



नीवे NIWE

Current Practices in Wind Power Forecasting & Scheduling



Bernd Kratz · Managing Director

2017-01-22

The logo for 'enercast' is displayed in a green, sans-serif font. To the right of the text is a circular icon divided into three segments: a green segment at the top, a red segment at the bottom right, and a white segment at the bottom left. The background of the entire slide is a composite image of a clear blue sky with a bright sun, two white wind turbines, and a field of blue solar panels in the foreground.

**We increase the value of
renewable energy by up to 25%**

Company at a Glance

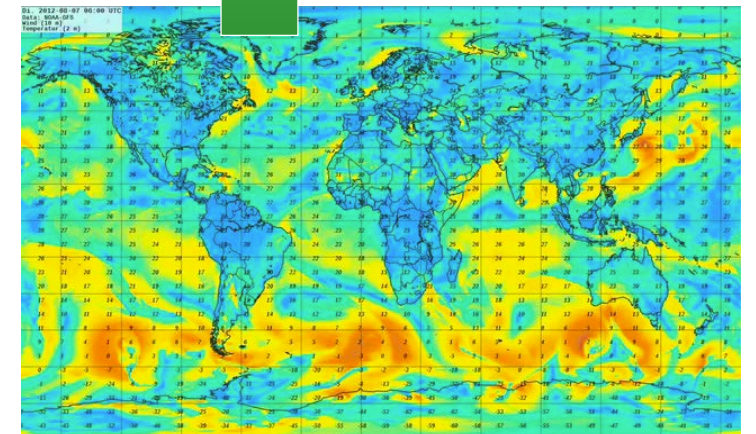
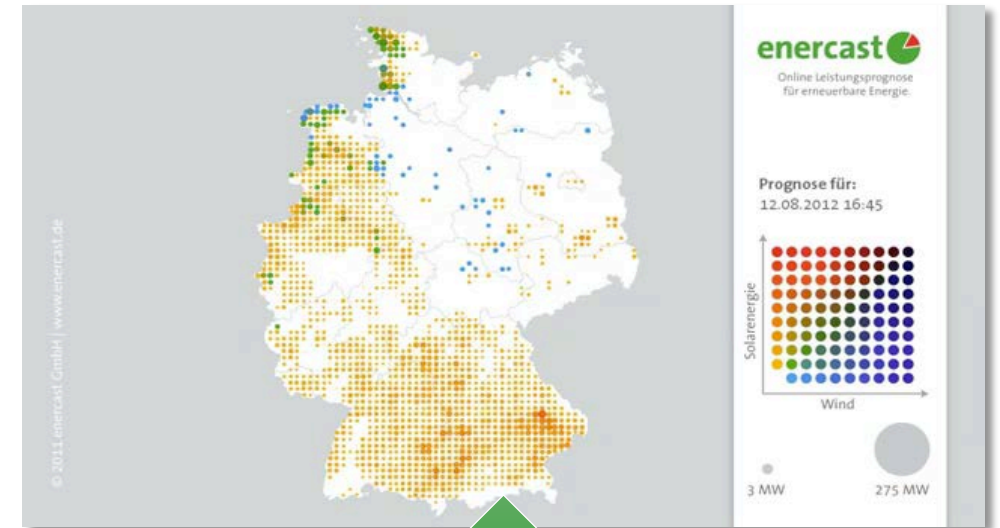
- Founded 2011 in Kassel, Germany
- 3-year CAGR: 47%
- Forecasting 80 gigawatts of renewable energy around the world
- 35 dedicated professionals (engineers, computer scientists, data scientists, mathematicians, physicists, meteorologists)
- Venture capital from two of Germany's top funds: Innogy Venture Capital, High-Tech Gründerfonds
- Partnerships with Fraunhofer IWES and Kassel University

Source: Science Park Kassel



We Deliver

- Award-winning power forecasts for wind and solar
- Superior forecast quality due to artificial intelligence (self-learning neural networks)
- Ensemble forecasts using top notch weather data and exclusive Fraunhofer IWES algorithms
- Software-as-a-service tool suite providing our users with interactive access to weather intelligence
- Robust, performant, industrial-strength delivery – transmitting 700.000 data sets around the clock and around the world
- Applied artificial intelligence know-how enabling process optimization for essential industries



Power Forecasts for Renewable Energy

14,049
sites

Maximizing
economic benefit
for operators

79,695
megawatts
installed

Providing data for
grid stability

700,000
data sets
per day

Enabling
energy trading

18
countries

Powering the
digitization of
infrastructure

Applied Artificial Intelligence Drives Our Business



Energy Forecasting



Power Forecasts for
Renewable Energy

Energy Digitization



Optimization of
Smart Grids

Applied Artificial Intelligence



Process Optimization
for Essential Industries

Products

Projects

Serving a Wide Range of Customers



SIEMENS

e.on



Wachstum erleben.

VIESSMANN



enel

TRÄNSNET BW



HITACHI
Inspire the Next



Partnership with Fraunhofer IWES

- Fraunhofer IWES is Germany's most renowned research institution in the field of renewable energies.
- Fraunhofer IWES was founded in 1988 from ISET e. V. and has 26 years of experience in the field of renewable energy.
- Enercast has exclusive rights to the Fraunhofer prediction algorithms.
- In Fraunhofer IWES, more than 500 scientists are working on the different topics of renewable energy.

