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Harvesting Local Energy: A Case Study of Community-Led Bioenergy Development in Galena, Alaska

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Abstract: Community-led bioenergy projects show great promise to address a range of issues for remote and Indigenous Arctic communities that typically rely on diesel for meeting their energy demands. However, there is very little research devoted to better understanding what makes individual projects successful. In this study, we analyze the case of the Galena Bioenergy Project (Alaska)—a biomass heating project that uses locally sourced woody biomass to help meet the heating demands of a large educational campus. Using project documents and other publicly available reports, we evaluate the project's success using three indicators: operational, environmental, and community level socio-economic benefits. We find that the project shows signs of success in all three respects. It has a reliable fuel supply chain for operations, makes contributions towards greenhouse gas reductions by replacing diesel and has improved energy and economic security for the community. We also examine enabling factors behind the project's success and identify the following factors as crucial: community-level input and support, state level financial support, access to forest biomass with no competing use, predictable demand and committed leadership. Our findings have important implications for other remote communities across the Boreal zone—especially those with nearby forest resources. Our examination of this case study ultimately highlights potential pathways for long-term success and, more specifically, shows how biomass resources might be best utilized through community-led initiatives to sustainably support energy security in Arctic communities.

Keywords: Indigenous energy; energy security; interior Alaska; off-grid energy; distributed energy generation; biomass energy

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1. Introduction

Catalyzed by the UN's Sustainable Development Goals and emission reduction targets set under the Paris agreement, a global clean energy transition is underway. In this pursuit, several renewable energy technologies are increasingly being relied upon. For many communities, especially those in northern and remote regions, bioenergy is one of the most promising sources that can help meet global climate commitments while responding to local energy needs. While other types of renewable energy are highlighted more often, the global contribution of biomass is five times higher than wind and solar PV combined [1] and is likely to play a crucial role in deep decarbonization moving forward [2].

There are many different types of bioenergy feedstocks, though woody biomass sourced from forests is available in abundance, provided the resource is properly managed [3]. Woody biomass can be an optimal energy source, particularly for remote communities with ample forest resources in their proximity. Woody-biomass-based energy projects also offer a lot of promise as a replacement for diesel-based power plants, meeting community energy needs with much lower environmental impacts and better, more local economic opportunities [4–6]. Often generated as residue from harvesting activities or forest-related industries, woody biomass has the potential to satisfy around 18% of global primary energy consumption by 2050 [7].

Remote Arctic communities often have isolated off-grid energy systems. In Northern Canada and Alaska alone, there are over 300 remote off-grid communities that rely primarily on diesel to meet their energy needs. Many of these communities pay almost twice as much for diesel as compared to southern urbanized areas [8]. Fuel price volatility and reliance on long-distance fuel shipments and storage, due to geographic remoteness and seasonal road access, add to the uncertainties of fuel availability. As such, there is growing interest in renewable energy systems amongst northern and Indigenous communities [9,10], especially those projects with direct local involvement and benefits. Such community-led initiatives have long been explored under the nebulous concept of "community energy" [11,12]. Through a comprehensive literature review, Brummer [13] arrives at a common understanding about community energy across different geographies. In terms of benefits to the community, the author presents several categories, including economic benefits, community-building and self-realization, and climate protection. Across this broader literature, community participation in energy development—in the form of development and ownership—has been argued to be a means for energy self-sufficiency [14] and sovereignty [15]. These elements are even more salient for remote Indigenous communities, as energy development in such communities occurs with the backdrop of historical inequities and colonial legacies [10,16,17], which continue to influence the socio-political environment around energy and resource development. For example, bioenergy requires access to land; thus Indigenous ownership [16] of forested land in Alaska (Very few Alaskan tribes own land; rather, the Alaska Native-lands Claim Settlement Act (ANCSA) designated ownership of select lands to native corporations. These original 12 corporations act as for-profit entities with shareholders. This arrangement is unique to Alaska and very different from how tribes were treated in the contiguous U.S. or Canada.) has clear implications for bioenergy development and ownership opportunities. In Canada, Indigenous–settler reconciliation efforts are increasingly steering engagements between government agencies and Indigenous communities [17]. Moreover, it has been argued that renewable energy development could be a vehicle to address the 'dual energy justice challenge'—a goal of simultaneous climate change mitigation and Indigenous–settler reconciliation [18]. Isolated communities are often close to vast forested areas, making bioenergy a viable option for strengthening energy independence, security, and self-sufficiency [14,19,20].

Relying on forest biomass for meeting energy needs in remote communities is not a new concept [19,21,22]. In fact, the traditional use of biomass (i.e., for household heating and cooking) contributes to around 10% of total global energy supply even today [1]. However, this form of biomass energy is very inefficient and is associated with several health and environmental problems. On the contrary, modern bioenergy—which uses biomass-based power plants to produce heat and/or electricity—holds much promise as a renewable energy source. Innovation in biomass feedstock production [20,23] and conversion technology [24–27], coupled with a wider push for sustainable energy [28,29], has spurred growth in modern bioenergy generation. For remote communities seeking alternative energy generation, bioenergy has been found to be cost-competitive against the status quo of diesel-based systems [6]. Additionally, unlike solar or wind-based alternatives, bioenergy does not suffer from the constraints of intermittency and the need for storage capability.

