Analysis of the impact of positive and negative criteria on the siting of wind turbines in Flanders

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1. Abstract

If Flanders wants to reach its target of 10.5% renewable energy by 2020 it has to step up the realisation of one of the most important contributors to reach this goal: the siting of wind turbines. The current share of wind energy within the production of renewable energy must grow from 13% to 18%. This would mean more than a doubling of the current installed power production or an increase of 80MW of installed wind turbines each year. Siting wind turbines in the highly urbanised region of Flanders without facing limiting factors is however very challenging. Several policy areas have formulated restrictions regarding wind turbines. This paper wants to analyse the impact of positive and negative criteria on the siting of wind turbines in order to support vision making processes for the future of wind turbines in Flanders.

Data concerning applications for building wind turbines, authorized wind turbines and actual built wind turbines are being collected by the Spatial Development Department Flanders. Based on this data a GIS analysis will be done to first of all determine where the applications for wind turbines, the authorized wind turbines and the currently built wind turbines are sited and if they comply with the restrictions set and if not which of the restrictions are not as strict as they seem. On the other side the same analysis will be done to see if the positive criteria to site a wind turbine are being respected. Second a calculation shall be done to define whether or not, with the current restrictions, enough wind turbines can be sited to meet the set goals.

2. Introduction

The European Climate and Energy package sets ambitious and binding targets for its climate and energy goals by 2020. These so called 20-20-20 targets have three objectives to reach by 2020: to reduce greenhouse gas emissions by 20% from the 1990 levels, to improve the EU's energy efficiency with 20% and to raise the share of EU energy consumption produced from renewable resources to 20%. This last target has been translated for Belgium in an increase of renewable energy resources of 13% (Directive 2009/28/EC). This in turn has been translated for the region of Flanders in a target of 10.5% renewable energy resources by 2020 (VR 2014 3101 DOC.0134/1BIS). This target, albeit low in comparison to the overall EU target is very ambitious when compared to the share of renewable resources in Flanders of 5.8% in 2013.

The recent communication of the European Commission (Document 52015DC0080) on the Energy Union is also focusing on decarbonising the economy. An ambitious climate policy will be an integral part of the Energy Union. The EU Energy policy should make Europe the number one in renewable energy. Moreover a new target for the share of renewable energy consumed in the EU by 2030 has been set at at least 27%. To achieve this 27% target new challenges must be faced.

This paper will focus on the production of renewable wind energy. This focus has been chosen because it is expected that in Flanders wind turbines, besides solar energy, have the most potential to produce a large amount of renewable energy. This potential however is not completely clear. To research the possibilities of wind turbines the Flemish Government has started the project of the 'Fast Lane' (VR 2015 2003 DOC.0246-1).

First of all this paper will focus on the territorial impact wind turbines have and the difficulties wind projects face in the densely urbanised region of Flanders. Second of all an analysis will be made to see where the applications for wind turbines, the authorized wind turbines and the currently built wind turbines are located and if this complies with the legislation set for siting wind turbines. After this a short GIS-analysis will be performed to see how much space in Flanders is available if we take the positive and negative siting criteria used in this paper into account and how many wind turbines can theoretically be placed. This will allow us to examine the possibilities of generating wind energy in Flanders. The paper will conclude with a discussion and an overall conclusion.

3. Territorial impact of renewable energy sources

Wind turbines have a large territorial impact, especially when they are clustered in groups of 5 or more turbines. Because renewable energy sources have a lower production compared to classic energy sources, their territorial footprint becomes much larger and thus the impact they have on our direct environment is much more prominent. To produce the same amount of energy a renewable energy source will need more hectares as compared to classic energy sources. An example can be given if we compare the nuclear power plant of Doel in Flanders. On a surface of 80 hectares almost 3.000MW is being produced. Converted to wind turbines of 3 MW each, this means a 1000 wind turbines are needed. If we place these turbines in a grid formation of 31 by 31 turbines with a distance of 500 meter between the turbines this would signify a surface of 22.500 hectares, or 1.7% of the whole of Flanders. Figure 1 illustrates this. This calculation is however based on the fact that the wind turbines would produce energy constantly at maximum capacity. In reality, wind turbines (as opposed to nuclear power plants that produce at almost 100% capacity) will only produce roughly at 25% of capacity.

