

# **Superconductor Market Research**

## **HTS in 2008**

Prepared by bentō strategy

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v4

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## 1. Executive Summary

An independent market survey of superconductivity industry professionals was conducted in February 2008. Over 400 respondents provided opinions and metrics for a variety of industry, technology and business attributes. The purpose of the survey is to gain quantitative information about potential HTS applications, ranking, timing and potential along with supporting qualitative information.

Some of the key findings include:

- Cable is still seen as the “holy grail” for the industry, followed by FCL. However, total system cost and reliability are seen as significant barriers to widespread adoption; while the innovative nature of FCL (once reliability is proven) should make it the first widespread HTS device used by the utility industry.
- With respect to market timing, Science/Technology and Medical are both near term markets, followed by Defense/Military. These represent applications where system performance outweighs the material cost and cooling constraints. Industry, Utility/Energy and Alternative Energy may begin in 2012, while Transportation will lag these markets.
- Utility/Energy adoption could be accelerated if the government mandated efficiency standards.
- \$300/kA-M is seen as a threshold for prototype production. Costs should reach \$100/kA-M or lower for initial commercial production.
- Firms most likely to commercialize an HTS device include: Sumitomo Electric, SuperPower, AMSC, Siemens, Nexans, Ultera/Southwire, GE, Toshiba and Bruker.
- Survey respondents indicate that the firms most likely to supply commercially viable 2G HTS wire within the next 36 months are: SuperPower, AMSC and Sumitomo Electric.
- Intent to purchase “research quantities” (<1,000 meters) over the next 36 months stays relatively constant, while intent to purchase 1,000 to 10,000 meters doubles in 12 and 36 months respectively, and >10,000 meters triples in 12 and 36 months respectively.

With the strong response and useful commentary, we hope to repeat this survey every twelve months to monitor trends and further refine our analysis.

This summary is a significantly condensed version of the client report and is intended for private distribution to survey respondents who requested the summary report.

Respectfully Submitted,

Bentō Strategy

## 2. Purpose and Process

Bento Strategy was engaged to conduct an independent market survey to evaluate the current state of the Superconductivity market. The primary purpose of this survey is to gain quantitative information about potential HTS applications, ranking, timing and potential along with supporting qualitative information.

Following the initial survey invitation on 13 February 2008, two reminders were sent and to those that began the survey but did not complete, two reminders were sent. The survey was closed on 5 March 2008 resulting in approximately three weeks to collect responses.

## 3. Key Findings

### 3.1. Significant Highlights

- Cable is still seen as the “holy grail” for the industry, followed by FCL. However, total system cost and reliability are seen as significant barriers to widespread adoption; while the innovative nature of FCL (once reliability is proven) should make it the first widespread HTS device used by the utility industry.
- With respect to market timing, Science/Technology and Medical are both near term markets, followed by Defense/Military. These represent applications where system performance outweighs the material cost and cooling constraints. Industry, Utility/Energy and Alternative Energy may begin in 2012, while Transportation will lag these markets.
- Utility/Energy adoption could be accelerated if the government mandated efficiency standards.
- Specific applications which HTS can more quickly penetrate/expand include current leads, High Field NMR and MRI, and Accelerator Magnets.
- Cost remains a significant concern and barrier to commercialization. However, for those applications that have non-HTS/LTS alternatives with similar performance characteristics, cryogenics and overall system reliability and maintenance will be significant obstacles.
- In regards to price for superconducting wire, \$300/kA-M is seen as a threshold for prototype production. Costs should reach \$100/kA-M or lower for initial commercial production.
- Product Performance is a strongly favored primary attribute with a 21% preference over Price.
- Firms most likely to commercialize an HTS device include: Sumitomo Electric, SuperPower, AMSC, Siemens, Nexans, Ultera/Southwire, GE, Toshiba and Bruker.
- Survey respondents indicate that the firms most likely to supply commercially viable 2G HTS wire within the next 36 months are: SuperPower, AMSC and Sumitomo Electric.
- For a project today, only 50% would choose 2G HTS. This may be as much of a market education issue as a price constraint.
- There seems to be some misinformation about the mechanical properties of 2G wire – strength, flexibility and ease of connection (joints).
- The absence of MgB2 in the study and the many comments regarding its application will be noted in the next version of the survey.
- Intent to purchase “research quantities” (<1,000 meters) over the next 36 months stays relatively constant, while intent to purchase 1,000 to 10,000 meters doubles in 12 and 36 months respectively, and >10,000 meters triples in 12 and 36 months respectively.
- Fundamental R&D in materials science and manufacturing process is vital to achieve cost reduction and government funding is still necessary for the technology to deliver upon its promise.
- Commercial firms should be cautious of abandoning their connection to the research community. News releases and papers should maintain scientific objectivity.

