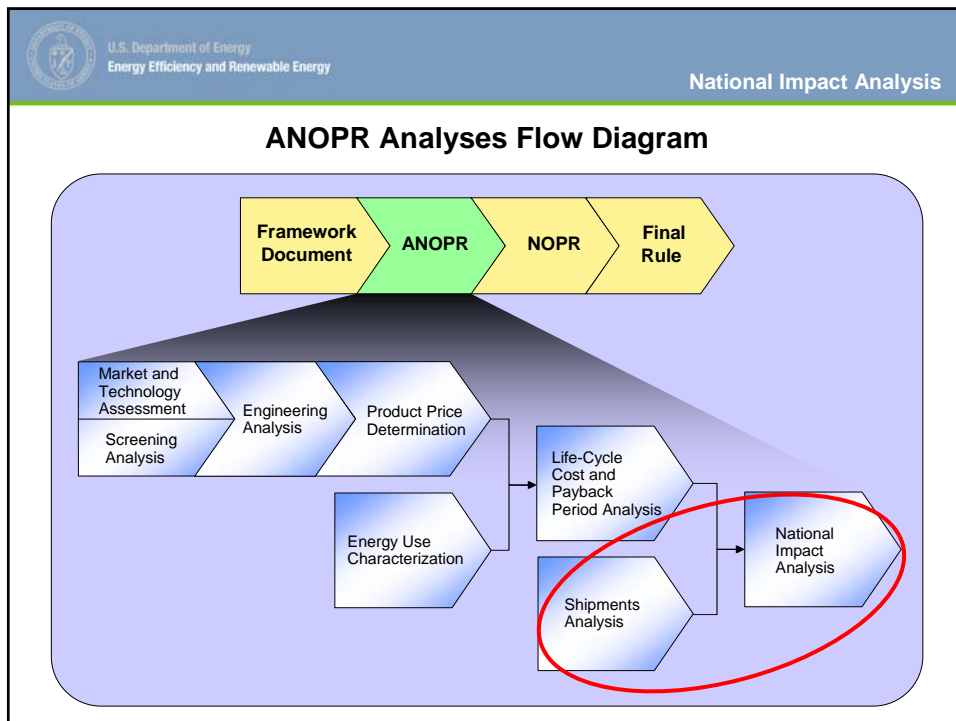
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Energy Efficiency and Renewable Energy


**Energy Conservation Standards for
General Service Fluorescent Lamps and Incandescent Reflector
Lamps
ANOPR Public Meeting**

