

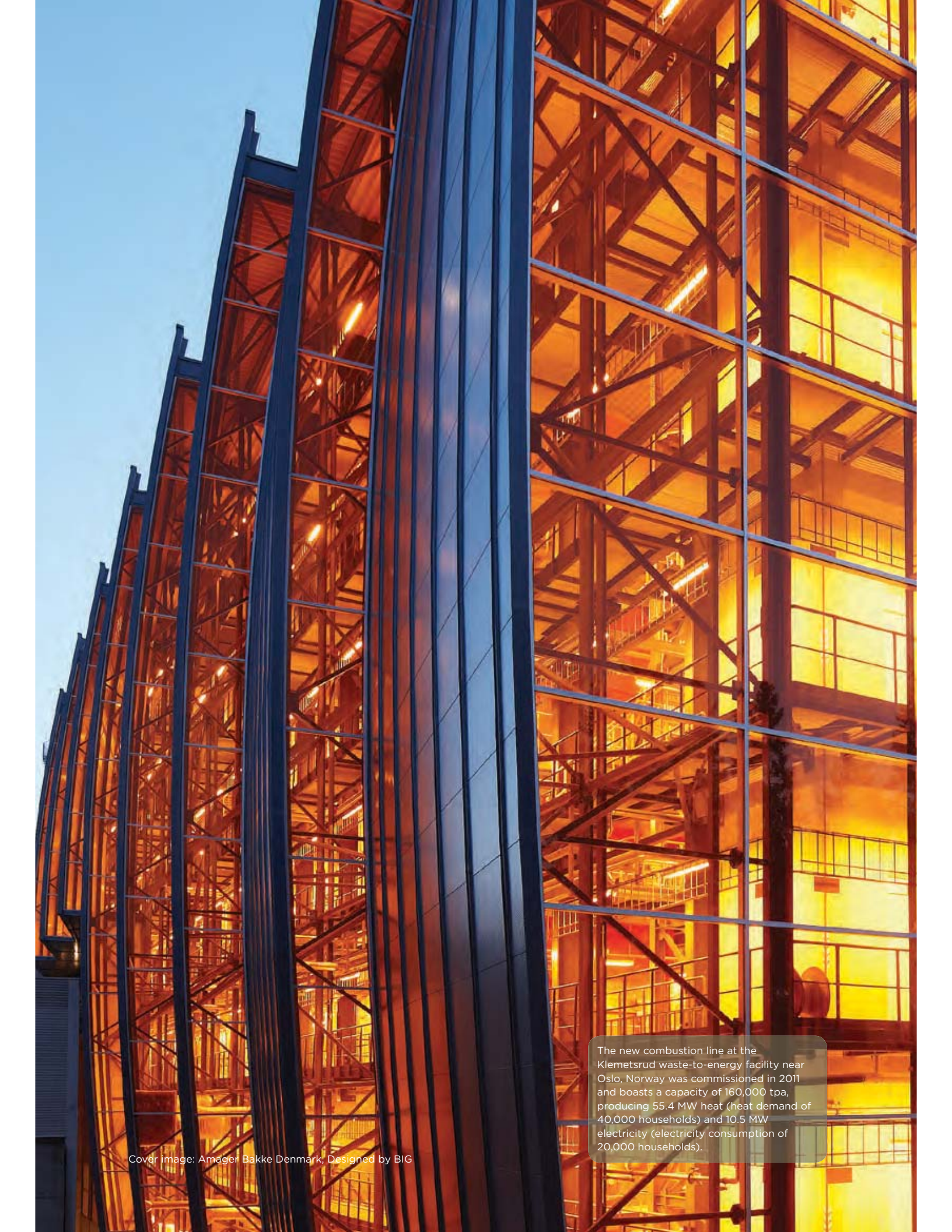
RAMBOLL

USING WASTE AS A RESOURCE

WASTE-TO-ENERGY
CONSULTING FROM IDEA TO REALITY

WWW.RAMBOLL.COM/WTE





The new combustion line at the Klemetsrud waste-to-energy facility near Oslo, Norway was commissioned in 2011 and boasts a capacity of 160,000 tpa, producing 55.4 MW heat (heat demand of 40,000 households) and 10.5 MW electricity (electricity consumption of 20,000 households).

WHAT WE CAN DO FOR YOU

Waste-to-energy

A waste-to-energy facility may generate a range of outputs: electricity, district heating, steam for industrial processes, desalinated seawater or even district cooling.

Where it is uneconomic or unsound to recycle, residual waste becomes a valuable local source of energy. The carbon footprint and environmental performance of a modern waste-to-energy facility is superior to many alternative waste treatment processes.

The most widely used and well proven waste-to-energy technology, is a moving grate on which the waste is combusted. This process is flexible and can be used with or without pre-treatment such as material recovery.

For special types of waste, fluidized bed technology may be an option.

Besides energy, the output includes flue gas, bottom ash and residues from flue gas treatment. The flue gas and any wastewaters are cleaned according to the local environmental standards prior to discharge. Metals can be recovered from the bottom ash which may be used for construction purposes, while the residues from flue gas treatment are sent to specialised treatment facilities for re-use, recycling or disposal.

Ramboll can provide you with well-considered advice throughout all phases of your project – from idea to reality based on our comprehensive experience from waste-to-energy projects all over the world.

Ramboll is a leading engineering, design and consultancy company founded in Denmark in 1945.

Today, we employ 13,000 globally and have especially strong representation in the Nordics, UK, North America, Continental Europe, Middle East and Asia Pacific. With more than 300 offices in 35 countries, Ramboll combines local experience with a global knowledgebase. Our range of multi-disciplinary activities stretches from sustainable energy to structural engineering.

OUR SERVICES

Project phase

Output/objective

Project planning

Decision-making basis

Project definition

Technical concept + tender documents

Procurement

High-quality facility at competitive price

Construction and testing

Fulfilment of contract requirements

Operational follow-up

High availability and strong performance

PROJECT PLANNING - MAKING THE DECISION

Ramboll has a thorough understanding of the role of waste-to-energy in integrated resource management. Our extensive experience of the preparation of waste and energy strategies around the world ensures that we can help our clients to make informed decisions.

Depending on size, a waste-to-energy facility can be an investment of several hundred million euros. A smaller facility is still a significant investment for the community, in which it will serve.

Before embarking on a project of this magnitude, a number of key factors need to be considered.

After recycling, how much waste will be generated? Is the waste suitable for thermal treatment? How can one sell the energy produced? What technologies are most appropriate? What is the optimum procurement route? What is the likely investment cost? What is the gate fee?

