RESEARCH & DEVELOPMENT

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2018 DOE Peer Review

Laboratory Demonstration of a Utility Grade Advanced Power Inverter (API)

Creare LLC

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Phase I & Phase II SBIR
DOE Energy Storage Program, Dr. Imre Gyuk
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What Are We Doing and Why?

- **Use SiC WBG technology to improve the value proposition for Grid Tied Energy Supplies:**
  - **SiC high voltage rating enables direct connection to medium voltage grids (3θ, 12.47 kV)** *(this is the enabling technology)*
  - **Eliminates 60 Hz transformer** *(reduces size)*
  - **High operating temperature eliminates liquid cooling** *(reduces size, improves reliability)*
  - **Creates modular building block for 500 kW to MW⁺** *(expands markets)*
  - **Achieves >2x power density improvement** *(customer benefit)*
  - **Reduces audible noise** *(customer benefit)*

Proposition: SiC devices can improve the value of grid tied energy supplies by reducing size and cost and improving reliability and end user satisfaction.

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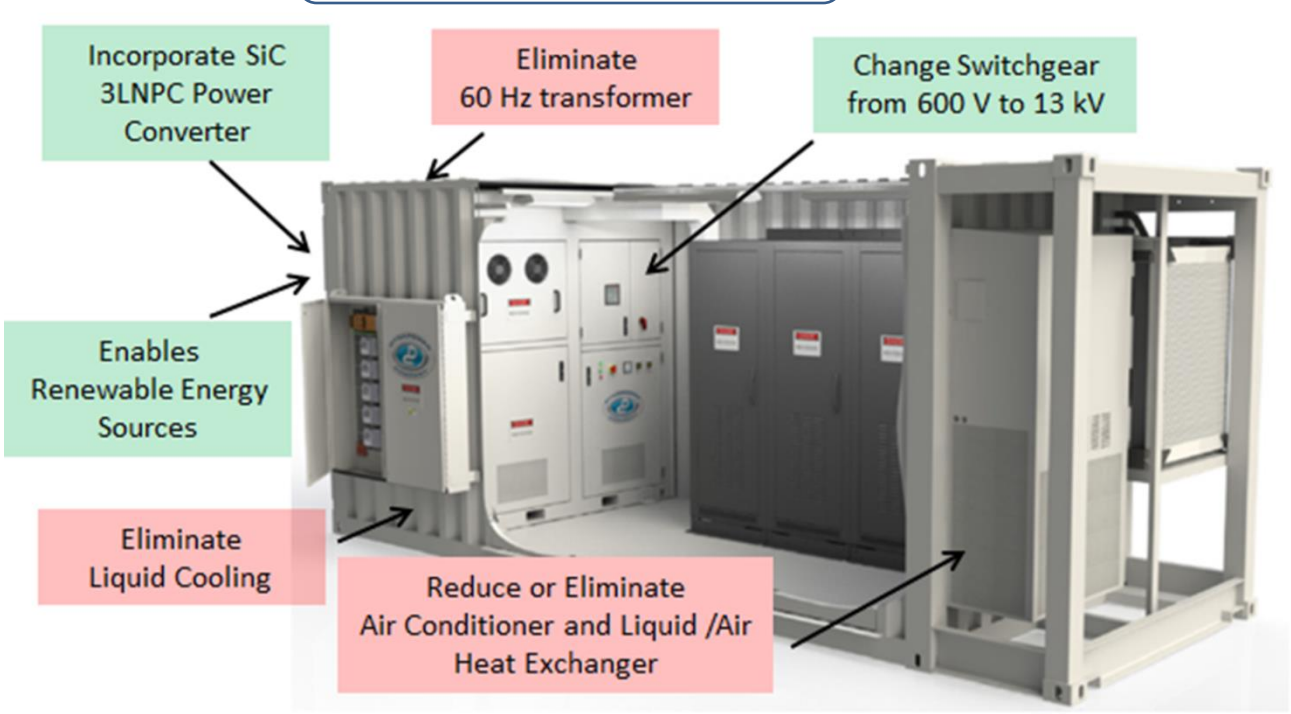
500 kW ESS In a Picture

Creare's ESS Improves Power Density and Reliability Over Existing Products.
~ SiC Semiconductors Provide the Enabling Technology ~

Existing 500 kVA Grid Tied Energy Storage Container (Dynapower)

