

**Lessons on Outdoor Warning Sirens:  
Should Maui's Sirens Have Stayed Silent?**

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**Author Note**

The original information in this title page has been modified for privacy reasons. This PDF is intended to be published for an audience with a general, non-academic interest in the use of siren systems and its derivatives. If you are interested in viewing the original work, or contacting the author or institution to which this paper was written for, please send a direct message to Bousai Guy.

It was in the early afternoon hours of Tuesday, 8 August 2023 when the residents of Lahaina, HI noticed smoke from what officials called an “apparent flare-up”. It was previously a bush fire caused by downed fire lines supposedly put out in the morning, which now was becoming out of control by 15:30 (Lin II, Petri, & Winton, 2023). Some residents prompted themselves to evacuate as they witnessed the fire spreading rapidly. Others, however, did not receive warnings of evacuation orders, the earliest appearing as early as around 14:00 (Bogel-Burroughs, Albeck-Ripka, & Mayorquin, 2023) – before the fire began to shut down a major road. Those closer to the coast only received warnings to act around 16:17 (Bogel-Burroughs, Kovaleski, Hubler, & Mellen, 2023).

The Maui wildfire is ranked the 5<sup>th</sup> deadliest wildfire in the history of the United States (Flowers, 2023) with 115 reported deaths (Carli, 2023). Amidst the many criticisms towards the government’s response, the policy decisions enacted by county emergency management regarding the use of its outdoor warning sirens has recently been up for debate. Hawaii touts that it has the “largest single integrated Outdoor Siren Warning System for Public Safety in the world” with over four hundred sirens installed across the state. It is capable of warning about natural and man-made emergencies including wildfires (State of Hawaii, n.d.). Furthermore, the Maui Emergency Management Agency (MEMA) agreed with this statement, designating a steady-tone signal in case of a natural disaster (Maui County, 2023). Yet, throughout the entire day of the wildfire, the county’s outdoor warning sirens remained completely silent.

It was not as if Maui had considered the possibility of Wildland-Urban Interface (WUI) fires before. A published hazard mitigation plan written by the county had indicated that the risk of wildfires was increasing especially on its west coast where Lahaina is located. Wildfires were not new to the state either, though they typically did not affect urban areas significantly (Lin II,

Petri, & Winton, 2023). Despite this, the MEMA's administrator Herman Andaya defended the decision to not sound any outdoor warning sirens. Sounding the sirens would have encouraged those who heard it to move inland towards the fire, thinking a tsunami was about to occur (Andone, 2023). Instead, MEMA had opted to push emergency notifications through other sources, which included television and phone networks.

This claim that it would have disseminated conflicting information appears rather puzzling, especially when there is now evidence that the selected means of mass notification were proven either inconsistent, ineffective, or poorly executed across those in the area. Purely from a policy-based standpoint, sounding the sirens would have saved lives. However, Andaya's rationale for not sounding the sirens was not entirely erroneous.

The use of outdoor warning sirens first appeared during World War II in Europe to warn of air raids. This practice was also adopted in Hawaii with sirens installed around the 1940s, reserved primarily for military use. Following a 1946 tsunami, officials realized that these sirens could be used to warn the public of tsunamis and other natural disasters, setting aside various "tones" for various threats (Kim, 2023).

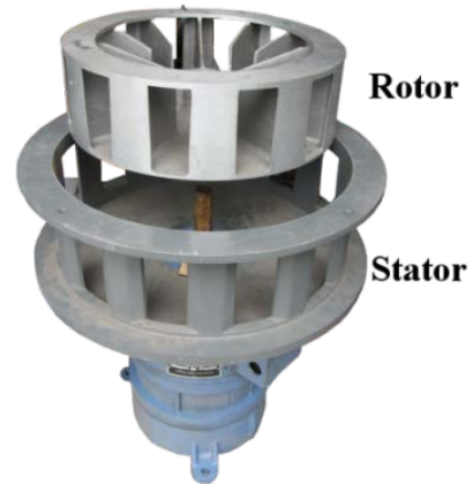
This system ultimately failed during the 1960 Hilo tsunami. Researchers found that most residents did not recognize or understand the siren tone specific to tsunamis (Kim, 2023). This, and along with the fact that sirens became popular across the continental U.S. during the Cold War era to warn both of attacks and natural disasters, led to the standardization of two distinct tones by the Federal Emergency Management Agency (FEMA): (1) *Attack*, a 3 to 5-minute wailing (rising-and-falling) tone for enemy threats such as a missile strike<sup>1</sup>, and (2) *Alert*, a 3 to

