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Power Shift: How DOE Efficiency Standards Could Reshape U.S. Transformer Market

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THE TOTAL ENERGY MIX:
POWERING THE FUTURE

JANUARY 20-22, 2026

HENRY B. GONZALEZ CONVENTION CENTER
SAN ANTONIO, TEXAS, USA

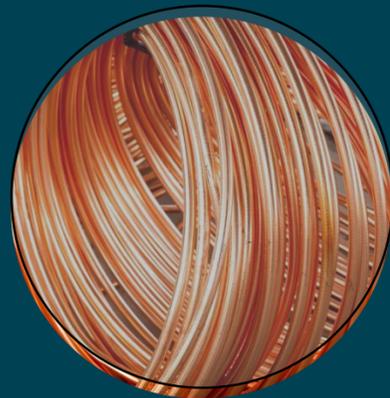
HOST UTILITY:



Agenda



**Introduction and
Why Efficiency
Matters**



**U.S. Market and
Copper's Role**



**DOE Efficiency
Standards**



**Modeling Study
Objectives**



**Modeling
Results and
Discussion**



**Key
Take-Aways**

Who We Are



Copper Development Association

A not-for-profit association of the North American copper industry.

We bring the value of copper and its alloys to society, to solve the challenges of today and tomorrow.

Codes, Standards, & Regulatory Advocacy | Technical Assistance | Scientific Research | Education & Training | Community Building | Policy Making

copper.org

Who We Are



Strategic Partnership

CDA is proud to be a strategic partner of the International Copper Association (ICA), a powerhouse of expertise committed to promoting, protecting and defending copper around the world.

With a diverse global team, ICA and its members harness the power of deep industry and market knowledge to drive cutting-edge advancements. Through research, data, and advocacy, ICA champions copper as the go-to material for industries across the globe.

Together, CDA and ICA are the voice of the copper industry

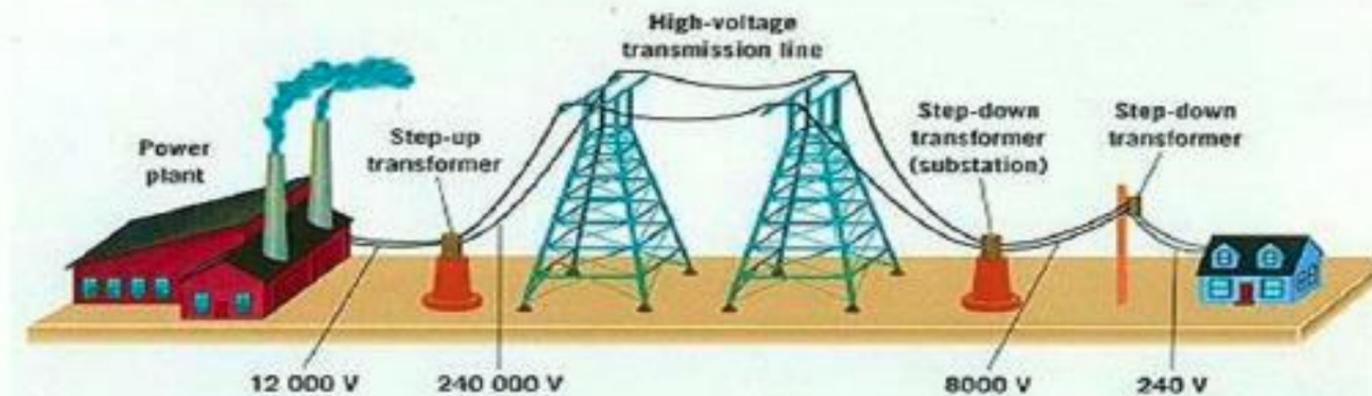
Introduction and Why Efficiency Matters

Introduction and Why Efficiency Matters

- Transformers are part of the electrical grid
- Transformers step up and down voltage
- Transformers come in various sizes based on rated power and application use
 - Power
 - Distribution
 - Specialty

Transmission and Distribution Network

How power is distributed in the transformer grid (illustrative figure): power transformers transfer energy to the transmission lines, and distribution transformers make that energy accessible to consumers.



A configuration of pole mounted transformers



Substation distribution transformer



A very large power transformer



Introduction and Why Efficiency Matters

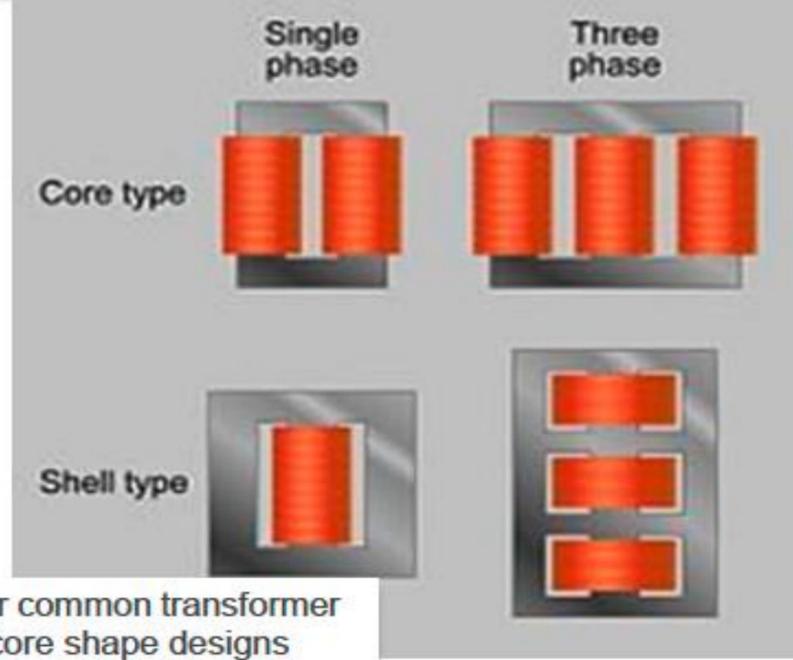
Transformer Core Designs

Transformer Design Considerations:

- ✓ Single or Three Phase
- ✓ Oil/Liquid or Dry Insulation
- ✓ Core Shape
- ✓ Application Setting
- ✓ Wiring Material Configurations

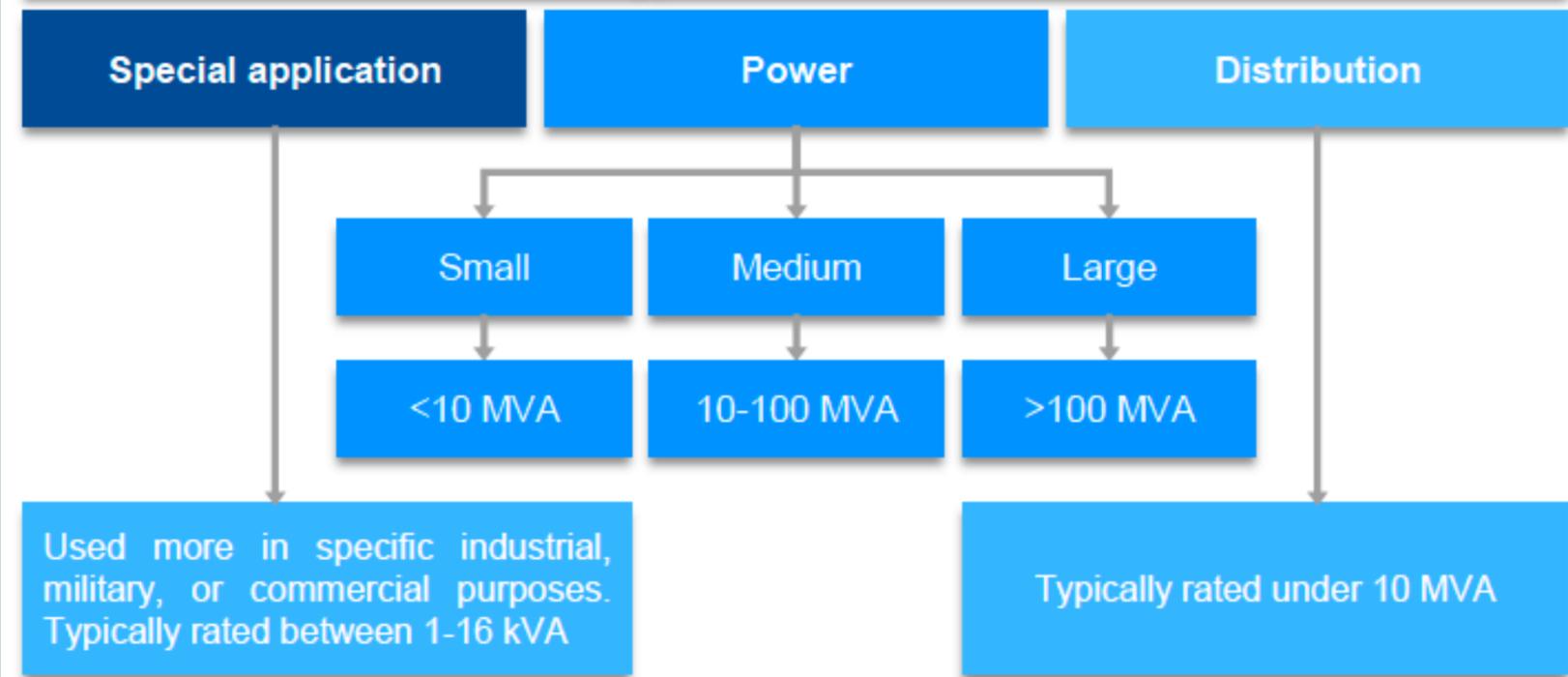


On the left, a dry-type transformer. On the right, a pole-mounted oil transformer.



