High Temperature Superconductivity Market Readiness Review

Office of Electricity Delivery and Energy Reliability

Investigation of the status of HTS technology, the requirements of key applications and barriers to future success

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These are several HTS technology and systems-level challenges toward achieving successful device commercialization.

Application	Critical HTS Technology Challenges	Critical Engineering / Application Challenges
Power Cable	• Reduce heat leak from the cryostat, improve efficiency of cryogenics, reduce AC losses, improve cost-performance ratio of HTS wire • Simpler, more robust and cost effective cryostat designs	• System reliability, splices, designs for low maintenance • Thermal and hydraulic issues over long lengths, fault current tolerance • Business models for cryocooler maintenance
Synchronous Condenser	• Improve cost-performance ratio of HTS wire at field	•Optimization for application, larger sizes
Fault Current Limiter	• Understand quench characteristics at high voltages and currents	• Electro-mechanical design requirements, cycling characteristics, device lifetime
Industrial Motor	• Improve cost-performance ratio of HTS wire at field, improve performance of cryogenics	• System reliability, low cost packaged system
Utility Generator	• Improve cost-performance ratio of HTS wire at field, identify suitable dielectric materials, improve cryogenics	• Going to larger sizes, system reliability, low cost packaged system
Wind Generator	• Improve cost-performance ratio of HTS wire at field, improve cryogenics	• Small and lightweight, larger sizes, design challenges in offshore marine environment
Transformer	• Reduce AC losses, improve cost-performance ratio of HTS wire, identify suitable dielectric materials	• Larger sizes, low cost packaged system, system reliability • Develop load tap changing technology

The HTS program currently has a significant level of early stage R&D on conductor and balance of system components.

	Examples of HTS Project Areas		
	Discovery Research	**Targeted Research and Development**	**Technology Maturation and Deployment**
Conductor Research (Wire Technology)	• Magnetic flux pinning • Control of nanodefects & interfaces • Higher Tc superconductivity • Multilayers/Buffers	• Near-isotropic high-pinning superconductors	• Isotropic YBCO superconductor
Conductor Research (Wire Manufacturing)	• Filament Development • Tape transposition • Dielectric architecture • HTS film deposition rate >100 m/hr of 1,000 A/cm tape	• 1,000 A/cm width at 77K • Kilometer lengths • Production rate 10,000 km/yr	• 2nd Generation Wire Manufacture <$50/kA-m
SPI (Devices, Applications, & Balance of System)	• High voltage dielectrics	• Cryorefrigeration • Pre-commercial high-efficiency superconducting power delivery systems	• Prototype motors, generators, transformers, FCL devices based on 2G

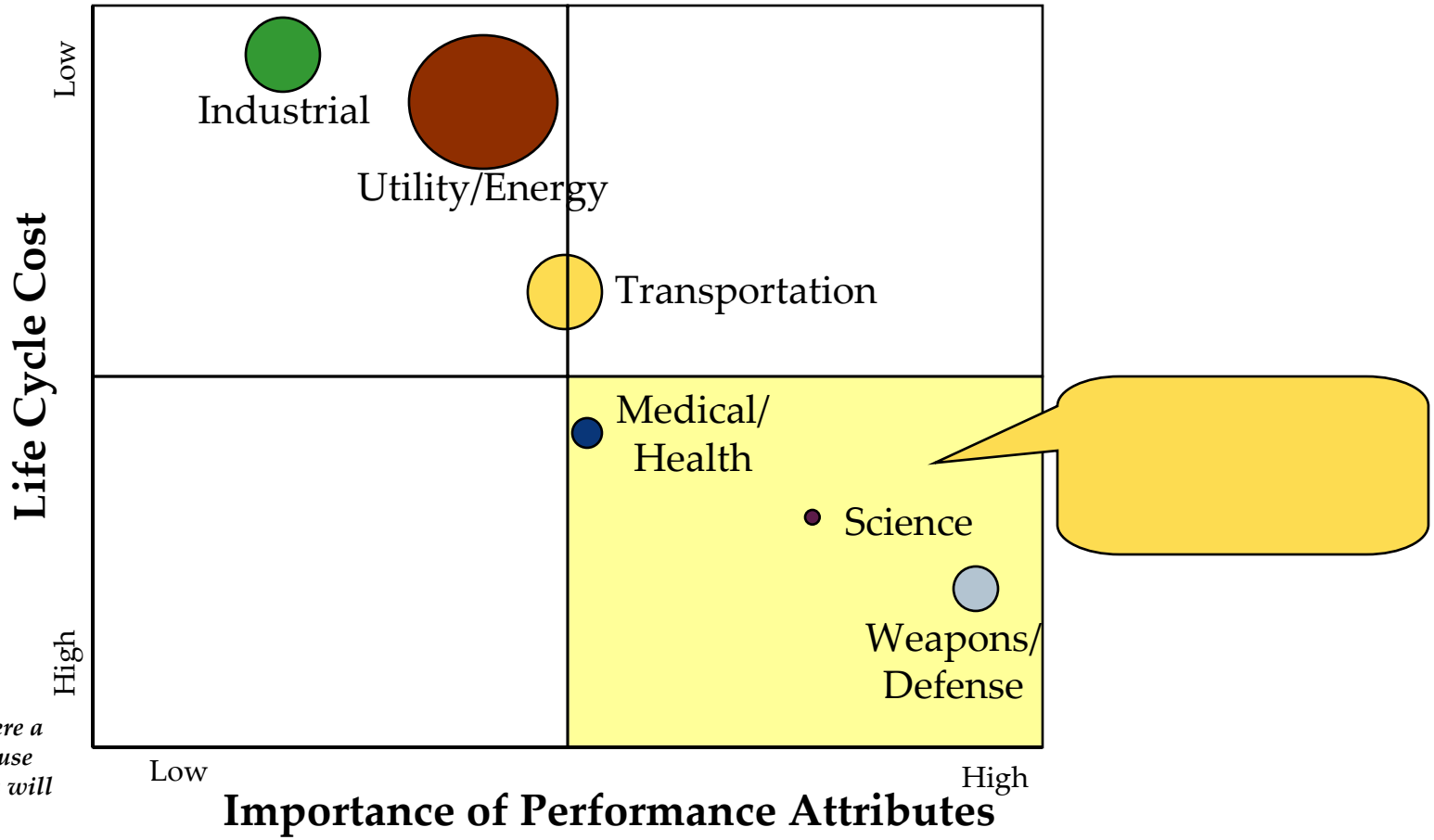
As currently funded, the DOE program does not support all areas requiring development

The most important near term energy and utility markets appear to be fault current limiters and synchronous condensers.

- Due to the relative clarity and strength of their value propositions, the strongest early markets for HTS are likely to be fault current limiters and synchronous condensers. Mass markets such as cable, transformers and generators that value low impedance and energy density will emerge much later.
- New applications in energy and utilities are likely to value the small and light characteristics such as off-shore wind turbines. Other new applications may emerge when there is more opportunity to experiment with the technology.
- We do not fully understand how long it will take to develop these markets, but it is likely to take 5-10 years of niche applications and experimentation in most segments before broader, mass markets develop.
- It is not clear today if HTS offers a compelling value proposition in many of the important applications that will demand higher volumes of wire and as a result more application studies, demonstrations and government support will be required to develop these markets.

It is likely to take 5-10 years of application studies, experimentation and demonstrations before broader markets develop.

In addition to assigning high value to HTS attributes, it is likely that market segments such as Defense and possibly Science may be prepared to pay the most for the technology.



Note: Applications where a government is the end-use customer, life cycle costs will be less important.

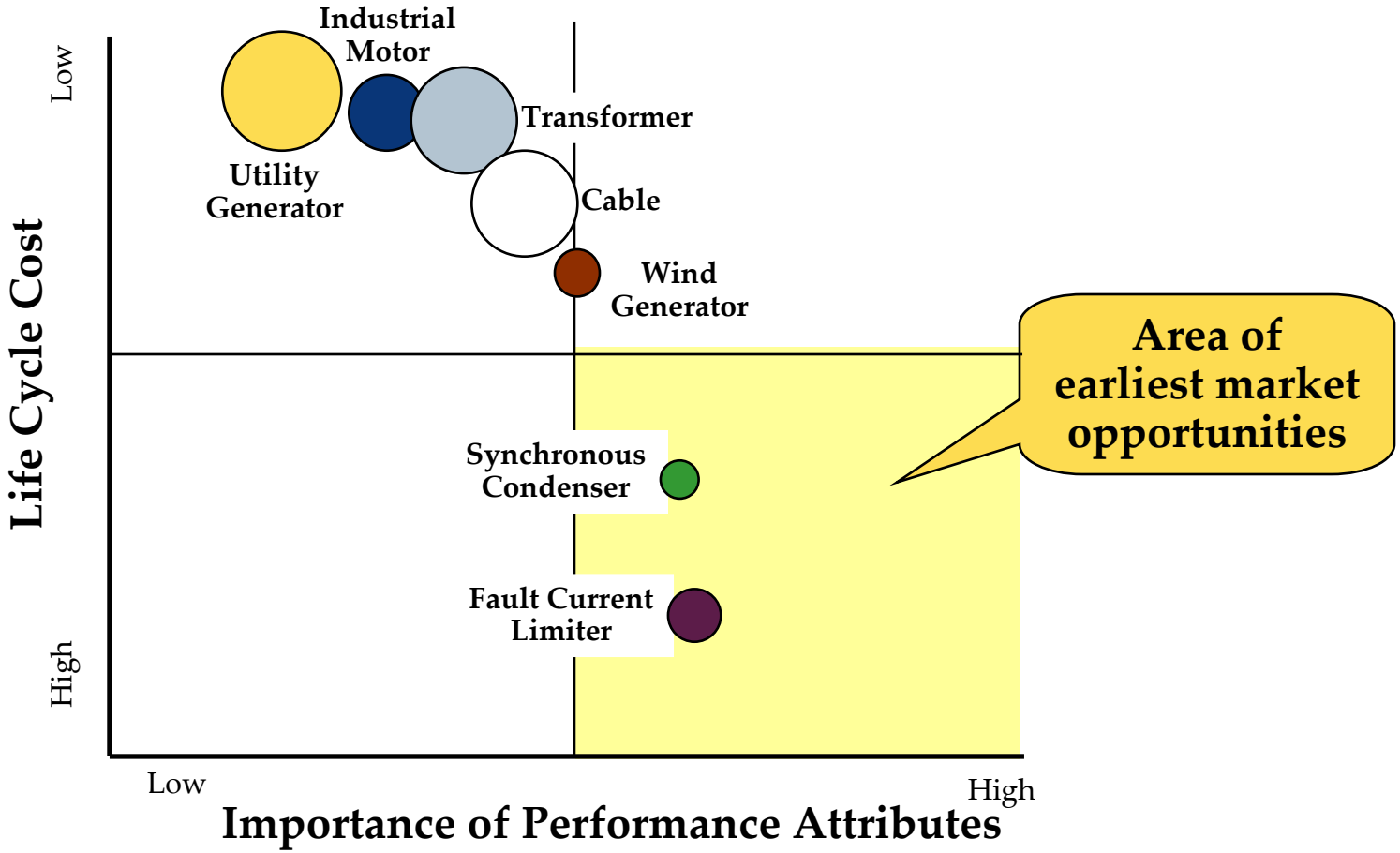
Note: The size of the ball denotes approximate market size.

The Utility/Energy market may be largest long-term opportunity, but will require HTS sales from other segments to drive improvements in the cost-performance ratio before 2020.

	Time Frame						
	2006	2010	2014	2018	2022	2026	2030
Utility/Energy			●	●	●	●	●
Weapons/Defense		●	●	●	●	●	●
Transportation			●	●	●	●	●
Industrial				●	●	●	●
Medical/Health				●	●	●	●
Science		●	●	●	●	●	●

Source: NCI Analysis

In the utility/energy market the majority of potential applications value low life cycle costs more than specific performance attributes.



Note: The size of the ball denotes approximate market size.