National Impact Analysis

**Building Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy**

March 10-11, 2008





U.S. Department of Energy
Energy Efficiency and Renewable Energy

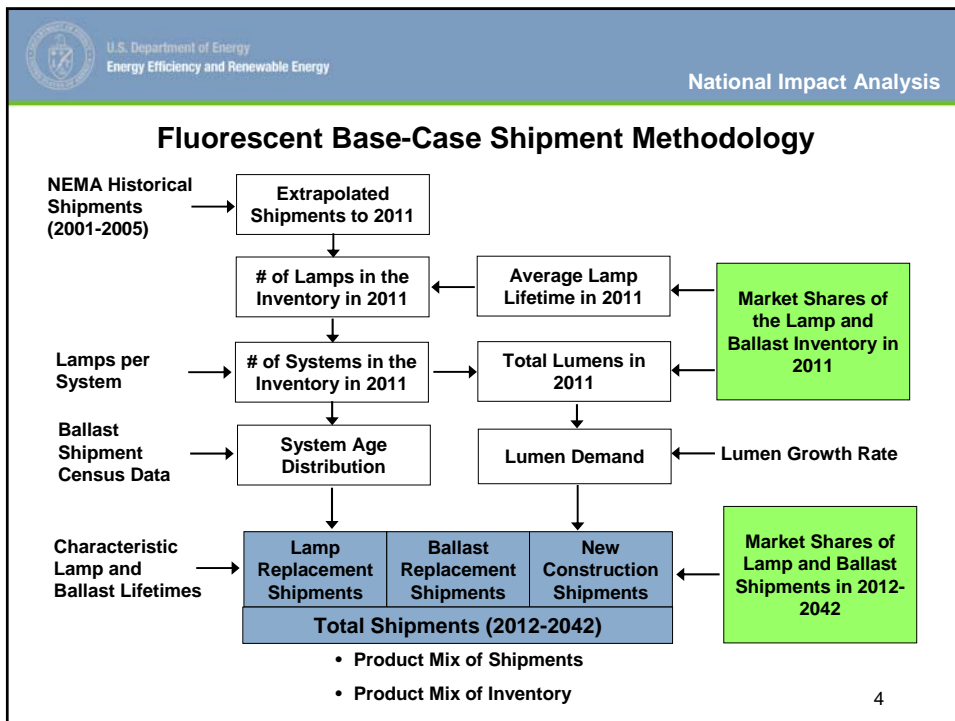
National Impact Analysis

Purpose

- **Shipments Analysis**
 - To estimate lamp shipments and the product mix of the stock over time (2012-2042) in the base case and standards case.

- **National Impact Analysis**
 - To estimate the National Energy Savings (NES) from GSFL and IRL efficacy standards at different levels.
 - To estimate the national economic impact on the nation (or the Net Present Value (NPV)) from GSFL and IRL efficacy standards at different levels.

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National Impact Analysis

2011 Fluorescent Lamp Stocks

- NEMA provided data from 2001 to 2005 for fluorescent lamp shipments
- DOE assumes that NEMA shipments represent 90% of total fluorescent lamp shipments
- 2011 lamp stocks calculated from lamp average lifetimes determined by assumed market shares of lamp inventory in 2011

Lamp Type	Lamp Stock (millions)
4-foot T8 medium bipin	1,670
4-foot T12 medium bipin	626
8-foot T8 single pin slimline	28
8-foot T12 single pin slimline	72
8-foot T8 recessed double contact HO	1
8-foot T12 recessed double contact HO	63

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National Impact Analysis

Base-Case Shipment Forecast Assumptions: 4-foot Medium Bipin

- **New Construction: Exponential growth of total lumens serviced by 4-foot medium bipin lamps and 8-foot single pin slimline lamps**
 - 1.6% annual growth rate obtained from growth in CBECS commercial building floor space
 - All new construction results in the purchase of 4-foot T8 lamp-and-ballast systems
- **Ballast Replacement: 14 year ballast service lifetime**
 - No new 4-foot T12 MBP magnetic ballast purchases after 2009 (2000 Ballast Rulemaking)
 - As 4-foot T8, 4-foot T12, and some 8-foot T12 SP slimline ballasts retire, new 4-foot T8 lamp-and-ballast systems are purchased as system replacements
- **Currently, the model assumes commercial operating hours and electricity prices**

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National Impact Analysis

**Base-Case Shipment Forecast Assumptions:
8-foot SP Slimline**

- **No new construction modeled**
 - Historical shipments indicate a decline in total 8-foot SP slimline shipments
- **Ballast Replacement: 14 year ballast service lifetime**
 - No new 8-foot T12 SP slimline magnetic ballast purchases after 2009 (2000 Ballast Rulemaking)
 - As 8-foot T12 SP slimline ballasts retire, 10% of those systems are replaced with 8-foot T8 SP slimline lamp-and-ballast systems and 90% are replaced with two 4-foot T8 MBP lamp-and-ballast systems
 - As 8-foot T8 SP slimline ballast retire, new 8-foot T8 SP slimline lamp-and-ballast systems are purchased as system replacements
- **Currently, the model assumes commercial operating hours and electricity prices**

