Lessons learned from solar measurements in the Nordics

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Why on-site measurements?

- More accurate power production estimate
  → stronger foundation for investment decisions

- Satellite imagery methods yield higher uncertainty at:
  - Higher latitudes
  - Very snowy areas
  - Very cloudy areas

- Need measurements for performance monitoring in the production phase anyway

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Challenges in the Nordics

- Cold winter climate and snow
  - Added uncertainty due to snow and rime on sensors
  - High power consumption due to heated sensors
  - Comprehensive groundwork due to frost in ground
- High latitude
  - Shadow – relative sensor placement
  - Low potential for power production for off-grid stations during winter
- Often remote locations
  - Require off-grid power solutions
  - High running cost for maintenance/cleaning

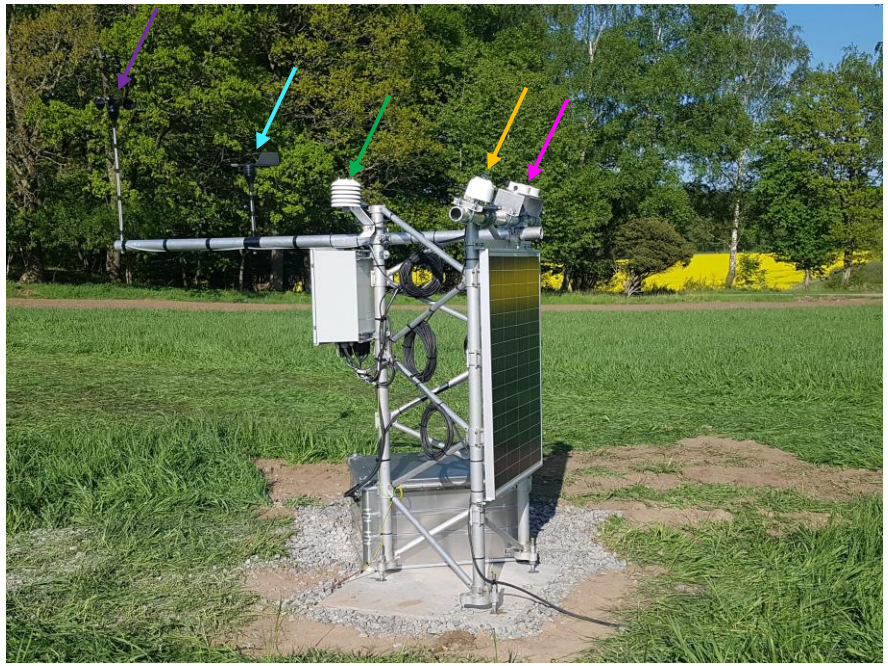
Typical solar measurement station

Measurements - sensors

- GHI
- GTI
- Albedo
- PV temp
- Ambient temp
- Wind speed
- Wind direction
- Soiling
- Rain
- Snow
- Humidity

