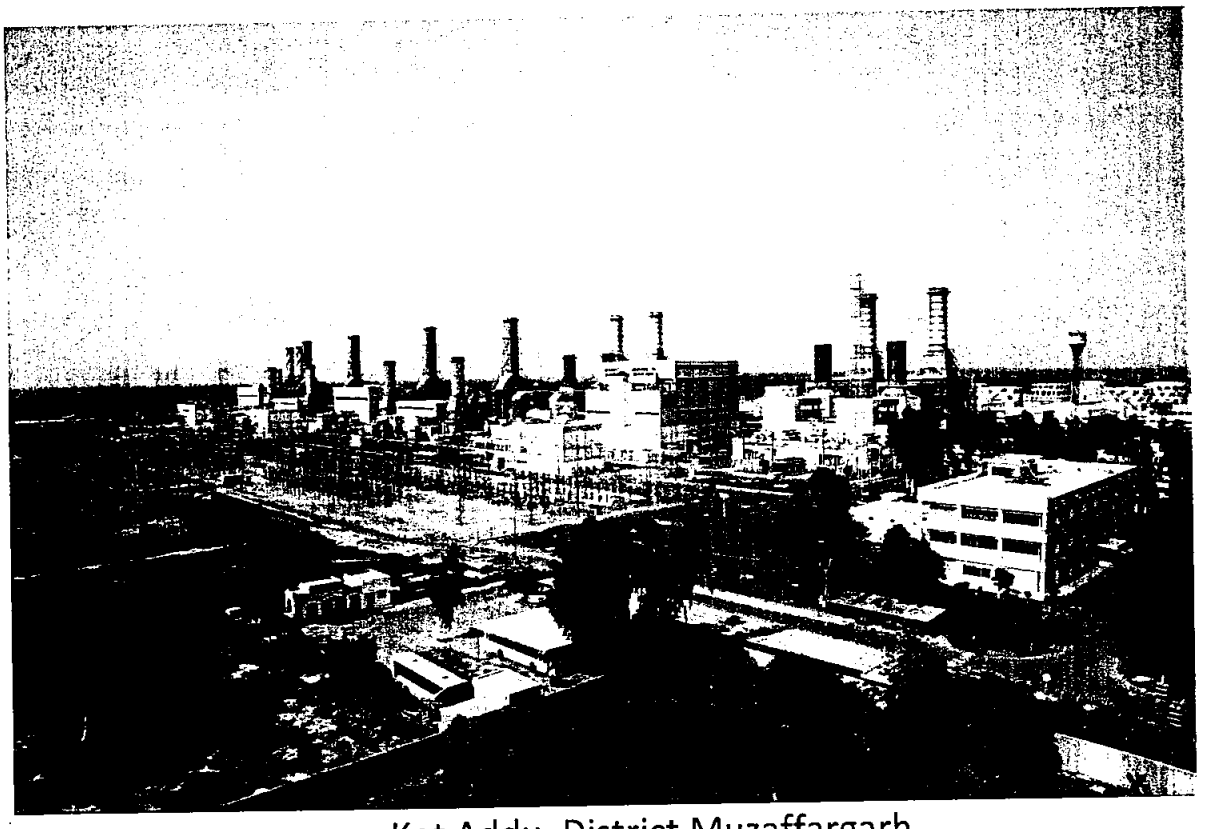
Intended for
Kot Addu Power Company

Document type
Report

Date
June 2021

KAPCO PLANT REMAINING LIFE ASSESSMENT STUDY

Kot Addu Power Company Limited (KAPCO)



Kot Addu, District Muzaffargarh

Pakistan

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KAPCO PLANT REMAINING LIFE ASSESSMENT STUDY

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Abbreviations

ADC	Annual Dependable Capacity Test
bar	Bars (pressure)
Bar(a)	Bars (absolute pressure)
Bar(g)	Bars (gauge pressure)
CDP	Compressor Discharge Pressure
CDT	Compressor Discharge Temperature
CW	Cooling water
CV	Calorific value
CCR	Central Control Room
CCGT	Combined cycle gas turbine
°C	Degrees Centigrade
COD	Commercial Operation Date
DPT	Dye Penetrant Test
EE	Exciter End
EOH	Equivalent Operating hours
FSR	Full Stator Rewind
Gas	Natural Gas
GT	Gas Turbine
HP	High pressure
LP	Low Pressure
HV	High voltage
HHV	Higher heating value
HSD	High Speed Diesel
HRSG	Heat Recovery Steam Generator
IDC	Initial Dependable Capacity Test 1996
IPP	Independent Power Producer
IEC	International Electro technical Commission
ISO	International Organization for Standardization
KAPCO	Kot Addu Power Company
kV	Kilovolt
km	Kilometer
kWh	Kilowatt hour
kW	Killowatt
KKS	Kraftwerk-Kennzeichen System
kJ	Kilojoules
LV	Low voltage
LHV	Lower heating value
LTSA	Long Term Supply Agreement
LSFO	Low Sulphur Furnace oil
MW	Megawatts
m	Meter

mm	Millimeter
mm WC	Millimeter of Water Column
MCR	Maximum continuous rating
m/S	Meters per second
m^3	Cubic meter
MV	Medium voltage
MW	Megawatts
m^2	Square meter
mbar	Milli bar
MJ	Mega joule
MPI	Magnetic Particle Inspection
MVA	Mega volt-amp
NDE	Non Destructive Examination
NDT	Non Destructive Testing
OH	Operating Hour(s)
OCGT	Open cycle gas turbine
O&M	Operating and maintenance
OEM	Original equipment manufacturer
OTC	Outlet Temperature Corrected
PM	Preventive Maintenance
PPA	Power Purchase Agreement
PSO	Pakistan State Oil
RUL	Remaining Useful Life
Si3D	Siemens Innovative 3-Dimensional design
SNGPL	Sui Northern Gas Pipelines Ltd
STG	Steam Turbine Generation Unit
sec	Second
TE	Turbine End
TET	Turbine Exhaust Temperature
TMCR	Turbine continuous maximum rating
t/h	Tones per hour
Unit	Gas Turbine or Steam Turbine Generation Unit
UT	Ultrasonic Testing
UTG	Ultrasonic thickness gauging
WAPDA	Water and Power Development Authority

Definitions

Commercial Availability: Availability of Plant excluding weighted Unscheduled Outages

Commercial Availability= ((Complex Capacity-Weighted Unscheduled Outage) x100)/(Complex Capacity)

Plant Availability: Availability of Plant excluding Schedule and Unscheduled Outages

Plant Availability = ((Complex Capacity- Scheduled Outages-Unscheduled Outages) x100)/(Complex Capacity)

1. EXECUTIVE SUMMARY

1.1. Introduction

Ramboll has been contracted by Kot Addu Power Company (KAPCO) to undertake a technical assessment of the remaining life of the KAPCO combined cycle power plant located at Kot Addu, District Muzaffargarh, Punjab in Pakistan. This assessment has been based on data provided to Ramboll by KAPCO which included plant O&M records and other 3rd party condition assessment reports, equipment inspections and NDT studies previously commissioned by KAPCO.

1.2. Rationales for Life Assessment Study

KAPCO combined cycle power Plant was built in phases from 1985 to 1996 by Water and Power Development Authority ("WAPDA"). It is the largest IPP operating in the mid country and supplying electricity through Six (6) 132 KV and Six (6) 220 KV feeders. KAPCO is the only CCGT power plant capable of operating on 3 types of fuel i.e. Gas, Low Sulphur Furnace Oil (LSFO) and High Speed Diesel (HSD). This multifuel capability makes KAPCO plant a backbone for the national grid.

Combined cycle power plant are typically constructed using a design life of 25-30 years. However, a specified Design Life does not necessarily dictate a finite life expectancy or mandatory retirement of the plant. Experience shows that the operating life can be enhanced by a further 15-20 years with the requisite capital expenditure and excellent maintenance practices.

KAPCO has an agreement of 25 years with power purchaser WAPDA that is expiring on 25 June 2021.

KAPCO units has been operating since past 25 to 30 years. It is necessary to assess aging impacts and to determine residual useful life of KAPCO generating units and auxiliaries so that for the same term PPA (Power Purchase Agreement) extension may be granted in sake of national interest as per clauses of extension within current PPA.

1.3. Scope and Methodology

Scope of study included residual life assessment of major equipment of CCGT plant e.g. Gas Turbine, Steam Turbine, HRSG, Generator, Unit Transformer, Instrumentation and Control System, Auxiliaries and Buildings and Structures.

This Life Assessment study has been conducted on the basis of Plant design data, Current Operating parameters, Units Operations and Maintenance History, Current operating performance, Life Assessment and NDT reports, condition monitoring test reports, Operator's own assessment in view of O&M challenges for the plant, World' Thermal Power plants Operating life trends and Ramboll's experience of power plant life extension projects.

Units have been studied Module wise (in configuration 2+1 i.e. two gas turbines and one steam turbine) for design data, technical limits, current operating conditions and parameters, past and current unit performance to develop a qualitative base line. World trends for plant life have been discussed.

The key aspects from recent major inspections, modifications, upgradations and condition monitoring test results have been reviewed.

Electrical major components e.g. Generator, Unit transformers healthiness and residual life has been assessed based on current offload/on load test results, NDTs and test results conducted during major inspections.

Important Auxiliaries and BOP equipment prone to aging, healthiness has been checked for residual life assessment.

Buildings and Civil structure integrity assessment reports has been reviewed for checking healthiness and fitness for units' future operations.

The main Plant components remaining life has been assessed based on design life, operating hours, NDTs and test results conducted during major outages and current unit conditions and with consideration to the experience of other life extension projects, globally.

The study has been concluded with remaining useful life assessment of the units along with recommendations.

1.4. Outline of KAPCO Plant Layout

KAPCO power plant comprises 10 Gas Turbines, 10 Heat Recovery Steam Generators (HRSG) and 5 Steam turbines. The Plant has been divided into 3 blocks, maintenance wise (Blocks 1, 2, 3) as well as efficiency wise in descending order Energy Blocks 1, 2 and 3. The Plant has been further subdivided into five modules with each module comprising two Gas turbines, two HRSGs and one Steam turbine. The five modules are Module-1; GT-1, GT-3 and STG-9; Module-2; GT-2, GT-4 and STG-10; Module-3; GT-5, GT-6 and STG-11; Module-4; GT-7, GT-8 and STG-12 and Module-5; GT-13, GT-14 and STG-15

1.5. Overview and Study of Plant for Qualitative Analysis

The design data and technical limits of the gas turbines, HRSGs and STG in each of the five modules have been discussed in regard to current O&M history and expected remaining life.

Units' current operating parameters have been investigated and compared with IDC parameters. Comparison has shown that all units are operating near to, or better, than IDC parameters. In spite of aging impacts on the units, all units' loading capacity in MW has been well maintained compared to IDC (Initial Dependable Capacity 1996). That is considered a direct consequence of excellent Operations and Maintenance strategy and Upgrades.

All Gas Turbine units can operate on all 3 fuels, Natural Gas, HSD and LSFO except GT-3 and 4 which can operate only on Gas and HSD.

GT-1, 2, 5, 6, 13, 14 and STG-9, 11, 12, 15 have undergone midlife control change.

GT-1, and GT-2 have undergone upgrade of the Inlet Guide Vanes (IGVs) from fixed to modulating to reduce stresses on turbine hot gas path components and to avoid compressor surge.

GT-3 has undergone replacement of the Excitation system with a new one. GT-3 and 4 HMI and Information system has been upgraded to Siemens Win CC.

GT-5 and GT-8 have undergone Hot Gas path up-gradation which has improved their exhaust temperature control curves i.e. increase in Turbine inlet temperature hence maintaining and improving loading Capacity.

GT-13 and GT-14 have undergone Siemens Si3D upgrades of the 1st two stages of the turbine. STG-10 has undergone installation of modified 1st stage moving blades for heat rate improvement and new LP turbine erosion protection rings of the last 3 stages.

All units' schedule outages e.g. MOH, HGPI and CI are being performed well in time as per OEM recommended intervals and/or criteria of OH, EOH and no. of starts.

Module wise average Plant Availability has been approximately 85% over the past five years which is excellent.

1.6. World trends in the Operating Life of Thermal Power Plants

World trends has been discussed in regard to thermal power plants, life cycle, deterioration impacts, maintenance strategies, World operating power plants life and age before retirements.

Operating life of a power station before decommissioning can be extended 20 to 25 years over the original design life in account of conservative design assumptions and well-managed repair and maintenance schedules including necessary capital expenditure to replace worn components.

In Europe, about 25000 MW of thermal power plants are in age range 30 to 60 years that is exceeding their design life of 30 years. The capacity-weighted average age of operating coal facilities in US is 39 years. In US, the most common age of recently retired Coal units is 50-60 years, Natural Gas Steam units 40-50 years, and for Combustion Turbine units it is 40-50 years.

The actual operating hours of a plant also needs to be considered as high-pressure, high temperature, components such as the heat recovery steam generators, main steam pipework, steam turbine are subject to material creep over an extended period of operation, in addition to the usual life limiting aspects of fatigue, erosion corrosion etc.

Whether thermal power plants are kept in operation, refurbished, placed on standby or decommissioned at their design life remains primarily an economic decision for the owner depending upon the unit condition and maintenance cost. More stringent environmental legislation may also be a deciding factor to retire a power plant if the environmental upgrade costs are too prohibitive. This has been the case for many of the coal-fired power plants in Europe.

1.7. Plant Major Components Remaining Life Assessment

Remaining life assessment has been discussed module wise for all major components of the units. Gas Turbine, Steam Turbine, HRSGs including main electrical equipment e.g. Generator, Transformers, condition monitoring tests has been discussed.

For all Gas turbine units, hot gas path components e.g. combustors, fuel nozzles, GT blades and vanes etc are being replaced periodically on HGPI and MOH as per OEM recommendation. One complete set of turbine blade/bucket and vane/nozzle is available in store as a strategic spare for each model of Gas Turbine at KAPCO.

Module-1 units: GT-1 last MOH was performed in Feb-March 2021. GT-3 last major inspection was performed in Feb-March 2018. STG-9 major overhaul was performed recently in Feb-March 2021. The overall condition of GT-1, GT-3 and STG-9 is satisfactory as analyzed from visual inspections, NDTs conducted during these outages e.g. DPT, Hardness testing, MPI and UT.

GT-1, GT-3 and STG-9 remaining life is assessed to be 10, 19 and 11 years respectively based on the current operating hours of each unit.

HRSG-1 and 3 expected remaining life is assessed to be 12-15 years based on recent boiler inspection, NDTs and life assessment conducted by SGS in March 2021 for HRSG-01. The condition of HRSG-01 is considered to be representative of HRSG-03 as HRSG-03 has much lesser operating hours.

GT-1 Generator was overhauled in Feb-March 2021. Overall Generator condition is considered to be **Good** based on test reports e.g. ELCID, IR, and PI etc. During the inspection findings were observed on Generator rotor J Straps which were replaced with new. GT-3 Generator electrical tests and inspections conducted in October 2020 have shown healthy condition. It is considered that GT-1, and GT-3 Generators may be satisfactorily kept in operation for the next 10 years with condition monitoring.

GT-1 Unit Transformer life assessment tests were conducted on a sample basis in Block-1 and the test results are satisfactory. GT-3 Unit Transformers oil analysis reports are showing some paper aging. However, the overall condition of the Unit transformers is considered **Acceptable to Satisfactory**.

GT-1 is operating with a new control system with remaining life of 17 years. GT-3 control system is old yet operating satisfactorily with spares availability in KAPCO Stores.

ST-9 is of ABB design and manufacture, having a single flow HP and double flow LP cylinder. The steam turbine is rated at a nominal 112 MW with steam conditions of 46.9 bar and 495ºC. The ST is directly coupled to an ABB air cooled generator of rating 132 MVA at 11 kV. A major turbine overhaul was performed recently in Feb-March 2021. The overall condition of the ST is considered to be **Satisfactory** as analyzed from visual inspections and NDTs conducted during these outages e.g. DPT, Hardness testing, MPI and UT. STG-9 control system was replaced with new SPPA-3000 in 2016. Generator overhauling was carried out in Feb-Mar 2021 and its condition is considered **Satisfactory** and may be kept in operation for next 10-15 years. Although the ST Unit Transformers oil analysis reports indicated some paper aging, the overall condition of the Unit transformers is considered **Acceptable to Satisfactory**.

Module-2 units: GT-2 and GT-4 minimum remaining life is assessed to be 11 and 19 years based on current operating hours and overall **Satisfactory** condition as observed from recent inspection reports.

HRSG-2 and HRSG-4 expected remaining life is assessed to be 12-15 years based on the above mentioned HRSG-01 sample inspections, NDT and life assessment reports. HRSGs-1, 2, 3 and 4 are the same design from the same supplier.

GT-2 Generator was overhauled in Feb 2018. Siemens reported "No thermal or thermo mechanical aging phenomena were detected". It is considered GT-2 and GT-4 Generators may be satisfactorily kept in operation for next 10-12 years with scheduled condition monitoring checks.

GT-2 Unit Transformer life assessment tests were conducted in 2016 by ABB on a sample basis in Block-1 and test results were satisfactory. GT-4 Unit Transformer oil analysis report is showing satisfactory results. STG-10 Transformer oil analysis report is showing some degassing which will be tested again. However, operating parameters and electrical test results are normal and overall condition of the Unit transformers is considered to be **Satisfactory**.

GT-2 is operating with latest control system Siemens SPPA T3000 with minimum remaining life of 13 years. GT-4 and STG-10 control system is old yet operating satisfactorily with spares availability in KAPCO Stores. Moreover, control system spares obtained from STG-9 control system replacement are available for STG-10.

ST-10 is of ABB design and manufacture, having a single flow HP and double flow LP cylinder. The steam turbine is rated at a nominal 112 MW with steam conditions of 46.9 bar and 495ºC. ST-10 is directly

coupled to an ABB air cooled generator of rating 132 MVA at 11 kV. A major overhaul of ST-10 was performed in Sep-Oct 2013. Modified 1st stage moving blades and Installation of new LP turbine erosion protection rings of the last 3 stages were installed during 2013. Overall condition is considered satisfactory based on a minor inspection carried out in 2016. Generator overhauling was carried in Feb-Mar 2016 and its condition is considered **Good** and the Generators may be kept in operation for the next 10-15 years with condition monitoring. STG-10 Unit Transformer oil analysis report is showing some degassing which will be tested again. However, operating parameters and electrical test results are normal and the overall condition of the ST-10 Unit transformer is satisfactory.

Module-3 units GT-5, GT-6 and STG-11 remaining life is assessed to be 14, 13 and 15 years based on the current operating hours and overall **Good** condition as observed from recent inspection reports of HGPI/MOH 2017 and Combustion Inspection March 2021.

HRSGs-11A, 11B, 12A and 12B are of same model. Life assessment of HRSG-11A and 11B has been conducted on sample basis in Nov 2020 and the same condition is predicted for the other two HRSGs. Based on life assessment report, routine maintenance inspections; HRSG-11A and 11B expected remaining life is greater than 15 years.

GT-5 and GT-6 Generators have been in service since commissioning. Based on monitoring test recommendation, conductive paint activity on stator winding has been carried out. Generator rotor flux report for GT-5 and 6 found **Satisfactory**. Full Stator rewind (FSR) material is available on site as strategic spare for GT-5, 6 and 7 Stators.

Generator rotor flux report indicates no significant fault and can continue its normal operation. Expected remaining life of the newly rewound STG-11 generator is considered greater than 15 years.

GT-5, 6 and STG-11 Unit TF Oil analysis reports indicate no internal fault and the condition is considered **Satisfactory**.

GT-5 and GT-6 are operating with GE's latest control system Mark VIe with remaining life of 17 years. The STG-11 control system ALSTOM ALSPA Controsteam V3 was upgraded in 2009 and the minimum remaining life is considered greater than 10 years.

ST-11 is of GEC Alstom design and manufacture, having a single cylinder (combined HP/LP). The steam turbine is rated at a nominal 103 MW with steam conditions of 40 bar and 511ºC. The steam turbine is directly coupled to a GEC Alstom air-cooled generator of rating 121.64 MVA at 11 kV. A major overhaul of the turbine was performed in 2017. Overall condition is considered **Satisfactory** based on a minor inspection carried out in Feb-Mar 2020. A full Stator rewind was done in 2017 and its condition is considered **Very Good**. Generators may be kept in operation for next 15 years with regular condition monitoring checks. STG-11 Unit Transformer oil analysis report indicates the analyzed winding paper ageing markers (furans, methanol) have no significant paper ageing and thus quality of winding paper can be assessed as **Very Good.**

Module-4 units: GT-7, GT-8 and STG-12 remaining life is assessed to be 13, 12 and 14 years based on the current operating hours and the **Good** overall condition as observed from recent inspection reports 2021, 2019 and 2017 respectively.

GT-7 and GT-8 hot gas path upgradation was performed during outages in Sep-Oct 2010 and 2011 respectively.

Based on life assessment report (HRSG11A and 11B) in 2020 on sample basis, HRSG-12B previous report 2013 and routine maintenance inspections; HRSG-12A and 12B expected remaining life is considered greater than 15 years.

GT-7 Generator condition is considered **Satisfactory**, that is the same as for GT-5 and GT-6. A full stator rewind (FSR) material is available on site as strategic spare. GT-8 and STG-12 Generator full stator rewind was conducted in 2015 and the expected remaining life is greater than 15 years.

GT-7, GT-8 and STG-12 Unit Transformer Oil analysis reports and electrical tests and operating parameters indicate no internal fault and condition is considered **Satisfactory**.

GT-7 and GT-8 are operating with the old GE Speedtronic Mark IV control system which can be further operated reliably for next 10 to 12 years with the availability of control system spares in KAPCO stores and spares obtained from the control system replacement of GT5 and GT-6. STG-12 control system is ALSTOM ALSPA Controsteam V3 upgraded in 2011 and the remaining life is considered greater than 10 years.

ST-12 is of GEC Alstom design and manufacture, having a single cylinder (combined HP/LP). The steam turbine is rated at a nominal 103 MW with steam conditions 40 bar and 511ºC. The steam turbine is directly coupled to a GEC Alstom air-cooled generator of rating 121.64 MVA at 11 kV. A turbine major overhaul was performed in 2015. The overall condition is considered **Satisfactory** based on a minor inspection carried out in Feb-Mar 2020. Full Stator rewind was done in 2015 and its condition is considered **Very Good**. The Generators may be kept in operation for next 15 years with scheduled condition monitoring. STG-12 Unit Transformer oil analysis report indicates the analysed winding paper ageing markers (furans, methanol) have no significant paper ageing and thus quality of winding paper can be assessed as **Very Good**.

Module-5 units: GT-13, GT-14 and STG-15 remaining life is assessed to be 10, 11 and 10 years based on the current operating hours and assessed condition.

Overall condition of units GT-13, GT-14 and STG-15 reported **Satisfactory to Good** during visual inspections and NDTs performed in the last MOH October 2019 and CI November 2020. NDTs performed during MOH included, Ultrasonic Testing, Magnetic Particle Test, Dye Penetrant Test and Hardness Test. HRSG-13 and 14 remaining life assessment conducted which included visual inspections and NDTs e.g. Ultrasonic thickness gauging, DPT, MPI, Hardness testing and Metallography.

Based on life assessment report which revealed no significant deterioration and routine maintenance inspections; expected remaining life of HRSG-13 and 14 is greater than 15 years.

GT-13 and GT-14 Generator condition is reported **Good** with minimum remaining life of 12-15 years on the basis of assessment tests conducted by Siemens.

GT-13, 14 and STG-15 Unit Transformer Oil analysis reports indicate no internal fault and condition is considered **Good** and remaining life is assessed 12-15 years.

GT-13, 14 and STG-15 Aux, HRSG-13 and HRSG-14 old control system has been replaced with new state of the art SPPA T3000 control system in Feb-March 2021. STG-15 control system already replaced to SPPA T3000. Hence the Control system can be operated reliably for further 15-20 years.

ST-15 is of Siemens design and manufacture, having two cylinders (single flow HP and double flow LP). This steam turbine is rated at a nominal 148 MW with steam conditions 57 bar and 528ºC. The steam turbine is directly coupled to a Siemens air-cooled generator of rating 175MVA at 11kV. The overall condition of STG-15 is reported **Satisfactory** to **Good** during visual inspections and NDTs performed in

the last minor / major overhauling. STG-15 control system was replaced with new SPPA-3000 in 2015. STG-15 Generator condition is reported **Good** with minimum remaining life of 12-15 years on the basis of assessment tests conducted by Siemens. STG-15 Unit Transformer Oil analysis reports indicate no internal fault and condition is considered **Good** and remaining life is assessed 12-15 years. There is no indication of thermal or electrical faults reported in the transformer.

Cooling tower and Water treatment plant for all units are in healthy condition and can be kept in service for next 12-15 years. For cooling tower structure of the STGs water proofing and repairs have been performed.

Buildings and Civil structure integrity life assessment has been conducted for all units. Visual inspections and NDTs were conducted which included concrete compressive strength measurement by Rebound Hammer and Crack Depth Measurement by Ultrasonic Pulse Velocity Test and ultrasonic method. Identified cracks were repaired as recommended. Overall condition of civil structures and buildings is observed **Satisfactory**. We envisage remaining useful life of 20 years on the basis of a typical 50 years expected design life but assuming on-going condition assessment and maintenance being required.

1.8. Operations and Maintenance Practices

The Operations and Maintenance practices at the KAPCO Plant have been studied. Well established Local Procedures and Safety Rules are implemented at site to ensure safe and smooth operations of plant and safety of employees at work.

Maintenance management is working effectively through usage of Computerized Maintenance management system (CMMS).

Integrated Management system is implemented with accreditations of ISO9001 for Quality, ISO14001 for Environment and OHSAS18001 for Occupational Health and Safety.

KAPCO is complying all regulatory requirements in regard to Environment management system. All emissions of air, water and noise relating to plant operations are within limits established by Punjab Environment Protection agency.

Historic major modifications, upgrades and improvement projects are summarized which has ensured safe, reliable and efficient operations of plant along with human safety.

Spares inventory has been maintained in KAPCO stores for routine maintenance of units as well as for strategic spares for replacement of equipment if breakdown occurs.

Above 30,000 spare parts are stored in KAPCO Stores for Gas Turbines, Steam Turbines and Auxiliaries relating to Mechanical, Instrument and Electrical Equipment. This large volume of spares will help ensure the KAPCO Plant continues to achieve reliable operation and high Plant Availability in coming years.

1.9. Conclusion and Recommendations

Based on the O&M records, 3rd party condition assessment reports, qualitative and analytical study and life extension experience from other projects, it is Ramboll's opinion that the KAPCO Plant could continue to operate for a minimum further 10 years on the basis that the Plant continues to be operated as previous i.e. baseload and is maintained as per statutory and OEM requirements and the recommendations from recent, and future, plant inspections reports are implemented.

Module wise residual life assessment has been concluded as;

a) **Module-1** (GT-1, GT-3 and STG-9) plant is in overall **Satisfactory** condition and expected Remaining life is assessed to be a minimum of **10** years. The following replacements/upgrades are recommended in the next MOH;

i. GT-1-3 replacement of air intake filters in case Differential pressure approaches upper limit
ii. STG-9 replacement of Row-1 blades
iii. HRSG-1-3 Insulation and Cladding to be replaced in next MOH from deteriorated surfaces.
iv. Cooling Tower structure inspections and repair with Tam Seal at portions showing corrosion effect

b) **Module-2** (GT-2, GT-4 and STG-10) Plant is in overall **Satisfactory** condition and expected Remaining life is assessed to be a minimum of **10** years. The following replacements/upgrades are recommended in the next MOH;

i. GT-2-4 replacement of air intake filters as the Differential pressure approaches upper limit
ii. STG 10 replacement of Cooling Tower Fill material

c) **Module-3** (GT-5, GT-6 and STG-11) Plant is in overall **Good** condition and expected Remaining life is assessed to be a minimum of **10** years. The following replacements/upgrades are recommended in the next MOH;

i. HRSG 11 A-B Flue Gases Ducts renovation due to aging factor, availing each shutdown opportunity
ii. STG-11 replacement of cooling tower fan blades

d) **Module-4** (GT-7, GT-8 and STG-12) Plant is in overall **Good** condition and expected Remaining life is assessed to be a minimum of **10** years. The following replacements/upgrades are recommended in the next MOH;

i. GT-7 recommendation by OEM to replace compressor aft brush seals and honey-comb seals for better performance.
ii. STG-12 replacement of cooling tower fan blades and fill material

e) **Module-5** (GT-13, GT-14 and STG-15): This is the highest efficiency CCGT plant in Pakistan which can also operate on LSFO. The Plant is in overall **Satisfactory to Good** condition and expected remaining design life is assessed to be a minimum of **10** years. The following replacements/upgrades are recommended in the next MOH;

i. Replacement of compressor blades for GT-13 and 14 (No finding reported till date)
ii. GT-13 and GT14 Corrosion Prevention Painting of filter house at external surface
iii. Repair of concrete structure of Cooling Tower and Clarifiers of STG-15
iv. Renovation of Thermal Insulation of GT-13 and GT14 and HRSG-13 and HRSG14

f) **All Civil Buildings and Structures** integrity assessment has indicated overall condition to be **Satisfactory**, except some minor cracks and concrete corrosion. Expected Remaining useful life of Buildings and Structure is 20 years on the basis of 50 years design life.

2. INTRODUCTION

2.1. The Company

Kot Addu Power Company limited (KAPCO) Pakistan is the largest IPP of Pakistan with name plate capacity of 1600 MW. Kot Addu Power Plant (the "Power Plant") was built by the Pakistan Water and Power Development Authority ("WAPDA") in five phases between 1985 and 1996 at its present location in Kot Addu, District Muzaffargarh, Punjab. In April 1996, Kot Addu Power Company Limited ("KAPCO") was incorporated as a public limited company under the Companies Ordinance, 1984 with the objective of acquiring the Power Plant from WAPDA. The principal activities of Kot Addu Power Company limited (KAPCO) Pakistan are the ownership, operation and maintenance of the 1600 MW power plant at Kot Addu, Punjab Pakistan. The Company sells the electrical energy produced from its power plant to its customer, Central Power Purchasing Authority CPPA-G Pakistan.

The KAPCO power plant is Pakistan's largest combined cycle power plant and comprises 10 gas turbines, 10 heat recovery steam generators and 5 steam turbines. The power plant has the capability of using three different fuels to generate electricity, namely: Natural Gas, Low Sulphur Furnace Oil (LSFO) and High Speed Diesel (HSD).

2.2. Background

Combined cycle power plants are typically constructed using a design life of 25 - 30 years, with the design of civil structures up to 50 – 60 years. A number of hot, warm and cold starts are also specified together with the expected number of operating hours per year, typically 8,000 hours, which equates to a typical design life of 200,000 - 240,000 operating hours.

The hot gas path components need repair and replacing according to the OEM maintenance program several times during this plant design life calendar period.

Most combined-cycle power plants - regardless of scheduled gas turbine, steam turbine, and other major equipment O&M practices - display signs of aging and fatigue beyond 20 to 25 years of age after their initial commercial operation date.

Gas turbine, heat recovery steam generator and steam turbine components are exposed to stress caused by temperature or static and dynamic loading, low-cycle fatigue (LCF) and high-cycle fatigue (HCF), erosion, oxidation and high temperature corrosion as well as mechanical stress and wear. The high-pressure, high temperature, components also experience material creep over time.

Operating life can be enhanced further 15-20 years beyond design life with periodic replacements of major components as per ongoing maintenance schedule and refurbishment of equipment. Therefore 40-50 years is not an unusual operating life for a combined-cycle power plant.

A specified Design Life does not necessarily or inherently dictate a finite life expectancy or mandatory re tirement of the plant and hundreds of power plants around the World have demonstrated economic operating life 15-20 years in excess of typical design life.

Replacement of control and instrumentation systems with new one, during midlife of power plant is typical refurbishment. Such new control and instrumentation equipment generally results from the obsolescence of much of hardware and the consequent lack of spares availability.

More frequent inspections, NDT and maintenance of the overall plant is usually required as a plant ages requiring repairs or replacement of components.

Throughout the plant operation, KAPCO generating units have demonstrated, high plant availability and enhanced plant performance in regard to both plant capacity as well as efficiency due to excellent maintenance schedules, OEM recommended upgrades and plant operations as per OEM guidelines.

