An Arctic Daily Solar Photovoltaic Load Coverage Factor Map for Passenger Electric Vehicles

Michelle Wilber
Alaska Center for Energy and Power,
University of Alaska Fairbanks

ACEP Alaska Center for Energy and Power

UAF UNIVERSITY OF ALASKA FAIRBANKS

Question: How well can PV cover EV charging?

Motivation: Low-emission power generation is crucial to a beneficial and equitable transition to electric vehicles (EVs)

Method: A daily Load Coverage Factor (LCF) is calculated for an equal amount of installed solar PV capacity and daily driving distance for different global locations

- PVWatts and PVGIS used to model daily output of 1-5kW of installed Photovoltaics (PV)
- Energy use of a passenger EV driven 48km/day was modeled – this is highly temperature dependent!
  - Crowd-sourced Alaska data used to extend data to -40ºC

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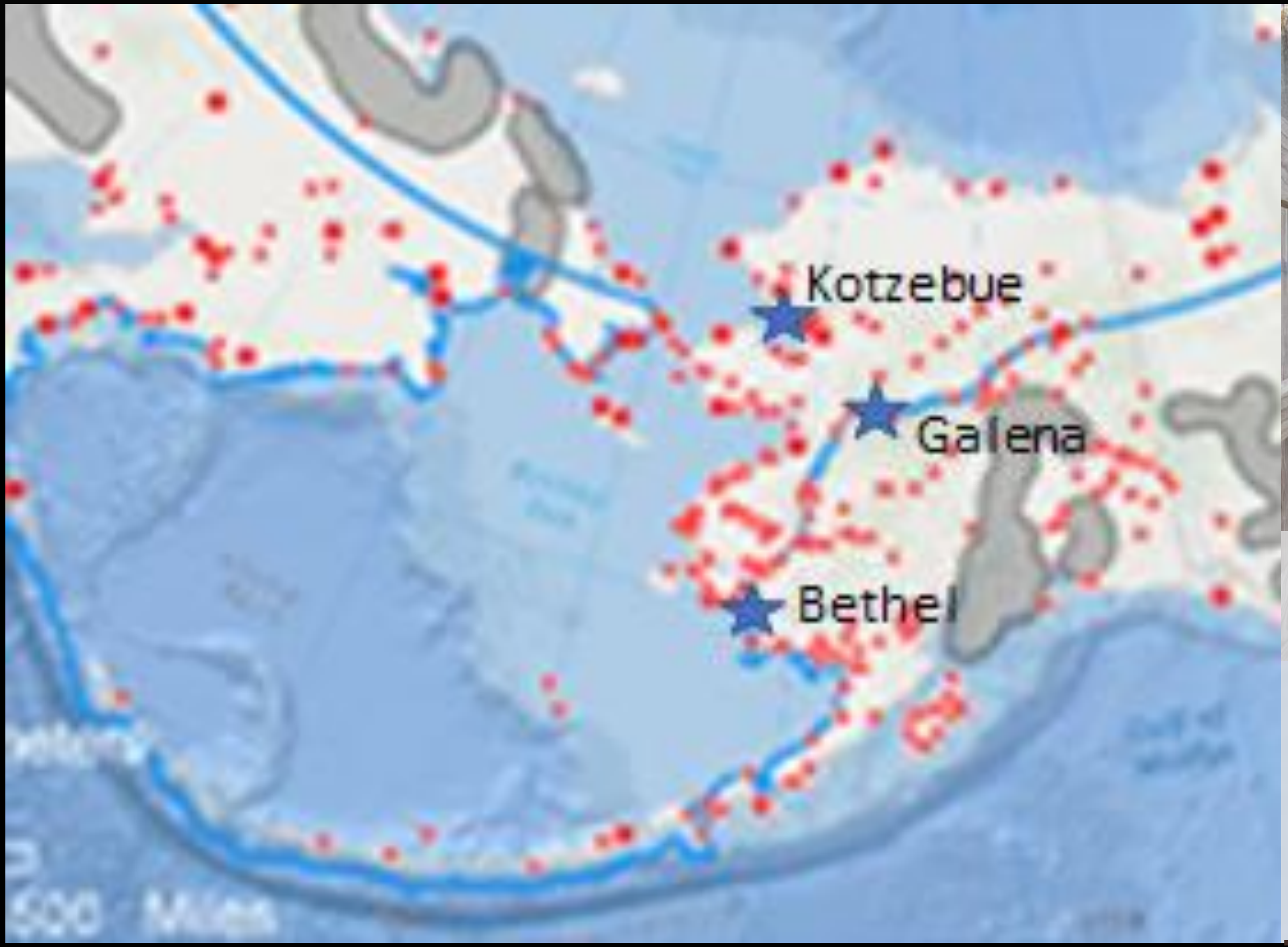
NSF NNA Planning - Electric Vehicles in the Arctic



