Indigenous Data Sovereignty, Circular Systems, and Solarpunk Solutions for a Sustainable Future

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Recent advancements in Artificial Intelligence (AI) and data center infrastructure have brought the global cloud computing market to the forefront of conversations about sustainability and energy use. Current policy and infrastructure for data centers prioritize economic gain and resource extraction, inherently unsustainable models which generate massive amounts of energy and heat waste. Our team proposes the formation of policy around earth-friendly computation practices rooted in Indigenous models of circular systems of sustainability. By looking to alternative systems of sustainability rooted in Indigenous values of *aloha 'āina*, or love for the land, we find examples of traditional ecological knowledge (TEK) that can be imagined alongside Solarpunk visions for a more sustainable future. One in which technology works with the environment, reusing electronic waste (e-waste) and improving data life cycles.

Keywords: sustainability, cloud computing, Indigenous Data Sovereignty, environmental policy, heat waste, solarpunk, Indigenous futurism

1. Data Center Infrastructure and Environmental Impact

The energy industry is the top contributor to the growing climate crisis, with fossil fuel burning being the main culprit for decades. However, in recent years the rapid growth of data center infrastructure — driven by advancements in Artificial Intelligence (AI) and Graphics Processing Unit (GPU) technology — has become a significant contributor to global heat emissions and electronic waste (e-waste). The GPU, originally designed for rendering 3D graphics, has accelerated AI training, contributing to immense concentrations in heat waste from data centers. Modern bioinformatics, like other disciplines reliant on large-scale computation, is contributing to the environmental impact of data centers (Grealey et al., 2022). This rise in heat production poses critical questions about the environmental cost of accelerated computing in both the AI sector and biocomputing more broadly, necessitating new policies and sustainable infrastructure to mitigate these impacts.

As the AI sector has continued to boom in recent years, several large corporations have cornered the market in key areas including NVIDIA's monopoly as the sole producer of the GPU, and Amazon Web Services as they have the money and reach to build numerous data centers around the globe. This should concern communities who wish to retain control and ownership over their data. NVIDIA's monopoly over the GPU led to a "141% increase in the company's data center segment compared to the previous quarter" indicating the massive interest in AI technology (De Vries, 2023).

Additionally, companies like Microsoft and Google's parent company Alphabet have led the push to integrate generative AI into basic web searches, creating their chatbots Bing Chat and Bard, after seeing the success of Open AI's ChatGPT, leading to a significant increase in energy use and heat waste (De Vries, 2023). In a 2023 study, researchers estimated that if generative AI was integrated into every Google search, it would result in an energy use increase as high as 29.3 TWh per year which is the equivalent of the yearly energy use of an entire country the size of Ireland (De Vries, 2023). Despite the fact that this study was only published last year and the authors predicted that Google would not integrate AI into their searches due to the significant energy and monetary costs – an estimated 100 billion U.S. dollars for a year of server space – at the time of writing this article, Google currently has generative AI answers at the top of most Google searches. When considering the fact that 2023 and 2024 have consistently broken heat records, the need to investigate the environmental impacts of AI and data center infrastructure is more pressing than ever.

1.2 Current infrastructure model

The current infrastructure model for deciding where to build data centers is based around Western ideologies of economic gain, terraformation, and extraction of resources. These values are inherently opposed to sustainability and in direct conflict with environmental protection laws

such as the Executive Orders on Climate issued by President Joe Biden in January 2021 that seek to reduce emissions to net zero economy-wide by 2050 and emphasize the transition to clean energy (U.S. Council on Environmental Quality, 2021). Despite these types of laws, current environmental oversight on how data center infrastructure contributes to these emissions does not do enough. Current policies surrounding the environmental impact of AI call for "voluntary reporting" from data centers on the amounts of energy used and how their infrastructure affects the environment (Markey, et.al. 2024). Voluntary reporting is flawed in its conception because statistics are often underreported and there is no oversight or enforcement. Instead, these bills serve as a smokescreen for companies to hide behind while pretending that they are altruistically reporting their emissions. Therefore, the most popular cloud service companies including Amazon Web Services, Microsoft Azure, and Google Cloud, hold a majority of the power in the cloud computing market and are projected to continue making "Year-over-Year" (YoY) increases in profit revenue (AAG IT, 2024).

Data center locations are notoriously secretive and the largest companies within the sector, Amazon Web Services, Google, and Microsoft, often go to great lengths to not advertise their locations. Buildings are usually non-descript with high security measures as the only indication that there is valuable data being held inside. However, although these data centers may be inconspicuous to the average passerby, they are not invisible under infrared visualization. Data centers can be located through heat mapping GIS sensing technology which highlights the central problem with the current "status quo" – the immense amount of heat being generated by computational action (Johnson-Zafiris, 2024).

1.3 Proposed Policies: Earth Friendly Computation (EFC 574)

In this paper, we propose the formation of policies around the construction and location of data center infrastructure, entitled "EFC 574" which stands for Earth Friendly Computation among the 574 federally recognized Indigenous tribes located in the so-called United States (*See Figure 1*). Proposed policies would be structured around Indigenous values of land stewardship, circular systems of sustainability, and data sovereignty. Drawing upon lessons from the past and applying them to the future, we can begin to imagine a world in which technology and nature are intertwined harmoniously, rather than at odds with one another.

Building upon discourse from environmental justice and Indigenous futurism through the lens of the genre Solarpunk, we propose alternative solutions rooted in tangible decolonial actions of sovereignty. Inspired by the wisdom of Robin Wall Kimmerer's *Braiding Sweetgrass*, we hope to show how Indigenous values of sustainability and working to serve nature through cycles of renewal instead of linear extraction can be visualized in the data center industry (Kimmerer, 2013). In doing so, we hope to provide a blueprint for Indigenous Data Sovereignty rooted in the sovereignty of our lands.

Figure 1: Indian Lands of Federally Recognized Tribes of the United States
Map of the 574 federally recognized tribes and their regional designations within the United States from the Bureau of Indian Affairs.

