15.03.2024

Snow losses & snow loss prediction

2024 High Latitude PV workshop

Mari B. Øgaard

mari.ogaard@ife.no

Should be considered in:

Yield modeling

System design

O&M

Forcasting

Outline

- How is snow loss considered in Norway today?
- Snow loss quantification
- Snow loss modeling

How is snow loss considered in Norway today?

Not at all

"It is not sunny in the winter anyway"

"We have had very low snow losses in our installations" (last year)

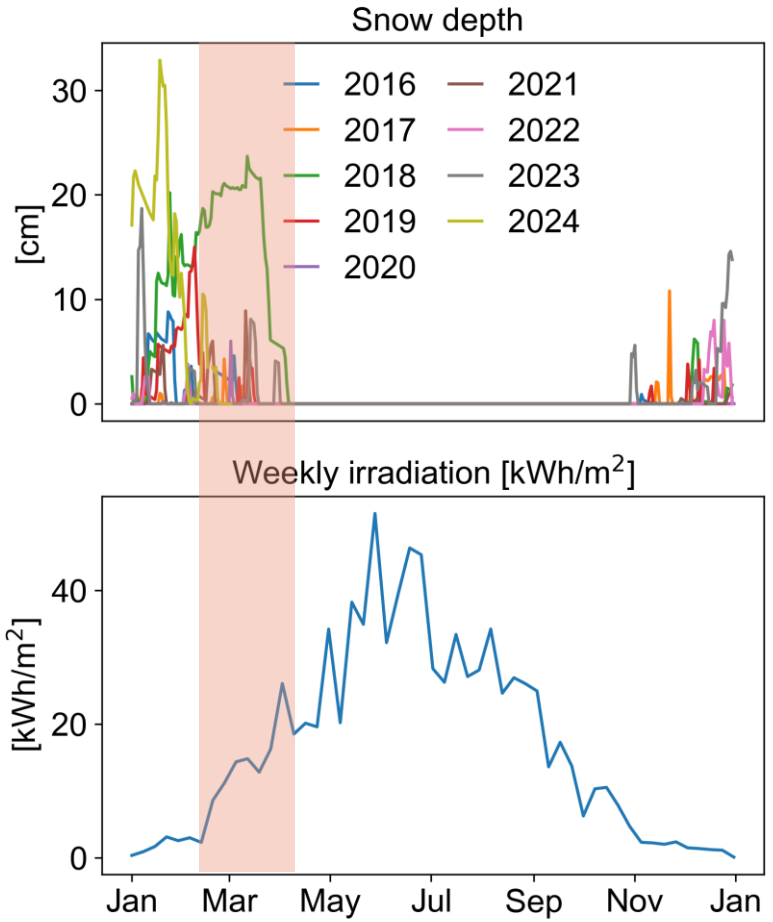
PVsyst-modeling: table values.

Suggested monthly soiling loss values (**15-25** deg tilt)

	J	F	M	A	M	J	J	A	S	O	N	D
Stavanger	10	10	2	2	2	2	2	2	2	2	2	10
Oslo	40	50	40	2	2	2	2	2	2	2	10	30
Trondheim	40	50	30	5	2	2	2	2	2	2	10	35

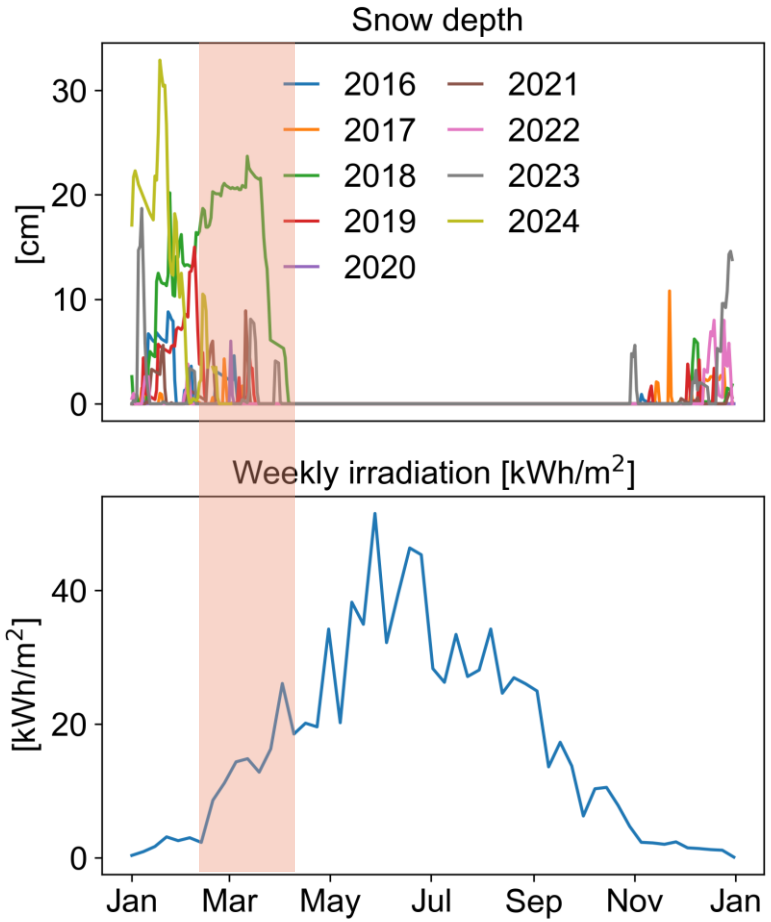
++++

"This does not work. Overestimated/Underestimated snow losses for my installation" (last year)



