Developing associative models to guide typological strategies for better integrating Waste to Energy plants in an urban context

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Abstract

Despite many advantages may be offered including architectural expertise in the design and delivery of industrial buildings and power plants, in recent times it has generally been excluded from this process, probably because of the lack of clearly defined roles for architecture to play in the formulation of these, typically complex and technical, buildings. As population densities increase, growing numbers of Waste-to-Energy (WtE) plants may be needed to cope with mounting volumes of waste, particularly in urban areas. The two-year investigation on WtE by the Harvard University's Graduate School of Design: "Architecture and Waste: A(Re)Planned Obsolescence" (2017), offers guidelines and tools allowing designers, the public and other major stakeholders to reconsider the role of architecture in the design of industrial facilities and demonstrate that architects' contributions can be crucial to integrating WtE plants within their context and counteracting negative public perceptions of such facilities. This paper provides a detailed account of the development and application of these design tools to waste to energy architectural projects.

Keywords

Waste to Energy, Industrial Typology, Associative Modelling, Parametric Design

Received: April 2018 / Accepted: June 2018

DOI: 10.13128/RV-22996 - www.fupress.net/index.php/ri-vista/

Introduction

The design research project described in this paper was part of a larger funded research initiative conducted through the collaborative efforts of faculty and researchers from the Harvard Graduate School of Design. The specific research project covered by this paper was carried out by the GSD Waste to Energy Design Lab operating under the overall aegis of WtE Design Lab between 2014 and 2017 and was led by the authors of this paper.

The Waste to Energy Design Lab (WtE Design Lab) was tasked with a general mandate to identify the roles that Architecture may play in the design of waste to energy facilities as well as explore the tools and processes that may be developed to support this process. The Design Research was sponsored by Tyrens Trust.

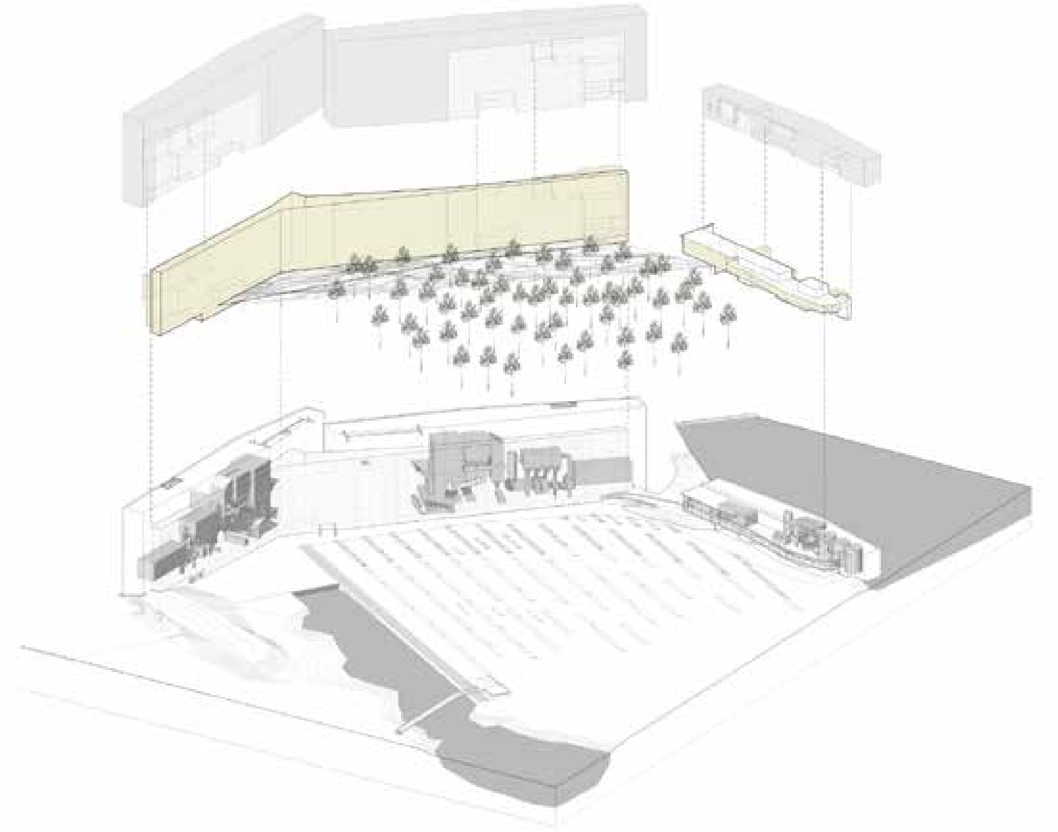
In the last decade despite the emergence of transformational infrastructural and industrial projects borne out of economic and ecological challenges, the role of the designer and specifically the architect remains minor or non-existent in this field. This is in part due to the fact that there is the perception of a lack of a clearly-defined roles that architects can play in the process as it has come to be perceived solely through technical and engineering concerns.

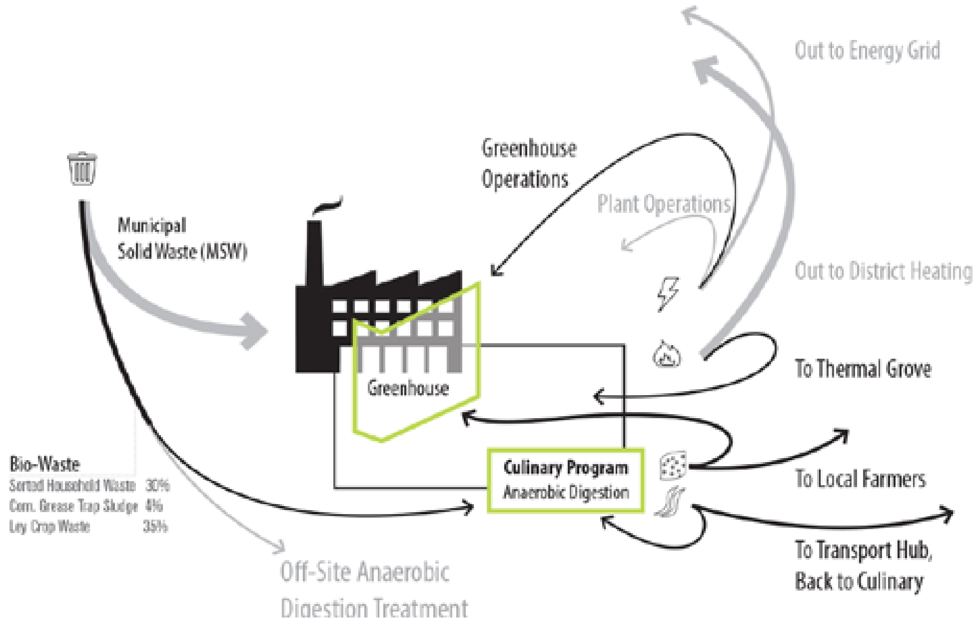
However, the projected increase in the construction of industrial buildings within urban and peri-urban contexts to facilitate the transformation of energy infrastructures towards clean energy practices (such as waste to energy plants) in countries like Sweden, present an opportunity for the engagement of architects (Kara et al., 2017).

One of the pressing needs surrounding this trend is the development of design strategies that allow for sensitively integrating these facilities closer to urban areas, which are its fuel source. To keep transportation costs to a sustainable level, WtE plants would be better placed closer to urban centers. A reduction in traffic associated with the operations of these facilities and a corresponding decrease in pollution are likely benefits for such an urban siting strategy. (Fig.1)

The skillset as well as the disciplinary and professional remit of the architect, makes them well placed as key agents in addressing how these often-large buildings may be integrated both physically and programmatically within urban or suburban contexts in an appropriate manner as well as addressing how the generally negative perception of industrial buildings may be addressed through design.

This research sought to develop design strategies and tools, which allow architects to envision and test the technical feasibility of different plant configurations that allow for a variety of plant sizes to coexist with residential or other programs in an ur-




Out to Energy Grid
Greenhouse
Operations
Plant Operations
Municipal
Solid Waste (MSW)
Out to District Heating
To Thermal Grove
Greenhouse
Culinary Program
Anaerobic Digestion
To Local Farmers
Bio-Waste
Sorted Household Waste 30%
Com. Grease Trap Sludge 4%
Ley Crop Waste 35%
To Transport Hub,
Back to Culinary
Off-Site Anaerobic
Digestion Treatment

opposite page
Fig. 1 – Large-scale integration strategy by Laura Smead and Felipe Oropeza Jr, WtE Design Lab.
Fig. 2 – Thermal Grove, project developed by Michael Clapp and Mike Jonhson at Harvard University, Graduate School of Design under the supervision of Hanif Kara and Leire Asensio Villoria.

ban context, thus potentially strengthening the case for WtE plants in denser areas.

Through our research and survey of existing projects at the WtE Design Lab, we found that in the rare occasions when an architect is involved in these types of projects, their role can often be reduced to the scope of designing the envelope and they are rarely involved with the interior organization of these plants. We believe that this is partially due to a lack of tools and design handbooks/literature that allows architects to engage with the technical complexity of the equipment associated with these buildings.

