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WIND POWER-DRIVEN PIPELESS DISTRICT HEATING AS A MEAN OF FAST TRANSITION TO ZERO-EMISSION HEATING SOURCES – ASSESSMENT OF POTENTIAL FOR URBAN AND SUBURBAN AREA ON THE EXAMPLE OF KRAKÓW CITY (POLAND)

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ABSTRACT

Areas dealing with poor air quality may be significantly supported in their struggles, if district heating systems are established. Unfortunately, it is not always feasible to supply detached houses in comparatively remoted districts. Yet, all those buildings are usually connected to local electric grid, which may be easily upgraded. Thus, there is a real opportunity to use electric grid as a mean to reduce air pollution. Simultaneously, wind turbines present potential in providing electric energy with low CO_2 footprint, what not always is a case if electricity is bought from national grid. This paper is to present a concept of heat receivers supplied in heat with electricity produced in dedicated wind farm and transferred via local electric grid. Simulation of needed system size and assessment of the potential for Kraków, Poland (Central Europe) is presented along with algorithm and analysis of system performance over typical meteorological year.

Keywords: RES DH, wind power, district heating, power-to-grid (Max. 6)

NOMENCLATURE

Abbreviations	
RES	renewable energy source
O&M	operation and maintenance
WT	wind turbine

1. INTRODUCTION

One of the Polish cities most affected with smog and one of the most dedicated to eliminating it is Kraków city in the south of Poland. In the present year, a total ban on the use of solid fuels in individual and small heat sources begins to bind, which leads to various difficulties. City development consists of buildings of various age and constructions, often suited exclusively for high-temperature heating. In such conditions, gas heating is comparatively expensive due to lack of steam condensation leading to significant energy waste. District heating not always is an option, especially in remote settlements or architectural monuments, in which a range of modification is strongly limited. Thus, electric heaters may be a reasonable heat source. If powered with 100% grid energy mix, it would entail vast CO_2 emission, yet proper use of RES may change this situation drastically.

For Central Europe's climate, it is remarkable that during winter season wind power production is highest [1]. This correlation may be beneficial for the development of the power-to-heat concept, both on industrial and individual scale. Wind power is one of the cheapest and most regulated renewable energy sources for urban and suburban areas. Simultaneously, these areas deal with air pollution and effective power distribution for them is challenging. Thus, wind power turbines may be perceived as a way to locally provide cheap power useful for home appliances and heating from the non-emitting source. The present work is to present a method of wind power potential assessment in urban and suburban areas on the example of Kraków City (Poland) and its closest vicinity.

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2. 100% RENEWABLE VIRTUAL DISTRICT HEATING

2.1 Power to heat - why to decrease entropy?

consumers, where electricity would be transferred into heat in individual heat storage. Related accounts would be settled via energy cooperative responsible for energy