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National Impact Analysis

**Base-Case Shipment Forecast Assumptions:
8-foot RDC High Output**

- **No new construction modeled**
 - Historical shipments indicate relatively flat 8-foot RDC HO shipments
 - All new construction assumed to be serviced by other technologies (e.g., T5)
- **Initial (2012) stock of only T12 lamps are modeled**
 - T8 lamps accounted for less than 2% of total 8-foot RDC HO shipments in 2005
- **Ballast Replacement: 10 year ballast service lifetime**
 - As 8-foot T12 RDC HO ballasts retire, new electronic 8-foot T12 RDC HO lamp-and-ballast systems are purchased as system replacements
- **Currently, the model assumes industrial operating hours and electricity prices**

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National Impact Analysis

Base-Case Market-Share Matrices

- **Two base-case market share (product mix) inputs for each lamp type:**
 - Product mix of the lamp and ballast inventory in 2011
 - Product mix of new system shipments after from 2012 to 2042
- **The shipment model assumes that when a lamp fails it is replaced with the same lamp**
- **Key Inputs into the Matrices:**
 - Lamp wattage distributions (e.g., 32W, 30W, 28W, 25W)
 - Lamp efficacy distributions (CSLs)
 - Ballast factor distributions (e.g., 0.88, 0.78, 0.75)
 - Correlation of the above properties to obtain system distributions

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National Impact Analysis

4-foot Medium Bipin Base-Case Market Share Matrix Inputs

4-foot T8 MBP Electronic Systems				4-foot T12 MBP Magnetic Systems		
System Characteristic		2012 Shipment Distribution	2042 Shipment Distribution	System Characteristic		2012 Inventory Distribution
Lamp Wattage	32W	90%	60%	Lamp Wattage	40W	31%
	30W	4%	15%		34W	69%
	28W	6%	17%	Lamp Efficacy	CSL0	56%
	25W	0%	8%		CSL1	22%
Lamp Efficacy	CSL2	43%	12%		CSL2	14%
	CSL3	29%	10%		CSL3	8%
	CSL4	15%	35%			
	CSL5	13%	43%			
Ballast Factor	0.88	90%	54%	Complete 4-foot MBP base-case market share matrices are presented in Tables 9.3.3 and 9.3.4 in Chapter 9 of the ANOPR TSD.		
	0.78	5%	33%			
	0.75	5%	13%			

