Wind Farm Layout Optimization: Evolutionary strategies using the EPFL Gaussian wake model

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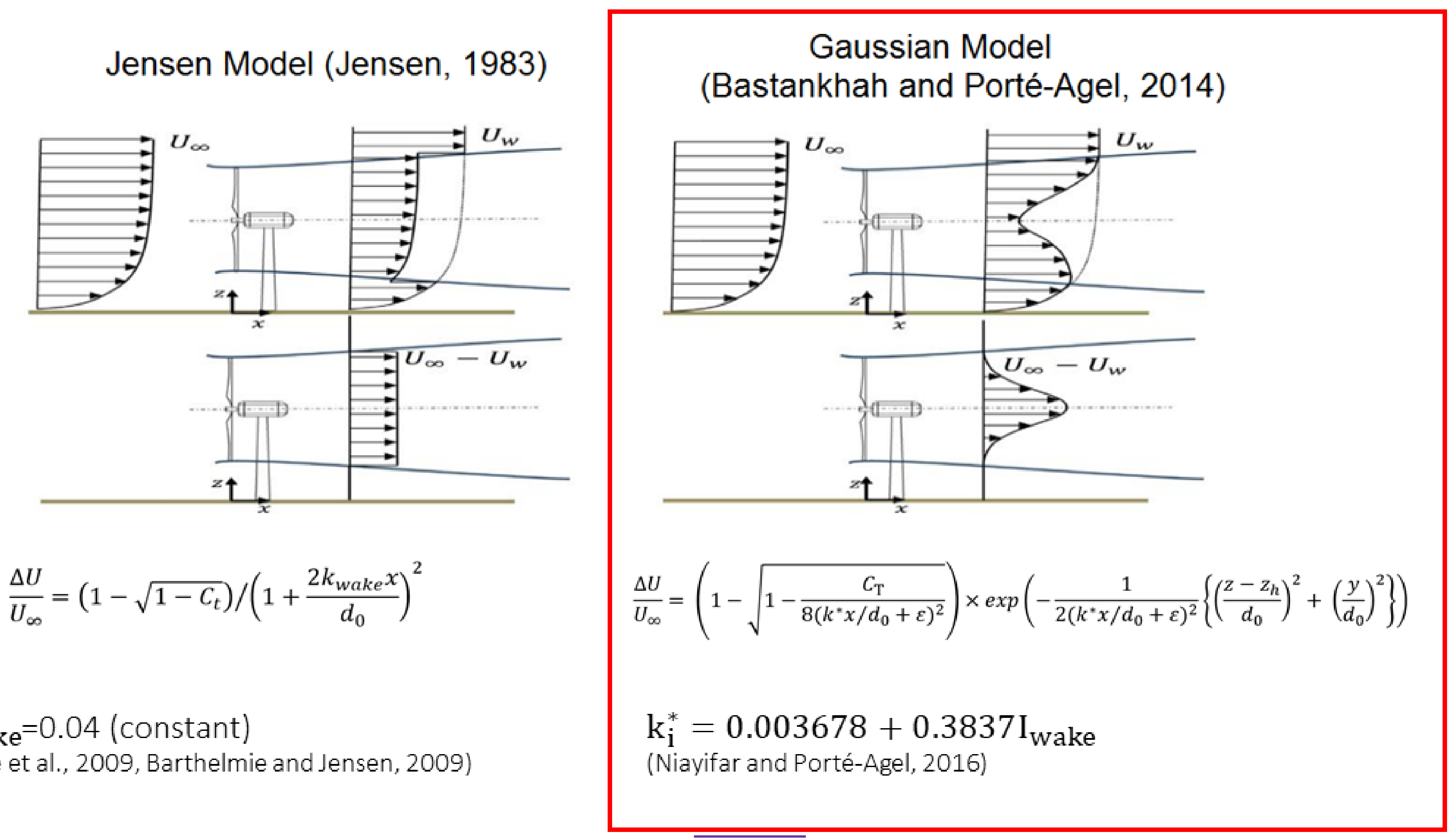
A Realistic Wind Farm Optimization Framework

