ARV

CLIMATE POSITIVE CIRCULAR COMMUNITIES

D7.3 - CITY FINE RESOLUTION WEATHER FORECASTING AT DEMO SITES

WP7 - EFFICIENT OPERATION AND FLEXIBILITY

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[1] ARV is a Norwegian word meaning "heritage" or "legacy". It reflects the emphasis on circularity, a key aspect in reaching the project's main goal of boosting the building renovation rate in Europe.

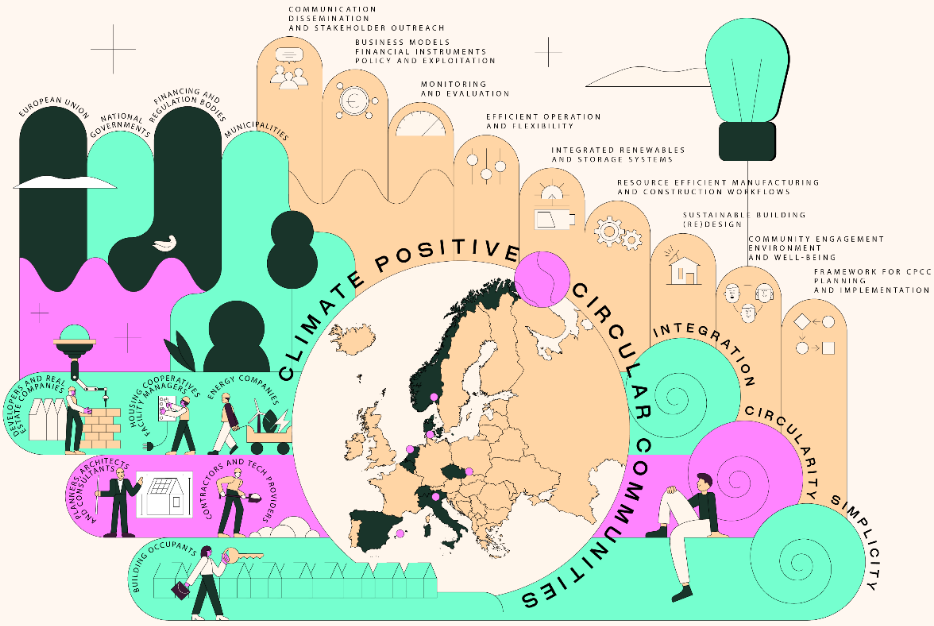
ABOUT THE ARV PROJECT

The vision of the ARV project is to contribute to speedy and wide scale implementation of Climate Positive Circular Communities (CPCC) where people can thrive and prosper for generations to come. The overall aim is to demonstrate and validate attractive, resilient, and affordable solutions for CPCC that will significantly speed up the deep energy renovations and the deployment of energy and climate measures in the construction and energy industries. To achieve this, the ARV project will employ a novel concept relying on a combination of 3 conceptual pillars, 6 demonstration projects, and 9 thematic focus areas.

The 3 conceptual pillars are integration, circularity, and simplicity. **Integration** in ARV means the coupling of people, buildings, and energy systems, through multi-stakeholder co-creation and use of innovative digital tools. **Circularity** in ARV means a systematic way of addressing circular economy through integrated use of Life Cycle Assessment, digital logbooks, and material banks. **Simplicity** in ARV means to make the solutions easy to understand and use for all stakeholders, from manufacturers to end-users.

The 6 demonstration projects are urban regeneration projects in 6 locations around Europe. They have been carefully selected to represent the different European climates and contexts, and due to their high ambitions in environmental, social, and economic sustainability. Renovation of social housing and public buildings are specifically focused. Together, they will demonstrate more than 50 innovations in more than 150,000 m^2 of buildings.

The 9 thematic focus areas are 1) Effective planning and implementation of CPCCs, 2) Enhancing citizen engagement, environment, and well-being, 3) Sustainable building re(design) 4) Resource efficient manufacturing and construction workflows, 5) Smart integration of renewables and storage systems, 6) Effective management of energy and flexibility, 7) Continuous monitoring and evaluation, 8) New business models and financial mechanisms, policy instruments and exploitation, and 9) Effective communication, dissemination, and stakeholder outreach.