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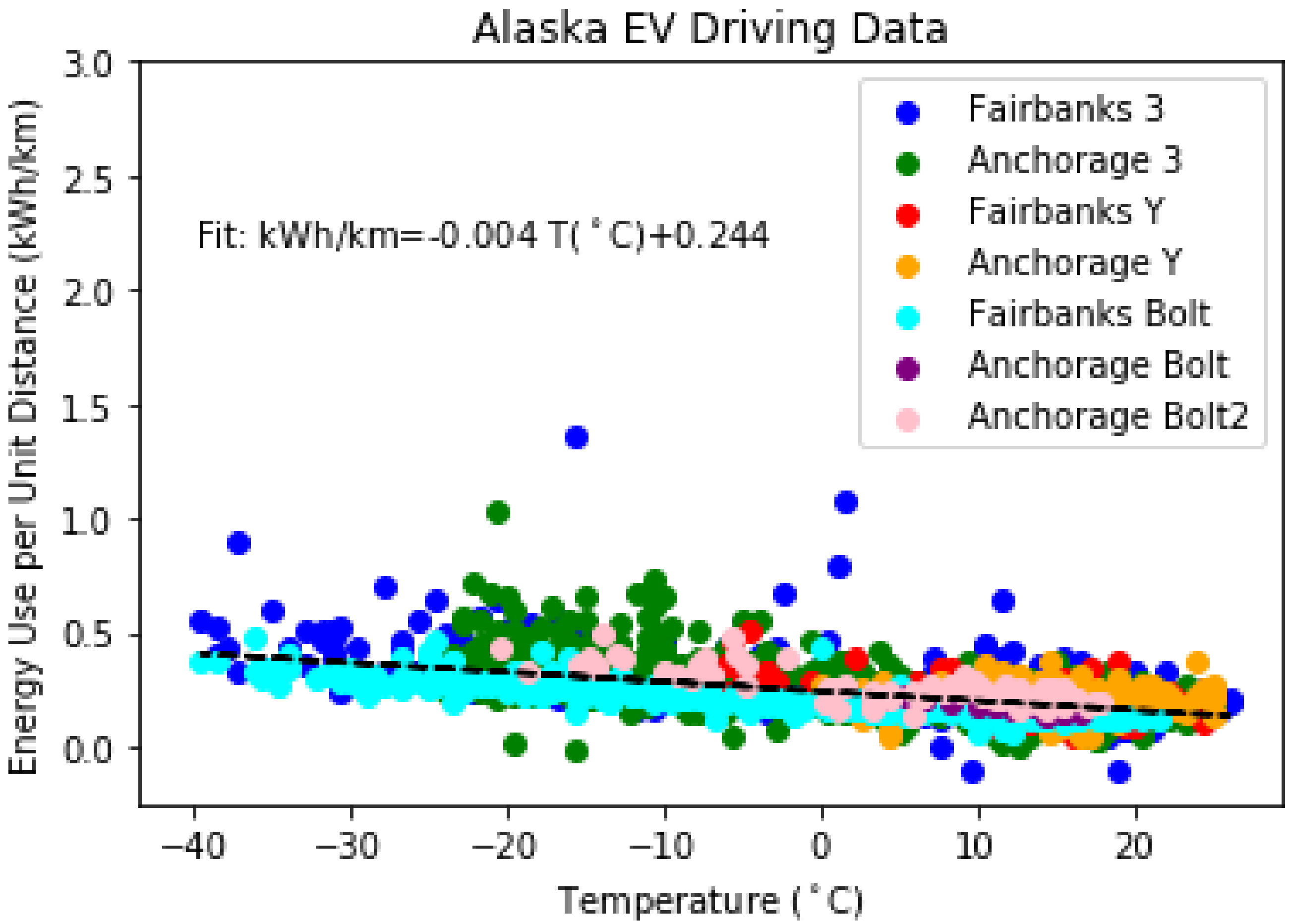
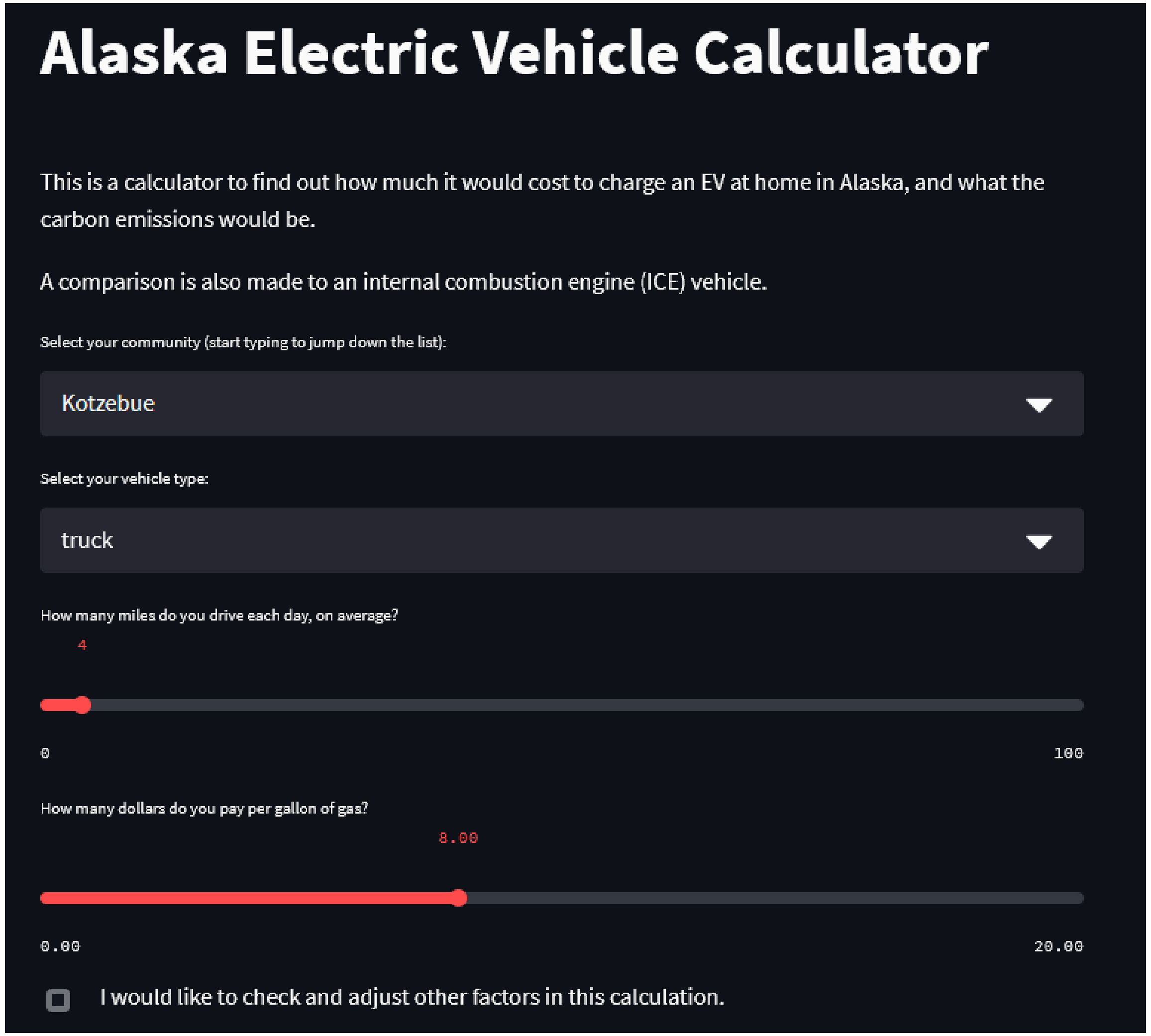
Need: Low temperature Energy use for EVs

