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Experiences with Two Reliability Data Collection Efforts

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Wind Reliability Experts Meeting

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Outline

- **Data Collected by GL Garrad Hassan and DNVKEMA for NREL**
  - Motivations and Approach
  - Results
  - Observations and Challenges
- **Wind Turbine Gearbox Reliability/Failure Database**
  - Motivations and Approach
  - Results
  - Observations and Challenges
- **Opportunities**

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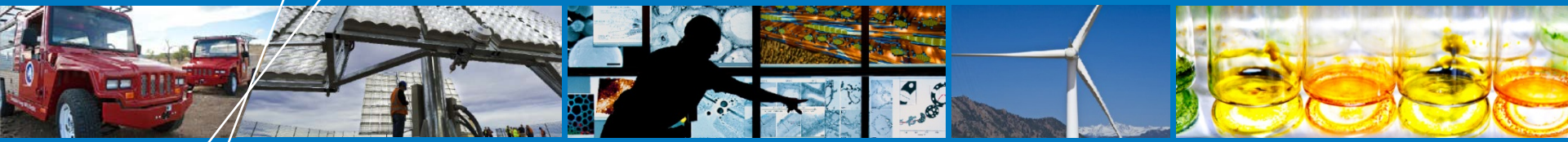


Data Collected by GL Garrad Hassan and DNVKEMA for NREL

