REDUCING CONSUMER ELECTRONICS' IMPACTS WITH GALLIUM NITRIDE (GaN) POWER SEMICONDUCTORS

COMPARISON OF LIFE CYCLE IMPACTS FOR CONSUMER CHARGING USING GaN TECHNOLOGY IN PLACE OF Si CHARGERS.

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WHAT IS A POWER SEMICONDUCTOR?

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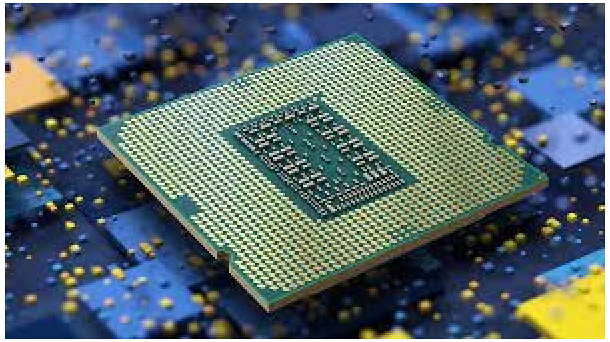
Microprocessor



Power Semiconductor

Consumes power through processing data / information

Converts power from one form to another based on end use requirement

WHAT IS A POWER SEMICONDUCTOR?

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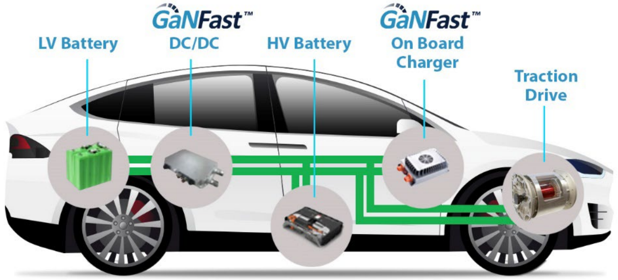
Power Semiconductor

Converts power from one form to another based on end use requirement

Consumer/ Mobile

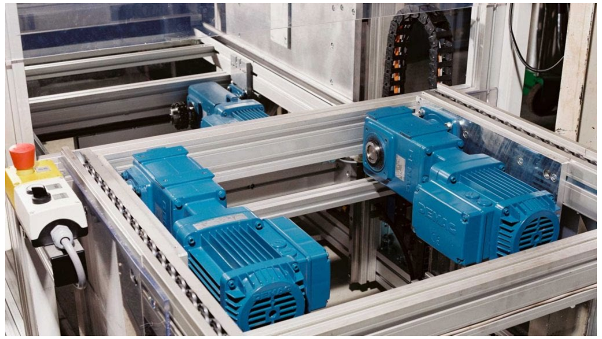
Datacenter

eMobility



Solar

Motors



WHAT IS A POWER SEMICONDUCTOR?

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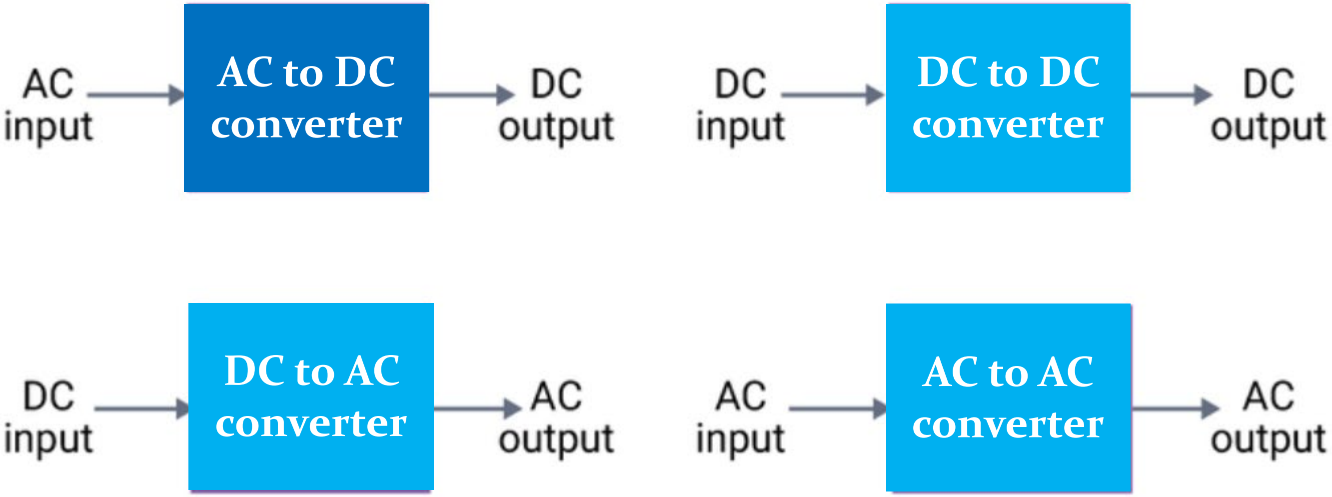
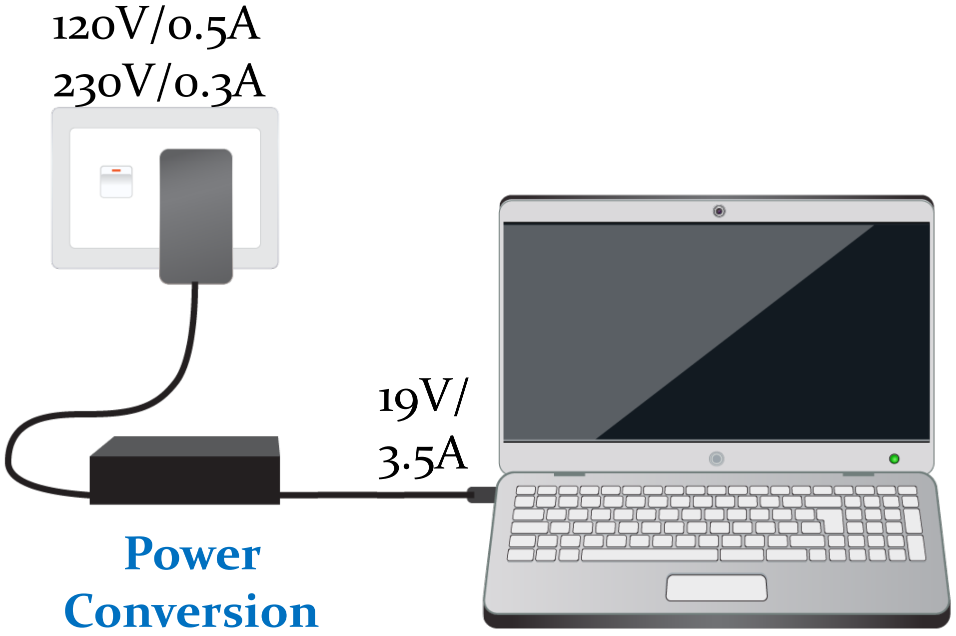
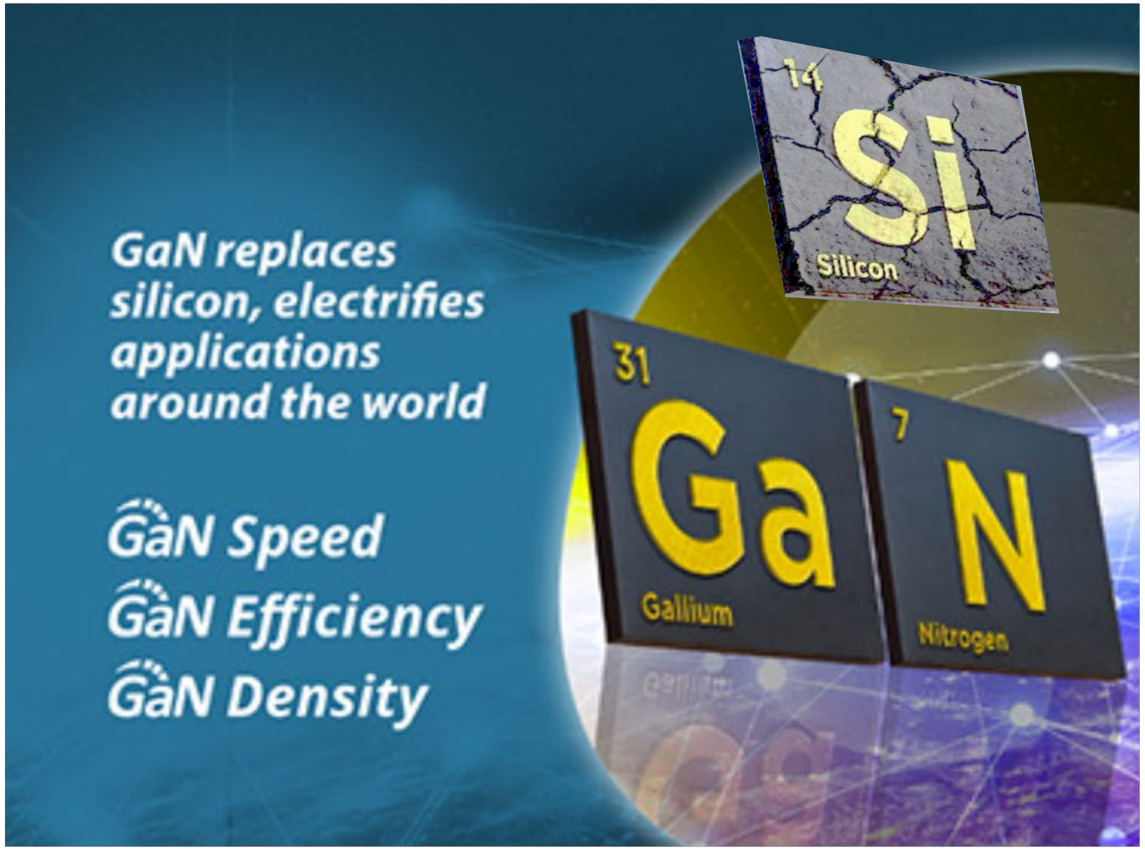
Power Semiconductors efficiently convert power into a more useful form



Consumer/Mobile



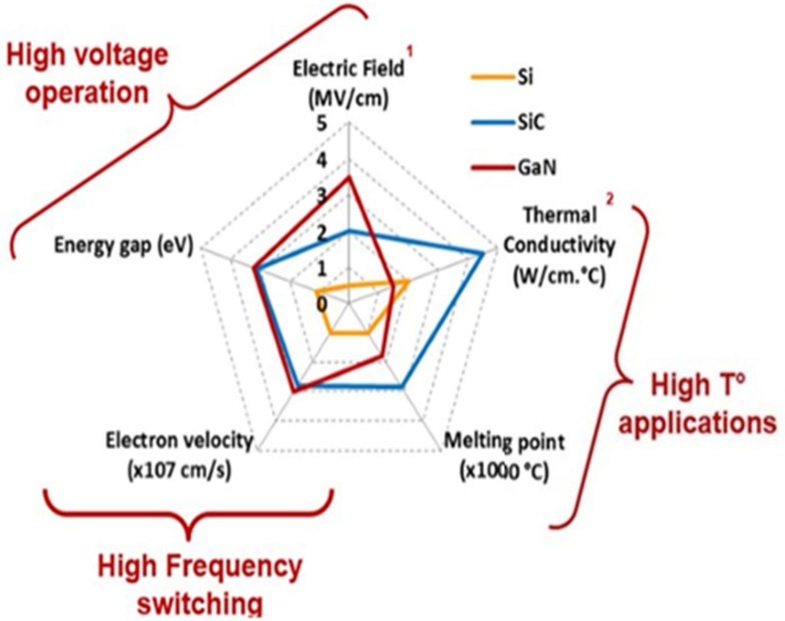
WHAT IS GaN? WHAT IS THE BENEFIT?



- New semiconductor material
  - "Silicon chip" → "GaN Chip"

- 20x faster
- 5x smaller
- 2x more efficient

Speed & efficiency translate to more power, faster charging in smaller size & weight



WHAT IS GaN? WHAT IS THE BENEFIT?

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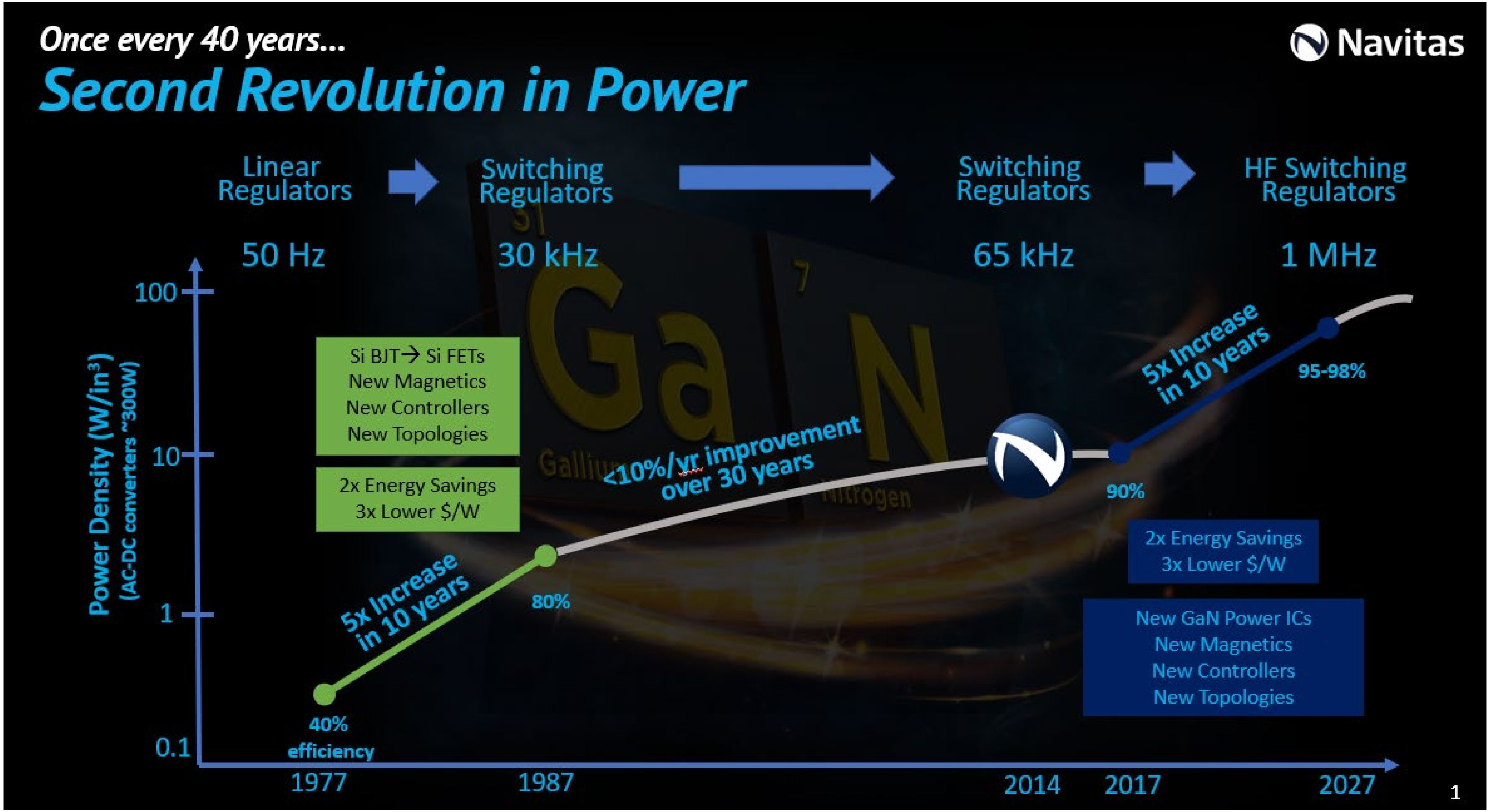

WHAT IS GaN? WHAT IS THE BENEFIT?

