Wind Turbine Gearbox Lubrication: Performance, Selection, and Cleanliness

Presented at the STLE Lubrication Products & Practices Seminar

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Presentation Outline

- Overview of Wind Energy Market
- Lubricant Performance
- Lubricant Selection
- Importance of Lubricant Cleanliness

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Wind Turbines

- Windpower Intelligence (WPI) research is based on country pipelines of announced wind farms (>5 MW) that are at various stages of development, and estimated to come online at some point over the next ten years, although the majority of which is likely to be built and operating in the next five years.

- Forecasts include all onshore and offshore development

- WPI always tries to source this information from individual developers, but in many cases it is necessary for WPI to apply its own estimated year, which is based on an average time of development.

Source: Global Markets for Wind Power (2010-20)

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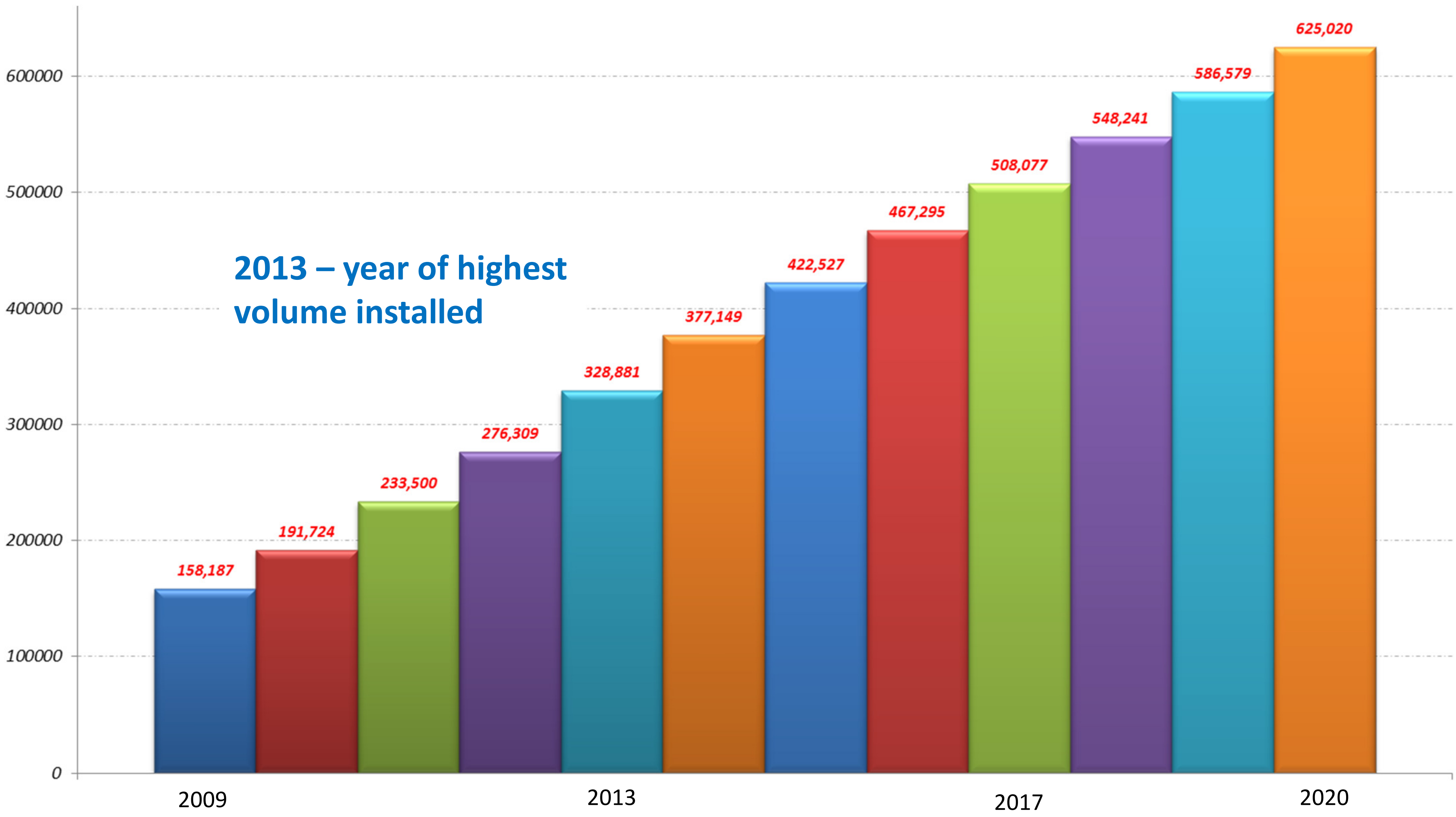
Wind Energy Market

Wind Turbines – Global Overview (MW)