NREL's Interest In Operations Expenditures (OpEx) Data Is Multi-Faceted

- **Minimizing OpEx could increase plant profitability while helping to support a lower cost of energy.**

- **Understanding opportunities for reductions in OpEx requires a baseline level of knowledge of:**
  - OpEx
  - System or plant availability
  - Major component replacement rates

- **Publicly available empirical data on the variables listed above are limited in scope and resolution.**

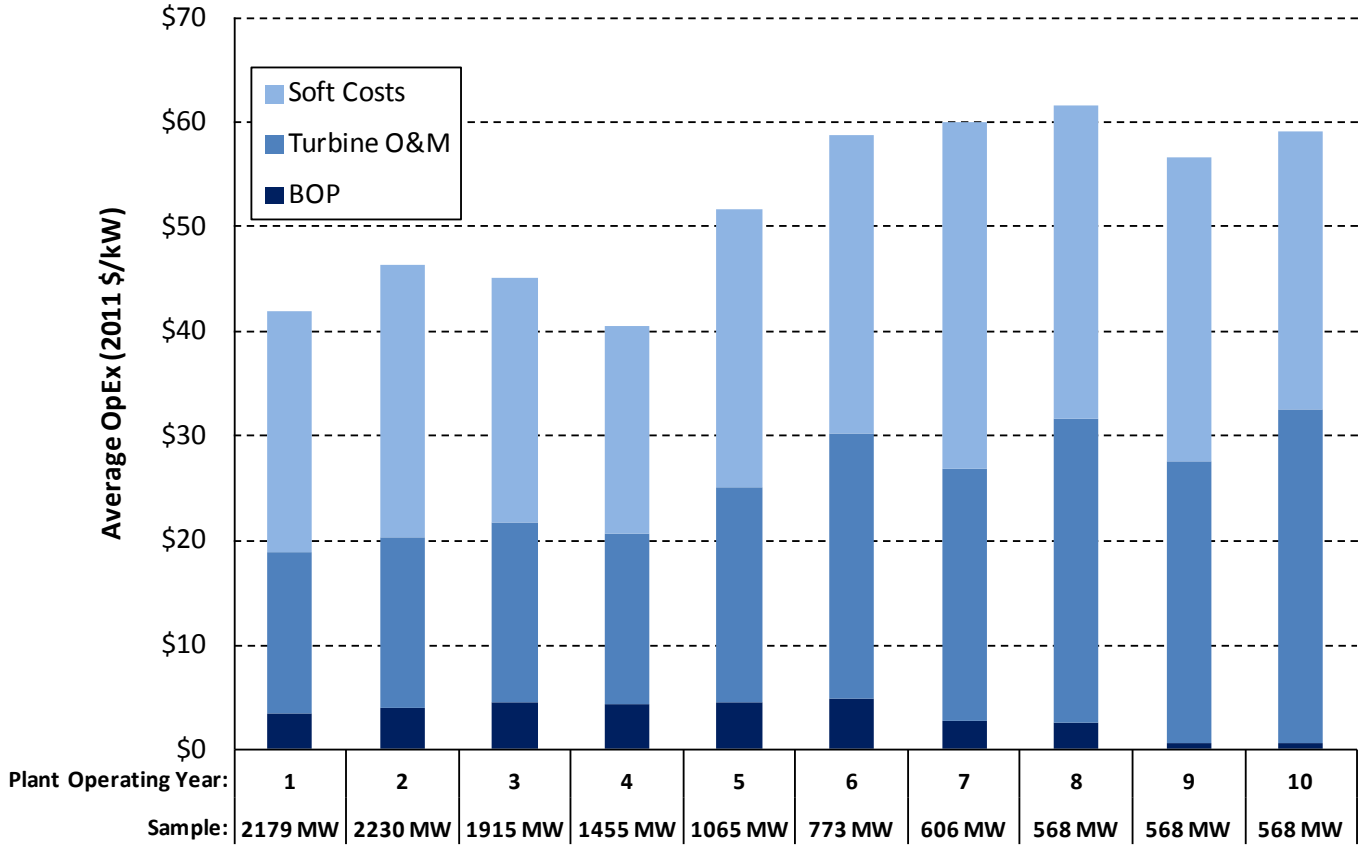
An empirically derived baseline of OpEx and component failures, and experience-based insights into recent trends are useful for R&D decision-making and industry benchmarking.

