
TORINO, 11-04-2013

PREDICTIVE ANALYTICS

TO MANAGE DISPATCHMENT OF INTERMITTENT ENERGY SOURCES:

R as Computational And Analytic Tool In A Real Business Application

Alessandra Padriali, i4C

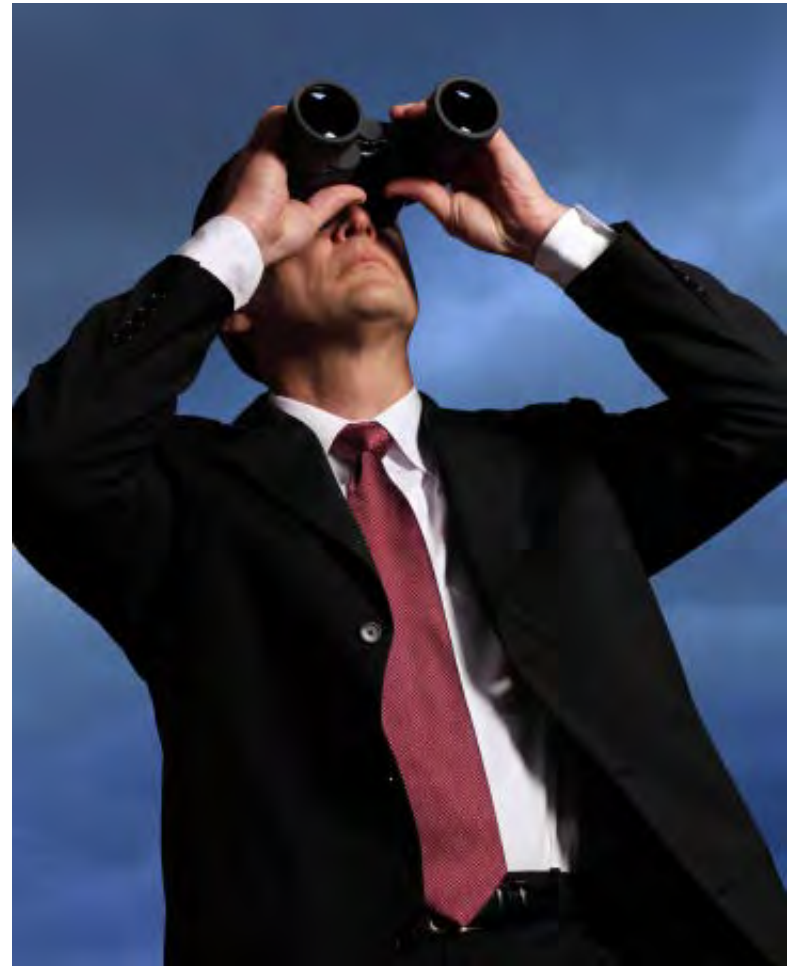
VISION

IN A WORLD OF **NUMBERS**,
WE PROVIDE YOU THE ONES UPON YOU
CAN BASE YOUR **DECISIONS**.

WE BELIEVE COMPANIES CAN REACH
EXCELLENCE ONLY IF THEY USE AS MUCH
DATA AS POSSIBLE TO DRIVE ACTIONS

ADVANCED ANALYTICS TO FORESEE
FUTURE EVENTS AND

APPLICATIONS TO SUPPORT DECISIONS AT
ANY LEVEL.



ADVANCED ANALYTIC APPLICATIONS

We realize AAA based on Advanced Analytics, the most advanced predictive methodologies. Our AAA forecast and predict accurately and provide a considerable ROI

1

INDUSTRY SPECIFIC ANALYTICS

i4C AAA integrate a deep business knowledge with advanced analytics. The reliability of the result is ensured by a strong vertical expertise

2

EMBEDDED IN PROCESSES

Our Advanced Analytics Application are strongly focused on business processes, the only way to allow them express their full potential

3

BUSINESS FOCUS

We provide AAA that are business user oriented. To achieve high accuracy it is not required a methodological or IT knowledge but only business expertise

4

ACTIONABLE RESULTS

We transform valuable information into business actions and make possible to trigger in real time the main decisional processes