Although Gas Turbine operations on Low Sulphur furnace oil in past several years has impacted in form of hot corrosion erosion and causes increased maintenance. Inspite of these challenges, KAPCO power complex has maintained high availability factor. In the future, more generation is envisaged on Gas fuel due to supply of RLNG which will reduce maintenance.

KAPCO has followed best practices of Operations and Maintenance as advised by the equipment OEMs and adhered to the recommended periodic maintenance schedules. This has resulted in high plant availability and optimum plant performance.

Determining the amount of reliable residual useful life of the KAPCO generating units is very important so as to make firm commitments with the Power Purchaser, as unavailability under the Power Purchase Agreement has heavy financial consequences.

KAPCO Power purchase agreement of 25 years with the Power Purchaser CPPA (G) is expiring in June 2021, however, 16 months extension has been agreed as Other Force Majeure Event (OFME) under LD settlement agreement.

2.3. Objective

As the PPA term is ending in June 2021 and KAPCO is looking to continue business and serve the Country, it is important to conduct a study to ascertain the useful Residual life of KAPCO units so that PPA Term renewal can be negotiated accordingly.

2.4. Scope of Work

Scope of Study includes Residual life assessment of all KAPCO units and related major equipment;

- Gas Turbine
- Steam Turbine
- HRSG
- Generator
- Unit Transformer
- Instrumentation and Control System
- BOP and Auxiliaries e.g. Cooling Tower, Water Treatment Plant
- Buildings and Structures

2.5. Approach and Methodology:

This Life Assessment study has been conducted on the following basis;

1- Plant Design data and OEM recommendations
2- Units Operations and Maintenance History
3- Plant Current Operational Data
4- Plant Current Environment Performance Data
5- Plant Major upgrades and replacements
6- Plant Components NDTs conducted during major outages
7- Life assessment reports as conducted by third party during Major Outages
8- Plant routine Operational and Safety Tests
9- Electrical systems routine tests, major outages testing and condition monitoring tests
10- Operator's experience for plant operations and maintenance
11- Plant Current O&M Practices and Procedures
12- World's Thermal power industry standards and best practices
13- Ramboll's experience of life extension projects

2.5.1. Life Assessment Methodology:

The following methodology has been adopted for Life Assessment study of the KAPCO units;

- Review of the technical design and present condition of the KAPCO units.
- Review of operating records, units operating and maintenance history
- Review of Current Plant Performance vs design Performance to assess aging impact
- Theoretical analyses on design criteria and operational experience from similar units and components in the World
- Module wise detailed analysis of major components for residual life
- Review of 3rd party inspection reports and non-destructive testing (NDT) conducted during recent major outages of critical components e.g. for HRSG life assessment during MOH which includes, Dimension checks, Hardness tests, Replica extraction, Magnetic particle test, ultrasonic examination, etc.
- Review of 3rd party Generator and other major electrical components on-load and off-load testing and NDT reports.
- Review of 3rd party reports for inspections and testing of major /critical structures i.e. foundations of the Gas/Steam Turbine and Generator, Cooling Towers, etc.
- Review 3rd party reports for the technical design and present conditions of, Generator, Transformers, Auxiliaries and BOP for the assessment work.

3. OUTLINE OF KAPCO PLANT LAYOUT

KAPCO power plant consists of five modules as per plant configuration. Each module consists of two Gas Turbines, two HRSGs and one steam turbine. Maintenance wise the Plant has been divided into Maintenance Block-1, 2 and 3. Similarly, efficiency wise the Plant has been divided into Energy Block-1 (which is the highest efficiency), Energy Block-2 and Energy Block-3 (which is least efficient block). Below is the plant layout as per configuration mentioned herein;

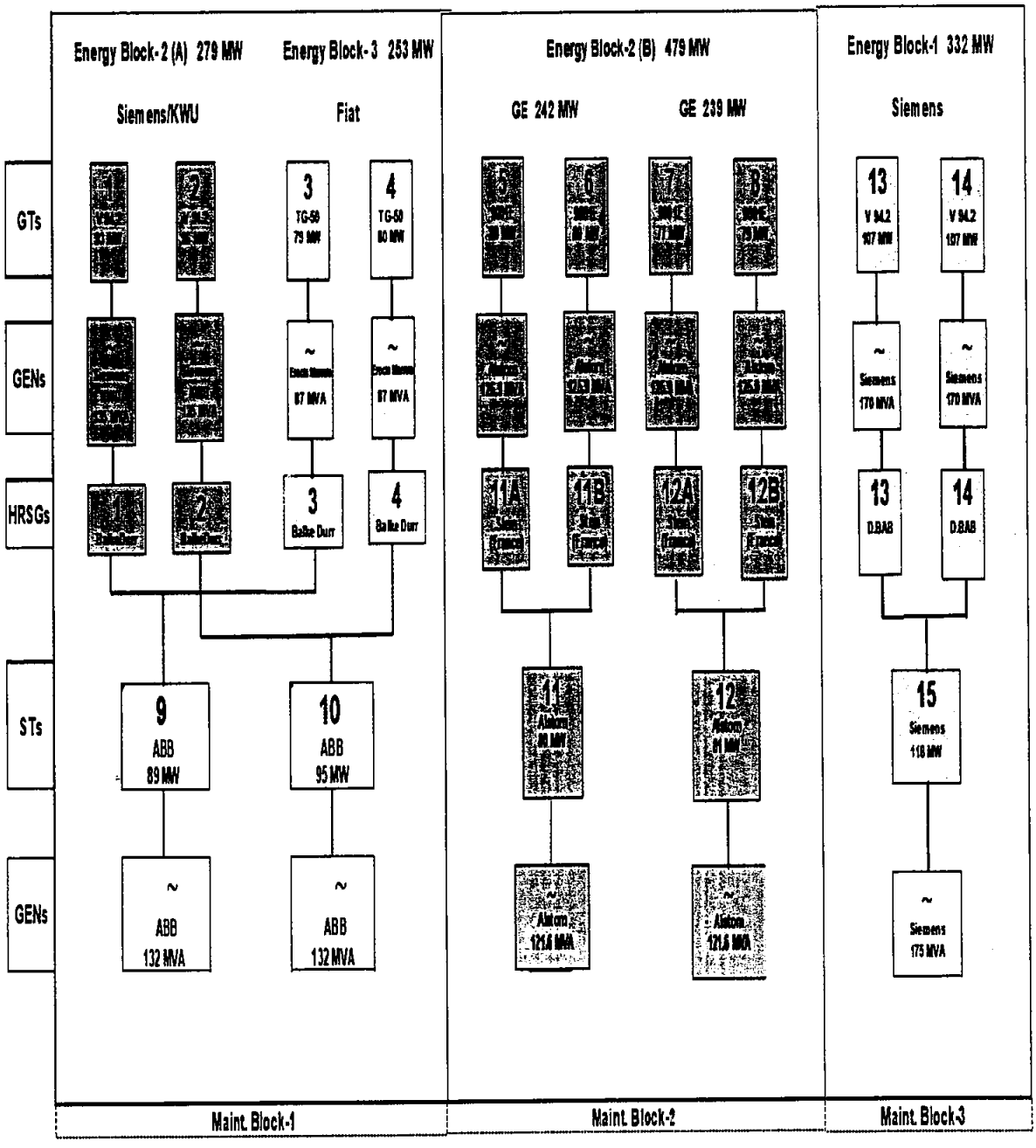


Figure 3- 1 KAPCO Plant Layout

4. OVERVIEW AND STUDY OF KAPCO GENERATION UNITS

4.1. Overview of KAPCO Module-1

KAPCO Module-1 consists of two gas turbines, two heat recovery steam generators (HRSGs) and one steam turbine. Gas turbine GT-1 is Siemens V94.2 type and was commissioned in January 1987 in open cycle mode on HSD fuel.

Gas turbine GT-3 is Fiat TG50D type and was commissioned in March 1987 in open cycle mode on HSD fuel.

Module-1 open cycle gas turbines GT-1 and GT-3 were converted to combined cycle mode after commissioning of Heat Recovery Steam Generators; HRSG-1 and HRSG-3 along with steam turbine STG-9 in 1991.

GT-1 was commissioned on Furnace oil and Gas in 1991. GT-3 was also commissioned on Gas fuel in February 1991. GT-3 cannot operate on Furnace oil.

Module-1 configuration is as follows: GT-1 + HRSG-1, GT-3 + HRSG-3 and STG-9

4.1.1. Design and Current Operating conditions of Module-1 Units:

4.1.2. Design Data and Technical Limits of Module-1 Units:

Gas Turbine GT-1 has operated satisfactorily since its commissioning in 1987 with periodic replacements of hot gas path components as per the OEM recommended maintenance cycle. Below is the design data of GT-1 which is valid for current unit operation;

Table 4.1: GT-1 Design Data

Sr. No	Description	GT 1
1.	Model	V-94.2
2.	Manufacturer	KWU(Germany)
3.	Base Load rating at 15°C	125.5 MW (HSD)
4	Starting time up to 3000 RPM	4 Minutes
5	Turbine Inlet Temp	1050°C
6	Turbine Exhaust Temp at full load	507 to 550°C
7	Auto loading gradient	i. 11 MW/minute up to base load ii. Onward 4 MW/Min
8	Overall Efficiency	28.8 %

Initially GT-1 had fixed position IGVs which were then upgraded to be modulating IGVs in 2005 to reduce thermal stresses and to control compressor surge.

GT-1 Control system has been replaced from the old ISKMATIC to a modern Siemens SPPAT3000 in 2016 to enhance unit reliability.

Gas Turbine GT-3 has operated satisfactorily since its commissioning in 1987 with periodic replacements of hot gas path components as per the OEM recommended maintenance cycle. Below is the design data of GT-3 which is valid for current unit operation;

Table 4.2: GT-3 Design Data

Sr. No	Description	GT 3
1.	Model	TG-50D
2.	Manufacturer	GIE(Italy)
3.	Base Load rating at 15°C	96.08 MW (HSD)
4	Starting time up to 3000 RPM	25 Minutes.
5	Turbine Inlet Temp	1050°C
6	Turbine Exhaust Temp at full load	553 to 610°C
7	Auto loading gradient	6 MW/Min
8	Overall Efficiency	27.4 %

Steam Turbine STG-9 is of ABB make and has operated satisfactorily since its commissioning in 1991. Below is the design data of steam turbine Unit-9 which is still valid for current unit operation;

Table 4.3: STG-9 Design Data

Sr.No.	Description	Units STG 9
1.	Make	ABB, Germany
2.	Type	DK2056
3.	Rated Power	112.2 MW
4.	Live Steam (for steam turbine) Inlet Press	47.9
5.	Live Steam Temperature °C	495
6.	Secondary Steam (for de-aeration) Inlet	3.99
7.	Secondary Steam Temperature °C	190.6
8.	Vacuum (Bar)	0.091

9.	Generator rating	132 MVA @ 50 Cold Air Temp
10.	Unit Transformer rating	135 MVA

Heat Recovery steam generators HRSG-1 and HRSG-3 are in operation since COD 1991 without any major problems. Below is the design data for HRSG-1 and HRSG-3 which are operating at design capacity.

Table 4. 4: HRSG-1 and HRSG-3 Design Data

HRSG-1: Balke Durr	
Steam Flow	208 t/h
Design Pressure	62 bar(g)
Superheater Outlet Pressure	47.1 bar(g)
Superheated Steam temperature	505°C
Total Heating Surface	58180 m^2
HRSG-3: Balke Durr	
Steam Flow	180.8 t/h
Design Pressure	62 bar(g)
Superheater Outlet Pressure	48 bar(g)
Superheated Steam temperature	500°C
Total Heating Surface	54182 m^2

4.1.3. Current Operating Data of Module-1 Units

Following data of Annual Dependable Capacity Test performed on dated 01-07-2020 shows that Module-1 units are operating near to or better than IDC parameters (IDC Initial dependable Capacity Test 1996) owing to prudent operating procedures and excellent maintenance strategy;

Table 4.5: Module-1 Operating Data

Gas Turbine No. 1 at 36°C ADC & 34°C IDC ambient temperature on LSFO							
Reading	Real Load	Reactive Load	CDP	CDT	OTC	Inlet Loss	Exhaust Loss
	MW	MVAR	bar	°C	°C	Pascal	mbar
ADC-2020	94	19	8	342	488	500	21
IDC-1996	90.0	-7.4	8	340.0	488	600	21.0
Gas Turbine No. 3 at 36°C ADC & 34°C IDC ambient temperature, ADC on Gas & IDC on HSD							

Reading	Real Load	Reactive Load	CDP	CDT	TET	Inlet Loss	Exhaust Loss
	MW	MVAR	bar	°C	°C	mm of H2O	mbar
ADC-2020	77	25	10	399	582	122	19
IDC-1996	80	17	9	397	576	71	13

Steam Turbine No. 9							
Reading	Real Load	Reactive	HP Inlet	HP Inlet	Ex Press	CW Inlet	Cooling Tower Fans
	MW	MVAR	Press bar	Temp °C	bar	Temp °C	in service
ADC-2020	101	23	41	493	0.11	32	6
IDC-1996	92	2	42	480	0.235	32	6

	HRSG-1				HRSG-3			
Reading	HP Steam	HP Steam	FW Inlet	Flue Gas	HP Steam	HP Steam	FW Inlet	Flue Gas
	Press bar	Temp °C	Temp °C	Temp °C	Press bar	Temp °C	Temp °C	Temp °C
ADC-2020	42	487	119	181	42	498	117	147
IDC-1996	41	480.6	130	192	42	497.8	132	160

4.1.4. Operating Record of Module-1 Units

Following data shows operating hours, No. of starts, trips of module-1 units since commissioning till 31 March 2021.

No. of starts are higher for GT-3 in regard to its total Operating hours <100,000.

Table 4.6: Operating Record Module-1

Module-1 Operating Record since Commissioning to March 2021			
	GT-1	**GT-3**	**STG-9**
Date of commissioning	18-Jan-87	12-Mar-87	28-Jan-91
Total No. of Starts	3862	4612	2600
Operating Hours (OH)	171801	93920	165469
No. of Trips	311	113	180

4.1.5. Maintenance Record and History of Module-1 Units

Module-1 Units are operated at base-load, within the original equipment manufacturer (OEM) guidelines. Depending upon the Equivalent Operating Hours of the unit, the following periodic maintenance tasks are performed:

Gas turbines:

- Combustion inspection
- Hot gas path inspection (Not needed for GT-1 as per OEM recommendation)
- Major Overhauling

Generators:

- Schedule inspection every year
- Major inspection after every 60000 EOH

Steam turbine:

- Minor Overhauling/Inspection/Borescope examination
- Major Overhauling

GT-1 and GT-2 combustion inspections are executed by the KAPCO team whilst the MOH is executed by Siemens' Engineers. As per the maintenance life cycle, all spare parts used for replacement are supplied by the OEM, Siemens, in accordance with LTSA (Long Term Supply Agreement).

For GT-3 and GT-4 all maintenance tasks are performed by the KAPCO team. Spares are supplied by Ethos Energy (successor of Fiat).

Table 4.7: Maintenance Record Module-1

ACTIVITY	DATA ITEMS	GT-1	GT-3	STG-9
COMBUSTION INSPECTION	Last CI Inspection Dates	01-Feb-21 To 31-Mar-21	01-Sep-19 To 08-Sep-19	- - -
HOT GAS PATH INSPECTION/MINOR OVERHAULING	Last HGPI Dates	- -	11-Feb-18 To 27-Mar-18	01-Feb-21 To 31-Mar-21
MAJOR OVER HAULING	Last MOH Dates	01-Feb-21 To 31-Mar-21	11-Feb-18 To 27-Mar-18	01-Feb-21 To 31-Mar-21

4.1.6. Operating Performance of Module-1

Below is the past five years operating performance of the Module-1 Units which shows that the Units are operating with best commercial performance figures with high availability factor.

Average plant availability factor of above 85% and Commercial availability of above 95% is comparable to new plants in the power market.

Table 4.8: Operating Performance of Module-1

Gas Turbine GT-1		
Year	**Plant Availability %**	**Commercial Availability %**
2015-16	75	94
2016-17	91	97
2017-18	92	97
2018-19	93	98
2019-20	94	97
Average	90	97
Gas Turbine GT-3		
Year	**Plant Availability %**	**Commercial Availability %**
2015-16	76	94
2016-17	90	95
2017-18	83	97
2018-19	84	98
2019-20	93	97
Average	87	96
Steam Turbine STG-9		
Year	**Plant Availability %**	**Commercial Availability %**
2015-16	74	94
2016-17	90	96
2017-18	87	97
2018-19	88	97
2019-20	93	97
Average	88	96

4.1.7. Qualitative Conditional Assessment of Module-1 Units

Following is the qualitative conditional assessment of Module-1 Units;

Table 4.9: Qualitative Conditional Assessment

Unit #	Operating Parameters Maintained per IDC	Schedule Maintenance Performed	Upgraded	Upgrade Type	Spares Inventory Maintained	Overall Condition Rating	Overall Unit Condition
GT-1	Yes	Yes	Yes	-IGVs Modulating - Control Change	Yes	8	Satisfactory
GT-3	Yes	Yes	Yes	New Excitation System	Yes	6	Acceptable
STG-9	Yes	Yes	Yes	Control system Change	Yes	8	Satisfactory
HRSG-1	Yes	Yes	No	NA	Yes	8	Satisfactory
HRSG-3	Yes	Yes	No	NA	Yes	9	Good

Condition Rating Criteria 1-10:

Rating 9-10 = Good; Rating 7-8 = Satisfactory; Rating 4-6 = Acceptable; Rating 1-3 = Unacceptable

4.2. Overview of KAPCO Module-2

KAPCO Module-2 consists of gas turbines GT-2 and GT-4, heat recovery steam generators HRSG-2 and HRSG-4 and steam turbine STG-10. Gas turbine GT-2 of Siemens V94.2 type was commissioned in January 1987 in open cycle mode on HSD fuel.

Gas turbine GT-4 of Fiat TG50D type was commissioned in May 1987 in open cycle mode on HSD fuel.

GT-2 was commissioned on furnace oil and gas in 1991. GT-4 was also commissioned on gas fuel in February 1991. GT-4 cannot operate on furnace oil.

Module-2 open cycle gas turbines GT-2 and GT-4 were converted to combined cycle mode after commissioning of HRSG-2 and HRSG-4 along with steam turbine STG-10 in 1991.

Module-2 configuration is as follows: GT-2 + HRSG-2, GT-4 + HRSG-4 and STG-10

4.2.1. Design and Current Operating conditions of Module-2 Units:

4.2.2. Design Data and Technical Limits of Module-2 Units

Gas Turbine GT-2 is in operation satisfactorily since its commissioning in 1987 with periodic replacements of hot gas path components as per OEM recommended maintenance cycle. Below is the design data of GT-2 which is valid for current unit operation;

Table 4.10: Design Data of GT-2

Sr. No	Description	GT 2
1.	Model	V-94.2
2.	Manufacturer	KWU(Germany)
3.	Base Load rating at 15°C	125.5 MW (HSD)
4	Starting time up to 3000 RPM	4 Minutes
5	Turbine Inlet Temp.	1050°C
6	Turbine Exhaust Temp at full load	507 to 550°C
7	Auto loading gradient	i. 11 MW/minute up to base load ii. Onward 4 MW/Min
8	Overall Efficiency	28.8 %

Initially GT-2 had fixed position IGVs which were then upgraded to be modulating IGVs in 2005 to reduce thermal stresses and to control compressor surge. The GT-2 Control system has been replaced from the old ISKMATIC to a modern Siemens SPPAT3000 in 2013 to enhance unit reliability.

Gas Turbine GT-4 has operated satisfactorily since its commissioning in 1987 with periodic replacements of hot gas path components as per the OEM recommended maintenance cycle. Below is the design data of GT-4 which is valid for current unit operation;

Table 4.11: Design Data of GT-4

Sr. No	Description	GT 4
1.	Model	TG-50D
2.	Manufacturer	GIE(Italy)
3.	Base Load rating at 15°C	96.08 MW (HSD)
4	Starting time up to 3000 RPM	25 Minutes.
5	Turbine Inlet Temp	1050°C
6	Turbine Exhaust Temp at full load	553 to 610°C
7	Auto loading gradient	6 MW/Min
8	Overall Efficiency	27.4 %

Steam Turbine STG-10 is of ABB make and has operated satisfactorily since its commissioning in 1991. Below is the design data of steam turbine unit-10 which is still valid for current unit operation;

Table 4.12: Design Data of STG-10

Sr.No.	Description	Units STG 10
1.	Make	ABB, Germany
2.	Type	DK2056
3.	Rated Power	112.2 MW
4.	Live Steam (for steam turbine) Inlet Press (Bar)	47.9
5.	Live Steam Temperature °C	495
6.	Secondary Steam (for de-aeration) Inlet Press (Bar)	3.99
7.	Secondary Steam Temperature °C	190.6
8.	Vacuum (Bar)	0.091
9.	Generator rating	132 MVA @ 50 C Cold Air Temp

10.	Unit Transformer rating	135 MVA

STG-10 has undergone installation of modified 1st stage moving blades for load improvement and new LP turbine erosion protection rings of last 3 stages.

Heat Recovery steam generators HRSG-2 and HRSG-4 of Balke Durr Germany are in operation since COD 1991 without any major problems. Below is the design data for HRSG-2 and HRSG-4, both can be operated near to rated tonnage capacity and design parameters.

Table 4.13: Design Data of HRSG-2 and 4

HRSG-2: Balke Durr	
Steam Flow	208 t/h
Design Pressure	62 bar(g)
Super heater Outlet Pressure	47.1 bar(g)
Superheated Steam temperature	505°C
Total Heating Surface	58180 m^2
HRSG-4: Balke Durr	
Steam Flow	180.8 t/h
Design Pressure	62 bar(g)
super heater Outlet Pressure	48 bar(g)
Superheated Steam temperature	500°C
Total Heating Surface	54182 m^2

4.2.3. Current Operating Data of Module-2 Units:

Following data of Annual Dependable Capacity Test performed on dated 04-07-2020 shows that Module-2 units are operating near to or better than IDC parameters (IDC Initial dependable Capacity Test 1996) owing to prudent operating procedures and excellent maintenance strategy;

Table 4.14: Operating Data of Module-2

Gas Turbine No. 2: 42 °C IDC & 34°C ADC ambient temperature on LSFO							
Reading	Real Load	Reactive Load	CDP	CDT	OTC	Inlet Loss	Exhaust Loss
	MW	MVAR	bar	°C	°C	Pascal	mbar
ADC-2020	94	26	8	342	488	400	21
IDC-1996	92	22	8.4	350	488	700	20.0
Gas Turbine No. 4: 42 °C IDC & 34°C ADC ambient temperature; ADC on Gas & IDC on HSD Fuel							
Reading	Real Load	Reactive Load	CDP	CDT	TET	Inlet Loss	Exhaust Loss
	MW	MVAR	bar	°C	°C	mm of H2O	mbar

ADC-2020	77	26	10	395	582	113	17
IDC-1996	74	9	10	404	577	64	15

Steam Turbine No. 10							
Reading	Real Load	Reactive	HP Inlet	HP Inlet	Ex Press	CW Inlet	Cooling Tower Fans
	MW	MVAR	Press bar	Temp °C	bar	Temp °C	in service
ADC-2020	98	15	41	490	0.11	34	6
IDC-1996	94	13	43	456	0.18	34	6

	HRSG-2				HRSG-4			
Reading	HP Steam	HP Steam	FW Inlet	Flue Gas	HP Steam	HP Steam	FW Inlet	Flue Gas
	Press bar	Temp °C	Temp °C	Temp °C	Press bar	Temp °C	Temp °C	Temp °C
ADC-2020	42	492	122	165	42	497	123	157
IDC-1996	44	499	125	190	40	500	122	160

4.2.4. Operating Record of Module-2 Units

Following data shows the operating hours, No. of starts, trips of the Module-2 Units since commissioning till 31 March 2021.

No. of starts are higher for GT-4 in regard to its total Operating hours <100,000.

Table 4.15: Operating Record of Module-2

Module-2 Operating Record since Commissioning to March 2021			
	GT-2	GT-4	STG-10
Date of commissioning	14-Jan-87	02-May-87	08-March-91
Total No. of Starts	4315	4987	2905
Operating Hours (OH)	162106	93756	157017
No. of Trips	218	87	188

4.2.5. Maintenance Record and History of Module-2 Units

Module-2 units are operated at base-load, within the original equipment manufacturer (OEM) guidelines. Following periodic maintenance tasks are performed:

Gas turbines:

- Combustion inspection

- Hot gas path inspection (Not needed for GT-2 as per OEM recommendation)
- Major Overhauling

Generators:

- Schedule inspection every year
- Major inspection after every 60000 EOH

Steam turbine:

- Minor Overhauling/Inspection/Borescope examination
- Major Overhauling

Table 4.16: Operating Record of Module-2

Activity	Data Items	GT-2	GT-4	STG-10
Combustion Inspection	Last CI Inspection Dates	10-Feb-21 To 16-Feb-21	21-Sep-19 To 27-Sep-19	-
Hot gas path inspection/Minor overhauling	Last HGPI Dates	- -	14-Sep-17 To 09-Nov-17	15-Feb-16 To 29-Mar-16
Major Over hauling	Last MOH Dates	01-Feb-18 To 26-Mar-18	15-Feb-16 To 29-Mar-16	01-Sep-13 To 29-Oct-13

4.2.6. Operating Performance of Module-2

Below is the past five years operating performance of Module-2 Units which shows that the Units are operating with best performance in comparison to IDC values and with high availability factor.

Average plant availability factor of above 85% and Commercial availability of above 95% is comparable to new plants in the power market.

Table 4.17: Operating Performance of Module-2

Gas Turbine GT-2		
Year	Plant Availability %	Commercial Availability %
2015-16	79	95
2016-17	93	98
2017-18	78	98
2018-19	80	97
2019-20	92	96
Average	86	97
Gas Turbine GT-4		
Year	Plant Availability %	Commercial Availability %
2015-16	84	97
2016-17	93	95
2017-18	79	97
2018-19	94	97
2019-20	93	99
Average	89	97
Steam Turbine STG-10		
Year	Plant Availability %	Commercial Availability %
2015-16	81	95
2016-17	93	96
2017-18	79	97
2018-19	87	97
2019-20	92	97
Average	88	97

4.2.7. Qualitative Conditional Assessment of Module-2 Units

Following is the qualitative conditional assessment of Module-2 Units;

Table 4.18: Qualitative Conditional Assessment

Unit #	Operating Parameters Maintained per IDC	Schedule Maintenance Performed	Upgraded	Upgrade Type	Spares Inventory Maintained	Overall Condition Rating	Overall Unit Condition
GT-2	Yes	Yes	Yes	-IGVs Modulating - Control Change	Yes	7	Satisfactory
GT-4	Yes	Yes	Yes	New Data Acquisition System	Yes	6	Acceptable
STG-10	Yes	Yes	Yes	Improved 1st stage moving blades	Yes	8	Satisfactory
HRSG-2	Yes	Yes	No	NA	Yes	9	Good
HRSG-4	Yes	Yes	No	NA	Yes	9	Good

Condition Rating Criteria 1-10:

Rating 9-10 = Good; Rating 7-8 = Satisfactory; Rating 4-6 = Acceptable; Rating 1-3 = Unacceptable

Keeping in view the Module-1 and 2 performance in preceding years, current operating conditions and upgrades performed on the Units it is envisaged that if current O&M practices are continued, Module-1 and 2 units can be further operated for a minimum further 10 years with good performance and high plant availability.

4.3. Overview of KAPCO Module-3

KAPCO Module-3 consists of Gas turbines GT-5 and GT-6, heat recovery steam generators HRSG-11A and HRSG-11B and steam turbine STG-11. Gas turbines GT-5 and GT-6 are of GE MS9001E type and were commissioned in Nov and Dec 1988 respectively in open cycle mode on HSD fuel.

GT-5 was commissioned on Furnace oil and Gas in May 1989 and May 1995 respectively. GT-6 was commissioned on Furnace oil and Gas in Jul 1989 and May 1995 respectively.

Module-3 open cycle gas turbines GT-5 and GT-6 were converted to combined cycle mode after commissioning of HRSG-11A and HRSG-11B along with steam turbine STG-11 in 1995.

Module-3 configuration is as follows: GT-5 + HRSG-11A, GT-6 + HRSG-11B and STG-11

4.3.1. Design and Current Operating conditions of Module-3 Units:

4.3.2. Design Data and Technical Limits of Module-3 Units

Gas Turbines GT-5 and 6 have operated satisfactorily since their commissioning in 1989 with periodic replacements of hot gas path components as per OEM recommended maintenance cycle. Below is the design data of GT-5 and GT-6 which is valid for current units operation;

Table 4.19: Design Data GT-5 and GT-6

Sr. No	Description	GT-5 & GT-6
1.	Model	PG-9141 Type 9001 E
2.	Manufacturer	M/S ALSTHOM France.
3.	Base Load Rating at 15 °C	106 MW on HSD & 94.65 on FO
4	Starting time up to 3000 RPM	10 Minutes
5	Turbine Inlet Temp	1085°C on HSD & 1029°C on FO
6	Turbine Exhaust Temp at full load	528°C on HSD & 489°C on FO
7	Auto loading gradient	8 MW/minute
8	Overall Efficiency	31.5 %

GT-5 and GT-6 Control systems have been replaced from the old GE Mark-IV to GE Mark-VIe in 2015 to enhance unit reliability.

GT-5 and GT-6 Hot Gas path up-gradation was carried out in 2011 which enhanced the load capacity of the Units.

Steam Turbine STG-11 is of RATEAU, France and has operated satisfactorily since its commissioning in 1995. Below is the design data of steam turbine Unit-11 which is valid for current unit operation;

Table 4.20: Design Data STG-11

1.	Make	RATEAU, France
2.	Type	VEGA209 110B
3.	Rated Power	103.4 MW
4.	Live Steam (for steam turbine) Inlet Press (Bar)	40
5.	Live Steam Temperature °C	510.8
6.	Secondary Steam (for de-aeration) Inlet Press (Bar)	-
7.	Secondary Steam Temperature °C	-
8.	Vacuum (Bar)	0.091
9.	Generator rating	121.647 MVA @ 36 C Cold Air Temperature
10.	Unit Transformer rating	125 MVA

Heat recovery steam generators HRSG-11A and 11B of Stein Industries France have operated since COD 1995 without any major problems. Below is the design data for HRSG-11A and 11B, both can be operated near to rated tonnage capacity and design parameters.

Table 4.21: Design Data HRSG-11A and B

Rated Steam Flow	151 T/H on LSFO & 173 T/H on Gas
Design Pressure	51 bar(g)
Superheater Outlet Pressure	35.8 bar(g) on LSFO & 42 bar(g) on Gas
Superheated Steam temperature	476°C on LSFO & 512°C on Gas
Total Heating Surface	56386 m^2

4.3.3. Current Operating Data of Module-3

Following data of Annual Dependable Capacity Test performed on 06-07-2020 shows that Module-3 units are operating near to or better than IDC parameters (Initial dependable Capacity Test 1996) at corrected ambient conditions owing to units up-gradations, KAPCO prudent operating practices and excellent maintenance strategy;

Table 4.22: Operating Data of Module-3

Gas Turbine No. 5 at 39°C ADC & 37°C IDC ambient temperature; on LSFO							
Reading	Real Load	Reactive Load	CDP	CDT	TET	Inlet Loss	Exhaust Loss
	MW	MVAR	bar	°C	°C	Pascal	mmWC
ADC-2020	72.0	14.0	9.20	358	500	603	140.0
IDC-1996	74.0	10	9	-	507	130	69

Gas Turbine No. 6 at 39°C ADC & 37°C IDC ambient temperature; on LSFO							
Reading	Real Load	Reactive Load	CDP	CDT	TET	Inlet Loss	Exhaust Loss
	MW	MVAR	bar	°C	°C	Pascal	mmWC
ADC-2020	72.0	20.0	9.10	360	504.0	474	140.0
IDC-1996	76.0	11	9	-	506	176	64

Steam Turbine No. 11							
Reading	Real Load	Reactive	HP Inlet	HP Inlet	Ex Press	CW Inlet	Cooling Tower Fans
	MW	MVAR	Press bar	Temp °C	bar(g)	Temp °C	in service
ADC-2020	76	13	32	411	-0.89	39	6
IDC-1996	76	9	33	467	-0.88	39	6

	HRSG-11A				HRSG-11B			
Reading	HP Steam	HP Steam	FW Inlet	Flue Gas	HP Steam	HP Steam	FW Inlet	Flue Gas
	Press bar	Temp °C	Temp °C	Temp °C	Press bar	Temp °C	Temp °C	Temp °C
ADC-2020	33	473	140	158	32	484	140	159
IDC-1996	34	472	141	165	34	469	142	163

4.3.4. Operating Record of Module-3 Units

Following data shows operating hours, No. of starts, trips of Module-3 units since commissioning till 31 March 2021.

