BUILDING TECHNOLOGIES PROGRAM

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Liquid-Immersed Distribution Transformers Energy Conservation Program Supplementary Analysis

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June 20, 2012

Public Meeting Agenda

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

1. Welcome, Opening Remarks
2. History
3. Added Equipment Classes, TSLs
4. Scaling
5. Economic Results
6. Comments Sought

Welcome and Introduction

- Introductions
- Role of the Facilitator
- Ground Rules (norms)
  - Listen as an ally
  - Use short, succinct statements/keep to the point
  - Hold sidebar conversations outside the room
  - Focus on issues, not personalities
  - One person speak at a time (raise hand to be recognized; state your name for the record)
  - Set cell phones to silent/vibrate
- Housekeeping Items
- Agenda Review
- Opening Remarks

Purpose of the Public Meeting

- Invite comment on new equipment classes and energy conservation levels for liquid-immersed distribution transformers.
- Present methodologies and characterize results of the rulemaking analyses.
- Provide a forum for public discussion of rulemaking issues.
- Encourage interested parties to submit data, information, and written comments.
- Describe next steps in the rulemaking.

Comments from Participants

- Participants are invited to provide summary comments or statements and raise additional issues for discussion.

- Comment period closes June 29, 2012.

Feedback Is Requested

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- **In all correspondence, please refer to the Distribution Transformers rulemaking by:**
  - Distribution Transformers Rulemaking,
  - Docket Number EE–2010–BT–STD–0048, and
  - Regulatory Identification Number (RIN) 1904–AC04

- **Email:** DistributionTransformers-2010-STD-0048@ee.doe.gov

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- **Comment period closes:** June 29, 2012

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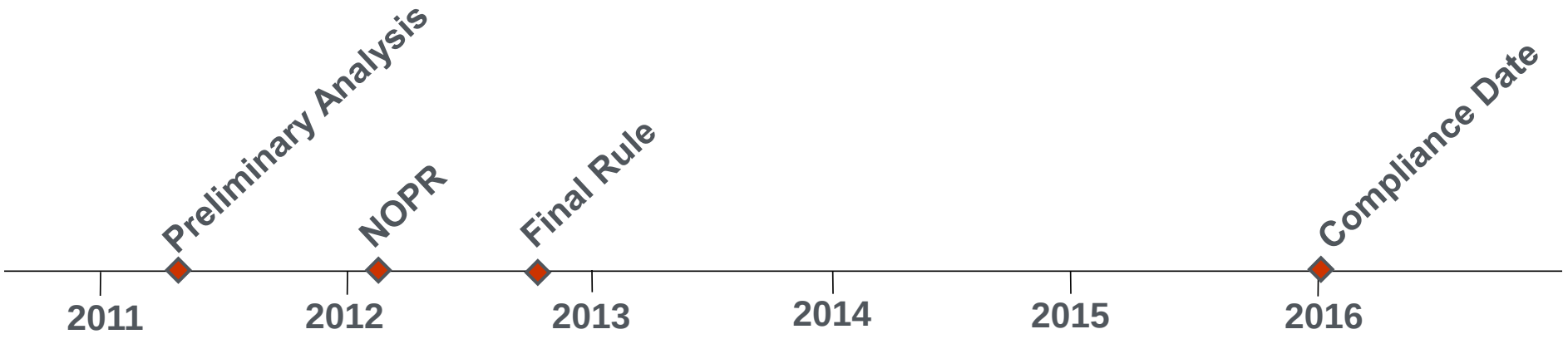
Regulatory History

- EPACT 2005 set standards for low-voltage dry-type (LVDT) distribution transformers at the NEMA TP 1-2002 level.
- October 2007 – DOE issued a final rule establishing standards for liquid-immersed and medium-voltage dry-type (MVDT) distribution transformers. (72 FR 58190). DOE was sued on that rule concerning issues of environmental compliance. That suit was settled.
- As a result of the settlement agreement, compliance was required in 2010 with the standards established in 2007 final rule. However, DOE agreed to an expedited timeline to determine whether to amend standards for liquid-immersed and MVDT distribution transformers.
- DOE published a Notice of Proposed Rulemaking on February 10, 2012.
- Final Rule must be published by October 1, 2012, according to settlement agreement.

Distribution Transformers Rulemaking Schedule



Milestone	Date
Issuance of NOPR	*February 1, 2012*
Federal Register Notice of Public Meeting and Availability of the NOPR Technical Support Document	*February 10, 2012*
Issue Final Rule	*October 1, 2012*
Compliance Date	*January 1, 2016*

Supplementary Analysis

- Many interested parties submitted written comment supporting new equipment classes for liquid-immersed distribution transformers
  - Pole-mounted transformers
  - Network- and vault-based transformers
  - 200 kV BIL ratings

- In response, DOE provides supplementary analysis with several new trial standard levels (TSLs) and Equipment Classes (ECs) for liquid-immersed distribution transformers
  - New TSLs, lettered “A” through “D,” provide separate standards for pole-mounted, network/vault-based, and 200 kV BIL ratings

- Supplementary analysis conducted with NOPR analysis data and tools

- No modifications have been made to any dry-type transformer classes

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Equipment Class Rationale

- Equipment classes carefully chosen
  - Maximize energy savings
  - Maintain equipment utility
  - Minimize regulatory complexity

- Stakeholder support generally strong for new liquid-immersed equipment classes
  - Separation of pole-mounted
  - Separation of network- and vault-based
  - Separation of 200 kV BIL

Equipment Class Rationale

- Network- and Vault-based Transformers
  - In concrete vaults of fixed size and great enlargement cost
  - ~90% of market already using H0, the highest possible grade for stacked core construction
  - Usual option to use better grade not available
  - Increasing transformer size only path to higher efficiency
  - Market size ~5% by kVA

- 200 kV BIL Transformers
  - High BIL ratings protect against voltage transients
  - Reduce ability to reach higher efficiency
  - Precedent in DOE's treatment of MVDTs
  - Market size ~1% by KVA

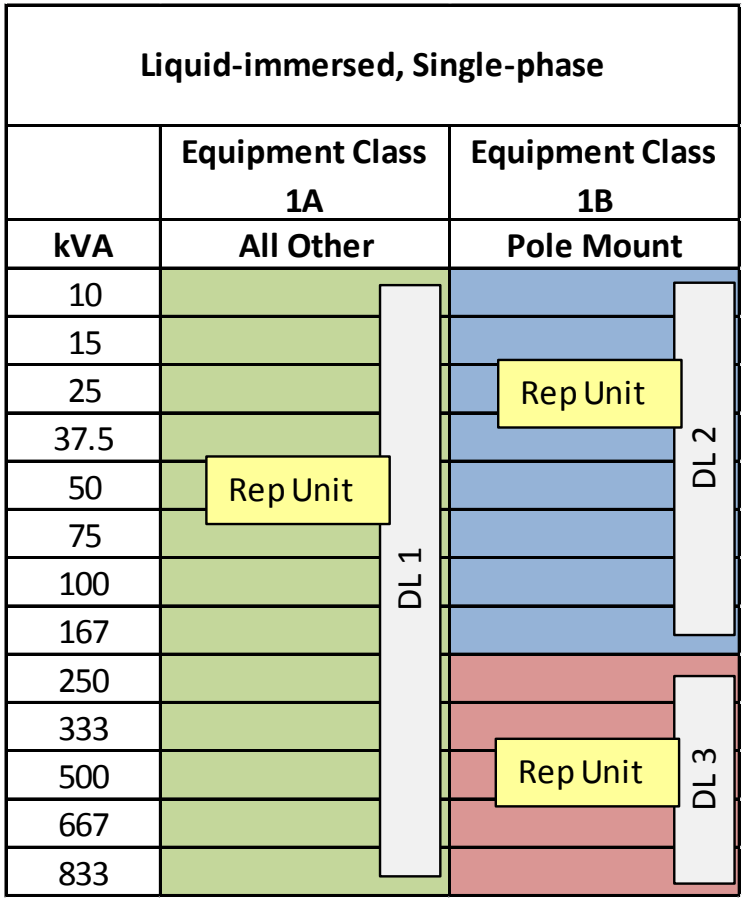
Equipment Class Structure

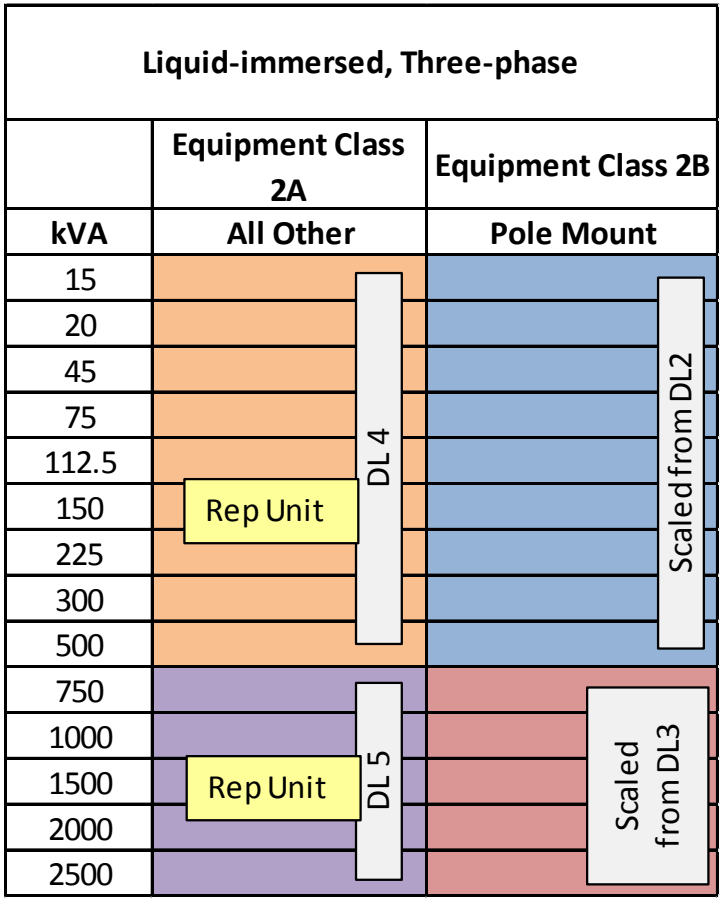
EC	Phase	Type
1	1	All
2	3	All

EC	Phase	Type
1a	1	All other
1b	1	Pole
1c	1	N/V
1d	1	200 kV
2a	3	All other
2b	3	Pole
2c	3	N/V
2d	3	200 kV