5

VERTICAL KNOWLEDGE

FINANCE



TELCO



ENERGY



RETAIL



MANUFACTURING



1

2

3

4

5

WHY RENEAWABLES

METHODOLOGICAL APPROACH

TECHNOLOGICAL APPROACH

HAVE A LOOK

WHY RENEAWABLES

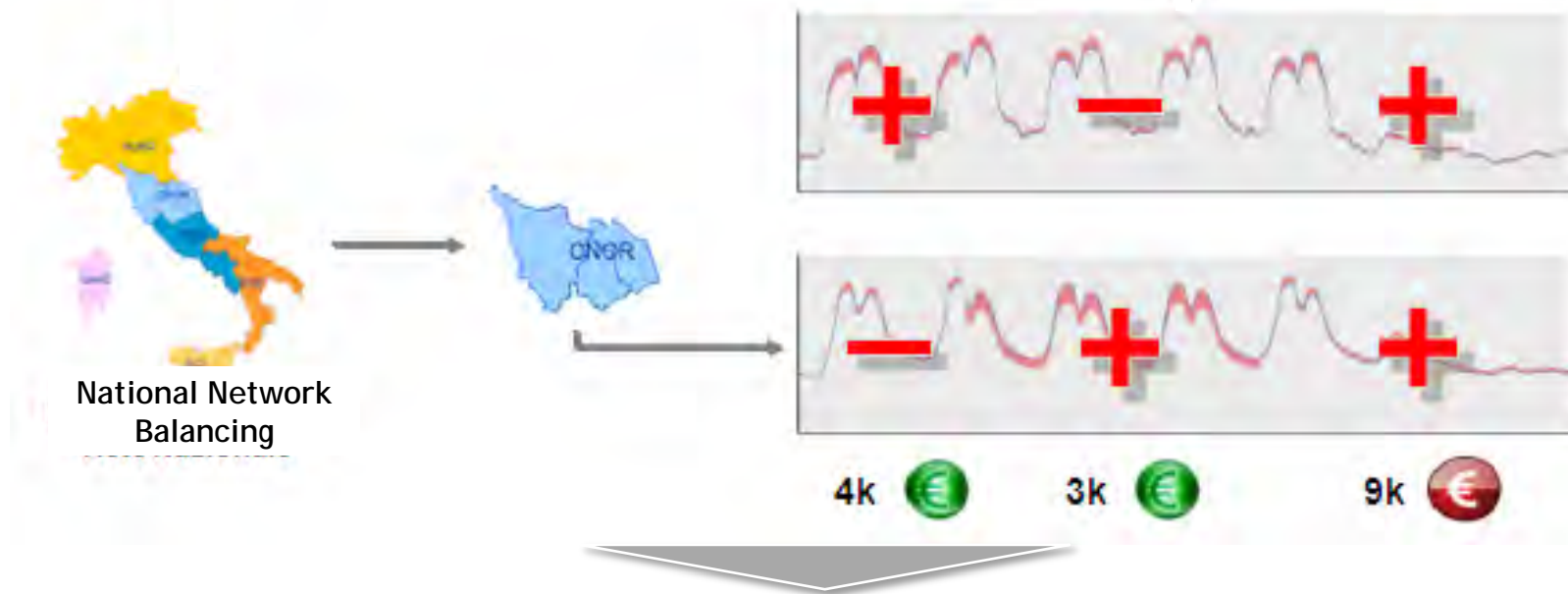
METHODOLOGICAL APPROACH

TECHNOLOGICAL APPROACH

HAVE A LOOK

KEY FACT

AEEG (Italian National Authority for Gas and Energy) with 493/2012/R/efr has resolved to charge energy players for unbalancing costs even if coming from Intermittent Renewable Energy Sources



Many energy companies which own Renewable Farms from now on will have to deal with **UNPREDICTED COSTS**, unless they find a **SOLUTION** to refine the energy production program, **DAILY** communicated to the Energy Market Owner



BUSINESS CHALLENGE

- Renewable Power Sources: Wind Energy, Hydro Turbines and PV devices
- Renewables power sources are **INTERMITTENT**
 - A lot of environmental variables influence energy production
 - Predict complex phenomena occurrence: Turbulence, Air Density
- Non linear effects given by farm **GEOMETRICAL** structure
- **MECHANICAL** response variability: saturation, inertia, cut-off

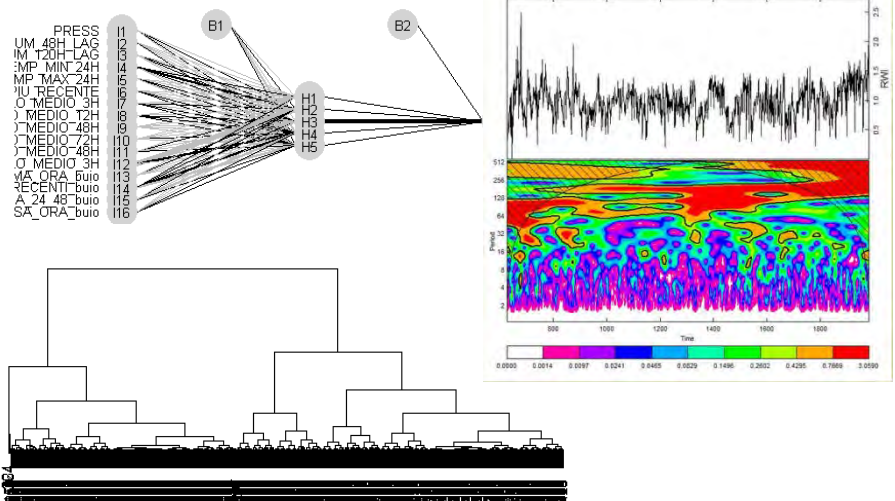
ENGINE CHOICE: R

R ENGINE

- R is a language strongly focused on computational and analytics purposes
- Plenty of highly advanced packages perform almost any mathematical algorithm, even the most complicated simulations
- Packages: nnet, cluster, wavelet, mgcv, and many others..



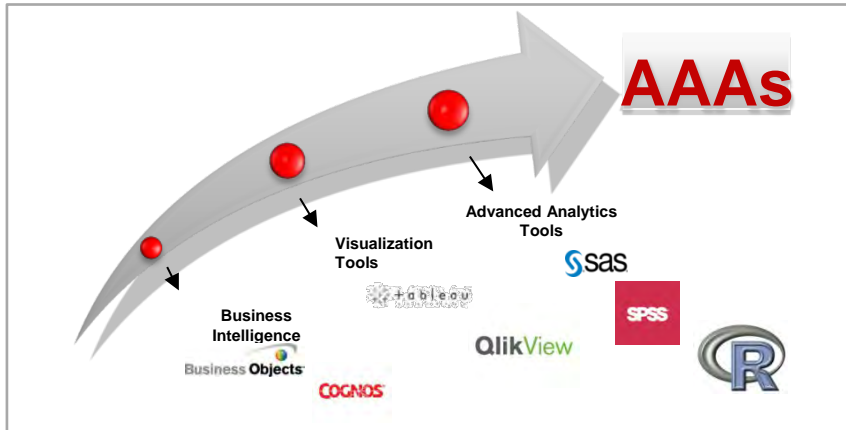
```
Loading required package: timeseries
Loading required package: timeDate
>
>
> library(nnet)
> library(mgcv)
This is mgcv 1.7-22. For overview type 'help("mgcv-package")'.
> library(forecast)
This is forecast 4.02
> |
```



ADVANCED METHODS DO NOT
NECESSARILY MEAN EFFECTIVENESS
WHY R IS NOT AS WIDESPREAD AS IT
WOULD DESERVE?
WHAT ELSE IS NEEDED?

