CONCEPTS FOR INTEGRATING PV INTO RURAL ALASKAN HOUSING AND UTILITIES

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INTRODUCTION

The potential for solar energy applications in Alaska has long suffered from the notion that the sun simply doesn't offer any hope for Alaskans. From roughly 15th November until the end of January, little solar radiation indeed is available. Optimizing a system to collect it for that period is not economically feasible. However there are a 230 more hours of possible sunlight at the Arctic Circle than at the Equator. The problem with solar energy for Alaskan latitudes is that it is very dynamic, not reliable, and is out of phase with the heating and major electrical loads in the state. Yet solar energy is ever present, on site, not subject to transportation system failures, it creates few environmental problems, and perhaps most important at all, solar energy is not inflationary.

Recently Alaska has been included in the establishments of coalitions around the country for the Million Solar Roofs Initiative. The author is the chair of the Alaska Million Solar Roofs Coalition. One of the major problems we confront is enhancing the credibility of solar energy for applications in Alaska, particularly photovoltaic applications, the subject of this conference. A fertile approach to achieving this, is to integrate photovoltaics into the building stock in Alaska. In order to do this competently and cleverly, we need to have a clear understanding of solar geometries and the natural conditions in Alaska from a climatic point of view, which will affect the performance of those photovoltaic systems in a building context.

ALASKAN SOLAR GEOMETRY AND IMPLICATIONS FOR BUILDING DESIGN

Alaska's low sun angles provide a very interesting opportunity for solar architectural thinking. Figure 1 from (Seifert, 1981) makes this point very clearly. It is a plot of the annual average solar radiation on a vertical, south-facing surface: the south wall or façade of a building. Because of our annual climatic conditions of cloud and snow cover over the winter and spring, this plot has some rather counterintuitive information to divulge.

The plot shown is for Palmer, Alaska. Radiation on the south surface peaks in March and April and then declines all the way through December quickly building again through January and February. February and March typically offer the clearest weather of the year. Therefore, building facades, particularly south facing walls get a lot of solar radiation. South facing vertical collection areas also have the advantage that they don't need to be kept free of snow throughout the long winter in Alaska. Any orientation other than vertical will enhance the accumulation of snow, obviously a serious problem in Alaska for most of the year.

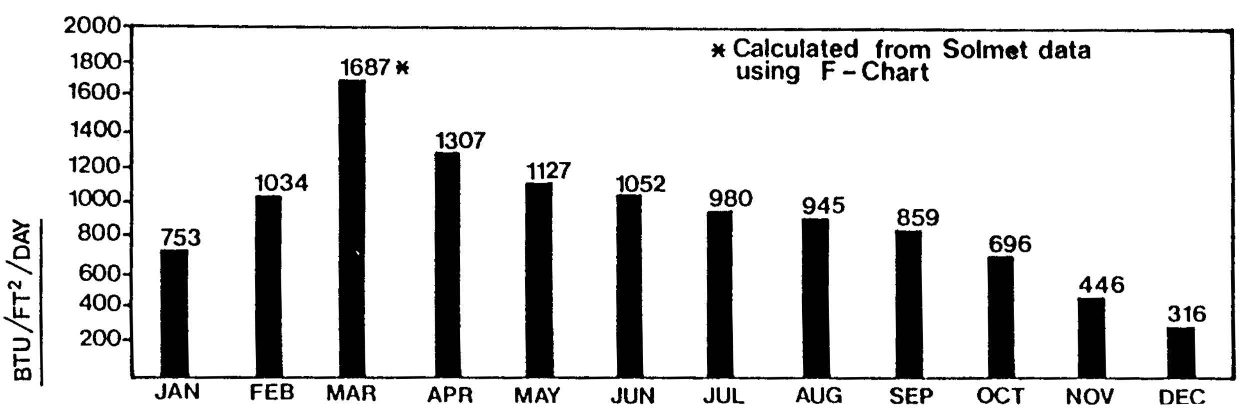

Fig. 1. Average solar radiation on a vertical south facing surface, Matanuska, Alaska.

This insight has already been gleaned by clever Alaskans. Figure 2 shows an example of exactly the kind of inferred optimization for south facing surfaces that the solar geometry of Alaska dictates. Let's look a little more closely at that geometry to clarify this picture.

