



Energy Technologies Area

Lawrence Berkeley National Laboratory

Effects of land-based wind turbine upsizing on community sound levels and power and energy density

LBNL Release Webinar

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- Please submit questions via the Q&A window
- This webinar will be recorded

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Agenda

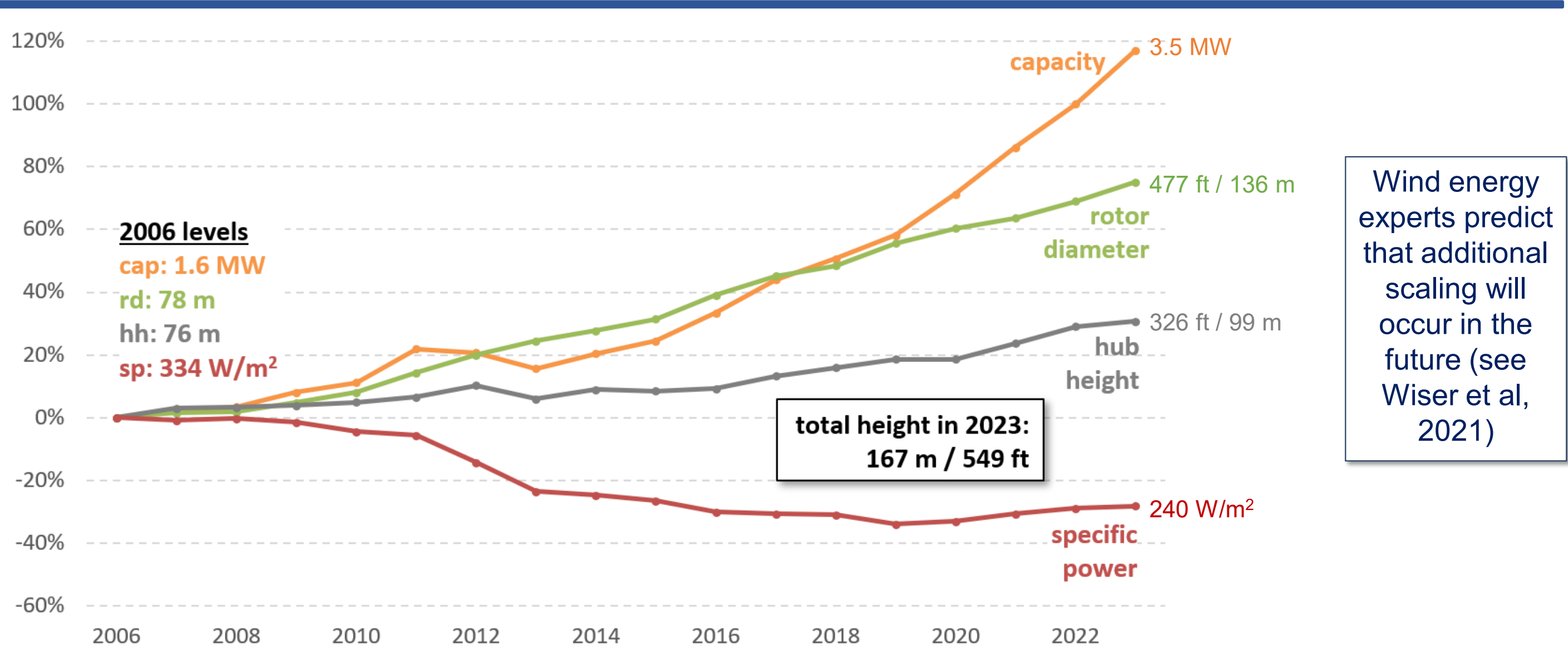
- Background
- Data and Methodology
- Results
- Takeaways



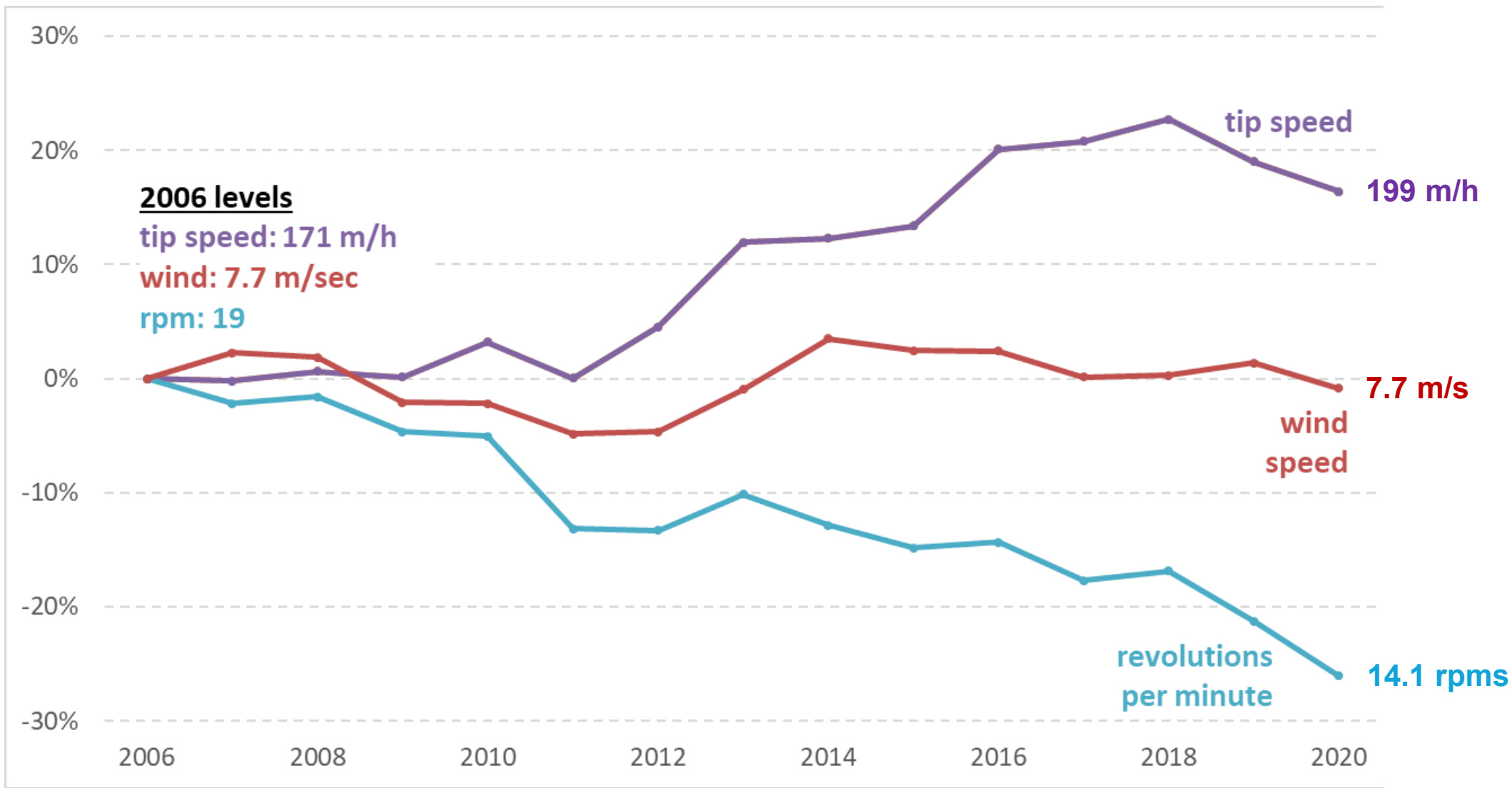
Source: Metaefficient, The Tallest Wind Turbines in the US Installed in Texas. 1/18/2008



Average U.S. Turbine Hub Height, Rated Capacity and Rotor Diameter Have Increased Considerably Over Time, Lowering Specific Power



Rated Rotor RPM Has Declined Over Time, As Tip Speeds Have Increased, While Wind Speed Has Remained Flat



- As rotors get longer, they must spin more slowly to keep tip speeds under control
- Despite that, tip speeds have steadily increased
- Tip speed is considered a key contributor to turbine sound emissions
- Flat wind speed, coupled with lower specific power, has resulted in increased capacity factors

Sources of Turbine Sound Are Varied (and Changing Over Time) And Aerodynamics Are A Key Contributor

- Largest contributors to sound are, in this order:

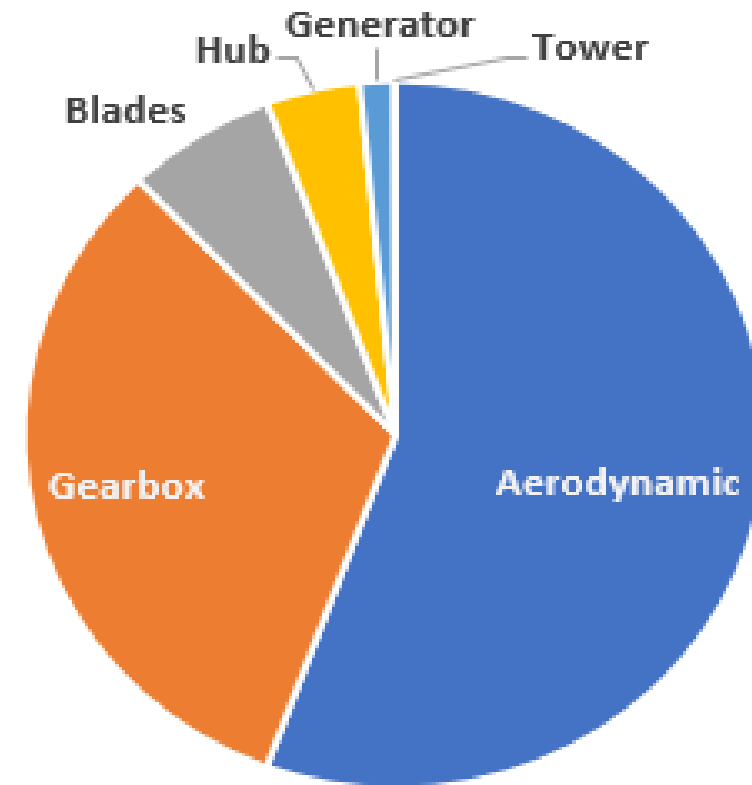
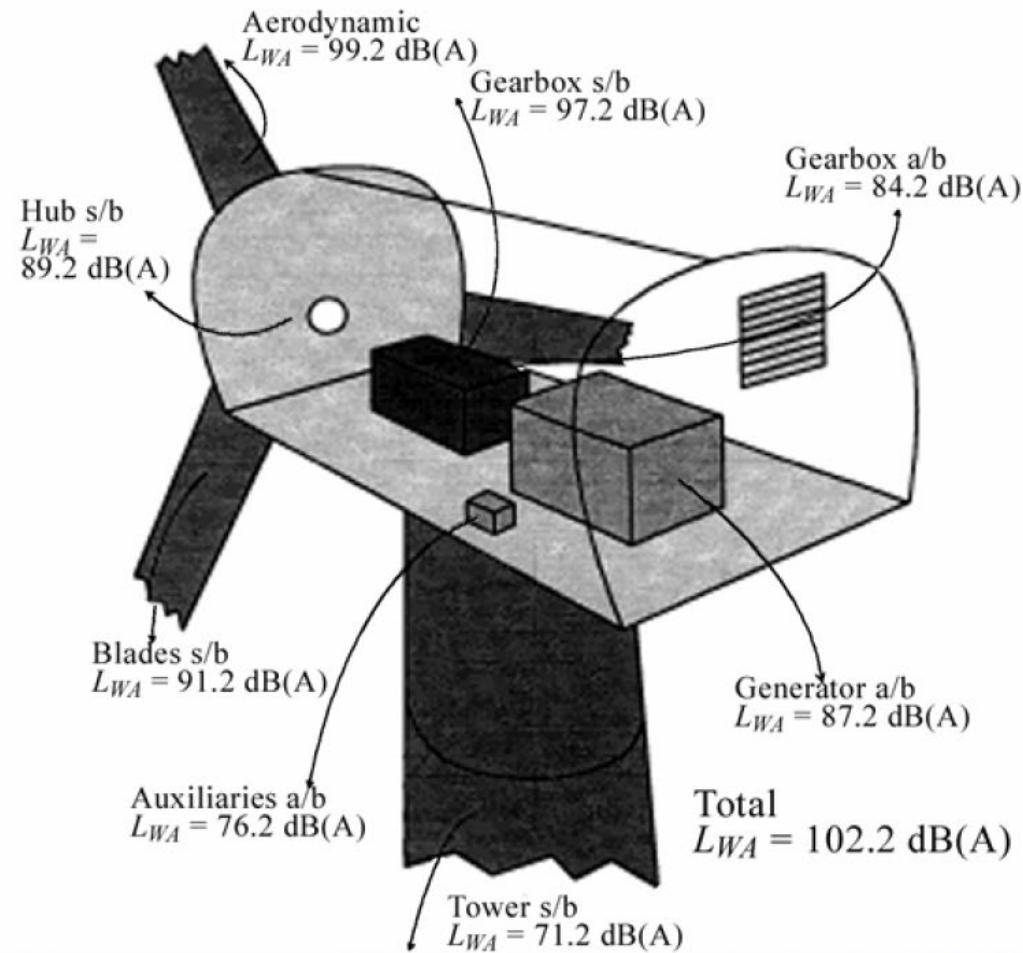
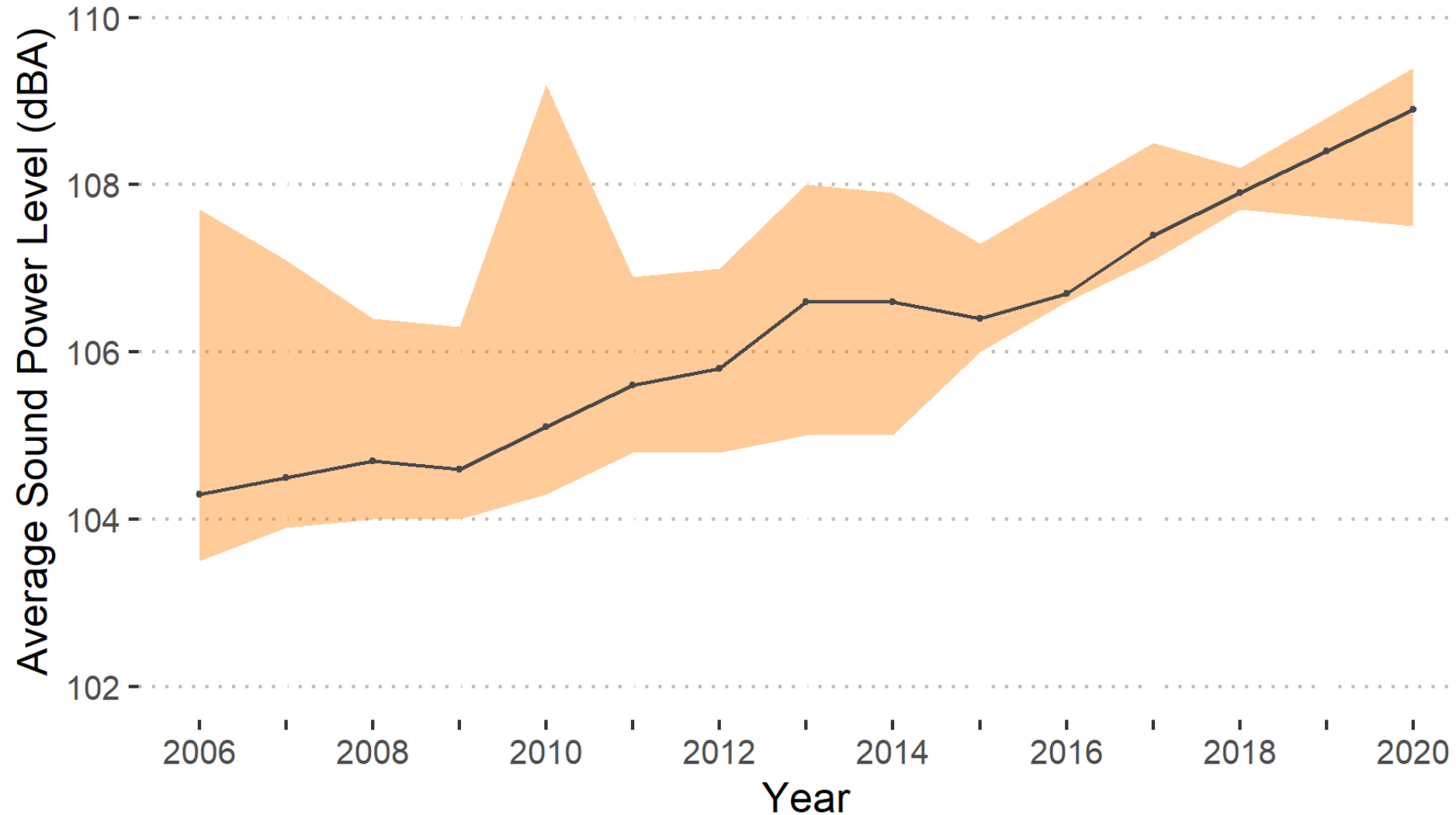


Figure 5. Components and Total Sound Power Level of a Wind Turbine

source: Rogers & Manwell (2004) Wind Turbine Noise Issues

Accordingly, Sound Power Level Of Turbines Has Increased Over Time As Well



- Turbine “sound power” level” represents the sound energy emitted by the wind turbine
- The average sound power level of turbines installed since 2013 has exceeded 106 dBA and reached >108 dBA in 2020.