Key: Eliminate Add



Nominal Existing Generation System

- 500 kW, 250 kW-hr
- 23 x 8 x 10 ft.
- Includes AC & DC switchgear
- Optional: solar recombiner (600 – 1000 V PV arrays)
- Optional: 4 x 2 x 4 ft. 480:480 transformer
- 3 x 7 x 10 ft. 250 kW-hr Li-ion battery
- Ramp rate control, frequency regulation, VAR support
- Seamless dynamic transfer

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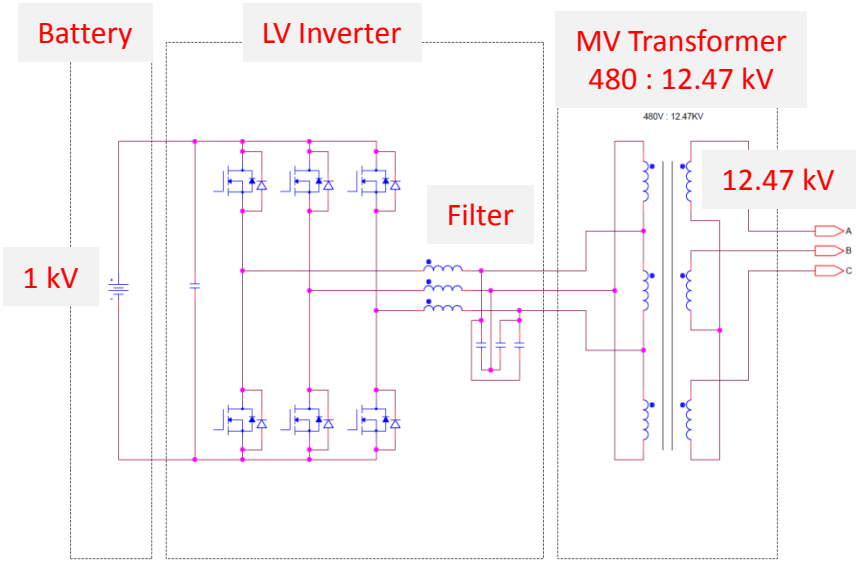
How Are We Doing This?

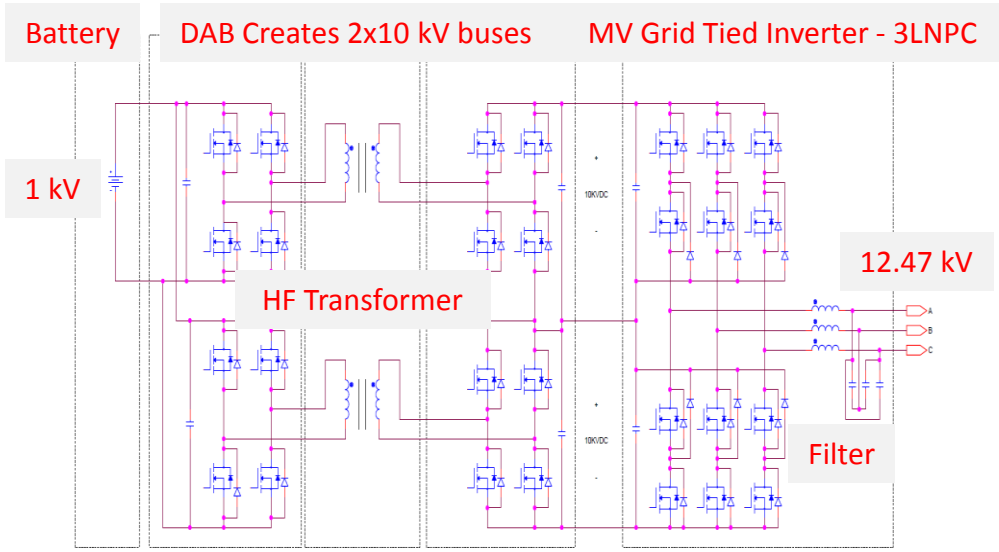
Conventional Inverter Design



Limitations of this design:

- Requires 480 : 12.47 kV transformer for grid connect.
- Silicon MOSFETs or IGBTs require liquid cooling (~ 50°C).
- Filter is large and also requires liquid cooling.
- 60 Hz transformer emits acoustic noise.