How is snow loss considered in Norway today?

Huge need for more data and knowledge!

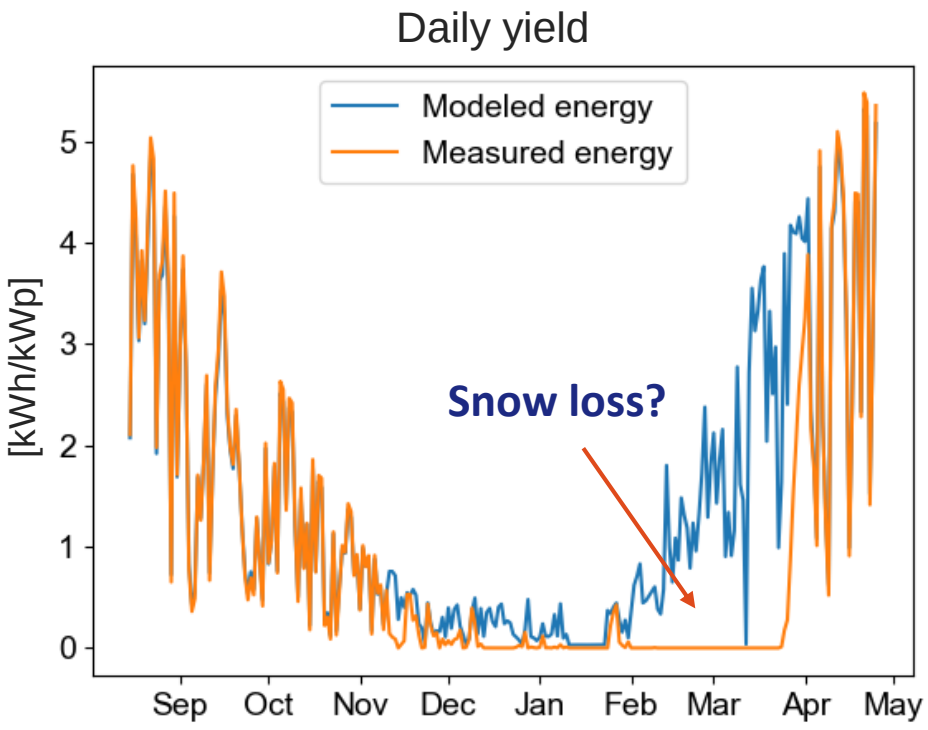


Outline

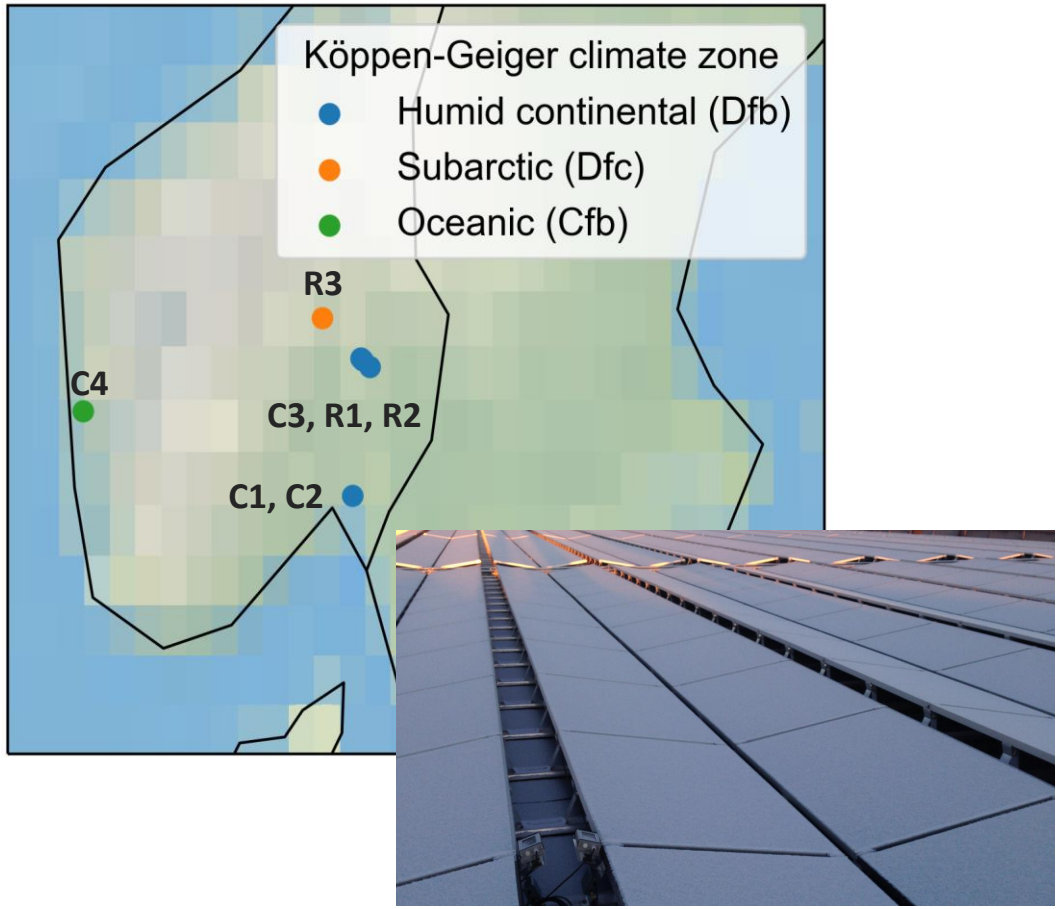
- How is snow loss considered in Norway today?
- Snow loss quantification
- Snow loss modeling

