Snow loads and coatings

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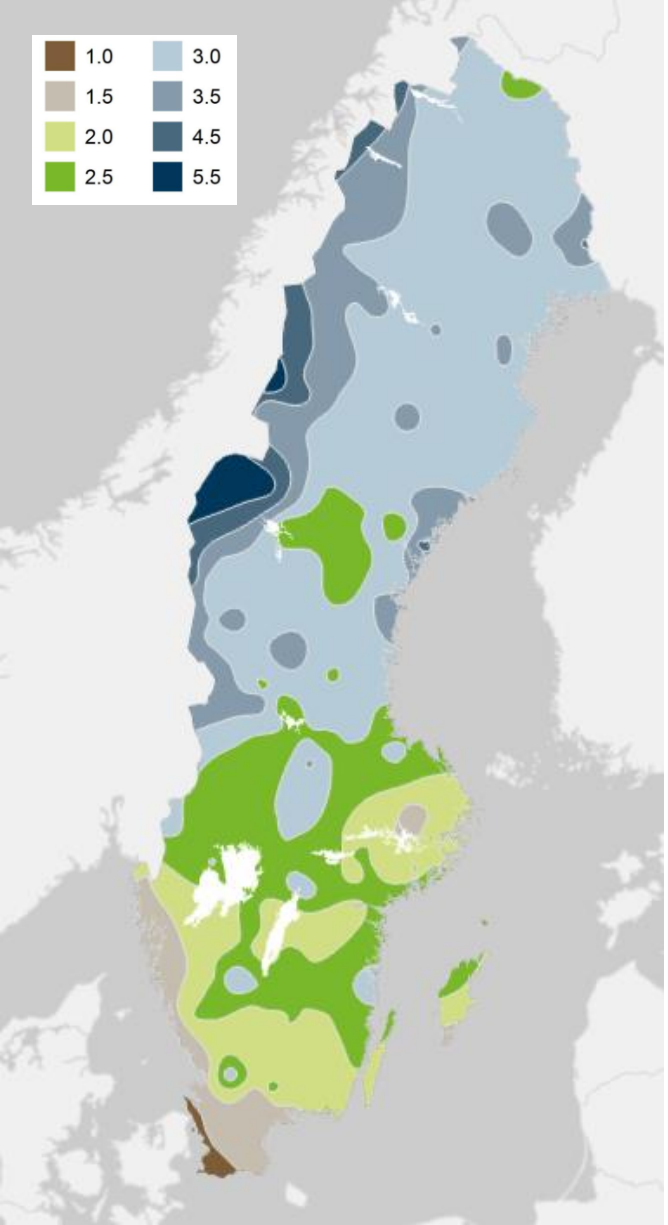

Snow load zones

- 50 year (2% chance) maximum snow load on ground
- Buildings must comply with regulations
- Most of 60 °N area is >3 kN/m^2.
- Build-out of PV is so far *mostly* building (roof) applied PV

- Snow loads can affect 1. Roofs and 2. PV modules

- Reality is quite different from the lab
  - Inhomogenous tests still at 25C and for short durations.

Figure: Boverket, https://gis2.boverket.se/portal/apps/storymaps/stories/d78de3c1b9bb44368b37b18870468658, accessed 2024-03-12

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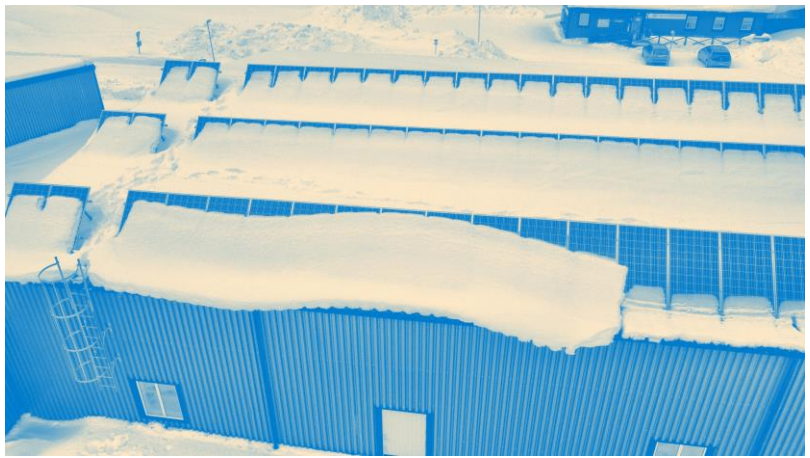
How snow accumulates

We monitored 30 PV plants across different parts of Sweden. Manual measurements, drones, surveillance cameras etc.