ANSWER: ACTIONABILITY

PLAYGROUND



TOOLS VS AAAs

WHEN CLASSICAL ANALYTICS TOOLS WOULD FAIL:

- Users with little or **no methodological skills**
- Large problems in need of **automation**
- Integration into **Business Process** is essential
- Strong Vertical **Market knowledge** is key

KEY DIFFERENTIATORS

- 1 **INDUSTRY SPECIFIC:** integration allows embedded industry knowledge
- 2 **BUSINESS DRIVEN:** to gain widespread use, apps should be designed for business users and focused on business results, hiding advanced analytics complexity
- 3 **ACTIONABLE:** easy integration in an enterprise operational environment is a key point to let AAAs drive business process action

BUSINESS PAIN

- Technology oriented treatment
- Weather Forecast Errors
- Dispatchment Program Definition
- Allowance Boundaries

KEY FEATURES

- Power Source Entity:
 - Multi-technology
 - Registry of Technology-oriented Attributes
- Technology specific allowance definition
- Re Weather Station Entity
 - Multi-provider and Weather Station
 - Multiple time-horizon data loading
- Automated association Algorithm
- Forecasting functionalities
 - Advanced Algorithms
 - Customized Models
- Allowance-net KPI calculation

WHY RENEAWABLES

METHODOLOGICAL APPROACH

TECHNOLOGICAL APPROACH

HAVE A LOOK

INPUT MANAGEMENT



SourceID	Parameter Type	Parameter Description	Parameter Value
WTFarm1	Series	EnergyProd	
WTFarm1	StdRespOutputPower	WorkingCond	
WTFarm1	StdRespWindSpeeds	WorkingCond	
WTFarm1	Tech Parameters	MaxPower	15000,00000
WTFarm1	Tech Parameters	Loss	0,00000
WTFarm1	Mechanical Attrib	HubHeight	61,50000
WTFarm1	Mechanical Attrib	Diameter	77,00000
WTFarm1	Mechanical Attrib	AirDensity	1,22500
WTFarm1	Mechanical Attrib	CutoffLow	3,00000
WTFarm1	Mechanical Attrib	CutoffUp	25,00000

Object specific and
encoded format
Time series in a data
frame object, vectors

	StdRespWindSpeeds	StdRespOutputPower	StdRespWindDir
1	0	0	30
2	1	0	30
3	2	0	30
4	3	2	30
5	4	91	30
6	5	197	30
7	6	371	30
8	7	610	30
9	8	969	30

	serie	WINDSPD_MS_P1	WINDDIR_DEG_P1	WINDSPD_MS_P2
1	-2.231667	4.710000	158	3.3
2	53.686667	5.846667	101	1.4
3	235.358332	3.831667	119	1.4
4	1734.763326	3.525000	141	1.7
5	1855.234985	3.455000	149	1.9
6	2040.138346	4.016667	156	1.9
7	2041.481689	4.535000	156	2.2
8	2031.278320	4.776667	162	2.8
9	2028.299988	6.403333	167	2.8

INPUT MANAGEMENT

```
17 PUT(variables, "CutoffUpperSpeed", Wind_Turbin.CutoffUpperSpeed);
18 PUT(variables, "ShortAutoUnbalAllow", Wind_Turbin.ShortAutoUnbalAllow);
19 PUT(variables, "ShortMixUnbalAllow", Wind_Turbin.ShortMixUnbalAllow);
20 PUT(variables, "ShortAutoPowNormMAPE", Wind_Turbin.ShortAutoPowNormMAPE);
21 PUT(variables, "ShortMixPowNormMAPE", Wind_Turbin.ShortMixPowNormMAPE);
22 PUT(variables, "WindSpeed", Wind_Turbin.WindSpeed);
23 PUT(variables, "AvailabilityE", Wind_Turbin.AvailabilityProfile($modelStartDate,
    $forecastEndDate));
24
25 VAR StdRespWindDirections = LIB_Renewable.getWindTurbinStdRespDirection(Wind_Turbin);
26 PUT(variables, "StdRespWindDirections", StdRespWindDirections);
27 VAR StdRespWindSpeeds = LIB_Renewable.getWindTurbinStdRespSpeed(Wind_Turbin);
28 PUT(variables, "StdRespWindSpeeds", StdRespWindSpeeds);
29 VAR StdRespOutputPower = LIB_Renewable.getWindTurbinStdRespOutput(Wind_Turbin);
30 PUT(variables, "StdRespOutputPower", StdRespOutputPower);
31
32
33 return variables;
34
35 library(mgcv)
36
37 if(!is.null(serie)){
38   if(!is.null(X)){
39     if(any(!is.na(X))){
40       #se il DF della covariata contiene meno righe del vettore serie lo riempio di NA
```

Injection
Syntax

Data	
×	26484 obs. of 7 variables
hourlyFrame	17268 obs. of 2 variables
Values	
AirDensity	1.237
Allowance	0.2
CutoffLowerSpeed	3
CutoffUpperSpeed	25
Diameter	30
Elevation	100