- Transformer Designs vary based on application demands and power size
- Conductors are copper and/or aluminum
- Cores are grain oriented electrical steel (GOES) or amorphous alloys

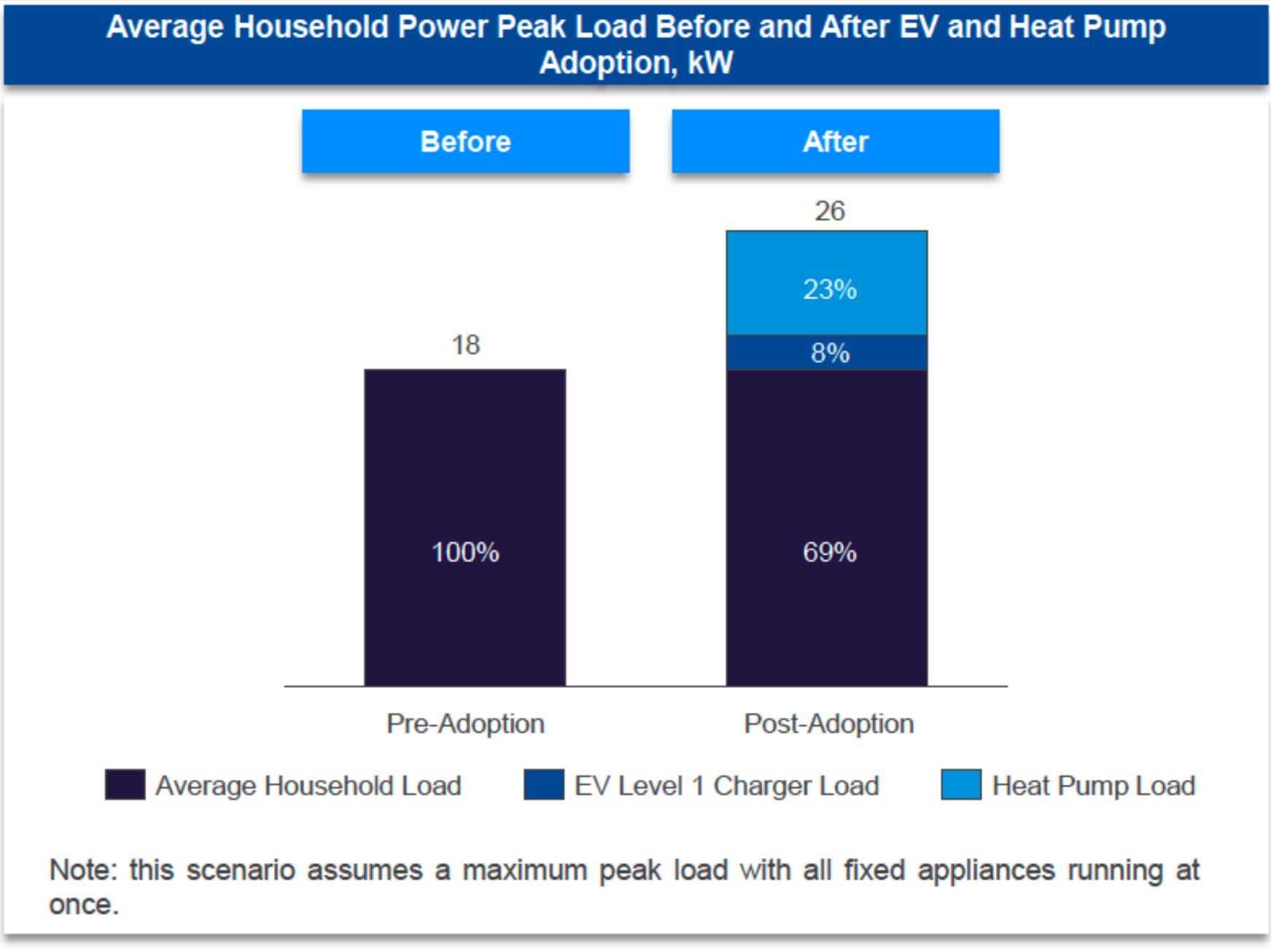
Types of transformer



Introduction and Why Efficiency Matters

Key Household Electrification Changes			
	EV Charging		Battery Storage and Charging
	Heat Pump Clothes Dryer		Induction Cooking
	Heat Pump Climate Control		Heat Pump Water Heater

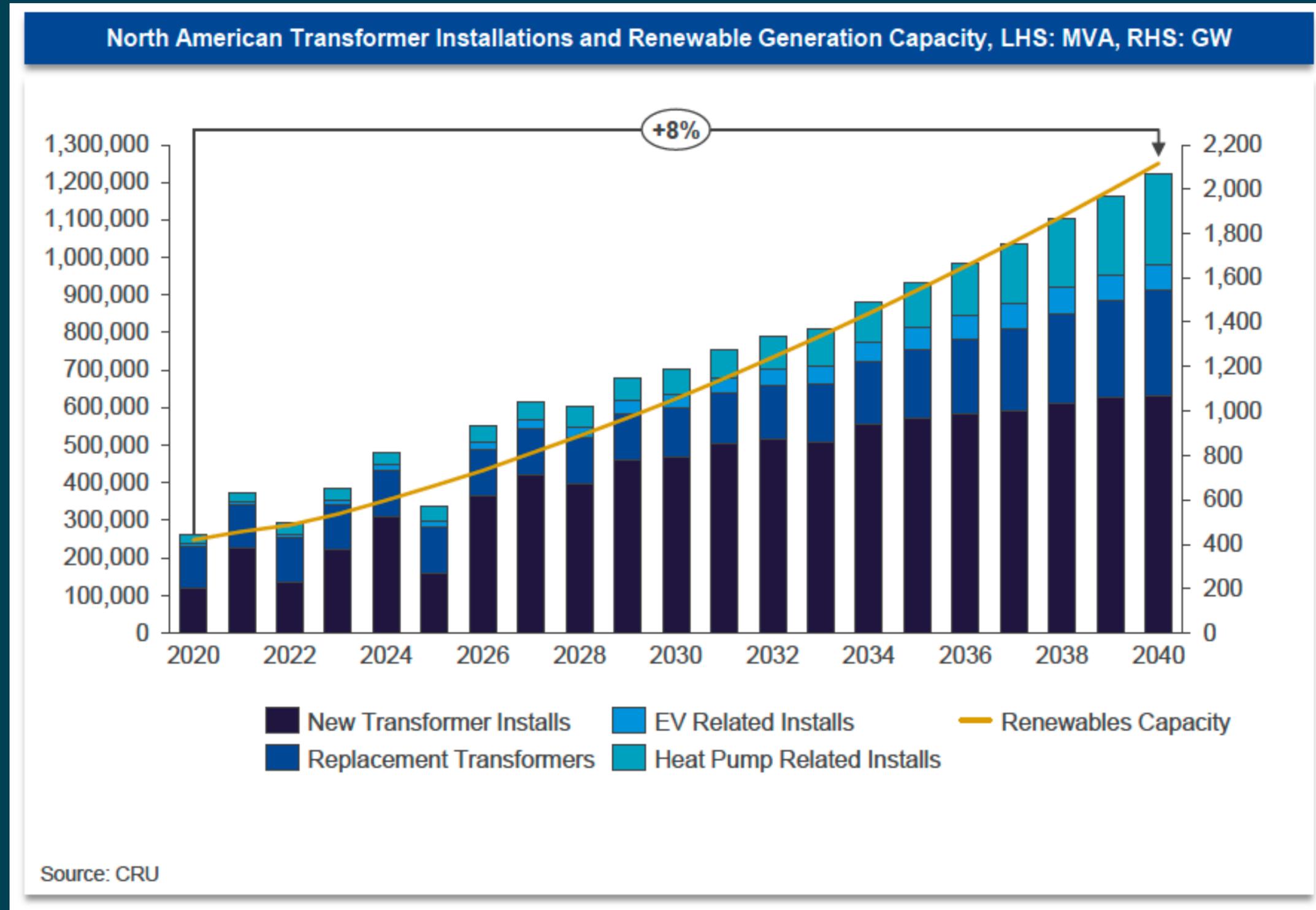
Transformer loads and demands are expected to increase significantly as electrification deepens and spreads



Source: CRU

Introduction and Why Efficiency Matters

- Transformer installations are expected to grow along with renewable energy capacity
- Majority are New Transformer installations followed by Replacements
- EV Charging and Heat Pump installations drive significant additional demands



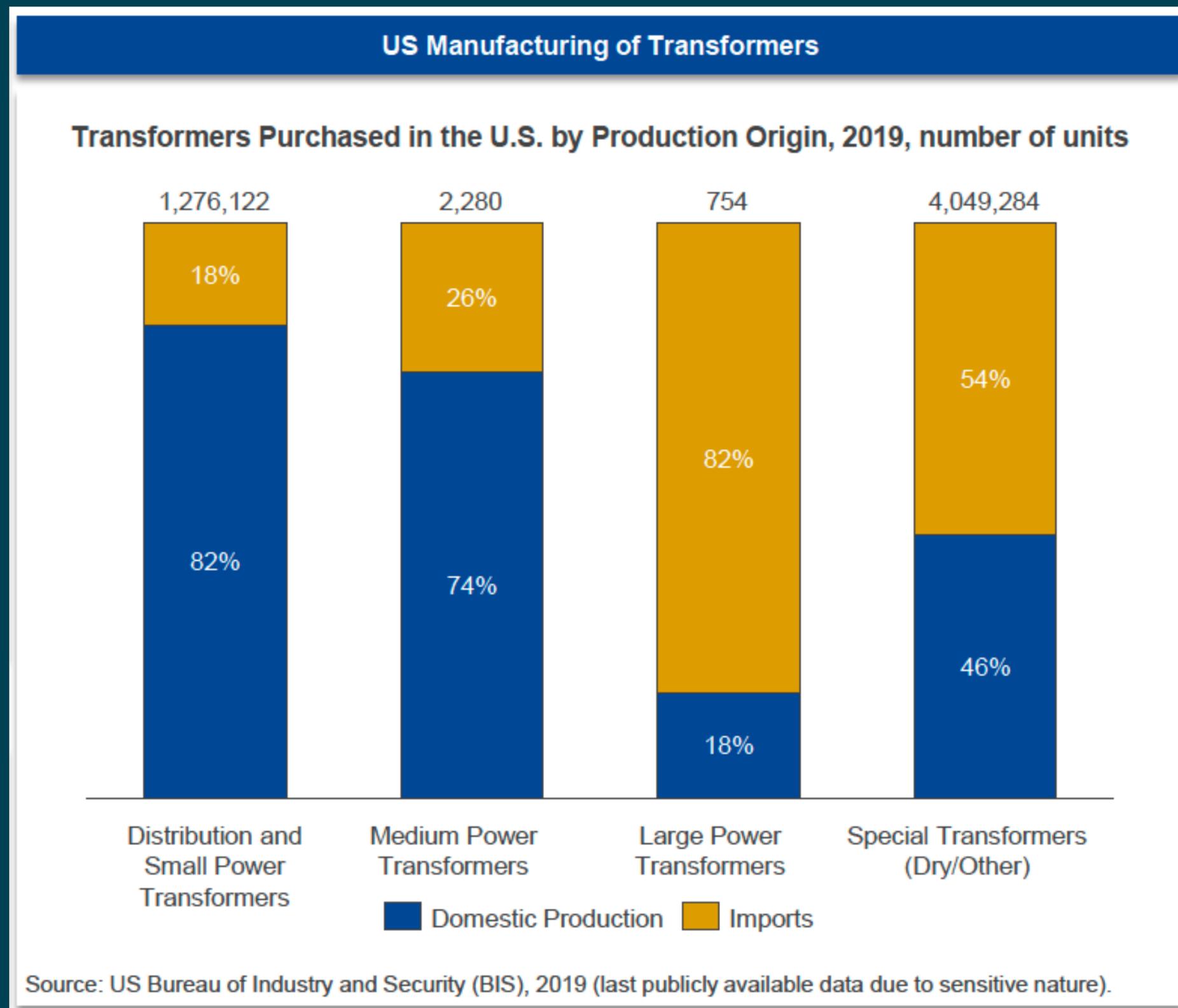
Introduction and *Why Efficiency Matters*

