

CONFERENZA FINALE

Bolzano, KLIMAHOUSE – Sala Ceredale, 24 gennaio 2019

“Tegole innovative per il risparmio energetico e il comfort estivo”

SENSAPIRO, il software per il calcolo delle prestazioni del tetto ventilato

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Michele Bottarelli, Università di Ferrara, Architettura

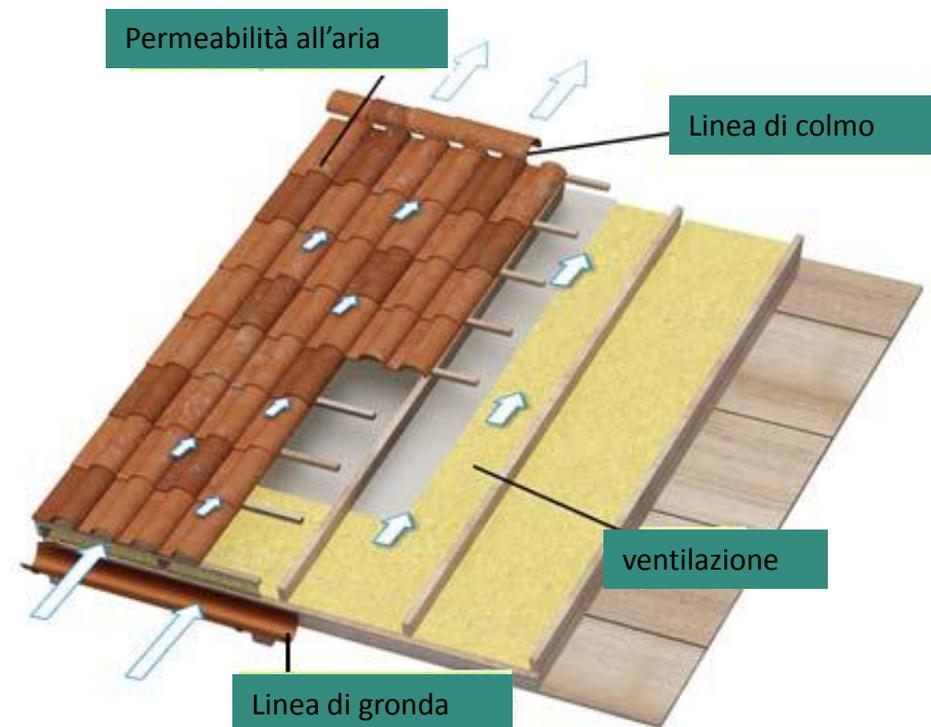
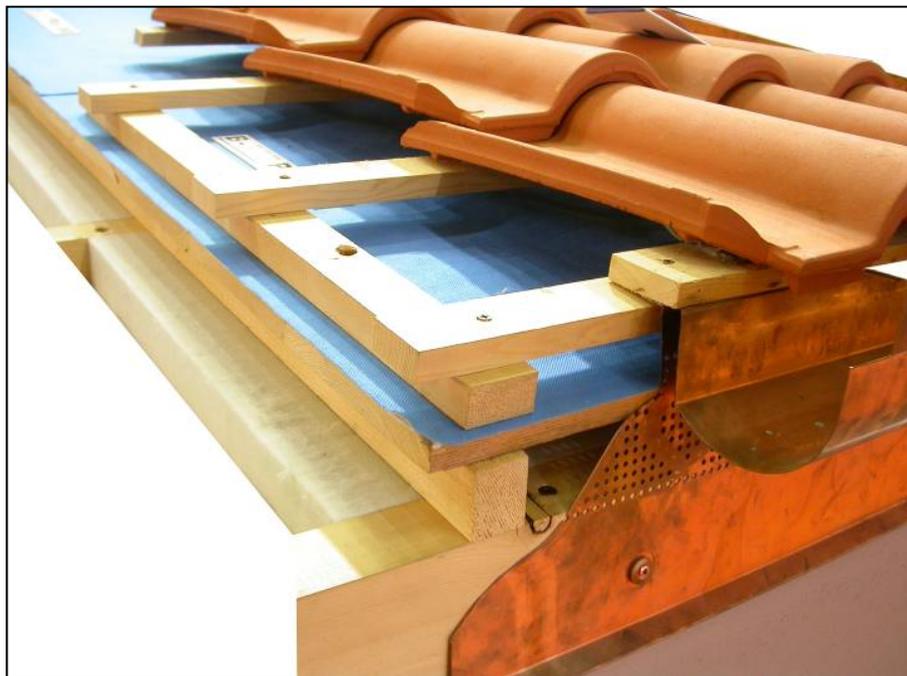


HIGH ENERGY SAVINGS IN BUILDING COOLING BY ROOF TILES SHAPE OPTIMIZATION TOWARD A BETTER ABOVE SHEATHING VENTILATION

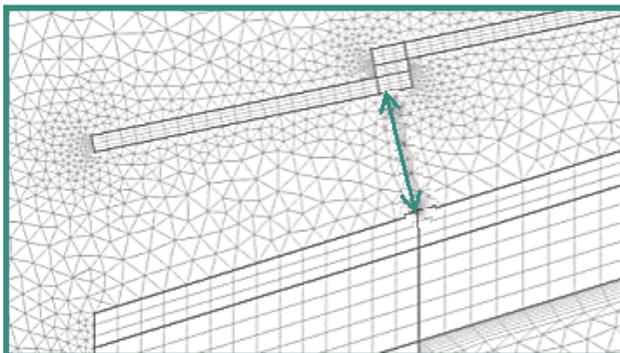


Università degli Studi di Ferrara

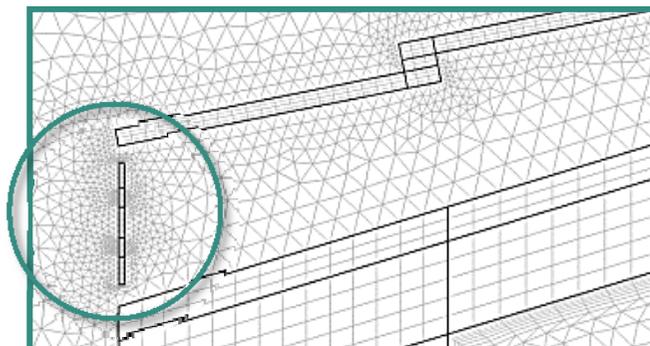
Nei tetti ventilati l'aria entra dalla linea di **gronda** ed esce dalla linea di **colmo**.
Aumentare la permeabilità all'aria fra le tegole migliora questa prestazione.