Note: “All other” refers to what had been “pad-mounted” in the supplementary analysis and includes any transformers not meeting other definitions

Design Line Implication





Trial Standard Levels

- DOE has added four new TSLs

EC	DL	Phase	Type	Trial Standard Levels by Efficiency Level				
				1	A	B	C	D
1A	1	1	all other	EL 1	EL 1	EL 1.5	EL 2	EL 2
1B	2	1	pole	EL 0	EL 0.5	EL 0.5	EL 2	EL 1
1B	3	1	pole	EL 1	EL 1	EL 1	EL 2	EL 1
2A	4	3	all other	EL 1	EL 1	EL 1.5	EL 2	EL 2
2A	5	3	all other	EL 1	EL 1	EL 1.5	EL 2	EL 2
2B	-	3	pole	-	scaled	scaled	scaled	scaled
1C	-	1	network/ vault	-	EL 0	EL 0	EL 0	EL 0
1D	-	1	≥ 200 kV BIL	-	EL 0	EL 0	EL 0	EL 0
2C	-	3	network/ vault	-	EL 0	EL 0	EL 0	EL 0
2D	-	3	≥ 200 kV BIL	-	EL 0	EL 0	EL 0	EL 0

Loss Table

					TSL												
DL	**EC**	**Phase**	**kVA**	**Type**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**A**	**B**	**C**	**D**	
1	1a	1	50	All	0	1	1	1	2	3	4	6	1	1.5	2	2	
2	1b	1	25	Pole	0	0	1	1	2	3	4	6	0.5	0.5	2	1	
3	1b	1	500	Pole	0	1	1	2	4	3	5	7	1	1	2	1	**EL**
4	2a	3	150	All	0	1	1	1	2	3	5	7	1	1.5	2	2	
5	2a	3	1500	All	0	1	1	2	4	3	4	6	1	1.5	2	2	
1	1a	1	50	All	99.08%	99.16%	99.16%	99.16%	99.22%	99.25%	99.31%	99.50%	99.16%	99.19%	99.22%	99.22%	
2	1b	1	25	Pole	98.91%	98.91%	99.00%	99.00%	99.07%	99.11%	99.18%	99.41%	98.95%	98.95%	99.07%	99.00%	
3	1b	1	500	Pole	99.42%	99.48%	99.48%	99.51%	99.57%	99.54%	99.61%	99.73%	99.48%	99.48%	99.51%	99.50%	**Efficiency**
4	2a	3	150	All	99.08%	99.16%	99.16%	99.16%	99.22%	99.25%	99.31%	99.60%	99.16%	99.19%	99.22%	99.22%	
5	2a	3	1500	All	99.42%	99.48%	99.48%	99.51%	99.57%	99.54%	99.61%	99.69%	99.48%	99.49%	99.51%	99.51%	
1	1a	1	50	All	232	212	212	212	197	189	174	126	212	204	197	197	
2	1b	1	25	Pole	138	138	126	126	117	112	103	74	133	133	117	126	
3	1b	1	500	Pole	1458	1307	1307	1231	1080	1155	979	677	1307	1307	1231	1256	**Loss (W)**
4	2a	3	150	All	696	635	635	635	590	567	521	301	635	612	590	590	
5	2a	3	1500	All	4375	3920	3920	3693	3239	3466	2936	2332	3920	3807	3693	3693	
1	1a	1	50	All	0%	9%	9%	9%	15%	19%	25%	46%	9%	12%	15%	15%	
2	1b	1	25	Pole	0%	0%	8%	8%	15%	19%	25%	46%	4%	4%	15%	8%	
3	1b	1	500	Pole	0%	10%	10%	16%	26%	21%	33%	54%	10%	10%	16%	14%	**% Loss Reduction**
4	2a	3	150	All	0%	9%	9%	9%	15%	19%	25%	57%	9%	12%	15%	15%	
5	2a	3	1500	All	0%	10%	10%	16%	26%	21%	33%	47%	10%	13%	16%	16%	

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Scaling

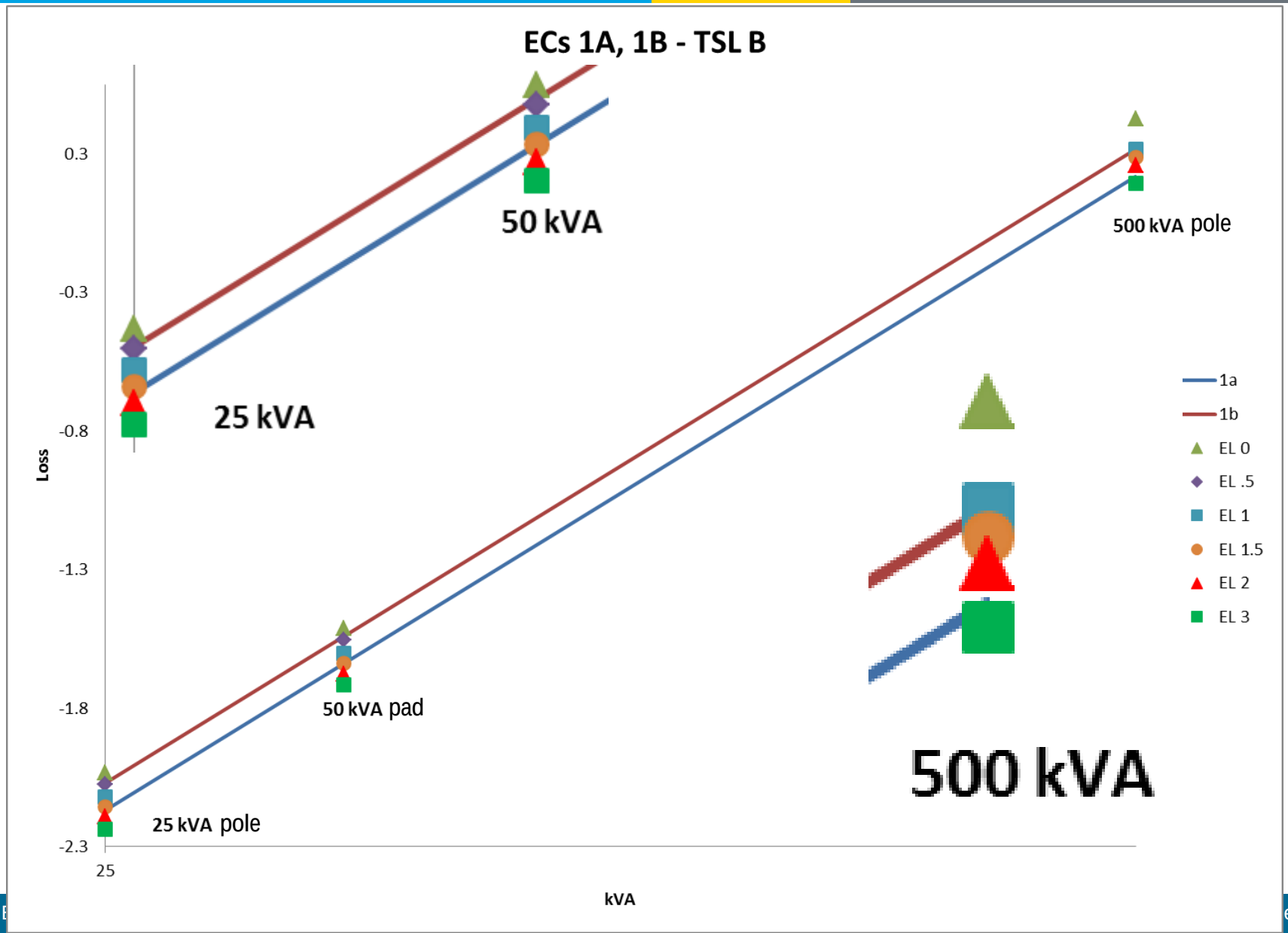
- TSLs contain efficiency levels for representative units
- DOE scales TSL values to kVA ratings not directly analyzed
- Most equipment classes (ECs) have at least two representative units
  - In these cases standard derived by fitting a line in logarithmic space (log Loss vs log kVA)
- For ECs with a single point, several options exist