## 4. Survey Analysis – Summary and Highlights

### 4.1. Introduction

In most cases, the responses have been sorted in descending order from the most popular or highest frequency response to the lowest frequency response. Matrix questions have a “Rating Average” that allows the results to be sorted independent of the absolute number of responses. Percentage values include a “Response Count” that represents the percentage of responses for the specific item from all answers provided (not all answer options required a response).

### 4.2. Section 2: About Yourself

<b>1. In what Country/Region are you primarily located?</b>	
<b>Answer Options</b>	<b>Response Percent</b>
Western Europe	36%
United States	23%
Japan	12%
Korea	6%
China	4%
Eastern Europe	4%
Russia	4%
Australia/New Zealand	2%
Other (please specify)	2%
South America	2%
Taiwan	1%
India/Pakistan	1%
Canada	1%
Other Asia	0%
Africa	0%
Mexico	0%
Central America	0%

40% of the respondents were located in Europe, 23% in the US and 22% in Asia, with the remainder located throughout the rest of the world.

<b>2. In what industry/organization do you primarily work?</b>	
<b>Answer Options</b>	<b>Response Percent</b>
Academia	44%
Government Laboratory/Institute	26%
General Industry	13%
Private/Commercial Research	10%
Other (please specify)	7%
Utility	3%
Government	2%
Medical	1%
Alternative Energy	1%
Military/Defense	1%
Transportation	1%
Security	0%

Concentration of respondents in Academics (44%) and Government (28%) match expectations.

<b>3. Approximately how many people work within your entire organization?</b>	
<b>Answer Options</b>	<b>Response Percent</b>
1	1%
2-10	12%
11-50	18%
51-100	7%
101-500	14%
501-1,000	10%
1,001-5,000	19%
5001+	18%

Increasing distribution in larger organizations meets expectations given industry/organization distribution.

<b>4. What is your primary role or responsibility?</b>	
<b>Answer Options</b>	<b>Response Percent</b>
Academic Researcher	43%
Project or Program Management	12%
Executive (CEO, Owner, President, Vice President, etc.)	9%
Engineering	9%
Government Research	9%
Commercial R&D	8%
Other (please specify)	7%
Other Technical	2%
Other Commercial	1%

Results generally meet expectations. Third highest category in Executive role is somewhat surprising.

**5. What type of HTS Projects / Applications / Technology are you primarily working on?**

The number of responses here was very encouraging and reveals a wide range of projects (details in next section). From the responses, we performed a key word frequency analysis to determine the most popular projects/applications and technologies. We eliminated common terms such as HTS, Superconductor, research, etc. and combined near matches (e.g. SFCL and FCL, Cable and Power Cable) and singular/plural.

4.3. Section 3: Industry Development

**1. For each of the following applications, in which do you think use of HTS technology may provide important commercial advantages? By Application, we mean a niche or specialized device, not necessarily all potential uses. If you do not have an opinion please leave the row blank.**