Despite the maturation of bioenergy technologies over the past decade, development is still not without its challenges. Supply chains are quite complex [30], making it difficult for sustainable energy production, as the transportation and processing of biomass add costs and emissions. There are also issues with scale. For example, the smallest possible bioenergy systems are still more than 10 kW in size, which are not suitable for household-level or stand-alone installations (unlike solar PV) [31,32]. One of the most important challenges is that of feedstock availability and sustainability—both the long-term sustainability of the project and whether the resource base is renewable. Of course, there are other non-technical factors such as regulatory frameworks, integration with existing infrastructure, and public perceptions, which can all create barriers to development [33]. Due to many of these challenges, bioenergy is not always considered as a viable off-grid solution for electrification in developing countries [34]. However, pilot projects across the developing world are receiving coverage by researchers and development organizations to more carefully assess the role bioenergy can play in meeting electrification goals in developing regions [35–39]. There has been much less scholarly attention to bioenergy development in developed countries, including Canada and the US. A lot of woody biomass from North America is exported to be used in large scale biomass generation facilities in Europe and Asia [40]; however, there is still plenty available for remote Northern communities themselves. Thousands of inhabitants in such communities live in or near the abundant boreal forest; yet, there are a number of risks and barriers to biomass development, including high initial costs, geographic remoteness, limited local expertise and capacity, and climate change [41]. There are studies that focus on forest-based biomass energy in specific locations or areas. For example, Maeir et al. performed a life cycle assessment of forest-biomass based bioenergy in British Columbia [42]. There are also modeling-based feasibility studies, such as for Quebec [43] or Oregon [44].

In terms of bioenergy success stories, there are even fewer examples. In an Indigenous-focused study, Mansuy et al. [45] examine the feasibility in an urbanized First Nation region in Northern Alberta and find that bioenergy is not cost-competitive. In terms of understanding non-technical aspects, Vandever [46] find that in Fort Yukon, Alaska, the main motivation to move away from diesel-based generation is because of the high cost of diesel, rather than minimizing the greenhouse gas (GHG) footprint of fossil fuel use. Whitney et al. [47] cover all of Alaska and summarize the cost variations of installing biomass based boilers. Deep-dive case studies into specific bioenergy projects are even more rare. Blair and Mabee [48] model multiple bioenergy scenarios, including the production of renewable natural gas for a forest-based community in Ontario to study its economic and environmental impacts. Buss et al. [49] analyze the GHG mitigation potential of replacing diesel infrastructure with wood-based energy generation under two different feedstock options. This project has remained a pilot for several years.

In summary, bioenergy development holds considerable promise as a local, renewable energy source in a variety of ways, but it is not without its challenges. Although bioenergy has received some attention in the scholarly literature, there are few papers that focus on the success stories and lessons learned, especially within northern and remote communities. Hundreds of remote northern communities spanning across the Boreal region have renewable energy projects that are essentially experiments in independence and sustainability. Closely examining such projects is essential to understand their impact and contribution towards local and non-local goals. This case study is one such examination of a specific community bioenergy project in a remote northern community: the Galena biomass project, which has been operational since 2016 in interior Alaska. In this study, we explore the project's success based on a select category of benefits of community-based energy, as summarized by Brummer [12]. In doing so, we address two primary and interrelated research questions:

1. What indicators of success are evident through the development and operation of the Galena bioenergy project?
2. What are the enabling factors behind the project's success?

That is, the purpose of this study is two-fold. First, to assess the project's success and second to identify the factors behind its success. In doing so, we extract valuable lessons for similar remote communities living in and around the Boreal zone.

Case Study Description

The town of Galena is in the interior region of the state of Alaska, United States (Figure 1). Located on the north bank of the Yukon River, the town is in the Subarctic climate zone and witnesses extremely cold long winters and short cool summers. With a population of around 400, Galena is accessible only by air or by water. During summer thaw, the Yukon River provides transport by boat or barges, and during winter, the same river is a conduit for the use of all-terrain vehicles or snow machines. The town is home to the Galena Interior Learning Academy (GILA), a boarding school located on a former Air Force base (operational until 2008) that also offers vocational training programs. GILA is the only educational institution of its kind in the region and is responsible for the town's population increase of about 200 persons during the school session every year.

Figure 1. The location of the case-study site. Galena is a town in the Interior Alaska region, and the Galena Interior Learning Academy (GILA) is located at the eastern end of the town. (Source: Apple maps, accessed on 21 June 2022).

Ownership of the Air Force base was officially transferred to the City of Galena in late 2008. The former base used a diesel-powered steam-boiler and steam-based distribution system to heat 14 buildings on the campus, relying on nearly 230,000 gallons of fuel annually. In 2016, a 4.6 MMBtu biomass (wood chip) boiler was installed, producing hot water rather than steam. The distribution system was thus upgraded with new supply and return lines suitable for a glycol/hot-water transfer medium. Since the old steam distribution utilidor was abandoned, a new domestic water line was required to service each campus building. When the Air Force left Galena, they gifted a sizeable diesel reserve to the city–suitable for approximately ten years. Community leadership had, essentially, 8 years to identify an alternative. Moreover, the existing bulk fuel storage facilities were decommissioned for any future fuel transfers. Diesel had previously been delivered via barge and pumped from the riverbank to on-site storage tanks. This transfer system had been removed prior to ownership transfer. Moving to biomass did not fully replace diesel use but reduced it so that it was used as a supplementary fuel during the heating season (to ~50k gallons per year).