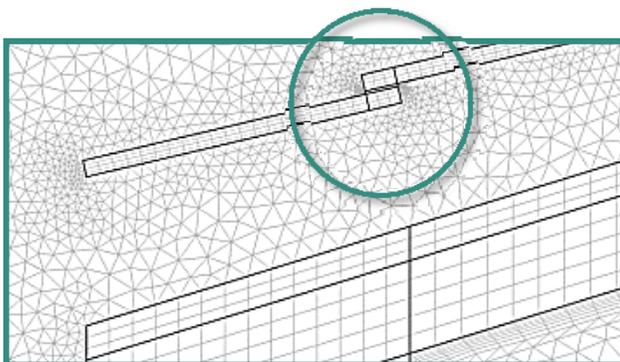
modifiche



**Strato di ventilazione
4/8 cm**



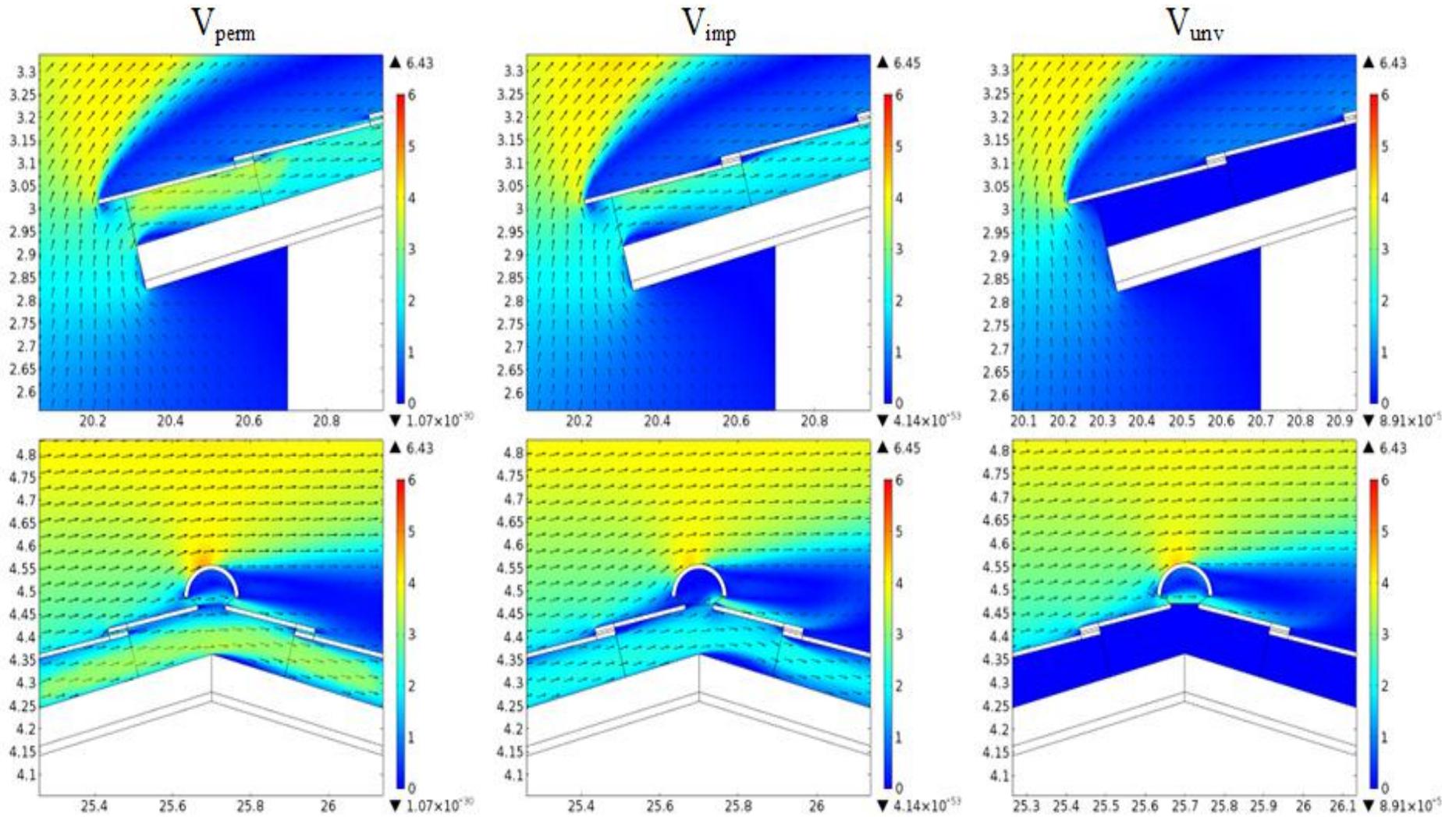
**Apertura in gronda
0-50-100%**



**Permeabilità all'aria
0.0/2.5/9.0 mm**



Tetto ventilato

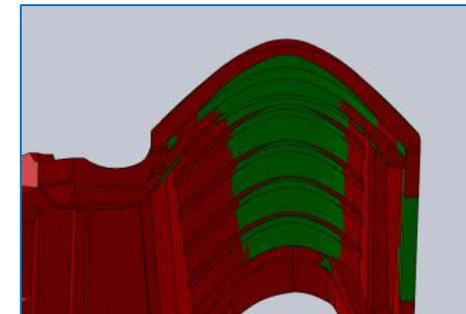
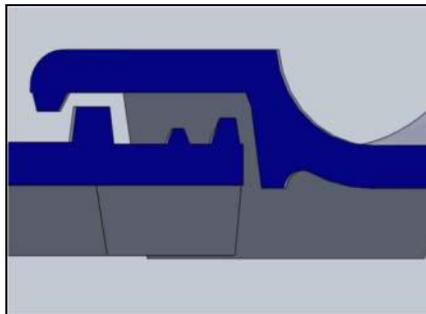
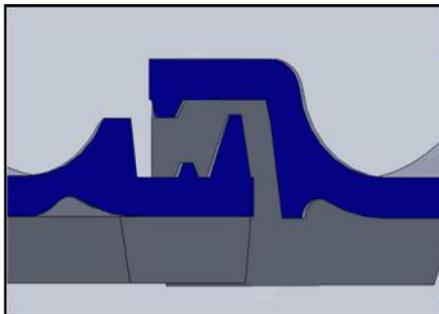
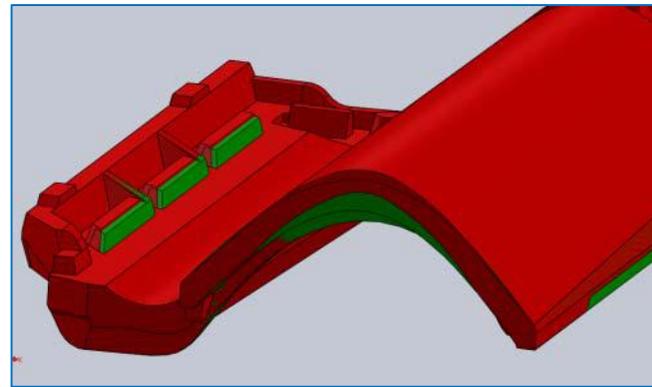
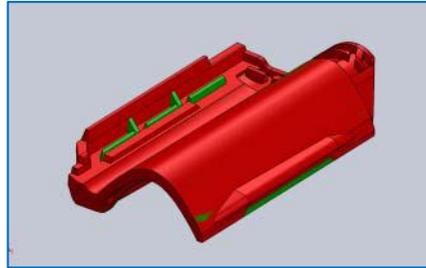
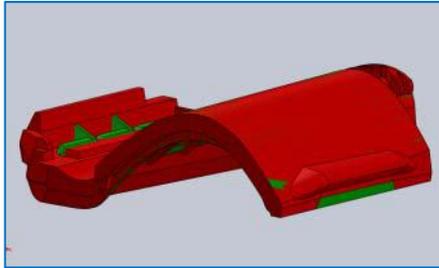




