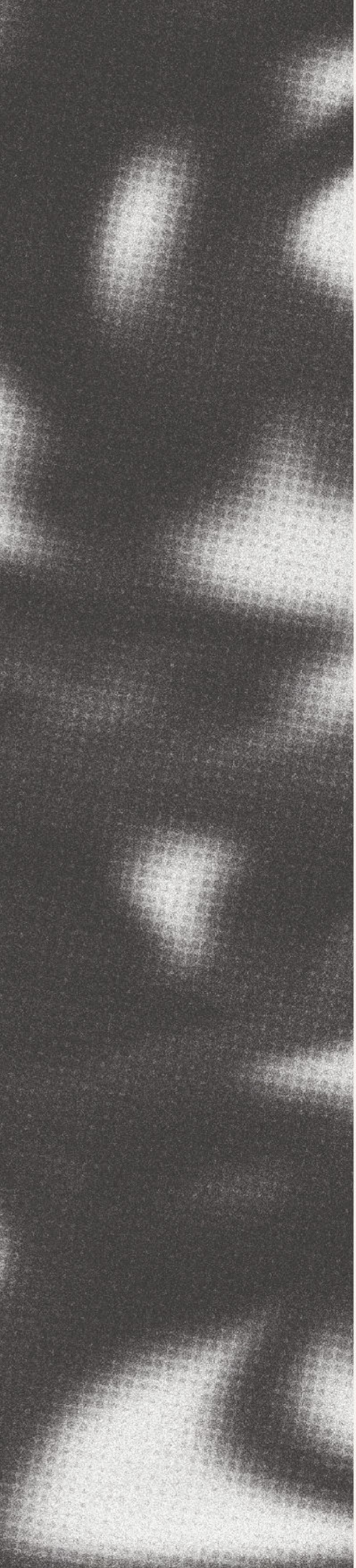


Phoenix

BUSHFIRE MONITOR FOR HIGH-VOLTAGE TRANSMISSION LINES

RESEARCH REPORT

JAN HENDRIK BEKKER | N9722408 | ID7 CAPSTONE DNB311

Authenticity Statement

This is to certify that to the best of my knowledge, the content of this report is my own work. This report has not been submitted for any subject or for other purposes. I certify that the intellectual content of this report is the product of my own work and that all the assistance received in preparing this report and sources have been acknowledged.

Your name: **Jan Bekker**

Student number: **n9722408**

Date: **10|09|2023**

AI Use Statement

I have utilised Generative AI in this report (ChapGPT) to summarise and analyse interview dialogue.

Your name: **Jan Bekker**

Student number: **n9722408**

Date: **10|09|2023**

Abstract.

This report explores the impact of bushfires on electricity transmission networks. It shows that the duration, intensity, and scale of bushfires will increase substantially by the year 2050 based on the projected effects of climate change. This report provides insights into the vulnerability of transmission lines, shows the stakeholders impacted by bushfires near transmission lines, and considers current technologies and solutions and their limitations. These findings, based on a literature review and primary research in the form of surveys and expert interviews, will bring to light opportunities for innovation. Finally, this report will showcase five concepts as suggestions for potential solutions.

Contents

PHASE ONE.

1.1 Introduction.

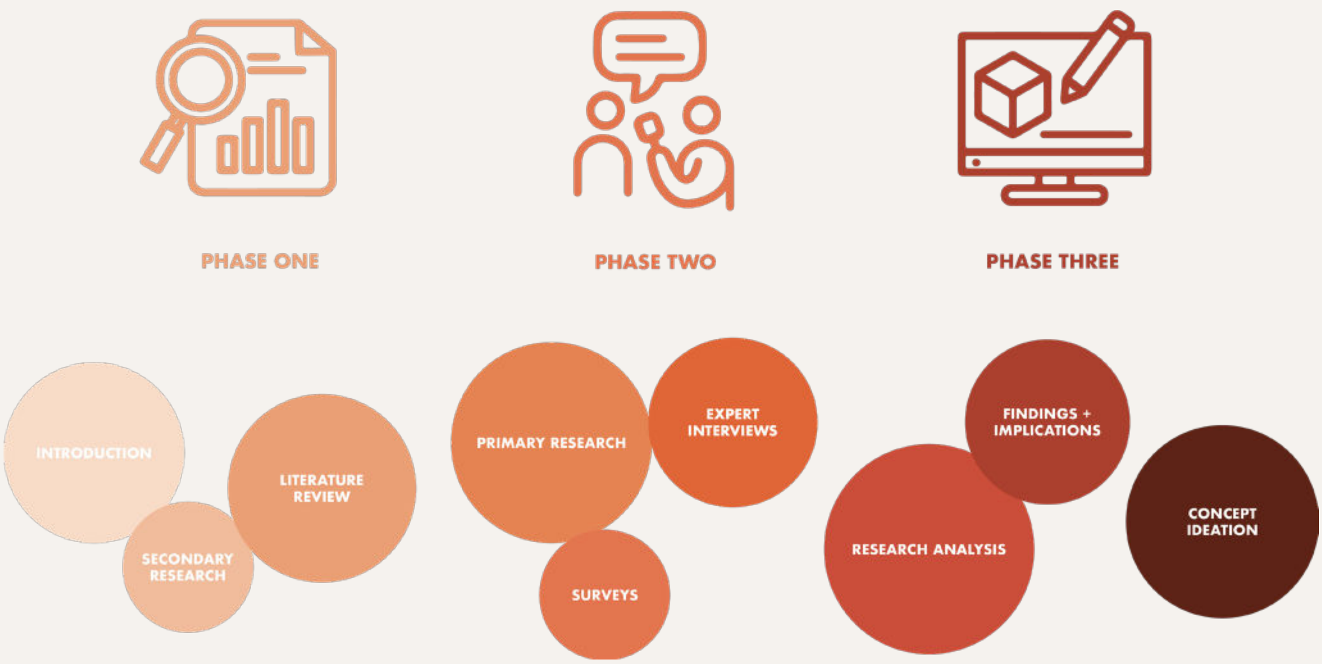
Bushfires, a devastating reality that has heavily impacted many people's lives throughout history, are set to increase in duration, intensity, and scale by the year 2050 due to the projected effects of climate change. While innovations and research studies are already underway, it is essential to recognise that much more is needed to develop new solutions to cope with what is and prepare for what will be. It is crucial to consider the future to acknowledge that this devastating reality today will continue to impact the world at large in the future.

While the direct impact of bushfires is felt by many, this report aims explicitly to reveal the risk that bushfires pose to the electricity transmission networks that power the state of Queensland in Australia. The following literature review and research will show that the two main stakeholders within this context are first responder firefighters and power supply company workers.

The findings in this report stem from two forms of research: secondary, in the form of a literature review, and primary, in the form of interviews and surveys. In the first case, care was taken to uncover and analyse relevant publications to comprehensively understand topics such as future climate predictions, the impact of bushfires, the vulnerability of transmission lines, the critical nature of electricity and the safety risks for first responders. This section will also consider and evaluate opposing opinions and suggestions.