We prepare assessments to answer clients' questions and to provide the basis for investment decisions.

Ramboll prepared '**A Decision Maker's Guide to Municipal Solid Waste Incineration**' for the World Bank. The guide describes many of the initial considerations to be made before initiating a waste-to-

energy project.

When the feasibility of the project has been established and the project structure is defined and agreed upon, we assist with the next steps of the project. Permits from the authorities are applied for, environmental impact assessments are prepared, and the siting and overall layout of the facility are discussed. In this context, we also assist our clients in their communication with stakeholders.

Often, we prepare 3D animations, to give clients and stakeholders a virtual tour of their future facility.

West Palm Beach, USA

The waste-to-energy facility has been in commercial operation since 2015 and process approximately 1 million tonnes of household waste, producing 95 MW (gross) electricity.



Image by: SWA



Ramboll assisted Lincolnshire County Council in the procurement of a new waste-to-energy plant. After entering commercial operation in 2014, the plant is capable of treating 150,000 tpa of residual waste and recovering both heat and power.

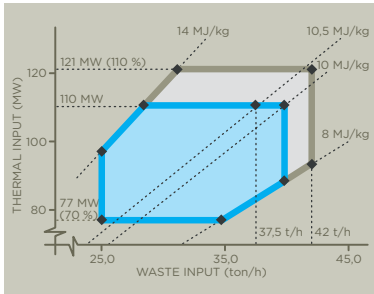


“THE ENVIRONMENTAL AND ECONOMICALLY OPTIMAL SOLUTION FOR A CLEANER REGION.”

- MARTIN BRUNNER, RAMBOLL,
PROJECT MANAGER FOR THE RENERGIA
WASTE-TO-ENERGY PLANT

The new waste-to-energy facility in Lucerne, Switzerland has a capacity of 200,000 tpa, producing 70 MW boiler output and 28 MW electricity.

PROJECT DEFINITION - SPECIFYING THE TECHNICAL CONCEPT



Combustion diagram.

Which technologies should be used? How to establish the combustion diagram for the facility? Should we consider one, two or more units? How should the facility tie in with existing infrastructure? How can we optimise the energy output? What are the key design parameters? What is the breakdown of capital and operating costs? How should risks be allocated? What are the project milestones? When can the facility operations commence? The project definition phase addresses all of these questions and many more.

The project is defined in accordance with our clients' expectations and this ensures that their requirements are fully incorporated in to the project.

We know the waste-to-energy technology suppliers. Working on many projects has taught us how to identify the problems and pitfalls

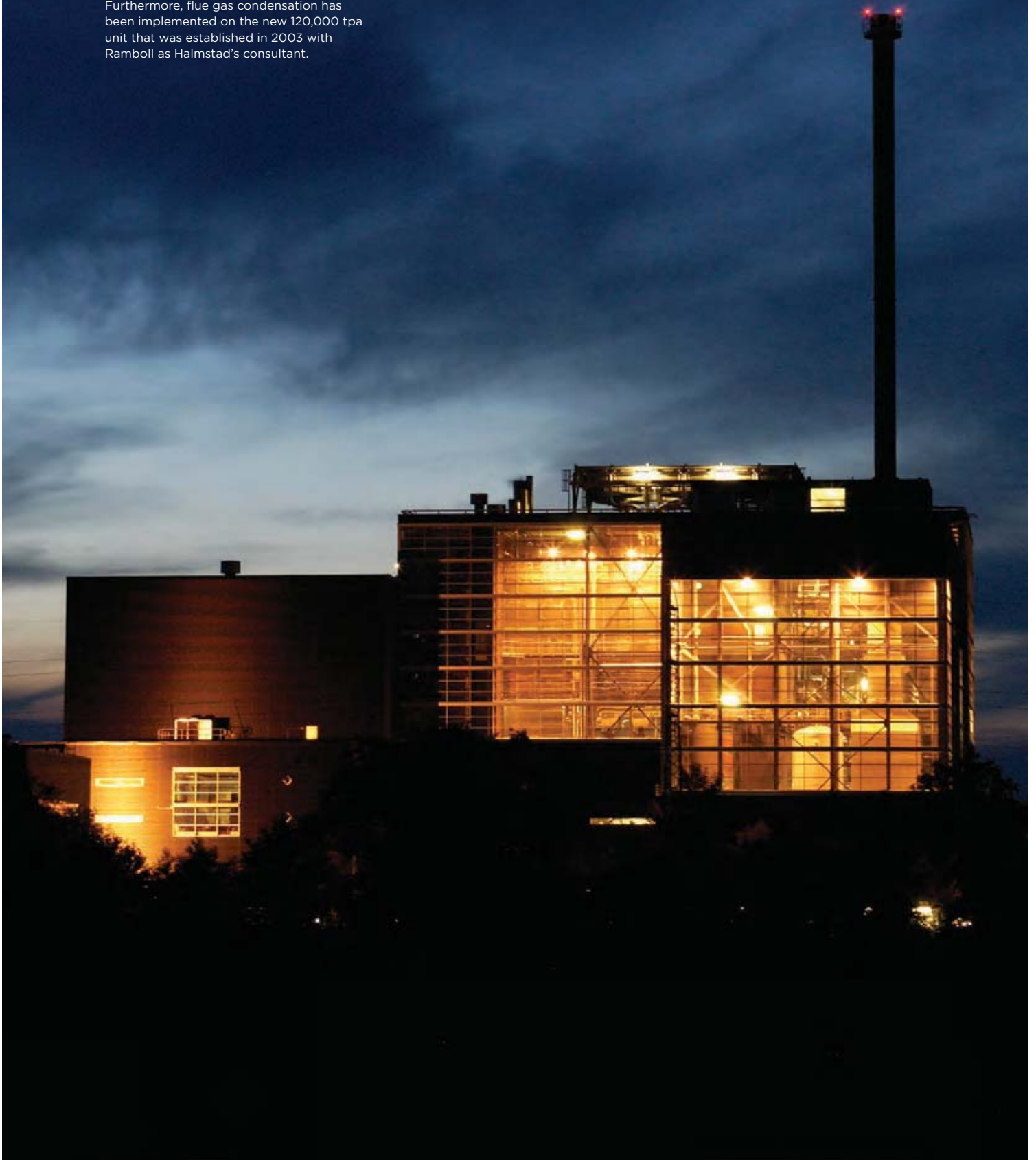
of key equipment and processes. We are always closely involved in the detailed technical solutions and their implementation, both when the facility is tendered as a turn-key contract and when it is tendered through a number of lots. We use the most advanced process design tools.