- Minimum Efficiency Standards are established to control impacts of electrical losses → electrical losses decrease as efficiencies increase
- Increasing electrical efficiency reduces wasted electricity, improving operational costs and emissions simultaneously, and even more important as demands grow to reduce additional power plant and materials demands
- Increasing efficiency comes at a cost, requiring more or upgraded materials, and Total Cost of Ownership (TCO) models determine payback benefits
- The more electricity produced and used, the more costly and wasteful inefficiency becomes. For instance, the US uses on average nearly 4 trillion kWh of electricity annually (4,000 TWh), and a loss of just 0.1% is 40 million kWh (40 TWh)
 - Based on \$0.20/kWh, this costs \$0.8 trillion per year (US GDP ~ \$30 trillion/year)
 - Based on 300g CO₂/kWh, this costs 12 million tons of carbon emissions per year (US CO₂ emissions ~ 5-6 billion tons)

U.S. Market and Copper's Role

U.S. Market and Copper's Role

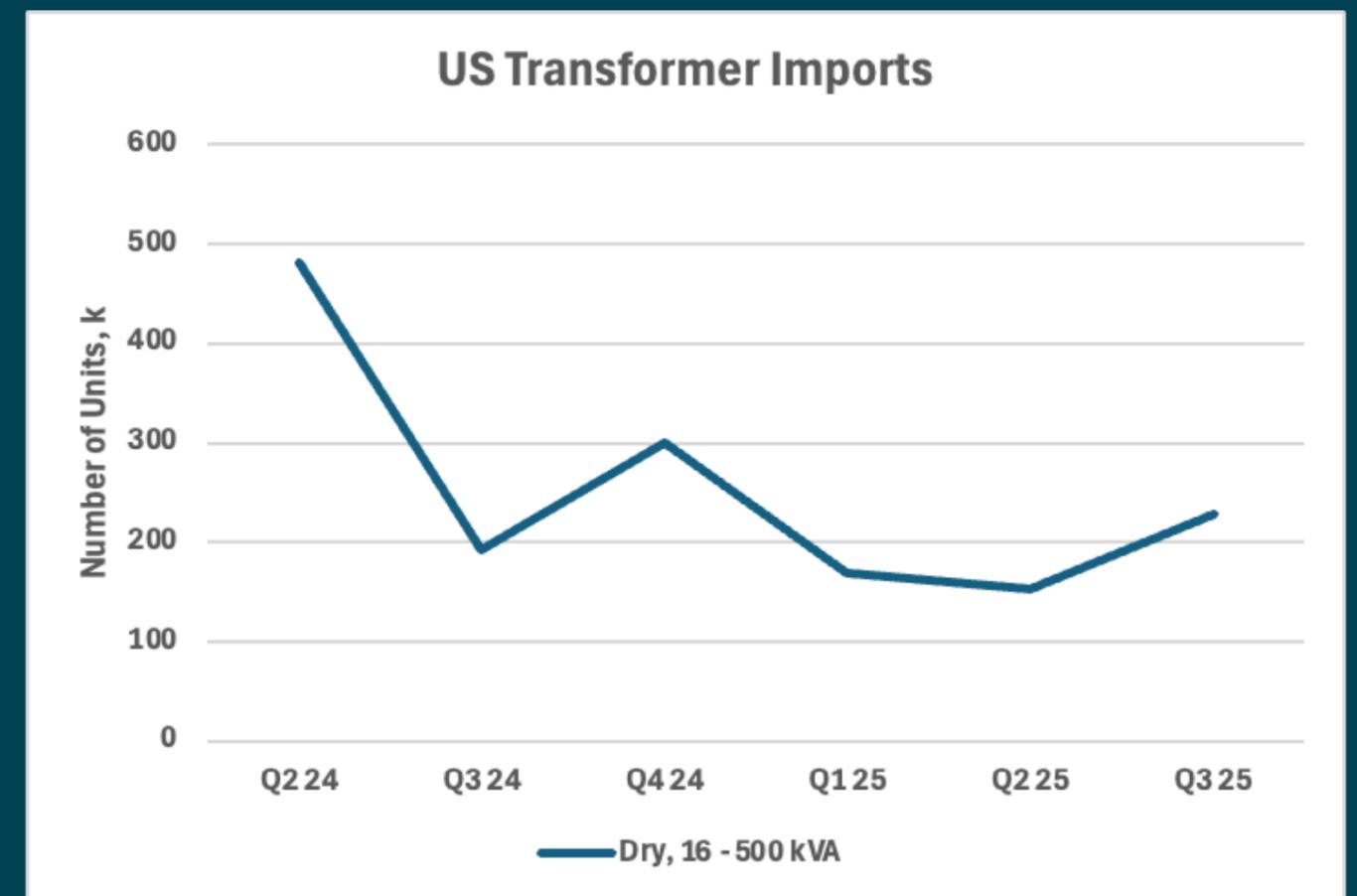
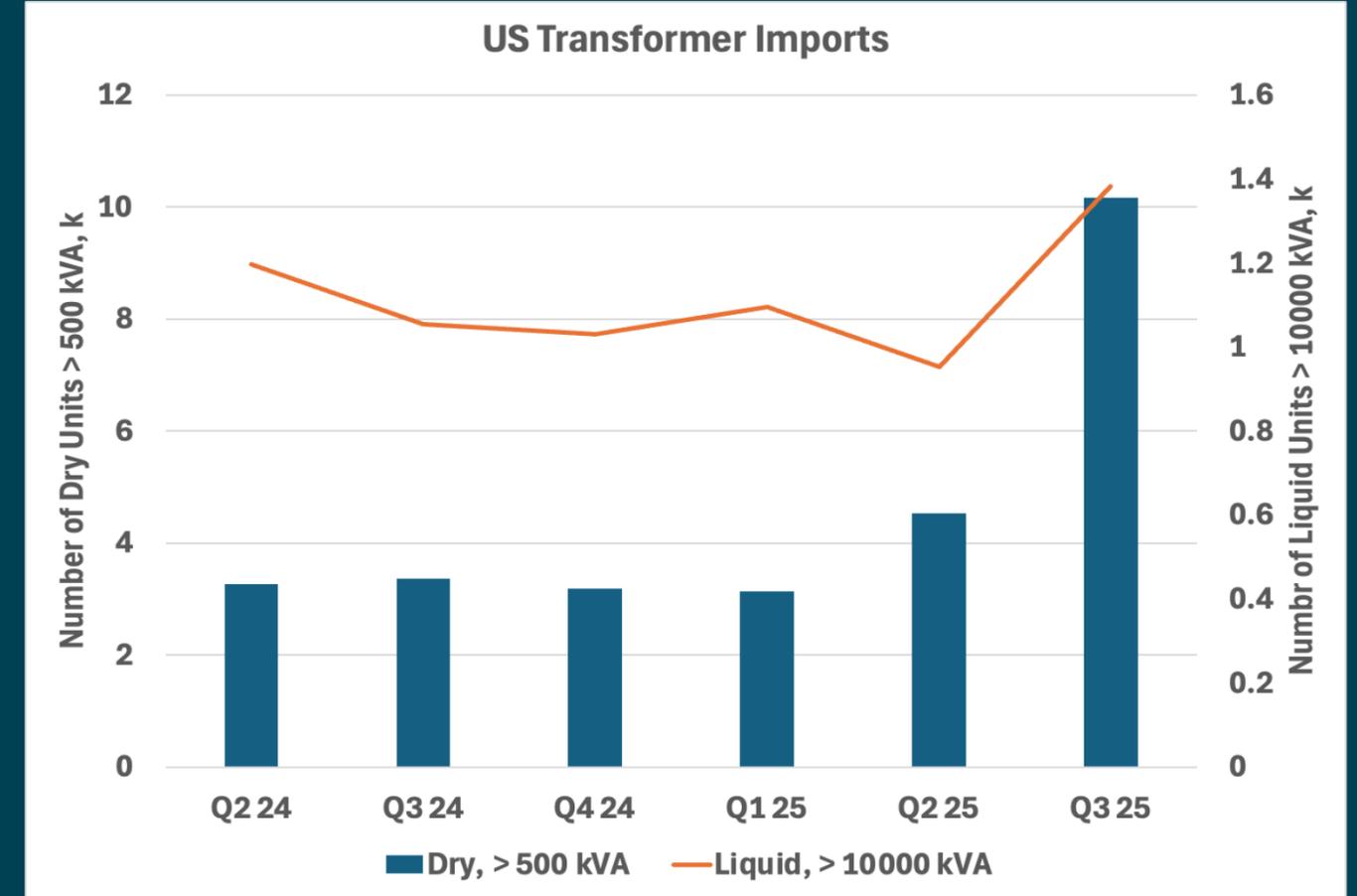
- US imports a portion of its purchased transformers
- Specialty transformers account for most purchases with over half imported
- Less than 20% of Large Power Transformers are produced domestically, an acknowledged national security threat
- Distribution and Small Power Transformers > 400x the purchases of Medium + Large Power Transformers



U.S. Market and Copper's Role

- Transformer Import trends illustrate Dry >500 kVA and Liquid >10,000 kVA transformers are up over +200% and +31%, respectively, in Q325 vs. Q324
- Dry transformers 16-500 kVA imports have dropped, but remain one of the largest at hundreds of thousands imported annually
- “In 2025, imports will account for an estimated 80% of US power transformer supply and 50% of the distribution transformer supply.”