The Galena bioenergy project is comprised of three components: fuel harvesting and processing; boilers for energy generation; and a heat distribution system including end-use buildings. The schematic provided in Figure 2 shows the biomass flow, energy conversion, and end use. The first component is entirely new, but the boiler and the heat distribution system already existed for the diesel-based operations. However, the bioenergy project development included multiple technological changes: the changing of distribution pipes, conversion of diesel boilers from steam to hot-water, installation of a wood boiler, and establishment of a fuel harvesting and processing system. The utility that operates the boiler and delivers heat to GILA is owned by the City of Galena, which relies on the Sustainable Energy for Galena Alaska (SEGA; a non-profit organization responsible for fuel harvesting and processing), to provide wood chips for fuel. SEGA is a joint initiative between the Galena City School District, City of Galena, and Louden Tribal Council, and these three entities serve as its founding members. Access to forest biomass is enabled via a timber sale agreement (TSA), finalized in 2015, between the City of Galena and the Native corporation Gana-A'Yoo Ltd. The city formally assigned all responsibilities of harvesting and land access to SEGA. The corporation manages forested land around Galena, and the TSA provided SEGA with a bit more than 4500 acres of land for harvesting biomass.

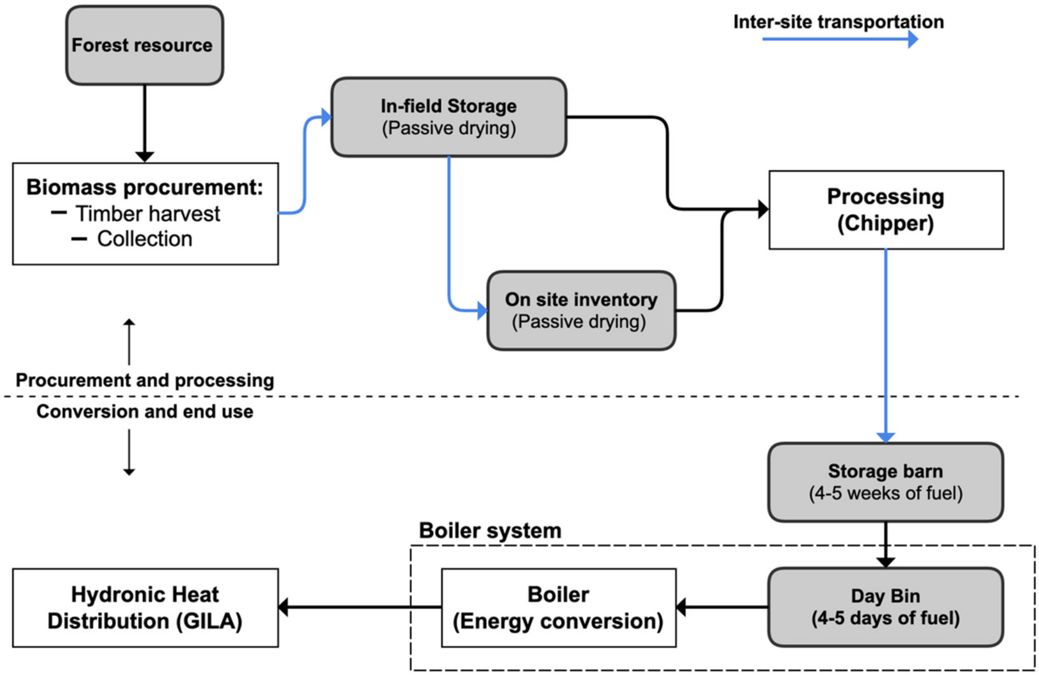

Figure 2. Schematic for Galena bioenergy project.

2. Materials and Methods

Our analysis of the Galena bioenergy project relied primarily on a review of related documentation (Table 1), which include planning and operations documents related (n = 4) and other documents containing public discussion covering the project (n = 9), including two transcribed video documentaries that contain interviews with various project actors and community members. Project documents were directed to us by SEGA (but many of them are available online in the public domain) and consist of planning and operational documents, which generally include the technical specifics of the project. These primary documents were supplemented by secondary documents gathered through online searches using the terms "Galena" and "biomass", sorting by relevance and including only those documents that covered the Galena project and with relevance to at least one of our two research questions (i.e., indicators of, and factors behind success). We also conducted an in-depth interview with a key project partner, which was fully transcribed. This interview was not meant to be representative, but rather to help us tell the 'full story' of the Galena biomass project, help us to understand a more comprehensive range of factors for and behind the project's success, and to validate our interpretation of the documents reviewed.

Our approach was guided by our two overarching questions, focused on indicators of, and factors for success. For the former, we referred to the community energy benefits indicators identified in the synthesis by Brummer [13], which informed our focus on specific indicators. For the latter, we approached our analysis of the collected data thematically [50], allowing for emergent themes. Such an approach reflects the tenets of grounded theory [51,52] and, more specifically, the notion that the lessons emerging from the case study are not confined by our interpretations of pre-existing theory, but rather informed by what is happening within the data and thus reflecting the realities of the case study context [53]. Doing so helped us to not only answer our overarching questions, but also to produce insights that were not necessarily captured in our literature-based framing.