Table 4.23: Operating Record of Module-3

Module-3 Operating Record since Commissioning to March 2021			
	GT-5	GT-6	STG-11
Date of commissioning	14-Nov-88	29-Dec-88	04-Mar-95
Total No. of Eq Starts	4,240	4,413	2761
Operating Hours (OH)	144150	152072	128560
No. of Trips	201	179	239

4.3.5. Maintenance Record and History of Module-3 Units

Module-3 units are operated at base-load, within the original equipment manufacturer (OEM) guidelines. As per OEM recommendations, following periodic maintenance tasks are performed:

Gas turbines:
- Combustion inspection
- Hot gas path inspection
- Major Overhauling

Generators:
- Minor inspection after every 15000 Generator EOH
- Major Overhaul after every 46000 Generator EOH

Steam turbine:
- Minor Overhauling/Inspection/Borescope examination
- Major Overhauling

Table 4.24: Maintenance Record of Module-3

Activity	Data Items	GT-5	GT-6	STG-11
Combustion Inspection	Last CI Inspection Dates	01-Mar-21 To 05-Mar-21	01-Mar-21 To 05-Mar-21	-
Hot Gas Path Inspection/Minor Overhauling	Last HGPI Dates	11-Sep-17 To 30-Oct-17	11-Sep-17 To 30-Oct-17	01-Feb-20 To 31-Mar-20
Major Over Hauling	Last MOH Dates	16-Oct-11 To 03-Dec-11	16-Oct-11 To 03-Dec-11	11-Sep-17 To 30-Oct-17

4.3.6. Operating Performance of Module-3

Below is the past five years Plant Availability performance of Module-3 units which shows that Module-3 units are operating with best commercial performance with high availability factor.

Table 4.25: Maintenance Record of Module-3

Gas Turbine GT-5		
Year	Plant Availability %	Commercial Availability %
2015-16	82.8	97.8
2016-17	92.7	97.6
2017-18	80.8	95.8
2018-19	95.3	94.8
2019-20	94.0	97.0
Average	87.0	95.0
Gas Turbine GT-6		
Year	**Plant Availability %**	**Commercial Availability %**
2015-16	82	98
2016-17	82	88
2017-18	80	95
2018-19	95	92
2019-20	92	96
Average	84	92
Steam Turbine STG-11		
Year	**Plant Availability %**	**Commercial Availability %**
2015-16	82	97
2016-17	87	92
2017-18	80	95
2018-19	95	93
2019-20	93	96
Average	83	91

4.3.7. Qualitative Conditional Assessment of Module-3 Units

Following is the qualitative conditional assessment of Module-3 Units;

Table 4.26: Qualitative Conditional Assessment

Unit #	Operating Parameters Maintained per IDC	Schedule Maintenance Performed	Upgraded	Upgrade Type	Spares Inventory Maintained	Overall Condition Rating	Overall Unit Condition
GT-5	Yes	Yes	Yes	-Hot Gas Path Upgrade - Control System Change	Yes	8	Satisfactory
GT-6	Yes	Yes	Yes	-Hot Gas Path Upgrade - Control System Change	Yes	8	Satisfactory
STG-11	Yes	Yes	Yes	-Generator Rewind - Control System Change	Yes	8	Satisfactory
HRSG-11A	Yes	Yes	No	NA	Yes	9	Good
HRSG-11B	Yes	Yes	No	NA	Yes	9	Good

Condition Rating Criteria 1-10:

Rating 9-10 = Good; Rating 7-8 = Satisfactory; Rating 4-6 = Acceptable; Rating 1-3 = Unacceptable

4.4. Overview of KAPCO Module-4

KAPCO Module-4 consists of Gas turbines GT-7 and G-T8, heat recovery steam generators HRSG-12A and HRSG-12B and steam turbine STG-12. Gas turbines GT-7 and GT-8 of GE MS9001E type were commissioned in Jan and April 1989 respectively in open cycle mode on HSD fuel.

GT-7 was commissioned on Furnace oil and Gas in Aug 1989 and May 1995 respectively. GT-8 was commissioned on Furnace oil and Gas in Sep 1989 and May 1995 respectively.

Module-4 open cycle gas turbines GT-7 and GT-8 were converted to combined cycle mode after commissioning of HRSGs; HRSG-12A and 12B along with steam turbine STG-12 in April 1995.

Module-4 configuration is as follows: GT-7 + HRSG-12A, GT-8 + HRSG-12B and STG-12

4.4.1. Design and Current Operating conditions of Module-4 Units:

4.4.2. Design Data and Technical Limits of Module-4 Units

Gas Turbines GT-7 and 8 are in operation satisfactorily since their commissioning with periodic replacements of hot gas path components as per OEM recommended maintenance cycle. Below is the design data of GT-7 and GT-8 which is valid for current units operation;

Table 4.27: Design Data GT-7 and GT-8

Sr. No	Description	GT-7 & GT-8
1.	Model	PG-9141 Type 9001 E
2.	Manufacturer	ALSTHOM France.
3.	Base Load Rating at 15°C	106 MW on HSD & 94.65 on FO
4	Starting time up to 3000 RPM	10 Minutes
5	Turbine Inlet Temp	1085°C on HSD & 1029°C on FO
6	Turbine Exhaust Temp at full load	528°C on HSD & 489°C on FO
7	Auto loading gradient	8 MW/minute
8	Overall Efficiency	31.5 %

GT-7 and GT-8 Control system is the old GE Mark-IV which is operating reliably with availability of additional spares obtained from replacement of GT-5 and GT-6 control system.

GT-7 and GT-8 Hot Gas path up-gradation were carried out in 2011 and 2010 respectively which enhanced the load capacity of the units.

Steam Turbine STG-12 is of RATEAU, France and has operated satisfactorily since its commissioning in 1995. Below is the design data of steam turbine Unit-12 which is valid for current unit operation;

Table 4.28: Design Data of STG-12

Sr.No	Description	Units STG 12
1.	Make	RATEAU, France
2.	Type	VEGA209 110B
3.	Rated Power	103.4 MW
4.	Live Steam (for steam turbine) Inlet Press (Bar)	40
5.	Live Steam Temperature °C	510.8
6.	Secondary Steam (for de-aeration) Inlet Press (Bar)	-
7.	Secondary Steam Temperature °C	-
8.	Vacuum (Bar)	0.091
9.	Generator rating	121.647 MVA @ 36°C Cold Air Temperature
10.	Unit Transformer rating	125 MVA

Heat recovery steam generators HRSG-12A and 12B of Stein Industries France have operated since COD 1995 without any major problems. Below is the design data for HRSG-12A and 12B, both can be operated near to rated tonnage capacity and design parameters.

Table 4.29: Design Data of HRSG-12A and B

HRSG-12A&B: Stein Industries France	
Rated Steam Flow	151 T/H on LSFO & 173 T/H on Gas
Design Pressure	51 bar(g)
Superheater Outlet Pressure	35.8 bar(g) on LSFO & 42 bar(g) on Gas
Superheated Steam temperature	476°C on LSFO & 512°C on Gas
Total Heating Surface	56386 m^2

4.4.3. Current Operating Data of Module-4 Units

Following data of Annual Dependable Capacity Test performed on 06-07-2020 depicts that Module-4 units are operating near to or better than IDC parameters (IDC Initial dependable Capacity Test 1996) owing to the Units up-gradations, KAPCO prudent operating practices and excellent maintenance strategy;

Table 4.30: Operating Data of Module-4

Gas Turbine No. 7 at 32°C ADC & 32.5°C IDC ambient temperature; on LSFO							
Reading	Real Load	Reactive Load	CDP	CDT	TET	Inlet Loss	Exhaust Loss
	MW	MVAR	bar	°C	°C	Pascal	mmWC
ADC-2020	81	10	9	349	499	573	155
IDC-1996	79	10	9	-	505	-	25

Gas Turbine No. 8 at 32°C ADC & 32.5°C IDC ambient temperature; on LSFO							
Reading	Real Load	Reactive Load	CDP	CDT	TET	Inlet Loss	Exhaust Loss
	MW	MVAR	bar	°C	°C	Pascal	mmWC
ADC-2020	80	14	9	351	501	621	156
IDC-1996	82	10	9	350	502	-	26

Steam Turbine No. 12							
Reading	Real Load	Reactive	HP Inlet	HP Inlet	Ex Press	CW Inlet	Cooling Tower Fans
	MW	MVAR	Press bar	Temp °C	bar(g)	Temp °C	in service
ADC-2020	78	9	34	465	-0.891	35	6
IDC-1996	81	12	33	476	-0.896	34	6

	HRSG-12A				HRSG-12B			
Reading	HP Steam	HP Steam	FW Inlet	Flue Gas	HP Steam	HP Steam	FW Inlet	Flue Gas
	Press bar	Temp °C	Temp °C	Temp °C	Press bar	Temp °C	Temp °C	Temp °C
ADC-2020	35	460	142	162	35	471	142	162
IDC-1996	34	480	143	163	33	480	143	163

4.4.4. Operating Record of Module-4 Units

Following data shows operating hours, No. of starts, trips of Module-4 units since commissioning till 31 March 2021.

Table 4.31: Operating Record of Module-4

Module-4 Operating Record since Commissioning to March 2021			
	GT-7	GT-8	STG-12
Date of commissioning	19-Jan-89	24-Apr-89	05-Apr-95
Total No. of Eq Starts*	1710	3635	2735
Operating Hours (OH)	152405	157488	139812
No. of Trips	161	226	257

4.4.5. Maintenance Record and History of Module-4 Units

Module-4 units are operated at base-load, within the original equipment manufacturer (OEM) guidelines. As per OEM recommendations, following periodic maintenance tasks are performed:

Gas turbines:
- Combustion inspection (CI)
- Hot gas path inspection (HGPI)
- Major Overhauling (MOH)

Generators:
- Minor inspection after every 15000 Generator EOH
- Major Overhaul after every 46000 Generator EOH

Steam turbine:
- Minor Overhauling/Inspection/Borescope examination
- Major Overhauling

Table 4.32: Maintenance Record of Module-4

Activity	Data Items	GT-7	GT-8	STG-12
Combustion Inspection	Last CI Inspection Dates	01-Feb-21 To 22-March-21	11-Feb-21 To 02-Mar-21	-
Hot gas path inspection/Minor Overhauling	Last HGPI Dates	01-Feb-21 To 22-March-21	01-Feb-19 To 28-Feb-19	11-Feb-21 To 02-Mar-21
Major Over hauling	Last MOH Dates	01-Feb-21 To 22-March-21	01-Feb-19 To 28-Feb-19	11-Feb-15 To 24-Mar-15

GT-5, 6, 7 and 8 CI, HGPI and MOH, all maintenance tasks are executed by KAPCO team. Spare parts used for the GTs and STGs routine maintenance are supplied by the respective OEMs GE/Alstom.

4.4.6. Operating Performance of Module-4

Below is the past five years Commercial performance of Module-4 units which shows that Module-4 units are operating with best commercial performance with high availability factor.

Table 4.33: Operating Performance of Module-4

Gas Turbine GT-7		
Year	Plant Availability %	Commercial Availability %
2015-16	84	92
2016-17	81	97
2017-18	92	97
2018-19	93	97
2019-20	94	97
Average	88	96
Gas Turbine GT-8		
Year	Plant Availability %	Commercial Availability %
2015-16	77	87
2016-17	80	97
2017-18	90	94
2018-19	91	93
2019-20	87	97
Average	83	94
Steam Turbine STG-12		
Year	Plant Availability %	Commercial Availability %
2015-16	78	87
2016-17	80	97
2017-18	90	95
2018-19	91	95
2019-20	90	97
Average	85	95

4.4.7. Qualitative Conditional Assessment of Module-4 Units

Following is the qualitative conditional assessment of Module-4 Units;

Table 4.34: Qualitative Conditional Assessment

Unit #	Operating Parameters Maintained per IDC	Schedule Maintenance Performed	Upgraded	Upgrade Type	Spares Inventory Maintained	Overall Condition Rating	Overall Unit Condition
GT-7	Yes	Yes	Yes	-Hot Gas Path Upgrade -Rotor Replaced with new	Yes	7	Satisfactory
GT-8	Yes	Yes	Yes	-Hot Gas Path Upgrade -Rotor Refurbished -Generator Stator rewind	Yes	8	Satisfactory
STG-12	Yes	Yes	Yes	-Generator Stator rewind - Control System Change	Yes	9	Good
HRSG-12A	Yes	Yes	No	NA	Yes	9	Good
HRSG-12B	Yes	Yes	No	NA	Yes	9	Good
Condition Rating Criteria 1-10: Rating 9-10 = Good; Rating 7-8 = Satisfactory; Rating 4-6 = Acceptable; Rating 1-3 = Unacceptable							

Keeping in view the Module-3 and 4 performance in preceding years, current operating conditions and upgrades performed on units it is envisage that if current O&M practices are continued, Module-3 and 4 units can be further operated for a minimum further 10 years with good performance figures and high plant availability.

4.5. Overview of KAPCO Module-5

KAPCO Module-5 consists of Gas turbines GT-13 and GT-14, heat recovery steam generators HRSG-13 and HRSG-14 and steam turbine STG-15. Gas turbines GT-13 and GT-14 of Siemens V94.2 were commissioned in Oct 1994 in open cycle mode on Gas fuel and are the newest of all the Gas Turbines in the KAPCO Complex.

GT-13 was commissioned on liquid fuel HSD and Furnace oil in April and May 1995 respectively.

GT-14 was commissioned on liquid fuel HSD and Furnace oil in March and April 1995 respectively.

Module-5 open cycle gas turbines GT-13 and GT-14 were converted to combined cycle mode after commissioning of HRSG-13 and HRSH-14 along with steam turbine STG-15 in Sep 1996.

Module-5 configuration is as follows: GT-13 + HRSG-13, GT-14 + HRSG-14 and STG-15

4.5.1. Design and Current Operating conditions of Module-5

4.5.2. Design Data and Technical Limits of Module-5 Units

Gas Turbines GT-13 and 14 have operated satisfactorily since their commissioning with periodic replacements of hot gas path components as per OEM recommended maintenance cycle. Below is the design data of GT-13 and GT-14;

Table 4.35: Design Data of GT-13 and GT-14

Sr. No	Description	GT-13 a GT-14
1.	Model	V-94.2
2.	Manufacturer	SIEMENS (Germany)
3.	Base Load rating at 15°C	139 MW (HSD), 143.8 MW (GAS), 123 MW (F.O)
4	Starting time up to 3000 RPM.	4 Minutes
5	Turbine Inlet Temp	1050°C
6	Turbine Exhaust	530 to 550°C Temp at full load
7	Auto loading gradient	i) 11 MW/Minute up to base load
8	Overall Efficiency	(32 % on BFO), (32% on HSD), (32.5% on GAS)

*Turbine inlet and exhaust temperature values has been revised around 5°C after Si3D upgrade

GT-13 and GT-14 old Control system Siemens TELEPERM ME has been replaced with a new Control system SPPAT3000 in Feb-March 2021.

GT-13 and GT-14 Si3D turbine blades up-gradation was carried out in 2011 which enhanced the load capacity

Steam Turbine STG-15 is of Siemens, Germany and has operated satisfactorily since its commissioning in 1995. It is a 2 cylinder turbine with HP and LP portions and a water cooled condenser.

Below is the design data of steam turbine Unit-15 which is valid for current unit operation;

Table 4.36: Design Data of STG-15

Sr.No	Description	Unit STG 15
1.	Make	Siemens, Germany
2.	Type:	030-16, N30-2X5-B-9
3.	Rated Power	148.6 MW
4.	Live Steam (for steam turbine) Inlet Press (Bar)	57
5.	Live Steam Temperature °C	528
6.	Secondary Steam (for de-aeration) Inlet Press (Bar)	5.78
7.	Secondary Steam Temperature °C	221
8.	Vacuum (Bar)	0.091
9.	Generator rating	175 MVA @ 40°C Cold Air Temperature
10.	Unit Transformer rating	190 MVA

STG-15 Control system has been replaced from the old Siemens TELEPERM ME to a new SPPAT3000 in 2015.

Heat Recovery steam generators HRSG-13 and 14 of Babcock Germany have operated since COD 1995. HRSG-13 and 14 LP Evaporator bends were replaced in 2013 and 2016 due to frequent leakages as a consequence of flow accelerated corrosion. HRSG-13 and 14 are now operating satisfactorily without any major problem. Below is the design data for HRSG-13 and 14, both are operating at rated tonnage capacity and design parameters.

Table 4.37: Design Data of HRSG-13 and 14

HRSG-13&14: Babcock Germany	
Year of Manufacture	1995
Rated Steam Flow	64 Kg/sec
Design Pressure	75 bar(g)
Super-heater Outlet Pressure	59 bar(g)
Superheated Steam temperature	530°C
Total Heating Surface area	84094 m2

4.5.3. Current Operating Data of Module-5 Units

Following data of Annual Dependable Capacity Test performed on dated 03-07-2020 depicts that Module-5 units are operating near to or better than IDC parameters corrected to same ambient conditions (IDC Initial dependable Capacity Test Aug 1997) owing to units up-gradations, KAPCO prudent operating practices and excellent maintenance strategy;

Table 4.38: Operating Data of Module-5

Gas Turbine No. 13 at 31°C ADC & 37°C IDC ambient temperature; on LSFO							
Reading	Real Load	Reactive Load	CDP	CDT	OTC	Inlet Loss	Exhaust Loss
	MW	MVAR	bar	°C	°C	mbar	mbar
ADC-2020	115	25	9	347	506	0.96	23
IDC-1997	105	28	9	353	505	5	21

Gas Turbine No. 14 at 31°C ADC & 37°C IDC ambient temperature; on LSFO							
Reading	Real Load	Reactive Load	CDP	CDT	OTC	Inlet Loss	Exhaust Loss
	MW	MVAR	bar	°C	°C	mbar	mmWC
ADC-2020	112	25	9	345	503	1.3	18
IDC-1997	106	19	9	352	504	6	21

Steam Turbine No. 15							
Reading	Real Load	Reactive	HP Inlet	HP Inlet	Ex Press	CW Inlet	Cooling Tower Fans
	MW	MVAR	Press bar	Temp °C	bar(g)	Temp °C	in service
ADC-2020	115	28	47	502	-0.88	34	6
IDC-1997	113	33	47	484	-0.88	34	6

	HRSG-13				HRSG-14			
Reading	HP Steam	HP Steam	FW Inlet	Flue Gas	HP Steam	HP Steam	FW Inlet	Flue Gas
	Press bar	Temp °C	Temp °C	Temp °C	Press bar	Temp °C	Temp °C	Temp °C
ADC-2020	47	509	128	165	47	509	128	166
IDC-1997	48	494	147	180	47	488	147	182

4.5.4. Operating Record of Module-5 Units

Following data shows operating hours, No. of starts, trips of Module-5 units since commissioning till 31 March 2021.

Table 4.39: Operating Record of Module-5

Module-5 Operating Record since Commissioning to June 2019			
	GT-13	GT-14	STG-15
Date of commissioning	12-Oct-94	19-Oct-94	10-Sep-96
Total No. of Starts	2047	2260	657
Operating Hours (OH)	176245	170947	179741
No. of Trips	158	146	151

4.5.5. Maintenance Record and History of Module-5 Units

Module-5 units are operated at base-load, within the original equipment manufacturer (OEM) guidelines. Depending upon the Equivalent Operating hours of the Unit and OEM recommendations, following periodic maintenance tasks are performed:

Gas turbines:
- Combustion inspection (CI)
- Major Overhauling (MOH)

Generators:
- Schedule inspection every year
- Major inspection after every 60,000 EOH (Condition based)

Steam turbine:
- Minor Overhauling/Inspection/Borescope examination
- Major Overhauling

GT-13 and GT-14 Combustion inspection is executed by the KAPCO team while the MOH is executed by Siemens' Engineers. As per the maintenance life cycle, all spare parts used for replacement, are supplied by the OEM, Siemens, in accordance with the LTSA (Long Term Supply Agreement). Due to excellent maintenance workmanship and genuine spare parts usage, units are operating smoothly with high availability factor. Below is the overview for the Outages performed as per OEM recommended interval;

Table 4.40: Maintenance Record of Module-5

Activity	Data Items	GT-13	GT-14	STG-15
Combustion Inspection	Last CI Inspection Dates	16-Nov-20 To 20-Nov-20	16-Nov-20 To 20-Nov-20	-

Hot gas path inspection/Minor Overhauling	Last HGPI Dates	-	-	01-Sep-16 To 04-Nov-16
Major Over hauling	Last MOH Dates	01-Sep-19 To 30-Oct-19	01-Sep-19 To 30-Oct-19	01-Feb-10 To 25-Apr-10

4.5.6. Operating Performance of Module-5

Below is the past five years operating performance of Module-5 units which shows that Module-5 units are operating with best commercial performance figures and with high availability factor.
Average plant availability factor of 86% and Commercial availability of above 95% is comparable to new plants in the power market.

Table 4.41: Operating Performance of Module-5

Gas Turbine GT-13		
Year	**Plant Availability %**	**Commercial Availability %**
2015-16	92	98
2016-17	76	99
2017-18	92	98
2018-19	91	96
2019-20	78*	96
Average	86	97
Gas Turbine GT-14		
Year	**Plant Availability %**	**Commercial Availability %**
2015-16	90	95
2016-17	77	96
2017-18	91	98
2018-19	94	95
2019-20	80	97
Average	86	96
Steam Turbine STG-15		
Year	**Plant Availability %**	**Commercial Availability %**
2015-16	90	96
2016-17	73	97
2017-18	91	98
2018-19	92	95
2019-20	78	96
Average	84	96

*GT-13-14 & STG-15 Plant Availability FY 2016-17 & 2019-20 is less in comparison due to schedule MOH Oct-Nov 2016 & Sep-Oct 2019

4.5.7. Qualitative Conditional Assessment of Module-5 Units

Following is the qualitative conditional assessment of Module-5 Units;

Table 4.42: Qualitative Conditional Assessment of Module-5

Unit #	Operating Parameters Maintained per IDC	Schedule Maintenance Performed	Upgraded	Upgrade Type	Spares Inventory Maintained	Overall Condition Rating	Overall Unit Condition
GT-13	Yes	Yes	Yes	-Si3D Turbine Blades Upgrade - Control System Change	Yes	7	Satisfactory
GT-14	Yes	Yes	Yes	-Si3D Turbine Blades Upgrade - Control System Change	Yes	7	Satisfactory
STG-15	Yes	Yes	Yes	- Control System Change	Yes	9	Good
HRSG-13	Yes	Yes	No	NA	Yes	9	Good
HRSG-14	Yes	Yes	No	NA	Yes	9	Good

Condition Rating Criteria 1-10:

Rating 9-10 = Good; Rating 7-8 = Satisfactory; Rating 4-6 = Acceptable; Rating 1-3 = Unacceptable

Keeping in view the Module-5 performance in preceding years, current operating conditions and recent upgrades performed on the Units it is envisaged that if current O&M practices are continued, Module-5 units can be further operated for minimum further 10 years with good performance figures and high plant availability.

5. WORLD TRENDS IN OPERATING LIFE OF THERMAL POWER PLANTS

5.1. Definitions

In order to discuss how long a plant will operate for it is important to discuss the following widely used phrases.

5.1.1. Operating life

The operating life of a power station can be defined as the length of time in years after commissioning that a plant will generate, or has been generating electricity before being decommissioned.

5.1.2. Economic life

The economic life of a plant refers to a prediction of how long it will be generating based on specific economic criteria such as remaining profitable. The economic life is usually discussed within the context of a forecast of certain financial factors such as future electricity prices, fuel costs and investment required to extend the life of the plant. A plant reaching the end of its economic life suggests it would then be decommissioned, however there are situations where the plant may be retained in an operational state, a state of readiness to return to service, or mothballed.

5.1.3. Design life

The design life refers to the length of time used in engineering design and manufacture specifications for the plant. Design life is typically defined in terms of operating hours which are then translated into an expected calendar lifetime depending on the operating regime – base load, peaking etc. A plant could be designed to operate for 25-30 years in a specific operating regime which, for example, dictates the use of specific alloys or thickness of heat shielding equipment. A change in operating regime can affect the assets calendar lifetime.

5.1.4. Heat rate

When forecasting plant life, it is useful to consider impacts of time and operating regime on the heat rate or efficiency of the power station. Heat rate is usually measured as kJ/KWh, and indicates the amount of fuel energy (kJ) required to generate a unit of electricity (kWh). Therefore, the lower the heat rate the higher the efficiency of the plant.

Plant heat rate or efficiency will degrade over time with use due to the wearing of components. Routine maintenance and overhauls are designed to minimize the effects of degradation and maintain the heat rate as close to the original design criteria as possible over the life of the plant. Restoring the heat rate back to the original design or better, requires significant investment and often involves replacement of the majority of components with technically superior equivalents.

Plant heat rate can be one of the major factors influencing plant life, as efficiency ultimately impacts economic viability. If the heat rate has degraded to the extent that significant capital investment is required to restore the heat rate and the benefits of such investment do not provide a positive economic return, a decision can be made to decommission the plant.

5.2. Factors influencing the plant life

5.2.1. General

In most cases power plant can have its life extended by a factor of 50-100% over the original design life. This arises in part from the conservative assumptions made in the original design process and in part is a consequence of well-managed repair and maintenance in these plants. In addition, the civil works of a plant are generally designed with a longer design life than the equipment, which means it is possible to replace equipment without having to build new civil works.

These factors have resulted in many power plants the world over operating well beyond their nominal 25 – 30 year design life.

5.2.2. Life limiting factors

For an operating power plant, the main technological life limiting issues are:

- The creep life of high temperature components. This is typically limited to boiler pressure parts, high temperature pipework and the heavy wall thickness and/or non-symmetrical high pressure (HP) steam turbine components (e.g. emergency stop valves, bypass valves, governor valves, steam chests, HP cylinder casings, HP nozzle rings). It may include the HP turbine rotor, both shaft and disks. Fatigue life of rotating components, components subject to repeated temperature change, and components subject fluctuating loads and vibration.
- Erosion – primarily related to gas side solid particle erosion of the boiler pressure parts. However, water and steam side erosion can also be an issue, particularly in low pressure steam turbines.
- Corrosion
- Technological obsolescence – primarily an issue with controls and instrumentation and electrical systems.
- Environmental compliance – environmental consents are only granted for limited periods and emission compliance, particularly if the environment is subsequently degraded or regulations become more stringent, may require major emissions control equipment (e.g. Low NOx Burners, flue gas desulfurization (FGD), carbon capture etc).

5.3. World trends of life of coal and gas power stations

5.3.1. USA

Coal-fired electricity generators accounted for 25% of operating electricity generating capacity in the United States and generated about 30% of U.S. electricity in 2016. Most coal-fired capacity (88%) was built between 1950 and 1990,

Approximately 70% of the existing USA coal fueled power plant fleet is greater than 30 years old, as shown in the below Figure 5.1. The capacity-weighted average age of operating coal facilities is 39 years.

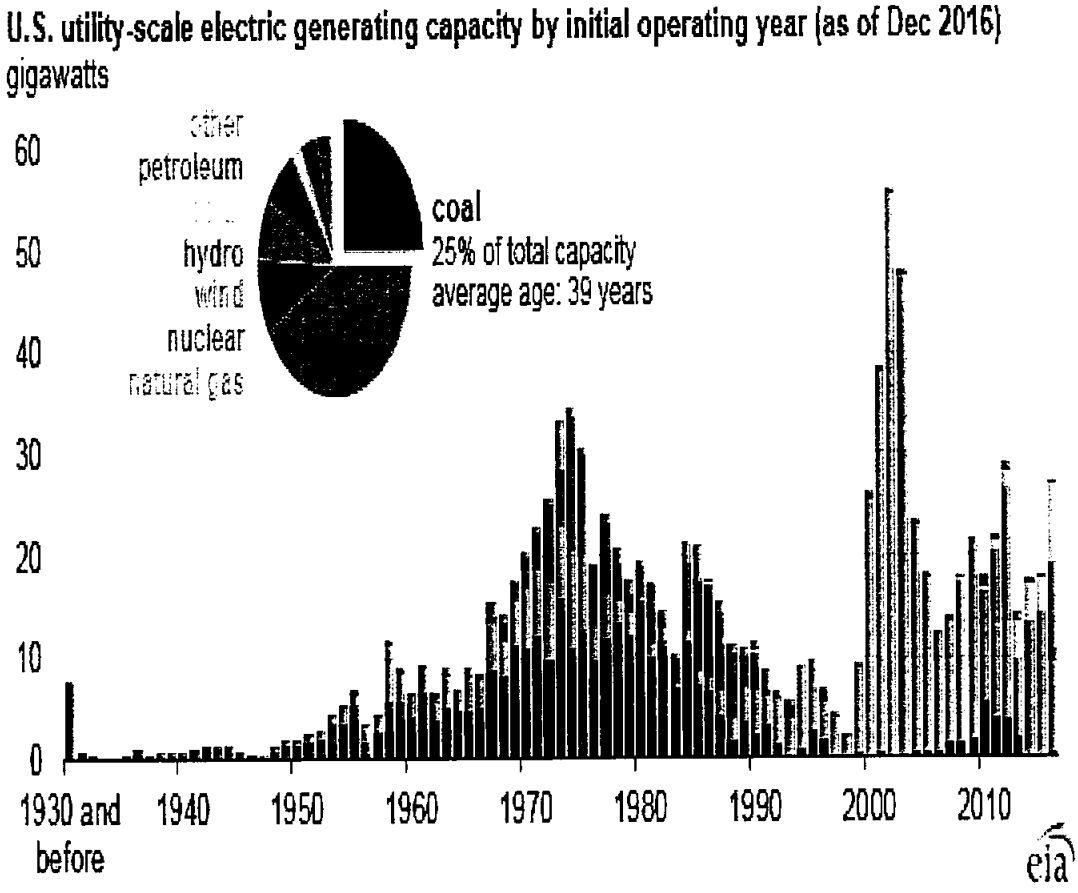


Figure: 5. 1: US Power Generating Capacity

https://www.eia.gov/todayinenergy/detail.php?id=30812

5.3.2. Europe

European power plants are also maintained well beyond the original design life as shown in the below Figure 5.2;

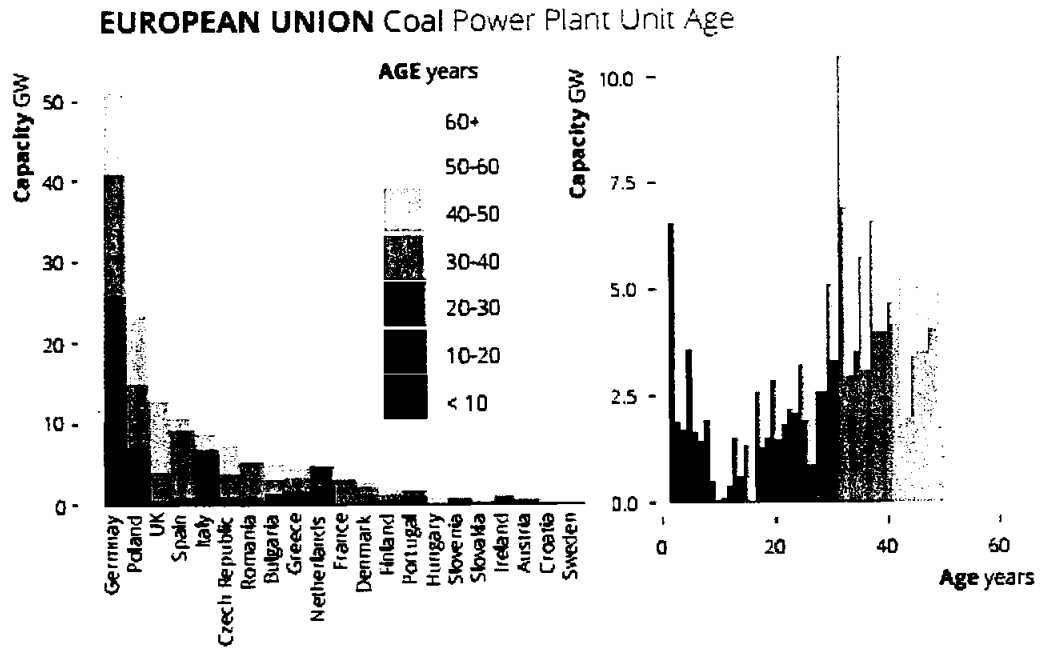


Figure: 5. 2: European Union Coal Power Plant Unit age

Ref: A Stress Test for Coal in Europe Feb 2017

About capacity 25000 MW of thermal power plants are in age range 30 to 60 years that is exceeding their design life of 30 years.