Snow loss quantification

Snow loss =
modeled energy – measured energy



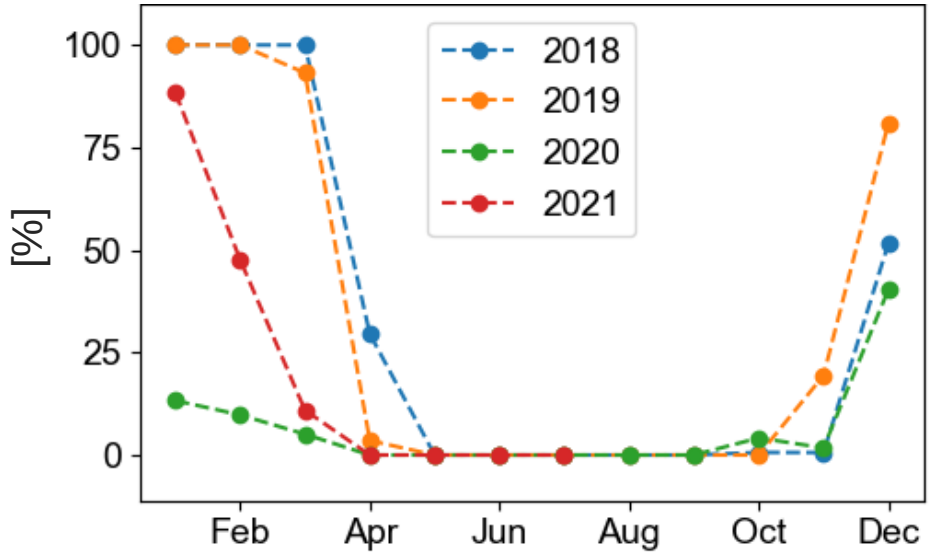
Dataset: 4 commercial and
3 residential installations



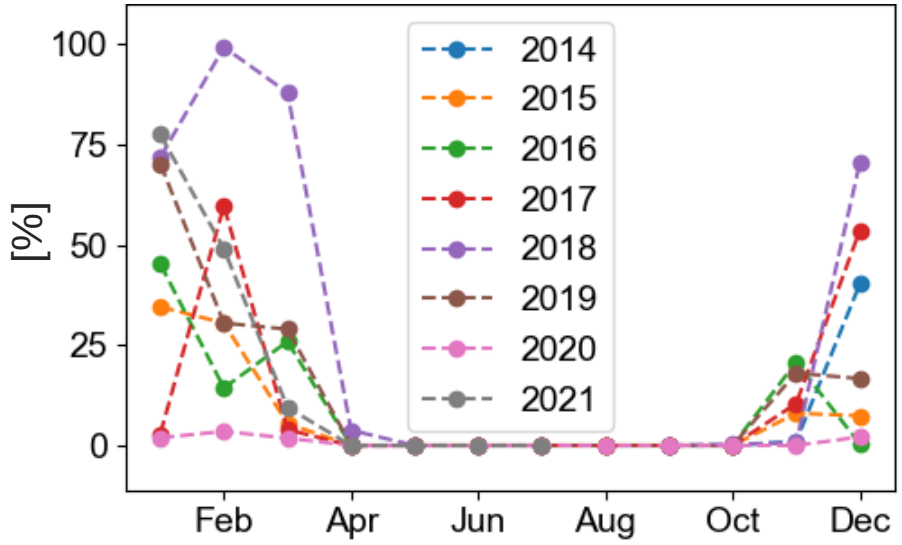
Weather impact:
regional and inter/intra-annual variation