Obiettivo del progetto HEROTile è stato:

- Riprogettare il design delle tegole
- Confrontarne le prestazioni con le tegole standard
- Verificare le prestazioni con test al vero

24 soluzioni progettate e testate di tegola portoghese e marsigliese



Matrice di valutazione

Parameter	Case_01n	Case_02n	Case_03n	Case_04n	Case_05n	Case_06m	Case_07m	Case_08mb	Case_09m	Case_10m
Air permeability	1.77	2.17	1.51	1.92	1.73	1.36	1.33	1.58	1.81	1.31
Waterproof	-1.00	-0.36	-0.07	0.14	-0.54	-0.54	-0.79	-1.00	-1.00	-0.79
Conformity of standard regulation	0.00	0.00	-0.21	-0.48	-0.48	0.00	-0.48	0.00	0.00	0.00
Aesthetic index	0.00	-0.48	-0.33	-0.15	-1.00	-0.33	-0.33	0.00	-0.37	0.33
Line production cost	-0.46	-0.64	-0.64	-1.00	-1.00	0.00	-0.46	0.00	0.00	0.00
Unitary cost	-0.13	-0.13	-0.35	-0.35	-1.00	0.00	-0.13	0.00	0.00	0.00
Mechanical performance	-0.44	-0.44	-0.44	-0.44	-1.00	0.00	-0.20	0.00	0.00	0.00
Installation cost	-0.23	-0.23	-0.46	-0.46	-0.77	0.00	-0.54	0.00	-0.23	0.00
Commercial index	0.00	0.29	0.21	0.46	-0.82	-0.07	0.11	0.21	-0.25	0.46
	0.28	0.57	0.17	0.30	-2.24	0.56	-0.32	0.49	0.37	0.48



3

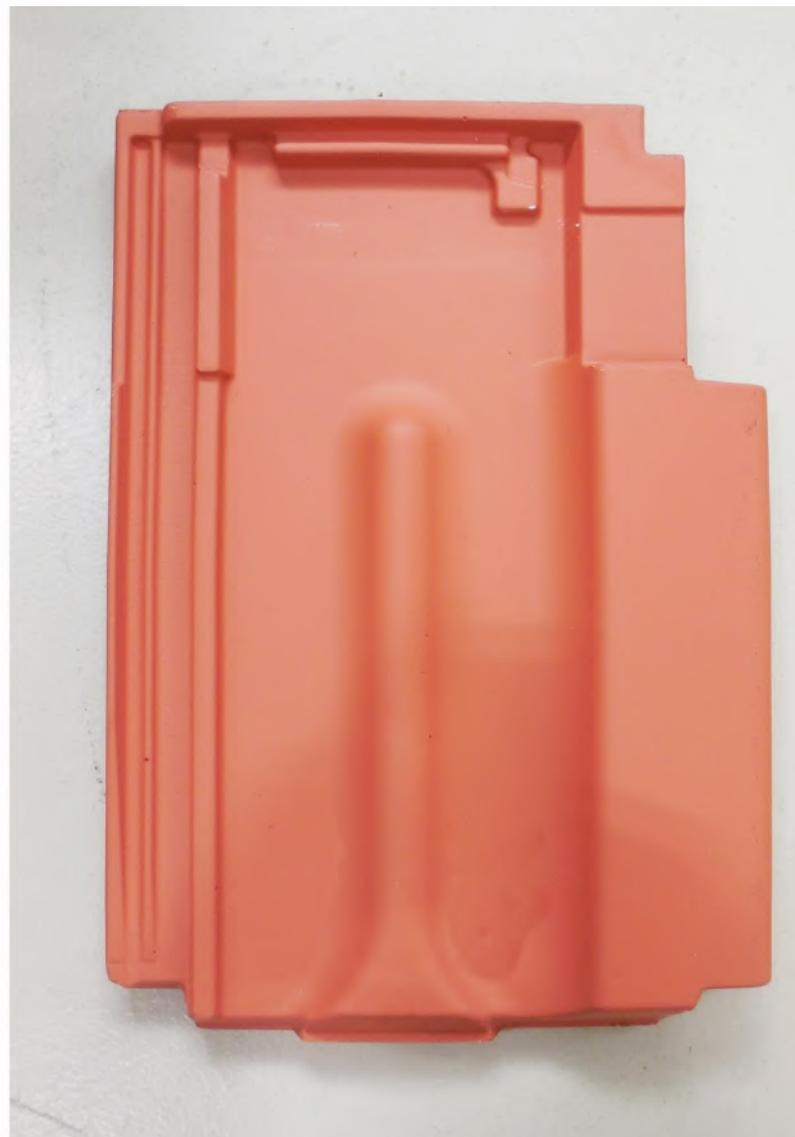


Test in galleria del vento e messa in produzione



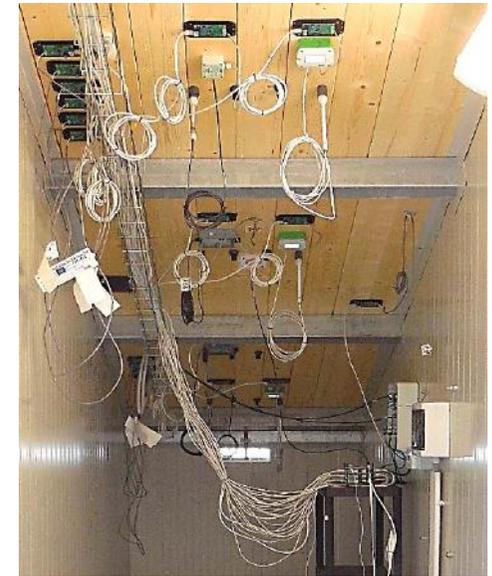
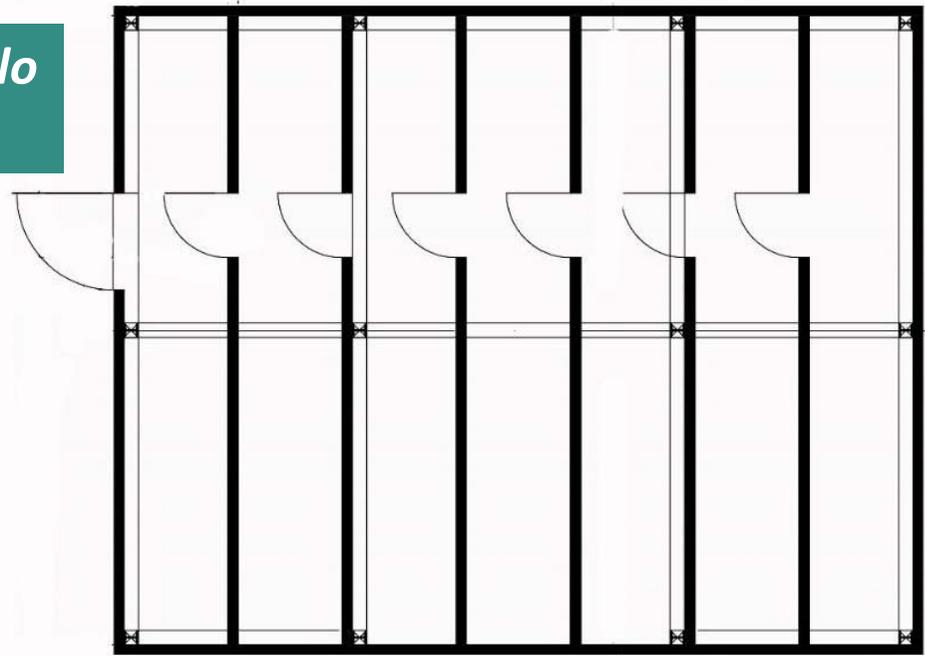
portoghese Herotile