While several parallel lines of inquiry were pursued within the WtE Design Lab, this paper will specifically cover the lab's development of associative digital models that are intended to operate as design aids and tools for designers in the elaboration of waste to energy facilities.

The development of associative models[1] for use in parametric or associative design can help to alleviate this technical hurdle for architects, particularly in the earlier stages of the design process. The tool has the potential to allow architects to generate other building configurations that allow these facilities to be better integrated within existing urban or suburban fabrics while still accounting for technical feasibility.

Associative modelling and design are a maturing area of exploration in architecture and are being adopted widely by the professional field. These tools and processes are often used to support the design of technically complex building types such as high rises or are also used to reverse engineer complex forms for buildability. However, there are no known precedents of associative models developed specifically for the architectural design of waste to energy facilities and the development of the first example of such tools by the WtE lab is the subject of this paper.

The aims of this paper are to provide an account of how this novel associative modelling tool for the design of waste to energy facilities was developed. The paper outlines the considerations, methods and aims for the tool as well as reflections on its efficacy in application.

The research process included opportunities to track and evaluate the application of the tool in a few actual design processes. The paper will describe these exercises and reflect on as well as evaluate actual practical applicability of these tools. Reflections on the applicability of the associative models will be framed by considerations on how seamlessly the integration of the tool in the design process was, how it functioned as a tool for collaboration with other parties involved in the design process (such as engi-

Fig. 3-4 – Thermal Grove, project developed by Michael Clapp and Mike Jonhson at Harvard University, Graduate School of Design under the supervision of Hanif Kara and Leire Asensio Villoria.

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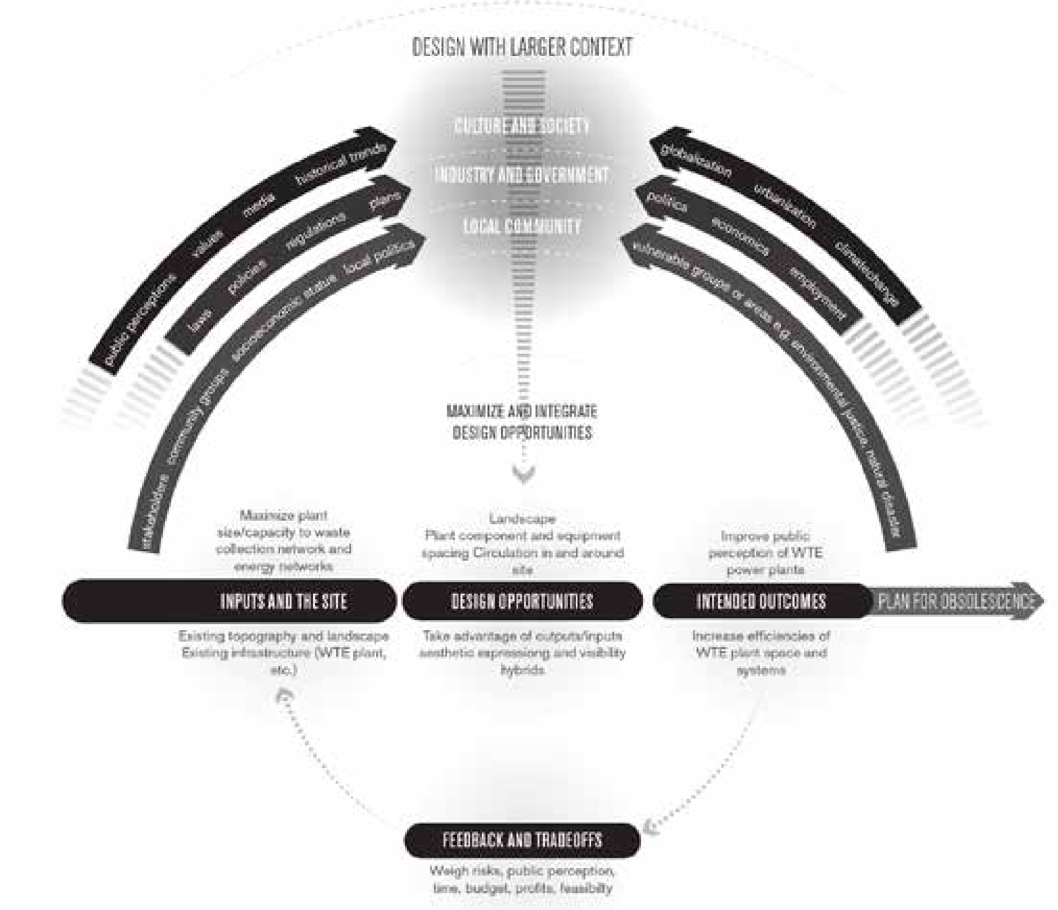
Fig. 5 – Waste, Reuse, and the PARKspace, project developed by Felipe Oropeza Jr. at Harvard University, Graduate School of Design under the supervision of Hanif Kara and Leire Asensio Villoria.



neers) and its capacity to allow for the development of schematic designs of novel WtE facility configurations while allowing for real-time checks for technical feasibility and its effects on wider urban systems as well as contexts.

Method and Materials

In this paper, we will place specific emphasis on the methods that we developed for integrating data and parameters associated with WtE facilities into a computational architectural and urban design generation as well as evaluation process. More specifically, this culminated in the development of associative design models that link digital spatial models to parameters and limits that define the operational integrity of WtE facilities as well as the capacity for real-time evaluation of the measurable performance and potential transgression of these technical limits of different design instantiations.

This project focused on decoding the crucial operations and internal organization of these types of plants as well as siting considerations. One consideration adopted by the team involved the generation of a manual/handbook that indexes each of the components that form these plants. The WtE Design Lab developed both an inventory of the different components that form these plants, specifying their spatial requirements (dimensions, distance to other components, accessibility and maintenance needs, etc.) describing their function as well as dimensional and spatial constraints. These constraints were integrated into a spatial 3D digital model as modeling limits that would allow architects to test a variety of organizations while checking for technical performance in real time. A second equally important consideration was the generation of a tool that would allow to test the viability of different scenarios for locating such facilities in different sites (with their associated constraints) also in real-time.

A parametric framework for design and analysis was generated by integrating information from the inputs and outputs required and generated by these plants as well as the technical handbook that describes the dimensional and spatial constraints of each of the plant's components[2].

The WtE Design Lab developed two associative models to help designers test various options to better integrate a WtE plant in a given context. These tools were tested in a series of sites with a varying set of conditions and constraints, allowing us to assess the effectiveness of the proposed tools, offering insights and findings on their applicability and the extent of support it offers designers in devising design proposals for specific WtE buildings.

Within the WtE lab's design research team, a series of design explorations were conducted by using the associative models to test the implementation of WtE plants in a series of urban and rural contexts, each of them with their specific population densities, urban fabric and thus varying typical urban block sizes. The sites used for this test were Barcelona, Beijing, New York, Boston, Stockholm, Phoenix and Preston, CT.

A second and third test was conducted in the context of an upper level graduate design studio as well as a graduate seminar course offered at the Harvard GSD where the associative models as well as a range of design strategies were handed to a group of students to aid them in the development of WtE schemes that responded to a number of contexts, two sites in the US, Preston and Bridgeport in CT, and two sites in Sweden, Vasteras and Hogdalen District in Stockholm.

The associative models account for a range of plant sizes as well as populations densities. The waste collection catchment area, strength of the energy network and the diversity of waste delivery transportation (such as road, train, boat, or ENVAC systems) are greatly impacted by the size and density of the surrounding communities. These metrics of communities are also a major consideration for which plant size (physical footprint) and capacity will work best.

The associative model developed in the lab accounts both for the district-heating output displaying the area that would be served by the plant given the urban density and programmatic distribution as well as for the possibility of compensating with a large energy-intensive program some of them already coded in the model.

Because WtE facilities are much more effective at generating heat than electricity, combined heat and power (CHP) plants are considered the more efficient and less polluting model rather than electricity producing boilers alone. In contexts where district-heating networks are available, WtE facilities are more cost-effective and efficient sources of energy.

When comparing two of the primary sites of study adopted for this design research; Sweden and the United States, district-heating networks are found to be far less prevalent in the US. Locating complementary programs near the plant is a strategy that can compensate for this lack of district-heating networks in the US. Programs such as a large energy-intensive facility like a stadium, hospital, or university could create a more localized heating network and improve the plant's efficiency. Various forms of district-heating energy systems (usually run on natural gas but also related with local renewable fuels (Henning and Gabremedhin, 2011; Ulloa, 2007) are already located within central business districts, university campuses and medical centers in the United States.

Associative Model I - Measuring associations between waste collection networks with electricity and heat distribution systems is possible at the city scale. The waste inputs and energy outputs associated with various scales of WtE plants are made available to designers and stakeholders in real-time through the associative model developed by the lab. The model is constructed to offer users (such as an architect, city planner, engineer, plant operator) the capacity to define a range of inputs (urban density, desired WtE plant size and the projected programs to be serviced by the plant) that are then evaluated and return outputs such as waste collection catchment area, urban area serviced in electricity and heat by the plant, and a datum for the maximum area that could be served by an associated vacuum waste collection system (Fig.6).

