2009

Power Technology Roadmap

Trends 2008 – 2013

Presenter

Carl Blake

Co-Chairs PSMA PTRM Committee

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Transphorm Inc.

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To quote Charles Dickens

“These are the best of times and the worst of times”

Never before have we seen such demand for energy savings

&

Most of us have never seen such a challenging economy

Outline

- **PSMA PTRM Background**
  - History
  - Methodology
- **Key Trends**
  - Energy efficiency
  - Compound semiconductors
  - Digital control
- **Specific Projections**
  - Ac-dc front end trends
  - Dc-dc Isolated trends
- **Need Volunteers**

PSMA

- **Power Sources Manufacturers Association**
  - One of the sponsors of APEC
    - Along with PELS and IAS
  - Nonprofit multinational association

Roadmap Report

- PSMA Publishes the Roadmap primarily for its members
  - Each Regular and Associate member gets a copy
  - Each participant gets a copy
  - Can be purchased by anyone else

- The PSMA PTRM is unique
  - All inputs and analysis are done by respected knowledgeable leaders in the industry rather than 3rd party analysts.

Roadmap History

- **1st Workshop Generated Roadmap in 1994**
  - Workshop was led by Bob Freund, AT&T Bell Laboratories
- **Subsequent Workshops:**
  - 1997, 2000, 2003, 2006, 2008
- **Purpose of Technology Roadmap is Communication**
  - Technology roadmaps are essential for feedback to/from suppliers, customers, universities and manufacturers to cross industry fragmentation and focus solutions.
- **New Methodology Begun with this Report for 2009**

Methodology

- Gather Data
  - Presentations from users
  - Suppliers
  - Market research
  - Technology
- Analyze Data
  - Breakout groups
  - Compile trends
  - Summarize trends into tables
  - Present results

Keep what worked well – try to over come the limitations

Old vs. New Data Gathering

- **Old Method**
  - Invite industry experts to one day workshop
  - Morning presentations limited to 20 minutes each
  - Afternoon to analyze and compile data
  - Report results

Old vs. New (contd.)

- **New Method**
  - Invite industry experts to participate in a series of conference calls
    - Calls were planned for 1 hour, recorded and continued depending upon Q & A
    - Presentations and call audio available during analysis
    - Five months to gather data in weekly calls
    - Three months to analyze data
    - Review results of breakout groups in September

Why a New Method?

- **A Single Day Workshop**
  - **Limited participation to 30 people at most**
    - There were more than 50 people involved this year
  - **Results were dependent upon the breath of knowledge of workshop attendees**
    - New method allowed several experts in each area to participate
  - **There was little opportunity to react to new data or gather additional information**
    - Extra topics were added to clarify trends
  - **Required travel to a single location**
    - Benefit was undivided attention once there

Presentations (17)

- **Two users of power supplies and dc-dc converters**
  - Discussed the future power demands for computing.
- **Six component suppliers**
  - The component presentations examined semiconductor IC trends, power component technology trends, magnetic materials and inductive winding trends as well as the trends in capacitor technology.
- **Three market perspectives**
  - Discussed impact of new regulations, new markets and network infrastructure
- **Three technology presentations.**
  - Examined the influence of digital technologies, advanced packaging and university research in progress at around the world
- **Three presentations from the previous roadmap**
  - University view of digital technology, power supplies for telecom and capacitor technology

Roadmap Teams

Breakout Groups –a Key Ingredient

AC-DC Front End PS – led by E. Herbert

AC-DC External PS – led by A. Tu

DC-DC Isolated Converter – led by H. Lee

DC-DC POL Converter – led by A. Alderman

Each group containing industry experts in

- **Circuits and architecture**
- **Packaging**
- **Components**
- **Oversight & economics**

>50 Industry Participants

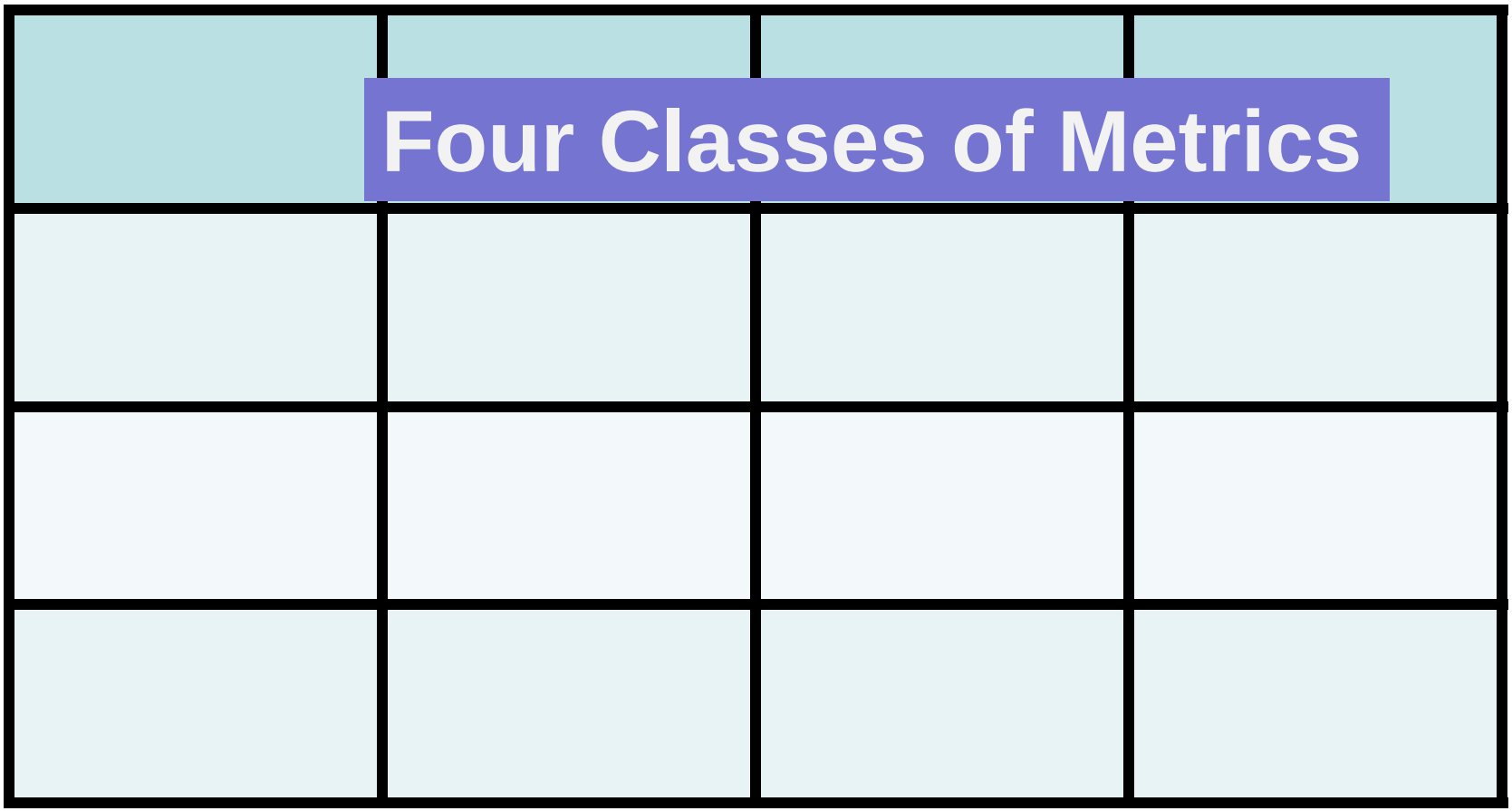
Consultants – 8
PS manufacturers – 8
Suppliers – 11

- Anagenesis Inc.
- Bel Power Inc.
- Bruce Carsten Associates
- Center for Power Electronics (CPES)
- Coilcraft
- Dell
- Delta Energy Systems (Arizona) Inc.
- Delta Products Corporation
- Emerson Network Power
- Fairchild Semiconductor
- Horizon Consultants Ltd.
- IBC Corp.
- IBM
- IMS Research
- Independent Inventor
- Intel
- Magnetics
- Maxwell Technologies