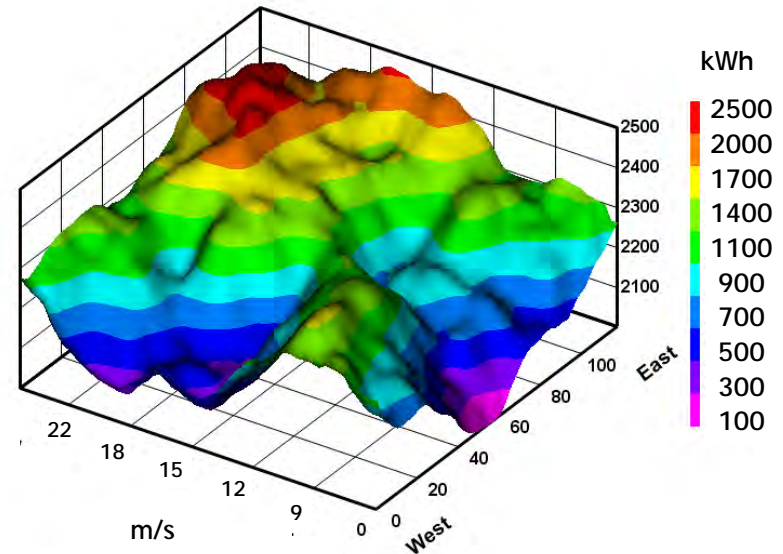
Rdata.out

Methodological Approach

As suggested by Z. Nie and J. S Racine, R Journal December 2012, we made use of nonparametric Regression Splines for Continuous and Categorical Predictors

We found a 2D surface which fitted the Energy Production behaviour

We added other predictors as Regression Splines independent from the surface to compute a General Additive Model



Implementation

```
Model <- gam(data=Data, method="GCV. Cp", formula = serie ~  
+ t2(WindTurbin_Z1_WndMs_Fore1_ms, WindTurbin_Z1_DrcDeg_Fore1_a, k=36) + +  
t2(WindTurbin_Z2_WndMs_Fore1_ms, WindTurbin_Z2_DrcDeg_Fore1_a, k=36) + +  
t2(WindTurbin_Z3_WndMs_Fore1_ms, WindTurbin_Z1_DrcDeg_Fore1_a, k=36) + +  
s(WindTurbin_Z1_WndMs_Fore1_ms_LAG1, k=5) + + s(WindTurbin_Z2_WndMs_Fore1_ms_LAG1, k=5) + +  
s(WindTurbin_Z3_WndMs_Fore1_ms_LAG1, k=5))
```

WHY RENEAWABLES

METHODOLOGICAL APPROACH

TECHNOLOGICAL APPROACH

HAVE A LOOK

STARTING POINT



i4C solution for Energy Management vertically integrated with user's business process

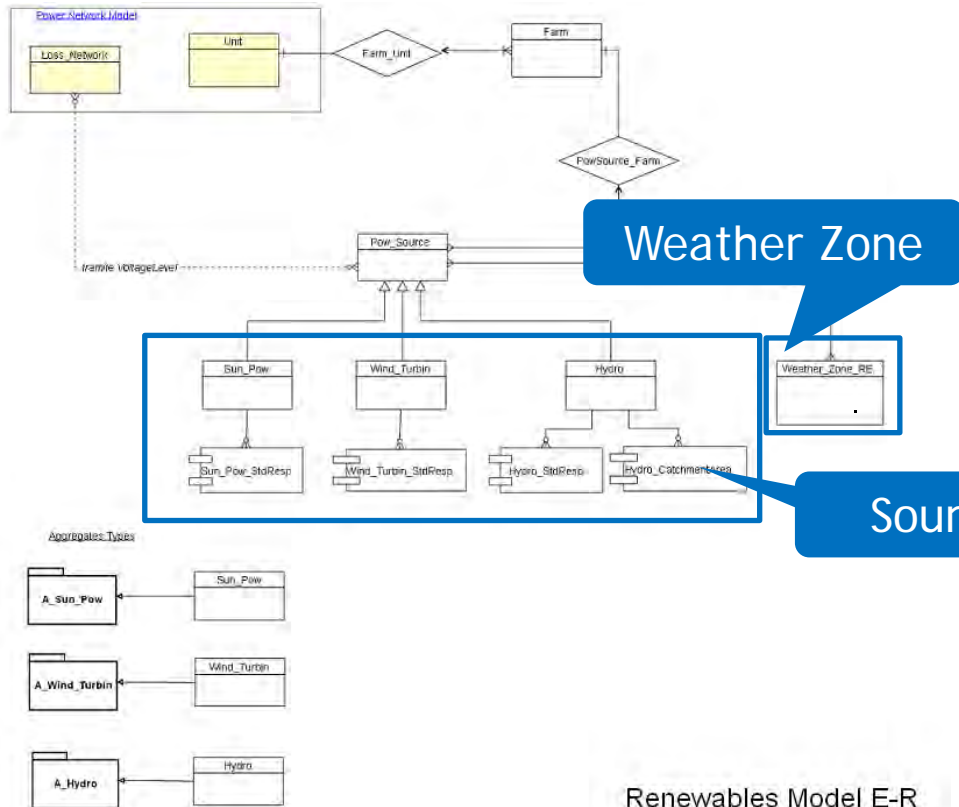


R integration used for both forecasting and analysis purposes

BUSINESS NEED

Advanced Forecasting Algorithms vertically integrated with user's business process and R engine





The screenshot shows the i4C software interface. The sidebar menu includes:

- PREFERITI**
- PARCO RINNOVABILI**
- Franchigia per Rinnovabili
- Generatore Eolico
- Generatore Idroelettrico
- Generatore Solare
- KPI Setup
- Livello di tensione
- Macro Area
- Meteo Configurazione Caricamento
- Meteo File
- Nazione
- Parco Rinnovabili
- Stazione Meteo per Rinnovabili
- Unità
- Zona

The main content area shows a table with 30 elements found:

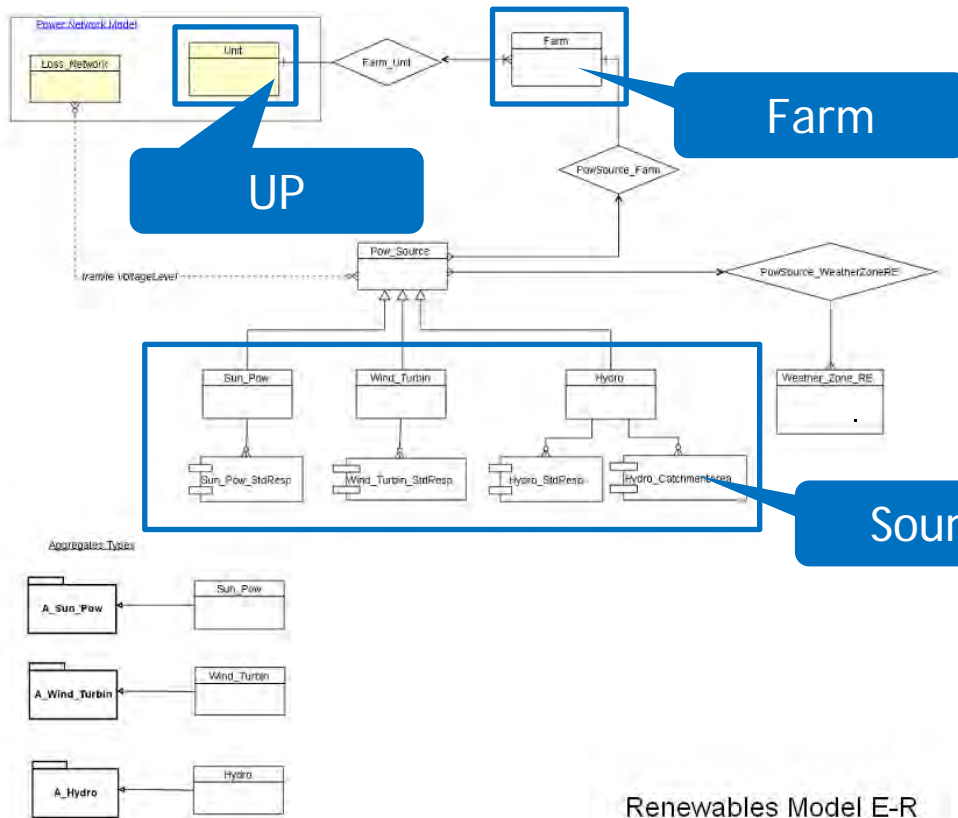
Tutte le Viste

30 elementi trovati

Mostra tipo entità

Id	Nome
IT001E00266104	IT001E002
IT001E00199391	IT001E341
IT001E001526338	IT001E495
IT001E719242618	IT001E719
IT001E719242685	IT001E719
IT001E719243975	IT001E719
IT001E719244068	IT001E719
IT001E719244131	IT001E719
IT001E719244271	IT001E719
IT001E719244327	IT001E719244027 - INNOVATION POWERED BY ANALYTICS

TECHNOLOGICAL APPROACH



Renewables Model E-R

The screenshot shows the i4C software interface. At the top, there are tabs for **PREFERITI** and **PARCO RINNOVABILI**. A sidebar on the right lists various navigation options:

- Franchigia per Rinnovabili
- Generatore Eolico
- Generatore Idroelettrico
- Generatore Solare
- KPI Setup
- Livello di tensione
- Macro Area
- Meteo Configurazione Caricamento
- Meteo File
- Nazione
- Parco Rinnovabili
- Stazione Meteo per Rinnovabili
- Unità
- Zona

The main content area displays **30 elementi trovati** (30 elements found) and a table of results:

Tutte le Viste

Mostra tipo entità

Id	Nome
IT001E7192426104	IT001E002
IT001E7192426104	IT001E341
IT001E7192426104	IT001E495
IT001E719242618	IT001E719
IT001E719242685	IT001E719
IT001E719243975	IT001E719
IT001E719244068	IT001E719
IT001E719244131	IT001E719
IT001E719244271	IT001E719
IT001E719244327	IT001E719244027 - INNOVATION POWERED BY ANALYTICS

WHY RENEAWABLES

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HAVE A LOOK

HAVE A LOOK: MODEL SET UP

Step1: Automated Zone Association

Associazione automatica Generatori - Stazioni Meteo - As Is

Zone associate per generatore

Generatore ↕	Zona 1 ↕	Zona 1 km ↕	Zona 2 ↕	Zona 2 km ↕	Zona 3 ↕	Zona 3 km ↕
TROIA2	TROIA	-	-	-	-	-

Clicca su **Avanti** per modificare le zone

Step2: Model definition

Modifica Modello: Wind R Model (Sintassi R)

Modello con stima

Lista di riferimento per i parametri R

Sintassi Formula

Sintassi Stima

Sintassi Previsione

Named Model

Editable Syntax Box

Zone & Predictor selection

Gestione Covariate

Home	Gruppo	
Wind Turbin - Zone #1 - Wind Speed Intradays	Wind Turbin Intradays Drivers	X
Wind Turbin - Zone #1 - Wind Direction Intradays	Wind Turbin Intradays Drivers	X
Wind Turbin - Zone #2 - Wind Speed Intradays	Wind Turbin Intradays Drivers	X
Wind Turbin - Zone #2 - Wind Direction Intradays	Wind Turbin Intradays Drivers	X

Covariate selezionate

- Wind Turbin - Zone #1 - Wind Direction Intradays
- Wind Turbin - Zone #1 - Wind Speed Intradays
- Wind Turbin - Zone #2 - Wind Direction Intradays
- Wind Turbin - Zone #2 - Wind Speed Intradays

Covariate disponibili nel gruppo

- Wind Turbin - Zone #1 - Coverage Lo Intradays
- Wind Turbin - Zone #1 - Coverage Me Intradays
- Wind Turbin - Zone #1 - Coverage Hi Intradays
- Wind Turbin - Zone #1 - Coverage Tot Intradays
- Wind Turbin - Zone #1 - Irradiation Drc Intradays
- Wind Turbin - Zone #1 - Irradiation Dff Intradays