Source: Fraunhofer IWES



Working with all TSOs in Germany

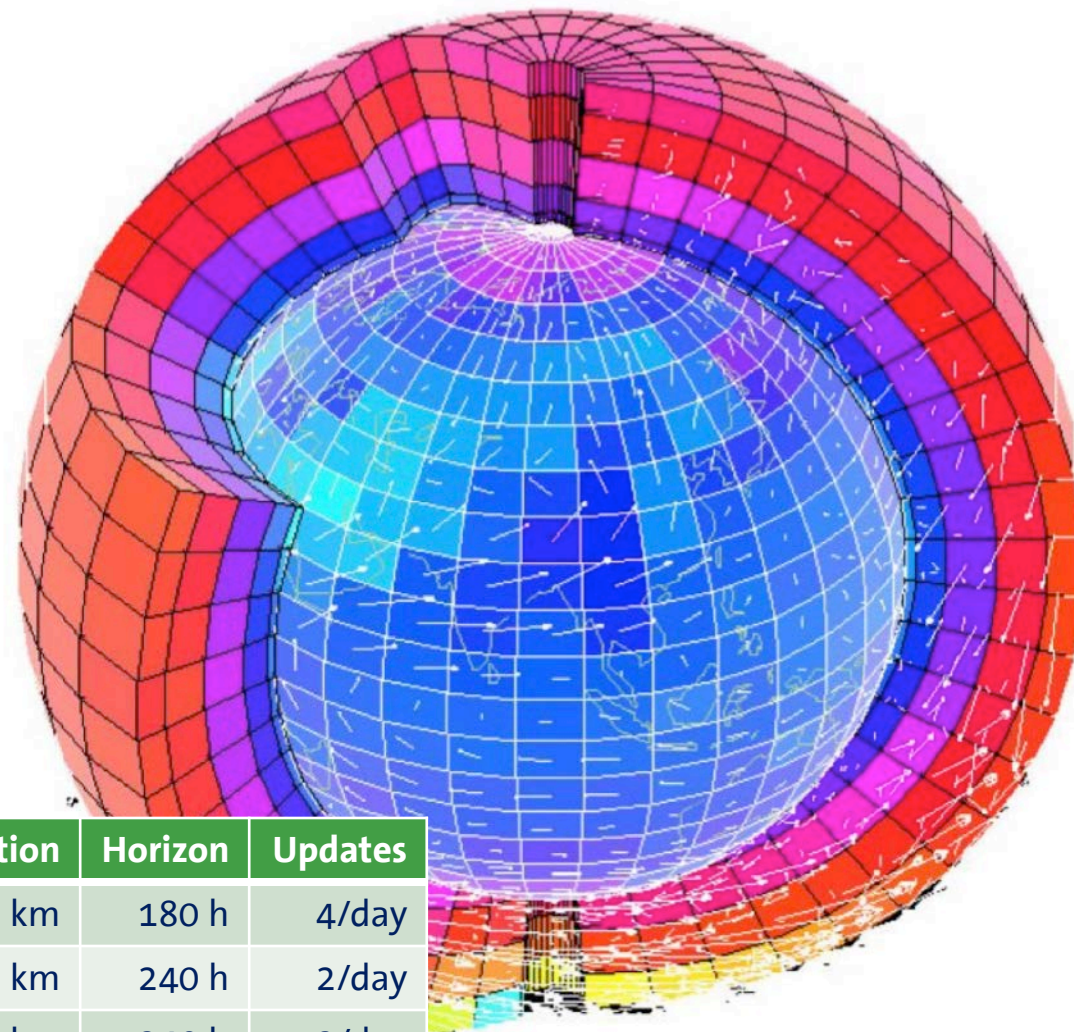
- **TenneT TSO**
operates an extra-high voltage grid with a total length of around 10,700 kilometers in Germany
- **50Hertz Transmission**
operates the extra-high voltage grid in eastern Germany with a length of 9,750 kilometers
- **Amprion**
has the longest extra-high voltage network in Germany with a length of approx. 11,000 km.
- **TransnetBW**
operates a transmission grid with a length of 3,200 km.