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<sup>1</sup> Example of the "attack" tone: <https://www.youtube.com/watch?v=Yaie4Z878zo>

5-minute steady tone for “peacetime disasters” such as a tsunami or tornado<sup>2</sup> (Office of Civil and Defence Mobilization, 1959). No all-clear signal was specified.

At the time, the technology for sirens was basic, working on the mechanics of air flow to produce a distinct tone. The earliest sirens used a combination of a rotating rotor that would force air through a steady stator as shown in Figure 1. The alternating “open-close” mechanism in quick succession would produce a tone dependent on how fast the rotor was spinning and the size of the openings (Space and Naval Warfare Systems Center Atlantic, 2015).



*Figure 1 - A rotor and stator of a siren separated, courtesy of Space and Naval Warfare Systems Center Atlantic.*

Although these mechanical sirens are simple and dependable for many years, the disadvantage is that it can only produce a basic set of tones without significant modifications: a wailing tone, and a steady tone, all controlled by whether the motor spinning the rotor is on or off. This gave rise to the production of electronic sirens, which could produce a variety of tones outside of a wailing or steady tone, as well as spoken messages. Electronic sirens, therefore, can specify more hazards to take action directly, but are only most beneficial at a shorter distance than their mechanical counterparts (Laidlaw, 2010). It is worth noting that both technologies are used today, and both can even be found in the same municipality. For example, Stillwater, OK uses both mechanical and electronic sirens, the mechanical being used for its suburban neighborhoods where more coverage is desired, and electronic used for more populated areas like on-campus and public parks to allow for detailed verbal communication.

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<sup>2</sup> Example of the “alert” tone: <https://www.youtube.com/watch?v=IQ3wsWgYLKI>

With siren use being common across many communities in the U.S., it is appropriate to ask what the point of the sirens are. Every community faces its own “primary” threats, hence this question is not easy to answer. For example, Stillwater, OK will more than likely face the threat of a tornado, whereas Benicia, CA – a location not highly prone to tornadoes – might use their sirens to warn about incidents at its local refinery such as a chemical release. As a result, these tones will convey different meanings for any given person. These threats typically require a prompt response from the public to protect themselves (National Institute of Standards and Technology, 2017). The time-sensitive nature makes it imperative to communicate the right information as directly as possible, especially when the situation is highly volatile.

The difficulty in addressing this originates from two key factors. To start off, basic siren tones are easy to recognize especially if one lives in an area that uses them on a regular basis (Laidlaw, 2010). As a result, they are easily associated with certain threats. These associations are not necessarily incorrect – for example, hearing the alert tone in Oklahoma likely means a tornado will affect the area – but can be problematic when locating to different areas that face different regular threats. Suppose a student who grew up in Oklahoma visits Benicia, CA where a shelter-in-place warning is issued for a refinery spill and sounds the same alert tone used in Oklahoma for tornadoes. Sirens alone do not communicate any information other than a set of arbitrarily defined tones (Federal Emergency Management Agency, 2006). As a result, the student might shelter in a sturdy building, but might do so under the wrong assumption that a severe storm is about to hit the city.

To make matters worse, cities may choose to include other siren tones that deviate from FEMA’s recommended two-tone practice (National Institute of Standards and Technology, 2017). This stems from the *authority having jurisdiction*-equivalent model used in fire

protection, where local emergency management agencies may have certain nuances to solutions from a frequent problem or interest. While this works to adapt quickly to the needs of each individual city, this becomes problematic for warning populations of a transient nature. For sirens, there may be other siren tones used to signal specific emergencies such as floods, severe thunderstorms (excluding tornadoes), or even the end of an emergency. Because the meaning of siren tones are rather arbitrary, this can pose a challenge in understanding what each tone means to those who are not familiar with the area.