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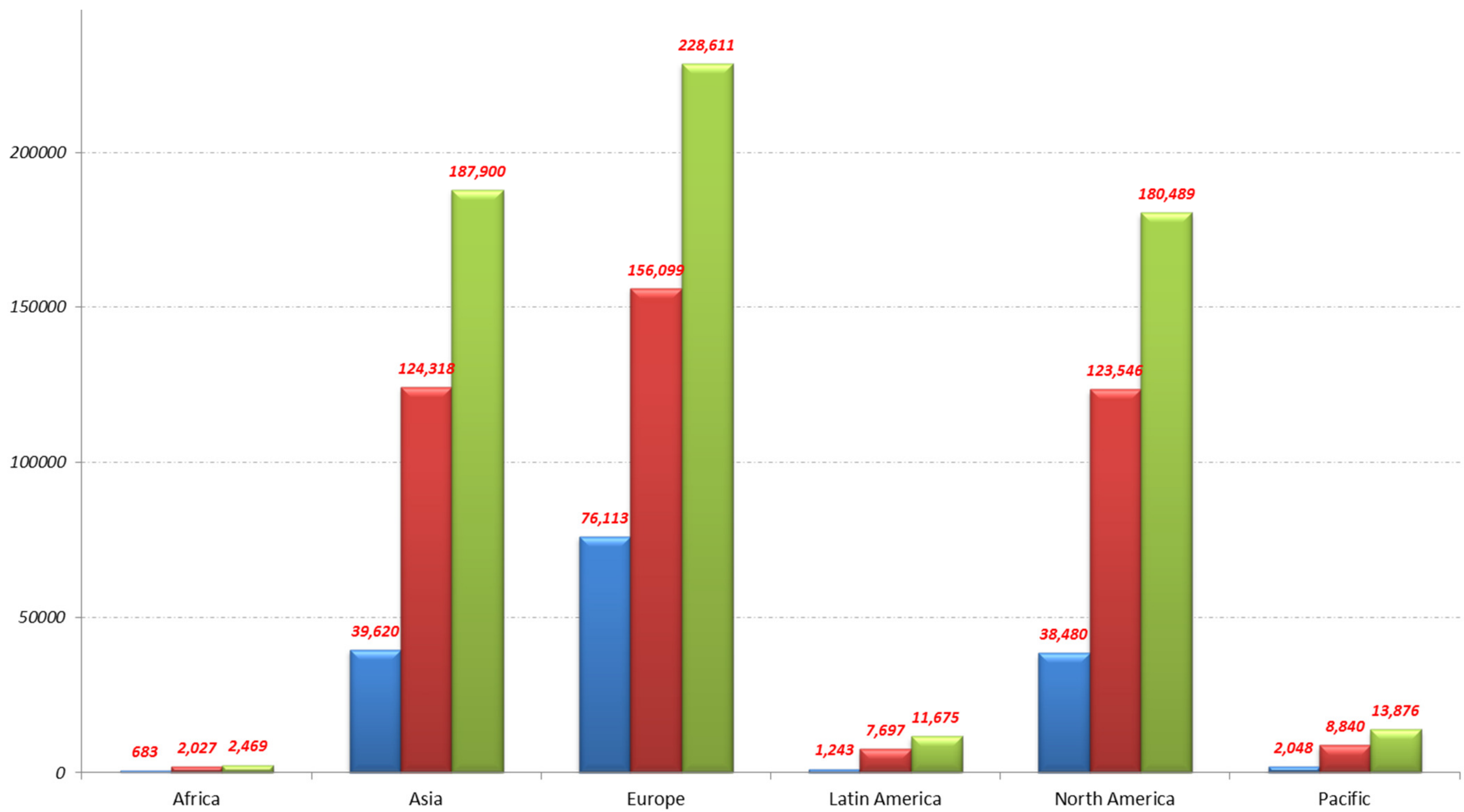
Wind Energy Market

Wind Turbines – Expected Growth per Region 2009-2015-2020 (MW)



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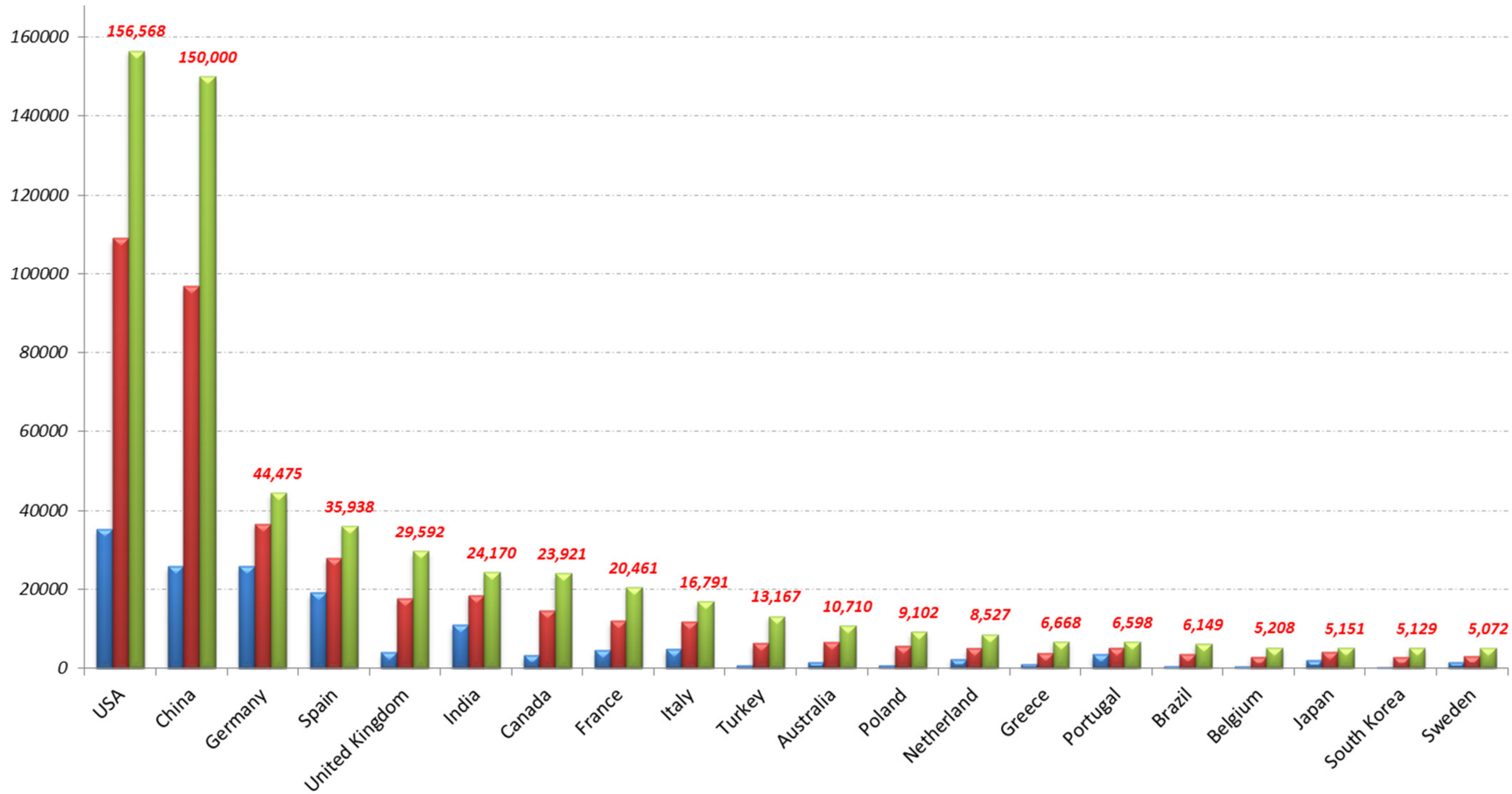
Wind Turbine – Top 20 countries in 2020 (MW)