65W AC/DC adapter
80-90% efficiency = 6.5-13W wasted

65W AC/DC adapter
93% efficiency = 4.5W wasted

WHAT IS GaN? WHAT IS THE BENEFIT?

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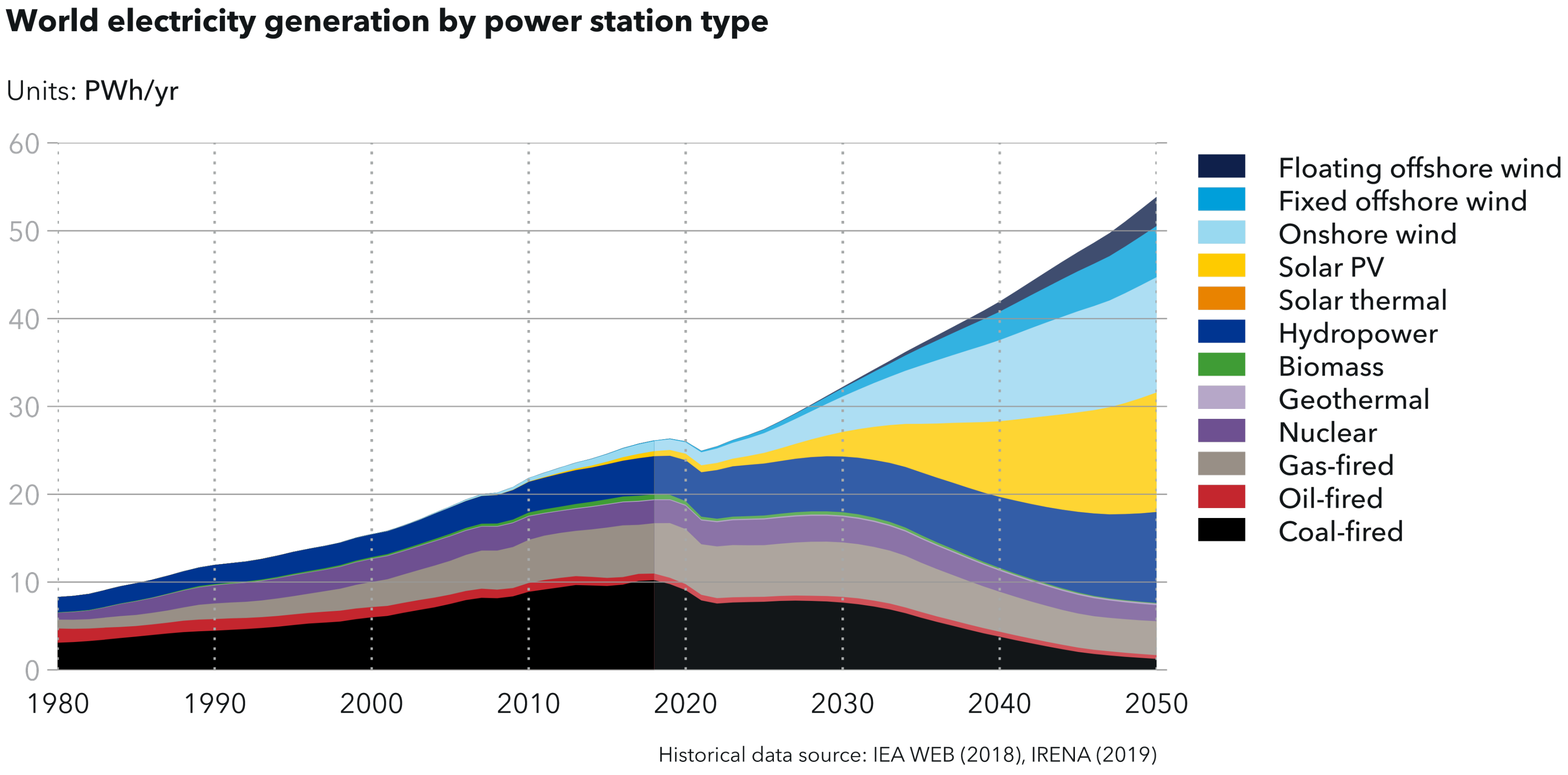
Fossil Fuel → Electric = increased impact of efficient electricity conversion



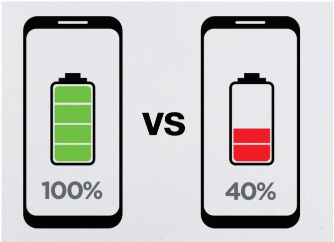
INITIAL DESIGN FOCUS – MOBILE CHARGERS

- Implement GaN Technology in the mobile charging market to:

Reduce Size/Materials

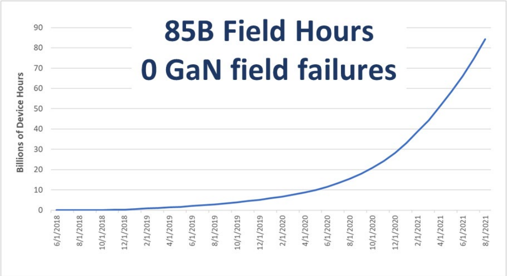
Increased Efficiency
(less wasted energy)

Reduce Charging Time



Enable Fewer Chargers

Prove Field Reliability



- With so much material and energy savings – how do we quantify the Sustainability benefits of GaN?

STUDY GOAL & SCOPE

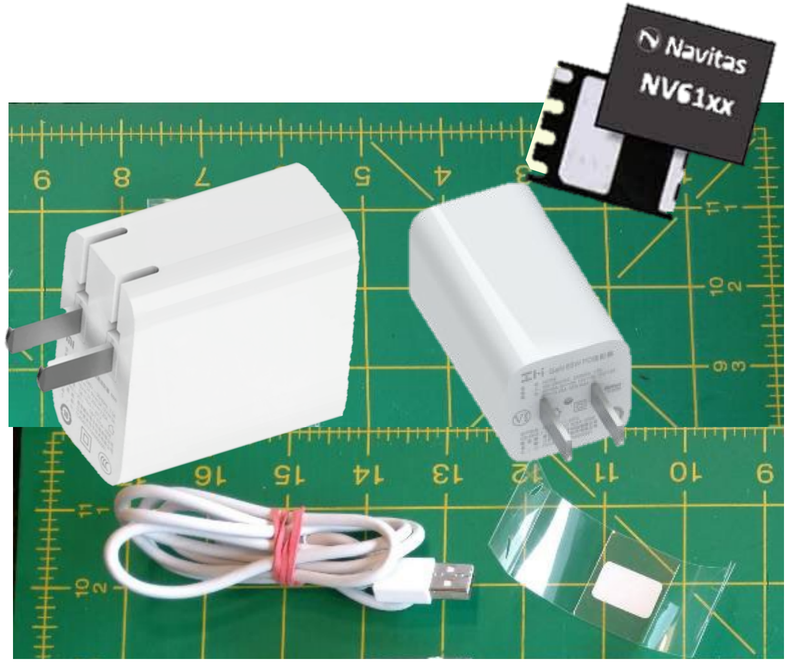
- Assess the potential life cycle environmental benefits of GaN power semiconductors in place of conventional Si;
- Confirm alignment of life cycle impacts with product intent; and
- Understand potential hotspots and design factors.

Functional Units I & II: 1 wafer, 1 die

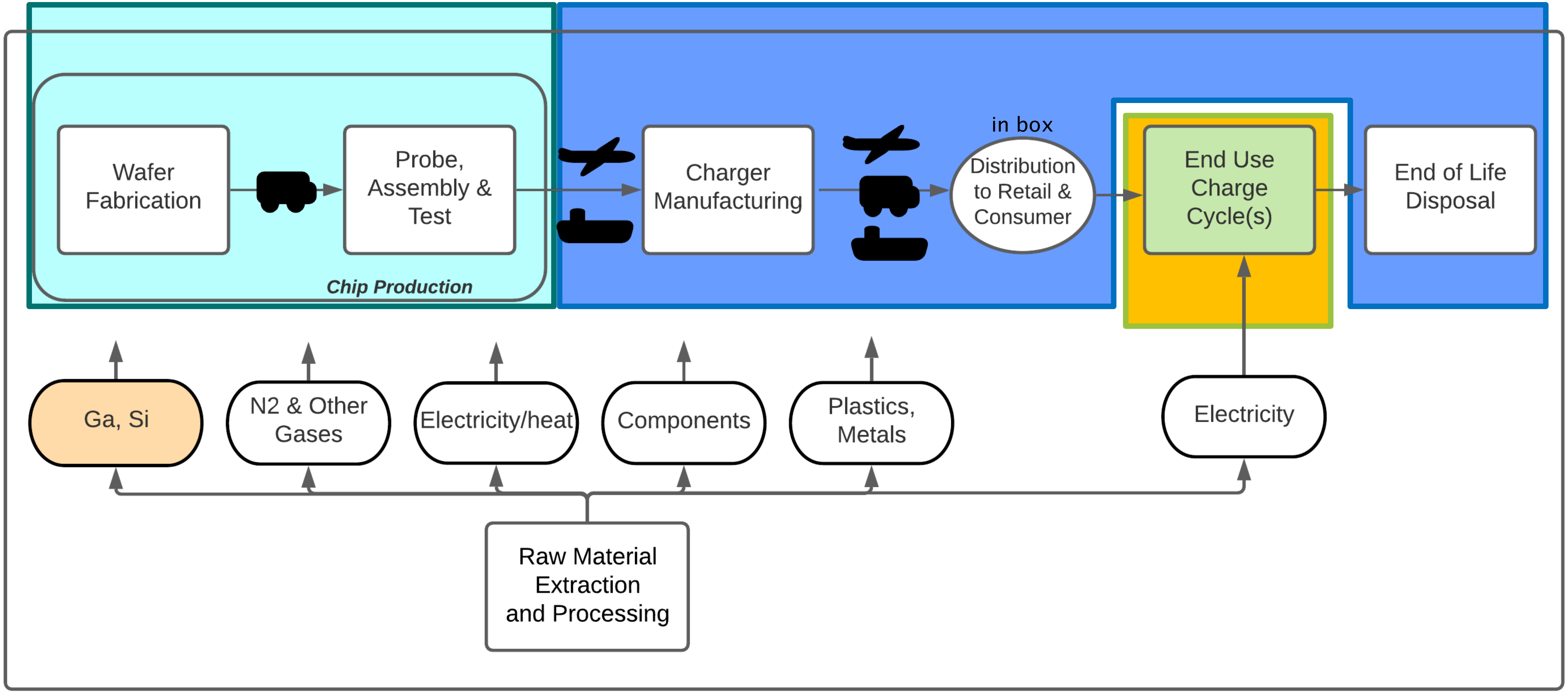
- Production of GaN and Si power semiconductor wafers (6”, 8”, respectively) and dies

Functional Unit III: “charging a laptop over charger life”

- Provision of charging service in the US & China –with 65W GaN-based and Si-based chargers



SYSTEM BOUNDARY



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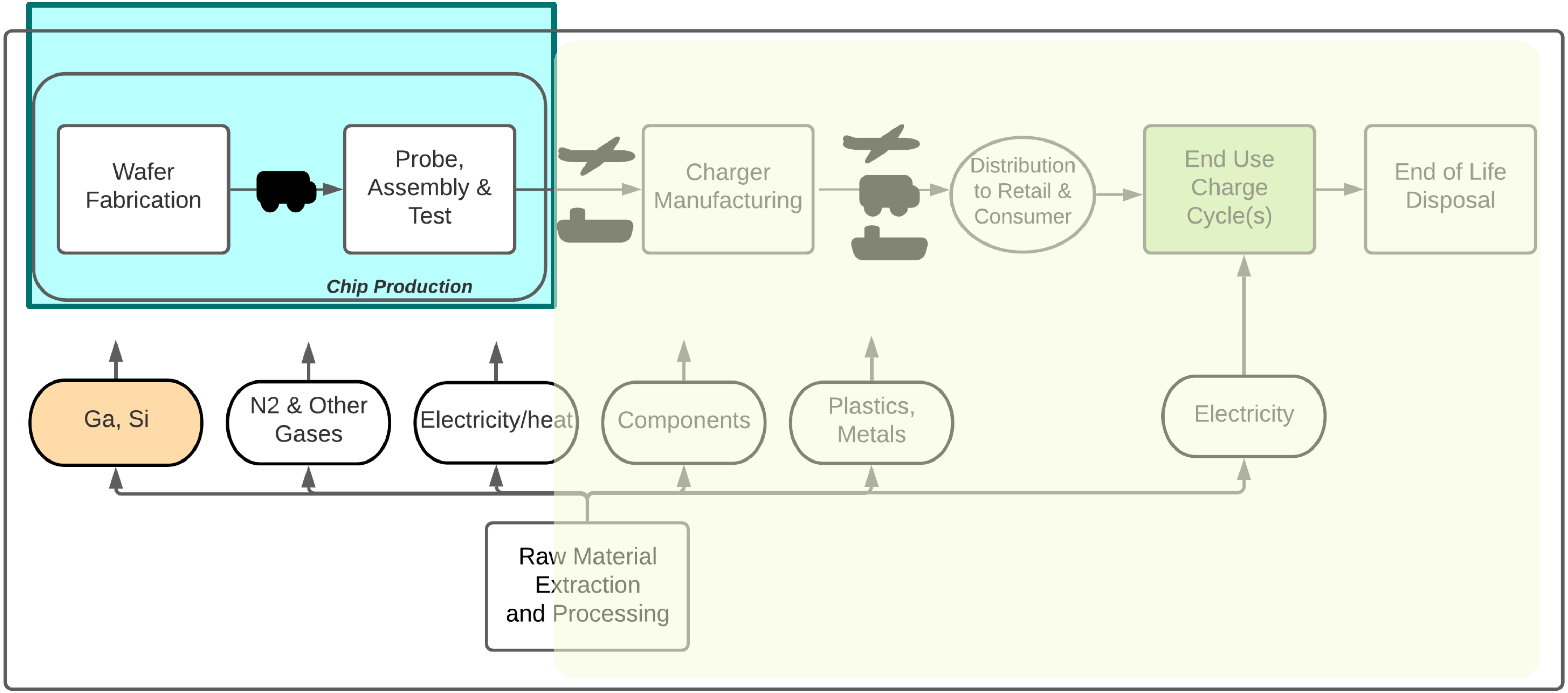
TECHNICAL DETAILS