Different Turbine Layout **Evolutionary Algorithms have** been designed and implemented with the **goal** to optimize the performance of real wind farms in operation in Europe. The flow dynamics framework relies on a **wind turbine wake model** (EPFL, 2014) that has shown a **higher accuracy** compared to the traditionally used wake models. Three optimization perspectives have been considered: power output maximization, power density optimization and multi-objective optimization, considering well resolved wind roses and free (non-gridded) turbine positioning.

The EPFL Gaussian model: A more accurate velocity deficit model

A **new analytical wake model** developed at **WiRE** (EPFL, 2014) has been used for the first time to a realistic WFLO framework. The model applies a Gaussian profile of the velocity deficit downstream of the turbine, and has shown **higher accuracy** than the traditionally used wake models.



$$\frac{\Delta U}{U_\infty} = \left(1-\sqrt{1-C_t}\right)\Big/\left(1+\frac{2k_{wake}x}{d_0}\right)^2$$

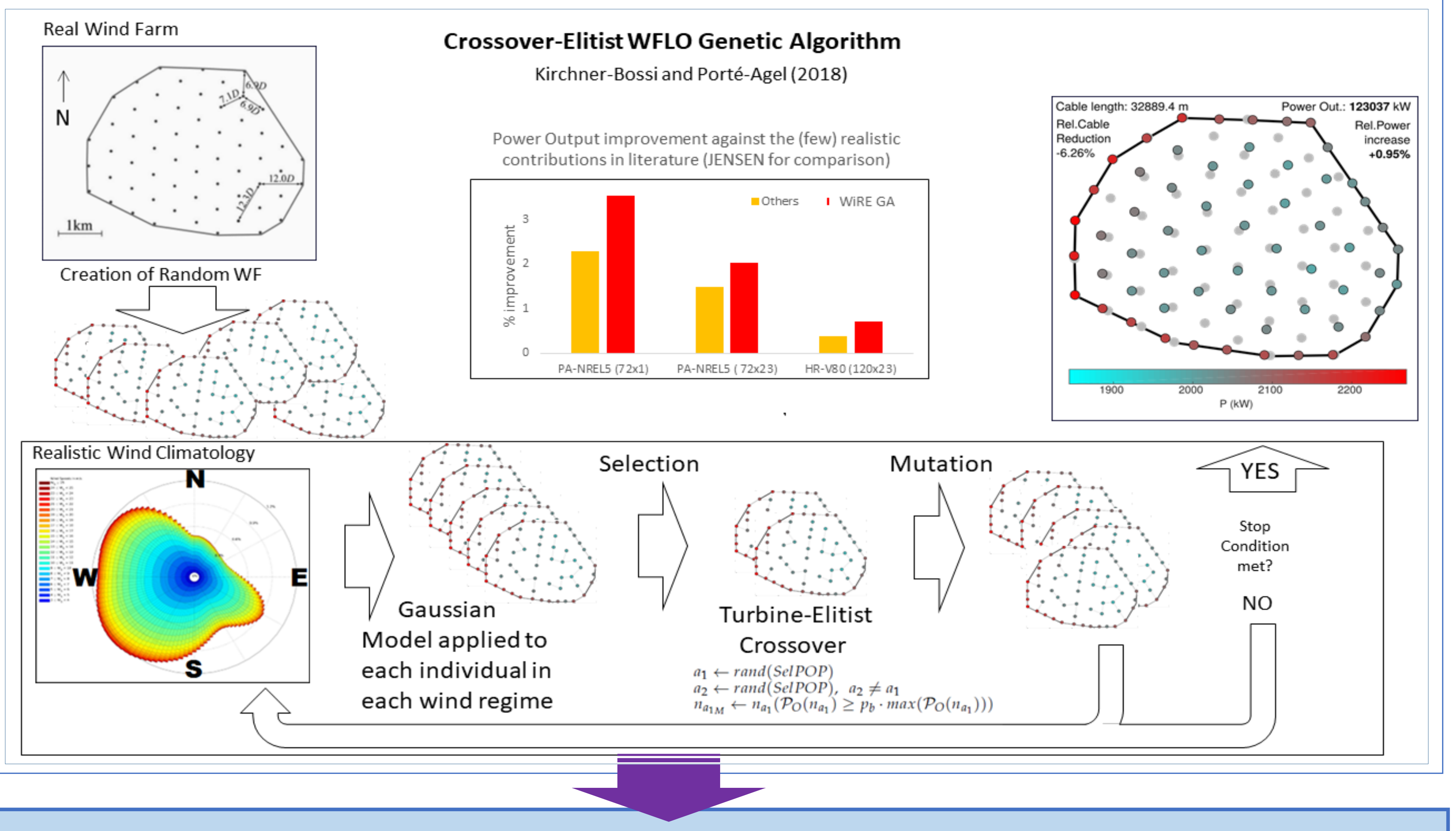
k_{wake}=0.04 (constant)
(Cleve et al., 2009, Barthelmie and Jensen, 2009)

