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Time Tested Applications of Solar Energy in Rome

Kelly Kobashigawa September 16, 2013

Introduction

The Roman Empire was known for its efficiency and skill in engineering technologies. As their society became more lavish and populated, a sophisticated culture began to complement their technical abilities. One of their major structural accomplishments was the construction of the various baths around Rome. These bathhouses were some of the first places in which vaults, domes, and large windows were found. By the fourth century A.D., there were more than 800 baths in the city of Rome (Borrelli & Targia, 2008). Not only were these buildings magnificent in structure, they were exemplary in solar design.

Romans were proficient in expanding upon and improving the ideas of others as seen in their use of Greek architecture techniques. The Greeks used many solar energy technologies that were adopted by the Romans. The Baths of Caracalla and the Forum Baths at Ostia will be used as examples of how the ancient Roman Empire used passive solar energy and radiant heating. The process of these techniques will also be analyzed. The longevity of passive solar energy and radiant heating is evident as they can still be integrated into the technology that is used today. Just as the Romans improved on past technologies, society today uses Roman ideas as a basis for design and engineering. There has been immense growth in the field of renewable energy and green technology in recent years. This essay aims to examine the transformation of passive solar energy and [[#|radiant heat]] from ancient to modern times, as well as determine what the present state of renewable energy in Rome is today.

Emergence of Public Baths in Rome

The society of Rome placed importance on all aspects of life and maximized the time spent on any task, including undertakings as basic as hygiene. For this reason, the public baths were built on a large and luxurious scale. The baths had a social as well as a hygienic function. After a long day in the hot Roman sun or cold winter, you could bathe, refresh, and lounge about with companions. It is difficult to imagine the scale of these baths as most have deteriorated to ruins, but the ancient Romans spared no expense for these grand meeting places.

The Baths of Caracalla, officially known as the Thermae Antoninianae, is one of the largest bathhouses in Rome and can still be viewed by archaeologists, scientists, and tourists today. These baths were erected on the outskirts of the city in 212 A.D. and completed in 235 A.D. The actual construction took 9000 workers and five years (Borrelli & Targia, 2008). A new aqueduct, the Aqua Nova Antoniniana, was built to supply water to the baths. Since the Baths of Caracalla was a public place, people of all economic standings and backgrounds had access to this extravagant building. The baths covered about 50 acres and included swimming pools, exercise yards, a stadium, steam rooms, libraries, meeting rooms, fountains, and other amenities, all of which were enclosed in formal gardens known as xystus. See Figure 1. Thick concrete was used to build the infrastructure of the baths. This foundation was ornately decorated with mosaics on the floors, marble on the walls, gilded stucco and glass mosaics on the ceilings, and marble columns (Borrelli & Targia, 2008). See Figures 2 and 3.

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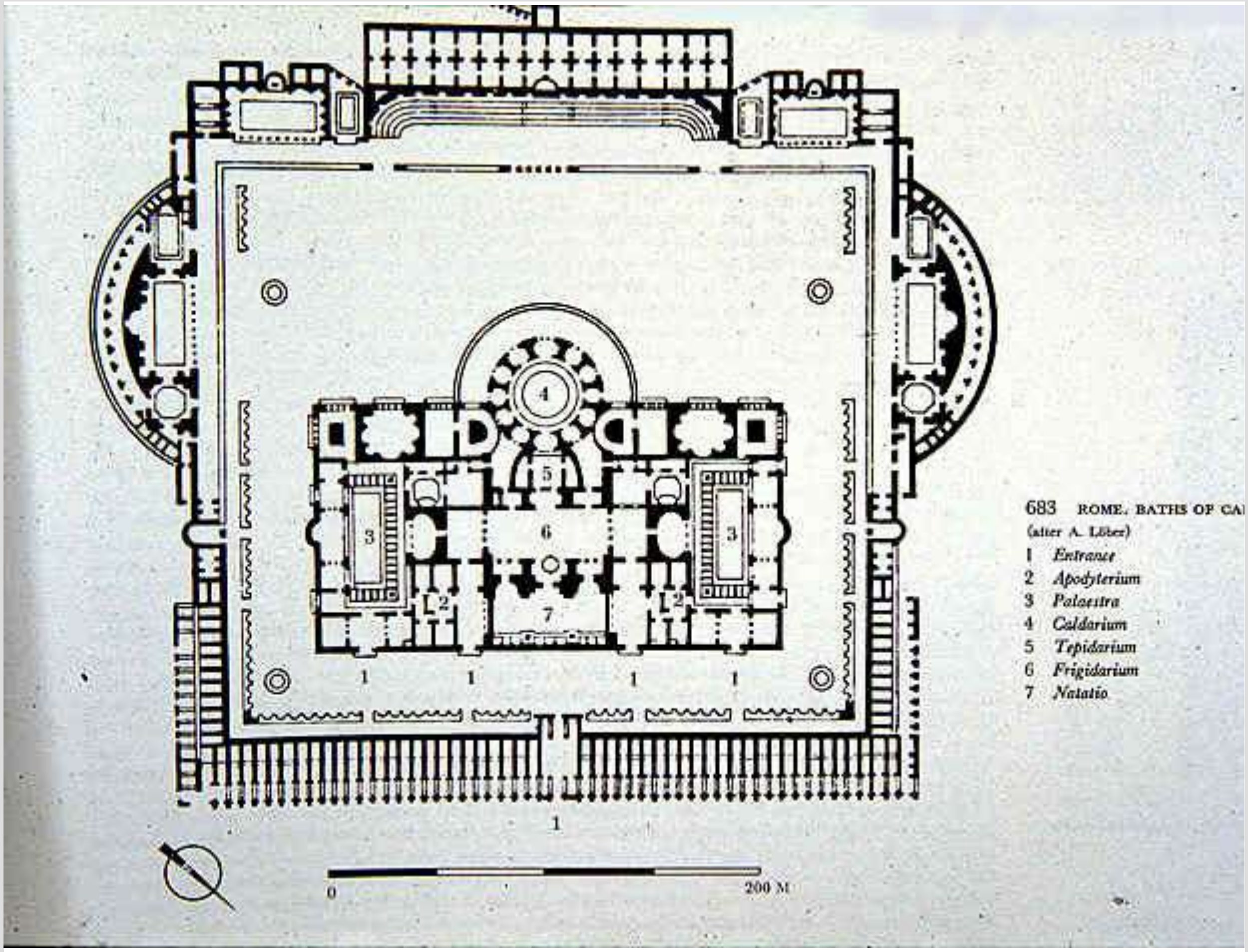