Observations from Jukkasjärvi (67 °N) to Borås (57°N).



Why care about snow loads?

1. Snow loads can destroy plants, roofs, and buildings
2. PV may affect the size of the snow loads, their spatial distribution, and how they can be managed
3. Careless installation or management can lead to damage

Manual measurements

- Snow depth and density
  - Ladder and caution
  - Sewage pipe, scale, shovel
  - Drone
  - Own measurements complemented with snow depth data from SMHI

Observed maximum load vs. construction code

- Manual measurement of max load during winters 19/20 & 21/22
- Older construction codes insufficient
- Modern codes: Mean is reasonable but no margin
- Wind, snowfall, and exposure gives the high numbers!
- Snow is often removed from roofs at high latitudes, but how to do it with PV modules in the way?

Conclusion: Older buildings with PV may see snow loads that exceed the construction codes – also without PV!

Modern codes are better.

Id.	Snow load zone [kN/m²]	Build year	Snow load [kN/m²]	Diff. Dim [%]	Diff. EKS11 [%]
Luleå 1	3	1995	1,45	-51	-52
Luleå 2	3	2008	2,32	-3	-9
Piteå 1*	3	1989–2003	2,06	3	-29
Piteå 2	3	2017	2,58	1	1
Piteå 3	3	2014	0,83	-65	-73
Piteå 4*	3	40-tal	1,46	4	-39
Umeå 1	3	efter 2006	1,24	-59	-59
Umeå 2	3	2014	2,58	8	-21
Umeå 3	3	1959	1,57	5	-35
Umeå 4a	3	2000	3,85	28	24
Umeå 4b	3	1971	2,47	70	-3
Östersund 1	2,5	Okänt	1,81	-	-17

* Difficult to establish construction code.

Visit in the county of Västerbotten after a snow storm

- Back side looks ok – nice weather as well!
- Open agricultural landscape, strong winds and heavy snow fall in February 2021.

Front side

- About two meters of snow on the roof and modules
- Wind transported and affected snow – high density. ~3,9 kN/m^2
- Old house turned into office…
- Snow must be removed!

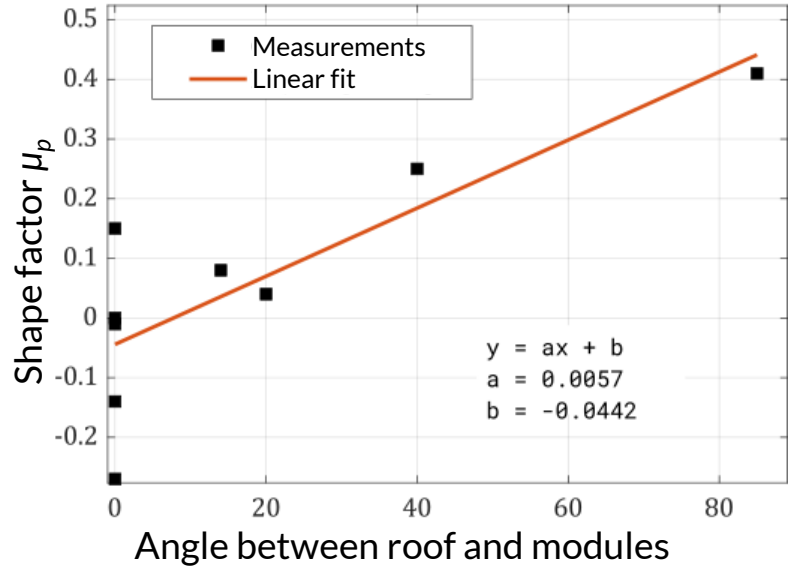
Additional snow load with tilted modules

Distinct trend:

- Higher tilt gives more accumulated snow on the roofs.
- Roof parallell gives lower loads?
- Snow load (*s*) was translated to a roof shape factor addition (μ_p) to exclude factors such as roof tilt and snow depth, see graph ->

$$s = (\mu_i + \mu_p) \cdot C_e \cdot C_t \cdot s_k$$

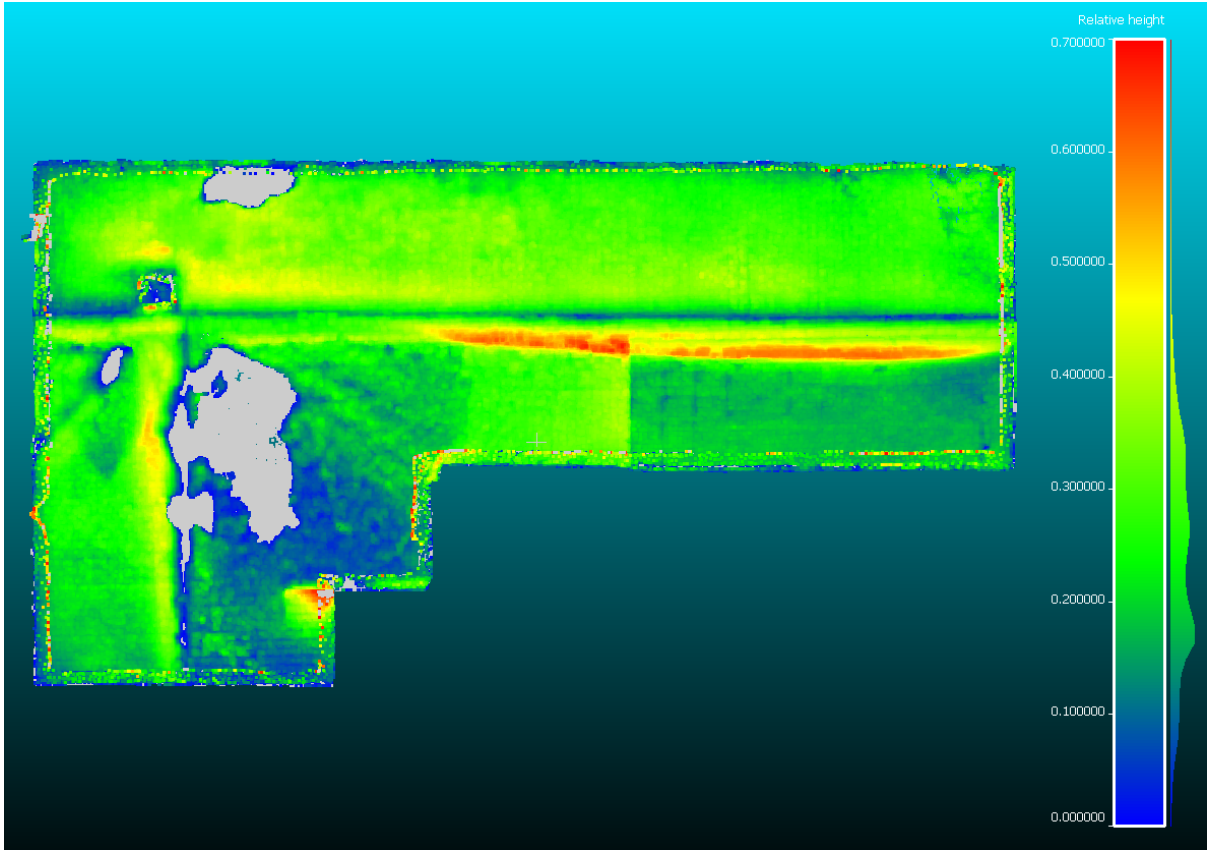
$$\mu_p = \frac{d}{C_e \cdot C_t \cdot d_{ground}} - \mu_i$$



Snow distribution on complex roofs

- Snow loads vary across the roofs
- Measurement position determines the outcome..
- Requires a better method than manual snow measurements.