This Increase Might Be Mitigated By Serrated Trailing Edge Treatments and Noise Reduced Operations

- **Serrated trailing edges (STE) (see example)**
 - reduces sound by ~ 1.5 dBA
 - Is becoming more common
 - 25% of installations in 2019 had STE, ~ 50% in 2021, and likely 100% in future
- **Noise reduced operation (NRO)** is when a turbine RPM is slowed, yet via blade angle, torque is increased, such that relatively similar power is generated despite slower RPM. With lower RPM, sound is reduced.
 - Because of the increase in torque, stress is added to turbine blade and towers and gearbox
 - Used only in specific situations for single or small sets of turbines (we are told)

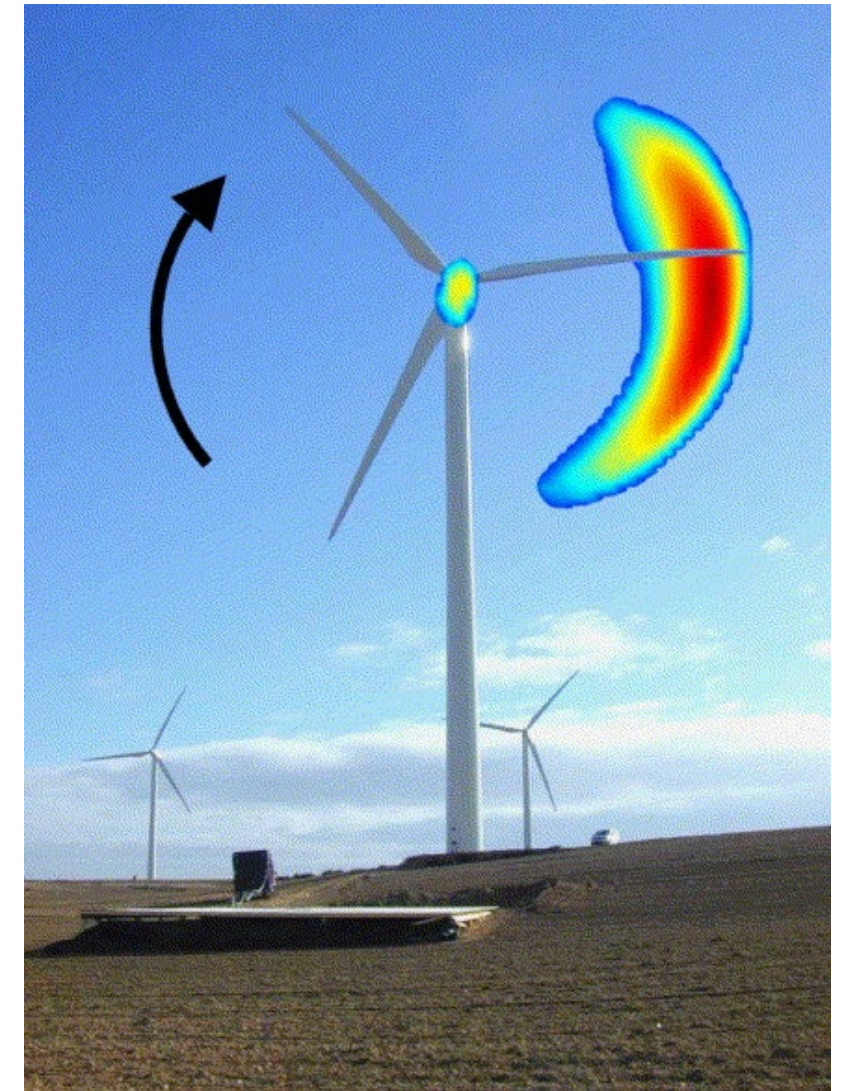
Serrated Trailing Edge Example



Source: Oerlemans (2009)
c/o Barone (2011)

Why Does Sound From Turbines Matter?

- It's a wind project design constraint in most U.S. areas
- Sound is also heavily regulated outside the U.S.
- Turbine noise is one of the major impacts that people living near turbines experience
- Turbine sound power levels (or sound emissions) have been increasing over time
- Turbines, which need to be sited near transmission, will likely be placed in areas of higher population densities over time



Source: Oerlemans (2007)

What Do These Changes Mean For An Average Community?



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Louder Turbines
Larger Blades and
Higher Hubs
so, Larger Setbacks
but
Higher Nameplate Capacity
Higher Capacity Factor



Data and Methodology

Source: Nordex



Hypothetical Developments: Then, Now & Future



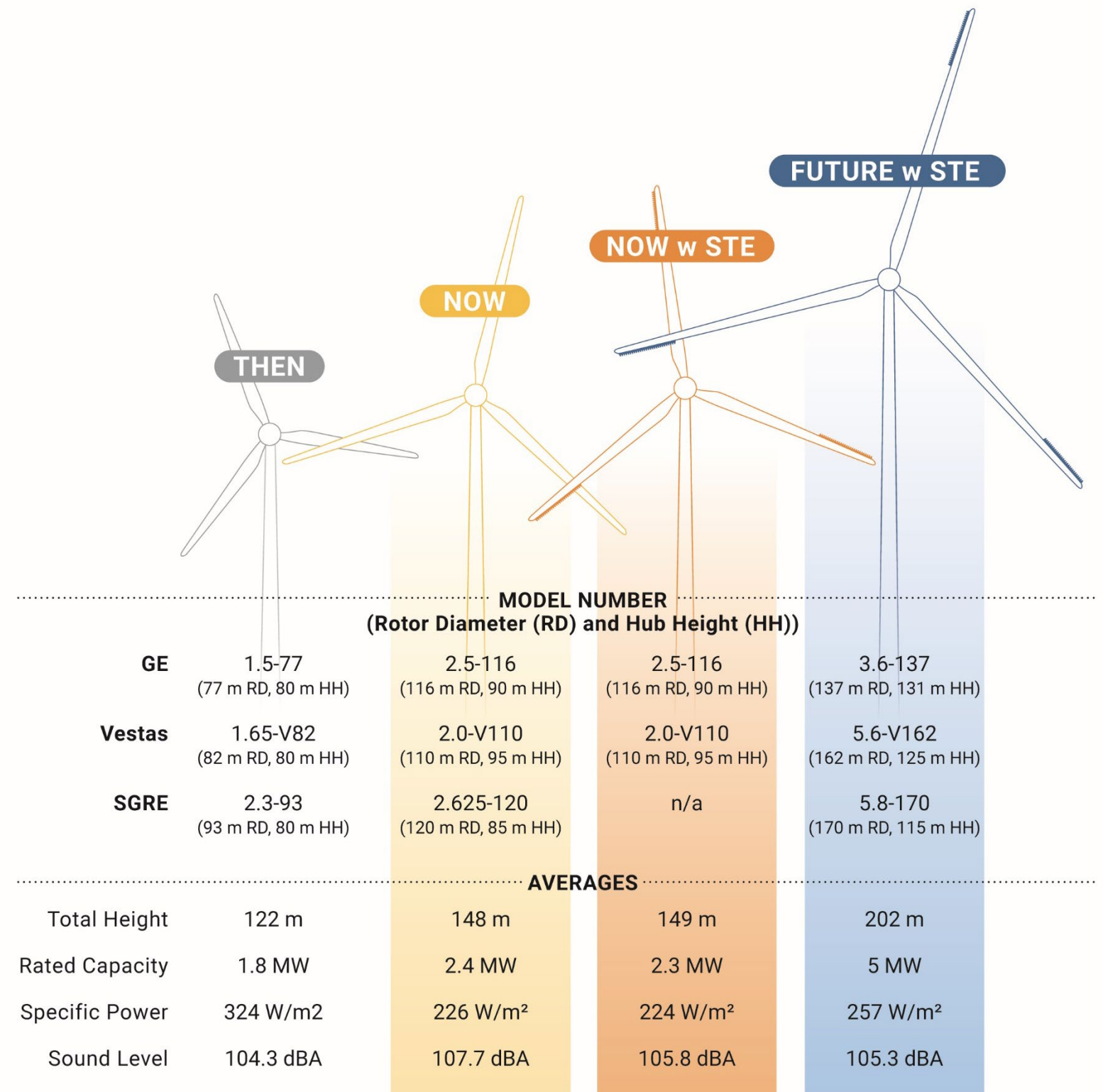
- **Purpose:** To better understand how turbine characteristic changes over time impact communities.
- **Approach:** Use two previously built sites, and “re-develop” them on the desktop using old (“then”), current (“now”), and future turbines from the same OEMs, using the same project design criteria.
- **Examine Changes in:**
 - Number of turbines
 - Project capacity
 - Annual energy output
 - Community sound levels (participants and non-participants)
 - Land use

“Will communities be better or worse off with future turbines?”