Figure 1. Floor plan of the Baths of Caracalla. Source: http://www.shafe.co.uk/art/Rome-_Baths_of_Caracalla_(plan).asp

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Figure 2. Use of Domes and Arches.


Figure 3. Original mosaic pieces used to decorate the Baths of Caracalla

These enormous structures could hold 1,600 bathers at a time and about 6,000 to 8,000 per day (Borrelli & Targia, 2008). Men and women could use different parts of the facilities or were allotted separate times for bathing. They would enter the baths visit the changing rooms, swim in the large pools called natatio, and then move from three different baths that increased in temperature. The three baths included a cold-water bath (frigidaria), a mid-temperature bath (tepidarium), and a hot bath (caldarium). To gain a perspective of the size of these rooms, the circular, domed caldarium at the Baths of Caracalla was nearly as large as the Pantheon (Borrelli & Targia, 2008). The Baths of Caracalla were abandoned in 537 A.D. during the siege of Rome by Vitiges the Goth. The majority of the population fled to the center of the city where more protection could be offered to them. This left the Baths vulnerable to deterioration and theft. Starting in the 12th century, valuable materials began to be stripped from the building. Columns, marble, brick, and metal were some of the coveted items. These goods were then dispersed across Rome in various buildings. Some of the columns from the Baths ended up in famous churches such as the Santa Maria in Trastevere. The Baths also contained many priceless pieces of artwork from sculptures to frescoes. The Belvedere torso, which was a piece that profoundly inspired Michelangelo, was found in the Baths of Caracalla and now resides at the Vatican Museum (Borrelli & Targia, 2008). Although not much remains of the Baths of Caracalla today, visitors can still get a sense of the grandeur that the Baths once exuded.

On a slightly smaller scale were the Forum Baths at Ostia. These baths were more for the elite and financed by the imperial government early in the second century A.D. There are many inscriptions around the Forum Baths that pay homage to the various contributors and financers of the structure. The Forum Baths at Ostia had the same basic layout as the Baths of Caracalla and was the largest public bath in Ostia. The various rooms at the forum baths included the standard frigidarium, tepidaria, and caldarium, but also had rooms for sun-bathing (heliocaminus) and a sauna (sudatorium). See Figure 4 and 5. The Forum Baths received water through an Ostian aqueduct, which was then channeled into a large cistern and transferred to a waterwheel operated by slaves ("Regio I", 2006). Today, visitors can experience the exposed brick and concrete that laid the foundation of the Forum Baths. See Figure 6. Identical to the Baths of Caracalla, the Forum Baths were ornately decorated with marble and black and white mosaics. There are still cavities that remain in the walls where various terracotta and marble sculptures were housed. See Figure 7. It is believed that many of the decorative aspects of the Forum Baths were composed of reused material and it is unsure which statues found in the building originated there. After Ostia was abandoned, materials were taken from the bath in the early 19th century and mostly likely at previous times as well. The major excavation of the Forum Baths at Ostia took place from 1920 – 1941 ("Regio I", 2006).

Figure 4. Floor plan of the Forum Baths. Source: http://www.ostia-antica.org/regio1/12/12-6.htm

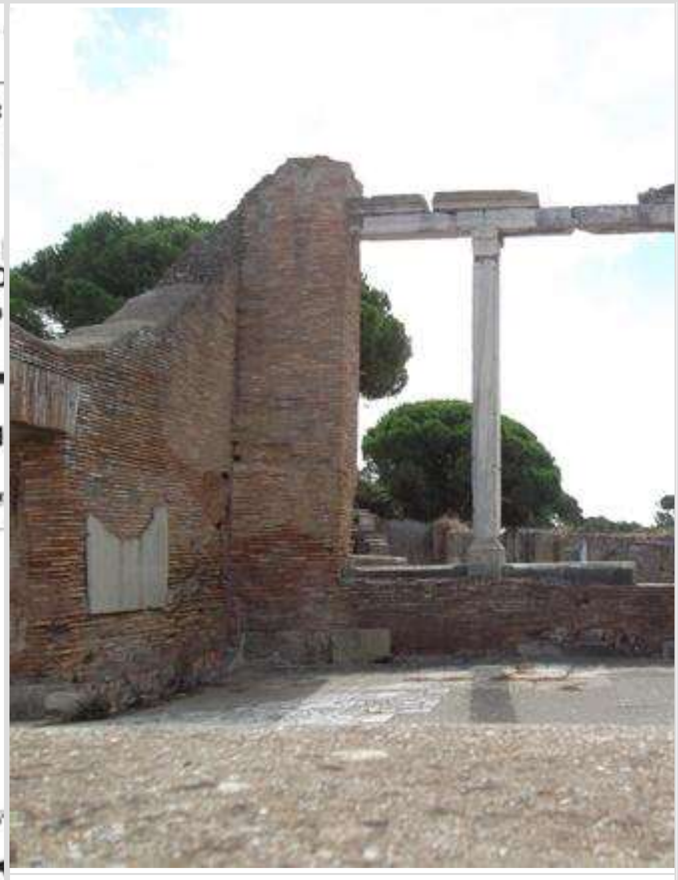
Figure 5. Window of the caldarium.