Answer Options	HTS provides very important commercial advantages	HTS is important, but not the leading factor	Neutral - no advantage or disadvantage	Many other factors are more important than HTS	HTS does not provide meaningful commercial advantages	Rating Average	Response Count
Fault Current Limiter	66%	25%	7%	2%	0%	4.56	93%
Current Leads	61%	26%	10%	3%	0%	4.46	88%
Power Cable	59%	32%	3%	5%	1%	4.42	92%
NMR	53%	33%	10%	3%	1%	4.32	87%
High Energy Physics / Research Magnets	56%	27%	9%	6%	1%	4.31	87%
SQUID based technologies	49%	30%	15%	5%	2%	4.21	82%
MRI	49%	32%	11%	5%	3%	4.18	87%
Marine Power (Motor, Generator)	44%	38%	11%	7%	1%	4.16	86%
Rail Transportation (Maglev, Transformer)	36%	35%	16%	9%	4%	3.90	84%
SMES	32%	34%	22%	7%	5%	3.81	82%
Transformer	25%	44%	18%	11%	2%	3.80	89%
Defense Applications (list)	28%	38%	20%	11%	3%	3.78	68%
Space Applications (list)	28%	37%	23%	9%	3%	3.77	69%
Utility Generator	18%	46%	21%	12%	3%	3.65	83%
Industrial Motor	20%	46%	16%	13%	5%	3.62	86%
Wind Generator	22%	34%	24%	14%	6%	3.54	84%
Other Industrial (list)	15%	30%	38%	11%	6%	3.35	45%
Other/List (please specify) / Comments							15%

For the top seven applications, approximately 50% of the respondents believe that HTS provides very important commercial advantages.

<b>2. Of the applications listed above, with which are you personally most familiar?</b>				
<b>Answer Options</b>	<b>Very Familiar</b>	<b>Moderately Familiar</b>	<b>Not Familiar</b>	<b>Response Count</b>
Power Cable	48%	43%	9%	89%
Fault Current Limiter	46%	43%	11%	89%
Current Leads	40%	41%	18%	86%
High Energy Physics / Research Magnets	33%	38%	29%	86%
MRI	30%	39%	31%	85%
Transformer	29%	46%	25%	84%
SMES	28%	42%	31%	84%
NMR	28%	38%	34%	84%
Industrial Motor	20%	50%	30%	83%
Marine Power (Motor, Generator)	20%	48%	32%	82%
Rail Transportation (Maglev, Transformer)	20%	41%	39%	81%
Utility Generator	19%	44%	37%	82%
SQUID based technologies	17%	32%	50%	82%
Wind Generator	13%	41%	46%	82%
Defense Applications (list)	12%	28%	60%	71%
Space Applications (list)	9%	31%	60%	72%
Other Industrial (list)	8%	28%	64%	55%
Other/List (please specify) / Comments				9%

Unsurprisingly, the majority of the respondents are very familiar with Power Cable and FCL applications.

**3. For any of the applications above where you have indicated that HTS provides important commercial advantages and with which you are very familiar, please indicate specific applications and/or performance requirements that will be required to achieve success.**

Respondents were very generous with their comments. There were many that indicate 2G HTS will become increasingly valuable for very high field magnets in both research and clinical MRI/NMR applications. Others point out that once wire cost falls as expected, the cooling/cryogenics will become the next critical issue for adoption.

<b>4. Please indicate the year when you believe there will be initial commercial demand for HTS devices in the following industries. By commercial demand, we mean the purchase of an HTS device that is competitive with an available non-HTS device. If you do not know or do not have an opinion, please leave the row blank.</b>								
<b>Answer Options</b>	<b>2008</b>	<b>2010</b>	<b>2012</b>	<b>2014</b>	<b>2016</b>	<b>2018</b>	<b>2020+</b>	<b>Response Count</b>
Science/Technology	31%	29%	22%	9%	4%	1%	4%	87%
Medical	24%	27%	22%	13%	8%	3%	5%	83%
Defense/Military	12%	29%	20%	12%	11%	3%	11%	74%
Industrial	6%	16%	26%	20%	12%	6%	13%	76%
Utility/Energy	5%	15%	27%	24%	9%	7%	14%	83%
Alternative Energy	2%	14%	27%	18%	14%	6%	18%	77%
Transportation	2%	7%	20%	21%	16%	9%	26%	79%
							Comments	10%

For this question we believe that looking at the “> 50% pairs” helps to interpret the market timing question. Science/Technology along with Medical are both near term markets, followed by Defense/Military. Industry, Utility/Energy and Alternative Energy begin in 2012 followed by the Transportation market.