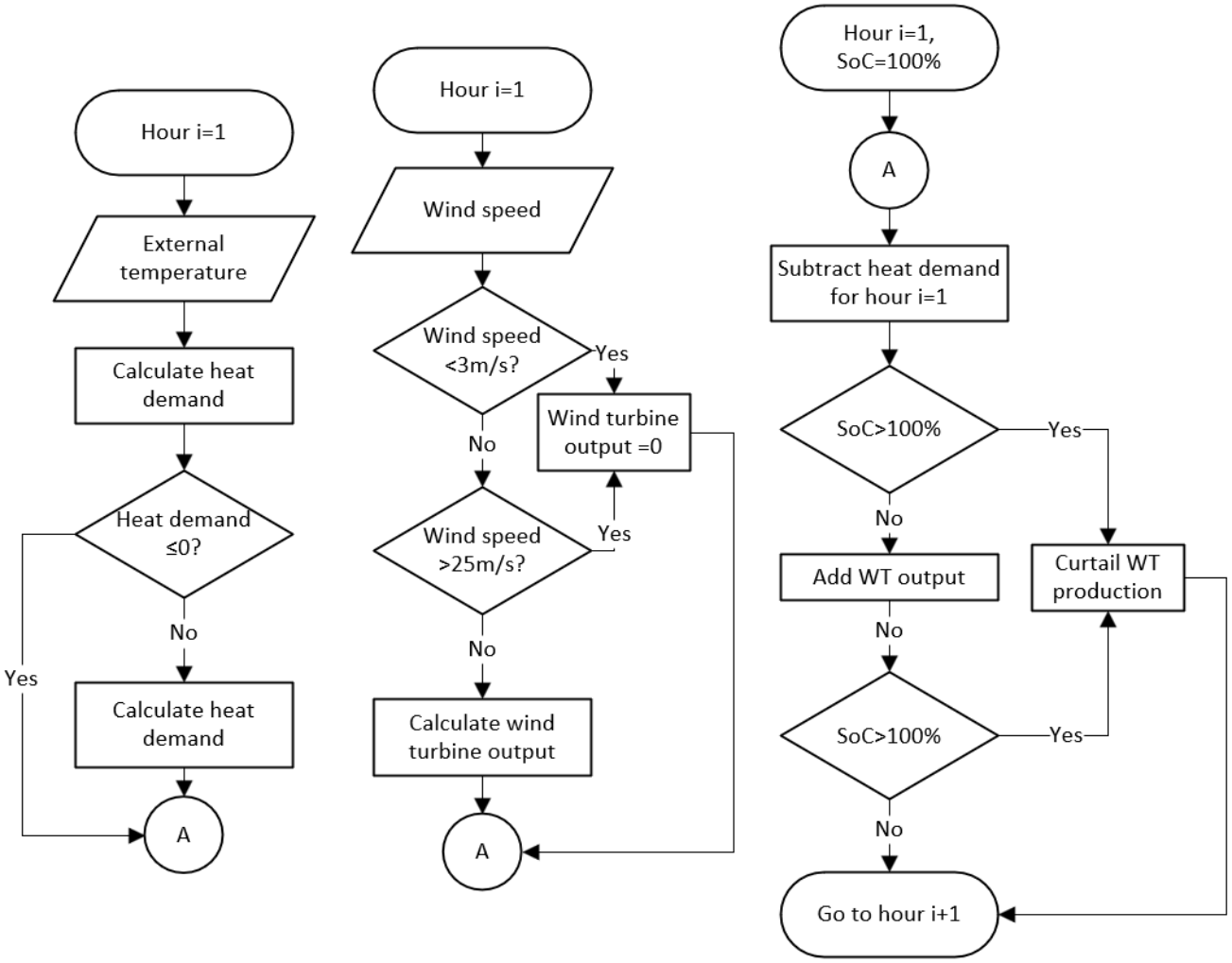

Fig 1 Performed computation algorithm.

The individual solution may be easily applied among not neighboring heat consumers, as the vast majority of houses in urban areas are connected to grid with cables sufficient for heating purposes or their hook-ups may be easily repurposed. Space heating powered with electricity entails no low emission of pollutants and gives the opportunity of the increasing use of energy from renewable energy sources (RESs) along with increasing its share in the national grid. Specifically, it may be powered with energy sourced from dedicated RES. Thus, although electricity is more useful than heat, the power-to-heat concept may be justified by environmental reasons.

2.2 *How to realize?*

The concept assumes the possibility of energy transmission via the public power grid to heat

balancing and O&M of energy sources. Energy cooperatives are in Poland perceived as an opportunity of improving air quality, which often is harmful during the heating season. Such initiatives are treated preferentially in Polish legislative, nevertheless, most regulations bind commonly. For example, no one is allowed to rear new wind turbine in distance from nearest dwellings smaller than 10x of its total height. This significantly limits space available for wind power harvesting and, simultaneously, decreases effective on-shore wind power potential.

2.3 Material and methods

The 25km buffer from the city boundaries has been created and used to clip development zones. Then 1km buffer around development zones has been created. Such distance corresponds to wind turbine of 100m

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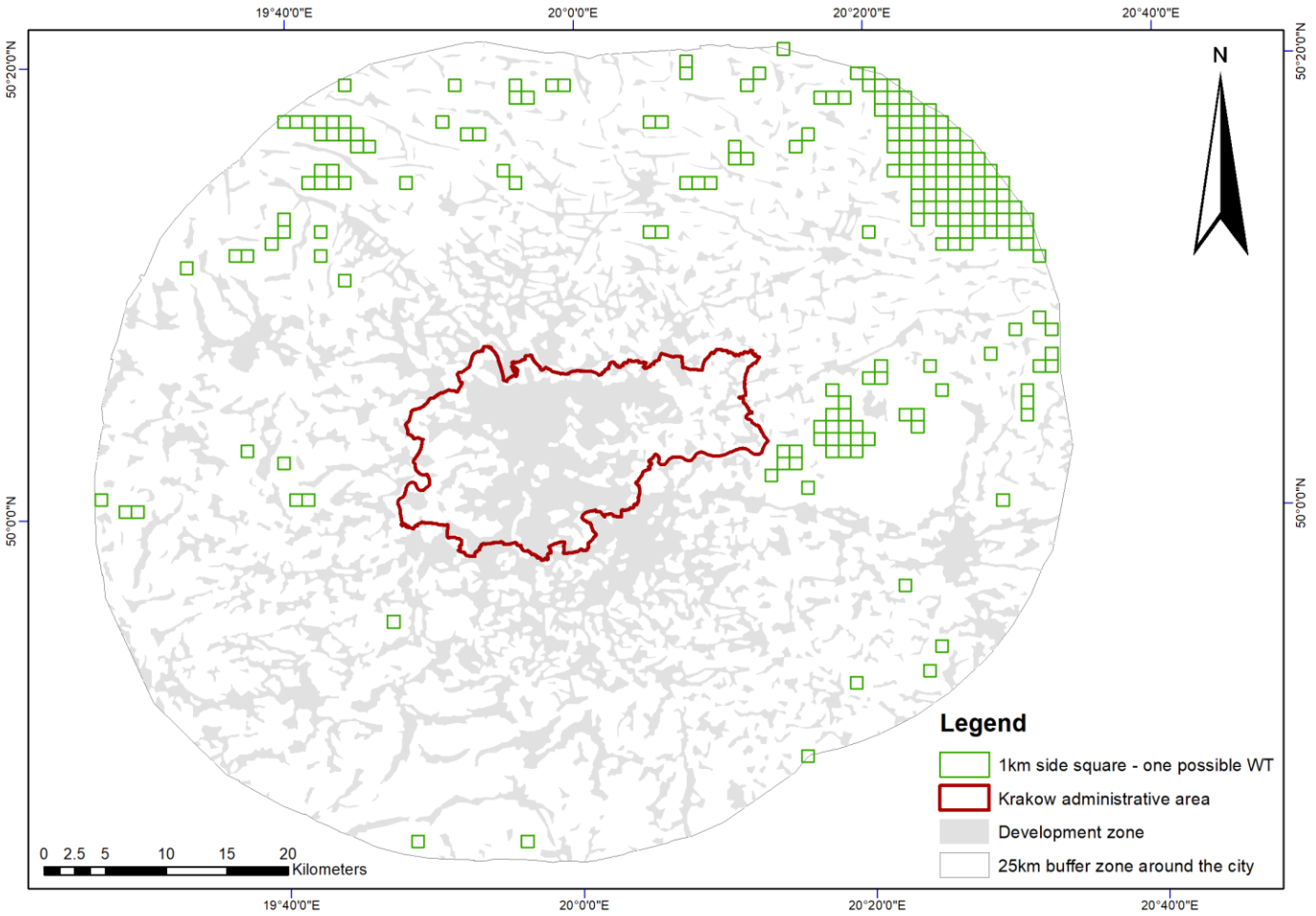