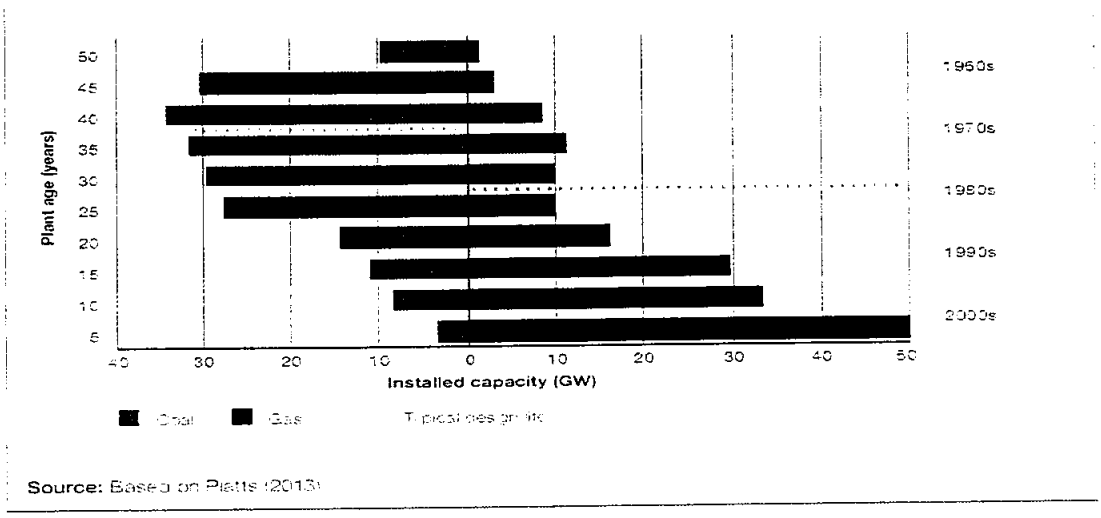
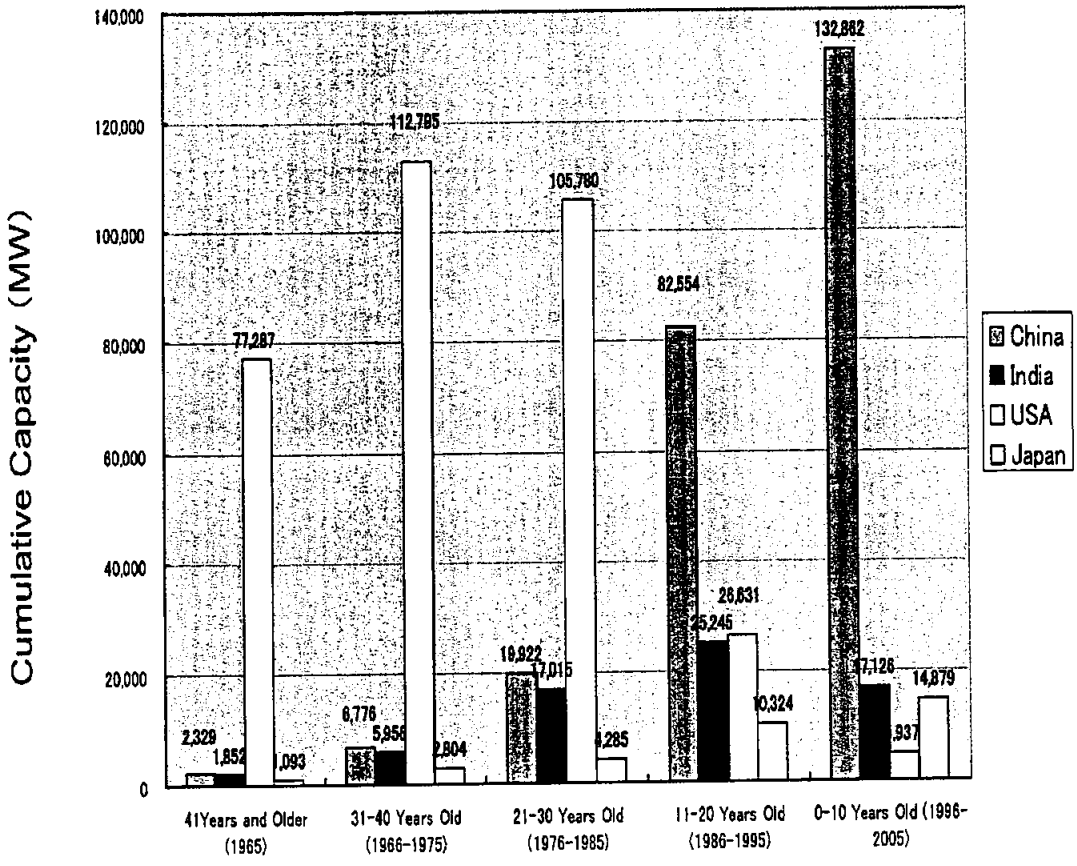


Figure: 5. 3: European Power Plants' age by fuel

The trend in age of coal-fueled plants in Europe is similar to that in the USA. However, compared to the USA, where the gas-fueled power plants are relatively young, the European gas-fueled plants are on average older.

5.3.3. Other

Power plants in the developing countries of China and India are more recent compared to the ones in the USA, and most of them have not yet reached their nominal design life. This is illustrated by the following Figure (Age of power plants compared between countries) which compares the age of existing coal-fuelled power plants in China, USA, India and Japan in 2007.



Sources: **Pradeep J. Tharakan, USAID-ECO-Asia Clean Development and Climate Program,** ASEAN Energy Business Forum (AEBF) 22nd -24th Aug.,2007 and Coal Note 2005/2006

Figure: 5. 4: Power Plants' age by Country

5.3.4. Power Project Age of Recent and Planned Retirements in US

The below charts present histograms of project age of recent and planned retirements for US coal plants, natural-gas steam (NGST) plants, combustion turbine (CT) plants, and combined-cycle gas turbine (CCGT) plants.

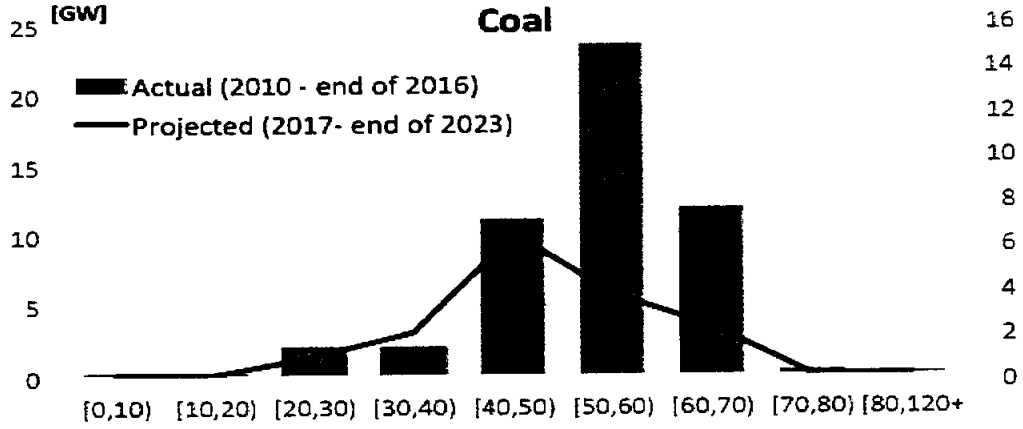
Several observations are apparent from these charts:

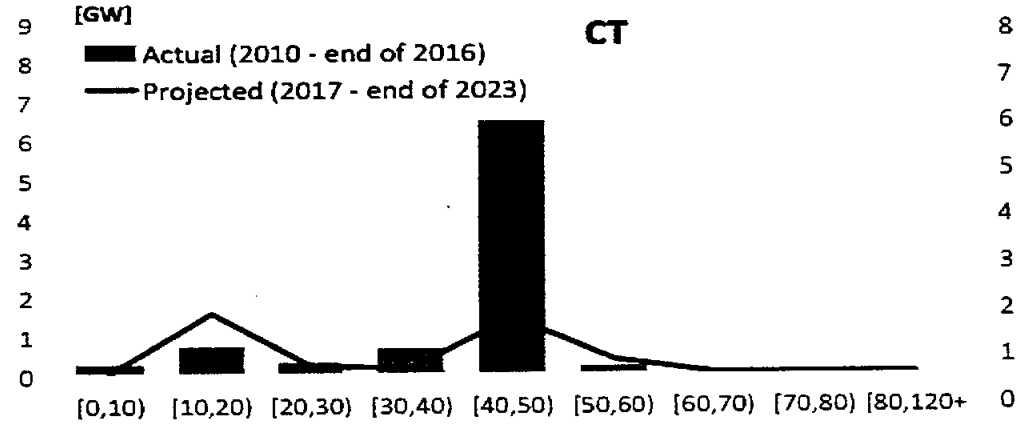
Recently retired plants have been relatively old, across all generation types

- The most common age of recently retired coal units is 50-60 years
- The most common age of recently retired NGST units is 40-50 years
- The most common age of recently retired CT units is 40-50 years
- The most common age of recently retired nuclear units is 30-40 years

Plants with announced retirement dates are also relatively old, based on expected age at retirement

- Nuclear and NGST plants planned for retirement will be older than recently retired plants
- Coal, CT and CCGT plants planned for retirement will be slightly younger than recently retired plants





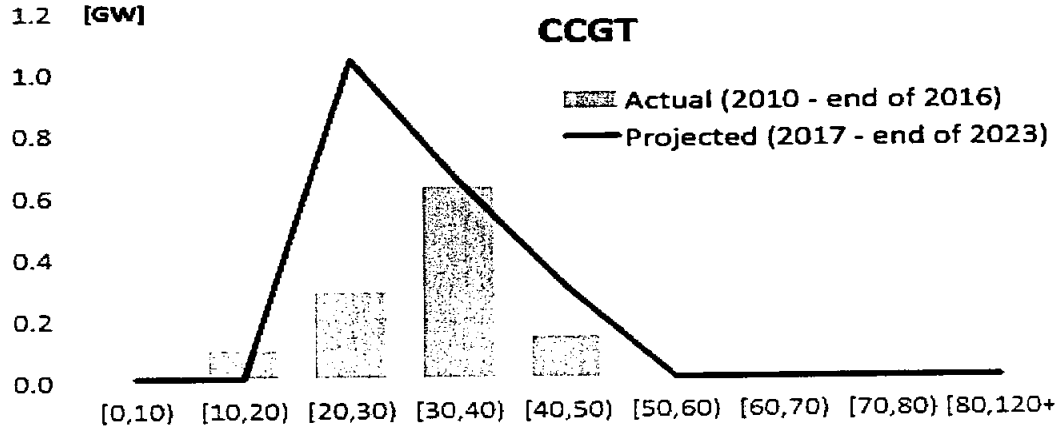


Figure: 5. 5: Power Project Age of Recent and Planned Retirements in US

Ref: Energy Analysis and Environmental Impacts Division Lawrence Berkeley National Laboratory Nov 2017

5.4. Recap

As observed some coal fueled steam and natural gas turbines are 40-50 years old and still in operation 20 years beyond the original nominal calendar design life.

Traditionally, a calendar design life is equated to operating hours based on a nominal 8,000 per year to take account of scheduled and unscheduled outages and the fact that the plant will not usually operate 8,760 hours per year. Therefore a 30-year plant life equates to 240,000 operating hours.

Whilst the original design life of a CCGT plant is typically 25-30 years, the average life of retirement for CCGT plant is 40-50 years, or 320,000 hours based on 40 years and 8,000 operating hours per year.

Notwithstanding that plants can operate for an age of 40-50 years, the equipment operating design life usually means replacements and upgrades are required throughout that period and the frequency of maintenance generally increases as the plants ages.

Whether thermal power plants are kept in operation, refurbished, placed on standby or decommissioned at their design life remains primarily an economic decision for the owner depending upon the unit condition and maintenance cost. The introduction of more stringent Environmental regulations may also be a factor in whether it is cost effective to upgrade a plant to meet latest emissions criteria.

6. PLANT COMPONENTS RESIDUAL LIFE ASSESSMENT

6.1. Module-1 Plant Component Residual Life Assessment

6.1.1. Gas Turbine Unit 1, 3 and Steam Turbine Unit-9

GT-1 and 3 Hot gas path components are being replaced periodically on MOH/HGPI as per recommended intervals by OEM. One set of vanes and blades is available in store as a strategic spare.

Gas Turbine GT-1: Last Major Overhauling (MOH) was conducted in Feb-March 2021. The compressor blades have been in service since commissioning. During visual inspections and NDTs performed during the MOH, the condition of the compressor blades were found to be satisfactory. In the event some findings appear in the next MOH, replacement of the compressor blades is recommended.

Air intake system structure is in healthy condition. New air intake filters are available in the market.

Compressor Diaphragms stages 1-9 were replaced with refurbished and new diaphragms were installed for stages 10-16 in 2011. The condition of the compressor diaphragms was reported to be satisfactory in the MOH of 2021.

New mixing chambers were installed in March 2016 during the MOH and the expected remaining life is 15 years.

Gas Turbine GT-3: Overall condition of GT-3 was reported as satisfactory during visual inspections and NDTs performed in the MOH of 2016 and HGPI in 2018. One complete GT rotor is available for GT-3 and GT-4 as a strategic spare.

Steam Turbine STG-9 condition was found to be satisfactory during recent MOH Feb-March 2021. Mandatory spares are available in KAPCO Stores.

Following is the expected Remaining Life of Module-1 units as per current operating regime;

Table 6. 1: Remaining Life of Module-1 Units

Unit #	Operating Hours in Design Life of 30 years	Operating Hours in Extended Design Life of 40 years*	KAPCO Operating Hours COD to Mar-2021	Remaining Operating Hours In Extended Design Life of 40 years	Remaining Design life (Years)
GT-1	240,000	320,00	171,801	148,199	19
GT-3	240,000	320,00	93,920	226,080	28
STG-9	240,000	320,00	165,469	154,531	19

Module-1 Units are expected to operate for minimum further 10 years without any major concern.

*CCGT Operating Life expectancy before retirement is 40 years (320,000 hours based on 8,000 operating hours/year) ref section 5.3.4 and 5.4 of this document.

6.1.2. Module-1 HRSG 1 and 3

HRSG-1 to 4 are of same model and make of Balke Durr, Germany. All four heat recovery steam generators have operated satisfactorily since their commissioning.

Life assessment of HRSG-1 was conducted by SGS Pakistan on sample basis among all four HRSGs of Block-1 (Module-1 and 2). The same condition about life assessment is predicted for the other three HRSGs i.e. HRSG-2, 3 and 4 as these HRSGs have fewer operating hours and have generally been operated and maintained the same.

HRSG-1 inspections relating to life assessment have been conducted during the recent major overhauling of STG-9 Feb- March 2021 and no significant deterioration observed.

(see Appendix-1: Remnant Life assessment of HRSG-1).

High pressure parts of HRSG 1, were inspected by SGS. The purpose of inspection was to evaluate the present conditions of high-pressure parts and assess their reliability for further use on the basis of their microstructure and wall-thickness.

Following inspection techniques were used for life assessment study of HRSG-1.

- Visual Inspections
- Ultrasonic Thickness Measurement
- Ultrasonic Flaw Detection
- Dye Penetrant Testing
- Magnetic Particle Inspection
- Hardness Testing
- Metallographic examination

Scope of work for complete inspection and remaining life assessment of HRSG 1 included following inspections and NDTs;

- Visual inspection of HP and LP drums, tubes, headers, for localized and uniform corrosion, deposits, erosion, pitting etc.
- Visual inspection of protective coating/insulation for damages
- Visual inspection for corrosion under insulation (CUI)
- Visual inspection of all structural steel parts including ducts, platforms, handrails and structural steel supports for ducts/piping for any visual defects.
- Visual inspection of tube bends and headers
- Visual inspection and DPT of steam header pipe welds for cracks
- Visual inspection of all accessible weld joints of HP Drum/LP separator, like shell, heads and nozzles.

- Hardness testing of HP drum, LP drum and headers.
- Ultrasonic flaw detection of suspected weld joints of HP drum, LP drum.
- MPI/DPT of selected weld joints
- Metallographic testing of boiler pressure parts.
- Ultrasonic thickness gauging of HP drum, headers, tubes, soot blowers, as per ASME codes to find out overall view of current metal condition for fitness.

Remaining Life of HRSG-1 was calculated, comparing component's thickness at installation and current thickness gauging 2021 using remaining corrosion allowance. All major components' life is calculated greater than 20 years.

Also, HRSG-1 and 3 mandatory inspections are carried out in every schedule outage of GT-1 and GT-3 by the Boiler Engineer, Mechanical Engineer and Plant Chemist.

Inspections were also performed in Feb 2021 and both HRSGs condition found satisfactory.

Based on life assessment reports, and routine maintenance inspections, it is expected that with the current operating regime, ***HRSG-1 and 3 may be operated reliably for next 10-15 years.***

6.1.3. Module-1 Unit's Generator 1, 3 and 9

Following are the technical specifications for Module-1 and 2 Units' Generators

Table 6.2: technical specifications of Module-1 and 2 Generators

Technical Specifications	GT-1-2	GT-3-4	STG-9-10
Type:	TLRI 108/41	SGTIC 243704	WX 21L-064LL
Make:	KWU	ERCOLEMARELLI	ABB
Rated Out Put (MVA):	135	87	132
Power Factor:	0.85	0.85	0.85
Rated Voltage (KV):	10.5	11.0	11.0
Rated Current (A):	7423	4567	6928
Frequency (HZ):	50	50	50
Gen Cooling System	Air Cooled	Air Cooled	Air Cooled
Cold air temp	55°C	55°C	33.3°C

6.1.3.1. GT-1 Unit Generator

GT-1 Unit Generator of Siemens make has operated satisfactorily since its commissioning. Routine offload, on load, test results showed its healthy condition.

Unit-1 Generator major overhauling has been conducted in Feb-March 2021. During inspection, findings were observed on the Generator rotor J Straps which were then replaced with new. Generator inspections during the outage showed overall Generator condition as Good.

All operating parameters e.g. winding temperature, cold air temperature are in normal range.

Based on recent MOH test results Feb 2021, routine condition monitoring tests and operating conditions, ***we envisage that Unit-1 Generator can be operated reliably for next 10-12 years.***

6.1.3.2. **GT-3 Unit Generator**

GT-3 Unit Generator is of Ercole Marrelle make and is operating satisfactorily since its commissioning. Routine offload/on load test results are showing its healthy condition.

Generator tests, e.g. Insulation Resistance, Loop Resistance of Rotor and Stator and Megger testing were conducted during October 2020, all results are satisfactory.

All operational parameter found OK. ***We envisage that U-3 generator can be operated for next 10 years based on its condition and spares availability in store.***

6.1.3.3. **STG-9 Unit Generator**

STG-9 Unit Generator is of Alstom make and is operating satisfactorily since its commissioning. Routine offload/on load test results are showing its healthy condition. Its major overhauling has been executed in Feb-March, 2021. All electrical tests conducted for Generator Stator and Rotor during outage Feb-2021 are showing results within normal range.

All operating parameters e.g. winding temperature, cold air temperature are normal.

Based on routine condition monitoring tests and operating conditions, ***we envisage that Unit-9 generator can be operated reliably for next 10 years.***

6.1.3.4. **Summary of Remaining life of Module-1 Generators**

Below is the summary for Remaining life of Module-1 Unit Generators derived from condition monitoring tests performed as described in preceding paragraphs;

Table 6.3: Remaining life of Module-1 Generators

Units	COD	Make	Overall Condition Rating	Overall Generator Condition	Expected Remaining life (Years)
GT-1	18-01-1987	Siemens	9	Good	10-12
GT-3	12-03-1987	Ercole Marrelle	7	Satisfactory	10
STG-9	28-01-1991	Alstom	8	Satisfactory	10
Condition Rating Criteria 1-10: Rating 9-10 = Good; Rating 7-8 = Satisfactory; Rating 4-6 = Acceptable; Rating 1-3 = Unacceptable					

6.1.4. Module-1 Unit's Step-Up Transformer 1, 3 and 9

Following are the technical Specifications for Module-1 and 2 Units' Transformers

Table 6.4: Technical specifications of Module-1 and 2 Transformers

Technical Specifications	GT-1-2	GT-3-4	STG-9-10
Make	TRAFO UNION	ANSALDO	TOSHIBA
Rated Power (MVA)	117.6/147	77/95.5	90/135
Rated Voltage KV	10.5/139	11.139	11/139
Rated Frequency (HZ)	50	50	50
No of Phases	3	3	3
Rated Current (A)	8083/611	5012/396	7090/561
Type of Cooling	ONAN/ONAF	ONAN/ ONAF	ONAN/ ONAF
Temp. Rise Winding/Oil	55/50 °C	55/50 °C	55/50 °C

6.1.4.1. **Unit-1 Step-Up Transformer 1BAT01 Condition Monitoring**

U-1 Step-Up Transformer testing was performed in 2019 by Siemens at the KAPCO Complex (see Appendix-2: GT-1 Unit TF 1BAT01 Life assessment).

Field testing has been carried out to identify adverse trends in the aging of the transformer and its accessories.

Siemens performed the following tests and inspection on the Power Transformers as per the following scope of work:

- Insulation Resistance and PI Test
- Transformer Turns Ratio Test
- Winding Resistance Test (HV/MV)
- Overall Capacitance and Dissipation Factor Test (Windings / Bushings)
- Leakage Reactance Test
- Excitation Current Test
- Sweep Frequency Response Analysis
- Dielectric Frequency Response Analysis
- Visual Inspection Report

Field testing performed for 1BAT01 concluded, the condition of the transformer as **Normal** as per below details

Trafo Tag No.	Tests								Overall Assessment
	IR	TTR	WR	C&DF	LR	EC	SFRA	DFRA	
01BAT	√	√	√	√	√	√	Mod	√	Normal

√: Satisfactory; X: Unsatisfactory; Mod.: Moderate; Sev: Severe; N/A: Not Applicable

Oil Analysis report for the test conducted in May 2020 has also verified the satisfactory condition of TF. Following is the conclusion from oil analysis report (Appendix-2: Unit-1 TF 1BAT01 Oil Analysis Report);

- "The evolution of the dissolved gases can be considered as normal. There is no indication of thermal or electrical faults in the transformer.
- The water content and relative saturation of the oil can be considered as normal.
- The analysis of paper ageing markers does indicate significant winding paper ageing. Based on the furans concentration the DP can be estimated between 350 and 550. When a DP-value lower than 200 is reached, the winding paper is considered as end-of-life.
- The next sample according to normal frequency. **No other action needed**"

Operating parameters of transformer e.g. Oil temperature, winding temperature etc. all are in normal range.

Thus, the overall condition of Unit-1 Step Up transformer is **Satisfactory**; that is code-1 for healthy equipment operating normally.

6.1.4.2. **Unit-3 Step-Up Transformer 3BAT01 Condition Monitoring**

Transformer Oil analysis tests were performed in May 2020 by LABORELEC Belgium (Appendix-2 Unit-3 TF 3BAT01 Oil Analysis Report).

Following is the conclusion from the oil analysis;

"The evolution of the dissolved gases can be considered as normal. There is no indication of thermal or electrical faults in the transformer. The oil properties that were investigated indicate severe oil degradation (high tan delta, high color, acidity). The analysis of paper ageing markers does also indicate significant winding paper ageing. The oil tests potentially corrosive."

All electrical tests conducted for Transformers are showing satisfactory results.

Operating parameters of transformer e.g. Oil temperature, winding temperature etc all are in normal range.

Thus, the overall condition of Unit-3 Step Up transformer is **Acceptable**; that is code-2 i.e. equipment can keep operating normally with increased frequency of condition monitoring test.

6.1.4.3. **Unit-9 Step-Up Transformer D1BAT01 Condition Monitoring**

Transformer Oil analysis tests were performed in May 2020 by M/S LABORELEC Belgium (Appendix-2 Unit-9 TF D1BAT01 Oil Analysis Report). Following is the conclusion from oil analysis;

"The evolution of the dissolved gases can be considered as relatively stable. The water content and relative saturation of the oil can be considered as normal. The analysed winding paper ageing markers (alcohols) indicate beginning of paper ageing and quality of winding paper can be assessed as still good (DP-value >600). The next sample according to normal frequency. No other action needed."

Operating parameters of transformer e.g. Oil temperature, winding temperature etc all are in normal range. Thus, the overall condition of Unit-9 Step Up transformer is **Satisfactory**; that is code-1 i.e. that is code-1 for healthy equipment operating normally.

6.1.4.4. Summary of Module-1 Units Transformer Condition Monitoring

Depending upon above assessments and the recent tests conducted for condition monitoring of unit step up transformers of module-1, healthiness is confirmed as per below summary table;

Table 6. 5: Overall Condition Assessment of Module-1 Unit Transformers

Unit	Unit Transformer	Overall Condition code	Overall Condition Status
GT-1	1BAT01	1	Satisfactory
GT-3	3BAT01	2	Acceptable
STG-9	D1BAT01	1	Satisfactory

Condition Code 1: Healthy Equipment Operating Normally
Condition Code 2: Early indication of operational fault. Frequency of test is increased (usually 6 months depending on the indicated problem) until either the condition worsens or until we are satisfied that the condition is not active and we would then push the testing interval out) No abnormality of Gas, Oil and Paper condition

6.1.5. Control System of Module-1 Units

6.1.5.1. GT-1 Control System

To enhance unit operating reliability, GT-1 old ISKMATIC control system was replaced in 2016 with state of the art fourth generation SPPA T3000 DCS of Siemens and the SFC / Excitation systems with GE Semipole D-4 versions.

The useful life of industrial electronic components is about 20 years. **Hence Remaining Useful life of unit-1 control system is considered not less than 16 years.**

6.1.5.2. GT-3 Control System

At GT-3, FIAT HIGH control system is in operation since commissioning. It is an old control system yet is operating satisfactorily with availability of spares in KAPCO Stores.

The existing Excitation system at GT-3 is GE Semipole D4.0 which was installed in 2017. It is a new system and spares / OEM support is available.

6.1.5.3. STG-9, HRSG-1, 3 and BOP Control System

STG-9 along with HRSG-1 and 3 and BOP; the old control system of ABB PROCONTROL Decontic K and SIEMENS TELEPERM ME has been replaced in 2016 with state-of-the-art fourth generation SPPA T3000 DCS of Siemens. It has enhanced unit availability and integrity.

Remaining Useful life of Unit-9 control system is considered not less than 16 years.

6.1.5.4. Summary of Remaining life of Module-1 Control Systems

Below is the summary of remaining life of Module-1 unit's control systems;

Table 6.6: Remaining life of Module-1 unit's control systems

Control System Module-1 GT-1, GT-3 & STG-9 Remaining Life		
Unit	Control System	Expected Remaining Life (Years)
GT 1	Siemens SPPA T3000	16
GT 3	Fiat Hi	10*
STG-9, HRSG 1 & 3 & BOP	Siemens SPPA T3000	16
*GT-3 control system may operate for next 10 years with availability of spares in KAPCO Stores		

6.1.6. Cooling Tower System for STG-9 of Module-1

Cooling Tower structure visual inspections were performed during the last schedule outages and Concrete Corrosion was reported at different locations. Civil structure water proofing and repairs were performed.

Tam Seal was applied which waterproofs and provides in-depth concrete protection. After applying the TAM sealing the cooling tower structure is observed **good.** (Also see 5.6 5.6. Buildings and Civil Structure Integrity Assessment)

Cooling Tower fan, PMs (Preventive maintenance) are performed as per manufacturer recommended intervals. PMs records are available in the computer aided maintenance management system (Q4-CAMM). Mandatory spare parts inventory is maintained.

CW Pumps and piping Inspection / life assessment was conducted by SGS and no significant marks of deterioration observed. Thereafter, inspection is carried out by KAPCO team during schedule outages and no abnormality has been observed.

It is considered that the Cooling Tower system can be operated reliably for next 12 years.

6.1.7. Water Treatment Plant Module-1 and 2

Preventative Maintenances (PMs) are performed as per manufacturer recommended intervals. PMs records are available in the computer aided maintenance management system (Q4-CAMM). Mandatory spare parts inventory is maintained. Water Treatment plants are in healthy conditions and are operating without any trouble.

It is considered that the Water Treatment Plants can be operated reliably for next 12 years.

6.2. Module-2 Plant Components' Residual Life Assessment

6.2.1. Gas Turbine Unit 2, 4 and Steam Turbine Unit-10

Gas Turbine GT-2: Hot gas path components are being replaced periodically on MOH as per recommended EOH by the OEM Siemens. One complete set of turbine vanes and blades is available as a strategic spare.

The overall condition of GT-2 was observed as Satisfactory during visual inspections and NDTs performed in the last MOH/eHGPI Feb-March 2018.

Scope of visual inspection and NDTs included;

- Ultrasonic Testing of Compressor bearing, Turbine bearing, Gas Burner, Compressor vanes,
- Magnetic Particle Test of Compressor vane carrier, Compressor blades, Rotor, Compressor and Turbine wheel discs, Intermediate shaft, Front Hollow shaft, Compressor and Turbine vane carriers, Bearings, etc.
- Dye Penetrant Test was performed for Compressor and Turbine bearing, Compressor vane rings, Gas Premix Burners, Mixing chamber of combustion chambers, Inner Casing, Turbine stator vanes stage-4, Compressor and Turbine vane carriers, exhaust casing etc.

Overall NDT results were categorized Acceptable except few observations which were addressed in MOH activities e.g. Inner Casing ground out and build-up welding.

Air intake system structure is in healthy condition. New air intake filters are available in the market.

The compressor blades stages 1-12 have been in service since commissioning. New compressor blades stages 13-16 were installed in 2002 and are in service since then. During inspection in the last MOH Feb-March 2018, no recordable indication was reported in NDT report March 2018 and the condition of compressor blades were found to be satisfactory. In case if some findings appear in the next MOH, compressor blades are recommended to be replaced.

New IGVs were installed in 2009 and expected remaining useful life is 10-15 years henceforth.

All stages of GT-2 compressor diaphragms were replaced during the 2002 MOH with new ones. The condition of the compressor diaphragms was found satisfactory in the MOH 2018.

Gas Turbine GT-4: Hot gas path components are being replaced periodically with each MOH as per recommended EOH by OEM. One set of vanes and blades is available in store as a strategic spare.

New Compressor blades were installed in 1999 and are in service without any findings.

The overall condition of GT-4 was found to be satisfactory during the MOH 2016 and HGPI 2017. One complete GT rotor is available for GT-3 and GT-4 as a strategic spare.

Steam Turbine STG-10 condition found satisfactory during last Minor Inspection Feb-April 2016. Last MOH was performed in Sep-Oct 2013. During the MOH, modified 1st stage moving blades and new LP turbine erosion protection rings of the last 3 stages were installed which enhance turbine performance and integrity.

Mandatory spares are maintained for the steam turbine and are available in store.

Following is the expected Remaining Life summary of Module-2 units as per current operating regime;

Table 6. 7: Remaining Life of Module-2 Units

Unit #	Operating Hours in Design Life of 30 years	Operating Hours in Extended Design Life of 40 years*	KAPCO Operating Hours COD to Mar-2021	Remaining Operating Hours In Extended Design Life of 40 years	Remaining Design life (Years)
GT-2	240,000	320,00	162,106	157,894	20
GT-4	240,000	320,00	93,756	226,244	28
STG-10	240,000	320,00	157,017	162,983	20

Module-2 Units are expected to operate for minimum further 10 years without any major concern.

*CCGT Operating Life expectancy before retirement is 40 years (320,000 hours based on 8,000 operating hours/year) ref section 5.3.4 and 5.4 of this document.