Monthly snow loss, flat roof systems

Central, inland (C3)

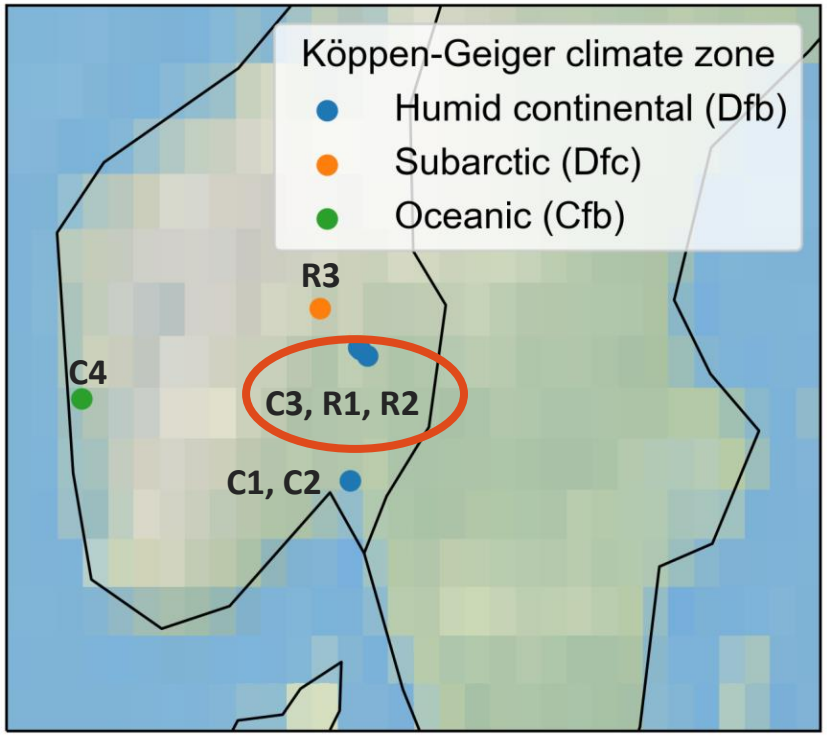


Oslofjord area (C1)