We know the applicable and emerging rules and regulations. Ramboll is influential in the development and application of new legislation in this sector. This puts us in a unique position to anticipate future requirements and can help to ensure facilities take account of tomorrow's standards.



Access walkways.
Photo, right: Stellan Stebe.

The owner of the waste-to-energy facility in Halmstad, Sweden, has chosen to upgrade several parts of the facility to optimise operations. For instance, the flue gas treatment system has been upgraded, and the convection part and economisers of the old units have been replaced. Furthermore, flue gas condensation has been implemented on the new 120,000 tpa unit that was established in 2003 with Ramboll as Halmstad's consultant.



PROCUREMENT - BUYING THE FACILITY

The objective of the procurement process is to ensure value for money through a high-quality contract with a reputable bidder at a competitive price. In this phase, we short-list the suppliers of mechanical and electrical equipment and civil works contractors in a prequalification procedure, we prepare tender documents, and we conduct a professional procurement process.

Ramboll has broad experience using many types of procurement route. We provide assistance to plant owners and operators for the procurement of facilities on a design-build basis, as well as to local or regional authorities in their procurement of Public-Private Partnership waste management contracts.

We have procured facilities through one or several lots for mechanical and electrical equipment and for civil works. The objective is to balance risks, gain maximum bidder interest and to obtain the lowest prices. Ramboll fully understands the risks and interfaces of each approach and this specialist knowledge provides the opportunity to explore a greater range of options with our clients.

Ramboll has prepared tender documents for more than 90 new waste-to-energy facilities and retrofits, and have a very well-proven format for both technical specifications and commercial conditions.

We can provide:

- Output-based key performance requirements that the contractor must comply with using its own good design, or
- Detailed specifications to ensure that the contractor does not cut corners in its design.

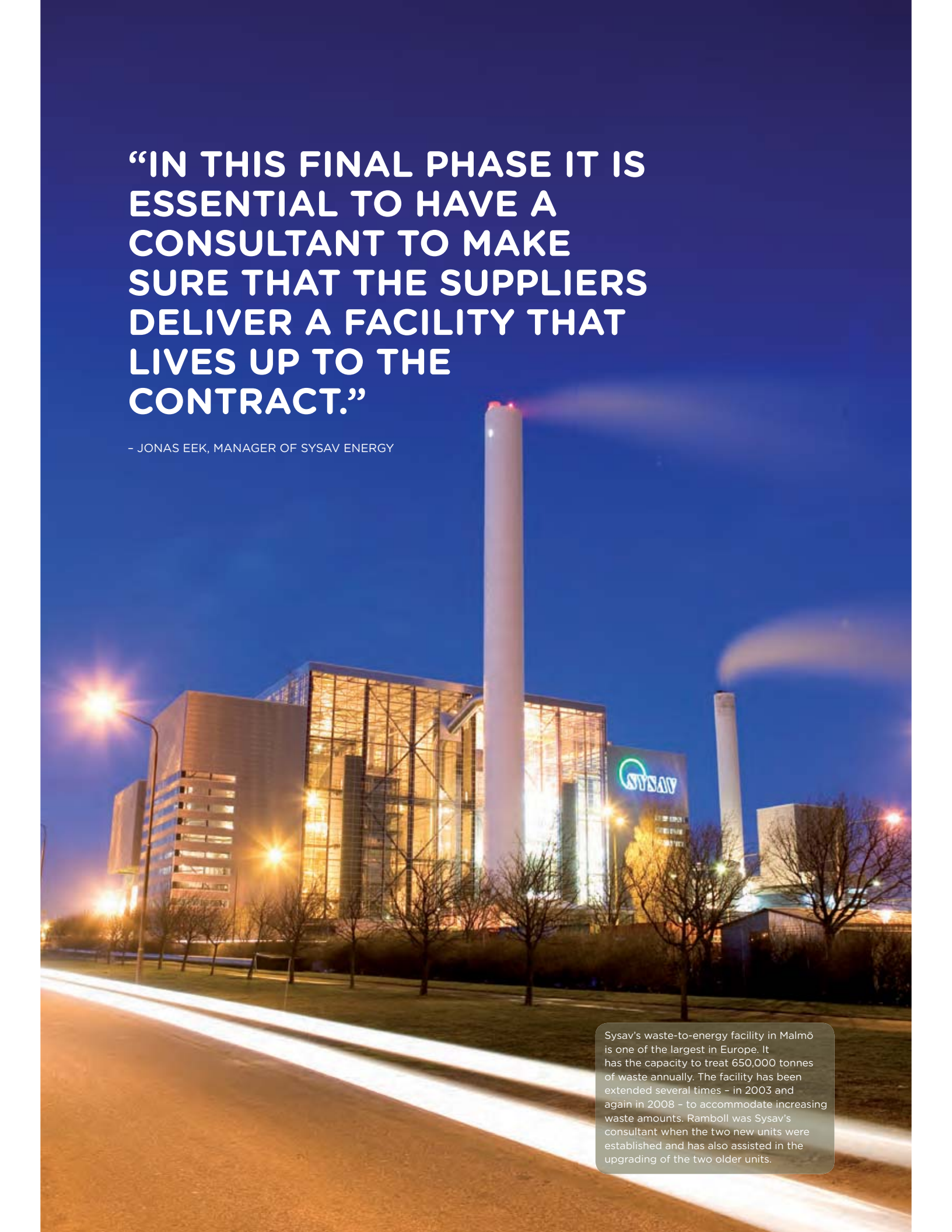
Ramboll's commercial conditions have been tried and tested over many years, and they are well known by all the relevant suppliers. A well-known contract format is one way to reduce perceived bidder risk and increase bidder interest.

Architectural vision of a 1,000,000 tpa waste-to-energy plant in Abu Dhabi, United Arab Emirates to help achieving 80% landfill diversion target.



“IN THIS FINAL PHASE IT IS ESSENTIAL TO HAVE A CONSULTANT TO MAKE SURE THAT THE SUPPLIERS DELIVER A FACILITY THAT LIVES UP TO THE CONTRACT.”

- JONAS EEK, MANAGER OF SYSAV ENERGY



Sysav's waste-to-energy facility in Malmö is one of the largest in Europe. It has the capacity to treat 650,000 tonnes of waste annually. The facility has been extended several times - in 2003 and again in 2008 - to accommodate increasing waste amounts. Ramboll was Sysav's consultant when the two new units were established and has also assisted in the upgrading of the two older units.