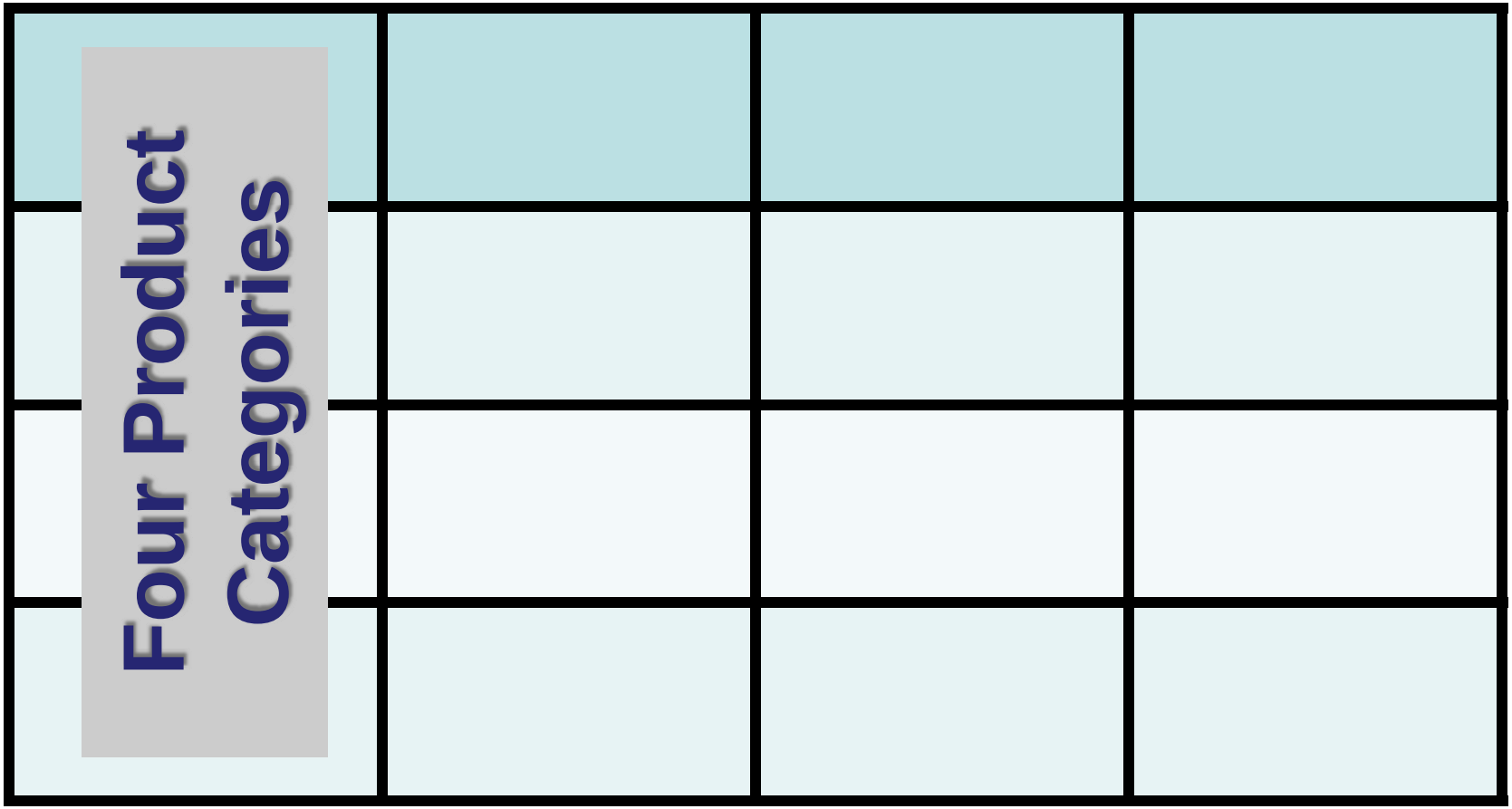
Users – 6
Universities – 3

- Murata Power Solutions
- ON Semiconductor
- Paumanouk
- Power Electronic Strategies
- Power Integrations
- Qspeed Semiconductor
- RAF Tabtronics LLC
- Raytheon
- ROAL Electronics USA, Inc.
- Skyline Marketing
- SL Power
- Texas Instruments
- Transphorm Inc.
- Tyndall National Institute
- University at Buffalo
- Vu1
- Zilker Labs (Intersil)

Report Tables



Report Tables



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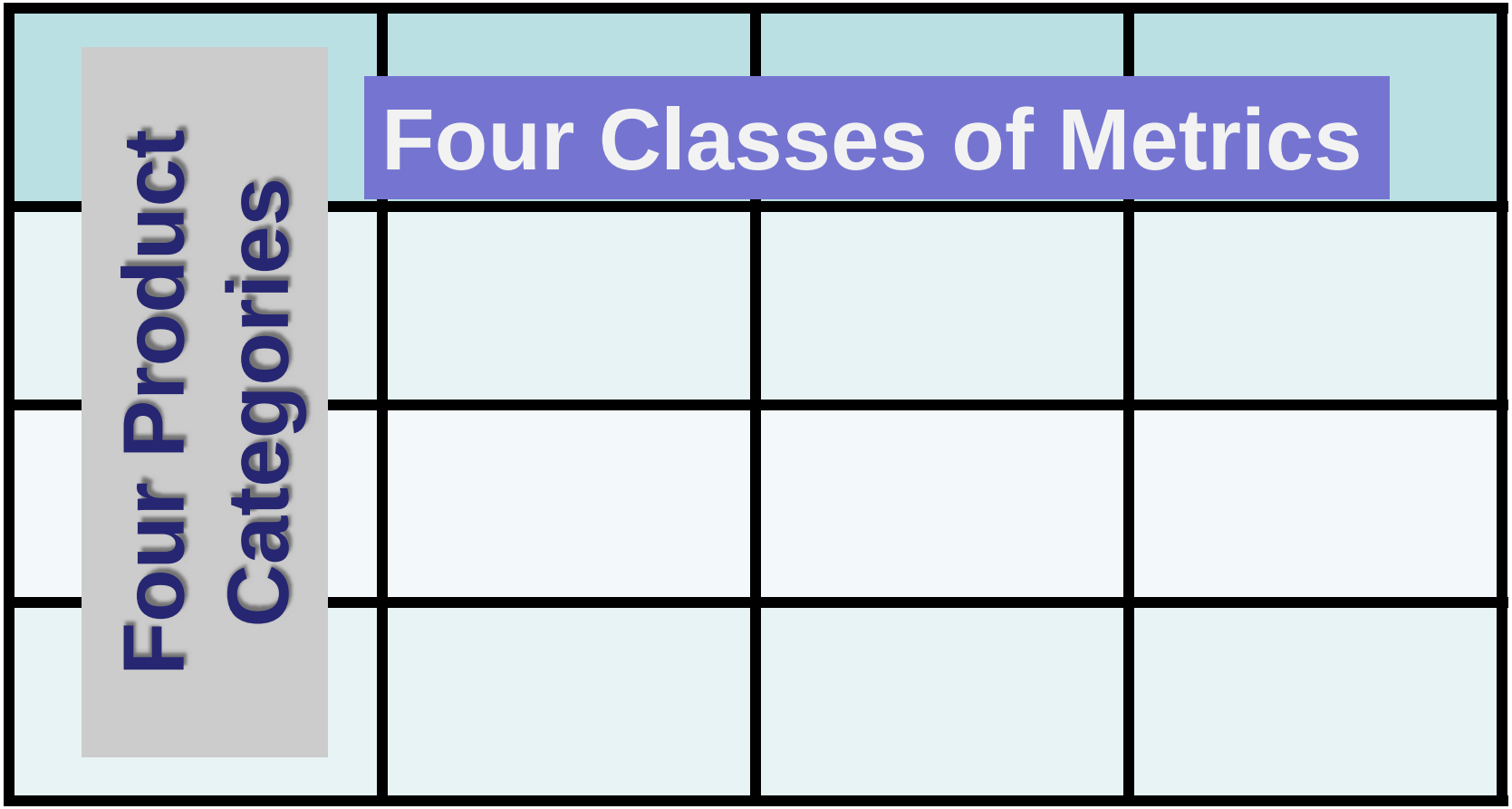