Data Housed By Project Partners GL Garrad Hassan and DNVKEMA Were Analyzed Independently, with a Focus on Three Metrics

- **Historical OpEx**
- **Historical "plant" or "system" availability**
  - Not to be confused with manufacturer, contractual, or technical availability
- **Major component failure rates and typical repair costs**
  - Blades, gearboxes, generators
  - Sensitivities in failure rates as a result of serial failures were also explored

- **The combined GL Garrad Hassan and DNVKEMA sample represents about 10 GW of operating wind plants**
- **Data shown today represent analysis completed by the respective partners for NREL**

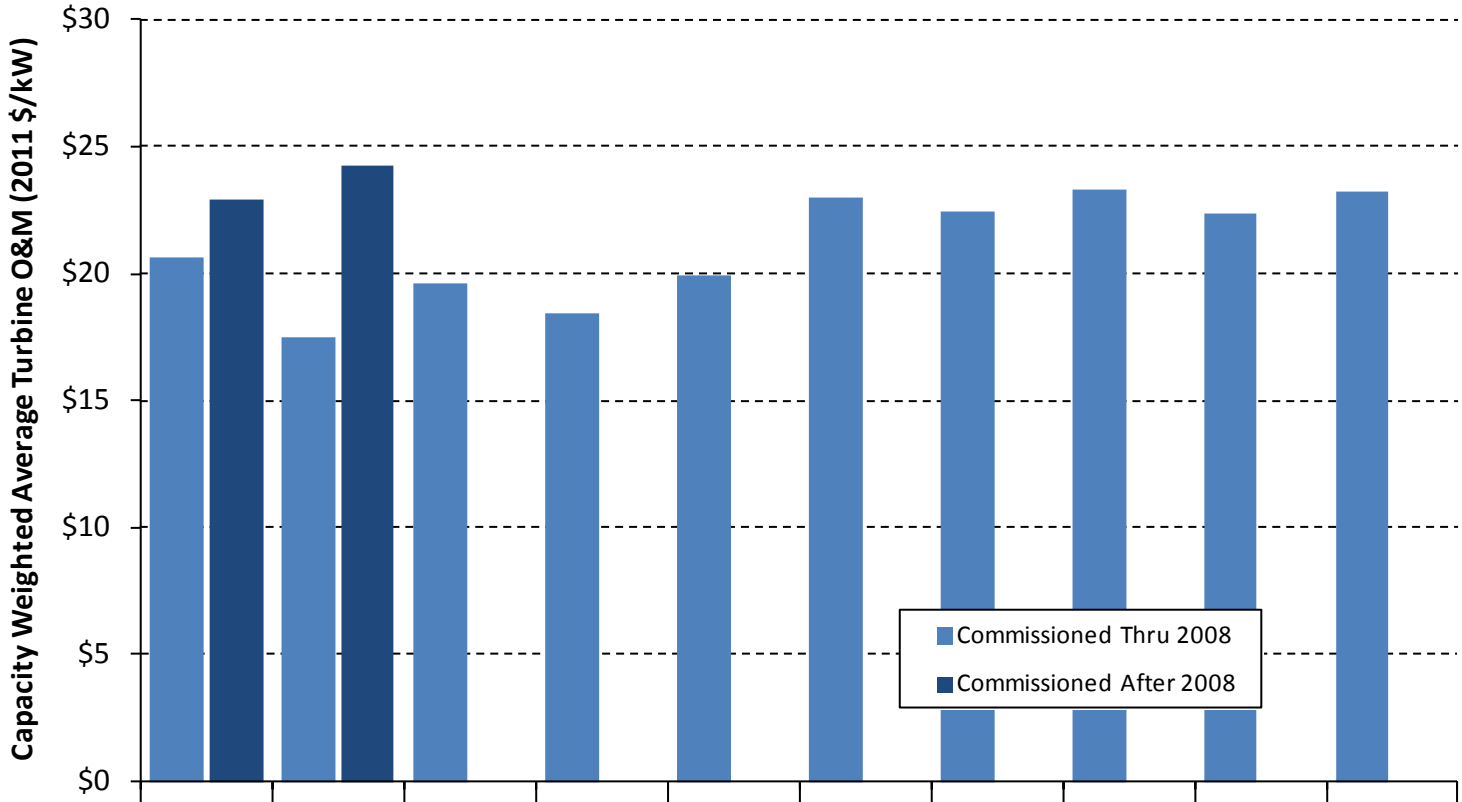
Data from DNVKEMA for Projects Commissioned Through 2009 Suggest OpEx Initially of $40-$50/kW and Increasing Over Time



Data Source: DNVKEMA
Note: Sample does not contain data for projects commissioned after 2009

- **Increases are primarily attributed to unscheduled maintenance and increases in soft costs (e.g., audit compliance, system operator fees, other fees, royalty payments)**
- **Preliminary analysis of additional data and including more recent projects suggests this trend is sensitive to servicing agreement terms as well as regional competition**

GL Garrad Hassan's Sample Shows Turbine O&M Expenditures Increasing for More Recent Projects



Operating Year:	1	2	3	4	5	6	7	8	9	10
Comissioned Thru 2008:	2230 MW	2761 MW	3324 MW	2988 MW	2181 MW	1689 MW	1978 MW	2085 MW	604 MW	280 MW
Commissioned After 2008:	991 MW	1239 MW								