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Figure 6. Bathing area at the Forum Baths


Figure 7. Cavity to hold a sculpture at the Forum Baths.

The Green Technology of Ancient Rome

Heating structures that were on the scale of the baths was a difficult undertaking. Being such an efficient society, Rome relied on direct heat from the sun and radiant heat to create the temperature variations within the baths. For the warmest rooms, it is estimated that the floor and inside wall surfaces were held at about 38°C through convection and radiation during the winter (Ring, 1996). In his article, Ring also states that the heat of the walls had to be greater than that of normal skin temperature which is around 34°C. If the temperature dropped below 34°C, the bather would radiate heat to the walls, as well as lose heat by convection should they be in contact with the surfaces of the bath. In this case, the bathers would not be able to retain their body heat and the caldarium and sweat rooms would not have their heating function. The design of the Baths of Caracalla and the Forum Baths at Ostia were such that there were many large south-facing windows so that the sun could heat and provide natural light to the warm sections of the baths. See Figure 8. Glazing the south-facing windows helped trap heat and the hollow tiles used in the floors radiated heat. The facades of the hot rooms received sunlight from early afternoon to sunset, which were the most popular hours for Romans to bathe. The thick walls and floors had the ability to store thermal energy so that the Baths wouldn't cool down too substantially at night. It was also important that there were large wooden shutters over the window areas to retain heat. Using the sun to heat the baths helped to reduce fuel usage, even during the winter. In the summer months, the structure naturally provided shade to maintain the correct temperature of the cooler rooms (Ring, 1996).

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Figure 8. Remains of the caldarium at the Baths of Caracalla

Passive [[#|solar heating]] was only a supplemental resource to the hypocaust system used by the Romans. Hypocausts were first used during Hellenistic times around the fourth and fifth century B.C. The Romans improved the hypocaust system through more conductive materials and by channeling the flow of the heat. The Roman hypocausts were hollow floors that consisted of brick and limestone supports, called pilae. The height of these supports was usually tall enough for a person to walk through for any maintenance issues (Basaran & Ilken, 1998). The floor, or suspentura, that covered the system was made of brick and mortar. Flue gas was produced by burning charcoal or wood in a furnace known as the praefurnium. See Figure 9,10, and 11. The flue gas had the ability to provide heat to many of the amenities in the bath because of its transfer ability and radiation. This gas heated water in large copper or bronze tanks. Chimneys were also used to create a flow of flue gas to heat the pools. The hypocaust system heated the floors easily as the gas rose. The gas then provided heat to the walls through tubuli which were small gaps or tubes that were inserted in the wall. The tubuli helped to sustain an even temperature and prevent condensation on the walls. See Figures 12 and 13.

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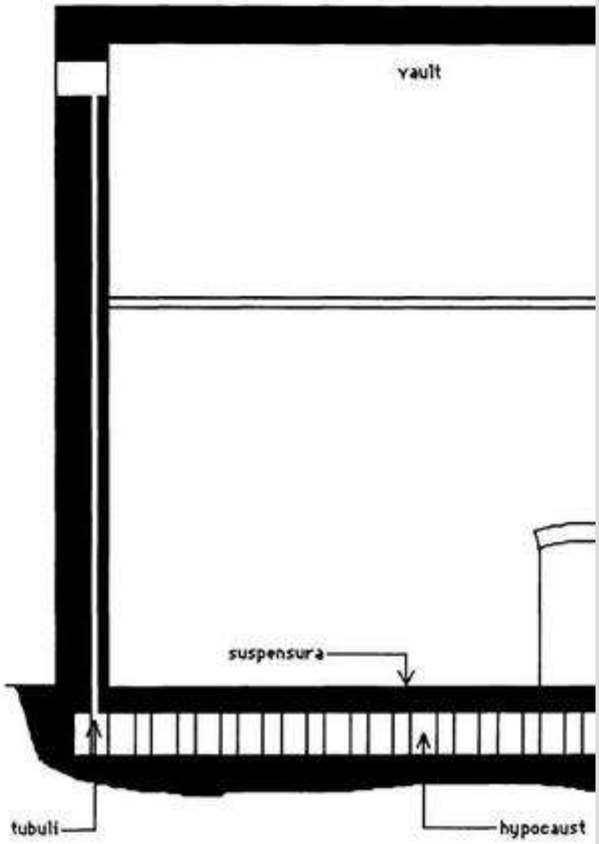

Figure 9. Parts of the hypocaust. Source: Ring (1996).