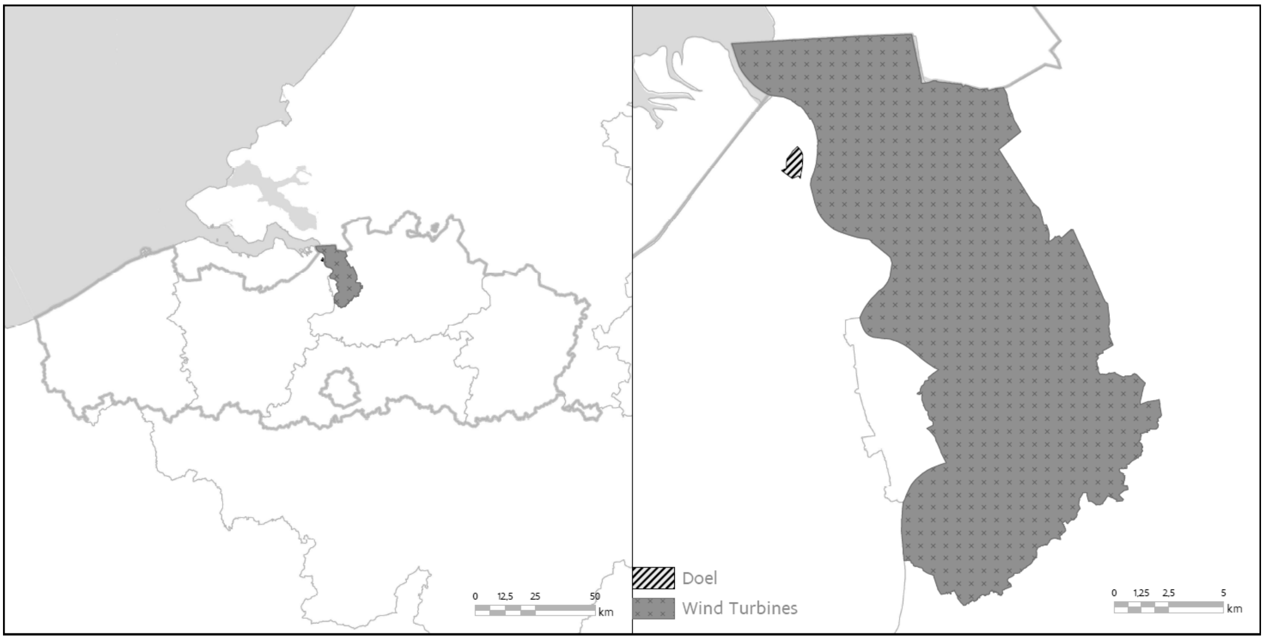

Figure 1: Territorial impact of renewable energy resources

If we focus on the current numbers and targets for wind energy we can see that within the production of renewable energy the share of wind energy is 13%. By 2020 this share should grow to 18%. If we recalculate this share in power that needs to be generated, the current installed power production of 490 MW in 2014 should rise to 1.064 MW by 2020. This would mean an increase of 80 MW each year (VR 2014 3101 DOC.0134/1BIS). Two additional factors need to be taken into account. First of all the potential for other renewable energy sources, like biomass energy, seems to be limited and secondly the targets set for 2020 are no end goal. As mentioned above the target for 2030 has already been set on at least 27% and an increase towards 2050 can be expected.

Although many new wind turbine projects are started in Flanders, until now the realisation of these projects is lagging behind. The main issue is to find an appropriate location. The high population density and the dispersed built up area contribute to the relative lack of suitable sites (Lastro Bravo et. al, 2011). The large share of built up area also contributes to other limiting factors like infrastructure and aviation limitations. Additional limitations are set by bird and habitat directive areas and nature and forest reserves. As a consequence the locations to site wind turbines are limited and decreasing due to the increasing development.