11 Different Turbines

3 OEMs

- **Then:** Most popular in U.S. for OEM in the last 10 years (2011-2020)
- **Now:** Most popular in the U.S. for OEM the last 2 years (2019-2020)
- **Now w STE:** Same as Now but with serrated trailing edges (STE) (*no STE SGRE Now model available*)
- **Future w STE:**
 - Appears in American Clean Power (ACP) Association “under development” dataset
 - Confirmed sales in the U.S.
 - ~ 200 meters in total height
 - Specific power < 300 W/m²
 - Rotor diameter ≤ 170 m
 - STE included standard



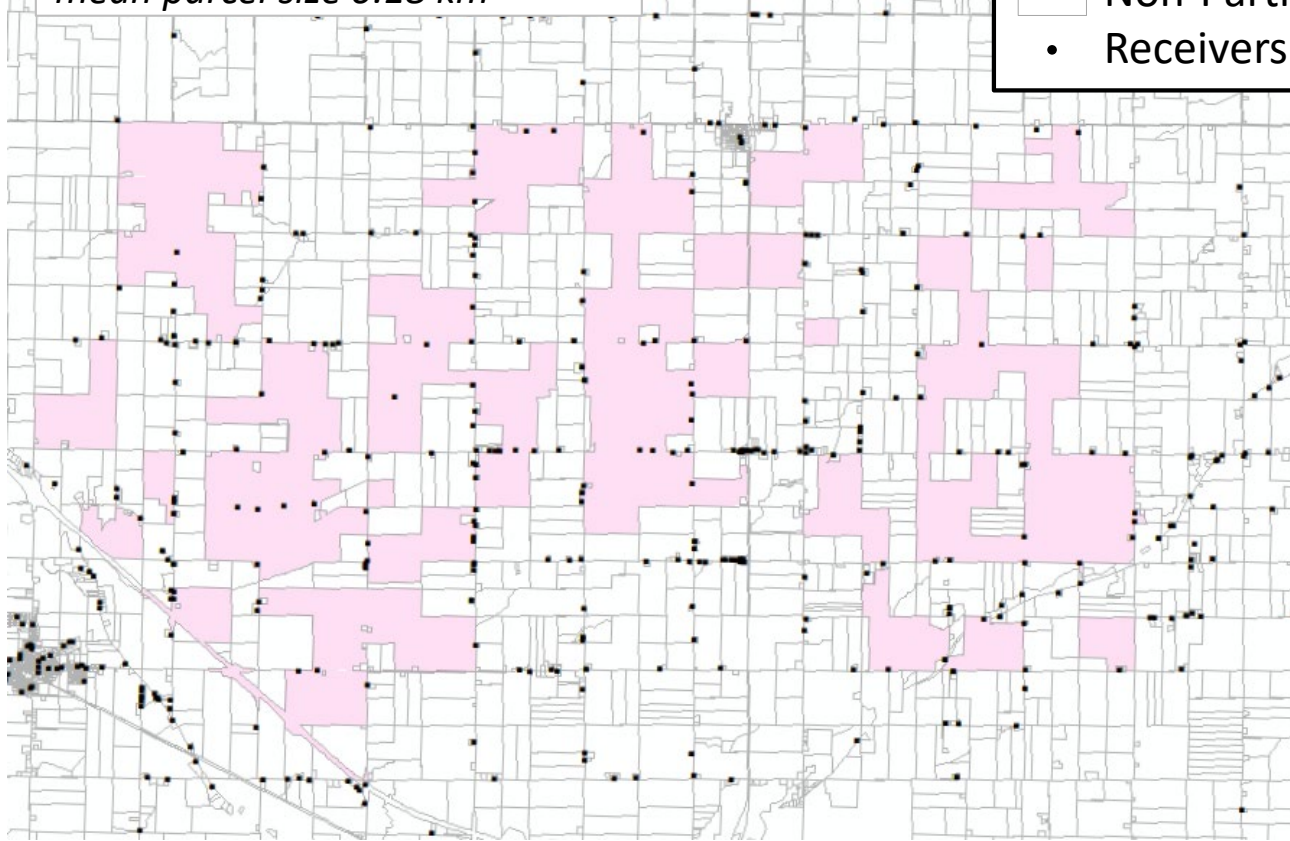
22 Total Projects: Each Of The 11 Turbines Are Used To Build Projects At Each of 2 Prototypical U.S. Sites

Site 1

370 receivers;
263 participant parcels covering
49 km² in total;
mean parcel size 0.18 km²

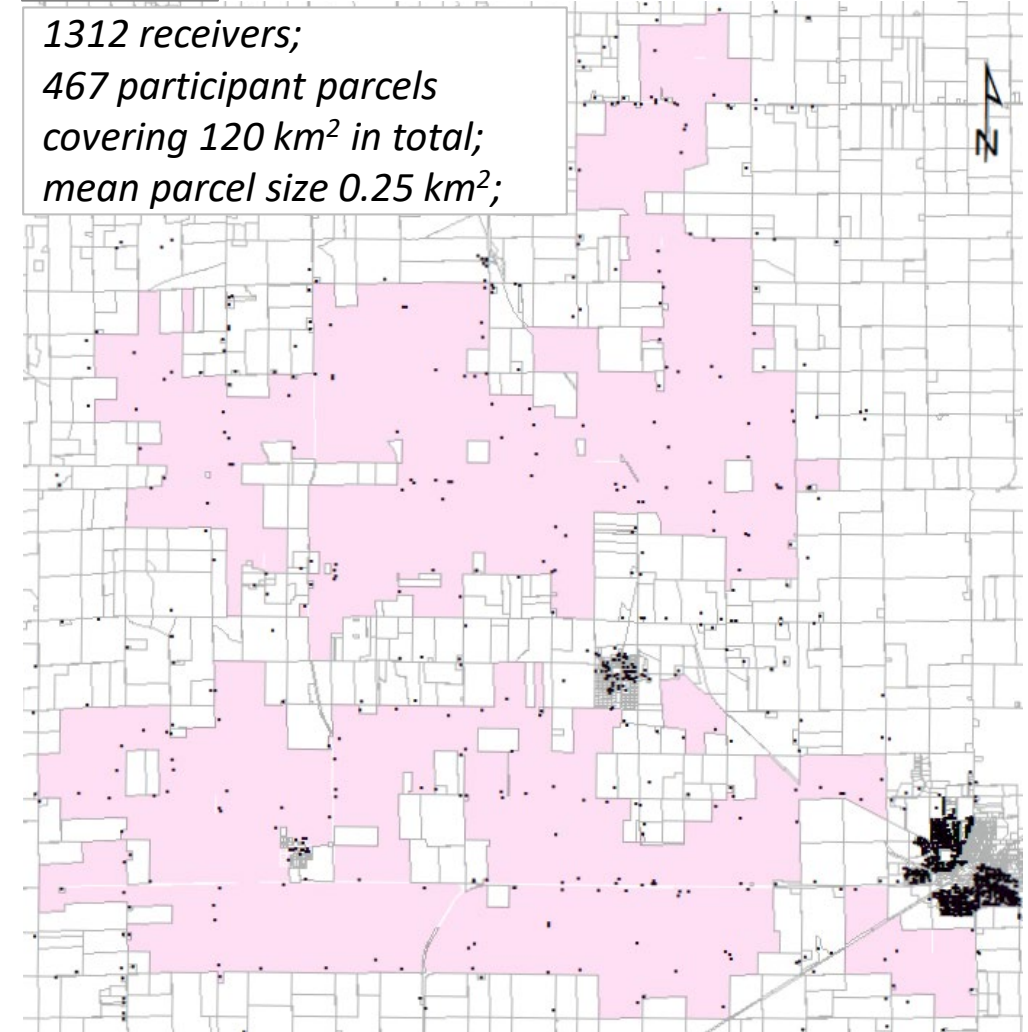
Legend

- Participating Parcels
- Non-Participating Parcels
- Receivers



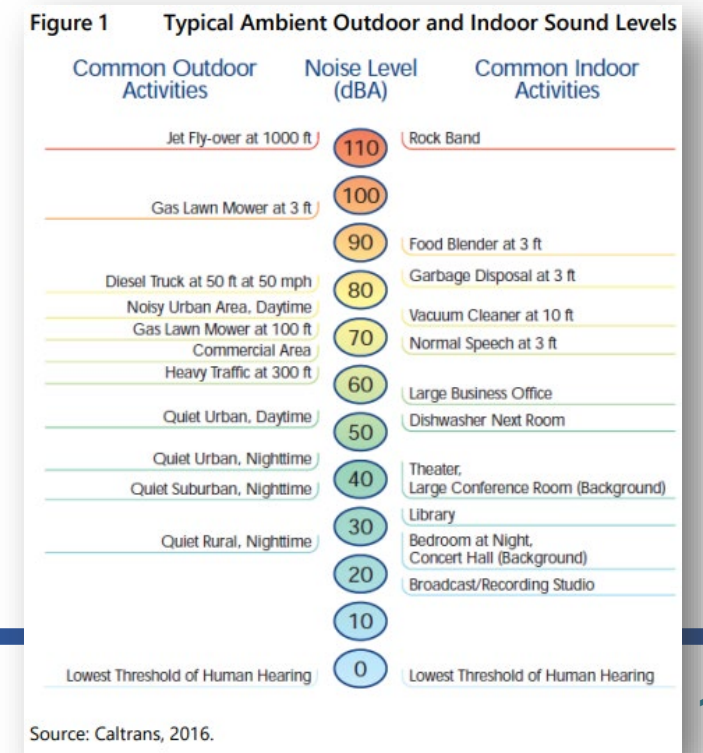
Site 2

1312 receivers;
467 participant parcels covering
120 km² in total;
mean parcel size 0.25 km²