Figure 10. Remains of a hypocaust at the Forum Baths at Ostia

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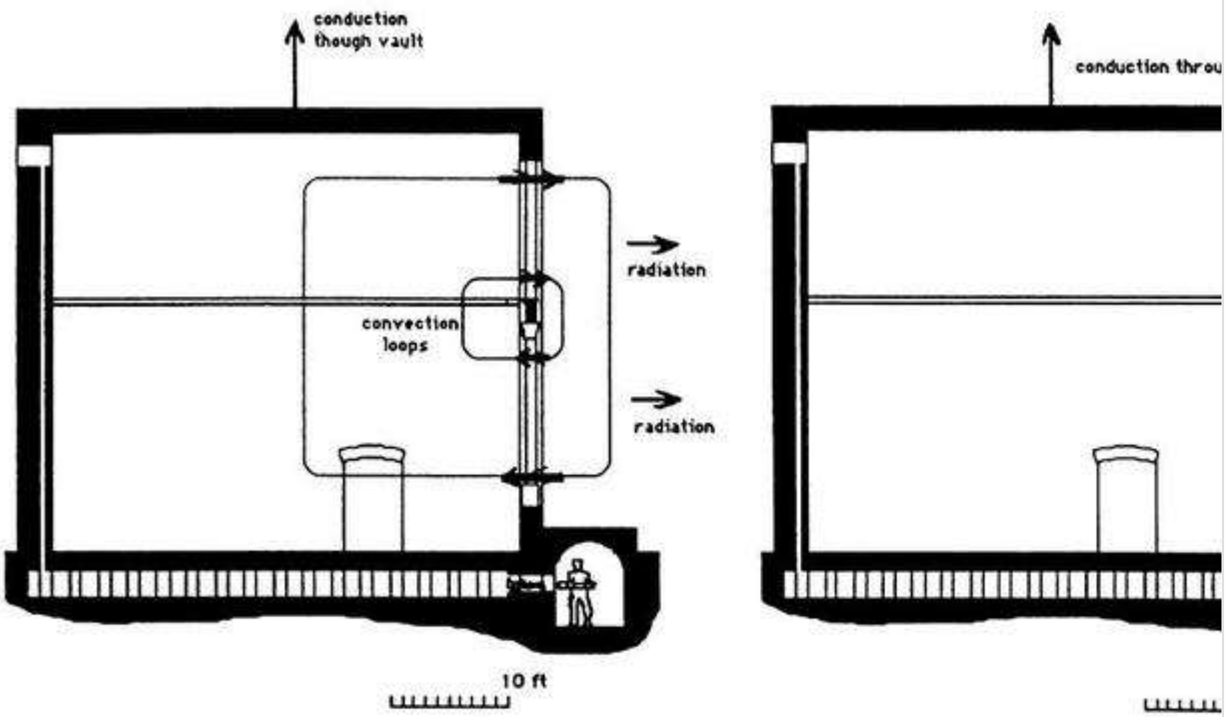

Figure 11. How heat flows through the hypocaust. Source: Ring (1996).

In an academic article, Basaran & Ilken (1998) explains the various studies that have been done to analyze the effects of heating the Roman baths using the hypocaust system. Kretzschmer and Hüser performed experiments on a reconstructed bath that was similar to baths during Roman times. Jorio and Rook used results from Hüser's experiments to calculate conditions in the Stabian Baths and Welwyn Villa Baths. In Kretzschmer's experiment, he observed a hypocaust system in the bath and recorded various temperatures in the furnace. The temperature of the room was 21°C and the flue gas was at 60°C – 63°C. Hüser found that the average floor temperature was 18°C and the floor temperature closer to the furnace was 38°C. Jorio concluded from his experimental data that it would require 7 kg of wood per hour to achieve a temperature of 35°C in the 114 square meter caldarium of the Stabian Baths. Rook found for the Welwyn Villa Baths it would require 13 kg of wood to keep the caldarium at 70°C and the tepidarium at 55°C, but only over an area of 15 m2. Through studies of Turkish baths with Finnish saunas, Brödner hypothesized temperatures ranging from 23°C - 25°C for the tepidarium, 32°C - 33°C for the caldarium, and 37°C for the sudatorium. These experiments give a rough idea of what temperatures might have been produced by the hypocausts. Jorio and Rooks experiments show that although hypocausts were efficient, it would have taken a substantial amount of fuel to heat the gases. As fuel costs were increasing during this time in the Roman Empire, there would have been an impetus to rely more on passive solar energy and an aim to limit the use of the hypocausts.

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Figure 12. Exposed tubuli in the wall.

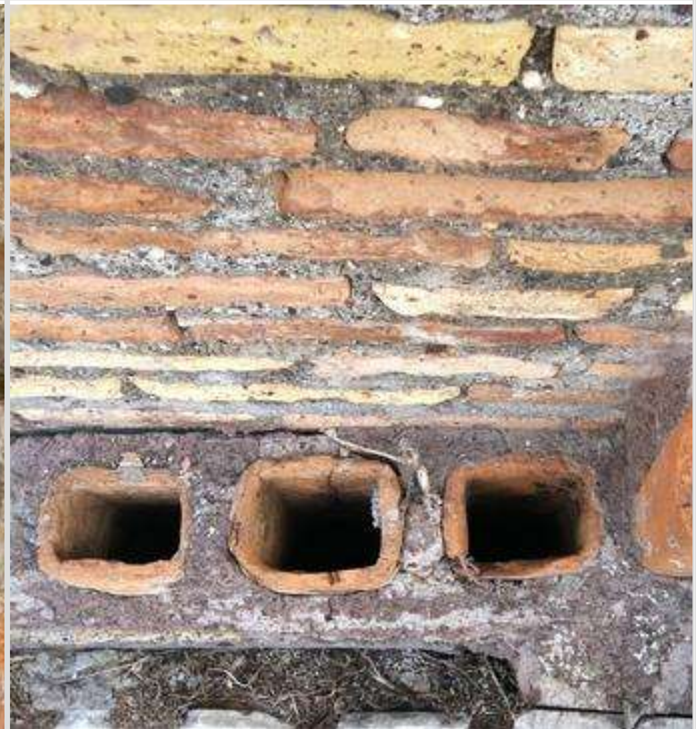

Figure 13. Tubuli inlaid in the foundation of the wall.