The ARV project is an Innovation Action that has received funding under the Green Deal Call LC-GD-4-1-2020 - Building and renovating in an energy and resource efficient way. The project started in January 2022 and has a project period of 4 years, until December 2025. The project is coordinated by the Norwegian University of Science and Technology and involves 35 partners from 8 different European Countries.

EXECUTIVE SUMMARY

Weather within urban areas and cities can vary greatly due to local effects. This can be problematic for thermal comfort and energy solutions for individual houses and businesses, as global or regional weather models do often not capture local conditions with adequate precision. ARV partner ENFOR has developed and operates a software solution, called MetFor™, that delivers a locally optimized weather forecast which can add significant value to highly weather dependent business activities. MetFor™ is based on advanced machine learning, forming a self-learning system. By combining meteorological forecasts and measurements from a local weather station, the system is not only able to produce accurate weather forecasts, but can also automatically and continuously improve the forecasts as more data is received over time

Weather predictions from MetFor™ are used as input for heat demand forecasting, as it improves the forecast accuracy. This enables district heating companies and others to operate their networks and production facilities more efficiently, saving fuel costs and reducing CO_2 emissions.

The report includes a description of the city fine resolution weather forecasting solution to be implemented for the ARV demo sites.

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1. INTRODUCTION

Weather within urban areas and cities can vary greatly due to local effects. This can be problematic for thermal comfort and energy solutions for individual houses and businesses, as global or regional weather models do often not capture local conditions with adequate precision. ENFOR has developed and operates a software solution, MetFor™ that delivers a locally optimized weather forecast which can add significant value to highly weather dependent business activities.

Weather predictions from MetFor™ are used as input for heat demand forecasting, as it improves the forecast accuracy. This enables district heating companies and others to operate their networks and production facilities more efficiently, saving fuel costs and reducing CO_2 emissions (ENFOR, n.d.).

2. OBJECTIVES

ENFOR's weather forecasting algorithm is to be deployed for the ARV sites with the aim to provide reliable weather information for heat solutions at the demo sites.

3. INPUT DATA SOURCES

This chapter includes information about the data streams used for the forecasting algorithms.

3.1. WEATHER OBSERVATIONS

Weather observations from the ARV demo sites, shown on figure 1, are not yet available. The forecasting solution is thus demonstrated for nearby weather stations and expected to be updated later when such observations from the sites become available. High quality measurements are obtained from the publicly available NOAA Integrated Surface dataset (ISD). The nearest available weather station to each of the demo sites is chosen, see table 1.

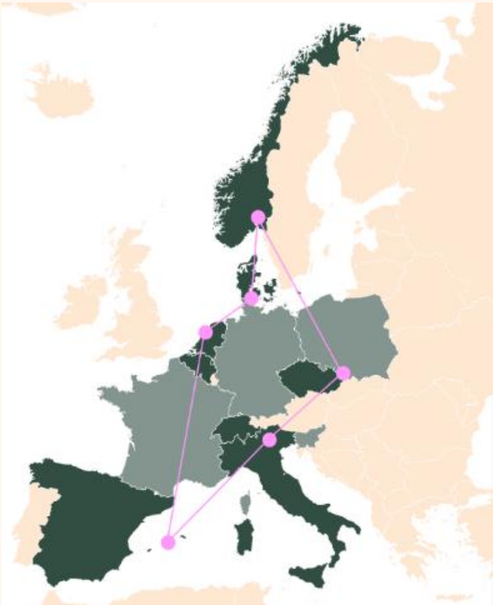

***Figure 1**. Map of the ARV demo projects.*

***Table 1**. Weather station locations.*

Site	Latitude [°]	Longitude [°]	Distance to ARV site [km]	Measurement resolution [min]
Sønderborg	54.96	9.79	6.4	30
Trento	46.02	11.12	6.2	60
Palma	39.55	2.73	7.3	30
Utrecht	52.10	5.18	7.6	60
Oslo	59.95	50.72	3.7	60
Karvina	50.05	18.2	43.8	60

3.2. WEATHER FORECAST DATA

The best available weather forecast models for each site are used. This includes 5 global models and 4 regional models. Data is retrieved as soon as it is available from the different model centers. Point data is then extracted from four nearest grid points using bilinear interpolation.