«< < 1 2 3 > >>

HAVE A LOOK: FORECAST

Step3: Forecast Visualization and Analysis

Forecast Management

From: 01/01/2010 0 To: /01/2010 16. 23 Update Export

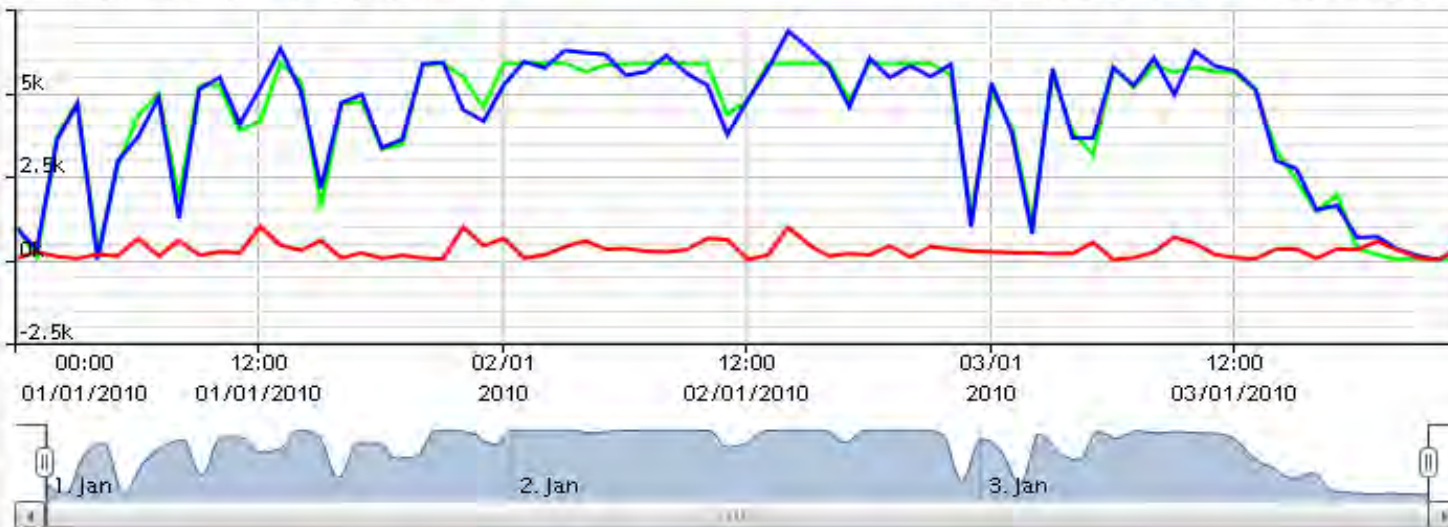
Graph Table

Forecast series type: Automatic forecast Graph type: Line Time granularity: Hourly

Actual Forecasts Error

Zoom 1m 3m 6m YTD 1y All

From 01/01/2010 To 03/01/2010



SP Auto + Man (%): SP Auto (%): 0.51751 SP Man (%):

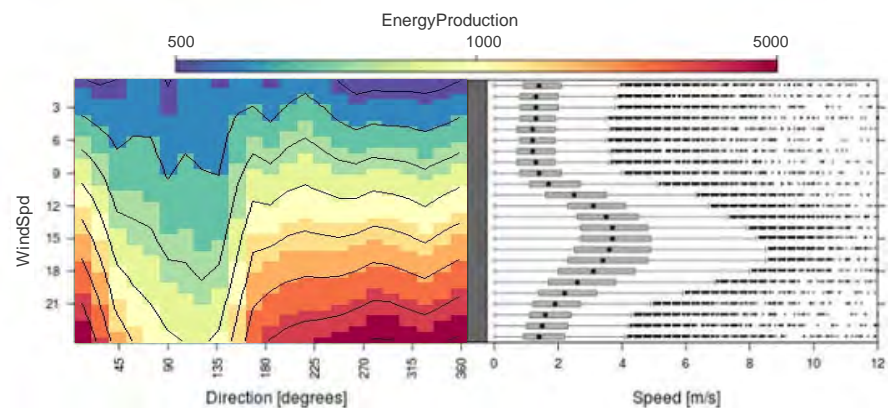
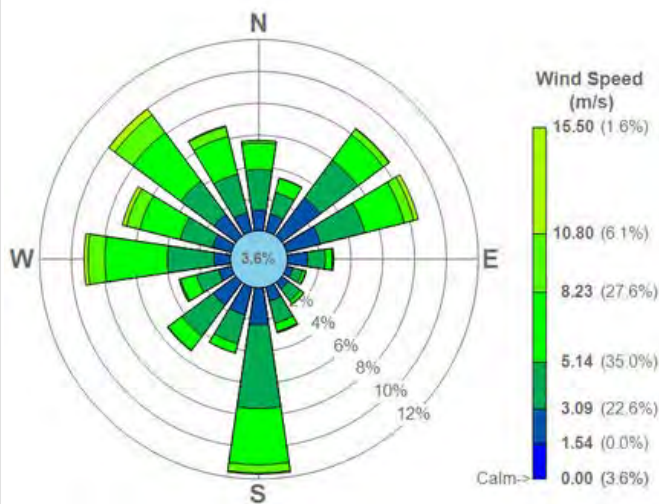
Exit