Until now wind turbines have mainly been placed close to big structures like ports, industrial areas, highways and power lines. The selection of these locations helps to minimise the visual and landscapes impact and to reduce noise pollution by wind turbines. Former wind turbine projects were mostly small scale with 3 to 4 turbines due to the current restrictions. To reach the target on renewable energy production like explained in the introduction, these small scale projects will not suffice

4. Analysis wind turbines Flanders

Data concerning applications for building wind turbines, authorized wind turbines and actual built wind turbines are being collected by the Spatial Development Department Flanders. Applications for wind turbines are daily updated. In order to check whether or not a wind turbine has actually been built a yearly monitoring is performed based on aerial pictures to see if the authorized wind turbines have effectively been built. Due to this yearly manual check-up the data has a significant delay. The monitoring performed in May 2015 was based on the newly released aerial pictures taken between January 2014 and May 2014. This means a delay of 1 - 1.5 years is present in the data on built wind turbines.

On the 8th of June 2015 812 files for wind turbines have been submitted. One file can contain several wind turbines. In total 2492 applications for individual wind turbines have been submitted. Because this study only wants to analyse the bigger turbines we have filtered the database in order to only work with the data of wind turbines with a minimum tower height of 70 meter and a minimal total height of 110 meter. After this selection 2165 wind turbines were selected. Table 1 shows in more detail the status of the wind turbine applications.

Status	Number
Refused	652
In Application	45
Withdrawn	634
Inquiry	10
Returned	142
Automatically expired	17
Authorized	636
Renunciation	25
Unknown	4
Total	2165

Table 1: Status of wind turbine applications

If we have a closer look at the 2165 applications the data shows that 636 are authorized. Of the authorized wind turbines 272 are built in Flanders. Figure 2 shows that in the past almost all the authorized applications for wind turbines in Flanders have been built. The share of built wind turbines however rapidly decreases for the last five years.

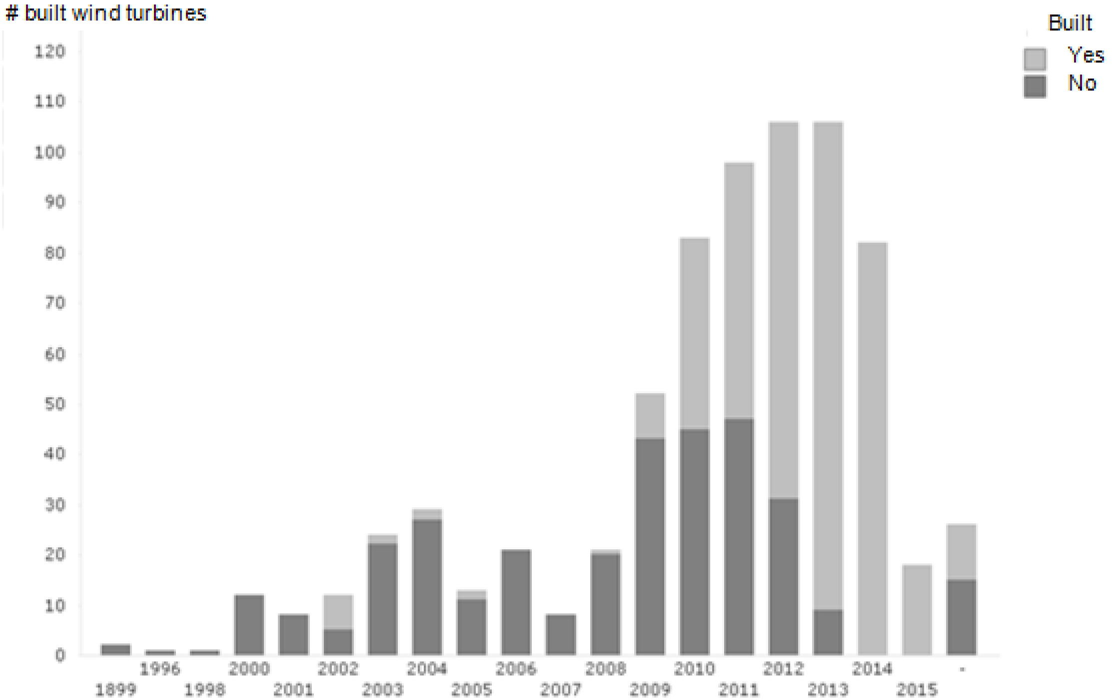

Figure 2: Built and non-built authorized wind turbines

The last update on built wind turbines that was performed in May 2015 shows a clear increase of authorized wind turbines being built starting from 2009. Figure 3 shows the delay between the moment of authorization and the actual building of the turbine. If this information is combined with the figure above we can conclude that delays of up to five years are common in wind projects.