All Projects Used The Same Design Assumptions And Noise Regulations Based On Those "Typical" in Several U.S. States

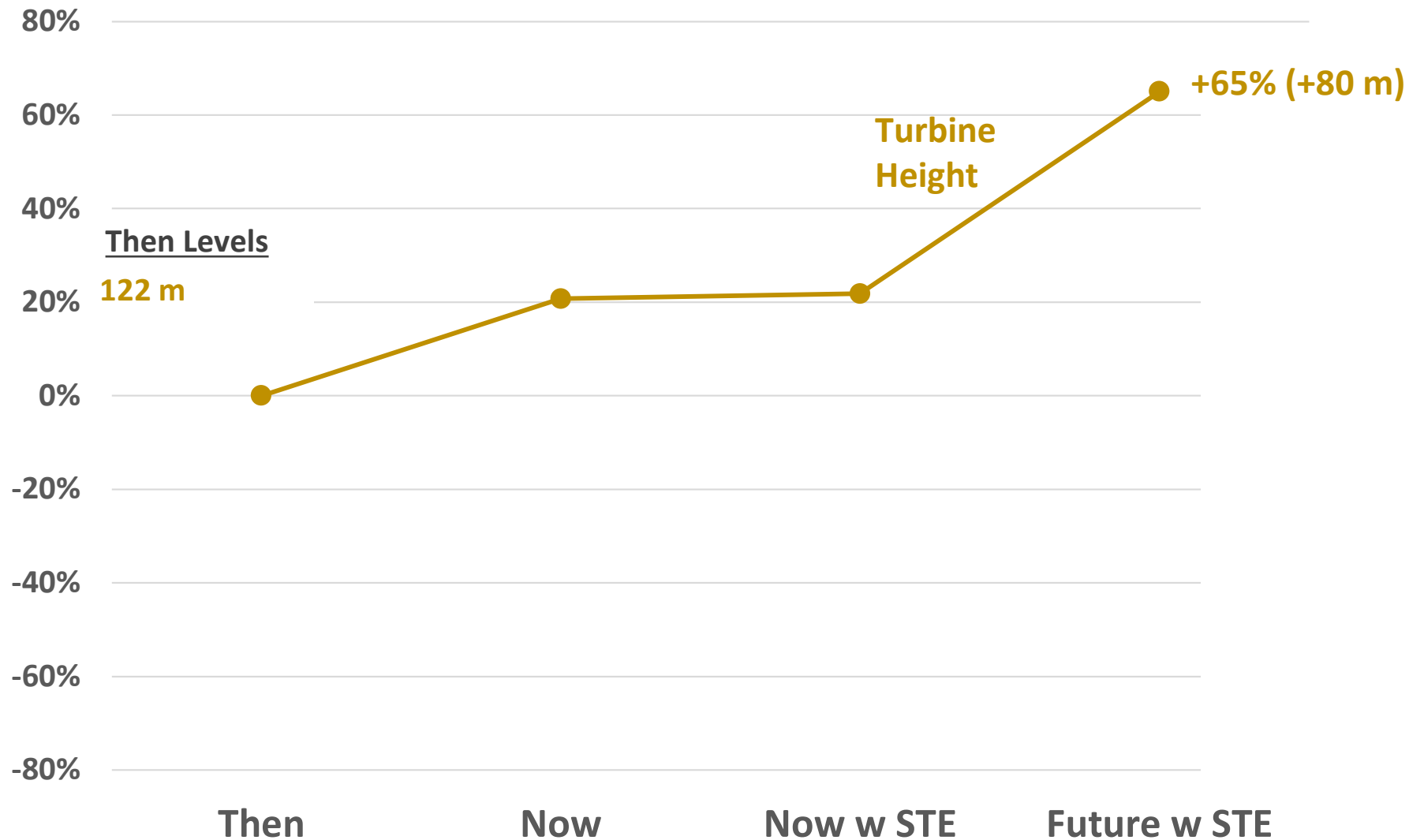
- Design “rules” and assumptions:
 - Total turbine height = hub height + $\frac{1}{2}$ rotor diameter
 - Setbacks: Turbines have a minimum property and roadway setback distance of 1.3x total turbine height
 - Spacing: Turbines are spaced using an ellipse method with the primary axis (based on prevailing wind direction) of 8 rotor diameters (row-to-row) and a perpendicular secondary axis of 5 rotor diameters (side-to-side)
- Design noise regulations (for sound “pressure” levels on the ground):
 - Participating residences have a maximum sound of 50 dBA ($L_{eq1h-max}$)
 - Non-participating residences have a maximum sound of 45 dBA ($L_{eq1h-max}$)
- Design goal and considerations:
 - Optimize siting for annual project output (MWh/year), while respecting setback, spacing, and noise regulation restrictions.
 - Wind turbine availability not considered
 - Only energy production losses related to wake effects are considered (I.e., not grid availability, transmission losses, etc.)





Source: Pixabay

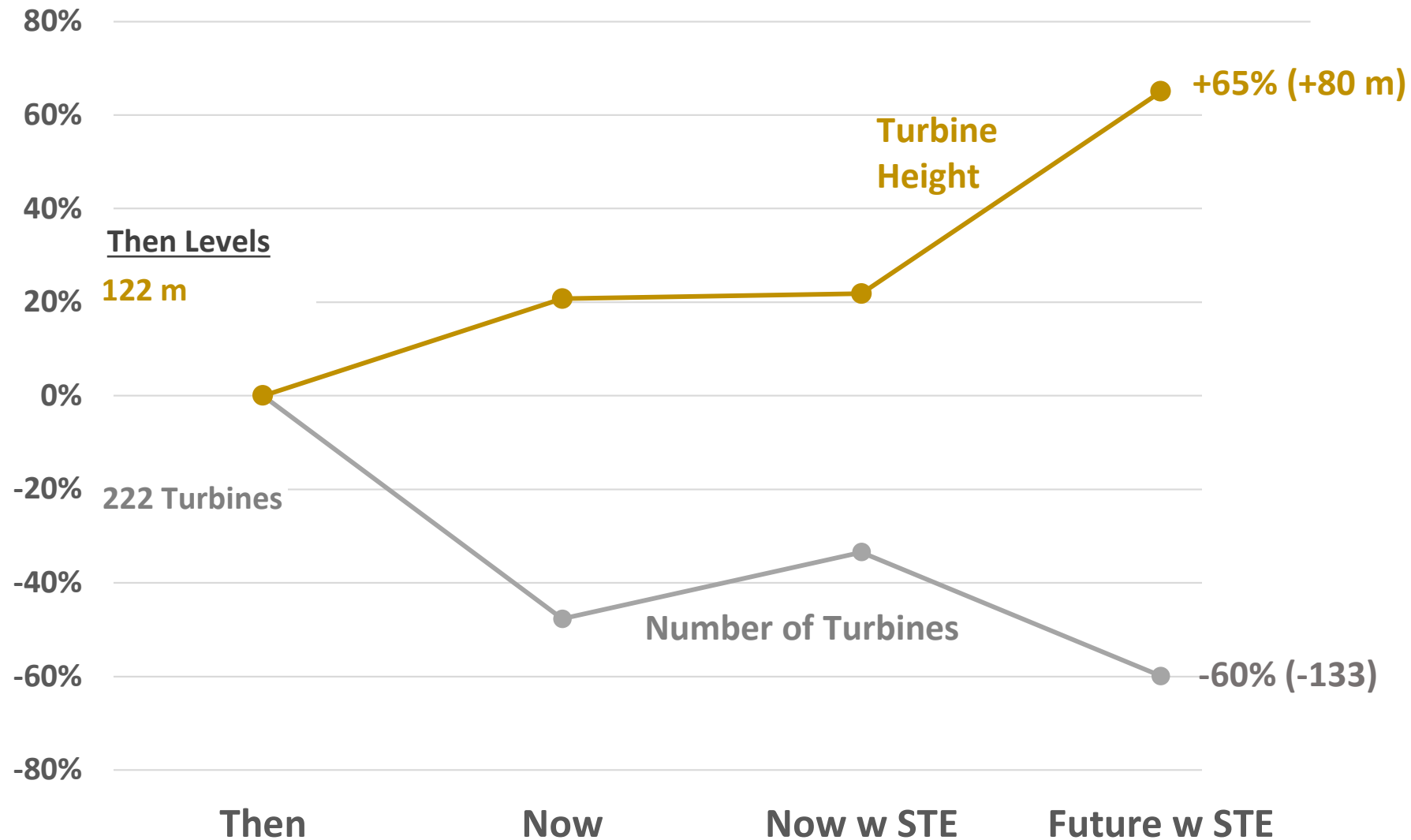
From “Then” to “Future” Turbines, There Are Consistent Increases In Both Installed Capacity and Output, As Turbine Counts Dropped