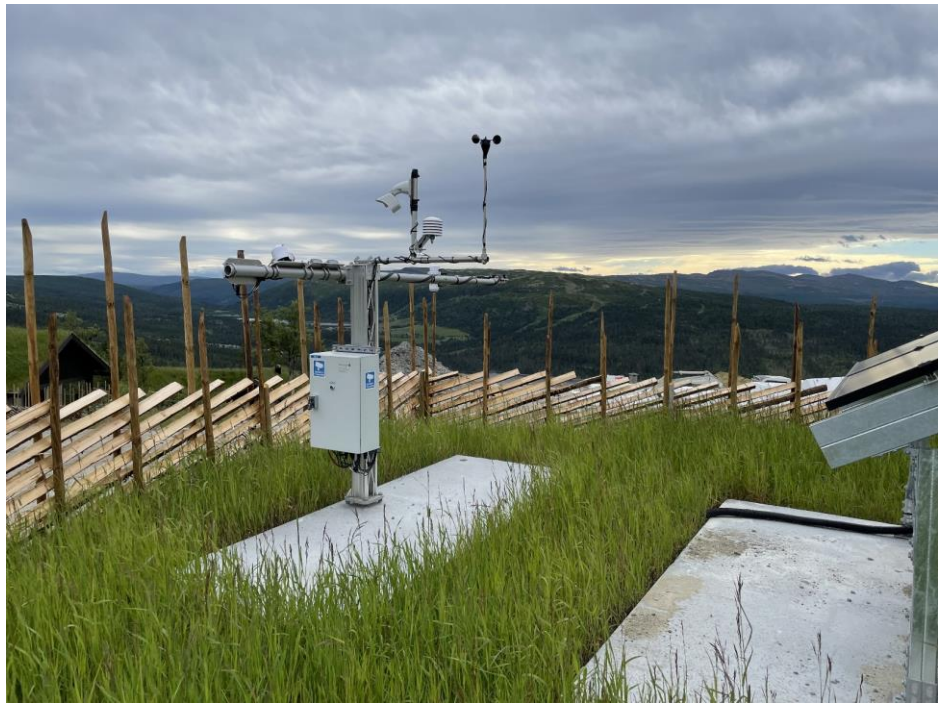
Other considerations

- Need for ventilators?
- Power availability
- Foundation – frost, surface
- Sensor placement – shadows, albedo stand, snow depth
- Maintenance
- Web camera – eyes on site



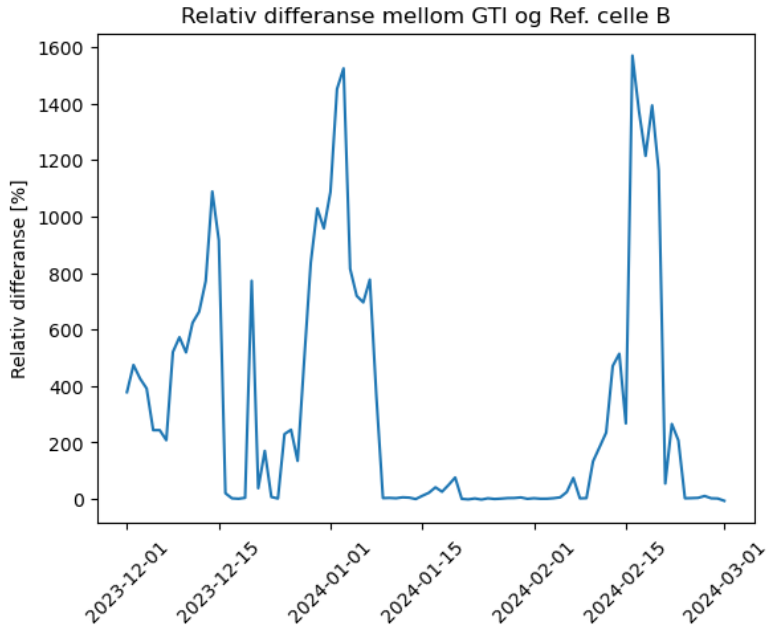
Research project: Test site for solar power in harsh winter climate

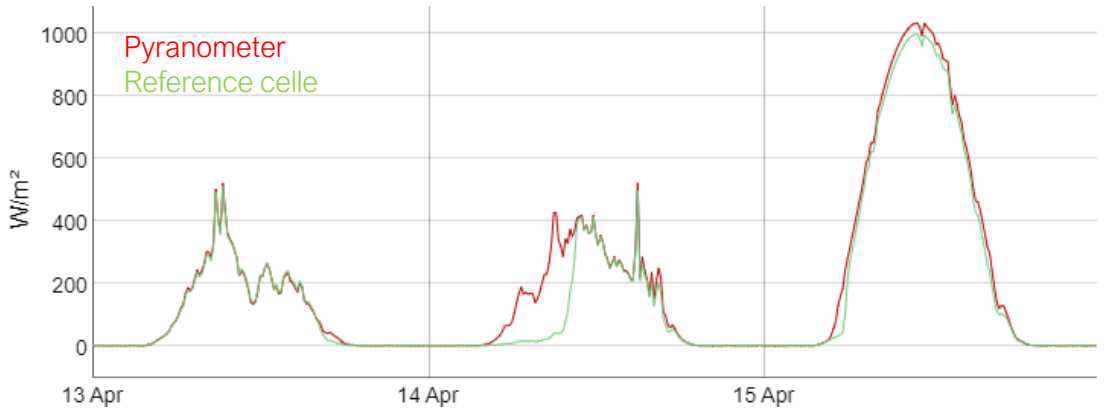
- Gålå ~ 1000 m.a.s.l
- Bifacial and monofacial PV modules, different orientation
- «Typical» solar station installed.
  - External ventilators on all 4 pyranometers.
  - Web camera for eyes on site



Pyranometer data: Ventilators work!