Scaling

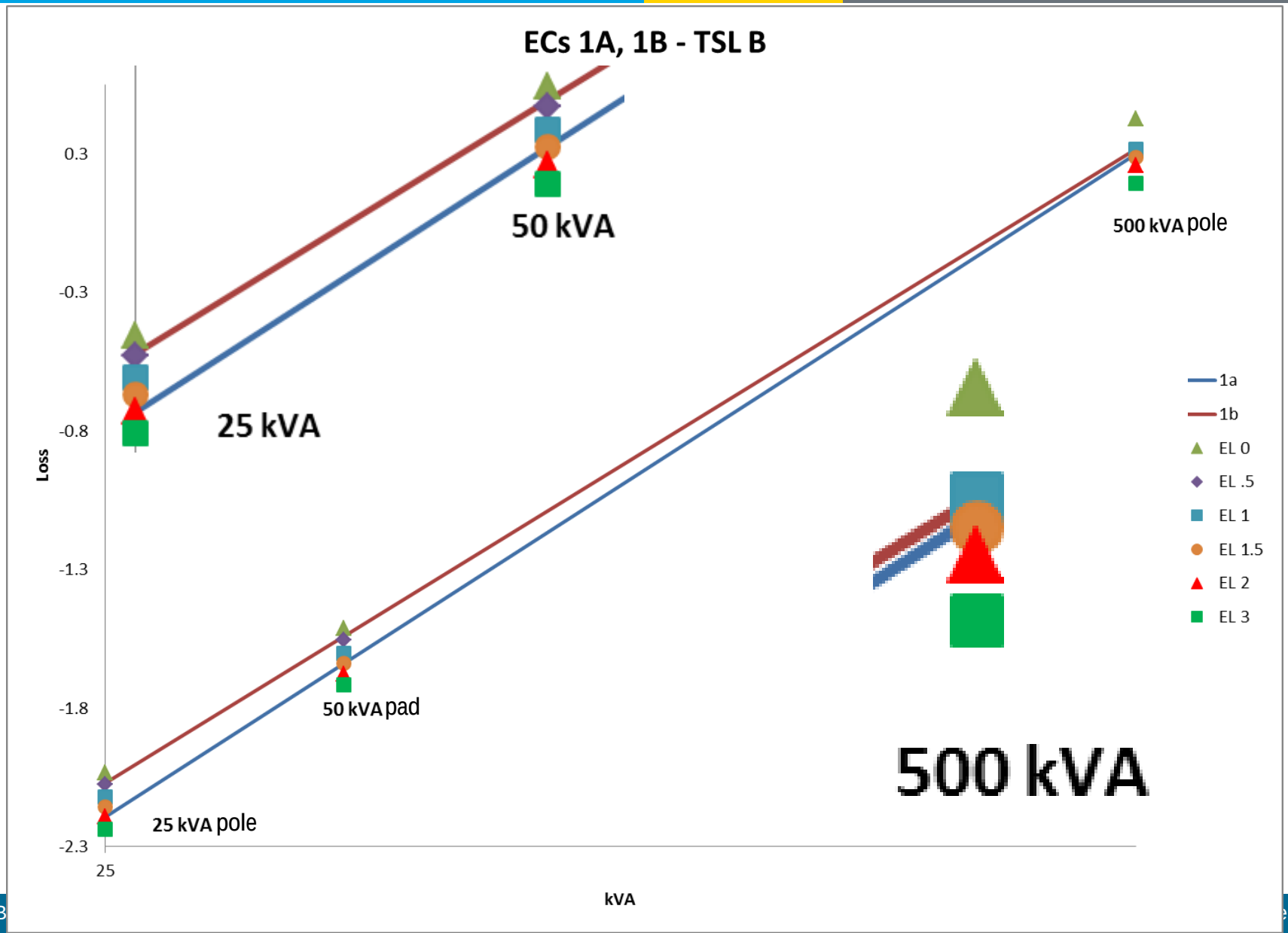
- **Two Scaling Points**
  - Class 1B (single-phase, pole-mounted)
    - Generated using Design Lines 2 and 3
  - Class 2A (three-phase, all other)
    - Generated using Design Lines 4 and 5
  - Class 2B (three-phase, pole-mounted)
    - Scaled from 1B, using phase harmonization

- **One Scaling Point**
  - Class 1A (single-phase, all other)
    - Generated using Design Line 1

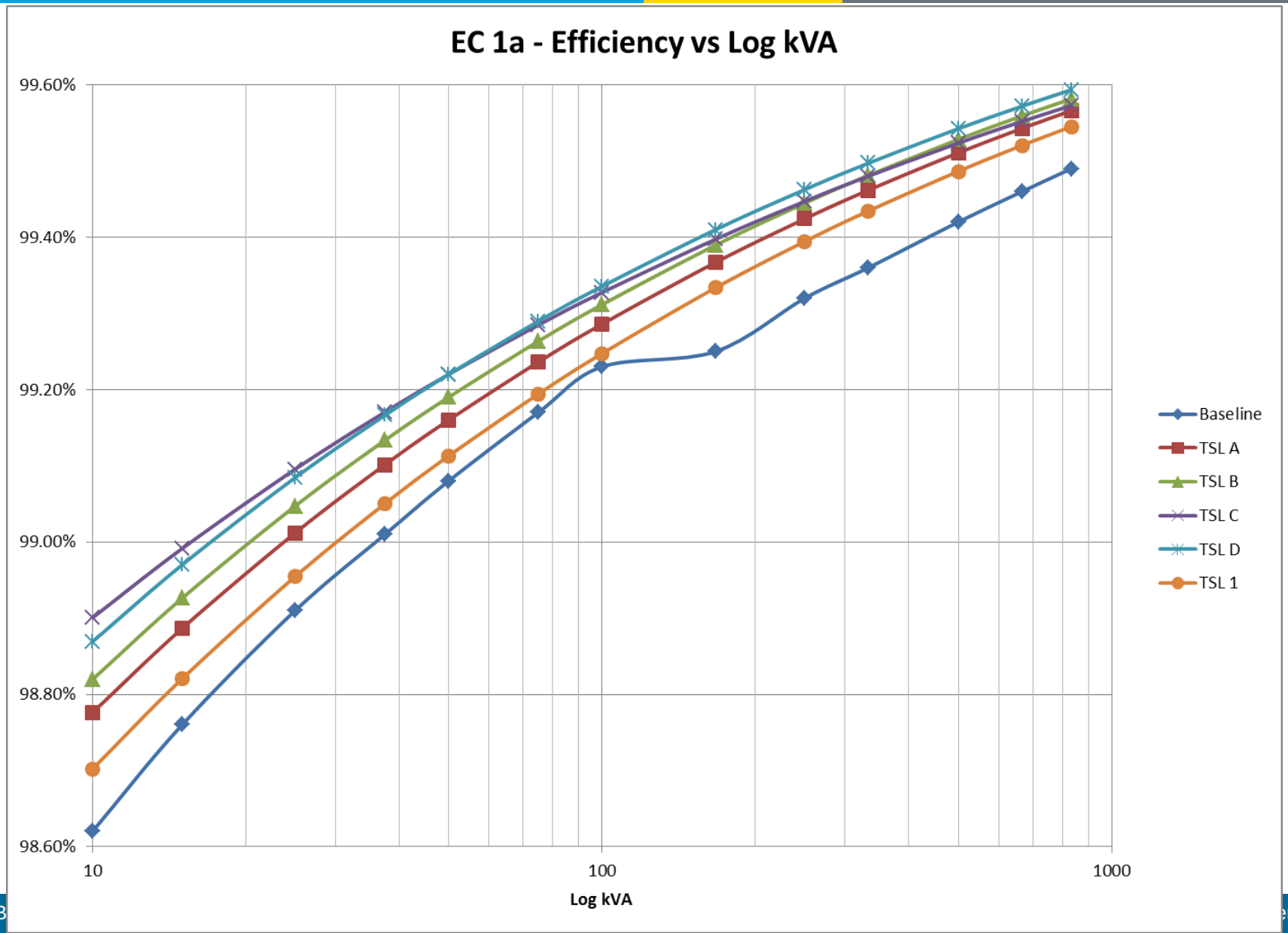
EC 1 – TSL B (Parallel)