Creating Best-in-Class Forecasts

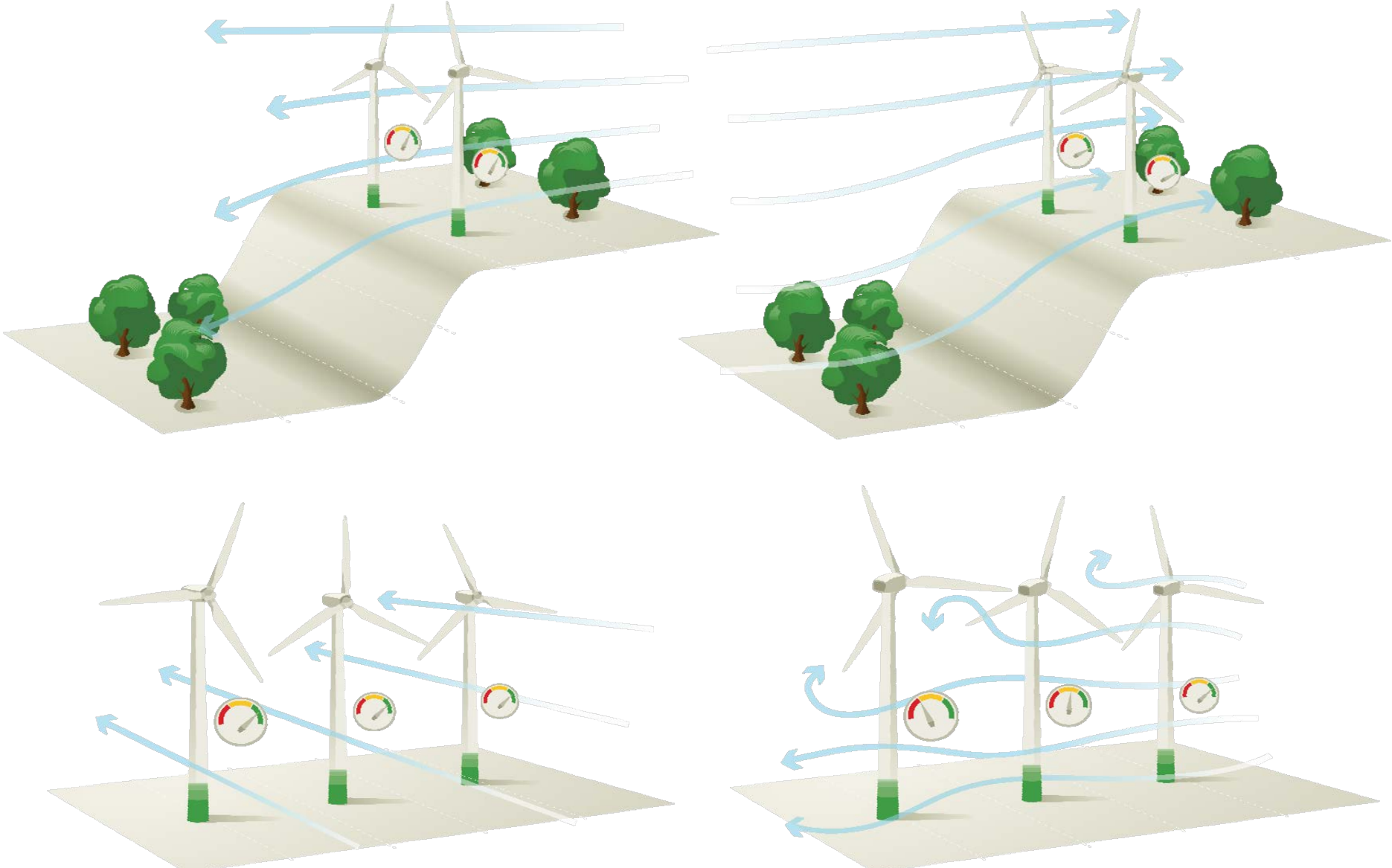
Numerical Weather Prediction (NWP) Models

- 8-12 models from the leading global providers
 - COSMO, ICON, ECMWF, GFS, CMC, Euro4, JMA, ...
- Data from 3 satellite feeds
 - Transvalor, LSA-SAF, NOAA GHI
- 150 GB meteorological data per day
- Over 3 years (600 TB) of fast access data
- Horizon of up to 30 days
- Site-specific ensemble configuration

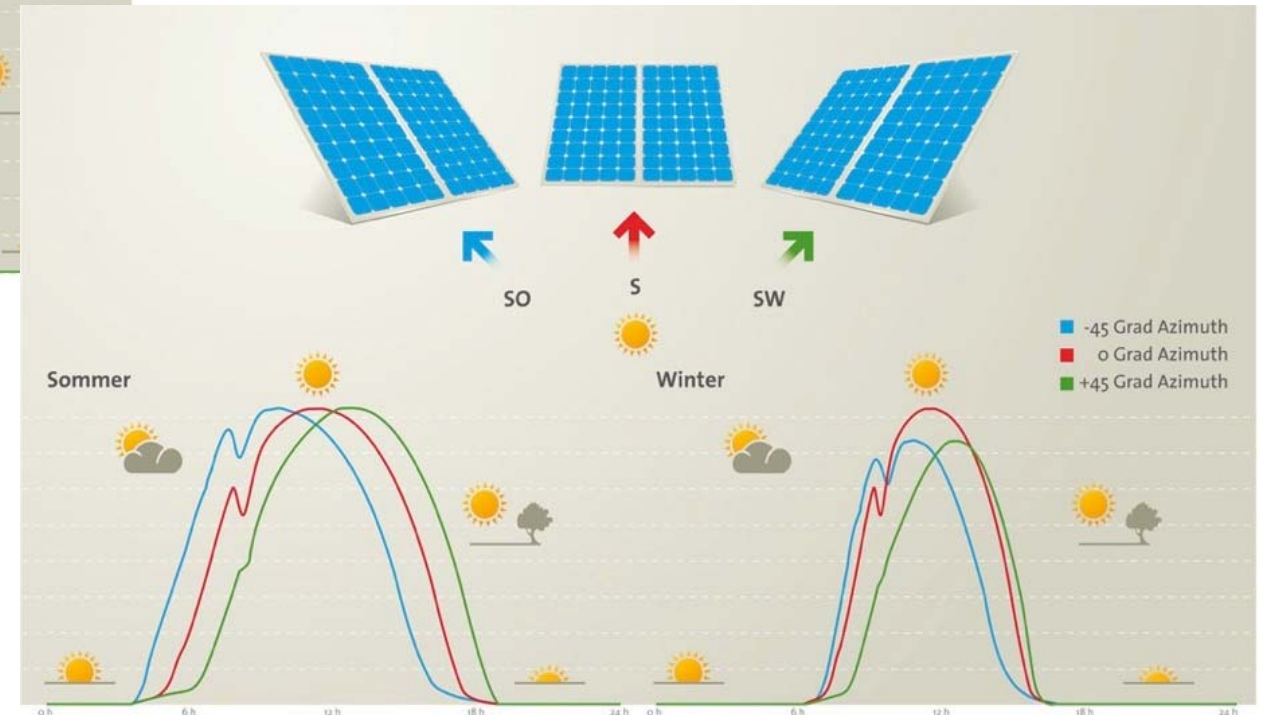


Examples	Resolution	Horizon	Updates
GFS	40x40 km	180 h	4/day
ECMWF	10x10 km	240 h	2/day
GDPS	25x25 km	240 h	2/day
ICON_WORLD	18x18 km	174 h	4/day
COSMO_DE	3x3 km	18 h	8/day