marsigliese Herotile





*Università di Ferrara, Tecnopolo
CAI Factory, Yeruham (Israele)*





Sperimentazione al vero

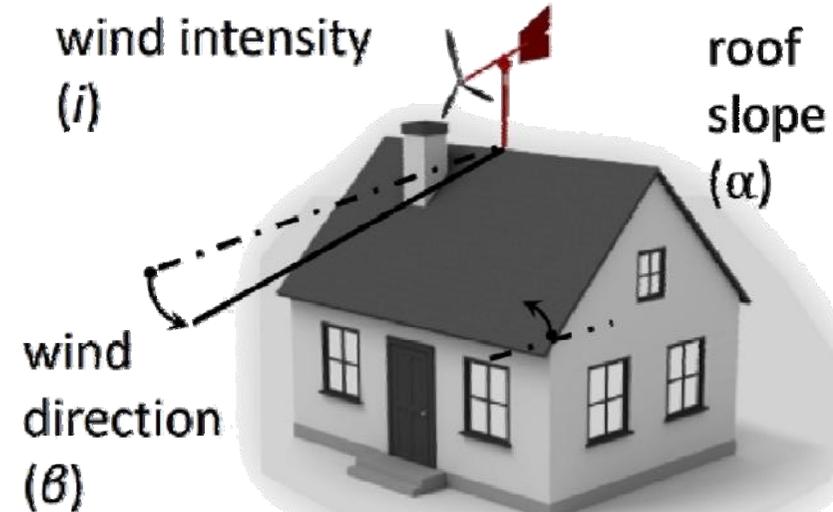
*Reggio Emilia (Italia)
Saragozza (Spagna)*



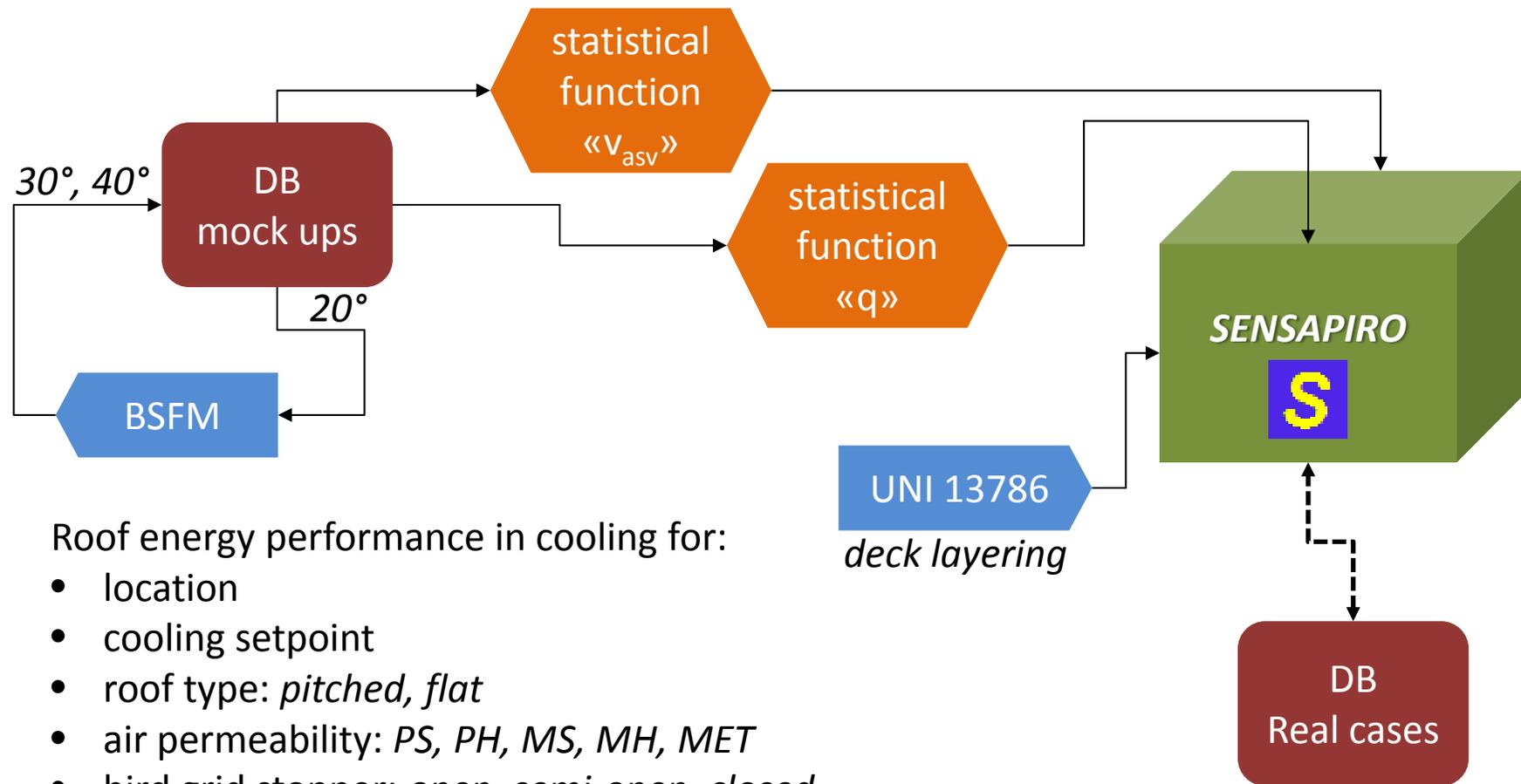
Task	Start	End	Duration	Resources	Cost	Progress
1.1.1	2018-01-01	2018-01-05	5	1	1000	100%
1.1.2	2018-01-06	2018-01-10	5	1	1000	100%
1.1.3	2018-01-11	2018-01-15	5	1	1000	100%
1.1.4	2018-01-16	2018-01-20	5	1	1000	100%
1.1.5	2018-01-21	2018-01-25	5	1	1000	100%
1.1.6	2018-01-26	2018-02-01	6	1	1000	100%
1.1.7	2018-02-02	2018-02-07	6	1	1000	100%
1.1.8	2018-02-08	2018-02-13	6	1	1000	100%
1.1.9	2018-02-14	2018-02-19	6	1	1000	100%
1.1.10	2018-02-20	2018-02-25	6	1	1000	100%
1.1.11	2018-02-26	2018-03-01	6	1	1000	100%
1.1.12	2018-03-02	2018-03-07	6	1	1000	100%
1.1.13	2018-03-08	2018-03-13	6	1	1000	100%
1.1.14	2018-03-14	2018-03-19	6	1	1000	100%
1.1.15	2018-03-20	2018-03-25	6	1	1000	100%
1.1.16	2018-03-26	2018-03-31	6	1	1000	100%
1.1.17	2018-04-01	2018-04-06	6	1	1000	100%
1.1.18	2018-04-07	2018-04-12	6	1	1000	100%
1.1.19	2018-04-13	2018-04-18	6	1	1000	100%
1.1.20	2018-04-19	2018-04-24	6	1	1000	100%
1.1.21	2018-04-25	2018-04-30	6	1	1000	100%
1.1.22	2018-05-01	2018-05-06	6	1	1000	100%
1.1.23	2018-05-07	2018-05-12	6	1	1000	100%
1.1.24	2018-05-13	2018-05-18	6	1	1000	100%
1.1.25	2018-05-19	2018-05-24	6	1	1000	100%
1.1.26	2018-05-25	2018-05-30	6	1	1000	100%
1.1.27	2018-05-31	2018-06-05	6	1	1000	100%
1.1.28	2018-06-06	2018-06-11	6	1	1000	100%
1.1.29	2018-06-12	2018-06-17	6	1	1000	100%
1.1.30	2018-06-18	2018-06-23	6	1	1000	100%
1.1.31	2018-06-24	2018-06-29	6	1	1000	100%
1.1.32	2018-06-30	2018-07-05	6	1	1000	100%
1.1.33	2018-07-06	2018-07-11	6	1	1000	100%
1.1.34	2018-07-12	2018-07-17	6	1	1000	100%
1.1.35	2018-07-18	2018-07-23	6	1	1000	100%
1.1.36	2018-07-24	2018-07-29	6	1	1000	100%
1.1.37	2018-07-30	2018-08-04	6	1	1000	100%
1.1.38	2018-08-05	2018-08-10	6	1	1000	100%
1.1.39	2018-08-11	2018-08-16	6	1	1000	100%
1.1.40	2018-08-17	2018-08-22	6	1	1000	100%
1.1.41	2018-08-23	2018-08-28	6	1	1000	100%
1.1.42	2018-08-29	2018-09-03	6	1	1000	100%
1.1.43	2018-09-04	2018-09-09	6	1	1000	100%
1.1.44	2018-09-10	2018-09-15	6	1	1000	100%
1.1.45	2018-09-16	2018-09-21	6	1	1000	100%
1.1.46	2018-09-22	2018-09-27	6	1	1000	100%
1.1.47	2018-09-28	2018-10-03	6	1	1000	100%
1.1.48	2018-10-04	2018-10-09	6	1	1000	100%
1.1.49	2018-10-10	2018-10-15	6	1	1000	100%
1.1.50	2018-10-16	2018-10-21	6	1	1000	100%
1.1.51	2018-10-22	2018-10-27	6	1	1000	100%
1.1.52	2018-10-28	2018-11-02	6	1	1000	100%
1.1.53	2018-11-03	2018-11-08	6	1	1000	100%
1.1.54	2018-11-09	2018-11-14	6	1	1000	100%
1.1.55	2018-11-15	2018-11-20	6	1	1000	100%
1.1.56	2018-11-21	2018-11-26	6	1	1000	100%
1.1.57	2018-11-27	2018-12-02	6	1	1000	100%
1.1.58	2018-12-03	2018-12-08	6	1	1000	100%
1.1.59	2018-12-09	2018-12-14	6	1	1000	100%
1.1.60	2018-12-15	2018-12-20	6	1	1000	100%
1.1.61	2018-12-21	2018-12-26	6	1	1000	100%
1.1.62	2018-12-27	2018-12-31	5	1	1000	100%