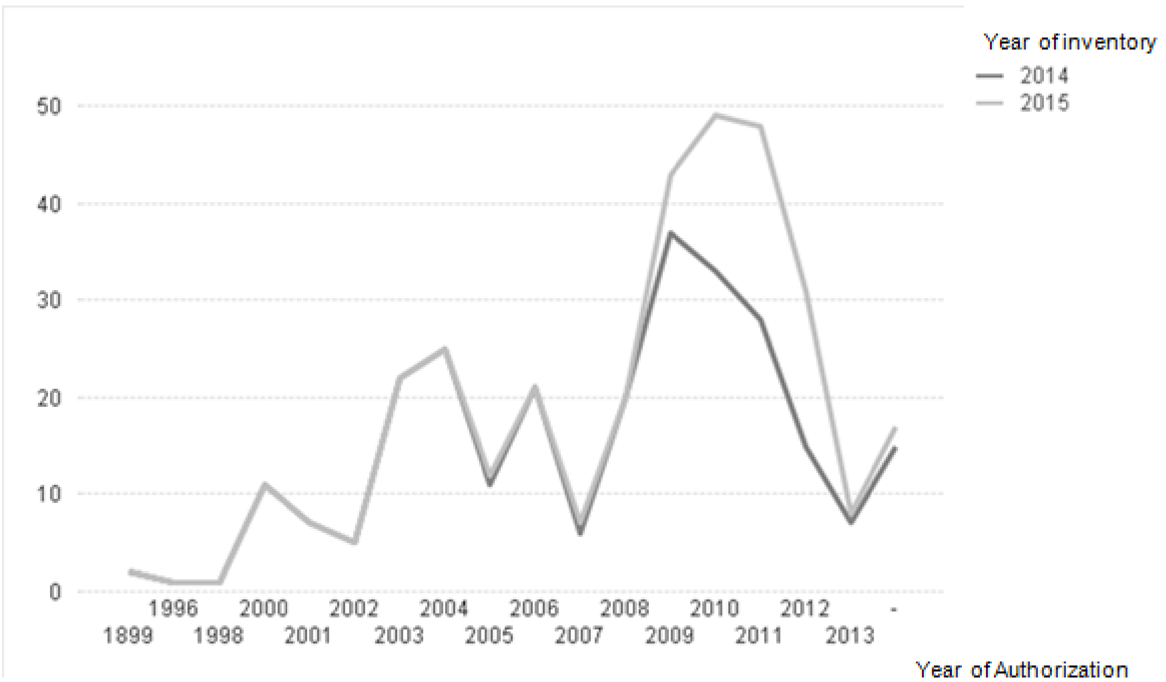

Figure 3: Difference between built wind turbines in 2014 and 2015

This conclusion is confirmed by ODE that states that a large part of the wind projects are delayed by legal procedures (Standaard 17/07/2015).However many legal procedures have ended in 2015, which clears the way for these wind turbines for being built. According to the same article the year 2015 will reach the goal set by the Flemish Government of 80 new wind turbines.

4.1 Land use category

In order to gain insight into the realisations of wind turbines with the current wind turbine policy a GIS analysis has been conducted to see in which land use category the applications for wind turbines, the authorized wind turbines and the currently built wind turbines are sited. According to legislation RO/2014/02 spatial policy should aim to concentrate wind turbines in port areas and industrial sites or close to large landscape defining infrastructures like highways, railroads, rivers, canals and power lines. Another possibility is to site wind turbines close to larger urban areas. Since 2009 wind turbines are also allowed in agricultural areas. Table 2 shows the distribution of wind turbines over the different land use categories.