The platform used by the WtE Design Lab to develop this associative model is a plugin for the digital three-dimensional modeling software Rhinoceros called Grasshopper with additional customized components scripted in the C# programming language.

The associative model is established to relate to a given city's population density, city fabric, urban density, parcel size, waste production, as well as heat and electricity consumption per capita. However, it does not factor for geological barriers to district heating, potential losses in electric and heat trans-

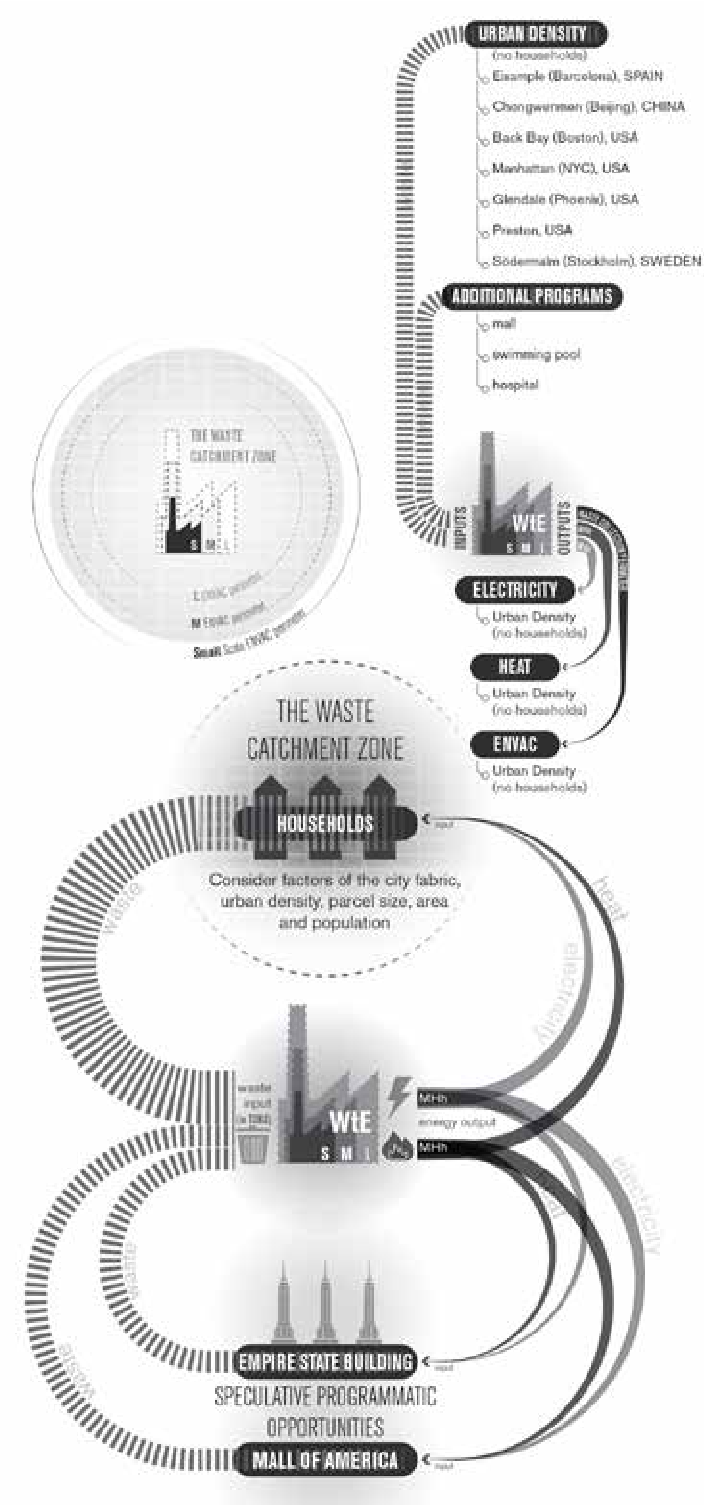


Fig. 6 – Large-scale integration strategy by Laura Smead and Felipe Oropeza Jr, WtE Design Lab.

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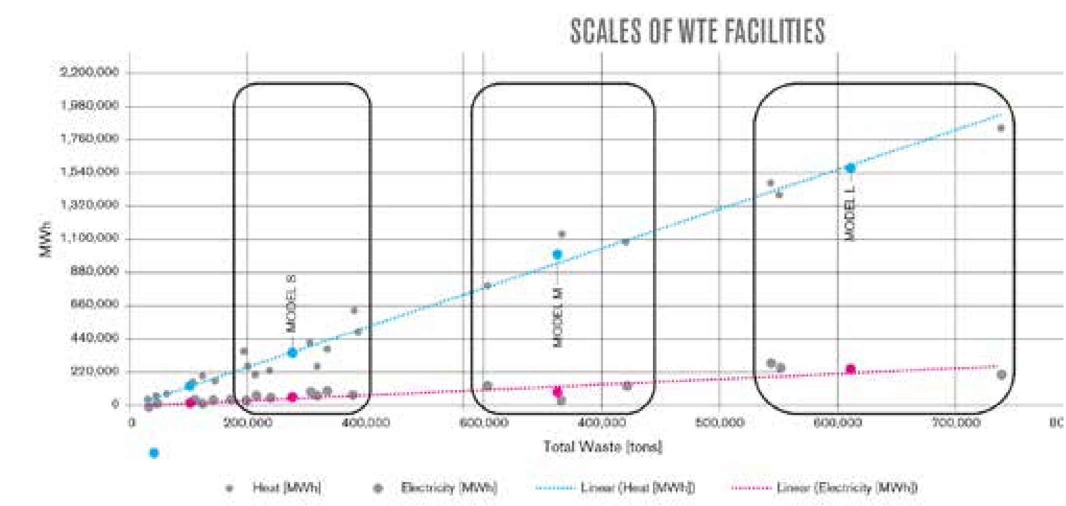
Fig. 7 – Scales of WtE Facilities by Georgios Athanasopoulos and Felix Raspall Gali, WtE Design Lab.

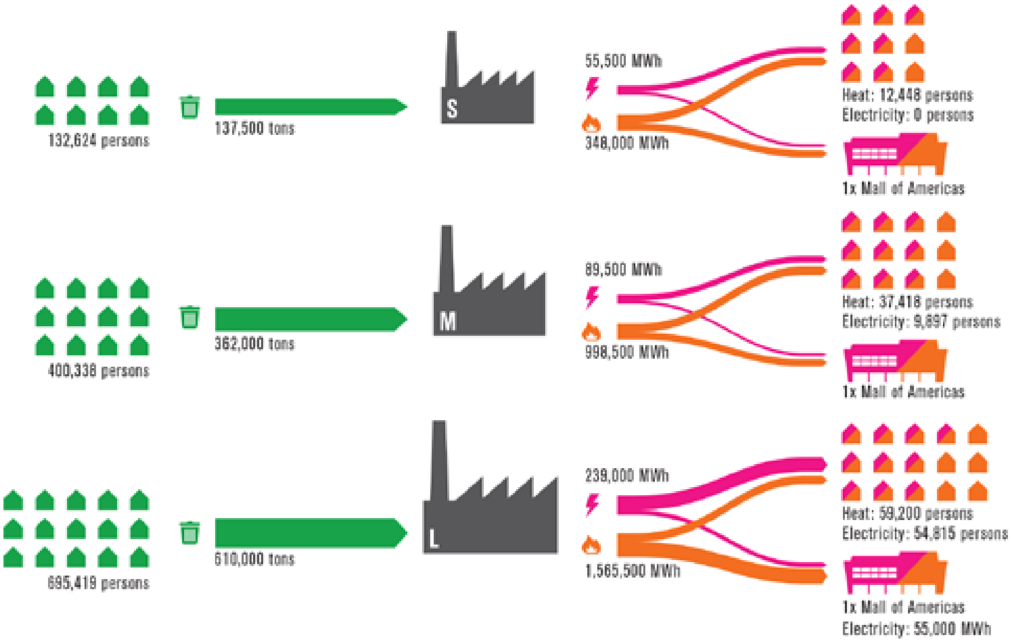


mission, land values, transportation costs or household size.

A range of existing urban density inputs based on model urban areas are already coded as defaults in the associative model. While the input values are variable and easily customized by the user, the urban densities of Barcelona's Eixample, Beijing's Chingwenmen, Boston's Back Bay, Manhattan, Phoenix's Glendale, Preston in Conneticut and Södermalm in Stockholm as well as three industry typical plant sizes; small (100,000 to 200,000 tonnes of waste), medium (300,000 to 400,000 tonnes of waste) and large (550,000 to 750,000 tonnes of waste) are established as default input options in the associative model (Fig.7). A series of programs that could be served by the plant such as residential, hospitals, swimming pools, or malls are also established as default measurable options. This offers the user the ability to measure and test the efficiency and general metrics of different scenarios. For example, one may investigate how many Empire State Buildings a medium-sized plant can feed and how that affects the input and output of the urban grid through the model. Another scenario could be the examination of an existing model such as the Mall of Americas, where the model affords us the ability to see how much waste the complex is providing to the plant and how much of its energy needs are covered (Fig.8).