Inventory	
Primary data	Test data (energy use & efficiency, including standby or parasitic energy consumption), product teardowns, BoM data **Primary component fabrication: literature, expert input**
Background data	Secondary components – library data (ecoinvent 3.7, GaBi electronics extensions 2021) ecoinvent 3.7, Market and literature values, expert consultation
Geography & Logistics	
Manufacturing	Fabrication (wafer, die) - Taiwan, Grid electricity Chargers – Guandong, China, Grid electricity
US Use	West Coast US, WECC Grid or Household solar Via air from Taiwan, sensitivity for ocean transport
Chinese Use	Guangdong Province, Chinese Grid or Household solar Via air from Taiwan, sensitivity for ocean transport
Use/Operating	
Charger life (default)	3 years (used 50 weeks/year, 5 days/week for 3 years, charger unplugged rest of time)
Usage scenarios	Business travel, business office, business+home office, home use
Impact Model(s) & Tools	
IAMs	IPCC 2013 100y; ReCiPe 2016 Endpoint H/A; AWARE; CED
Tool(s)	SimaPro 9.1.1

POWER SEMICONDUCTOR PRODUCTION



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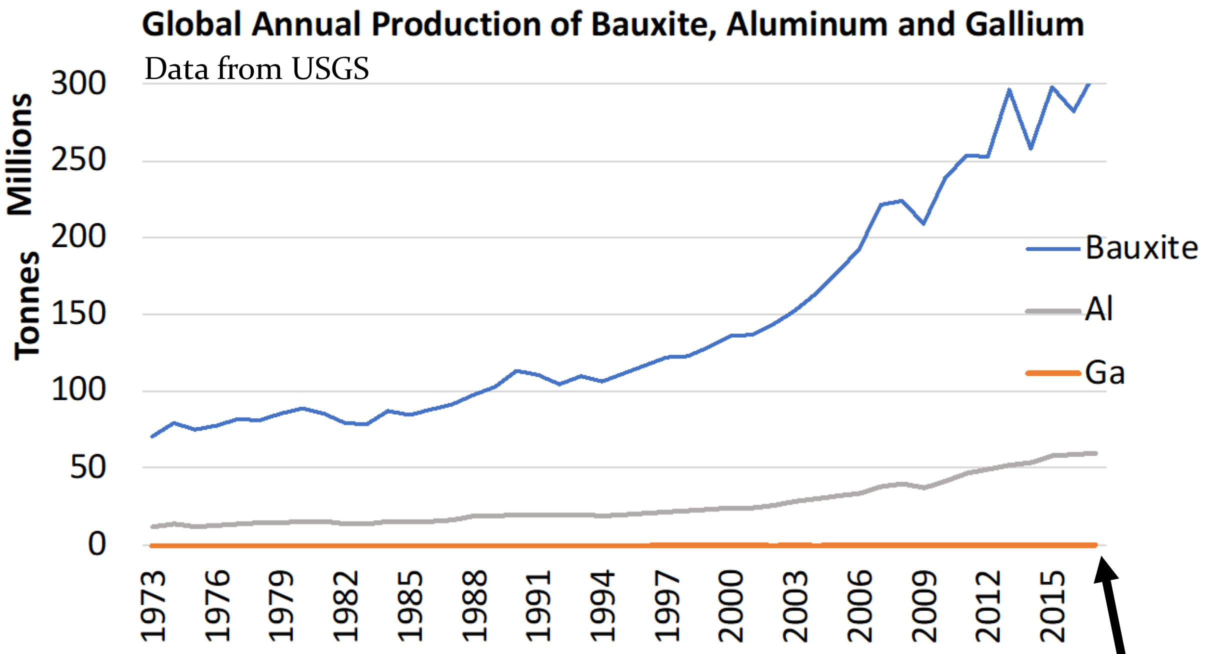
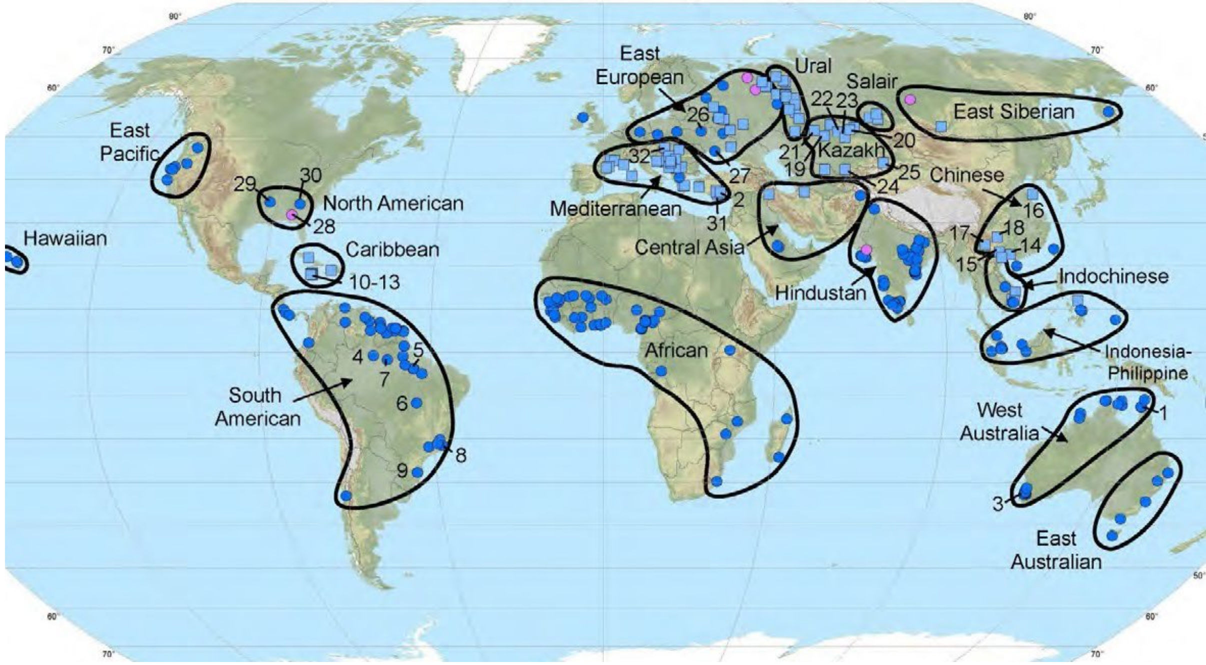
Ga IS A BYPRODUCT OF BAUXITE PROCESSING



2019 Ga production 350,000 kg

Bauxite Deposits



USGS

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HIGH VOLTAGE Si vs GaN COMPARISON

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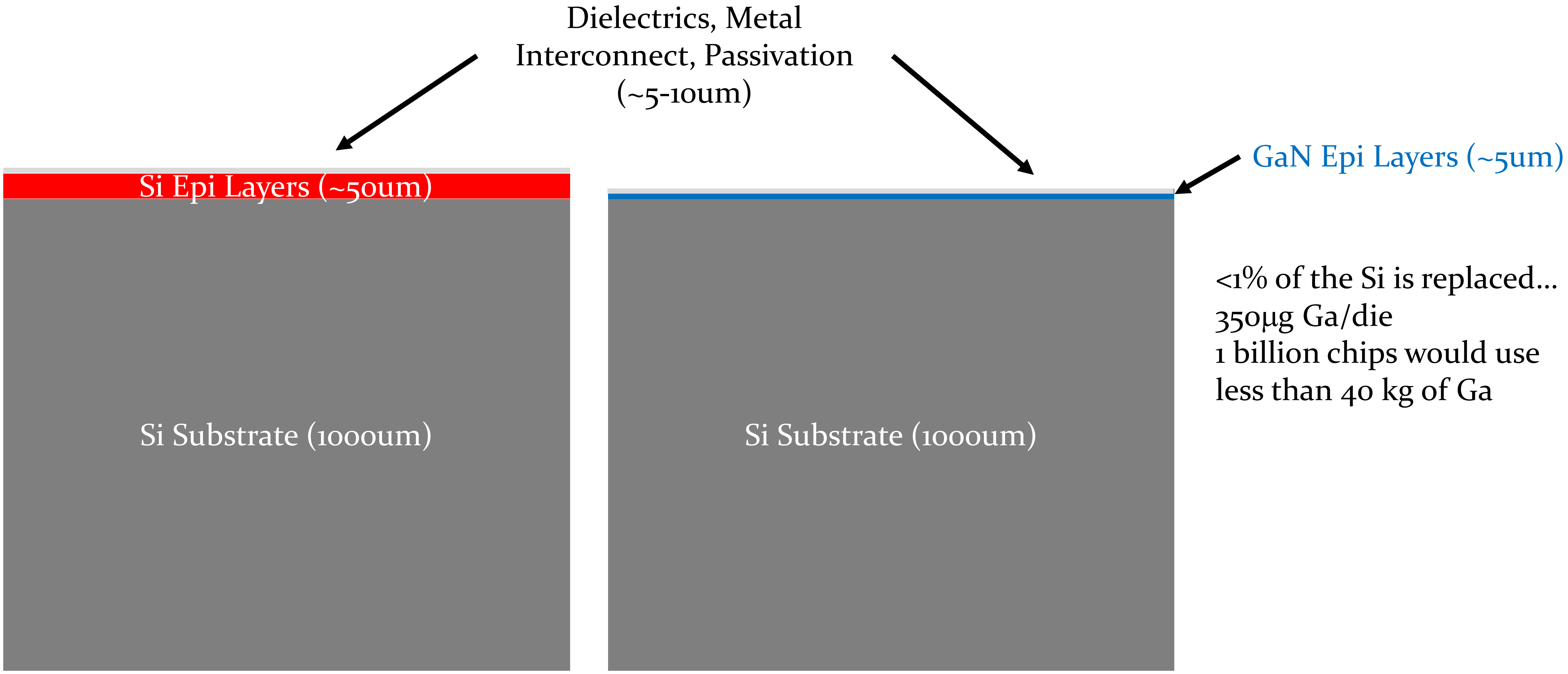

Si High Voltage MOSFET

GaN High Voltage HEMT

<1% of the Si is replaced…
350µg Ga/die
1 billion chips would use less than 40 kg of Ga

HIGH VOLTAGE Si vs GaN COMPARISON

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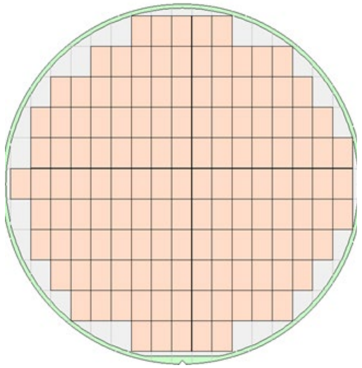
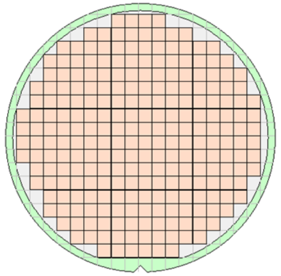
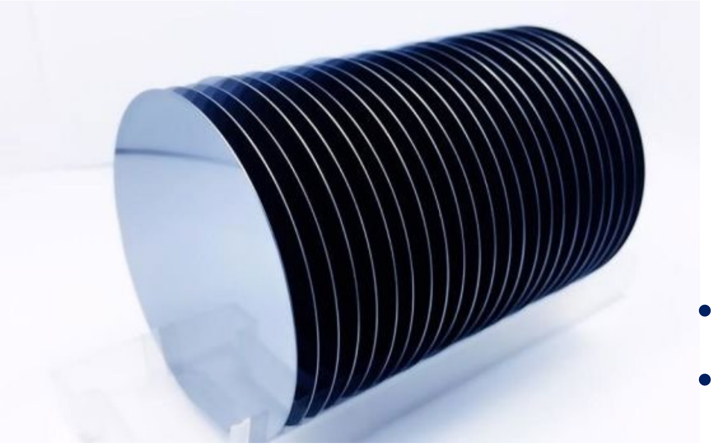
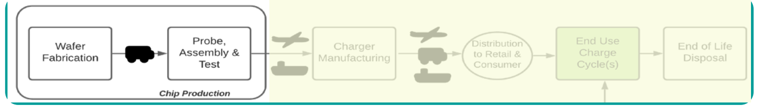
	Si High Voltage MOSFET	GaN HEMT
Material	Si wafer	Si wafer
Wafer Diameter	8”	6”
Starting Wafer Thickness	500-1000um	1000um
Finished Wafer Thickness	100-200um	250-300um
Die per wafer (equivalent device)	1	1.7



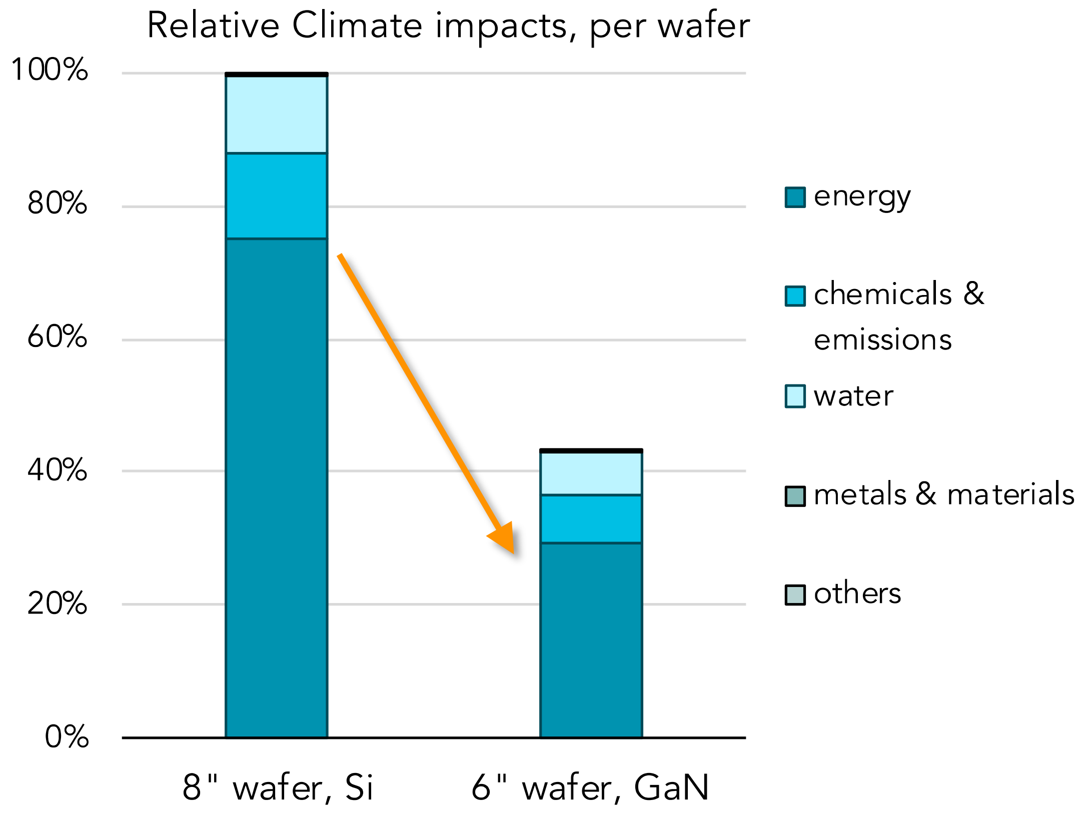




- After GaN epi, GaN technology is similar to existing CMOS processing technology
- Existing (sometimes idle) 6” and 8” fab capacity/infrastructure can be used with small investment