Data Source: GL Garrad Hassan

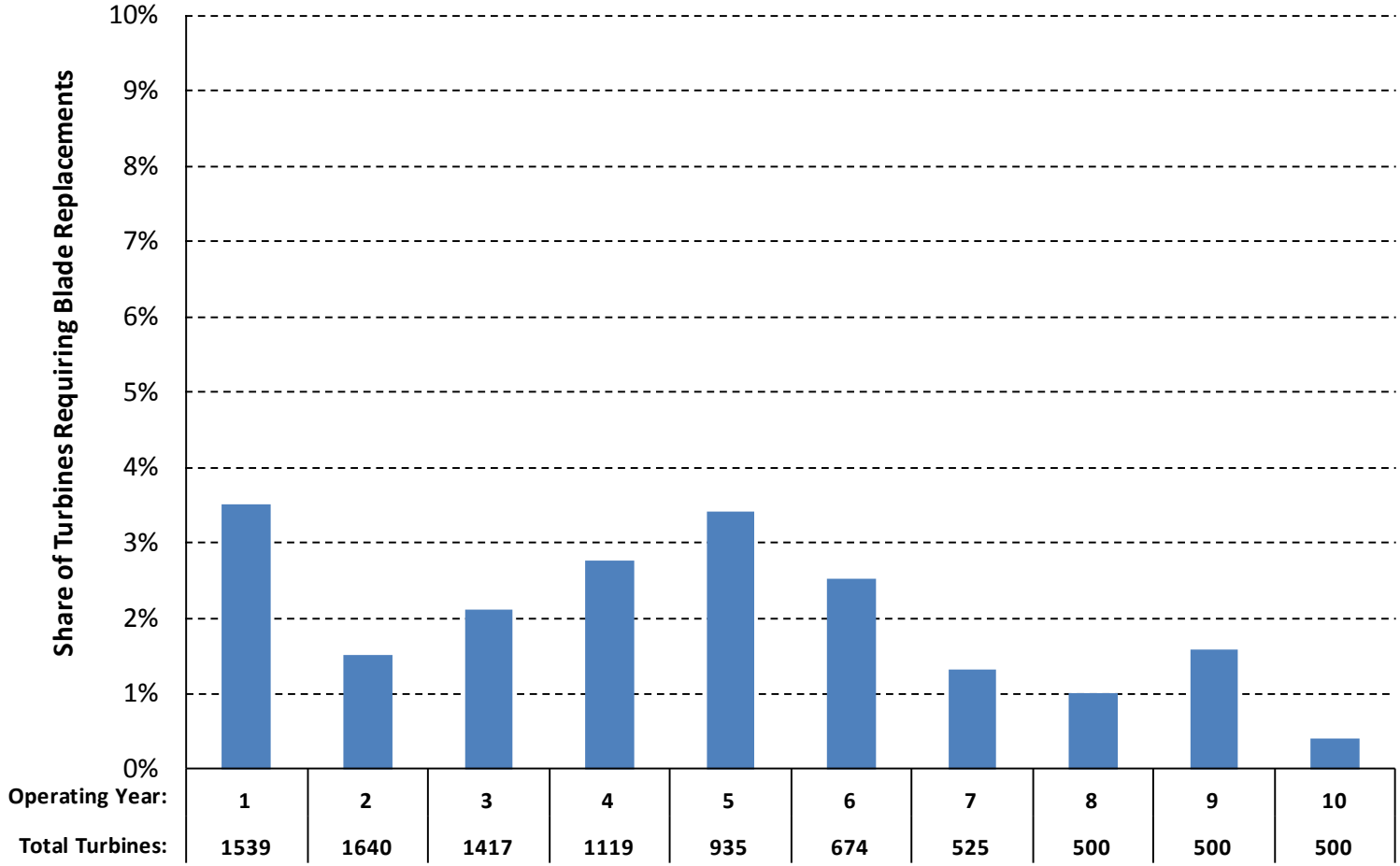
Potential OpEx reductions resulting from enhanced turbine reliability may be offset by deployment of more complex equipment or operations across a broader array of wind regimes; sample size, servicing agreement details, and market forces also affect the trends.

When Adjusting for Curtailment, System Availability Appears Stable At About 95% Through At Least Year Five

Source: GL Garrad Hassan

When factoring in curtailment, sample-wide system availability is about 93% (after year 2); minimization of plant downtime may at some point require consideration of power system policy and planning.