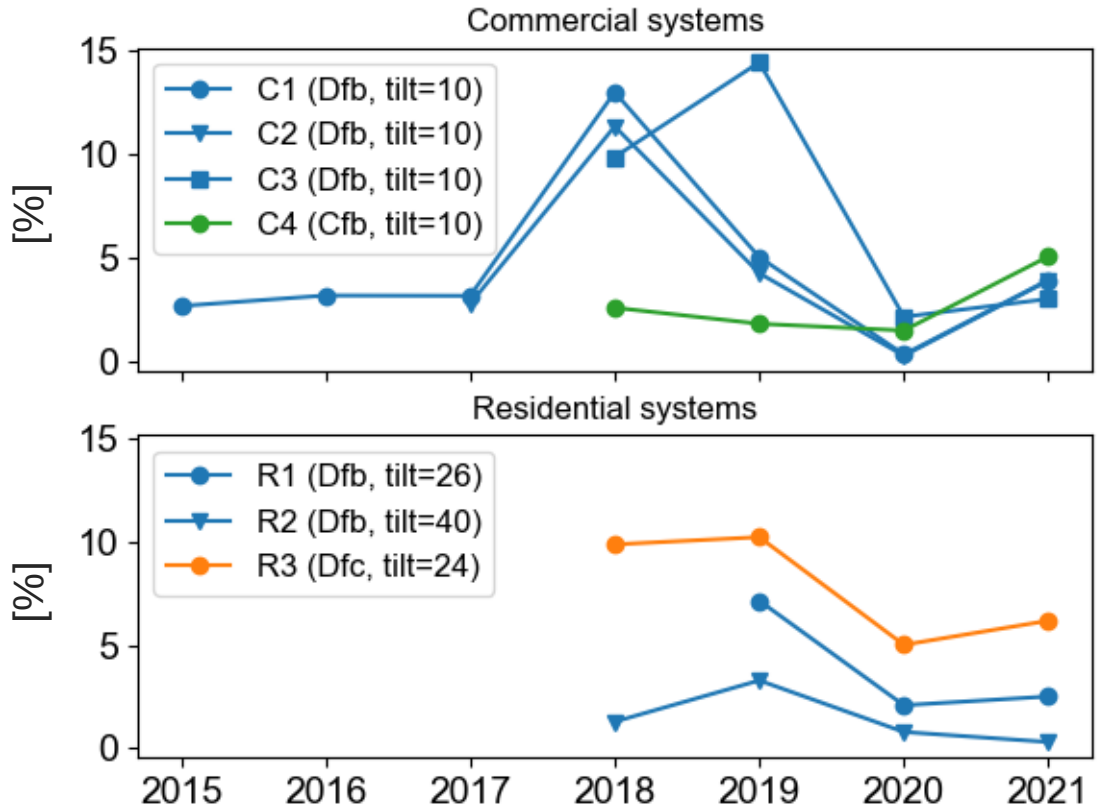


Weather impact: regional and inter/intra-annual variation

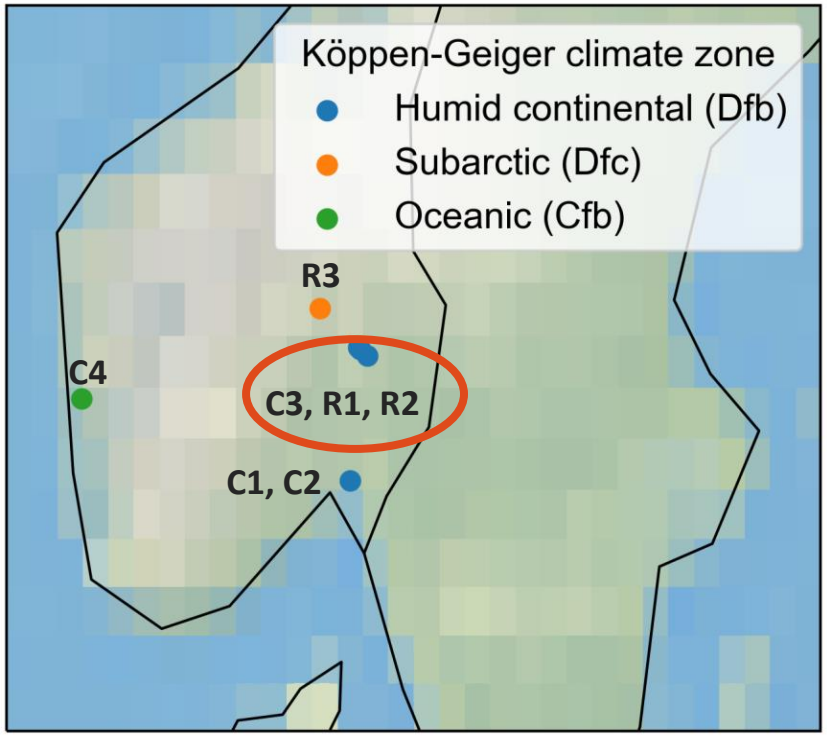
Oceanic climate: lower losses
Subarctic climate: higher losses

