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From Technology to a Landmark –Selected Thermal Waste Processing Plants in Europe

Agnieszka Wojtowicz-Wrobel¹

¹ City Renewal Division, Institute of Cities and Regions Design, Faculty of Architecture, Cracow University of Technology, Warszawska24'St, 31-155 Cracow, Poland

awojtowicz@pk.edu.pl

Abstract. Rising pollution levels and the amount of generated municipal waste places new challenges before modern cities. These are challenges of a technological, economic, social, as well as a spatial and architectural character. These challenges, when architectural matters are concerned, are often strictly associated with technological conditions. New solutions in the field of technological installations can constitute limitations in design terms, or quite the contrary - they can be treated as guidelines in the case of the creation of a new form. The goal of this article is to provide an answer to two questions: In what manner (in the case of thermal municipal waste processing plants) is the shape of a structure determined by technological solutions? In addition, in what scope does the effect of mutual architectural and technological dependencies in the form of a building affect the immediate surroundings of such plants and - on a wider scale - the space of a city. A significant element of this article is also an attempt at determining whether currently designed new thermal municipal waste processing plants are being located in a manner that gives them the capacity to also play a considerable role in the crystallisation of the structure of a city or of suburban areas, including metropolitan ones. One country that has been faced with the challenge of building new thermal waste processing plants is Italy, due to the considerable problem of managing municipal waste and the associated environmental and social problems. The research performed by the author included an analysis of a selection of thermal waste processing plants located in Italy. Afterwards, as a part of a case study analysis, those structures that stood out against the analysed set either due to distinct architectural features or a higher capacity for spatial impact were presented. The case study presented by the author formed the basis for a discussion about the subject of architectural form and the significance of pro-environmental structures with a hybrid form of use within space. The conclusions drawn from the study can also be useful as models of implementing pro-environmental solutions in other countries that are currently facing an unsolved problem of stockpiling municipal waste.

1. Introduction – research structure

The research contained below is a part of the author's work on a cycle of publications focusing on structures that have new, pro-environmental forms of use as innovative elements of urban and suburban structures. The ongoing research refers to two groups of structures: thermal waste treatment plants and wastewater treatment plants. The research performed as a part of the abovementioned cycle of publications focuses on the following subject groups:



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- the significance of thermal waste processing plants and wastewater treatment plants as viewed by the public,
- their significance as architectural forms,
- location and accessibility,
- spatial relations, significance in urban and suburban tissue,
- technological matters (against the backdrop of the subject of architecture, urban design and spatial planning).

The research performed by the author can be depicted in the form of the following table scheme (Table 1):

Table 1. Table scheme of the research performed by the author - matrix structure.

	Social	Architecture	Locations/ Accessibility	Urban Relations	Technical Issues
Thermal Waste Processing Plants	S/TWPP	A/TWPP	L/TWPP	U/TWPP	<u>T/TWPP</u>
Wastewater Treatment Plant	S/WTP	A/WTP	L/WTP	U/WTP	T/WTP

The matrix structure that was employed makes it possible to clearly present both the idea of the research, as well as the work that has so far been performed in a given field. This type of structure - even though it is the most commonly used one in organisation schemes, also sees effective use in the systematising of scientific research in the field of architecture, urban design and spatial planning (cf. B. Podhalański, 2017 [1]). As a part of a cycle concerning two types of structures with new pro-environmental functions, the author has performed and published studies concerning social problems (S/TWPP - „Social reception of thermal waste processing system structures”), architectural ones (A/TWPP-„The beauty of ecotechnology - thermal waste processing plants as a structures that increase the attractiveness of city spaces”), problems concerning location (L/TWPP - „Thermal waste processing system structures. Questions of location and accessibility - polish experiences”) as well as spatial relations (U/TWPP - „On the cusp of spatial challenges - the thermal waste processing plant as an element of urban space”) in reference to currently built thermal waste processing plants. This article concerns technological matters, primarily their influence on the architectural form of a given structure and thus its indirect influence on the space of cities and of suburban areas, on the example of selected thermal waste processing plants.