- Effective snow remover
- Ensures good quality irradiance data with reduced uncertainty.
- Relative difference between ref B and GTI – 325%
- 4 x 9W requires grid connection





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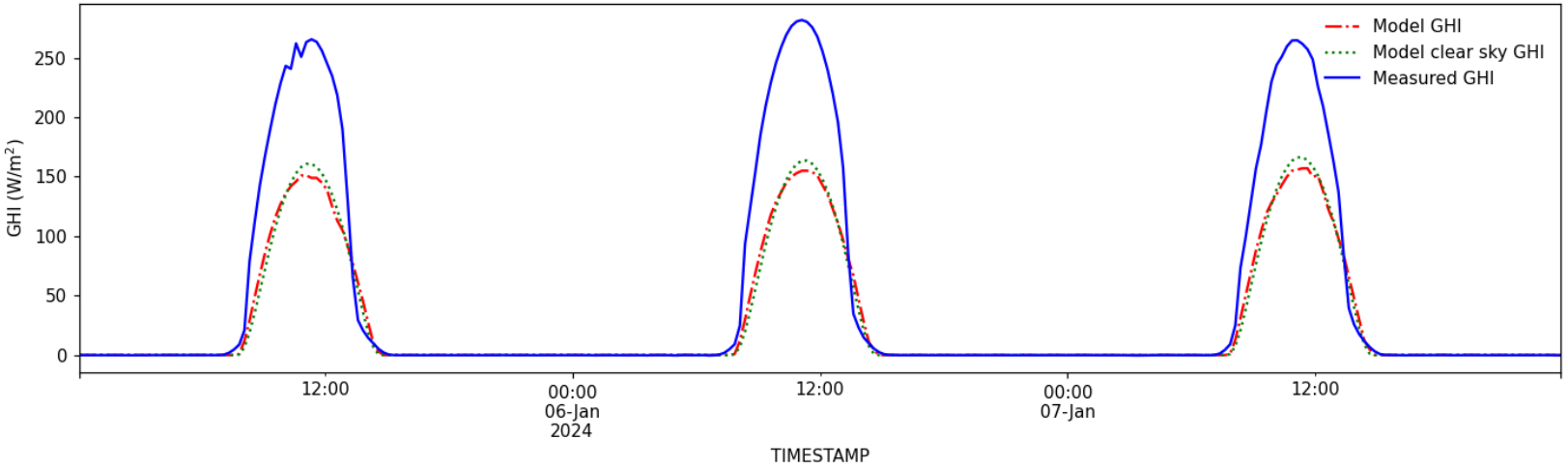
Pyranometer data: What about internal dome heating?

- Only ½ season with data so far
- There seem to be some effect
- Not as effective as external
- Only 1.4W per pyranometer
- Doable for off-grid station

Abnormally high measured irradiance

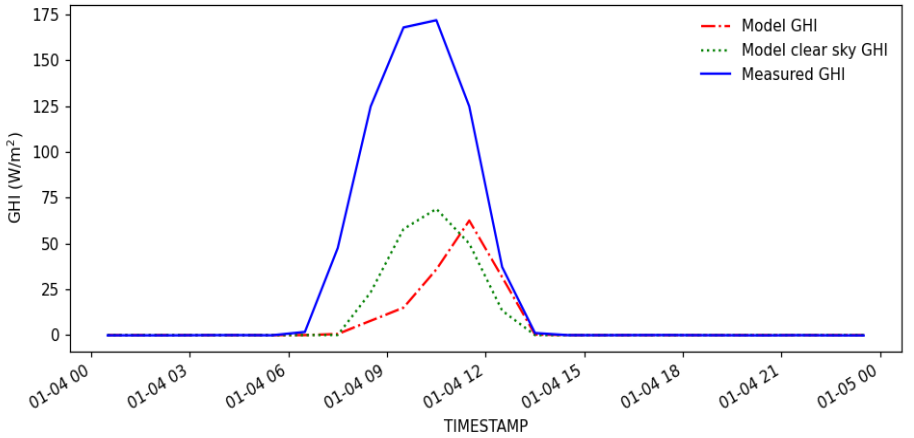


- Some days during the winter, the measured GHI was more than 50% higher than what you would expect. This occurred on 6-15 days at each measurement station.
- The plot shows examples of days with unusually high measured GHI (blue line) compared to satellite-based modelled irradiance (red dashed line) and to simple estimations of clear sky irradiance (green dotted line).