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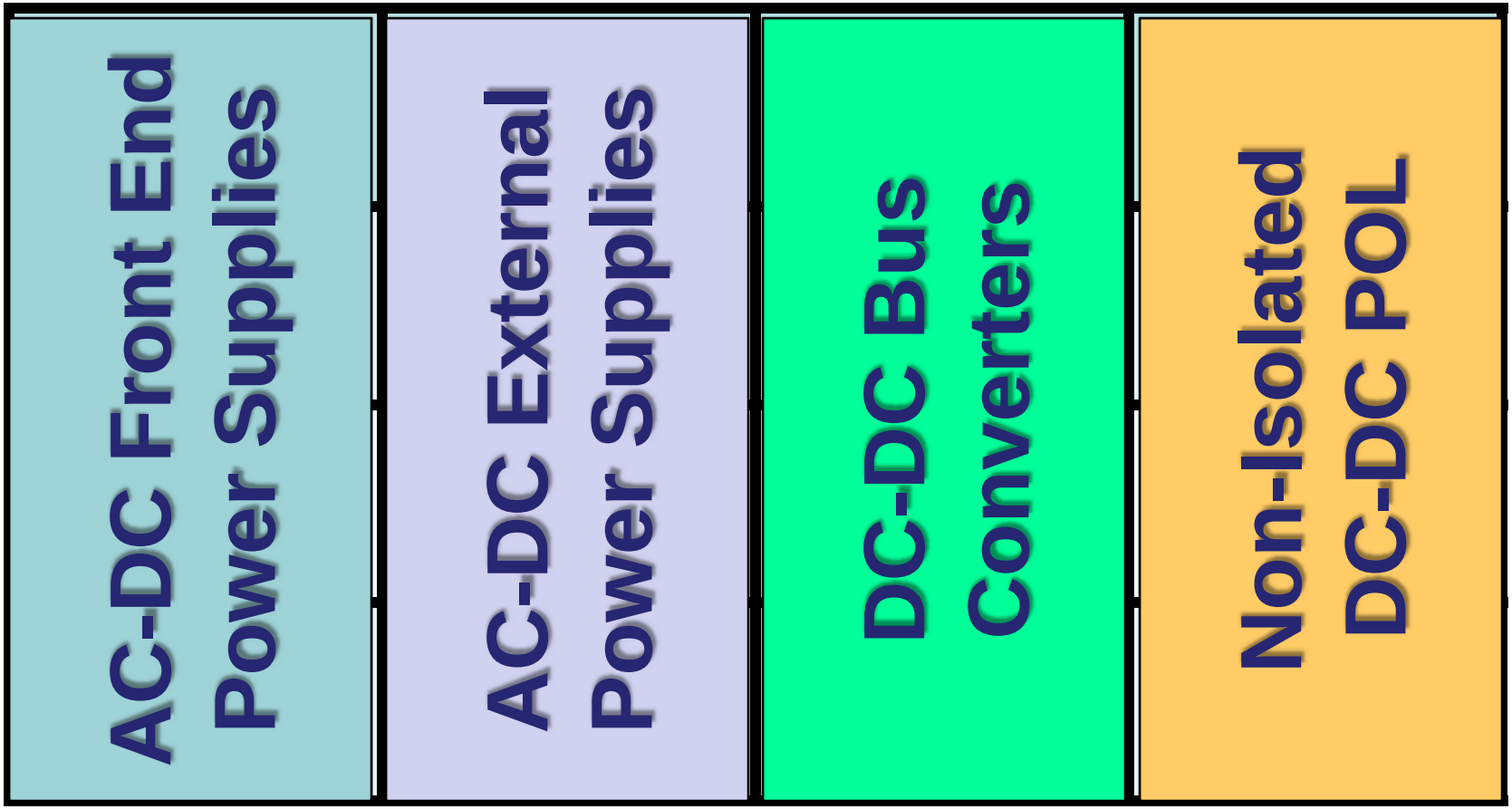

Report Tables

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General Requirements

Circuit Design and Implementation

Component Technology

Packaging, Physical Design, Thermal Management, Assembly Technology

Specific Trends Projections

Technology		2008				2010				2013			
		Early			Mature	Early			Mature	Early			Mature
Integrated SR + controller		1	2					3	4				4
PFC controllers	Boost converter				4				4				4
	Single-stage		2					3				3	
	Interleaved		2					3				3	
	Bridgeless	1					2					3	
Resonant controllers	LLC half-bridge			3					4				4
	QR flyback		2	3				3	4				4
Sync. rectifier drivers	Buck-derived / flyback		2	3				3	4				4
	Resonant converters	1	2				2	3				3	
	Adoption	1	2	3	4	1	2	3	4	1	2	3	4

Adoption key:

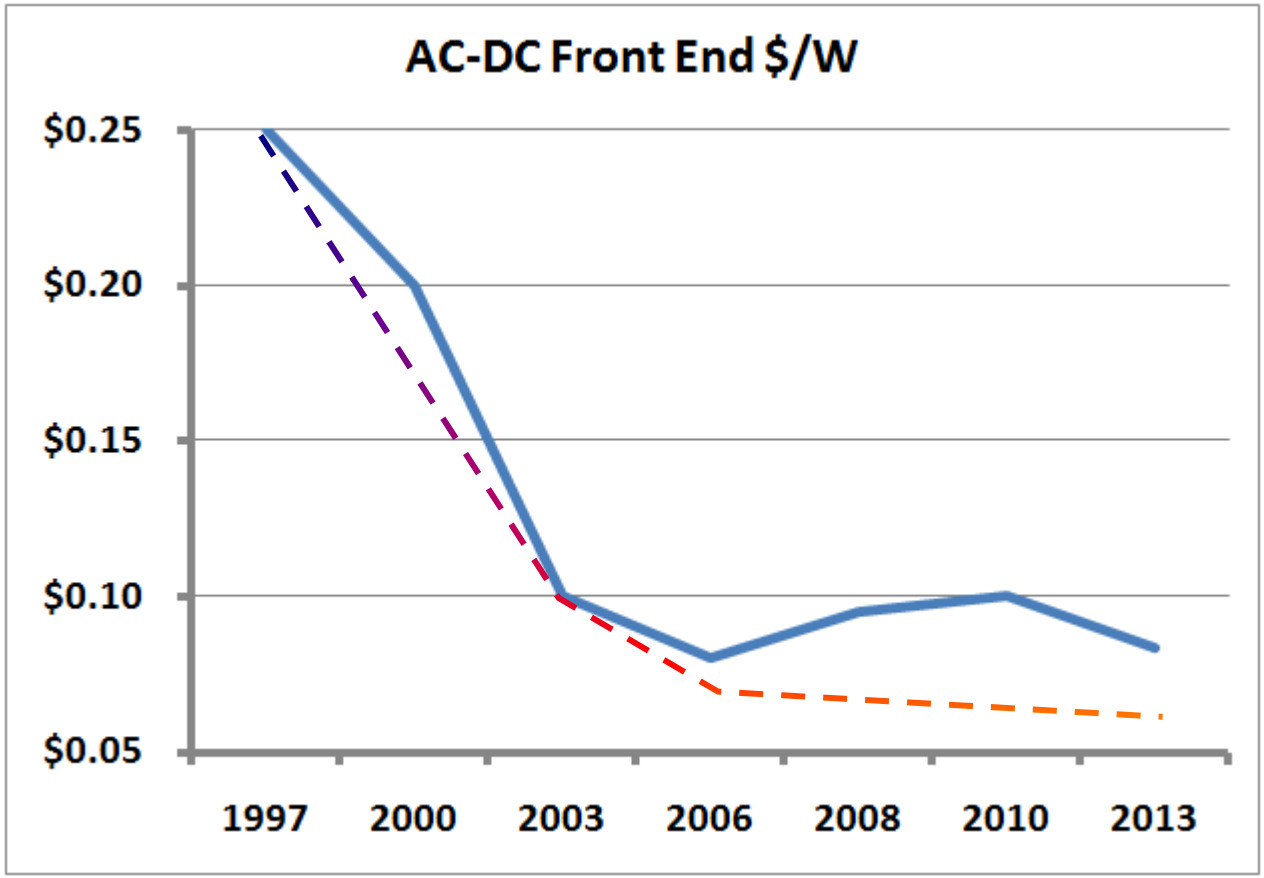
1. Experimental/Laboratory Exploration, Research & Development
2. Early Adopter
3. Mature: Niche Use
4. Mature mainstream Use

AC-DC "Front End"