Creare's SiC Grid Tied Inverter Design



Improvements:

- SiC MOSFETs enable direct grid connection to 12.47 kV.
- 60 Hz transformer replaced with (2) smaller (10X) high frequency (20 kHz) transformers.
- Transformer is audibly quieter.
- Liquid cooling is eliminated.
- Filter faces lower current, reduced losses and harmonics.

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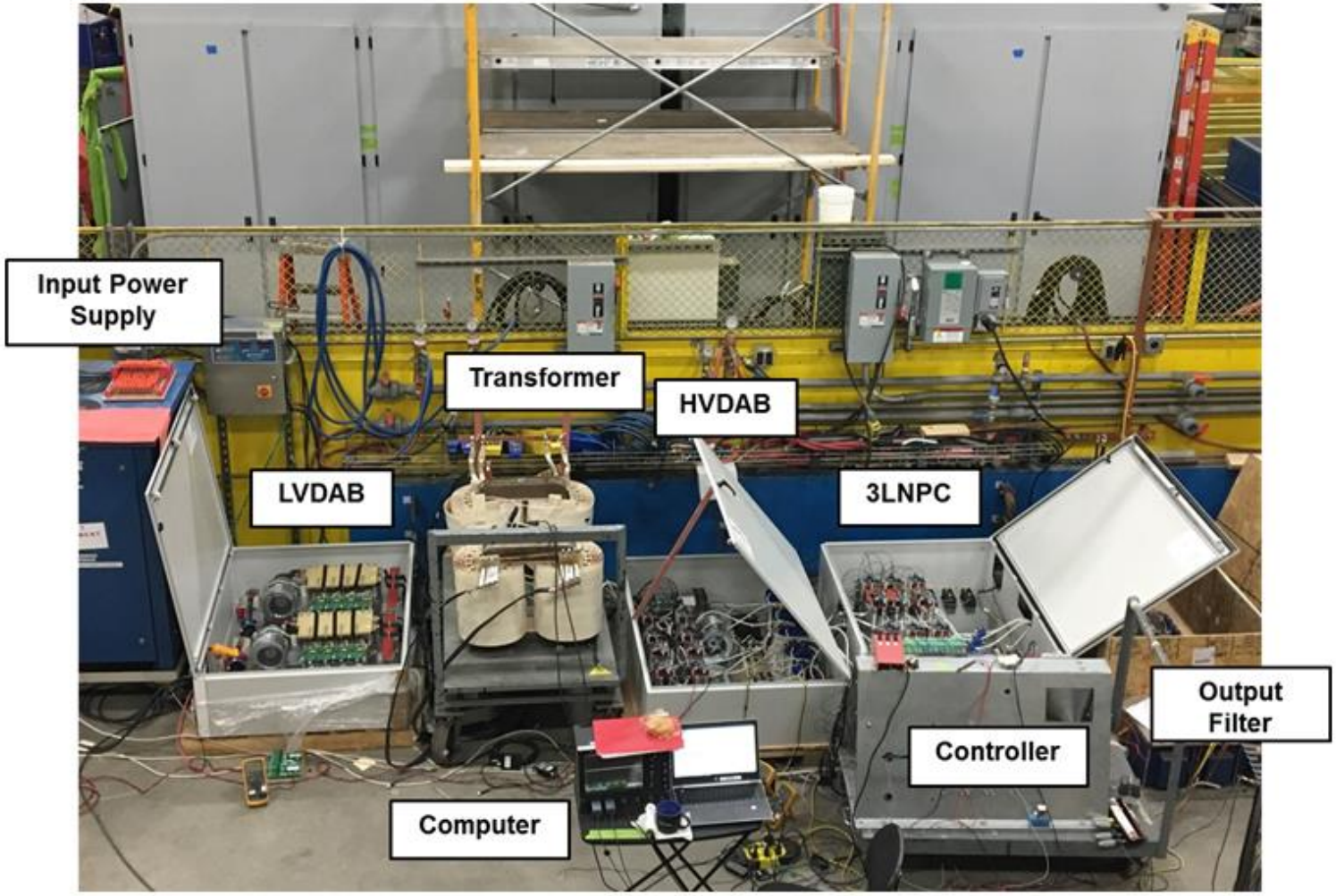
What Have We Done So far?