CONSTRUCTION, COMMISSIONING AND TESTING

- BUILDING THE FACILITY

Ramboll masters all the technical disciplines which are associated with the design, construction and operation of waste-to-energy facilities. This expertise is a precondition for proper review and supervision during design finalisation and through construction.

To ensure that technical objectives are fulfilled, Ramboll follows up on the contract within a range of areas, using tools specifically developed for the purposes of the construction phase of the project. Our focus is on:

- Review and approval of detailed design and key sub-contractors.
- Interface management.
- Supervision of construction, commissioning and testing.
- Provisional acceptance.
- Contract management and administration – payment, bonds, programming, penalties, deductions, claims etc.

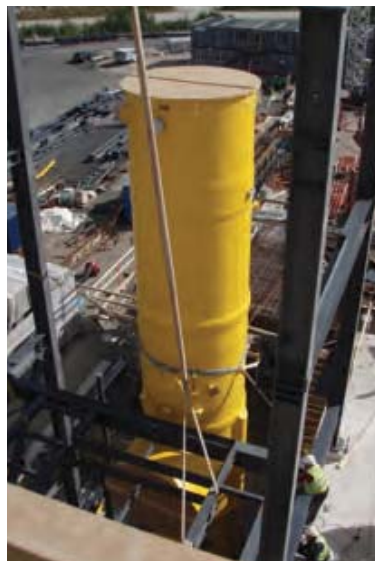
Our unique waste-to-energy expertise relates to mechanical and electrical equipment. As a large international and multidisciplinary consultant we also advise on civil works; in most of our waste-to-energy projects we are responsible for both.

The overall objective of this phase is to ensure that the supplier fulfils the requirements of the contract.

In other words, we safeguard our clients' interests in relation to the suppliers' performance.

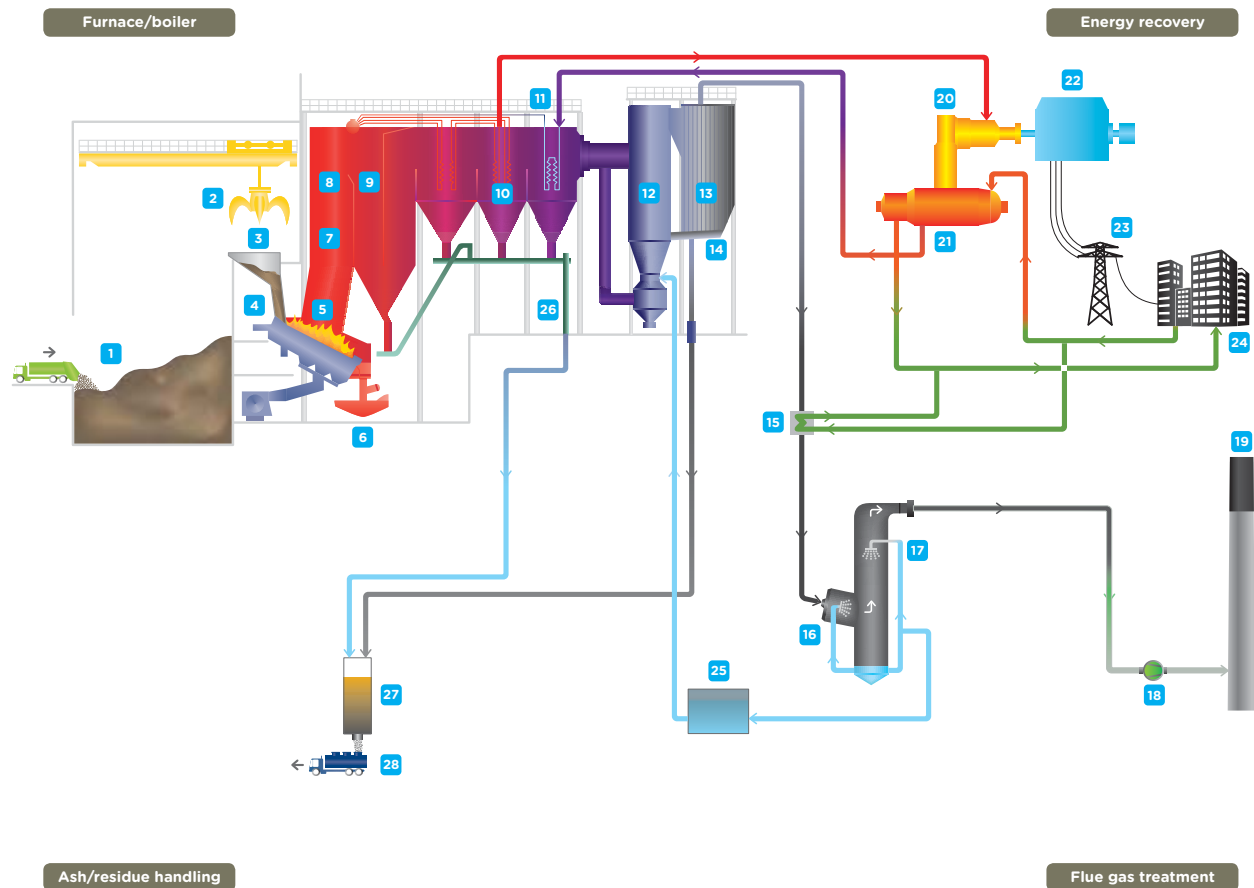
Sysav construction site.

The 88,000 tpa facility in Uddevalla, Sweden, was founded on solid rock. The building foundation consists of 20,000 cubic metres of concrete and 1,700 tonnes of reinforcing steel. The facility was inaugurated in January 2009.



WASTE-TO-ENERGY FACILITY

- WITH DRY/SEMI-DRY FLUE GAS TREATMENT SYSTEM



Furnace/boiler: 1. Bunker 2. Grab 3. Hopper/feed chute 4. Feeder ram 5. Grate 6. Bottom ash discharger 7. Furnace 8. Afterburning chamber 9. Radiation part 10. Convection part 11. Economiser **Flue gas treatment:** 12. Reactor for acid gas absorption 13. Bag house filter 14. Residue recirculation 15. Economiser 16. Quench **Flue gas treatment:** 17. Scrubber (optional) 18. ID fan 19. Stack **Energy recovery:** 20. Turbine 21. Condenser 22. Generator 23. Electrical output 24. Heat output **Ash/residue handling:** 25. Process water tank 26. Boiler ash conveying system 27. Silo for ash and FGT residue 28. Ash/residue discharge

OPERATIONAL FOLLOW-UP - MAKING SURE THE FACILITY CONTINUES TO WORK



Brescia, Italy: Crane automation.

Provisional takeover of the waste-to-energy facility marks the beginning of the guarantee period, typically of two years' duration.