	2003	2008 Forecast from 2003	2008 Actual	2013 Forecast
Cost ($/W)*	0.10 – 0.20	0.08 – 0.14	0.095 – 0.14	0.08 – 0.12.5
Density (W/in^3)	3 – 10	10 – 25	8 - 18	13 - 38
MTBF (kH)	500	750 +	550	750 +
Efficiency	80 – 85%	85 – 92%	88 – 94%	92 – 96%
Switching frequency (kHz)	100 – 200	100 – 500	95% < 500	92% < 500
Time to market	6 – 9 months	3 – 6	9	7
Control	Analog	Digital	15% Digital	30% Digital

* At high unit volume

Efficiency Impact on PS Market



The increased environmental awareness of energy utilization has focused attention on the value of energy savings
For the 1st time the $/W has increased

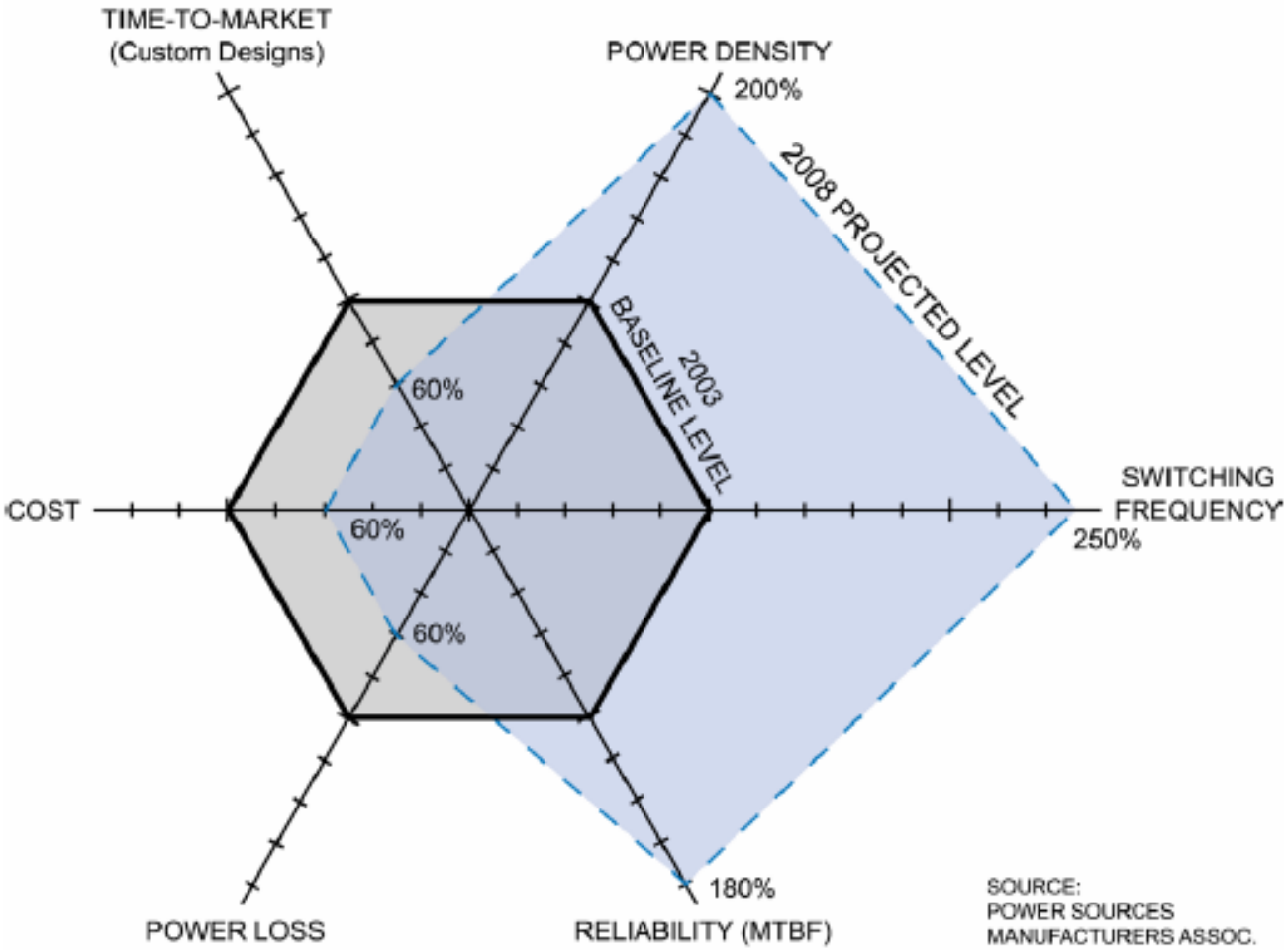
AC-DC "Front End" Density

	2003	2008 Forecast from 2003	2008 Actual	2013 Forecast
Density (W/in^3)	**3 – 10**	**10 – 25**	**8 - 23**	**13 - 38**

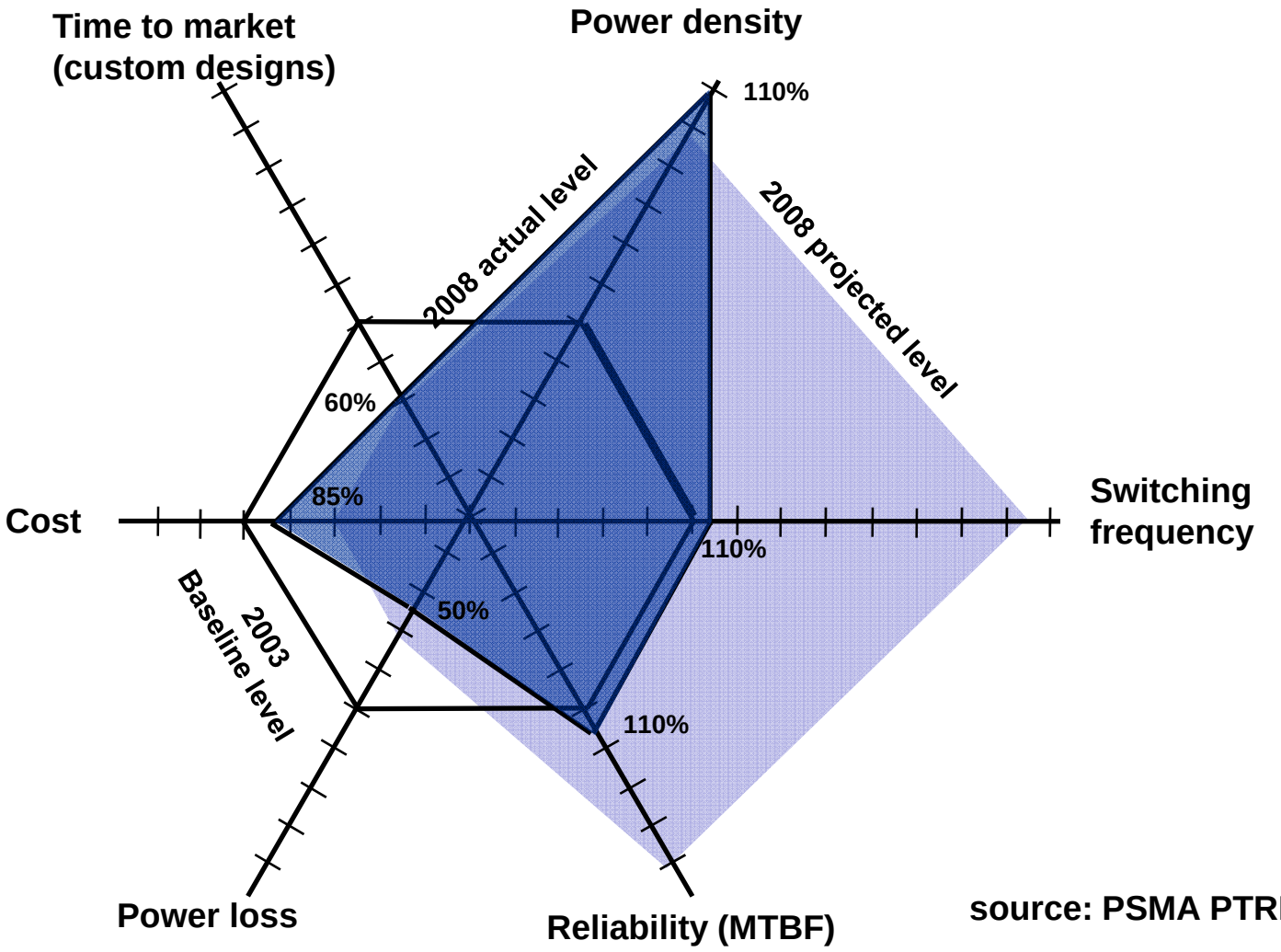
But let's look at the detail in this latest roadmap