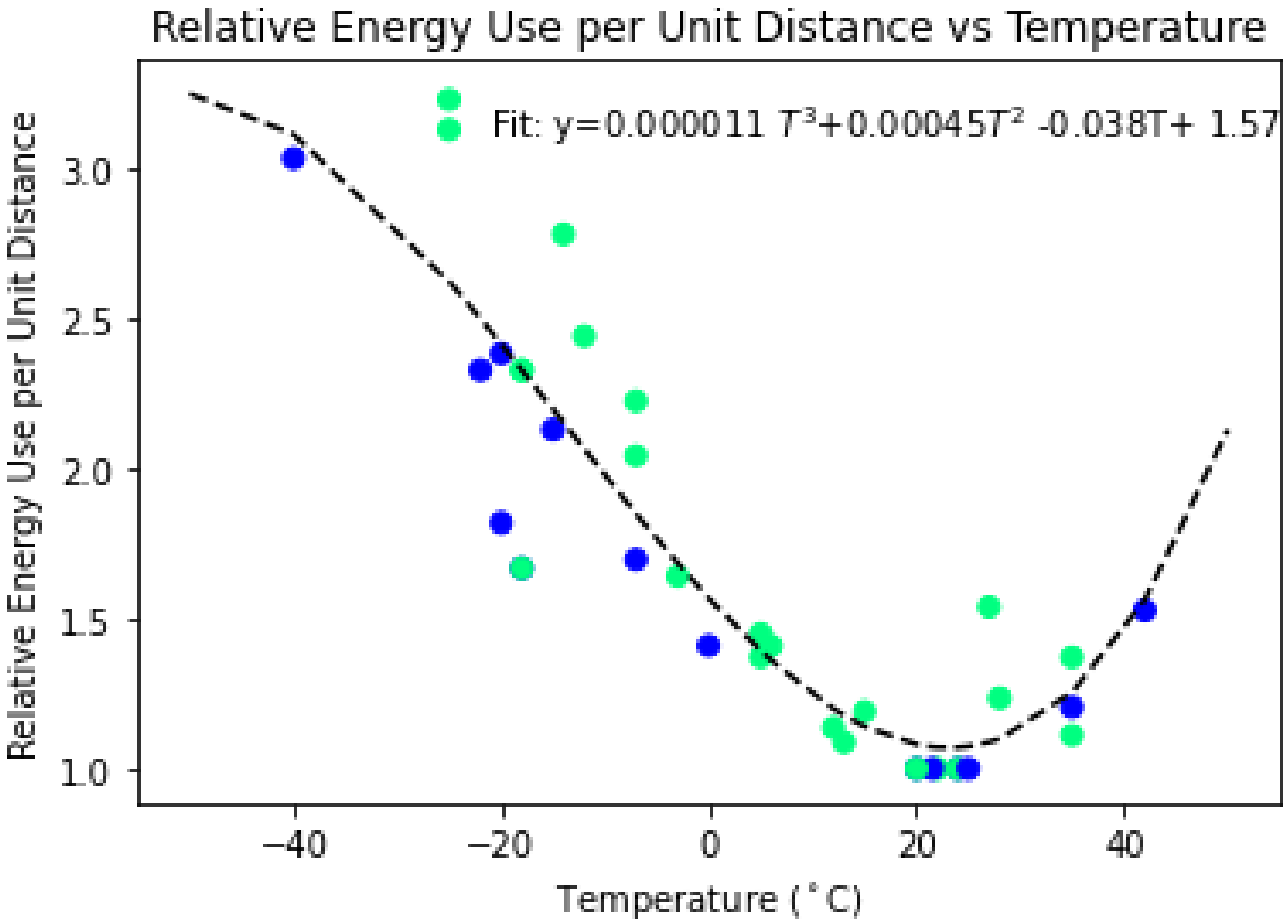


Crowdsourced trip level data for seven EVs in Alaska, based in either the cities of Fairbanks or Anchorage, with a linear fit to the energy use per unit distance (kWh/km) vs. ambient temperature (°C).

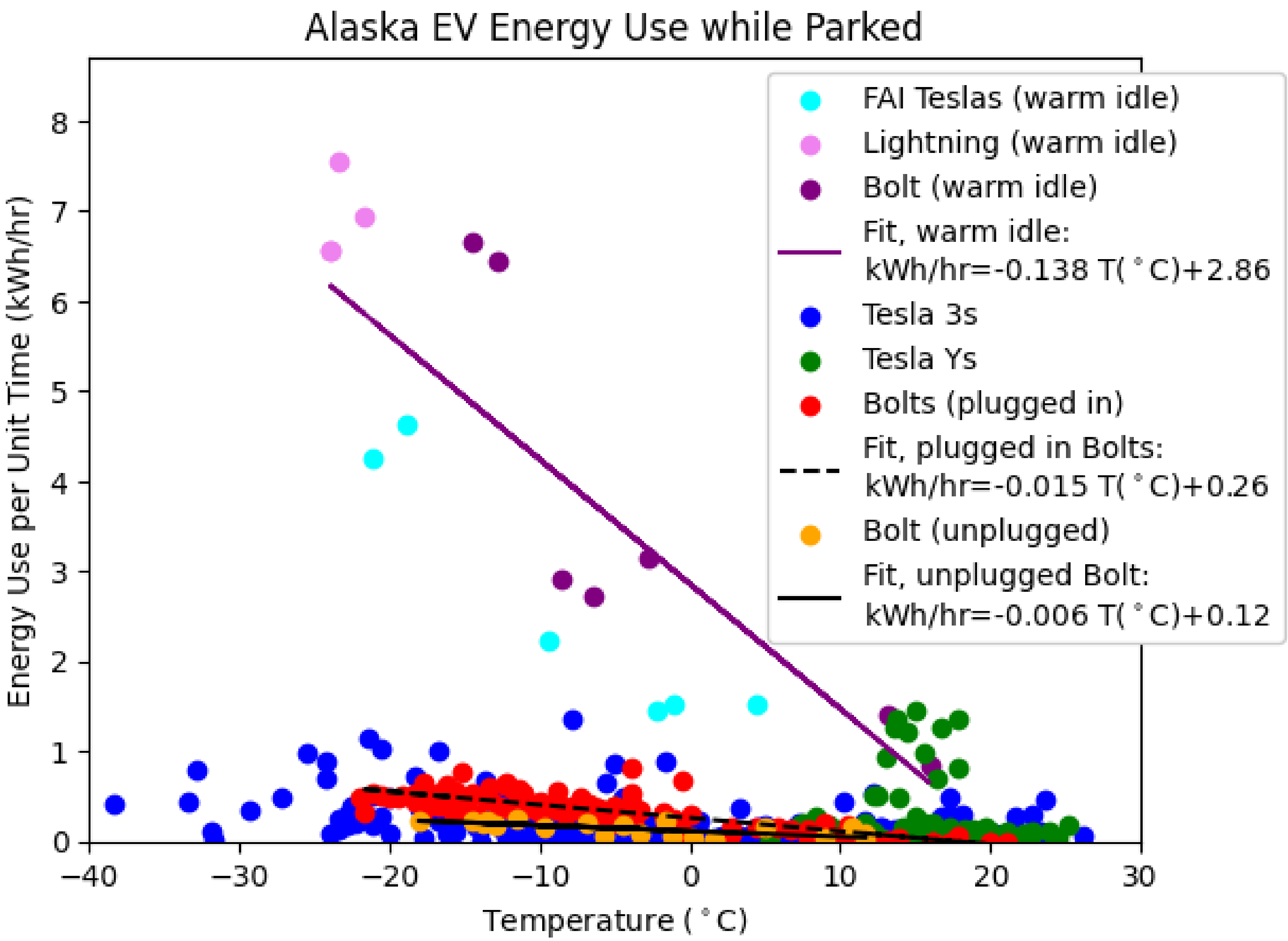
To model energy use of an EV:

- Need a relationship between energy used and temperature (both driving and parked)
- Assume a use case – trip details (time, length, etc)
- Need a time-series of local temperature data (in our case, PVWatts and PVGIS temperature data)



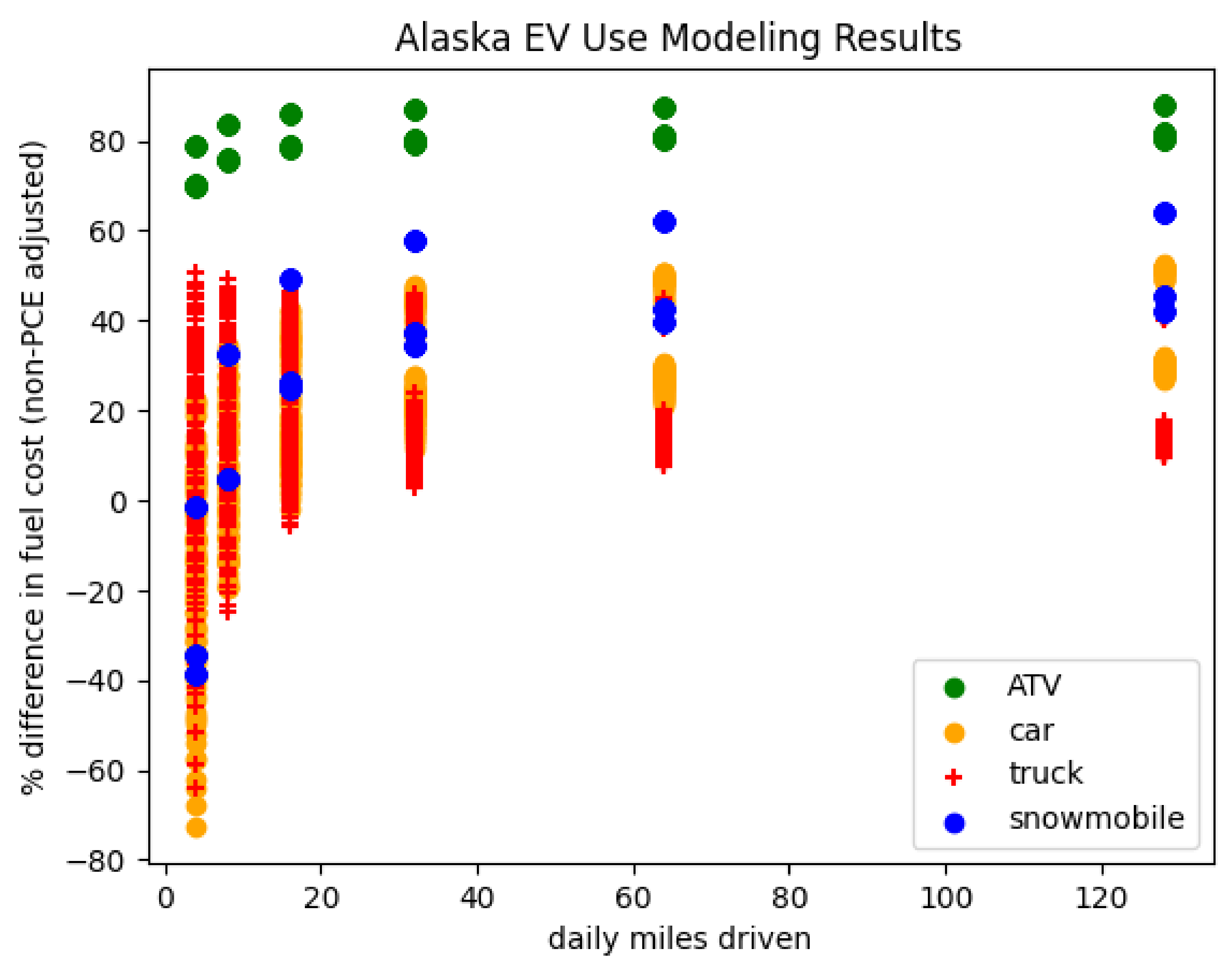


Effect of temperature on energy use per distance relative to the optimal (lowest) energy use per distance for passenger EVs from the literature [1,2,3,4,5] and from points on the linear fit in Figure 1. The third order polynomial fit is shown by the dashed line and the equation given. Blue data points are from studies reporting averages and fits to many EVs and trials, and green data points are data from one or two EVs during one or two trials. All points are weighted equally.



Crowdsourced parked energy use data (generally at daily or overnight timescales) for nine EVs (two Tesla Model 3s, two Tesla Model Ys, two Ford Lightnings and three Chevy Bolts) in Alaska with a linear fit to the energy use per hour (kWh/hour) vs. ambient temperature (°C).

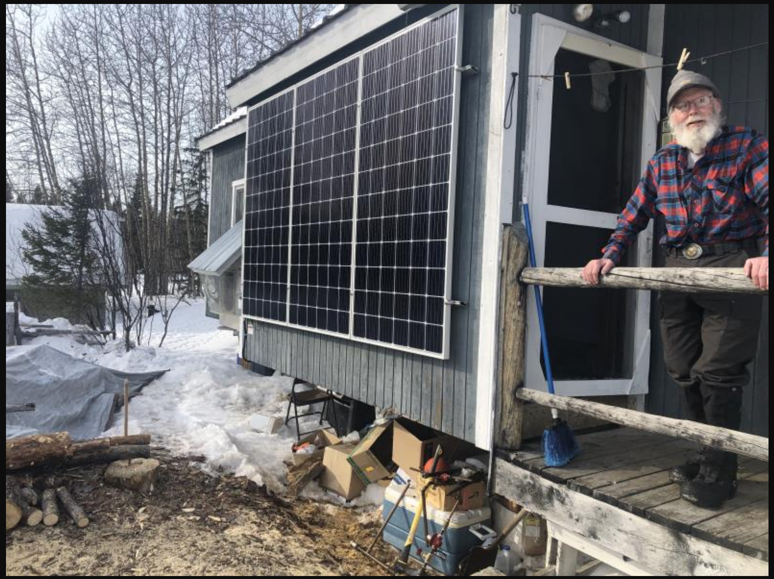
Modeling of scenarios in the Arctic, EVs often end up more expensive and 'dirty' than ICE