Table 1. The dataset used for thematic analysis for this study.

ID	Data Type	Name	Description
V01	Documentary video	From Trees to Heat video [54]	Short film on the bioenergy project
V02	Documentary video	Galena Biomass Energy Project Overview video [55]	Short film on the bioenergy project
PL01	Planning document	Forestry inventory report [56]	Report by a professional forester to assess the biomass availability ahead of the project, submitted to Louden Tribal Council
PL02	Planning document	Conceptual Design Report [57]	A detailed scenario analysis reported prepared for the City of Galena by a group of private sector organizations (engineering and energy consulting firms)
PL03	Planning document	Timber Harvest Management Plan [58]	The harvest management plan prepared by Tim Kalke in 2015, also graduate thesis towards a master's program completed at Oregon State University
OD01	Operations document	Detailed plan of harvesting operations (and map) [File S1]	2019–20 season harvest operations details submitted to the Division of Forestry (State of Alaska) by SEGA
PD01	Public discussion	notice of public meeting [59]	Public meeting organized (March 2013) by the Galena City Council, Galena City School Board, and Louden Tribal Council, to discuss the formalization of the SEGA corporation
PD02	Public discussion	GCSD Reitan letter [60]	Letter by Galena City School District to the GCSD members sharing details about the bioenergy project (February 2013)
PD03	Public discussion	2019 Public presentation [61]	Presentation by SEGA about the project for Alaska Energy Authority
PD04	Public discussion	2022 Public webinar [62]	Webinar presentation by SEGA about the project at CASES webinar series
PD05	Public discussion	FEMA case study [63]	A case study by the Federal Emergency Management Agency (USA) about energy generation in Galena
M01	Media coverage	Budding energy article by AK Biz Mag 2020 [64]	Media coverage about bioenergy projects in Alaska (includes Galena as well)
M02	Media Coverage	TVEP report-SFY 2018 [65]	Technical and Vocational Education Program report for fiscal year 2018 by the Alaska Department of Labor and Workforce Development, featuring a coverage of Galena biomass project
IN01	Interview transcript	In person interview with key project partner	The interview was conducted in Nov 2021 with a professional forester who was involved with the project in the early stages

3. Results

The results are presented below in two main sections. First, we provide a brief assessment of the Galena biomass project's success, based on three key indicators emerging from the analysis: operational, environmental, and community benefits (Table 2). This is followed by a presentation of the key factors enabling project success.

Table 2. Indicators and enabling factors of project success.

Indicators of Success		Factors of Success	
Operational	• Long-term fuel supply • Economic stability • Operational stability	Community-based input and support	• Early and genuine engagement • Strong community involvement and support
Environmental	• GHG emission reductions • Reduced air pollution • Forest health	Financial support	• State level support
Community benefits	• Sustaining GILA campus • Economic and energy security	Supply–demand advantages	• Abundance of biomass resource • No competing use of biomass • Predictable demand
		Committed staff and leadership	• Dependable staff • Strong and sustained project leadership

3.1. Indicators of Project Success

3.1.1. Operational Success

The operational success of the Galena project is evident through three key sub-indicators: (i) a long-term fuel supply, (ii) economic viability, and (iii) operational stability. First, the fuel supply for the project was secured through a long-term timber sale agreement (TSA) between the City of Galena and Gana-A'Yoo Ltd. (i.e., the landowner). However, even before the TSA, a detailed forest inventory assessment was conducted (PL01) to estimate biomass availability within a 20-mile radius from the center of Galena. This assessment suggested that within this area there is adequate vegetation to meet the heat demand for more than 100 years. Through the TSA, SEGA obtained access to 4720 acres of forested land owned by Gana-A'Yoo. After a 5-year review, this area expanded to 15,000 acres (PD04).

As far as project economics are concerned, it is hard to analyze given the documentary evidence available for this study. However, the planning stage documents reveal that several alternatives were compared for their economic feasibilities, with assumptions around future diesel as well as wood prices. Even if most conservative fuel prices are to be considered (i.e., low diesel price, and high wood price), using wood-fired boilers showed annual savings of approximately USD 346,000 and a payback of 8.7 years (PL02). At these conservative estimates, upgrading the heating distribution system from steam-based to a hot water system was to bring in USD 2.5 million in savings over 20 years, but switching the boiler system from diesel to wood in addition to that, estimated over USD 6 million in savings over a 20-year period (PL02). We should note that these estimates assume a diesel price of over USD 5 per gallon, which is high and does not necessarily portray the reality for the project since the Air Force left behind a subsidized access to diesel fuel for a few years. However, in the longer term, the savings estimates are much more valid, especially given the current volatility of fuel-price globally, whereas of June 2022, diesel stood at over USD 5.50 per gallon. In this context, economic considerations went far beyond the expected returns or payback periods. Wood use was not only chosen to reduce operational costs but also "fuel price variability" and "supply risk" (PL02), which it certainly has, as we show in the rest of the study.

A third sub-indicator of operational success is the quality of operations in terms of fulfilling the purpose of providing reliable service to the end user, the buildings on GILA campus. Partly as a result of a long-term fuel supply and cost effectiveness, the bioenergy project has been successfully able to support the school's operations. This becomes clear from the sentiments shared by the principal of GILA in 2016, who noted: "*[the] bottom line is if we didn't have some other energy source there's a good chance we wouldn't be able to operate . . . it's not a matter of trying to make things better, it's truly a matter of survival.*" (V01).