	2008 Forecast from 2003	2010 Forecast from 2006	2008 Actual	2013 Forecast
Density (W/in^3)	**10 – 25**	**8 – 30**	**8 - 23**	**13 - 38**
Power Conversion Density Most economical Highest practical Leading edge		 8 W/in³ 15 W/in³ 30 W/in³	 8 W/in³ 18 W/in³ 23 W/in³	 13 W/in³ 25 W/in³ 38 W/in³

2008 AC-DC as Projected in 2003

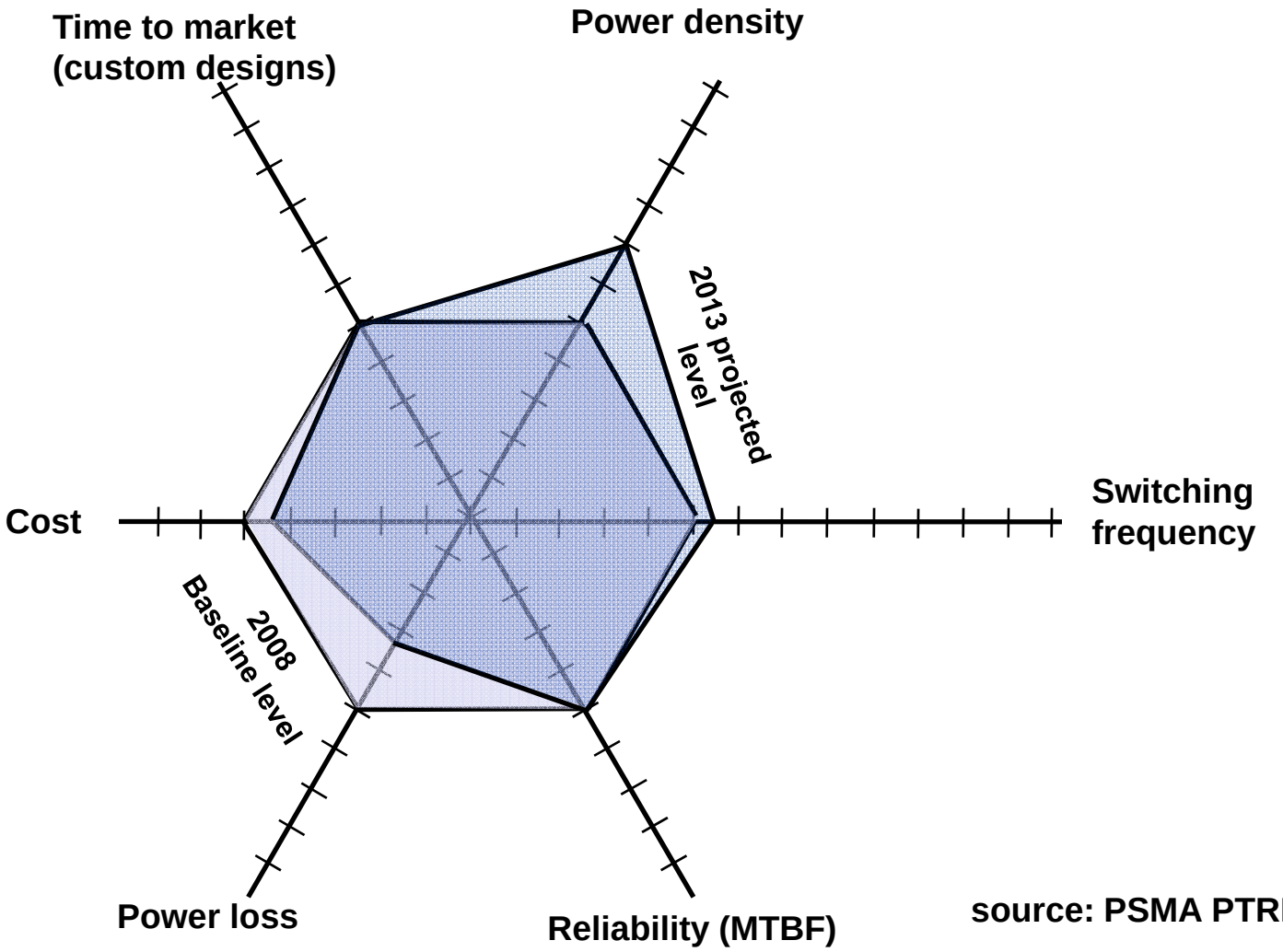


AC-DC Front End Actual vs. Forecast



source: PSMA PTRM

AC-AC Front End, 2013 Forecast



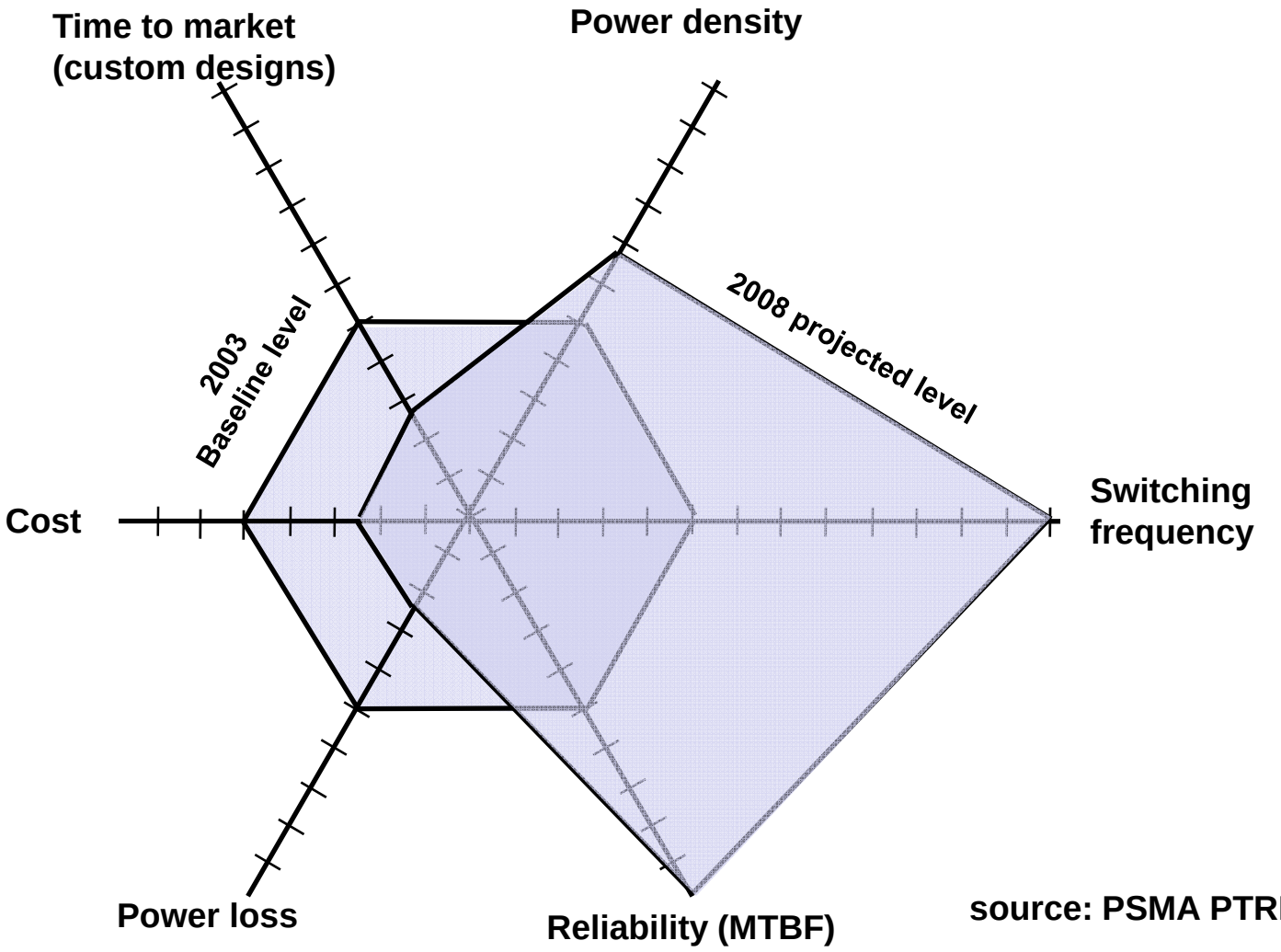
source: PSMA PTRM

DC-DC Isolated Brick or Intermediate bus converter

	2003	2008 Forecast from 2003	2008 Actual	2013 Forecast
Cost ($/W)*	0.40 – 0.60	0.20 – 0.45	0.075	0.058
Density (W/in^3)	75	100	300	400
MTBF (MH)	1 - 2	4	3 - 5	3 - 5
Efficiency	85 – 93%	90 – 95%	89 – 94%	92 – 95%
Switching frequency (kHz)	200 – 300	300 – 1000	90% < 500	85% < 500
Time to market	Off the shelf	Off the shelf	Off the shelf	Off the shelf
Control	Analog	Digital	Mixed	Mixed