**5. Of the following companies, who do you think will have the highest probability of successfully commercializing an HTS Device? By HTS Device, we mean a product or application utilizing HTS technology. If you are unfamiliar with the company, please leave the row blank.**

Answer Options	High Probability	Good Probability	Neutral Probability	Low Probability	Zero Probability	Rating Average	Response Count
Sumitomo Electric, Inc.	65%	29%	7%	0%	0%	4.58	84%
SuperPower	59%	33%	7%	1%	1%	4.48	85%
American Superconductor (AMSC)	59%	33%	5%	2%	1%	4.48	93%
Siemens	41%	45%	11%	2%	0%	4.24	79%
Nexans	41%	38%	18%	3%	0%	4.16	79%
Ultera/Southwire	33%	36%	27%	5%	0%	3.96	59%
General Electric	24%	46%	24%	6%	0%	3.88	69%
Toshiba	22%	43%	28%	7%	0%	3.80	60%
Bruker	29%	31%	31%	8%	1%	3.78	60%
Furukawa	23%	39%	28%	9%	1%	3.76	60%
Theva	21%	42%	29%	7%	1%	3.76	64%
Zenergy (SC Power / Trithor / Australian Superconductor)	21%	35%	33%	9%	1%	3.66	58%
HTS-110	14%	38%	37%	10%	0%	3.57	52%
HyperTech	12%	39%	39%	9%	1%	3.54	58%
LS Cable	15%	33%	42%	10%	0%	3.54	45%
Waukesha Electric Systems	12%	35%	43%	8%	2%	3.46	55%
Alstom	12%	36%	37%	13%	2%	3.43	64%
LS Industrial Systems	11%	28%	49%	11%	0%	3.39	44%
Oswald	11%	31%	46%	10%	2%	3.39	48%
ABB	9%	35%	42%	14%	1%	3.36	65%
Chubu	12%	27%	44%	15%	2%	3.32	49%
Hyundai	7%	25%	53%	13%	1%	3.22	48%
Innopower	7%	22%	55%	13%	2%	3.19	49%
Doosan	5%	23%	55%	16%	2%	3.14	41%
Baldor-Reliance-Dodge	6%	19%	55%	17%	2%	3.10	46%
Condumex	4%	8%	67%	18%	3%	2.93	41%
Other (please specify) / Comments							10%

Respondents suggest Sumitomo Electric, SuperPower and AMSC as the most likely companies to commercialize an HTS Device.

4.4. Section 4: Technology Development

**1. Wire: Of the following technical attributes, which are the most important to the commercial success of HTS applications? If you are not familiar with a category or do not have an opinion, leave the row blank.**

Answer Options	Critical for Commercial Success	Very Important for Success	Neutral - not important or unimportant	Minor Importance for Success	Unimportant	Rating Average	Response Count
High Engineering Current Density	49%	43%	7%	1%	0%	4.42	92%
In-Field Performance	44%	50%	5%	1%	0%	4.39	90%
High Ic	46%	44%	9%	1%	0%	4.38	91%
Ic Uniformity	44%	46%	9%	0%	0%	4.35	88%
Low AC Losses	42%	48%	9%	1%	0%	4.33	90%
Mechanical Properties	39%	49%	11%	2%	0%	4.29	91%
Stabilization	39%	49%	11%	2%	0%	4.27	87%
Insulation	22%	45%	26%	6%	0%	3.96	85%
Geometry (width, thickness)	16%	46%	31%	6%	1%	3.86	88%
Other (please specify) / Comments							11%

For the technical attributes: Ic Uniformity, High Ic, High Engineering Current Density, and In-Field Performance were evenly split between Critical and Very Important for success. All other attributes were Very Important. The lower importance of geometry is perhaps a result of market unfamiliarity of the potential for different geometry or that at the current state of market development this is simply not yet a critical factor.

<b>2. Wire: What is the minimum splice-free wire length you consider necessary for commercial HTS applications?</b>	
<b>Answer Options</b>	<b>Response Percent</b>
100 meters	8%
200 meters	13%
500 meters	30%
1,000 meters	39%
Other (please specify)	10%

In terms of minimum splice-free length, while 1,000 meters was the largest response, almost 70% of the respondents indicate 500 meters or more. A question raised is market knowledge of the process to splice 2G wire.