From Then to Future:

- Turbine height increases by 80 meters
- 122 to 202 meters
- A 65% increase

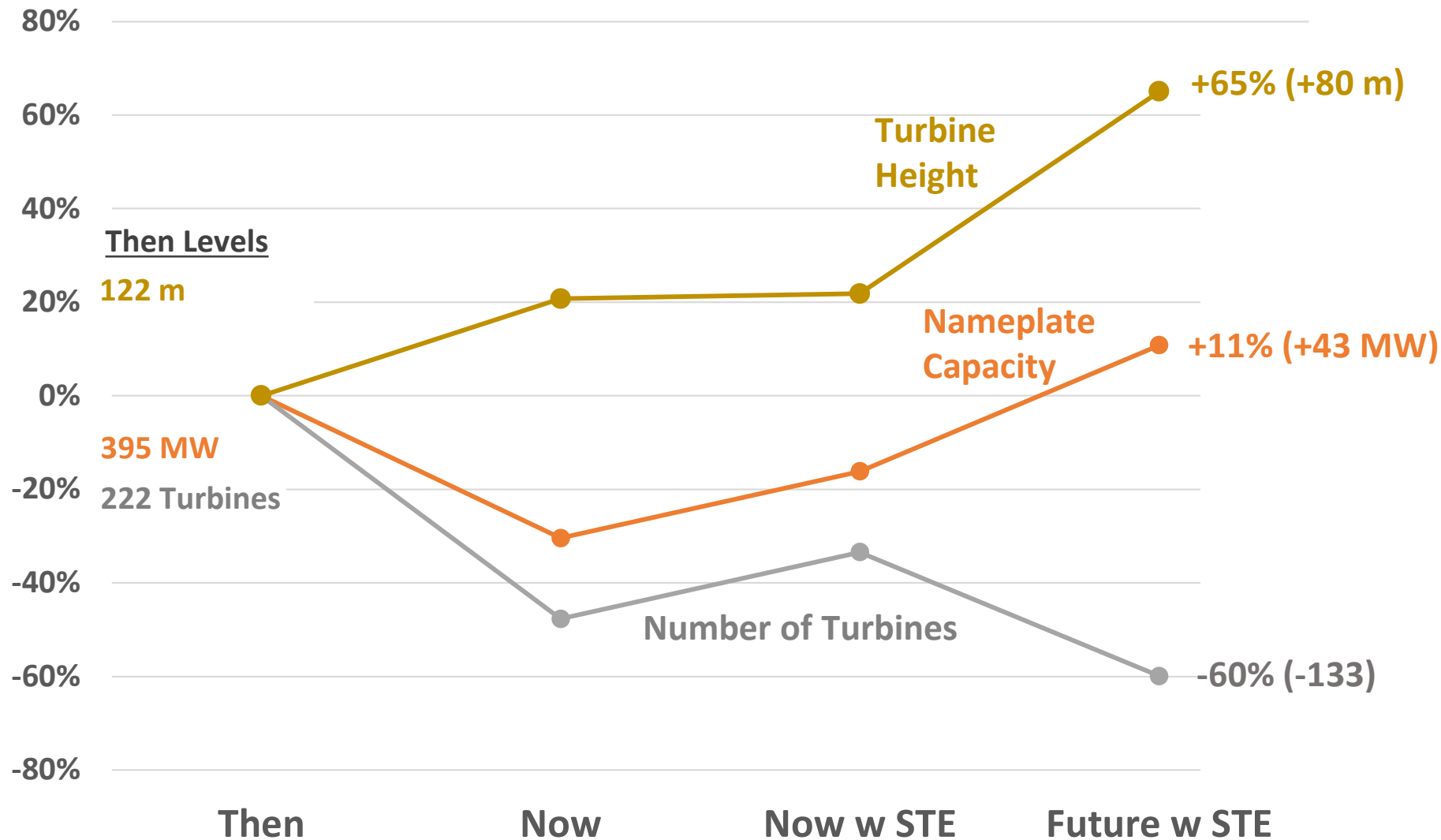
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Mostly because of this height increase:

- The number of turbines that can be sited decreases
- 222 to 89 turbines
- 60% decrease

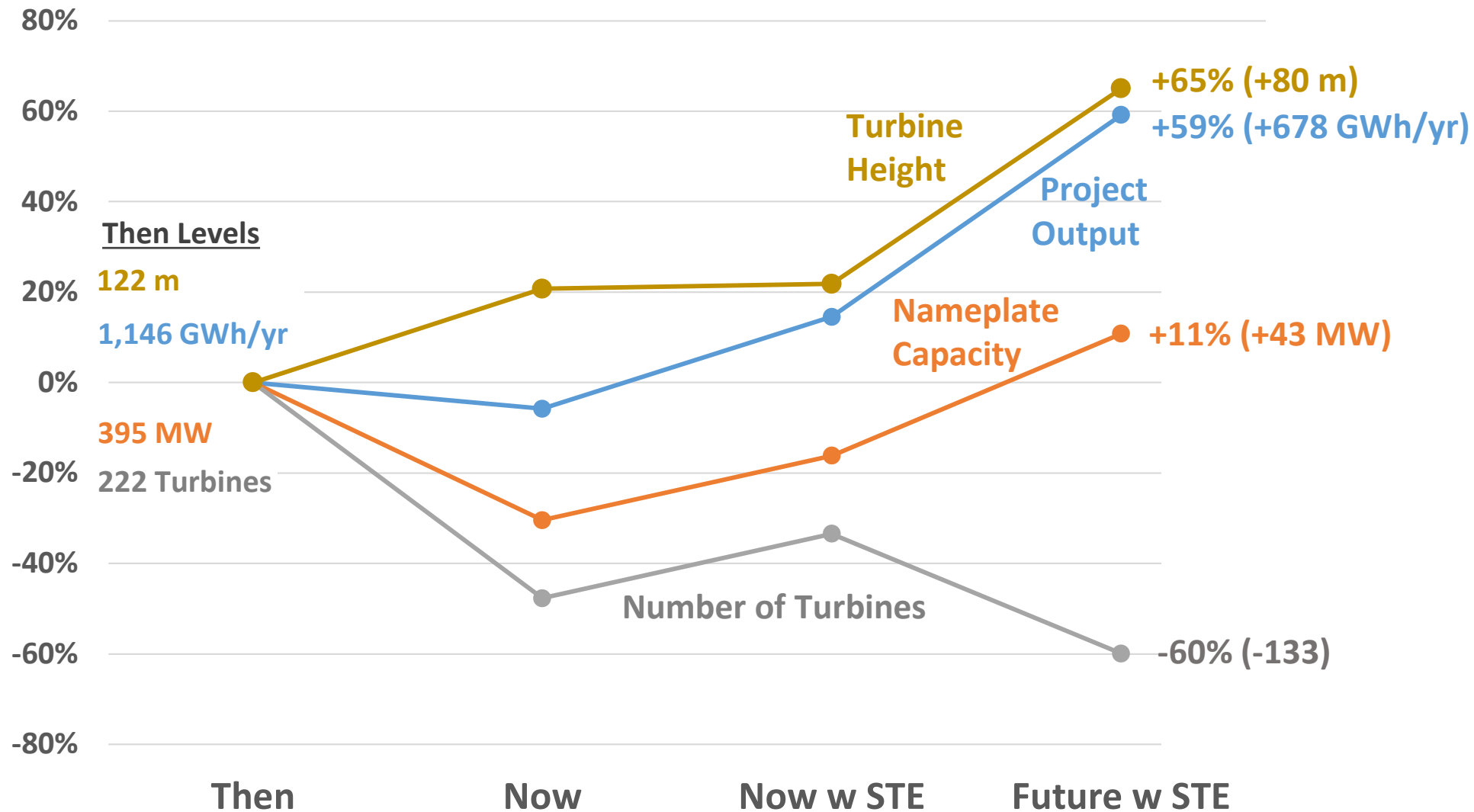
From “Then” to “Future” Turbines, There Are Consistent Increases In Both Installed Capacity and Output, As Turbine Counts Dropped



The total project capacity:

- Initially drops, not able to overcome the increase in size and sound power level
- But eventually increases
- 395 to 438 MW
- 11% increase