4. LOCALLY OPTIMIZED WEATHER FORECASTING SUMMARY

The goal of this chapter is to give a brief description of the deployed solution for locally optimized weather forecast (MetFor™) to be implemented for the ARV demo sites.

4.1 UNDERLYING PRINCIPLES AND KEY FEATURES

MetFor™ utilizes multiple weather models as input and finds the optimal weight of each model for the specific location. See Figure 2 for a schematic of the software platform. This provides more accurate forecast for the specific location. In addition, MetFor™ uses local online measurements to calibrate the weather forecast to the specific location. Systematic deviations between the metrological models at the specific location are identified and corrected. Short term deviations from weather model forecasts are also identified (using real time data) such that the local weather forecast is continuously adjusted to the actual situation. The short-term adjustment that corrects for temporal correlation of errors gives a significantly improved forecast on horizons up to 12 hours ahead.

MetFor™ is based on advanced machine learning, forming a self-learning system. By combining meteorological forecasts and measurements from a local weather station, the system is not only able to produce accurate weather forecasts, but can also automatically and continuously improve the forecasts as more data is received over time (ENFOR, n.d.).

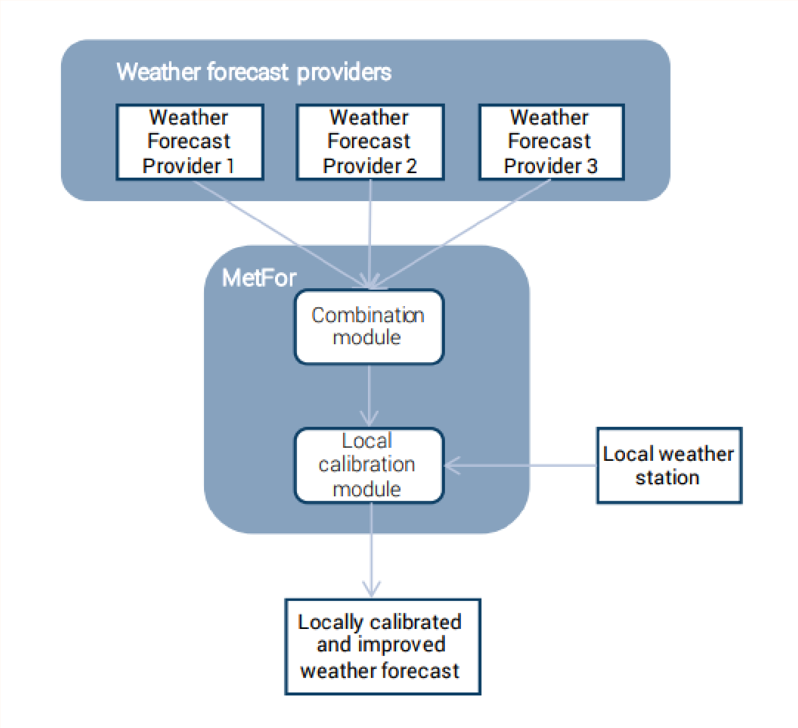

Figure 2. *A schematic of the MetFor™ platform (ENFOR, n.d.)*

4.2 DEPLOYED SOLUTION

In connection to this project, an upgrade has been developed for MetFor™ that supports more weather forecast providers, including higher resolution regional weather models. The new system has been applied to produce locally optimized weather output for sites within the ARV cities.

The model has been operated retrospectively, in realistic settings, from 1st of January 2020 to 1st of December 2022. This allows the model to find the optimal combination weights of available weather forecast sources, before being operated in real time.

Forecasted variables are 2m (2 meters) temperature, 10m (10 meters) wind speed, downwelling shortwave radiation (total) and relative humidity. The 2m temperature is calibrated with measurements. Other variables are combined using the best available sources of weather forecast data.

4.3 FORECAST EVALUATION

Surface temperatures have the most implications for heating solutions. Accurate temperature forecast is thus highly valuable. Figure 3 shows performance metrics of calibrated forecasts using MetFor™ and the Global Forecast System (GFS) weather forecast model from the National Centers for Environmental Prediction (NCEP). GFS is freely accessible and often forms a first basis to weather forecasting applications. The evaluation period is 01-10-2021 to 01-10-2022. Evaluation metrics are the root mean square error (RMSE), mean bias error (MBE), and Pearson correlation coefficient (r). The locally optimized forecast outperforms the GFS forecast at all forecast steps, with significantly lower RMSE and higher correlation. It is also nearly bias-free on average, whereas GFS tends to slightly underpredict temperature (negative bias).