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National Impact Analysis

Example Base-Case Market Share Matrix: 4-foot T8 MBP

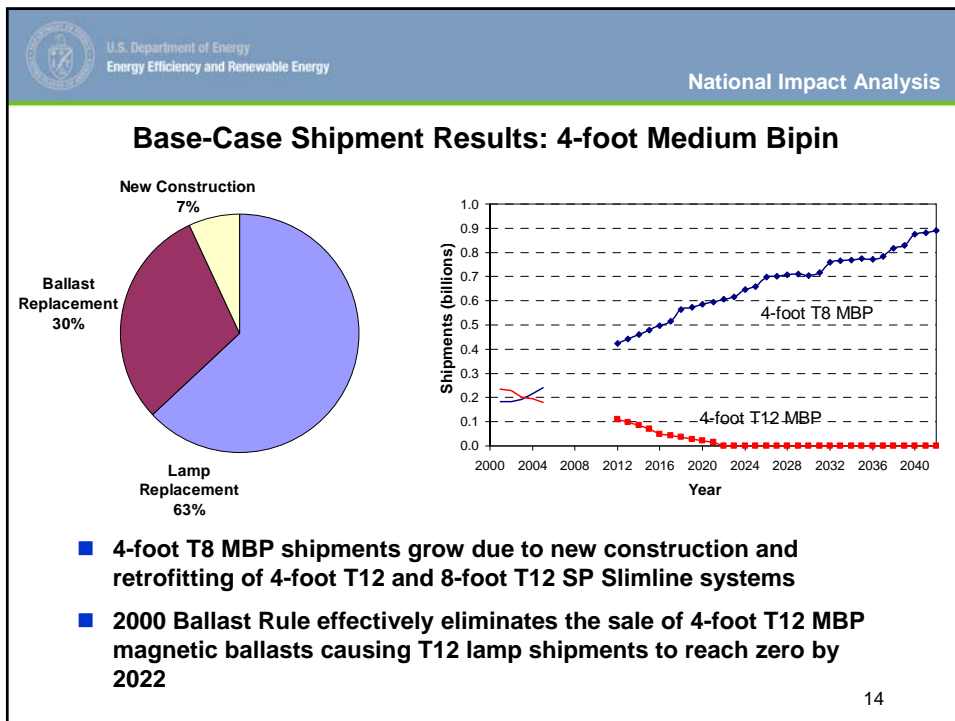
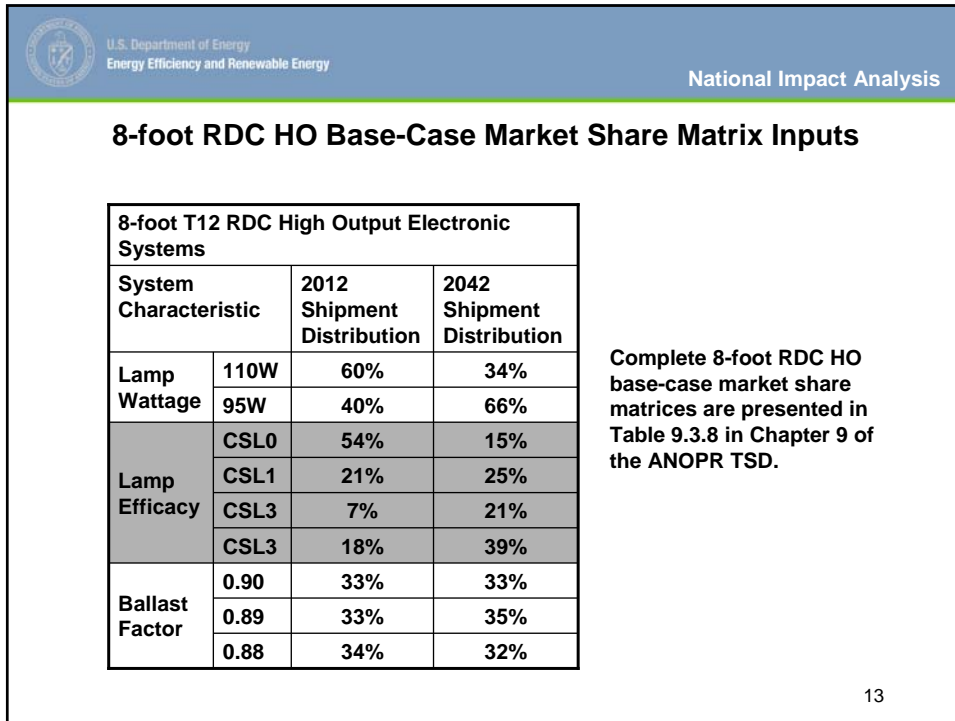
	CSL	Lamp Efficacy	Lamp Wattage	Lamp Lifetime	System Input Power	Installed Lamp Price	Mix of Systems Purchased in 2012 and Earlier	Mix of Systems Purchased in 2042		
		<i>lm/W</i>	<i>W</i>	<i>hrs</i>	<i>W</i>	<i>\$</i>	%	%		
BF	0.88	2	86.2	32.5	20,000	87.5	3.93	43	8	
		3	90.8	32.5	20,000	87.5	4.96	29	10	
		4	92.3	32.5	24,000	87.5	5.10	11	14	
		4	95.0	30.0	18,000	80.5	5.39	0	3	
		5	95.4	32.5	24,000	87.5	5.62	7	12	
		5	97.3	28.0	18,000	71.1	5.19	0	3	
			5	96.0	25.0	24,000	66.8	6.64	0	4
	0.78	2	86.2	32.5	20,000	78.5	3.93	0	4	
		3	90.8	32.5	20,000	78.5	4.96	0	0	
		4	92.3	32.5	24,000	78.5	5.10	0	6	
		4	95.0	30.0	18,000	72.4	5.39	2	6	
		5	95.4	32.5	24,000	78.5	5.62	0	6	
		5	97.3	28.0	18,000	63.3	5.19	3	7	
			5	96.0	25.0	24,000	58.1	6.64	0	4
	0.75	2	86.2	32.5	20,000	75.9	3.93	0	0	
3		90.8	32.5	20,000	75.9	4.96	0	0		
4		92.3	32.5	24,000	75.9	5.10	0	0		
4		95.0	30.0	18,000	70.0	5.39	2	6		
5		95.4	32.5	24,000	75.9	5.62	0	0		
5		97.3	28.0	18,000	60.9	5.19	3	7		
		5	96.0	25.0	24,000	55.5	6.64	0	0	
Total							100	100	11	

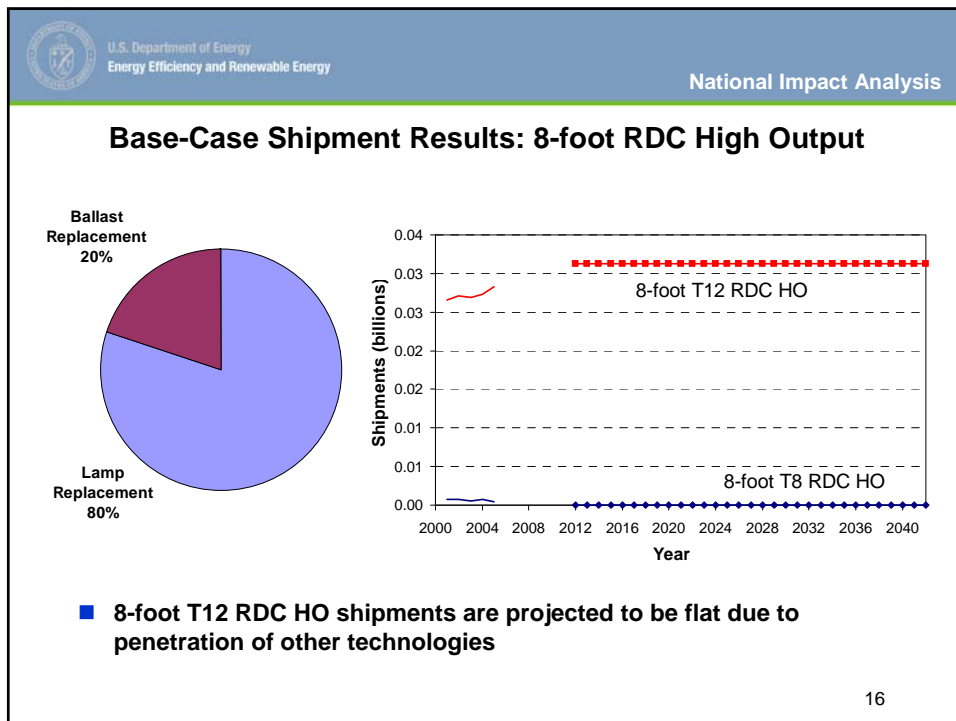
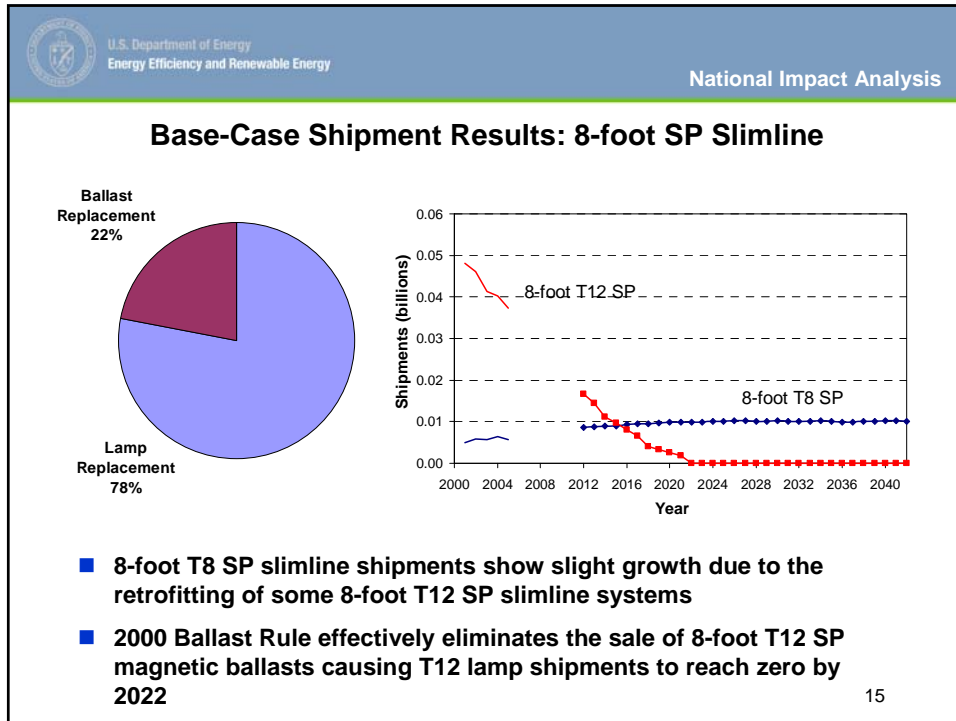
National Impact Analysis

