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Efficient shower water heater using new heat transfer method

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Abstract: *The presented project is about reducing overall power consumption of a shower water heater as well as reducing electrocution hazards which have been recorded and are accruing due to variety of reasons. Other features are lower weight and size that will help with having a portable device which is easy to install. The reduction in power consumed by shower water heater is impactful on how much power a single house would use per day. The mentioned power reduction will help renewable or green energies to be more practical when it comes to water heaters. Therefore using the green power a house can generate through various methods can be sufficient for the water heater. The project is using micro heating techniques in order to heat a small portion of water as it's passing through the heating elements which are cylinder shaped. Instead of heating a relatively larger amount of water that is the case with traditional electric water heaters, the new method heats up few milliliter of water at a time. Water temperature and PPM (parts per million) values are recorded for future references. The only part of the design which gets a proof of concept is the coil and each coil is considered a system. Never the less, all the possible compositions are explained with the reason why and how they are placed in the concept.*

Keywords: *Shower water heater, efficient heat transfer, Power consumption reduction, Heating element, Electrocution hazard reduction*

I. Introduction

The driving force behind coming up with the idea was the amount of energy everyday shower water heaters use which is relatively high if we are comparing it to other electrical devices in homes and the need to reduce energy consumption can open doors to tons of opportunities that may come along side for the current time period and the future. The novelty is toward implementing smart and yet affordable ideas into community's everyday life which in this case is going to be an affordable and power efficient shower water heater that can be built and commercialized fairly easily with today's technology and advancements. The purpose of the project is to come closer to an universal goal which is reducing power consumption and using green energies instead of fossil fuels which introduces a range of unknown and known problems to the matter of the fact.

This new method is going to reduce the power consumption of the shower water heater by changing the way water heats up that's by putting the heating elements in the shower head itself and minimizing the amount of water that's being reached by heating elements therefore reducing the power needed to heat up the water and it is going to open other power generating methods that were not efficient enough to be used for a power hungry water heater come in use for example a simple and rather mid-range solar panel that's commonly connected to a car battery can come in quite useful and practical.

From the title it's clear that many questions are going to be risen which are understandable and the presented article is going to answer all of them as well as any potential add-on or features that can increase the understanding on where this kind of system might stand if any. The goals that this project is aiming for is to reduce power used as much as possible down to less than 1000w/h compare to current water heaters that can consume up to 4.5hw and in some cases more. The other point is that a system with robust feathers could be design so that it can actually replace current water heaters and bring green energy more into mainstream now that shower water heaters can easily use the power that for example a single 250w/h solar panel can generate and restored via a battery due to its efficiency. The future of energy is in bringing more efficiency as well simplicity to everyday devices and choosing clever yet simple ideas to overcome decades long issues in this case water heater is on the top of the goal list.

Problem statement

The problems with current water heaters are listed as below:

- Reduce the power being consumed by electrical water heaters.
- Hazards like electrocution can easily happen if product is faulty or wires just rust away and make shorts since they run on such high power ratings.
- There's little room for improvement on any aspect of current water heater.
- They generally can't be portable.

II. Conventional electric water heaters

The project is concentrated on the conventional water heating devices and what issues arrive that it's needed to move on from these systems and it' crucial to improve on them for more efficient and safer options.

It's very important to take a warm shower depending on the situation and it's absolutely a necessity for a healthy life as it's a commonly encouraged habit to get rid of unwanted odors as it's more acceptable in society.

There've been studies [1] that show a home that was built in 1980 uses 5-7gallons, 1981-1991 uses 3.5gallons and 1992 until today is using 2.5gallons for each showering that takes place. The reduction in water usage is because of innovating newer and more efficient ways for the design of shower head. In older days the total amount of water used for showering was 750gallons per month and it has been cut in half thanks to today's innovations.