6.2.2. Module-2 HRSG 2 and 4

HRSG-1 to 4 are of same model and make of Balke Durr Germany. All four Heat Recovery steam generators have operated satisfactorily since their commissioning.

Life assessment of HRSG-1 was conducted on sample basis among all four HRSGs of Block-1 (Module-1 and 2). No major deterioration was reported with remaining life of all major components greater than 20 years. The same condition about life assessment is predicted for the other three HRSGs i.e. HRSG-2, 3 and 4 as these HRSGs have fewer operating hours and have generally been operated and maintained the same.

Also, HRSG-2 and 4 mandatory inspections are carried out in every schedule outage of GT-2 and GT-4 by the Boiler Engineer, Mechanical Engineer and Plant Chemist.

Last inspection was performed in Feb 2021 and both HRSGs condition were found to be satisfactory.

Based on life assessment reports and routine maintenance inspections; it is expected that with the current operating regime, ***HRSG-2 and 4 may be operated reliably for next 12-15 years.***

6.2.3. Module-2 Unit's Generators

6.2.4. GT-2 Unit Generator

GT-2 Unit Generator is of Siemens make and is operating satisfactorily since its commissioning. Its overhauling has been performed in Feb, 2018 under Siemens' Engineers supervision.

The following inspections and major tests were conducted:

- Visual inspection of generator end windings in accessible area

- Visual inspection of bar connections
- Visual inspection of Z brackets
- Partial discharge test
- Rotor Insulation Resistance Test
- Stator insulation Resistance test
- ELCID
- RSO

Siemens' Engineers reported "No thermal or thermo mechanical aging phenomena were detected. Reliability is not currently limited for the next operating period"

Overall condition of Generator is **Good.** ***It is considered that Unit-2 Generator can be operated for the next 10 years.***

6.2.4.1. **GT-4 Unit Generator**

GT-4 Unit Generator is of Ercole Marrelle make and has operated satisfactorily since its commissioning. Aging impacts were evident on a few parts e.g. cooler leakages etc which were addressed. Generator tests, e.g. Insulation Resistance, Loop Resistance of Rotor and Stator and Megger tests were conducted during Sep 2019, all results are satisfactory.

All operational parameter found OK. Overall condition of Generator is **Satisfactory.** ***We envisage that U-4 generator can be operated for next 10 years based on its condition and with spares availability in store.***

6.2.4.2. **STG-10 Unit Generator**

STG-10 Unit Generator is of Alstom make and is operating satisfactorily since its commissioning in January 1991. Alstom overhauled the Generator in 2016. Overall condition of Generator is considered **Good.**

However, Alstom stated for displaced U-channels of the rotor "The current state of displacement doesn't require immediate actions, since the cooling gas-inlets are still free and the insulation distance is still sufficient for the operating voltage. The displacement is likely to get bigger with further operation, eventually blocking the cooling gas-inlets or decreasing the insulation distance (creep age path) to a point were an earth-fault (contact of rotor winding with rotor body) is possible. Alstom recommended; 1) To monitor the displacement of the slot channels regularly at least once a year. 2) To measure and protocol (trend) the insulation resistance at least once a year. 3) The rotor earth fault protection should be checked and kept in good working order.

All operational parameter found OK. Recent electrical tests conducted are showing results normal.

Based on routine condition monitoring tests and operating conditions, ***we envisage that U-10 Generator can be operated reliably for next 10 years.***

6.2.4.3. Summary for Remaining life of Module-2 Generators

Below is the summary for Remaining life of Module-2 Unit's Generator derived from condition monitoring tests performed as described in preceding paragraphs;

Table 6. 8: Remaining life of Module-2 Generators

Units	COD	Make	Overall Condition Rating	Overall Generator Condition	Expected Remaining life (Years)
GT-2	14-01-1987	Siemens	8	Satisfactory	10
GT-4	02-05-1987	Ercole Marrelle	7	Satisfactory	10
STG-10	08-01-1991	Alstom	9	Good	10
Condition Rating Criteria 1-10: Rating 9-10 = Good; Rating 7-8 = Satisfactory; Rating 4-6 = Acceptable; Rating 1-3 = Unacceptable					

6.2.5. Module-2 Unit's Step-Up Transformer 2, 4 and 10

6.2.5.1. Unit-2 Step-Up Transformer 2BAT01 Condition Monitoring

GT-2 Unit Step-Up Transformer testing was performed for life assessment by ABB in 2016 on a sample basis in Block-1 units.

ABB performed the following tests along with visual inspection of the Power Transformers as per the specified scope of work:

- Winding Turn Ratio Test
- Vector Group Check
- Excitation Current Test
- Winding DC Resistance Test
- Winding Insulation Resistance Test
- Winding Tan Delta Test
- Winding Tan Delta Test
- FRA Frequency Response Analysis

All tests results were observed acceptable.

Also, the Transformer Oil analysis tests were performed in May 2020 by LABORELEC Belgium (Appendix-2 Unit-2 TF 2BAT01 Oil Analysis Report). Following is the conclusion from the oil analysis;

"The evolution of the dissolved gases (DGA) shows decreased concentrations. No indication of any specific evolving internal transformer fault.

The water content and relative saturation of the oil can be considered as normal.

The analysis of paper ageing markers does indicate significant winding paper ageing. Based on the furans concentration the DP can be estimated between 375 and 575. When a DP-value lower than 200 is reached, the winding paper is considered as end-of-life.

The next sample according to normal frequency. **No other action needed.**"

Furan Analysis report results are similar for test report 2019 and 2020 which shows no immediate concern for future operations.

Operating parameters of transformers e.g. Oil temperature, winding temperature all are in normal range.

Field testing performed for 2BAT01 concluded, condition of transformer as **Satisfactory** that is code-1 for healthy equipment operating normally.

6.2.5.2. Unit-4 Step-Up Transformer 4BAT01 Condition Monitoring

Transformer Oil analysis tests were performed in May 2020 by M/S LABORELEC Belgium (Appendix-2 Unit-4 TF 4BAT01 Oil Analysis Report). Following is the conclusion from the oil analysis;

"The evolution of the dissolved gases can be considered as stable. The water content and relative saturation of the oil can be considered as normal. The oil properties that were investigated indicate minor oil degradation.

The analysis of paper ageing markers does indicate limited winding paper ageing. Based on the furans and methanol concentration the DP can be estimated as >600 and the paper can still be considered as in good condition.

The next sample according to normal frequency. **No other action needed at this stage.**"

Operating parameters of transformers e.g. Oil temperature, winding temperature all are in normal range.

Thus, the overall condition of Unit-3 Step-Up transformer is **Satisfactory**; that is code-1 i.e. for healthy equipment operating normally.

6.2.5.3. Unit-10 Step-Up Transformer D2BAT01 Condition Monitoring

Transformer Oil analysis tests were performed in May 2020 by M/S LABORELEC Belgium (Appendix-2 Unit-10 TF D2BAT01 Oil Analysis Report). Following is the conclusion from oil analysis;

"The evolution of the dissolved gases shows an increase compared to the previous sample (01/2019) and shows similar gas pattern the sample of 05/2018 which can indicate that the previous sample was not from this transformer/ the right place. Nevertheless, the concentrations are also increased compared to the sample of 05/2018. Laborelec recommends to send a new sample within 3 - 6 months in order to follow-up the evolution. The concentrations of the gases can indicate the presence of overheating fault type (insufficient cooling or overloading) or possible stray gassing.

The water content and relative saturation of the oil can be considered as normal." New sample for oil analysis will be sent in 2021.

All electrical tests conducted are showing results in normal range.

Operating parameters of transformers e.g. Oil temperature, winding temperature all are in normal range.

Thus overall condition of Unit-10 Step Up transformer is **Satisfactory**; that is code-1 i.e. for healthy equipment operating normally.

6.2.5.4. Summary of Module-2 Unit's Transformer Condition Monitoring

Depending upon the above assessments and the recent tests conducted for condition monitoring of the Unit step-up transformers of Module-2, healthiness is confirmed as per below summary table;

Table 6. 9: Overall Condition Assessment of Module-2 Unit Transformers

Unit	Unit Transformer	Overall Condition code	Overall Condition Status
GT-2	1BAT01	1	**Satisfactory**
GT-4	4BAT01	1	**Satisfactory**
STG-10	D1BAT01	1	**Satisfactory**

Condition Code 1: Healthy Equipment Operating Normally
Condition Code 2: Early indication of operational fault. Frequency of test is increased (usually 6 months depending on the indicated problem) until either the condition worsens or until we are satisfied that the condition is not active and we would then push the testing interval out) No abnormality of Gas, Oil and Paper condition

6.2.6. Control System of Module-2 Units

6.2.6.1. GT-2 Control System

To enhance unit operating reliability, the GT-2 old ISKMATIC control system was replaced in 2013 with state of the art fourth generation SPPA T3000 DCS of Siemens and the SFC / Excitation systems with GE Semipole D-4 versions.

The useful life of industrial electronic components is about 20 years. ***Hence Remaining Useful life of Unit-2 control system is considered not less than 13 years.***

6.2.6.2. GT-4 Control System

At GT-4, the FIAT HIGH control system has operated since commissioning. It is an old control system yet operating satisfactorily with availability of spares in KAPCO Stores.

6.2.6.3. STG-10, HRSG-1, 3 and BOP Control System

STG-10 along-with HRSG-2 and 4 and BOP; is operating with the old control system of ABB Procontrol Decontic K and Siemens Teleperm ME. STG-10 control system is operating reliably with spares availability in KAPCO Stores. Moreover, spares obtained from STG-9 control system replacement are available for STG-10.

Below is the summary of Remaining life of Module-2 Units' control system;

Table 6. 10: Remaining life of Module-2 Unit's control systems

Control System Module-2 GT-2, GT-4 & STG-10 Remaining Life		
Unit	Control System	Expected Remaining Life (Years)
GT 2	Siemens SPPA T3000	13
GT 4	Fiat Hi	10*
STG-10, HRSG 2 & 4 & BOP	ABB Procontrol Decontic K & Siemens Teleperm ME	10**
*GT-4 control system may operate for next 10 years with availability of spares in KAPCO Stores **STG-10 control system may operate for next 10 years with availability of spares in KAPCO Stores and additional spares obtained from Control System replacement of STG-9.		

6.2.7. Cooling Tower System for STG-10 of Module-2

Cooling Tower structure visual inspections were performed during the last schedule outage. Concrete Corrosion was observed at different locations. Civil structure water proofing and repairs were performed.

Tam Seal was applied which waterproofs and provides in-depth concrete protection. After applying the TAM sealing cooling tower structure is observed **good.** (Also see 5.6 5.6. Buildings and Civil Structure Integrity Assessment)

Figure 6. 1: Cooling Tower STG-10

Cooling Tower fan, PMs (Preventive maintenance) are performed as per manufacturer recommended intervals. PMs records are available in the computer aided maintenance management system (Q4-CAMM). Mandatory spare parts inventory is maintained.

CW Pumps and piping Inspection is carried out by KAPCO team during schedule outages and no abnormality of great concern observed.

It is expected that the Cooling Tower system can be operated reliably for the next 12 years.

6.3. Module-3 Plant Components' Residual Life Assessment

6.3.1. Gas Turbine Unit 5, 6 and Steam Turbine Unit-11

Gas Turbine GT-5: Hot gas path components are being replaced periodically on CI, HGPI and MOH as per recommended EOH intervals by the OEM (GE). A minimum of one complete set of turbine buckets and nozzles is always available in store as a strategic spare.

One complete refurbished GT rotor is available for GTs-5 to 8 as a strategic spare. One complete set of compressor blades are also available as a strategic spare.

GT-5 compressor and turbine rotor was replaced with a refurbished rotor in 2011 and 2003 respectively. The compressor blades have been in service since commissioning and the overall condition is satisfactory.

The overall condition of Gas Turbine-5 unit was observed as being Good during inspections performed in HGPI Sep-Oct 2017.

The compressor casings have been in operation since commissioning. During inspections performed, no major observations were noted. Therefore, compressor casings may be kept in operation for next 10 years satisfactorily.

No major observations were noted for the Compressor Stator/Diaphragms, so keeping in view the present condition, these may also be kept in operation for next 10 years.

Gas Turbine GT-6: Hot gas path components are being replaced periodically on CI, HGPI and MOH as per recommended EOH intervals by the OEM (GE).

GT-6 compressor and turbine rotor was replaced with new and refurbished rotors in 1996 and 2006 respectively. The compressor blades have been in service since commissioning.

The overall condition of Gas Turbine-6 unit was observed as being **Good** during inspections performed in HGPI Sep-Oct 2017.

For Compressor Casings, during inspections performed in HGPI Sep-Oct 2017, no major observation has been noted. Therefore, it is considered that the compressor casings may be kept in operation for the next 10 years satisfactorily.

No major observations were noted for Compressor Stator/Diaphragms, so keeping in view the present condition, these may also be kept in operation for the next 10 years.

GT-5 and 6 hot gas path up-gradation was performed during the outage in Oct-Nov 2011, replacing components with improved metallurgy and design supplied by the OEM which also improved the Units' performance and enhanced the plant life.

Steam Turbine STG-11 schedule maintenance is performed as per OEM recommendations. Spares inventory is maintained in KAPCO Stores (See Appendix-6 for Strategic Spares)

STG-11 last Overhauling was conducted in Feb-March 2020.

The Turbine upper casing was removed. No cracks in the casing and other abnormalities were observed.

DPT of Turbine diaphragms was performed by Jiacco, Pakistan and no major abnormality was observed. Minor observation on the lower half diaphragm of Stage # 13 was addressed.

The Turbine rotor was removed and the corrosion condition of the blades was found to be found normal. Minor scaling was observed on the lower pressure side of rotor. Last stage blading was observed to be in good condition and all brazed leading edges were found to be intact. All blades were cleaned with sand-papers. Magnetic particle testing of all rotor stages was carried out. No cracks or other abnormalities were observed. Some of the gland seal packing was found to be bent, which were straightened. Gland seals were also found in good condition. Condition of the rotor was found satisfactory.

The overall condition of Steam Turbine Unit-11, including condenser, was observed to be satisfactory during inspections performed in MOH Sep-Oct 2017 and last Minor Overhauling Feb-March 2020.

Following is the expected Remaining Life Assessment summary of Module-3 units as per unit's condition and current operating regime;

Table 6. 11: Remaining Life of Module-3 Units

Unit #	Operating Hours in Design Life of 30 years	Operating Hours in Extended Design Life of 40 years*	KAPCO Operating Hours COD to Mar-2021	Remaining Operating Hours In Extended Design Life of 40 years	Remaining Design life (Years)
GT-5	240,000	320,00	144,150	175,850	22
GT-6	240,000	320,00	152,072	167,928	21
STG-11	240,000	320,00	128,560	191,440	24

Module-3 Units are expected to operate for minimum further 10 years without any major concern.

*CCGT Operating Life expectancy before retirement is 40 years (320,000 hours based on 8,000 operating hours/year) ref section 5.3.4 and 5.4 of this document.

6.3.2. Module-3 HRSG 11A and 11B

HRSGs 11A, 11B, 12A and 12B are of same model and make of Stein Industries France. All four Heat Recovery steam generators have operated satisfactorily since their commissioning.

Life assessment of HRSG-11A and 11B was conducted in Nov-2020 by SGS Pakistan on a sample basis among all four HRSGs of Block-2 (Module-3 and 4). The same condition about life assessment is predicted for HRSG-12A and 12B having almost same service life and operating conditions.

During inspections relating to life assessment for HRSG-11A and 11B no significant deterioration was observed except a few recommendations of improvement which are addressed e.g. Recommendation for HRSG-11A Corroded Insulation cladding outside HP Economizer (and HP Superheater for HRSG-11B) need to repair or replace. Hence, the corroded Insulation cladding outside HP Economizer (and HP Superheater for HRSG-11B) was replaced with new one as per recommendation.

(see Appendix-1: Remnant Life assessment of HRSG-11A and 11B).

Following inspection techniques were used for life assessment study of HRSG-11A and 11B.

- Visual Inspections
- Ultrasonic Thickness Measurement
- Ultrasonic Flaw Detection
- Dye Penetrant Testing
- Magnetic Particle Inspection
- Hardness Testing
- Metallographic examination

Scope of work for complete inspection and remaining life assessment of HRSG-11A and 11B included following inspections and NDTs;

- Visual inspection of HP drum, tubes, headers, for localized and uniform corrosion, deposits, erosion, pitting etc.
- Visual inspection of protective coating/insulation for damages
- Visual inspection for corrosion under insulation (CUI)
- Visual inspection of all structural steel parts including ducts, platforms, handrails and structural steel supports for ducts/piping for any visual defects.
- Visual inspection of tube bends and headers
- Visual inspection and DPT of steam header pipe welds for cracks
- Visual inspection of all accessible weld joints of HP Drum/LP separator, like shell, heads and nozzles.
- Hardness testing of HP drum, LP Separator and headers. 14 Locations from tube, 2 from each header, 4 locations from inside the drums
- Ultrasonic flaw detection of suspected weld joints of HP drum, LP Separator.
- MPI/DPT of selected weld joints
- Metallographic testing of boiler pressure parts like 2 from each HP drum, 1 for each LP Separator, 1 from each header to study the metallurgical changes, degradation and evaluation for its fitness for service.
- Ultrasonic thickness gauging was carried out from accessible locations, on the recommendations of API-510 inspector to find out overall metal loss in different equipment for remaining life calculations.

Remaining Life of HRSG-11A and 11B was calculated, comparing component's thickness at installation and current thickness gauging 2020 using remaining corrosion allowance.

For HRSG-11A all major components' remaining life is calculated greater than 40 years while HP Super Heater Outlet Header remaining life is calculated as 19.7 years.

For HRSG-11B all major components' remaining life is calculated greater than 45 years.

Also, HRSG-11A and 11B mandatory inspections are carried out in every schedule outage of GT-5 and GT-6 by the Boiler Engineer, Mechanical Engineer and Plant Chemist.

Last inspection was performed in March 2020 and both HRSGs condition found to be satisfactory.

Based on life assessment report and routine maintenance inspections; ***we expect that with the current operating regime, HRSG-11A and 11B can be operated reliably for next 10-15 years.***

6.3.3. Module-3 Unit's Generators

Following are the technical Specifications for Module-3 and 4 Units' Generators

Table 6.12: technical specifications of Module-3 and 4 Generators

Technical Specifications	GT-5-8	STG-11-12
Type:	T 229-320	T-229-320
Make:	ALSTHOM	ALSTHOM
Rated Out Put (MVA):	125.95	121.647
Power Factor:	0.85	0.85
Rated Voltage (KV):	11.5	11.5
Rated Current (A):	6223	6107
Frequency (HZ):	50	50
Gen Cooling System	Air Cooled	Air Cooled
Cold air temp	50°C	36°C

6.3.3.1. **GT-5 Unit Generator**

Condition monitoring testing of the Generator stator winding was carried out in Sep- 2015 by OEM (Alstom). On the basis of the tests, conductive paint activity on the stator winding was carried out in Sep-2015.

Generatortech flux probe was also installed to monitor Generator rotor healthiness during an outage in September 2015. Recent tests were conducted in Jan 2021 and data collected from the Generatortech flux probe. The quality of the flux probe waveforms were observed to be excellent. Analysis of the complete dataset shows very clearly there are no turn shorts in the GT-5 Generator rotor winding.

Installation of PD sensors by IRIS Canada was completed in Nov-2017 and hence PD monitoring started. PD Data collected for Jan 2021 has been analysed and summarized with the conclusion "Stable winding PD and low level, interphasal activity." Hence PD test results show healthy condition of the Generator Stator.

Generator rotor flux report and PD test Jan 2021 indicate that there is no significant faults on the Generator Rotor and Stator and it can continue its normal operation and hence Generator overall condition is considered to be **Satisfactory**.

Full Stator rewind Material (FSR) is available on-site as Strategic spare for GT-5, 6 and 7 Stators

We envisage that Unit-5 Generator can be operated for next 10 years based on current operating data and strategic spares availability in KAPCO stores.

6.3.3.2. **GT-6 Unit Generator**

Condition monitoring testing of the Generator stator winding has been carried out in Sep- 2015 by OEM (Alstom). On the basis of tests, conductive paint activity on the stator winding was carried out in Sep-2015.

Generatortech flux probe was also installed to monitor Generator rotor healthiness during the outage in October 2017. Recent tests conducted in Jan 2021 and data collected from the Generatortech flux probe

were analysed. The quality of the flux probe waveforms were observed to be excellent. Analysis of the complete dataset shows very clearly there are no turn shorts in the GT-6 Generator rotor winding.

Installation of PD sensors was completed in March 2019 during the outage. PD Data collected for Jan 2021 has been analysed and summarized with the conclusion "Increase in PD and low level, interphasal, deterioration of surface coatings". Hence PD test results show condition of Generator Stator **Satisfactory.**

Generator rotor flux report and PD test Jan 2021 indicate that there is no signification fault on Generator Rotor and Stator and it can continue its normal operation and, hence Generator overall condition is considered to be **Satisfactory.**

We envisage that Unit-6 Generator can be operated for the next 10 years based on current operating data and strategic spares availability in KAPCO stores.

6.3.3.3. **STG-11 Unit Generator**

On the basis of Conditioning Monitoring tests, Full stator rewind of STG-11 generator was completed in Sep/Oct 2017.

Generatortech flux probe was also installed to monitor the Generator rotor healthiness during the outage in October 2017. Recent tests conducted in Jan 2021 and data collected from the Generatortech flux probe were analysed. The quality of the flux probe waveforms were observed to be excellent. Analysis of the complete dataset shows very clearly there are no turn shorts in the STG-11 Generator rotor winding.

Installation of PD sensors was completed in March 2019 during the outage. PD Data collected for Jan 2021 has been analysed and summarized with conclusion "stable (slight decrease) winding PD and Typical level". Hence PD test results show condition of Generator Stator **Good.**

Generator rotor flux report and PD test Jan 2021 indicates that there is no fault on the Generator Rotor and Stator and, hence Generator overall condition is **Good.**

We expect that newly rewound STG-11 Generator may be kept in operation reliably for the next 20-25 years.

6.3.3.4. **Summary for Remaining life of Module-3 Generators**

Below is the summary for Remaining life of Module-3 Unit Generators in view of condition monitoring described in preceding paragraphs;

Table 6. 13: Remaining life of Module-3 Generators

Units	COD	Make	Overall Condition Rating	Overall Generator Condition	Expected Remaining life (Years)
GT-5	14-11-1988	Alsthom	8	Satisfactory	10
GT-6	29-12-1988	Alsthom	7	Satisfactory	10
STG-11	04-03-1995	Alsthom	9	Good	20

Condition Rating Criteria 1-10:
Rating 9-10 = Good; Rating 7-8 = Satisfactory; Rating 4-6 = Acceptable; Rating 1-3 = Unacceptable

6.3.4. Module-3 Unit's Step-Up Transformer 5, 6 and 11

Following are the technical Specifications for Module-3 and 4 Units' Transformers

Table 6.14: technical specifications of Module-3 and 4 Transformers

Technical Specifications	GT-5-8	STG-11-12
Make	ALSTHOM	ALSTHOM
Rated Power (MVA)	125	112/125
Rated Voltage KV (LV/HV)	11.5/240	11.5/240.18
Rated Frequency (HZ)	50	50
No of Phases	3	3
Rated Current (A) LV/HV)	6276/300	6276/300
Type of Cooling	ONAN/ONAF	ONAN/ ONAF
Temp. Rise Winding/Oil	55/50 °C	55/50 °C

6.3.4.1. GT-5 Unit Transformer 5BAT01 Condition Monitoring

Transformer Oil analysis tests were performed in May 2020 by LABORELEC Belgium (Appendix-2 Unit-5 TF 5BAT01 Oil Analysis Report). Following is the conclusion from the oil analysis;

"The evolution of the dissolved gases can be considered as relatively stable. This gas pattern indicates low temperature overheating (high load, insufficient cooling, ...) or stray gassing of the insulating oil.

The water content and relative saturation of the oil can be considered as normal.

The breakdown voltage acceptable for this type of transformer. The other properties that were investigated can be considered as normal.

The analysed winding paper ageing markers (furans, methanol) indicate no significant paper ageing and thus quality of winding paper can be assessed as very good (DP-value >800).

The next sample according to normal frequency. **No other action needed.**"

Operating parameters of transformer e.g. Oil temperature, winding temperature all are in normal range.

Thus, the overall condition of Unit-5 Step Up transformer is **Satisfactory**; that is code-1 i.e. for healthy equipment operating normally.

6.3.4.2. GT-6 Unit Transformer 6BAT01 Condition Monitoring

Transformer Oil analysis tests were performed in May 2020 by LABORELEC Belgium (Appendix-2 Unit-6 TF 6BAT01 Oil Analysis Report). Following is the conclusion from oil analysis;

"The evolution of the dissolved gases can be considered as normal. There is no indication of thermal or electrical faults in the transformer.

The water content and relative saturation of the oil can be considered as normal. The properties that were investigated can be considered as normal.

The analysed winding paper ageing markers (furans, methanol) indicate no significant paper ageing and thus quality of winding paper can be assessed as very good (DP-value >800).

The next sample according to normal frequency. **No other action needed.**"

Operating parameters of transformer e.g. Oil temperature, winding temperature all are in normal range.

Thus, the overall condition of Unit-6 Step Up transformer is **Satisfactory**; that is code-1 for healthy equipment operating normally.

6.3.4.3. STG-11 Unit Transformer 11CGEV001TR Condition Monitoring

Transformer Oil analysis tests were performed in May 2020 by LABORELEC Belgium (Appendix-2 Unit-11 TF 11CGE V001TF Oil Analysis Report). Following is the conclusion from the oil analysis;

"The evolution of the dissolved gases can be considered as acceptable. This gas pattern indicates low temperature overheating (high load, insufficient cooling, ...) or stray gassing of the insulating oil.

The water content and relative saturation of the oil can be considered as normal. The properties that were investigated can be considered as normal.

The analysed winding paper ageing markers (furans,methanol) indicate no significant paper ageing and thus quality of winding paper can be assessed as very good (DP-value >800).

The next sample according to normal frequency. **No other action needed**".

Operating parameters of transformer e.g. Oil temperature, winding temperature all are in normal range.

Thus, the overall condition of Unit-11 Step Up transformer is **Satisfactory**; that is code-1 for healthy equipment operating normally.

6.3.4.4. Summary Module-3 Unit's Transformer Condition Monitoring

Depending upon the above assessments and the recent tests conducted for condition monitoring of unit step up transformers of Module-3 described in preceding section, healthiness is confirmed as per below summary table;

Table 6.15: Overall Condition Assessment of Module-3 Unit Transformers

Unit	Unit Transformer	Overall Condition code	Overall Condition Status
GT-5	5BAT01	1	**Satisfactory**
GT-6	6BAT01	1	**Satisfactory**
STG-11	11CGEV001TR	1	**Satisfactory**

Condition Code 1: Healthy Equipment Operating Normally **Condition Code 2:** Early indication of operational fault. Frequency of test is increased (usually 6 months depending on the indicated problem) until either the condition worsens or until we are satisfied that the condition is not active and we would then push the testing interval out) No abnormality of Gas, Oil and Paper condition

6.3.5. Control System of Module-3 Units

6.3.5.1. GT-5 and 6 Control System

GT-5 and 6 Control system is GE's latest Unit Control System Mark VIe which was installed in 2015. The useful life of industrial electronic components is about 20 years, ***hence, the Remaining Useful life of Unit-5 and 6 control system is considered to be 15 years.***

6.3.5.2. STG-11 Control System

The control system for STG-11 is the ALSTOM ALSPA Controsteam V3 which was upgraded in 2009. The system is currently in production with a newer version. Spare parts have been maintained and support is available.

6.3.5.3. STG-11 Aux, HRSG-11A and 11B, and BOP Control System

STG-11 Aux, HRSG-11A and 11B and BOP old Control system T20 Micro Z of ALSTOM has been replaced with a new control system RX3I of General Electric (GE) in March 2020 which has enhanced the system integrity of the Boilers, Turbine Auxiliaries and BOP control system.

6.3.5.4. Summary of Module-3 Units Control System

Below is the summary of remaining life of Module-3 Unit's Control system

Table 6.16: Remaining life of Module-3 Unit's control systems

Control System Module-3 GT-5, GT-6 & STG-11		
Unit	Control System	Expected Remaining Life(Years)
GT 5 & 6	GE Speedtronic Mark VIe	15
STG-11	Alstom ALSPA Controsteam V3	10
STG-11 Aux, HRSG-11A & B, & BOP	GE RX3I	19

6.3.6. Cooling Tower System for STG-11 of Module-3

The Cooling Tower structure visual inspection is performed twice a year during schedule outage. Concrete Corrosion was observed at different locations. Civil structure water proofing and repairs has been performed. Tam Seal 10-F has been applied which waterproofs and provides in-depth concrete protection. After applying the TAM sealing the cooling tower structure is observed **Satisfactory**.

Cooling Tower fan, PMs (Preventive maintenance) are performed as per manufacturer recommended intervals. PMs records are available in the computer aided maintenance management system (Q4-

CAMM). Mandatory spare parts inventory is maintained e.g. 2 refurbished gearboxes for the cooling tower fan are available as spares. Overall condition of cooling tower fans is considered to be **Satisfactory**.

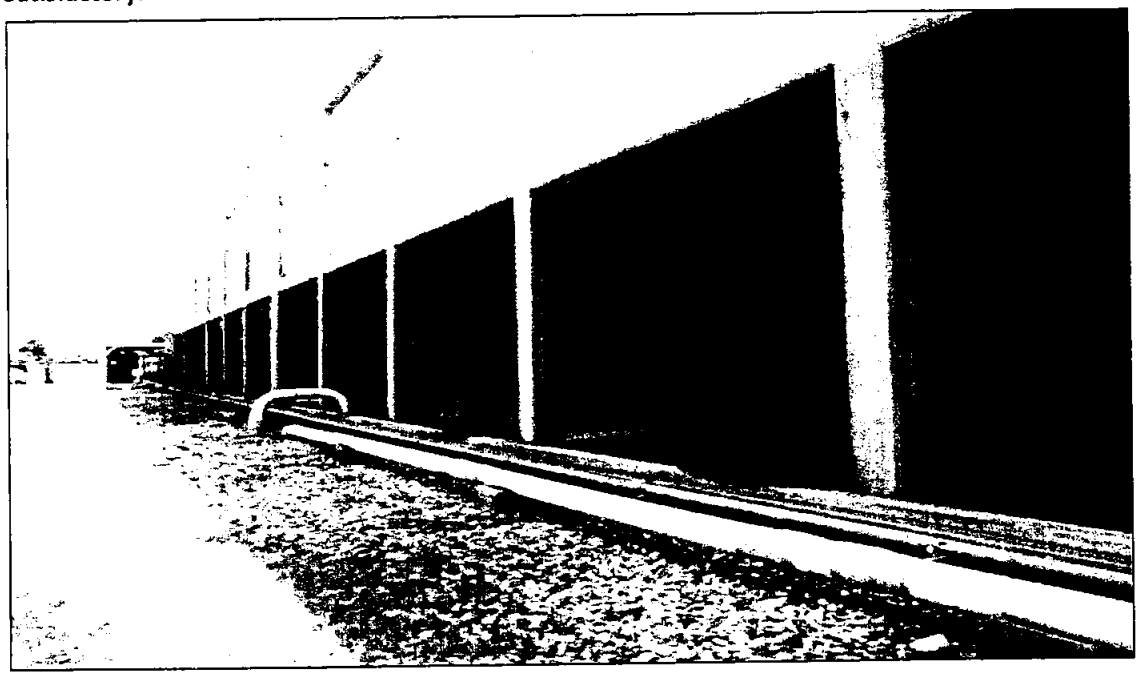


Figure 6. 2: Cooling Tower STG-11

CW Piping inspection is carried out by KAPCO team during schedule outages and piping condition is satisfactory.

CW Pumps were inspected during last schedule outage March 2020 and no abnormality observed.

As per above visual inspections and current condition monitoring it is envisaged that the Cooling Tower System can be operated reliably for the next 12 years.

6.4. Module-4 Plant Components' Residual Life Assessment

6.4.1. Gas Turbine Unit 7, 8 and Steam Turbine Unit-12

Gas Turbine GT-7: Hot gas path components are being replaced periodically on CI, HGPI and MOH as per recommended EOH intervals by the OEM (GE). One complete set of turbine buckets and nozzles is always available in store as a strategic spare.