Fig 2 Map presenting considered area – Kraków city and surroundings up to 25km from its administrative borders. Each and every green square represents an area in which one wind turbine might be built. Forests has been excluded.

height, here assumed to have a power of 2MW. Prospective are those parts of 25km buffer around the city, which do not intersect with buffers around development zones. Those sections have been discretized into 1km^2 squares. Only squares with their centroids within prospective parts of 25km buffer were taken into further considerations. If a centroid of the square was in the forest area, it has been excluded due to disadvantageous surface conditions. According to relevant maps from Global Wind Atlas, each square has the total potential of about 200MW. As this method does not provide reliable data for wind turbines placement and design (detailed local studies are required for such purposes), the power density has been set at 1% of general potential. Thus, each 1km^2 square represents one 2MW wind turbine. It may be useful for strategic potential assessment and providing general insight of possibilities to decision makers. Hereunder, it will be used to compare patterns of wind power production and heat demand. The heat demand itself was simulated for each hour using external temperature data and Polish norms (as presented in [2], [3]).

2.4 Theory/calculation

During the calculation process, each square has been assumed to be represented by the same meteorological data – typical meteorological year for Kraków Balice airport shared by the Polish State [4]. The simulation regarding WT capacity and heat demand proportion has been conducted along with sizing heat storage. The computational process has been presented in Fig. 1. As only space heating has been considered, summer months (May-September) has been removed from the dataset. Initial state of charge of heat storage was presumed to be 100%.

2.5 Results

Calculations showed that it is possible to establish a pipeless 100% renewable district heating which would represent complete reliability. The preliminary results

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are that for a given space heating demand the power of wind turbines should be 9 times of nominal heat demand, while energy storage should be sufficient to run the virtual DH autonomously for 219 hours. Total wind production was 5560 units, of which 70% has been curtailed (or might be disposable for other purposes). For each and every hour the storage contained enough energy to satisfy heat demand in the next hour.

2.6 Discussion

Above-mentioned tremendous numbers seem to result from so-called “wind droughts”, which in general are observed in historical and modern datasets in Polish conditions [1]. Providing all 211 available areas were used to utilise 1% of their wind potential, there is an opportunity to cover 47 MW heat demand for (equivalent to about 470 000 square meters of living space). This may be equivalent of about 4000 solid fuel boilers, leading to significant decrease of pollutants and CO_2 emissions.

2.7 Conclusions

Even close vicinity of big cities represent may represent significant wind power potential. In general, wind power and space heating demand are correlated, yet in detailed analyses this feature is not detectable for considered area. In spite of general correlation between space heating demand occurrence and wind power production, self-sufficient WT-driven district heating system does not seem to be feasible. Albeit technically possible, because of vast oversizing seems to be ecologically pointless and economically doubtable. For efficient utilization of wind power as source of electricity in power-to-heat concept, there is a need of a dispatchable baseload electricity source which would cooperate with wind turbines to provide needed energy. Then, wind turbines and heat storage might be significantly reduced. It would also allow decreasing electric grid load, as heat might be prepared ahead during night period considering wind forecast.

There are no rationales that although not applicable in Kraków city case, the model would not perform better in more windy area. Cities nearby seashore or in areas where heat demand is caused in majority by wind may benefit from applying proposed model.

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