Laboratory Prototype Test Setup



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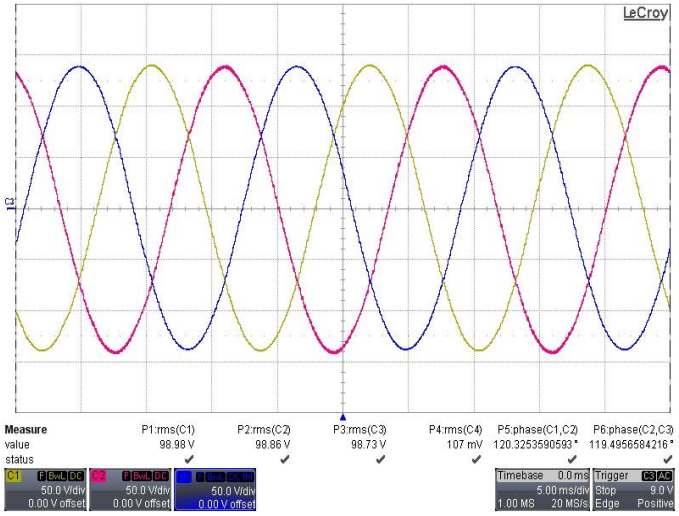
Test Results

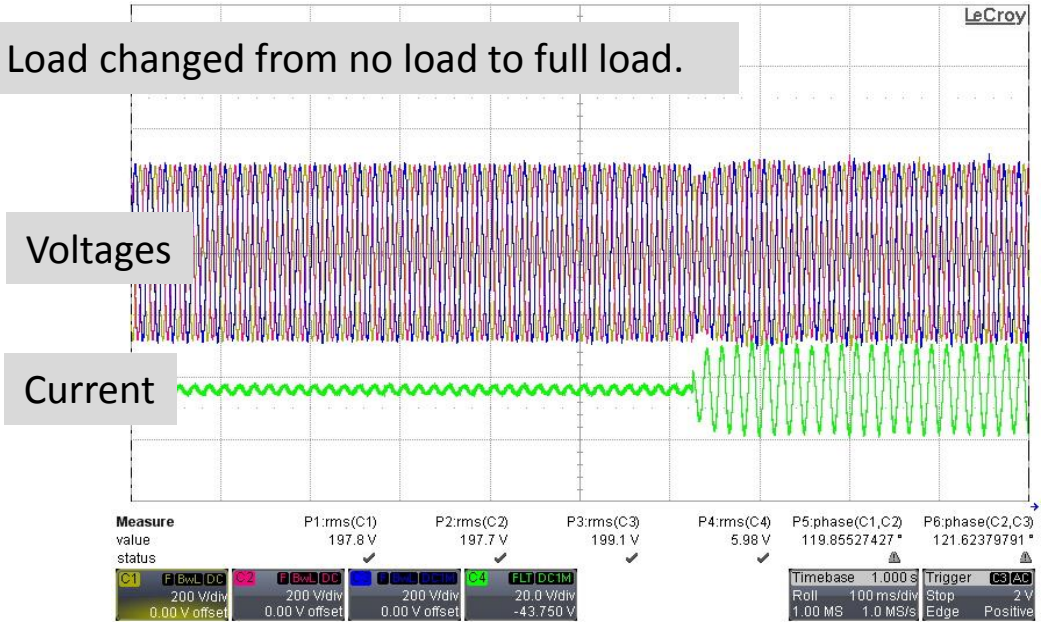
Three phase line-to-line output voltages.



For all test results shown:

- Preliminary low power, voltage and current testing
- Vin was 30 – 100 VDC
- DC Link is 120 VDC
- Fs = 20 kHz
- Load is 100 W per phase

Load changed from no load to full load.