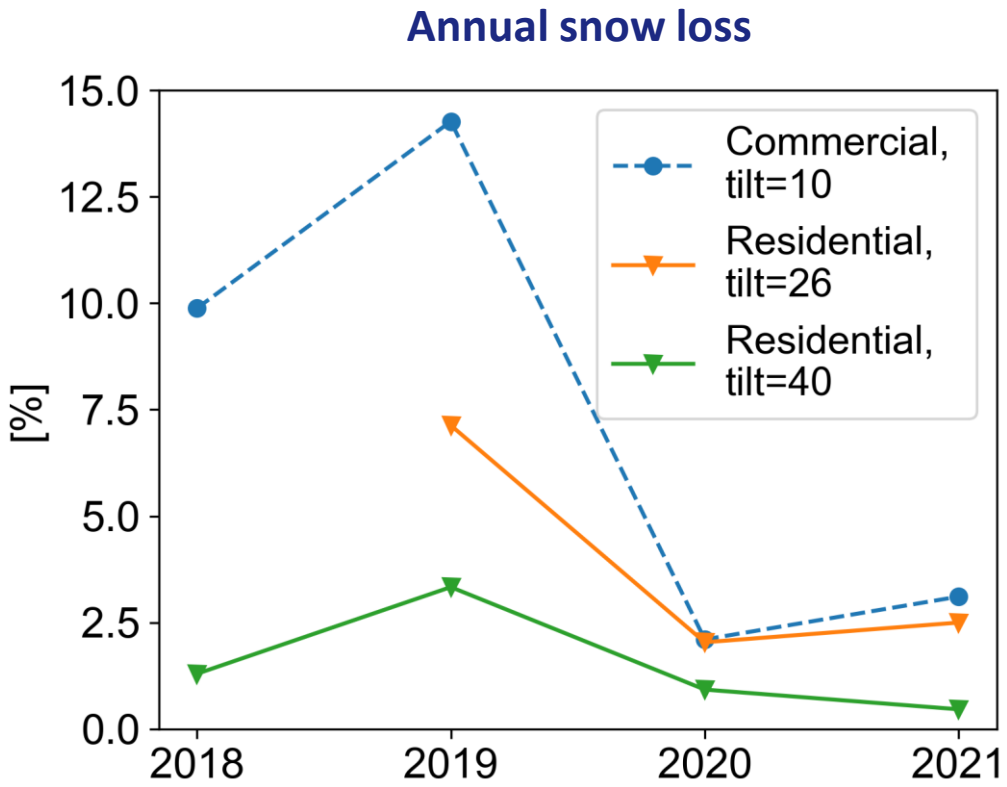


Annual snow loss



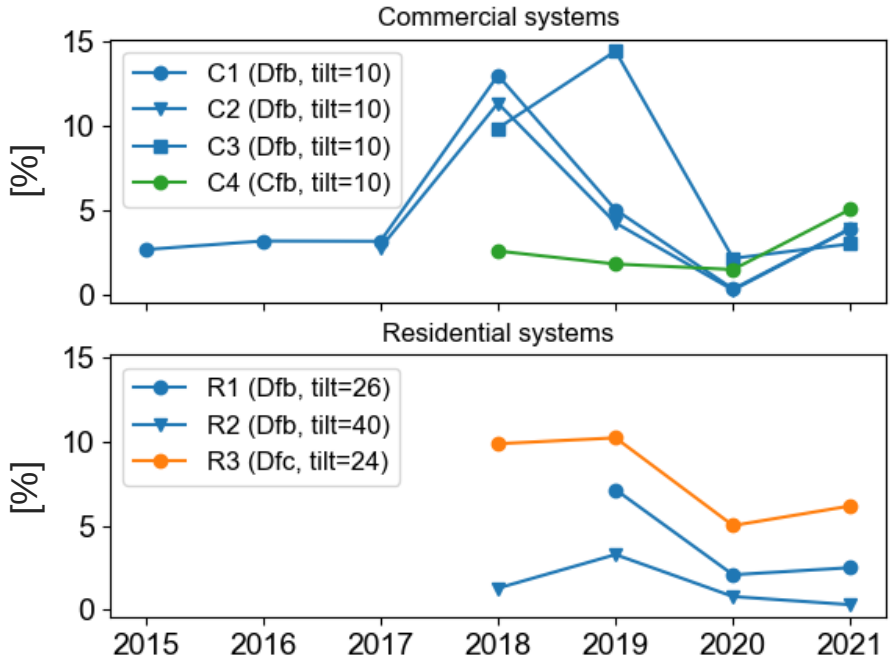
Installation impact: variation between systems in same area





Snow loss quantification – lessons learned

Annual snow loss



0-15% annual snow loss for studied systems

Impact of weather & installation-specific parameters → Large variations in losses

Historical data not enough to predict losses for a specific system in a given location.
Need modeling!

Outline

- How is snow loss considered in Norway today?
- Snow loss quantification
- Snow loss modeling

Snow loss modeling

Goal: “Good enough” snow loss estimation

Initial testing of snow loss models [1]:

Most promising results with NREL/Marion-model [2]

- Easy to modify!
- Suitable for daily/hourly snow loss-predictions!

[1] Øgaard et al., *Identifying snow in photovoltaic monitoring data for improved snow loss modeling and snow detection*, Solar Energy, 2021
[2] Marion et al., *Measured and modeled photovoltaic system energy losses from snow for Colorado and Wisconsin locations,* Solar Energy, 2013

NREL/Marion-snow loss model

Snow melting?

Temperature ↑, irradiance ↑

$Temp_{\ ambient} > \frac{Irradiance_{\ plane\ of\ array}}{m}$,

m = - 80 W/(m2 C)

How fast? ← Tilt, empirical coefficient

$Snow\ clearing\ amount = snow\ clearing\ coefficient\ * \sin(module\ tilt)$

Snow loss modeling

Goal: “Good enough” snow loss estimation

Initial testing of snow loss models [1]:

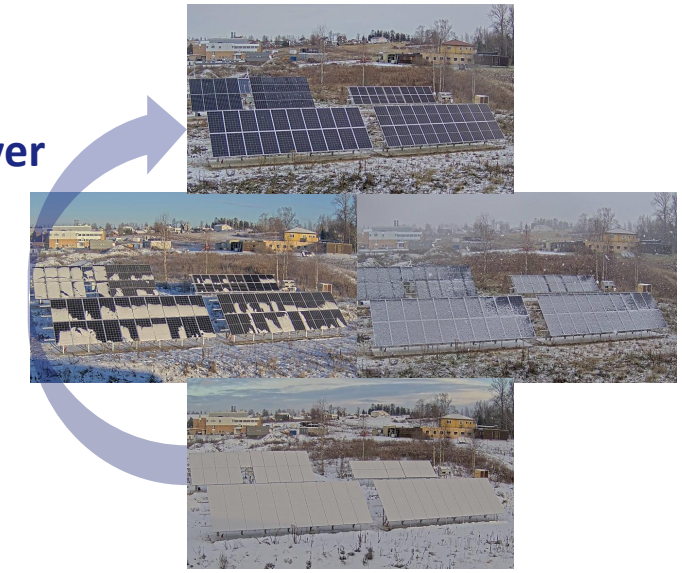
Most promising results with NREL/Marion-model [2]
- also suitable for daily/hourly snow loss-predictions!