In this period, we assist our clients to identify and document defects and make sure that the suppliers correct them. We also administer the guarantees and performance bonds. When the guarantee period ends, we ensure that the facility meets the contractual conditions before we recommend final takeover.

Our focus after final takeover is on the operation and maintenance of the waste-to-energy facility, with a view to maintain high availability and performance.

We also provide day-to-day technical assistance and support for complex trouble-shooting.

For example, on the Isle of Man we assist the Department of Local Government and the Environment to fulfil its continued obligations under the 25-year operating contract.

I/S Nordforbrænding in Hørsholm, Denmark, has installed a system to reduce the emission of NO_x.



Based on an inspection of Tynes Bay Waste Treatment Facility in Bermuda, Ramboll made proposals for upgrading the facility. We are also consultants for the establishment of a new 72,000 tpa unit.



Ramboll frequently performs technical reviews to determine the state of waste-to-energy facilities with a view to defining an upgrading strategy. In this case, the facility was London Waste EcoPark in the UK.

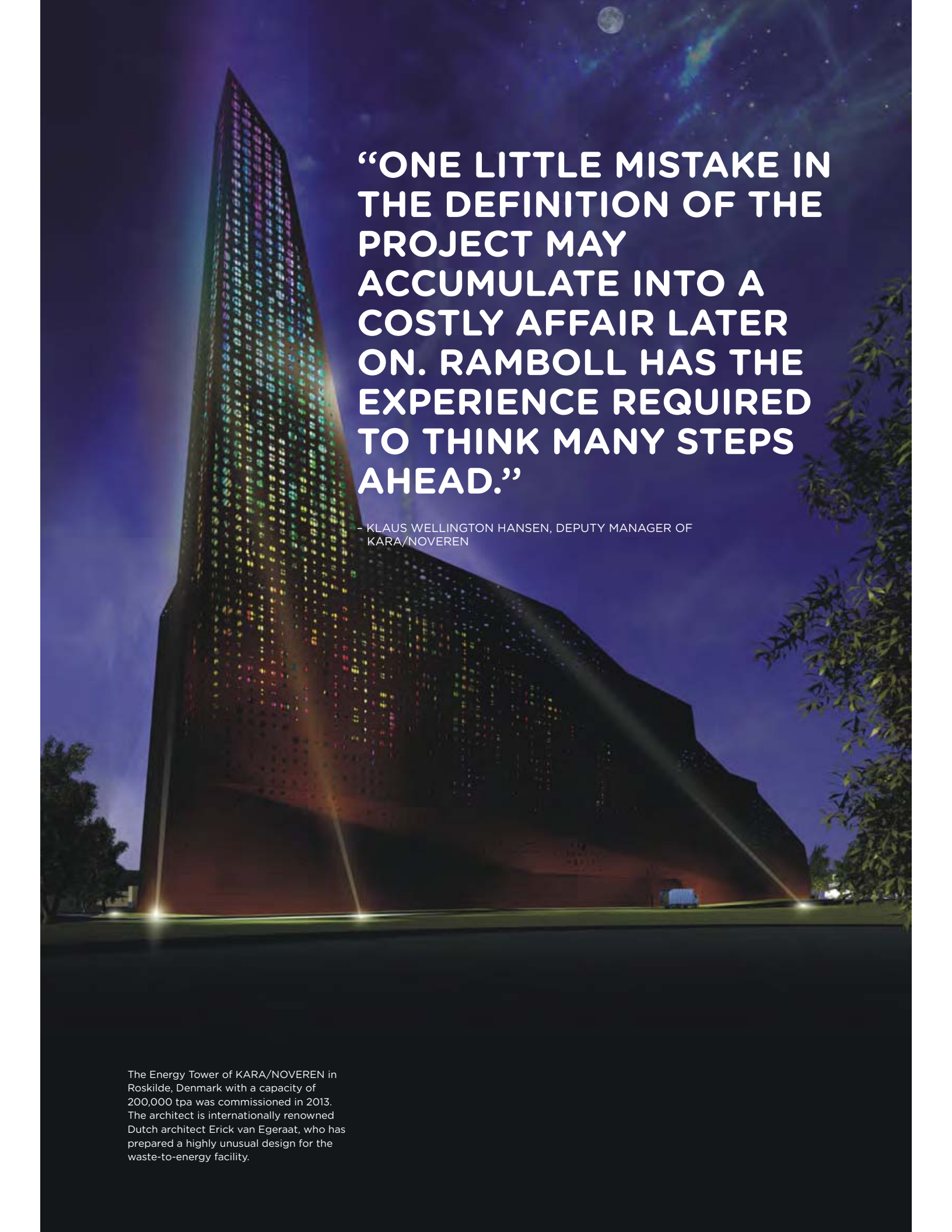


**”RAMBOLL ASSISTED US
ALL THE WAY FROM IDEA
TO REALITY. NOW THEY
ARE PROVIDING SUPPORT
TO THE OPERATOR FOR US,
ENSURING THAT OUR
ASPIRATIONS ARE MET.”**

- ALAN BLAIN, PROJECT DIRECTOR, ISLE OF MAN GOVERNMENT

Based on experience on the Isle of Man and many other projects, we understand the prevailing conditions on most islands. They include limited land availability and labour resources, waste fluctuations due to tourism, and the lack of economies of scale for some waste management processes. One fundamental issue on islands is that alternative ways of managing waste are normally scarce. Therefore, it becomes very important to ensure high availability throughout the planned operational life of the facility.



A tall, illuminated tower at night, featuring a grid of colorful lights (red, green, blue, yellow) that create a vibrant, multi-colored glow. The tower is set against a dark blue night sky with a full moon and stars. The tower's design is modern and industrial, with a series of vertical lines and horizontal bands of lights. The overall scene is dramatic and futuristic.

**“ONE LITTLE MISTAKE IN
THE DEFINITION OF THE
PROJECT MAY
ACCUMULATE INTO A
COSTLY AFFAIR LATER
ON. RAMBOLL HAS THE
EXPERIENCE REQUIRED
TO THINK MANY STEPS
AHEAD.”**

— KLAUS WELLINGTON HANSEN, DEPUTY MANAGER OF
KARA/NOVEREN

The Energy Tower of KARA/NOVEREN in Roskilde, Denmark with a capacity of 200,000 tpa was commissioned in 2013. The architect is internationally renowned Dutch architect Erick van Egeraat, who has prepared a highly unusual design for the waste-to-energy facility.

UPGRADING - MEETING NEW DEMANDS

A waste-to-energy facility typically has an operational lifetime in excess of 20 years. During this period, circumstances are bound to change.