HAVE A LOOK: PREDICTORS ANALYSIS

Analisi Predittori

Wind_Turbin TROIA2
Ambito di Previsione Previsione Eolico a breve

Risultato Dettagli



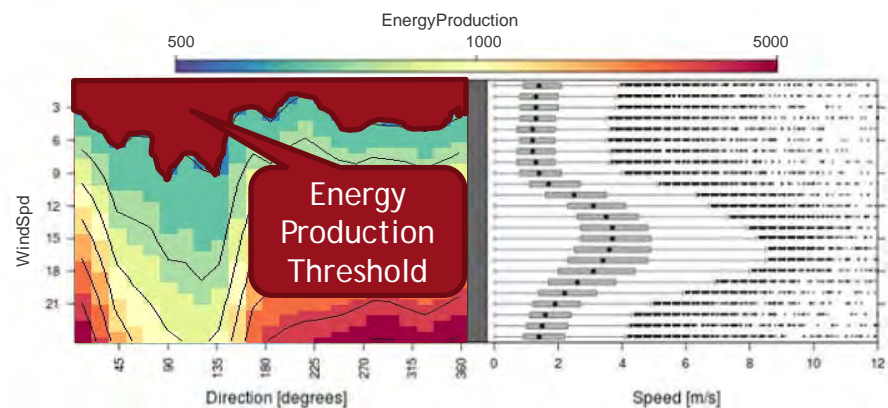
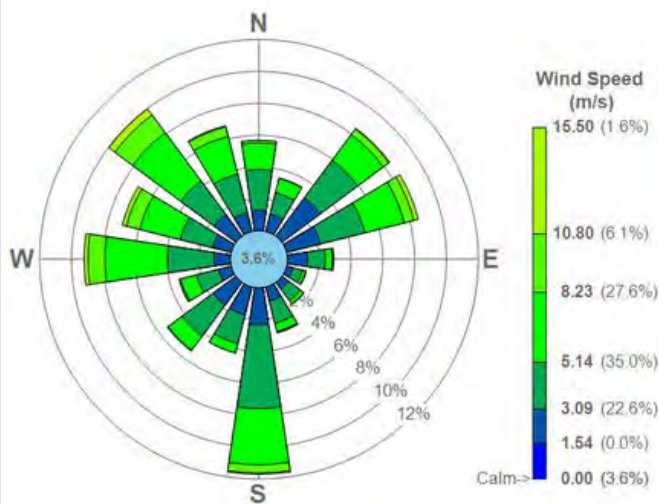
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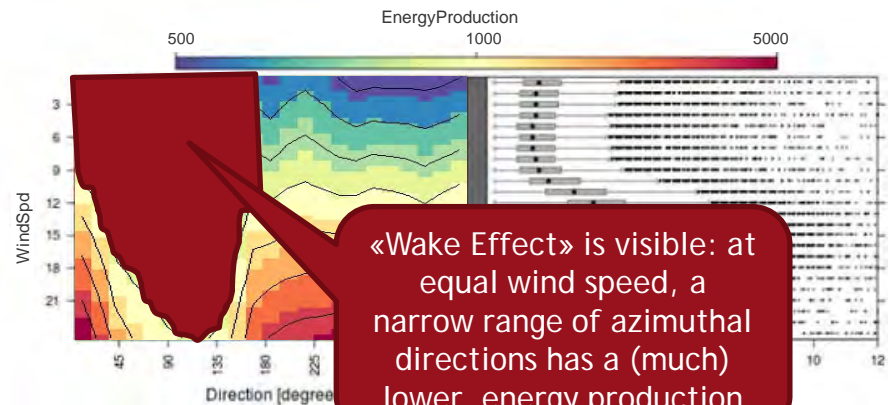
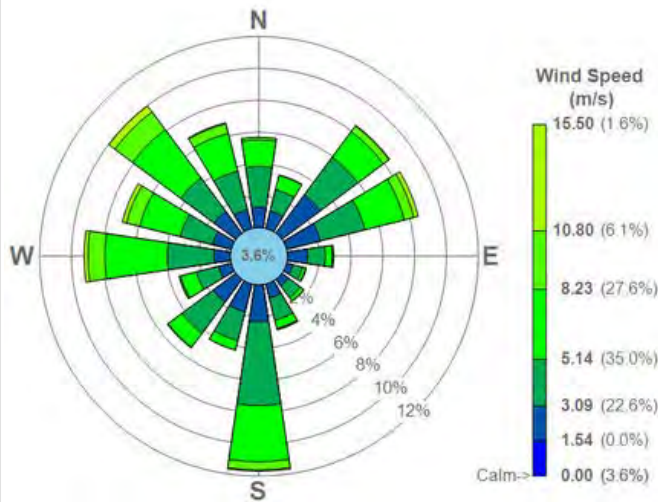
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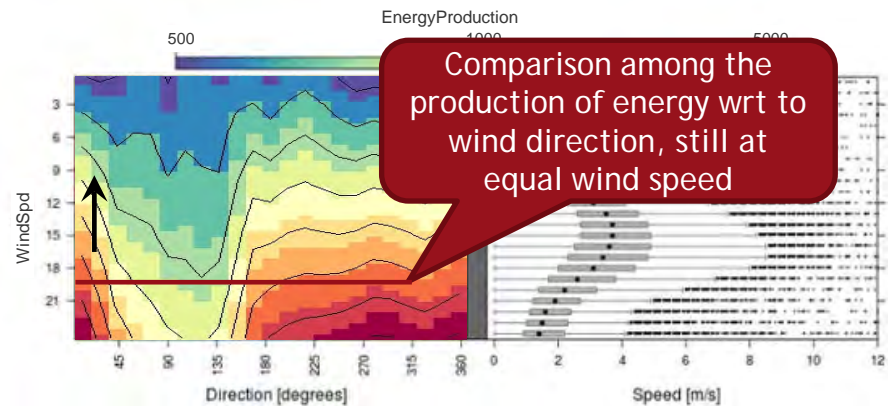
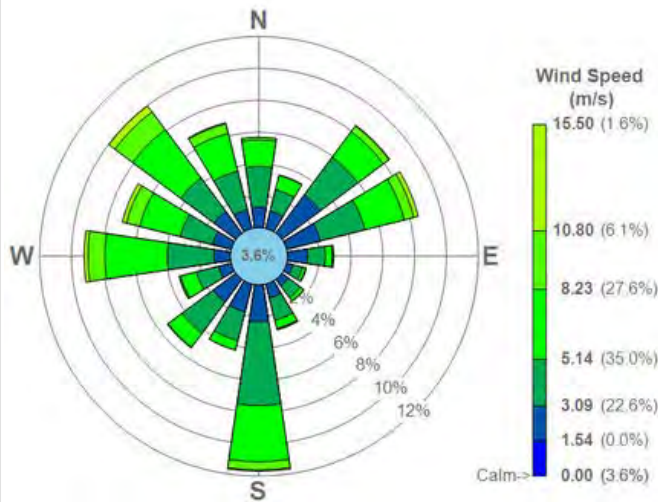
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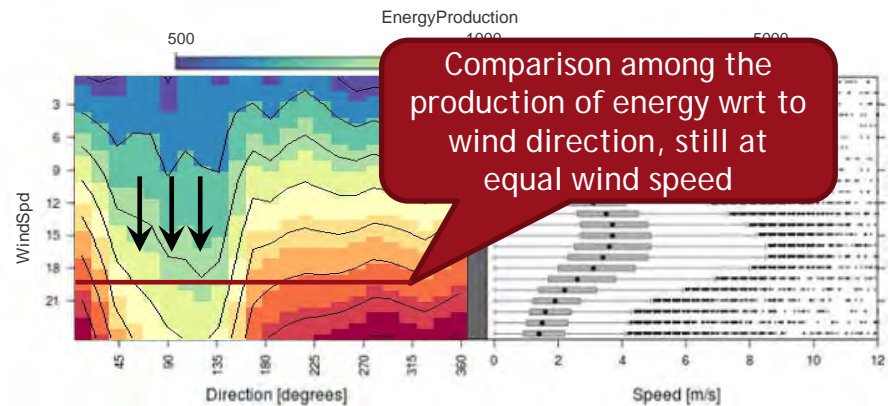
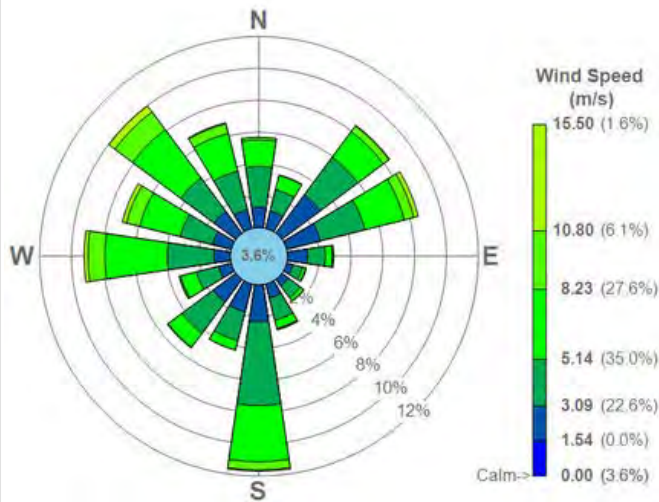
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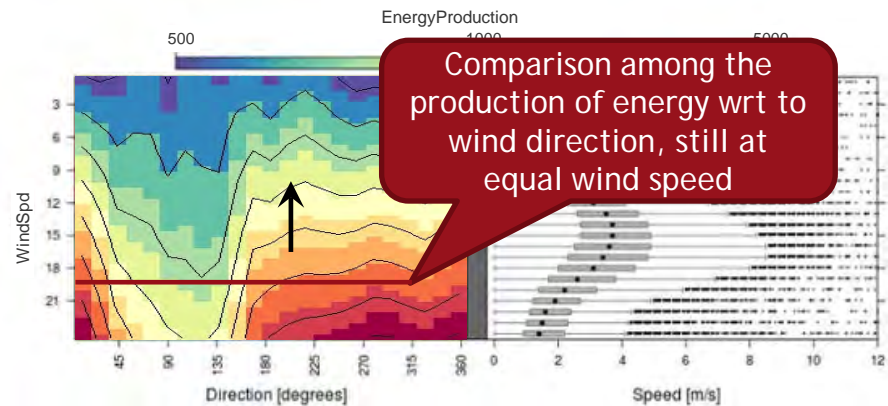