$$\frac{\Delta U}{U_\infty} = \left(1-\sqrt{1-\frac{C_T}{8(k^*x/d_0+\varepsilon)^2}}\right)\times exp\left(-\frac{1}{2(k^*x/d_0+\varepsilon)^2}\left\{\left(\frac{z-z_h}{d_0}\right)^2+\left(\frac{y}{d_0}\right)^2\right\}\right)$$

$k_i^* = 0.003678 + 0.3837 I_{wake}$
(Niayifar and Porté-Agel, 2016)

An Ad-Hoc Wind Farm Genetic Algorithm

Genetic (Evolutionary) Algorithms are metaheuristic tools, designed to optimize high-multidimensional problems with lower computational cost compared to numerical simulations. Here **a new crossover-elitist** approach especially adapted to the **WFLO problem** has been introduced (EPFL2,2018).



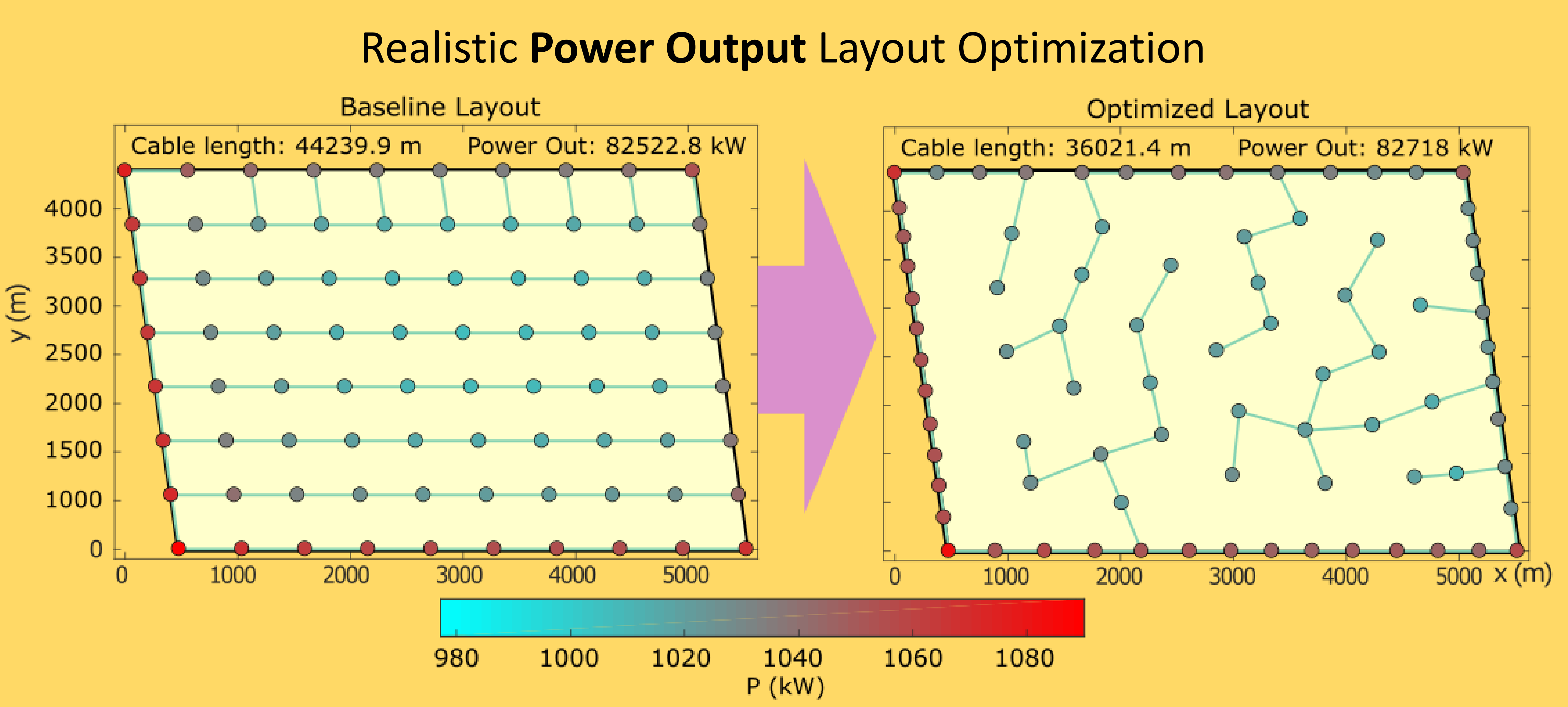
$a_1 \leftarrow rand(SelPOP)$
$a_2 \leftarrow rand(SelPOP),\ a_2 \neq a_1$
$n_{a_{1M}} \leftarrow n_{a_1}(\mathcal{P}_O(n_{a_1}) \geq p_b \cdot max(\mathcal{P}_O(n_{a_1})))$

Optimized Layout

The obtained layout **increases** the number of turbines in the **perimeter** of the wind farm with respect to the baseline.

This in turn allows the **turbines** at the **central** part of the domain to **increase** their **power** output compared to the baseline.

The overall performance **trade-off** is **positive** due to a higher performance of the inner turbines.