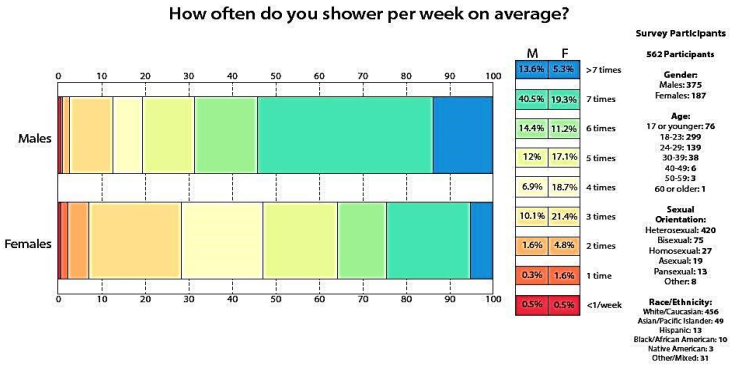

Figure 1: Example of how often people shower per week

Shower water heater s is a big part of modern civilized countries that isn't without logic. Ever since humanity is moving away from older days and raises its hygiene level just by taking a shower at the end of the day or several times per day as needed different methods and options come in, gas powered and electric heaters are on the top of the list.

Showering daily raises human awareness and refreshes the mod that can help increase vitality and productivity; the focus of this project is going to be on how water is being heated and what the possible choices in an electric water heater are.

Each different kind of water heater has its own list of issues and dangers as well as advantages over others that is going to be explained briefly in the following sections but never the less it has to be mentioned that the amount of power being used by all of them has raised most of the problems and dangerous hazards that will be minimized in this project. The universal method used to heat up water is by firstly creating a heat source that is powered by fossil fuels or electricity then the heat is transferred to the water usually in a reservoir as water is being rushed through. The topic explained above gets us to the point where society has to consider how much power is being used to warm up all that water, obviously it's lower than before but still it uses a considerable amount of power.

One of the problems with current devices is that at first water is too hot so the person has to stay outside of shower while water cools down until the point that they feel comfortable that will result in power and water loss. The preferred temperature is different for almost everyone but the temperature which is a bit higher than normal body temperature is in the comfort zone. According to a company called EPA[2] humans waste so much water and power specially when it comes to showering and there have been too little of proper education about that and it's a part of the problem the other part is the actual method that can be used to heat up the water.A new study suggests that many water heaters are set dangerously high. Wendy Shields is a scientist at the Johns Hopkins School of Public Health who studies home injury risks. Shields wanted to look at home water heaters because she says she couldn't understand why tap water burns are still common, causing an estimated 1,500 hospital admissions and 100 deaths per year. Back in 1988, the Consumer Product Safety [3] Commission recommended that water heater manufacturers preset the maximum temperature at 120 degrees Fahrenheit to prevent burns. And the manufacturers voluntarily followed those recommendations — supposedly.The heat core is going to do the heat transferring in a water heater system which the power requirement varies depending on the type of situation, that means if a household is going to need lots of heated water for showering for multiple people the reservoir usually has to be bigger with gas powered water heater and how fast they desire the heating to be performed system's power requirements change never the less plenty of water is being wasted in this phase of an ordinary water heater.

The whole heat transferring operation is the same as when someone pours water over their car while it was out under the sun for couple of hours except it's going to be a constant and repetitive action with heat transfer in water heaters.

III. Novel heat transfer method

The design as shown in Figure 2 will present the whole optimum design that includes power delivery system that can works partially with renewable energy gathered from water and of course it can work with various different green/renewable energy sources. The main part of the design is no doubt the shower head which has heating elements and is in fact the novelty of this project.

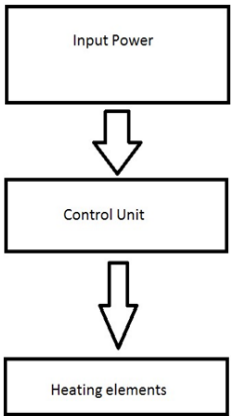

Figure 2: System methodology

For shower head, many different models have been purchased to find the one that is the most suitable as for the spacing inside the shower even though a brand new showerhead could be 3D printed but that would take time and materials in typical 3D printers are not usually suitable for this type of use.

The method heating elements are used can be found in Figure 3, the resistance wires are coiled with 7 wraps and 0.3 inner coil diameter then put inside a 1cm plastic yet preferably ceramic tube which will be attached to the inner surface of the shower head just on the top of the openings where water disperses outward.

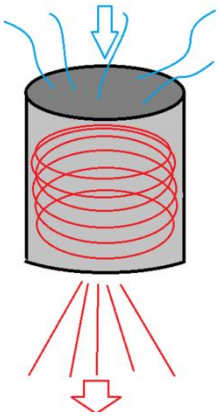

Figure 3: A single coil head, water passing through

Water is going to pass through these small coils in a very small quantity as in few milliliters compare to a normal water heater that heats up half to a litter of water at a time there for the overall power consumption is reduced exponentially. As far as prototype development goes it's rather challenging to make all the elements and install them as well as wiring but if the product goes to mass manufacturing phase the whole process is going to be way easier and faster.The number of heating elements placed on a shower head will determine the power usage and for demonstration purposes the number of installed heating cores is going to be 16.