Photogrammetry – Inhomogenous snow distribution



Snow loads on modules in-field

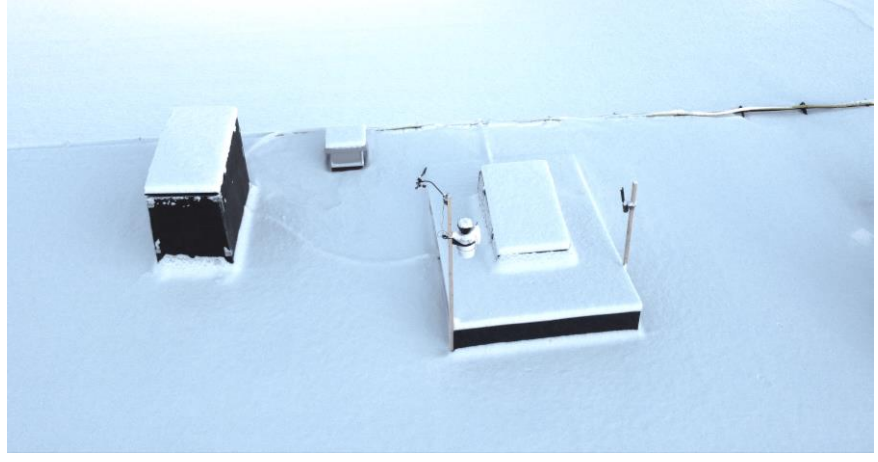
Measured loads and deflection of modules in the field (Piteå)

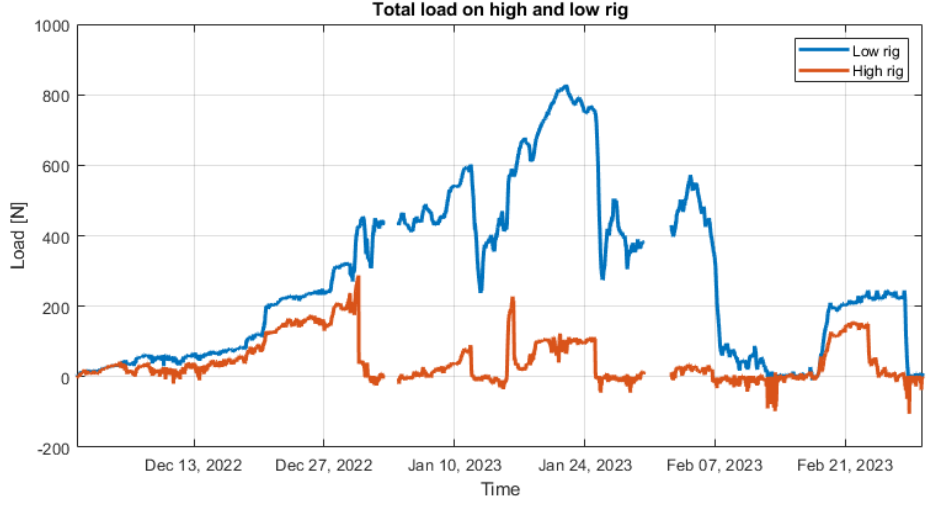
- Two cases

- High: rig collects less snow
- Low: Ground interference for low rig
- Low: Higher loads for extended period

Also measured distribution

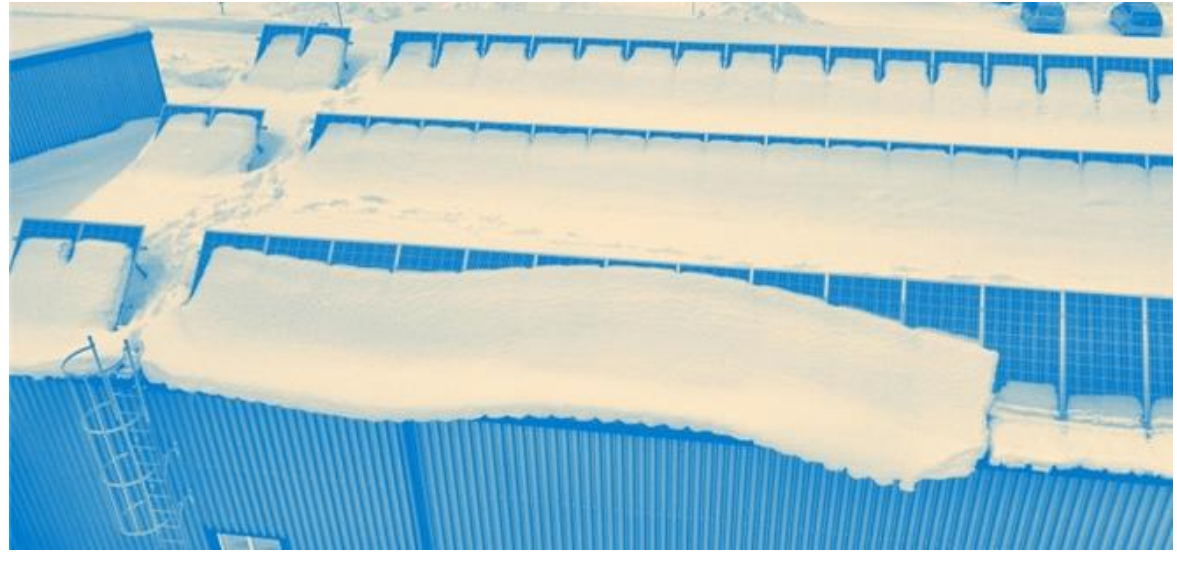
- Lower part: higher loads
- Low: More pronounced and distinct differences within module