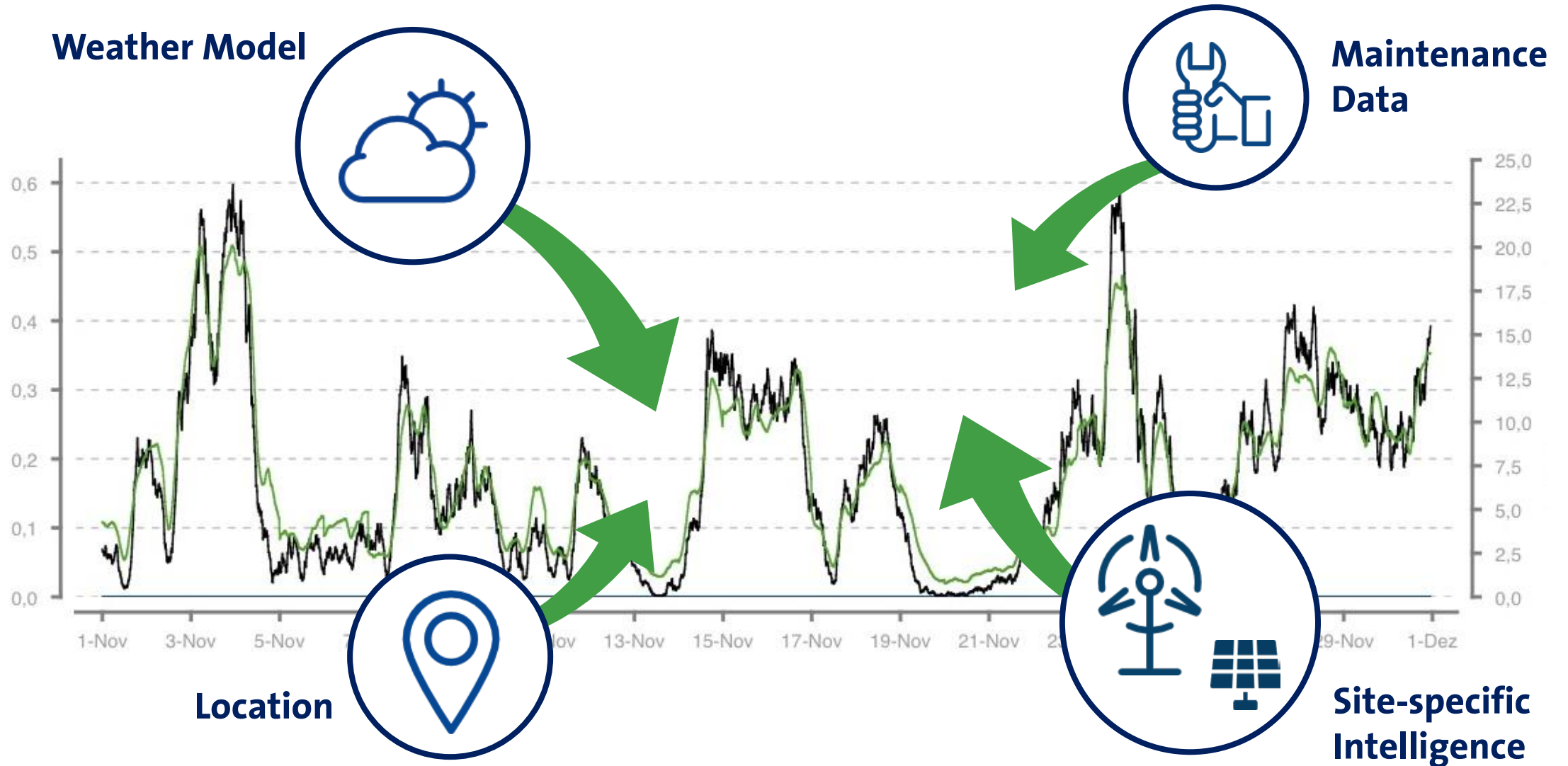
Translating Weather Into Power Forecasts



Translating Solar Irradiation Into Power Forecasts

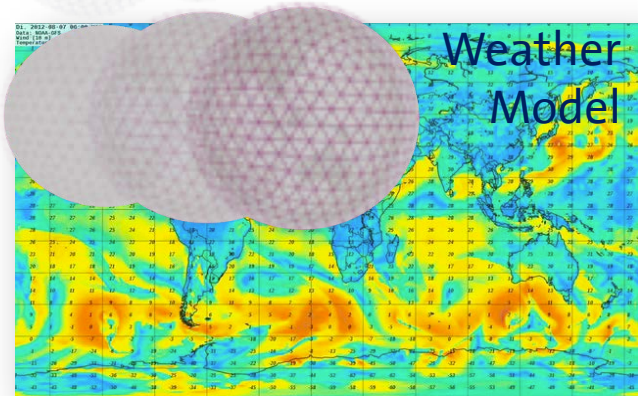
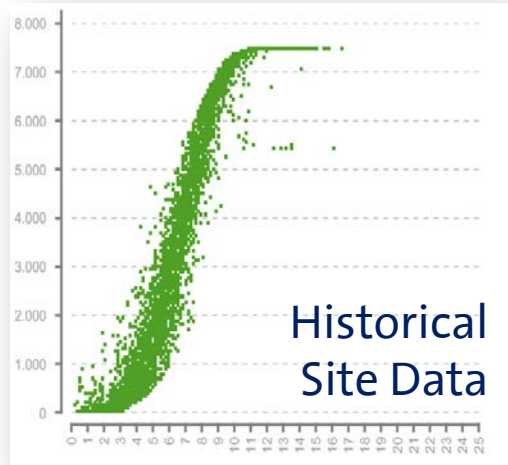