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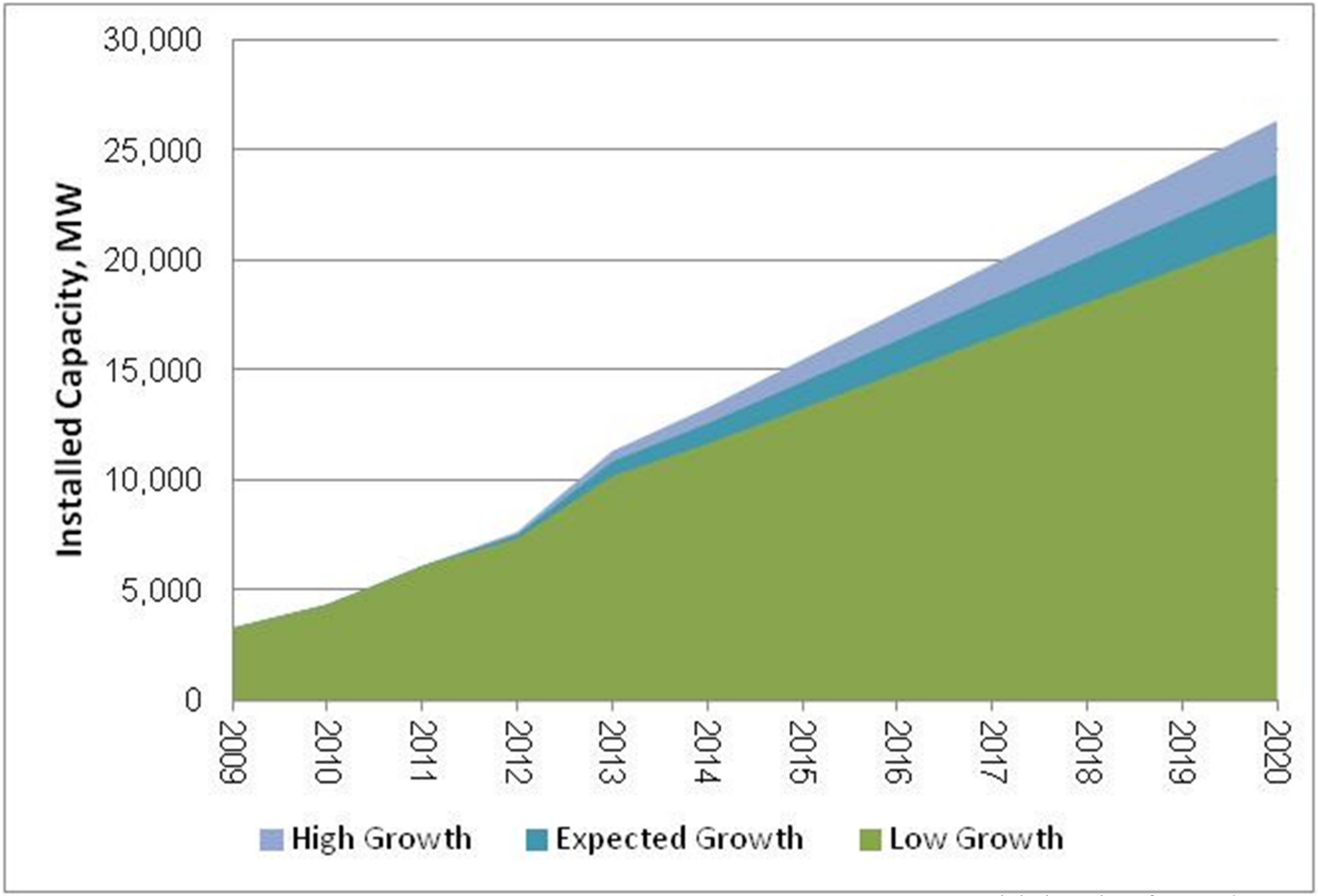
Source: Global Markets for Wind Power (2010-20)