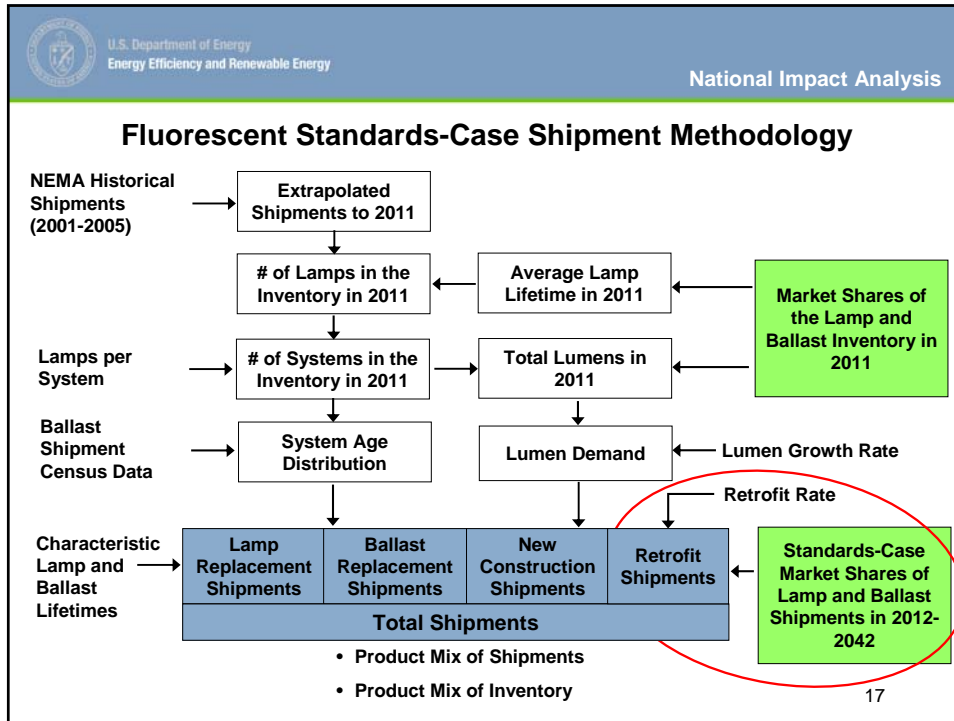
8-foot SP Slimline Base-Case Market Share Matrix Inputs

