**solar radiation**

* direct normal irradiance (DNI): part of NEN, plane perpendicular to solar beam (ideal tracking)
* direct horizontal irradiance: irradiance on a horizontal plane , with

h = solar altitude (with correction for parallax and refraction)

* diffuse horizontal irradiance: diffuse light on horizontal plane (diffuse by atmosphere, measured at ground level)
* global horizontal irradiance: direct horizontal + diffuse horizontal
* ground reflected irradiance: diffuse radiation reflected from the ground surface, fraction of the global horizontal irradiance
* global irradiance on surface: sum of direct, diffuse and reflected diffuse

What is measured by the weather stations? direct horizontal

In NEN:

globale zonnestraling: gemeten? Ja, de Bilt globale zoninstraling (op horizontaal vlak?)

diffuse zonnestraling: afgeleid? (diffuus + direct = globaal)

directe zonnestraling: afgeleid? (diffuus + direct = globaal)

directe normale zonnestraling: gemeten/theoretisch/afgeleid? niet gemeten

NEN 5060 pag 10 noemt methode om maandoverrgangen glad te trekken: NEN-EN-ISO 15927-4

**direct insolation on an inclined surface**

I\_direct\_surface = cos(theta) \* I\_direct\_normal

I\_direct\_surface = cos(theta)/sin(h) \* I\_horizontal

cos(theta) = max(0, sin(h)\*cos(beta)+cos(h)\*sin(beta)\*cos(A-gamma)

h: solar altitude

A: solar azimuth (what definition north= 0 or south = 0)

beta: inclination of surface (zero = horizontal)

gamma: azimuth surface (south = 0, east -90, west = 90)

theta= angle between surface normal and direction of sun

<https://github.com/pvedu/photovoltaic> contains a library of python functions used in photovoltaics

**PV-panel**

**temp pv:** vgl. 3.5.1 (Dictaat Marc) dependent windspeed and global insolation on panel = direct +diffuse + reflected

A linear dependency of the efficiency on the cell temperature may be assumed:

parameters: some reference value at reference temp, and a shift in efficiency per degree

Joao Gomes et al, Minimizing the impact of shading at oblique solar angles in ... , 2014: assumes a constant efficiency for a insolation levels of 0 to 1000 W/m2

chengquan Xiao et al., Impact of solar irradiance intensity and temperature on the performance ..., 2014, shows a near constant efficiency over the range 400 – 1000 W/m2, for lower insolation levels the efficiency drops, in a nonlinear fashion. this trend can be found in other articles as well

(<https://www.semanticscholar.org/paper/Efficiency-VS.-irradiance-characterization-of-PV-Donovan-Bourne/f3f6bd7c8379ee52da7435d7aa6f2d1404772ca9/figure/0>)

<https://www.researchgate.net/publication/263243375_Improvement_in_Perturb_and_Observe_Method_for_Maximum_Power_Point_Tracking_of_PV_Panel>

Improvement in Perturb and Observe Method for Maximum Power Point Tracking of PV Panel

(<https://www.researchgate.net/publication/263243375_Improvement_in_Perturb_and_Observe_Method_for_Maximum_Power_Point_Tracking_of_PV_Panel>)

gives a set of equations for the load current as a function of the temp, reverse saturation current, and voltage based on a basic circuit model of the PV panel. They show computed efficiency curves as function of the insolation for different temps

What do we want?

## PV-panel

Is a surface with orientation

* **area**: surface area in square meters
* **inclination**: angle with the horizontal plane (0 to 90 degrees)
* **azimuth**: angle with due south direction -180 to 180 degrees

PV-specific properties

* **nominal\_operation\_temp:** spec from data sheet
* **nominal\_efficiency:** efficiency at nominal operation temp, spec from data sheet
* **efficiecy\_loss\_parameter**
* get insolation level at a given time (global insolation based on orientation and surface area + time + weather)
  + global insolation = direct + diffuse + reflected
    - direct depends on orientation, time of day (sun location), NEN-direct insolation on horizontal plane?
    - diffuse (directly from NEN)
    - reflected

NEN provides global on horizontal plane. diffuse is orientation independent, direct is orientation dependent.

* temperature computation vgl 3.5.1 dictaat marc (input windspeed, amb temp, insolation)

More detailed model in app B1.



T\_a --> amb. temp from the NEN

v\_w --> wind\_speed from NEN

I\_g,s --> global insolation from NEN

* efficiency factor, function of temp and insolation level **+ panel parameters** (first implementation only temp)



T\_cell --> from computation above

eta\_cell,N --> parameter from panel specs (example value from lecture notes **fig 3.5.4** module efficiency: 0.183 / 18.3 %)

T\_cell,N --> parameter from panel specs, (example value from lecture notes **fig 3.5.4** nominal operating temp: 45 degrees Celsius)

gamma\_T --> parameter from panel specs, (example value from lecture notes **fig 3.5.4** P\_mpp: -0.41 %/degree --> gamma\_T -0.0041

to do: check correctness of the interpretation of the specs from data sheet

* output power ( efficiency factor, insolation level)

output\_power = eta\_cell \* global\_insolation

eta\_cell --> from computation above

global\_insolation --> from NEN

At this moment the electrical output is disconnected from the rest of the house, when the model is extended to electrical energy we can hook this up. (of course a output of the electrical output can be generated and plotted when desired.)

# Thermal collector

heat balance eq. 4.2.1 dictaat: useful energy yield based on (surface area, heat removal factor, absorbed solar radiation, heat loss coeff, inlet temp – amb temp)

efficiency factor = useful energy/(global insolation\*surface area)

appendix C. gives an detailed model description of a flat plate collector.

Do we want to implement this? Is there an implementation available?

I guess we need to do this as it is all about the heat transfer to the fluids.

Large set of parameters, is this practically available?

What is the interface?

# collector

Surface with orientation:

* **area**: surface area in square meters
* **inclination**: angle with the horizontal plane (0 to 90 degrees)
* **azimuth**: angle with due south direction -180 to 180 degrees
* useful energy yield collector:



A\_c --> area collector (input property)

F\_R --> heat removal factor, how do we get this? (section 4.2.4)

S --> absorbed solar irradiation, how do we get this (section 4.2.2)

U\_L --> heat loss coeff, how do we get this (section 4.2.5)

T\_fi --> inlet temp collector fluid, This should come from the heat pump?

T\_a --> ambient temp, from NEN

Is this what we need? Or do we need something that computes the Temp of the returning collector fluid. How to use the solar collector in the house model?

What will be the interface with the heatpump??

* Insolation absorbed by collector:

