Overview
Route Map and Summary

Gas Turbine Air Treatment Decision Guide

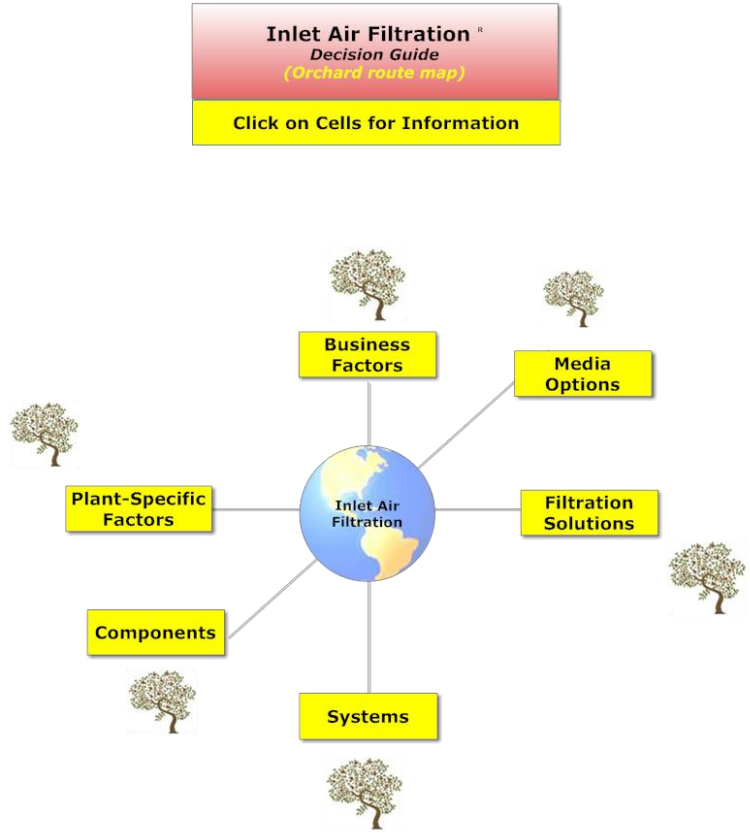
Business Factors

Regulatory

- U.S
- EU
- China
- Other

Economic

- Macro
- Micro
  - Plant life
  - Parasitic power cost



Regulatory, Economic and Site Specific Impacts on Filter Choice

Subject	Slide Contributor	Relevant decision
Regulatory Impacts	McIlvaine	Gas and renewable generation will grow as coal and nuclear plants are retired
Priority Ranking	Barilla	What factors must clearly be considered vs. more "grey" factors?
Overview of Environmental Conditions	GE	What challenges are presented by various regional environments?
Coastal, Marine and Offshore Conditions	**McIlvaine**	What considerations are involved in designing air inlet filtration systems for coastal environments?
Desert Conditions	McIlvaine	Same – for desert environments.
Arctic Conditions	McIlvaine	Same – for arctic environments.
Tropical Conditions	McIlvaine	Same – for tropical environments.

Regulatory Impacts:
Gas turbine capacity will grow as regulations shift the energy mix away from coal and nuclear generation

Coal plants are being retired worldwide due to environmental concerns and regulations

- Mercury, particulates, SO2, NOx
- Greenhouse gas regulations such as New Source Performance Standards (NSPS) for new plants and Clean Power Plant Program for existing plants in the U.S.

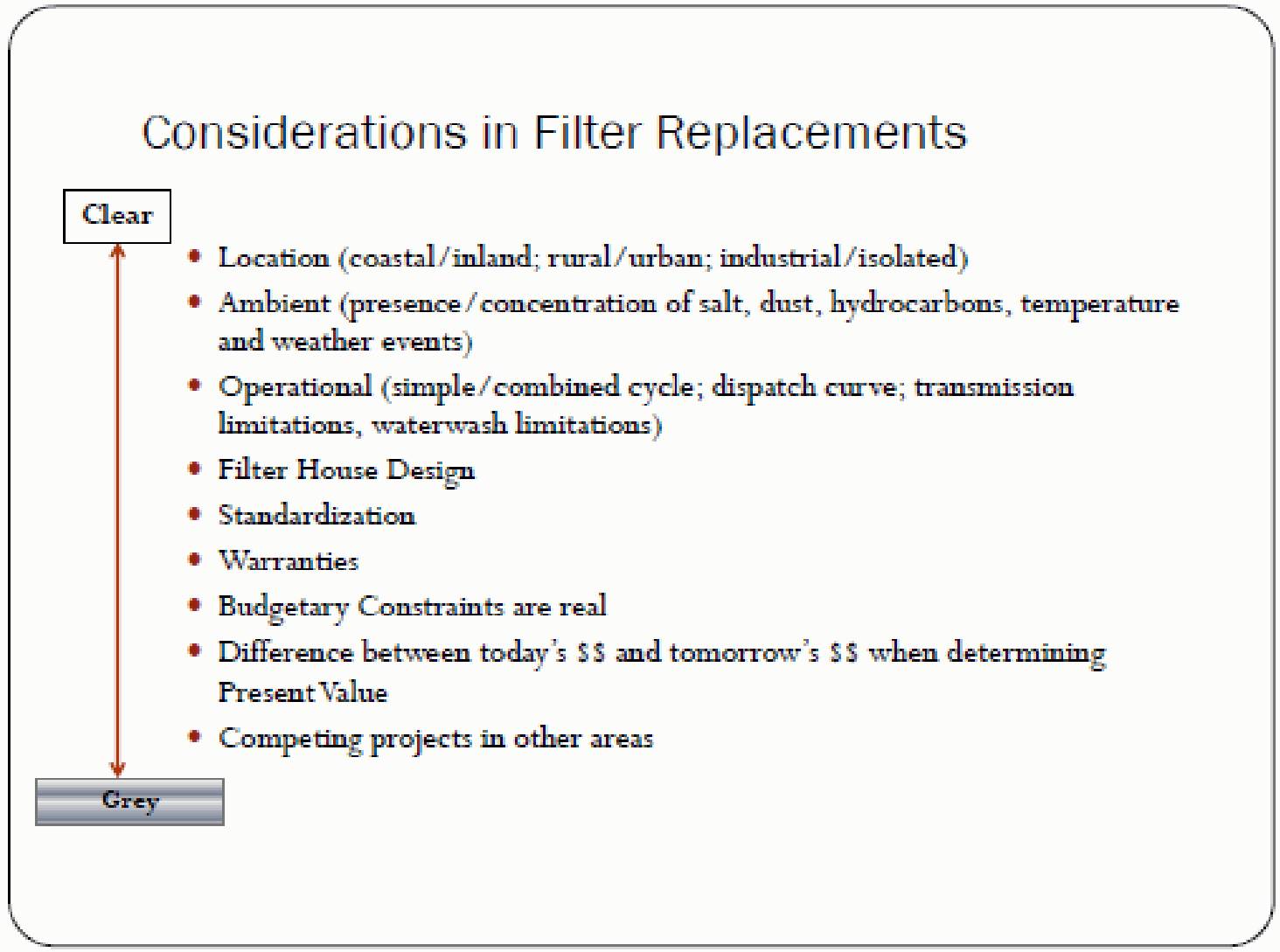
Nuclear plants are being retired in Japan, Germany and elsewhere as a consequence of the Fukushima disaster

Gas-fired power generation will increase to fill the gap

In addition, greenhouse gas regulations are promoting ***renewable energy***, which will require quick-start gas-fired units for backup

Priority ranking of filter selection factors (Barilla)

Gas Turbine Inlet Filters - Value Considerations in Filter Selection by Paul Barilla - Hot Topic Hour May 15, 2014



Plant specific factors

Environment

- Coastal
- Marine
- Offshore
- Desert
- Arctic
- tropical

Combustion

- turbine design
- Fuel additives
- Fuel
- Heat recovery

Conditions encountered depending on location (GE)

Environment type	Salt levels	Dust levels	Other challenges
Marine	High	Low	Bulk water
Offshore	High	Medium	Vapors
Coastal	Medium	Medium	Vapors
Dusty	None	High	Vapors
Dusty Coastal	Medium	High	Vapors
Desert	None	Very High	-
Urban	None	Medium	Vapors
Sub... Arctic	-	-	Snow and Ice
Sub… Tropical	-	-	Bulk water