Ben Boucher
Wood Mackenzie



Source: Datamyne

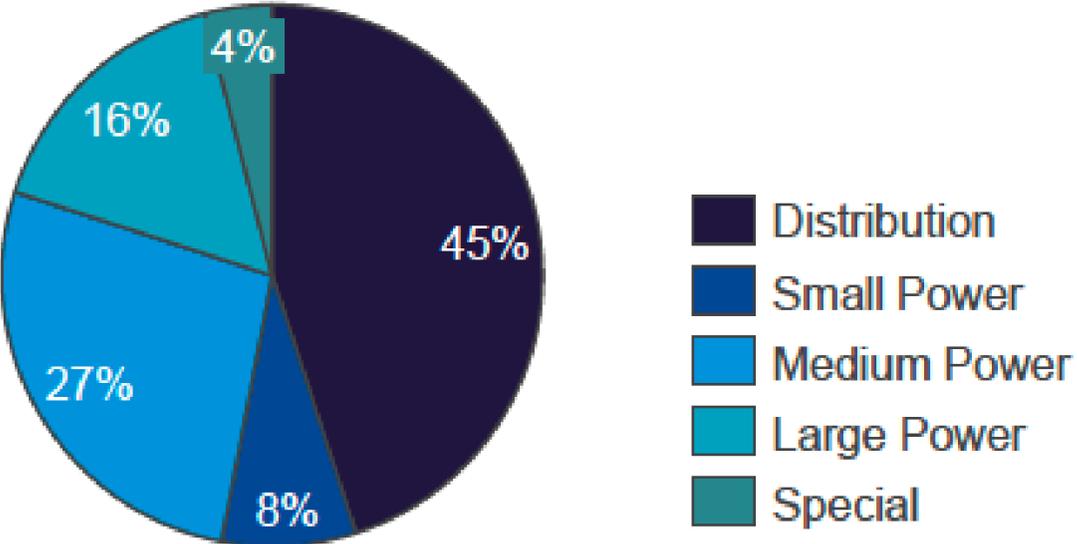
U.S. Market and Copper's Role

Share of Total US Unit Purchases by Transformer Type, 2019

Special and distribution transformers constitute the bulk of total transformers purchased by the U.S. market.



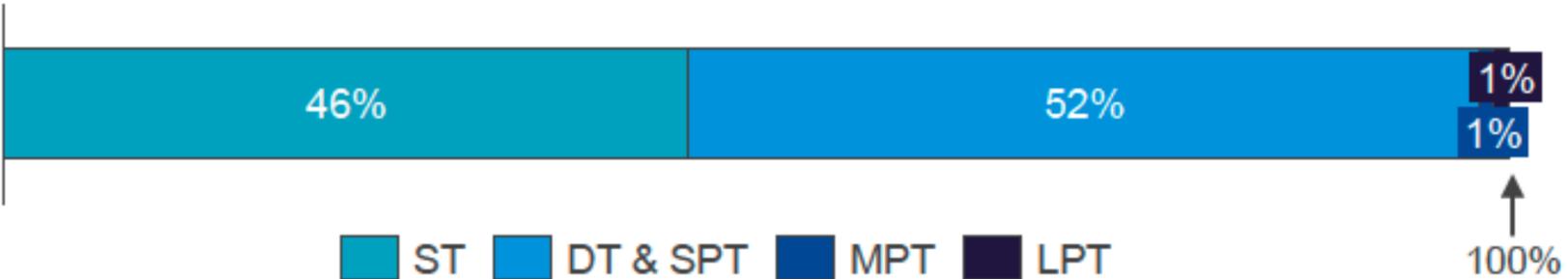
Market Share of Copper Consumed by Transformer Type



Source: CRU

Share of Total US Produced Transformers Sold in 2019

Special, distribution, and small power transformers constitute the bulk of domestically produced units for the US market.



100%

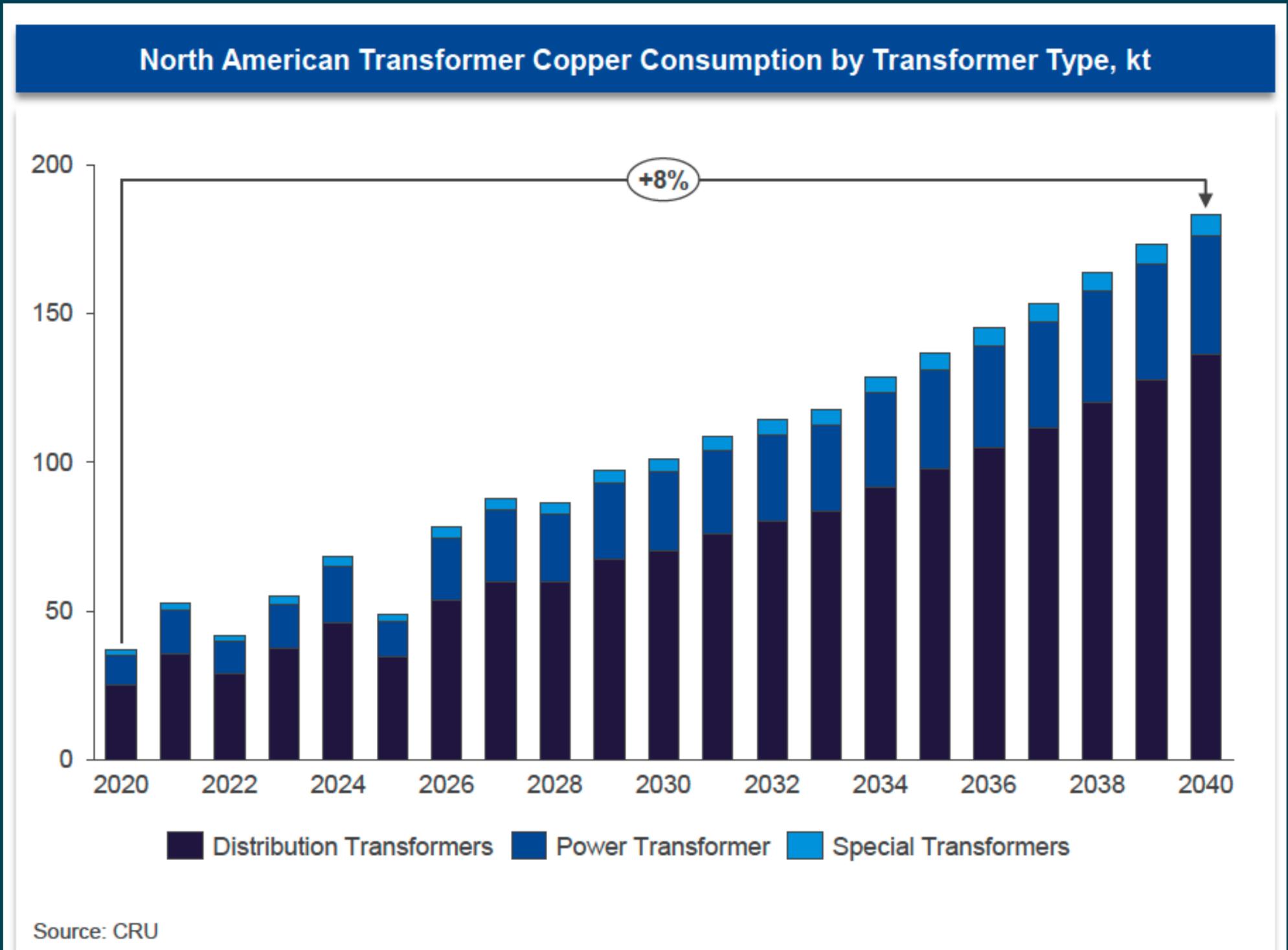
Source: CRU

Distribution and Small Power Transformers account for

- nearly a quarter of US purchases and half of US production
- over half of the copper applied across domestically manufactured transformers

U.S. Market and Copper's Role

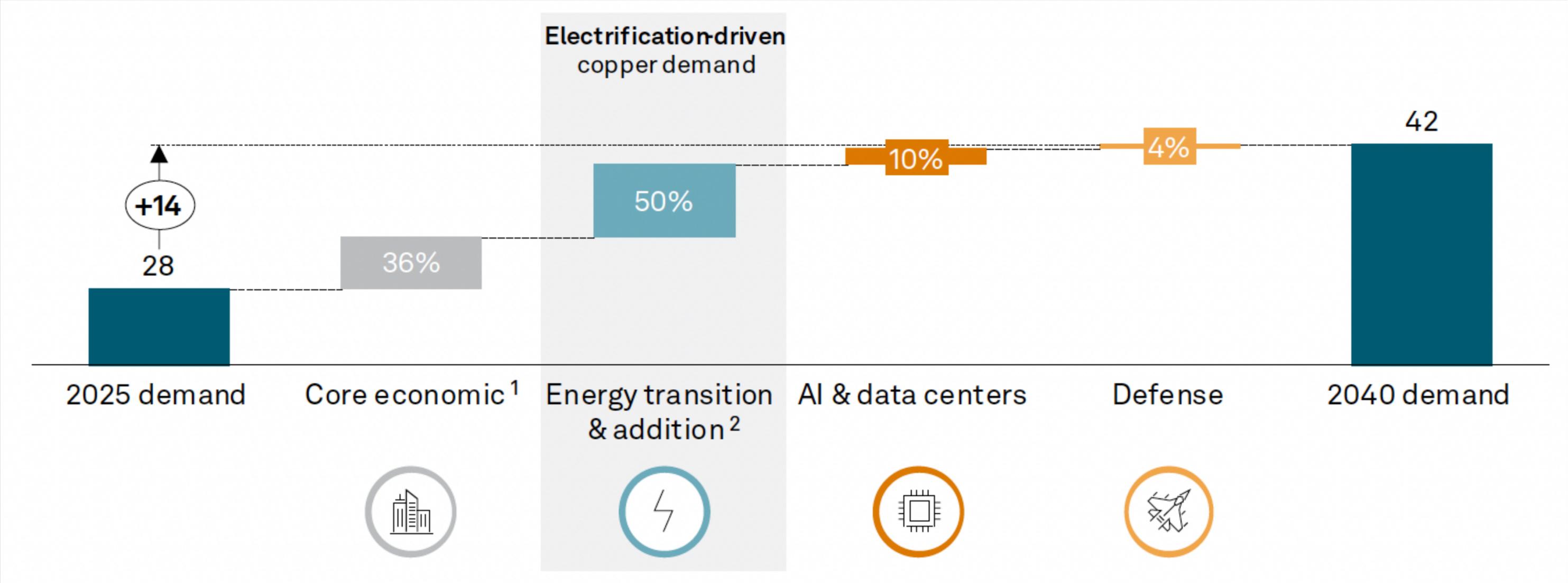
- Transformer installations are expected to grow as grid expands and is upgraded, including domestically produced and imported
- Copper in transformers continues to grow with Distribution Transformers holding a majority share



Note: The chart shows the cumulative copper content in all the transformers consumed by the North American market.