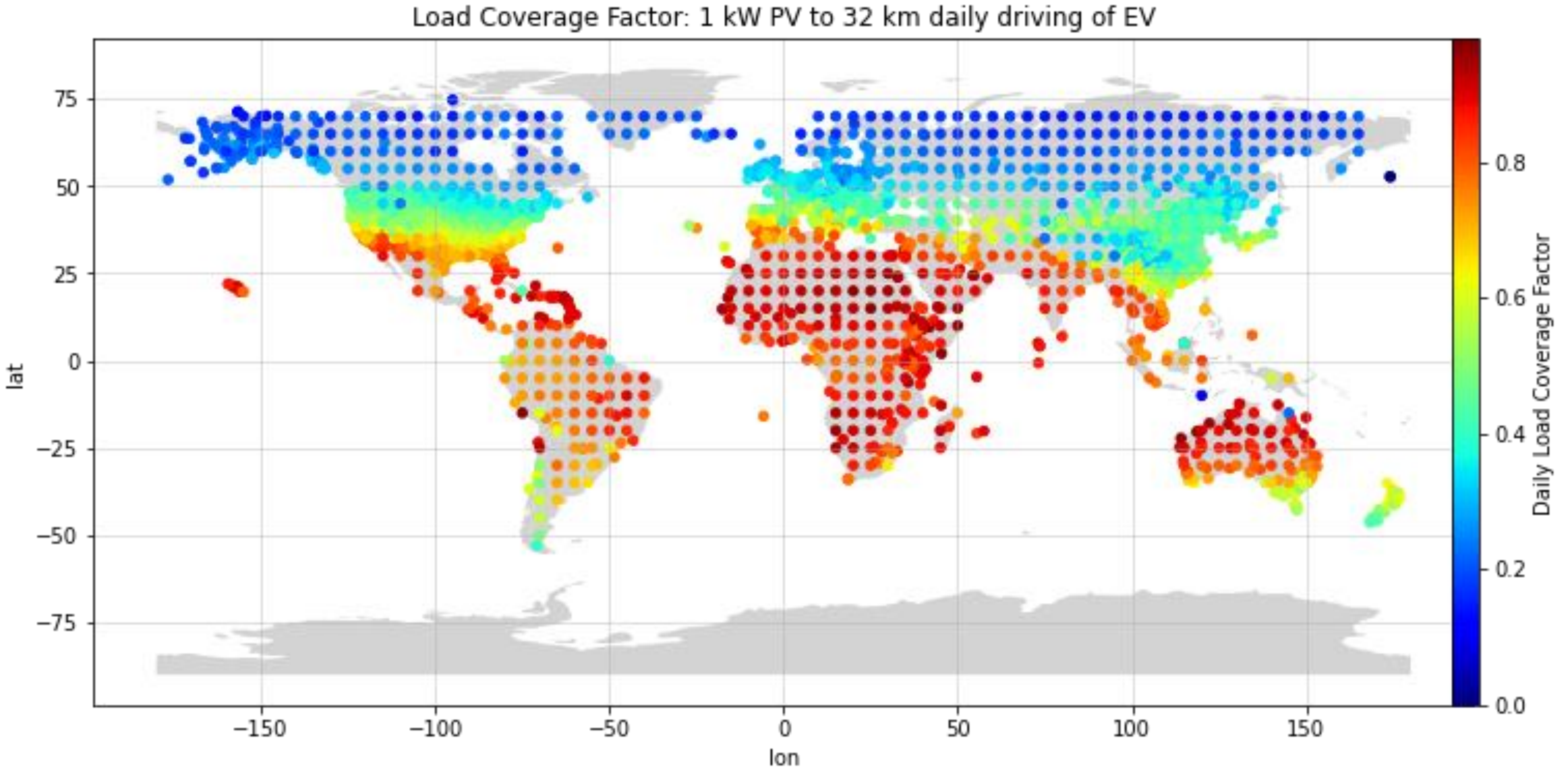
Daily Load Coverage Factor [6]

$$LCF = \sum_{i=1}^{n} min(L_i, G_i) / \sum_{i=1}^{n} L_i$$

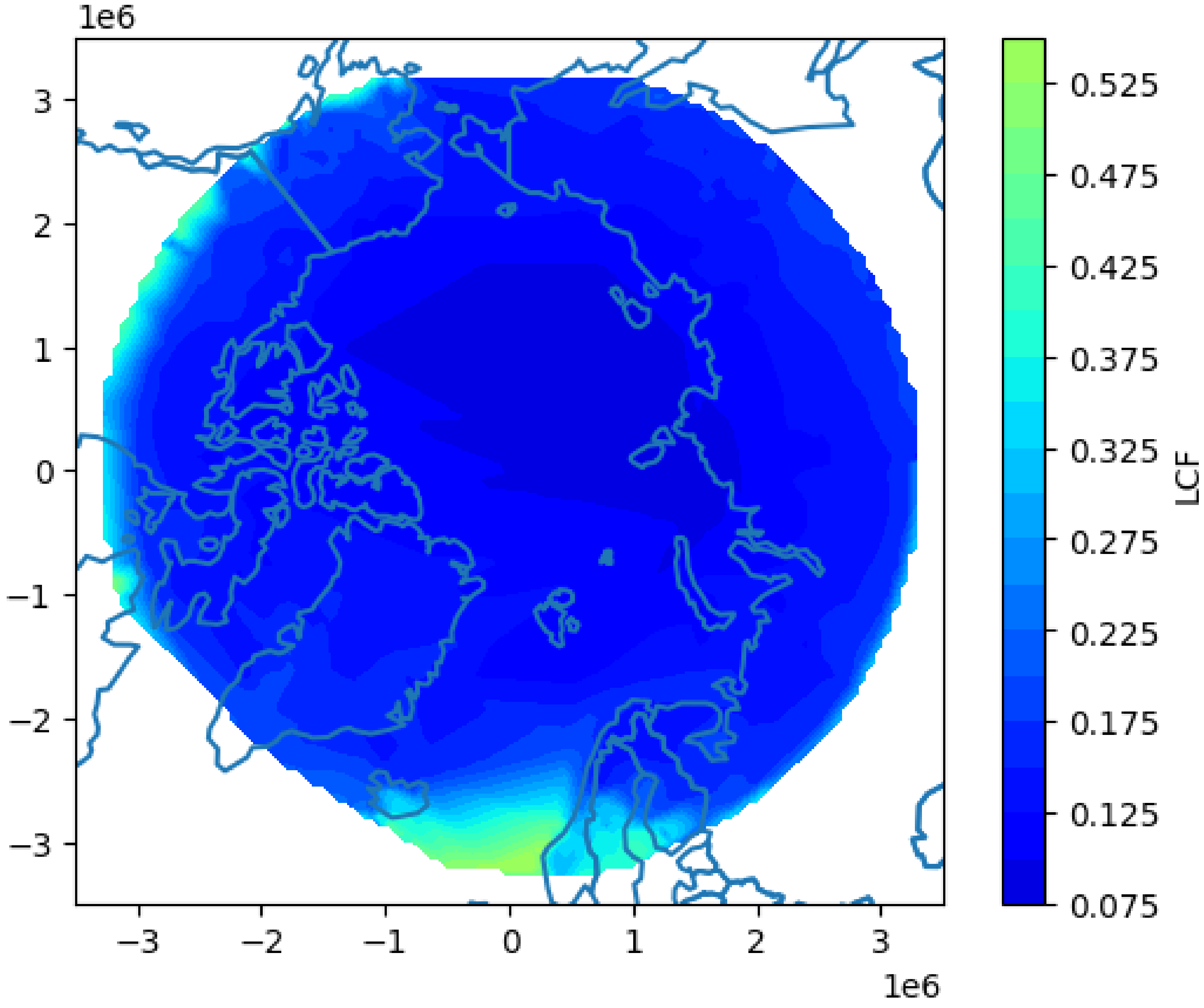
- subscript *i* refers to the daily values,
- *n* is the total number of days in the analysis and should be a multiple of 365 (complete years),
- L_i are the daily EV energy loads,
- G_i are the daily solar PV generation totals.



