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1	Journal of Wind Engineering and Industrial Aerodynamics
2	
3	Aerodynamic performance enhancement of a Savonius wind
4	turbine using an axisymmetric deflector
5	
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16	
17	Abstract
18	The installation of wind turbines in urban sites requires consideration of the wind characteristics
19	affecting the energy production (turbulence, environment roughness due to the surrounding
20	buildings), the self-starting capability and the type, hence the performance, of the wind turbine. In
21	this paper, a three-dimensional CFD analysis of an aerodynamic Savonius wind turbine is performed
22	under steady wind conditions. The inclusion of a deflector was also investigated, and the
23 24	performance compared to the initial design.
24 25	Results of the 3D analysis showed that an optimized axisymmetric deflector improves the power
25 26	coefficient in all wind directions and over the entire operating range of the turbine. The deflector
20 27	with respect to the wind speed
27 28	with respect to the who speed.
20	Keywords: Vertical axis wind turbine transient three-dimensional simulation, power coefficient.
30	Savonius rotor, aerodynamics
31	
32	
33	1. Introduction
34	
35	Wind energy is a powerful, efficient, and sustainable source of electricity. Yet urban wind
36	turbines represent a negligible part of the total number of wind turbines (less than 10,000 in
37	France). They are part of the small wind category (between 1 and 36 kW) according to the French
38	(ADEME, 2015) and British (IRENA, 2015) segmentations, and are grouped under the name "small
39	wind" in the USA (Clausen et Wood, 2000).
40	Until the late 2010s, interest in Urban Wind Turbines (UWT) was modest compared to other
41	categories. In spite of the recently implemented optimized systems, UWTs display average
42	efficiency, are not necessarily cheap and pose reliability problems. For all these reasons, the interest
43	towards these systems, and the associated research, remains limited, although they constitute an
44	additional energy source and can thus contribute to the energy autonomy of individuals and small
45 46	companies. The main scientific nurgie is to improve their efficiency by considering both the urban
40 17	focuses on periodynamic optimization of a Savenius wind turbing in view of their perticular
47 78	characteristics such as self-starting capability and structural stability (Vodero and Date 1000)
40 10	Wenehenuhun et al. 2015)
	wenenenddun et al., 2013j.
50	



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Fig. 1. Examples of Savonius wind turbines.

The Savonius rotor consists of two vertical half-cylinders rotating around a vertical axis, but whose planar ends are offset from each other. Different shapes exist, as seen in Fig. 1.

57 The extensive bibliographic references on this topic help understand the dynamic behavior of this

- 58 type of wind turbine; the difference in drag forces between the convex and concave blades produces
- a mechanical torque which ensures the rotation of turbine around its axis, as depicted in Fig. 2.
 However, the wide range of turbine geometries, wind speeds and experimental conditions makes it

However, the wide range of turbine geometries, wind speeds and experimental codifficult to compare wind turbines and select the optimal one.

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Fig. 2. Operating principle of a Savonius wind turbine (Mohamed, 2013).

The results of numerical simulations performed on new Savonius wind turbine designs (static or dynamic) are usually presented by comparing the developed torque, the torque coefficient C_T (Eq.1) and the power coefficient C_P (Eq.2), relative to the rotational speed (for the dynamic models) (Mauro et al., 2019; Meziane et al., 2020; Zakaria et al., 2020; Marinic et al., 2019).

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$$C_T = \frac{T}{0.5 \rho V_{\infty}^2 A R} \tag{1}$$

 $C_{\rm P} = \frac{T \,\omega}{0.5 \,\rho \, V_{\infty}^3 \,A} \tag{2}$

75

76 T is the torque developed around the axis of the wind turbine, ω is the rotational speed of the wind 77 turbine, ρ is the air density, V_{∞} is the free airstream velocity and A is the swept area.

Fig. 3 summarizes the orders of magnitude for C_P coefficients to be used depending on tip-speed ratio λ (Eq. 3), which is defined as follows:

80 81

$$\lambda = \frac{R * \omega}{V_{\infty}} \tag{3}$$

82 with R the radius of the turbine.



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Fig.3. Power coefficient C_P for different wind turbine designs vs. tip-speed ratio λ (Alabdali et al.,

2020).