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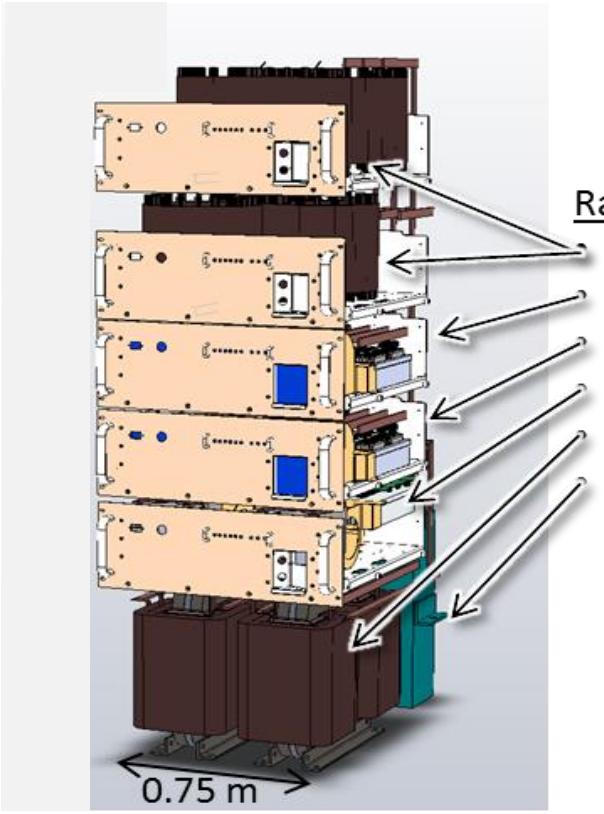
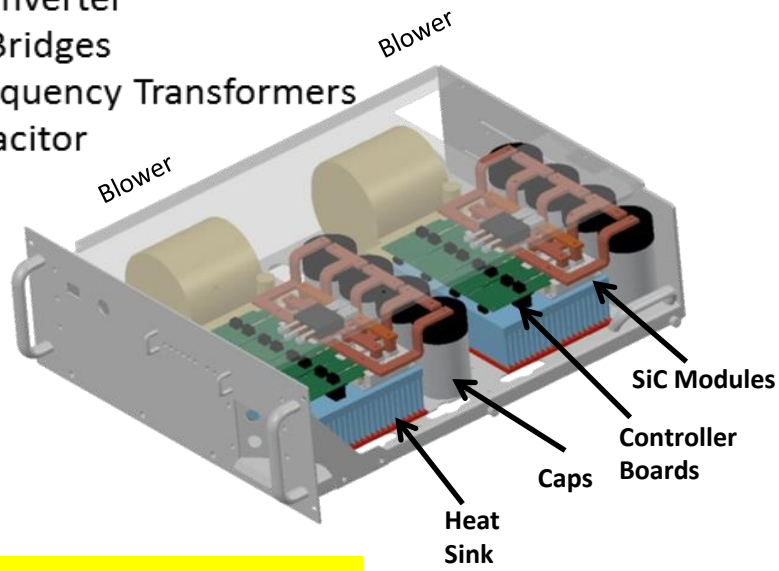
What Work Still Remains?

Optimize Packaging and Test at Full Scale Power



Rack Mounted Modules:

- Output Filter Inductors
- High Voltage Full Bridges
- 3 LNPC Grid Tied Inverter
- Low Voltage Full Bridges
- Compact High Frequency Transformers
- Output Filter Capacitor



Substantial size reduction is achieved by elimination of liquid cooling and transformer.