ENERGY DRIVES ENVIRONMENTAL IMPACTS IN FABRICATION



Decreased impacts for GaN power semiconductors arise from:

1. Decreased energy needs in fabrication due to fewer furnace and other processes than for conventional Si wafer production

2. Decreased material and processing due to significantly smaller epitaxial thickness for GaN typography

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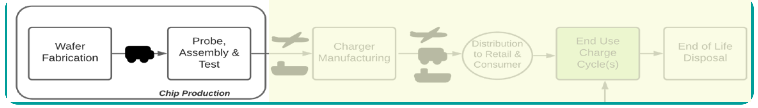
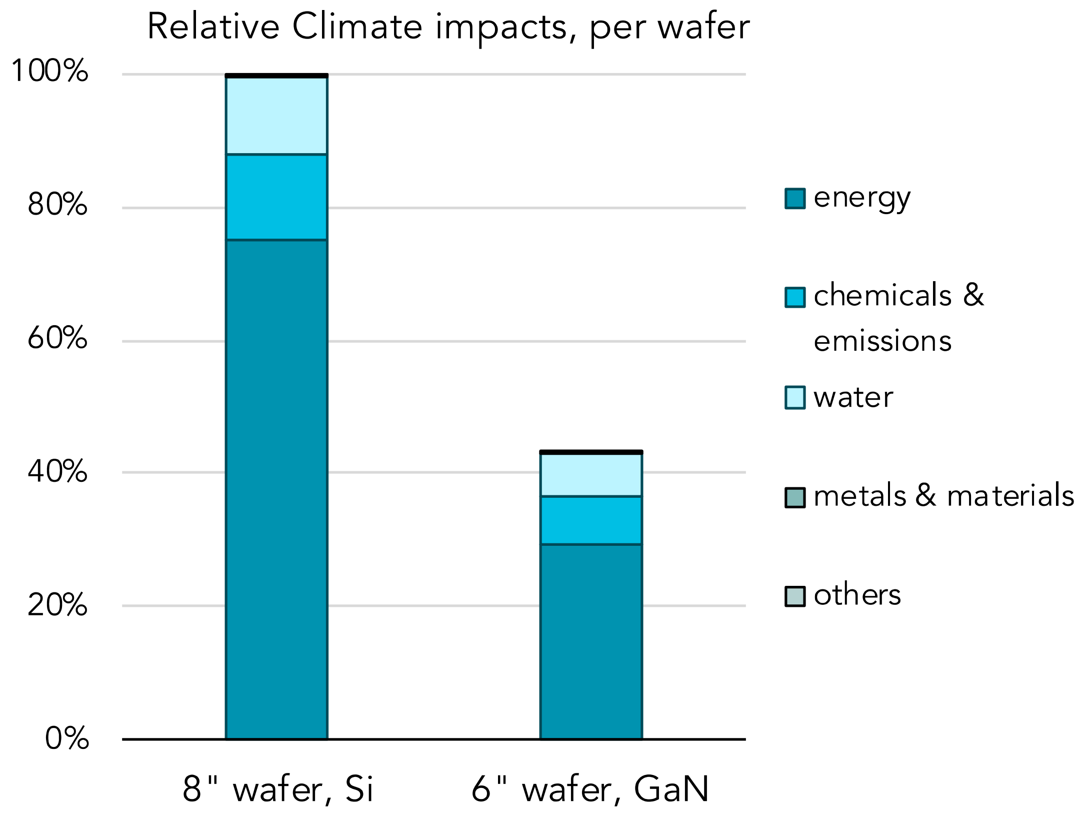
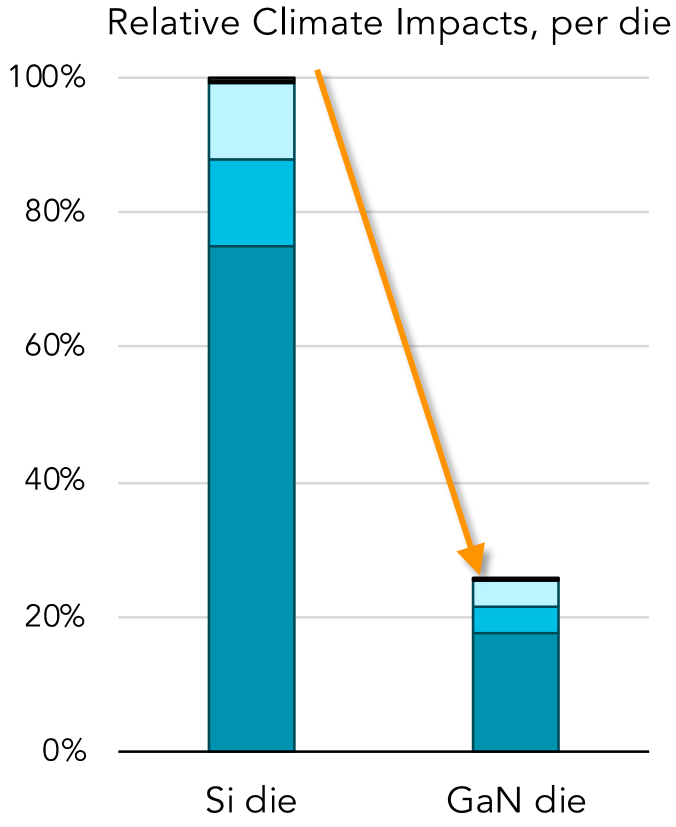


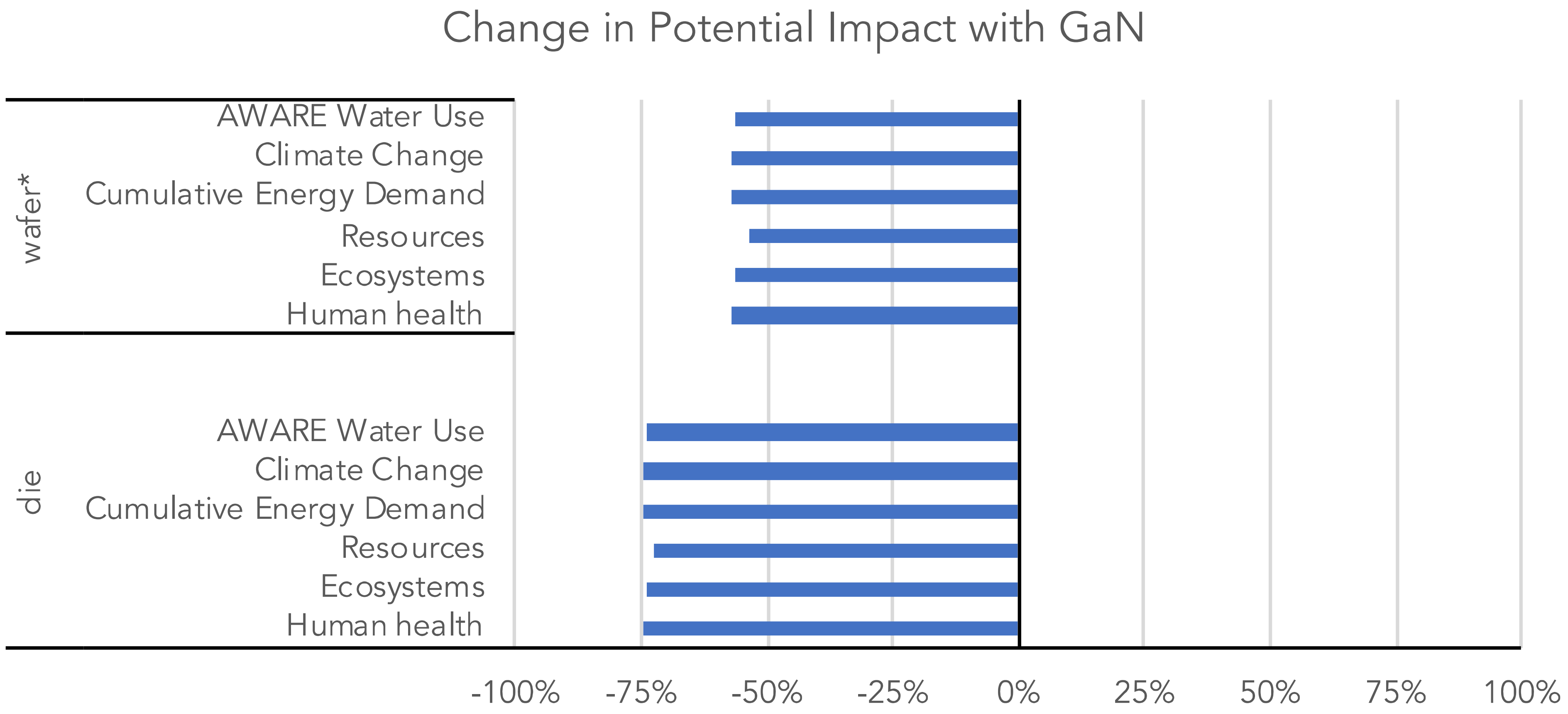
GaN'S SMALL DIE SIZE MEANS MANY MORE DIE PER WAFER





Decreased impacts for GaN power semiconductor arise from ~70% smaller size die, so 30%+ more GaN die/wafer

WAFER & DIE IMPACTS FOR GaN RELATIVE TO Si: reduction in all assessed categories



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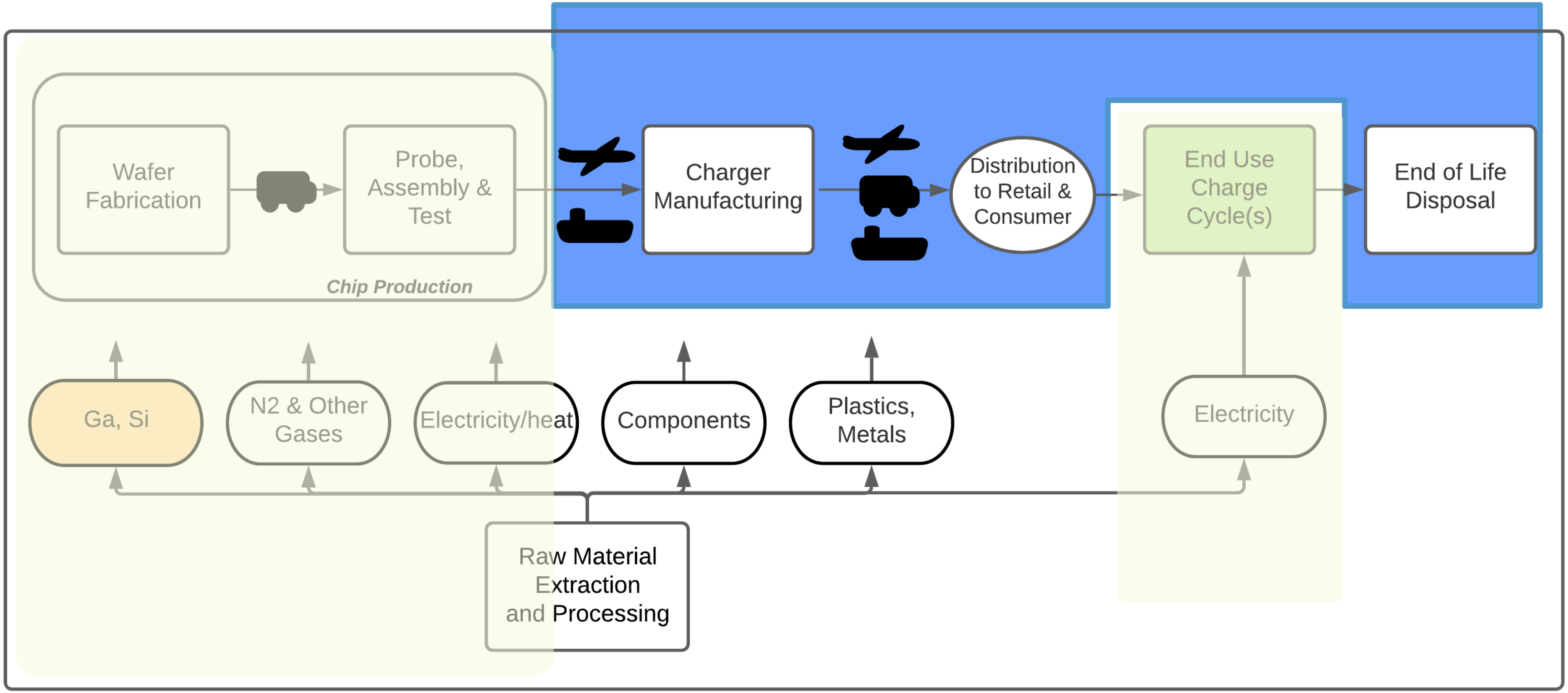
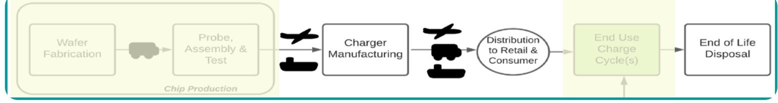
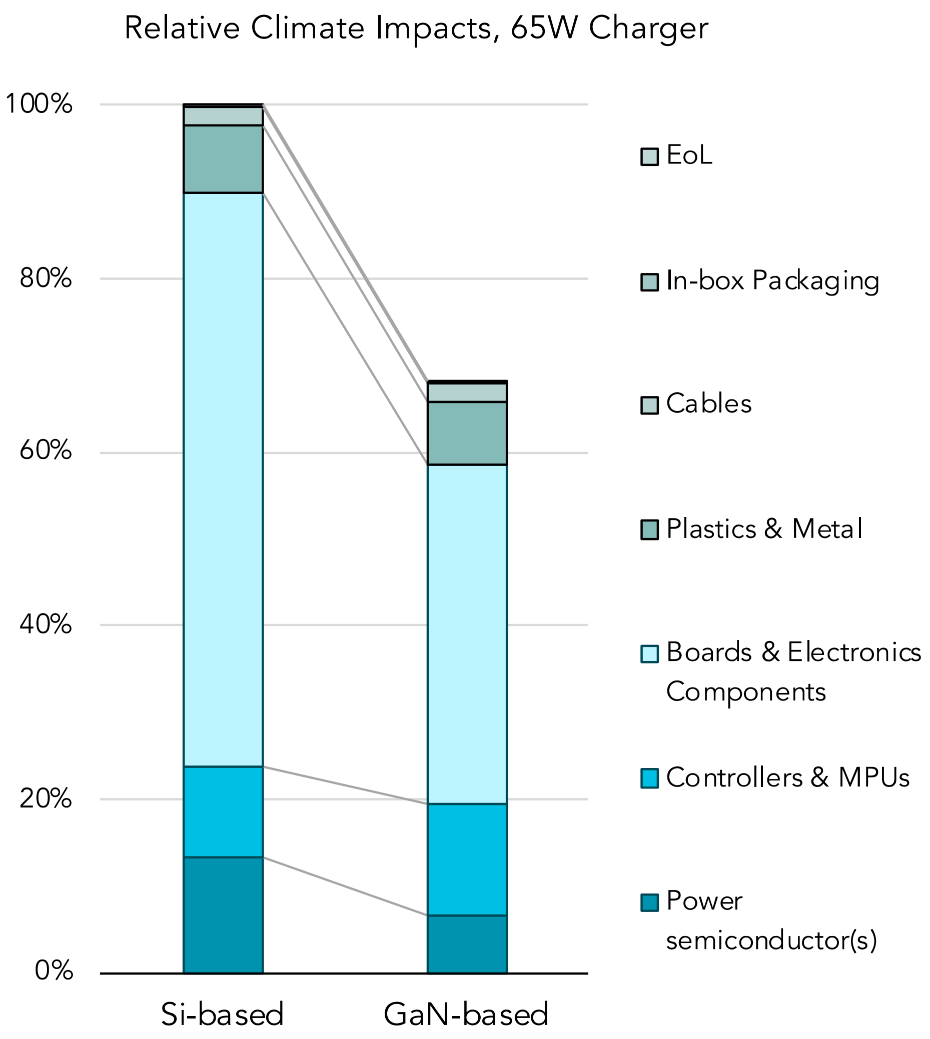
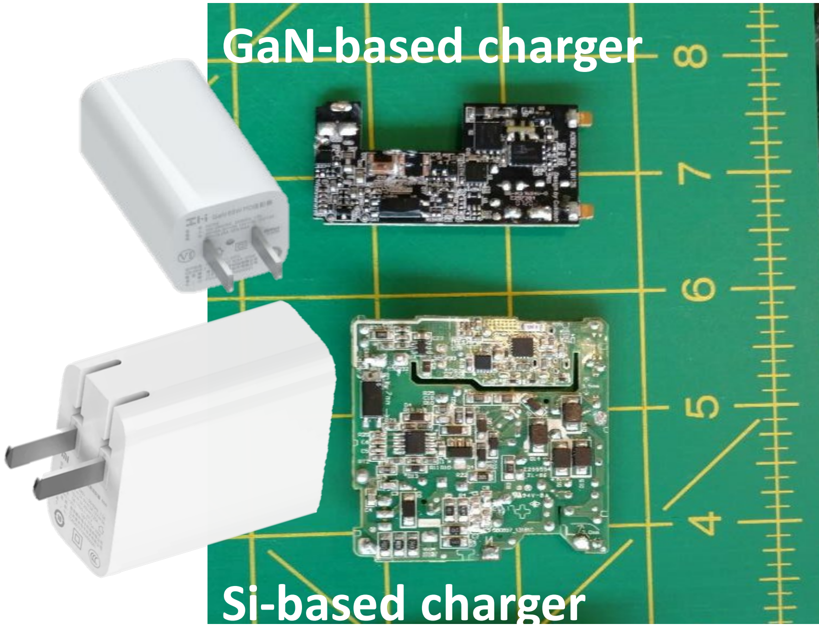
CHARGER PRODUCTION, DISTRIBUTION & DISPOSAL