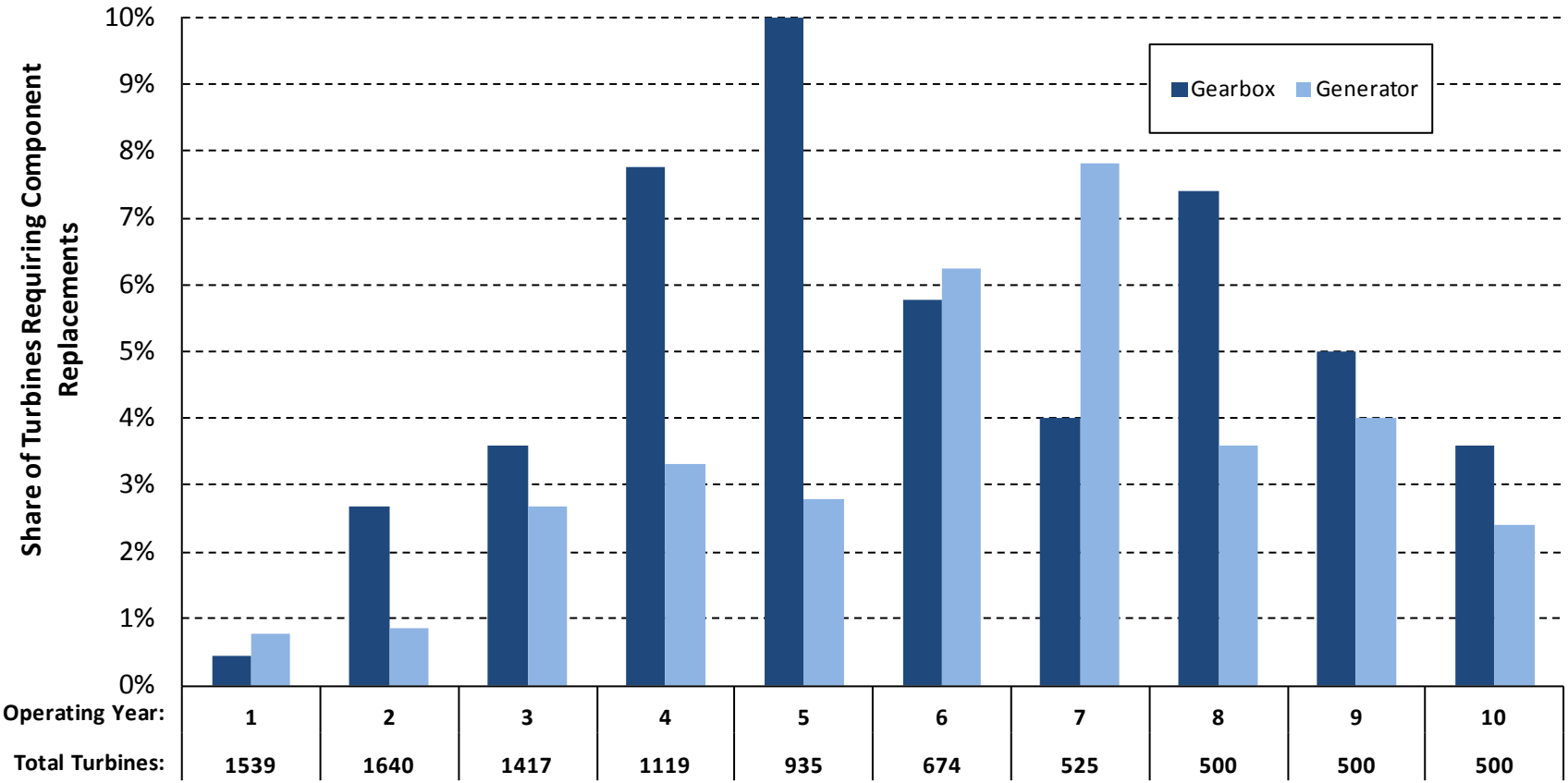
Annually, 1 to 3% of Turbines Require Blade Replacements with Spikes in Years 1 and 5



Data Source: DNVKEMA

- **Blade replacements in years 1 and 2 are typically the result of manufacturing defects or damage that occurs during transport and construction.**
- **On average, about 2% of turbines per year (through 10 years of operations) require blade replacements; lightning strikes are the most commonly noted cause of failure.**

More Turbines Require Gearbox and Generator Replacements



Data Source: DNVKEMA

- **Average gearbox failure rate over 10 years of operations is estimated at 5%, peaked in years 4, 5 and 8.**
- **The average generator failure rate is somewhat lower and over 10 years of operations is estimated at 3.5%, peaked in years 6 and 7.**
- **Serial failures were observed to have a noteworthy effect on gearbox and generator failure rates, potentially skewing the results.**

Observations

- **Unscheduled maintenance remains a significant source of uncertainty for the industry**
  - Failure rates and unscheduled maintenance are the principal drivers of uncertainty around OpEx estimates.
  - Value of condition monitoring is not yet fully understood.