Experiencing Roman Baths

- **Observations and Inferences**
- While visiting both the Baths of Caracalla and the Forum Baths at Ostia, it was interesting to experience firsthand something that was so integral to Roman culture. At the Forum Baths at Ostia, I was able to feel the warmth of the sun on the bricks and the differences between the surfaces that were in the sun and shade. Through the gradient of temperatures, I could tell which areas had been exposed to the sun for a longer period of time. I was able to sit in the sudatorium at the Forum Baths and confirmed that this room received a lot of sunlight and warmth. The circular structure of the sudatorium was ideal for sitting and socializing. The windows of the caldarium at the Forum Baths probably covered a third of the wall. There were three adjacent windows about 6 meters tall and 3 meters wide and would have captured plenty of sunlight. The planning of the baths seems to have been extensive and well thought out.

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- The Baths of Caracalla far exceeded my expectations on the size and scale of the complex. It is surprising that its construction only took 5 years. The skeleton of the building alone contained many layers of brick and mortar, so to have a layer of marble on top of that foundation is hard to imagine. I did not expect the walls of the baths to be so high, estimates of the height of the walls are around 40 to 45 meters. The Baths of Caracalla are exemplary of the idea that Rome is full of contradictions. For a society that strived for efficiency and advanced engineering techniques, they were also very concerned with aesthetics and somewhat excessive decorations. The overarching vaults and high domes were unnecessary towards the function of the Baths. The caldarium at the Baths of Caracalla had a high-ceilinged dome that wouldn't aid in retaining heat as any heat in the air would rise. The vastness of the walls also expended materials when they could have reduced the impact and cost of the baths. The excess aspects of the Baths demonstrated the wealth of the upper echelon of Rome. Surprisingly, with the amount of money funneled into the Baths of Caracalla, all inhabitants of Rome had access to the facilities free of charge. This is telling of the value that was placed on Roman society and community. In a sense, Rome strived to exemplify a society that was more evolved than that of the people they conquered. Below are the Baths of Caracalla and the Forum Baths at Ostia located on a map.

View Larger Map

View Larger Map

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Here are some personal pictures taken at various Roman baths. Enjoy the music selection.

Combining Ancient and Modern Heating Systems
As we look for new ways to clean and conserve the energy we use today, we look to the past to sustain our future. Passive solar energy and radiant heating are such simple methods that can be easily integrated into architectural design. Passive solar energy requires little to no excess technology, but instead utilizes smart design which includes knowing how to work with the surrounding environment to maximize energy efficiency. Researchers have developed designs that can have 10 times less of a heating demand than standard housing (Atiko et al., 2013). New

legislation, mostly in Europe, has provided incentive for more passive solar energy houses to be constructed. The top five European countries to participate in producing passive solar buildings are Germany, Austria, Switzerland, France, and Sweden. Germany currently has more than 4,000 passive solar houses (Atiko et al., 2013).

- **Components of Passive Solar Design**
- The basis of passive solar design is collecting heat from the sun and storing it in various materials. The materials that store heat are known as thermal mass; these materials commonly include concrete, brick, stone, and tile. The heat capacity of the design depends on the amount of glazing in the window and how much thermal mass the structure contains. The ratio of the ideal amount of these two elements changes with climate. For most structures, it is recommended that windows of the building face 30° of true south and should receive direct sunlight from 9:00 to 15:00 ("Passive Solar Home Design", n.d.). During the warmer months, the windows need to be properly shaded to reduce the amount of heat that is absorbed. The process of the passive solar design system is carried out by conduction, convection, and radiation. Conduction moves heat through contact with surfaces, convection distributes heat through gases, liquids, and air flow, and radiation transfers heat to objects that are in close proximity to the source of energy. Passive Solar heat can be controlled through the use of fans, vents, and dampers which can stop or produce the heat flow.

- With findings from their research, Atikol et al. (2013) discuss an example of a house with passive solar energy infused with current heating technologies. See Figure 14. A key factor of passive solar design is ensuring that there are south facing surfaces identical to the Roman bath designs. For this house, one wall of the living room faces south. The living room is intended to be used mostly in the evenings. The courtyard, which would not be in direct sunlight, is to be used during the summer seasons. For colder northern climates, it would be energy efficient to construct south-facing windows that cover 35% to 40% of the south wall surface to take advantage of the natural heating and reduce the use of artificial lighting [green, yellow]. A thermal storage wall, also known as a Trombe wall, is suggested to supply heat during the winter seasons. See Figure 15. The Trombe wall is made of heavy, reinforced concrete and painted black to absorb solar heat. This wall can collect and store energy to be used when there is less sunlight. Overhangs or canopies are put above the windows and Trombe wall to regulate the solar heat absorption at different times of the year. In addition, shades made of lightweight, reflective material or window shutters are necessary wherever the structure will receive an abundance of solar radiation during the summer months. Adversely, the windows will be double-glazed polyvinyl chloride (PVC) frames to reduce heat losses during the winter. The entire building and the roof will be insulated with five centimeter thick polystyrene boards to reduce heat loss through conduction. Through thermal performance analysis, the temperature of the living room was found to be within 18°C – 24°C, with the kitchen being about 17°C and the entrance room at 15°C. The living room in this house requires 1720 kWh of power during the winter. The Trombe wall supplies 636.8 kWh and the passive solar energy provides 258.3 kWh. So, there is still a deficiency of 824.9 kWh which would need to be supplied by a central heating system. However, for this project, combining passive solar heating, a Trombe wall, and a standard heating system could save this homeowner 1,171 EUR in annual electricity costs.