Secondly, primary research has been conducted according to qualitative data with triangulation methodology using two complementing research methods: expert interviews and surveys. Through expert interviews, the aim is to bring to light opportunities and needs, as well as be able to discuss current developments and future opportunities and understand existing limitations. Additionally, the results from a short survey will be discussed. This survey was intended to collect data that will help inform the risks and opportunities and discover valuable information that can prompt future innovation in this area.

Furthermore, this report discusses current solutions, emerging technologies, and research and development gaps, as well as highlight areas for innovation. Potential solutions in the form of concept designs will be presented towards the end of the report. The preceding report will directly inform these concepts, and findings will directly impact their features and functionality.



[Above: Project Structure]

1.2 Literature Review.

Considering the context of the world in 2050 is mind-blowing. From three-dimensional printed dinners, and Artificial Intelligence assistants at home to the Metaverse, Virtual Reality and Augmented Reality are becoming part of daily life. Some forecasts describe a form of a technological utopia; however, other reports on what life in 2050 could look like seem relatively bleak. Underpinning all this technological advancement is the impact of the industrial revolution.

Now, beyond doubt, there is a consensus among scientists that this rapid increase in greenhouse gas emissions has led to an irreversible impact on our environment. The effect is what is now known as Climate change *(Yerlikaya et al., 2020).*

Although the effects of climate change echo far and wide, this report will begin with a focus on the increased duration, intensity, and scale of bushfires by the year 2050, showing that, because bushfires will remain in our future, it is vital to develop new and innovative solutions to be better prepared. Like many other natural disasters, bushfires leave destruction and heartache in its wake. The effects are felt by all who come across its path, which can be seen throughout history through disasters such as the Black Friday bushfires, the wildfires in Brazil, or, more recently, the fires in Canada and Hawaii. Connecting these two outlooks of the future is the critical nature of Electricity Transmission Lines. Future predictions show a world filled with technological advancement that will require a secure electrical transmission network to thrive.

These networks, however, are vulnerable in the path of the ever-increasing bushfires in the future world that is feeling the effects of climate change. The following literature review will consider the infrastructure vulnerability, its critical nature, and the stakeholders impacted by bushfires near transmission lines. It will consider the existing products and technologies and highlight the need for innovation and development in this area.

Firstly, the increased risk, defined as *"the severity of an event, and the probability of its occurrence." (Jahn et al., 2022)* of bushfire emergencies by the year 2050 can be attributed to climate forecast modelling. Current climate modelling shows higher temperatures with increased *"frequency, magnitude and duration." (Messner et al., 2011)* along with reduced precipitation (Yerlikaya et al., 2020). According to Clarke *(2011)*, effects such as these will produce *"a longer overall fire season."*

The probability of such extreme fire emergencies has been predicted to increase by 25% by the year 2050 compared to the early 2000's *(Pitman et al., 2007).* This finding by Pitman and his colleagues agrees with previous studies in this field; this shows a high degree of consistency, demonstrating that although these are future predictions, they are dependable nonetheless. These fires will produce a self-perpetuating negative effect on the climate through the increase of CO_2, CH_4 and other gas emissions, as stated by Huang *(2015),* which shows that there is a real need to develop solutions for this area, considering ways to increase safety in an immediate sense and to prepare for the threat that will be.

Having established the inevitable risk of increased bushfire emergencies in the future, it becomes imperative to highlight the impact of and on transmission lines within this context. Jahn *(2022)* states that transmission lines may profoundly impact communities in two ways.

Firstly, transmission lines might become sources of ignition for bushfires, and this can be through events such as equipment or infrastructure failure and high impedance faults, which is when nearby vegetation comes into contact with powerlines. *(Kandanaarachchi et al., 2021).* It is critical to note at this stage that although the percentage of wildfires caused by transmission lines is nominal, their magnitude is noticeably more significant; according to Mitchell *(2013), "Power line fires average ten times larger than other fires."*

While the significance of bushfire ignition by powerlines is clear, the other disastrous impact on communities needs to be addressed. That is, to emphasise the critical nature of transmission line infrastructure. Bushfires around transmission lines can lead to *"widespread power outages" (Xu et al., 2016),* which may lead to dire consequences on communities, such as, but not limited to, the loss of communication, impact on transportation methods and road safety and the loss of healthcare services etcetera as suggested by Broome & Smith *(2012).* Concerns such as these have led Broome and Smith to ask *"[when would the] benefits of shutting off power outweigh the significant costs, burdens, and risks that would be imposed on customers and communities in the areas where power is shut off".*

As a result of these findings, the best action to take is to minimise the impact of fires on transmission lines and relevant affected stakeholders, such as emergency response personnel, rather than de-energising the lines.

Although the solution is not that straightforward, as Tusnio *(2010)* argues that powerlines that are not de-energised pose significant danger to fire emergency first responders. These risks included electrocution through direct or indirect contact with the powerline, leakage current, an electrical arc or physical injury from damaged infrastructure or equipment. Tusnio *(2010)* further explained that these injuries may be severe, even fatal, and suggests that they may come about due to *"insufficient knowledge of electric shock hazards, electric shock effects or methods of prevention or unawareness of the danger during a rescue operation."*

At this point, it is crucial to discuss existing technologies and solutions to minimise the effects of bushfires on powerlines.

One popular suggestion is to convert overhead transmission lines into underground ones, which has been said to decrease the likelihood of igniting bushfires and protect powerlines from the damaging effects of bushfires. Furthermore, this would secure critical electricity supply during emergencies. However, while this option sounds ideal, it has limitations, with the main disadvantages being the high cost of doing so and the difficulty with ongoing maintenance of the underground lines *(Taylor & Roald, 2022).*

Considering that vast stretches of powerlines will remain above ground for the foreseeable future, another mitigation option must be discussed. That is the process of backburning and managing encroaching and unstable vegetation, as Yoonseok *(2009)* mentions. He also mentions the limitations of current procedures, stating that *"most utility firms heavily rely on men-centric powerline monitoring methods which are time-consuming and very costly, and also, hazardous work."* According to Clarke & White *(2008)*, one issue that has risen over vegetation management is the need to protect native species. They, therefore, suggest that keeping fire danger low while having diverse vegetation would require procedures such as *"spot spraying emergent saplings and problem plants and mosaic slashing."*

In contrast to this approach, companies have begun to widely adopt technologies such as satellite systems to monitor bushfires in a way that *"saves money, resources and time." (Davies et al., 2008).* Davies continues by explaining the interconnectedness of satellite monitoring, with the ability to send up-to-date alerts to staff members' mobile devices. This technology keeps relevant stakeholders up to date with critical information.

However, this technology has some limitations as a stand-alone solution. Some of these limitations, as outlined by San-Miguel-Ayanz & Ravail *(2005),* include false fire detection due to elements such as cloud cover and ground overheating, as well as delayed fire detection through the detection of smoke plumes, which are only visible sometime after the fire has begun and potentially inaccurate in location relative to the fire due to the impact of wind redirecting the smoke.

While many other emerging technologies, such as weather monitoring devices for powerlines, firefighting drones and cameras equipped with artificial intelligence, are being refined, much is still in development. For industrial designers, there is potential to develop further in this area, especially in real-time detailed monitoring and equipping first responders with this accurate real-time information to protect them from harm.