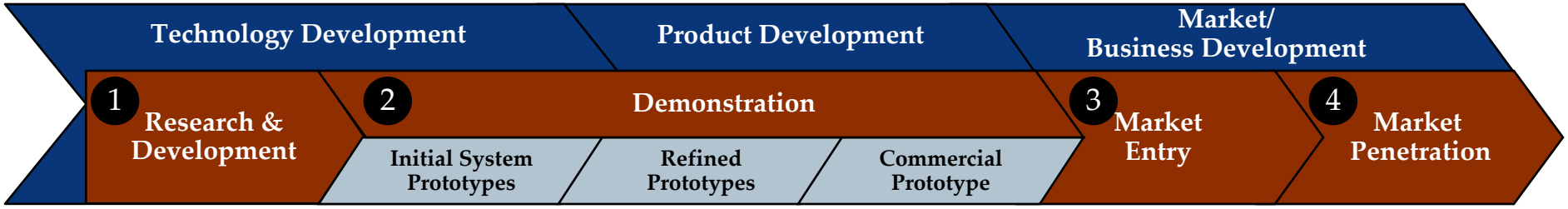
In the utility/energy market, the applications that appear to value performance attributes of HTS most are Fault Current Limiters and Synchronous Condensers.

	Utility/Energy Market - Importance of Performance Attributes					
	Small & Light	High Power Density	Low Impedance	High Efficiency	High Field	Overall
Power Cable	●	●	●	●	○	●
Synchronous Condenser	●	●	●	●	●	●
Fault Current Limiter*	●	●	●	●	○	●
Industrial Motor	●	●	●	●	●	●
Utility Generator	○	○	●	●	●	●
Wind Generator	●	●	●	●	●	●
Transformer	●	●	●	●	○	●

Source: NCI Analysis

* Fault current limiters also rely on the inherent quench properties of HTS.

HTS cables are likely to enter the market on a commercial basis around 2014, but additional stages of demonstration will be required.



ongoing	2006	2008	2011	2014	2017
•Understand major technical issues, demonstrate key technical concepts •Develop solutions to major technical issues •Define system requirements **Project Examples** •DTE Cable Project •Southwire Carrollton Project	•Initial system prototypes using 1G HTS wire •Debug components •Demonstrate technology in field environment. **Project Examples** •Southwire/AEP •LIPA/AMSC •Albany/ SuperPower	•Refine initial system with experience from prototypes •Demonstrate value proposition in the field and business model **Projects** •Full scale demonstration using 2G wire •Full functionality •Progress toward cost goals for major components	•Full size system in "commercial" operating environment •Demonstrate future economics, acceptable market and technical risk •Gov. support for industry standards **Projects** •Commercial cable project without backup option	•Formal business model for maintenance •Early movers •Demonstrate value for broader market opportunities **Projects** •Customer driven cable project, without government support	•Market penetration accelerates •Focus on lowering system costs •Increasing diversity of product offerings

In addition to wire cost and performance improvement, significant work will be required on devices for utility and energy applications.

- 2G HTS wire cost and performance goals required for early commercial energy and utility applications will not be achieved until after 2010.
- Once HTS wire is on track to achieve the goals, there will be much more work required to design, develop, and test devices that will leverage the benefits of the technology.
  - Experience from the current round of cable demonstration projects will help map out the needs and objectives for additional rounds of cable demonstrations that will target understanding benefits.
  - In other areas, such as fault current limiters and transformers, we need to build devices, test them in the lab and in the field before we understand the real value propositions.
  - In each device area, we will need to perform several rounds of testing and verification before the utility industry will consider these devices in lieu of their traditional solutions.

How large are the markets for these devices and how long will it take to develop them?

- The most attractive attributes of HTS technology appear to be related to the small and light characteristics of devices when used in important energy applications.
- The application benefits of HTS devices will not be fully understood until several demonstrations can be performed in each segment.
  - Experimentation is required in order to understand the impact of key benefits, such as low impedance, fault current limiting, high power density and low losses.
  - Utility planners do not have the knowledge and the tools to adequately account for many of these benefits.
- Business models need to be developed that provide utilities with operations and maintenance support required for cryogenic systems.
- Market development will require continued government support to offset added cost and risk for early demonstration projects before a real commercial market will develop.

We need to do a better job of engaging the utility customers in order to accelerate the adoption of HTS technology.

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