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88 It is worth noting that Savonius wind turbines are meant to be used in the lowest wind velocity 89 conditions. Together with its high starting torque, which translates into the possibility of starting 90 without back-up power, makes them perfectly suitable for urban areas where wind speed is 91 naturally lower than in rural areas.

92 However, the Savonius rotor ranks low in terms of power coefficient value, but this may be of 93 interest because the low induced tip-speed ratio translates into low acoustic nuisance (Mojica et al., 94 2019). This wind turbine, similarly to the Darrieus for that matter, also has the ability to take 95 advantage of wind in all directions, without the need for a detection and control system which are 96 mandatory for horizontal axis models. The Savonius wind turbine is also structurally superior to 97 others and is therefore able to better resist the turbulent winds encountered in urban areas.

98 Several researchers and engineers have proposed innovative systems to increase the airflow to 99 the turbine. Although the Betz limit caps the maximum fraction of power that a wind turbine can 100 extract from the available wind at 59.3%, this limit may be extended by using an air converging 101 system. Botempo et al. (2020) studied the development of an ideal air deflector upstream of a wind 102 turbine and proved that the Betz limit can be exceeded.

- 103 Indeed, the power extracted from the wind is directly related to the velocity difference upstream 104 and downstream of the wind turbine. Any increase in upstream wind velocity will increase the 105 efficiency of the system: to this end, deflectors concentrate the mass flow of the wind toward the 106 working area of the turbine, which increases the incoming wind speed. As seen in Fig. 4, several deflector designs have been developed over the last 40 years. Alexander et al. (1978) studied the 107 108 combination of a flat and circular shield (Fig. 4a), and calculated C_{Pmax} =0.243. Morcos et al. (1981) used a flat-shaped baffle plate facing the wind turbine (Fig. 4b) and reported C_{Pmax}=0.34. Ogawa et 109 110 al. (1986) used a V-shaped baffle plate (Fig. 4c) which resulted in a C_{Pmax} value of 0.212. Shaughnessy 111 et al. (1992) investigated another type of V-shaped wind concentrator (Fig. 4d) which increases 112 power by nearly 19.7% compared to a standard rotor with no deflector.
- 113 Circular deflectors (Fig. 4e) have also been investigated to decrease the wind pressure exerted on 114 the convex blade (Yonghai et al., 2009). The use of concentration deflectors (Fig. 4f) upstream of the 115 rotor minimizes the flow on the returning blade to reduce the negative torque (Burcin et al., 2010). 116 One more paper discusses the integration of an obstacle shield (Fig. 4g) to lower the negative torque, which improves the rotor performance by up to 30% (Mohammed et al., 2010). Golecha et 117 118 al. (2011) used a deflector plate (Fig. 4h) upstream of the advancing blade and achieved a 50% 119 increase in performance over the semi-circular bladed rotor. Roy et al. (2014) used wind deflectors 120 at the inlet (Fig. 4i) and obtained C_{Pmax} =0.32. Guide vanes (Fig. 4i) also improve the rotor 121 performance (El-Askary et al., 2015). Finally, a conveyor-deflector curtain (Fig. 4k) placed in a 122 conventional Savonius rotor increased C_P up to 0.30 (Tartuferi et al., 2015).
- 123 124





Fig. 4. Different convergent designs for Savonius wind turbines.

129 The main drawback of these systems is operating mode, which increases the turbine efficiency 130 for one wind direction only.

131 Moreover, numerical studies focusing on the performance of deflectors are usually performed in 2D, 132 without considering the wake effect, the height/diameter ratio of the wind turbing or the presence

without considering the wake effect, the height/diameter ratio of the wind turbine or the presenceof end plates. It can be assumed that their results may be optimistic compared to experimental data.

Some of these deflectors require a steering mechanism for proper alignment with the wind direction, but these additional devices consume energy, add complexity and weak points in the maintenance.

137 The objective of this study is therefore to propose a system able to concentrate the incoming airflow

from all directions while remaining simple in design, with no energy-consuming steering mechanism

139 to reduce future maintenance interventions.