2. Indigenous Leadership in Earth-Friendly Computation

Current models for data center construction contribute to the already devastating effects of climate change and colonial extraction on Indigenous communities. From diverting and polluting water tables, to mining and extracting dangerous elements for technological components, extractive processes currently threaten the already precariously limited resources in areas like drought-prone Nevada, or the rising sea levels and sand erosion of the California coast (Fernández‑Llamazares et.al., 2020). As highlighted by Potawatomi scholar Kyle Whyte, climate mitigation strategies often fail to consider how they will impact Indigenous communities, who disproportionately experience the impacts of climate change, leading to a dilemma in which urgent races to adapt to climate change and prevent increases in temperature are implemented without the necessary "kin relationships" to sustain such changes (Whyte, 2019). Instead, EFC 574 provides a pathway for Indigenous communities to further empower Indigenous Data Sovereignty principals through decentralized data center infrastructure. Indigenous communities are poised to lead the way in earth-friendly computation policies by shifting the focus away from Western ideologies of linear consumption and toward sustainable practices inspired by closed loop or circular economy systems like the Hawaiian ahupua'a, a land division system based on the value of aloha ʻāina, the Hawaiian term for circular systems of care in which the people and the land are continuously reciprocating care for each other (Vitousek and Beamer, 2013; Beamer, 2023; Smith, 2021). In Hawaiian resource management, every system is connected to feeding

each other; fish feed the people, leftover food waste feeds the fish, the fish ponds make the soil fertile, and the plants grow strong, which in turn feed the people and the fish (Beamer, 2023). This sort of closed loop circular economy allowed island communities throughout the pacific to thrive for centuries, developing nuanced techniques for recycling resources (Vitousek and Beamer, 2013) . Importantly, we emphasize the weaving of Traditional Ecological Knowledge (TEK) like the ahupua'a system and aloha 'āina values with Western technology and imaginative concepts like Solarpunk, rather than absorbing one into the other (Whyte, 2013).

Applying such an approach to data center infrastructure, we suggest the creation of a federated decentralized network where Indigenous communities can choose to retain control and possession of their data rather than sending it off to a centralized cloud at a large corporation like Amazon Web Services (Boscarino et al., 2022). By creating a decentralized network of data centers where servers are built on Indigenous sovereign land, with sustainable technologies that aim to work with the environment rather than against it, we aim to enact "good relations with the land" as described by Métis scholar Max Liboiron in *Pollution is Colonialism* (Liboiron, 2021). Liboiron's use of anticolonial science to critique the plastic industry provides a framework for moving away from Western ideologies of extraction and unsustainable profit. Similarly, we hope to show how being in good relations with the land is important for sustainable data computation. Land is central to this argument; the concept of data sovereignty and its connection to the land is important since data can not be considered sovereign if it is not on sovereign land.

2.2 Addressing Heat Waste through Circular Systems

In addition to data sovereignty concerns, the heat waste generated by centralized cloud computing contributes to the current climate crisis through the demands of air conditioning, water extraction for liquid cooling, and the creation of heat waste as a byproduct. Several solutions have been proposed including Sea Water Air Conditioning (SWAC) a method of cooling which relies on a network of cooling tubes that run continuous seawater through in order to cool down components (Elahee and Jugoo, 2013). This is one solution that could be helpful in areas along coastlines, particularly in communities where sea levels are rising quickly and forcing the abandonment of structures. If these structures could be reinforced for SWAC and repurposed into data centers this would be one example of earth friendly computation where technologies work with nature rather than against it. However, it is important to consider the ways in which these technologies can be misappropriated. While utilizing water to cool components might be a helpful tool, we must be careful not to reproduce the same kinds of water exploitation and pollution that are already occurring throughout Indigenous lands (Fernández‐Llamazares et.al., 2020).

Inspired by our Indigenous and Islander roots, we propose looking to circular systems of sustainability like "the *moku* system" of "biocultural resource management" in the Hawaiian islands (Winter et al., 2018). This pre-contact system divided the islands into socio-ecological sections from mauka to makai (mountain to ocean) called an ahupua'a, which are often referred

to as models of sustainability (Winter et al., 2018). This system was unique because it took into account all the different regions, weather patterns, resources, and conservation needs that were unique to various parts of the island. The Hawaiian islands include a diverse range of climate types, with the Koppen classification system being used as early as 1937 to highlight the five different types of climate commonly experienced including; humid tropical, arid and semi-arid, temperate cold continental, and ice or alpine climates (Jones and Bellaire, 1937; Peel et al., 2007). Given the diversity of climate and the limited landmass, the *moku* system was developed to be sustainably integrated into the landscape demonstrating how watershed systems can be implemented in data center construction without having to shape the earth to bend to the will of current infrastructure models. Drawing from these systems of knowledge we propose looking to speculative visions of the future for inspiration on policy regarding sustainable data center infrastructure and earth-friendly computation.

2.3 E-waste and Data Centers

In addition to concerns around heat waste, electronic waste (e-waste) is also a major issue in current data center infrastructure. One proposed solution is to repurpose old GPU technology to build out these sovereign data centers. Technological components under the current standard are often built with planned obsolescence in mind, pushing for constant upgrades in order to maintain performance. However, there are still many less intensive computing tasks that these older components could be repurposed to handle. Therefore, in addition to rethinking the locations of data centers, our team also proposes the formation of policy around recycling GPU and CPU components into these new sovereign data centers in order to maintain the cyclical pattern of reuse and renewable energy. This is where envisioning futures through the lens of the Solarpunk genre can be helpful, as it allows us to step outside the current energy landscape and imagine what a stronger investment in solar energy use could look like for data centers.

2.4 Indigenous Futurism and Solarpunk Solutions

Solarpunk is a term that describes the utopian vision of a futuristic society in which technology is intertwined with nature and facilitates sustainable innovation and development (Wagner and Wieland, 2022). Indigenous communities around the world have been inspired to envision futures through the lens of these Solarpunk themes coupled with already established networks of Indigenous sovereignty (Reina-Rozo et al., 2024). Indigenous futurism is about taking the values that our communities are built around – such as sustainability, circular closed loop systems, and TEK practices – and forming policies that will begin to push back against the centuries of colonial extraction and destruction of ecosystems. In turning to such solutions, we begin to imagine a world that unsettles the status quo, in which data centers are thought of as inert and isolated ‘heat objects’. Instead, data centers are ontologically understood as non-human kin (TallBear, 2017; Lewis et al., 2018), whose heating, cooling, and other infrastructural needs are always already entangled with their landscape in harmonious circular systems of reciprocal renewal.