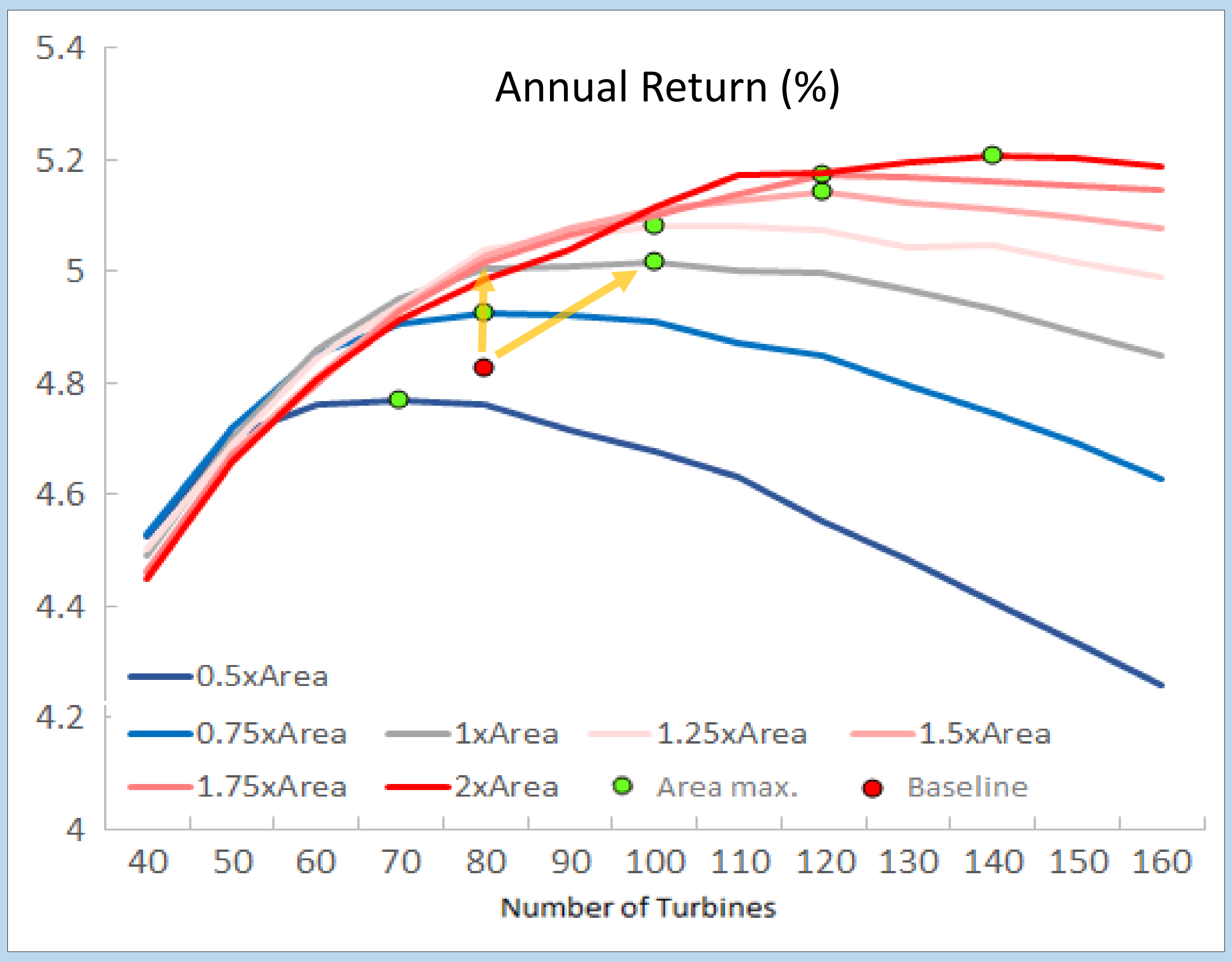
Significant improvements

We obtained a **16-18% reduction of the electricity cable** length, when increasing the overall wind **power output 0.24**-**0.89%**.

In addition, the method is shown to **outperform other** optimization **methods** in literature applied to **similar cases**.