- **Competition and risk management are expected to continue to influence OpEx and servicing strategies**
  - Servicing and OpEx management strategies have evolved in the last decade; continued evolution entails:
    - ✓ More sophisticated electronic reporting and better documentation
    - ✓ Consideration of regional climate, turbulence, and shear in cost models

Challenges

- **The absence of standardized reporting throughout the industry makes comparisons across operations-related datasets very difficult.**

- **Limited data for older projects make conclusions for plants operating in the 7-10 year timeframe more tentative.**
  - The time required to gather years of operational data will continue to make it difficult to understand how technological developments affect OpEx.

- **Operations servicing remains dynamic and may create continued data and reporting challenges in the future.**

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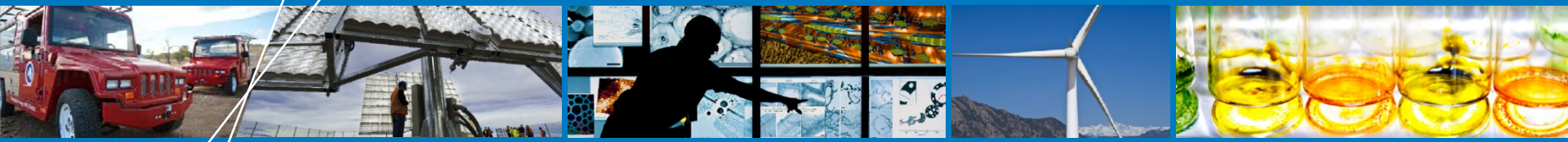
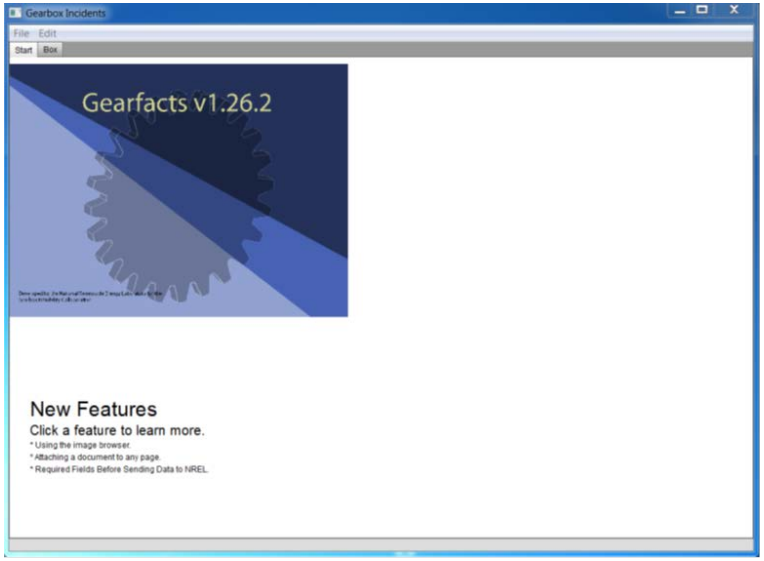


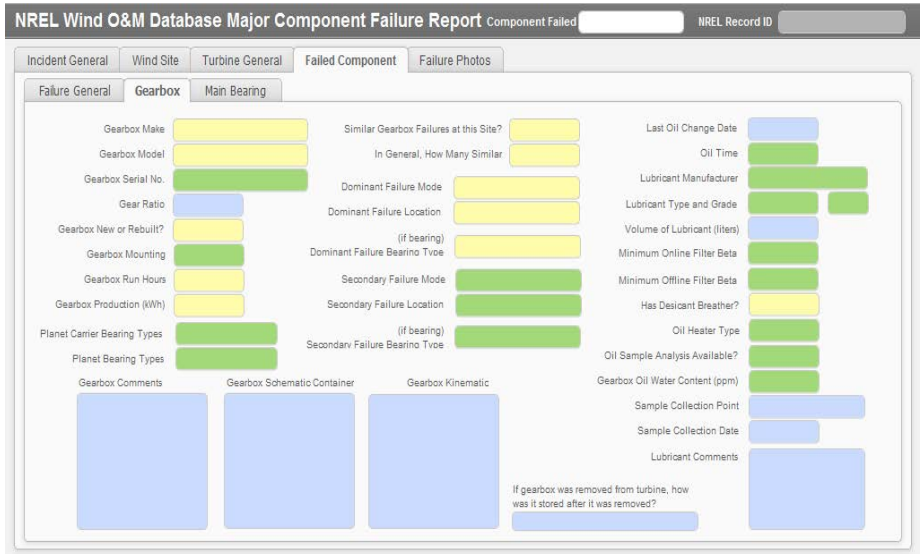
Wind Turbine Gearbox Reliability/Failure Database