For example, in the case of heat waste, excess heat generated by machine components inside a data center could be harnessed and redirected into other appliances that would otherwise need to generate more energy for heating. Imagine a data center located next to a gym or a salon where the excess heat could be funneled into a heating, ventilation and air conditioning (HVAC) system attached to heated floors or hooded hair drying stations. In a cold environment it could be redirected into district heating for homes (Ding et al., 2024). The applications are endless if we just shift our thinking from "we must create more energy" to "how do we re-use the energy we already have" and the first step in this paradigm shift is to re-think the way data centers are constructed and located.

Our team proposes reforming the data center industry by emphasizing these values through public policy. Building on the already established networks throughout Indigenous communities we hope to build policy around the establishment of data center nodes located on sovereign Indigenous lands. Tribal Nations would be asked if they would like to establish their own independent data centers on their land and should they choose to share any pieces of information with other communities, organizations, or other entities, they would have full control and autonomy to do so without having to go through third party companies that could exploit or endanger their data.

3. Importance of Sovereign Indigenous Nations Controlling Their Data

Current models for cloud computing rely on centralized networks that force users to surrender consent, ownership, and other rights in order to use those services (Boscarino et al., 2022; Mackey et al., 2022). This should be considered particularly alarming in the context of genomic data and the future of precision medicine. Standard Practices for storing data do not take into account the massive multiplicity of data being generated through genetic research, both by for-profit companies like 23 and Me, and by health industries (Mackey et al., 2022). Indigenous communities can be leaders in this space by implementing decentralized federated networks for genetic research at places like The Native BioData Consortium (NBDC) (Boscarino et al., 2022). Located in The Cheyenne River Reservation, NBDC, would be the first demonstration of one of these data center "nodes" serving as an example of the power of Indigenous data sovereignty applications in the medical field.

This is important for many reasons, first through the implementation of edge computing, which aims to bring technology out of the lab and into the field, data could be kept closer to the point of collection, creating less computational energy (Raith et al., 2023). Secondly, this would allow Indigenous communities to choose with whom and under what circumstances they would like to share such data giving them more autonomy over their data (Mackey et al., 2022). Additionally, this would also be an opportunity for communities to engage with meaningful medical research that is urgently needed in their specific communities. As mentioned by Tuck and Yang in their highly cited paper, *Decolonization is not a metaphor,* the decolonization of the data and tech services needs to be grounded in sovereignty and that is rooted in the land (Tuck and Yang, 2012). Ownership and control over Indigenous peoples' data is integral to the fight for

sovereignty and decolonization (Walter and Carroll, 2020). When a community is forced to use a large corporation for their data processing services, they have to sign away at least some part of ownership, consent, and/or rights to that data. All too often "green computing" solutions are offered in ways that systemically harm Indigenous communities by clustering benefits around the most wealthy and pushing the harm on to marginalized communities. In the context of data center infrastructure, the result is building centers in low income areas, diverting water away from the community for machine cooling, and venting heat waste and other harmful emissions into the surrounding air. Instead, we propose a solution that is oriented in Indigenous epistemologies of sustainability and circular systems, based on TEK maintained by Indigenous communities around the world since time immemorial (Vitousek and Beamer, 2013; Whyte, 2013; Smith, 2021).

3.1 Digital Anthropology and Indigenous Data Sovereignty

Frameworks from the newly rising field of digital anthropology allow us to conceptualize the massive amounts of data being collected and stored in cloud servers. In recent years scholars have highlighted the need for digital archivists and anthropologists who can apply their archaeological excavation skills to the digital realm (Geismar and Knox, 2021). This should raise concern for communities who have a history of being exploited and their data stolen. As more and more information is stored on cloud servers and housed in data centers, this build up of digital clutter generates massive amounts of heat waste driving an ever rising need for additional cooling systems. This in turn leads to more exploitation of Indigenous lands and values for the sake of maintaining unsustainable systems. Through the formation of policy around data center construction and infrastructure and by emphasizing the need for Indigenous perspectives in shaping future sustainable policy, we hope to provide an alternative path for communities to opt out of such digital excavation and retain full sovereignty and control over their data.

3.2 Biological Data

The importance of Indigenous Data Sovereignty and the need for a decentralized data center network can be seen in examples of genomic data related to human health as well as environmental data. Since the inception of the Human Genome Project scientists and entrepreneurs have been racing to mine and map the human genome in order to commodify and control specific genes for the sake of drug development (Sunder Rajan, 2006). This has created a dangerous mainstream framework for economic value to be the main driver behind decisions about data use including whose genome gets studied and for what purposes.

Similarly, in the case of environmental data, the need for bioremediation solutions to clean up pollution through the use of synthetic biology and metagenomics, presents a precarious dilemma. Researchers who want to develop solutions, but fear having those genetic discoveries patented by large corporations which in turn sell the solutions back to the communities in need for a profit are in a difficult position. Synthetic biology is poised to harness the power of

biotechnology to create bioremediation solutions (Rylott, 2020), but at what cost to the communities which are most affected by climate change and pollution? Instead, through the lens of a circular economy, we propose protections for Indigenous Data Sovereignty that go hand in hand with our proposed policies for more sustainable data center infrastructure.

3.3 New GIS Tools to Guide the Development of Policy

Advancements in Geographic Information Systems (GIS) technology have decentralized the power of map making, allowing more communities to have a say in their territories' self-determination. For example, GIS mapping technology has been used to track the repercussions of the Morrill Act of 1862, which granted land to U.S. colleges and universities by expropriating nearly 11 million acres of Indigenous land. This land, scattered across 24 Western states, became the financial foundation for many of today's top universities. The money raised from land sales remains on university ledgers today, and some states still hold unsold parcels and mineral rights, which continue generating revenue for higher education institutions. The act masked a massive wealth transfer, contributing to the violent history of North American colonization. Scholars have used GIS tools to map how these land transfers occurred showing the money trail and corruption through story maps (Ahtone and Lee, 2020). Additionally, Scholars are already implementing GIS technology to combat environmental risks with algorithms that analyze and predict complex wildfire patterns (He, 2022).