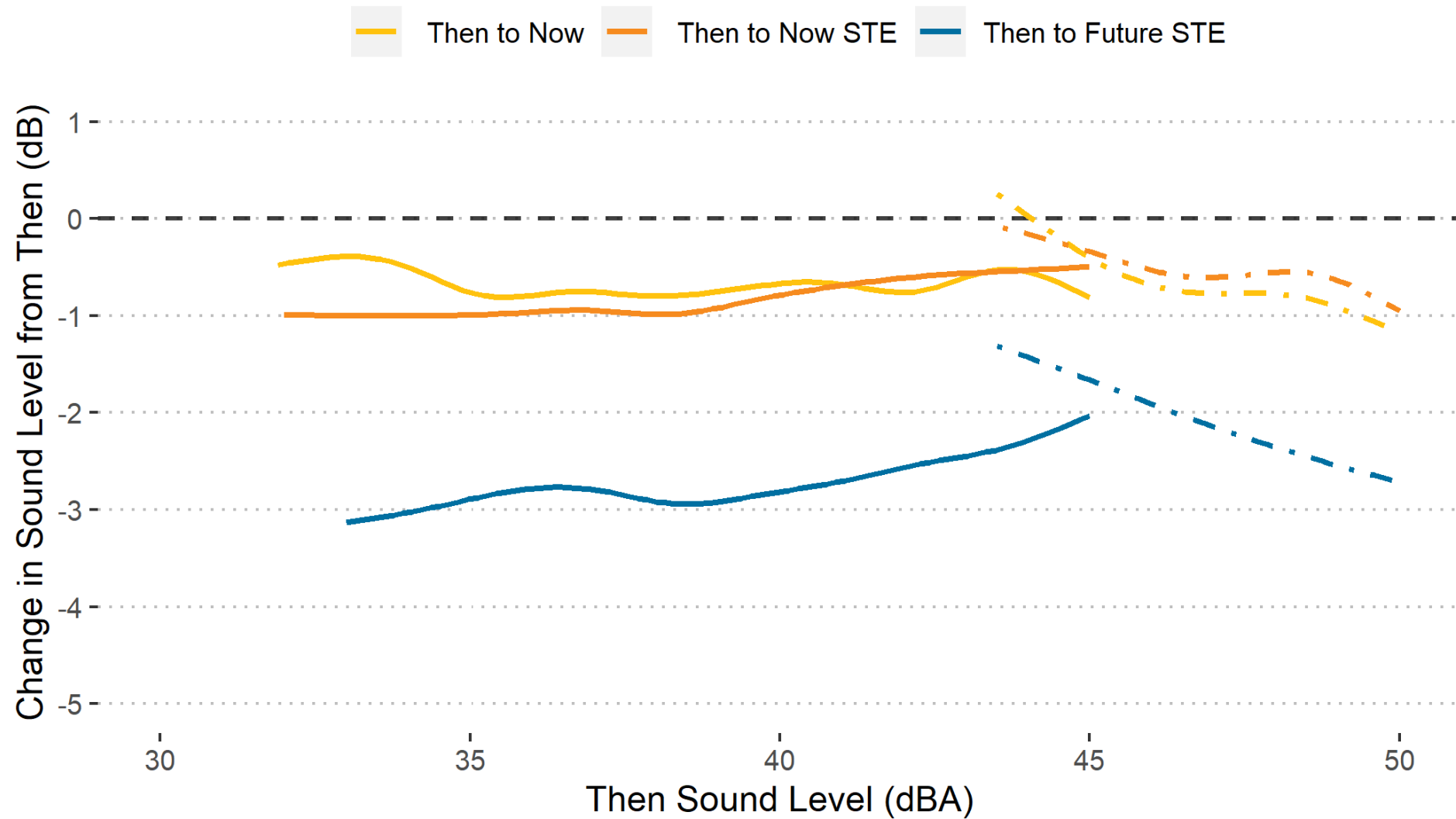
From “Then” to “Future” Turbines, There Are Consistent Increases In Both Installed Capacity and Output, As Turbine Counts Dropped



Total project output:

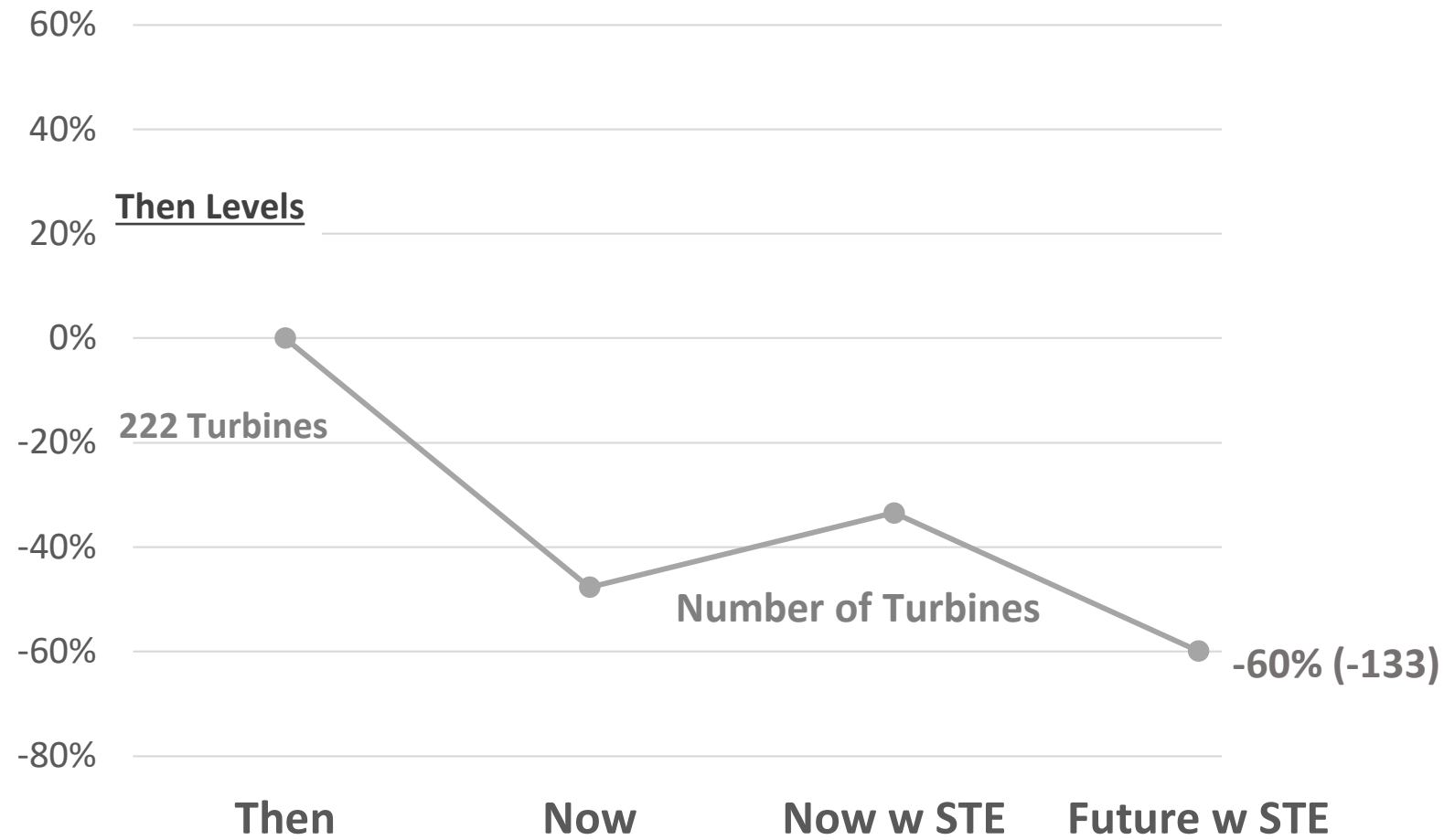
- Increases by 59%
- Because of the lower specific power (higher capacity factor by ~4%) and higher nameplate capacity (by 11%)
- Higher capacity and output might lead in increased economic benefits

As The Projects Moved From “Then” to “Future” Turbines, We See A Consistent Drop In Estimated Sound Levels At Homes