Components of a Power Forecast

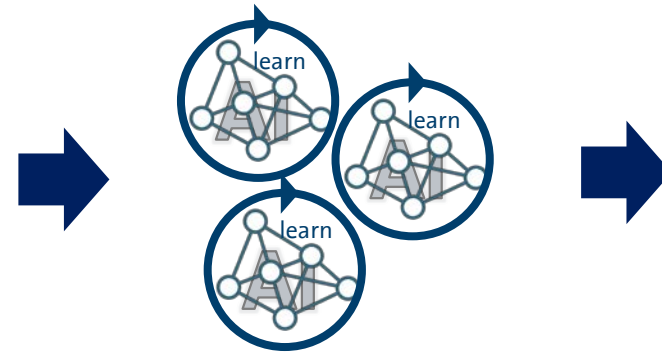


Forecast Based on Applied Artificial Intelligence

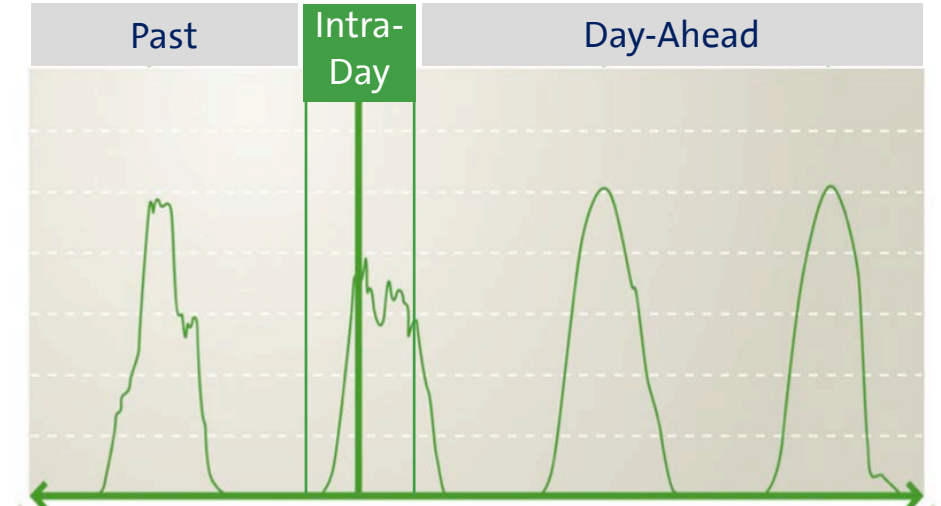
Weather Model + Historical Site Data



Artificial Neural Networks (ANN)



Site-Specific Forecast



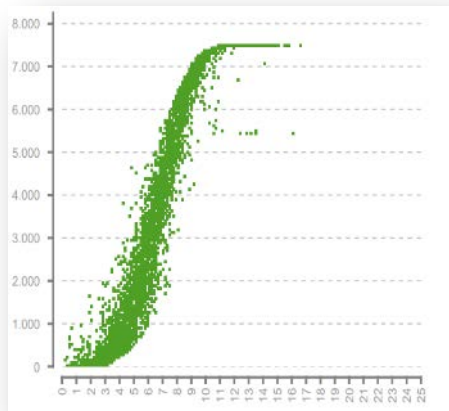
Each ANN trains (learns) the impact of weather on power output based on historical model output, combined with historical site data

Multiple ANN in competitive mode – best win...

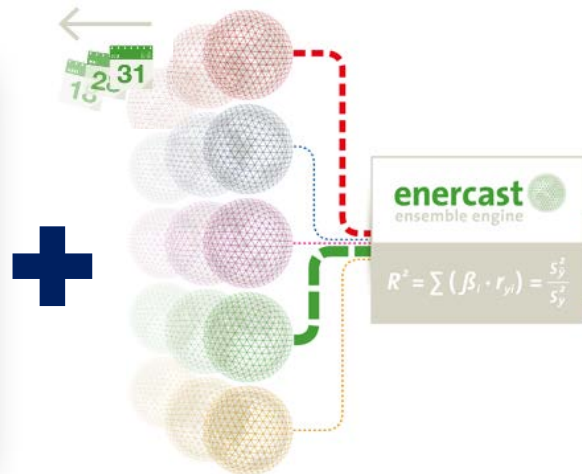
Smart Ensembling Algorithm for Superior Accuracy

- Combination of multiple weather models
- Hundreds of ANN in competitive mode yield site-specific selection of the optimal model (exclusive algorithm developed with Fraunhofer IWES)
- Automatic selection of the best ANN