As the demand for data centers escalates, so does the urgency around identifying environmentally favorable locations for their construction. We propose the development of policy utilizing tools to assess and identify the most appropriate way to integrate data center infrastructure into existing landscapes. Considering variables such as climate vulnerability, natural resource availability, biodiversity hubs and other unique environmental variables, we plan to build out a prototype resource tool which Indigenous communities can be in control of for strategic guiding of sustainable data center development (*See, Figure 2*). Looking at the Agua Caliente Band of Cahuilla Indian (ACBCI) Reservation as an example, due to its unique reservation boundaries which form a sort of checkerboard pattern, we can see that there are solar and wind resources which could be beneficial in building out sustainable data centers, as well as areas with high biodiversity which should be considered and protected as infrastructure is developed. Looking at the Intersection of Resources map, we see that the northwestern quadrant of the ACBCI Reservation where solar and wind resources are abundant but biodiversity hubs are not present, would be the most ideal place to construct a data center. Our aim is to guide decision-makers, including policymakers and industry leaders, in coming up with informed choices that balance the need for data center expansion with environmental responsibility. Our suitability map tool would include geolocating information to make these sites easy to identify. Ultimately, we strive to promote sustainable development in the digital infrastructure sector, ensuring a greener and more efficient future for data centers worldwide.

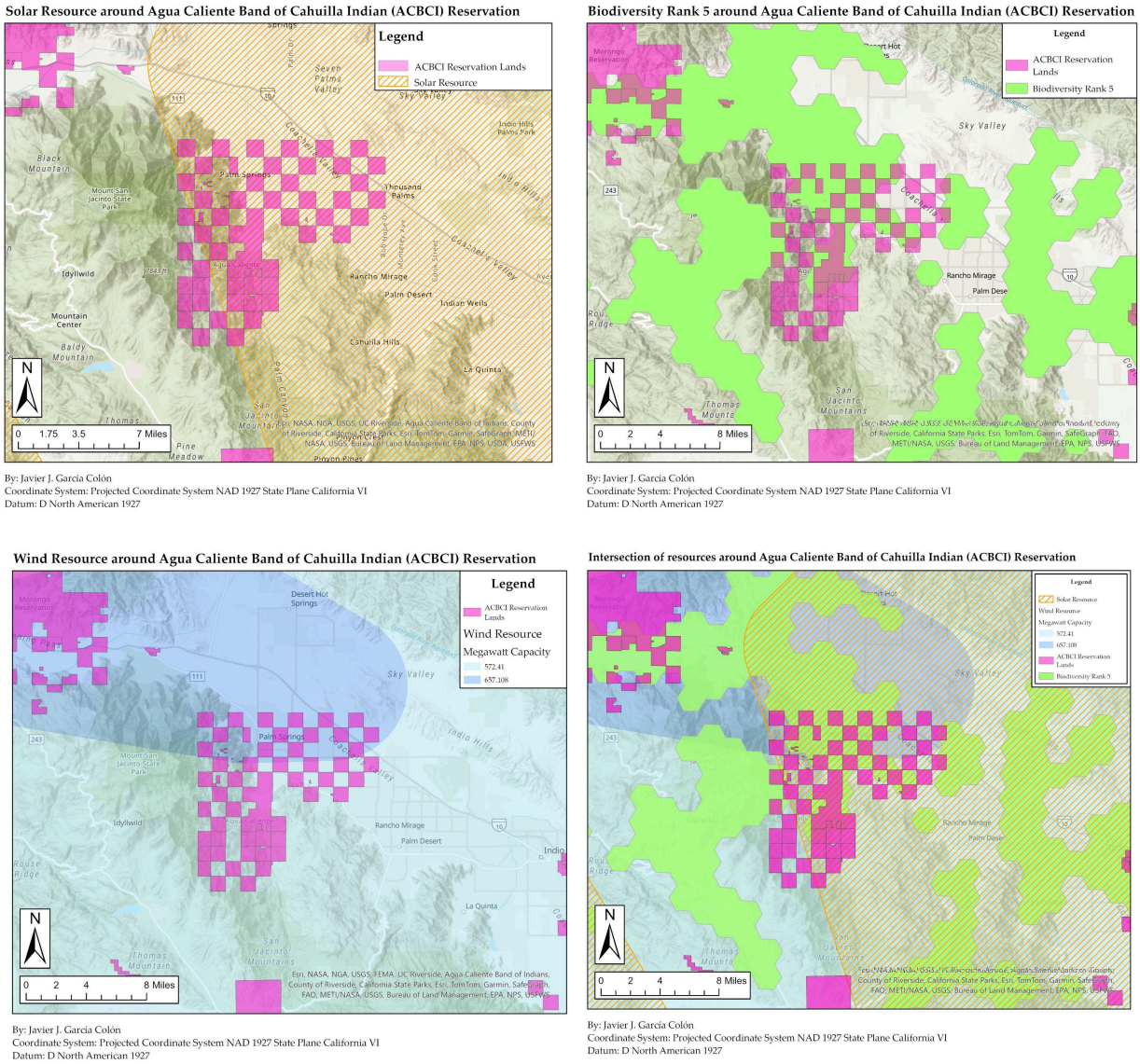

Figure 2: Suitability Maps for Data Center Locations within The Agua Caliente Band of Cahuilla Indians (ACBCI) Reservation *(see appendix for larger maps)*

4. Conclusion

In considering the future of AI and data center policy, we are concerned about the exponential increases in data center construction, the implementation of generative AI into basic web searches, and heat waste production driven by current models of western expansion and extraction. By looking to alternative systems of sustainability rooted in Indigenous values of *aloha ʻāina*, or love for the land, we find examples of TEK that can be integrated into Solarpunk visions of a future that integrates technology with the environment, reusing electronic waste (e-waste) and improving data life cycles for a more sustainable future.