In conclusion, the literature review showed that the climate crisis is a reality now and in the future. It was shown through multiple unanimous sources that weather patterns and climate changes will contribute to increasing fire danger in magnitude, frequency and duration. These effects are predicted to be felt across Queensland by the year 2050, while it remains an issue today. These sources showed that this is a critical area to develop for today to understand what can be done in the future.

It was then shown that electrical transmission lines are critical infrastructure to our society. The vulnerability of transmission lines in the context of bushfires was discussed, and as a result, the need for safety and protection was highlighted. They were also proved to be a risk as a potential ignition source for future bushfires through events such as faults, vegetation damage or line-to-ground arcing.

The risks, however, were shown to be not on the lines alone but on the fire emergency first responders and vulnerable people reliant on energy supply, such as those in hospitals or other care facilities.

Furthermore, solutions such as underground powerlines, vegetation control and satellite monitoring were discussed, showing their current benefit, and outlining their constraints.

Finally, limitations of this literature review include the size of the research team, being one researcher, the limited use of research terminology and the time allotted, as deeper study could be done in this area if each of these limitations could be overcome.

PHASE TWO.

2.1 Research Methods + Methodology.

Primary research has been conducted to affirm results found in the literature review and to find relevant qualitative and quantitative data in areas specific to this report, especially considering knowledge gaps and information that would be beneficial from an industrial design perspective. This section will outline which methods and methodologies were used, why and how they were deployed.

The methodology undergirding this section is an approach known as qualitative research with triangulation, which consists of the use of two different forms of research in order to increase the credibility and validity of the information gathered.

A survey was the first primary research method implemented as a part of this research. This survey was created on Google Forms with a link to provide web access. When opening the link at the top of the survey, a disclaimer was displayed that consent would be given by participating. The survey itself *(see appendix 1)* consisted of eleven questions, which were asked in the form of multiple choice (7), short response (3), and linear scale (1). The reasoning behind using these question types was to reduce the time needed for a participant to complete the survey due to the high number of multiple-choice questions while allowing them to expand and share their knowledge in a few short response answers.

A social media post was made to present the opportunity for firefighters and energy company workers to contact the researcher to accept the invitation to participate in the survey. Initially, this was a slow process, as the number of friends who are firefighters, volunteer firefighters or electricity company workers turned out to be few.

In a search for more participants, the Queensland Fire Emergency Services (QFES) were contacted via an in-person visit, phone call, email, and social media, resulting in minimal responses. After that, a vital energy supply company was contacted and asked if they would be willing to ask a few employees to answer the survey; this led to significant survey results from seventeen participants, which was needed for this research to be successful. While significant insight was gained, more participants would have increased the rigour and value of the research conducted.

Secondly, two expert interviews were conducted with employees from an electrical company. Expert interviews were chosen for their complimentary nature to surveys as they allow for deeper and more detailed discussion. For this research method, eight questions were drawn up, each serving a different purpose. Some questions (see appendix…) were explicitly created to generate discussion and bring a semi-formal nature to the interview, while others were more direct, requiring more specific answers. These were created to gather various information while allowing the interviewee to discuss their expert knowledge with greater freedom. The semi-formal structure proved very beneficial as quality information was gathered from discussions that were not planned. The benefit of interviewing two experts became apparent through their answers and the generated discussion. However, both were relevant in their own right; they came from different perspectives, providing a broader data set.

These interviewees were approached by family members of the researcher and were given consent forms for participating in the interview and having audio recorded. The Microsoft Teams meetings were scheduled after the participant signed and returned the consent forms. While the interviews were taking place, Otter, a mobile application for dictation and audio recording, was used to create a transcript.

These text files were converted into a Word document to make corrections to the transcript while listening to the audio, which was done to ensure the clarity and accuracy of the research. These transcripts were then exported to a digital markup application where they were read through, highlighting important information in different colours for different categories: stakeholders, activities, context, technology, and opportunities *(see appendix 2).* These transcripts were then exported to ChatGPT, where the AI program was asked to categorise and summarise the interview. These summaries outlining stakeholders and opportunities were also analysed using the same system as the transcripts *(see appendix 3).* More importantly, the expert interviews and the analysis of the transcripts resulted in the following findings.

In summary, two research methods were used: a survey consisting of various question types to optimise the experience for participants, allowing for quick responses and the opportunity to expand their thoughts on some questions. Additionally, two interviews were held with experts from an energy supply company. These interviews were conducted in a semi-formal manner, allowing for precise answers as well as plenty of time for open discussion.

2.2 Research Analysis + Findings.

In order to gain insight, the research that has been conducted must be analysed. In this section, both the survey results and interviews will be discussed, including presenting the results, highlighting essential findings and elaborating on how the research was analysed to extract relevant information.

Firstly, the survey conducted resulted in responses from seventeen participants. Interestingly, although this survey was anonymous, patterns were observed as responses came in. For instance, when the survey was sent out to firefighters and emergency services volunteers, specific results came in, while when the survey was sent out among power company workers, a different perspective was apparent through the results. This observation is important to consider to understand areas of expertise and perspective, as well as limitations potentially on how the questions were phrased. While this is the case, valuable trends in the results can be seen, the only notable difference being the estimation of the danger around powerlines during bushfire events. Power company workers tended to rate the danger much higher. At the same time, firefighters had slightly lower estimations of the danger, which can be due to different knowledge bases and expertise, which may impact the perception of danger. Further, the survey results revealed key findings categorised as risk, stakeholders, technology, context, and future thought.

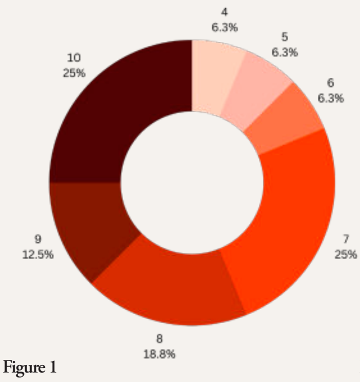


Figure 1

Figure 2

The participants were first asked to rate the danger of fires near transmission lines from one to ten, with one being low and ten being extremely high. While there was a spread of information *(see figure 1)*, the average answer was 7.8, which is within the top 25% and indicates the importance of safety in these situations *(see figure 2)*. Interestingly, when asked how often fires near transmission lines get reported, the answer varied dramatically, with 5.9% saying fortnightly, 35.5% saying monthly, and the majority, 58.8%, saying that it is too inconsistent to answer, as it varies depending on a multitude of factors including the weather, season, and location *(see figure 3)*. Furthermore, throughout the survey results, it was clear that three main stakeholders were involved within this context: the power supply company workers, emergency workers, and the community at large. When asked which would have the most significant impact on lowering the damage of bushfires on transmission towers, the top three answers consisted of 'more controlled back burning' (29.7%), 'better and earlier detection' (21.9%) and 'better monitoring and sensors' (15.6%) *(see figure 4)*. When asked to discuss frustrations in detecting, reaching, mitigating, or extinguishing bushfires near transmission towers, participants highlighted the risk of electrical arcing of transmission lines, which can result in extreme injury or fatality.