In Alaska's Technical and Vocational Education Program Report for the fiscal year 2018 (M02), the bioenergy project was identified as a success story for providing "the GILA campuses with an affordable fuel source after the fuel left from the Air Force was almost depleted". There is also evidence of smooth operations at the supply end of the project. Public presentations by SEGA (e.g., PD03, PD04) highlight seven successful harvest seasons, at the rate of 25 acres/year. Since the bioenergy project rests on the quality of the harvesting and feedstock production processes, it serves as an indicator of the overall health of project operations.

3.1.2. Environmental Success

When considering environmental aspects, two clear areas of success emerge: (i) GHG emission reductions and (ii) sensitivity to forest health. The first area of success is largely attributed to the baseline scenario of energy use being from diesel-based generation. There is considerable evidence from the document analysis to suggest that, in the absence of bioenergy generation, there would have been a continuation of diesel use, albeit with new boilers and some efficiency improvements. In the baseline case, without any efficiency upgrade, around 230,000 gallons of diesel were being used annually (PL02, PD04). Moving to biomass fuel and efficiency upgrades together have resulted in displacement of approximately 195,000 gallons, 95,000 gallons of which are attributed to the use of biomass (PD04). This implies a GHG emission reduction of ~1000 tCO2 [66]. The environmental benefits of using bioenergy are also acknowledged by those in the community. For example, as noted by the superintendent of the Galena school district: "*[the new biomass system is] using* *a sustainable resource that will grow back and then we're not just burning fossil fuels. And I think ultimately that that's good not only for the environment but for this region*" (V02).

As far as the impact of harvesting on forest health is concerned, we find evidence for two considerations. First is the scale of likely impact, and the second is the presence of mitigation strategies within the project. Scale-wise, harvest levels are negligible vis a vis the available forest inventory. According to the Forest Inventory Report (PL01), the total biomass inventory within 16 miles of Galena can offer 20,000 dry tons (conservative estimate in PL01) per year for up to 100 years. Even though the timber sale area only has ~4700 acres of forested land, at the annual average harvest of 1600 green tons and 25 acres (PL03), the project has so far only used less than 5% of the available resource. This shows the abundant availability of biomass and the very small footprint of the project. The community also is conscientious about the sustainability of forest cover due to bioenergy operations. This is evident especially among the staff working the harvesting equipment, as indicated by a SEGA worker, who said: "*We're trying to leave as small footprint as we can because you know for one thing is respectful to land that's something that should be taken into account*" (V01).

To keep the ecological impact minimal, we find that there are mitigation strategies and the "Harvest Practices" section in the Timber Harvest and Management Plan (PL03) lays these out. One of the most important strategies identified is to limit harvesting to the winter, "in order to protect ground vegetation and reduce exposure of mineral soil." The harvest operations plan (OD01) submitted by SEGA to the Division of Forestry verifies this as they show that harvesting is performed only during winter. The intended harvesting operations aim to reduce the physical effects of the logging and transportation equipment. The harvest area is to be accessed when enough frost as accumulated for bearing the equipment load without impacting the soil (PL03).

An additional aspect of environmental impact is worth highlighting here—air pollution. Although the evidence analyzed does not include anything substantial about air pollution, an inference could be made given the GHG reduction scope of the project. A comparison [67] of pollutant emissions between biomass- and diesel-based power generation shows that bioenergy reduces SOx and NOx emissions but is higher on the scale (on per MWh basis) when it comes to PM10 (Particulate matter of 10 micrometers or less) emissions. Having said that, given the size of many small remote communities, air quality is often not a major concern in terms of energy production, a point emphasized by the Executive Director of Alaska Energy Authority: "*Most of the communities with these systems do not have air quality issues and this is not a major concern*" (M01).

3.1.3. Community Benefits

The Galena bioenergy project has generated several community benefits. First and foremost is its contribution towards energy security. Moving from a sole dependence on imported fuel to locally available renewable resources improves energy security for the community. The case study analysis by FEMA (PD04) puts it clearly: "Transitioning to a sustainable fuel source decreases Galena's dependence on expensive and intermittent deliveries which are vulnerable to supply chain disruptions."

Even though the end user of the energy produced is one specific school campus, the school plays an extremely important role not only for Galena, but in the region. As explained by GILA's Principal: "we've got a school here that serves 80 different communities, kids coming from all over the place. We've got strong academic program of a very strong career and technical education program" (V01).

Energy security is complemented by economic security. The results suggest this has occurred in three ways. First, long-term cost savings in expenditures for heat energy. Cost savings was a major mitigation for the Galena biomass project, as indicated in the Timber Harvest Management Plan: "the wood-boiler system will provide cost savings of nearly 50% for the end consumer" (PL03). Further evidence from other documents analyzed bears out this expectation. In public discussions about annual average consumptions and expenditures (PD03), for example, the average expenditure on wood is USD 414,000 (1600 green tons), and (diesel) oil displacement due to the project (i.e., efficiency upgrades and wood fuel) is 195,000 gallons. At USD 5.5/gallon, the cost of oil would then be over USD 1 million, indicating savings of over USD 600,000 annually, attributed both to a fuel switch and efficiency upgrades. We must note that the diesel reserves left behind by the Air Force ensured heavily subsided fuel for the boilers, but the reserves were to only last till 2017 (PL03). Therefore, the cost savings implied are meant for the long term.