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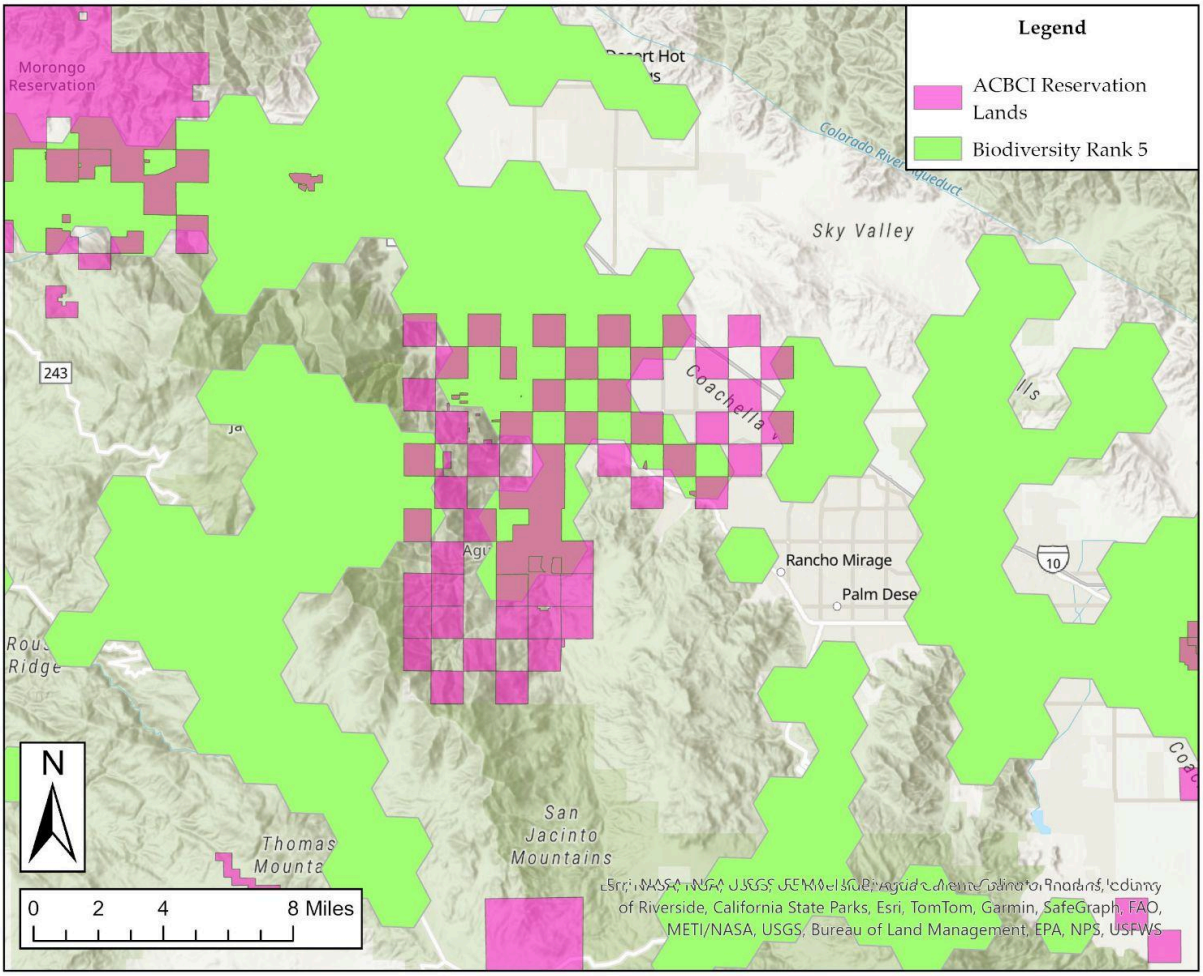
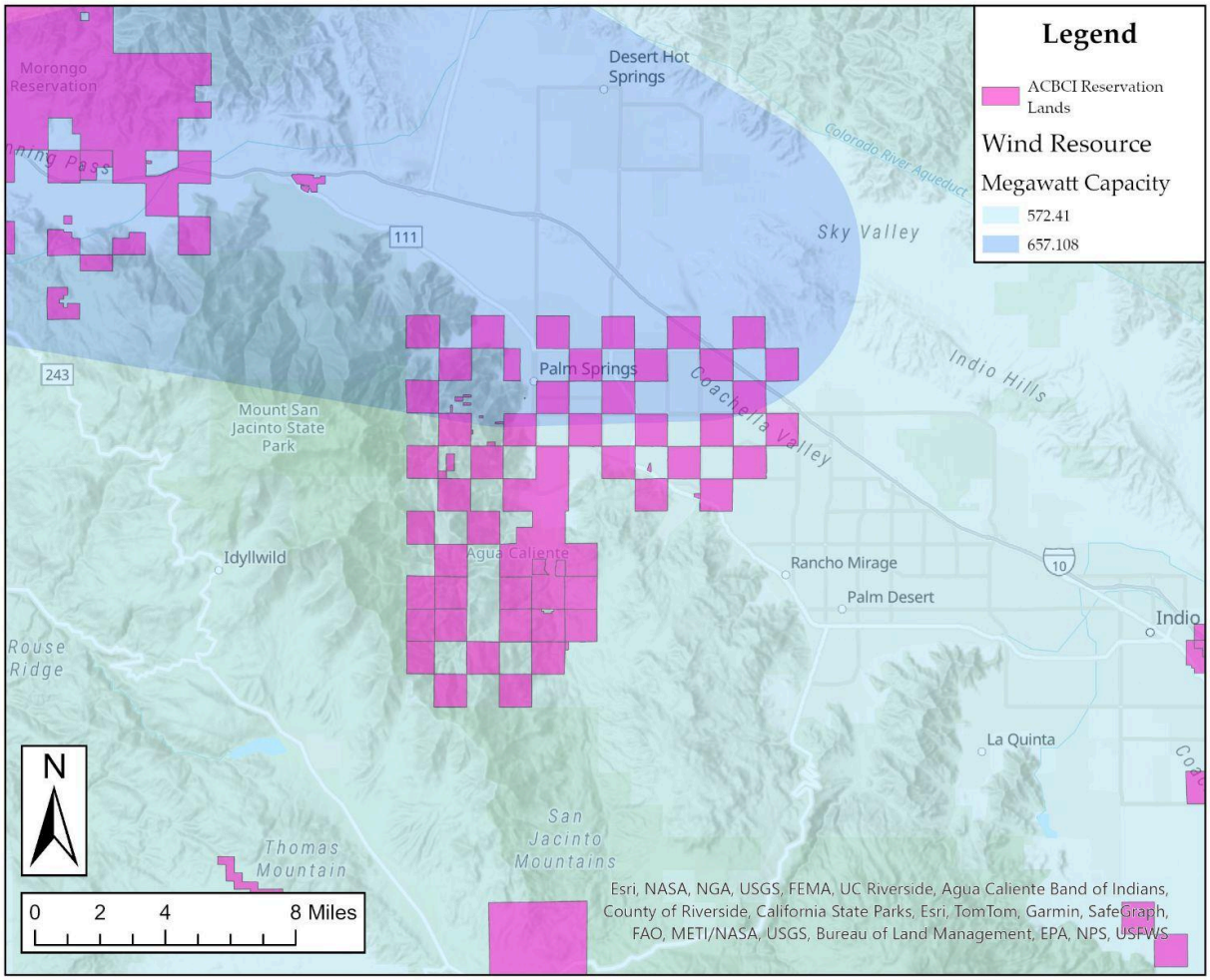
Appendix