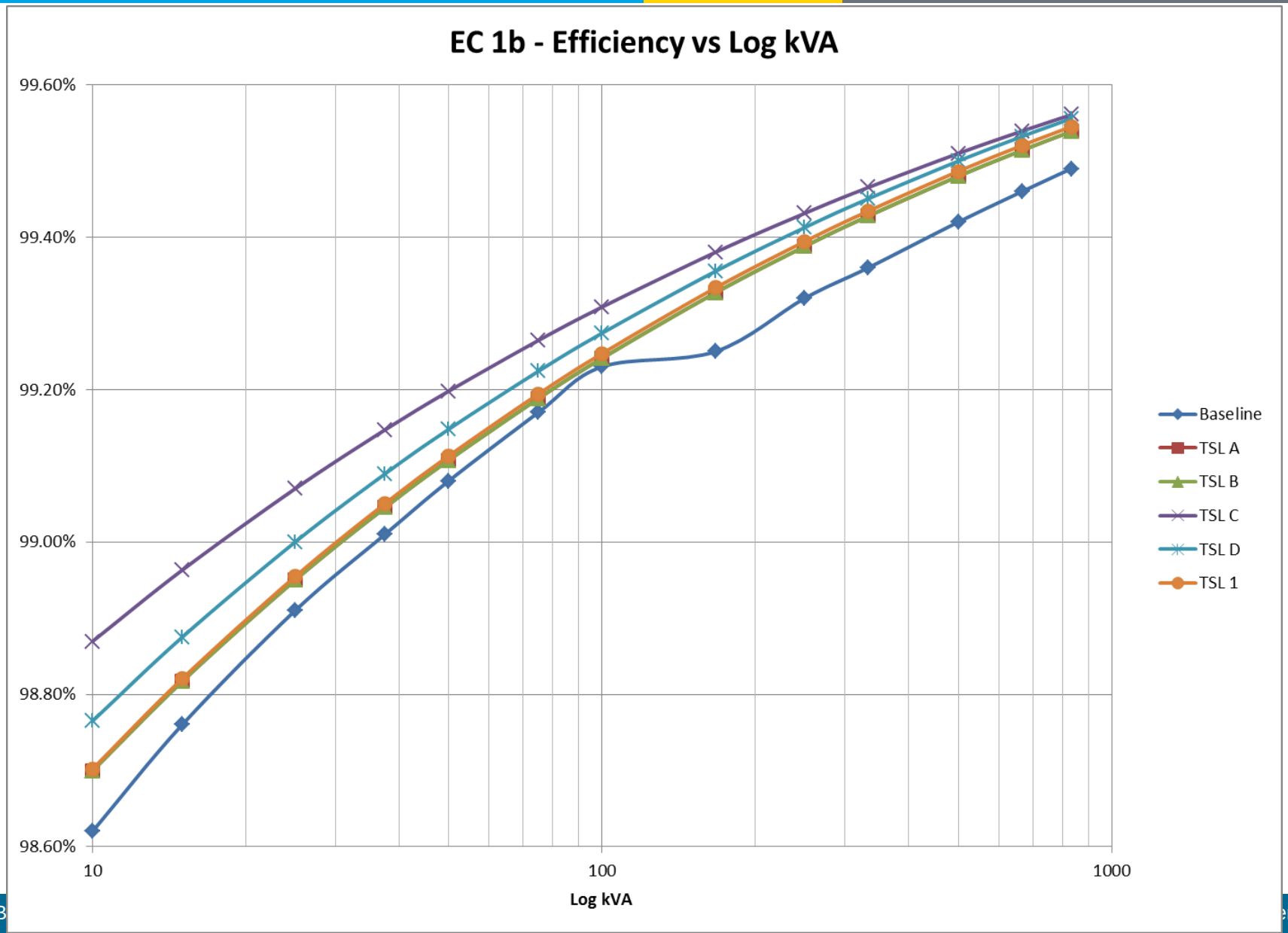
EC 1 – TSL B (Converging)