Canadian Wind Market – Growth Scenarios



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Source: Global Markets for Wind Power (2010-20)

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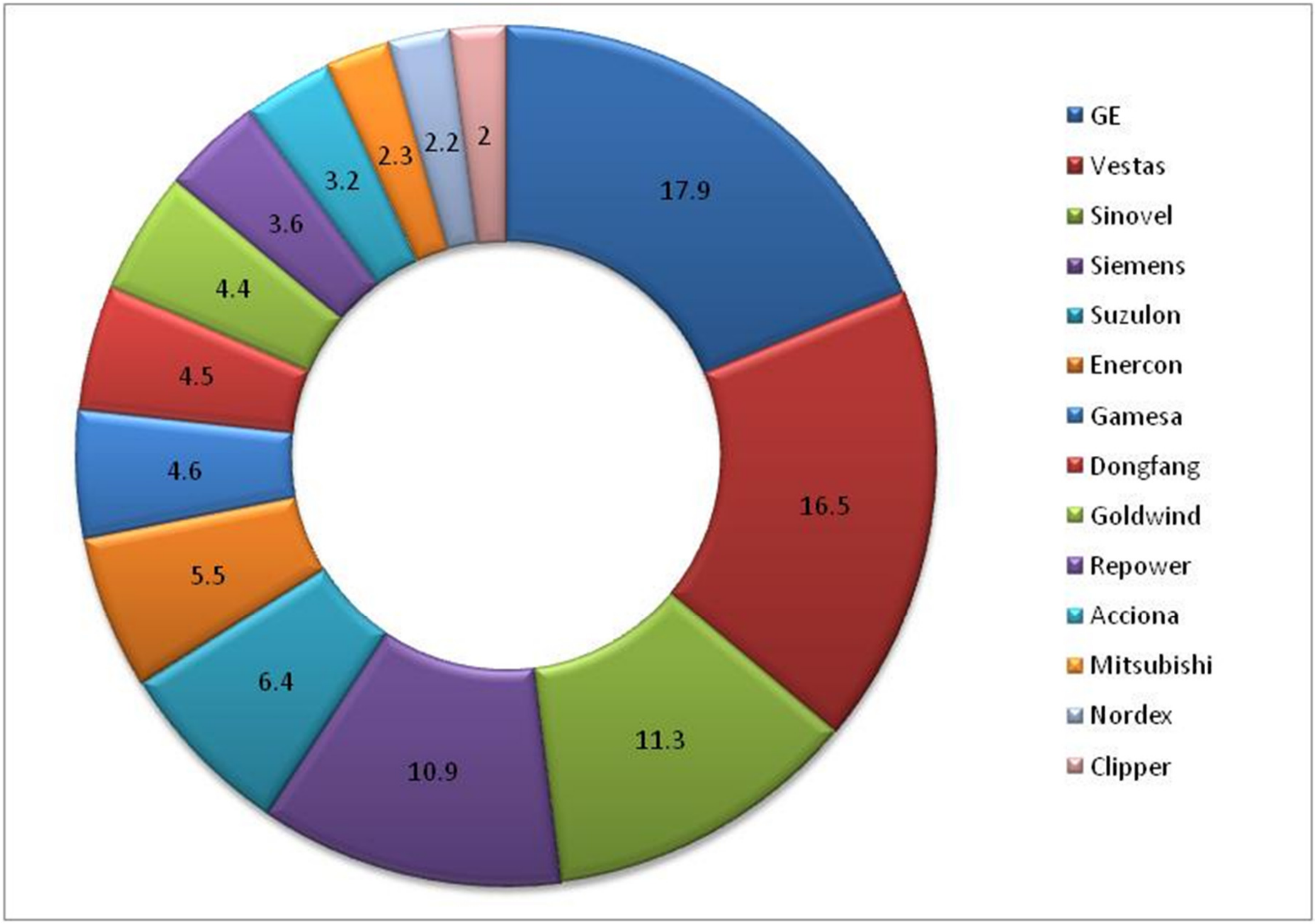
Wind Energy Market

Wind Turbine Manufactures – Market Share % 2010



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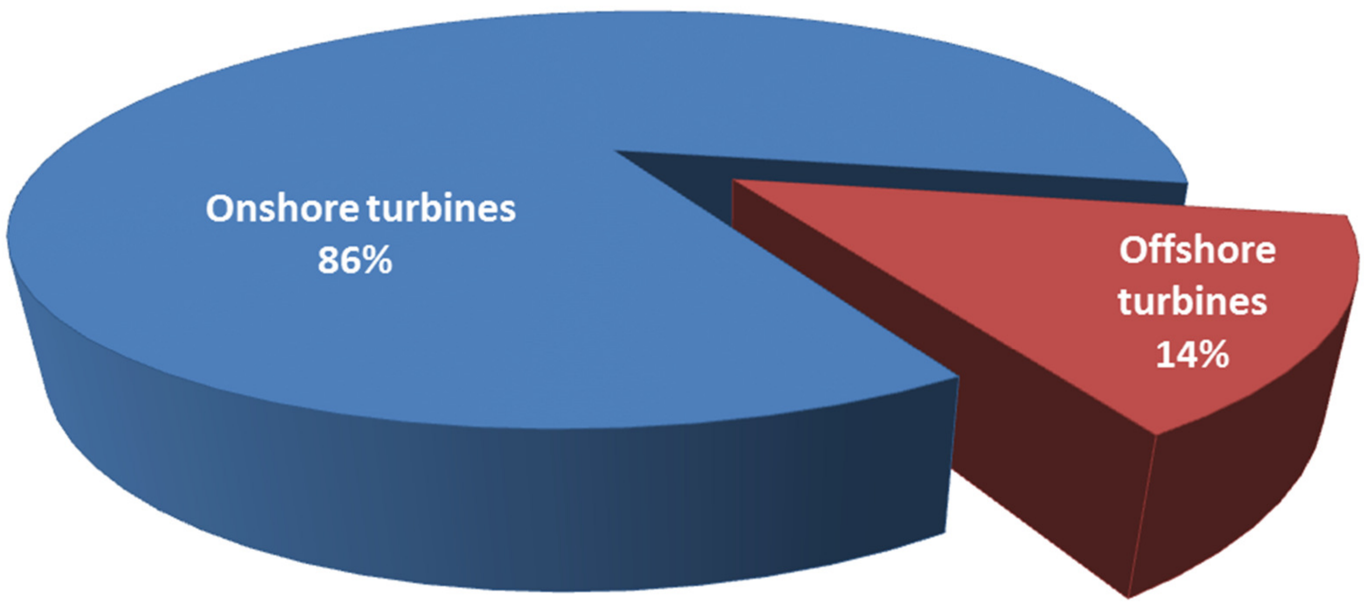
Source: Global Markets for Wind Power (2010-20)