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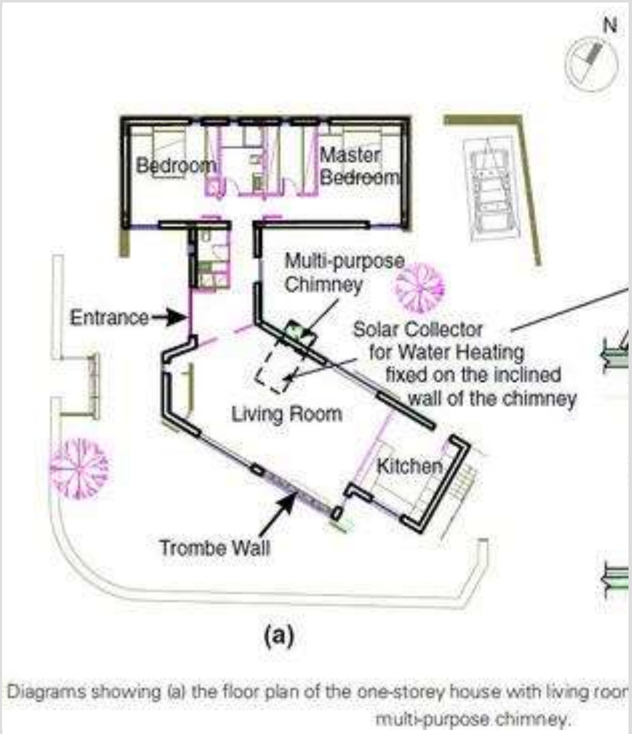

Figure 14. Source: Atikol et al. (2013).

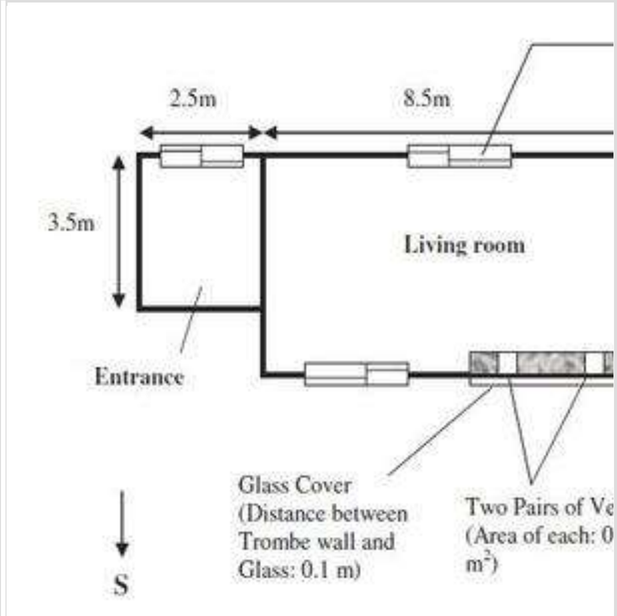

Figure 15. Set up of the Trombe wall. Source: Atikol et al. (2013).

- Every home design needs to be assessed for its solar energy capabilities since each project has unique components and challenges. The studies of Hachem and Athienitis (2013) support that it is efficient for the ratio of the surfaces of the house that face south versus its perpendicular façade to be 1.2 to 1.3 and 1.3 to 1.7 for cooler climates. To account for conditions such as these, passive solar design should become part of the design process rather than an addition after the house is built. A standard process needs to be developed to evaluate an energy conscious design for a building. One idea is to create software that analyzes the most efficient and cost-effective way to use solar technologies with the design of the house (Atiko et al., 2013). Architects can then incorporate this information into the aesthetic design of the house. A downfall of these solar designs is that the initial costs of construction are very high. A Trombe wall is one of the less expensive technologies. The initial investment for the installation of a Trombe wall is around 1,100 EUR. For the study mentioned in (Atiko et al., 2013) article, it is believed that this thermal storage wall will save about 48 EUR per year. The costs of these solar strategies would generally be economically viable over the course of a long time ownership. There needs to be motivation for homeowners to make these investments, whether it is through government incentives or better marketing strategies.
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- **Radiant Heating Techniques**
- There are a few types of radiant heating that are common technologies today. These include radiant floor heating and radiant panels used in ceilings and walls. Radiant heating is essentially a form of the hypocaust systems used in ancient Rome. It has been found that forced-air heating, which is common in North America, is not as efficient as a radiant heating system. Heat is lost to air ducts and vents when forced-air heating is used. The most efficient type of radiant heating, especially in cold climates, is the hydronic or liquid-based system. These systems don't use much energy and can be heated with gas, oil-fired boilers, wood-fired boilers, solar water

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heaters, or a combination of these methods. A hydronic system works by heating water and pumping it through tubes that are under the floor. The tubes are built into the concrete foundation of the floor as a method known as, "wet installation" ("Radiant Heating", n.d.). Recently "dry floors" are becoming more common. This method of installation involves installing the tubing in a space under the floor which is faster and less expensive to build compared to a wet installation. With dry floors, the temperature of the system is increased because the air space containing the tubes has to be heated. In general, ceramic tile is the best material for radiant floor heating because it is a good conductor and stores thermal energy. Any material that insulates the floor, such as vinyl, laminate, carpeting, or wood will make heating less efficient. The other side of radiant heating is paneling used in ceilings and walls. These panels are made of aluminum and can use electricity or hot water carried through tubing to produce heat. Most panels use electricity, as water tubing can lead to leaking. Radiant heat panels can be expensive to use, but can save energy and reduce costs when operated in rooms that are not used often. Panels are also one of the easiest heating technologies to control because they can heat and cool quickly. Another factor of radiant heat panels is that you feel the most heat when you are close to the panel. This poses a challenge for ceiling mounted panels ("Radiant Heating", n.d.).