2. Aesthetic problems - research background

Just as the role of spatial landmarks is essential in the shaping of the structure of cities, the role of function in the shaping of the form of a structure is equally important. The functions performed by structures that surround us is, for obvious reasons, placed first by the average user of a city, which is why their significance is of fundamental importance in urban tissue. Forms of use can also be associated with meeting needs. However, the beauty of a structure, although intangible (and thus more difficult to define than a directly defined "function"), is also equally important. Visual aspects are also associated with meeting needs, but these are needs of a different type - a need for beauty. Beauty in this point of view has constituted a significant element of scientific studies numerous times, both in reference to the theory - understood here in a multi-planar manner - of art, as well as from the point of view of social and psychological studies. In the hierarchy of needs as defined in 1943 by Maslow [2], which has become the basis for further scientific discussions (cf. [3] and others), the need to experience beauty and aesthetics can be counted among the higher needs within his pyramidal layout,

located in the group of self-actualisation needs (Figure 1). The necessity of satisfying aesthetic needs is placed at an equal level with, for instance, the satisfying of the need for knowledge.

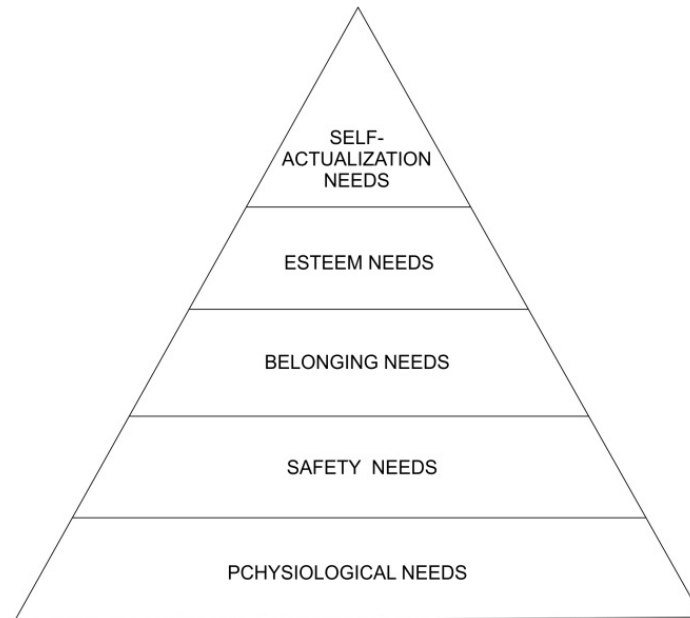


Figure 1. The pyramid of needs according to A. H. Maslow, original work based on source materials, [2]

Architecture can be defined as the art of shaping space [4], which is why works created as a part of this art can be analysed from the perspective of categories of broadly understood beauty. It is thanks to aesthetics and composition, rhythm, shade or texture that we can label some structures - without regard for their function - as being received as visually attractive, while others as being unattractive. From this point of view, the role of landmarks as structures that are visually distinct within an urban space becomes particularly significant [5].

The principle of defining architecture as a field of art can be analogously referred to urban structures - as sets of such elements. We are more eager to reside in some urban structures while others do not attract our attention. From the point of view of a "standard resident", functionality seems to be more important in reference to daily life, while aesthetics or composition - although they are equally important there - appear to gain in significance when we are analysing a given space from the point of view of, for instance, matters of attractiveness for tourists, and not in terms of daily life. It can be assumed that the historicity of structures or a lack thereof is not important here, as - in general - both protected rural medieval layouts with preserved buildings [6], urban layouts with narrow streets and church towers dominating the landscape [7], as well as large modern metropolises with tissue following contemporary design [8] all have their fans. Beauty and harmony, composition or, on the contrary - a "controlled decomposition" can speak of the attractiveness of a structure, space or complex of buildings.

The protection of the environment of human life is strictly tied with urban efforts and the relations and influence of urban morphology on environmental problems is a significant and permanently topical subject of research [9]. Works of architecture featuring technological and industrial forms of use constitute an interesting group in reference to matters of architectural aesthetics. On the one hand, they are structures in which aesthetic qualities have often played a secondary role. Their functional significance was of primary importance and the massing was decidedly determined by engineering solutions. Such an approach, concentrating mainly on the technological side of a structure while ignoring its architectural qualities has been particularly observable since the second half of the

twentieth century. This is not a rule, of course, nevertheless the tendency to chiefly focus on the utilitarian aspects of structures of this type is encountered very often. Thermal waste processing plants are a specific example here. Due to their function and - generally - negative public reception, they have usually been placed in the outer zones of cities and without much care for the architectural qualities of each structure. Particularly in the second half of the twentieth century were structures with this form of use built not only as - as we say - a technical structure enabling the possibility of performing technological actions. Architecture constituted but a "functional envelope" for the technology hidden inside (Figure 2).