140 The aerodynamic optimization of the wind turbine requires the addition of a single part, with simple

141 design and manufacturing, namely an axisymmetric deflector that requires no alignment in the wind

142 direction. To the best of the authors' knowledge, such device has never been studied before in the

- 143 literature. For this purpose, a Savonius wind turbine has been parameterized, and a 3D numerical
- 144 optimization has been performed to define the optimal dimensional characteristics of the deflector.
- 145 In a second step, the numerical results have been compared with experimental data from the 146 literature for validation purposes.
- 147 Results obtained from the 3D numerical model will help define potential improvements in the 148 turbine performance, by adding an optimal deflector in an urban operating environment.
- 149
- 150 2. Methodology
- 151

- 152 2.1. Geometry of the Savonius wind turbine model
- The main geometric parameters impacting the performance of the Savonius rotor are summarized inFig. 5 and are defined as follows:
- The blades of a Savonius wind turbine are typically between 1 and 3 in number. As
 mentioned by previous studies (Ross et al., 2011; Akwa et al., 2012), we selected a 2-blade
 system which features the best performance and power coefficient.
- The ratio of turbine height to turbine diameter called Aspect Ratio $A_R = H/D$. Sobczak et al. (2018) note that an A_R ratio between 1.0 and 2.0 is a good compromise between performance and compactness. We selected $A_R = 1.66$, defined by height H=1.5m and diameter D= 0.9 m.
- The presence or absence of end plates on which the blades rest to channel the incident flow.
 Saha et al. (2008) recommend an optimal ratio of 1.1 between the plates and rotor diameters.
- The dimensionless gap width defined by ratio e/d. According to Fujisawa et al. (1991), turbine efficiency is optimal for a value of 0.15. Blackwell et al. (1977) propose a range from 0.1 to 0.15, while Menet (2004) advises a value 0.242 and Akwa et al. (2012) 0.15. In view of these recommendations, we opt for an overlap value of 0.15.



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Fig. 5. Geometric parameters of the Savonius wind turbine (Roy et al., 2018).

- 172173 2.2. Key features of the deflector
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As shown in Fig. 6, the convergent has a simple, axisymmetric shape. The profile consists of a truncated cone whose dimensions will be defined by a geometric optimization on the following parameters: A is the gap between the convergent and the turbine; B, the large diameter of the truncated cone; C, the small diameter of the truncated cone and D the height of the truncated cone. The deflector truncated cones are non-rotating fixed. Although the mounting system of the deflectors is not represented in Fig. 6, it is thought to be completely dissociated and independent from the turbine structure.





Fig. 6. Geometry of the deflector used.

The optimization of these dimensional parameters aims at maximizing the static torque developed around the turbine axis. 3D optimization is achieved using the ANSYS[©] response surface tool. After setting the geometric constraints of our input parameters A, B, C and D and the target output parameter, a sensitivity study is proposed in the form of a response surface with respect to the most influential parameters. After several iterations, the optimal dimensions obtained for the deflector are: A = 5 cm; B = 150 cm; C = 105 cm and D = 75 cm.

193 2.3. Geometric parameters of the numerical model

194

195 The present study is based on a dynamic three-dimensional CFD simulation. The geometry of the 196 urban wind turbine was created using ANSYS DesignModeler[®] software. The use of a sliding mesh to 197 simulate the rotation of the wind turbine around its axis required the creation of 2 domains: one 198 stationary and one rotating. The dimensions of the computational domain shown in Fig. 7 were 199 chosen according to the recommendations of El-Askary et al. (2015). Computations and postprocessing were performed using FLUENT[©] 2020 R2. Several rotational speeds are imposed to the 200 201 rotating subdomain to model the aerodynamic performance of the wind turbine over the entire 202 operating range.

Boundary conditions involve a no-slip condition on the fixed walls of the stationary domain, as well as on the deflector and wind turbine. A constant velocity of 7 m/s with a turbulence intensity of 5% is imposed at the inlet of the computational domain and a pressure-outlet condition (constant atmospheric pressure) is imposed at the outlet.

The velocity used for the calculation of power coefficient C_P is rectified according to (Eq.4; Eq.5) to account for the flow concentration induced by the external domain walls:

209
$$V = V_{\infty}(1 + \varepsilon_t)$$
(4)

$$\epsilon_{t} = \frac{1}{4} \frac{A_{t}}{A_{ut}}$$

with A_t the frontal section of the wind turbine and A_{wt} the fixed section of the domain (Ross et al.,
2011; Jeong et al., 2018).

(5)



Fig. 7. Domain dimensions and boundary conditions.