Biodiversity Rank 5 around Agua Caliente Band of Cahuilla Indian (ACBCI) Reservation



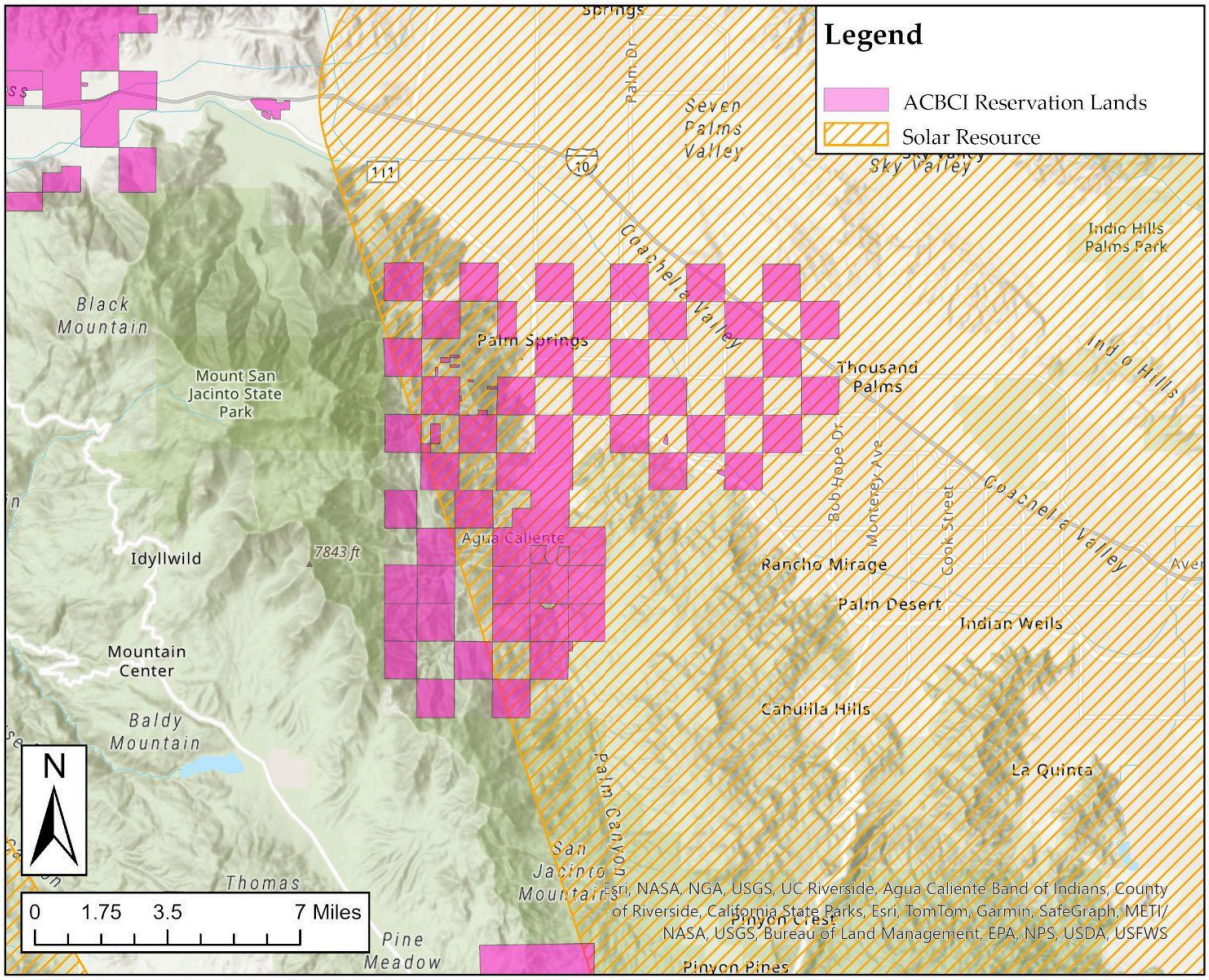
By: Javier J. García Colón
Coordinate System: Projected Coordinate System NAD 1927 State Plane California VI
Datum: D North American 1927