GT-7 compressor and turbine rotor was replaced with a new one in 2005 and 2003 respectively.

The overall condition of Gas Turbine-7 unit was observed to be **Satisfactory** during visual inspections and NDTs performed in the recent MOH Feb-March 2021. Bearings 1, 2, 3 and the thrust bearing were replaced during the outage activities. All hot gas path components including turbine blades and vanes were replaced as per OEM recommended interval.

It is recommended by the OEM to replace the compressor aft brush seals and honey-comb seals in the next major inspections, or whenever the inner barrel is removed, for better performance.

The Compressor Casings are the original installed. During inspections performed in the recent MOH, no major observation has been noted. Therefore, it is anticipated that the compressor casings may be kept in operation for the next 10-12 years satisfactorily.

No major observation has been noted for the Compressor Stator/Diaphragms, Turbine Vane carriers etc. so keeping in view the present condition, these may also be kept in operation for next 10-12 years.

Gas Turbine GT-8: Hot gas path components are being replaced periodically on CI, HGPI and MOH as per recommended EOH intervals by the OEM (GE).

The GT-8 Compressor and turbine rotor were in service since 2002 and 2007 but were replaced in Feb 2019 with a refurbished, compressor and turbine rotor. Expected life of the GT rotor is assessed to be 15 years.

The Compressor Casings are the original installed. During inspections performed, no major observation has been noted. Therefore, it is anticipated that the compressor casings may be kept in operation for next 10 years satisfactorily.

No major observation has been noted for the Compressor Stator/Diaphragms, so keeping in view the present condition, these may also be kept in operation for next 10 years.

Overall condition of Gas Turbine-8 unit was observed to be **Good** during visual inspections and NDTs performed in the Major Outage Feb 2019.

GT-7 and 8 hot gas path up-gradation was performed in the Outages Sep-Oct 2010 and 2011 respectively, replacing components with improved metallurgy and design supplied by the OEM, which also improved the Units' performance and enhanced the plant life.

Steam Turbine STG-12 Turbine Rotor was found satisfactory during the last major inspection in Feb-March, 2017. Also, the same is noted by the GE Inspection Engineer in the Major Overhaul report of Feb-Mar, 2015.

Turbine Diaphragms were inspected and repaired through welding by the company, KPS, in the last outage of Feb-March, 2017. Last stage blading's stellite strips were also replaced.

The overall condition of Steam Turbine Unit-12 and condenser was observed to be **Good** in visual inspections and NDTs performed during the last outages in 2017 and 2018.

In Feb 2021, Minor Inspection of STG-12 was conducted, the condition of Turbine and Turbine bearings were assessed and found normal.

Following is the expected Remaining Life Assessment summary of Module-4 units as per the current operating regime;

Table 6.17: Remaining Life of Module-4 Units

Unit #	Operating Hours in Design Life of 30 years	Operating Hours in Extended Design Life of 40 years*	KAPCO Operating Hours COD to Mar-2021	Remaining Operating Hours In Extended Design Life of 40 years	Remaining Design life (Years)
GT-7	240,000	320,00	152,405	167595	21
GT-8	240,000	320,00	157,488	162512	20
STG-12	240,000	320,00	139,812	180188	23

Module-4 Units are expected to operate for minimum further 10 years without any major concern.

*CCGT Operating Life expectancy before retirement is 40 years (320,000 hours based on 8,000 operating hours/year) ref section 5.3.4 and 5.4 of this document.

6.4.2. Module-4 HRSG 12A and 12B

HRSG-11A, HRSG-11B, HRSG-12A and HRSG12-B are of the same model and make of Stein Industries. All four Heat Recovery steam generators have operated satisfactorily since their commissioning in 1995.

Life assessment of HRSG-11A and B has been conducted in Nov 2020 on a sample basis among all four HRSGs of Module-3 and 4. No major deterioration was reported with remaining life of all major components greater than 20 years. The same condition about life assessment is predicted for the other two HRSGs HRSG-12A and 12B having almost same service life and operating conditions.

HRSG-12B inspections relating to life assessment were also conducted by the company, Inspectest, in 2013 which shown similar results.

Also, HRSG-12A and 12B mandatory inspections are carried out in every schedule outage of GT-7 and GT-8 by the Boiler Engineer, Mechanical Engineer and Plant Chemist.

The last inspection was performed in October 2020 and both HRSGs condition were found to be satisfactory.

Based on life assessment reports and routine maintenance inspections; we expect that with the current operating regime, ***HRSG-12A and 12B may be operated reliably for the next 12-15 years.***

6.4.3. Module-4 Unit's Generators

6.4.3.1. GT-7 Unit Generator

Condition monitoring test of the Generator stator winding was carried out during the MOH of Feb-2015 by OEM (Alstom).

The following visual inspections and tests were performed for the stator;

- Visual Inspection for cleanliness and healthiness check of Overhang supports, Phase rings and leads, Generator terminals, Overhang insulation, Corona protection, Coil end-insulation / Insulating caps and stator core
- Boroscopic inspection of stator bars (4 NDE rings, 4 DE rings, 4 middle rings)
- Continuity and insulation resistance check of stator temperature probes
- Stator bar - core Alpha Coefficient measurement
- ELCID
- Slot wedging test
- Winding resistance measurement

And for rotor;

- Visual Inspection of rotor after removing rotor retaining ring
- Insulation resistance measurement
- Winding resistance measurement
- RSO measurement

On the basis of tests, conductive paint activity on the stator winding was carried out during the outage in Feb-2017.

Generatortech flux probe was also installed to monitor Generator rotor healthiness during the outage in Sep 2015. Recent tests conducted in Jan 2021 and data collected from the Generatortech flux probe were analysed. The quality of the flux probe waveforms were observed to be excellent. Analysis of the complete dataset shows the previously detected turn short in Coil 1B has remained clear. The turn short in Coil 7B (first detected in December 2018) continues to be seen in the current test. When active, Coil 7B turn short would not be creating a measurable increase in rotor vibration and will not increase heating significantly.

Installation of PD sensors were completed in March 2019 during the outage. PD Data collected for Jan 2021 has been analysed and summarized with the conclusion "Stable (slight decrease) winding PD and low level". Hence PD test results show condition of Generator Stator **Good**.

The Generator rotor flux report and the PD test Jan 2021 indicate that there is no significant fault on the Generator Rotor and Stator and it can continue its normal operation and, hence Generator overall condition is **Satisfactory**.

Additionally, Full Stator Rewind (FSR) material is available onsite as strategic spare for GT-5, 6 and 7 to perform FSR as and when required.

We envisage that Unit-7 Generator can be operated for the next 10 years based on current operating data and strategic spares availability in KAPCO stores.

6.4.3.2. **GT-8 Unit Generator**

On the basis of conditioning monitoring tests, Full stator rewind (FSR) of the Generator was carried out in Oct / Nov-2015.

Generatortech flux probe was also installed to monitor the Generator rotor healthiness during the outage in October 2017.

Recent tests conducted in Jan 2021 and data collected from the Generatortech flux probe were analysed. The quality of the flux probe waveforms were observed to be excellent. Analysis of the

complete dataset shows that the previously detected turn short in Coil 7A turn short has remained clear and the Coil 6B short was constant in all loads that could have seen a turn short in the #6 coils. The highest recorded loads did not show the Coil 6B turn short, but they would not be expected to see a turn short in the #6 coils. When active, Coil 6B turn short would not be creating a measurable increase in rotor vibration and will not increase heating significantly.

Installation of PD sensors were completed in March 2019 during the outage. PD Data collected for Jan 2021 has been analysed and summarized with conclusion "Fluctuations in winding PD and Negligible level, normal voids". Hence PD test results show condition of Generator Stator **Good**.

Generator rotor flux report and PD test Jan 2021 indicates that there is no fault on Generator Rotor and Stator and, hence Generator overall condition is **Good**.

We expect that the newly rewound GT-8 Generator may be kept in operation reliably for next 20-25 years without any major concern.

6.4.3.3. **STG-12 Unit Generator**

On the basis of conditioning monitoring tests, Full stator rewind (FSR) of the Generator was carried out in Oct / Nov-2015.

Generatortech flux probe was also installed to monitor the Generator rotor healthiness during the outage in October 2017.

Recent tests conducted in Jan 2021 and data collected from the Generatortech flux probe have been analysed. The quality of the flux probe waveforms were observed to be excellent. "Analysis of the complete dataset shows the previously detected turn short in Coil 6A is still in effect. When active, Coil 6A turn short would not be creating a measurable increase in rotor vibration and will not increase heating significantly."

Installation of PD sensors was completed in March 2019 during the outage. PD Data collected for Jan 2021 has been analysed and summarized with conclusion "Stable winding PD and Low level. Voids in ground-wall insulation." Hence PD test results show condition of Generator Stator **Good**.

The Generator rotor flux report and PD test Jan 2021 indicates that there is no fault on the Generator Rotor and Stator and, hence, the Generator overall condition is **Good**.

We expect that the newly rewound STG-12 Generator may be kept in operation reliably for next 20-25 years without any major concern.

6.4.3.4. **Summary for Remaining life of Module-4 Generators**

Below is the summary for Remaining life of Module-4 Unit Generators in view of condition monitoring described in preceding paragraphs;

Table 6.18: Remaining life of Module-4 Generators

Units	COD	Make	Overall Condition Rating	Overall Generator Condition	Expected Remaining life (Years)
GT-7	19-01-1989	Alsthom	8	Satisfactory	10
GT-8	24-01-1989	Alsthom	9	Good	20*
STG-12	05-04-1995	Alsthom	9	Good	20*

*GT-8 and STG-12 Generator has undergone Full stator rewind (FSR) in 2015.

Condition Rating Criteria 1-10:

Rating 9-10 = Good; Rating 7-8 = Satisfactory; Rating 4-6 = Acceptable; Rating 1-3 = Unacceptable

6.4.4. Module-4 Unit's Step-Up Transformer 7, 8 and 12

6.4.4.1. GT-7 Unit Transformer 7BAT01 Condition Monitoring

Transformer Oil analysis tests were performed in May 2020 by LABORELEC Belgium (Appendix-2 Unit-7 TF 7BAT01 Oil Analysis Report). Following is the conclusion from the oil analysis;

"The evolution of the dissolved gases can be considered as normal. There is no indication of thermal or electrical faults in the transformer.

The water content and relative saturation of the oil can be considered as normal. The properties that were investigated can be considered as normal.

The analysed winding paper ageing markers (furans, methanol) indicate beginning of paper ageing and the quality of winding paper can be assessed as still good (DP-value >600).

The next sample according to normal frequency. **No other action needed.**"

All operating parameters of transformer e.g. Oil temperature, winding temperature are in normal range.

Thus, the overall condition of Unit-7 Step-Up transformer is **Satisfactory**; that is code-1 for healthy equipment operating normally.

6.4.4.2. GT-8 Unit Transformer 8BAT01 Condition Monitoring

Transformer Oil analysis tests were performed in May 2020 by M/S LABORELEC Belgium (Appendix-2 Unit-8 TF 8BAT01 Oil Analysis Report). Following is the conclusion from the oil analysis;

"The evolution of the dissolved gases can be considered as normal. There is no indication of thermal or electrical faults in the transformer. The properties that were investigated can be considered as normal.

The analysed winding paper ageing markers (furans, methanol) indicate no significant paper ageing and thus quality of winding paper can be assessed as very good (DP-value >800).

The next sample according to normal frequency. No other action needed."

All operating parameters of transformer e.g. Oil temperature, winding temperature are in normal range.

Thus, the overall condition of Unit-8 Step-Up transformer is **Satisfactory**; that is code-1 for healthy equipment operating normally.

6.4.4.3. STG-12 Unit Transformer 11CGEV001TR Condition Monitoring

Transformer Oil analysis tests were performed in May 2020 by M/S LABORELEC Belgium (Appendix-2 Unit-12 TF 12CGE V001TF Oil Analysis Report). Following is the conclusion from the oil analysis;

"The evolution of the dissolved gases can be considered as relatively stable and acceptable. This gas pattern indicates low temperature overheating (high load, insufficient cooling, ...) or stray gassing of the insulating oil. The water content and relative saturation of the oil can be considered as normal. The properties that were investigated can be considered as normal. The analysed winding paper ageing markers (furans, methanol) do not indicate any paper ageing and thus quality of winding paper can be assessed as very good (DP-value >800). The next sample according to normal frequency. No other action needed".

All operating parameters of transformer e.g. Oil temperature, winding temperature are in normal range.

Thus, the overall condition of Unit-12 Step Up transformer is **Satisfactory**; that is code-1 for healthy equipment operating normally.

6.4.4.4. Summary Module-4 Unit's Transformer Condition Monitoring

Depending upon above assessments and the recent tests conducted for condition monitoring of unit step-up transformers of Module-4 described in preceding section, healthiness is confirmed as per below summary table;

Table 6. 19: Overall Condition Assessment of Module-4 Unit Transformers

Unit	Unit Transformer	Overall Condition code	Overall Condition Status
GT-7	7BAT01	1	**Satisfactory**
GT-8	8BAT01	1	**Satisfactory**
STG-12	12CGEV001TR	1	**Satisfactory**

Condition Code 1: Healthy Equipment Operating Normally
Condition Code 2: Early indication of operational fault. Frequency of test is increased (usually 6 months depending on the indicated problem) until either the condition worsens or until we are satisfied that the condition is not active and we would then push the testing interval out) No abnormality of Gas, Oil and Paper condition

6.4.5. Control System of Module-4 Units

6.4.5.1. GT-7 and 8 Control System

The control system installed on GT-7 and 8 is GE Speedtronic Mark IV which is old yet operating satisfactorily. This Control system can be further operated reliably for the next 12 to 15 years with the availability of control system spares in KAPCO stores and spares obtained from control system replacement of GT-5 and 6.

6.4.5.2. STG-12 Control System

The control system at STG-12 is ALSTOM ALSPA Controsteam V3 which was upgraded in 2011. The system is currently in production with a newer version. Spare parts have been maintained and support is available.

6.4.5.3. STG-12 Aux, HRSG-12A and 12B, and BOP Control System

The system supplied by ALSTOM (GE) is old but has operated satisfactorily since commissioning of the units. This Control system can be further operated reliably for next 12 to 15 years with the availability of control system spares in KAPCO stores. As an optimized strategy, spare parts removed from STG-11 control system replacement will also be used on STG-12.

6.4.5.4. Summary of Module-4 Units Control System

Below is the summary of remaining life of Module-4 Unit's Control system;

Table 6. 20: Remaining life of Module-4 Unit's control systems

Control System Module-4 GT-7, GT-8 & STG-12		
Unit	Control System	Expected Remaining Life (Years)
GT 7 & 8	GE Speedtronic Mark IV	10*
STG-12	Alstom ALSPA Controsteam V3	11
STG-12 Aux, HRSG-12A & 12B, & BOP	Alstom T20 Micro Z	10**

*GT-7-8 control system may operate for next 10 years with availability of spares in KAPCO Stores and additional spares obtained from Control System replacement of GT-5-6
**STG-12 control system may operate for next 10 years with availability of spares in KAPCO Stores and additional spares obtained from Control System replacement of STG-11.

6.4.6. Cooling Tower System for STG-12 of Module-4

Cooling Tower structure visual inspections were performed and Concrete Corrosion was reported at different locations. Civil structure water proofing and repairs have been performed.

Tam Seal 10-F was applied which waterproofs and provides in-depth concrete protection. After applying the TAM sealing the cooling tower structure is observed "**Good**".

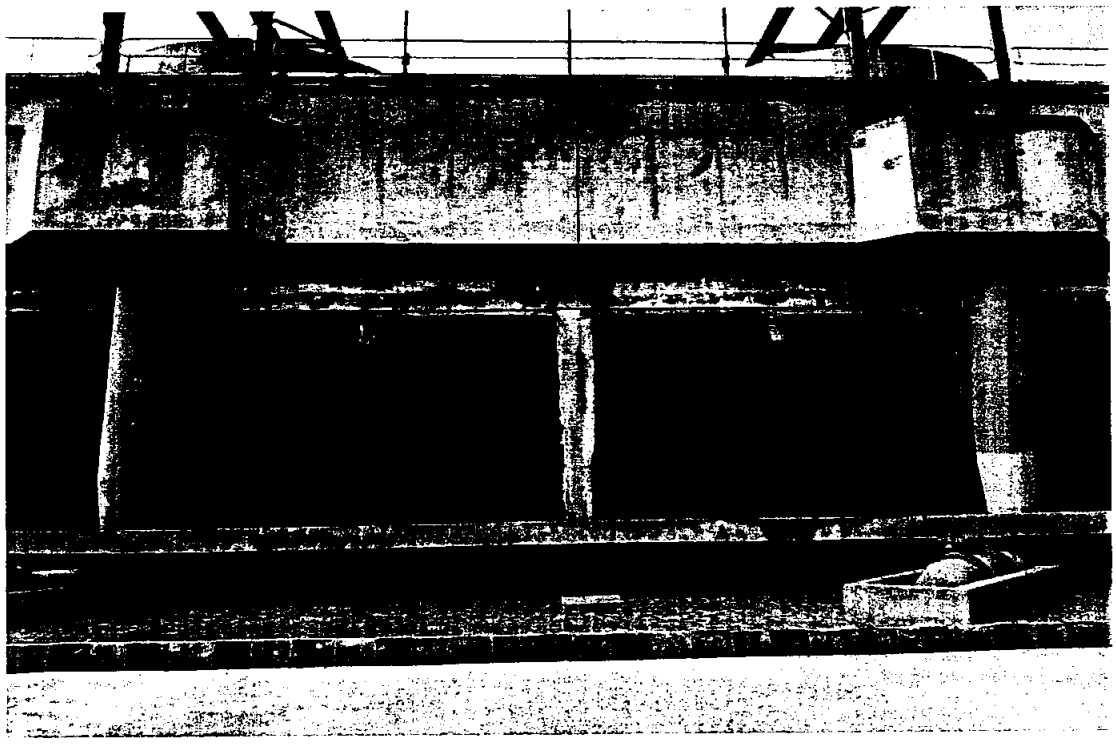


Figure 6. 3: Cooling Tower of STG-12

Cooling Tower fan, PMs (Preventive maintenance) are performed as per manufacturer recommended intervals. PMs records are available in the computer aided maintenance management system (Q4-CAMM). Mandatory spare parts inventory is maintained e.g. 1 refurbished gearbox for the cooling tower fan is available as spare.

Moreover, considering further 10 years operation beyond 2021, cooling tower fan blades and fill material may be needed to be replaced, if inspections decide this.

CW Piping inspection is carried out by KAPCO team during scheduled outages and piping condition is reported to be satisfactory.

Cooling Tower Fans and CW Pumps were inspected during the last schedule outage in Feb-March 2021 and no abnormality was reported.

As per above inspections and current condition monitoring it is envisaged that the Cooling Tower System can be operated reliably for the next 12 years.

6.5. Module-5 Plant Components' Residual Life Assessment

6.5.1. Gas Turbine Unit 13, 14 and Steam Turbine Unit-15

Gas Turbine GT-13 and GT-14: Hot gas path components e.g. Turbine blades/vanes, Combustion chamber bricks, nozzles, etc. are being replaced periodically on MOH and CI as per recommended EOH intervals by the OEM (Siemens). One complete set of turbine blades and vanes is always available in KAPCO stores as a strategic spare.

GT-13 and 14 Si3D blades up-gradation was performed in the Outage Sep 2011 for the 1st two stages of the turbine (keeping last 2 stages the same). Installation of Siemens (innovative 3-dimensional) Si3D blades with new Nickel based material, improved cooling air path and optimized aerodynamic aerofoil design improved the Units' performance.

Last Major Overhauling (MOH) was conducted in Sep-October 2019. Turbine blades/vanes were replaced as per recommended EOH.

GT-13 and 14 compressor vanes were replaced with new ones in 2010 and 2013 respectively.

The compressor blades have been in service since commissioning. During visual inspections and NDTs performed in the MOH 2019, no findings were reported and the condition of the compressor blades was found to be satisfactory. In the event some findings appear in the next MOH, the compressor blades are recommended to be replaced.

Air Intake filters are to be replaced in 2021.

Following NDTs were performed in the MOH 2019 for condition assessment of Gas Turbine parts after dismantling;

- Ultrasonic Testing
- Magnetic Particle Test
- Dye Penetrant Test
- Hardness Test

The scope of the visual inspection and extended NDTs for LTE included;

- Ultrasonic Testing of Compressor bearing, Turbine bearing, Gas Burner, Mixing Chamber Casing, Inner casing, Compressor Discs, Turbine Discs, Tie Rod, Intermediate shaft, Front, centre and rear hollow shaft, Burner carrier, Premix Burner, Combustion chamber shell, dome, Fuel Oil piping, cooling air-line, Blow off air-line, Fuel Gas piping etc.
- Magnetic Particle Test of Compressor vane carrier, Compressor vanes, Compressor blades, Combustion chamber shell, Compressor and Turbine wheel discs, Intermediate shaft, Front, centre and rear hollow shaft, Tie-rod, Compressor and Turbine vane carriers, etc.
- Dye Penetrant Test was performed for Compressor and Turbine bearing, Burner Gas Distributor, Mixing chamber of combustion chambers, Inner Casing, Tie-rod, Exhaust casing liner, Turbine exhaust diffuser, Fuel Oil piping, cooling airline, Blow off airline, Fuel Gas piping etc.
- Hardness Test for Centre Casing and Front Hollow shaft

The overall NDT results were categorized as acceptable except for a few minor observations which were addressed in the MOH 2019 activities e.g. indications on Mixing casing and Exhaust casing liner which were ground out and rewelding work performed as corrective measure etc.

The overall condition of both units Gas Turbine-13 and 14 observed "**Good**" during visual inspections and NDTs performed in last MOH Sep-Oct 2019 and recent schedule outages.

Steam Turbine STG-15 last major overhauling was performed from Feb to April 2010. During the MOH visual inspections and NDTs, Turbine HP/LP rotor and casings were found in good condition except for a few minor indications which were attended as a part of the MOH activities.

Afterwards, Minor Overhauling inspection has been performed in Oct 2016.

Following NDE techniques were applied by the Siemens' NDE Specialist;

- Ultrasonic Testing
- Dye Penetrant Test

Scope of visual inspection and NDEs included;

- Ultrasonic Testing of turbine bearings, bearing pads, and turbine foundation bolts
- Dye Penetrant Test of turbine bearings, bearing pads, Steam Turbine Emergency Stop Valve, Control Valve, HP Bypass valve, turbine casing drain valves etc.

Overall NDT results were categorized as acceptable except for a few minor observations on the HP Bypass control valve spindle but it was categorized as useable. Also, the Steam turbine casing drain valve cone was replaced as per Dye Penetrant Test indication.

Boroscopy inspection of the HP and LP steam turbine Last Stages and Cross over pipe were performed by Siemens' Engineers. During the Boroscopy inspections no abnormality was observed.

The overall condition of Steam Turbine Unit-15 and condenser is reported as **"Good"** in visual inspections and NDTs performed during the outages in 2010 to 2016.

STG-15 HP Steam stop and control valve actuators were overhauled during the GT-13 and 14 MOH in 2019.

Following is the expected Remaining Life Assessment summary of Module-5 Units as per the Units' condition assessment and operating regime;

Table 6.21: Remaining Life of Module-5 Units

Unit #	Operating Hours in Design Life of 30 years	Operating Hours in Extended Design Life of 40 years*	KAPCO Operating Hours COD to Mar-2021	Remaining Operating Hours In Extended Design Life of 40 years	Remaining Design life (Years)
GT-13	240,000	320,00	176,245	143755	18
GT-14	240,000	320,00	170,947	149053	19
STG-15	240,000	320,00	179,741	140259	18

Module-5 Units are expected to operate for minimum further 10 years without any major concern.

*CCGT Operating Life expectancy before retirement is 40 years (320,000 hours based on 8,000 operating hours/year) ref section 5.3.4 and 5.4 of this document.

6.5.2. Module-5 HRSG 13 and 14

HRSG-13 and 14 complete inspection and remaining life assessment was carried out from Sep-Oct 2019 by SGS, Pakistan (Appendix-1: Remaining Life Assessment HRSG-13 and 14).

During inspections relating to life assessment for HRSG-13 and 14 no significant deterioration was reported except a few recommendations of improvement which have been addressed e.g.

Recommendation for HRSG-13 Sulphur deposition should be cleaned/washed out from tube fins to optimize efficiency, HRSG-13 and 14 are washed keeping in view the increased stack temperature, which indicates washing is required, as per recommendation. Observed cracks in the cyclone drum (LP Drum) were welded for both HRSG-13 and 14 and recommended to keep monitoring in every following outage.

Scope of work for complete inspection and remaining life assessment of HRSG-13 and 14 included the following inspections and NDTs;

- Visual inspection of HP and LP drums, tubes, headers, for localized and uniform corrosion, deposits, erosion, pitting etc.
- Visual inspection of economizer regarding fins condition
- Visual inspection of protective coating/insulation for damages
- Visual inspection regarding internal corrosion and pitting including evaluation of pitting /
- corrosion for fitness
- Visual inspection of all structural steel parts including ducts, platforms, handrails and structural steel supports for ducts/piping for any visual defects.
- Visual inspection of tube bends and headers
- Visual inspection and DPT of steam header pipe welds for cracks
- Visual inspection of all accessible weld joints of HP Drum/LP separator, like shell, heads and nozzles.
- Hardness testing of HP drum, LP drum tubes and headers, 28 location from tubes, 2 from each header, 4 locations from inside the drums.
- Ultrasonic flaw detection of suspected weld joints of HP drum, LP drum.
- MPI/DPT of selected weld joints
- Metallographic testing of boiler pressure parts like 3 from each drum, one from each header to study the metallurgical changes, degradation and evaluation for its fitness for service.
- Ultrasonic thickness gauging of HP drum, headers, tubes, soot blowers, as per ASME codes to find out overall view of current metal condition for fitness.

No major anomalies were observed in the microstructure of pressure parts observed through Reflected Light Microscopy.

Remaining Life of HRSG-13 and 14 was calculated for the available data, comparing each component's thickness at installation and the current thickness gauging in 2019, then using the remaining corrosion allowance to assess remaining life. Major components' life was calculated greater than 30 years for HRSG-13 and 20 years for HRSG-14.

On the basis of above inspections, it was concluded that HRSG 13 and 14 is in **satisfactory** condition as tube modules, HP and LP drums and Header NDT inspection resulted in no major deficiency.

Also, HRSG-13 and 14 mandatory inspections are also carried out in scheduled outages of GT-13 and GT-14 by the Boiler Engineer, Mechanical Engineer and Plant Chemist.

Both HRSGs condition was found satisfactory during an inspection performed in Feb 2021.

Based on the life assessment report which revealed no significant deterioration and routine maintenance inspections; we expect that with the current operating regime, ***HRSG-13 and 14 may be operated reliably for the next 10-15 years.***

6.5.3. Module-5 Units' Generators

Following are the technical Specifications for Module-5 Units' Generators;

Table 6.22: Technical Specifications of Module-5 Units' Generators

Technical Specifications	GT-13-14	STG-15
Type	TLRI 108/36	TLRI 108/41
Rated Power Capacity	170 MVA	175 MVA
Rated Voltage (L-L)	11 KV ±10%	11 KV ±10%
Phases	3Ø; YY.	3Ø; YY.
Rated Output Current	8923A	9185A
Speed	3000Rpm	3000Rpm
Frequency	50HZ	50HZ
Power Factor	0.85	0.85
Gen Cooling System	Air Cooled	Air Cooled
Cold air temp	40°C	40°C
Make	Siemens Germany	Siemens Germany

6.5.3.1. GT-13 and GT-14 Unit Generators

Condition monitoring tests of GT-13 and 14 Generators were carried out during the Minor Overhauling in Sep-Oct 2019 in the presence of the OEM's Inspection Engineers (Siemens).

Following Visual inspections and tests were performed for the stator;

- Visual Inspection for cleanliness and healthiness check of stator, TE and EE end windings, cooler enclosure etc.
- Insulation resistance test
- Winding resistance measurement

and for rotor;

- Boroscopic Inspection of rotor
- Insulation resistance measurement
- Winding resistance measurement

All stator and rotor test results are reported satisfactory except for a few minor observations of cleanliness which has been attended. A visual inspection of the Generator cooler and cooler enclosure was performed, no sign of water leakage was noticed in the cooler, piping, water boxes and flanges. Checking of the J-strips, slip rings, grounding system was performed and found normal.

Routine offload, on load, test results are showing healthy condition for both Generators. Overall condition of Generators is considered "**Good**".

Based on the MOH test results, routine condition monitoring tests and operating conditions, ***we envisage that Unit-13 and 14 Generators can be operated reliably for the next 10-12 years.***

6.5.3.2. **STG-15 Unit Generator**

Medium overhauling of STG-15 Generator was carried out in Sep-Oct 2019. Condition monitoring tests of the Generator and visual/NDT inspections were carried out in the presence of the OEM's Engineers (Siemens).

NDT (PT) of rotor fan blades (TE & EE) was done by Siemens' Inspection Engineers and no finding was observed.

Checking was carried out for J-strips, slip rings, grounding system, generator cooling circuit and coolers etc which were found to be normal.

The following electrical tests of the Generator Stator / Rotor were carried out.

- Insulation resistance of stator.
- Loop resistance of stator.
- Insulation resistance of rotor.
- Loop resistance of rotor.

All test results are observed satisfactory with no findings reported. Routine offload, on load, test results are showing its healthy condition. Overall condition of the Generator is considered "**Good**".

Based on MOH test results, routine condition monitoring tests and operating conditions, **we envisage that Unit-15 Generator can be operated reliably for next 12-15 years.**

6.5.3.3. **Summary for Remaining life of Module-5 Generators**

Below is the summary for remaining life of Module-5 Unit Generators in view of condition monitoring described in preceding paragraphs and operating conditions;

Table 6.23: Remaining life of Module-5 Generators

Units	COD	Make	Overall Condition Rating	Overall Generator Condition	Expected Remaining life (Years)
GT-13	10-12-1994	Siemens	9	Good	10-12
GT-14	19-10-1994	Siemens	9	Good	10-12
STG-15	09-10-1996	Siemens	9	Good	12-15
Condition Rating Criteria 1-10: Rating 9-10 = Good; Rating 7-8 = Satisfactory; Rating 4-6 = Acceptable; Rating 1-3 = Unacceptable					

6.5.4. Module-5 Unit's Step-Up Transformer 13, 14 and 15

Following are the technical Specifications for Module-5 Units' Transformers

Table 6.24: technical specifications of Module-5 Transformers

Technical Specifications	GT-13-14	STG-15
Make	TRAFO UNION	TRAFO UNION
Rated Power (MVA)	168	190
Rated Voltage KV (LV/HV)	11 / 258	11 / 258
Rated Frequency (HZ)	50	50
No of Phases	3	3
Rated Current (A) LV/HV)	8819/422	8083/661
Type of Cooling	ONAN/ONAF	ONAN/ ONAF
Temp. Rise Winding/Oil	55/50 °C	55/50 °C

6.5.4.1. GT-13 and 14 and STG-15 Unit Transformers 13BAT01, 14BAT01 and 15BAT01 Condition Monitoring

During the Outage in Sep-Oct 2019, for all 03 Unit Transformers 13BAT01, 14BAT01 and 15BAT01, the following Electrical tests were executed by 3rd party Avotech Engg Services.

a) Insulation Resistance,

b) Turn Ratio,

c) Excitation Current,

d) SFRA and

e) Magnetic Balance.

f) Short Circuit Impedance

g) Winding Resistance Tests

h) Oil Tests carried out: DGA , Oil Break down Voltage test, Moisture test, Oil Acidity, Interfacial Tension, Corrosive sulphur, Furan Analysis test.

The test results reported no abnormality on any of three Unit transformers.

Transformer Oil analysis tests has been performed in May 2020 by LABORELEC Belgium (Appendix-2 Unit-13 TF 13BAT01, Unit-14 TF 14BAT01 and Unit-15 TF 15BAT01 Oil Analysis Report).

Following is the conclusion from oil analysis report for all three Transformers; "The evolution of the dissolved gases can be considered as normal. There is no indication of thermal or electrical faults in the transformer. The water content and relative saturation of the oil can be considered as normal."