For tested roof systems
Original coefficients: predicted too fast snow clearing during thick snow covers

Tested simple solution to solve this
Fitted two sets (thin snow covers/thick snow covers) of empirical parameters + snow > system height = no sliding

Snowfall → Snow cover

Snow melting → Snow clears off



Snow melting? ← Temperature ↑, irradiance ↑
How fast? ← Tilt, empirical coefficient

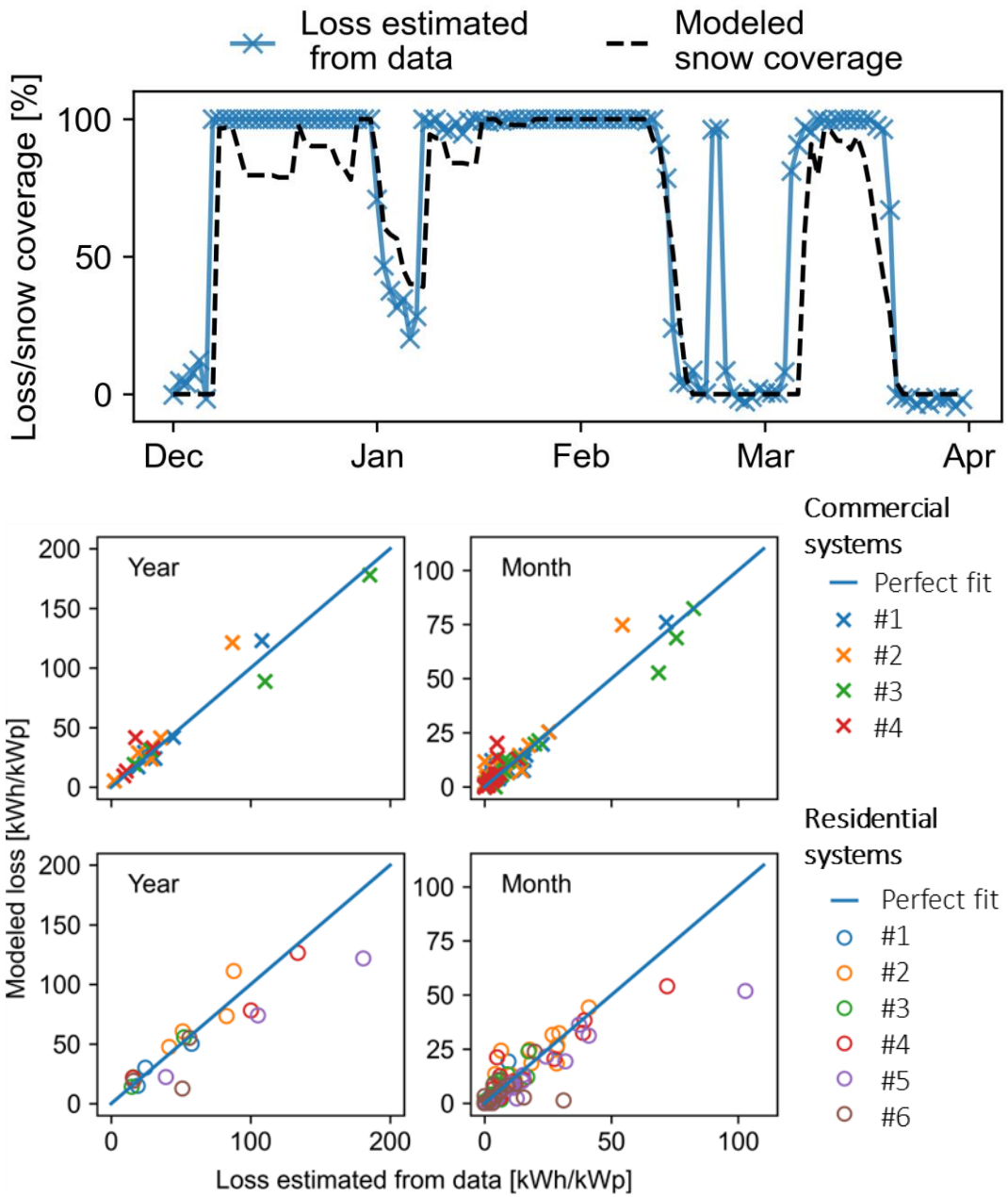
[1] Øgaard et al., *Identifying snow in photovoltaic monitoring data for improved snow loss modeling and snow detection*, Solar Energy, 2021
[2] Marion et al., *Measured and modeled photovoltaic system energy losses from snow for Colorado and Wisconsin locations*, Solar Energy, 2013

Dataset: Commercial + residential systems

- «Identical» system design within the two categories – different weather/snow conditions

  → Same set of empirical parameters should work for all of them!