A second element of local economic security relates to the financial "flow" surrounding the energy project. The project has resulted in money remaining within the community. Over USD 415,000 of new money has been introduced to the local economy due to the project (PD04). In the Trees to Heat video documentary (V01), the school superintendent says "[the project] captured our heat costs and kept them here in Galena so that we are not basically sending our dollars out of the community through Crowley, going to Nenana, Fairbanks and where else, that those monies are captured here it's, created local jobs where that money stays here and I think that's been the biggest benefit."

The third element is the project's contribution towards economic growth in the community. Bioenergy operations, especially biomass harvesting and processing, have created jobs for the community that did not exist before. This benefit has been acknowledged by state level agencies. For example, as noted by the Alaska Energy Authority (M01): "These systems also help to keep money in the local community by providing jobs to locals for maintenance, project management, wood harvesting, and stoking the boilers ... [and] money in the local community doesn't just mean jobs, but it also creates a positive feedback loop for the economy".

Perhaps the best evidence of the biomass project providing new, local economic opportunities is the "branching-out" of SEGA into other sectors. SEGA is now also a construction contractor, making it a local construction business serving the community, which usually relies on outside contractors. Recent public presentations about the project (PD04) present evidence of the recent construction projects that SEGA has been involved in (Figure 3). Because SEGA is one of the few local construction contractors for the city of Galena, their success is also a boom for the local economy.

Figure 3. SEGA has expanded into construction in Galena. The image shows a recent building (with interiors) completed by SEGA.

3.2. Enabling Factors behind Project Success

Through our thematic analysis, we identified four main factors crucial to the success of the Galena bioenergy project described above. Here, we categorize these as community-based input and support, funding/policy support, supply–demand advantages, and committed staff and leadership (Table 2).

3.2.1. Community-Based Input and Support

Project successes were driven in part by the community's overall support for the project, which was cultivated at the early stages of project planning. In one of the earliest project documents found (February 2013), the school district superintendent describes how vital it is that the views of residents are considered through healthy collaboration:

> "*It is important for all of our community stakeholders to be fully aware of the steps that are being taken in the community to develop a sustainable future. It is unfortunately obvious that how we have always conducted business in Galena will not provide the future that we want for this community and our children. We need to collaboratively take steps that will reduce our energy costs so that we can build a sustainable economic foundation in this wonderful rural community we all live in*." (V02)

This sentiment is reiterated through a (March 2013) Notice of Public Meeting (PD01), which highlights how the council, school board, and Louden (Tribal Council) Board of Directors are open to public input, stressing that no decisions have been made and that they value the community's opinions. Included in the meeting notice is a clear statement indicating that: "*Nothing has been decided, and everything is subject to change. Each of the various boards and councils will need to formally adopt plans for the project before it can proceed*."

Such evidence points to the "co-design" approach being increasingly discussed within the energy transitions literature, e.g., [68,69], where community participation is not limited to only being informed and of providing consent, but also involved in more technical aspects of project development as well. Reflecting on pre-project planning, a few years after the project became operational, a representative with the City of Galena describes the degree to which the community was involved and how much the project team valued their views:

> "*When I first got involved in it, I had no idea what they were talking about ... [but] we got the community involved in it, we got their input, if they wanted to move forward with it and it was a go, we had tons of community meetings there's quite a few of them we did you know to bring the community in because they had to be involved in this, they had to make the decision if the city wanted to go this way. I think it's very important to get your residents and your people in the community behind, doing a project like this*." (V02)

Seemingly as a result of this process, our analysis suggests that the community has become widely supportive of the project and of a new way of heating the GILA campus. We were unable to identify any negative perspectives about the project, either in project documentation or through media searches. The overall positive public support for the project is evident in FEMA's 2019 case study (PD05), noting that "*the high level of community involvement and input was ultimately what made this project a success*" and in a documentary produced by the Tanana Chiefs Conference (V02), which mentions that "*The whole community of Galena supports their Biomass project*." Looking ahead, SEGA's general manager describes how this kind of community-driven development approach will continue in the years to come, with young people to decide how Galena will move forward regarding its energy choices: "*it's not us who is going to decide that (energy futures), that's going to be the future generations; which is also part of this, is getting the youth involved and changing your way of thinking a little bit about how we do things and how we fuel our utilities and we fuel our community*." (PD04).

3.2.2. Financial Support

A second underlying factor influencing the success of the Galena biomass project was the funding support it received. The project has received support from multiple agencies at the state level. For example, the project received a USD 3.4 million start-up grant from the Alaska Energy Authority (PL03) under the Renewable Energy Fund. That said, a "significant financial risk" was also taken by the project, as an additional USD 4 million in loans were secured from the Alaska Housing Finance Corporation and the Alaska Department of Environmental Conservation to convert the heat distribution facility and replace water mains throughout the GILA campus to enable heat distribution (V02).

In addition, pertinent to SEGA's harvesting operations, the Alaska Energy Authority provided an additional USD 500,000 grant toward the purchasing of harvesting equipment (PL03). Although there is no direct financial support from the federal level, the project was one of the recommendations made by the National Renewable Energy Laboratory (NREL) in 2013 (PD05), when an energy audit was performed after the 2012 floods in Galena, to identify opportunities of energy system improvements for the community. The 2019 FEMA report also notes the importance of "*support from federal and state agency partners committed to collaborating with community members*" (PD05).