U.S. Market and Copper's Role

Projected Copper Demands



Source: S&P Global: "Copper in the Age of AI"

The world requires 50% more copper to satisfy demands by 2040 and half of this in support of electrification, including transformers

DOE Efficiency Standards

DOE Efficiency Standards

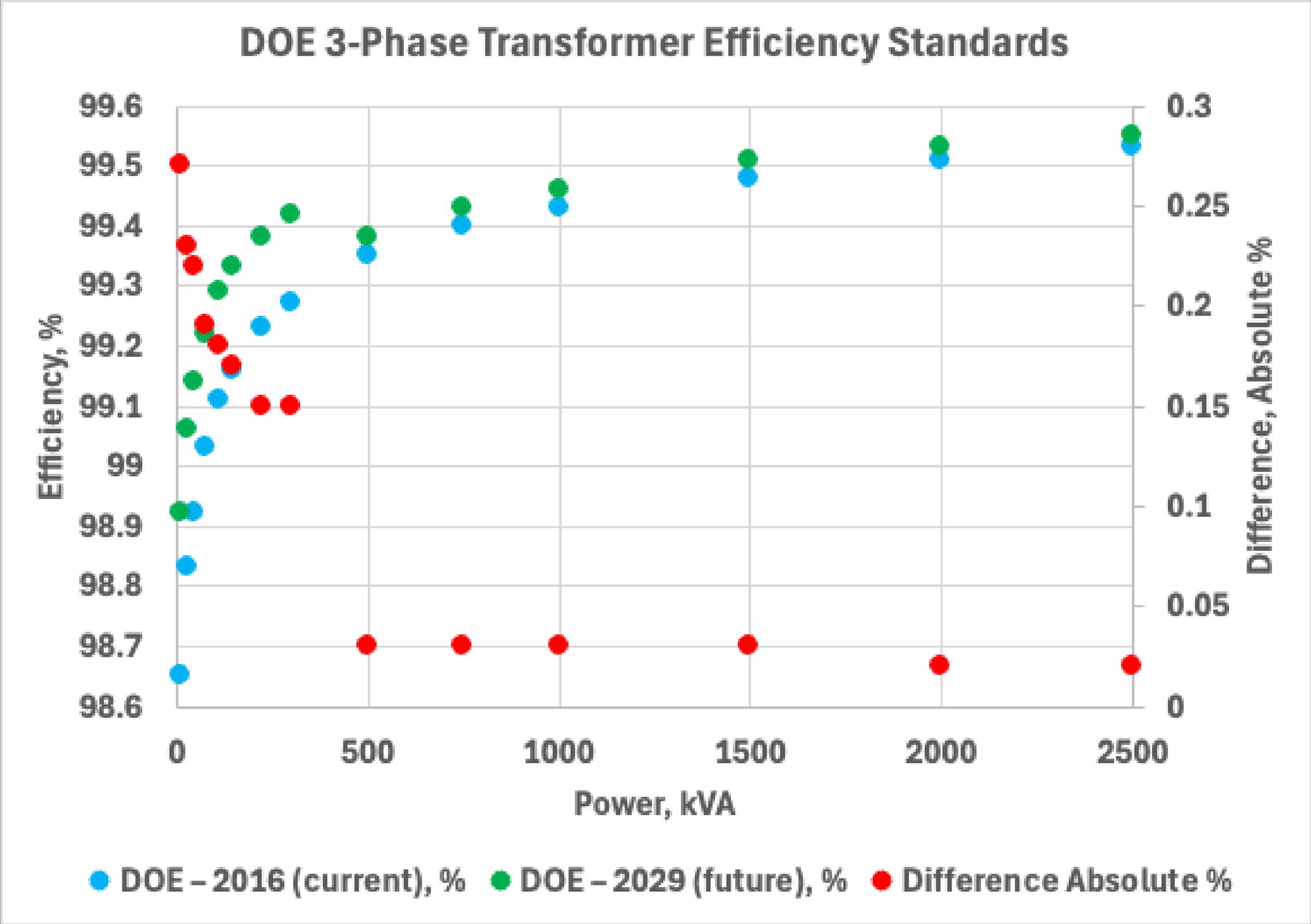
- Finalized in April 2024, Distribution Transformers, including liquid immersed, low and medium voltage dry type, and single and three phase
- US has over 60 million distribution transformers across grid network with millions added annually; distribution transformers are expected to more than triple by 2050
- Goals are to increase resiliency and efficiency of the power grid, support manufacturing jobs, and save money on electricity costs (\$824M/year) while accelerating affordable, reliable, and clean electricity
- Takes effect in 2029 (extended), providing 5 years for the industry to accommodate needed supply chain shifts, such as that of core materials from grain oriented electrical steel (GOES) to amorphous alloys in some applications
- \$14B in cost savings and 85 million tons of CO2 emissions reduced over 30 years

DOE Efficiency Standards

2024 Efficiency Ruling Summary for Three Phase Transformers

Power kVA	DOE – 2016 (current), %	DOE – 2029 (future), %	Difference Absolute %
15	98.65	98.92	0.27
30	98.83	99.06	0.23
45	98.92	99.14	0.22
75	99.03	99.22	0.19
112.5	99.11	99.29	0.18
150	99.16	99.33	0.17
225	99.23	99.38	0.15
300	99.27	99.42	0.15
500	99.35	99.38	0.03
750	99.40	99.43	0.03
1000	99.43	99.46	0.03
1500	99.48	99.51	0.03
2000	99.51	99.53	0.02
2500	99.53	99.55	0.02

DOE Efficiency Standards



Modeling Study Objectives

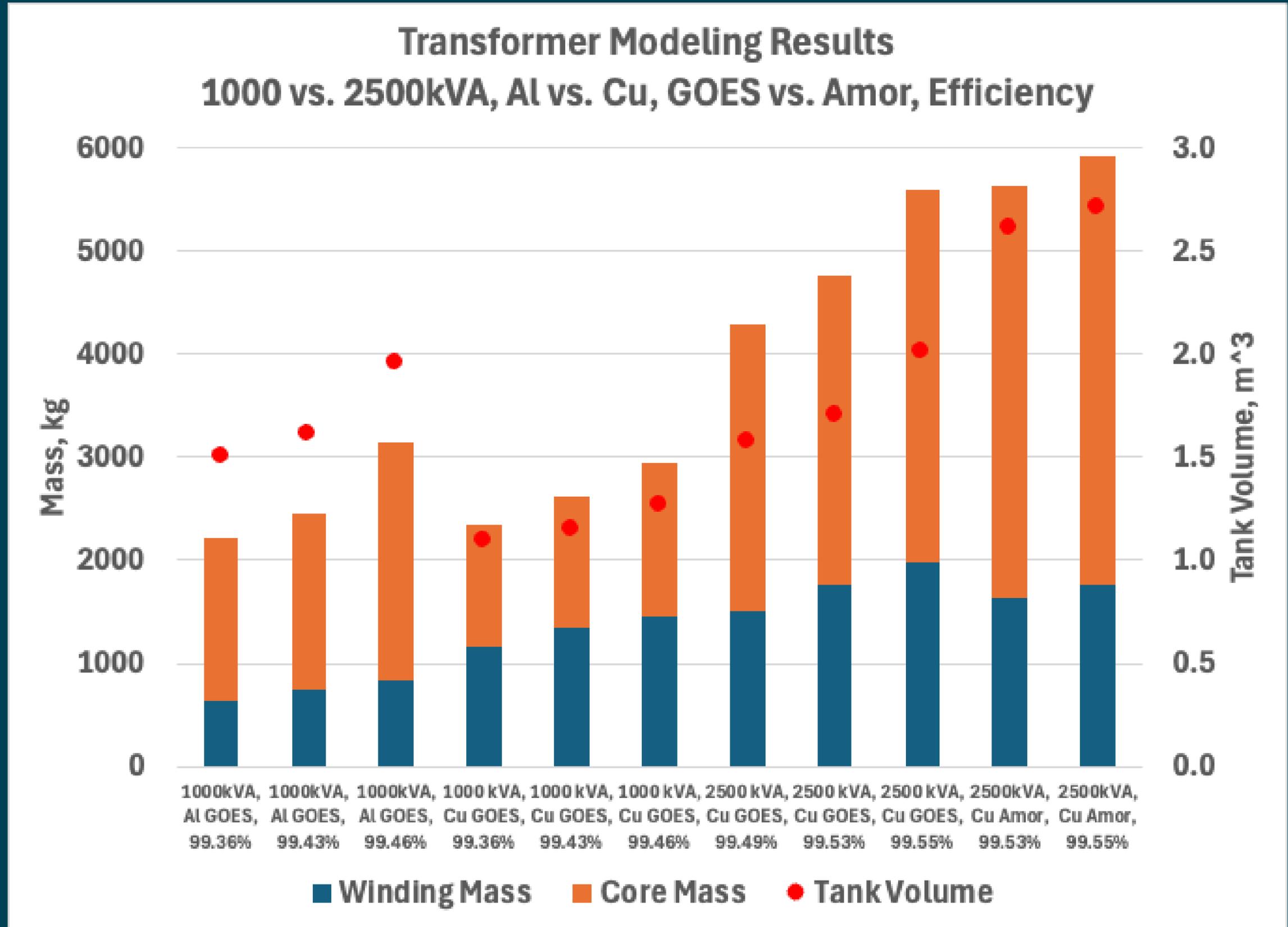
Modeling Study Objectives

- How much copper is required in distribution transformers and how does its content change across power size, efficiency, as well as applied core materials?
- How much more overall copper is required for distribution transformers across the US based on increased efficiency standards?
- What growth in size and mass are expected in distribution transformers because of efficiency improvements?
- How do aluminum conductors compare with copper in distribution transformers across power size, efficiency, as well as applied core materials?
- What advantages does copper gain over aluminum in distribution transformers as efficiency requirements increase?