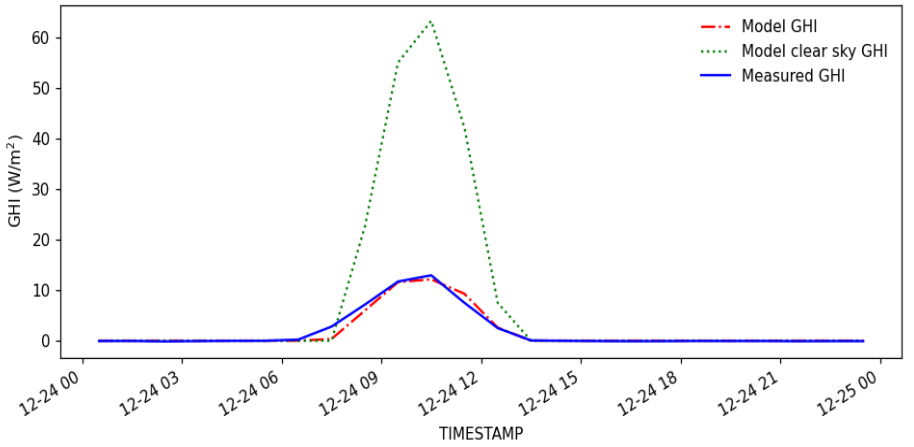
Effect of icing and snow on pyranometers

- Typically, snow would reduce measured irradiance by blocking light, but it also diffuses and reflects light.
- Increased irradiance measurements usually occurs after a warm humid day followed by a cold clear-sky day or days.
- This icing effect was also seen after cleaning due to water from the washcloth freezes

Frost on dome led to higher irradiance



Snow on dome led to measured irradiance equal to modelled irradiance



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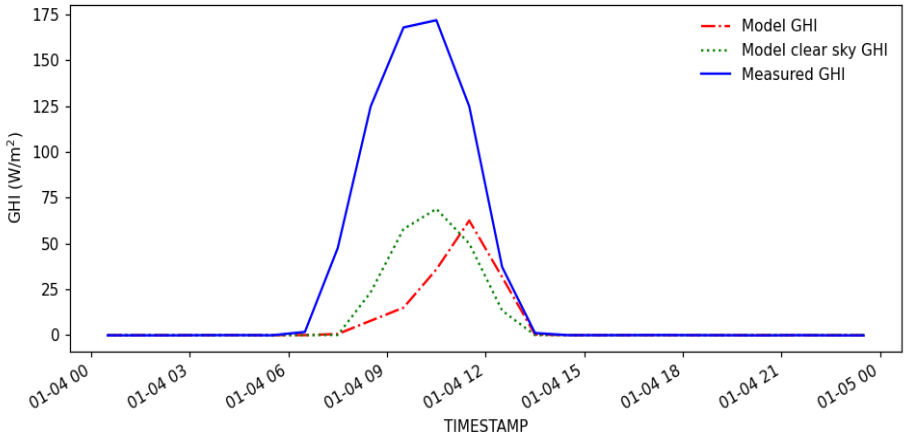
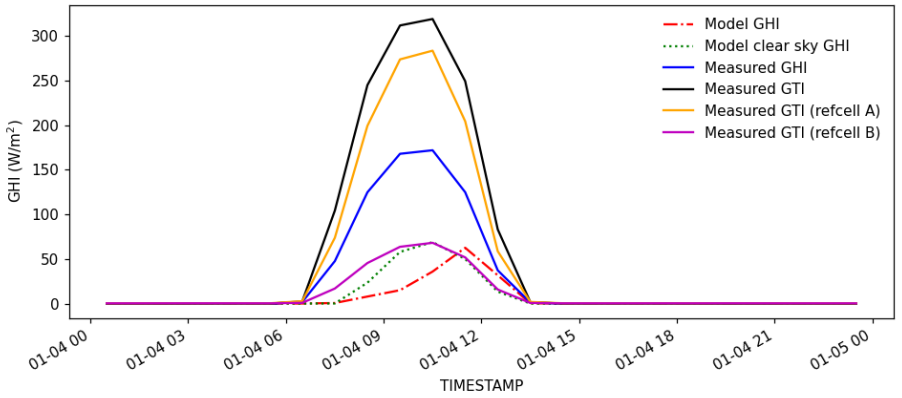
Effect of icing and snow on ref cells

- We do not have modelled GTI data to compare with, but ref cell is relatively close to measured GTI
- Assuming same level of increase on GTI as GHI, ref cell data seem to increase with a thin layer of frost.
- How will this affect a full-size PV panel?