Figure 3 is a sun path diagram for 60°N latitude, approximately the latitude of Anchorage. Even at noon on June 21st, the summer solstice, the maximum solar elevation angle for Anchorage is about 53° above the horizon. All of the direct solar radiation and all of the positions of the sun are enclosed in an angle looking due south, at or less than that 53° angle. Thinking of this in a spherical geometric sense, the only place on a building which gets direct sun for most of the year is the south façade. All of the direct sun comes from a position in the sky within the southern most quarter of the sky dome. Clearly this is where you'd want to put your collectors, especially if they were not tilted or optimized for collection by tracking.

Building shape becomes crucial in integrating solar collection. Rural building designs must be simplified and customized for the rural audience, where typically houses are built according to a stereotypical model. The model is replicated for the number of houses at a particular village or site for a year in which they get a new housing increment. What is suggested is using the efforts of the industry and the skills of architects and engineers to design an integrative, inexpensive, modular, easily repeatable design, incorporating what we know about the performance of solar buildings and the climatic and the solar geometry implications for building a house in Alaska.

As soon as one begins to look into the optimization of the south façade, several subtle complications emerge. One is to provide an adequate amount of daylighting to enter the interior of the house such that an optimum use of natural lighting is afforded. At the same time, any space on the south façade used for lighting will not be available for solar collection using PV. Optimally spacing these two important uses for solar radiation in an appropriate, esthetic, and effective way is a serious design challenge. There is after all, only so much south façade you can put into a normal building. At the same time, this begs the question of whether there might not be geometries other than cubes and rectangular shapes to look at for optimization, which would afford a better utilization of the south façade of the building. An example is shown in Figure 4 of a façade, which uses transparent photovoltaic panels.

The photovoltaic cells are in this example, mounted in a glass protective case, such that all of the area except the actual cells themselves is transparent, providing lighting and photovoltaic gain at the same time. Especially for clerestory-type lighting, this may be an ideal technique to integrate into the same window system, a photovoltaic gain as well as indirect natural lighting. This is a product which is already available from Pilkington Glass, Gelsenkirchen, Germany.

Fig. 2. An example home employing vertical, south facing photovoltaic panels, and daylighting.