Modeling Results and Discussion

Modeling Results and Discussion

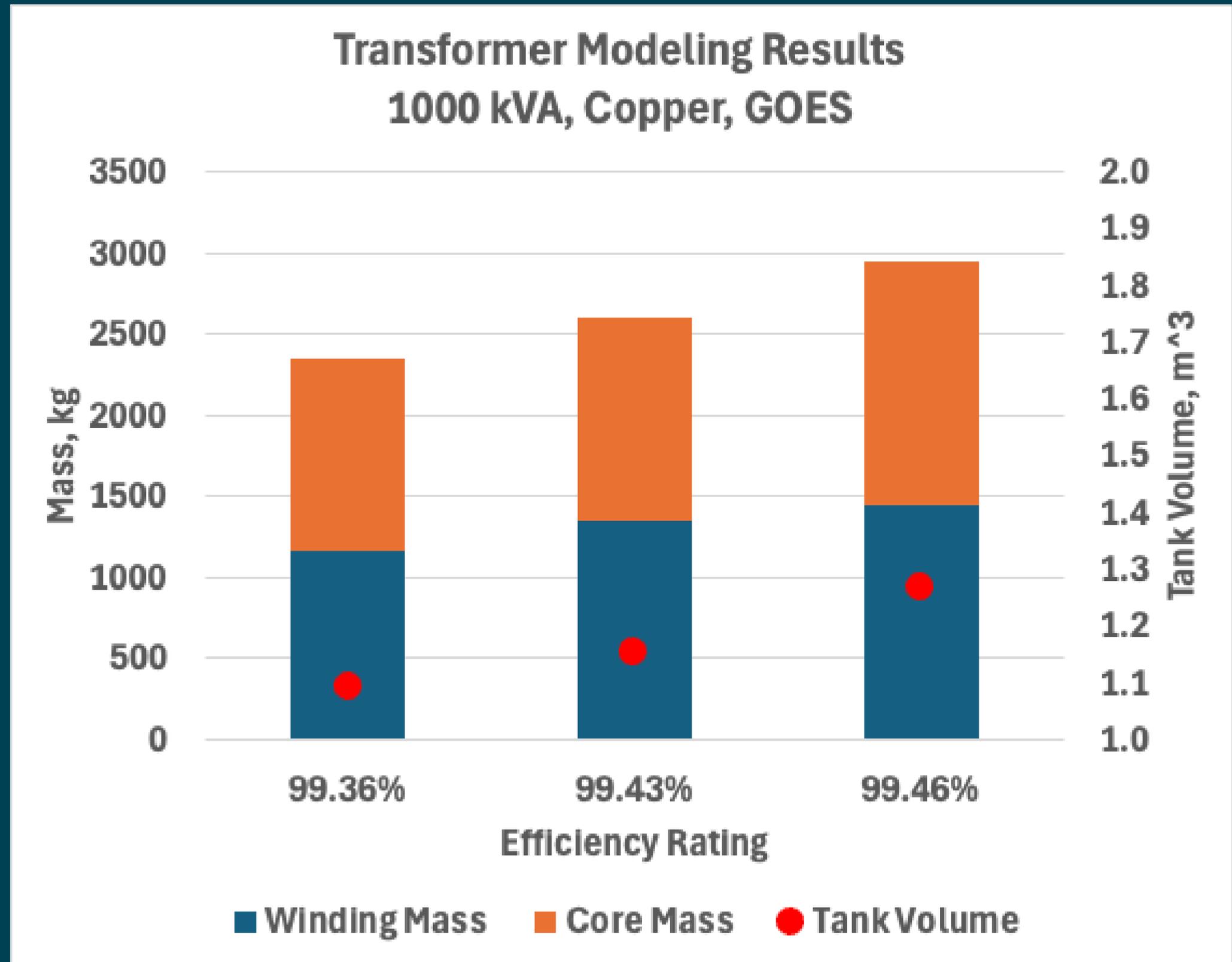
- Collective results, following slides quantify comparisons
- Each design compared across 2-3 efficiency levels
 - FUTURE ruling (2029)
 - CURRENT ruling
 - PAST ruling
- Windings are Copper, Aluminum is compared at 1000 kVA
- GOES cores, Amorphous is compared at 2500 kVA with Copper windings



Cu

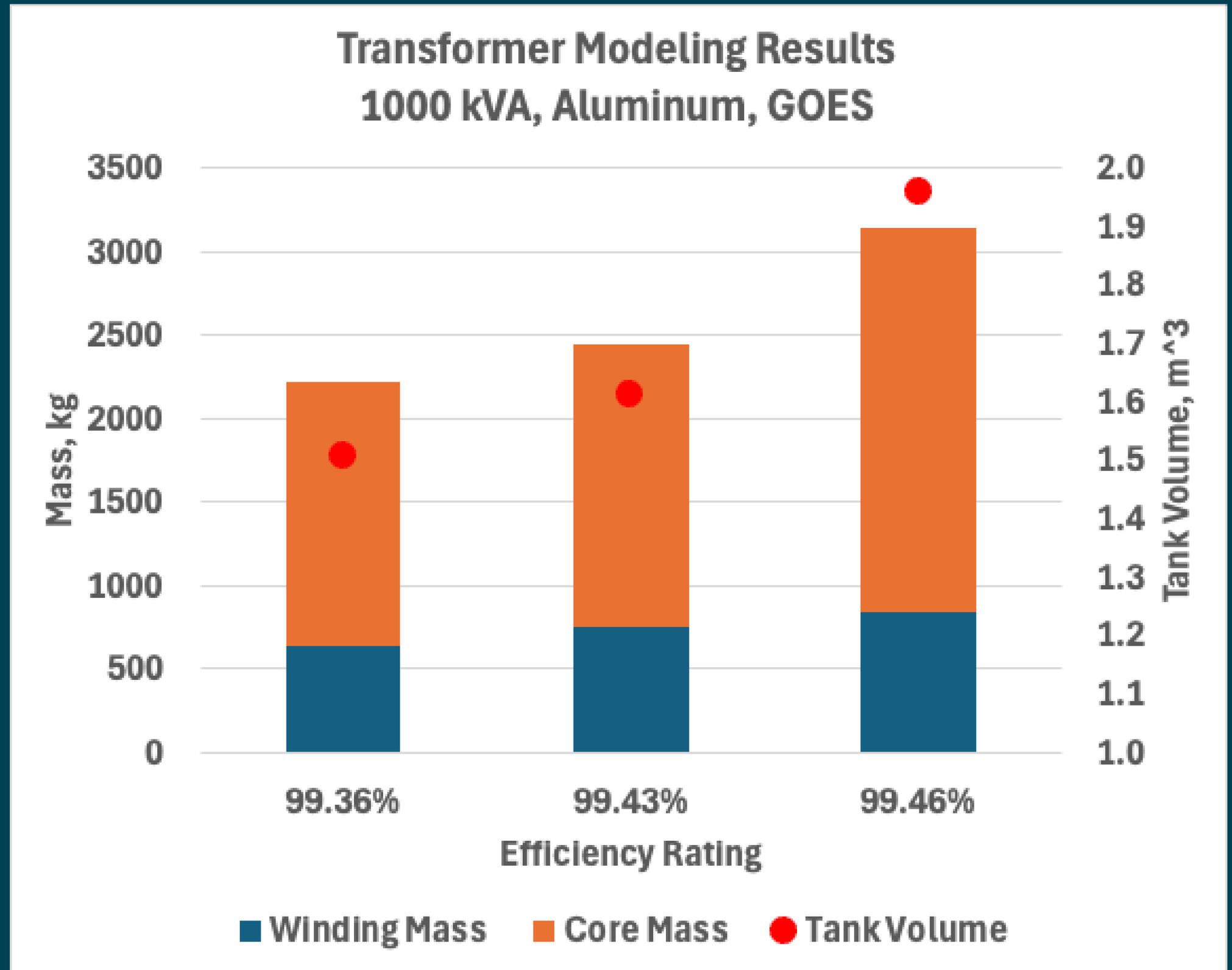
Modeling Results and Discussion

- CURRENT to FUTURE, +0.03%
 - Total Mass, +13%
 - Winding Mass, +7%
 - Core Mass, +19%
 - Tank Volume, +10%
- PAST to CURRENT, +0.07%
 - Total Mass, +11%
 - Winding Mass, +15%
 - Core Mass, +7%
 - Tank Volume, +13%
- Although the FUTURE rating increase is less than half that of the PAST, its effect on size and mass is similar → each incremental step increase costs more than the last



Modeling Results and Discussion

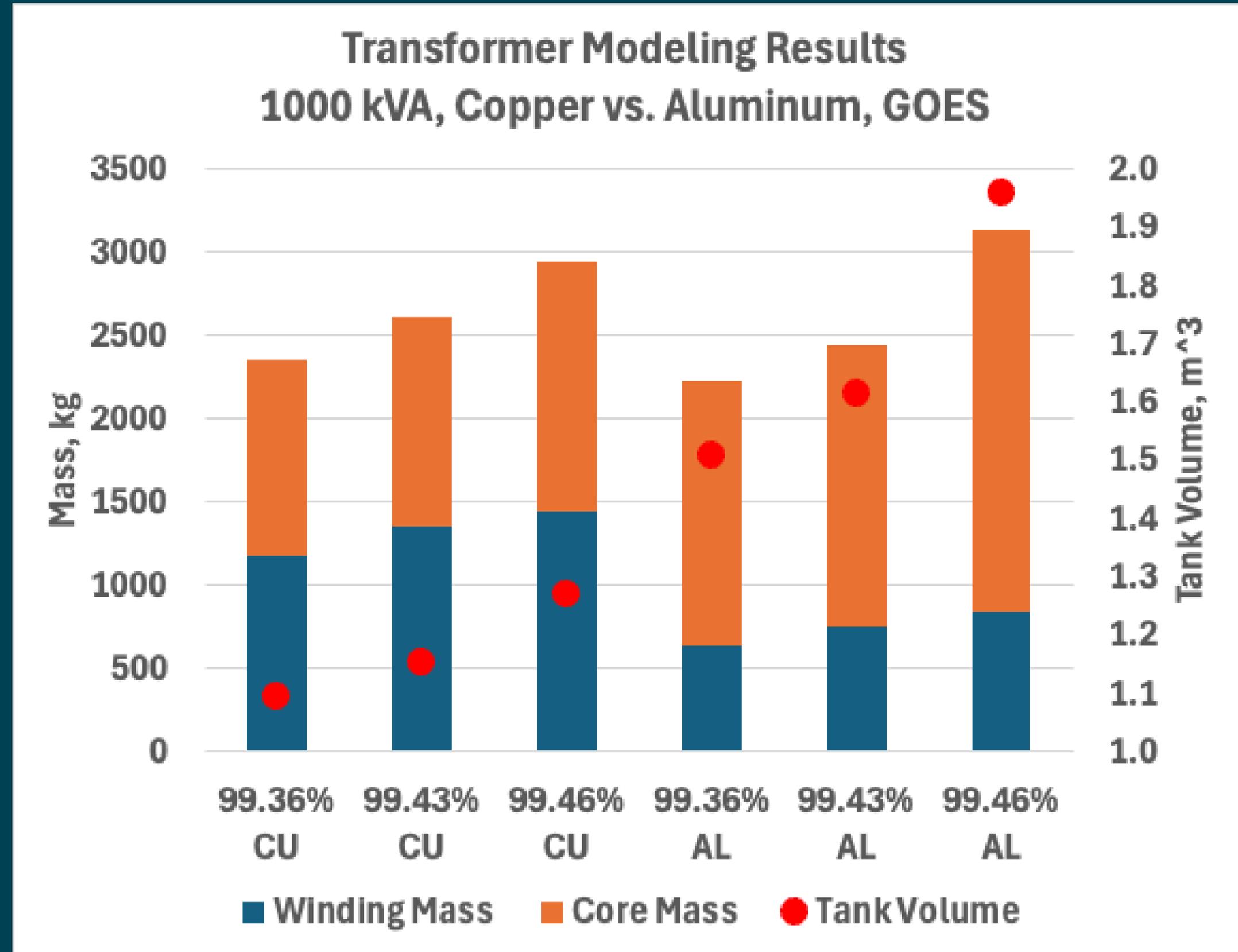
- CURRENT to FUTURE, +0.03%
 - Total Mass, +28%
 - Winding Mass, +12%
 - Core Mass, +35%
 - Tank Volume, +21%
- PAST to CURRENT, +0.07%
 - Total Mass, +10%
 - Winding Mass, +18%
 - Core Mass, +7%
 - Tank Volume, +7%
- As efficiency increases, aluminum systems increase their material demands more quickly than copper systems



Modeling Results and Discussion

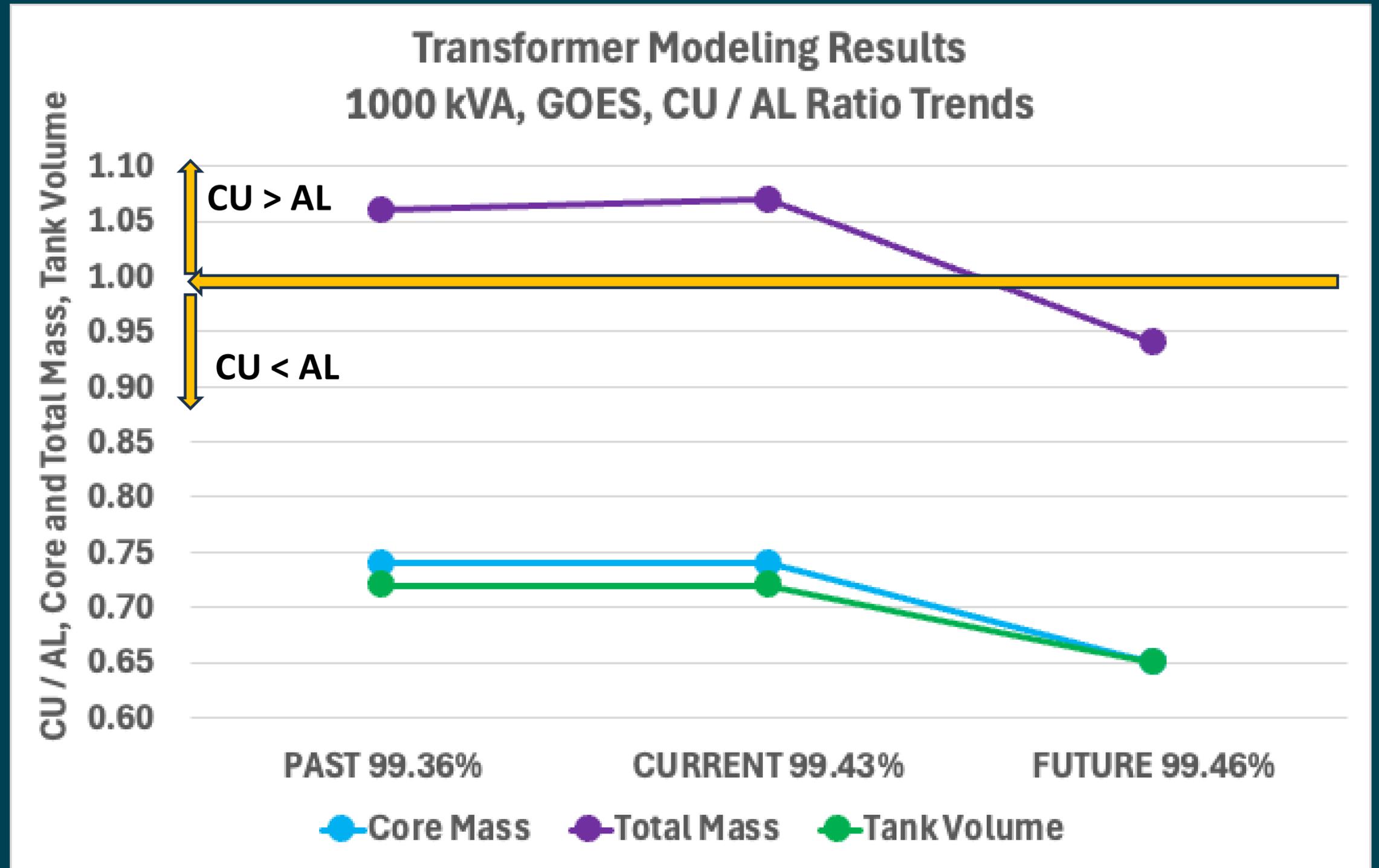
Ratio of CU / AL

- FUTURE, 99.46%
 - Total Mass, 0.94
 - Winding Mass, 1.73
 - Core Mass, 0.65
 - Tank Volume, 0.65
- CURRENT, 99.43%
 - Total Mass, 1.07
 - Winding Mass, 1.80
 - Core Mass, 0.74
 - Tank Volume, 0.72
- PAST, 99.36%
 - Total Mass, 1.06
 - Winding Mass, 1.84
 - Core Mass, 0.74
 - Tank Volume, 0.72



Modeling Results and Discussion

- As Efficiencies increase, CU / AL Ratios decrease
- Reductions in CU / AL Ratios signal advantages for copper conductors
- Copper always has a size advantage with its higher conductivity, offering smaller packages
- As efficiencies increase, copper gains mass advantage → smaller and lighter



Modeling Results and Discussion

2500 kVA, Copper, GOES

- CURRENT to FUTURE, +0.02%

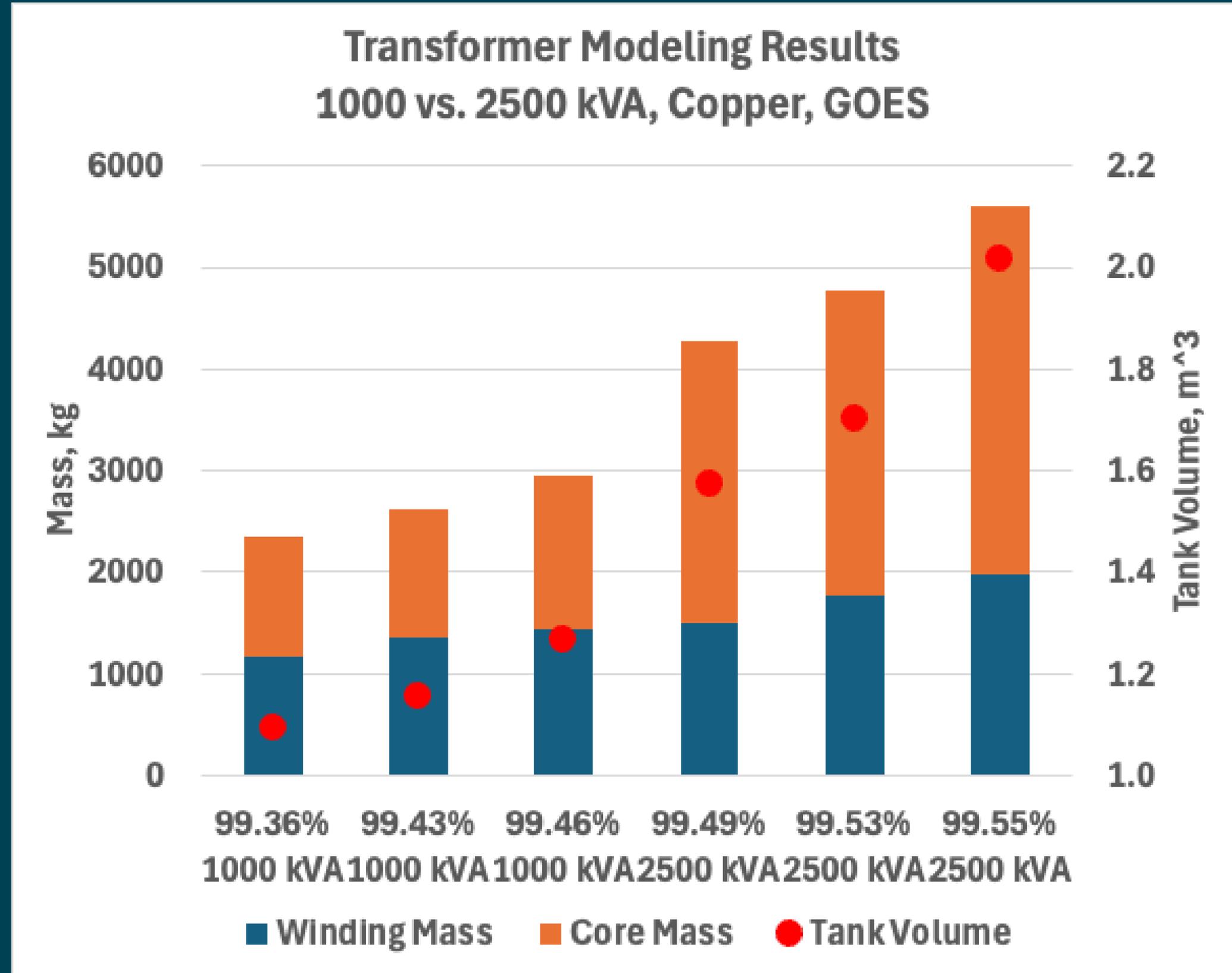
- Total Mass, +18%
- Winding Mass, +12%
- Core Mass, +21%
- Tank Volume, +19%