Frost on dome led to higher irradiance

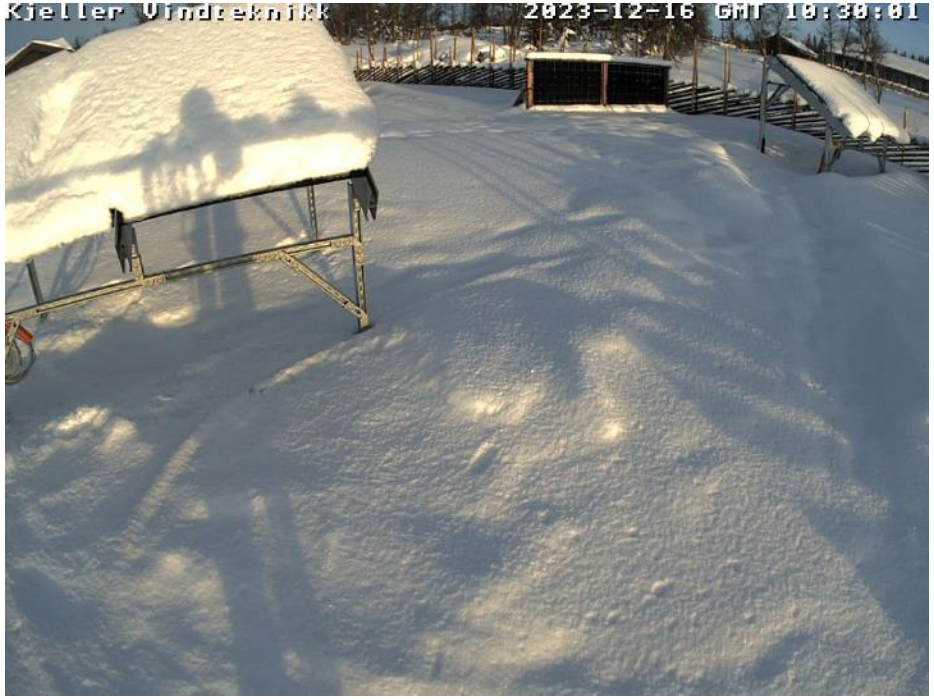


Snow and frost on ref cells



Web camera helps us understand our data

- The camera provides a very useful dataset that helps us understand our data a lot better.
- Captures issues and processes



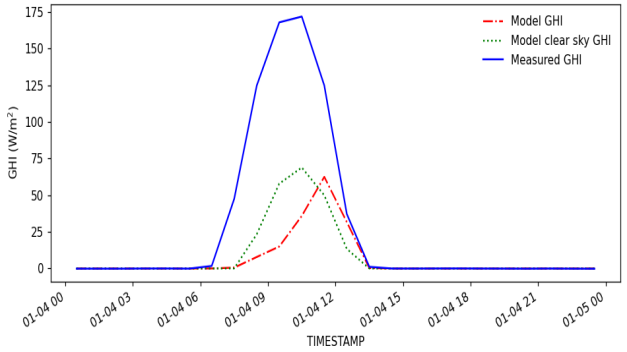
Shadowing

- Can be switched off when not active so doable for off-grid stations
- Can be challenging to place to not cast shadows

Melting

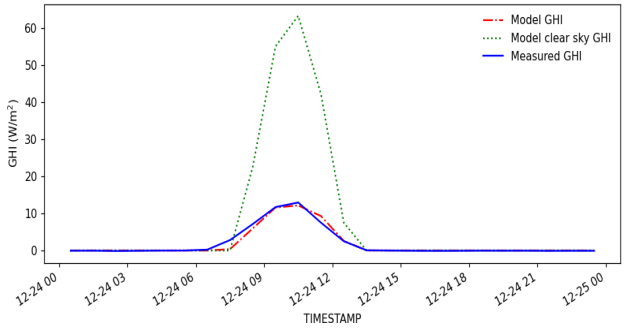
Camera is particularly useful in cold climate

Are our ventilators working properly?