Wind Resource around Agua Caliente Band of Cahuilla Indian (ACBCI) Reservation



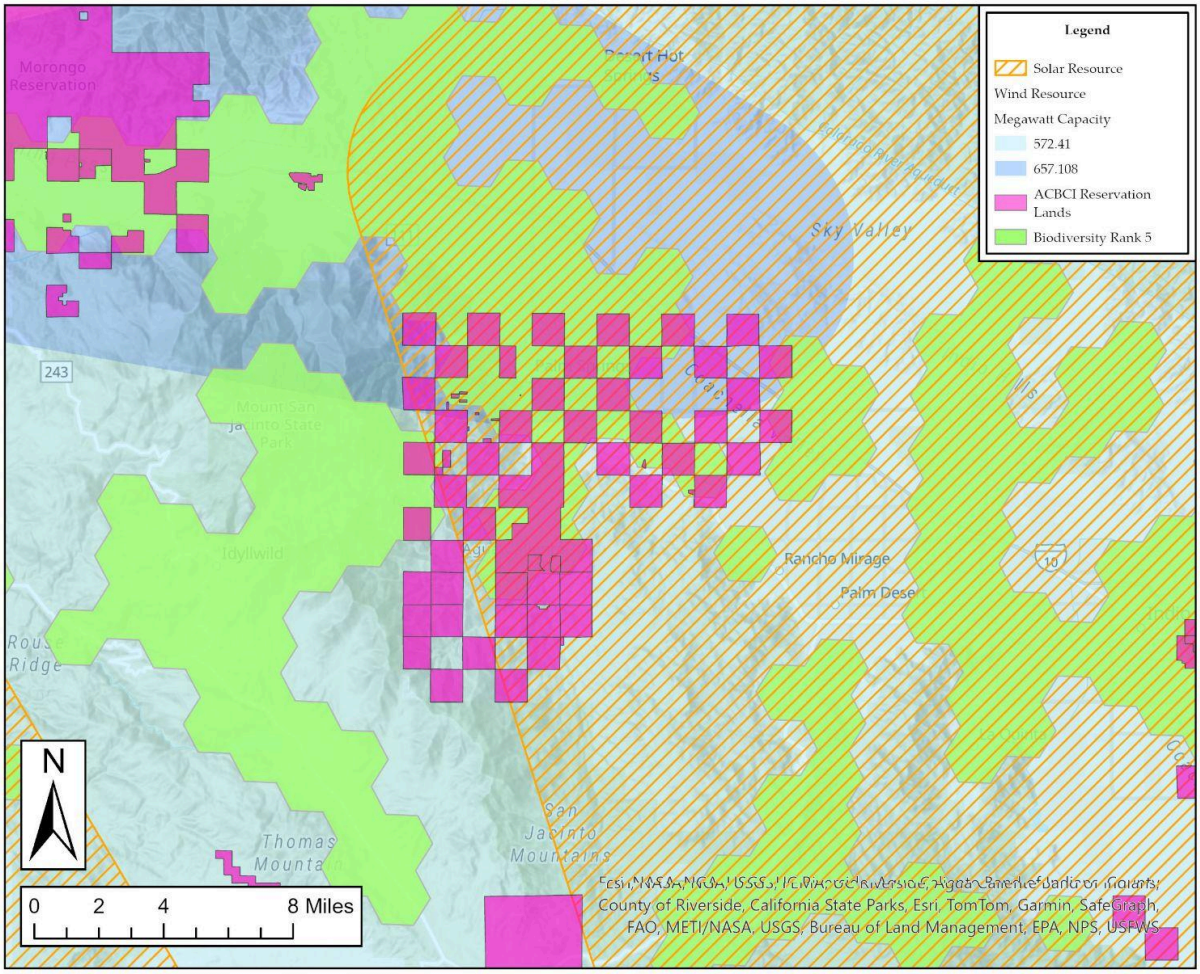
By: Javier J. García Colón
Coordinate System: Projected Coordinate System NAD 1927 State Plane California VI
Datum: D North American 1927

Solar Resource around Agua Caliente Band of Cahuilla Indian (ACBCI) Reservation



By: Javier J. García Colón
Coordinate System: Projected Coordinate System NAD 1927 State Plane California VI
Datum: D North American 1927

Intersection of resources around Agua Caliente Band of Cahuilla Indian (ACBCI) Reservation



By: Javier J. García Colón
Coordinate System: Projected Coordinate System NAD 1927 State Plane California VI
Datum: D North American 1927

References

1. Ahtone, T. & Lee, R. (2020, March 30). *Land-grab universities*. High Country News. http://www.hcn.org/issues/52-4/indigenous-affairs-education-land-grab-universities/
2. Beamer, K., Elkington, K., Souza, P., Tuma, A., Thorenz, A., Köhler, S., Kukea-Shultz, K., Kotubetey, K., & Winter, K. (2023). Island and Indigenous systems of circularity: How Hawai‘i can inform the development of universal circular economy policy goals. Ecology and Society, 28(1), art9. https://doi.org/10.5751/ES-13656-280109
3. Boscarino, N., Cartwright, R. A., Fox, K., & Tsosie, K. S. (2022). Federated learning and Indigenous genomic data sovereignty. Nature Machine Intelligence, 4(11), 909–911. https://doi.org/10.1038/s42256-022-00551-y