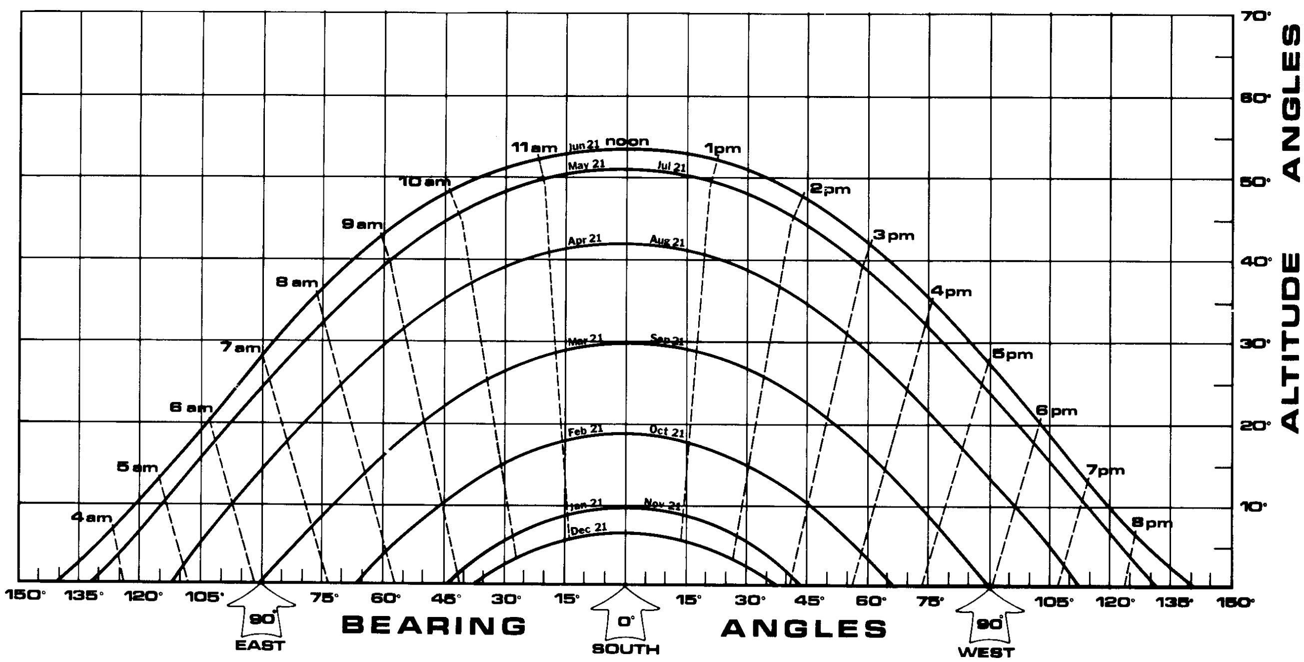

Fig. 3. Sun path diagram for 60°N latitude.

Fig. 4. An example of a façade using partially transparent photovoltaic panels, providing both PV and daylighting.

In addition to the building design and spacial features of photovoltaic and passive integration to buildings, an important aspect in the Alaskan case is how to get PV integrated into the utility grid in Rural Alaska. Rural Alaska presents a very big challenge in this area, not only because it is in Alaska, off grid, and has some of the most expensive power in the world, but also because of the annual variability and the load for electricity and lighting being maximum when the amount of photovoltaic energy is minimum.

In the past the author was involved in trying to solve this problem using a demand side analysis of energy loads. One of the insights from any analysis one undertakes of integrating PV into a standard electrical grid is the recognition that PV makes much more economic and physical sense, if electrical demand is reduced by energy efficient lighting and appliance loads. Demand side reductions and conservation, including energy efficient housing, are also necessary goals of this technique and especially good public policy. Largely this model already exists in Alaska as we have a thermal efficiency standard and HUD's level of building design, airtightness, and energy efficiency is steadily improving. In the author's experience, a team he worked with estimated the power needs of a house designed to operate off photovoltaic solar (Lime Village, Alaska) in an original effort to bring electric utilities to this community which had none until 1995. Although details on the estimate for the power needs is not available due to space constraints for this paper, the appliance loads were estimated according to what was the minimum power requirement, AC or DC, necessary to provide the electrical comfort, or cooking services required to maintain a reasonably good lifestyle without creating unnecessarily large electrical load.

The appliances which were included in the analysis, were DC lighting, a Sunfrost 24 volt DC refrigerator, a standard radio/stereo, a solid state color TV, a blender, a mixer, and a small microwave oven with a wattage range of about 800 watts. With this type of base load, admittedly this kind of demand side management is somewhat preemptive of personal consumer choice, and in a community which has no electric power this seems to be a good approach. It's also a way to control growth in electricity consumption power. Note that none of the appliances included in the list are "heavy thermal" appliances, like electric stoves or other heating devices. All those are presumed to be provided in rural Alaska by fossil fuel technologies. Ultimately, this kind of demand side load design resulted in a typical daily assumed load of 3238 watt hours per day, a number which includes conversion of 2263 watt-hours to AC from DC with an assumed inverter efficiency of 85%.

When we do the calculation for sizing both the battery and the PV array, we find that most standard sizing calculations tend to oversize both the battery and the PV array because of our generally limited peak hours of sunlight. Probably a better way to size the system would be to assume a design period for nine months of the year, from February 1 through November 1, thereby writing off and forgiving the poor performance during the wintertime. The reason this option is suggested is that if you use a standard collector sizing calculation for the Lower 48, you will tend to oversize by as much as 50% the required PV array for a load such as that calculated for a Lime Village home.

Due to space constraints in this paper, we'll not be able to delve deeply into the options for hybridizing an off-grid village sized electric utility system in Rural Alaska with PV onsite in homes. Consequently, how we might integrate those two systems together to optimize their performance is not examined. Hopefully this will be undertaken by the new Million Solar Roofs Coalition in Alaska.

REFERENCES

Richard D. Seifert, *Solar Design Manual for Alaska*, Bulletin of the Institute of Water Resources, Vol. 1, University of Alaska Fairbanks, Fairbanks, Alaska 99775-6180.

Hermann Scheer, *A Solar Manifesto*, James and James, Science Publishers, Ltd., 5 Castle Road, London NW1, 8PR UK. 218 pages.

Richard D. Seifert, "Taking a Few Energetic Strides Toward a Sustainable Future," paper presented at the 'Can the Last Frontier Have a Sustainable Future?' Conference, Anchorage, Alaska, July 22-23, 1999. 11 pages.