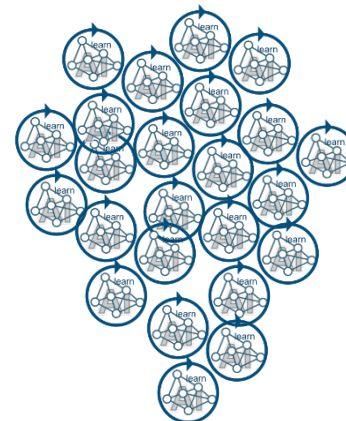
Historical Site Data



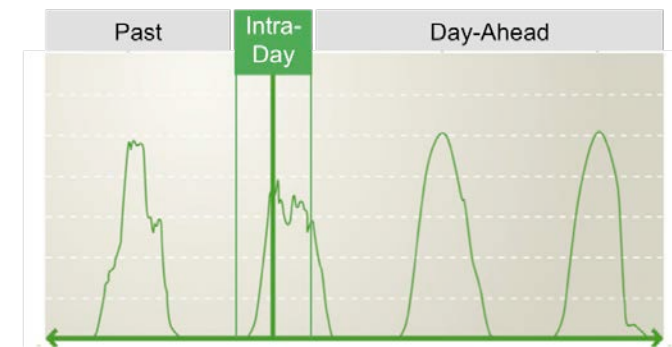
Multiple Weather Models



Automatic ANN Selection



Site-Specific Forecast

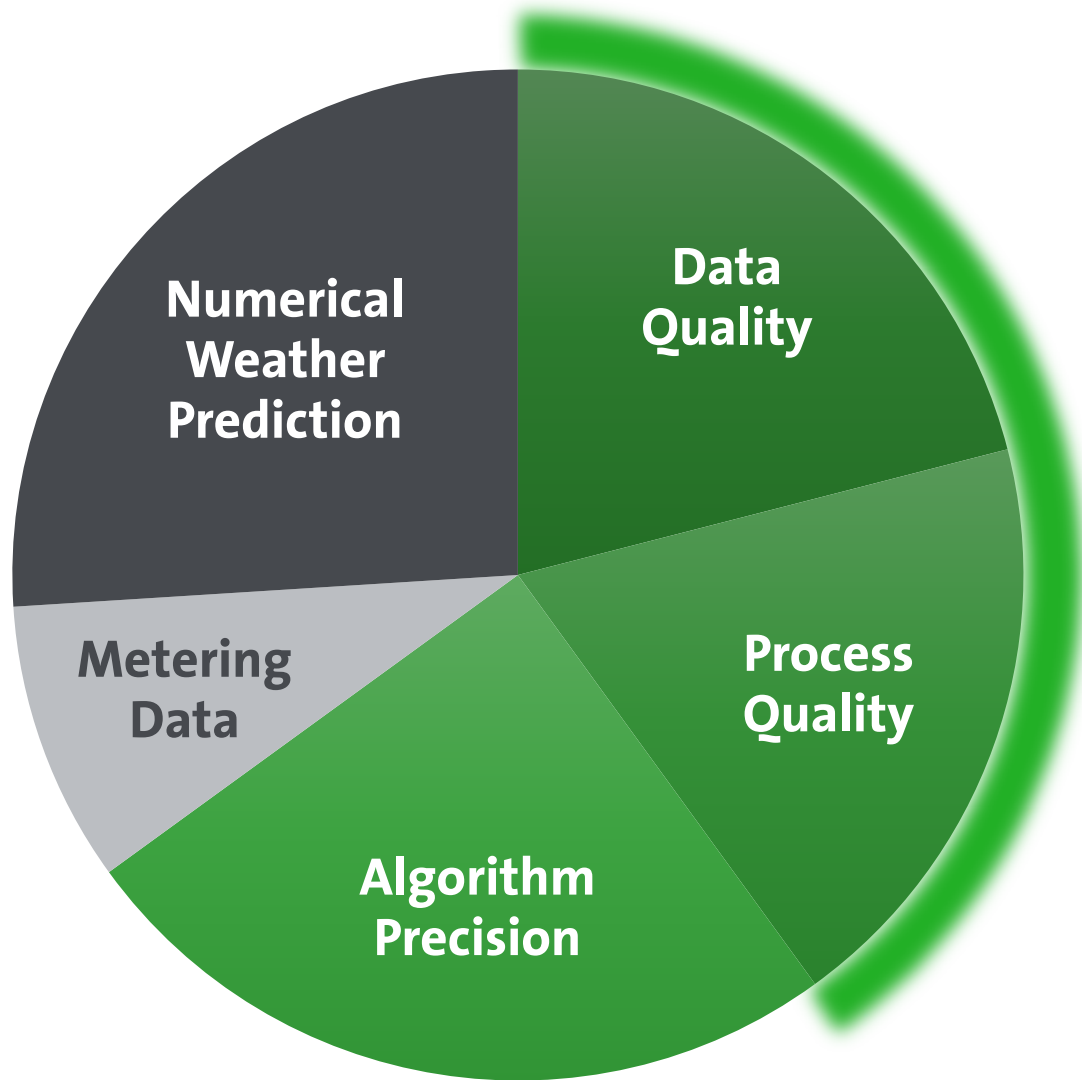


Weather Intelligence Is Big Data Analytics

- Exclusive MeteoStore X repository gives users instant access to 10 years of NWP models worldwide
 - Instant calculation of localized timeline of all models
 - Accessing up to 10,000 co-ordinates in a single request
- Smart validation and cleansing of incoming data
- On-the-fly, server-side refinement of output data
 - Artificial intelligence algorithms supply users with lean, high-value, application-specific results
 - Big data analytics of NWP generate site-specific ensembles
- Training of over 2,000 artificial neural networks per site
- Processing over 100,000 measurement signals and over 600,000 outgoing data sets every day

Source: DARPA/Wikimedia Commons

Data Quality Drives Forecast Quality



- About one third of forecast quality losses are caused by unprecise or faulty data or processes
- enercast uses artificial intelligence combined with interactive tools to help our customers get the most out of the real-life data they have

Delivering Best-in-Class Products

Weather Intelligence At Your Fingertips



Intuitive, web-based user interface provides access to all your assets, your data, your forecasts – from anywhere and any device

The screenshot displays the enercast web application interface. At the top, there is a navigation bar with icons for Sites, Clearing, Forecasts, Weather, Assessment, Trader, Intelligence, Plans, and API. The main content area is divided into several sections:

- Site Evaluation:** A map of Europe with markers for various sites. Below the map, there is a list of sites with their names and locations.
- Sites:** A map of Germany with markers for various sites. Below the map, there is a table with columns for Type, Name, Location, Groups, Metering Data, Data, Quality, Logs, Maintenance, Delivery, and Forecast.
- Period:** A section for selecting a time period, with a date range from 2017-05-01 to 2017-05-31 and buttons for years 2014, 2015, 2016, and 2017.