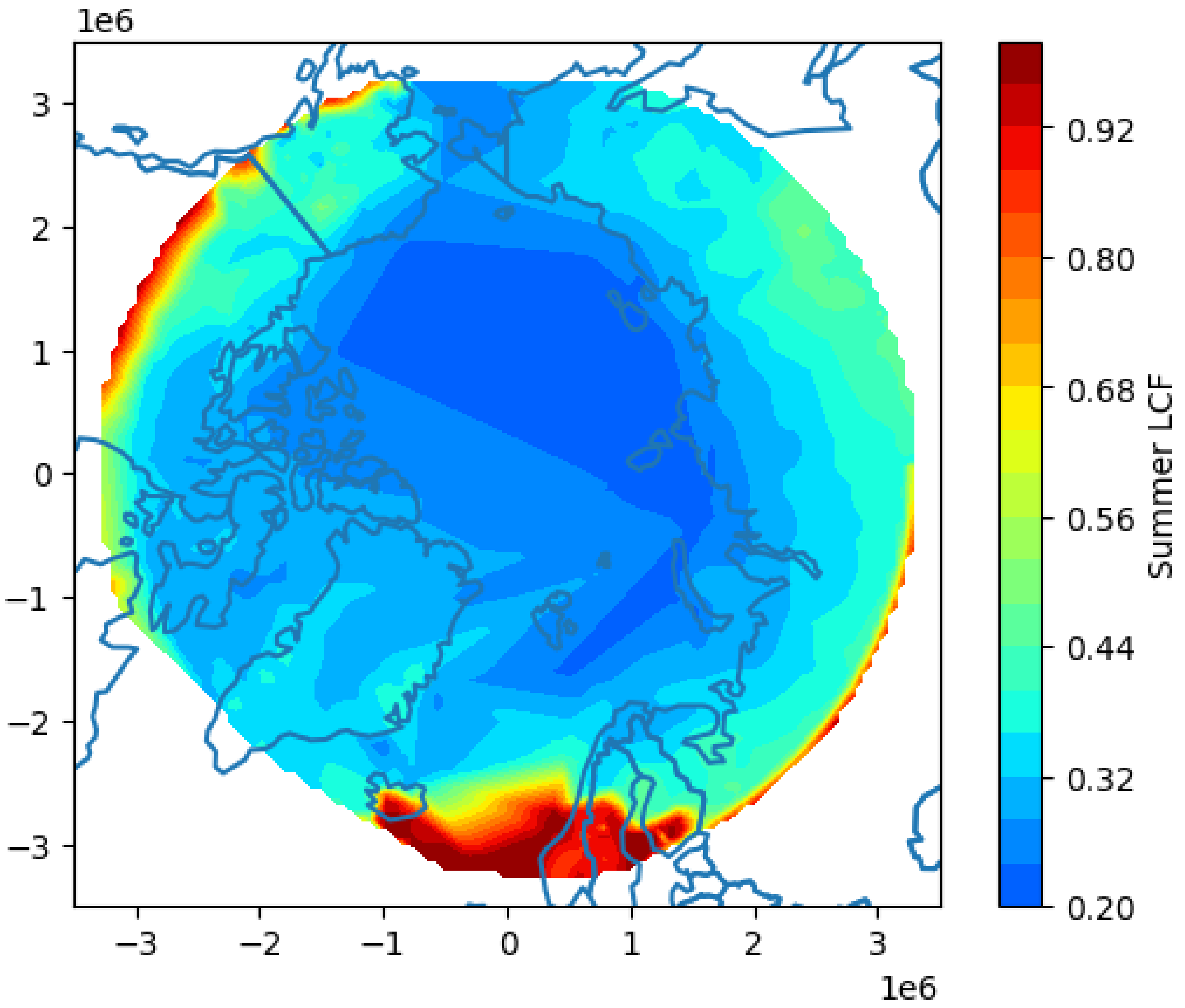
Global LCF Map



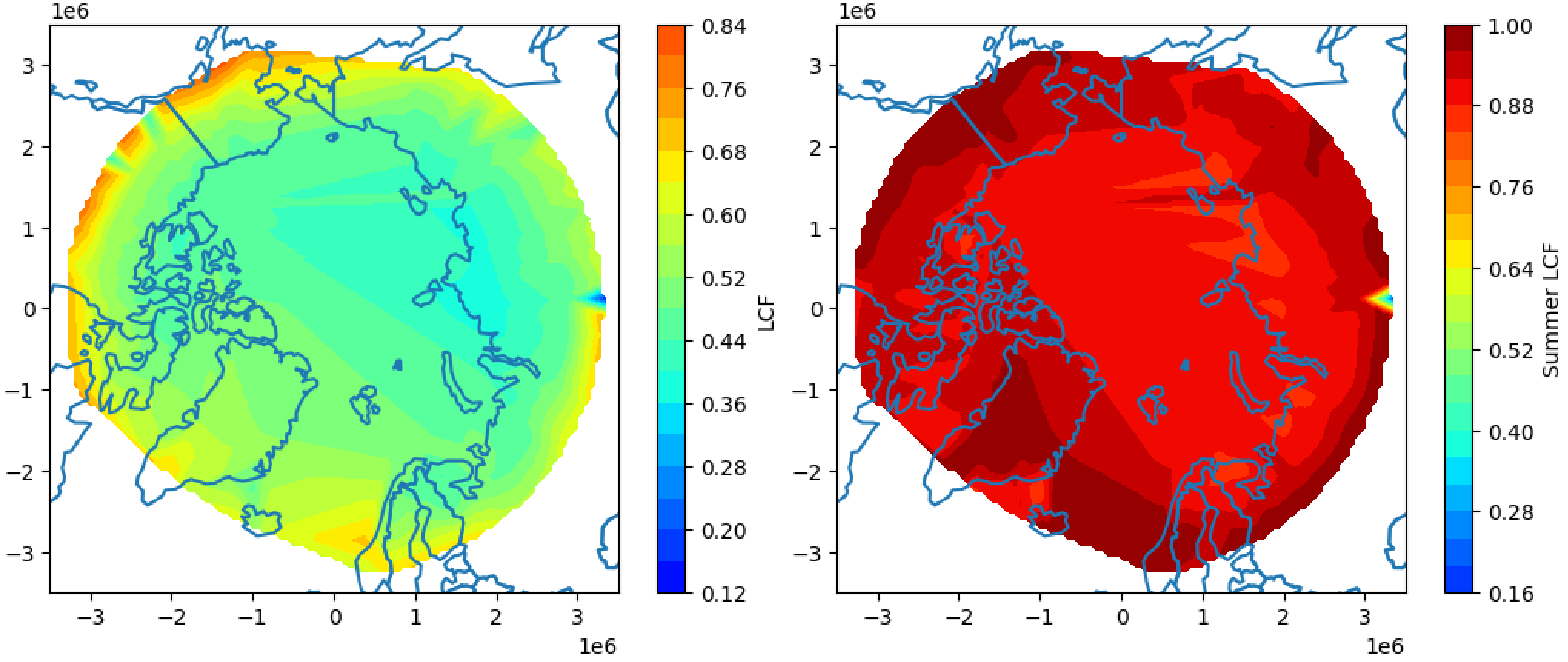
Arctic LCF Map - 1 kW PV to 48 km daily driving