Figure 2. Thermal waste processing plant in which architecture plays the role of a functional envelope of its technological installation, Gioia Tauro, Italy.

3. Technological solutions - research field

Since the start of the twenty-first century we have observed considerable technological progress in terms of the management of municipal waste and using it to reclaim energy. This has been caused by, among other factors, the necessity to search for new solutions as the amount of waste being produced is constantly rising while available resources are being depleted. In terms of waste management, its segregation is, indisputably, the most important, followed by its reuse in accordance with the idea of the Circular Economy¹. The thermal treatment of municipal waste is thus the final element of the cycle of a product's use - however, it is not a necessary element, as even with a significant rise in awareness concerning the significance of recycling, there will always be types of waste that cannot be recycled and reused.

The method of processing municipal waste requires constant development and efforts to this end are being made. In terms of the search for new technological solutions, on the one hand we are seeing a lot of focus on the effectiveness of installations; their energy efficiency, the length of waste

¹ Circular Economy is an idea whose principle is based on the reuse of products to the greatest possible degree. It lowers both the amount of produced waste, as well as increasing the reuse of resources. The idea of circular economy is the opposite of a Linear Economy. The idea of a Circular Economy is one of the main elements being introduced by the European Commission as a part of pro-environmental efforts. [10]

processing, their types and variable calorificity, while on the other, on their safety (lowering the amount of harmful substances being produced during the technological process, modernising methods of exhaust purification, appropriate and safe use of post-process remains, etc.). From the point of view of engineering, we can observe two forms of efforts in relation to technology: on the one hand, new technological systems are being introduced, which is being done with varying degrees of success, while on the other, already existing processes are being perfected. In terms of public reception - which in the case of thermal waste processing plants is an exceptionally important and constantly discussed subject [11], efforts aimed at the introduction of new technological systems (often not fully tested, but that are not negatively associated with "burning trash") are met with more acceptance than the modernisation of already existing systems, which are strictly linked with the idea of thermal waste processing [12].

The search for more effective means of waste management has led to a situation in which we can currently list various different types of systems that meet this need. New technologies, from the conceptual stage to that of their implementation and actual use, undergo a series of tests. Oftentimes, solutions that would appear faultless and above average on the basis of their idea alone, could not rise up to the challenge on a larger scale. Equally often, implementations that worked on the scale of a laboratory model, and even on the scale of an actually working model installation, would not pass the test of working on actual waste processing. Technologies were proven faulty due to, for instance, the length and amount of processed waste, due to the inability to effectively incinerate waste with variable parameters (e.g. municipal waste with varying levels of water content over a yearly cycle), or have even turned out to be - when faced with actual use - too faulty or, in the long term, too costly for their introduction to be a favourable solution. From among the actually used technological systems seen in thermal waste processing plants, we can list technologies based on grate furnaces, rotary or oscillating kilns, fluidised beds, as well as technologies utilising pyrolysis and gasification. We are also seeing installations that utilise combined technologies (e.g. one processing line works on the basis of a grate furnace, while the other on the basis of a rotary kiln or fluidised bed).

Table 2, which has been placed below, provides an overview of the types of technologies employed in thermal waste processing plants in nineteen selected European countries. The table includes five of the most commonly used types of furnaces (movable grate, rotary kiln, fluidised bed, gasification, pyrolysis). One of the groups contains all the technologies sporadically used among all the analysed structures, as well as those structures in which several different processing lines utilising different technologies are used. In addition, those thermal waste processing plants which operate and in the case of which no information could be obtained regarding the type of their installation, have been listed separately. The listing contains a total of 467 functioning plants, of which ninety have been excluded from further percentage analysis due to the aforementioned lack of data. From among the 377 plants whose technical data was available, as many as 301 operate using grate-based technology, which constitutes 80% of the entire analysed group. Furthermore, we should also note the fact that the second-largest group (12% - other technologies and mixed technologies), in the case of mixed technologies, the vast majority is based on at least one grate-based thermal waste processing line. It can thus be assumed that close to 90% of the analysed structures work using a movable grate furnace. Only up to 5% of plants use fluidised bed technology, while 2,5% employ a rotary kiln, with up to 1,5% of the plants included in the list using thermal waste processing technology employing gasification or pyrolysis.