Wind Turbines – Global Market Share 2010-2012



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Source: Global Markets for Wind Power (2010-20)

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Lubricant Performance

Wind Turbine Lubricants

- Why are Improved Lubricants Desired For Wind Turbines

- Wind Farms very often in remote areas e.g. offshore
- Failure is extremely costly
  - Replacement/repair and loss of power (income)
    - Micropitting
    - Bearing failure
    - Sludge
- Warranty issues for OEM
- Access for oil change is difficult and expensive
- Extended drain requirements require synthetic base stocks

Wind turbine gearboxes offer challenges not found in conventional industrial applications

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Functions of a Lubricant

- Lubrication
  – Reduces friction and wear by introducing a lubricating film between moving parts
- Cooling
  – Helps dissipate heat away from the critical parts of the equipment
- Cleaning and suspending
  – Facilitates smooth operation of equipment by removing and suspending products, such as carbon, sludge, and varnish
- Protection
  – Prevents metal damage due to oxidation and corrosion

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What Lubricant Properties Are Wanted?

- Suitable viscosity
- High film strength
- Low pour point
- Lubricity
- Low corrosivity
- Good water tolerance
- Good cleansing and dispersing ability
- Non-toxicity
- Low flammability
- Protection against micropitting
- Good filterability

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What's in a Typical Gear Oil?

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Base Oil	+	Additives
90-99%		1-10%
Mineral oil		Extreme pressure
Polyalphaolefin (PAO)		Antiwear
Polyalkyleneglycol (PAG)		Rust inhibitor
Vegetable oil		Dispersant
Synthetic Ester		Friction modifier
		Demulsifier
		Metal deactivator
		Oxidation inhibitor
		Antifoam

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Additives and Their Functions

- Dispersant
  - Suspends by-products of oxidation (deposit precursors) and lubricant decomposition in oil. Ordinarily, these materials will separate out of oil. It, therefore, keeps equipment parts clean.
- Detergent
  - Primarily neutralizes acidic products that result from oxidation of fuel, lubricant, and impurities. It can also act as a suspending and cleaning agent and rust inhibitor.
- Oxidation inhibitor
  - Slows down the rate of oxidation of the oil, hence controls increase in oil viscosity.
- Friction modifier
  - Increases the durability of lubricant film, lowers friction, and hence leads to improved efficiency. Helps form durable film between the metal surfaces, thereby allowing smooth motion of the surfaces.
- EP/antiwear agent
  - Minimizes wear by making chemical film on surfaces that are in contact.
- Emulsifier
  - Allows mixing of water and organics (oil or additives).
- Demulsifier
  - Facilitates separation of water from contaminated lubricant.
- Pour point depressant
  - Lowers the temperature at which the lubricant flows, thereby making low-temperature operation possible.
- Foam inhibitor
  - Minimizes foam formation.
- Rust and corrosion inhibitors
  - Help form a barrier between chemically active species and the metal surface.
- Viscosity modifier
  - Preferentially thickens oil at high temperature.

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Lubrication Fundamentals

Functions of a Lubricant

Lubrication	Protection
Friction modifier Antiwear EP Foam inhibitors	Oxidation Inhibitors Corrosion Inhibitors Detergents (TBN)
Cooling	**Cleaning**
Viscosity modifiers Pour point depressant	Dispersants Detergents