Besides offering the capacity for locating these plants in a variety of urban densities and fabrics, the investigation into alternative plant configurations was also framed by an ambition to allow for testing the feasibility of different WtE building volumes and configurations that may be more suitable for integration or hybridization with other programs. This complementary or integrated relationship with other programs has efficiency, environmental and operational benefits while also establishing associations with these facilities that could potentially positively address public perception of urban integrated industrial buildings.

More complex scenarios that associate WtE operations with combinations of different hybrid uses and programs are also integrated as capabilities within the model. Through the associative model, realistic proposals for a complete WtE program is made more accessible to designers while also allowing for the study of comparatively different scenarios to aid in the decision-making process related to identifying optimum or most appropriate plant sizes for specific locations and hybridization programs. Two different notation or diagrammatic systems



are established for representing or visualizing the input and output data. For the first notation system, a planimetric interface is adopted to allow for the clear visualization of the typical urban fabric, size of the WtE plant, waste collection catchment area (green), urban area served electricity by the plant (blue), urban area served heat by the plant (red), and the potential use of vacuum waste collection system (represented by a dashed line).

Associative Model II - A second notation system adopts a systems visualization format that resonates with the Odum diagram, which place the data and information variables into a flow diagram of associated or relational inputs and outputs. WtE plant size as well as the size of other programs served by the plant are linked by lines of varying thickness that represent that value of the specific input and output. One graph visualizes the relationship between the city and the plant in terms of spatial ratios of inputs and outputs while the latter translates it in a quantitative manner.

Offering the user the ability to test different design scenarios with ease and allowing for the search of better integration of the plant into a given urban context, all the information in the associative model can be modified and updated in real time. For example, the ratios between inputs and outputs of each plant type size are similar, however when adapting these ratios to different cities, we may see where some types may be more optimal than others.

A second associative model was developed to address the more immediate and tangible spatial and formal consequences of organizing the constituents of the WtE plant into different configurations. The WtE Design Lab produced this model to allow for the generation of a variety of possible configurations that a WtE plant could adopt, while allowing for a real-time evaluation of each organizational instantiations technical and economic feasibility. This model accounts for all the components that form a WtE plant as well as all the constraints attached to them. It allows designers to move components

Fig. 9 – WtE components in typical order by Daniel Hemmendinger, Alkistis Mavroeidi, Felix Raspall Gali, WtE Design Lab.