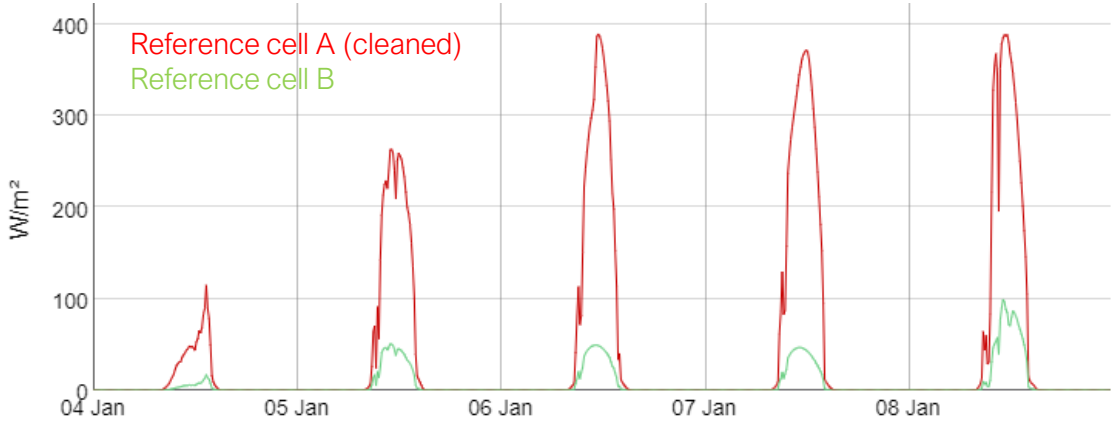
Eyes on the issue helps understand strange measurements?

Is it time for cleaning or maintenance?