- There are projects taking place today that are working to combine the benefits of passive solar energy and radiant heating. Referred to as natural conditioning systems (NCS), passive solar energy and radiant heating absorb and store solar energy and can be incorporated with existing conditioning systems. Mercado, Esteves, Filippin, & Larsen (2013) describe a system called SIRASOL that does not have to face the Equator to receive adequate solar energy. The geometry of this system is simple as it is based on the position of the sun. SIRASOL is composed of a pyramidal glass fixture that is attached to the roof of a building. The glass captures solar heat and transfers it to a steel plate inserted in the ceiling that serves as a radiation panel. The space between the glass and panel creates an air chamber where the hot air is contained and radiated to the room below. See Figure 16. Researchers behind SIRASOL performed a thermal network analysis of the through which they found that this system was capable of producing a comfortable temperature for a space. Through their calculations, the temperature of the panel reaches 65°C when it is exposed to solar radiation levels of 500-550 W/m2. The temperature of the panel is only affected by solar radiation and does not change with outside or inside temperatures. As long as the solar radiation can be controlled by the surface area of the panel, SIRASOL will be able to effectively transform solar energy into radiant heat.
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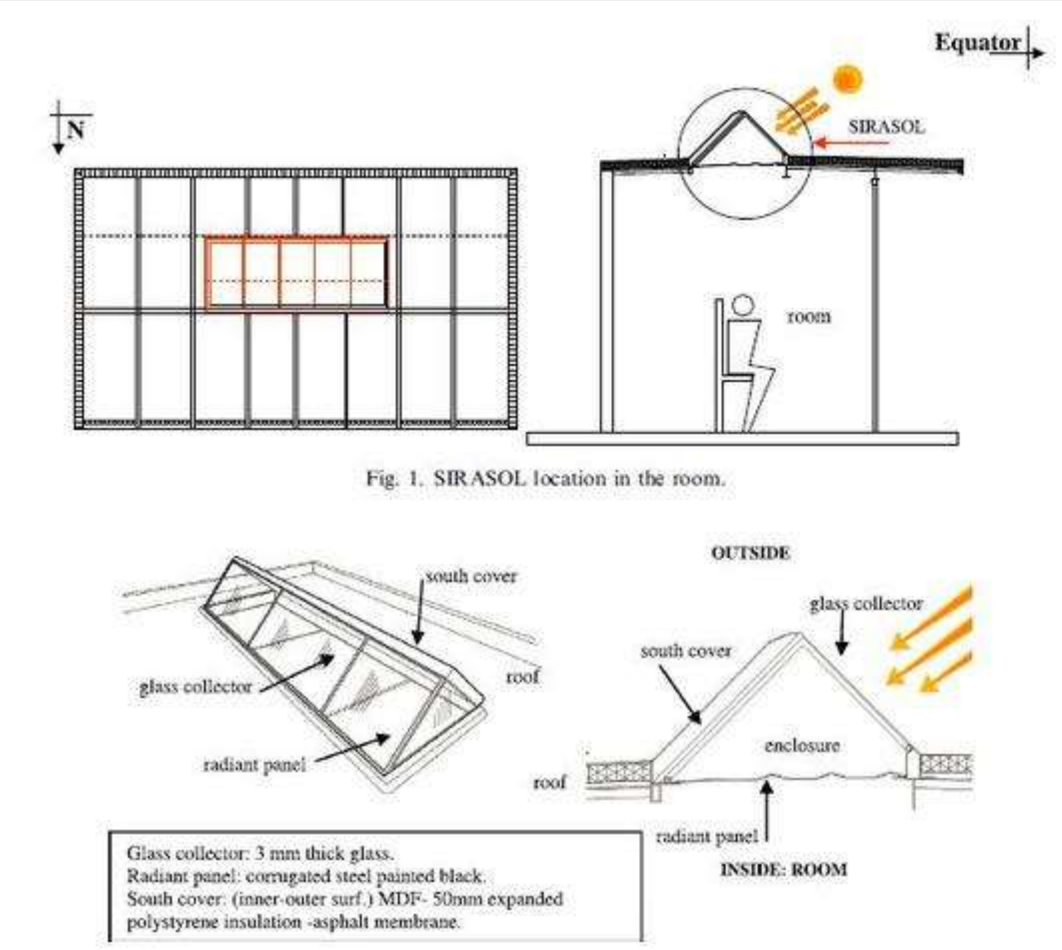

Figure 16. Source: Victoria Mercado et al. (2013).

- **Direct Comparison**
- Passive solar energy has existed for centuries, so the basic technique we use today has not evolved drastically from what was used in ancient Rome. The Romans used solar energy to heat bathhouses; however, today it seems most feasible to incorporate solar heat into houses. The main difference between ancient and modern times is trying to combine passive solar energy with either other modern solar technologies or standard heating technologies that are currently installed in buildings. Although, the Romans did combine solar energy and radiant heating which is continued evidence of their ingenuity. Radiant heat is also a lasting technology that has had small variations made to it. Today, water is heated through tubes instead of heating gas under the floor. It is not discussed in depth on how Romans were able to control the amount of heat that the baths absorbed because modern technology uses shades, fans, vents, and various systems to keep a consistent temperature. During the summer months in Rome, it seems as though the temperature would exceed comfort levels. It is possible that wooden window shutters were used not only to keep heat in but to block it out during the hot seasons. Today, it's still a mystery as to how the Roman Empire was able to achieve many of their engineering and architectural feats. Romans paved the way for efficient design of many of the technologies we use today and have given us the ability to take existing systems and improve them rather than creating brand new designs.