Land use category	Applications	Authorized	Built
Residential use	2	1	1
Recreational services	6	0	0
Natural areas	12	1	0
Other green areas	51	11	5
Forestry	2	0	0
Agriculture	1236	234	100
Industry	421	187	84
Industry in the ports	278	138	68
Other uses (Infrastructure, utilities and services and mining)	108	35	14
Total	2116	607	272

Table 2: Distribution of wind turbines over land use categories

From this table we can conclude that most wind turbines are built in industrial zones (the categories ‘Industry’ and Industry in the ports’), with a total of 152 turbines. Almost half of the applications in industrial zones are authorized. The second largest share of wind turbines are built in agricultural zones. The table shows that most applications are done in agricultural zone, but only one fifth of those applications are authorized. Although the siting of wind turbines in agricultural zones is allowed according to spatial planning legislation, the integration of these turbines into the landscape is not guaranteed. Spatial policy aims at concentrating wind turbines in larger clusters in order to minimise the landscape impact. The proliferation of turbines in the agricultural zones could have negative effects in the already densely built up and scattered landscape of Flanders.

4.2 Positive Criteria

The spatial policy legislation on wind turbines has been further translated into positive criteria that indicate areas where wind turbines are wanted. Industrial areas and harbour areas and their immediate surrounding are suitable for siting wind turbines because of their impact on the landscape, but also because of the direct spatial coupling between production and use. The industrial areas in Flanders are very much spread over the whole region. Only the bigger industrial sites of larger than 5 hectares are taken into account.

In order to take large infrastructures into account a buffer of 250 meter has been applied to these objects. This buffer of 250 meter will allow the wind turbines to be aligned parallel to the infrastructure in a line configuration in order to emphasize the shape of the infrastructure. Placing the turbines in a larger grid next to an infrastructure element is not allowed. To reach this goal the buffer only has a width of 250 meters.

The legislation also mentions the possibility of siting wind turbines close to larger urban areas. In Flanders larger urban areas are defined in planning processes defined in spatial plans. The disadvantage however of using this dataset is that is does not take into account the urban cores in the country side. To remedy this lack of data the areas in Flanders where the soil is sealed for more than 50% are also taken into account as a positive criteria.

Utility and service areas, although not mentioned in the official legislation, can also be included into the positive criteria due to the nature of the activities in these zones. Lastly the surroundings of already built wind turbines are also included. Siting wind turbines in groups or in line formations are preferred. Table 3 shows the distribution of wind turbines over the different positive criteria. This time the total number of wind turbines does not count up to 272 due to the fact that the zones of the positive criteria can be overlapping each other.

Positive criteria	Applications	Authorized	Built
Existing industrial sites, buffer 250 m	946	399	190
Planned industrial sites, buffer 250 m	639	260	125
Harbour area	278	138	68
Railways, buffer 250 m	240	84	40
Highways, buffer 250 m	616	158	78
Primary roads, buffer 250 m	276	77	26
Waterways, buffer 250 m	340	121	60
Sealed soil > 50%	347	168	51
Planned urban areas	304	121	66
Surrounding of utility and service areas	23	14	12
Surrounding of built wind turbines	40	18	15

Table 3: Distribution of wind turbines over positive criteria

Like the analysis on distribution of wind turbines over land use categories we can conclude from the analysis on distribution of wind turbines over positive criteria that most applications for wind turbines, authorized wind turbines and built wind turbines are located in the industrial zones. More than 40% of the applications in all three types of industrial zones get authorized. However only half of those authorized wind turbines has actually been built.

What this analysis further reveals are the large numbers of applications for wind turbines especially along highways and, to a lesser extent, waterways. The success rate of these applications is however significantly lower with only one fourth of the applications being authorized for wind turbines along high ways and primary roads. The rate of authorization is higher for turbines along railroads and waterways. One third of those turbines are authorized. Again, only about half of the authorized wind turbines along line elements have effectively been built. These numbers do however show that the spatial policy aiming to concentrate wind turbines in industrial areas and close to large landscape defining infrastructure is working.

Almost half of the applications for wind turbines in an area of more than 50% sealed soil get authorized. This is one of the highest success rates. The actual building of these turbines is however one of the lowest with only 30% built. A different picture can be seen for the wind turbines in the planned urban zones. With a success rate for the applications of almost 40% and with more than 50% being built, planned urban zones are the third most common place to site wind turbines. The placing of wind turbines in urban areas is difficult due to the proximity of housing. In general a distance of at least 300 meter should be respected due to safety restrictions and sound and shadow flicker. This distance is however not always respected as can also be seen from the analysis on negative criteria below.