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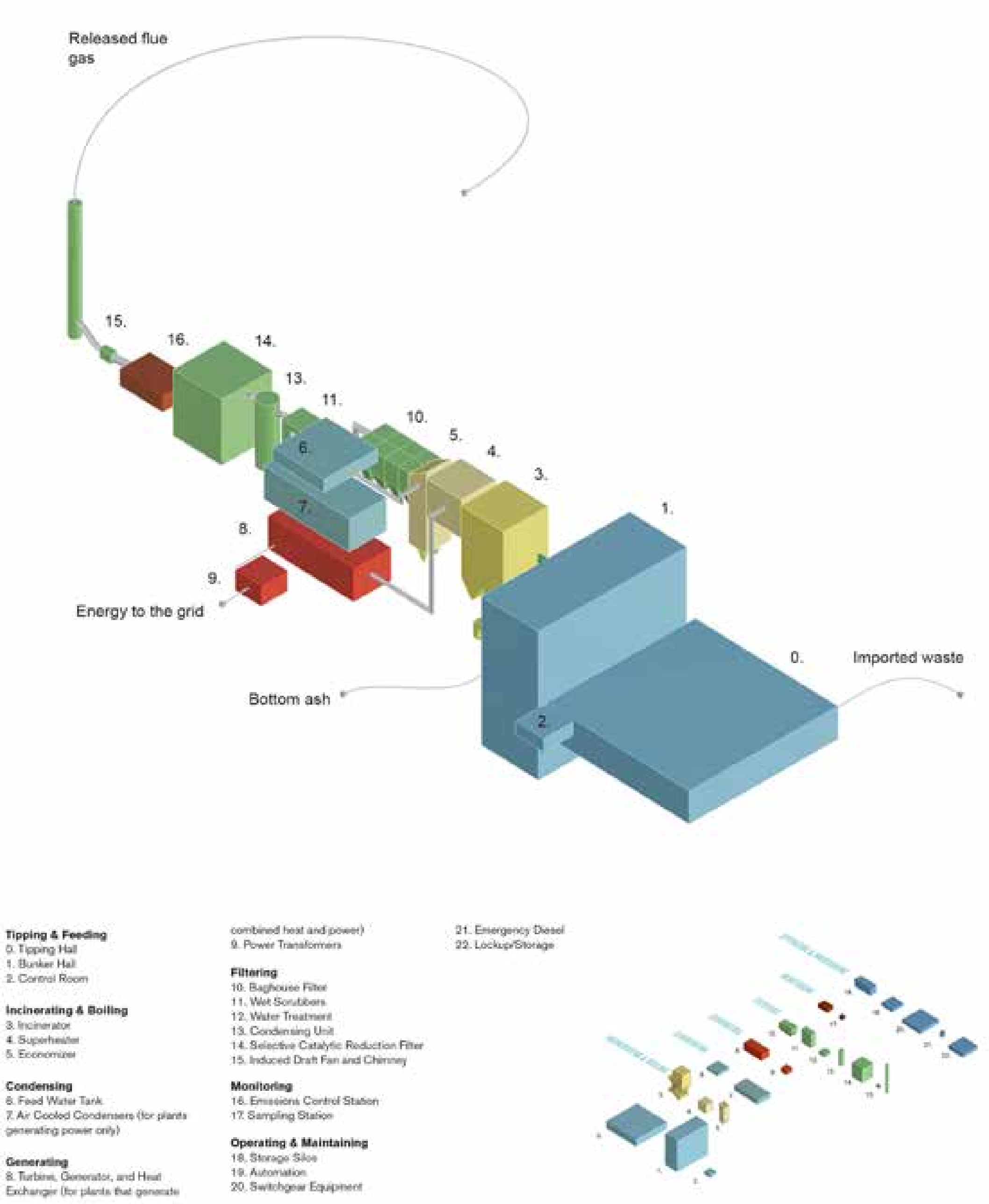
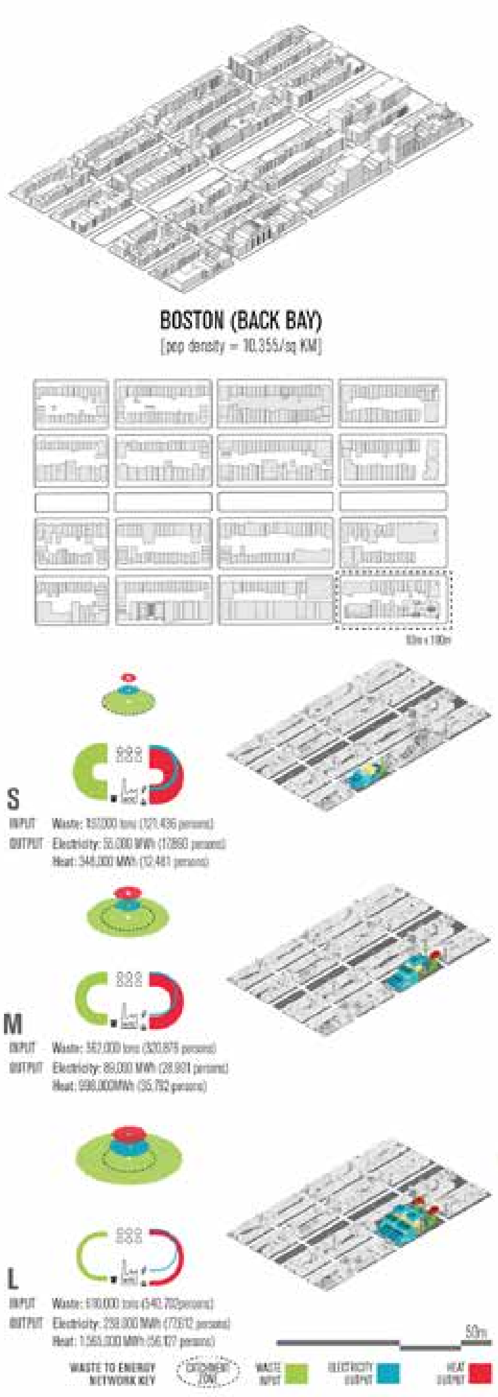
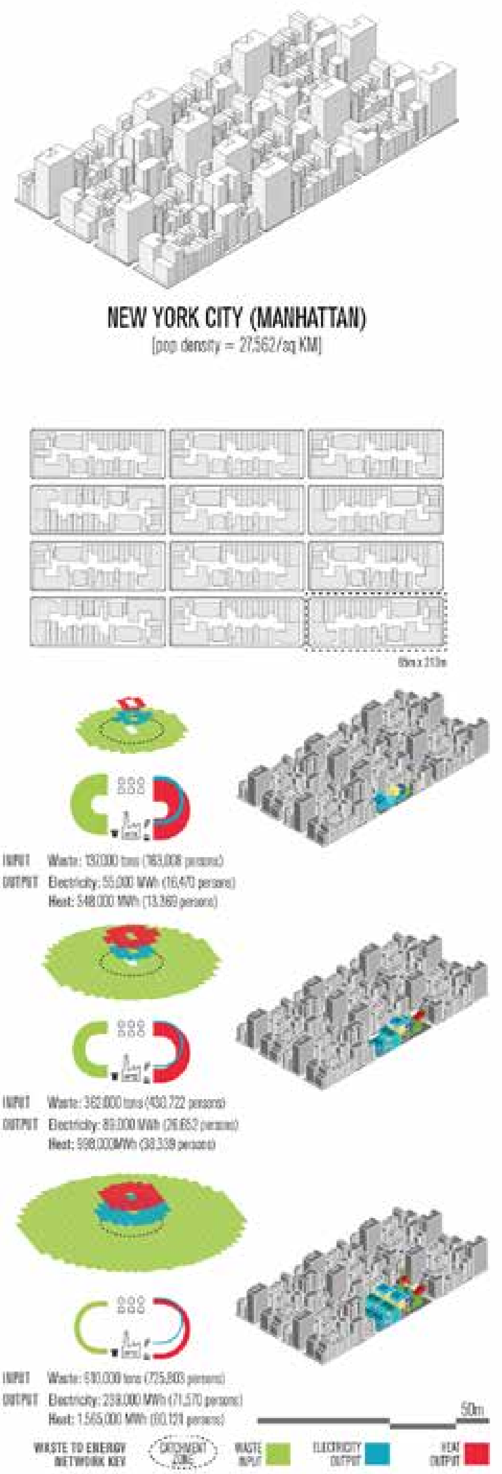
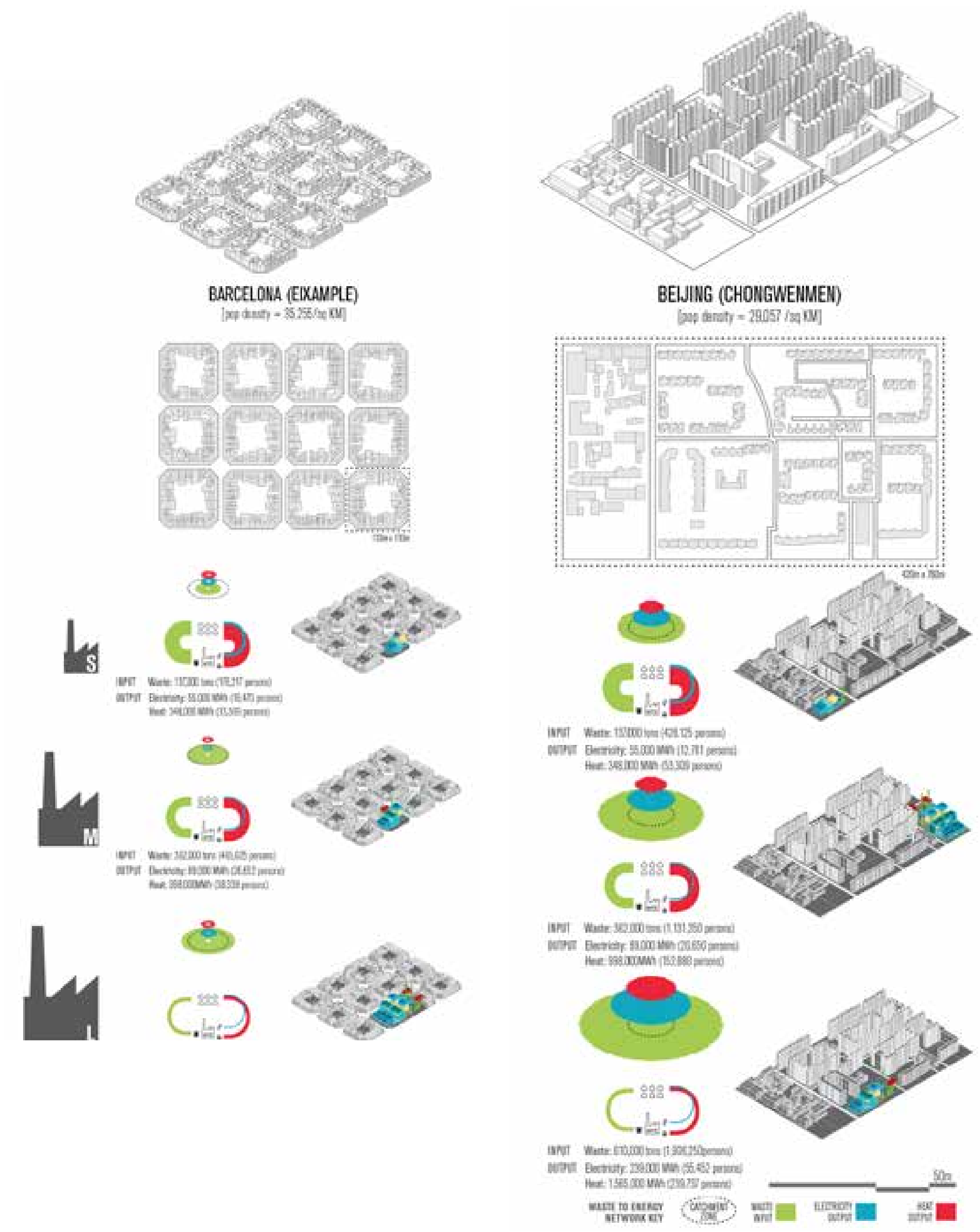
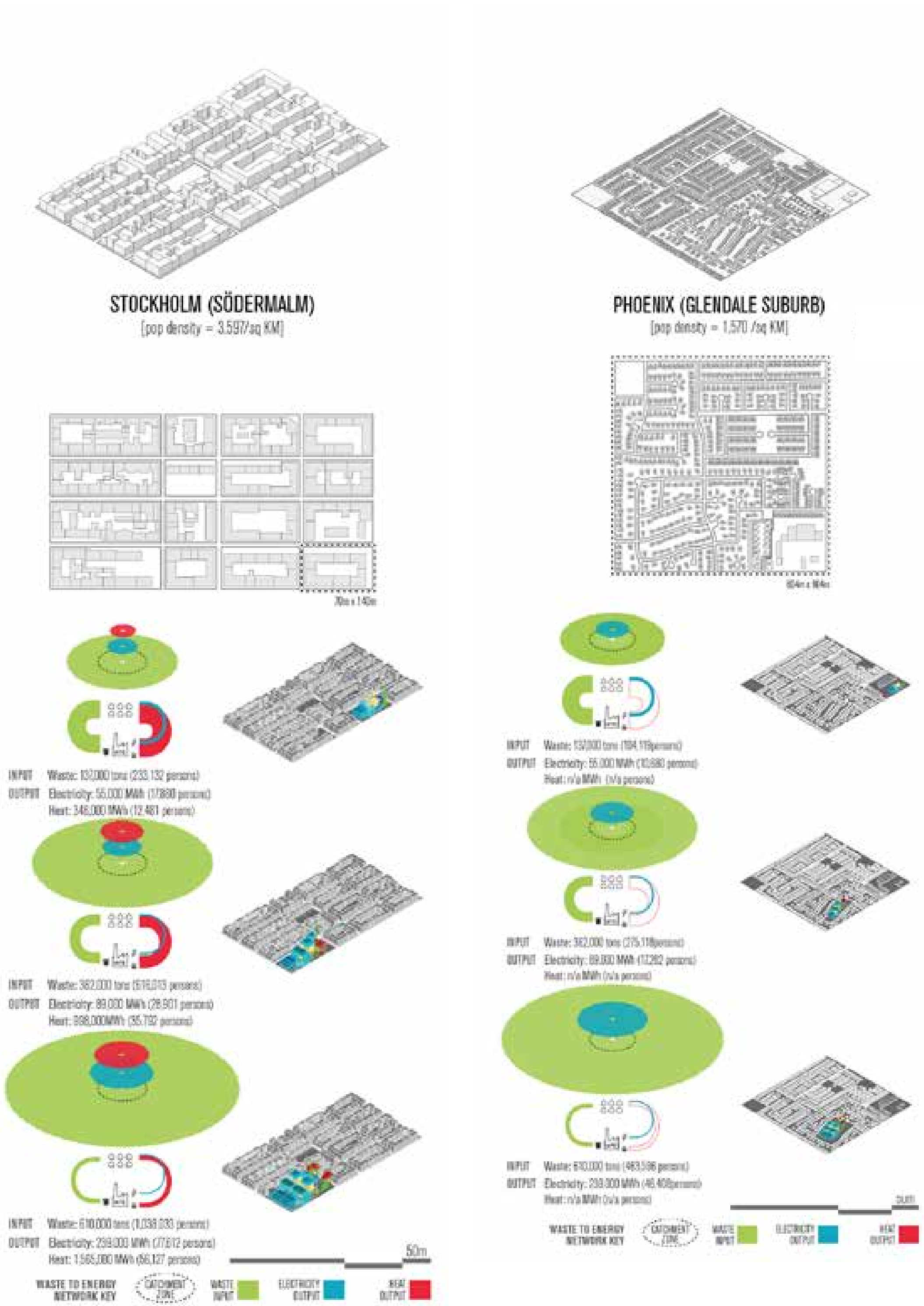
Fig. 8 – Hybrid inputs and outputs by Alkistis Mavroeidi, WtE Design Lab.