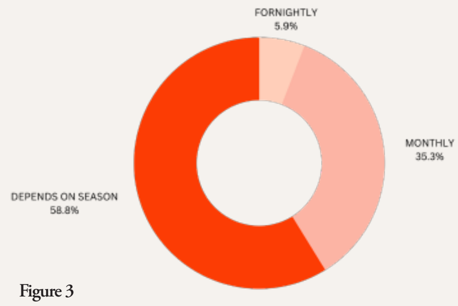


Figure 3

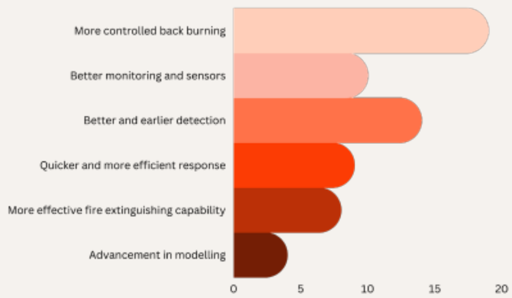


Figure 4

Additionally, the speed of detection and movement of satellites is currently slow, and modelling can be better to help predict future fire events more accurately. Knowledge of terrain, vegetation, weather, and fire behaviour in real-time currently needs to be improved. Additionally, multiple participants pointed out that a lack of electrical knowledge is a concern, which can have devastating effects as one participant noted, "There is a very real danger to firefighters if they attempt to fight fires near HV feeders where the smoke and fire is conductive and can create a conductive path to ground near where the firefights are. This puts them at great risk of high voltage electrocution." Additional points to consider, as suggested by participant responses, include the need for better line monitoring, the potential for drone firefighting technologies, monitoring remote potential ignition, the importance of real-time ground-based camera systems in conjunction with satellite technology, improved data collection for accurate risk analysis, early detection, alarm, and suppression of fire. Another critical piece of information that was revealed through the research was that of the importance of the local community in two main ways, in their vulnerability in these situations, as well as the crucial role they play in detecting fires, as seen in the survey results where 15 responses (88.2%) indicated that locals were the primary way in which fires are discovered. This question also showed the current reliance on manned patrols

(35.53% of voters) while also indicating the importance of the adoption of new technology, such as satellites (52.9% of voters) and unmanned sensors (17.6% of voters), to detect fires *(see figure 5).*

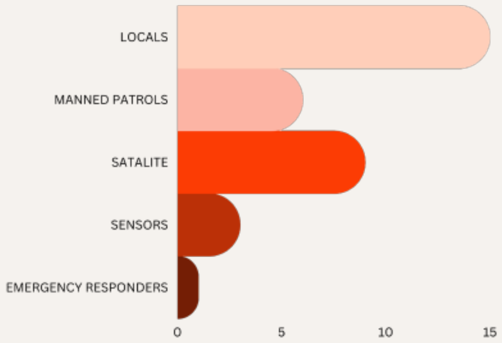


Figure 5

The lower percentages of the answers involving technology align with findings from another question, where 58.8% of participants indicated that the current systems and technologies in place are inadequate for dealing with bushfires near transmission towers *(see figure 6).* At the same time, another question about technology, specifically communication, highlighted the reliance on technology to relay important information, most notably through mobile phones (82.4%), automated alarms (52.9%) and radios (47.1%) *(see figure 7).* Overall, the survey consolidated available knowledge in understanding risks around transmission lines during fire emergencies while highlighting new opportunities for further research and thoughtful innovation.

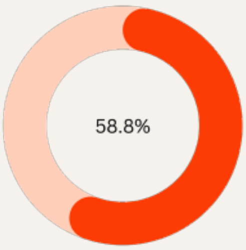


Figure 6

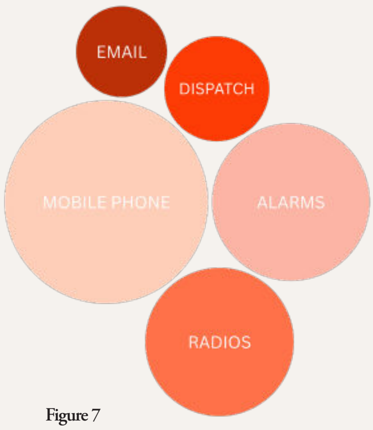


Figure 7

Secondly, the expert interviews will be discussed. Although the two interviews were based on the same questions, they yielded different responses, highlighting the importance of having different expert perspectives.

Firstly, the diverse effects on different stakeholders became clear through these interviews. While it was expected that the participants would discuss the effects on their own power company, other stakeholders such as first responders, locals, construction site workers near power lines and even the effects on whole communities were discussed, which shows the drastic impact of fires near transmission lines. Additionally, various impacts were discussed, from physical harm through possible electrocution to losing power in communities, which could have far-reaching effects. Again, this was a crucial result from the interviews that highlight the real-world impact on real lives, supporting the crucial nature of this subject matter. At the same time, one expert indicated that, while transmission lines may cause bushfires, it doesn't happen all that often, saying that less than five per cent of bushfires globally are caused by networks, with most of these being lower voltage lines. These ignitions are primarily thought to be from either vegetation interference with the powerlines or component failures. Changing perspectives, Expert A indicated that, while powerline infrastructure in Queensland is quite durable and resilient to fire due to their concrete and steel construction, passing bushfires can cause breakdowns in the insulation of the lines, which can lead to electrical arcing between lines. It was also indicated that the heat could cause powerlines to sag, significantly increasing the risk of a flashover or fault.

The interview also included questions about future preparedness, which was met with answers indicating that the company is aware of future risks and increased bushfire frequency. Their company is investing in research and is interested in any solutions being developed to increase the security of their infrastructure. Another essential point is that Expert B discussed a multi-billion-dollar project of building a super-grid, high-voltage transmission line system across Queensland. Interestingly, it will all be above-ground, standard construction, and they have indicated that this structure will also remain a part of their future infrastructure. Additionally, points of concern and opportunity were discussed. At this stage, both experts expressed their desire for more effective real-time monitoring to fully understand what is happening around high-risk situations near transmission lines. They indicated that some systems are already in place for monitoring their sub-stations. At the same time, long stretches of transmission lines remain in rural areas far from those monitor systems they already have in place. At this stage, Expert A indicated their fondness for satellite technology, especially with the hope of deploying more satellites.

In contrast, the Expert B indicated the limitations of satellite technology in not fulfilling what they need in a monitoring solution. At this stage the importance of automation was discussed, indicating that the future ideal would be to eliminate the need for humans to be exposed to the dangers at play. As a possible solution, both experts suggested that drone technology may be of use, although Expert B shared the limitations, saying that drones cannot fly too close to fires due to the thick smoke and heat. Additionally, concerns about firefighter safety were mentioned a few times, indicating that these stakeholders are most vulnerable in these situations. Expert A commented on the lack of electrical knowledge being a major concern. In light of this, technologies such as artificial intelligence and cameras were discussed to guide firefighters to be aware of electrical dangers in real-time. Technologies for a solution like this were discussed such as the corona camera, which can detect and indicate where electrical current may be leaking and lidar and infrared to scan the environment around them. Lastly, it was determined that it is imperative for any solutions to fit in with the system already established around Queensland, making sure that technology integrates smoothly.