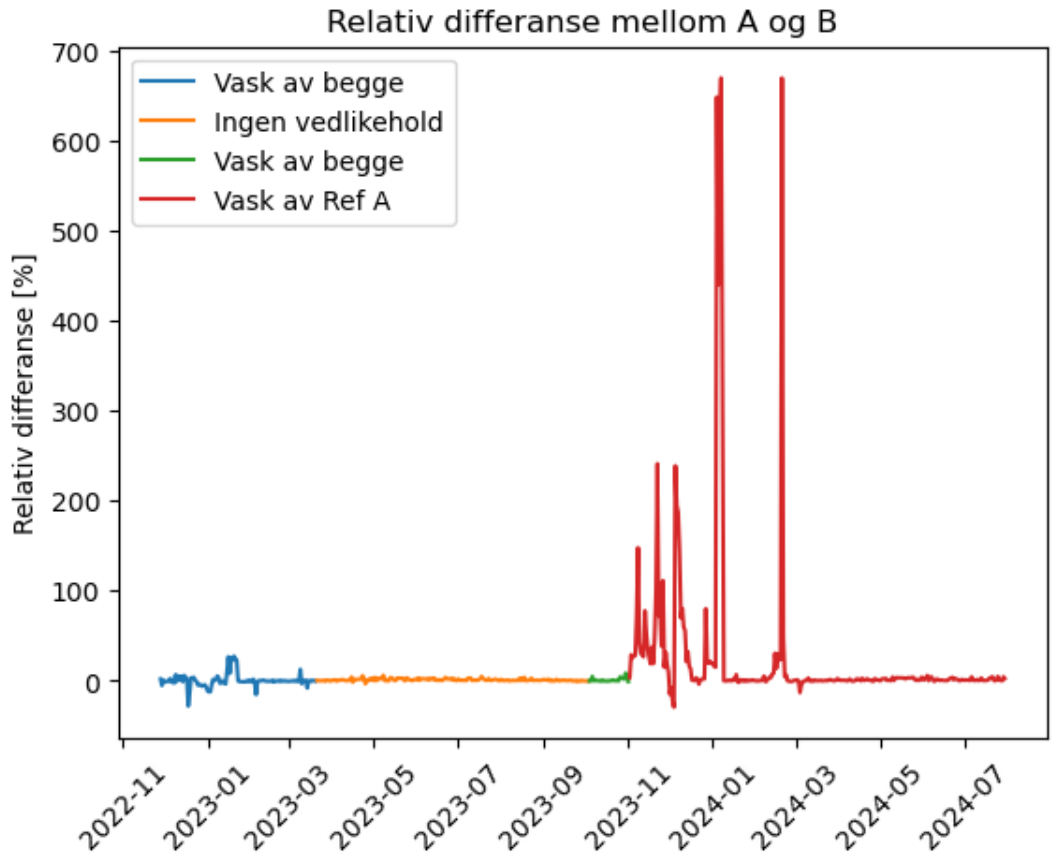


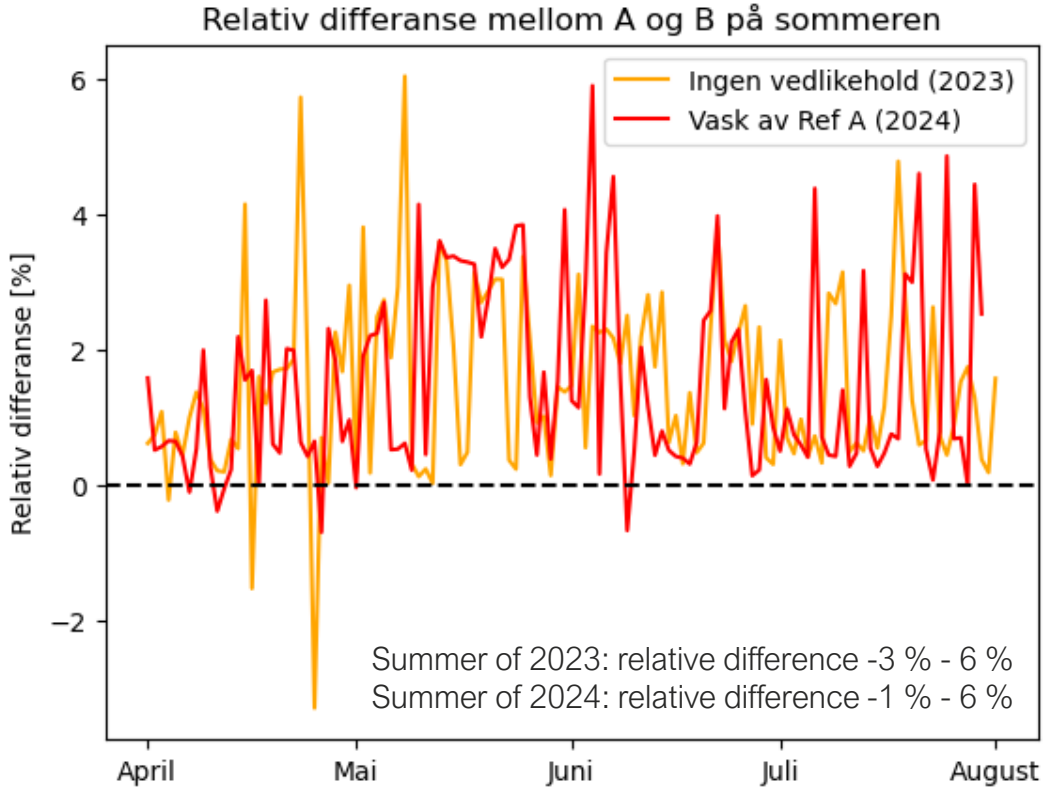
Maintenance

- Solar stations require frequent visits
  - Cleaning pyranometers and ref cells
- Compared irradiation measured by two reference cells
- Reference cell A is cleaned every 2 weeks
- Period: November to February
- 24 % more irradiation when cleaned



Maintenance – cleaning one ref cell





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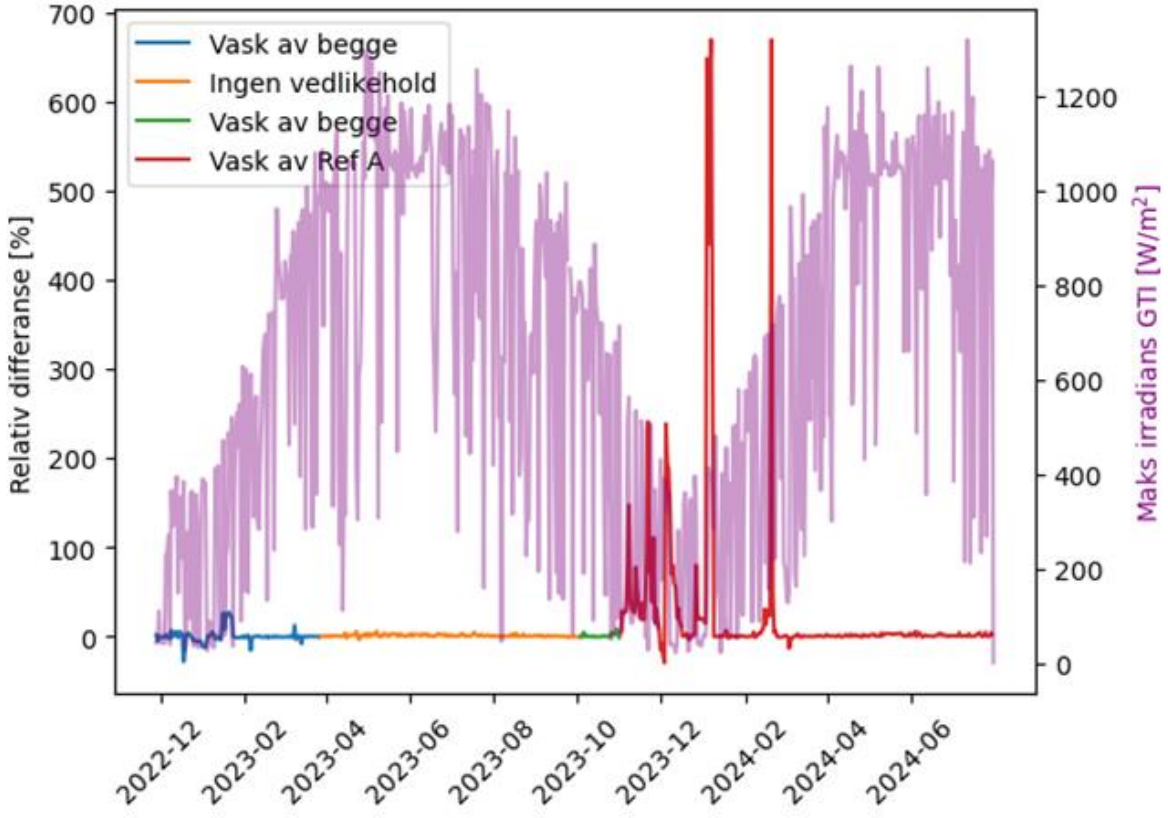