BOSTON (BACK BAY)
[pop density = 10,355/sq KM]
50m x 190m
S
INPUT Waste: 150,000 tons (121,436 persons)
OUTPUT Electricity: 55,000 MWh (17,860 persons)
Heat: 344,000 MWh (12,481 persons)
M
INPUT Waste: 357,000 tons (320,876 persons)
OUTPUT Electricity: 89,000 MWh (28,981 persons)
Heat: 998,000MWh (35,792 persons)
L
INPUT Waste: 610,000 tons (540,702persons)
OUTPUT Electricity: 238,000 MWh (77,612 persons)
Heat: 1,565,000 MWh (56,127 persons)
50m
WASTE TO ENERGY NETWORK KEY
CATCHMENT ZONE
WASTE INPUT
ELECTRICITY OUTPUT
HEAT OUTPUT


NEW YORK CITY (MANHATTAN)
[pop density = 27,562/sq KM]
65m x 213m
INPUT Waste: 130,000 tons (163,008 persons)
OUTPUT Electricity: 55,000 MWh (16,470 persons)
Heat: 348,000 MWh (13,369 persons)
INPUT Waste: 362,000 tons (430,722 persons)
OUTPUT Electricity: 89,000 MWh (26,652 persons)
Heat: 998,000MWh (38,339 persons)
INPUT Waste: 610,000 tons (725,803 persons)
OUTPUT Electricity: 238,000 MWh (71,570 persons)
Heat: 1,565,000 MWh (60,121 persons)
50m
WASTE TO ENERGY NETWORK KEY
CATCHMENT ZONE
WASTE INPUT
ELECTRICITY OUTPUT
HEAT OUTPUT


BARCELONA (EIXAMPLE)
[pop density = 35,256 /sq KM]
133m x 133m
S
INPUT Waste: 137,000 tons (170,217 persons)
OUTPUT Electricity: 55,000 MWh (10,471 persons)
Heat: 348,000 MWh (33,565 persons)
M
INPUT Waste: 342,000 tons (405,625 persons)
OUTPUT Electricity: 89,000 MWh (26,657 persons)
Heat: 998,000MWh (58,338 persons)
L
BEIJING (CHONGWENMEN)
[pop density = 29,057 /sq KM]
420m x 780m
INPUT Waste: 137,000 tons (428,125 persons)
OUTPUT Electricity: 55,000 MWh (12,781 persons)
Heat: 348,000 MWh (53,309 persons)
INPUT Waste: 362,000 tons (1,131,250 persons)
OUTPUT Electricity: 89,000 MWh (20,650 persons)
Heat: 998,000MWh (153,888 persons)
INPUT Waste: 610,000 tons (1,906,250persons)
OUTPUT Electricity: 239,000 MWh (55,452 persons)
Heat: 1,565,000 MWh (239,757 persons)
50m
WASTE TO ENERGY NETWORK KEY
CATCHMENT ZONE
WASTE INPUT
ELECTRICITY OUTPUT
HEAT OUTPUT


STOCKHOLM (SÖDERMALM)
[pop density = 3.597/sq KM]
70m x 140m
INPUT Waste: 132,000 tons (233,132 persons)
OUTPUT Electricity: 55,000 MWh (17,880 persons)
Heat: 346,000 MWh (12,481 persons)
INPUT Waste: 382,000 tons (616,013 persons)
OUTPUT Electricity: 89,000 MWh (28,901 persons)
Heat: 998,000MWh (35,792 persons)
INPUT Waste: 610,000 tons (1,038,030 persons)
OUTPUT Electricity: 239,000 MWh (77,612 persons)
Heat: 1,565,000 MWh (56,127 persons)
50m
WASTE TO ENERGY NETWORK KEY
CATCHMENT ZONE
WASTE INPUT
ELECTRICITY OUTPUT
HEAT OUTPUT
PHOENIX (GLENDALE SUBURB)
[pop density = 1,570 /sq KM]
804m x 804m
INPUT Waste: 137,000 tons (104,119persons)
OUTPUT Electricity: 55,000 MWh (10,680 persons)
Heat: n/a MWh (n/a persons)
INPUT Waste: 362,000 tons (275,118persons)
OUTPUT Electricity: 89,000 MWh (17,282 persons)
Heat: n/a MWh (n/a persons)
INPUT Waste: 610,000 tons (463,596 persons)
OUTPUT Electricity: 239,000 MWh (46,408persons)
Heat: n/a MWh (n/a persons)
WASTE TO ENERGY NETWORK KEY
CATCHMENT ZONE
WASTE INPUT
ELECTRICITY OUTPUT
HEAT OUTPUT

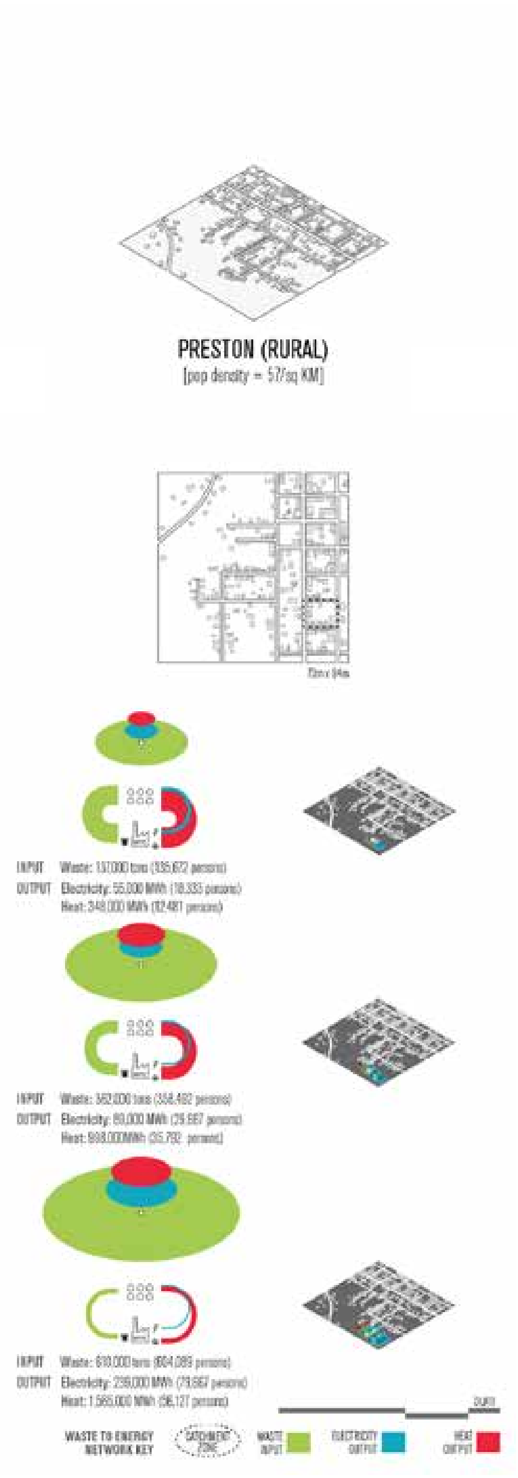


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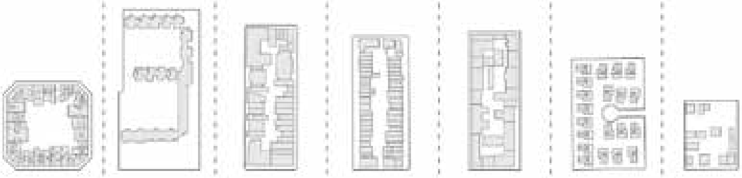
Fig. 10-17 – WtE associative model network comparisons by Alkistis Mavroeidi, WtE Design Lab.

around to create novel WtE configurations where components can be moved, rotated, and stacked, and the model is able to detect problems, such as collisions, proximity constraints, and more in real time. This offers designers a faster front end process of iterative designing that allows for locating a better integration of facility designs within a given urban context and plot size. (Fig.9)

The central premise underpinning the development of this associative model is that every component of a WtE plant has connections to others or that nothing within this waste to energy system works in isolation. The relevant connections and parameters need to be accounted for so that a qualified and relatively efficient design decision making is enabled. The associative model facilitates this process by re-computing these connections at ease and highlighting areas of conflict so they may be provisionally addressed seamlessly within the early design process.