Come risolvere il problema

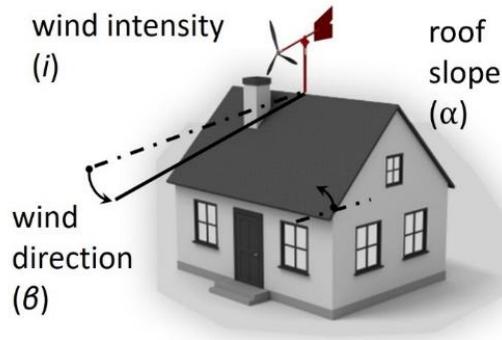


Metodologia



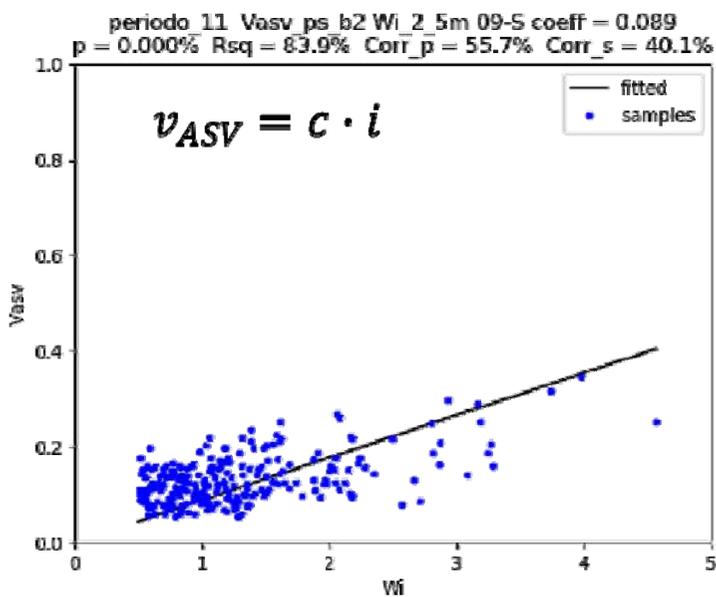
Ventilazione sottomanto

$$v_{ASV} = F(i)$$

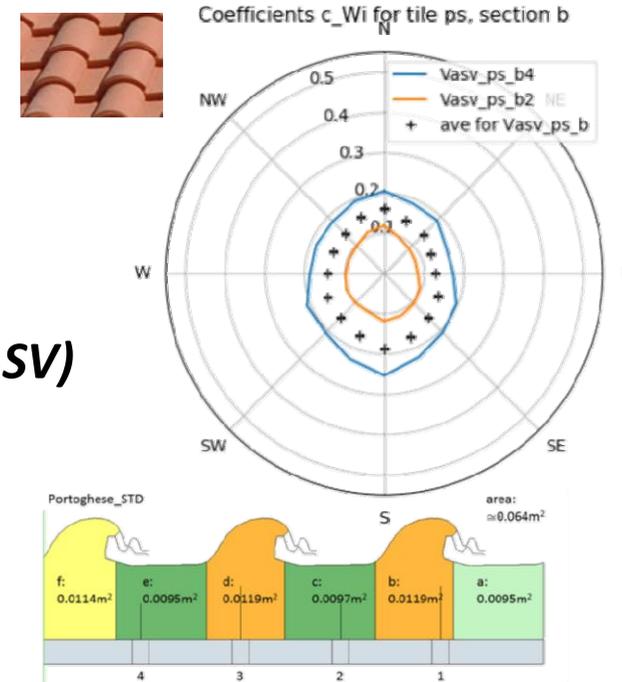


the function “F” changes according:

- roof type (PS,PH,MS,MH,MET)
- stopping bird (closed, 50% or 100% open)
- wind direction (16)
- pitch slope (20, 30* and 40* deg)



DATASET of 720 values
 (file *coeff_polar_ASV*)



Apporto termico

$$q = a_0 + a_1 Z_{irr} + a_2 GH + a_3 V_{ASV} + a_4 V_w$$

heat gain [Wh m⁻² day⁻¹] solar gain degree hours ASV impact wind run

V_{ASV} is calculated from the previous former relationship
 Z_{irr} , GH and V_w follow weather data and air conditioning setpoint

Parameters from a_0 to a_4 change according to:

- roof types (P_{std} , P_{hero} , M_{std} , M_{hero} , MET , $FLAT$)
- roof orientation (16 sectors)
- roof pitch (20°, 30°, 40°)
- eave types (*closed*, *semi-open*, *open*)

***DATASET of
864 values
(file coeff_q)***

Intermediate parameters are linearly interpolated

SENSAPIRO

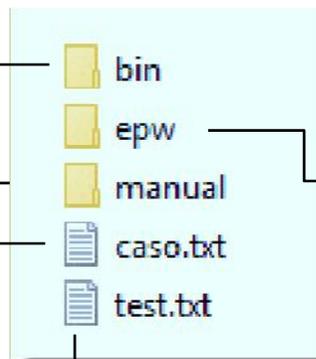


<https://energyplus.net/weather>

- DB**
 - coeff_polar_ASV
 - coeff_q
- program**
 - itextsharp.dll
- parameters**
 - layers.txt
 - parameters.txt
- program**
 - sensapiro.exe

User guide (PDF)

simulation files



The screenshot shows the EnergyPlus website's 'Weather Data' page. It includes a navigation bar with 'EnergyPlus', 'Downloads', 'Documentation', 'Support & Training', 'Licensing', 'Weather', and 'Log in'. The main content area has a 'Weather Data' heading, a description of data availability, and two sections: 'View Weather Data' with a region selection dropdown (currently showing 'Africa (WMO Region 1)') and a 'Search Weather Data' section with a 'Keyword Search' input field and a 'Search' button. Below is a 'Browse Weather Data' section with a map of Europe and the Middle East showing location markers.



Schermata iniziale

SENSAPIRO V1.0

Software ENergy SAVings Pitched ROofs

LOCALIZZAZIONE

SELEZIONA FILE EPW Anno 2005

D:\PdR_internazionali\Life Cottopossagno_C5 - Sensapiro_FINALE_03\epw\ITA_Bologna-Borgo.Panigale.161400_JGDG.epw

Latitudine (deg) 44,53 Sovrascrivi

Longitudine (deg) 11,30 Sovrascrivi

Timezone 1 Sovrascrivi

Contesto urbano urbano molto denso urbano denso

PERIODO

da 15

a 15

Gennaio
Febbraio
Marzo
Aprile
Maggio
Giugno
Luglio
Agosto
Settembre
Ottobre
Novembre
Dicembre

Gennaio
Febbraio
Marzo
Aprile
Maggio
Giugno
Luglio
Agosto
Settembre
Ottobre
Novembre
Dicembre

LAYERS

Numero di layers 1 2 3

CONFIGURA

PARAMETRI TETTO

Quota media tetto (m) 8

Tilt tetto (deg) 20

Azimut tetto (deg) 45

Tipo tetto Portoghese STD Portoghese HERO

Gronda Chiusa Semichiusa

Temperatura di Setpoint (°C) 26

Fattore ASV 1

lock chart scale

CALCOLA

Dati orari

Dati giornalieri

Salva configurazione

Carica configurazione

lifeHEROTILE

Life

About

CHIUDI

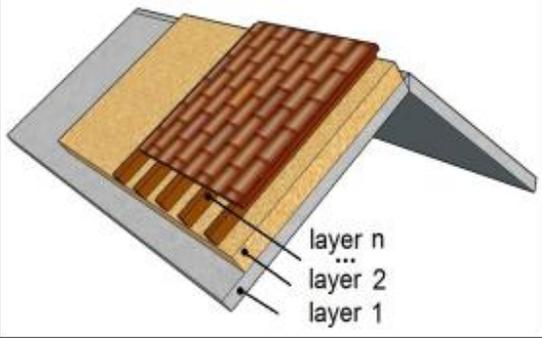
With the contribution of the LIFE financial instrument of the European Community

UNI EN ISO 13786:2018 Thermal performance of building components - Dynamic thermal characteristics - Calculation methods

Layers
↔ - □ ×

LAYERS

Layer 1 to Layer n	Thickness (mm)	Thermal conductivity (W/mK)	Density (kg/m ³)	Specific heat capacity (J/kgK)
L1 Intonaco calce cemento ▾	20	0,9	1800	1000
L2 Solaio in laterocemento (20+6) ▾	260	0,74	1150	1000
L3 XPS ▾	60	0,032	35	1450
L4 Membrana in PVC ▾	5	0,15	1200	900



Calculate

CLOSE

0,15284

Decrement factor = 0,15284

Thermal transmittance phase shift = 9,979 (h)

Periodic thermal transmittance = 0,062 (W / m² K)