New and more stringent environmental regulations may be introduced, which may require our clients to upgrade or establish new environmental protection systems at the facility.

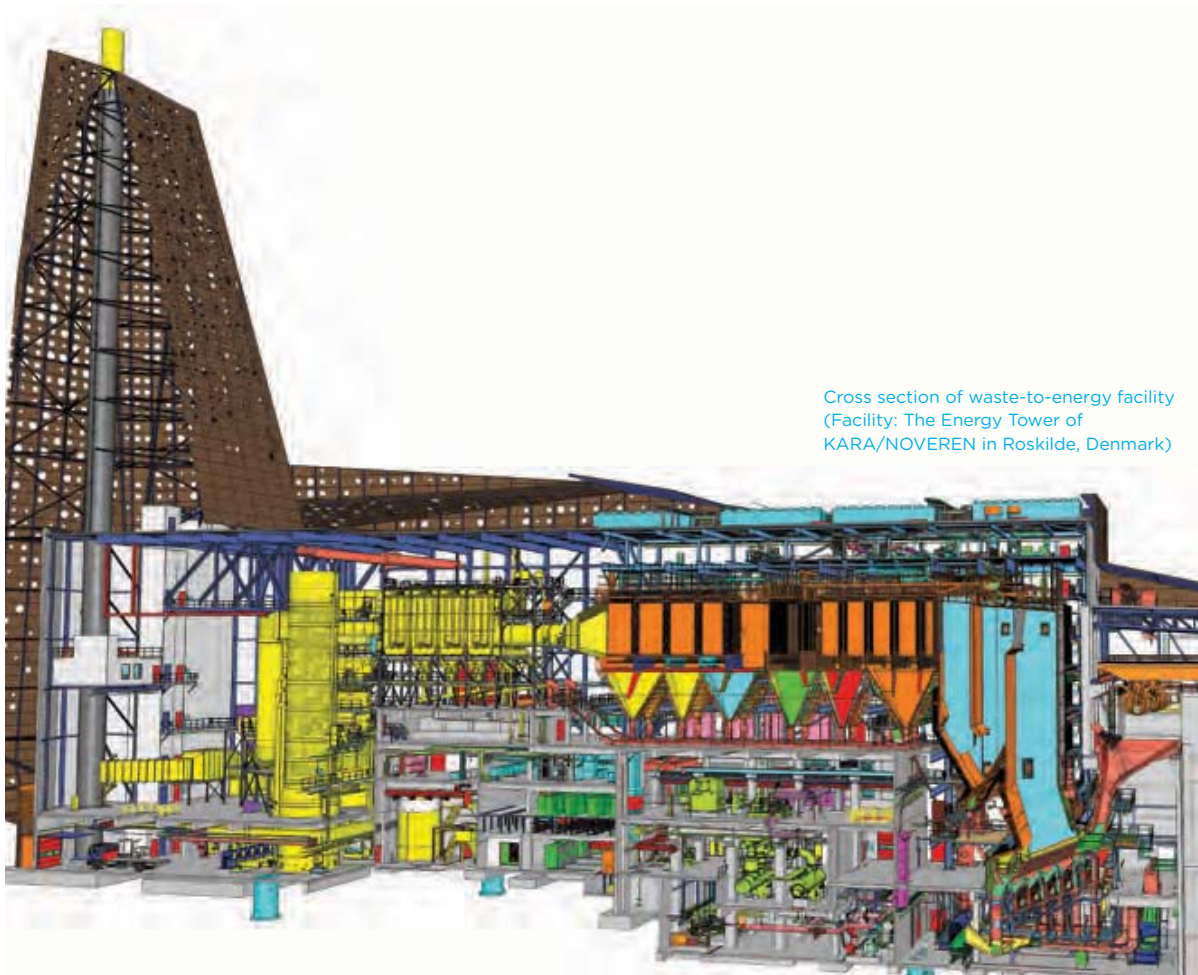
Operational circumstances may call for changes; for instance, a replacement of the grate to increase the lifetime of the facility.

New or further developed technologies may pave the way for increased efficiency; for instance, installing an economiser or flue gas condensation.

Ramboll has been involved in a large number of retrofits to operational waste-to-energy facilities.

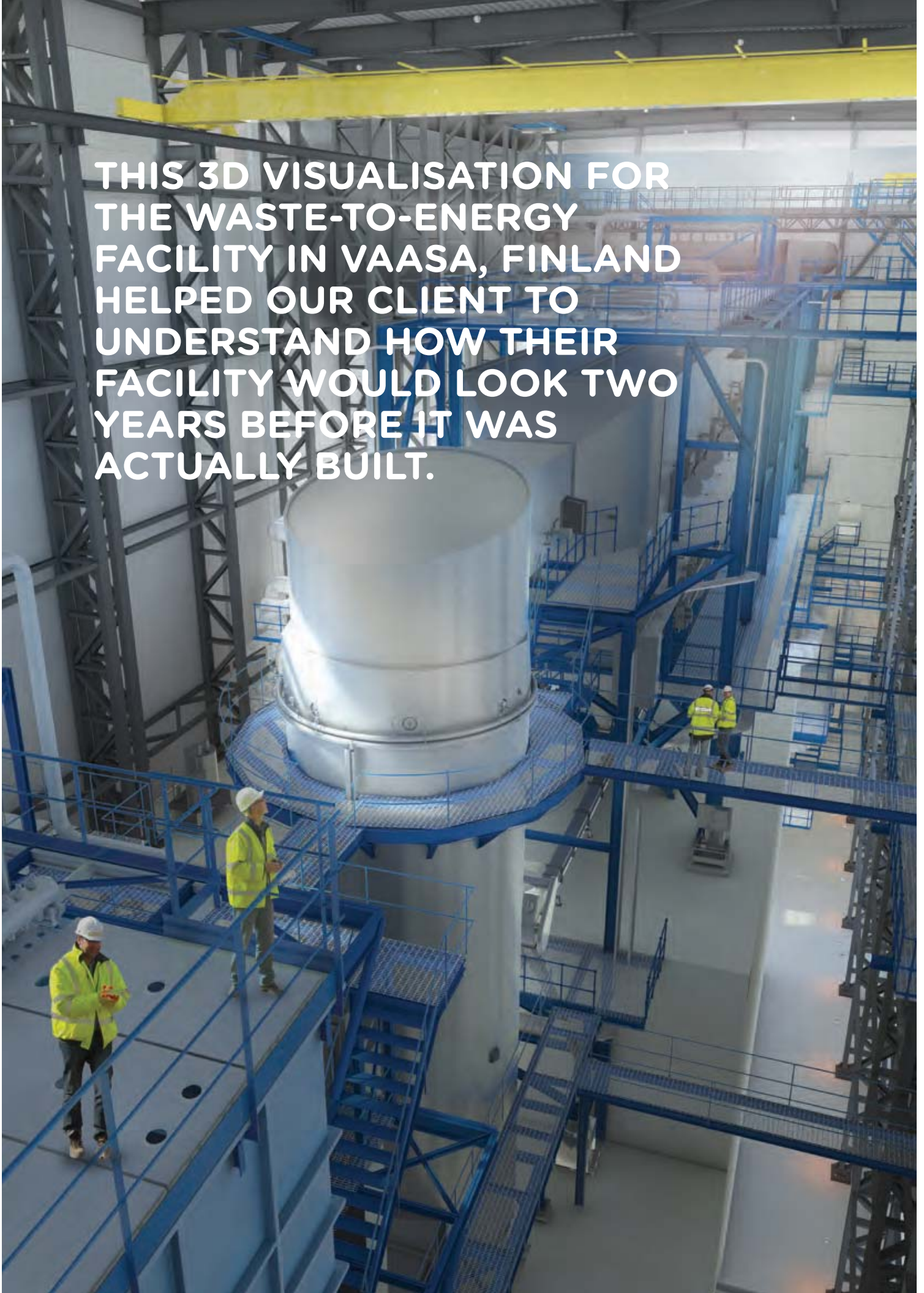
We are used to working around the constraints of an existing building and managing the interfaces with existing equipment and systems.