Snow load conclusions

- Tilted modules on flat or low pitch roofs:
  - Collect more snow on roof
  - Snow sliding is hindered by ground interference
  - Higher loads in lower part of modules
- Old buildings in northern Sweden appear to be weak compared to maximum snowload they actually see.
- Roof parallell systems can collect *less* snow but it depends on exposure and surroundings.
- Complex roofs are hard to predict and snow distribution can be very inhomogeneous – method!
- **Plan for snow removal when installing PV if the roof will require it!**



! Tilted modules on low pitch roofs of old buildings could be a risk construction !

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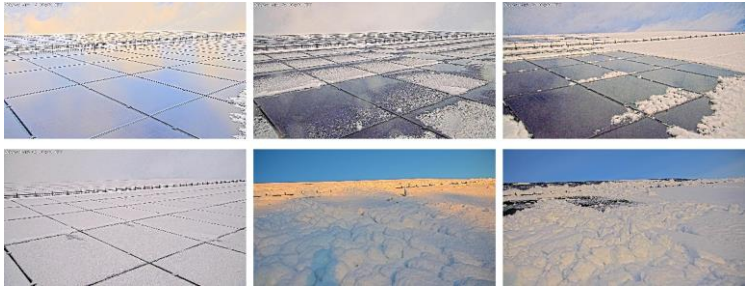
Can snow shading really be that bad?

Lindbäcks Bygg (Haraholmen, Piteå)

Argument for snow phobic coatings

The influence of icephobic nanomaterial coatings on solar cell panels at high latitudes
Solar Energy. Vol. 248, 2022.
https://doi.org/10.1016/j.solener.2022.11.005.



Facilitating Large-Scale Snow Shedding from In-Field Solar Arrays using Icephobic Surfaces with Low-Interfacial Toughness
Adv.Mat.Tech., 2021.
https://doi.org/10.1002/admt.202101032

- Snow losses can be substantial!
- Passive and automatic method

Figures: from cited papers.

Issues and requirements for snowphobic coatings

1. Effectiveness

2. Durability

3. Transmittance
   - Coating itself
   - Dirt accumulation

4. Environmental friendliness –
   (no F, no micro plastics, solvents)

5. Ease of application or reapplication

Alaska study

- *Snow coverage was substantially reduced during winter!*
- Differences depending on the type of snow
- Application of coating in field was problematic
- Transmittance changed over time and coating peeled.