4. De Vries, A. (2023). The growing energy footprint of artificial intelligence. *Joule*, *7*(10), 2191–2194. https://doi.org/10.1016/j.joule.2023.09.004
5. Ding, W., Ebrahimi, B., Kim, B.-D., Devenport, C. L., & Childress, A. E. (2024). Analysis of Anthropogenic Waste Heat Emission from an Academic Data Center. *Energies*, *17*(8), 1835. https://doi.org/10.3390/en17081835
6. Elahee, K., & Jugoo, S. (2013). Ocean Thermal Energy for Air-conditioning: Case Study of a Green Data Center. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *35*(7), 679–684. https://doi.org/10.1080/15567036.2010.504941
7. *Engineering for Heat Waves*. (2023, October 4). American Scientist. https://www.americanscientist.org/article/engineering-for-heat-waves
8. Fernández‐Llamazares, Á., Garteizgogeascoa, M., Basu, N., Brondizio, E. S., Cabeza, M., Martínez‐Alier, J., McElwee, P., & Reyes‐García, V. (2020). A State‐of‐the‐Art Review of Indigenous Peoples and Environmental Pollution. Integrated Environmental Assessment and Management, 16(3), 324–341. https://doi.org/10.1002/ieam.4239
9. Fuchs, H., Shehabi, A., Ganeshalingam, M., Desroches, L.-B., Lim, B., Roth, K., & Tsao, A. (2020). Comparing datasets of volume servers to illuminate their energy use in data centers. *Energy Efficiency*, *13*(3), 379–392. https://doi.org/10.1007/s12053-019-09809-8
10. Grealey, J., Lannelongue, L., Saw, W.-Y., Marten, J., Méric, G., Ruiz-Carmona, S., & Inouye, M. (2022). The Carbon Footprint of Bioinformatics. Molecular Biology and Evolution, 39(3), msac034. https://doi.org/10.1093/molbev/msac034
11. He, W., Shirowzhan, S., & Pettit, C. J. (2022). GIS and Machine Learning for Analysing Influencing Factors of Bushfires Using 40-Year Spatio-Temporal Bushfire Data. *ISPRS International Journal of Geo-Information,* 11(6), Article 6. https://doi.org/10.3390/ijgi11060336
12. Johnson-Zafiris, M. (2024, April 11). Reclaiming Akwesasne's Pollution Data [powerpoint presentation]. U.S. Indigenous Data Sovereignty & Governance Summit 2024, Tucson, Arizona. usindigenousdatanetwork.org/2024/01/11/reclaiming-akwesasnes-pollution-data/
13. Jones, S. B., & Bellaire, R. (1937). The Classification of Hawaiian Climates: A Comparison of the Koppen and Thornthwaite Systems. *Geographical Review*, *27*(1), 112. https://doi.org/10.2307/209664
14. Kimmerer, R. W. (2013). *Braiding sweetgrass : Indigenous wisdom, scientific knowledge, and the teachings of plants* (First edition.). Milkweed Editions.
15. Lewis, J. E., Arista, N., Pechawis, A., & Kite, S. (2018). Making Kin with the Machines. Journal of Design and Science. https://doi.org/10.21428/bfafd97b
16. Mackey, T. K., Calac, A. J., Chenna Keshava, B. S., Yracheta, J., Tsosie, K. S., & Fox, K. (2022). Establishing a blockchain-enabled Indigenous data sovereignty framework for genomic data. *Cell*, *185*(15), 2626–2631. https://doi.org/10.1016/j.cell.2022.06.030
17. Peel, M. C., Finlayson, B. L., & McMahon, T. A. (2007). Updated world map of the Koppen-Geiger climate classification. *Hydrol. Earth Syst. Sci.*

18. Raith, P., Nastic, S., & Dustdar, S. (2023). Serverless Edge Computing—Where We Are and What Lies Ahead. *IEEE Internet Computing*, *27*(3), 50–64. https://doi.org/10.1109/MIC.2023.3260939
19. Reina-Rozo, J. D., Castro, A., Zambrano-Caviedes, F., & Epieyu, A. N. (2024). Technologies to embrace the sun: solarpunk-based project as an exploration for a just energy transition. Revista Iberoamericana de Estudios de Desarrollo, 13(1), 162–187. https://doi.org/10.26754/ojs_ried/ijds.871
20. Rylott, E. L., & Bruce, N. C. (2020). How synthetic biology can help bioremediation. Current Opinion in Chemical Biology, 58, 86–95. https://doi.org/10.1016/j.cbpa.2020.07.004
21. Smith, L. T. (2021). Decolonizing methodologies : research and Indigenous peoples (Third edition.). Zed Books. https://doi.org/10.5040/9781350225282
22. Sunder Rajan, K. (2006). Biocapital : the constitution of postgenomic life. Duke University Press.
23. TallBear, K. (2017). Beyond the Life/Not-Life Binary: A Feminist-Indigenous Reading of Cryopreservation, Interspecies Thinking, and the New Materialisms. In J. Radin & E. Kowal (Eds.), Cryopolitics (pp. 179–202). The MIT Press. https://doi.org/10.7551/mitpress/10456.003.0015
24. *The Latest Cloud Computing Statistics (updated June 2024) | AAG IT Support*. (n.d.). Retrieved August 1, 2024, from https://aag-it.com/the-latest-cloud-computing-statistics/
25. Tuck, E., & Yang, K. W. (n.d.). *Decolonization is not a metaphor*.
26. U.S. Council on Environmental Quality. (2021). *Update to the regulations implementing the procedural provisions of the National Environmental Policy Act*. Regulations.gov. https://www.regulations.gov/docket/CEQ-2021-0002/unified-agenda
27. Vitousek, P., & Beamer, K. (2013). Traditional Ecological Values, Knowledge, and Practices in Twenty-First Century Hawai‘i. In R. Rozzi, S. T. A. Pickett, C. Palmer, J. J. Armesto, & J. B. Callicott (Eds.), *Linking Ecology and Ethics for a Changing World* (pp. 63–70). Springer Netherlands. https://doi.org/10.1007/978-94-007-7470-4_5
28. Wagner, P., & Wieland, B. C. (2022). *Almanac for the Anthropocene : A Compendium of Solarpunk Futures*. (1st ed.). West Virginia University Press.
29. Wahlroos, M., Pärssinen, M., Rinne, S., Syri, S., & Manner, J. (2018). Future views on waste heat utilization – Case of data centers in Northern Europe. *Renewable and Sustainable Energy Reviews*, *82*, 1749–1764. https://doi.org/10.1016/j.rser.2017.10.058
30. Whyte, K. (2020). Too late for indigenous climate justice: Ecological and relational tipping points. WIREs Climate Change, 11(1), e603. https://doi.org/10.1002/wcc.603
31. Whyte, K. P. (2013). On the role of traditional ecological knowledge as a collaborative concept: A philosophical study. *Ecological Processes*, *2*(1), 7. https://doi.org/10.1186/2192-1709-2-7
32. Winter, K. B., Beamer, K., Vaughan, M. B., Friedlander, A. M., Kido, M. H., Whitehead, A. N., Akutagawa, M. K. H., Kurashima, N., Lucas, M. P., & Nyberg, B. (2018). The Moku

System: Managing Biocultural Resources for Abundance within Social-Ecological Regions in Hawai‘i. *Sustainability*, *10*(10), 3554. https://doi.org/10.3390/su10103554