With this associative model, the WtE Design Lab tested a number of strategies for better adapting WtE plants to a range of urban contexts. The strategies were coded as compacting, stacking, fragmenting, bridging, surrounding, and burying and were tested in three urban contexts—Manhattan, Boston's Back Bay, and Stockholm's Södermalm.



		BARCELONA (EIXAMPLE)	BEIJING (CHONGWENMEN)	NEW YORK CITY (MANHATTAN)	BOSTON (BACK BAY)	STOCKHOLM (SÖDERMALM)	PHOENIX (GLENDALE)	PRESTON (RURAL)
		SMALL WTE PLANT (i = 100k - 200k tons/yr)						
S	**EXISTING**		■	+	+	+	+	+
MEDIUM SCALE STRATEGIES see pgs. XX	compacting	+	+	+	+	+	+	+
	stacking	+	+	+	+	+	+	+
	fragmenting	+	+	+	+	+	+	+
	bridging	+	+	+	+	+	+	+
	surrounding	+	+	+	+	+	+	+
	burying	+	+	+	O	+	+	+
		MEDIUM WTE PLANT (i = 300k - 450k tons/yr)						
M	**EXISTING**	+	+	+	+	+	+	+
MEDIUM SCALE STRATEGIES see pgs. XX	compacting	+	+	+	+	+	+	+
	stacking	+	+	+	+	+	+	+
	fragmenting	+	+	+	+	+	+	+
	bridging	+	+	+	+	+	+	+
	surrounding	+	+	+	+	+	O	O
	burying	+	+	O	O	+	+	+
		LARGE WTE PLANT (i = 550k - 750k tons/yr)						
L	**EXISTING**	O	+	O	O	O	+	+
MEDIUM SCALE STRATEGIES see pgs. XX	compacting	+	+	+	+	+	+	+
	stacking	+	+	+	+	+	+	+
	fragmenting	+	+	+	+	+	+	+
	bridging	+	+	+	+	+	+	+
	surrounding	O	O	O	O	O	O	O
	burying	+	+	O	O	+	+	+

\+ compatible with urban fabric   O incompatible with urban fabric

opposite page
Fig. 18 – WtE associative model network comparisons by Alkistis Mavroeidi, WtE Design Lab.

Output and Data Analysis

The associative model was used in testing the implementation of WtE plant within a series of urban and rural contexts, each of them with their specific population densities, grid systems, urban fabric and thus varying typical urban block sizes.

Some of the findings from these different explorations are outlined in the following sections, where the design opportunities and efficiencies found to have been offered by the associative models are elaborated (Fig 10-18). For the associative model 1:

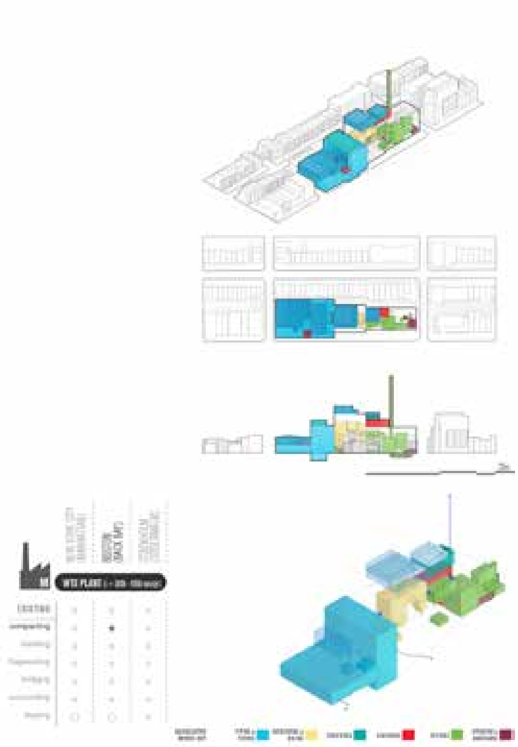
- Generally, the input/output ratio is more optimal with smaller plants. However, conversely, a dense city benefits from larger-scale plants, as it can produce substantial energy while minimizing waste transportation costs.
- The effect radius of larger plants generally surpasses the size of the city itself in low-density rural areas (such as Preston). Locating large WtE plants in low-density rural areas is often one of the most popular solutions; however, integration in these cases is minimal. The input radii are large while electricity and heating outputs fail to correspond to an analogous ratio.
- The effectiveness and economic advantage of WtE plants located in areas with the capacity for district heating is significantly higher than areas that cannot support a district heating system. However, in colder climates (such as Boston, USA), the waste input requirements for heating consumption surpasses that of the volumes needed for electricity supply and therefore these two different resources will be distributed at different effect radii.

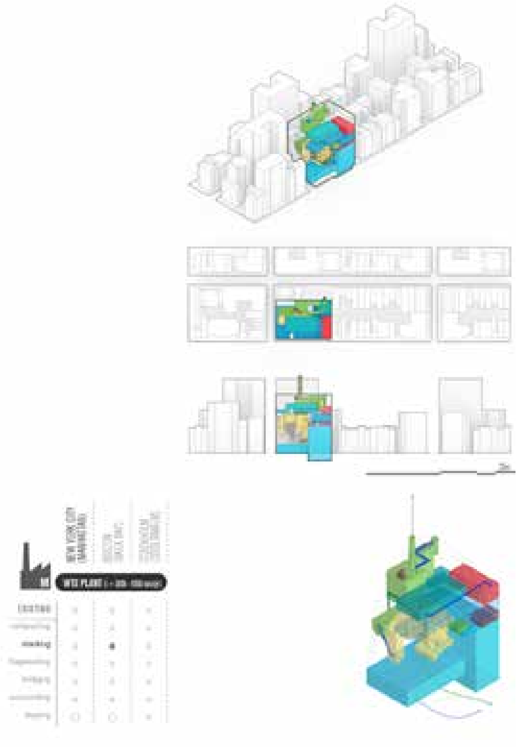
For associative model 2: the application explorations for associative model 2 leverages the capacity for the tool to test different configurations of the WtE plant components to arrange varying building volumes that may better address a diversity of site constraints and conditions. Several design strategies emerged out of this application process with a range of novel arrangements emerging from the negotiation of the requirements of the plant buildings with strict site limitations, while still retaining its technically viability (Fig.19).

Boston (Back Bay)

A notable urban development, Boston's Back Bay follows a pattern of infill and consolidation on reclaimed land. Unlike the rest of Boston, the Back Bay was plotted in a planned grid of narrow streets and sidewalks. Today it is one of the most densely populated areas in Boston, generally consisting of low- to mid-rise buildings with a relatively small urban grain.

This scenario is aimed toward reducing the building


WTE PLANT
EXISTING
compacting


NEW YORK CITY
MANHATTAN
WTE PLANT
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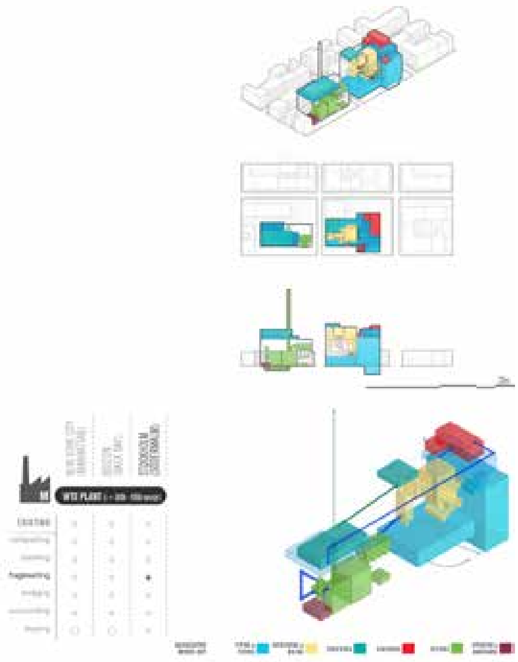
stacking


WTE PLANT
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fragmenting

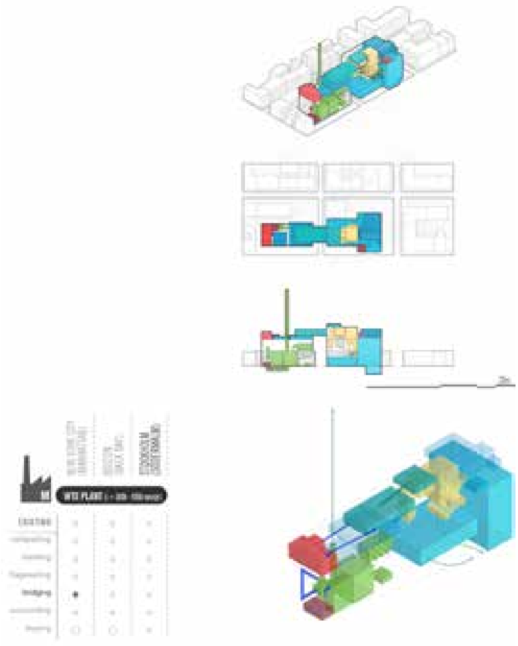
WTE PLANT
EXISTING
bridging

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Fig. 19-23 – Medium-scale strategy per urban context, comparison matrix by Alberto Embriz de Salvatierra, WtE Design Lab.

footprint and height which was achieved through compacting the WtE components to fit and operate within the limits of a typical urban block in this neighborhood. The various operations of the plant are arranged in a linear but efficient sequence. An effort is made to respect existing parcel boundaries while maintaining an accessible perimeter for buffering and maintenance purposes (Fig.20).