Type	Name	Location	Groups	Metering Data	Data	Quality	Logs	Maintenance	Delivery	Forecast
WP	WP Soniefstein	(49.4733/7.2268)		Upload Choose						Forecast #1
WP	WP Alahcim	(49.7503/8.2898)		Upload Choose						Forecast #1
PV	PV1	(50.0164/8.9923)		Upload Choose						Forecast #1
PV	PV1	(50.0164/8.9923)		Upload Choose						Forecast #1
WP	WP Elsdorf-Lunzenau	(50.9667/12.7167)		Upload Choose						Forecast #1
WP	WP Blauskuenlinie	(50.0517/12.2253)		Upload Choose						Forecast #1



Comprehensive Product Suite

- Renewable energy forecasts
- Area forecasts
- Site assessment
- Data cleansing
- Weather data feeds



Configurations Tailored to Your Needs

- Week Ahead, Month Ahead
 - Horizon max. 30 days
 - 1 forecast in 24 hours
- Day Ahead
 - Based on a weather model ensemble
 - Horizon 24 hours of the next day
 - Minimum of 4 updates till 12:00 h
- Intraday
 - Based on a weather model ensemble
 - 24 updates
 - Horizon 24 hours
- Real Time
 - Based on weather model ensemble, satellite measurements or live metering data
 - Updated every 15 minutes



Continuous Quality Monitoring



KPI monitoring

- Power distribution
- Power forecast vs. actuals
- nRMSE, MAE, ...
- Correlation weather vs. power

enercast
Online-Leistungsprozess für erneuerbare Energien

Customer: Company
Facility-ID: 2182d2e0-b18d-4017-bc6d-f9df42413850
Period of Analysis: 1.1.2016 - 15.8.2017

www.enercast.de



enercast - Quality Sheet

Site: ercast GmbH
DAT_AHEAD

Longitude: 12.193013333333333; Latitude: 55.120000000000004

Electric:	11000.0 kW
P:	11000.0 kW
PL1:	10.50 kW
PL2:	1025.7487 kW
Product:	1500.000 kW
Efficiency:	4.9917%
Loss:	11.0614%
Loss:	4.530%
Loss:	0.0708%
Loss:	47.82%

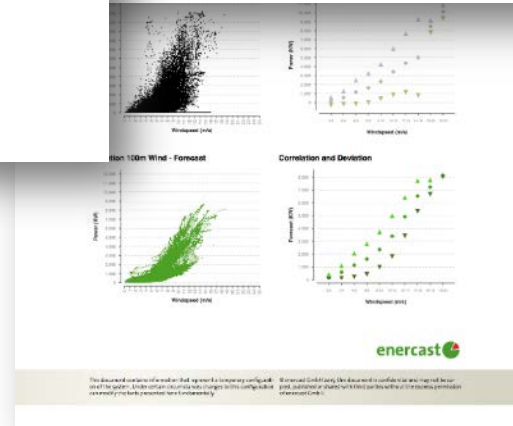
Mean Absolute Error (MAE)

$$MAE = \frac{1}{n} \sum_{t=1}^n |P_{t,actual} - P_{t,forecast}|$$

Root Mean Square Error (RMSE)

$$RMSE = \sqrt{\frac{1}{n} \sum_{t=1}^n (P_{t,actual} - P_{t,forecast})^2}$$

Coefficient of Correlation

$$r = \frac{\sum_{t=1}^n (P_{t,actual} - \bar{P}_{actual})(P_{t,forecast} - \bar{P}_{forecast})}{\sqrt{\sum_{t=1}^n (P_{t,actual} - \bar{P}_{actual})^2 \sum_{t=1}^n (P_{t,forecast} - \bar{P}_{forecast})^2}}$$