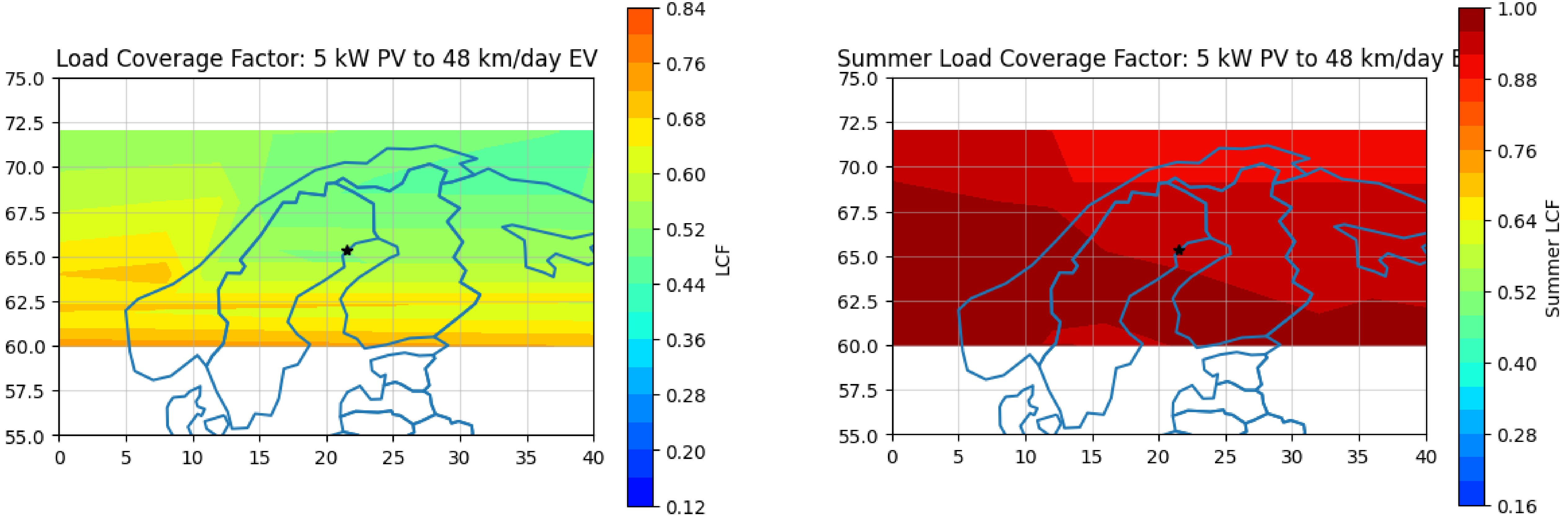
Summer Arctic LCF Map - 1 kW PV to 48 km daily driving