It is worth noting that the practice of non-standardized tones appears seldom followed outside the U.S. Other countries, too, use sirens for a variety of local hazards with the extent of details communicated based on the equipment installed. However, these tones are all standardized across the country. Germany, for example, designates two primary tones for public use: “Warning” and “All Clear” (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe, 2022). The primary purpose is to direct others to get information as quickly as possible from another source, not necessarily prompt a specific

action. Austria follows a similar approach, distinguishing emergencies with a “Warning” signal to get information, and an “Alarm” signal to seek shelter immediately shown in Figure 2 (Bundesministerium für Inneres, 2023). Japan takes a more detailed approach, using mostly



Figure 2 - An Austrian flyer showing the different signals “Warning”, “Alarm”, and “All Clear”, and what to do for each.

electronic sirens that broadcast designated short attention-grabbing tones for a designated hazard before verbally communicating detailed threat information and specific actions to take<sup>3</sup>.

These factors taken into account highlight critical limitations when it comes to using outdoor warning sirens. To start off, there exists a public perception that sirens are a highly effective means of warning about an impending disaster. It makes sense – sirens are there, provided by the government, ready to sound if need be with no public action required. While this does show that the public is willing to rely on outdoor warning sirens, this assumption is true only to the extent where the public is both familiar with the siren tones and associates it with a disaster. Again, this association is not always accurate and does not guarantee the correct response which depends on perception of risk. Additionally, a generic “alert tone” may not be enough for a person to change the risk perceived from other sources. The public might also not consider other factors such as its use at night when much of the public is asleep and might not hear it, and indoor locations where insulating features of a building can block out a siren’s sound (Laidlaw, 2010).

Sirens alone are not a practical means of communicating detailed information unless the system is specifically designed to do so. With municipalities across the country split between using mechanical and electronic systems, sometimes using both at the same time, the amount of information communicated at once will not be the same. Very rarely do sirens specify the *what* to do, the *when* to do, the *where*, the *why*, and the *who* giving information – all of which are essential information in facilitating the correct perception of risk and thus the correct response. Also, siren systems are set up on a jurisdictional basis, letting local governments dictate how

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<sup>3</sup> Example of a siren system in Japan, used to alert of a missile launch from North Korea:  
<https://www.youtube.com/watch?v=gkX8FCKNGHc>

sirens are to operate for their area – including when they sound as demonstrated in the Maui wildfire. As a result of inconsistent messaging, lack of comprehension, credibility, or perceived risk of the hazard can increase the likelihood of incorrect public responses or no response at all (National Institute of Standards and Technology, 2017).

One improvement that's been recommended by NIST was to standardize the signals used so that a more consistent message can be sought after each time. The question remains: What message does the public need to hear in order to take action? If the purpose of an outdoor warning siren is to specify the hazard so the public takes correct action immediately, this will require massive infrastructure upgrades to existing warning systems or creatively manipulating the motors simple mechanical warning sirens to produce more “distinct” wailing tones. It also comes with the drawback of needing to educate others, which can take time. On the other hand, if the purpose of the system is to encourage others to seek information, a single warning tone is easy to implement, and the initial response required from a person is a single choice. However, valuable time could be wasted trying to seek information before the intended response is yielded.

There also comes the question as to whether an “all clear” signal should be used. While it is uncommon to encounter this signal in the U.S., it remains a highly debated topic as to whether sirens should also communicate the closure of an event. Some areas, including Stillwater, avoid using one as “it can create confusion” (City of Stillwater, Oklahoma, n.d.). However, other countries designate an “all clear” signal as a way of encouraging others to continue seeking information even though imminent danger has passed. There is little evidence for both sides of the argument (National Institute of Standards and Technology, 2017).