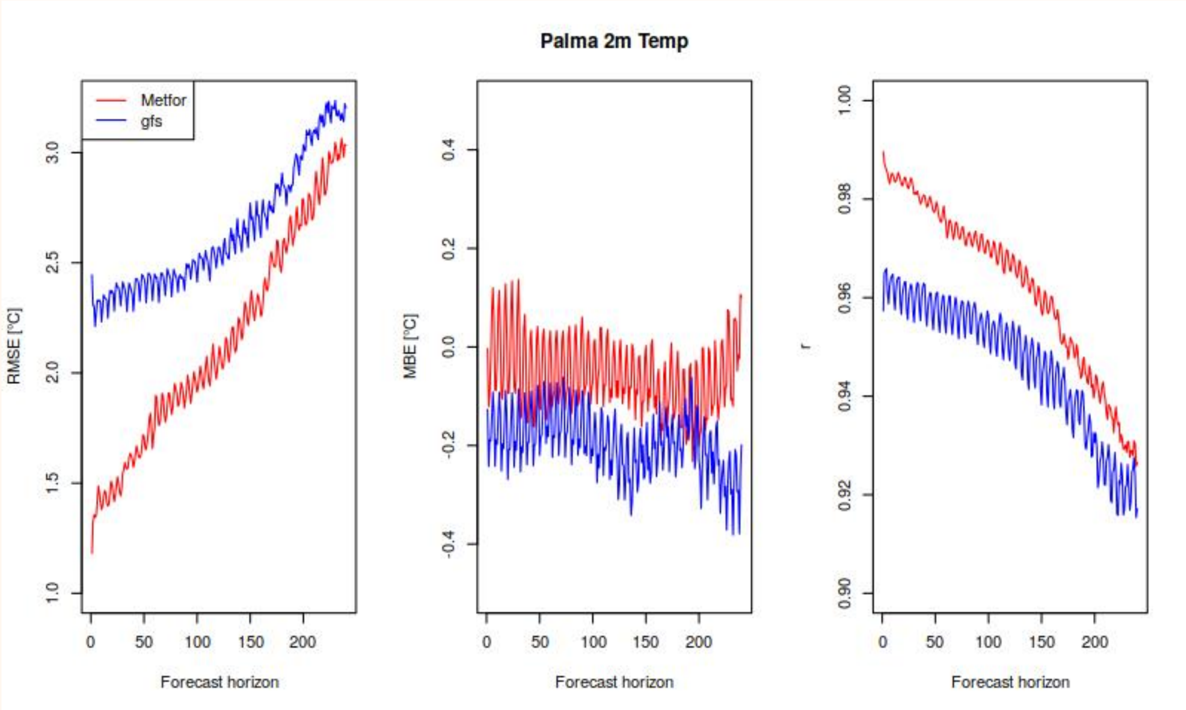

Figure 3*. A comparison of average performance metrics for temperature forecasts between the locally optimized MetFor™ solution and GFS.*

5. FORECAST OUTPUT AND HOW TO USE IT

This section describes the forecast output, how to use it and where to download it from. The forecast system produces output on an hourly basis, in simple comma separated text file format. Each model update provides 10 days ahead coverage in hourly granularity. The output is exported to a sftp server, see information in Table 2.

Table 2: Forecast details*.*

SFTP access information	Type = sftp Server = commserver.enfor.dk (Port number 2222) User = arvf Password = DvgzEwHjAc29
Output format	To_client/metfor3p0/<Site>_<Prediction time>.csv With time of prediction being '%Y%m%D%H' on UTC.
Output parameters	TimePredUTC – Forecast valid time in UTC (period-ending) AirTmpPre – Temperature @ 2m a.g.l. WndSpdPre – Wind speed @ 10m a.g.l. TRaDwnPre – Downwelling shortwave total radiation @ surface RelHumPre – Relative humidity @ 2m a.g.l.