The heating elements are chosen from a bid variety of elements like Nichol or titanium wire, Since the electrical resistance of a conductor such as a copper wire is dependent upon collisional processes within the wire, the resistance could be expected to increase with temperature since there will be more collisions. An intuitive approach to temperature dependence leads one to expect a fractional change in resistance which is proportional to the temperature change:

$$\frac{\Delta R}{R_0} = \alpha \Delta T \qquad \alpha = \text{temperature coefficient of resistance.}$$

On other hand, expressed in terms of the resistance at some standard temperature from a reference table:

$$\frac{R-R_0}{R_0} = \alpha(T-T_0) \quad \text{or} \quad R = R_0[1 + \alpha(T-T_0)]$$

The shower head design found today on market are not very friendly to such modification that needs to be done in this project so option for shower head are very limited and to assemble a similar situation that can work as a shower might be the only way to do a proper prototype testing. There is a possibility that more than one opening can be fed from a single coil which also needs more testing and yet to be determined but if so it will decrease the power consumption and the number of active component in a shower head. The overview of the predicted design is similar to a normal electric shower heater except way smaller and compact to minimize the amount of water being heated. It's as if every few shower head water outflow openings have their own micro electric heaters. The idea of micro heating anything is not completely new but it hasn't been done before in this very specific area so it definitely packs load of difficulties and issues especially when it comes to identifying parts and putting them together.

For the housing of the coils the best option is going to be a rubber like tube that is less than 0.5cm in diameters and made out of silicon but there are issues with getting these materials because they are used in manufacturing and can be very difficult to come by there for the tube for this project is mostly going to be made out of plastic.

For the method chosen for heating elements experiments will be ran but there had been several more models but didn't seem to be suitable for this specific project.

- Coils are placed inside the showerhead and there's a tube around it.
- Coils are inside the showerhead without any tubes
- Coils are on the outside of the shower head and are fully coated with silicon material.
- Coils are on the outside of the showerhead inside a tube.

This is going to be a designing decision based on experimentations on which one is going to be optimal and gives us the best efficiency. The shower-head is no normal and everyday used item; it has been designed to suite the type of coil better as well as looking aesthetically pleasant.

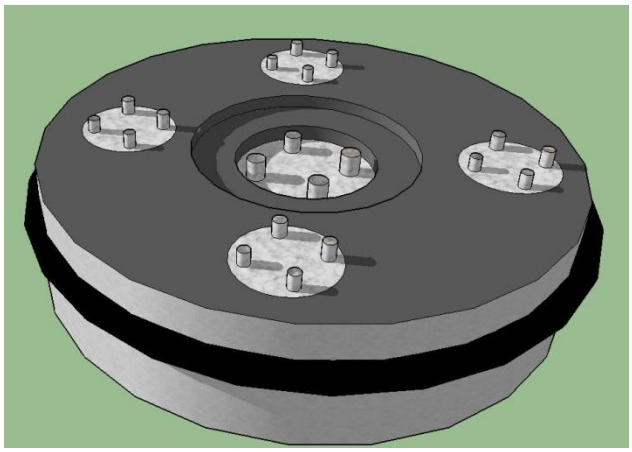

Figure 3: A modelled showerhead with multiple coils installed

In the figure above it's apparent that there are limited number of coils and opening available and that due to limiting the maximum input power and help to reduce the consumption, each coil is considered a system and all the coils are working in parallel with each other so for the final and after design power calculation it is important to fully understand the potential with each coil and get a readable and solid data from to use it for the rest of the coils. Each system is predicted to use 50w or less and it'll be finalized after fully testing a single coil simulated in a situation alike a shower-head since it's not possible to do a full shower-head testing and prototyping due to constrains on time.

As for how the coils are connected the figure below will help to explain.