3.2.3. Supply–Demand Advantages

There are certain physical factors that helped the Galena project become sustainable and achieve operational success. These relate to the supply–demand dynamic particular to the local geography of Galena. Together, these three factors at the two ends of the supply chain helped to the project achieve the kind of operational success as described in the above section.

The first advantage is at the supply end. The biomass resource for this project is available in abundance and has no other competing use. Both the Forest Inventory Report (PL01) and the Timber Harvest Management Plan (PL03) highlight that abundant biomass resources (i.e., trees) were (and still are) available surrounding the community. The biomass inventory details from the Forest Inventory Report (PL01) showed that, as of January 2012, there was close to 8 million dry tons of biomass inventory within a 25-mile radius of Galena. With a very conservative consumption estimate of ~20,000 tons per year, the 8 million dry tons could last close to 400 years. Since current harvestable area is specific and allows access to only ~4720 acres of land, we should look at the reality of how much has been harvested since the project started. The average annual harvest since operation is just 1600 tons (PD03), which makes the harvested area ~25 acres/year since 2015. At this rate, the current TSA area offers a sustainable resource. Moreover, as mentioned earlier, the timber sale area has now been expanded to 15,000 acres. The sustainable harvest plan was developed based on a 100-year regenerative rotation (V02). The second element (also at the supply end) that makes biomass availability sustainable is the fact that there is no real competing commercial use of the biomass harvested (i.e., paper birch) from the forest, mostly due to the distance from sizable markets. Other species present in the harvest area, especially white spruce, are used for residential heating by the local population living near the forests. Therefore, during early operations, SEGA decided to avoid competing with residential wood gatherers and harvest paper birch. SEGA's general manager and their logging instructor describe this unique geographic advantage, explaining:

> "*it's not the type of timber that you're going to be able to make a whole lot of lumber out of, but that definitely is not our purpose. Our purpose is to provide [an] affordable, renewable fuel source for the school.*" (V01)

This finding is confirmed in our interview with a project partner as well (IN01), as he stressed that the project has been quite "lucky" in that the main harvested species—paper birch—is not used in building construction.

The third advantage is at the demand side and has to do with the end user of the energy produced. As outlined in the case study description, the bioenergy operation basically emerged as modifications to an existing heating system within the GILA campus (PL02). Twenty-two of the fifty campus buildings were connected to the central boiler for heating, and that arrangement has remained the same after the project (i.e., with a fuel switch and heat distribution upgrade) (PL02, PL03). This ensures that the heat load is not highly variable year to year, and any likely structural change is easily predictable. It only varies based on the weather and the seasonal occupancy schedule. This predictability of end use makes it easy for feedstock provision and plays a role in the operational success of the project.

3.2.4. Committed Staff and Leadership

Last, but arguably most important to the success of the Galena project, was the unique combination of key individual leadership and project staff. In that respect, one of the biggest challenges for SEGA is human capacity (PD04). This was confirmed in our conversation with a key project partner as well, that finding committed and trained staff that can work on the project over the long-term can be a challenge—especially over the winter months when people tend to move down to more southern US states (IN01). However, as we learned through the sources examined in our analysis, the project has witnessed high levels of dedication among technical staff. This is supported by other data as well, including within a video documentary:

> "*One story that especially stood out was when [Name of biomass plant operator] got a call at 2:00 a.m. on an early Saturday morning that the heat distribution system had gone down. It was 30 below outside and the campus was cooling down fast. He had about two hours to get the system back online before a major freeze damage would start setting in. Keep in mind [Name] had called it a day hours before after putting in a full shift at work. Passing the issue on to someone else or waiting for a tech to fly in from Fairbanks was not an option. If he didn't start troubleshooting the system immediately and find a way to fix the problem a chain reaction of system failures would occur. So he called a friend to come pick him up and drive him to the heat plant. [Name] diligently fixed the problem and got the heat flowing again just in the nick of time*." (V01)

A high level of commitment is shown by staff who are dedicated to staying in Galena (IN01), and they are the ones who eventually end up being long-term employees at SEGA.

Perhaps even more impactful in terms of the project's success is a dedicated set of leaders who were associated with the project in the early stages and sustained it over the long-term. The 2019 report from the FEMA (PD05) cited that the project was "locally-driven by strong local leadership". One such leader, who has been instrumental throughout the project, was Galena's City Manager. In a 2018 documentary about the project (V02), her contribution is described as having talented leadership ability in "pulling people together from all walks of life and personalities", motivating people to "accomplish seemingly unreachable goals," and thus being "a key orchestrator of the biomass heat project since its early beginnings". The role leadership has played in the project was emphasized by the key project partner as well (IN01). Referring to the SEGA manager, who has been with the project since day one, the interviewee stated, "*It's so key to have one person that sees the process through from very early in the stage into the operating arena of the project*." (IN01).