* At high unit volume

DC-DC Isolated, Actual vs. Forecast



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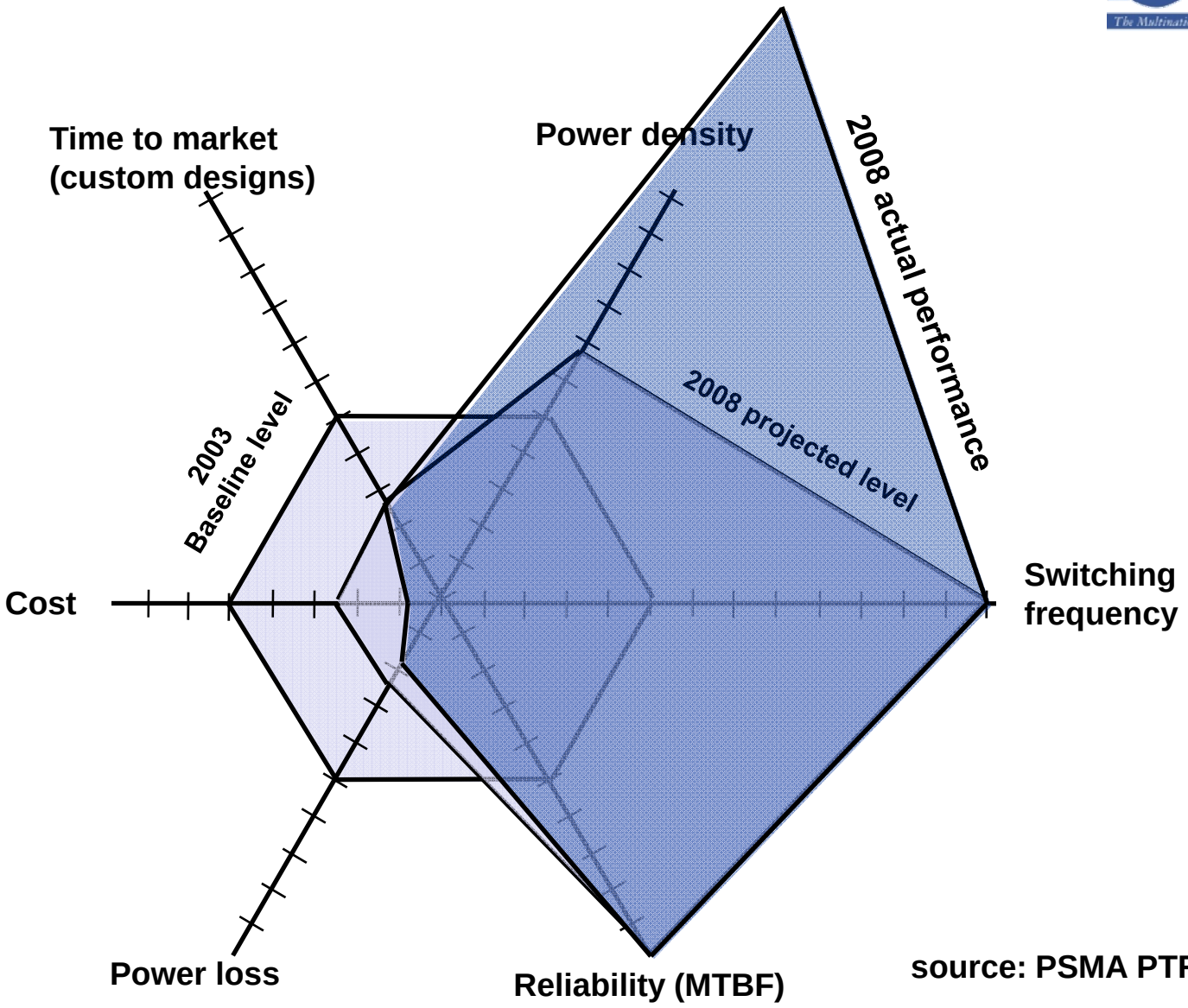
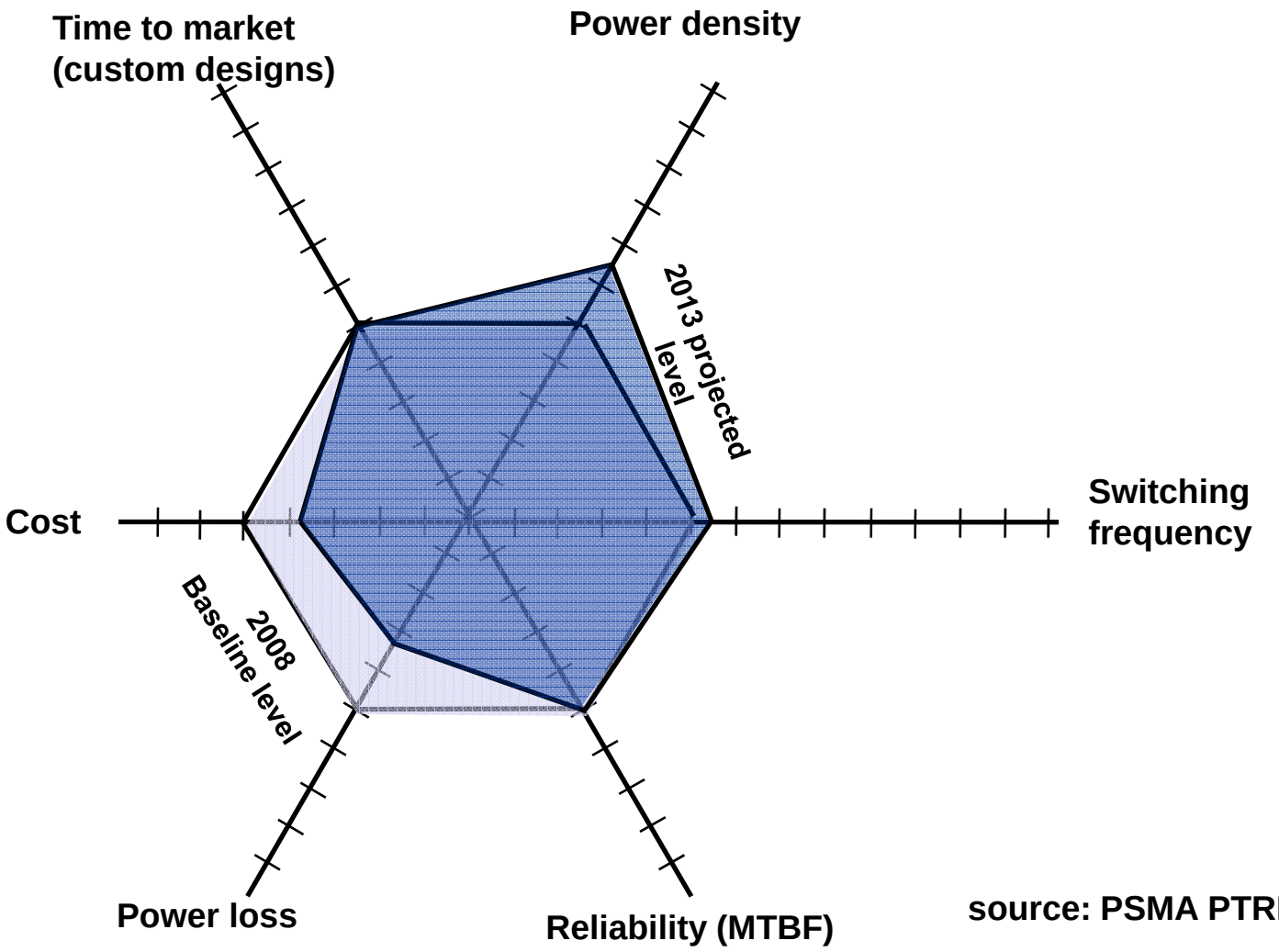
DC-DC Isolated, Actual vs. Forecast



source: PSMA PTRM

DC-DC Isolated, 2013 Forecast



source: PSMA PTRM

Drivers, Enablers, Barriers

- **Drivers**
  - Energy conservation is driving higher efficiency
    - New standards are being adopted rapidly around the world.