DEMATERIALIZATION: USING THE GaN CHIP DECREASED CHARGER COMPONENTS AND WEIGHTS





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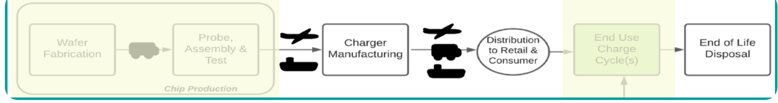

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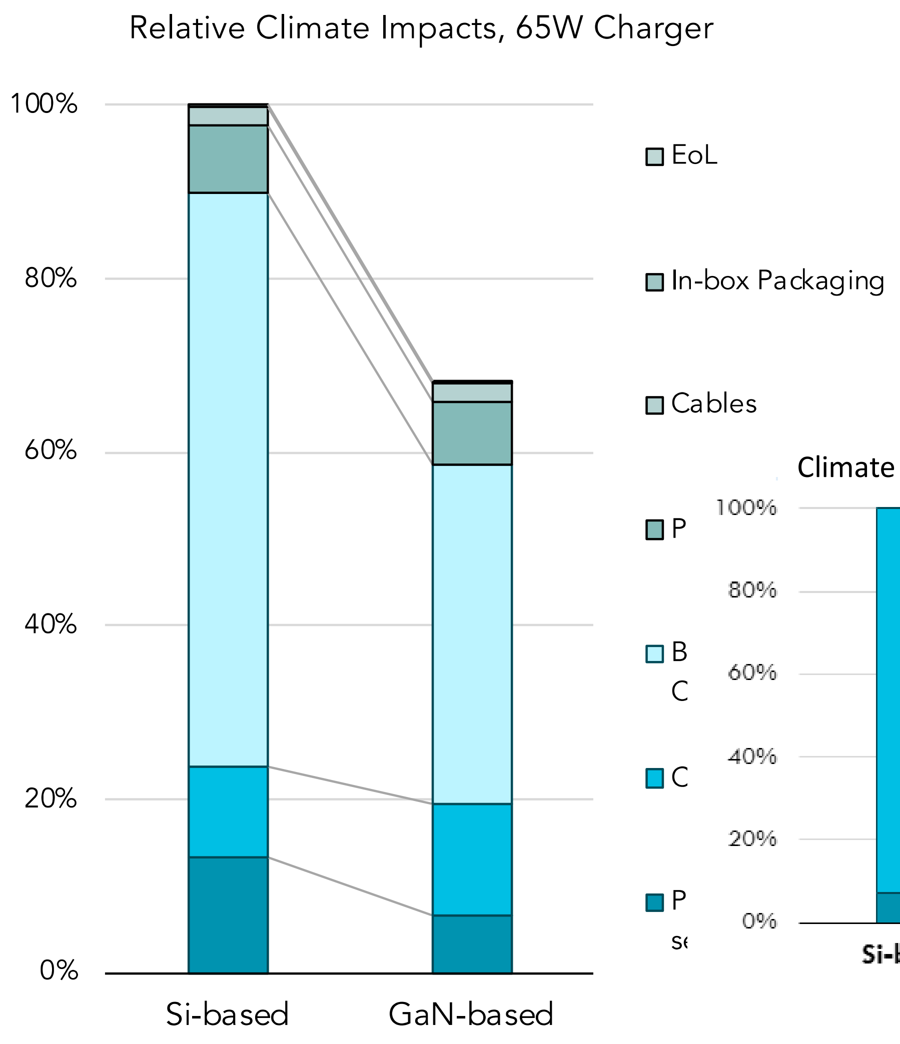

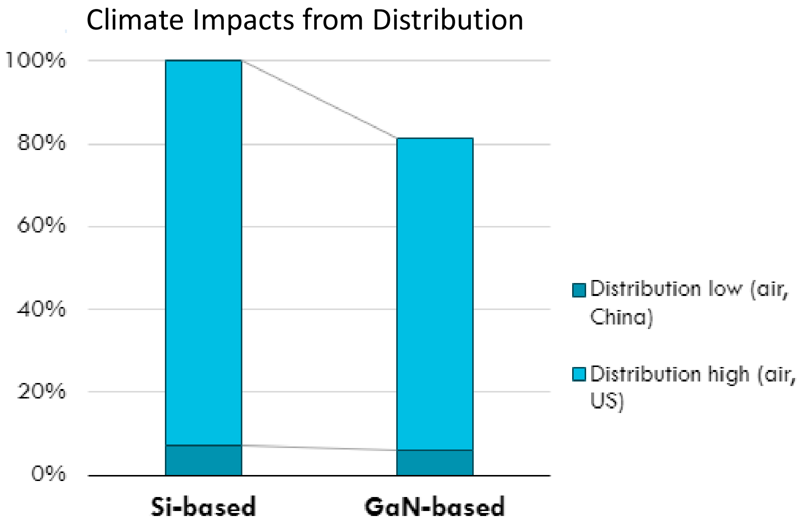

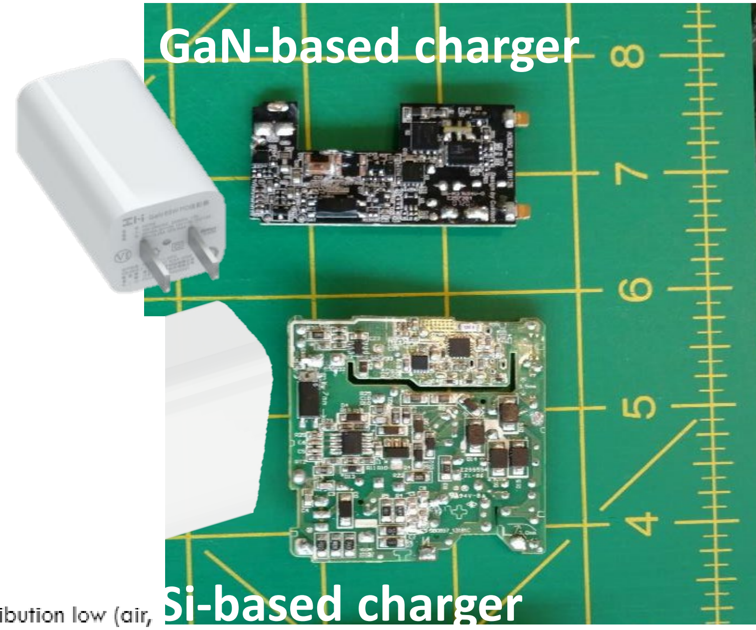

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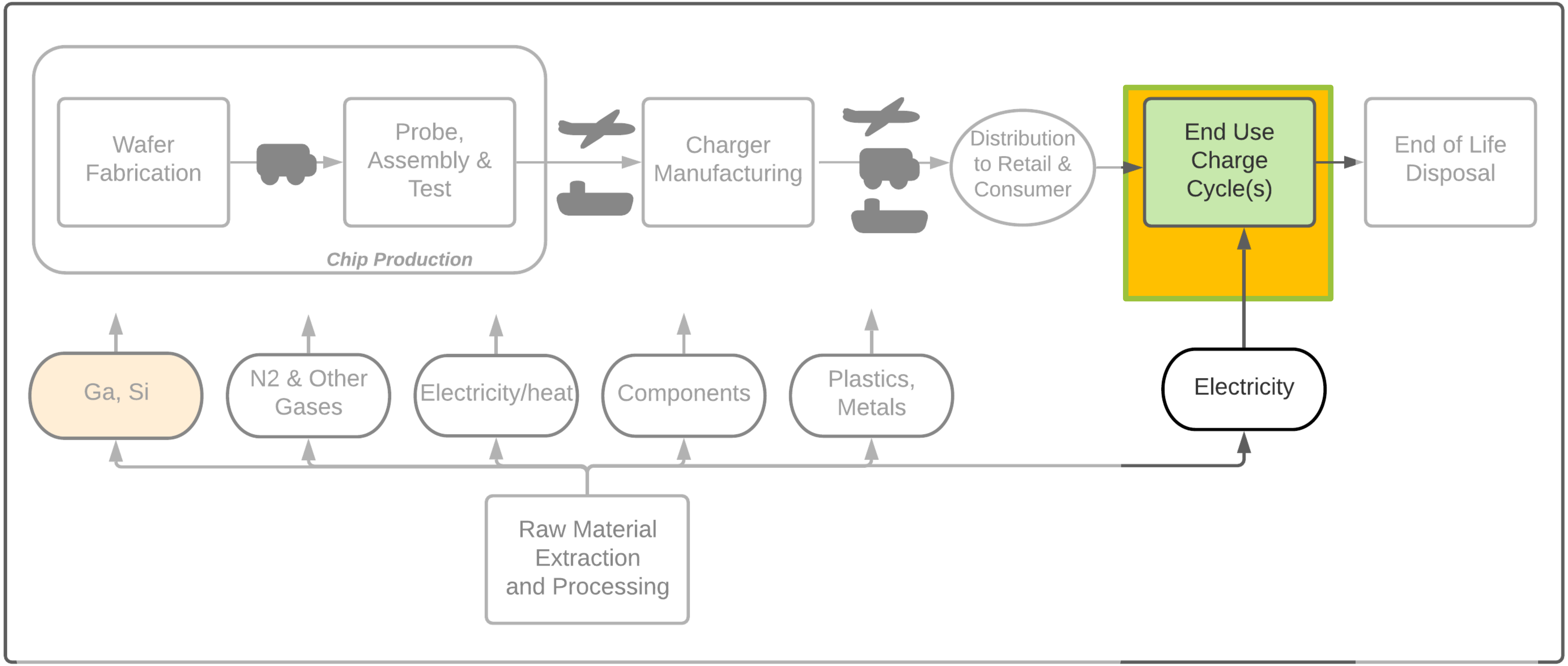
USE PHASE