- PAST to CURRENT, +0.04%

- Total Mass, +11%
- Winding Mass, +17%
- Core Mass, +8%
- Tank Volume, +8%

- 1000 to 2500 kVA FUTURE

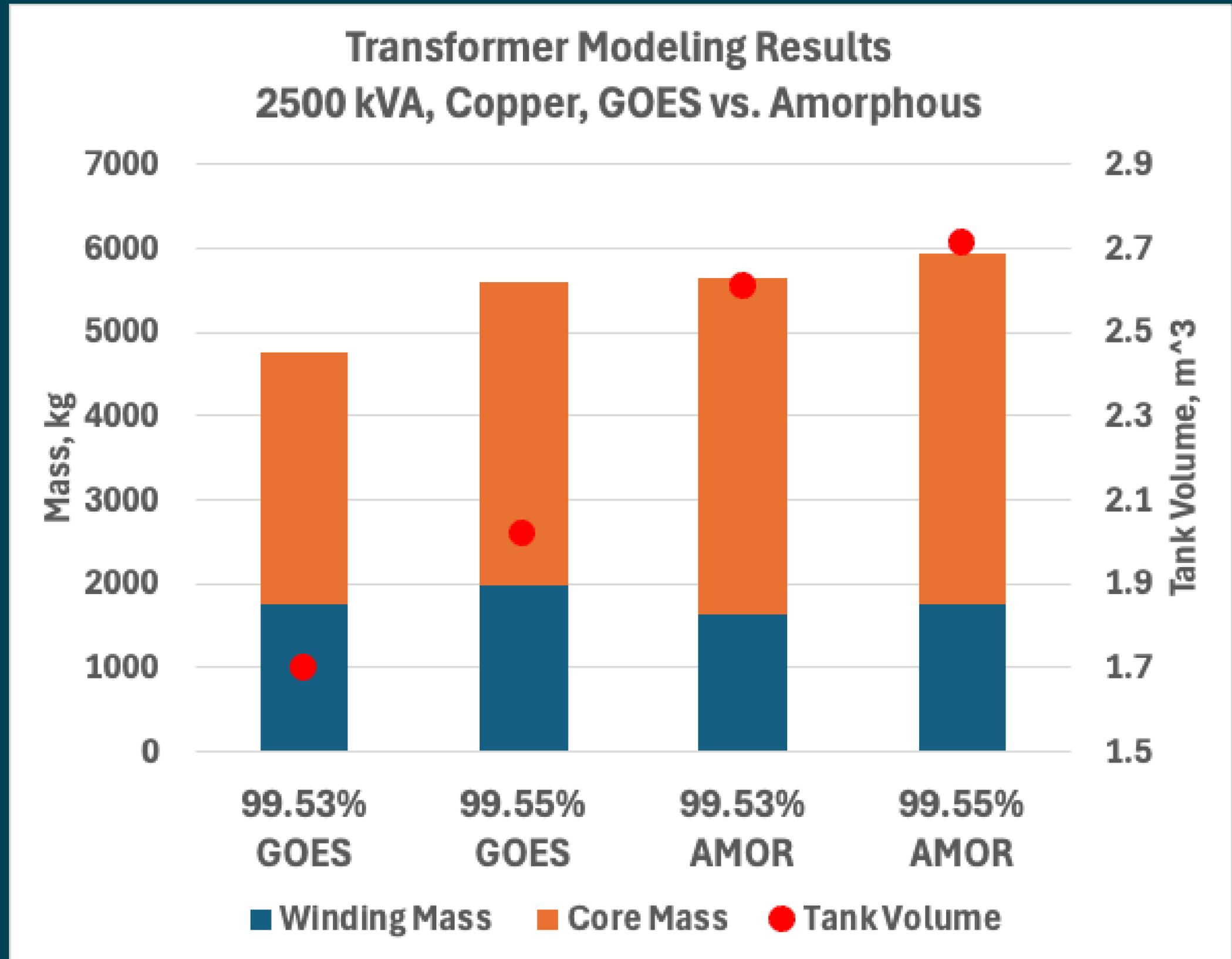
- Total Mass, +90%
- Winding Mass, +37%
- Core Mass, +141%
- Tank Volume, +59%



Modeling Results and Discussion

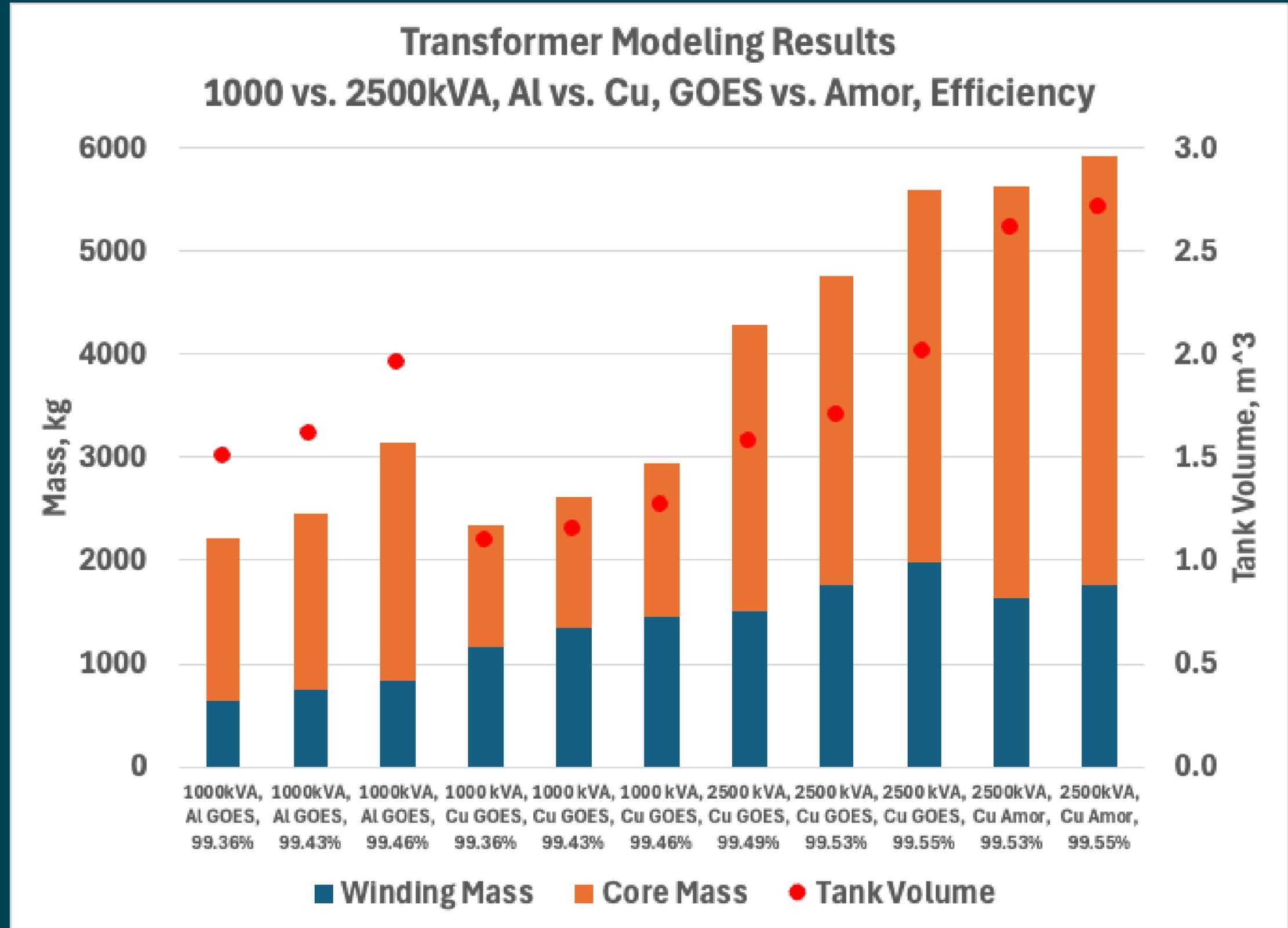
2500 kVA, Copper

- GOES to AMOR, CURRENT
 - Total Mass, +18%
 - Winding Mass, -7%
 - Core Mass, +33%
 - Tank Volume, +53%
- GOES to AMOR, FUTURE
 - Total Mass, +6%
 - Winding Mass, -11%
 - Core Mass, +15%
 - Tank Volume, +34%
- CURRENT GOES to FUTURE AMOR
 - Total Mass, +24%
 - Winding Mass, 0%
 - Core Mass, +39%
 - Tank Volume, +59%



Modeling Results and Discussion

- As efficiencies increase, copper conductor systems gain size and mass advantages
- Aluminum retains a winding mass advantage, but its core mass and size significantly increases
- Conversions from GOES to Amorphous cores negate additional conductor mass requirements and adds significant core mass and size



Key Take-Aways

Key Take-Aways

1

Transformers are key components in power grid with electrification demands booming over upcoming decades.

2

Transformer efficiency improvements yield significant cumulative cost savings and emissions reductions.

3

Copper is a critical material and overall copper demand in transformers increases as sales and efficiencies increase.

4

Increased efficiency gives copper advantages of smaller sizes and lower mass, and conductor content is slightly reduced with amorphous cores.

Stay Engaged!

Copper Age

2.0



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POWERGEN™

THANK YOU!

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Cu International Copper Association

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