In summary, both research methods led to gathering significant and beneficial insight and information into the context of bushfires near transmission lines. While the dangers of this context were confirmed, other areas of concern within the context were uncovered, which included dangers posed to firefighters, workers near transmission lines and communities that might experience power loss due to the bushfire impacts on the transmission lines. The benefits and limitations of current technologies, such as communication and monitoring methods, were discussed. Needs and opportunities were learned, such as better monitoring of powerlines and better training for firefighters during these high-risk scenarios.

Overview.

17 *SURVEY PARTICIPANTS*

187 *QUESTIONS ANSWERED*

2 *INDUSTRY EXPERTS INTERVIEWED*

OVER **AN HOUR** *OF INTERVIEW DIALOGUE ANALYSED*

PHASE THREE.

3.1 Discussion + Implications.

A cohesive medley of information concerning bushfires near transmission lines was discovered through the literature review, survey results and expert interview analysis.

Firstly, it became clear through these avenues that bushfires and their impact on transmission lines is a genuine concern for today and remains a concern for the future. The dire impact of powerlines affected by bushfires was also revealed, indicating that the effects may lead to severe injury, potentially leading to fatality, and the wide-reaching impact of leading to communities without power, which was shown to be a critical issue. The corroboration of the research with the literature indicates that this is an area of need, indicating an opportunity for an industrial design solution to make a difference.

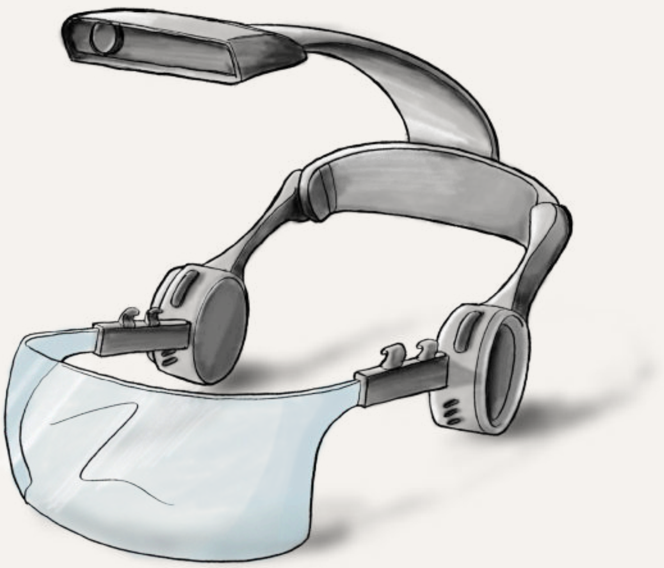
To further discuss the findings, the two main stakeholders will be considered. Firstly, the emergency responders and firefighters. Through the literature review, surveys and expert interviews, these stakeholders were indicated to be the most vulnerable. Their proximity to the context of fire near transmission lines puts them directly at risk. Here, some specific opportunities were uncovered: the opportunity for better education and training in this context and harnessing the capability of technology to indicate where electrical risk may be present to firefighters. This training could breach firefighters' general electrical knowledge gap, which is a predominant issue that puts them at risk.

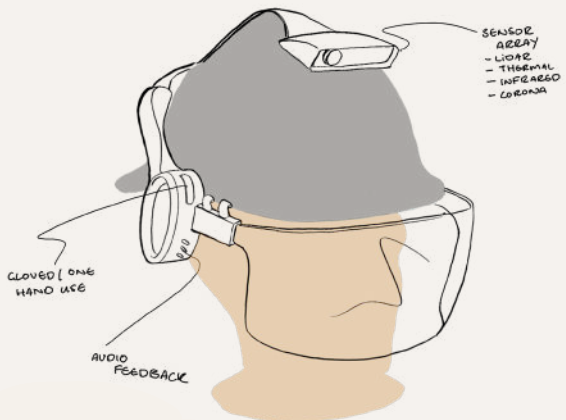
Furthermore, the other major stakeholder was found to be the power supply company itself. Here, more specific opportunities were uncovered due to the nature of the research undertaken. These areas of opportunity came in light of discussion of the limitations of current technology such as limited camera coverage, and limitations of satellite technology and availability. A significant opportunity was the need for accurate, real-time monitoring devices that can be deployable to areas at risk, as needed, which could be to rural areas, where technology such as this still needs to be installed. According to research, these sensors must collect at least some data about wind and weather, vegetation, smoke, fire behaviour, proximity and location, and electrical charge, as indicated by the literature review, surveys and expert interviews. Another point discussed was the future of automation, to remove the need for humans to be exposed to dangerous situations.

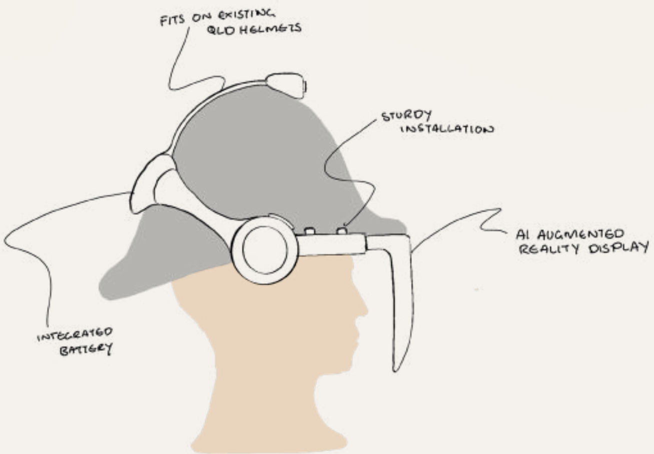
3.2 Concept Sketches.

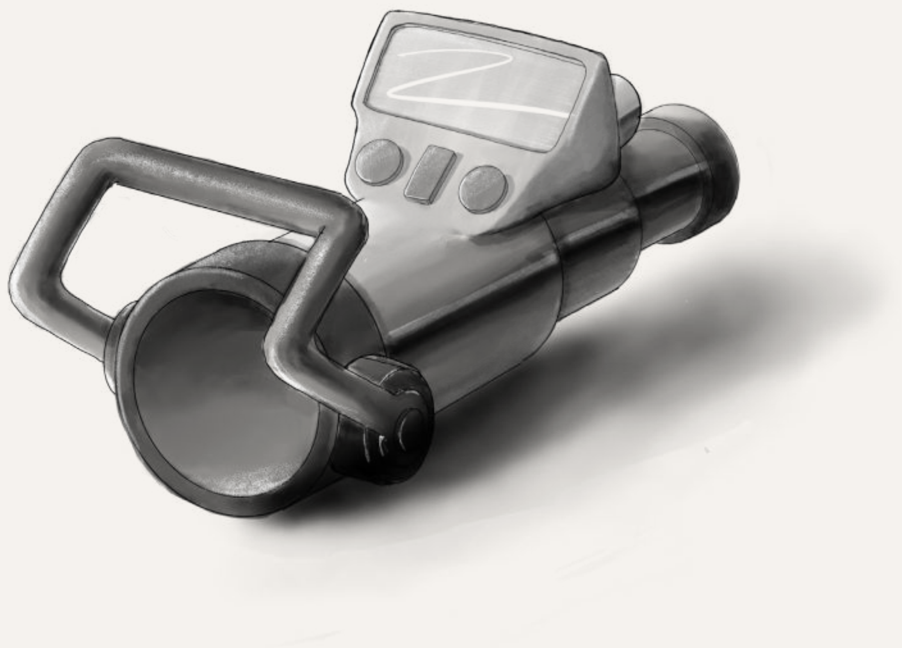
The following concepts aim to address the opportunity areas uncovered throughout the preceding report.