- **Enablers**
  - New semiconductor materials such as SiC and GaN will have the most significant impact upon the industry during the next five years.
  - New digital control will enable more efficient no load and light load operation. It will also reduce component count to enable lower cost.

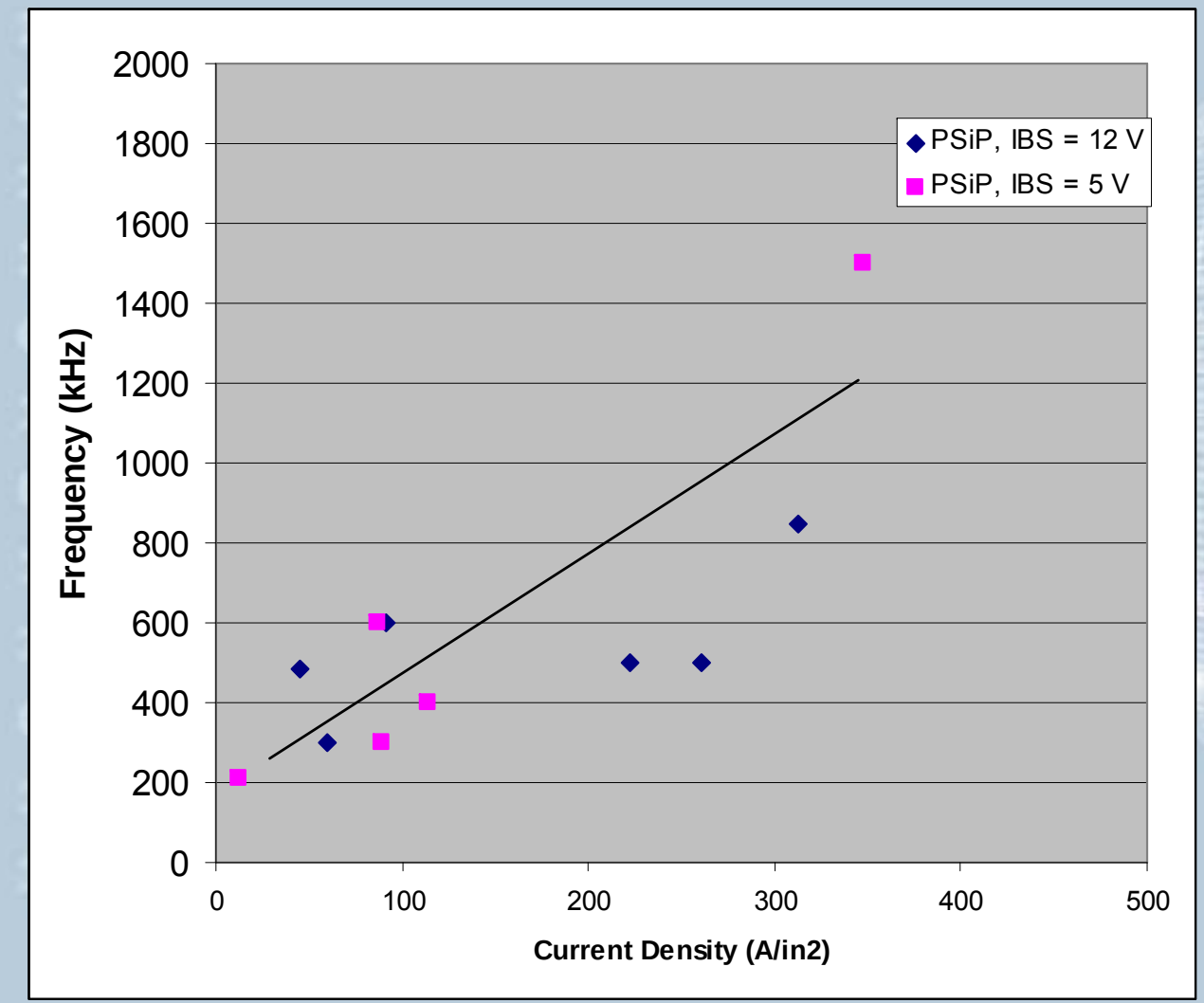
- **Barriers**
  - Thermal management remains a barrier to smaller size, higher efficiency minimizes this barrier.

Similar to those in the Roadmap

- **There are several papers being presented at APEC that are based upon the same subjects**

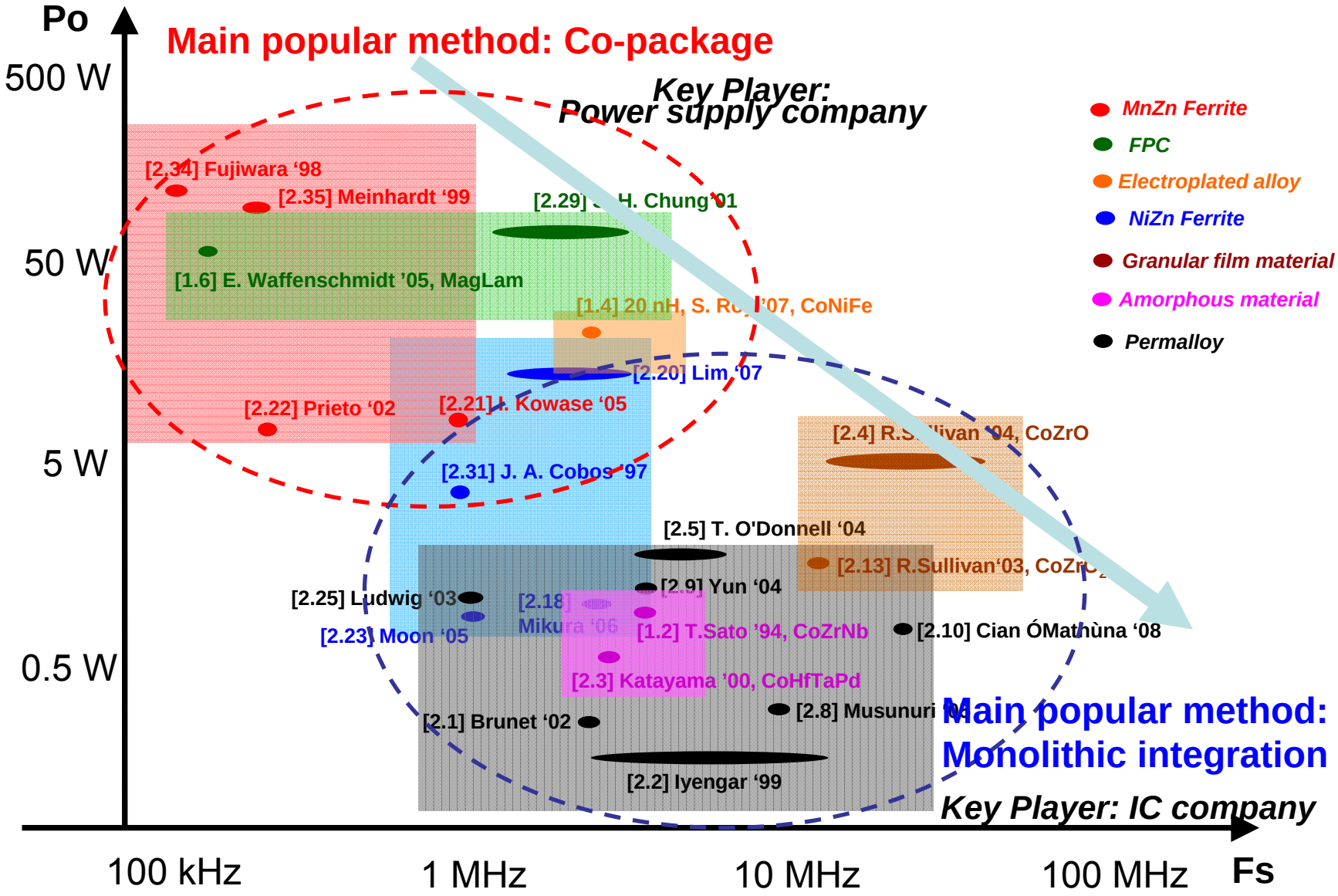
- **The papers are:**
  - **Power Supply on Chip – Has the Ship Come In?** *Cian O'Mathuna, Tyndall National Institute* (in the Plenary session today)
  - **SP5.7:"Technology Survey and Trends for Integrated High Frequency DC-DC Converter"** *F. Lee, Center for Power Electronics Systems* (Thursday at 5 pm in Thurgood Marshall N.)
  - **SP1.7: "SiC and GaN Power Devices: Market Status and Perspectives"** *P. Roussel, Yole Development (Tuesday 11:30 in* Thurgood Marshall N.)
  - **S.10 "Energy Efficiency Specifications and Standards Activity for Power Supplies"** *Arnold Alderman, Anagenesis, Sunday*