The small number of wind turbines sited close to other wind turbines supports the statement made above that most former wind turbine projects are small scale and the building of wind turbines in Flanders is to haphazard. A larger vision on where wind turbines should be sited in the Flemish landscape is missing again adding to the already fragmented region.

4.3 Negative Criteria

Besides positive siting criteria a large number of negative siting criteria can be listed. These criteria are mainly formulated by other policy areas or due to safety restrictions. The negative criteria define areas where currently no wind turbines are allowed or where strict restrictions should be taken into account.

First of all several types of natural areas are restricted for wind turbines. These are the birds and habitat directive areas (except for industrial areas sited in these areas), areas part of the Flemish ecological network and areas part of the support network of the ecological network, nature reserves and forest reserves. Due to their natural value wind turbines are not desirable.

Areas with a high landscape value are also restricted for wind turbines. Besides anchor sites, protected archaeological sites, protected landscapes, protected monuments, protected cityscapes and UNESCO sites, large open spaces bigger than 1000 hectares are also excluded. Due to the dense built up area, large open spaces are rare and should be preserved. To determine this open space the indicator of contiguity of open space is being used. These are contiguous areas with a surface of at least a 1000 hectares that are not cut through by mayor infrastructure or build up areas. All those areas are excluded from placing wind turbines except a buffer of 250 meter around highways and a buffer of 750 meter around existing wind turbines. The spatially vulnerable areas are also being excluded.

Regarding safety several restrictions need to be taken into account. The rotor turning above an industrial building is not allowed (buffer of 50 meter if the rotor diameter is 100 meter) and a minimum distance needs to be applied with respect to power lines, pipelines and seveso installations (150m, 150m and 200m respectively). A buffer of 300 meter is applied around planned residential areas and individual residential buildings. Existing wind turbines also need a buffer of 500m.

National defence policy has indicated several zones with different types of restrictions. In the high danger zone and the radar zone no wind turbines are allowed. In the Aerodrome Control Zone and the Military Reserve Aerodrome a height restriction of 122 meter applies. In the PAN-OPS zones height restrictions based on individual analysis applies. Finally in the Military training areas beaconing is required.

To conclude the list of negative criteria the Belgian Air Traffic Control has two types of restrictions. In a 10 km zone around the DVOR navigation beacon a limited number of turbines can be placed. Outside the radius of 10 km wind turbines are allowed. Within 15 km of the radar zone a detailed study is needed to determine the effects of the turbines. Table 4 shows the distribution of wind turbines over the negative criteria.

Negative Criteria	Applications	Authorized	Built
Habitat directive (without Industrial sites)	1	0	0
Bird directive (without Industrial sites)	41	20	1
Nature reserves	0	0	0
Forest reserves	0	0	0
Flemish Ecological network	1	0	0
Anchor sites	12	0	0
Protected archaeological sites	1	0	0
Protected landscapes	3	0	0
Protected monuments	0	0	0
Protected cityscapes	0	0	0
Unesco	0	0	0
Spatially vulnerable areas	50	19	12
Planned residential area, buffer 300m	171	41	18
Industrial buildings, buffer 50 m	223	96	37
Residential buildings, buffer 300 m	1144	322	147
Railways, buffer 50 m	10	4	2
Highways, buffer 50 m	11	3	3
Primary roads, buffer 50 m	4	0	0
Waterways, buffer 50 m	11	2	1
Power lines, buffer 150m	161	37	18
Pipelines, buffer 150m	152	36	24
Seveso installations, buffer 200m	30	8	2
Defence Radar Zone	74	13	11
Defence Military Reserve Aerodrome	124	21	13
Defence Aerodrome Control Zone	151	11	5
Defence High Danger Zone	19	5	0
Belgocontrol Radar Zone	76	10	3
Belgocontrol Orange Zone	394	88	45
Built wind turbines, buffer 500m	555	314	272
Authorized wind turbines, buffer 500 m	1260	626	272
Open space > 1000ha, except highways	185	23	12

Table 4: Distribution of wind turbines over negative criteria

This spatial analysis on the wind turbine data compared with negative siting criteria shows that not all the criteria are respected. Especially in the areas with high nature value and the areas with heritage value none, or almost none, of the applications for wind turbines are being authorized. The 20 turbines which are authorized in bird directive area are all in the same municipality.