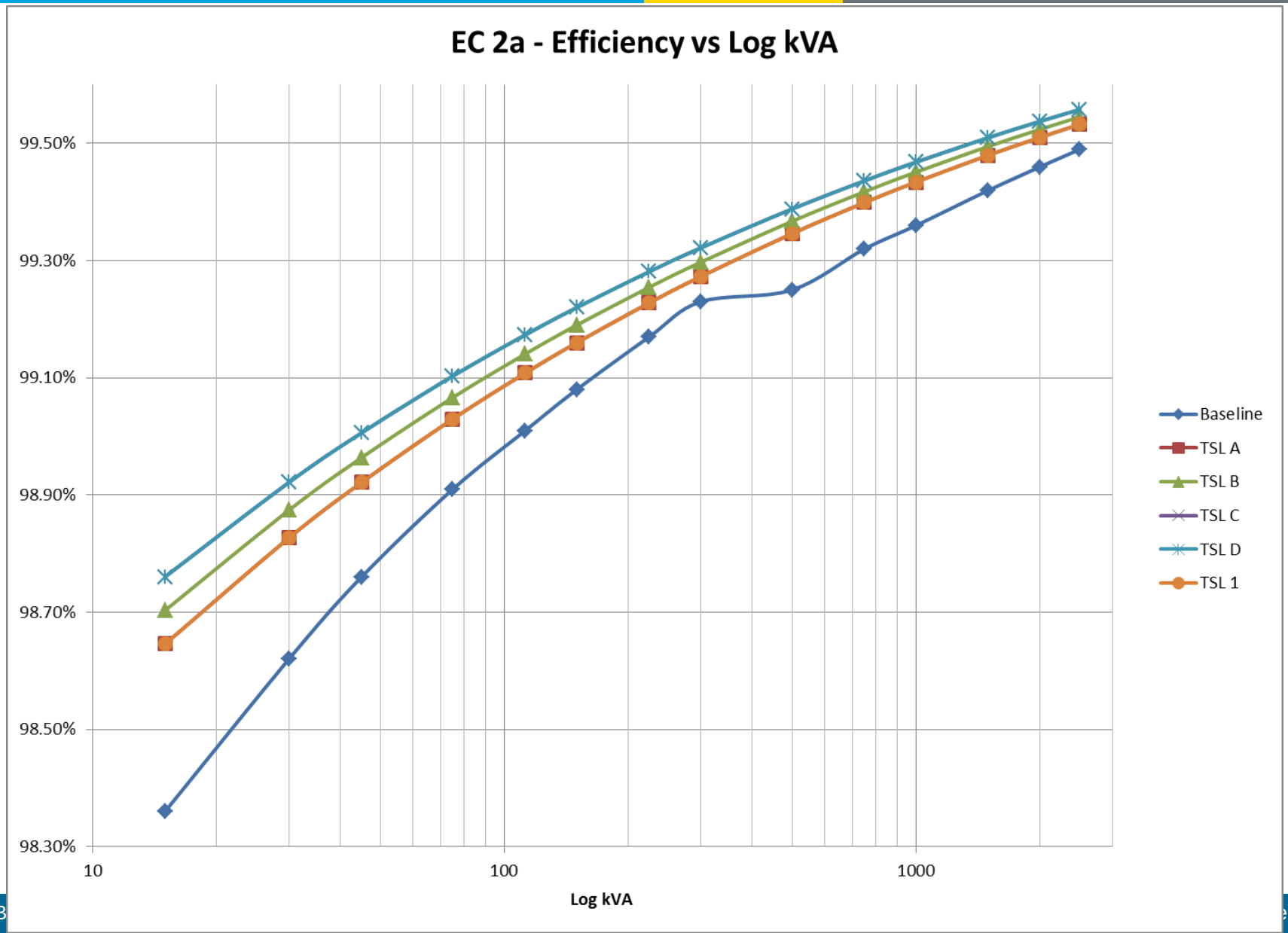
TSL Plots – EC 1a



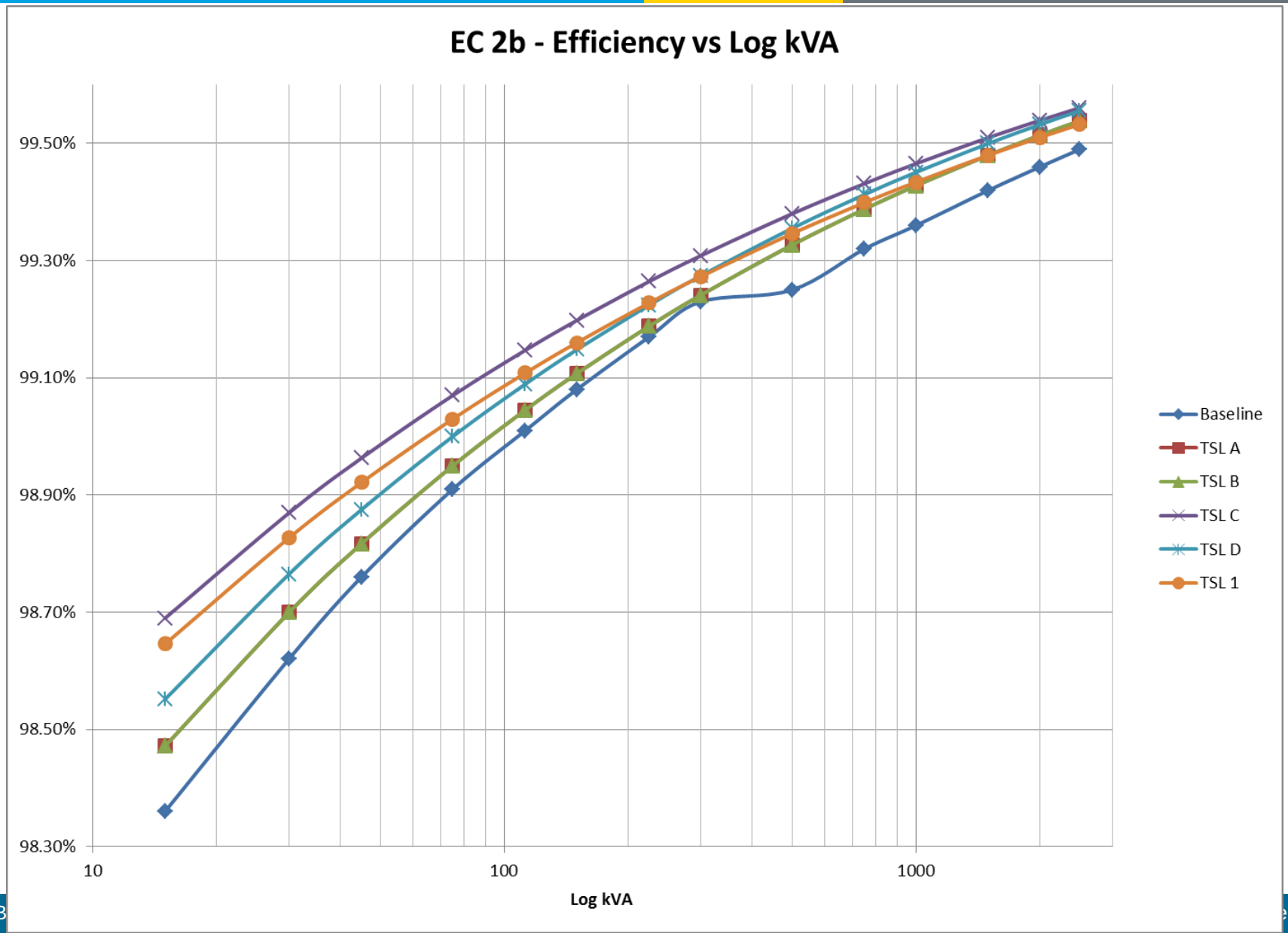
TSL Plots – EC 1b



TSL Plots – EC 2a



TSL Plots – EC 2b



Standards Tables – TSL A

TSL A							
EC	1a		1b		2a		2b
Type	LI, all other		LI, pole-mounted		LI, all other		LI, pole-mounted
Phase	1		1		3		3
BIL	-		-		-		-
10	98.78%	**10**	98.70%	**15**	98.65%	**15**	98.47%
15	98.89%	**15**	98.82%	**30**	98.83%	**30**	98.70%
25	99.01%	**25**	98.95%	**45**	98.92%	**45**	98.82%
37.5	99.10%	**37.5**	99.05%	**75**	99.03%	**75**	98.95%
50	99.16%	**50**	99.11%	**112.5**	99.11%	**112.5**	99.05%
75	99.24%	**75**	99.19%	**150**	99.16%	**150**	99.11%
100	99.29%	**100**	99.24%	**225**	99.23%	**225**	99.19%
167	99.37%	**167**	99.33%	**300**	99.27%	**300**	99.24%
250	99.42%	**250**	99.39%	**500**	99.35%	**500**	99.33%
333	99.46%	**333**	99.43%	**750**	99.40%	**750**	99.39%
500	99.51%	**500**	99.48%	**1000**	99.43%	**1000**	99.43%
667	99.54%	**667**	99.51%	**1500**	99.48%	**1500**	99.48%
833	99.57%	**833**	99.54%	**2000**	99.51%	**2000**	99.51%
				2500	99.53%	**2500**	99.54%

Standards Tables – TSL B

TSL B							
EC	1a		1b		2a		2b
Type	LI, all other		LI, pole-mounted		LI, all other		LI, pole-mounted
Phase	1		1		3		3
BIL	-		-		-		-
10	98.82%	**10**	98.70%	**15**	98.70%	**15**	98.47%
15	98.93%	**15**	98.82%	**30**	98.87%	**30**	98.70%
25	99.05%	**25**	98.95%	**45**	98.96%	**45**	98.82%
37.5	99.13%	**37.5**	99.05%	**75**	99.07%	**75**	98.95%
50	99.19%	**50**	99.11%	**112.5**	99.14%	**112.5**	99.05%
75	99.26%	**75**	99.19%	**150**	99.19%	**150**	99.11%
100	99.31%	**100**	99.24%	**225**	99.25%	**225**	99.19%
167	99.39%	**167**	99.33%	**300**	99.30%	**300**	99.24%
250	99.44%	**250**	99.39%	**500**	99.37%	**500**	99.33%
333	99.48%	**333**	99.43%	**750**	99.42%	**750**	99.39%
500	99.53%	**500**	99.48%	**1000**	99.45%	**1000**	99.43%
667	99.56%	**667**	99.51%	**1500**	99.49%	**1500**	99.48%
833	99.58%	**833**	99.54%	**2000**	99.52%	**2000**	99.51%
				2500	99.55%	**2500**	99.54%

Standards Tables – TSL C

TSL C							
EC	1a		1b		2a		2b
Type	LI, all other		LI, pole-mounted		LI, all other		LI, pole-mounted
Phase	1		1		3		3
BIL	-		-		-		-
10	98.90%	**10**	98.87%	**15**	98.76%	**15**	98.69%
15	98.99%	**15**	98.96%	**30**	98.92%	**30**	98.87%
25	99.10%	**25**	99.07%	**45**	99.01%	**45**	98.96%
37.5	99.17%	**37.5**	99.15%	**75**	99.10%	**75**	99.07%
50	99.22%	**50**	99.20%	**112.5**	99.17%	**112.5**	99.15%
75	99.28%	**75**	99.26%	**150**	99.22%	**150**	99.20%
100	99.33%	**100**	99.31%	**225**	99.28%	**225**	99.26%
167	99.40%	**167**	99.38%	**300**	99.32%	**300**	99.31%
250	99.45%	**250**	99.43%	**500**	99.39%	**500**	99.38%
333	99.48%	**333**	99.47%	**750**	99.44%	**750**	99.43%
500	99.52%	**500**	99.51%	**1000**	99.47%	**1000**	99.47%
667	99.55%	**667**	99.54%	**1500**	99.51%	**1500**	99.51%
833	99.57%	**833**	99.56%	**2000**	99.54%	**2000**	99.54%
				2500	99.56%	**2500**	99.56%

Standards Tables – TSL D

TSL D							
EC	1a		1b		2a		2b
Type	LI, all other		LI, pole-mounted		LI, all other		LI, pole-mounted
Phase	1		1		3		3
BIL	-		-		-		-
10	98.87%	**10**	98.76%	**15**	98.76%	**15**	98.55%
15	98.97%	**15**	98.87%	**30**	98.92%	**30**	98.76%
25	99.08%	**25**	99.00%	**45**	99.01%	**45**	98.87%
37.5	99.17%	**37.5**	99.09%	**75**	99.10%	**75**	99.00%
50	99.22%	**50**	99.15%	**112.5**	99.17%	**112.5**	99.09%
75	99.29%	**75**	99.22%	**150**	99.22%	**150**	99.15%
100	99.34%	**100**	99.27%	**225**	99.28%	**225**	99.22%
167	99.41%	**167**	99.36%	**300**	99.32%	**300**	99.27%
250	99.46%	**250**	99.41%	**500**	99.39%	**500**	99.36%
333	99.50%	**333**	99.45%	**750**	99.44%	**750**	99.41%
500	99.54%	**500**	99.50%	**1000**	99.47%	**1000**	99.45%
667	99.57%	**667**	99.53%	**1500**	99.51%	**1500**	99.50%
833	99.59%	**833**	99.56%	**2000**	99.54%	**2000**	99.53%
				2500	99.56%	**2500**	99.56%

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Economic Results: LCC & PBP Results

Equipment Class 1A – Design Line 1, 50 kVA, 1Φ

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Life-Cycle Cost Results

	Efficiency Level						
	1	1.5	2	3	4	5	6
Efficiency (%)	99.16	99.19	99.22	99.25	99.31	99.42	99.5
Transformers with Net Increase in LCC (%)	57.94	36.3	4.77	4.77	8	13.63	55.36
Transformers with No Impact on LCC (%)	0.23	0.1	0.23	0.23	0	0	0
Transformers with Net LCC Savings (%)	41.83	63.6	95	95	92	86.37	44.64
Mean LCC Savings ($)	36	305	641	641	532	629	50
Median LCC Savings ($)	-64	44	650	650	540	563	-104

Proposed Standard

New Efficiency Level

Payback Period Results

	Efficiency Level						
	1	1.5	2	3	4	5	6
Mean Payback (Years)	32.2	21.1	8.2	8.2	10.4	12	19.9
Median Payback (Years)	20.2	17.9	7.9	7.9	10	11.5	19.2
Transformers having Well Defined Payback (%)	85.02	89.4	99.77	99.77	99.89	99.99	99.95
Transformers having Undefined Payback (%)	14.98	10.6	0.23	0.23	0.11	0.01	0.05
Mean Retail Cost ($)	2,244	2,240	2,446	2,446	2,549	2,802	3,333
Mean Installation Costs ($)	2,230	2,229	2,271	2,271	2,344	2,415	2,606
Mean Operating Costs ($)	209	218	156	156	153	132	126
Mean Incremental First Cost ($)	327	327	569	569	746	1,070	1,792
Mean Operating Cost Savings ($)	18	21	71	71	74	95	100
Payback of Average Transformer	18.2	15.8	8	8	10.1	11.2	17.8

Economic Results: LCC & PBP Results

Equipment Class 1B – Design Line 2, 25 kVA, 1Φ, Pole-mount

Life-Cycle Cost Results

	Efficiency Level							
	0.5	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Efficiency (%)	98.95	99	99.07	99.11	99.18	99.31	99.41	99.46
Transformers with Net LCC Cost (%)	42.8	14.23	9.82	11.2	15.75	58.18	80.16	86.51
Transformers with No Change in LCC (%)	3.7	0	0	0	0	0	0	0
Transformers with Net LCC Benefit (%)	53.5	85.77	90.18	88.8	84.25	41.82	19.84	13.49
Mean LCC Savings ($)	54	309	338	300	250	-445	-736	-599
Median LCC Savings ($)	**20**	322	341	308	262	-91	-390	-535