Motivation and Approach

- Main objectives are to categorize top gearbox failure modes, identify possible root causes, and direct future gearbox reliability and availability-related activities for researchers, operators, and all other parties along gearbox supply chain.



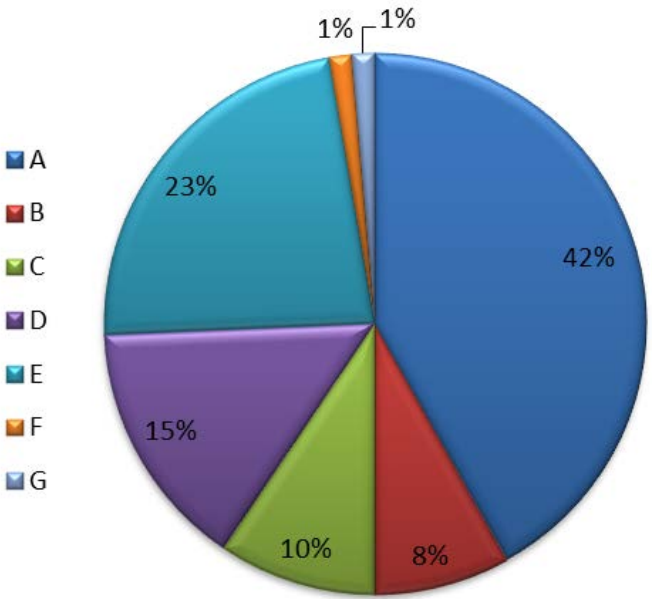
- Collect gearbox failure event data at very detailed and summary levels highlighting damaged components, failure modes and possible root causes; Non-disclosure agreements signed with each partner.



Partners and Data

- About 20 partners including turbine/gearbox manufactures, owners/operators, gearbox rebuild shops, and operation & maintenance (O&M) service providers.
- Assets of owner/operator partners of this database represent ~31% of the U.S. end of 2012 wind capacity.
- The database contains 289 gearbox failure incidents with 257 confirmable damage records (Notes: one incident may have multiple damage records; need to have standardized data reporting)

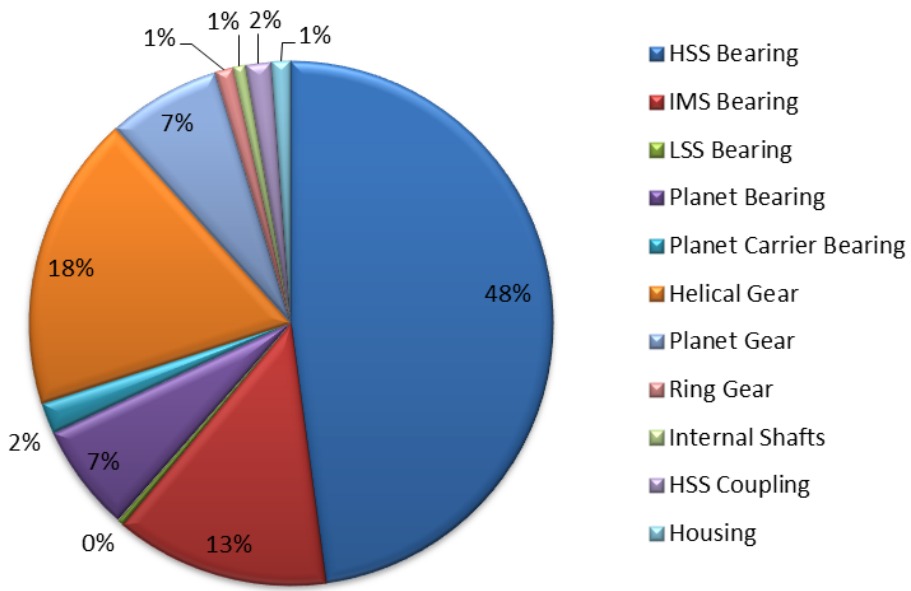
Owners and Operators	10
Turbine OEMs	3
Gearbox OEMs	2
O&M Service Provider	2
Failure Analysis Partner	1
Gearbox Rebuild Shop	1