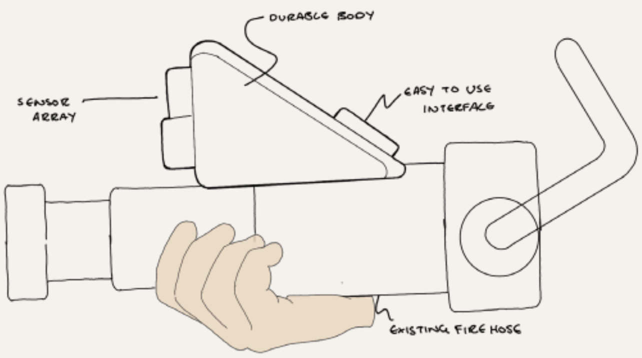
The first concept, **the AR Firefighting Visor**, is a concept that has been designed for the safety of firefighters in the context of bushfires near transmission lines. This concept aims to equip firefighters with a sixth sense, using AI risk indicators via sensor inputs. The input method is an array of sensors mounted on the top of the existing firefighting helmet, consisting of infrared, thermal, lidar and corona cameras. These will display an accurate AR overlay that can indicate precisely where fires are through thick smoke, revealing hot spots that remain a risk. However, the primary advantage of this concept comes in the form of the corona camera, which can display electrical risks to the firefighter in real time, eliminating the electrical knowledge gap and ensuring improved safety for first responders. Additionally, this design has been equipped with audio input and output so that the firefighter can seamlessly ask for information to be displayed on the visor and be warned about any dangers before it is too late.

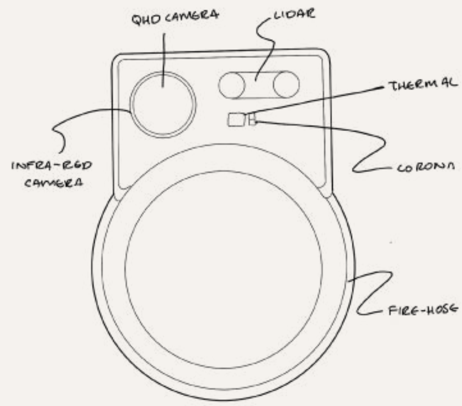






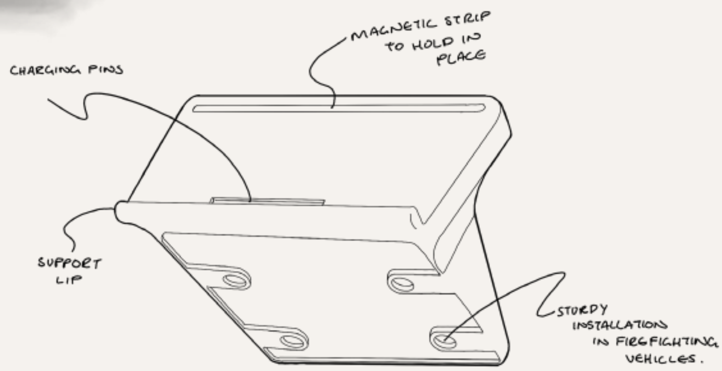


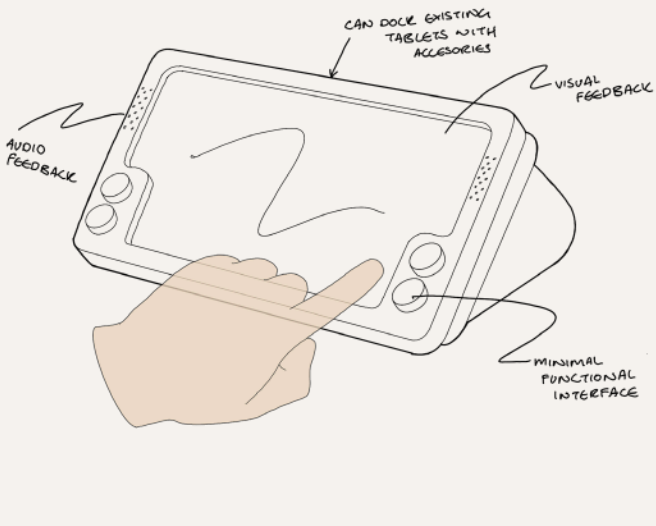


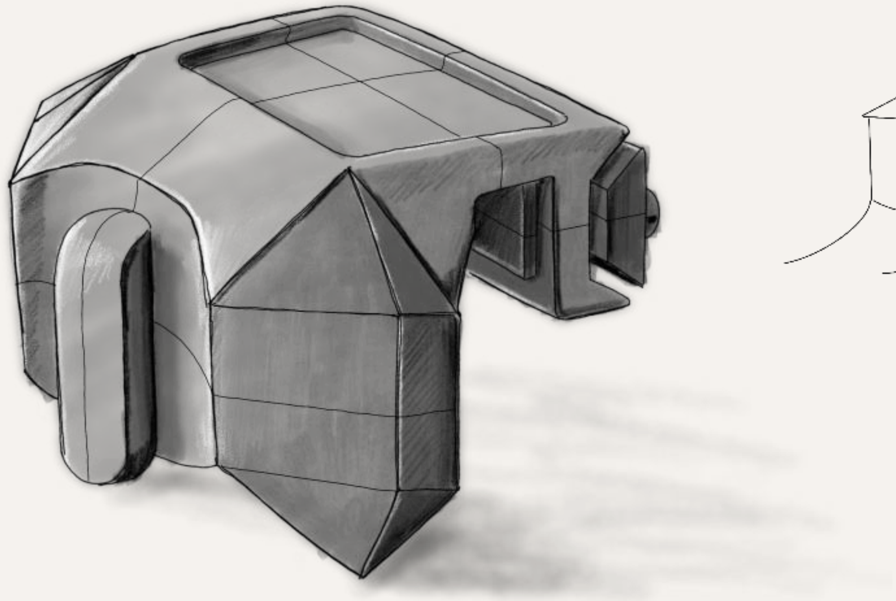


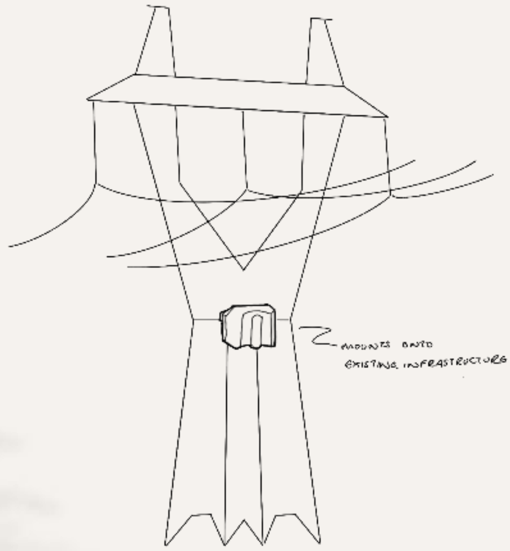
The second concept, the **AI Hose Assistant**, has also been designed with firefighters in mind. This design is similar in technology compared to the first concept, comprised of an array of sensors to detect dangers posed to first responders to bushfires near transmission lines. Although this concept is different in its application, it is designed to be installed on the nozzle end of the firefighting hoses. Here, through an AR interface, the design can guide the firefighter on where to point the hose, ensuring all fires and potential hot spots are e. Again, the main focus is that this design can warn firefighters of electrical dangers in real-time, ensuring their potential lack of knowledge concerning electrical risks does not put them in danger.