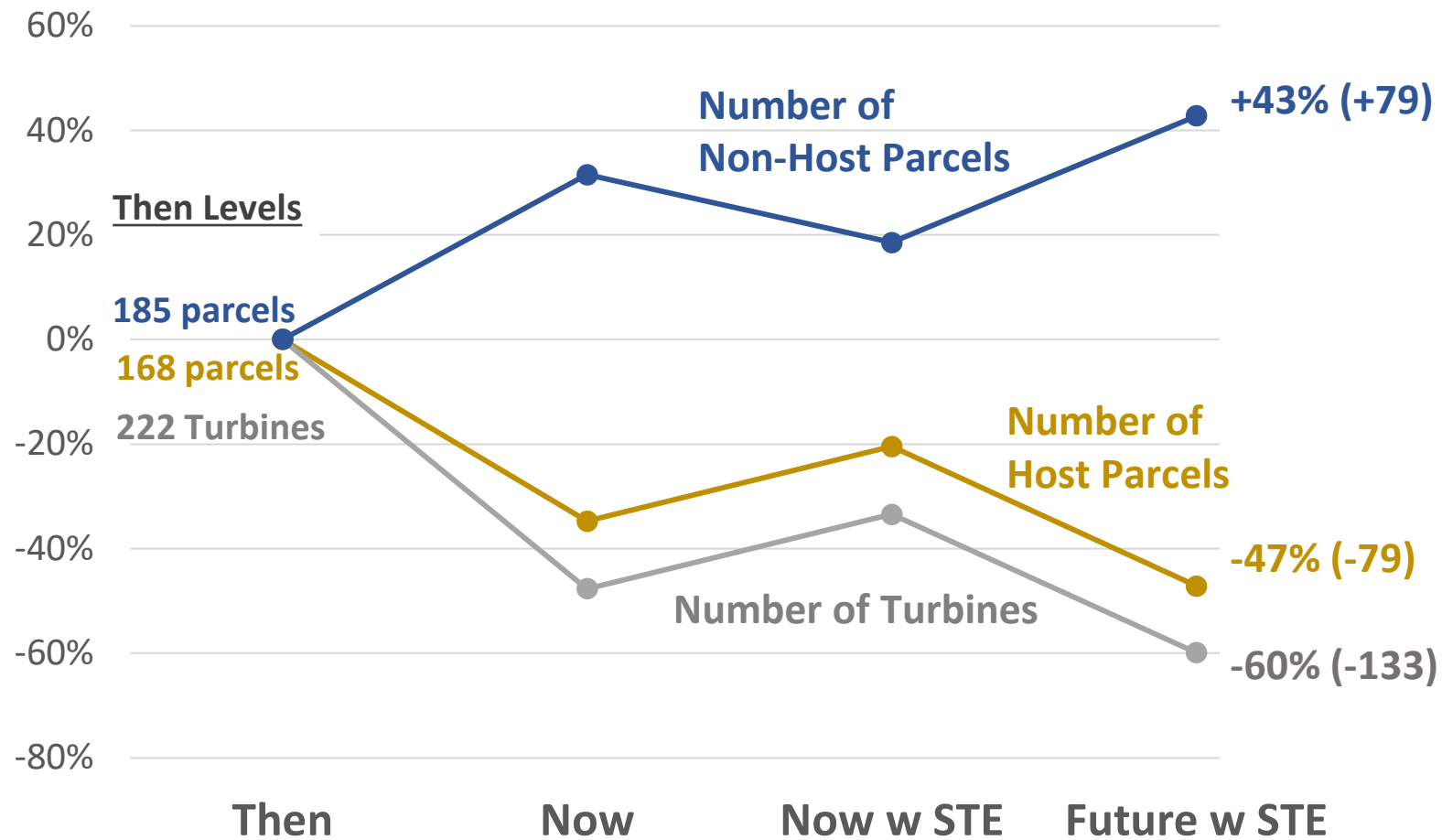


- On average receivers (i.e., home locations) experience lower sound levels as turbines scale
- Lower levels are apparent for both participating and non-participating receivers

With Fewer Turbines, Fewer Host Parcels Are Needed. Parcel Sizes Increase Too, Potentially Favoring Landowners With Larger Holdings

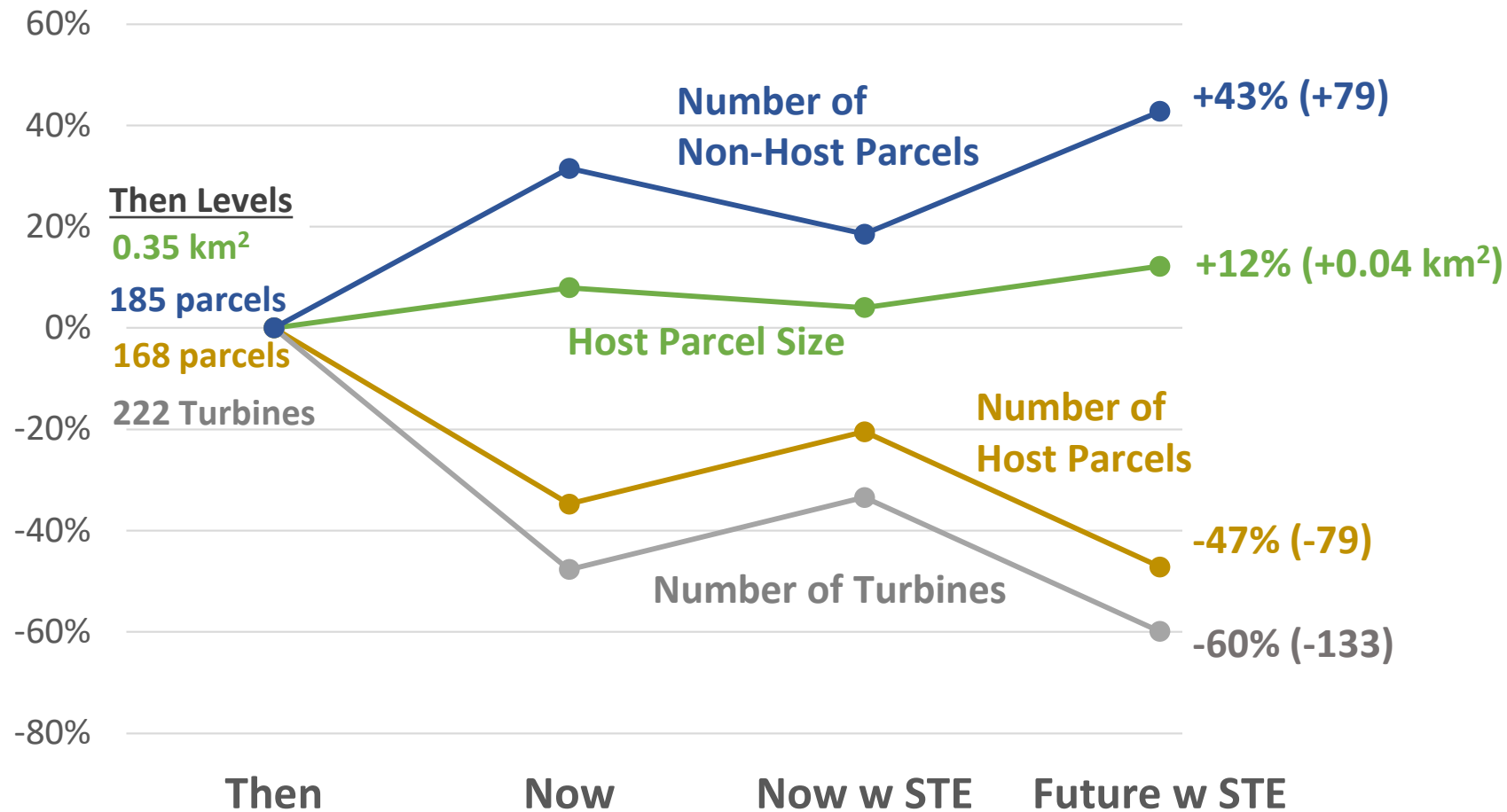


With Fewer Turbines, Fewer Host Parcels Are Needed. Parcel Sizes Increase Too, Potentially Favoring Landowners With Larger Holdings



- The number of host parcels decreases by almost 50% for Future projects

With Fewer Turbines, Fewer Host Parcels Are Needed. Parcel Sizes Increase Too, Potentially Favoring Landowners With Larger Holdings



- The number of host parcels decreases by almost 50% for Future projects
- As well average parcel size increases 12% to accommodate the larger turbines
- This change might favor landowners with larger holdings and discriminate against those (and areas with) with smaller parcel, creating greater disparity between those receiving larger benefits

Takeaways



Source:
https://en.wikipedia.org/wiki/Twin_Groves_Wind_Farm



Takeaways

- Significant turbine scaling is occurring with no sign of abating
- Despite decreasing RPMs we see a steady increase in tip speeds and turbine sound power levels.
- The increase in sound levels and tip speeds might indicate that communities hosting modern turbines will experience higher levels of turbine audibility than communities that are hosting older turbines
- But increased turbine heights and sound levels increase setbacks
- Our analysis finds that modern turbines to be deployed in the next 3-5 years will, potentially, significantly decrease the sounds levels communities experience, while simultaneously increasing installed capacity and annual energy output
- Increases in capacity and output will likely lead to increased tax benefits in the community
- But, the concentration of fewer turbines, on fewer (and larger) parcels might create disparities between those receiving and those not receiving substantial benefits unless addressed
- And, of course, larger turbines likely mean greater turbine visibility in the community, including the enhanced ability to see the turbines from further away

Thank You! Questions?

Contacts

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For more information

Visit the project landing page: <https://emp.lbl.gov/publications/effects-land-based-wind-turbine>

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