To further evaluate these contaminants, consider the following ad

Coastal, Marine and Offshore Conditions

Guideline for Gas Turbine Inlet Air Filtration Systems
Understanding the Benefits and Limitations of EPA Filtration--Filtration News, April 2015
Filtration Efficiency's Impact on Compressor Health--Filtration News, April 2015

- The main difference between coastal and land based applications is the concentration of ***salt*** in the atmosphere. Salt is a main contributor to corrosion and can lead to fouling of compressor blades.
- ***Coastal environments*** refer to gas turbines installed on land but within 10 miles of a salt-water shoreline. At 8 to 12 miles from the shoreline, salt concentrations in the air drop to natural background levels.
- ***Marine environments*** refer to gas turbines installed on vessels, where the inlet is generally within 100 feet from the ocean's surface.
- ***Offshore applications*** are typically oil production platforms with gas turbine inlets more that 100 feet from the ocean's surface.
- Air intake filtration systems must be designed to handle moisture and salt and are typically include:
  - Weather protection (such as a weather hood)
  - Vane separators or coalescers to address moisture
  - Pre-filters and/or high efficiency filters to address salt

Desert Conditions

- ***Dust and sand*** are the main contaminants in desert environments. Initial separators can remove the larger dust particles, followed by pre-filters and high efficiency filters to remove the smaller particles.
  - However, modern self-cleaning cartridge filters with pulse cleaning have largely replaced separator/pre-filter/high efficiency filter arrangements, which tend to be more expensive due to the cost of frequent filter change outs.
- Some desert locations experience periods of ***dense fog and high humidity***, particularly in coastal regions in the Middle East. The moisture can collect on the surface of cartridge and self-cleaning filters, causing the dirt to form a cake which reduces the effectiveness of the filter and pulse-cleaning
- mechanism.
- Air intake filtration systems in desert environments typically include:
  - Weather protection (such as a weather hood)
  - Vane separators or coalescers, where appropriate, to address <u>moisture</u>
  - Self-cleaning cartridge filters to address <u>dust and sand</u>

Arctic Conditions

Guideline for Gas Turbine Inlet Air Filtration Systems

- Arctic environments are characterized by lengthy periods of time with temperatures below 32° F (0° C). The main concern for air intake systems is the ***removal of snow and prevention of ice formation and buildup.***
- Inlet filter housings should be elevated to minimize the ***ingestion of snow and ice***, with consideration given to the expected height of snow in winter months.
- Weather hoods should have a large entrance areas which decreases velocity and the likelihood that show will be pulled into the filtration system.
- Ice can be formed if the temperature of humid air in the inlet system decreases, causing water particles to freeze. Moisture in the air can be due to:
  - ***Cooling tower drift.*** The plant should be laid out to minimize the potential cooling tower aerosols to enter the intake system.
  - ***Ice fog***, which typically starts to form at temperatures below -15° F,
- ***Anti-icing systems*** mix heated air (from compressor bleed or gas turbine exhaust) with cold inlet air. Alternatively, ***pulse cleaning systems*** have been found to be effective in preventing ice build up.
- Air intake filtration systems in artic environments include:
  - Elevated intake structures
  - Weather protection (such as a weather hood or louvers)
  - An anti-icing system with pre-filters OR self-cleaning filters
  - High efficiency filters

Tropical Conditions

Guideline for Gas Turbine Inlet Air Filtration Systems

- Tropical environments are characterized by high temperatures, high humidity, monsoons, high winds and insect swarms. Due to extensive vegetation, it is considered a low dust environment.
- The primary contaminants are ***water and insects, and salt*** for locations near the shoreline.
- Filtration systems in the topics are specifically built to handle large amounts of rain. Weather hoods are used as a primary defense, typically followed by a vane axial separator and coalescers to reduce water intake.
- Large area insect screens with low inlet velocities are used to block ingestion of insects.
- High temperatures and high humidity lead to the formation of mold fungus and corrosion. Therefore, all metal inlet parts should be made of corrosive resistant materials or coated with ***corrosion protection***.
- Air intake filtration systems in tropical environments include:
    - Weather protection (such as a weather hood)
    - Insect screens
    - Vane axial separator, coalesce
    - Pre-filter and high efficiency filter
    - Corrosion resistant metal parts