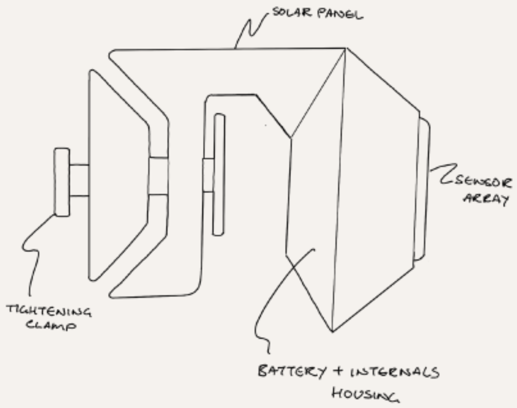
The third concept, the **AI Docked Monitor,** uses the same technology again. The reasoning behind it remains the same, as it has been designed to increase the safety of first responder firefighters. In this case, the technology is installed in a durable tablet-style casing. This tablet has been designed to be usable with thick firefighting gloves in a harsh environment. This tablet can scan a scene for dangers and hazards, clearly highlighting areas of concern using AR in real-time. The additional function of this design is that has been designed to be housed in a dock that is installed in bushfire response vehicles. The device aims to inform firefighters of these risks, even from far away as they approach the scene, which will also ensure it is always within reach, in a place where everyone will know where it is, and ensure it is always charged up and ready to go. The intention is that the one scanner will be able to link to multiple mobile devices so that the information gained can be sent to all the firefighters in the context so that they are all well-equipped and well-informed for their safety.