All operating parameters of transformers e.g. Oil temperature, winding temperature are in normal range.

Thus, the overall condition of Unit-13, Unit-14 and Unit-15 Step-Up transformers is "**Good**"; and designated code-1 is for healthy equipment operating normally.

6.5.4.2. **Summary of Module-5 Unit Transformers Condition Monitoring**

Depending upon above assessments and the recent tests conducted for condition monitoring of unit step up transformers of Module-5 described in preceding section, healthiness is confirmed as per below summary table;

Table 6.25: Overall Condition Assessment of Module-5 Unit Transformers

Unit	Unit Transformer	Overall Condition code	Overall Condition Status
GT-13	13BAT01	1	**Good**
GT-14	14BAT01	1	**Good**
STG-15	15BAT01	1	**Good**
Condition Code 1: Healthy Equipment Operating Normally **Condition Code 2:** Early indication of operational fault. Frequency of test is increased (usually 6 months depending on the indicated problem) until either the condition worsens or until we are satisfied that the condition is not active and we would then push the testing interval out) No abnormality of Gas, Oil and Paper condition			

6.5.5. Control System of Module-5 Units

6.5.5.1. **GT-13 and 14 Control System**

The GT-13 and 14 old Siemens TELEPERM ME Control system, operating since commissioning, was replaced with a state-of-the-art Siemens SPPA T3000 system in March 2021, which has enhanced the system integrity. Thus, the newly installed control system can be **expected to operate reliably for the next 20 years.**

6.5.5.2. **STG-15 Control System**

The STG-15 old control system was replaced with a state-of-the-art new control system (Siemens SPPA T3000) in Feb 2015. **Its remaining life is expected to be about 15 years.**

6.5.5.3. **STG-15 Aux, HRSG13 and 14, and BOP Control System**

The old Siemens TELEPERM ME Control system, operating since commissioning, was replaced with a state-of-the-art Siemens SPPA T3000 in March 2021, which has enhanced the system integrity. Thus, the newly installed control system can be **expected to operate reliably for the next 20 years.**

6.5.5.4. **Summary of Module-5 Units Control System**

Below is the summary of remaining life of Module-5 unit's control system;

Table 6.26: Remaining life of Module-5 unit's control systems

Control System Module-5 GT-13, GT-14 & STG-15 Remaining Life

Unit	Control System	Expected Remaining Life (Years)
GT 13 & 14	Siemens SPPA T3000	20
STG-15	Siemens SPPA T3000	15
STG-15 Aux, HRSG-12A & B, & BOP	Siemens SPPA T3000	20

6.5.6. Cooling Tower System for STG-15 of Module-5

Cooling Tower structure visual inspections were performed during the last scheduled outages. Concrete Corrosion was observed at different locations. Civil structure water proofing and repairs were performed.

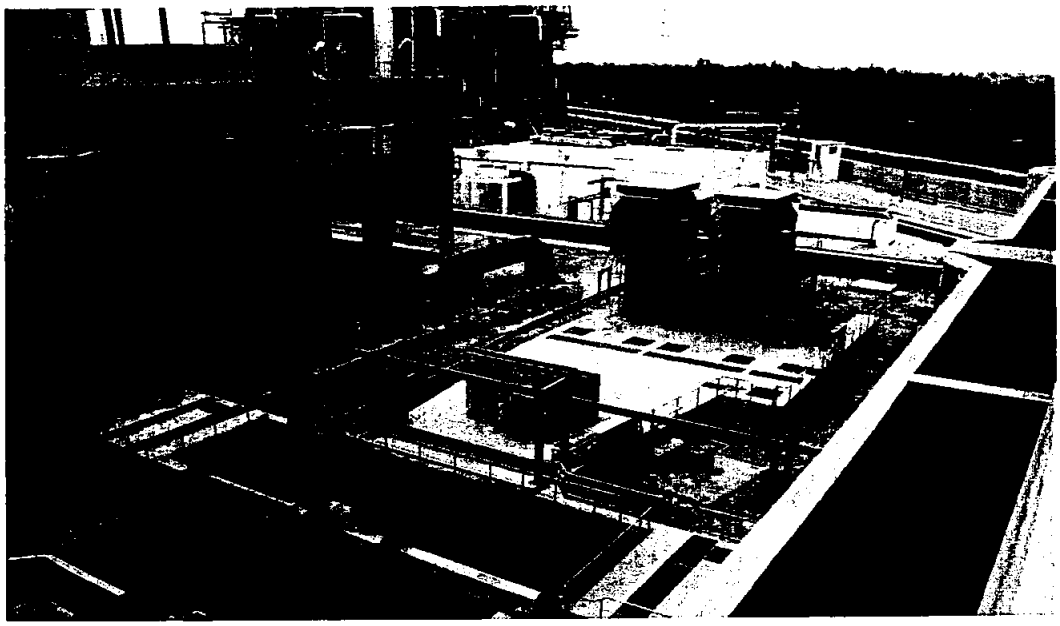


Figure 6. 4: Cooling Tower System STG-15

Tam Seal was applied which waterproofs and provides in-depth concrete protection. After applying the TAM sealing cooling tower structure is observed **good**.

Inspection of the CW Supply and return lines revealed that the internal coating is in **satisfactory** condition.

Epoxy coating of both CW Pumps Bell housing, impellers, Start-up filling pump has been carried out and overall condition **good** is observed.

Epoxy Paint coating is carried out on cooling Tower Risers, Headers and Piping and thus **good** condition is maintained;

Figure 6. 5: Circulating Water (CW) Pumps STG-15 for Cooling Tower

Cooling Tower fan, PMs (Preventive maintenance) are performed as per manufacturer recommended intervals. PMs records are available in the computer aided maintenance management system (Q4-CAMM). Mandatory spare parts inventory is maintained e.g. 2 refurbished gearboxes for the cooling tower fans are available as strategic spare (See Appendix-6 Strategic Spares List-Block-3).

As per above inspections and detailed condition monitoring, it is envisaged that the Cooling Tower System can be operated reliably for next 12 years.

6.5.7. Water treatment plant Block-3 Module-5

Water Treatment plant routine preventive maintenance is conducted on schedule and, therefore, is maintained in healthy conditions. The water treatment plant and auxiliaries are reported to be operating without any trouble. As per current excellent maintenance techniques applied and good operating conditions, **it is envisaged that the Water Treatment Plant can be operated reliably for the next 12-15 years.**

6.6. Buildings and Civil Structure Integrity Assessment

Civil structure integrity life assessment has been conducted by company, Inspect Test, (See Appendix-3 Building and Civil Structure Integrity Assessment).

Following buildings and structures were covered in above work scope;

- Administration Building
- Gas Turbine Buildings 1-2, 3-4, 5-6, 7-8, 13-14
- Steam Turbine Buildings 9-10,11-12, and 15
- Cooling Tower unit 9, 10, 11, 12 and 15
- Clarifier 9-10,11-12 and 15
- Water Treatment Building B-I, B-II and B-III

- Black Start Diesel Engine Building
- Central Control Room Building CCR-1, 2, 3

Scope of work included visual inspections and NDTs as outlined below;

- Visual inspections of all buildings and civil structure for corrosion,
- Identification of points of main load bearing areas of civil structure
- Identification cracks in the main structure
- Complete structure analysis of all damaged areas
- Concrete compressive strength measurement by Rebound Hammer / Compressive Strength Test.
- Crack Depth Measurement by Ultrasonic Pulse Velocity Test and ultrasonic method.

The following observations and recommendations were made;

- Number of horizontal, vertical and critical shear cracks were found which are to be repaired as per recommended procedure.
- All Damaged, rusted and Exposed Steel rebar to be repaired by the recommended procedure.
- Cooling tower and clarifier buildings should be repaired as rusted steel rebar were found and it is recommended that these buildings should be properly coated for water proofing and inspected periodically.
- Water Treatment / Pre-Treatment / Demin Plants were found in impaired condition. It is recommended that these buildings must apply acid resistance flooring with Epoxy Novolac which is ideal for harsh chemical and solvent resistant applications.
- Control of Water Treatment / Pre-Treatment / Demin Plants buildings impairment by avoiding leakage and accumulation of chemicals.
- Water seepage should be controlled as it may weaken the structure over time, by rusting the steel rebar. This can be done by applying a water-proof coating.
- It was advised that all repairs should be performed by recommended procedures.

Keeping in view above recommendations, civil structures and buildings have been repaired, or are in the process, as per suggested procedure. Overall Condition of civil structures and buildings is observed **Satisfactory**.

Power station buildings and structures are designed to have a minimum life of 50 years for general building design code compliance.

Keeping in view the current condition of buildings and structure we envisage remaining useful life 15-20 years with on-going checks and necessary repairs as and when needed.

7. OPERATIONS AND MAINTENANCE PRACTICES

7.1. Process Safety Management Systems

KAPCO Management has well established Local Procedures and Rules for Safety Management covering the below aspects;

1. KAPCO Safety Rules
2. Incidents Preparedness Reporting Response Investigation
3. Electrical Safety Procedure
4. Overhead Travelling cranes hoists and other lifting-devices
5. General Confined Spaces
6. Hot Work Procedure
7. Safety Documents Procedure
8. Health and Safety Hazards Identifications and-Risk Assessment
9. LV and MV Apparatus
10. Plant Emergency Shutdown
11. Working at height
12. Behaviour Based Safety Fresh-Eyes
13. High Voltage Apparatus
14. etc.

And for Chemical Control and Environment management the following Local Procedures are developed and are being followed;

1. Guidelines and rules for management of bulk chemicals
2. Air Emission control procedure
3. Effluent Water Control Procedure
4. Solid Waste Management Procedure
5. Environment Aspects Identification Procedure
6. etc.

7.2. Maintenance Management System

Operations and Maintenance activities are being planned, controlled and executed using Computerized Maintenance Management System Q4CAMM of Engica UK.

All Preventive Maintenance, Condition based Maintenance and Corrective Maintenance is managed through CMMS (Q4CAMM).

All Plant Equipment Preventive Maintenance work orders are raised as per set frequency i.e. Monthly, 3 Monthly, Yearly etc. according to OEM recommendations for the relevant section and are executed well in time in an effective and efficient manner.

The Work Orders are serially pre-numbered in the system and classified as under;

- **Fault Work Order**

Represents only those work orders relating to breakdown / failure of any equipment and/or system leading to loss of generation, efficiency, safety and/or adverse impact to the environment.

- **Ad-hoc Work Order**

Ad-hoc work order represents all those activities that relate to general services required, non-critical jobs and are not covered under Fault and PM work orders.

- **PM Work Order**

PM work orders are those that represent preventive maintenance activities only.

Operations Team initiates work order Fault or Adhoc in view of breakdown/failure of any equipment and improvement work required at the Plant. That work is planned and executed by the Maintenance Team in accordance to set Priority of work order to avoid Generation and Plant Performance Loss.

After completion of work, the Maintenance Team closes the work order recording.

- Effort (personnel) and Work Duration (hours) as man-hours
- Work undertaken in work done field

Some work orders are specialized e.g. SIMs, TILs, Risk Matrix and Plant Modifications as defined below;

Safety Information Memorandum (SIM) based work orders are raised to improve the conditions that caused the incidents.

Technical Information Letter (TIL) based work orders reflect a desired knowledge enhancement approach including safety and plant integrity as these relate to specialized information about the Units received from the OEM.

Risk Matrix is a periodic assessment of each section's equipment to determine criticality on the basis of being obsolete, health, life assessment, non-availability of spares and/or back-up, etc. In CAMM PMs are developed to initiate monthly Risk Matrices review.

Plant Modification means;

- A change in Reference Design datum, geometry, or materials; or
- Permanent change of setting, modes of operation, components in a control, interlock or protection system (which may include computer software); or
- The addition or permanent removal of components in a system or a complete system whereby a 'system' or 'component' includes plant, electrical apparatus, or load bearing structure or any combination of these.

All specialized Work Orders SIMs, TILs, Risk Matrix and Plant Modifications are raised by the Planning section. After completion of work all specialized Work Orders are closed by the Sectional head only.

7.3. Integrated Management System

Since July 2004, KAPCO has been compliant with the following accreditations to the Integrated Management System:

ISO 9001:2015 Quality Management System

ISO 14001:2015 Environmental Management System

OHSAS 18001:2007 Occupational Health and Safety Assessment Series (Occupational Health and Safety Management System)

7.4. Environment Management System

KAPCO has developed well established Policy Guidelines and Procedures for Environment Management system.

KAPCO is accredited and complying standard ISO 14001:2015 Environmental Management System.

Environment Performance Monitoring is being conducted on regular basis by EPA Certified Independent Consultant, in compliance with Pakistan Environment Protect Act (1997) and Punjab Environment Protection Agency standards.

Environment Monitoring at KAPCO Complex includes, monitoring of Air, Water and Noise Emissions generated from Operations of Gas Turbines, Steam Turbines, Boilers, Fuel Oil Treatment Plants etc.

Samples of Air emissions are taken at the stack of HRSGs and Boilers for checking NOX, SOx, and CO emissions in flue gases being disposed to the Environment.

Noise checking is conducted inside and outside the Plant boundary at different points.

Quality of waste-water being disposed is checked at the point of generation source and is controlled for disposal in compliance to Punjab EPA standards.

For Solid waste management collection and segregation is done for hazardous and non-hazardous waste. Hazardous waste stored in the Toxic/hazardous storage area is disposed off through

EPA approved contractor for final incineration.

Recent Report submitted to Punjab Environment Protection Agency (PEPA) as per statutory requirements is found in compliance, attached as Appendix-4 Environmental Compliance Report

All emissions relating to air, water and noise are well within limits set by Punjab Environment Quality Standards.

Ambient Air quality measured at 1.2 Km from Plant site is observed well within Air Quality Standard of PEPA.

In acknowledgement to accomplishment achieved for Environment protection, KAPCO has been awarded in 2020, Certificate of Appreciation from National Forum for Environment and Health.

7.5. Historic Major Modification Summary

Major Upgrades and Improvement Projects relating to Generation units, Environment and Health and Safety are documented as Appendix-5 Historic Major Modification Summary.

7.6. Spares Management

KAPCO has maintained adequate spares inventory for all generating units to ensure maximum Plant Availability and to reduce Unit down times.

Stock management is ensured through the Computerized Stock Management System Q4-Stock of Engica UK.

Each spare part is given a stock number, stock description, owning team, Re-Order Level and Re-Order quantity in the Computerized Stock Management System. When a spare part reaches Re-order level, the procurement process is initiated.

Above 30,000 spare parts are stored in the KAPCO Stores for the Gas Turbines, Steam Turbines and Auxiliaries relating to Mechanical, Instrument and Electrical Equipment.

List of Strategic spares is documented as Appendix-6 Strategic Spares List.

It is concluded that the large volume of spares inventory at KAPCO Complex is more than adequate for reliable operation of the KAPCO Plant to achieve maximum Plant Availability in coming years.

8. CONCLUSION AND RECOMMENDATIONS

The study has been conducted to assess the residual useful life of the KAPCO Plant main mechanical, civil, electrical and control equipment based on design criteria, current operating parameters, design and current performance, upgrades and major replacements, operation procedures and maintenance practices, major outage inspection reports, life assessment reports and condition monitoring test reports.

Each of the Module's 1-5 major equipment condition has been categorized as Good, Satisfactory or Acceptable.

Operating life before retirement of CCGTs has been observed 40-50 years around the World. This study has assumed a 40-year extended operating life based on a nominal 8,000 operating hours per year, which equates to lifetime operating hours of 320,000. The operating hours of the Units at KAPCO range between 94,000 to 180,000 indicating that the remaining life of the KAPCO units could be in the range 17 – 28 years, thus demonstrating that a life extension of 10 years being considered by KAPCO should be achievable with resulting good reliability and performance.

Significant inventory of strategic and mandatory spares has been maintained by KAPCO as per next 10 years operating plan which is of great sustenance in achieving the expected Remaining plant life.

Currently well-established policies and procedures are intact for Safety, Environment and Maintenance Management system along with implementation of Integrated management system which shall ensure safe and reliable operations of Plant for coming years as well.

Based on this qualitative and analytical study, module wise residual life assessment has been concluded as below;

a) **Module-1** (GT-1, GT-3 and STG-9) plant is in overall **Satisfactory** condition and expected Remaining life is assessed to be a minimum **10** years maintaining current best O&M practices and conducting mandatory upgrades, repairs/replacement as recommended time to time by OEM in major outages.

Plant load (MW), has been well maintained since IDC 1996. Average plant availability of last 5 years is above 85% which is excellent.

GT-1 Generator is in Good condition while GT-3 and STG-9 Generator condition is Satisfactory with expected Remaining life of 10 years.

The condition of Unit Transformers has been found to be 'Satisfactory to Acceptable'.

Cooling Tower and Water Treatment system is in satisfactory condition and can be operated reliably for next 10 years.

The following repairs/replacements/upgrades are recommended for Module-1 Units in the next MOH;

i. GT-1-3 replacement air intake filters when Differential pressure approaches upper limit
ii. STG-9 replacement of Row-1 blades
iii. HRSG-1-3 Insulation and Cladding to be replaced from deteriorated surfaces.

iv. Cooling Tower structure inspections and repair with Tam Seal at portions showing corrosion effect.

b) **Module-2** (GT-2, GT-4 and STG-10) plant is in overall **Satisfactory to Acceptable** condition and expected Remaining life is assessed to be a minimum **10** years maintaining current best O&M practices and conducting mandatory upgrades, repairs/replacement as recommended time to time by OEM in major outages.

Plant Load and other operating parameters are well maintained since IDC 1996. Average plant availability of last 5 years is above 86% which is excellent.

GT-2 and GT-4 Generator are in **Satisfactory** condition while STG-10 Generator condition is Good with expected Remaining life of 10-12 years.

The condition of Unit Transformers has been found to be **Satisfactory** for module-2 units.

The following repairs/replacements/upgrades are recommended for Module-2 Units in the next MOH;

i. GT-2 and GT-4 replace air intake filters when Differential pressure approaches upper limit

ii. STG 10 replacement of Cooling Tower Fill material.

c) **Module-3** (GT-5, GT-6 and STG-11) plant is in overall **Good** condition and expected Remaining life is assessed to be a minimum of **10** years maintaining current best O&M practices and conducting mandatory upgrades, repairs/replacements as recommended in major outages.

Plant load and other Performance indicators are well maintained since IDC. Hot Gas Path Up-gradation has been conducted to maintain ADC load. Average plant availability of last 5 years is 84%, which is good.

GT-5 and GT-6 Generators are in **Satisfactory** condition. STG-11 Generator is newly rewound and its overall condition is **Good**. Expected remaining life of the Generators is assessed to be above 10 years for GT-5 and 6 and around 20 years for STG-11.

The condition of Unit Transformers for all module-3 Units' is **Satisfactory**. GT-5 and GT-6 control systems have been replaced with new GE Mark VI.

Cooling Tower and Water Treatment systems are in **Satisfactory** condition and can be operated reliably for next 12 years with routine Preventive maintenance schedules.

The following repairs/replacements/upgrades are recommended for Module-3 Units in the next Major Outages;

i. HRSG 11 A-B Flue Gases Ducts renovation due to aging factor, availing each shutdown opportunity

ii. STG-11 replacement of cooling tower fan blades.

d) **Module-4** (GT-7, GT-8 and STG-12) plant is in overall **Satisfactory** to **Good** condition and expected Remaining life is assessed to be a minimum **10** years maintaining current best O&M practices.

Plant Load and other operating parameters are well maintained since IDC. Gas Turbines Hot Gas Path Up-gradation has been conducted to maintain ADC load. Average plant availability of last 5 years is around 85% which is excellent.

GT-7 Generator is in **Satisfactory** condition with expected remaining life of above 10 years. GT-8 and STG-12 Generators are newly rewound and their overall condition is **Good**. GT-8 and STG-12 expected remaining life is excess of 20 years.

The condition of Unit Transformers for all module-4 Units' is **Satisfactory**.

The following repairs/replacements/upgrades are recommended for Module-4 Units in the next Major Outages;

i. GT-7 recommendation by OEM to replace compressor aft brush seals and honey-comb seals in next major inspections for better performance.
ii. STG-12 replacement of cooling tower fan blades and fill material.

e) **Module-5** (GT-13, GT-14 and STG-15): This is the highest efficiency CCGT plant not only in KAPCO Complex but all over the Pakistan which can operate on 3 types of fuel e.g. LSFO, Natural Gas and HSD. Plant is in overall **Satisfactory to Good** condition and expected remaining design life is assessed to be a minimum **10** years maintaining current best O&M practices and conducting mandatory upgrades/repairs/replacement as recommended.

Plant has always demonstrated higher loading capacity than IDC due to excellent maintenance strategy. Gas Turbines have undergone turbine blades Si3d Up-gradation. Control system has been replaced recently with state-of-the-art Siemens SPPA-T3000. Average plant availability of last 5 years is 84%, which is good.

GT-13, 14 and STG-15 Generators and Unit Transformers overall condition is considered **Good** that is healthy equipment operating normally. Expected Remaining useful life is assessed 12-15 years.

Cooling Tower system and Water Treatment Plant is in **Satisfactory** condition and can be operated reliably for next 12 years with routine preventive and corrective maintenance

The following repairs/replacements/upgrades are recommended for Module-5 Units in the next Major Outages;

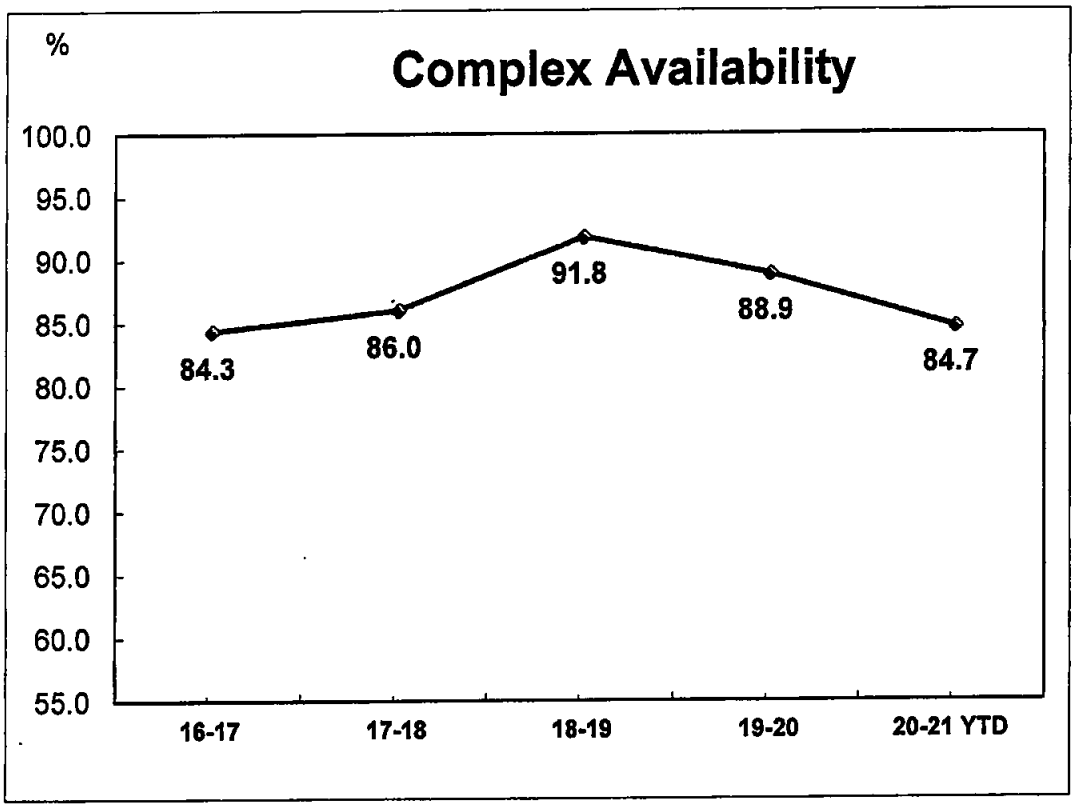
i. Replacement of compressor blades for GT-13 and 14 (No finding reported till date)

ii. GT-13-14 Corrosion Prevention Painting of filter house at external surface.
iii. Repair of concrete structure of Cooling Tower and Clarifiers of STG-15
iv. Renovation of Thermal Insulation of GT-13 and 14 and HRSG-13 and 14.

f) **All Civil buildings and structures** integrity assessment has been carried out which has indicated overall condition to be **Satisfactory**, except some minor cracks and concrete corrosion at various sections e.g. cooling tower concrete corrosion. Recommendations of this integrity assessment must be adhered for safe and reliable operation of plant.

ANNEXURE L

PLANT KPI GRAPHS


%
Complex Availability
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90.0
85.0
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75.0
70.0
65.0
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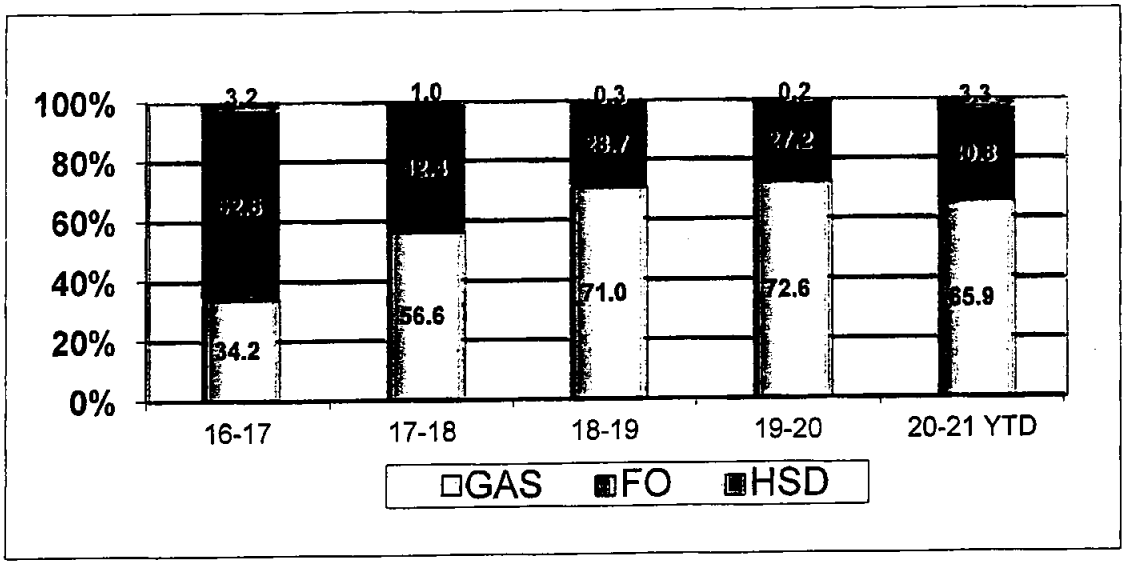
91.8
88.9
84.7
16-17
17-18
18-19
19-20
20-21 YTD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3.3
34.2
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16-17
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GAS
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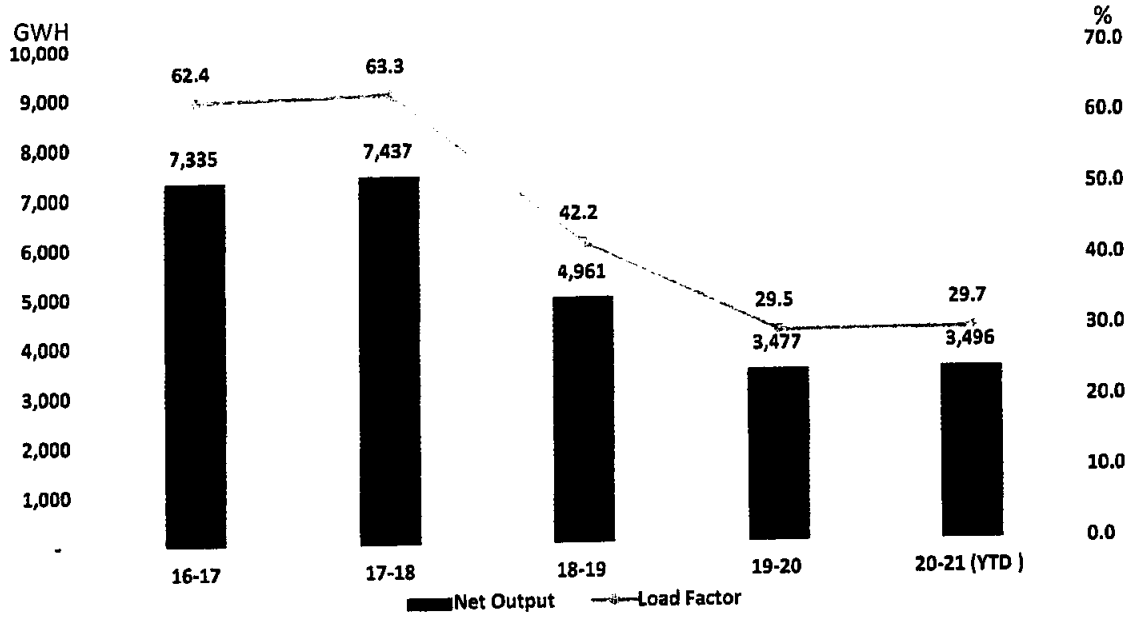
HSD


GWH
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-
%
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60.0
50.0
40.0
30.0
20.0
10.0
0.0
62.4
63.3
42.2
29.5
29.7
7,335
7,437
4,961
3,477
3,496
16-17
17-18
18-19
19-20
20-21 (YTD)
Net Output
Load Factor

ANNEXURE M

TECHNICAL LIMITS & UNIT START- UP TIMES

SCHEDULE 2

TECHNICAL LIMITS

1. Design Limits

1.1 Start-Ups

(a) The notice required by WAPDA to the Company to initiate start-up of a Unit and synchronize to the Grid System will vary according to the length of time the Unit has been shutdown. Tables 1A and 1B below show the length of notice (in minutes) required for various conditions of start-up for gas and steam Units. The steam turbine start times must be added to the start times of the gas turbines used to provide such turbines with steam.

For purposes of this Section 1.1, c/s shall mean "Cold Start", w/s shall mean "Warm Start", and h/s shall mean "Hot Start".

TABLE 1A
Start-Up Times for Gas Turbines

UNITS	1 — 2	3 — 4	5 — 8	13 — 14
Starting Time (minutes)	4	28	10	3.3

TABLE 1B
Start-Up Times for Steam Turbines

UNITS	9 — 10	11 — 12	15
Starting Time (minutes)	c/s — 140 w/s — 60 h/s — 15	c/s — 20 w/s — 20 h/s — 10	c/s — 42 w/s — 25 h/s — 15

The reference to starts, starting or started means the process of firing the boiler, running up the turbine generator and synchronizing it to the Grid System.

(b) Start-up of a Steam Turbine Unit shall be classified as set forth in Table 2 below:

TABLE 2			
UNITS	9 — 10	11 — 12	15
Drum Pressure** (bar)	c/s — <12 w/s — 12-20 h/s — >20	N/A	N/A
Steam Temperature**	N/A	c/s — <100°C w/s — 100-250°C h/s — >250°C	N/A
Time after Shutdown	N/A	N/A	c/s - >60 hours w/s - 6-60 hours h/s - <6 hours

** Classification has been provided on the basis of Drum Pressure or Steam Temperature depending on the classification provided by the manufacturer.

(c) The number of yearly steam turbine Unit start-ups shall be subject to the limits set forth in Table 3 below:

TABLE 3			
UNITS	9 — 10	11 — 12	15
Recommended Starts/Year	c/s — 5 w/s — 50 h/s — [**]	c/s — 8 w/s — 80 h/s — 365	No manufacturer limits

** To be agreed by the Engineer, WAPDA and the Purchaser prior to the completion of the IDC Test and the Functional Tests.

1.2 Complex loading

(a) The Unit load ramping rates are steady rates at which the load can be raised. The maximum design load ramping rates are shown below in (MW/minute) in Table 4. The maximum design load ramping rates shown below are subject to the results of the Functional Test described in Section 2.1(f) of Schedule 4.

TABLE 4							
UNITS	1 — 2	3 — 4	5 — 8	9 — 10	11 — 12	13 — 14	15
Ramping Rate	11* 30**	5	8	c/s - 1.5 w/s - 12 h/s - 20	c/s - 2 w/s - 3 h/s - 3	11* 30**	c/s - 14 w/s - 14 h/s - 14
Load Range (%)	20-90	0-100	0-100	0-100	c/s - 35-100 w/s - 35-100 h/s - 5-100	15-100	c/s - 0-50 w/s - 0-65 h/s - 0-80

* Normal
** Fast

(b) The Unit load ranges expressed in percentages in this Schedule refer to the gross load ranges, for which the maximum ramping rates apply. Ramping rates outside of these load ranges will be slower.