- A subsample of the data demonstrating the database represents almost all major gearbox OEMs

Results: Gearbox Damage Distribution

- Gearboxes fail in drastically different ways, among which bearings: ~ 70%; gears: ~ 26%; and others: ~ 4%.
- Top three components are: high speed shaft bearing, helical gear, and intermediate speed shaft bearing.
- Both bearing and gear faults are concentrated in the parallel section.
- Top gearbox failure mode is high or intermediate speed shaft bearing axial cracks.



	Damage Records	Bearings	Gears	Others
Planetary	44	23	21	9
IMS	N/A	34	47	
HSS	N/A	123		
Total	257	180	68	9

Be cautious in generalization of these results due to small population size and various hidden assumptions.

Observations and Challenges

- Gearbox reliability/failure database:
  - Valuable for supporting gearbox reliability R&D, manufacturing and maintenance activities
  - Most partners promised to actively support the data collection effort
- Gearboxes can fail in drastically different ways and ages
  - It appears that bearing/gear failures concentrate in parallel stage.
  - For the U.S. fleet, the top gearbox failure mode responsible for over 60% of reported failure is high speed or intermediate shaft bearing axial cracks.
- Challenges
  - The industry does not sufficiently understand the nature of the top bearing failure mode in wind turbine gearboxes so as to recommend scientific solutions.
  - Engage partners so they may actively share data
  - Need for standardization of terminology, data collection and reporting tools or format

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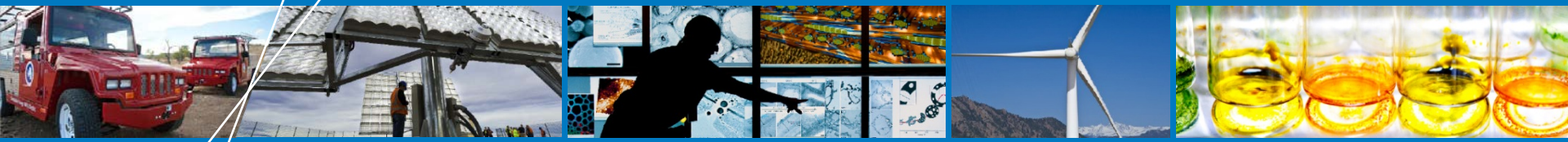

Opportunities

Opportunities

- **Historical OpEx, availability and replacement rates data**
  - Continue the data collection efforts with GL Garrad Hassan and DNVKEMA and renew the statistics
- **Gearbox reliability/failure data**
  - Extend to cover other major drivetrain subsystems with the intention of supporting future turbine reliability and availability activities
- **Need of standardization**
  - Terminology and data reporting/collection tools or format

Opportunities (*Continued*)

- **Collaboration among various data collection efforts**
  - Tie complementary results to provide baseline benchmark for the industry: e.g., historical availability data collected by NREL with current data from CREW
  - Share data partners by encouraging partners of one effort to sign up for the others: e.g., gearbox, blade and CREW reliability databases
  - Support each other by providing results or conducting data analysis as requested by the others, of course not violating agreements set up by each database with their partners
- **Need publicly available industry-wide information sharing at a level acceptable by all parties**
  - Challenging yet critical in order to truly advance the industry
- **Reliability data collection/information share at global level**

Thanks for your attention!

Special thanks to the U.S. Department of Energy, GL Garrad Hassan, DNVKEMA, and the Gearbox Reliability/Failure Database Project partners.


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