We can propose solutions to minimise disruption of the operation of the existing unit(s) and to ensure that maximum treatment capacity is maintained throughout the construction period.



Cross section of waste-to-energy facility
(Facility: The Energy Tower of
KARA/NOVEREN in Roskilde, Denmark)

THIS 3D VISUALISATION FOR THE WASTE-TO-ENERGY FACILITY IN VAASA, FINLAND HELPED OUR CLIENT TO UNDERSTAND HOW THEIR FACILITY WOULD LOOK TWO YEARS BEFORE IT WAS ACTUALLY BUILT.



OTHER SERVICES - SMARTER SOLUTIONS

BIOMA Online Plant Software

BIOMA is a software tool which determines the biogenic and fossil fractions contained within waste and is based on data already available as part of plant operations. The software is an easy-to-use and precise tool that assists in maximising revenues related to the biogenic fuel content and meets strict measurement requirements and standards.

BIOMA was developed by the Vienna University of Technology for the purpose of emission trading of CO₂ and green electricity sales. Its direct connection to the control system of the waste-to-energy facility ensures that BIOMA continuously delivers relevant results, including:

- Higher and lower heating value
- Green electricity production
- Plastic content of waste
- Water content of waste
- Fossil CO₂ emission

3D Visualisation

During the entire life-span of a waste-to-energy facility, 3D-visualisation plays an important role supporting the decision process.

During the planning stage 3D-visualisation can show the visible impact of different facility layouts of various locations. It can support decision makers in providing a clear picture for finally deciding on location and architectural matters.

During the design stage, 3D-visualisation is a strong tool for technicians and owners in making decisions, e.g. layout of control room, sightlines from crane-driver's seat, lighting levels etc.

For operational plants, 3D-visualisations help the review of potential modifications and retrofits.



3D-visualisation of all mechanical supplies modelled inside the building envelope.

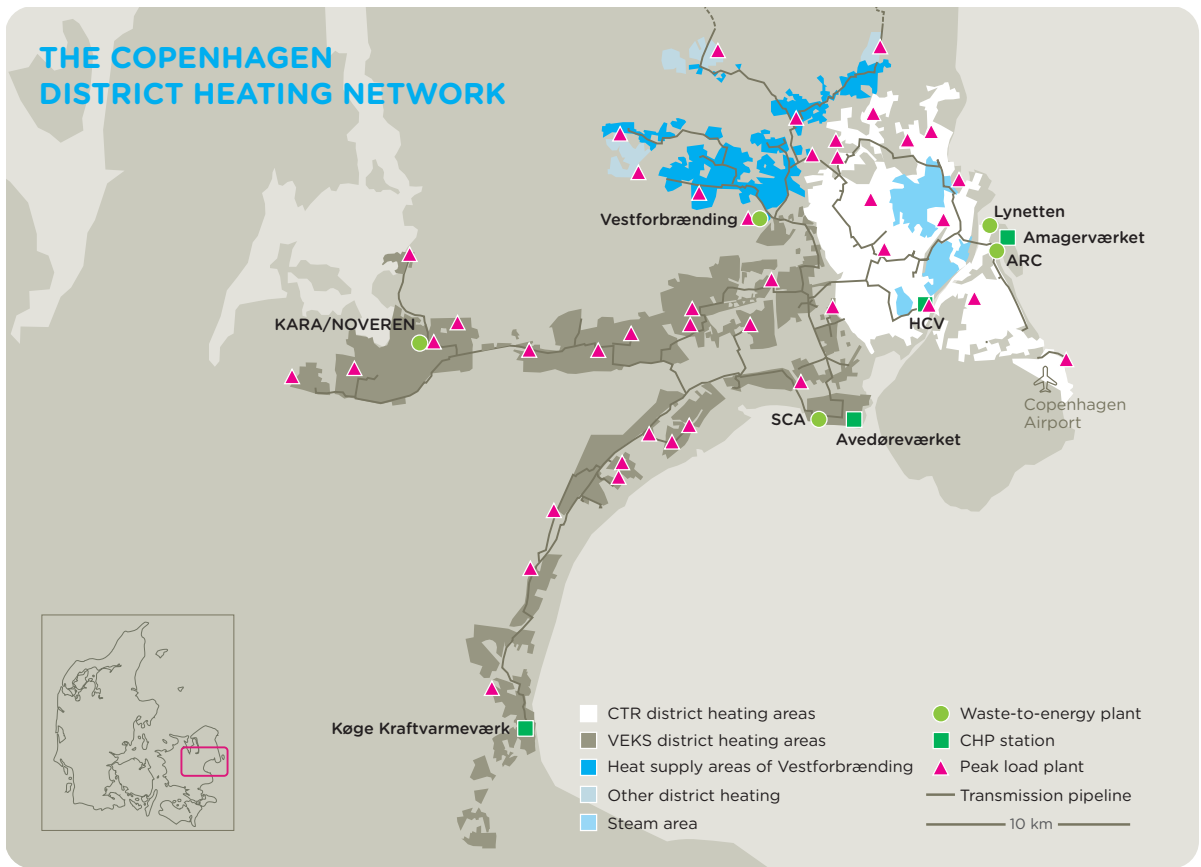
WASTE TO DISTRICT HEATING

The Copenhagen district heating network

- One of the largest and most sophisticated city-wide district heating networks in the world, supplying heat to a city with a population of more than one million people.
- The district heating network extends east to west for more than 50 km.
- Waste-to-energy produces one third of all heat for the greater Copenhagen area.