(c) Temperature Stabilization

(i) During cold start only, once reaching full speed and no loading, the Unit 15 load will be required to be held steady for twenty-five (25) minutes for temperature stabilization of the turbine during load increases.

(ii) Any required stabilization for Unit 9 and 10 loads will depend on axial/surface stresses controlled by turbomax.

(iii) Subject to turbine conditions the Company may shorten or waive the requirement for one or more of the stabilization periods.

(d) Step changes in Despatched load of up to 5% of each generator are allowable provided that the generator load is greater than 0%. After such step change the new Unit or Module load must be held constant for stabilization purposes in accordance with 1.2 (c) or for a pro-rata period for lesser step changes.

(e) The Units can withstand a full load rejection and remain in a safe condition. Provided the Complex auxiliaries are operated continuously, the Units can be re-synchronized within one hour provided that the reason for the load rejection has been removed.

(f) The Complex minimum continuous loading shall be 1 gas turbine Unit at baseload plus the associated steam turbine Unit.

(g) Base load operation of Units 1 & 2 shall be defined as the load associated with a corrected turbine exhaust temperature of not more than 487°C under

any circumstances. The maximum vanadium content of residual fuel oil permissible at this exhaust temperature is 25 ppm per the manufacturer's vanadium correction curve. Vanadium content levels in the fuel of 25-50 ppm shall require lower turbine exhaust temperatures in accordance with the manufacturer's vanadium correction curve.

1.3 Frequency, Power Factor, Voltage Limits and Droop Settings

(a) The Units within the Complex will operate at 100% load with a power factor in the range 0.85 lagging to 0.97/0.95 leading which range shall not be exceeded. At no time will the generator capability curves be exceeded.

(b) The Units can operate within the range ±10% on the 11 kV high voltage system which range shall not be exceeded; however, the exact voltage is different for each gas turbine Unit.

(c) The Complex can operate within the frequency range 49 Hertz to 51 Hertz, and in limited and exceptional cases from 47.5 Hertz to 52.5 Hertz, which range shall not be exceeded.

(d) The Complex or individual Units will be subject to tripping if frequency and/or voltage fluctuations outside the ranges stated in 1.3(b) and 1.3(c) occur.

(e) The Unit governor droop is adjustable in the 2-10% range.

(f) The automatic voltage regulator droop setting is adjustable in the 0-21% range.

(g) The existing 132 kV and 220 kV transmission lines are anticipated to have sufficient capacity when all 15 Units of the Complex are operating at full load. Two additional 220 kV transmission lines are being installed (scheduled completion mid 1996) in order to increase the transmission line reliability. If there is a transmission limitation before the two additional 220 kV transmission lines are completed, such transmission limitation shall be considered a Technical Limit.

(h) The generator reactive capability range in paragraph (a) above and the voltage regulation range in paragraph (b) above are each subject to change based on the results of the Functional Test described in Sections 2.1(d) and in 2.1(a), respectively.

2. Design Maintenance Limits

The cycle of Scheduled Outages is set out in Tables 5A and 5B below together with recommended durations for such inspections and outages. Time allotted for Scheduled Outages is provided for in Section 6.3 of this Agreement.

TABLE 5A
GAS TURBINE MAINTENANCE SCHEDULE AND RECOMMENDED DURATIONS

Unit No.	Equivalent Operating Hours for Inspection	Time Required for Combustion Inspection	Equivalent Operating Hours for HGP Inspection	Time Required for HGP Inspection	Equivalent Operating Hours for overhauling	Time Required for Overhauling
1	4000 hours	7 days	N.A.	N.A.	24000 hours	50 days
2	4000 hours	7 days	N.A.	N.A.	24000 hours	50 days
3	3000 hours	7 days	6000 hours	30 days	18000 hours	50 days
4	3000 hours	7 days	6000 hours	30 days	18000 hours	50 days
5	7500 hours	7 days	22500 hours	30 days	45000 hours	50 days
6	7500 hours	7 days	22500 hours	30 days	45000 hours	50 days
7	7500 hours	7 days	22500 hours	30 days	45000 hours	50 days
8	7500 hours	7 days	22500 hours	30 days	45000 hours	50 days
13	4000 hours	7 days	25000 hours	30 days	50000 hours	50 days
14	4000 hours	7 days	25000 hours	30 days	50000 hours	50 days

TABLE 5B
STEAM TURBINE MAINTENANCE SCHEDULE AND RECOMMENDED DURATIONS

Unit No.	Running Hours for Minor Overhaul	Time Required for Minor Overhaul	Running Hours for Major Overhaul	Time required for Major Overhaul
9 — 10	25000 hours	20 days	50000 hours	60 days
11 — 12	25000 hours	20 days	50000 hours	60 days
15	25000 hours	20 days	50000 hours	60 days

Scheduled Outages thereafter continue on a three to five (3 to 5) Year cycle which must be maintained. All boiler inspections will be completed within the above timescales.

The scheduling of maintenance inspections will be compatible with regulatory requirements. All regulatory inspections will be carried out during Scheduled Outages.

TECHNICAL LIMITS

3.2 Start -Up Times for Gas Turbines

UNITS		1-2	3-4	5-8	13-14
GT start to GT Synchronisation	(minutes)	4	28	10	3.3
Ramping Rate	MW / Min	11	5	8	11
Load Range for Ramping Rates		0-96 MW	0-80 MW	0-82 MW	0-107 MW
GT start to GT Base Load	(minutes)	13	44	20	13.0

Start -Up Times for Steam Turbines

UNITS	Module-1 (GT-1, 3 & STG-9) Module-2 (GT-2, 4 & STG-10)			Module-3 (GT-5, 6 & STG-11) Module-4 (GT-7, 8 & STG-12)			Module-5 (GT-13, 14 & STG-15)		
Start	Cold	Warm	Hot	Cold	Warm	Hot	Cold	Warm	Hot
GT Start to STG Synchronisation(minutes) (HRSG preparation + STG rolling)	168 (GT 3&4) 144 (GT 1&2)	88 (GT 3&4) 64 (GT 1&2)	58 (GT 3&4) 34 (GT 1&2)	150	105	65	180	91	74
STG Ramping Rates MW / Min	1.2	1.9	4.8	0.36 (1) & 2.35 (2)	0.58 (1) & 3.13 (2)	3.28	4	4	4.12
STG Load Range for Ramping Rates	0-95 MW	0-95 MW	0-95 MW	0-35 (1) MW & 35-82 (2) MW	0-35 (1) MW & 35-82 (2) MW	0-82 MW	0-118 MW	0-118 MW	0-118 MW
STG Synchronisation to STG Base Load (minutes)	80	50	20	110	75	25	30	30	29
Overall Module timing from first GT start to STG Base Load (minutes)	248 (GT 3&4) 224 (GT 1&2)	138 (GT 3&4) 114 (GT 1&2)	78 (GT 3&4) 54 (GT 1&2)	260	180	90	210	120	103

3.4

Average Module During start-up	Ramping Rates Full Module	1.1 (GT 3&4) 1.2 (GT 1&2)	1.9 (GT 3&4) 2.3 (GT 1&2)	3.4 (GT 3&4) 4.9 (GT 1&2)	0.9	1.3	2.7	1.5	2.6	3.1
	Half Module	0.6 (GT 3&4) 0.8 (GT 1&2)	0.9 (GT 3&4) 1.6 (GT 1&2)	1.9 (GT 3&4) 3.2 (GT 1&2)	0.5	0.7	1.5	0.9	1.6	1.9

Note: The sign (GT 3&4) indicates GT-3 or GT-4 is started initially and (GT 1&2) indicates GT-1 or GT-2 is started initially in the respective modules.
STG -11& 12 have two ramping rates in cold & warm start one from 0-35 MW & other from 35-82 MW as mentioned above.

3.5 Minimum Stable Loading

Module- 1 & 2 = 170 MW
Module- 3 & 4 = 165 MW
Module- 5 = 148 MW

3.7 Units Loading/Deloading Ramp Rates MW/Minute

Module	Minimum Load to Base Load	Base Load to Minimum Load
1&2	2.8	2.3
3&4	5.2	3.6
5	8.2	7.4

3.9 Classification of Starts

Units	9-10			11-12			15		
Start type	Hot	Warm	Cold	Hot	Warm (1)&(2)	Cold	Hot	Warm	Cold
Time after Shutdown (Hours)	<2	2-16	>16	<2	(1) 2-8 (2) 8-48	>48	<6	6-40	>40

ANNEXURE N

IMS CERTIFICATES

CERTIFICATE

TÜV AUSTRIA

Management System as per
OHSAS 18001 : 2007

In accordance with TÜV AUSTRIA procedures, it is hereby certified that

KAPCO

KOT ADDU POWER COMPANY LIMITED (KAPCO)
Kot Addu Power Complex, Kot Addu, District Muzaffargarh
PUNJAB PAKISTAN

Applies an Occupational Health & Safety Management System in line with the above Standard for the following Scope

OPERATION AND MAINTENANCE OF 1600 MW CCPP.

EA Scope / Risk category: 18, 25 / A

Certificate Registration No.: 2019119000001833

Valid until: 2021-05-11*

Lahore, 2019-05-13

[redacted]
CEO
Certification Body
at TÜV AUSTRIA

This certification was conducted in accordance with TÜV AUSTRIA auditing and certification procedures and is subject to regular surveillance audits.

* The validity of the present certificate is renewed provided that the audit, according to the Standard BS OHSAS 18001:2007, has a positive result, according to the Regulation of TÜV Austria Hellas.

TÜV AUSTRIA HELLAS
42B, Messogeion Ave.
GR-152 43 Athens, Greece
www.tuvaustriahellas.gr

CERTIFICATE

TÜV AUSTRIA

Management System as per
EN ISO 14001 : 2015

In accordance with TÜV AUSTRIA procedures, it is hereby certified that

KAPCO

KOT ADDU POWER COMPANY LIMITED (KAPCO)
Kot Addu Power Complex, Kot Addu, District Muzaffargarh
PUNJAB PAKISTAN

Applies an Environmental Management System in line with the above Standard for the following Scope

OPERATION AND MAINTENANCE OF 1600 MW CCPP.

Certificate Registration No.: 20051190001632

Valid until: 2022-05-12

[illegible]
CEO
Certification Body
at TÜV AUSTRIA

Lahore, 2019-05-13

This certification was conducted in accordance with TÜV AUSTRIA auditing and certification procedures and is subject to regular surveillance audits.

TÜV AUSTRIA HELLAS
429, Mesogeion Ave.
GR-153 43 Athens, Greece
www.tuvaustriahellas.gr

IAF [illegible]

01/7782-10-4

CERTIFICATE

TÜV AUSTRIA

Management System as per
EN ISO 9001 : 2015

In accordance with TÜV AUSTRIA procedures, it is hereby certified that:

KAPCO

KOT ADDU POWER COMPANY LIMITED (KAPCO)
Kot Addu Power Complex, Kot Addu, District Muzaffargarh
PUNJAB PAKISTAN

Applies a Quality Management System in line with the above Standard for the following Scope

OPERATION AND MAINTENANCE OF 1600 MW CCPP.

Certificate Registration No.: 20001190001631 Valid until: 2022-05-12

Lahore, 2019-05-13

Stefanie Wahr
CEO
Certification Body
at TÜV AUSTRIA

This certification was conducted in accordance with TÜV AUSTRIA auditing and certification procedures and is subject to regular surveillance audits.

TÜV AUSTRIA HELLAS
42B, Mesogeion Ave.
GR-153 43 Athens, Greece
www.tuvaustriahellas.gr

IAF

ZERTIFIKAT | CERTIFICATE | CERTIFICAT | CERTIFICADO | CERTIFICATO | 证书 | شهادة

QM/7901-19-4

ANNEXURE O

ENVIRONMENT MONITORING REPORTS

PAK GREEN ENVIRO-ENGINEERING (Pvt.) Ltd.

ISO/IEC 17025 : 2017 Accreditated Lab, ISO 9001:2015, 14001:2015, OHSAS 18001:2007

Doc.#: PGG/IMS/FF/063 | Issue Date: 13-Oct-17 | Issue # 01 | Rev. # 00

EPA Certified

Head Office: 46-M, Gulberg III, Lahore-Pakistan. Ph: +9242-35441444 Cell: 0303-4442334

TEST REPORT

Ref #: PGG/LAB/2021-1997/WW

Date: 07-June-21

Name of Industry/Client: Kot Addu Power Company Limited
Site Location: Kot Addu Power Complex, Kot Addu, District Muzaffargarh
Nature of sample: Waste water
Sampling By: Pak Green Laboratories
Sample source: Block # 1
Sampling type (Grab/Composite): Grab
Sample Code: WW-453
Date of sampling: 31-May-21

Results:

Sr. No.	Parameters	Unit	Method / Technique	PEQS	Results
1.	Temperature	°C	APHA-2550 B	40	35.9
2.	pH ^	---	APHA-4500-H+ B	6-9	8.31 at 35.9°C
3.	Biological Oxygen Demand (BOD_5 at 20 °C)^	mg/L	APHA-5210 D	80	10
4.	Chemical Oxygen Demand (COD) ^	mg/L	APHA-5220 B	150	16
5.	Total Suspended Solids (TSS) ^	mg/L	APHA-2540 D	200	12
6.	Total Dissolved Solids (TDS) ^	mg/L	APHA-2540 C	3500	2140
7.	Greases & Oil	mg/L	APHA-5520 B	10	4.8
8.	Phenolic Compound (As Phenol)	mg/L	APHA-5530 D	0.1	BDL
9.	Chloride (as Cl^-) ^	mg/L	APHA-4500-Cl B	1000	107
10.	Fluoride (F^-)	mg/L	APHA-4500-F D	10	3.806
11.	An Ionic detergent as MBAs	mg/L	APHA 5540 C	20	0.202
12.	Sulphate (SO_4^{2-}) ^	mg/L	APHA-4500-SO_4 C	600	190
13.	Sulphide (S^{2-})	mg/L	APHA-4500-S^{2-} F	1.0	BDL
14.	Ammonia (NH_3) ^	mg/L	APHA-4500NH_3 C	40	1.1
15.	Cadmium (Cd)^	mg/L	APHA-3111 B	0.1	0.0089
16	Chromium (Trivalent & Hexavalent)^	mg/L	APHA-3111 B	1.0	0.0108
17.	Copper (Cu)^	mg/L	APHA-3111 B	1.0	0.0216
18.	Lead (Pb)^	mg/L	APHA-3111 B	0.5	0.0108
19.	Mercury (Hg)	mg/L	APHA-3112 B	0.01	BDL
20.	Selenium (Se)	mg/L	APHA-3114 C	0.5	BDL
21.	Nickel (Ni)	mg/L	APHA-3111 B	1.0	0.0032

Pak Green Enviro-Engineering (Pvt) Ltd. Environmental Laboratories Division EPA Certified

PNAC LAB 180

Ref #: PGG/LAB/2021-1997/WW

Date: 07-June-21

Results:

Sr. No.	Parameters	Unit	Method / Technique	PEQS	Results
22.	Silver (Ag)	mg/L	APHA-3111 B	1.0	0.0113
23.	Total Toxic Metals (Cd, Cr, Cu, Pb, Hg, Se, Ni, Ag, As, Ba, B)	mg/L	-	2.0	0.0758
24.	Zinc (Zn)^	mg/L	APHA-3111 B	5.0	0.0223
25.	Arsenic (As)	mg/L	APHA-3114 C	1.0	0.0092
26.	Barium (Ba)	mg/L	APHA-3111 D	1.5	BDL
27.	Iron (Fe)^	mg/L	APHA-3111 B	8.0	0.0886
28.	Manganese (Mn)^	mg/L	APHA-3111 B	1.5	0.0171
29.	Boron (B)	mg/L	APHA-3111 D	6.0	BDL
30.	Chlorine (Cl_2)	mg/L	APHA-4500 Cl B	1.0	0.6
31.	Pesticide, herbicides, fungicides and insecticides	mg/L	ASTM-D5175	0.15	BDL
32.	Cyanide (as CN^{1-}) Total	mg/L	APHA-4500-CN F	1.0	BDL

.....End of Report.....

PEQS: Punjab Environmental Quality Standards ^PNAC Accredited BDL: Below Detection Limit

Remarks: All parameters are in compliance with PEQS Limits.

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- The responsibility of the ethical use of the results reported in this report lies with the client. Consequently, the laboratory is absolved of its responsibility for any claim that may result through the use by the client or others of the results appearing in this report.
- The leftover sample (if so available) shall be retained for fifteen days after the issuance of the report unless otherwise negotiated between the client and the laboratory.
- The report is not valid for any negotiations.

Lab. Analyst	Chief Analyst	Laboratory Incharge
QURAT-UL-AIN	MUHAMMAD RAZAULLAH	IFTIKHAR AHMED

PNAC LAB 180

PAK GREEN ENVIRO-ENGINEERING (Pvt.) Ltd.

ISO/IEC 17025 : 2017 Accreditated Lab, ISO 9001:2015, 14001:2015, OHSAS 18001:2007

Doc.#: PGG/IMS/FF/063 | Issue Date: 13-Oct-17 | Issue # 01 | Rev. # 00

EPA Certified

Head Office: 46-M, Gulberg III, Lahore-Pakistan. Ph: +9242-35441444 Cell: 0303-4442334

TEST REPORT

Ref #: PGG/LAB/2021-1998/WW

Date: 07-June-21

Name of Industry/Client:	Kot Addu Power Company Limited
Site Location:	Kot Addu Power Complex, Kot Addu, District Muzaffargarh
Nature of sample:	Waste water
Sampling By:	Pak Green Laboratories
Sample source:	Block # 2
Sampling type (Grab/Composite):	Grab
Sample Code:	WW-454
Date of sampling:	31-May-21

Results:

Sr. No.	Parameters	Unit	Method / Technique	PEQS	Results
1.	Temperature	°C	APHA-2550 B	40	38.0
2.	pH ^	---	APHA-4500-H⁺ B	6-9	8.22 at 38.0°C
3.	Biological Oxygen Demand (BOD_5 at 20 °C)^	mg/L	APHA-5210 D	80	11
4.	Chemical Oxygen Demand (COD) ^	mg/L	APHA-5220 B	150	16
5.	Total Suspended Solids (TSS) ^	mg/L	APHA-2540 D	200	08
6.	Total Dissolved Solids (TDS) ^	mg/L	APHA-2540 C	3500	2130
7.	Greases & Oil	mg/L	APHA-5520 B	10	5.6
8.	Phenolic Compound (As Phenol)	mg/L	APHA-5530 D	0.1	BDL
9.	Chloride (as Cl^-) ^	mg/L	APHA-4500-Cl B	1000	102
10.	Fluoride (F^-)	mg/L	APHA-4500-F-D	10	3.925
11.	An Ionic detergent as MBAs	mg/L	APHA 5540 C	20	0.080
12.	Sulphate (SO_4^{2-}) ^	mg/L	APHA-4500-SO_4 C	600	190
13.	Sulphide (S^{2-})	mg/L	APHA-4500-S^{2-} F	1.0	BDL
14.	Ammonia (NH_3) ^	mg/L	APHA-4500NH_3 C	40	1.9
15.	Cadmium (Cd)^	mg/L	APHA-3111 B	0.1	0.0086
16.	Chromium (Trivalent & Hexavalent)^	mg/L	APHA-3111 B	1.0	0.0116
17.	Copper (Cu)^	mg/L	APHA-3111 B	1.0	0.0198
18.	Lead (Pb)^	mg/L	APHA-3111 B	0.5	0.0096
19.	Mercury (Hg)	mg/L	APHA-3112 B	0.01	BDL
20.	Selenium (Se)	mg/L	APHA-3114 C	0.5	BDL
21.	Nickel (Ni)	mg/L	APHA-3111 B	1.0	0.0018

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PNAC LAB 180

PAK GREEN ENVIRO-ENGINEERING (Pvt.) Ltd.

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Doc.#: PGG/IMS/FF/063 | Issue Date: 13-Oct-17 | Issue # 01 | Rev. # 00

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Head Office: 46-M, Gulberg III, Lahore-Pakistan. Ph: +9242-35441444 Cell: 0303-4442334

Ref #: PGG/LAB/2021-1998/WW

Date: 07-June-21

Results:

Sr. No.	Parameters	Unit	Method / Technique	PEQS	Results
22.	Silver (Ag)	mg/L	APHA-3111 B	1.0	0.0108
23.	Total Toxic Metals (Cd, Cr, Cu, Pb, Hg, Se, Ni, Ag, As, Ba, B)	mg/L	-	2.0	0.0711
24.	Zinc (Zn)^	mg/L	APHA-3111 B	5.0	0.0213
25.	Arsenic (As)	mg/L	APHA-3114 C	1.0	0.0089
26.	Barium (Ba)	mg/L	APHA-3111 D	1.5	BDL
27.	Iron (Fe)^	mg/L	APHA-3111 B	8.0	0.0864
28.	Manganese (Mn)^	mg/L	APHA-3111 B	1.5	0.0163
29.	Boron (B)	mg/L	APHA-3111 D	6.0	BDL
30.	Chlorine (Cl_2)	mg/L	APHA-4500 Cl B	1.0	0.6
31.	Pesticide, herbicides, fungicides and insecticides	mg/L	ASTM-D5175	0.15	BDL
32.	Cyanide (as CN^{1-}) Total	mg/L	APHA-4500-CN F	1.0	BDL

.....End of Report.....

PEQS: Punjab Environmental Quality Standards **^PNAC Accredited** **BDL: Below Detection Limit**

Remarks: All parameters are in compliance with PEQS Limits.

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Lab. Analyst	Chief Analyst	Laboratory Incharge
QURAT-UL-AIN	MUHAMMAD RAZAULLAH	IFTIKHAR AHMED

Pak Green Enviro-Engineering (Pvt.) Ltd. Laboratories Division EPA Certified

PNAC LAB 180

TEST REPORT

Ref #: PGG/LAB/2021-1999/WW

Date: 07-June-21

Name of Industry/Client:	Kot Addu Power Company Limited
Site Location:	Kot Addu Power Complex, Kot Addu, District Muzaffargarh
Nature of sample:	Waste water
Sampling By:	Pak Green Laboratories
Sample source:	Block # 3 GMZ
Sampling type (Grab/Composite):	Grab
Sample Code:	WW-455
Date of sampling:	31-May-21

Results:

Sr. No.	Parameters	Unit	Method/ Technique	PEQS	Results
1.	Temperature	°C	APHA-2550 B	40	34.9
2.	pH ^	—	APHA-4500-H+ B	6-9	8.28 at 34.9°C
3.	Biological Oxygen Demand (BOD_5 at 20 °C)^	mg/L	APHA-5210 D	80	15
4.	Chemical Oxygen Demand (COD) ^	mg/L	APHA-5220 B	150	24
5.	Total Suspended Solids (TSS) ^	mg/L	APHA-2540 D	200	20
6.	Total Dissolved Solids (TDS) ^	mg/L	APHA-2540 C	3500	1800
7.	Greases & Oil	mg/L	APHA-5520 B	10	7.2
8.	Phenolic Compound (As Phenol)	mg/L	APHA-5530 D	0.1	BDL
9.	Chloride (as Cl^-) ^	mg/L	APHA-4500-Cl B	1000	97
10.	Fluoride (F^-)	mg/L	APHA-4500-F D	10	2.551
11.	An Ionic detergent as MBAs	mg/L	APHA 5540 C	20	0.065
12.	Sulphate (SO_4^{2-}) ^	mg/L	APHA-4500-SO_4 C	600	162
13.	Sulphide (S^{2-})	mg/L	APHA-4500-S^{2-} F	1.0	BDL
14.	Ammonia (NH_3) ^	mg/L	APHA-4500NH_3 C	40	1.5
15.	Cadmium (Cd)^	mg/L	APHA-3111 B	0.1	0.0082
16.	Chromium (Trivalent & Hexavalent)^	mg/L	APHA-3111 B	1.0	0.0116
17.	Copper (Cu)^	mg/L	APHA-3111 B	1.0	0.0168
18.	Lead (Pb)^	mg/L	APHA-3111 B	0.5	0.0094
19.	Mercury (Hg)	mg/L	APHA-3112 B	0.01	BDL
20.	Selenium (Se)	mg/L	APHA-3114 C	0.5	BDL
21.	Nickel (Ni)	mg/L	APHA-3111 B	1.0	0.0027

Green Enviro-Engineering (Pvt) Environmental Laboratories Division EPA Certified

PNAC LAB 180

PAK GREEN ENVIRO-ENGINEERING (Pvt.) Ltd.

ISO/IEC 17025 : 2017 Accreditated Lab, ISO 9001:2015, 14001:2015, OHSAS 18001:2007

Doc.#: PGG/IMS/FF/063	Issue Date: 13-Oct-17	Issue # 01	Rev. # 00

EPA Certified

Head Office: 46-M, Gulberg III, Lahore-Pakistan. Ph: +9242-35441444 Cell: 0303-4442334

Ref #: PGG/LAB/2021-1999/WW

Date: 07-June-21

Results:

Sr. No.	Parameters	Unit	Method / Technique	PEQS	Results
22.	Silver (Ag)	mg/L	APHA-3111 B	1.0	0.0144
23.	Total Toxic Metals (Cd, Cr, Cu, Pb, Hg, Se, Ni, Ag, As, Ba, B)	mg/L	-	2.0	0.0709
24.	Zinc (Zn)^	mg/L	APHA-3111 B	5.0	0.0193
25.	Arsenic (As)	mg/L	APHA-3114 C	1.0	0.0078
26.	Barium (Ba)	mg/L	APHA-3111 D	1.5	BDL
27.	Iron (Fe)^	mg/L	APHA-3111 B	8.0	0.0818
28.	Manganese (Mn)^	mg/L	APHA-3111 B	1.5	0.0119
29.	Boron (B)	mg/L	APHA-3111 D	6.0	BDL
30.	Chlorine (Cl_2)	mg/L	APHA-4500 Cl B	1.0	0.7
31.	Pesticide, herbicides, fungicides and insecticides	mg/L	ASTM-D5175	0.15	BDL
32.	Cyanide (as CN^-) Total	mg/L	APHA-4500-CN F	1.0	BDL

.....End of Report.....

PEQS: Punjab Environmental Quality Standards ^PNAC Accredited BDL: Below Detection Limit

Remarks: All parameters are in compliance with PEQS Limits.

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Lab. Analyst	Chief Analyst	Laboratory Incharge
QURAT-UL-AIN	MUHAMMAD RAZAULLAH	IFTIKHAR AHMED

Pak Green Enviro-Engineering (Pvt.) Ltd. Environmental Laboratories Division EPA Certified

PNAC LAB 180

PAK GREEN ENVIRO-ENGINEERING (Pvt.) Ltd.

ISO/IEC 17025 : 2017 Accreditated Lab, ISO 9001:2015, 14001:2015, OHSAS 18001:2007

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EPA Certified

Head Office: 46-M, Gulberg III, Lahore-Pakistan. Ph: +9242-35441444 Cell: 0303-4442334

TEST REPORT

Ref #: PGG/LAB/2021-1996/WW

Date: 07-June-21

Name of Industry/Client: Kot Addu Power Company Limited
Site Location: Kot Addu Power Complex, Kot Addu, District Muzaffargarh
Nature of sample: Waste water
Sampling By: Pak Green Laboratories
Sample source: CCR Pit # 3
Sampling type (Grab/Composite): Grab
Sample Code: WW-452
Date of sampling: 31-May-21

Results:

Sr. No.	Parameters	Unit	Method / Technique	PEQS	Results
1.	Temperature	°C	APHA-2550 B	40	35.2
2.	pH ^	---	APHA-4500-H+ B	6-9	7.94 at 35.2°C
3.	Biological Oxygen Demand (BOD_5 at 20 °C)^	mg/L	APHA-5210 D	80	05
4.	Chemical Oxygen Demand (COD) ^	mg/L	APHA-5220 B	150	08
5.	Total Suspended Solids (TSS) ^	mg/L	APHA-2540 D	200	10
6.	Total Dissolved Solids (TDS) ^	mg/L	APHA-2540 C	3500	1400
7.	Greases & Oil	mg/L	APHA-5520 B	10	0.24
8.	Phenolic Compound (As Phenol)	mg/L	APHA-5530 D	0.1	BDL
9.	Chloride (as Cl^-) ^	mg/L	APHA-4500-Cl B	1000	66
10.	Fluoride (F^-)	mg/L	APHA-4500-F D	10	2.725
11.	An Ionic detergent as MBAs	mg/L	APHA 5540 C	20	0.105
12.	Sulphate (SO_4^{2-}) ^	mg/L	APHA-4500-SO_4 C	600	130
13.	Sulphide (S^{2-})	mg/L	APHA-4500-S^{2-} F	1.0	BDL
14.	Ammonia (NH_3) ^	mg/L	APHA-4500NH_3 C	40	2.1
15.	Cadmium (Cd)^	mg/L	APHA-3111 B	0.1	0.0019
16.	Chromium (Trivalent & Hexavalent)^	mg/L	APHA-3111 B	1.0	0.0096
17.	Copper (Cu)^	mg/L	APHA-3111 B	1.0	0.0113
18.	Lead (Pb)^	mg/L	APHA-3111 B	0.5	0.0082
19.	Mercury (Hg)	mg/L	APHA-3112 B	0.01	BDL
20.	Selenium (Se)	mg/L	APHA-3114 C	0.5	BDL
21.	Nickel (Ni)	mg/L	APHA-3111 B	1.0	0.0016

Pak Green Enviro-Engineering (Pvt) Ltd. Environmental Laboratories Division EPA Certified

PNAC LAB 180

Ref #: PGG/LAB/2021-1996/WW

Date: 07-June-21

Results:

Sr. No.	Parameters	Unit	Method / Technique	PEQS	Results
22.	Silver (Ag)	mg/L	APHA-3111 B	1.0	0.0094
23.	Total Toxic Metals (Cd, Cr, Cu, Pb, Hg, Se, Ni, Ag, As, Ba, B)	mg/L	-	2.0	0.0467
24.	Zinc (Zn)^	mg/L	APHA-3111 B	5.0	0.0182
25.	Arsenic (As)	mg/L	APHA-3114 C	1.0	0.0047
26.	Barium (Ba)	mg/L	APHA-3111 D	1.5	BDL
27.	Iron (Fe)^	mg/L	APHA-3111 B	8.0	0.0413
28.	Manganese (Mn)^	mg/L	APHA-3111 B	1.5	0.0110
29.	Boron (B)	mg/L	APHA-3111 D	6.0	BDL
30.	Chlorine (Cl_2)	mg/L	APHA-4500 Cl B	1.0	0.5
31.	Pesticide, herbicides, fungicides and insecticides	mg/L	ASTM-D5175	0.15	BDL
32.	Cyanide (as CN^{1-}) Total	mg/L	APHA-4500-CN F	1.0	BDL

.....End of Report.....

PEQS: Punjab Environmental Quality Standards ^PNAC Accredited BDL: Below Detection Limit

Remarks: All parameters are in compliance with PEQS Limits.

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- This report should be reproduced as a whole and not in parts.
- Analysis was conducted on the request of proponent for his own use or PEQS compliance.
- Report cannot be used regarding compliance of any complaint, EPO or any other court case.
- The responsibility of the ethical use of the results reported in this report lies with the client. Consequently, the laboratory is absolved of its responsibility for any claim that may result through the use by the client or others of the results appearing in this report.
- The leftover sample (if so available) shall be retained for fifteen days after the issuance of the report unless otherwise negotiated between the client and the laboratory.
- The report is not valid for any negotiations.

Lab. Analyst	Chief Analyst	Laboratory Incharge
QURAT-UL-AIN	MUHAMMAD RAZAULLAH	GHAZANFAR AHMED

ANNEXURE P

CERTIFICATE OF APPRECIATION

NFEH
National Forum for
Environment & Health

Certificate

OF APPRECIATION

17th Annual Environment Excellence Awards 2020

After careful consideration of track record,
services and performance of

KOT ADDU POWER COMPANY LIMITED

This certificate is being awarded on 18th September 2020 - Karachi.

M. Naeem Qureshi,
President, NFEH
www.nfeh.org.pk