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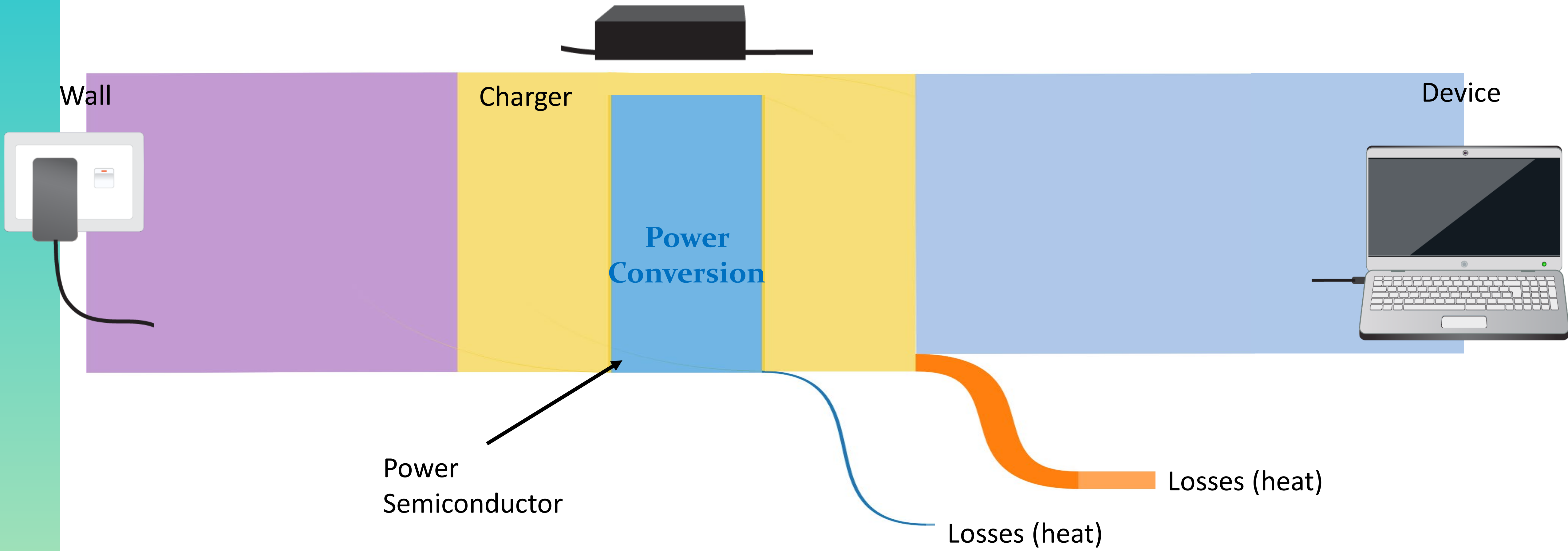
ENERGY FLOW IN CHARGING



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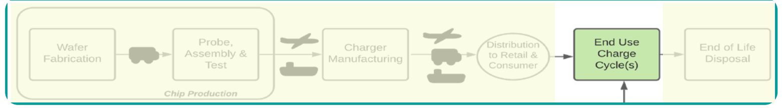
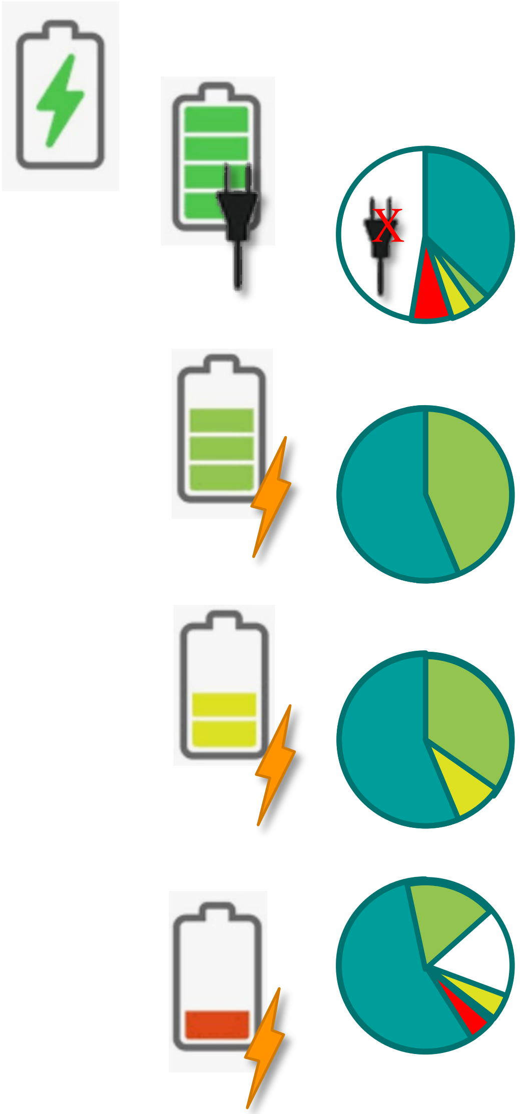


USE SCENARIOS



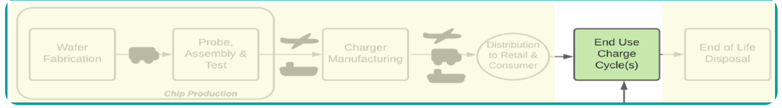
Business Travel

Business Home

Business Office

Personal Home

Scenario	Business Travel	Business Home	Business Office	Personal Home	Units
Continuous use					
hours	0	10	8.5	4	hours
% of base power	30%	30%	30%	30%	%
Not connected to charger					
Use on battery only					
hours	11	0.00	1.00	4.00	hours
% of base power	0%	0%	0%	0%	%
"Abandoned" plug					
hours	0	0.00	1.00	4.00	hours
% of base power used, 110/120V (GaN charger)	0.0724%	0.0724%	0.0724%	0.0724%	%
% of base power used, 220/230V (GaN charger)	0.1686%	0.1686%	0.1686%	0.1686%	%
Charge up, active					
hours	1.5			0.5	hours
% of base power delivered	100%			100%	%
hours	0.75		0.25	0.25	hours
% of base power delivered	50%		50%	50%	%
hours	0.75		0.25	0.25	hours
% of base power delivered	30%		30%	30%	%
Charge up, night					
hours	0.5				hours
% of base power delivered	100%				%
hours	0.25				hours
% of base power delivered	50%				%
hours	0.25				hours
% of base power delivered	30%				%
Fully charged, Plugged in, no use					
hours	9	14	14	15	hours
% of base power delivered	15%	15%	15%	15%	%
Total daily hours accounted for	24	24	24	24	



USE IS THE MOST SIGNIFICANT CONTRIBUTOR TO IMPACTS

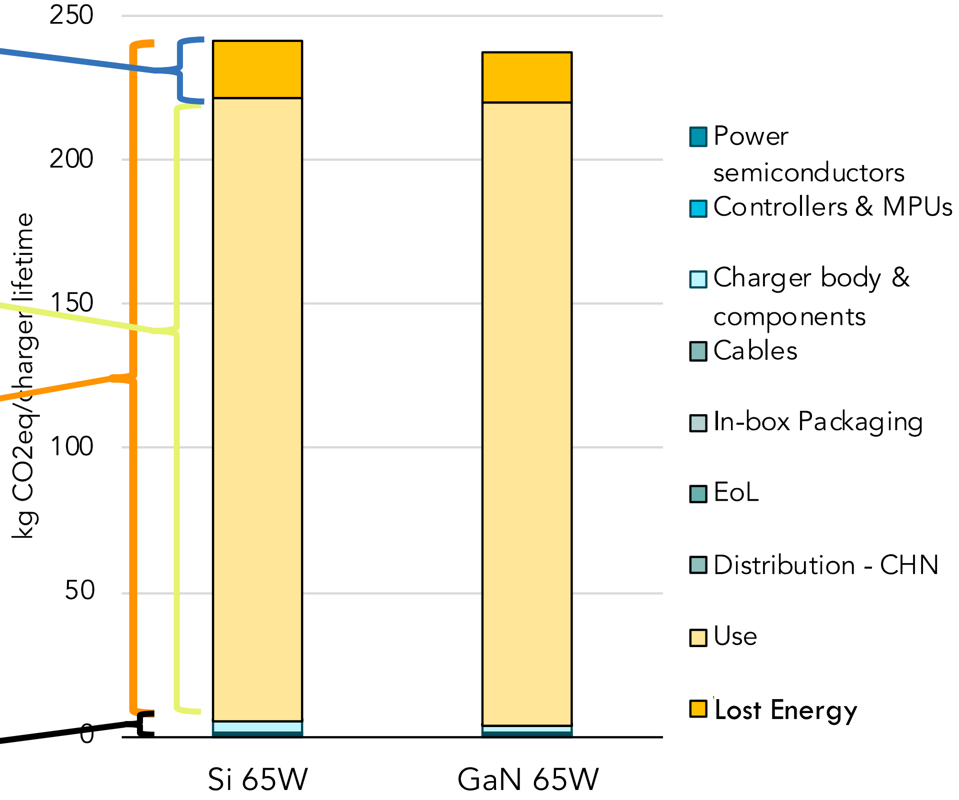
Lost energy, drawn but not delivered to device – a function of the efficiency of the power switch and charger

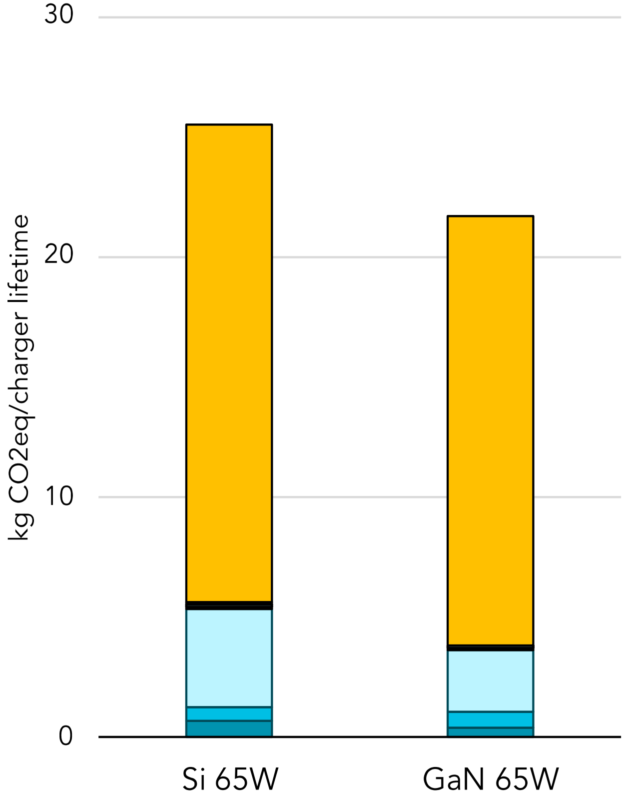
Usable energy delivered to device – dictated by device

All energy draw during use

Everything other than use

Work Travel Scenario (work untethered, plugged in only to charge)





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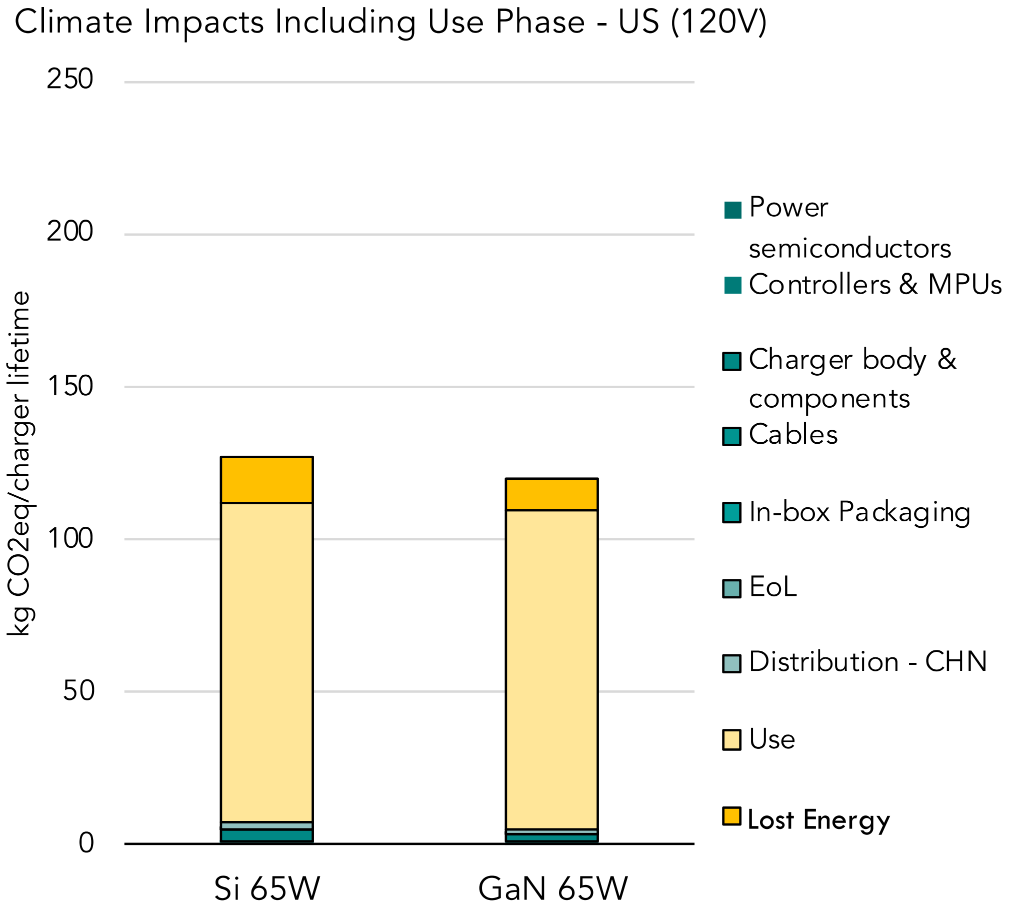
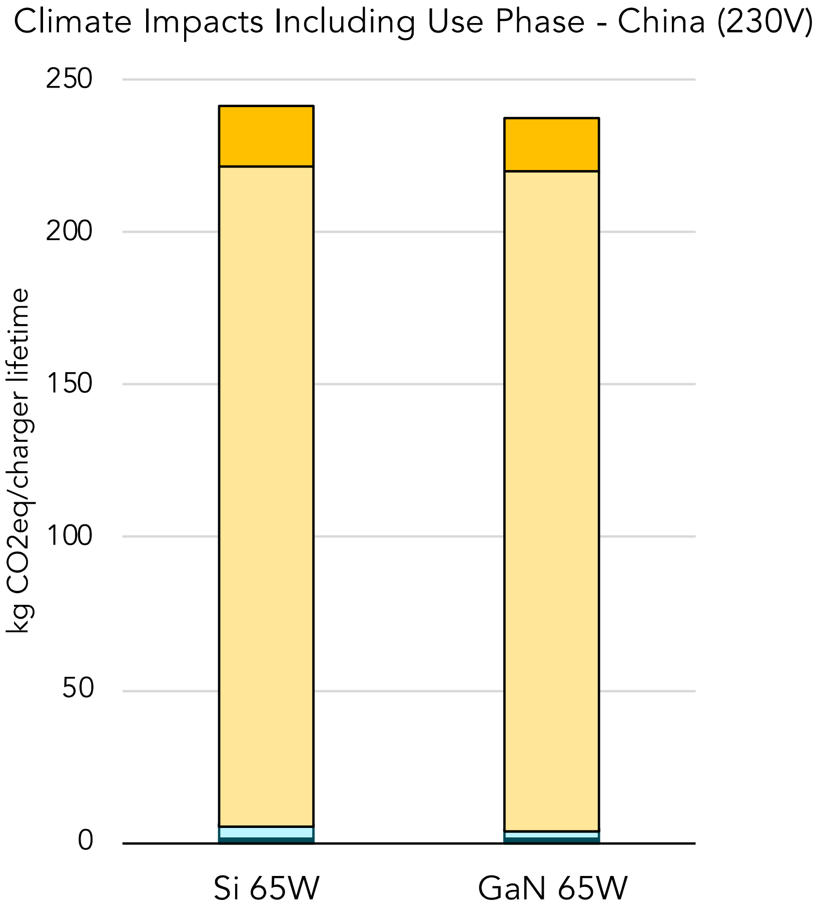
USE PHASE IMPACTS IN DIFFERENT REGIONS