Sirens alone cannot be the sole means of mass notification. With its limited ability to communicate the exact nature of the hazard in time, other methods such as radios, cell phones,



public visual displays, or social groups must also be promoted and integrated as part of a region's mass notification system. The human perception of outdoor warning sirens is skewed and could result in incorrect protective measures, often associating outdoor sirens with a *single* hazard instead of all hazards – hence why the phrase “tornado sirens” or “tsunami sirens”, though colloquial, needs to be treated as a misnomer.

Despite this, outdoor warning sirens should not be discouraged from being installed or used. As a passive warning method, it is accessible to populations with little to no public interaction required other than to hear the tone and know what to do. Unlike cell phone or radio technology, there is no need to set up or “opt-in” to alerts – all work to set it up is taken care by the local government (Laidlaw, 2010). Additionally, it can function as a redundant form of communication. Many victims from the Maui wildfires stated they never received alerts. In some cases, they received alerts after they began evacuating, citing poor cell service and power outages (Kim, 2023). The extent of this even affected tourists in hotels (Bogel-Burroughs, Kovalski, Hubler, & Mellen, 2023) – those who would be completely unfamiliar with the area's warning network. Perhaps sounding the sirens would have prompted many to seek some information, even if there was little familiarity with the warning tones and no obvious evidence of a wildfire headed straight towards the city.

Since the incident, the Hawaii Emergency Management Agency (HI-EMA) has since clarified that sirens can and should be used to warn of fires (Hurley, 2023). This falls in line with both FEMA's recommended guidelines and NFPA 1221, a standard written for implementing emergency service communications for an area, stating “[s]ystems shall be used for alerting the public to natural and man-made events, including tornadoes, hurricanes, floods, fire, and chemical releases, that can be expected to result in loss of life, endanger public health,

or destroy property” (14.3). While the interest of public safety was at heart, existing policy stated that sirens are meant for all hazards; a prompt evacuation can warrant sounding sirens. Not sounding the sirens could be a failure in the government’s duty to protect people from harm.

It is also plausible that the government failed to properly educate the public about siren signals and how to respond if one hears them. Because sirens are a passive warning method, some work must be done to educate others about the system. For Maui and much of Hawaii, there was a real misconception that existed: hearing sirens meant an imminent tsunami, and one should seek higher ground quickly. Tsunamis are a regular occurring emergency, hence this misconception was unconsciously accepted across multiple levels of the state including the government (Hurley, 2023). However, policy used in Hawaii stated that the alert signal does not necessarily imply tsunamis. This perception might not have been an issue if the public retained the understanding that the siren was only meant to communicate, “seek information.”

This phenomenon is not exclusive to Maui, however. The same can happen to many residents in Oklahoma, where a steady siren tone is often associated with a tornado. In fact, it’s done so often that the City of Stillwater appears to neglect any mention of other hazards on its website, exclusively dedicating its outdoor warning siren system to tornadoes only (City of Stillwater, Oklahoma, n.d.).

With the plethora of different hazards that are possible across the U.S., it would be of interest to revise the current siren signals and when to use them. Ideally, this would allow a uniform understanding of what each siren tone means regardless of location, hazards, and technology available. This would mean keeping the message simple but requiring prompt action from those who hear it: either seek shelter indoors or get information – one tone for each. This simplistic approach combines the action of “taking cover” for common weather-related threats

and uncommon attacks on the country – the spirit of the existing attack signal. Other situations may require a more complex response; thus, the existing alert signal can be used to communicate that an urgent message is being broadcast that the public must know about. Once the exact nature of the message is decided and written into policy, the information must be publicly available to avoid misconceptions. Already, this addresses the immediate *what, when, where,* and *who* related to the emergency. From there, information must be disseminated in other forms to communicate consistent information. This would answer the *why* of the hazard and specify further action to be taken.

This Maui wildfire had devastating outcomes and will likely be a case study require multiple rounds of failure analysis to see the whole picture of what needs to be improved. Out of this, the correct and consistent use of outdoor warning sirens has been put into question. Sirens communicate limited information to a limited environment, and its simple message can easily become twisted to fit the perceptions of the public. This does not completely mean it is useless, rather it is easily misunderstood. Regular updates to policy and effective public education can help mitigate the risks of using this century-old concept as part of a comprehensive mass notification network.

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