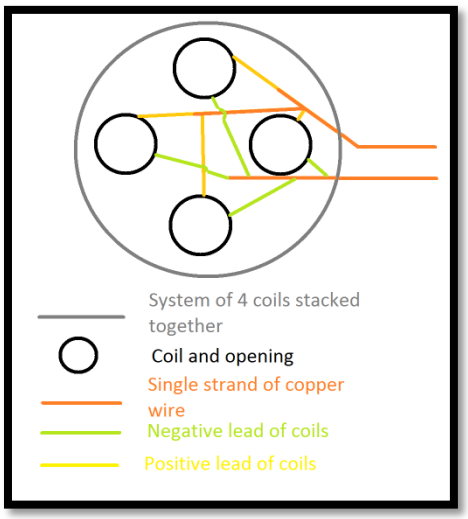

Figure 4: Coil lead configuration method for each stack

In figure 4 the arrangement of leads is presented for the full model, the lead length has been minimized due to the power that's going throw the coils is relatively high for the low gauges even though it'll not be of any danger to humans under any circumstance.

The use of copper strand is that copper especially with higher gauges tends not to heat up and pass current through with the least resistance. Even though it's not the best conductive material but it's cheap and is suitable for such situations. The copper strand helps to transport the power and not to add to the overall load as much.

The openings of the particular shower-head shown in figure 3 is the same as normal shower-head so the pressure is expected to be the same, there few efficient shower-heads on market that save water is the form that water gets minimized and the pressure increases and these products can make a good add-on to the presented idea of reducing power.

The controllers are on the shower-head itself and can be easily adjusted with a rubber ring that rotates.

IV. Impacts of the new water heater

The first thought is usually going to be lower electricity bill but really it gets bigger as analysis proceeds and enlarges, the new shower water heater can come with a totally different looks and features that has been presented and discussed which is something at the hands of designer teams where as they tweak and reshape the design yet it stays the same fundamentally so it's not any easy task to predict how it might be presented if the project had to go commercially available.

Never the less, it will leave an impact on different aspects that range from electricity bill up to saving the environment:

- Lower power consumption
- Lower hazardous dangers therefore low death rate caused by casual household items and generally increase safety levels in houses
- Portable easily and it can affect transportation of the products and easier handling
- Weights lighter which helps with lower costs on transportation
- Alternative power sources can be used since overall power consumption has been reduced
- Environmental friendly, less power required therefore less resources have to be used
- Easy installation so it can be accessible by anyone

V. Discussion and results

The testing proved to be difficult since there were the following issues:

- Coil's too small
- Available materials have low thermal threshold
- Unable to produce ceramic housing for coils
- Adhesives used where unreliable for multiple testing

As mentioned above, some of the issues during the testing were about lack of reachable materials so it proved to be one of the hardest obstacles to overcome. The materials is crucial for a functional and long-lasting

model is ceramic, ceramic has a very high temperature threshold and it can be used as the housing of the coils so that there isn't any water leakage and temperature is contained and won't raise the temperature of the showerhead itself and as for PPM value of the water it is 120mg/L and all the tests where done with the water from the source therefor the PPM stays the same. Another issue is to work with the coils since they are very small (0.2mm approximately) and can be fragile if not handled properly until they are glues in place and have a protective shell around them to keep them in place and the moving platform in this case water spreader introduced more issues than anticipated.

Due to all the discussed issues with the prototype it made it harder to use the same model over and over again for varies testing purposes so 4 different model had to be made to fully test the different angels of the project.

The main adhesive that was used is epoxy and a very small amount of super glue. Super glue was used initially to hold the coil in one place which right on top of the water exit opening, the super glue's only purpose is to hold the coil in place and then the outer portion of the coil will be covered with epoxy for a more permanent approach. As the coil heats up epoxy won't be able to last long which introduces a new issue whereas water will drop its temperature few times and it will make the temperature readings from water temperature sensor less accurate.

Coils are made from a resistive wire called Kanthal A-1. As the properties mentioned in methodology the wire has some good properties that can be used with minimal margin of error and how predictable it is under load. The gauge used is 28AWG and it's slim enough to make small coils and has the right resistance that doesn't require much power to increase the temperature as well as being responsive whereas it quickly heats up.

The resistance of each coil is approximately 1ohms and the three were several different wattages that coils have been tested on:

- 20watts
- 40watts
- 50watts

The first wave of experimentational coils were made with the same diameters because it didn't need to get any bigger otherwise it would use more unpractical power and simply take more place and the coil was placed in a plastic tube so that it could be isolated but it wasn't very efficient whereas the covering material wasn't in contact with the coil and water would just circulate more. It is very important to have a very well isolated coil so after testing it became apparent that the model had to be tweaked.