New York (Manhattan)

Manhattan's urban fabric is compact with high-rise development being the common practice. Such dense contextual conditions pose a serious challenge for typical industrial applications.

A significant reduction of building footprint by stacking the overall organization of WtE processes is required in this application. Proper access and means of waste delivery to the tipping hall are principal. However, the stacking creates new spatial relationships by rethinking the way space, heat, and enclosure can operate dynamically in section (Fig.21).

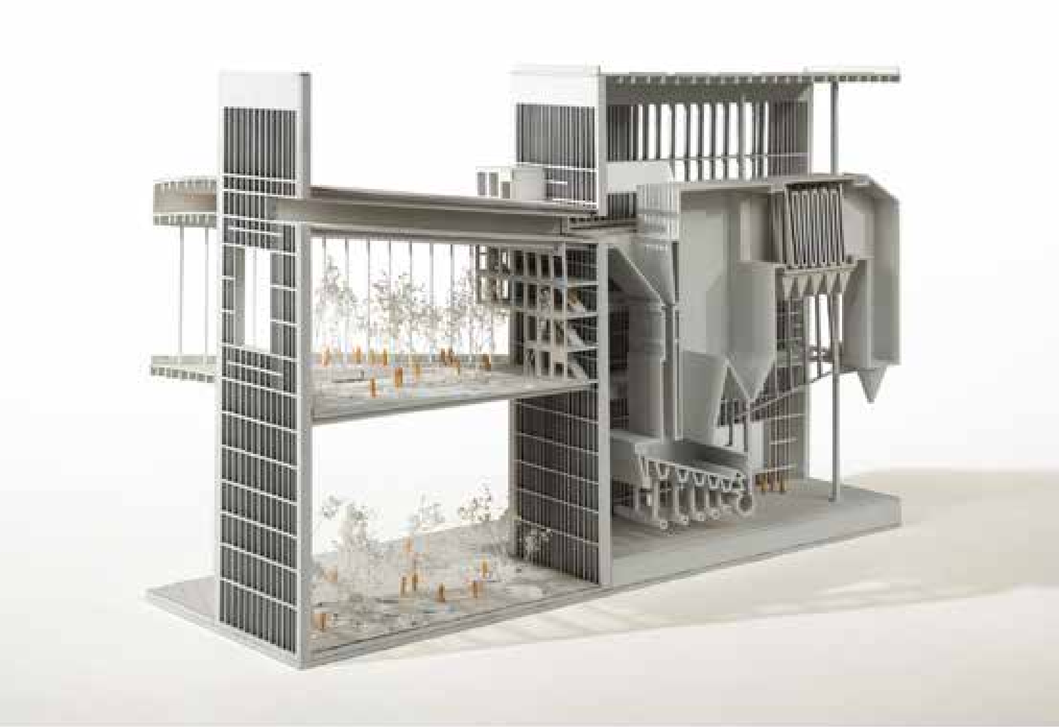
Stockholm (Södermalm)

Södermalm, a historic settlement, is the largest and one of the most densely populated boroughs in Stockholm. While pressure for development is now high, opportunities for building are scarce and developers need to forge creative strategies for development.

To achieve flexible integration into the urban context, the fragmentation of the components of the WtE plants, if developed strategically can be technically feasible. This will enable the location of constituents of the facility across a number of different available parcels rather than the potentially difficult task of consolidating existing properties to house the full plant building (Fig.22).

Another strategy for the integration of a WtE plant within Sodermalm's urban fabric, developed through the use of the associative model is achieved through an exploration of the potential of a conventional horizontal assembly of WtE components.

This speculative proposal involves elevating crucial WtE processes and components. This is done so that the plant may be accommodated within the city fabric yet allowing for pedestrian access through the fabric at a scale that currently exists. One major challenge with the introduction of industrial facilities in urban contexts is associated with the large and blank nature of these typologies, which can pose significant breaks in the continuity of the existing urban structure. This strategy is a means to address this by opening parts of the ground plane of the facility parcel as right of ways.



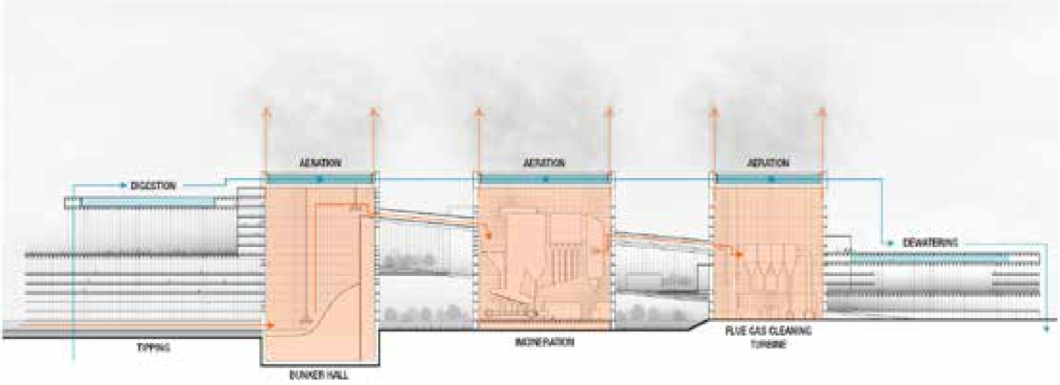


Fig. 26 – Progressive purification, project developed by David Hamm and Snoweria Zhang at Harvard University, Graduate School of Design under the supervision of Hanif Kara and Leire Asensio Villoria.

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Fig. 24-25 – Catalytic currents, project developed by Haggerty and Dana McKinney at Harvard University, Graduate School of Design under the supervision of Hanif Kara and Leire Asensio Villoria.

The associative model helped to test the technical feasibility of such an option. (Fig.23).

Conclusion

There is a generally accepted wisdom that industrial plants, including WtE plants, are better suited for rural or single-zoned industrial contexts. However, the location of a WtE plant closer to an urban context -even a city center- has a number of great benefits to its operation and has the potential to minimize its environmental footprint. Receiving waste directly from a plant's surroundings could help reduce transportation costs, allow for the implementation of efficient district heating, or make possible the development of hybrid facilities that integrate public life into the plant.

The WtE dLab at Harvard's Graduate School of Design invested in developing computational design tools as well as devising a taxonomy of design strategies for better integrating these facilities in urban contexts. These are intended to help guide and educate designers in being more resourceful when developing proposals for better integrated WtE plants while being mindful of their often-complex technical constraints.

It is intended that these tools can help facilitate the introduction of the much-needed participation of architects in the process of planning for these major energy infrastructural facilities. In specific countries such as Sweden, where there is an adoption of WtE technologies as crucial components of the national energy plans, the successful stewarding of the process of their integration within the wider built environment may well be determined by how well access to the management of the technical and engineering complexities of these projects may be given to architects. Indeed, as demonstrated through the design research conducted within the GSD WtE dLab and through the advanced option studio, with the help of these tools and design guides, the role of the architect in this process can certainly go beyond simple aesthetic flourish (Fig.24-27).

To gather valuable feedback regarding the effectiveness and applicability of the design tool in projects that encompassed a wide range of contexts and conditions, we conducted informal exit-interviews as well as we established more formal evaluations regarding their experiences, judgements, and their use of the associative tools. In the WtE lab, we also developed a large generated sample of design

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Fig. 26-27 – 5H Hybrid, project developed by Alberto Embriz de Salvatierra at Harvard University, Graduate School of Design under the supervision of Hanif Kara and Leire Asensio Villoria.

applications in varying contexts and related to different hybrid programming strategies. In both cases, the associative models were found to be valuable instruments that operated as an accomplice in the design process. However, it was generally found that the responses from the students and findings from the lab showed a consensus on the view that the associative models were good tools but did not constitute an automation of the design process and did not preclude the need for a designer. Rather, it was found that it enabled better understanding and access to the technical complexities of these infrastructures but still needed the involvement of professionals with a domain expertise in architectural, landscape and urban design.

Endnotes

[1] Associative design is a design practice that relates performance parameters with the development of geometric and organizational design models. The practice is invested in the use of multiple performance parameters and information as the main drivers of the design process. This design approach also affords the capacity to rapidly generate different iterations of design models based on changes to the variables of these related parameters.

[2] This technical handbook was created by the WtE Design Lab through an extensive literature review focused on the anatomy and technology that drives/constitutes a Waste-To-Energy facility as well as close collaboration with the engineer Christer Anderson, AF Industry.

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