215 216 2.3.1. Stationary and sliding meshes

Simulation of a system involving a rotating part is a challenge that requires the use of the sliding meshing method (Marmutova 2016), as the rotating motion of the rotor requires a separate region with different meshing requirements (deflectors are fixed). The stationary subdomain is obtained by extracting the rotating part and the designed deflector from the initial computational domain. Then the rotating subdomain is modeled and added as a separate cylinder, as seen in Fig. 8. An optimal interface between the two subdomains is achieved using the shared topology method at the geometry level, which the meshing is developed upon.

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- 225



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Fig. 8. Details of the stationary and sliding meshes.

227 228 An unstructured mesh was generated using Ansys meshing software and consists of 4.5 million 229 tetrahedral elements Fig. 8. A mesh sensitivity analysis was performed on a 4.5, 6 and 7 million 230 tetrahedral element meshes and showed no significant improvement in the accuracy of the output 231 torque. Downstream of the rotor, the mesh was refined to capture wake vortices. In addition, an 232 inflation mesh consisting of 18 layers of prismatic elements around the blades was created around 233 the airfoil to reach appropriate y+ values. The dimensionless height of the first mesh node adjacent 234 to wall y+ has a major impact on the simulation results. Indeed, the torque produced around the axis 235 of the wind turbine imposes a fine resolution of the viscous sublayer, hence the need for a y+ value 236 below 5 on the blades. This optimized mesh made it possible to achieve an average value of y+ of 1.8 237 on the turbine surface.

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249 2.3.2. Turbulence model

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251 The most widely used turbulence model to account for the aerodynamic behavior of 3D wind 252 turbines is Ko-SST (Rezaieha et al., 2019; Ghazalla et al., 2019; Alom et al., 2021). Several other 253 models are also implemented like TSST (Saheen et al., 2015) or Realizable K- ε (Mohammed et 254 Thevenin, 2010; Kumar et al., 2017). Numerical comparisons with experimental data from Blackwell 255 et al. (1977) showed that all these numerical models underestimate the experimental results, which 256 is consistent with studies by Ferrari et al. (2017) and Mohammed et al. (2010). It was also found that 257 the K₀–SST model is the most appropriate for our simulations, as seen in Fig. 10. This model was 258 therefore selected. 259



260

Fig. 10. Comparison of power coefficient C_P between experimental data from Blackwell et al. (1977) and the dynamic, K ω –SST-based simulation model with rotating mesh vs. velocity coefficient λ .

263

266 operating spectrum. As such, this parameter constitutes a reliable measure of the capacity of the 267 turbine to collect energy from the wind.

268

269 2.3.3. Simulation settings

270

To evaluate the wind turbine performance over the whole operating range, six values of tipspeed ratio λ were simulated (0.2 to 1.2, step 0.2). The values of λ , corresponding angular velocities and time steps used for each calculation are summarized in Tab.1.

The time step is set to a value corresponding to the time needed for the turbine to perform a 0.5° and -1° rotation for each value of λ . Such precaution avoids divergences in CFD computations (Marmutova 2016).

> λ 0.2 0.4 0.6 0.8 1 1.2 Angular velocity (rd.s⁻¹) 2.8 5.6 8.4 11.2 14 16.8 Time Step (s) 0.005 0.002 0.0015 0.0012 0.001 0.0008

278

277

 Table 1 Simulation settings.

Monitoring the torque developed around the wind turbine axis makes it possible to assess its aerodynamic performance. Indeed, in the case of an "ideal" rotating turbine (i.e. without friction), the value of torque would be zero for a constant, imposed wind velocity in a stationary regime. Therefore, it is sufficient to evaluate and compare, under identical conditions, the values of torque with and without a deflector to conclude on the induced impact on the intrinsic performance of the wind turbine. Practically, an increase in performance will translate in the resulted torque as well as the power coefficient C_P.

286

287 3. Results

288

 C_{T} and C_{P} coefficients are key indicators of the wind turbine performance and are widely used in the literature as a basis for comparison between numerical and experimental results. As shown in Eq.1 and Eq.2, for a constant wind velocity and an imposed angular velocity, calculating the torque delivered around the axis of the wind turbine is the only way of obtaining power coefficient C_{P} of the different wind turbines. As far as numerical simulations are concerned, only this physical parameter is able to predict the performance of the wind turbine proposed in this study. The

Torques delivered by conventional (without deflector) and updated (with deflector) wind turbine are plotted in Fig. 11, for all values of λ summarized in Tab. 1. It is noted that the torque representations shown in Fig. 11 were plotted after 5 complete revolutions to ensure stabilization of the results.