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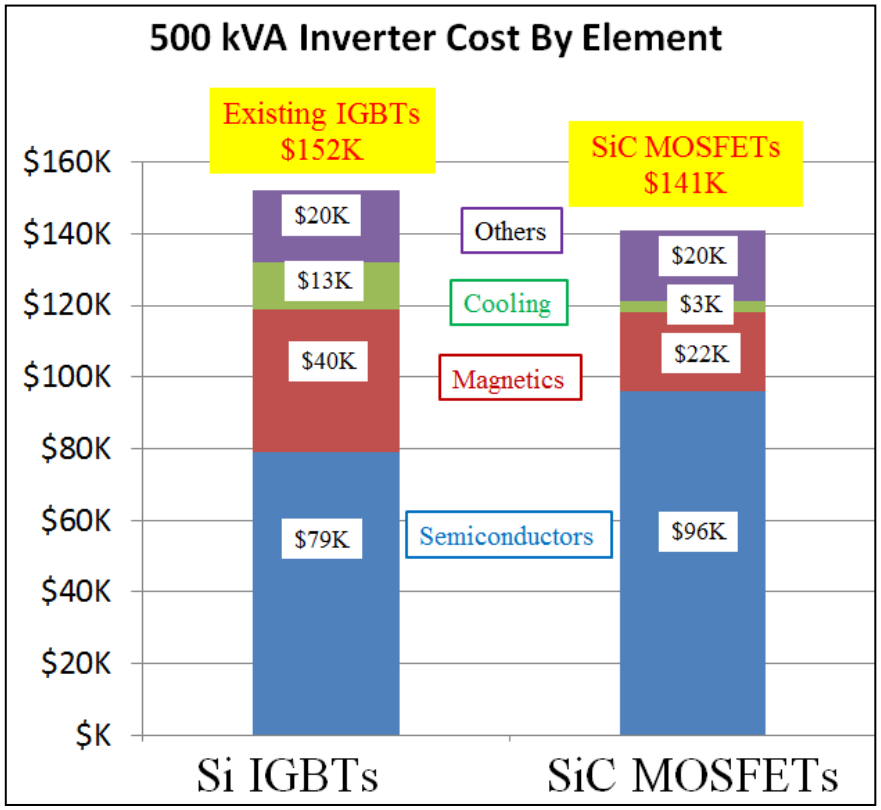
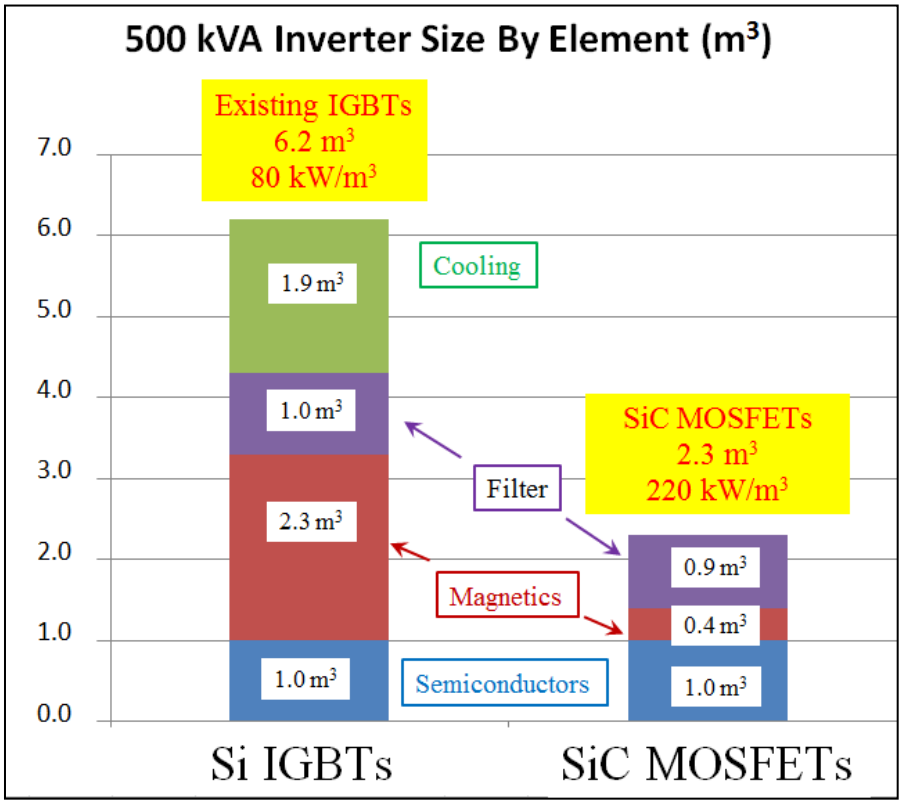
Benefits





Per unit costs are about the same.

Power density is 2.7X better.

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Cost and Size Comparison: SiC vs Si

Table 2. 500 kW Grid-Tied Inverter Volume Comparison			
Subsystem Description	Existing IGBT Design	Creare Phase II Detailed SiC Design	Creare Refined SiC Design
Transformer Volume (m^3)	2.3	**0.61**	**0.4**
Filter Volume (m^3)	1.0	**1.84**	**0.9**
Power Electronics Assembly Volume (m^3)	1.0	1.0	1.0
Cooling System Volume (m^3)	1.9	Included in electronic box	Included in electronic box
Combined Subsystem Volume (m^3)	**6.2**	**3.45**	**2.3**
Subsystem Power Density (kW/m^3)	81	145	216
Power Density Improvement Factor	–	**1.8**	**2.7**

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Acknowledgements

- **DOE Office of Electricity**
- **Dr. Imre Gyuk**
- **Dr. Stan Atcitty**

Thank you!

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