PSiP
Frequency vs. Current Density



Power Sources Manufacturers Association
The Multinational Power Electronics Association

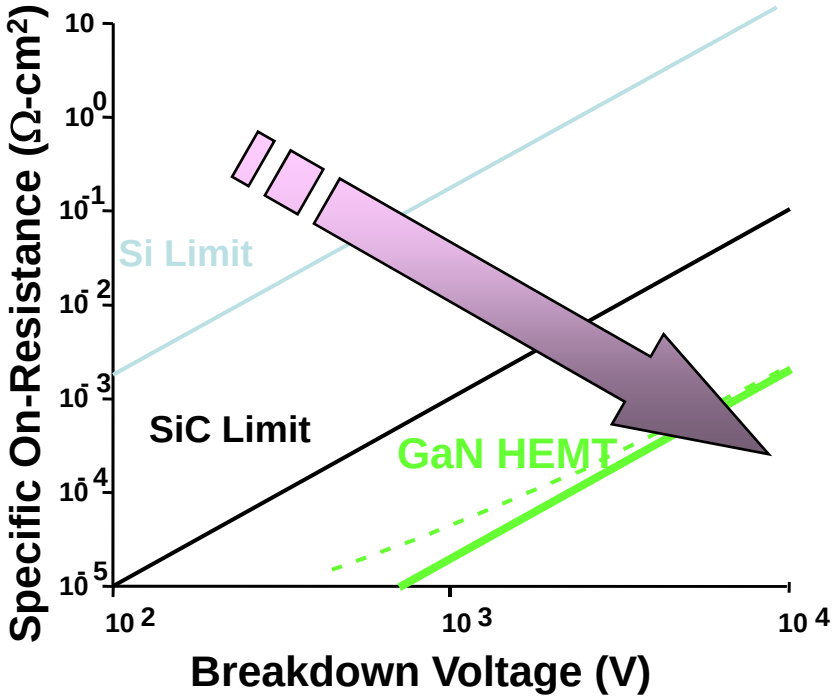
The Trend and Impact of Magnetic Material Development



Compound Semiconductors

- Substrate quality and price are improving
- Auto industry is providing renewed impetus with electric vehicle programs
- PFC boost diode using SiC reduces switching losses substantially.
- SiC JFET ----> 2009
- SiC BJT, GaN diode -----> 2010
- SiC MOSFET, GaN HEMT -----> 2011
- SiC will be very competitive in high voltage, high temperature applications
- GaN will be very competitive is all high voltage applications

Better semiconductor for power switching



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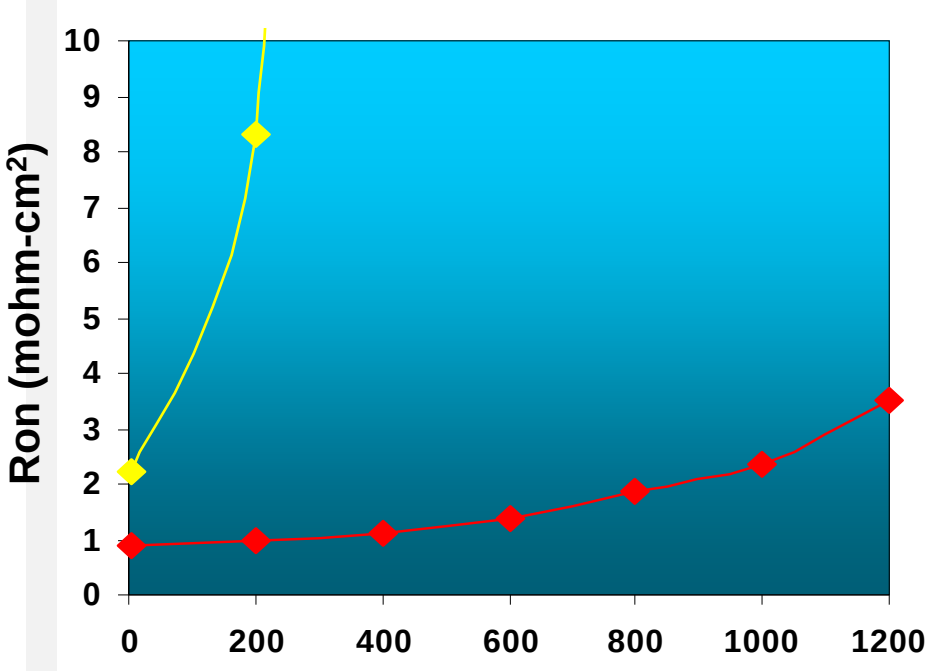

Major EPS Specs/Standards Summary

	ENERGY STAR EPS v2 (Eff 11/08)	EC CoC v3 (1/09)	EISA '07 & EC EcoDesign Directive (P)
Nameplate Output Power (Pno)	**Min Ave Efficiency in Active Mode[6]**	**Min Ave Efficiency in Active Mode [2]**	**Min Ave Efficiency in Active Mode**
≤ 1 W	≥ 0.480 * Pno + 0.140	≥ 0.44 * Pno + 0.145	0.5* Pno
> 1 to ≤ 36 W		≥ [0.08 * Ln (Pno)] + 0.585	
> 1 to ≤ 49 W	≥ [0.0626 * Ln (Pno)] + 0.622		
> 1 to ≤ 51 W			≥ [0.09 * Ln (Pno)] + 0.5
> 36 W		≥ 0.870	
> 49 W	≥ 0.870		
> 51 W			≥ 0.850
	No-load power [1]	**No-load power [3]**	**No-load power[5]**
< 50 W	0.3 W	0.3 W	0.5 W
> 50 to ≤ 250 W	0.5 W	0.5 W	0.5 W

NOTES: 1 AC-AC is ≤ 0.5 W for all power levels 2 Until 1/1/11, spec for mobile handheld battery powered apps - <1 W = ≥ 0.5 * Pno + 0.029, > 1 W, ≤ 8 W = ≥ 0095 * Pno + 0.529. 3 Spec for mobile handheld battery powered apps ≤ 8 W - ≤ 0.25 W until 12/31/10, ≤ 0.15 W after 1/1/11 4 Two years after effective date, spec changes to ESTAR v2 levels for >1 W 5 Two years after EcoDesign Directive effective date, its spec for < 50 W drops to 0.3 W 6 Standard PSU specs shown. Low V/ High I PSU are: ≤ 1 watt - ≥ 0.497 * Pno + 0.067, > 1 to ≤ 49 watts - ≥ [0.0750 * Ln (Pno)] + 0.561, > 49 watts - ≥ 0.860

Participate and benefit

- **The industry experts, segment leaders, etc. who participated in developing the roadmap are all people who volunteered their time**

- **All participants agree - If you give and share, you gain more than you gave**
  - There will be a postmortem of the 2009 roadmap and initial plans for the next roadmap on Wednesday at 12 noon in the McKinley Room (Mezzanine level) in the Marriott Wardman Park Hotel

- **Come and see if you are prepared to give and take and participate in the next roadmap!**

Thank You