Payback Period Results

	Efficiency Level							
	0.5	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mean Payback (Years)	18.3	10	9.7	11.3	13.4	27.9	32.7	30.3
Median Payback (Years)	6.47	6.9	8	9.5	11.5	18.7	24.3	26.3
Transformers having Well Defined Payback (%)	72	98.55	99.93	99.71	99.83	99.75	99.77	99.9
Transformers having Undefined Payback (%)	28	1.45	0.07	0.29	0.17	0.25	0.23	0.1
Mean Retail Cost ($)	1,281	1,437	1,480	1,530	1,598	1,846	2,052	2,577
Mean Installation Costs ($)	1635	1722	1761	1790	1859	2500	2678	2093
Mean Operating Costs ($)	146	101	95	93	89	79	75	71
Mean Incremental First Cost ($)	140	235	317	396	533	1,422	1,807	1,746
Mean Operating Cost Savings ($)	66	34	40	41	46	55	60	64
Payback of Average Transformer	2.1	7	8	9.6	11.7	25.8	30.2	27.4

Economic Results: LCC & PBP Results

Equipment Class 1B – Design Line 3, 500 kVA, 1Φ, Pole-mount

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Life-Cycle Cost Results

	Efficiency Level							
	1	1.5	2	3	4	5	6	7
Efficiency (%)	99.48	99.5	99.51	99.54	99.57	99.61	99.69	99.73
Transformers with Net Increase in LCC (%)	16.07	13.44	11.86	5.35	3.87	3.65	7.37	24.82
Transformers with No Impact on LCC (%)	0.35	0.35	0.3	0	0	0	0	0
Transformers with Net LCC Savings (%)	83.58	86.21	87.84	94.65	96.13	96.35	92.63	75.18
Mean LCC Savings ($)	2370	2777	3809	5218	5586	6576	6924	4294
Median LCC Savings ($)	1751	**2082**	3652	5269	5607	6631	6587	3421

Payback Period Results

	Efficiency Level							
	1	1.5	2	3	4	5	6	7
Mean Payback (Years)	9.2	8.2	6.7	5.6	5.4	6	9.4	15.2
Median Payback (Years)	6.1	6.4	4	4.6	4.7	5.2	8.1	13.3
Transformers having Well Defined Payback (%)	95.56	97.14	97.38	99.89	99.98	100	99.94	99.74
Transformers having Undefined Payback (%)	4.44	2.86	2.62	0.11	0.02	0	0.06	0.26
Mean Retail Cost ($)	8,546	**8,718**	8,944	9,534	9,679	10,280	12,500	15,917
Mean Installation Costs ($)	4,334	**4,374**	4,311	4,370	4,402	4,523	4,996	5,732
Mean Operating Costs ($)	1,222	**1,184**	1,104	984	957	872	724	656
Mean Incremental First Cost ($)	948	**1,161**	1,323	1,972	2,149	2,871	5,564	9,717
Mean Operating Cost Savings ($)	200	**238**	318	438	465	550	698	766
Payback of Average Transformer	4.7	**4.9**	4.2	4.5	4.6	5.2	8	12.7

- To address the pole replacement costs for DL3 DOE used the same pole replacement methodology that was used for DL2.
- RSMeans 2011 was used to estimate the range of appropriate installation costs for the heavier representative unit to include the use of a heavier crane, and additional crew.
- The estimated range of installation costs associated with pole replacement was increased to between $5,877 and $7,935
- The weight change-out threshold was increased by scaling the 150 pounds use for DL2 with the 0.75 scaling rule to 1,418 pounds for DL3.

Economic Results: LCC & PBP Results

Equipment Class 2A – Design Line 4, 150 kVA, 3Φ

Life-Cycle Cost Results

	Efficiency Level							
	1	**1.5**	**2**	**3**	**4**	**5**	**6**	**7**
Efficiency (%)	99.16	99.19	99.22	99.25	99.31	99.42	99.5	99.6
Transformers with Net LCC Cost (%)	5.95	12.62	1.91	1.91	1.86	1.82	4.87	31.1
Transformers with No Change in LCC (%)	0.58	0.62	0.58	0.58	0.58	0.17	0	0
Transformers with Net LCC Benefit (%)	93.47	86.76	97.51	97.51	97.56	98.01	95.13	63.87
Mean LCC Savings ($)	862	857	3356	3356	3362.3	3437.2	3193	1274
Median LCC Savings ($)	670	577	3418.7	3418.7	3423.6	3489.8	3054	956

Payback Period Results

	Efficiency Level							
	1	**1.5**	**2**	**3**	**4**	**5**	**6**	**7**
Mean Payback (Years)	6.6	9.4	4.4	4.4	4.4	4.6	8.2	15.1
Median Payback (Years)	5	7.2	4.1	4.1	4.1	4.3	7.9	14.6
Transformers having Well Defined Payback (%)	99.37	99.38%	99.27	99.27	99.33	99.81	99.94	94.96
Transformers having Undefined Payback (%)	0.63	0.62%	0.73	0.73	0.67	0.19	0.06	0.01
Mean Retail Cost ($)	5,894	5,892	6,443	6,443	6,451	6,536	7,615	10,601
Mean Installation Costs ($)	4,090	4,095	4,184	4,184	4,183	4,223	4,584	4,709
Mean Operating Costs ($)	668	420	483	483	482	471	400	334
Mean Incremental First Cost ($)	438	440	1,081	1,081	1,088	1,214	2,653	5,763
Mean Operating Cost Savings ($)	76	74	261	261	262	274	344	414
Payback of Average Transformer	5.7	6.0	4.1	4.1	4.1	4.4	7.7	13.9

Economic Results: LCC & PBP Results

Equipment Class 2A – Design Line 5, 1500 kVA, 3Φ

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Life-Cycle Cost Results

	Efficiency Level						
	1	1.5	2	3	4	5	6
Efficiency (%)	99.48	99.5	99.51	99.54	99.57	99.61	99.69
Transformers with Net Increase in LCC (%)	19.05	16.99	13.15	10.41	7.77	7.88	39.92
Transformers with No Impact on LCC (%)	0.39	0.28	0.09	0.01	0	0	0
Transformers with Net LCC Savings (%)	80.56	82.73	86.76	89.58	92.23	92.12	60.08
Mean LCC Savings ($)	7,787	9,010	10,288	11,395	12,513	12,746	3,626
Median LCC Savings ($)	8,300	9,649	10,741	11,658	12,666	12,838	3,083

Payback Period Results

	Efficiency Level						
	1	1.5	2	3	4	5	6
Mean Payback (Years)	7	7.3	6.5	7.8	7.8	9.7	18.7
Median Payback (Years)	4	4.1	4.2	5.7	6.3	8.3	16.9
Transformers having Well Defined Payback (%)	91.63	89.93	96.04	98.89	99.82	99.97	100
Transformers having Undefined Payback (%)	8.37	10.07	3.96	1.11	0.18	0.03	0
Mean Retail Cost ($)	28,574	**28,675**	29,040	30,872	31,980	35,448	56,798
Mean Installation Costs ($)	8,551	**8,589**	8,631	8,875	9,030	9,498	9,834
Mean Operating Costs ($)	3,407	**3,721**	3,259	3,105	2,994	2,802	2,185
Mean Incremental First Cost ($)	3,296	**3,434**	3,842	5,918	7,181	11,116	32,803
Mean Operating Cost Savings ($)	718	**693**	866	1,020	1,131	1,323	1,940
Payback of Average Transformer	4.6	**5.0**	4.4	5.8	6.3	8.4	16.9

Economic Results: NIA Results

Liquid-immersed Equipment Classes as presented in the NOPR

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Impacts for All Liquid-immersed Transformers

	TSL								NOPM TSL			
	Base	1	2	3	4	5	6	7	A	B	C	D
Transformer Shipments 2015-2044 (Billion KVA)	1.95	1.95	1.95	1.95	1.94	1.94	1.94	1.91	1.95	1.95	1.95	1.95
Equipment Cost ($Billions)	32.28	1.26	2.51	2.61	4.26	4.48	6.32	19.88	1.57	2	3.72	3.28
Operating Cost (Savings in TSLs) ($Billions)	23.26	2.01	4.03	4.33	7.22	7.13	8.08	11.64	2.5	3.21	6.71	6.28
Cumulative Source Savings 2044 (Quads)		0.36	0.74	0.82	1.44	1.42	1.7	2.7	0.45	0.6	1.3	1.20
Net Present Value at 3% Discount Rate ($Billions)		3.66	7.39	8.24	14.21	13.48	13.17	-1.11	4.66	6.04	13.51	12.93
Net Present Value at 7% Discount Rate ($Billions)		0.75	1.51	1.73	2.96	2.65	1.76	-8.25	0.93	1.21	2.99	3.00

DOE has proposed TSL 1 as the standard

Impacts for Equipment Class 1

	TSL								NOPM TSL			
	Base	1	2	3	4	5	6	7	A	B	C	D
Transformer Shipments 2015-2044 (Billion KVA)	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.79	0.80	0.80	0.80	0.80
Equipment Cost ($Billions)	22.36	0.52	1.78	1.79	2.61	3.03	4.05	12.11	0.84	1.13	2.6	2.16
Operating Cost (Savings in TSLs) ($Billions)	11.37	0.34	2.36	2.38	3.76	3.89	4.23	5.84	0.78	1.23	3.69	3.26
Cumulative Source Savings 2044 (Quads)		0.09	0.47	0.47	0.75	0.8	0.9	1.37	0.18	0.27	0.75	0.65
Net Present Value at 3% Discount Rate ($Billions)		0.13	3.87	3.93	6.64	6.28	5.51	-4.64	0.94	1.78	6.44	5.86
Net Present Value at 7% Discount Rate ($Billions)		-0.19	0.58	0.6	1.15	0.85	0.19	-6.27	-0.06	0.1	1.09	1.10