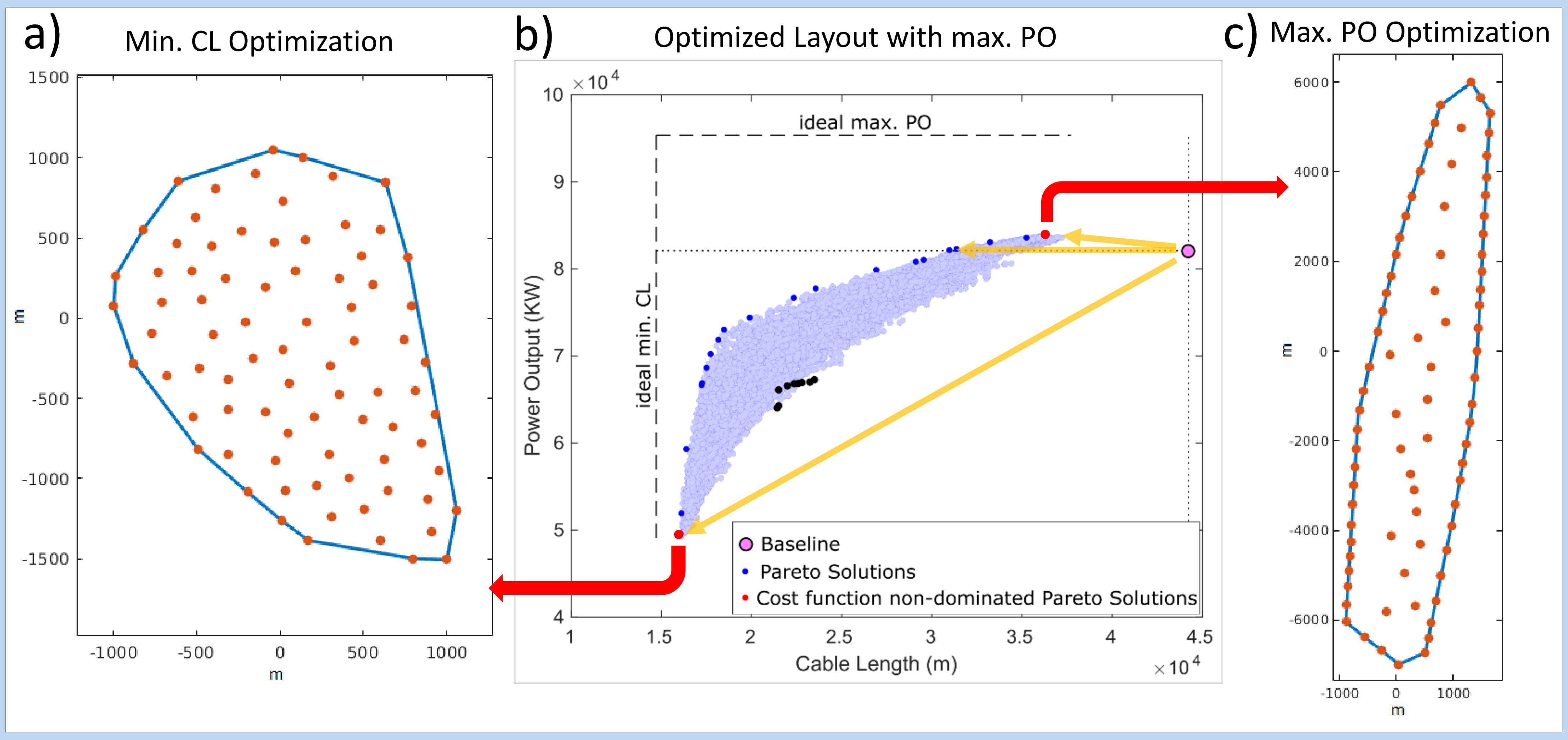
Optimization of the Annual Return according to the Number of Turbines and the Wind Farm Area Size

Preliminary results show that optimized layouts allow **higher Annual Returns** (**AR=5%**) than the original layout (**4.8%**). At the same time they allow for higher number of turbines. The highest AR (**5.2%**) is obtained for 1.75x the original area.



Area Shape-free Multi-Objective Optimization of the Power Output (PO) and the electricity Cable Length (CL)

A Multi-Objective Optimization of the Power Output and the Cable-Length provides a set of Pareto Solutions (Pareto Front, dark blue in Fig.b), that **allows the investor** to obtain a **personalized trade-off** between the electricity **Cable costs** and the **Power Output** performance. Results provide solutions with a **PO improvement up to >2%** (CL reduction of 14%, Fig c) until a **64% CL reduction** (Fig.a). Finally, a 23% CL reduction is obtained for a PO as in the baseline.



Acknowledgements

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References: **EPFL (2014)** Bastankhah, M., and Porté-Agel, F. A new analytical model for wind-turbine wakes. *Renewable Energy*, 1-8.

EPFL2 (2018) Kirchner-Bossi, N., and Porté-Agel, F. RealisticWind Farm Layout Optimization through Genetic Algorithms Using a GaussianWake Model. *Energies*, 11.12.