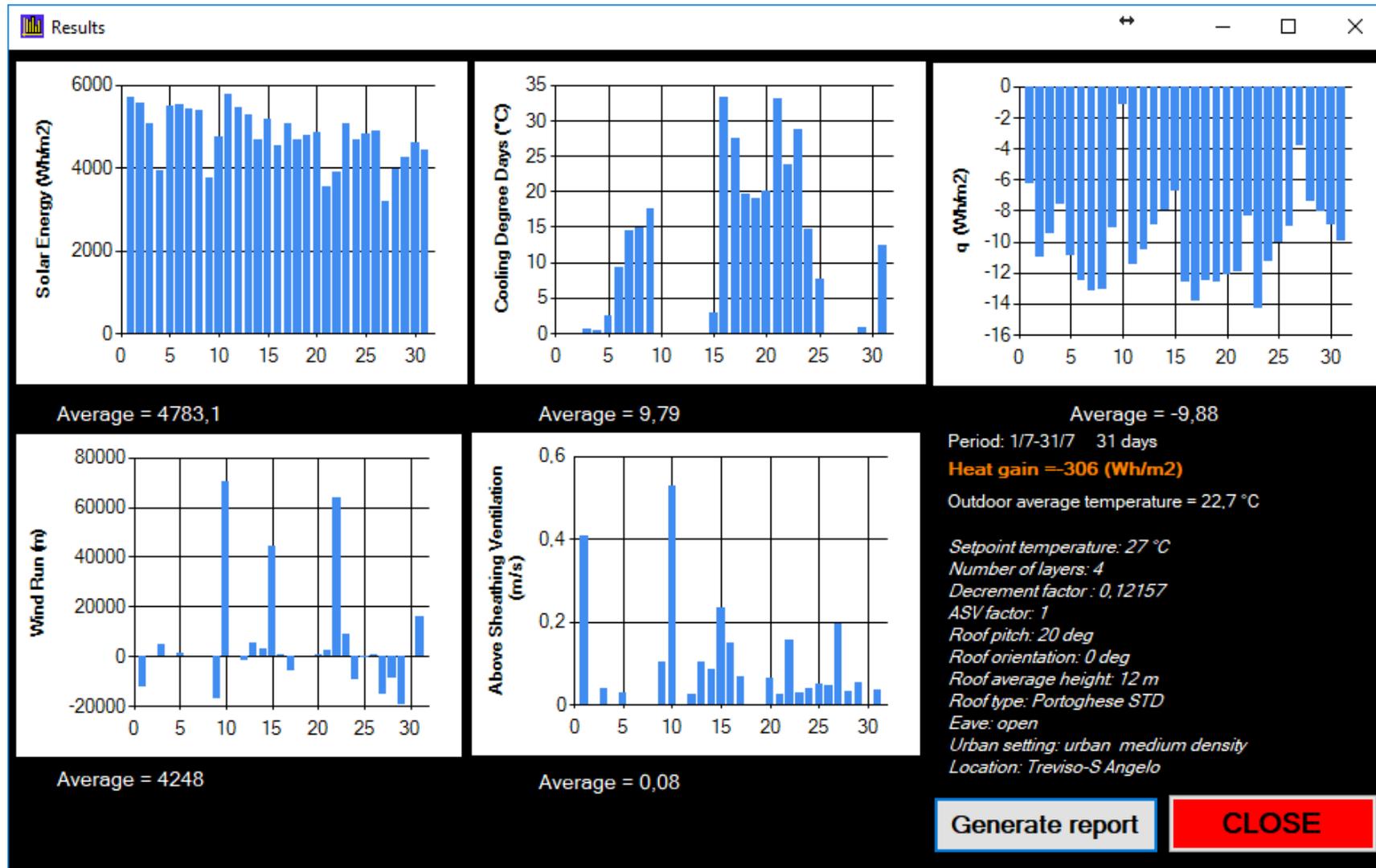
Internal thermal admittance = 4,511 (W / m² K)

External thermal admittance = 0,687 (W / m² K)

Component thermal resistance = 2,282 (m² K / W)

System thermal resistance = 2,452 (m² K / W)

Risultati (1/3)



Risultati (2/3)

G_0 , l'irraggiamento solare caricato dal file EPW [$W m^{-2}$];
 $T_{dry\ bulb}$, la temperatura di bulbo secco caricata dal file EPW [$^{\circ}C$];
 W_i , la velocità del vento caricato dal file EPW [$m s^{-1}$];
 $W_{i, new}$, la direzione del vento caricato dal file EPW [deg];
 $W_{i, new}$, la componente del vento incidente normalmente al tetto [$m s^{-1}$].

Data e ora	G_0	$T_{dry\ bulb}$	W_i	$W_{i, new}$	W_d
gg/mm/aaaa hh:mm	W/m^2	$^{\circ}C$	m/s	m/s	deg
01/01/2005 00:00	0	1	0	0	218
01/01/2005 01:00	0	0,4	0	0	203
01/01/2005 02:00	0	-0,6	0,8	0,732	59
01/01/2005 03:00	0	-1,8	0,8	0,732	50
01/01/2005 04:00	0	-2	0,8	0,732	276
01/01/2005 05:00	0	-1,8	1,6	1,463	46
01/01/2005 06:00	0	-1,2	1,6	1,463	252
01/01/2005 07:00	0	-0,6	1,6	1,463	28
01/01/2005 08:00	36	0,2	1,6	1,463	339
01/01/2005 09:00	100	1,2	0,8	0,732	155
01/01/2005 10:00	156	2,5	0,8	0,732	274
01/01/2005 11:00	193	4	0	0	78
01/01/2005 12:00	200	5,8	0	0	84
01/01/2005 13:00	176	6,7	0	0	335
01/01/2005 14:00	129	7,2	0	0	96
01/01/2005 15:00	71	7,4	0	0	66
01/01/2005 16:00	13	7,1	0	0	313
01/01/2005 17:00	0	6,5	0	0	91
01/01/2005 18:00	0	5,4	0	0	46
01/01/2005 19:00	0	5,1	0	0	134
01/01/2005 20:00	0	5	0	0	30
01/01/2005 21:00	0	5	0	0	113
01/01/2005 22:00	0	4,9	0	0	352
01/01/2005 23:00	0	4,7	0	0	202
02/01/2005 00:00	0	4,6	0	0	105
02/01/2005 01:00	0	4,5	0	0	241
02/01/2005 02:00	0	4,4	0	0	213

Giorno	GH	V_w	Z_{irr}	V_{asv}	q
gg/mm	$^{\circ}C$	m	Wh/m^2	m/s	$Wh/m^2\ day$
01/01	0	486	663	0,03	-2,4
02/01	0	487	0	0	-2,3
03/01	0	17772	495	0,14	8,5
04/01	0	0	508	0	-2,5
05/01	0	573	515	0,021	-1
06/01	0	-1292	419	0,226	15,7
07/01	0	35661	554	0,172	10,4
08/01	0	-5141	479	0,075	3,4
09/01	0	-24186	474	0,238	15,6
10/01	0	-12119	463	0,236	15,7
11/01	0	0	587	0	-3,6
12/01	0	31247	557	0,22	13,9
13/01	0	16672	337	0,17	12,9
14/01	0	5454	651	0,157	7,4
15/01	0	702	688	0,156	6,8
16/01	0	7854	666	0,205	10,9
17/01	0	14166	495	0,157	9,7
18/01	0	14498	610	0,143	7,1
19/01	0	-6548	751	0,037	-3,2
20/01	0	-667	714	0,181	8,3
21/01	0	0	723	0	-5,5
22/01	0	-6848	726	0,072	-0,2
23/01	0	0	798	0	-6,5
24/01	0	0	522	0	-2,7
25/01	0	0	273	0	0,7
26/01	0	-18540	587	0,14	6,7

GH , i gradi ora giornalieri riferiti al setpoint scelto [$^{\circ}C$];
 V_w , il wind run secondo l'orientamento del tetto [m];
 Z_{irr} , l'irraggiamento per la sola quota ortogonale al tetto [$Wh m^{-2}$];
 V_{asv} , la velocità media dell'aria nella camera di ventilazione [$m s^{-1}$];
 q , l'energia termica specifica entrante dalla copertura [$Wh m^{-2}$].