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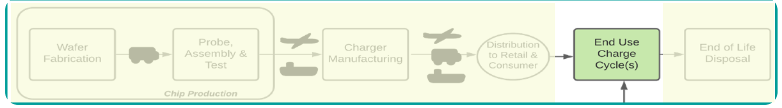

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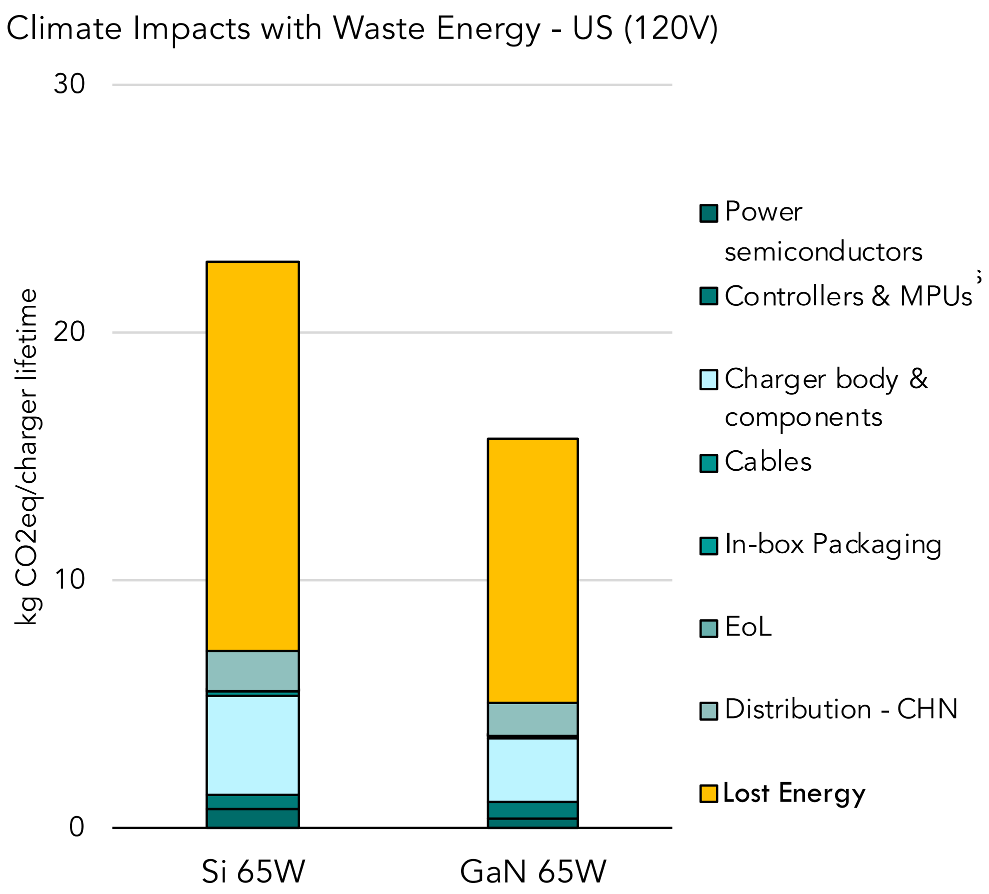

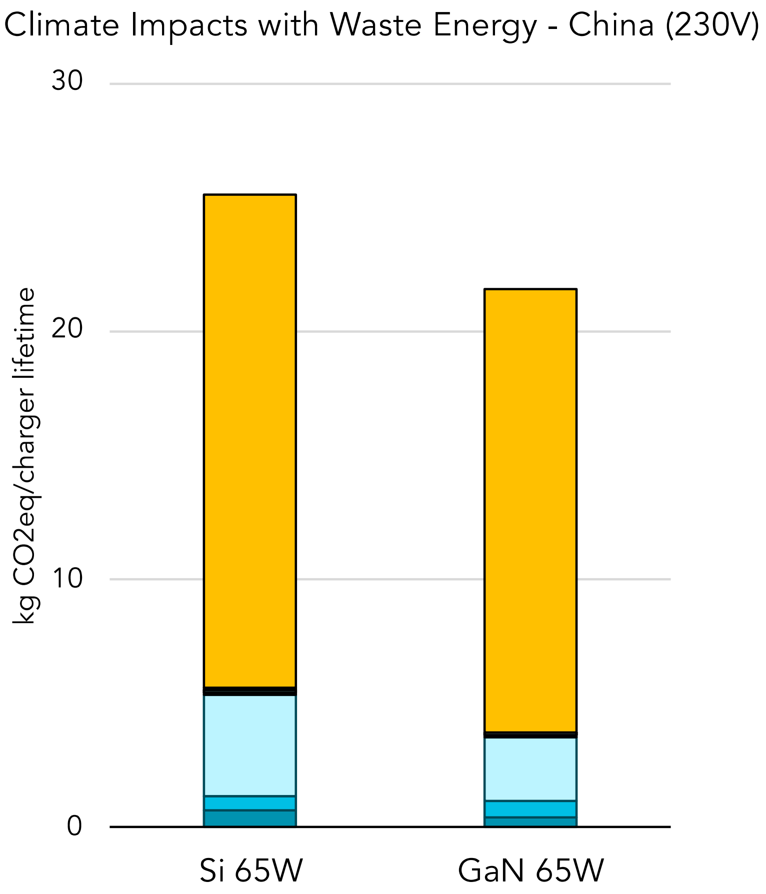

Work Travel Scenario (work untethered, plugged in only to charge)

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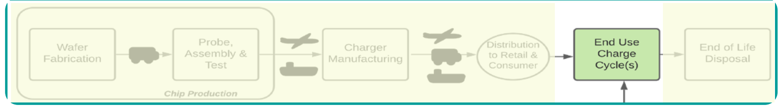
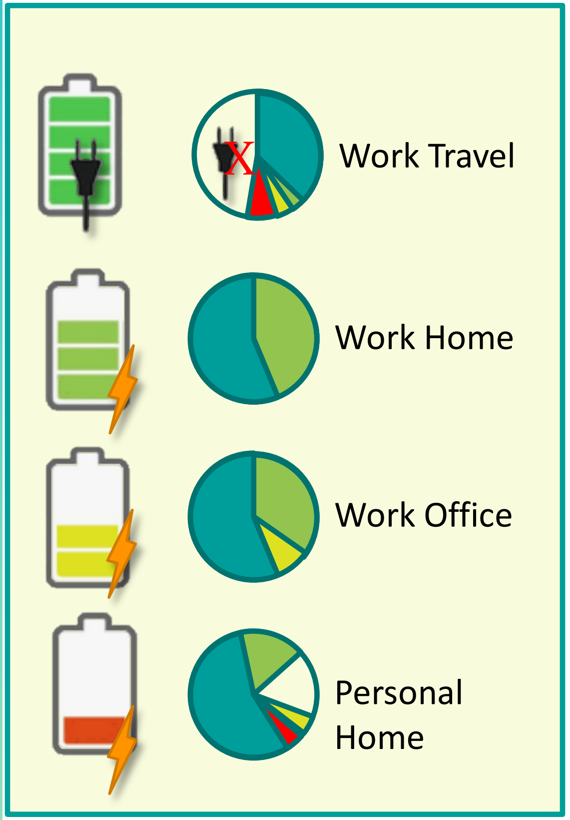
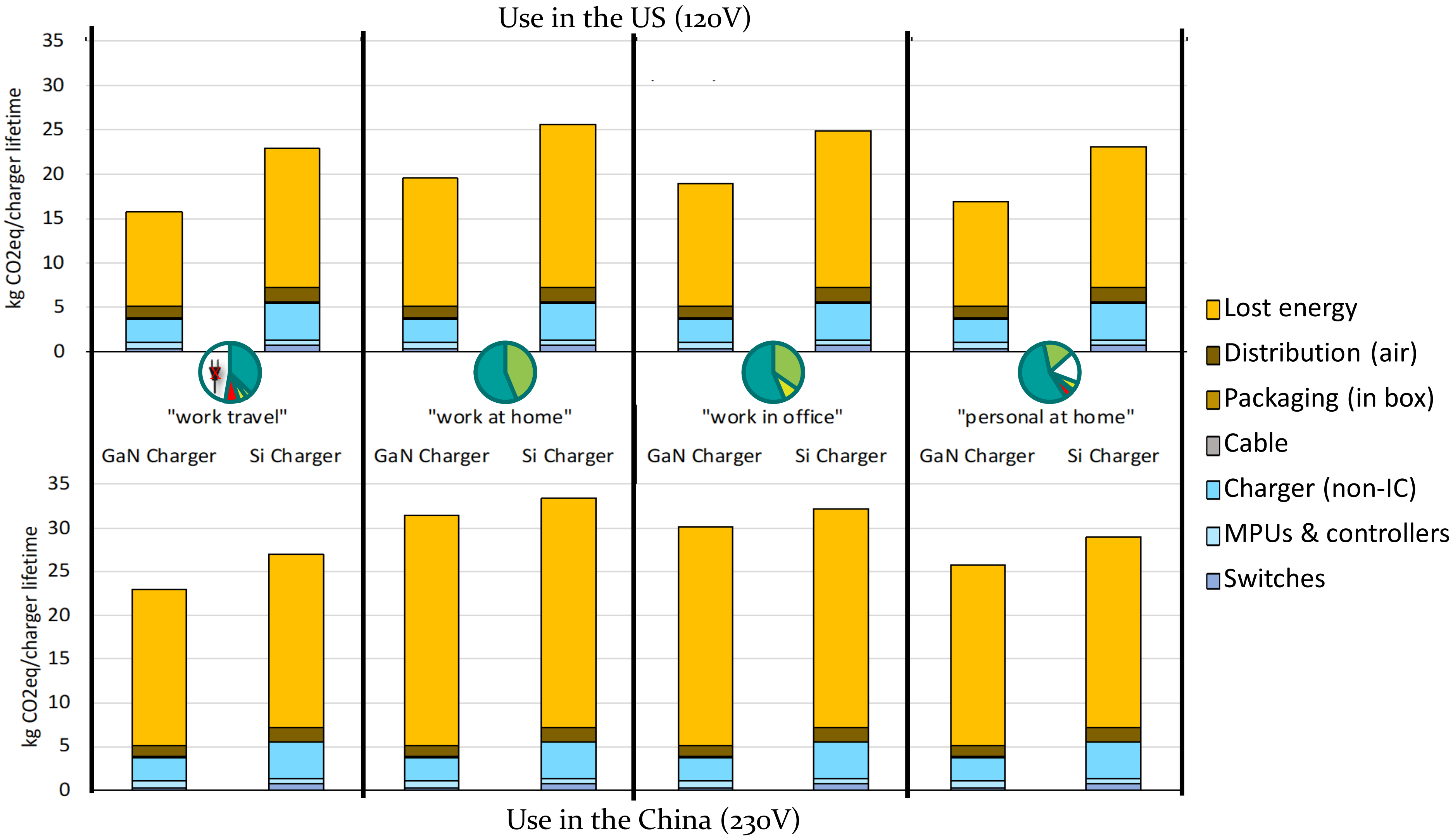


OTHER USE PATTERNS LOOK A BIT DIFFERENT





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LCA LEARNINGS – DESIGN CONSIDERATIONS

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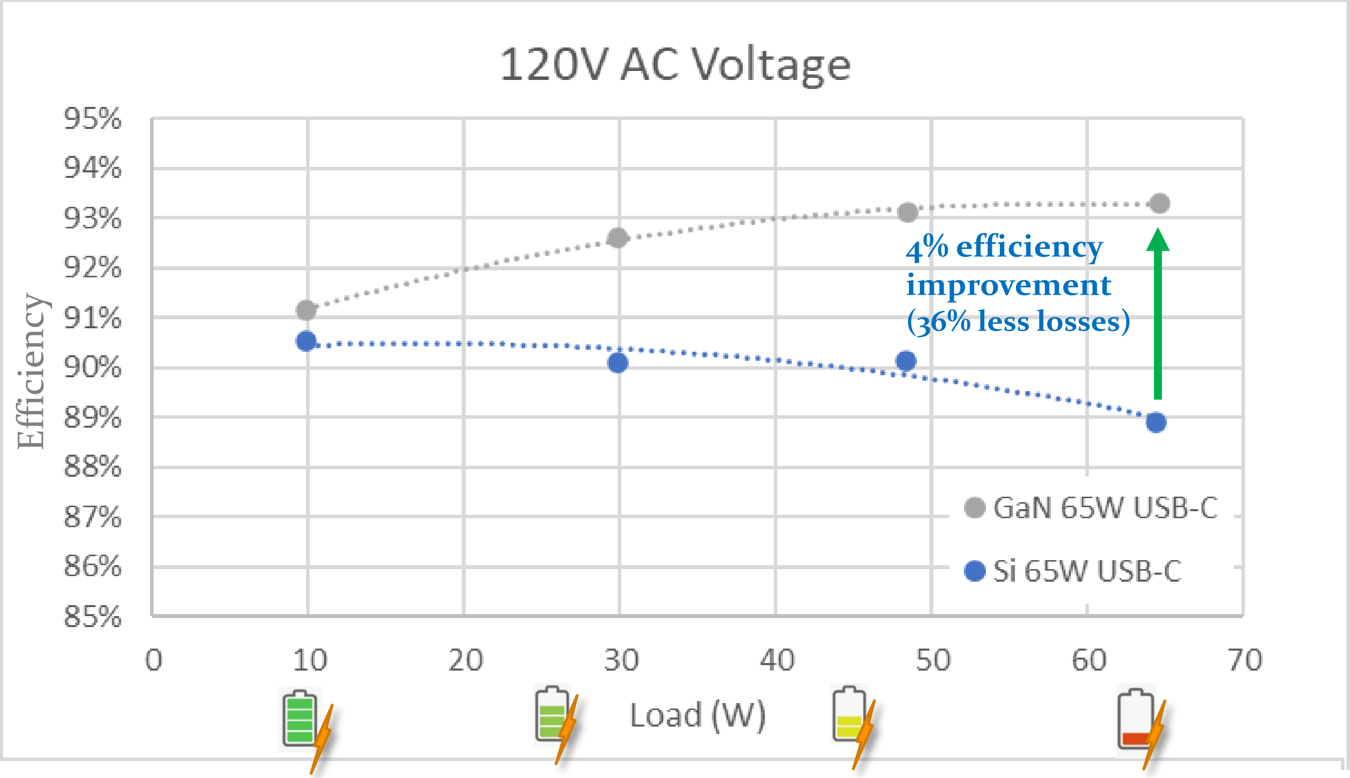
- Worst case power dissipation is at full load (65W) condition
  - **Defines adapter size → Key factor in manufacturing impacts and dematerialization opportunities**