F

The optimal solution would be to not have long leads coming off of the coil but in this prototype it wasn't simply feasible due to the lack of materials and components in hand. A thin copper plate is sufficient to secure the connection between resistive wire and the higher gauge copper that is connected to the power regulator so the resistance reading in this prototype aren't what they should be therefore some more power is required to reach the same heat. Coils were wrapped around a niddle of the size of a showerhead opening radius that is less than 0.5mm. In total there are 7 wraps of Kanthal, the wraps are all connected so that there won't be any spikes of temperature in certain areas of the coil. The fully connected coils make a unified resistive piece. The purpose behind using wrapping wire is to make any sort of heating core in any shape or form.Among the different methods available for testing the coils set on the outside of the showerhead showed the best results. The coil that is placed on the inside will have several disadvantages that makes it not-functional because water pressure is high inside the shower head and that makes water circulate at any chance it gets it means there'll be water circulating in the coils as well therefore there won't be any water passing through without disruption and fresher and cooler water manages to move in to the coil and push a little of warmed water out.

If coils have a good housing it improves the temperature stability and stops the possible water leakage from side and guarantees a steady stream of water. With silicon housing coils won't emit the heat outward and the heat is concentrated to the open area inside and it will improve the heating process. Another plus when we

have silicon housing for coils is that the showerhead itself won't heat up and become hot to touch there for the temperature stays normal and the device is very safe to touch. After powering the coil the resistance changes and it changes based on the fundamental characteristics of the material and in this case kanthal won't show significant changes which work in the favor of project. After providing 27watts of power to the sample coil the temperature increase was instant and it would instantly cool down as there was no power. Different materials give off different result and if there was more time in hand the material selection would be more efficient but never the less, the designed model is purely done to proof the center of the idea which is the coil is doable and can be achieved, the prototype is not made for commercial purposes as it is right now but with more time and investment the project can be converted into a fully functional system.The figure below is going to express how a final coil product might look like:

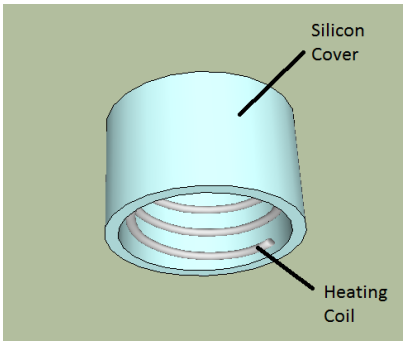

Figure 7: Final look of a coil housed by silicon

Here's how the final single coil system is setup with a good coverage of epoxy around it to simulate the situation of having silicon housing:

Figure 8: Prototyped coil for experimentations

After doing much tests and experimentations the results are to be compared with real-world data which is an ordinary shower water heater in specific the comparisons were done with a BEEBEST water heater model BWH 118E

the device can consume up to 4kw/h with a max output of 40 degrees of Celsius (figure 9) and as for mid-ranged it will give 36 degrees of Celsius (figure 10) which is expected to use over 2kw/h of power and by simulating the situation with the model at hand we can come up with results that can show how impactful it can be.The coils are to be tested with limited tries because the housing material for them is epoxy and it can't hold its bond when it's under temperatures such as 75 degrees of Celsius as it has been rated by all manufacturers of such materials. After 2-3 tests an entire new model had to be created but each new model will have the same characteristics and statistics of previous one. All the components which are epoxy mixture, water spreader, kanthal coil wraps are fabricated the same way. Below are the pictures taken while measuring the output temperature of water heater:

Figure 9: 36 Celsius, mid-power

Figure 10: 40 Celsius, full power

The tested parameters are the coils and the PPM yet other additional factors that can have an impact. The picture below was taken while doing the final experimentation with the modelled coil and it simulates the situation in a normal showerhead.

Figure 11: 27watts of power,37 degrees of Celsius(Model TDS-3 testing instrument)

Another experiment was done with the very model to see what's going to be the temperature if we crank up the wattage to 50 for each system, besides partially destroying the model sensor verified a 41 degrees of Celsius which is where the normal shower water heater can supply and provide with 4kw/h of power.