As it has already been mentioned, despite greater public acceptance of "new solutions" in terms of technological matters, actually employed systems prove that grate technologies which have been known for many years and have been constantly modernised, constitute the basis of currently operating thermal waste processing plants. It is a type of technology that is most often used and - in comparison to other types - one that is the most tested and safe at the current stage of technological development [12].

Table 2. Table listing of thermal waste processing plants operating in selected European countries, divided into types of the thermal waste processing technology employed by these plants; based on collected data [13] and other sources, for the year 2012 (original work, 2017).

Country:	Installation type:							Total:
	Movable grate	Rotary kiln	Fluidised bed	Gasification	Pyrolysis	Other/mixed	No data	
Austria	8	-	3	-	-	-	1	12
Belgium	6	-	-	-	-	1	9	16
Czech Rep.	2	-	-	-	-	-	1	3
Denmark	21	1	-	-	-	4	3	29
Finland	1	-	-	-	-	-	5	6
France	100	5	3	-	-	15	4	127
Germany	55	1	2	-	1	4	16	79
Hungary	1	-	-	-	-	-	-	1
Ireland	1	-	-	-	-	-	-	1
Italy	33	-	4	1	-	12	3	53
Netherlands	10	1	-	-	-	-	2	13
Norway	5	-	-	2	-	2	6	15
Portugal	3	-	-	-	-	-	-	3
Poland*	1	-	-	-	-	-	-	1
Slovakia	2	-	-	-	-	-	-	2
Spain	7	-	2	-	-	-	2	11
Sweden	17	-	3	-	-	4	10	34
Switzerland	23	-	-	-	-	-	7	30
United Kingdom	5	1	1	-	-	3	21	31
Total:	301	9	18	3	1	45	90	467

*installations in countries not belonging to the International Solid Waste Association

4. Discussion and case study

It should be highlighted that, despite technological differences among the most commonly used technologies listed in table 2, although the differences in engineering solutions are considerable, they do not exert a direct influence on the massing solutions of the plants. At the same time, the model "technology-massing" relations presented in this article feature grate technology solutions, due to the fact that they are the most frequently used. From an architectural point of view, of note is the fact that the massings of environmentally friendly waste processing plants, contrary to the vast majority of municipal services infrastructure structures, are not as highly defined (in general) by the type of employed technical solutions. Indisputably, the smokestack remains a plant's determinant and its main spatial landmark². Its height must reflect the technological requirements of employed technical and technological solutions. However, the remaining part of the installation does not significantly depart - in massing terms - from other large structures. It is, without a doubt, an advantage, when viewing such a plant as a spatial element within a city. Indisputably, the height of the smokestacks and the general size of an environmentally friendly incineration plant predestines such structures to play a - visually - significant role in the space of cities and suburban zones. It is for these reason that their architectural expression is such a significant element.

² An example of a visual comparison of smokestacks and the landmark of an old town on the basis of the Thermal Waste Processing Plant in Krakow and the tower of St. Mary's Church has been presented in the work of the designer of Krakow's environmentally friendly incineration plant - Bogusław Wówrzeczka [14]

Since the start of the twentieth century we have observed a considerable intensification of care for the architecture of waste processing plants. This is particularly evident on the example of newly built projects, where, apart from the obvious functional significance, we can also see great care for their architectural form, both in terms of composing their massing, the materials or in the context of a given structure's significance within space. In reference to architectural forms, we can also observe two approaches: one, in which the smokestack constitutes a visually significant and highly exposed element, often with a more moderate form of the massing of the plant, and one in which the massing is an expression of an architectural work, while the smokestack is merely a technological element, not as significant in architectural categories. One of the elements that have caused the quality of the architecture of thermal waste processing plants to considerably increase is the possibility to interweave socially significant forms of use into such structures. A significant part of the structures has in their offering the possibility of organising didactic trips or open days that can familiarise visitors with both the idea of the technological functioning of such structures as well as - in general - modern concepts of environmental protection, which such structures are in line with.