- The district heating network provides heat to 50 million square metres, corresponding to 425,000 households.
- Waste-to-energy provides the base load in Copenhagen's district heating network.

Ramboll has unparalleled expertise in district heating and Combined Heat and Power (CHP). We can advise on, and optimise, the interaction between waste-to-energy and district heating systems. Our district heating services include planning and feasibility studies, design, construction management and supervision, as well as projects related to operation and maintenance.



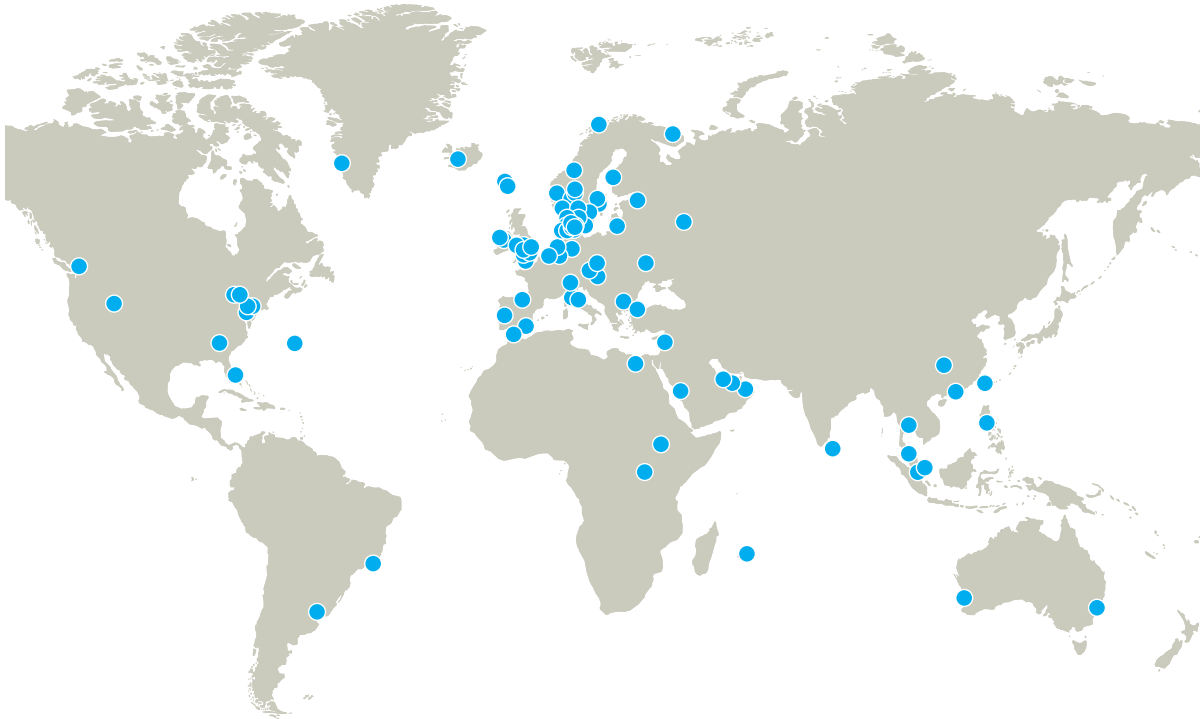


< Construction site of new waste-to-energy facility in SYSAV, Sweden. The facility is producing both heat and power and has a treatment capacity of 650,000 tpa.



< Control room. From here the operators have a complete over-view of the facility and can respond immediately to signals from the control and monitoring system.

OUR REFERENCES



Americas: Argentina, Bermuda, Brazil, Canada (British Columbia, Ontario), US (Georgia, Maryland, Pennsylvania, Florida, Utah) **Europe:** Austria, Belgium, Bulgaria, Czech Republic, Denmark, Faroe Islands, Finland, Italy, Germany, Gibraltar, Greenland, Hungary, Iceland, Ireland, Lithuania, Netherlands, Norway, Portugal, Russia, Spain, Sweden, Switzerland, Turkey, UK, Ukraine **Africa:** Egypt, Ethiopia, Uganda **Middle East:** Lebanon, Oman, Qatar, Saudi Arabia, UAE **Asia:** China, Hong Kong, Malaysia, Mauritius, Philippines, Singapore, Taiwan, Thailand **Australia:** Perth, Sydney

- Internationally recognised world-leading waste-to-energy consultancy
- 800 specialists working in energy production, energy efficiency, renewable energy and district heating
- 60+ dedicated waste-to-energy project managers and specialists serving the market through our centre of excellence in Copenhagen and a number of regional hubs

- Ramboll has worked on waste-to-energy projects in more than 45 countries around the world, providing consulting services for more than 155 new units and retrofits
- In-depth knowledge of processes, technologies, suppliers and facility operation
- Strong in-house expertise in contractual and financial matters
- Renowned expertise in district heating and CHP.

The combination of our experience and expertise means that we can provide no-learning-curve client support at every step of the project. In addition Ramboll always provides truly independent advice; as a matter of policy, we never work for suppliers of waste-to-energy technology.

An iconic design often is proposed in WtE projects to influence public perception and enhance a smooth planning application process.



THE AMAGER BAKKE WASTE-TO-ENERGY FACILITY IN COPENHAGEN, DENMARK IS CURRENTLY THE LARGEST NEW WASTE-TO-ENERGY PROJECT IN EUROPE. IT IS SCHEDULED FOR COMMISSIONING IN 2017. THE FLAGSHIP FACILITY WILL REPLACE THE EXISTING FACILITY, BOASTING AN INCREASE IN ENERGY EFFICIENCY OF UP TO 20%. THE ARCHITECT IS INTERNATIONALLY RENOWNED DANISH ARCHITECT GROUP BIG WHO HAS PREPARED A DESIGN FACILITATING A SKI SLOPE ON THE ROOF OF THE BUILDING. THE FACILITY WILL SUPPLY 190 MW LOW-CARBON HEAT (INCLUDING 40 MW BY FLUE GAS CONDENSATION) AND 57 MW ELECTRICITY TO COPENHAGEN.

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