Of these numbers, the results for the comparison located in a buffer around wind turbines can be ignored. It is logical that all the built wind turbines (272) are within a buffer of 500 meter of itself.

More striking are the relative large numbers of wind turbines close to residential buildings. A footnote should be added however on the data source of the residential buildings. Due to privacy reasons no official dataset on residential buildings in Flanders is currently available. Therefor an estimation has been done based on the selection of all the buildings located in residential land use zones. This estimation however has its flaws since not all buildings in residential zones are residential buildings. The numbers do however indicate that the safety restrictions in order to minimise sound and shadow flicker are not always respected. The wind turbines authorized and built in planned residential areas (with a buffer of 300 meter) are all except for one located in the buffer zone around the residential area.

If we have a closer look at the defence and aviation restrictions we can see that all of these zones can not be completely ruled out as a location for wind turbines. For the zones originating from Belgocontrol the rules are vague: ‘limited numbers are allowed’ or ‘a detailed study is needed’. These flexible rules have let to 48 built wind turbines so far. In two of the defence zones (high danger zones and radar zones) no wind turbines are allowed. But the numbers do show 11 built and 7 more authorized. All of these turbines are located on the edge of the zone. In the two other defence zones (Military Reserve Aerodrome and Aerodrome Control Zone) height restrictions limit the possibilities. After a more detailed look at the data however only the 5 built turbines in the Aerodrome Control Zone respect these limitations. All the other built and authorized turbines have a greater height.

Both the authorized and the built turbines within spatially vulnerable areas are mainly sited within the harbour area of Gent. Only a small number of built wind turbines do not respect the buffer around line elements and industrial buildings. After a more detailed analysis it showed that these turbines are built on the edge of the buffer zones. The higher amount of turbines on power lines and pipeline is due to the fact that these are underground lines and the dataset does not show the difference between lines above and underground.

Finally, the cause of the small number of authorized and built wind turbines in open space can be found in the fact that no official dataset for open space is available and therefor also not used when applications for wind turbines are examined.

5. Area available in Flanders for wind turbines

In this part a GIS analysis is performed in order to see how big the surface available for wind turbines in Flanders is if we take the above mentioned positive and negative criteria into account. First of all the surfaces of all the positive criteria are added up. This is the area where wind turbines are wanted. Second of all the surfaces of all the negative criteria are deduced form the positive criteria. According to the interpretation used in this paper the result of this exercise will give the total available space in Flanders for wind turbines.

As the analysis in section 4 shows, not all of the negative criteria are as strict as they seem. The analysis performed below should therefore be seen as a starting point in the search for suitable sites for wind turbines.

Figure 4 shows the result of the overlay analysis. As can be seen from the map, few areas in Flanders are not covered by negative restrictions. A total of 4200 hectares is still available in Flanders to site wind turbines. The harbours of Zeebrugge, Gent and Antwerp can easily be distinguished on the map as favourable places for wind turbines. If an algorithm is used to place as many turbines in those remaining areas with a distance of at least 500 meter between those turbines, a total of 854 could be placed. If the already authorized, but not yet built turbines are added up to this number, it would appear enough space is still available to build 80 wind turbines a year until 2020.