One of the examples of good practice in the shaping of the architectural form of such a plant is the thermal waste processing plant in Padua, with its distinct smokestack forming an identifiable element of the point of contact of urban tissue with an industrial zone (Figure 3). Of particular note is its form, which fully illustrates an approach that concentrates on the significance of the dominant element of this structure - the smokestacks, an aesthetic shaping of its massing as a whole, as well as the significance of the plant in the surrounding space.



Figure 3. Thermal waste processing plant - example of a built project of a city engineering services structure as a spatially significant form; Padua, Italy; phot. by the author, 2017

The thermal waste processing plant in Padua belongs to the Herambiente consortium - the largest Italian group working in the field of the management and broadly understood processing of waste. Waste processing plants are but one of the forms of Herambiente's activity. The company is the owner of, among other things, ten thermal waste processing plants in Italy. Apart from Padua, its installations are located in such cities like Trieste, Ferrara, Modena, Bologna, Faenza, Ravenna, Forli-Casena, Rimini as well as Pozilli. The first waste processing plant in Padua was built in the 1950's. It was the first Italian plant in which energy was generated through the incineration of waste - it was, at the time, a very modern approach. Both the first, as well as the later second line began operating in the 1960's, processing 140 (in the case of the first line) and 150 (in the case of the second) tons of waste every 24 hours. The contemporary environmentally friendly incineration plant in Padua, which meets all current standards both in terms of waste processing technology and environmental protection, has been operating in its current form since June 2010. It has three technological lines, all of which are based on the movable grate technology. The plant processes 600 tons of waste per 24 hours and accepts municipal waste, specialist non-dangerous waste, as well as medical waste that could constitute a source of infection. The technology is enveloped in an attractive massing, whose main dominant

feature is the plant's smokestack. The structure is located in the eastern part of the city, in an industrial zone located between the residential districts of San Gregorio, Camin and Oltre Brenta. The environmentally friendly incineration plant itself is located in the western part of the industrial zone, from the side of the city centre, at the point of contact with the district of San Gregorio and constitutes the first structure when viewed from the side of the city centre, which, thanks to its shape - effectively masks the remaining industrial structures, which have a less attractive architectural form. The location of the plant near the shore of a branch of the river Bacchiglione additionally causes it to be a visual attraction, which can be observed using the walking and bicycle paths that run along the watercourse from the centre of the city into open areas. It is, undoubtedly, a positive pro-environmental plant, not only for architectural reasons, but also location-related ones.

5. Conclusions

The placement of thermal waste processing plants in cities and suburbs is, undoubtedly, a new spatial challenge. The fact of the spatial significance of such structures due to their size (including their height) appears to be of particular significance. Based on the research and observations that were performed by the author, it can be concluded that:

- The most commonly used type of technology is a technology based on the use of movable grates. It is a well-known and tested technology that is also constantly being modernised, and is also capable of processing types of waste featuring varying energy parameters, contrary to many newer solutions (e.g. pyrolysis installations).
- The technology of waste processing (in general) significantly affects a given plant in the context of dominant elements (smokestacks), while - in comparison to other structures that provide municipal technical services - waste processing technology in and of itself (in relation to other elements of a massing) does not force significant constraints that would cause a structure to be clearly visually identified as a thermal waste processing plant. This provides wider possibilities in terms of the visual design of the massing.
- A certain freedom in the design of the massing of the structure and the simultaneous respect for the elements that dominate its composition is of particular significance in the case of the placement of thermal waste processing plants in urban areas. There, environmentally friendly incineration plants can play the part of a sort of "architectural hallmark - gateway" to a city.
- Due to the height of the dominant elements it is particularly important for such structures to be placed in such a manner that they can harmonise not only in terms of relations with their immediate surroundings, but also in the skylines and panoramas of cities, while taking into account further observation points.
- Due to two factors: the size of a plant and its dominant spatial elements, as well as due to the placement of such structures, it is very important that they are structures shaped using the highest standards of architectural quality.
- Using the latest built projects as a basis, we can observe a positive tendency in terms of the visual changes in these types of structures. Their designs are increasingly frequently chosen through a competition. The architectural care for not only the administrative and office section of these plants, but also for the entirety of their form and their surroundings is also observable.

While formulating the conclusions and observations made on the basis of the research that was performed by the author, we can observe that, in the case of thermal waste processing plants, technological solutions are of key importance not only because of environmental protection, sustainable development or due to economic concerns, but are also equally significant structures in urban or suburban tissue for visual reasons from the point of view of architecture and urban planning.

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