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Energy in Modern Rome and a Global Outlook

With the development of new technology across the globe, there is often an underuse of the basic and simplistic ways of the past. Society is focused on bigger, better, and faster. But many times, simplicity and small projects can have the greatest payoff. As there are more powerful methods of heating available today, radiant heating and passive solar energy are not at the forefront of design. These methods are not able to provide the total energy that is needed, but they could relieve some of the costs and environmental damages of the heating systems used today. Saving a fraction of energy is better than conserving none at all. Passive solar energy requires no extra machinery or maintenance, but only forethought in the design process. This technique involves gaining knowledge about the orientation of the building, installing shading devices, and using insulating materials something that can easily be incorporated into the design and construction of a building. It is apparent that solutions such as passive solar energy are not a priority. Hopefully, they will begin to be incorporated with larger solar projects that have more public interest such as photovoltaic panels.

Modern day Rome has struggled with energy efficiency, but recently has been making strides towards green technology solutions, specifically photovoltaic (PV) panels. Italy is ranked fifth as a producer of electricity from photovaltic cells (Rankin, 2008). This photovoltaic division will create more jobs and hopefully spurn more innovation in the green technology areas. However, it required heavy government incentives and having the highest electricity cost in Europe to accomplish this feat. Rome has an abundance of sunlight that should be taken advantage of, as it was in ancient times. There is also an ideal climate for passive solar energy and radiant heat since the hot season of Rome only lasts a couple months and the prominent winds would provide an easy source of ventilation and air flow. Passive solar energy and radiant heat would also highly benefit any off-grid consumers as Italy has had issues with grid capacity in some parts of the country. As Tom Rankin (2012) discusses in a recent article, serious efforts towards changing standards will only occur when it is absolutely necessary. For society as a whole, this would be when scarcity of materials and/or if pollution reaches a peak. Right now we seem to still be on an incline toward this event, although it feels imminent. Rome along with most societies today want products that have an immediate, tangible payoff, not necessarily a long term benefit.

Despite success with PV energy, many of the existing laws in Rome are counterproductive towards establishing more buildings that utilize green technology (Rankin, 2010). The policy for installing solar thermal energy, photovoltaic cells, and various other systems is unclear and often leads to legal issues with officials, resulting in illegal constructions. The laws surrounding the installation of renewable energy need to be simplified, standardized, and shared with the public. According to Tom Rankin, "Rome could reduce its fossil fuel consumption and related greenhouse gas emissions dramatically". Other possible solutions include evaluating and installing new systems in all government-owned properties. The changes that could be made are initiating energy conservation plans, insulating buildings properly, and adding in renewable sources of energy. Rankin states that government-owned buildings of Rome consume an abundance of energy. So starting at the government level could have a sizeable impact on reducing energy consumption, supporting the economy of green technology, and influencing privately owned companies. It is evident that in both ancient and modern times, government support is crucial for any large scale project or change.

Conclusion

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Ancient Rome is a vastly different world compared to Rome today, but the history that is encompassed in this city is unsurpassable. The numerous Baths around the Roman Empire serve to give a multifaceted look at the history of Roman culture at its peak and the complexities of their engineering. The layers that form a Roman Bath are analogous to the society as a whole. The Baths consist of sustainable materials such as concrete and brick foundations, the engineering feats of passive solar energy and radiant heat, and the elaborate decorations that set Rome apart from other cultures of the time. The sheer scale of some of the baths made them a central focus of Roman life. Although the baths are deteriorated, it is remarkable that the walls are still standing.

It is still evident today that the use of passive solar energy and radiant heating were efficient methods to heat the bathhouses. At both the Baths of Caracalla and the Forum Baths at Ostia, it is easy to understand how the large south-facing windows absorbed enough energy to heat the tepidarium, caldarium, heliocaminus, and sudatorium. It is impressive that Romans knew to use different techniques such as glazing and insulating materials. Although the Romans took many ideas from past societies, they improved on them to be more efficient. For example with hypocausts, Romans added the tubuli to the walls to transfer heat from the floors to the walls. With this method, only the surfaces of the building needed to remain hot and the temperature of the air was irrelevant.

The ideas of the ancient Romans were so progressive that they are still applicable today. There are many research initiatives taking place to integrate passive solar energy and radiant heat into our sources of energy. Europe has made many strides towards passive solar dwellings as they are a simple improvement. Radiant heat for floors, walls, and ceilings are becoming an accessible market for larger scale buildings. It is crucial to for the government, the public, designers, and engineers to be knowledgeable about simple strategies such as these. Many times it is not necessary to construct elaborate panels and machines to conserve energy. However there seems to be significant interest in using inexpensive techniques that produce a moderate amount of energy and combining them as the Romans combined passive solar energy and radiant heat.

Globally and specifically in Rome, small strides are being made towards becoming more energy efficient. As the need for renewable energy becomes more pressing, research and development in this area becomes a priority. It is essential for the government to be involved with these types of projects whether it is through incentives or by example. Ideally, the power lies in the people, but it is truly the government who makes the largest push. But with the numerous tools and knowledge available today, we have the ability to continue to make improvements to society. It is important to look to the past for their successes and not to wait for desperation to find inspiration. When looking at ancient times, we can see that simplicity is effective. Simplicity is an idea that is sometimes lacking and should more often be integrated into the engineering and design techniques of today. Through studying ancient and modern technologies, it is apparent that solar energy and systems such as radiant heat are powerful resources that have been and will continue to be integral to society.

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