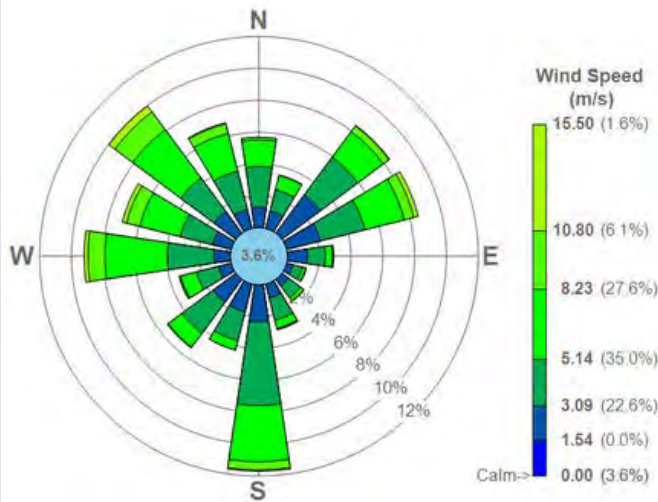
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- Renewable Energy Sources: a suitable application field for forecasting methods, driven by complex external effects
- R huge potential for such analysis can be enhanced by its integration into business processes: this is the only condition to make an application actionable
- Effectiveness: Advanced Analytics Application are more effective, because they can follow the user in all the phases of its business
- Integrating R with enterprise operational environments is a solution to gain R a wider audience, letting it express its full potential even when statistical/scientific expertise is not so deep



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