The forecasted data can be used in real time as input to heating system solution algorithms, providing information on the local weather conditions needed for optimal performance.

FUTURE UPDATES

This software described in this deliverable will updated as weather measurements become available from the demo sites to increase the accuracy.

REFERENCES

ENFOR. [n.d.]. *Locally Optimized Weather Forecast. Metfor*. Available at: https://ENFOR.dk/services/metfor/ (Accessed: 28 November 2022)

Smith, A., N. Lott, and R. Vose, 2011: The Integrated Surface Database: Recent Developments and Partnerships. *Bulletin of the American Meteorological Society, 92*, 704–708, doi:10.1175/2011BAMS3015.1

ACKNOWLEDGEMENTS AND DISCLAIMER

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101036723.

APPENDIX A – GLOSSARY OF TERMS

Table A.1 *Abbreviations used in the report.*

Abbreviation	Description	References
CPCC	Climate Positive Circular Communities.	See ARV Deliverable D2.1 for a detailed definition of CPCC
GFS	Global Forecast System	https://nomads.ncep.noaa.gov/txt_descriptions/GFS_doc.shtml
NCEP	National Centers for Environmental Prediction	https://www.weather.gov/ncep/
MBE	Mean Bias Error	
RMSE	Root Mean Square Error	

The forecast data can be accessed using any software to visualize and download data from sftps, like it could be FileZilla, WinScp or any other commercial solution available. An example below can be seen of the configuration needed using FileZilla:

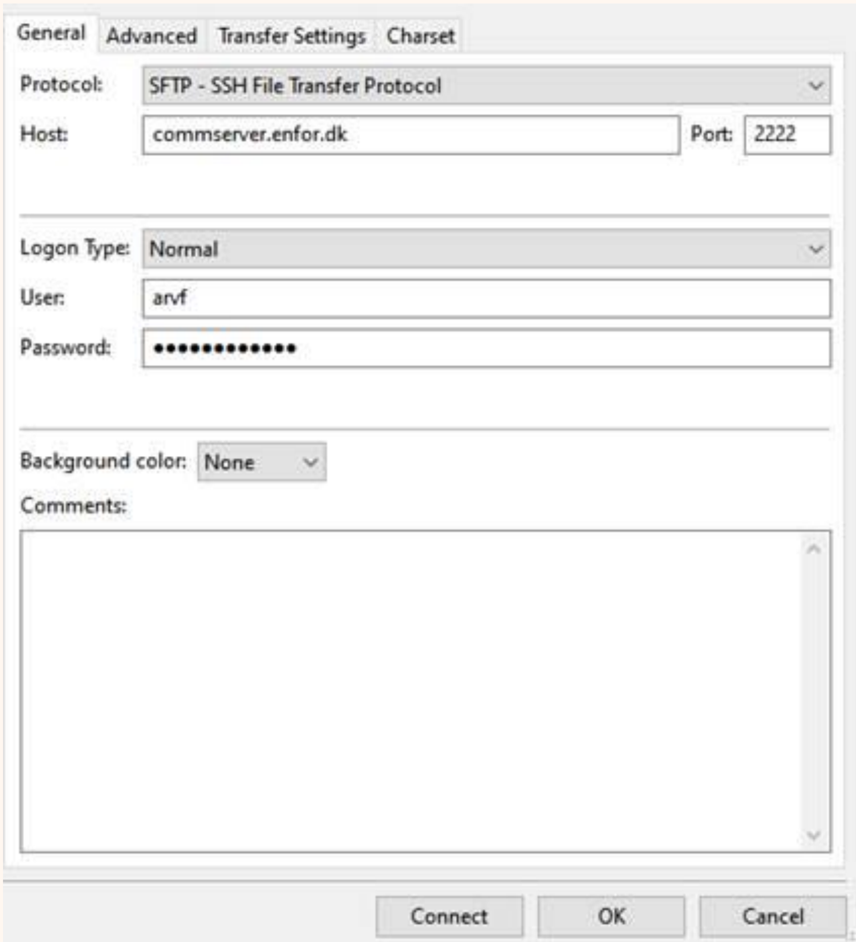

Figure A-1. *FileZilla login page example*

PARTNER LOGOS

WWW.GREENDEAL-ARV.EU