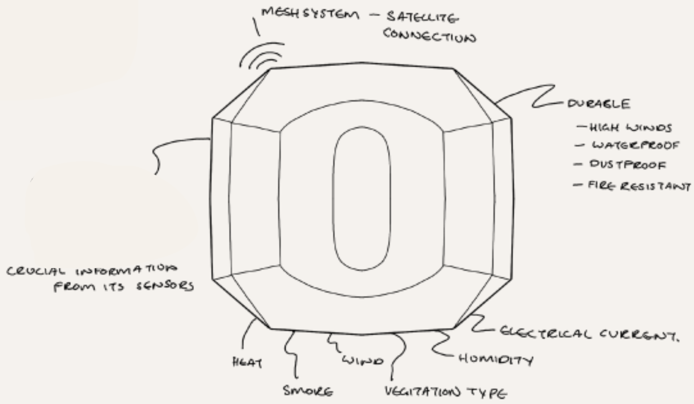






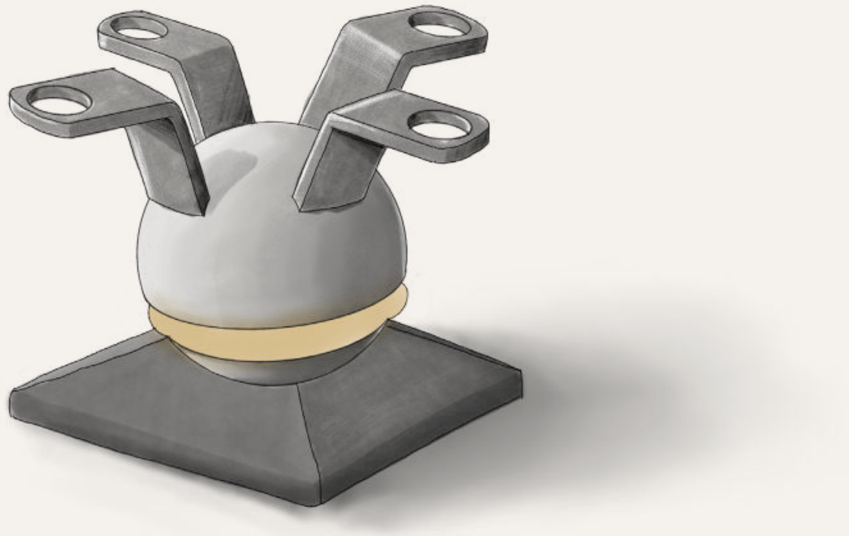


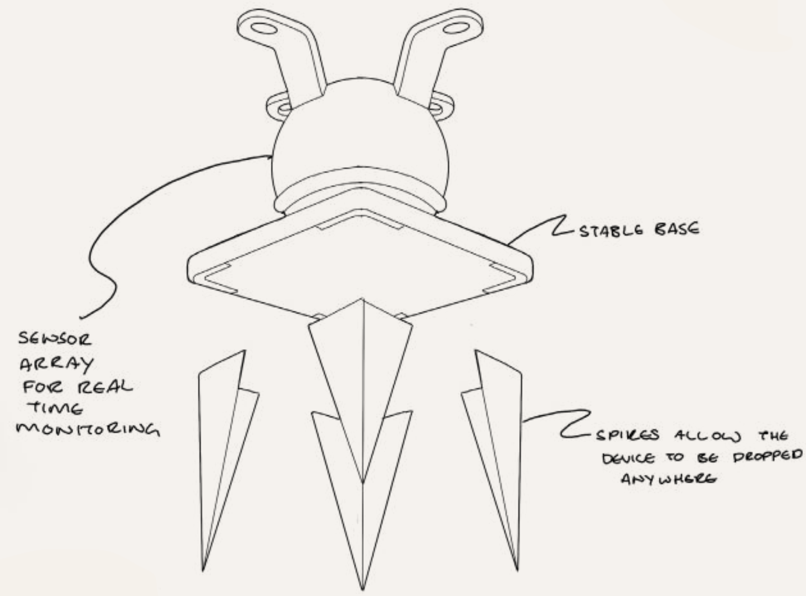


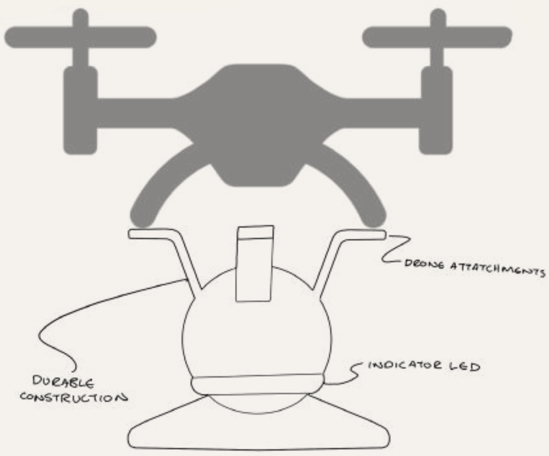


The following two concepts are designed for the other major stakeholders, the electrical supply companies. First, concept four, the **AI Mesh Deployable Monitor,** was designed for accurate, detailed, real-time monitoring as expressed by the electrical company experts. This design comprises an array of wind, temperature, vegetation type, smoke, and heat sensors encased in a highly durable and fireproof shell. This monitoring device has been designed to attach to existing powerline infrastructure, which can be deployed when potential high-risk situations arise. Multiple devices can be deployed to create a mesh of high-level, real-time monitoring to equip the electrical company to take fast, well-informed action in these situations. This system can be incorporated into their existing system and infrastructure seamlessly, adding value and capability. This design also includes satellite connection and mobile coverage to relay the data securely and reliably to the electrical company offices. These devices can be installed by a team of live-line workers who have been trained in this area. This may be a high-value addition at a reasonable price with immediate potential.

Lastly, the final concept, **the Automated Monitor**, consists of similar thinking as the previous design concept. In this case, the issue of automation was considered. This concept is a drone deployable monitor. The monitor can function similarly to the previous concept, giving power companies real-time weather, smoke, and fire information. The added benefit is that these monitors can be sent out to areas of risk in unmanned drones, providing fast solutions while decreasing the need for people to be exposed to dangerous situations. The concern with this is that functionality may need to be improved due to weight constraints, installation concerns and expense.







3.4 Conclusion

This report has explored the impact of bushfires on electricity transmission networks. It was shown through a literature review that, based on the projected effects of climate change, the duration, intensity, and scale of bushfires will increase substantially. The report also showed that transmission lines are vulnerable when exposed to bushfires, affecting further stakeholders such as emergency response personnel and electricity company workers. Current technologies and solutions were explored, and their limitations were considered. Furthermore, primary research was conducted through surveys and expert interviews. These were chosen to complete qualitative research with triangulation to add value and vigour. This research led to key findings and, when considered alongside the literature review, revealed various opportunities for innovation. These opportunities were considered, and concept designs were created based on their implications. These five solutions each targeted slightly different solutions, considering different stakeholders, different technologies and different contexts; however, each of these has proven to be valuable as they have been informed by a plethora of literature, primary research and experts in the field.

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Icons used from https://thenounproject.com

Appendix.

Appendix 1.

Wildfires

The submission or return of the completed survey is accepted as an indication of your consent to participate in this research project.

How often are firefighters called out to deal with bushfires near transmission towers?

- ◯ Daily
- ◯ Weekly
- ◯ Fortnightly
- ◯ Monthly
- ◯ Other...

On a scale from 1-10, how dangerous is a bush fire that is close in proximity to a transmission tower? (1= low danger, 10=extreme danger)

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

How are bush fires discovered?
(you can select multiple)

- ☐ Locals
- ☐ Manned Patrols
- ☐ Satalite
- ☐ Sensors
- ☐ Other...

How are bush fires called in?
(you can select multiple)

- ☐ '000' calls
- ☐ SES
- ☐ Directly to your organisation
- ☐ Social Media
- ☐ Automatic alarms
- ☐ Other...

In your opinion, are the current systems and technologies that are in place adequate for dealing with bushfires near transmission towers?

- ◯ Yes
- ◯ No

Do you know of any emerging technologies that may, by the year of 2050, be beneficial in dealing with bushfires near transmission towers?
(feel free to imagine what might be possible by that time, even if it not currently possible)

Long answer text

Is there anything that is frustrating in the process of detecting, reaching, mitigating or extinguishing bushfires near transmission towers?

Long answer text

How does the information about bushfires get relayed to different stakeholders e.g. emergency responders?
(You can check multiple)

- ☐ Mobile phone
- ☐ Automated alarms
- ☐ Radio's
- ☐ Other...

Of these, which would have the greatest impact on lowering the damage of bush fires on transmission towers?
(you can select multiple)

- ☐ More controlled back burning
- ☐ Better monitoring and sensors
- ☐ Better and earlier detection
- ☐ Quicker and more efficient response
- ☐ More effective fire extinguishing capability
- ☐ Other...

What sort of terrain are transmission towers built on?
(you can select multiple)

- ☐ Mountains
- ☐ Grassland
- ☐ Dense rainforests
- ☐ Urban areas
- ☐ Other...

How are the transmission lines at risk reached?

Short answer text

Appendix 2.

Jan 1:21
So as research and modeling in the field of climate change suggests by the year 2050 our world will be experiencing wildfires at a larger scale, duration and frequency. Have there been discussions in your circles about these future predictions?

Interviewee 1:39
Yes, when founding is very much focused on this and especially in the future, because we got to build a super grid we call it 500,000 fault lines and substations. So we have to be very much aware of it for one way we can to build these lines and also the potential impact to customers but more so to generate 10 generators that will be connected and generate this means it will be wind farms, solar farms, and battery storage facilities and more. So the importance of having a good connection to our pump hydro schemes, which will be a strong feed into your network. And we actually started with planning to have it in place by 2032. renewable generation by 2050. So 2030 to be 70% renewable generation, but then we can grow that until 2050. So we have to look at all the impacts of environmental on to this as well and prepare ourselves because the impact of losing a generator that generating the power into the grid is huge, because you depend so much on smaller, but more wide area Bell generation and mostly in the vulnerable areas in the outback, forestry areas potentially as well. So it's important thing for us to look into.

Appendix 3.

HUMAN SAFETY AT THE CENTRE OF THE DESIGN

1. **Safety and Reliability:** The primary objective of the product is to enhance safety for emergency services personnel, firefighters, and communities. It must provide a reliable method of monitoring transmission lines and detecting potential fire-related risks. *— MONITOR + DETECT*
2. **Compatibility and Integration:** The product must be designed to integrate with existing infrastructure, including transmission towers and power lines, without compromising their structural integrity or functionality. *— INTEGRATION IS KEY → ONE PART INTRODUCED INTO AN EXISTING SYSTEM.*
3. **Remote Sensing and Monitoring:** The product must leverage advanced remote sensing technologies, such as satellite-based monitoring, to provide real-time data on environmental conditions, including temperature, humidity, wind speed, and vegetation health. *→ + SPECIES?*
4. **Data Analytics and AI:** Incorporate data analytics and artificial intelligence to process the collected data and provide accurate risk assessments, enabling timely decision-making for fire prevention and response. *→ AT THE MOMENT THIS IS MANUALLY DONE? — THIS IS KEY*
5. **Minimal Environmental Impact:** The product's design should prioritize environmental sustainability and minimize its own ecological footprint, ensuring that its deployment does not contribute to additional environmental concerns. *→ IMPORTANT!*
6. **Cost-Effectiveness:** Strive for a cost-effective design that offers a reasonable return on investment for utility companies, governments, and other stakeholders involved in bush fire mitigation. *→ KEY CONSIDERATION FOR INTEGRATION IN THE REAL WORLD.*