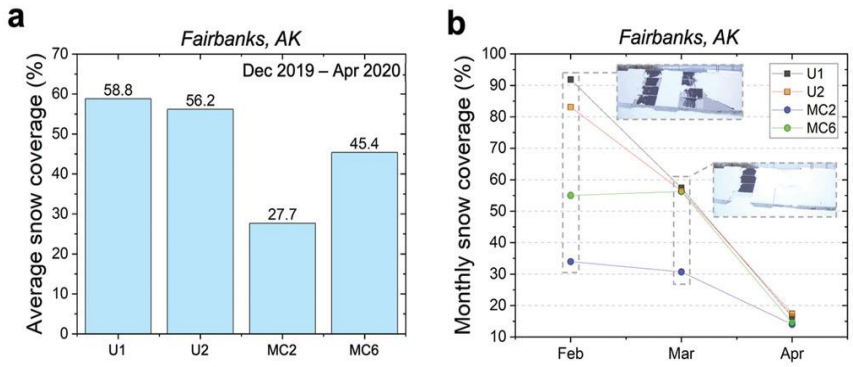
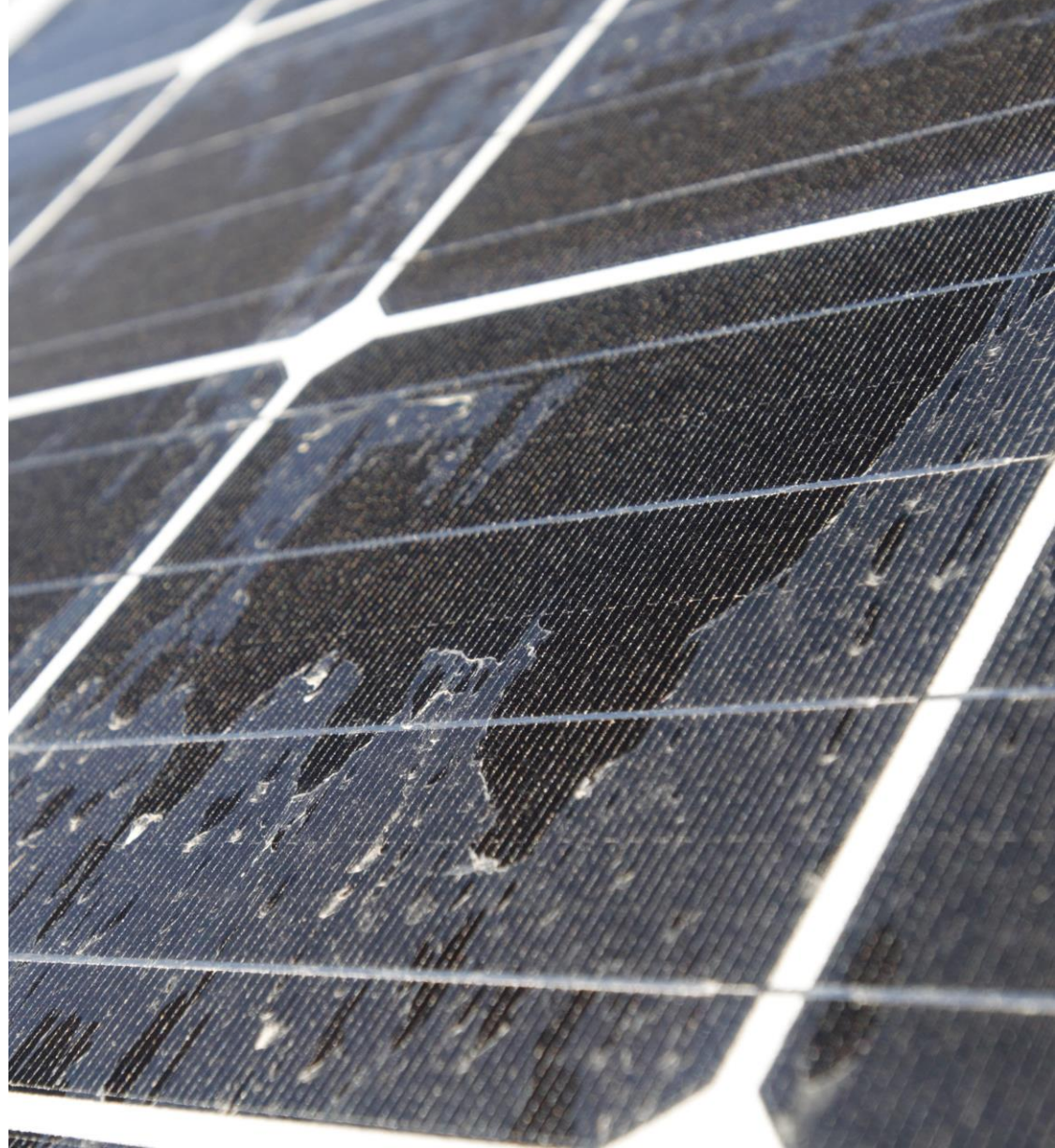
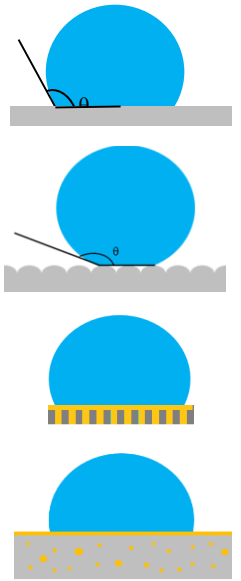