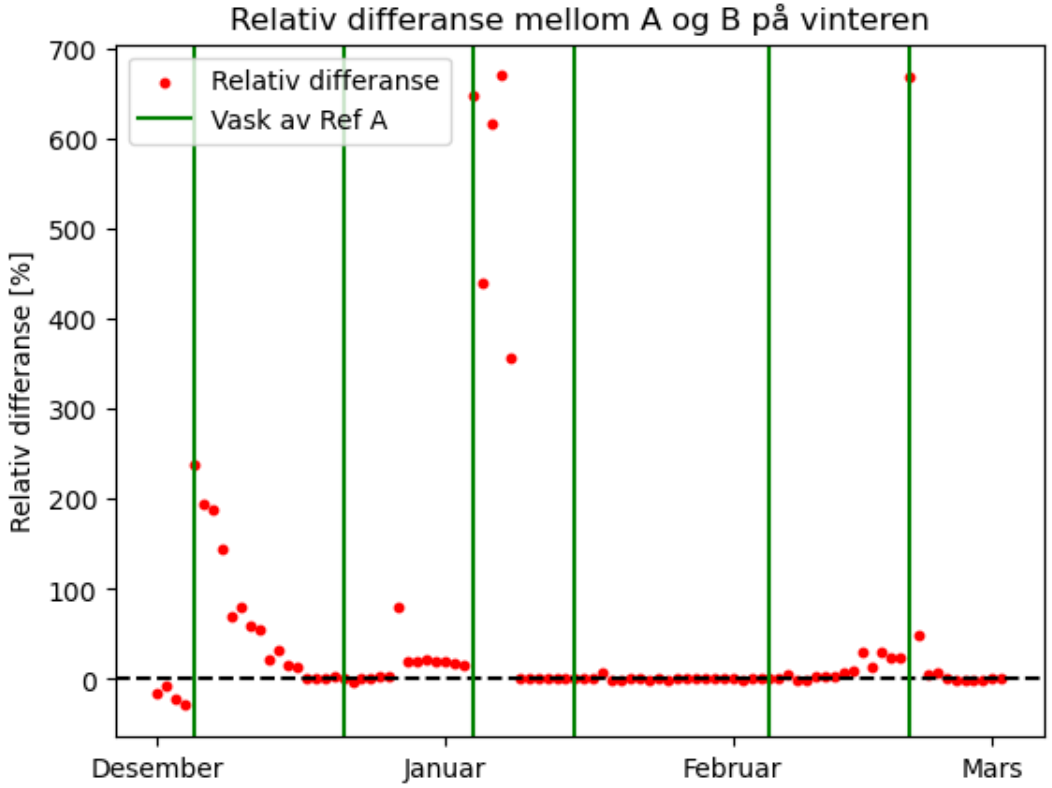

Winter of 2024: relative difference -29 % - 669%
Average relative difference: 53 %

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Summary

- Solar measurements are necessary for investment decisions
- Cold climate adds a few challenges
- Pyranometers with ventilators will give the best data in areas with cold climate, however, it is not always possible in a cost-effective way.
- Un-ventilated pyranometer data sometimes show increased irradiation when there is ice in the dome.
- Web camera on site gives a lot of advantages
  - Quality control of sensors – pyranometers and ref cells
  - More efficient maintenance schedule in winter

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Every day we improve everyday life