Figure 12: 50watts of power-41 degrees of Celsius (Model TDS-3 testing instrument)

Although the model got damaged during the last experimentation it's apparent that the feasibility and possibility of optimization on more proper and suitable materials can greatly improve the performance. So by taking a look at the modelled showerhead (figure 15) the total power consumption will be 432watts across 16 coil head placed around the showerhead and 540watts of power for the showerhead that has 20 coil heads and so forth.

The power conversion is something that can have penalties; the kind on conversion is when AC power is being converted into DC power. There are countless devices that have been improving since decades ago and their job is to simply convert power which can be seen with phone chargers and laptop power convertors and still there is a portion of power being wasted but luckily the numbers have been shrinking and will continue to do so which works in the favour of this project, after all said the overall system will use more power but it won't be any specific or considerable amount to behold after all the aim of the project is to reduce the power consumed for shower water heater along other important factors. After getting the results comparison is in order, as mentioned the comparison is done with a BEEBEST water heater. Below the direct yet approximate comparison is displayed:

BEEBEST	New water heater	
4kw/h – 40C	800w/h– 41C	Highest
2.5kw/h – 36C	432w/h– 36C	Lowest

Table 1: Result comparison

In table 1 the results are arranged next to each other for better understanding of the outcome. The showerhead model has 16 openings and if highest temperature is to be focused in some regions then the new efficient shower water heater will be able to deliver 41 degrees of Celsius while using 800watts and if it is compared to example shower water heater BEEBEST there's a 3.2kw/h reduction in power usage and if focus of the customer who is interested in mid-ranged heat then the new water heater can deliver 36 degrees while using only 432watts, the example water heater uses 2.5kw/h to deliver the same outcome which again it means the new water heater will save roughly 2.068kw/h. The project's efficiency varies based on what is the desired temperature, at max power the new shower water heater uses 1/5 of the example BEEBEST shower water heater and when it comes to mid-ranged heat the new system will use 1/5.8 of the example shower water heater.

VI. Conclusion

The novelty that the thesis is offering is toward implementing smart yet affordable ideas into community's everyday life which in this case is going to be an affordable and power efficient shower water heater that can be built and commercialized fairly easily with today's technology and advancements.The purpose of the project is to come closer to an universal goal which is reducing power consumption and using green energies instead of fossil fuels which introduces a range of unknown and known problems to the matter of the fact.The presented project is going to reduce the power consumption of the shower water heater by changing the way water heats up that's by putting the heating elements in the shower head itself and minimizing the amount of water that's being reached by heating elements therefore reducing the power needed to heat up the water.The main focus was on improving electrical shower water heater's design and exploiting different potentials that might proof useful in future of power saving as well as opening doors for green energies to be easily utilized for water heaters while they were not able to before.

The material for coil is kanthal due to its advantages and how tolerant it is under load compared to nichrome and other materials plus it's safe and does not release chemicals which is very helpful is just the material this project needed.The overall system is made out of several sub-systems and each play a big role, each coil is considered as a system in this project, the power supply will provide enough electricity for the coils and coils simply heat up and last but not least a controller circuit is needed to regulate the power and give commands to the power supply that how much power is needed and none of these functions work if there is no water running through the pipe all thanks to a tiny hydroelectric generator that works as a fail-safe component whereas it keeps the coils from heating up when it's propeller are bot rotating and relay switch stays on off mode and won't let any power to the coils.

After doing countless testing the right combination of components where discovered as well as their optimum performance. A coil of seven wraps round a niddle is placed on top of a showerhead opening and heats up the water that's passing through, the coil was originally planned to be placed on the inside of the showerhead but as experimentations showed it was not practical at all so the current approach which is covering the coil with some sort of material in optimum situation a silicon housing would work flawlessly but because it was not accessible epoxy was used to perform the tests.

The results showed a promising reduction in power, 432w/h in compare to 2.5kw/h to achieve a warm water of 36 degrees of Celsius. The efficiency decreases as input wattage increase so this new water heater is not suited for every situation for example very cold atmospheres.

As for the marketing, firstly a wide educational advocacy is in order to educated people on how important it is to save power and join this cause to ultimately lower environmental damages done by using high power required household devices. Afterword several months of product tweaking and optimization is required to get the best configuration and move on to the next phase which is mass manufacturing.After all said, there is a potential to utilize this idea to houses that meet the requirements and lower the risks like electrocution and bring a portable and efficient shower water heater.

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