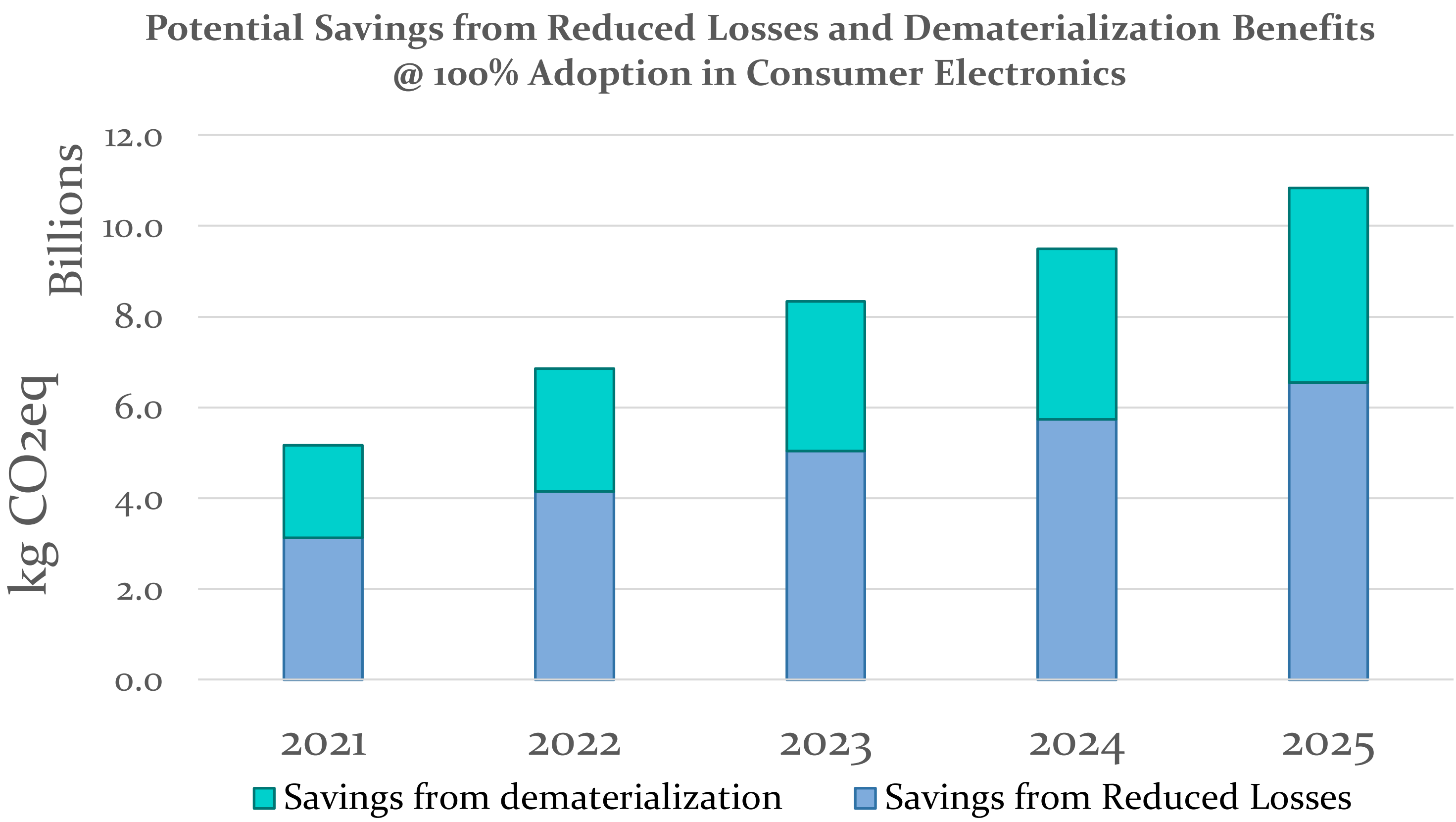


- The Use-cases for this study show tradeoffs for Use-Phase Impacts
  - Total energy use across various use-cases: 70% heavy load / 30% light load
  - Full load efficiency is more important for use cases that include more charging and less plugged-in non-use
  - Light load efficiency becomes a larger factor for applications normally plugged in with light/moderate use → needs optimization across the power range
- Geography impacts Use-Phase impacts
  - Most adapters are targeted for global use so must be optimized for both AC voltage conditions

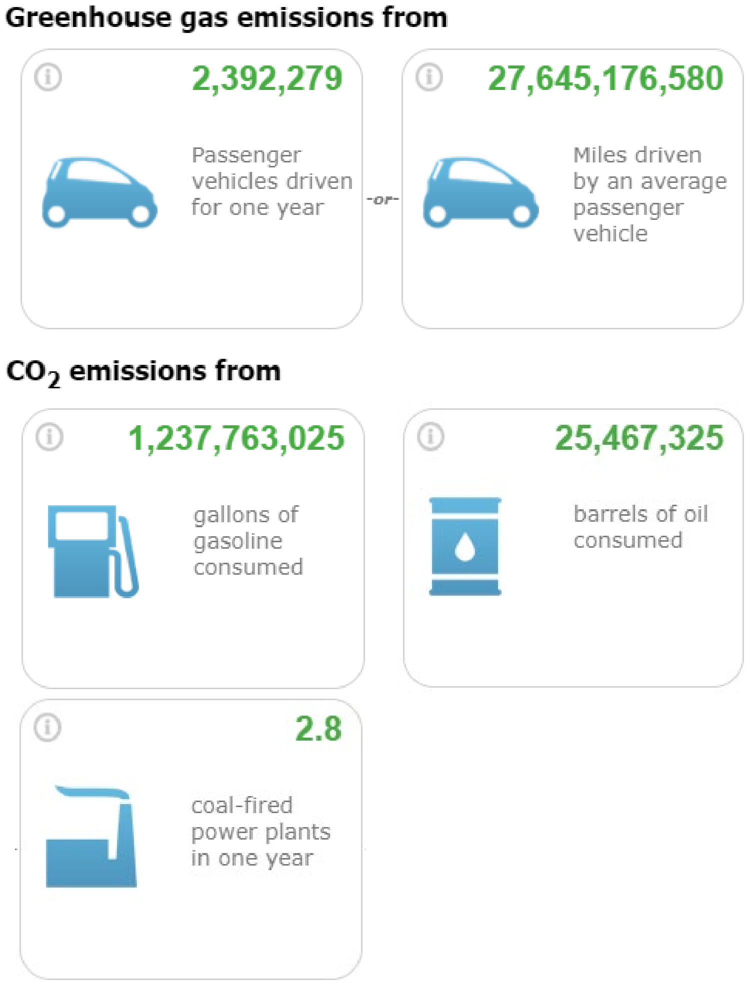
CURRENT FINDINGS & NEXT STEPS

- The results from the ongoing study
  - Are validating that the manufacturing impacts are on the order of the energy savings, so that both use and ‘dematerialization’ are relevant and need to be included in the the design and vision
  - Are demonstrating that full use cases on the end product are key to understanding how to optimize in order to capture the full benefit of the new technology
  - Have so far found no unforeseen consequences or tradeoffs
- Data gaps and data quality factors for key electronic components are unexpectedly challenging – primary data for fabrication is severely lacking, and literature data is a lot older than expected – uncertainty is high.
- The current study is examining only one of several significant applications for the GaN technology. Future work will look at additional consumer charging applications as well as industrial scale uses.

HOW SIGNIFICANT IS THE POTENTIAL BENEFIT FROM ADOPTION IN CONSUMER ELECTRONICS?



Based on forecast units by year for Phone/Tablet/Laptop/PC from industry research



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Thank you for your time.
We're happy to answer questions, now or later:

Caroline Taylor, PhD, caroline@earthshiftglobal.com

Anthony Schiro, anthony.schiro@navitassemi.com

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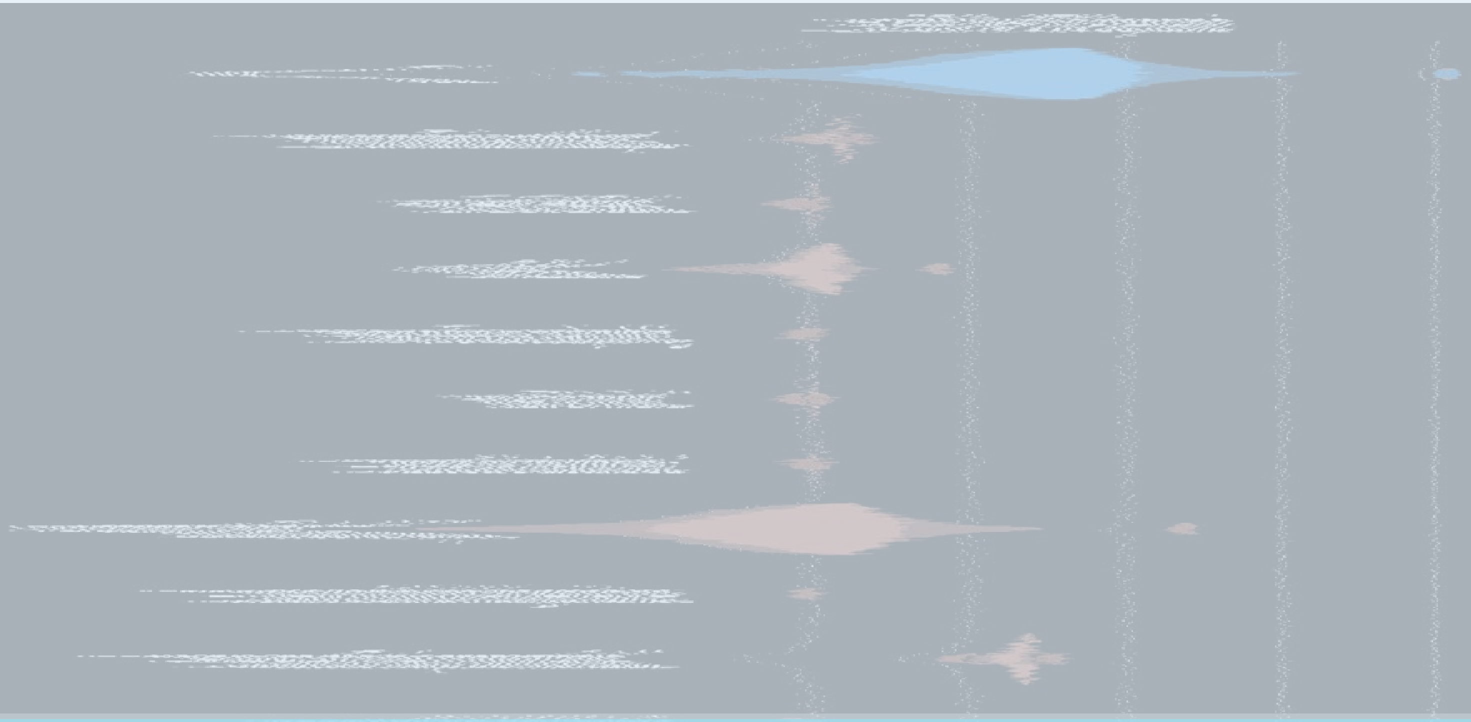
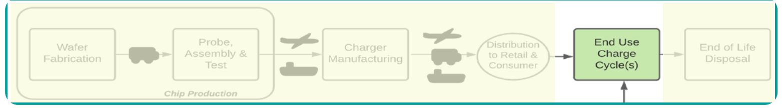
Navitas



SUPPLEMENTAL SLIDES



LAPTOP & CHARGING USE PATTERNS

Work Travel | Work Home | Work Office | Personal Home

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GaN 65W Charger

Packaging

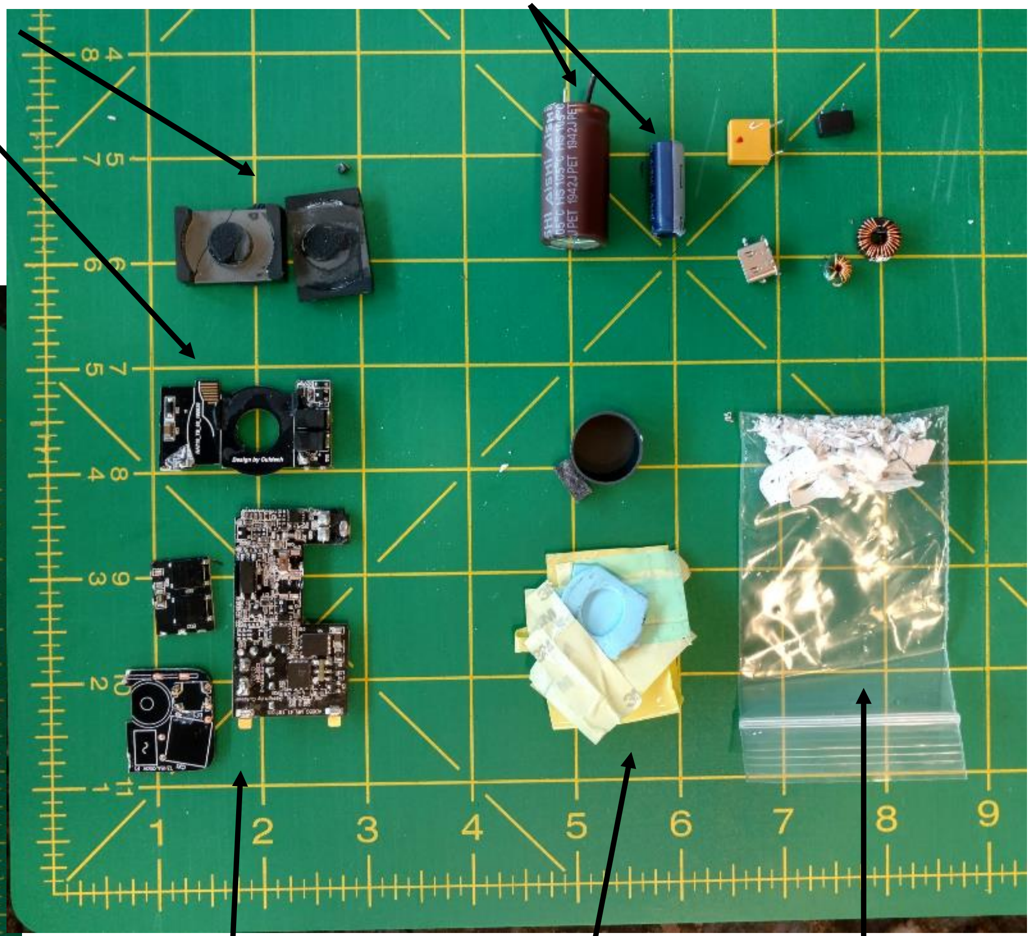
USB Cable

Plastic Case

Planar Transformer Magnet

Planar Transformer Board

Filter Capacitors



PC Boards

Rubber and Plastics Spacers

Potting Material

Copper Shielding and Misc. Metal

Si 65W Charger