<b>3. Wire: What price/performance in terms of US Dollars per kilo Amp-meter (kA-m) for HTS wire do you consider critical to foster commercial success for HTS applications (at 77K, self-field)?</b>					
<b>Answer Options</b>	<b>R&amp;D</b>	<b>Prototype Devices</b>	<b>Initial Production</b>	<b>Widespread Commercial Adoption</b>	<b>Response Count</b>
> \$500 / kA-m	87%	7%	2%	4%	40%
\$400 / kA-m	71%	23%	6%	0%	33%
\$300 / kA-m	63%	27%	7%	3%	34%
\$200 / kA-m	45%	48%	4%	2%	45%
\$150 / kA-m	29%	58%	12%	1%	36%
\$100 /kA-m	27%	46%	24%	3%	66%
\$75 /kA-m	15%	39%	35%	10%	35%
\$50 /kA-m	12%	32%	39%	17%	62%
\$35 /kA-m	5%	20%	51%	25%	43%
\$25 /kA-m	6%	12%	46%	37%	51%
\$15 /kA-m	3%	9%	34%	54%	44%
\$10 /kA-m	4%	3%	23%	70%	51%
< \$10/kA-m	6%	1%	3%	90%	47%
				Comments	11%

There is a clear pattern with reasonable overlap between price levels.

<b>4. Wire: If you needed to choose Superconducting wire for a project today, which would you select?</b>	
<b>Answer Options</b>	<b>Response Percent</b>
2G (YBCO)	51%
1G (BSCCO)	16%
LTS	14%
No Preference	12%
N/A	7%

Just over 50% would choose 2G YBCO for their project. A small but vocal group is very interested in MgB2.

5. Device: Of the following attributes, which are the most important to the commercial success of an HTS device to the end-customer?							
Answer Options	Critical for Commercial Success	Very Important for Success	Neutral - not important or unimportant	Minor Importance for Success	Unimportant	Rating Average	Response Count
Maintenance / Reliability	<b>56%</b>	39%	5%	0%	0%	4.51	152%
System Lifetime Cost	39%	<b>46%</b>	15%	1%	0%	4.31	148%
Initial System Cost	39%	<b>54%</b>	6%	1%	0%	4.22	150%
Efficiency / Reduction of Losses	32%	<b>53%</b>	11%	4%	0%	4.14	151%
Power Density	29%	<b>54%</b>	14%	2%	0%	4.10	146%
Size and Weight Improvements	31%	<b>48%</b>	19%	1%	1%	4.08	148%
Higher Magnetic Field	26%	<b>49%</b>	17%	6%	1%	3.93	143%
Environmental Benefits	17%	<b>51%</b>	24%	5%	2%	3.77	143%
Government Financial Support	20%	<b>40%</b>	32%	6%	2%	3.71	146%
Other Technical Capabilities	14%	36%	<b>40%</b>	6%	4%	3.49	46%
Other/List (please specify) / Comments							11%

Maintenance/Reliability overwhelmingly stands out as a Critical device success parameter; all other parameters are Very Important.

#### 4.5. Section 5: Technology Providers

1. Of the following HTS wire suppliers, which do think will be able to deliver commercially viable conductor within the next three (3) years? By <i>commercially viable</i> we mean in production quantities, with uniform characteristics and cost-effective. If you do not have an opinion or are not familiar with a supplier, please leave the row blank.							
Answer Options	High Probability	Good Probability	Neutral Probability	Low Probability	Zero Probability	Rating Average	Response Count
SuperPower	61%	28%	9%	2%	0%	4.48	87%
American Superconductor (AMSC)	58%	33%	7%	2%	0%	4.46	95%
Sumitomo Electric	51%	37%	10%	1%	0%	4.37	81%
Nexans	22%	31%	34%	11%	3%	3.58	66%
Bruker (EHTS)	15%	36%	38%	9%	1%	3.55	58%
Furukawa	16%	35%	34%	11%	3%	3.50	52%
Theva	17%	34%	36%	9%	5%	3.50	58%
Fujikura	14%	39%	33%	11%	3%	3.50	49%
Showa	9%	33%	37%	17%	4%	3.25	50%
Zenergy	12%	28%	38%	16%	6%	3.24	52%
Sunam	3%	23%	55%	15%	4%	3.06	39%
Chubu	4%	25%	50%	16%	5%	3.06	45%
MetOx	5%	20%	51%	17%	7%	2.98	44%
Other (please specify) / Comments							5%

AMSC and SuperPower are both seen as having essentially equally high probability, followed closely by SEI. There is a significant drop after the top three out of the high probability category. Again, MgB2 supporters pointed out the absence of a representative supplier.