Figure: Dhyani et al. Adv.Mat.Tech., 2021. https://doi.org/10.1002/admt.202101032
Photo: Chris Pike



Swedish ongoing study

Coating	T_{SW} (%)	Contact angle (°)
Bare glass	89,7	ca. 10
AR reference	93,3	34 ± 4
Hydrophobic (smooth)	93,6	105 ± 1
Superhydrophobic (rough)	91,2	160 ± 2
SLIPS (with lubricant)	92,8	105 ± 2
Elastomer (with lubricant)	89,8	106 ± 1



Commercial coatings don't appear to work very well.

Develop state-of-the-art coatings featuring different promising technologies.

Ultra-low adhesion vs. interfacial fracture

Ice adhesion < x100 compared to bare glass in lab.

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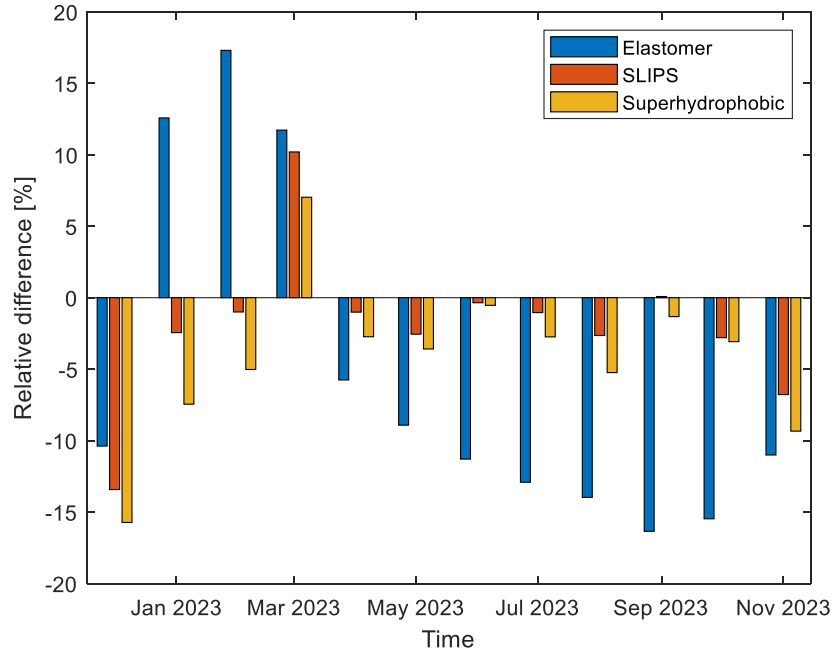
Some results from Swedish study

Coating id.	Annual transmittance
Elastomer	-9.3%
SLIPS	-0.8%
Superhydrophobic	-2.2%

- Small samples
- Snow season Dec-Apr, max snowdepth 2022-2023 was 85 cm. Temperature span about 60 ˚C.
- 0˚, 10˚, and 25˚tilt + in-field transmittance
- Big difference between lab and field!
- Long-term transmittance is paramount.



Coating conclusion

- Snow is variable – feasibility with one coating to rule them all?
- Lab is different from the field!
- Transmittance, durability and effectiveness all needs to be improved.
- Coatings have great potential
- Simple but hard problem to solve!

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- Snowloads are not seldom large compared to construction codes in northern Sweden
- Increased module tilt gives higher loads on the roofs
- Ground interference affects snow loads and yield
- Need to *plan* for snow removal when installing (rooftop) PV!

- Snow- and ice repellent coatings is an attractive solution to snow shading (and load) – not ready but industry seem interested.
- Transmittance, durability, effectiveness and environmental improvements needed!

Thank you!

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