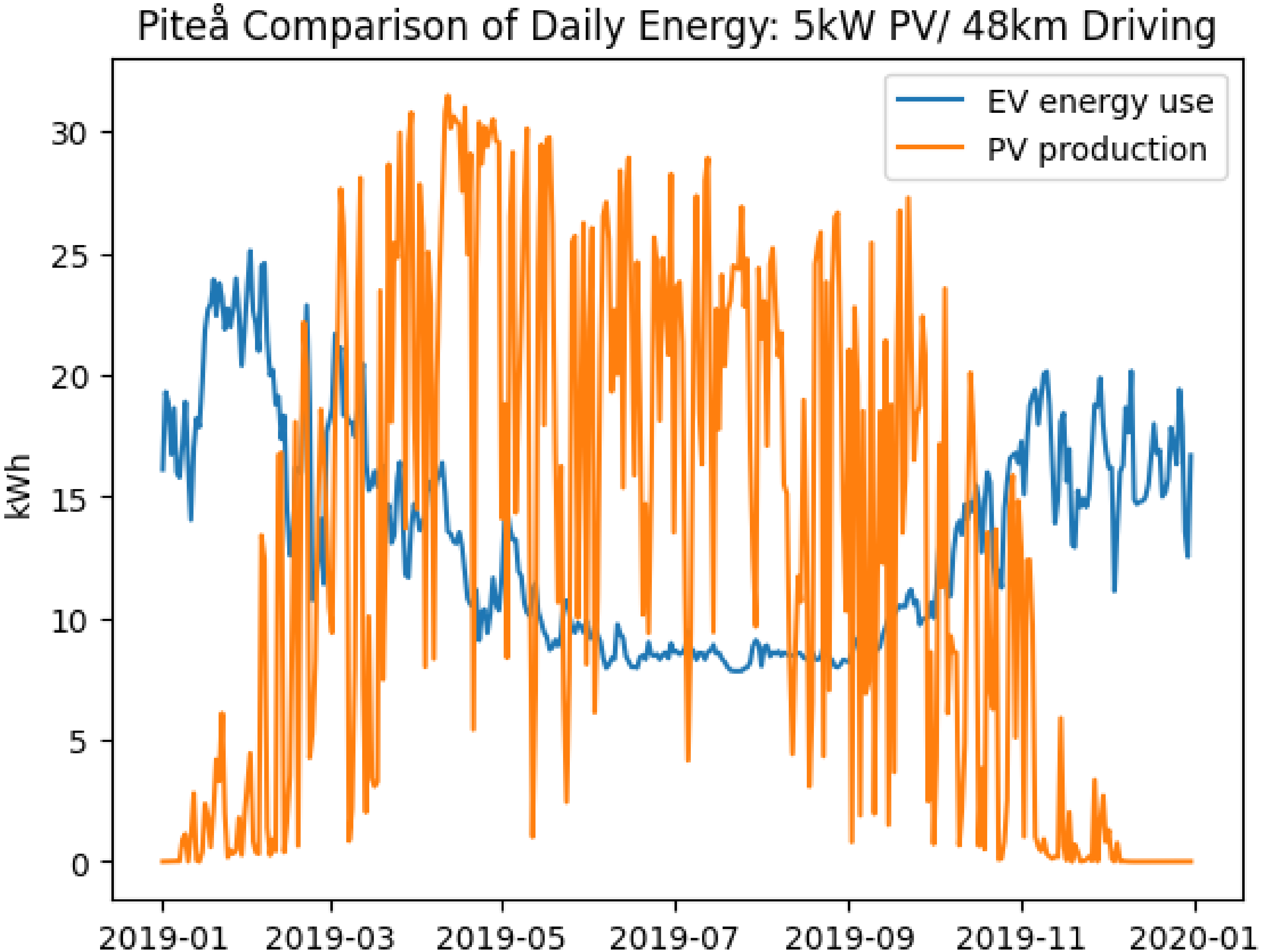


Arctic LCF Maps - 5 kW PV to 48 km daily driving

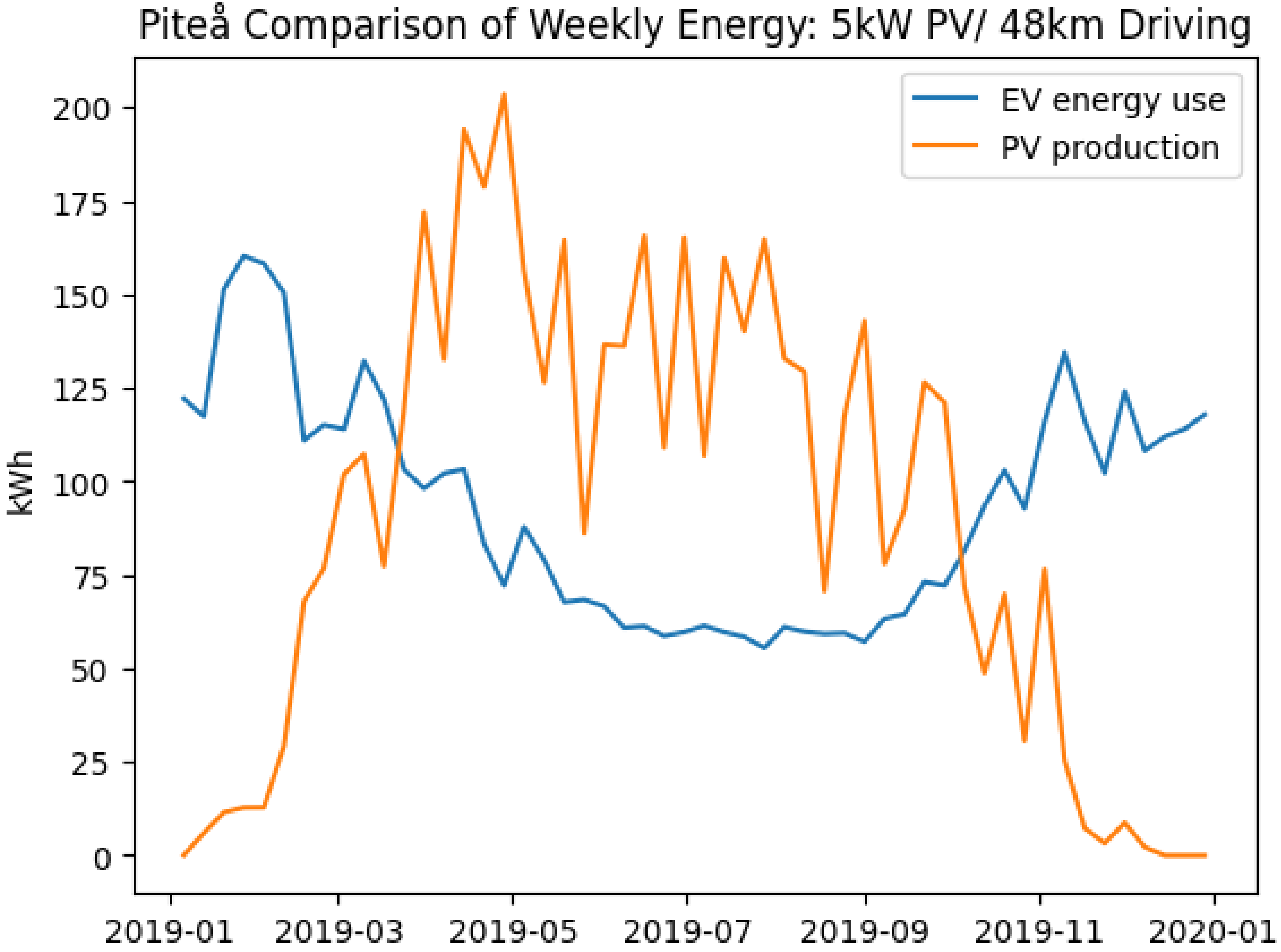


LCF Map - 5 kW PV to 48 km daily driving





Piteå Comparison of Daily Energy: 5kW PV/ 48km Driving
EV energy use
PV production
kWh
0
5
10
15
20
25
30
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01



In the summer weekly charging is possible for 48 km/day driving…

Results and further work

- Regions with lower local insulation and lower winter temperatures have lower LCF’s as expected
- The global south, especially Africa, seems to have a clear advantage in powering electrified transportation with solar PV generation
- Summer seasonal use matches better with solar in the Arctic as expected - but may need to pay attention to energy use in winter for battery conditioning
- While the results on whole are not surprising, the method allows quick analysis of multiple locations for optimal siting, expansion to other vehicle types and use cases.

References for this Presentation

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Thank You!

Contact: Michelle Wilber - mmwilber@alaska.edu

acep.uaf.edu

We would like to thank Nathan Williams for drawing our attention to the PVGIS tool, Kris Hall of Recharge Alaska and the Alaska EV drivers who graciously shared data, and the ongoing support and help of our ACEP Solar and Beneficial and Equitable Electrification team members, especially Chris Pike.

This project is part of the Arctic Regional Collaboration for Technology Innovation and Commercialization (ARCTIC) Program, an initiative supported by the Office of Naval Research (ONR) Award # N00014-18-S-B001. Details at: https://thearcticprogram.net/