winning

award

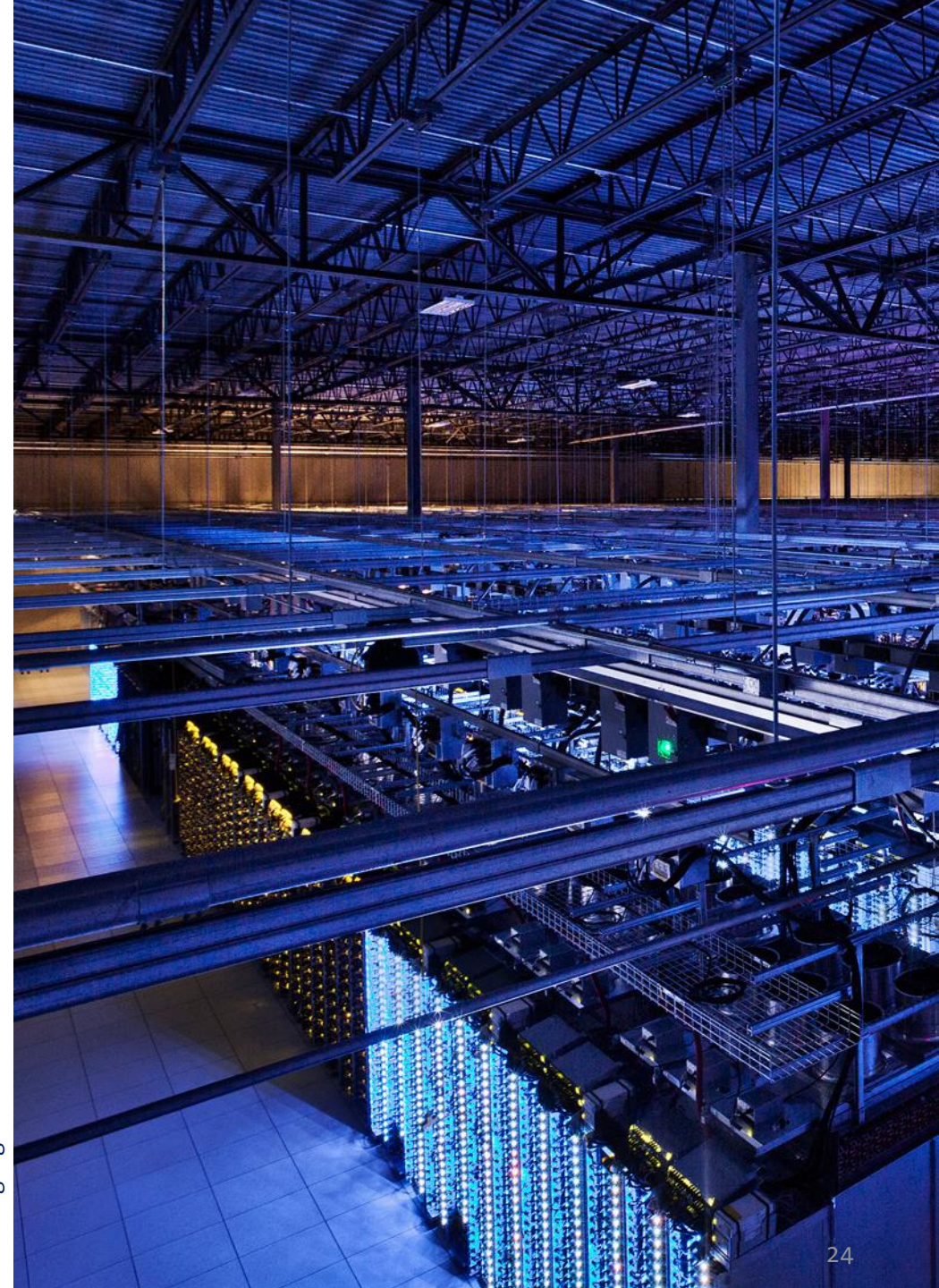
The WIG (Winning) Award for Best Regional Grid Operator awarded Enercast GmbH with the Innovation Award 2017. Enercast GmbH came in third in the services category.

The web service enercast placed third for the Innovation Award 2017 in the category of software which is awarded by the Initiative NetzeLand.

Robust Big Data Infrastructure

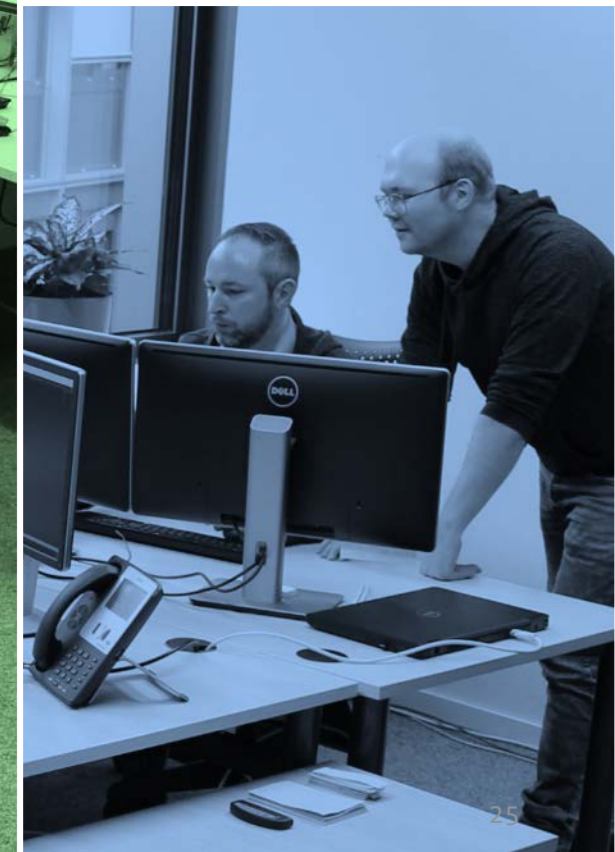
- Operating from 3 distributed, redundant, secure data centers in Germany since 2012
- 24/7 calculation, transmission, and monitoring
 - Automatic re-delivery upon transmission failure
- 600 TB of managed data – adding 150 GB per day
- Software-as-a-service for best scalability
- Extensible import/export structure
 - Over 700,000 data sets exchanged per day
 - Leading data formats: MSCONS, CSV, JSON, XML, ...
 - Protocols: REST, SOAP, ftp/sftp, secure mail

Source: google.com/datacenters



Customer Support At Your Side

- Standard
 - Continuous product updates and maintenance
 - Technical product support (e-mail only)
 - Response times subject to availability
- Professional
 - Phone support (during regular business hours)
 - 24 h initial response time (during business days)
 - Application and setup support
- Premium
 - 24/7 emergency hotline
 - 4 h initial response time (during business days)
 - Access to enercast analytics experts





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