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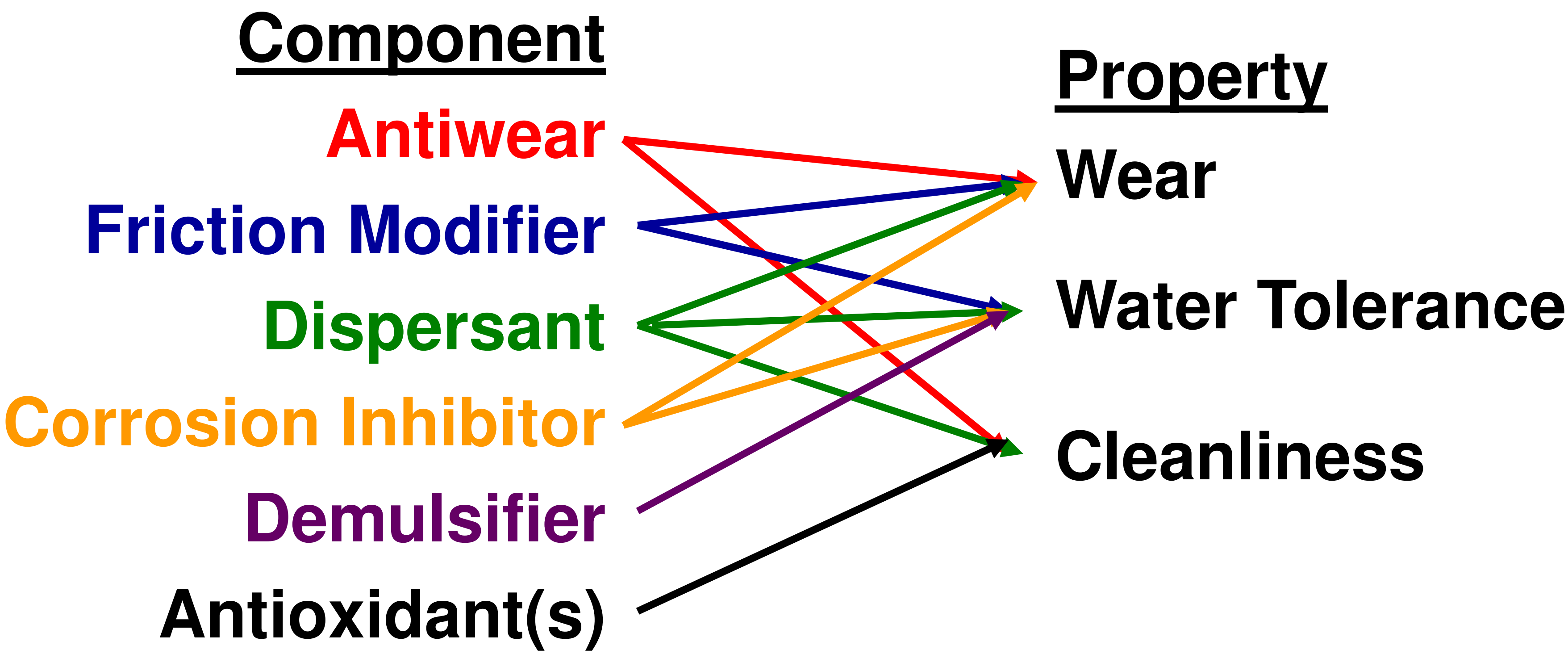
Formulation Balance is Critical



Because so many components of a formulation are surface active, they influence performance properties other than the intended property

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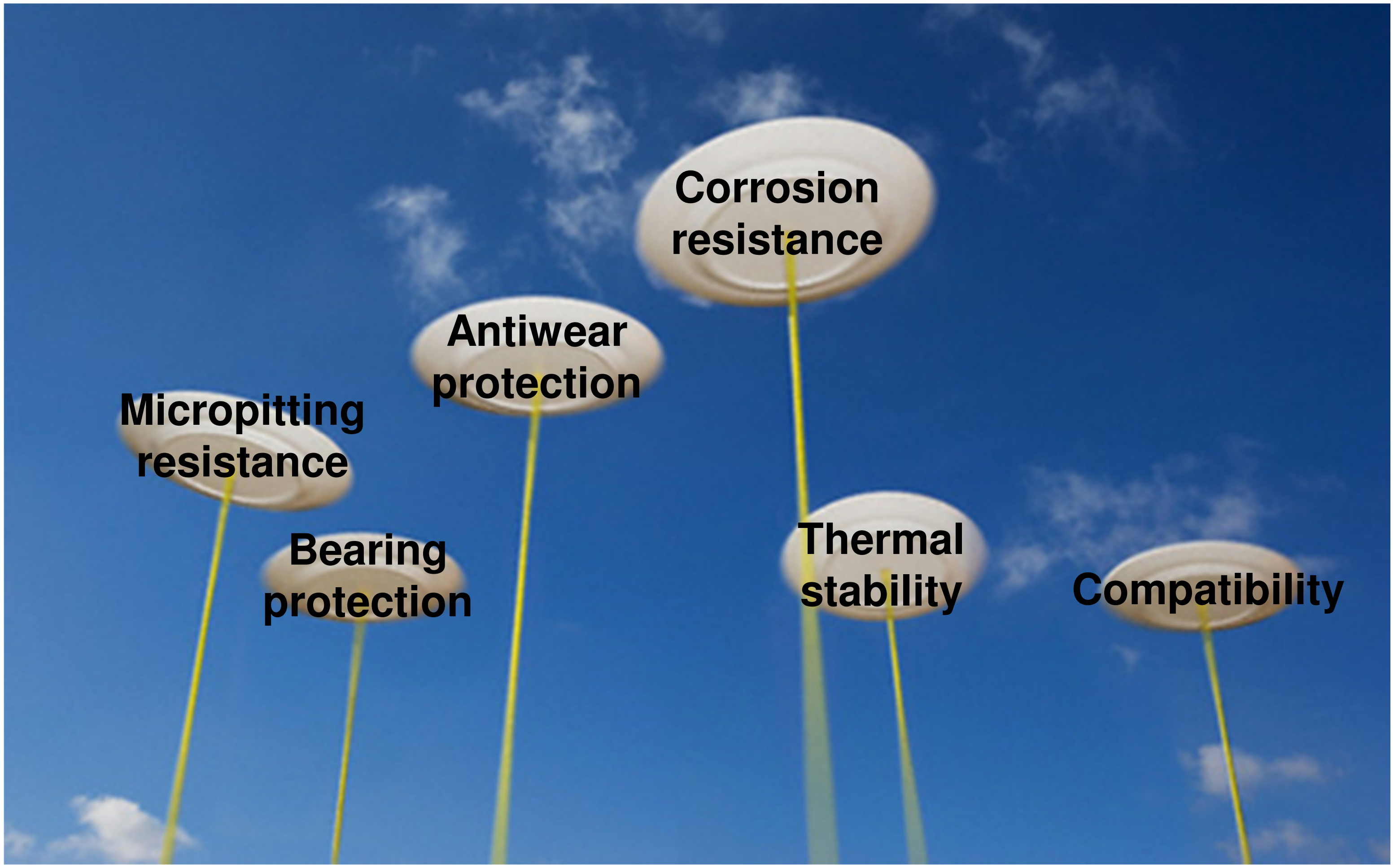
Formulating Oils…The Ultimate Balancing Act