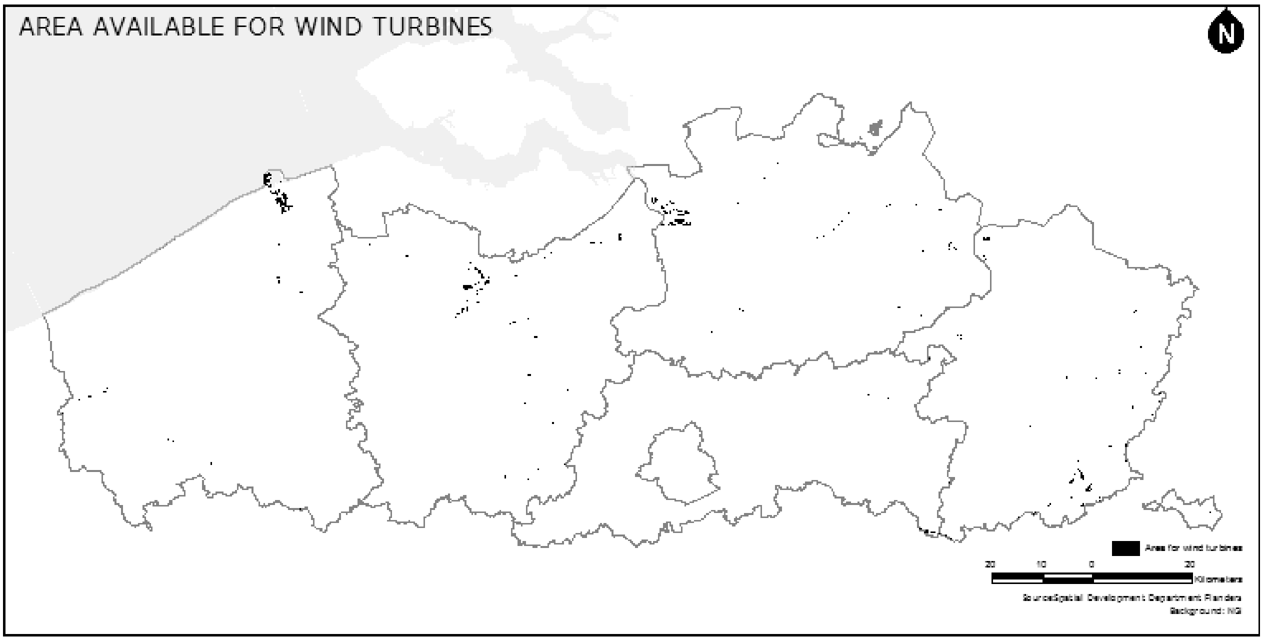

Figure 4: Area available for wind turbines

6. Conclusion and discussion

This paper wanted to give an overview of the current situation of wind turbines in Flanders, in order to support new vision making processes for the future of wind turbines in Flanders. The results suggest that although there seems to be limited space in Flanders a reasonable amount of 636 wind turbines did get authorized. If the numbers shown in figure 2, showing that almost all the authorized wind turbines before 2009 are also built, continue in the same way after 2009 the set target of 80 new wind turbines a year is within reach. The GIS overlay analysis seems to be consistent with this conclusion adding another 854 potential wind turbines.

There is however a significant delay between the date of authorization of a wind turbine and the date of building of a wind turbine. Further research is needed in order to find out what causes the delay and if it is possible to speed up the process. A first indication of the reason of delay is the reference to legal procedures, started by people in the direct surroundings of the planned wind turbines. What type of actions could avoid these legal procedures?

The fact that at the moment a significant amount of the authorized and even of the already built wind turbines are already situated in zones that are now seen as negative siting criteria also needs to be examined in further detail. These results suggest that each wind turbine project is unique and should be individually examined. An analysis done on the scale of Flanders is useful to establish an overall framework for the reviews of wind turbine projects, but place based approaches are still needed for individual projects.

This analysis is mainly based on GIS data. As explained above the Spatial Development Department keeps track of all the built wind turbines by a yearly manual overlay with the aerial pictures. There is however a large delay of more than a year on this data. Moreover, the database is only based on the authorizations from a planning perspective; besides this an environmental authorization is also needed. This data is not available at the moment. In order to monitor the Flemish process towards the 20-20-20 goals a more comprehensive database accessible for all is needed. Updates on the realisation of wind turbines should be done on a daily basis, based on the actual built turbine, not based on aerial pictures. Other data used in this analysis, like the data on residential buildings, industrial buildings, pipelines and power lines also need to be more detailed in order to refine the zones of negative criteria.

The big number of potential wind turbines is also given a false positive image for the actual possibilities. As stated above, from a spatial perspective it is desirable to cluster wind turbines in larger groups in order to minimise the impact they have on the landscape. A scattering of solitary wind turbines have a much larger impact on the landscape than several bigger clusters. The calculation of potential wind turbines did not take this fact into account and as a consequence has included many solitary wind turbines. This limitation in the results suggest further in depth research is needed in order to give a more realistic output.

So although a good first overview has been given on the current situation of wind turbines in Flanders, a lot is still unclear and needs further research. This research could address the limitations as stated above on data problems and clustering of wind turbines. Further study is also required on the reasons of the delay between the authorization of a wind turbine and the actual building of the turbine.

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