Furthermore, the pressure contours of these 2 wind turbines are displayed in Fig. 12 for two different angular positions in which torque is negative. Fig. 13 displays the pressure contours along with the velocity streamlines flowing through the wind turbine. Finally, Fig. 14 summarizes the performance of the wind turbines by evaluating the delivered torque versus angular velocity in RPM (Fig. 14a), and power coefficient C_P versus velocity coefficient λ (Fig. 14b).







- Fig. 12. Pressure contours in the median plane with and without convergent for an angular velocity
 of 160 RPM at different angular positions noted in Fig. 11f. (a) conventional wind turbine angular
 position 1, (b) wind turbine with deflector angular position 1, (c) conventional wind turbine angular position 2, (d) wind turbine with deflector angular position 2.





Fig. 14. (a) Delivered torque vs. angular velocity; (b) Comparison of C_P between experimental data
 from Blackwell et al. (1977), numerical results of the conventional wind turbine and of the wind
 turbine with convergent.

320

325 4. Discussion

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Fig. 11 shows that the evolution of torque value is periodic, with fluctuations around a mean value. The performance of the wind turbine depends on the angular position of the rotor, and reach higher values for given angular positions. By calculating the average torque for different tip speed ratios λ , the power coefficients C_P of different wind turbines can be obtained. Besides, knowledge of these fluctuations is valuable in the structural design of wind turbines.

Under a wind speed of 7 m.s⁻¹, the average torque of both wind turbines decreases as λ increases, 332 333 which is expected since relative wind velocity with respect to the rotating blades decreases with the 334 increase of the angular velocity. Fig. 11 shows similar curves for the two types of turbines, except that a noticeable offset from the ordinate axis is observed. The average torques vs. angular velocity 335 336 are shown in Fig. 14a. Clearly, the wind turbine with axisymmetric deflector delivers higher torques 337 compared to the conventional wind turbine under the same conditions and can be considered as 338 significantly more efficient. A similar conclusion may be drawn by analyzing Fig. 14b, with higher 339 values of coefficient C_P for the new design. It is worth noting that the C_P computation based on the 340 Eq. 2 used the same swept area A for the two proposed turbines, which is the only rotating in both 341 configurations.

The velocity streamlines plotted in Fig. 13 reflect the working mechanism of the proposed deflector. Naturally, the truncated cones redirect the airflow to the rotor which increases the mass flow rate of air moving through the turbine. Pressure upstream the rotor is increased, as reflected in Fig. 13.

Torque fluctuations are much more pronounced at low speeds, and the curves become smoother
and more sinusoidal at high angular velocities. Such result does not stem from numerical errors,
since all computations are carried out using a time step that corresponds to a rotation of 0.5° to -1°.

350 To study the aerodynamics at angular position 1 (negative torque, constant wind speed, angular 351 velocity 160 RPM, see Fig. 11f), the pressure contours have been plotted in Fig. 12c and Fig. 12d. The 352 difference between the upstream and downstream pressure around each blade defines the drag 353 force. Quite expectedly, the drag force on the driven blade is much larger than that on the driving 354 blade. Fig. 12c.d shows a more pronounced pressure contrast (red upstream / blue downstream) on 355 the driven blade compared to the driving paddle (green upstream / green downstream). The driven 356 blade therefore prevails, and the resulting torque is negative which induces braking of the wind 357 turbine at 1.5 s when the angular velocity of the turbine is at 160 RPM. It is also worth mentioning 358 that the average non-instantaneous torque has a positive value of 4.9 Nm (with convergent) and 359 4.1 Nm for a conventional Savonius wind turbine.

Regarding angular position 2 (positive torque, constant wind speed, angular velocity 160 360 361 RPM, see Fig. 12f), the pressure contours have been plotted in Fig. 12a and Fig. 12b. The pressure 362 contrast is more pronounced on the driving blade, leading to positive torque and acceleration of 363 the turbine at 1.62 s when the turbine is rotating at 160 RPM.

364 Considering a constant torque value of 6 Nm, the two turbines display different angular 365 velocities. Indeed, as shown in Fig. 14a, the conventional wind turbine rotates at 84 RPM, while the 366 convergent one can rotate at 126 RPM, i.e. an increase of 50% in angular velocity resulting in 367 significant gain in the power coefficient (see Eq.2).

368 Finally, the dynamic 3D simulation highlights that the wind turbine with optimized deflector 369 increases the Savonius performance coefficient by 25% over the entire speed range (including start-370 up), with C_{Pmax}=0.31, recorded for a velocity coefficient λ =1.0 (see Fig. 14b).

371 Table 2 presents literature results of studies conducted on deflectors, all with static unidirectional 372 orientation, i.e. concentration of wind coming from a predominant direction. These deflectors have 373 a negative impact on all other directions, unless a yaw mechanism is added. However, as mentioned 374 earlier, higher energy consumption and more complex design and maintenance should be 375 considered. Considering that urban winds are turbulent in both amplitude and direction, 376 axisymmetric deflectors will perform better and collect more energy. Yet systems featuring values of 377 C_{Pmax} greater than 0.31 are derived from experiments carried out in wind tunnels or 2D CFD 378 simulations, which are known to be more "optimistic" than 3D CFD simulations, as indicated by 379 Marinic et al. (2020) and Ferrari et al. (2017).

380

Authors	Design	Reported C _{Pmax}	Study	Wind concentrator
El-Askary et al., 2015	Curtain design	>0.5	2D CFD	Unidirectional
Burçin et al., 2010	Curtain design	0.38	Wind tunnel	Unidirectional
Morcos et al., 1981	Flat plate shield	0.34	Wind tunnel	Unidirectional
Roy et al., 2013	V-shaped deflector	0.32	Wind tunnel	Unidirectional
Present work	Axisymmetric deflector	0.31	3D CFD	Axisymmetric multidirectional
Tartuferi et al., 2015	Curtain design	0.3	2D CFD	Self-rotating
Yonghai et al., 2009	Deflector plate	0.28*	2D CFD	Unidirectional
Golecha et al., 2011	Deflector plate	0.26	Wind tunnel	Unidirectional
Mohamed et al., 2010	Obstacle shielding	0.25	2D CFD	Unidirectional
Mohamed et Thevenin, 2010	Obstacle shielding with guide vane	0.25	2D CFD	Unidirectional
Alexander et Holownia, 1978	Flat plate shield	0.24	Wind tunnel	Unidirectional
Ogawa et Yoshida, 1986	Deflector plate	0.22*	Wind tunnel	Unidirectional
Ogawa et Yoshida, 1986	Deflector plate	0.21	Wind tunnel	Unidirectional
Shaughnessy et Probert, 1992	V-shaped deflector	<0.12*	Wind tunnel	Unidirectional

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Table 2 C_{Pmax} reported in the literature for Savonius deflectors. The values of C_{Pmax} in studies marked 383 with an asterisk* were extrapolated.

384

385 The deflector design is easy to manufacture and can be independent of the wind turbine design. 386 It can be added to existing Savonius turbines at reasonable cost, or even be adapted to other types 387 of axial wind turbines, such as Darrieus turbines which offer higher levels of performance.

388 389

390 5. Conclusion

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392 In this work, a new type of deflector for the Savonius wind turbine is presented to improve its 393 performance. This deflector is an axisymmetric truncated cone, designed and optimized by a 394 numerical method. The main advantage of this shape is that it redirects the wind from all directions 395 into the Savonius blades. Current devices which are unidirectional fully functional for only one wind 396 direction unless they are equipped with a specific system of reorientation in the wind direction. The proposed solution has the advantage of being free of any risk of maladjustment or maintenance. It 397 398 does not require any specific mechanism because the deflectors are immobile. Comparisons 399 between experimental measurements from the literature and a numerical model with and without a 400 deflector were performed. Three-dimensional simulations with the KSST turbulence model have 401 demonstrated the potential of a wind turbine equipped with this deflector, as well as its advantages

over the solutions studied in the literature. This new deflector allows to reach a value of CPmax=0.31
 and thus to increase the performance of the wind turbine by 25% in all wind configurations

404 (intensity and direction) as well as at start-up, a key issue in the field of urban wind turbines.

405 Other works, both numerical and experimental, are in progress, and investigate the possible 406 improvements of this deflector, or on its behavior in an urban environment (presence of obstacles or 407 combination of several wind turbines and influence of the wakes, for example) as well as on its 408 adaptation to a Darrieus-type wind turbine.

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