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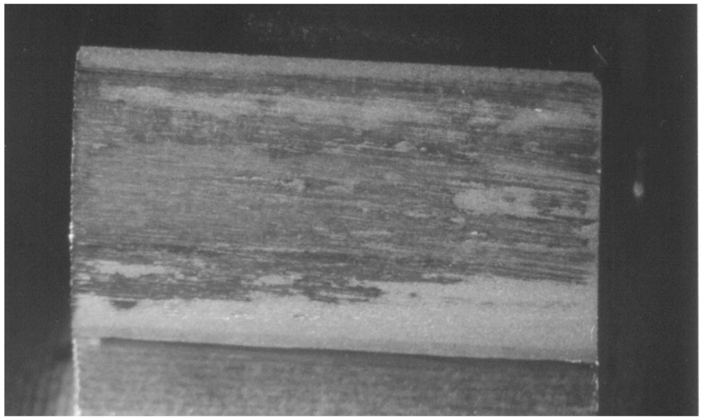
Key Tests

- General industrial gear bench tests: demulsibility, copper corrosion, rust, thermal stability
- Mechanical tests:
  - FZG scuffing tests A/8.3/90 and A/16.6/90
  - FVA-54 micropitting test: FZG based test using gears specifically designed to micropit; load stage and endurance portion of the test
  - FE-8 bearing test
- OEM specific tests
  - SKF – corrosion, volatility
  - Flender foam test
  - Filterability tests



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Lubricant Performance – Key Gear Oil Specifications

Winergy (Hansen wind, Eickhoff, Moventas wind, Bosch Rexroth wind, Vestas etc.)

FVA-54 @ 60℃, FAG 4 step bearing test, Flender foam @ other temps, additional paints & sealant compatibility, SKF tests, filterability, Field Trial

Siemens (Hansen IGO, Moventas IGO, RENK, JaKe etc.)

FVA-54 @ 90℃, Flender foam, paint & sealant compatibility, Freudenberg seals, double speed FZG

DIN 51517-3

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Sources of Information

- Wind turbine supplier
- Gearbox manufacturer
- Lubricant supplier
- ANSI/AGMA/AWEA 6006-A03

- Choice of lubricant depends on:
  - turbine size (power, lubricant volume)
  - turbine transmission design (gearing type, stages, bearing type)
  - range of operating conditions (speed, loads, temperatures)
  - start up considerations (low temperature issues)
  - filtration systems (pumping requirements, filter media, pore size)
  - lubricant delivery system (splash vs. pressure fed)

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Mineral Based or Synthetic Based

- Mineral – a mixture of hydrocarbons
  - have been used successfully for many years, typically have lower purchase cost
- Synthetic – manufactured to contain a very narrow range of hydrocarbons
  - Polyalphaolefin (PAO) may improve gearbox efficiency, increase oil change interval, increased lubricant film thickness
  - Polyalkyleneglycol (PAG) – excellent thermal stability; may have compatibility problems with other lubricants and materials
  - Synthetic Esters – some have poor stability in the presence of water; decreased film thickness in gear and bearing contacts
- Potential benefits of synthetic oils:
  - Expanded operating temperature range and viscosity characteristics
  - Improved thermal resistance
  - Longer oil drain interval