Risultati (3/3)

$$q = a_0 + a_1 Z_{irr} + a_2 GH + a_3 V_{ASV} + a_4 V_w$$

Date; GH; Ww; Zirr; Vasv; q
 01/01/2017;0;-3798,44393858224;2798,92852096494;0,0687173418719642;-29,0381701718562
 02/01/2017;0;-2267,86505011956;1790,78711602085;0,021514917231545;-18,6610948775617
 03/01/2017;0;15492,399645526;2588,8450184085;0,10556210875404;-23,0754862663808
 04/01/2017;0;-15777,2867471958;3075,66099114791;0,119241849733086;-29,2092430203239
 05/01/2017;0;64244,328142279;3082,52308856999;0,312278059996723;-13,5669835026212
 06/01/2017;0;802,350613827888;3523,87369448387;0,0712034104418175;-38,798597952598
 07/01/2017;0;-17966,744306899;3416,10368865982;0,0924471858946552;-35,9696154851305
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SENSAPIRO V1.0 - LIFE HEROTILE PROJECT

Setpoint temperature: 27°C

Decrement factor: 0,93631

Numbers of layers: 4

Roof pitch: 20deg

Roof orientation: 180°deg

Roof type: Portoghese HERO

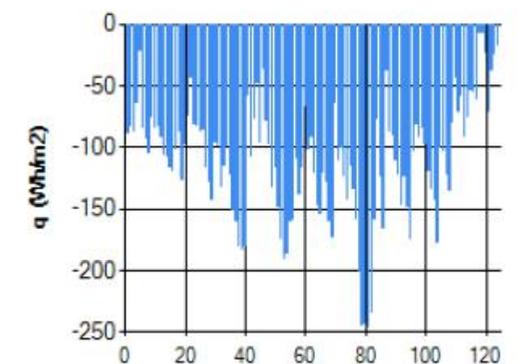
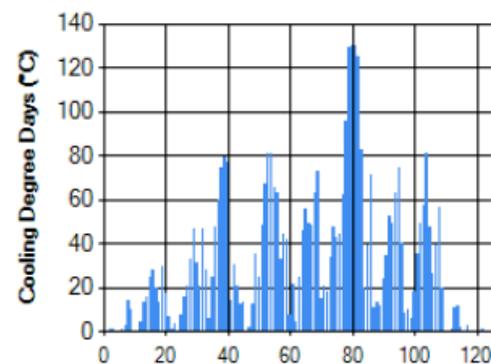
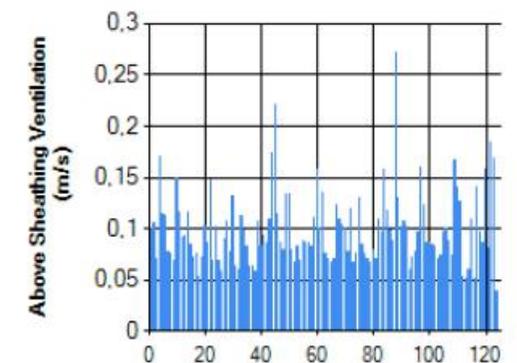
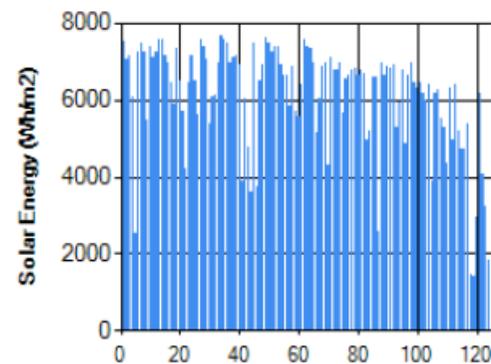
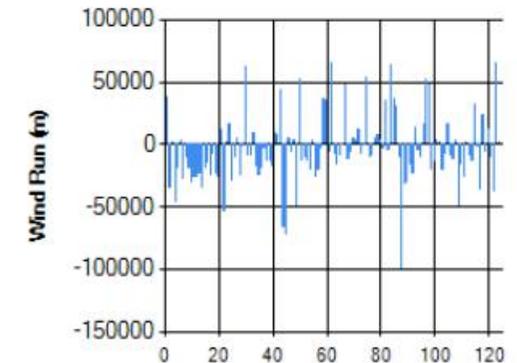
Eave type: semi-open

Location: Ferrara

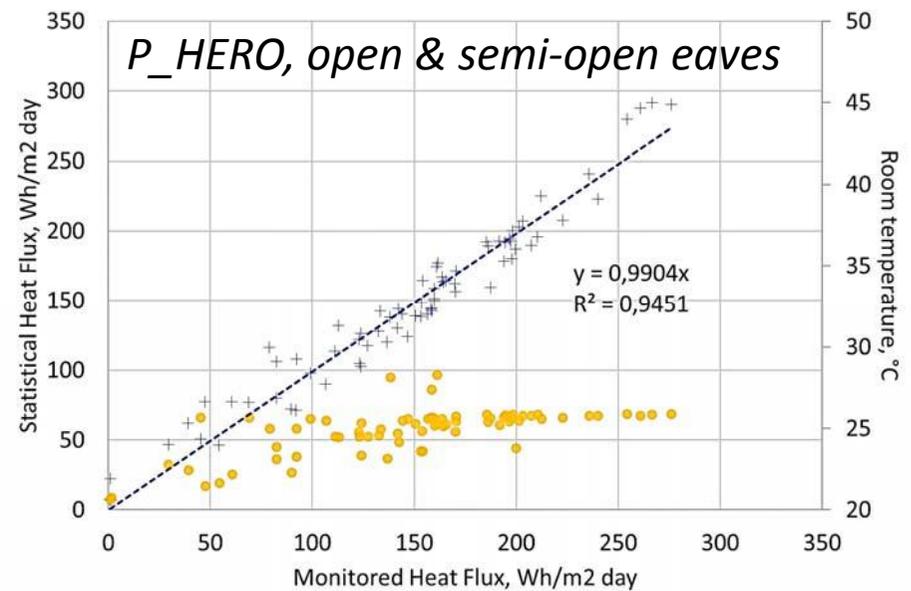
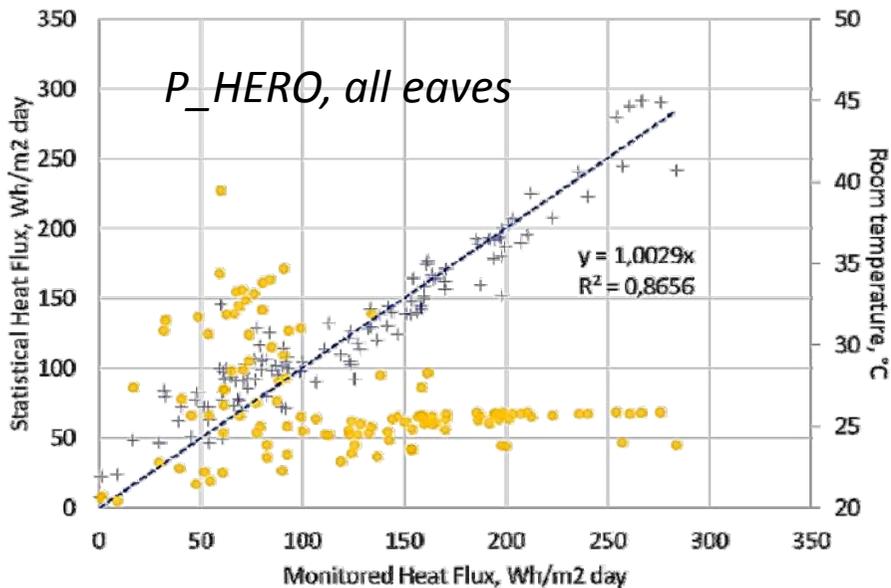
Roof average height: 8m

Urban setting: urban medium density

Period: 15/5-15/9 124 days



Ferrara 2017



Saragozza 2018

portoghese standard, non ventilata