- *Snow fall data:* modeled data from senorge.no



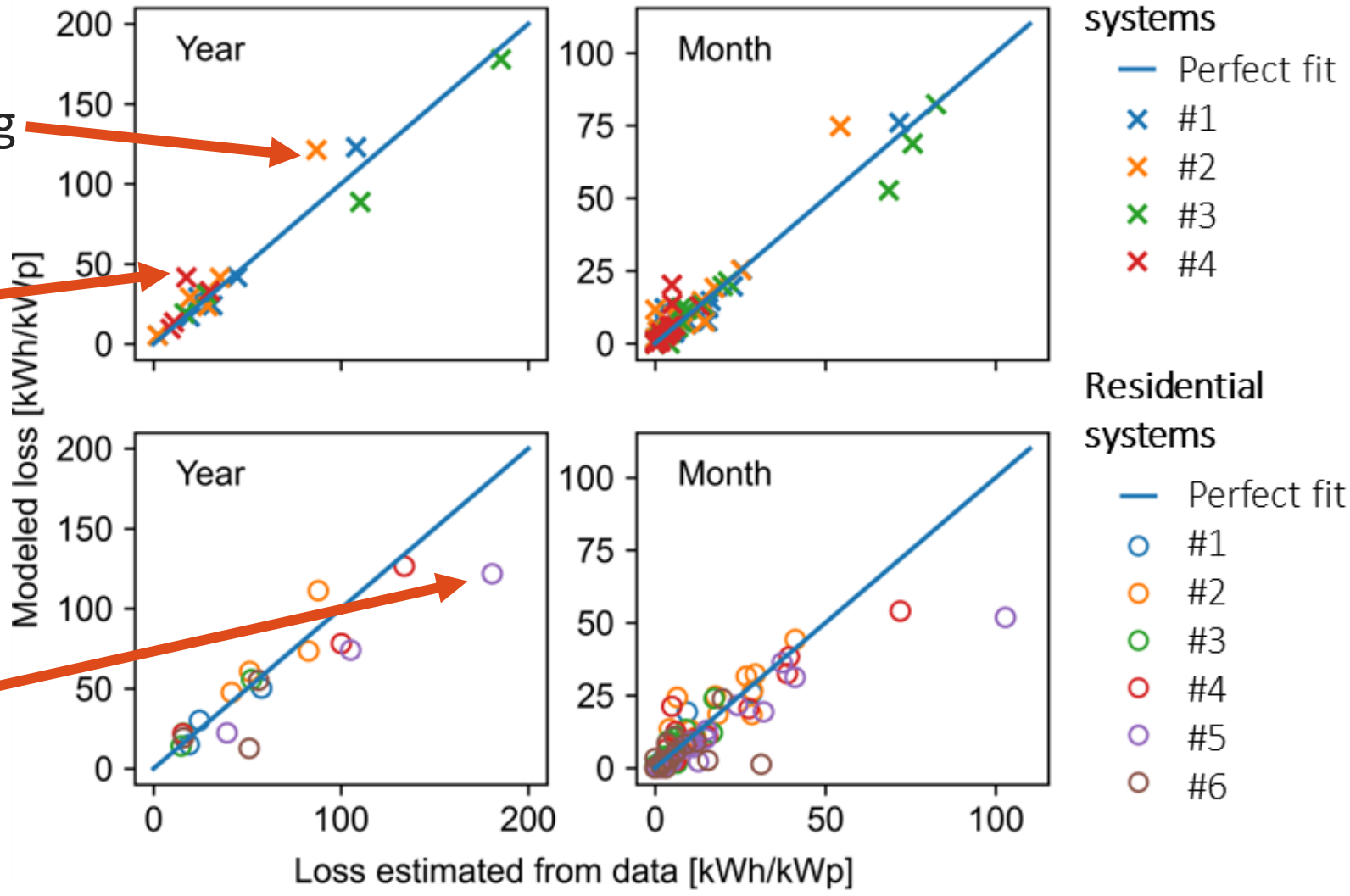
Øgaard et al., *Snow loss modeling for roof mounted photovoltaic systems: Improving the Marion snow loss model*, IEEE JPV, 2022.

High heat leakage from building

Rain/sleet

Larger errors - *effects of snow/weather conditions and system configuration not included in model*

Roof shading



Øgaard et al., *Snow loss modeling for roof mounted photovoltaic systems: Improving the Marion snow loss model*, IEEE JPV, 2022.

Snow loss modeling: lessons learned

- Good enough results for rough snow loss estimation!
- Challenges:
  - Around 0°C
    - Snow input data quality
    - Predictions
  - Non-uniformity in snow clearing/accumulation
- Can improve by taking more weather/snow & installation-specific parameters into account

Summary

Loss quantification:

0-15 % annual losses

Impact of weather & installation-specific parameters → Large variations

Modeling:

Good enough for rough estimations

Challenging around 0°C!

Can improve by taking more weather/snow & installation-specific parameters into account

Thank you for your attention!