Impacts for Equipment Class 2

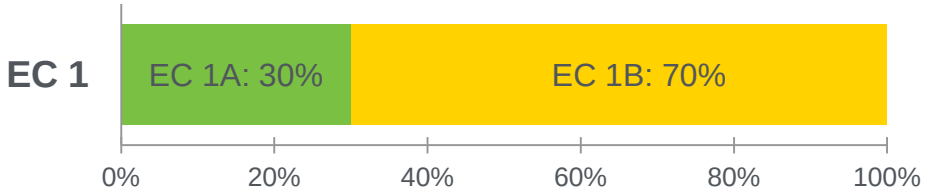
	TSL								NOPM TSL			
	Base	1	2	3	4	5	6	7	A	B	C	D
Transformer Shipments 2015-2044 (Billion KVA)	1.15	1.15	1.15	1.15	1.15	1.15	1.14	1.13	1.15	1.15	1.15	1.15
Equipment Cost ($Billions)	9.92	0.73	0.73	0.82	1.65	1.45	2.27	7.78	0.73	0.87	1.12	1.12
Operating Cost (Savings in TSLs) ($Billions)	11.88	1.67	1.67	1.95	3.46	3.25	3.84	5.8	1.72	1.98	3.01	3.01
Cumulative Source Savings 2044 (Quads)		0.27	0.27	0.35	0.69	0.63	0.8	1.33	0.27	0.33	0.55	0.55
Net Present Value at 3% Discount Rate ($Billions)		3.53	3.53	4.31	7.57	7.21	7.66	3.53	3.71	4.26	7.07	7.07
Net Present Value at 7% Discount Rate ($Billions)		0.94	0.94	1.13	1.82	1.8	1.57	-1.98	0.99	1.11	1.9	1.90

Economic Results: NIA Results

For Supplemental 1Φ Liquid-immersed Equipment Classes

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- To disaggregate the impacts for pad- and pole-mounted transformers from the equipment classes presented in the NOPR DOE associated the fraction of savings with the volume of capacity shipment for each of the new proposed equipment classes.
- DOE assumed 70% of single-phase liquid-immersed shipments by capacity are pole-mounted transformers



Impacts for Equipment Class 1A

	TSL								NOPM TSL			
	Base	1	2	3	4	5	6	7	A	B	C	D
Transformer Shipments 2015-2044 (Billion KVA)	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Equipment Cost ($Billions)	6.71	0.16	0.53	0.54	0.78	0.91	1.21	3.63	0.25	0.34	0.78	0.65
Operating Cost (Savings in TSLs) ($Billions)	3.41	0.1	0.71	0.72	1.13	1.17	1.27	1.75	0.23	0.37	1.11	0.98
Cumulative Source Savings 2044 (Quads)		0.03	0.14	0.14	0.23	0.24	0.27	0.41	0.05	0.08	0.22	0.19
Net Present Value at 3% Discount Rate ($Billions)		0.04	1.16	1.18	1.99	1.88	1.65	-1.39	0.28	0.53	1.93	1.76
Net Present Value at 7% Discount Rate ($Billions)		-0.06	0.17	0.18	0.34	0.26	0.06	-1.88	-0.02	0.03	0.33	0.33

Impacts for Equipment Class 1B – Pole Mounted Transformers

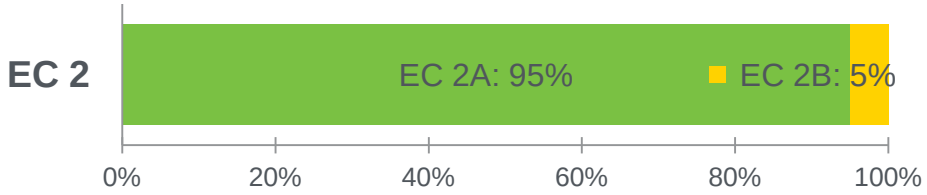
	TSL								NOPM TSL			
	Base	1	2	3	4	5	6	7	A	B	C	D
Transformer Shipments 2015-2044 (Billion KVA)	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.55	0.56	0.56	0.56	0.56
Equipment Cost ($Billions)	15.65	0.37	1.25	1.25	1.83	2.12	2.83	8.48	0.59	0.79	1.82	1.51
Operating Cost (Savings in TSLs) ($Billions)	7.96	0.24	1.65	1.67	2.63	2.72	2.96	4.09	0.55	0.86	2.58	2.28
Cumulative Source Savings 2044 (Quads)		0.07	0.33	0.33	0.53	0.56	0.63	0.96	0.13	0.19	0.52	0.45
Net Present Value at 3% Discount Rate ($Billions)		0.09	2.71	2.75	4.65	4.4	3.85	-3.25	0.66	1.24	4.51	4.10
Net Present Value at 7% Discount Rate ($Billions)		-0.13	0.41	0.42	0.8	0.6	0.13	-4.39	-0.04	0.07	0.77	0.77

Economic Results: NIA Results

For Supplemental 3Φ Liquid-immersed Equipment Classes

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- To disaggregate the impacts for pad- and pole-mounted transformers from the equipment classes presented in the NOPR DOE associated the fraction of savings with the volume of capacity shipment for each of the new proposed equipment classes.
- DOE assumed 5% of three-phase liquid-immersed shipments by capacity are pole-mounted transformers



Impacts for Equipment Class 2A

	TSL								NOPM TSL			
	Base	1	2	3	4	5	6	7	A	B	C	D
Transformer Shipments 2015-2044 (Billion KVA)	1.10	1.09	1.09	1.09	1.09	1.09	1.09	1.07	1.09	1.09	1.09	1.09
Equipment Cost ($Billions)	9.42	0.7	0.7	0.78	1.57	1.38	2.16	7.39	0.7	0.83	1.06	1.06
Operating Cost (Savings in TSLs) ($Billions)	11.29	1.58	1.58	1.85	3.29	3.08	3.65	5.51	1.64	1.88	2.86	2.86
Cumulative Source Savings 2044 (Quads)		0.26	0.26	0.33	0.65	0.6	0.76	1.26	0.26	0.31	0.53	0.53
Net Present Value at 3% Discount Rate ($Billions)		3.35	3.35	4.1	7.19	6.85	7.28	3.35	3.53	4.05	6.72	6.72
Net Present Value at 7% Discount Rate ($Billions)		0.89	0.89	1.07	1.72	1.71	1.49	-1.88	0.94	1.05	1.8	1.80

Impacts for Equipment Class 2B – Pole Mounted Transformers

	TSL								NOPM TSL			
	Base	1	2	3	4	5	6	7	A	B	C	D
Transformer Shipments 2015-2044 (Billion KVA)	0.060	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Equipment Cost ($Billions)	0.5	0.04	0.04	0.04	0.08	0.07	0.11	0.39	0.04	0.04	0.06	0.06
Operating Cost (Savings in TSLs) ($Billions)	0.59	0.08	0.08	0.1	0.17	0.16	0.19	0.29	0.09	0.1	0.15	0.15
Cumulative Source Savings 2044 (Quads)		0.01	0.01	0.02	0.03	0.03	0.04	0.07	0.01	0.02	0.03	0.03
Net Present Value at 3% Discount Rate ($Billions)		0.18	0.18	0.22	0.38	0.36	0.38	0.18	0.19	0.21	0.35	0.35
Net Present Value at 7% Discount Rate ($Billions)		0.05	0.05	0.06	0.09	0.09	0.08	-0.1	0.05	0.06	0.09	0.09

Economic Results: NIA Results

Summary of Results for Supplemental TSL A

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Summary of Key Results Proposed Rule vs. Supplemental TSLs

Equipment Class	Cumulative Source Savings 2044 (Quads)					Net Present Value at 3% Discount Rate ($Billions)					Net Present Value at 7% Discount Rate ($Billions)				
	TSL					TSL					TSL				
	1	A	B	C	D	1	A	B	C	D	1	A	B	C	D
EC 1 + EC 2	0.36	0.45	0.60	1.30	1.20	3.66	4.66	6.04	13.51	12.93	0.75	0.93	1.21	2.99	3.00
EC 1	0.09	0.18	0.27	0.75	0.65	0.13	0.94	1.78	6.44	5.86	-0.19	-0.06	0.1	1.09	1.10
EC 1A	0.03	0.05	0.08	0.22	0.19	0.04	0.28	0.53	1.93	1.76	-0.06	-0.02	0.03	0.33	0.33
EC 1B	0.07	0.13	0.19	0.52	0.45	0.09	0.66	1.24	4.51	4.10	-0.13	-0.04	0.07	0.77	0.77
EC 2	0.27	0.27	0.33	0.55	0.55	3.53	3.71	4.26	7.07	7.07	0.94	0.99	1.11	1.90	1.90
EC 2A	0.26	0.26	0.31	0.53	0.53	3.35	3.53	4.05	6.72	6.72	0.89	0.94	1.05	1.80	1.80
EC 2B	0.01	0.01	0.02	0.03	0.03	0.18	0.19	0.21	0.35	0.35	0.05	0.05	0.06	0.09	0.09