4. Discussion

In this study, we sought to advance our understanding of 'successful' bioenergy development via a case study of the remote, Arctic community of Galena, Alaska. In the context of climate change and renewable energy transitions, such northern contexts often escape academic inquiry. Our analysis has shown that the Galena project reflects many benefits of community energy projects as identified by Brummer [41], with economic and energy security being two of the most important indicators. Specifically in comparison to the base case of using a diesel-based system at GILA, the project has provided a much-needed boost to the local economy, keeping the school viable and benefits (i.e., jobs, economic security) within the community. SEGA's (the biomass collector and provider) expansion into other sectors, including construction, is further evidence of the overall positive economic impacts of the community-driven energy project. The Galena bioenergy project has addressed several key challenges, including ones that are common amongst remote northern communities. Specifically, this includes securing support for capital costs involved in the project, acquiring access to a local biomass resource, building a stable supply chain, and channeling community leadership and capacity. Overcoming these barriers has helped the Galena bioenergy project avoid many of the risks faced by similar communities [41]. Many such communities struggle to have bioenergy as a cost-competitive option because the feedstock (i.e., woody biomass) is often processed in distant areas, thus raising the delivered cost of the fuel. Buss et al. [46] show that in northern Canadian remote communities (in Northwest Territories and Manitoba), locally sourced wood chips could ensure cheaper energy production as compared to imported diesel or heating fuel. As illustrated by the Galena bioenergy project, access to a local biomass resource and the emergence of harvesting capacity within the community can together change the economics of biomass-based alternatives.

Although our initial focus in studying the Galena case study was not to specifically identify "drivers" behind this project, they do become quite apparent in our analysis. Specifically, our results suggest that the risk of an uncertain and expensive reliance on diesel was a primary driver for the community to seek an alternative like biomass. This scenario is not unique to Galena and is faced by other communities in Alaska as well. For example, in Fort Yukon, Vandever [69] finds that high costs of imported fuel (diesel) is a strong driver for the emergence of a biomass-based heating system. However, in the same study, the desire for higher energy independence, economic security, and the cultural significance of local forests also appears to be motivating factors. These drivers could be contrasted against the driver of climate change mitigation, given the dirty credentials of diesel. For example, studying community renewable energy in Australia, Mey and Hicks [70] find climate change concerns to be the top motivating factor. A lot of policy discourse on community renewable energy refers to emission reductions as a primary goal. Canada's policy initiatives targeted at remote communities—such as the off-grid diesel initiative—are developed under the national level GHG mitigation goals [71]. In the EU, Walsh [72] makes a direct link between the promotion of community driven energy projects and solving the climate crisis. For many remote, northern communities, however, transitions to local, renewable energy sources may be driven by a combination of more localized and immediate needs, including energy costs and the reliability of access to energy sources [72–74].

Irrespective of what motivates a particular community-based energy project, the factors behind its successful implementation and continued operation can provide important lessons and transferable learning opportunities. Such opportunities are important as notwithstanding the growth in community energy initiatives, there is still only limited sharing of the lessons learned from community energy frontrunners with on-the-ground experience [73–75]. As a result, there is limited opportunity for remote communities to learn from the successes of other communities and facilitate more efficient and effective community energy project design, implementation, and operation. This case study shows that, at least for communities living in and around the Boreal zone (with significant local forest resources), a combination of institutional support and community leadership can help achieve a fully community-based stable and sustainable bioenergy operation. However, certain unique, place-based factors should also be highlighted. The Galena bioenergy project has been fortunate in that it faces a predictable demand load and has access to biomass with no competing use.

While the documentary evidence highlights the success of the Galena bioenergy project across different indicators, it leaves some uncertainty regarding others. For example, our dataset contains insufficient information about actual forest health since biomass harvesting has started. During our conversation with a key project partner (IN01), it became clear that formal reforestation surveys are yet to be conducted on the harvested area, although during their informal visits they did find signs of regeneration (i.e., sprouting and natural seed fall). In addition, in our analysis we observed considerable support for this project in the community, but this evidence is about support shown at the institutional level (i.e., the school board, the city administration, and the tribal council). The literature indicates the importance of institutional support as foundational to the success of community energy projects [76,77]; however, broad-scale community support and trust are crucial for longer-term viability of community energy [78,79]. In our case study, we mainly highlighted the formal support of leadership and institutions. Community surveys and/or interviews would be required to understand community-level perceptions more fully around the Galena project, including the challenges, barriers, and benefits of the development.

5. Conclusions

We presented a case study of a bioenergy project in a remote Alaskan community (Galena), with the aim to explore the indicators of and the factors contributing to its success. Our findings show that the project has been successful operationally, environmentally and has generated community-level benefits that have enhanced economic and energy security. Such contributions reflect the potential benefits of community energy as identified in recent scholarship. Importantly, the factors contributing to the project's success include community and state level support, supply-demand specific advantages and committed staff and leadership. Such factors illustrate that success is very much dependent on the 'right' set of local and instructional conditions. Whether a similar set of conditions are probable, or even possible, across diverse circumpolar/Arctic communities, requires investigation. However, some of these, including having committed staff and leadership, are more likely to be transferable. We hope researchers, community leaders, and practitioners in bioenergy and broader renewable energy circles, can learn from this study to better understand how different 'recipes' of success may be created in different places with different energy goals. Although our analysis of the Galena bioenergy project was not exhaustive, and was based largely on secondary source materials, lessons from this case study may be valuable for similar remote communities with biomass resources, thus helping contribute to knowledge transfer across remote communities seeking local energy alternatives.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/en15134655/s1, File S1: Detailed plan of harvesting operations (and map).

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