**Mathematical Equations used for EnergyMonitor’s physics models**

For resources see references at end of document

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# Intensity Calculator

## Declination

obliquity = 0.4090877234 – 0.000000006981317008 \* dateTime

mean longitude = dateTime \* 0.01720279239 + 4.894967873

mean anomaly = dateTime \* 0.01720197034 + 6.240040768

where dateTime is the julian time since J2000

(Craig, 2021)

declination = asin( sin(obliquity) \* sin(ecliptic longitude) )

(Honsberg & Bowden, n.d.)

## Solar Timings

LSTM (Local Standard Time Meridian)



EoT (Equation of Time) 

Text

Description automatically generated with medium confidence

TC (Time Correction Factor)



LST (Local Solar Time)

A picture containing text, antenna

Description automatically generated

Where LT is the local time at the location and TC is in hours

HRA (Hour Angle)



(Honsberg & Bowden, n.d.)

## Elevation

Elevation = asin( sin(declination) \* sin(latitude) + cos(declination) \* cos(latitude) \* cos(HRA)

(Honsberg & Bowden, n.d.)

## Zenith

Zenith = 90 – elevation

(Honsberg & Bowden, n.d.)

## Azimuth

Azimuth = ( -sin(HRA) \* cos(declination) ) / sin(zenith)

If HRA > 0: Azimuth = 360 – abs(Azimuth)

(Honsberg & Bowden, n.d.)

## Airmass

Airmass = abs( 1 / ( cos(zenith) + (earth curvature)^-1.6364

Where earth curvature = 0.50572 \* (96.07995 – zenith)

(Craig, 2021)

## Direct Intensity

Direct intensity = 1.353 \* ( (1-height) \* (airmass multiplier) + a \* height)

Where height is the height in kilometers above sea level

and airmass multiplier = 0.7^temperature where temperature is in kelvin

(Honsberg & Bowden, n.d.)

## Global Intensity

Global intensity = 1.1 \* (direct intensity)

(Honsberg & Bowden, n.d.)

## Limitations

* A global intensity modifier of 10% is a ballpark figure however is dependent on conditions in the surrounding area such as foliage, urban developments, hills, or mountains

# Solar Array Model

## Incident intensity

Incident intensity = (global intensity) \* (temperature coefficient) \* (cloud cover coefficient)

Where the temperature coefficient is the number of the number of degrees over 298k the air temperature is / 100. The cloud cover coefficient is a percentage as to what percentage of the sky has clouds in it.

(Matuszko, 2011), (TheGreenAge, n.d.)

## Module Intensity

Module intensity = (incident intensity) \* ( cos(elevation) \* sin(panel angle) \* cos(panel direction – azimuth) + sin(elevation) \* sin(panel angle) )

Where the panel angle is angle of the solar panel relative to the horizontal and the panel direction is the bearing from due north

(Honsberg & Bowden, n.d.)

## Module Power

Module power = (module intensity) \* (panel area)

Where panel area is the area of photovoltaic panels in m^2

## Limitations

* Efficiency with regards to temperature is mostly decided by the panel temperature as opposed to air temperature, a variable that cannot be calculated or inputted
* Cloud cover is measured as a block value, it does not account for the different layers of cloud cover, all with different modifying factors to incident intensity
* Solar panels in the model have no maximum input power

# References

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