For All Liquid-Immersed Distribution Transformers: TSL A

- 0.45 quad of energy saved from 2016–2045
- Net increase of $0.93 billion in NPV at 7% discount rate and $4.66 billion at 3% discount
- For most equipment classes, the percentage of customers experiencing net benefit is greater than 60%
- Weight increase of between 4 and 10% for 1Φ pole-mounts, 9% for other 1Φ, < 5% for all 3Φ
- Volume increase 14% for 1Φ pole-mounts greater than 500 kVA, < 5% for all other 1Φ and 3Φ transformers
- Footprint increase 11% for 1Φ pole-mounts greater than 500 kVA, < 5% for all other 1Φ and 3Φ transformers
- Results are based LCC samples of transformers with the following core steels:
  - DL1: 88% M3; DL2: 90% M2; DL3: 40%/40% M3/SA1; DL4: 55%/35% ZDMH/M2; DL5 95% SA1

Economic Results: NIA Results

Summary of Results for Supplemental TSL B

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Summary of Key Results Proposed Rule vs. Supplemental TSLs

Equipment Class	Cumulative Source Savings 2044 (Quads)					Net Present Value at 3% Discount Rate ($Billions)					Net Present Value at 7% Discount Rate ($Billions)				
	TSL					TSL					TSL				
	1	A	B	C	D	1	A	B	C	D	1	A	B	C	D
EC 1 + EC 2	0.36	0.45	0.60	1.30	1.20	3.66	4.66	6.04	13.51	12.93	0.75	0.93	1.21	2.99	3.00
EC 1	0.09	0.18	0.27	0.75	0.65	0.13	0.94	1.78	6.44	5.86	-0.19	-0.06	0.1	1.09	1.10
EC 1A	0.03	0.05	0.08	0.22	0.19	0.04	0.28	0.53	1.93	1.76	-0.06	-0.02	0.03	0.33	0.33
EC 1B	0.07	0.13	0.19	0.52	0.45	0.09	0.66	1.24	4.51	4.10	-0.13	-0.04	0.07	0.77	0.77
EC 2	0.27	0.27	0.33	0.55	0.55	3.53	3.71	4.26	7.07	7.07	0.94	0.99	1.11	1.90	1.90
EC 2A	0.26	0.26	0.31	0.53	0.53	3.35	3.53	4.05	6.72	6.72	0.89	0.94	1.05	1.80	1.80
EC 2B	0.01	0.01	0.02	0.03	0.03	0.18	0.19	0.21	0.35	0.35	0.05	0.05	0.06	0.09	0.09

For All Liquid-Immersed Distribution Transformers: TSL B

- 0.6 quad of energy saved from 2016–2045
- Net increase of $1.21 billion in NPV at 7% discount rate and $6.04 billion at 3% discount
- For most equipment classes, the percentage of customers experiencing net benefit is greater than 80%
- Weight increase of between 4 and 10% for 1Φ pole-mounts,14% for other 1Φ, < 5% for all 3Φ
- Volume increase 14% for 1Φ pole-mounts greater than 500 kVA and <5% for smaller capacity pole-mounts, 10 % for all other 1Φ , and < 5% for all 3Φ transformers
- Footprint increase 11% for 1Φ pole-mounts greater than 500 kVA and <5% for smaller capacity pole-mounts, 10 % for all other 1Φ , and < 5% for all 3Φ transformers
- Results are based LCC samples of transformers with the following core steels:
  - DL1: 49%/46% SA1/M3; DL2: 90% M2; DL3: 40%/40% M3/SA1; DL4: 88%/11% ZDMH/SA1; DL5 100% SA1

Economic Results: NIA Results

Summary of Results for Supplemental TSL C

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Summary of Key Results Proposed Rule vs. Supplemental TSLs

Equipment Class	Cumulative Source Savings 2044 (Quads)					Net Present Value at 3% Discount Rate ($Billions)					Net Present Value at 7% Discount Rate ($Billions)				
	TSL					TSL					TSL				
	1	A	B	C	D	1	A	B	C	D	1	A	B	C	D
EC 1 + EC 2	0.36	0.45	0.60	1.30	1.20	3.66	4.66	6.04	13.51	12.93	0.75	0.93	1.21	2.99	3.00
EC 1	0.09	0.18	0.27	0.75	0.65	0.13	0.94	1.78	6.44	5.86	-0.19	-0.06	0.1	1.09	1.10
EC 1A	0.03	0.05	0.08	0.22	0.19	0.04	0.28	0.53	1.93	1.76	-0.06	-0.02	0.03	0.33	0.33
EC 1B	0.07	0.13	0.19	0.52	0.45	0.09	0.66	1.24	4.51	4.10	-0.13	-0.04	0.07	0.77	0.77
EC 2	0.27	0.27	0.33	0.55	0.55	3.53	3.71	4.26	7.07	7.07	0.94	0.99	1.11	1.90	1.90
EC 2A	0.26	0.26	0.31	0.53	0.53	3.35	3.53	4.05	6.72	6.72	0.89	0.94	1.05	1.80	1.80
EC 2B	0.01	0.01	0.02	0.03	0.03	0.18	0.19	0.21	0.35	0.35	0.05	0.05	0.06	0.09	0.09

For All Liquid-Immersed Distribution Transformers: TSL C

- 1.3 quads of energy saved from 2016–2045
- Net increase of $2.99 billion in NPV at 7% discount rate and $13.51 billion at 3% discount
- For most equipment classes, the percentage of customers experiencing net benefit is greater than 90%
- Weight increase between 6 and 18% for 1Φ pole-mounts,13% for other 1Φ, < 10% for all 3Φ
- Volume increase of 24% for 1Φ pole-mounts greater than 500 kVA and 20% for smaller capacity pole-mounts, 13 % for all other 1Φ , and < 10% for all 3Φ transformers
- Footprint increase 15% for 1Φ pole-mounts greater than 500 kVA and 7% for smaller capacity pole-mounts, 13 % for all other 1Φ , and < 10% for all 3Φ transformers
- Results are based LCC samples of transformers with the following core steels:
  - DL1: 100% SA1; DL2: 100 SA1; DL3: 79%/20% SA1/M2; DL4: 100% SA1; DL5 100% SA1

Economic Results: NIA Results

Summary of Results for Supplemental TSL D

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Summary of Key Results Proposed Rule vs. Supplemental TSLs

Equipment Class	Cumulative Source Savings 2044 (Quads)					Net Present Value at 3% Discount Rate ($Billions)					Net Present Value at 7% Discount Rate ($Billions)				
	TSL					TSL					TSL				
	1	A	B	C	D	1	A	B	C	D	1	A	B	C	D
EC 1 + EC 2	0.36	0.45	0.60	1.30	1.20	3.66	4.66	6.04	13.51	12.93	0.75	0.93	1.21	2.99	3.00
EC 1	0.09	0.18	0.27	0.75	0.65	0.13	0.94	1.78	6.44	5.86	-0.19	-0.06	0.1	1.09	1.10
EC 1A	0.03	0.05	0.08	0.22	0.19	0.04	0.28	0.53	1.93	1.76	-0.06	-0.02	0.03	0.33	0.33
EC 1B	0.07	0.13	0.19	0.52	0.45	0.09	0.66	1.24	4.51	4.10	-0.13	-0.04	0.07	0.77	0.77
EC 2	0.27	0.27	0.33	0.55	0.55	3.53	3.71	4.26	7.07	7.07	0.94	0.99	1.11	1.90	1.90
EC 2A	0.26	0.26	0.31	0.53	0.53	3.35	3.53	4.05	6.72	6.72	0.89	0.94	1.05	1.80	1.80
EC 2B	0.01	0.01	0.02	0.03	0.03	0.18	0.19	0.21	0.35	0.35	0.05	0.05	0.06	0.09	0.09

For All Liquid-Immersed Distribution Transformers: TSL D

- 1.2 quads of energy saved from 2016–2045
- Net increase of $12.93 billion in NPV at 7% discount rate and $3.00 billion at 3% discount
- For most equipment classes, the percentage of customers experiencing net benefit is greater than 90%
- Weight increase between 6 and 15% for 1Φ pole-mounts, 13% for other 1Φ, < 10% for all 3Φ
- Volume increase of 14% for 1Φ pole-mounts, 13 % for all other 1Φ , and < 10% for other 3Φ transformers
- Footprint increase 11% for 1Φ pole-mounts greater than 500 kVA and <5%% for smaller capacity pole-mounts, 13 % for all other 1Φ , and < 5% for other 3Φ transformers
- Results are based LCC samples of transformers with the following core steels:
  - DL1: 100% SA1; DL2: 98% SA1; DL3: 42%/42%/12% SA1/M3/ZDMH; DL4: 100% SA1; DL5 100% SA1

Public Meeting Agenda

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

1. Welcome, Opening Remarks
2. History
3. Added Equipment Classes, TSLs
4. Scaling
5. Economic Results
6. Comments Sought

Comments Sought

- DOE seeks comment on all aspects of the supplementary analysis and rulemaking at-large, but in particular on the following issues:
  - New equipment classes
    - Pole/Pad
    - Network/Vault
    - 200 kV BIL
  - New TSLs
  - Opportunity for Energy Savings
  - Appropriateness of efficiency levels for each class
  - Utility pole replacement costs
  - Shipment data for all types

Feedback Is Requested

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- **In all correspondence, please refer to the Distribution Transformers rulemaking by:**
  - Distribution Transformers Rulemaking,
  - Docket Number EE–2010–BT–STD–0048, and
  - Regulatory Identification Number (RIN) 1904–AC04

- **Email:** DistributionTransformers-2010-STD-0048@ee.doe.gov

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- **Comment period closes:** June 29, 2012