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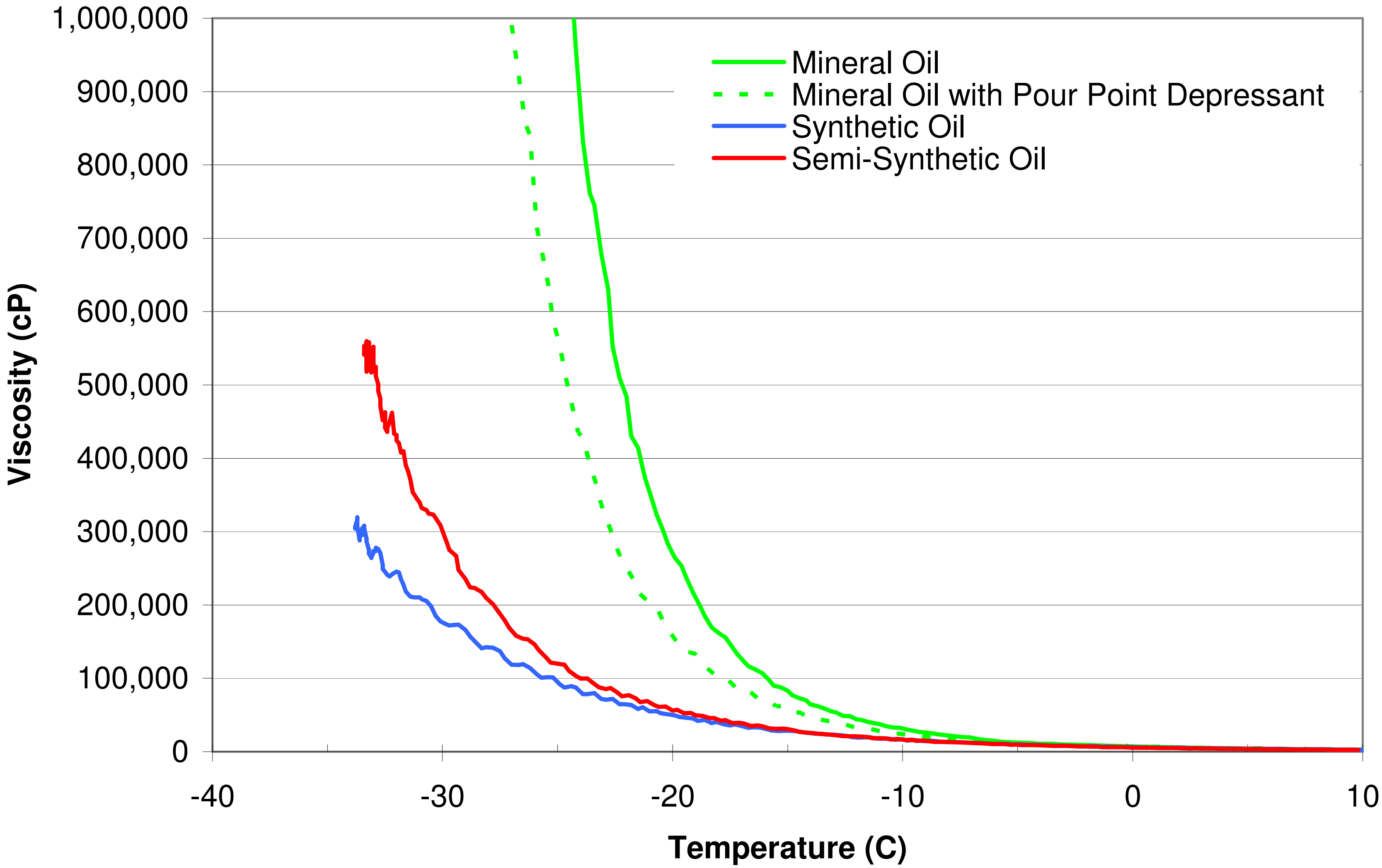
Lubricant Selection

Viscosity Versus Temperature for ISO 320 Gear Oils



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Points to Consider

- Anticipated oil life and what to base it on (calendar, oil analysis, etc.)
- Product data sheet
- Data/reports from field evaluations
- Compatibility with current lube
- Approvals/endorsements from equipment builders
- Have a discussion with your wind turbine supplier and/or oil supplier on your specific needs, including:
  - Special needs of your site and anticipated ambient conditions for each turbine
- Cost keeping in mind to look at the total cost versus only cost of the oil

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Sources of Contamination

- Residual manufacturing debris
- Material ingested through breathers
- Present in the new oil
- Inadvertently added during maintenance
- Internally generated materials such as wear debris

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Impact of Contamination

- Wear debris
  - Collateral damage; debris dents cause stress concentrators around the dent
    - Depends on hardness, size and ductility of the material
  - Particles can clog fine clearances and ports resulting in oil starvation
- Water
  - Corrosion
  - Degradation of lubricant including accelerated additive break down and foaming
  - Damaging to bearings
  - Potentially clog filters
  - May promote micropitting and/or lower fatigue life

To realize the benefits of a quality lubricant, steps should be taken to keep it clean and dry.

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How to Minimize Contamination and Its Impact

- Install desiccant filters on breathers
- Filter oil prior to filling utilizing quick-connect fitting on fill port
  - See AWEA/ANSI/AGMA 6006 for ISO 4406 cleanliness recommendations
- Clean and dry with a low lint rag around inspection and sample ports prior to opening
- Use of kidney-loop filtration systems
- Avoid operation of turbine when filter is in bypass mode
- Monitor particle contamination of drains samples
  - Additional tools are available to help identify the source of particles
- Use a lubricant that minimizes varnish formation since particles can stick to the material creating an abrasive surface
- Use an oil with good micropitting resistance

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Suggested Guidelines for Limits from ANSI/AGMA/AWEA 6006

Parameter	Method	Cautionary Level	Alarm Level
Viscosity change from ISO VG limits (KV at 40℃)	ISO 3104 ASTM D445	±10%	> ±20%
Wear elements	ASTM D5185	Fe: 75-100 ppm Cu: 50-75 ppm	Fe: >200 ppm Cu: >75 ppm
Silicon (Si) increase over new oil	ASTM D5185	15-20	>20
Acid Number increase over new oil	ISO 6619 ASTM D664	40%	> 75%
Sediment	Visual appearance	none	visible
Cleanliness	ISO 4406	-- / 17 / 14	-- / 18 / 15
Water	ISO 12937 ASTM D6304	500 ppm	>1000 ppm

In the absence of guidelines from the lubricant and/or wind turbine manufacturer, the above analysis limits are suggested. These limits are based on previous experience of the committee members.

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Summary

- Unfortunately for wind turbine gear oils, there is no universal answer for what is the best oil or type of oil
- By properly selecting a proper lubricant for the wind turbine gearbox
  - Minimize downtime
  - Reduce maintenance and repair costs
  - Increase productivity

Proper selection and condition monitoring of a lubricant is essential to achieving maximum service life for wind turbine gearboxes.

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