2. When evaluating potential suppliers for HTS wire, which attributes of the supplier do you consider most important? You may enter only one response per column (1-6), please rank the attributes from most important to least important.									
Answer Options	1 (Most Important)	2	3	4	5	6 (Least Important)	N/A	Rating Average	Response Count
Product Performance	<b>68%</b>	20%	8%	2%	1%	0%	1%	5.55	87%
Price	27%	<b>47%</b>	11%	8%	5%	1%	0%	4.81	88%
Ability to Deliver on Schedule	5%	12%	<b>29%</b>	21%	24%	10%	0%	3.22	87%
Custom Configuration (width, insulation, etc.)	3%	11%	<b>28%</b>	19%	20%	18%	1%	3.04	78%
Technical / Application Support	4%	11%	21%	<b>27%</b>	23%	14%	1%	3.04	77%
Company Stability / Reputation	5%	9%	13%	19%	18%	<b>34%</b>	3%	2.57	87%
Other (please specify) / Comments									2%

The message is quite clear: Product Performance is a strongly favored primary attribute with a 21% preference over Price.

<b>3. How much HTS wire did your organization purchase in the past 12 months?</b>						
Answer Options	None	< 100 meters	100 - 999 meters	1,000 - 10,000 meters	> 10,000 meters	Response Count
1G	63%	17%	9%	6%	5%	94%
2G	59%	23%	14%	4%	1%	90%
Other (please specify) / Comments						8%

<b>4. How much HTS wire does your organization plan to purchase in the <i>next</i> 12 months?</b>						
Answer Options	None	< 100 meters	100 - 999 meters	1,000 - 10,000 meters	> 10,000 meters	Response Count
1G	66%	18%	8%	5%	4%	83%
2G	48%	26%	17%	7%	3%	91%
Other (please specify) / Comments						8%

<b>5. How much HTS wire does your organization plan to purchase in the next 36 months?</b>						
Answer Options	None	< 100 meters	100 - 999 meters	1,000 - 10,000 meters	> 10,000 meters	Response Count
1G	59%	15%	9%	12%	6%	82%
2G	38%	21%	18%	14%	8%	90%
Other (please specify) / Comments						11%

This series of questions shows that the majority of respondents will not be purchasing commercial quantities of superconducting wire. However, for those that have purchasing plans for 1,000 to 10,000 meters of wire, demand doubles in 12 and 36 months, while those that intend to purchase more than 10,000 meters triples in the same period.

#### 4.6. Section 6: General Opinions

##### **1. In your opinion, what is the most interesting/important development in the Superconductivity industry you expect to happen in the next 24 months?**

FCL demonstration, continued reduction in 2G price along with increased production availability and commissioning of longer-length 2G cable demonstration projects were most frequently listed as the most interesting/important industry developments.

##### **2. In your opinion, what are the greatest obstacles to moderate commercial adoption of HTS devices in the next 36 months?**

Unsurprisingly, the clear theme was the system/application benefit needing to outweigh the system cost.

##### **3. What resources do you consult to learn about potential projects or applications, demonstrations, etc?**

No surprises, well-known conferences, academic journals and trade publications were listed.

#### 4.7. Section 7: Conclusion

##### **1. Would you like to receive a copy of the market study summary once it is completed?**

Over 90% of respondents requested a copy of the survey summary.

##### **2. May we contact you to clarify your answers or for additional information?**

Almost 50% of respondents indicated a willingness to be contacted for additional information.

### 5. Survey Results – “Intent to Purchase” Segmentation

For comparison and sub-segmentation, the responses were filtered to limit to those that have indicated purchase intent in the next 12 to 36 months for 1,000 meters or more of superconducting wire. Initially we segmented on non-government, non-academic industry respondents presuming this would provide a filter on “commercial” users. However, owing to large government (especially military) and scientific (e.g. fusion or high-energy physics applications), we believe the “Intent to Purchase” category is more representative of respondents with potential commercial sales opportunities over the next three years.

The results in general were not materially different from the un-segmented audience. Accordingly, we have not included the detailed responses in the external survey summary report. This indicates general industry concurrence between researchers and other “non-commercial” users with potential “commercial” users.