8-foot T8 SP Slimline Electronic Systems				8-foot T12 SP Slimline Magnetic Systems		
System Characteristic		2012 Shipment Distribution	2042 Shipment Distribution	System Characteristic		2012 Inventory Distribution
Lamp Wattage	59W	100%	70%	Lamp Wattage	75W	63%
	57W	0%	15%		Lamp Wattage	60W
	55W	0%	15%	Lamp Efficacy		CSL0
Lamp Efficacy	CSL3	44%	20%		CSL1	41%
	CSL4	48%	27%		CSL2	19%
	CSL5	8%	53%		CSL3	8%
Ballast Factor	0.88	70%	40%	Complete 8-foot SP slimline base-case market share matrices are presented in Tables 9.3.5 and 9.3.6 in Chapter 9 of the ANOPR TSD.		
	0.85	15%	33%			
	0.78	15%	27%			

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Energy Efficiency and Renewable Energy
- National Impact Analysis
- ### Fluorescent Standards-Case Shipment Methodology
- **Develop standards-case market-share matrices**
 - Use shipment scenarios to characterize how consumers will change purchase decisions with standards
 - Standards-case market share matrices show movement to higher efficacy lamps and alternate BF ballasts
 - Separate standards-case market-share matrices for lamp replacements on existing ballasts and for new system purchases
 - **Incorporate standards-induced retrofits**
 - Assumes that the increased first-cost of higher-efficacy 4-foot T12 MBP and 8-foot T12 SP lamps will result in additional voluntary retrofits in the standards case
 - Mandatory T12 ballast retrofits when no standard-compliant T12 lamps are available
 - **Recalculate shipments and stock product mixes**
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National Impact Analysis

Fluorescent Standards-Case Shipment Scenarios

- **Scenarios consider lamp price, system lumen output, and system energy consumption as drivers for consumer purchases**
- **Roll-up Scenario – “lower bound of energy savings”**
 - Only consumers purchasing below the candidate standard level analyzed, change purchase decisions in the standards case.
 - These consumers purchase the lowest first cost lamp option
- **Shift Scenario – “upper bound of energy savings”**
 - All consumers reevaluate their lamp and ballast purchase decisions
 - Consumers currently purchasing the lowest efficacy option, purchase the lowest first cost standards compliant lamp option
 - All other consumers purchase the lowest first-cost, energy-saving option

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National Impact Analysis

Fluorescent Lamp Standards-Case Retrofits

- **Increased Voluntary Magnetic T12 Ballast Retrofit at all CSLs**
 - Current trends indicate that consumers are retrofitting their existing 4-foot T12 MBP and 8-foot T12 SP slimline magnetic systems and are replacing them with the corresponding more cost-effective T8 electronic systems

```

graph LR
    A[Increased efficacy standard] --> B[Increased T12 lamp price]
    B --> C[Increased T12 retrofits]
    
```

- Increasing retrofit rate of 4-foot T12 MBP and 8-foot T12 SP systems in the standards case at each CSL

CSL	Retrofit Rate (% remaining stock per year)
1	10%
2	20%
3	30%
4	40%
5	50%

- **Mandatory T12 Ballast Retrofit**
 - At CSL4 and CSL5, no T12 lamps are standards-compliant. Therefore, upon T12 lamp failure, the entire T12 lamp-and-ballast system is retrofitted and replaced with a T8 system.

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National Impact Analysis

Fluorescent Shipment Forecasts

DOE invites comment on the methodology and data sources used to estimate initial lamps stocks in 2011. (Issue #11)

DOE invites comment on the fluorescent base-case and standards-case market share matrices. (Issue #10, Issue #12)

DOE invites comment on the fluorescent base-case shipment forecasts. (Issue #11)

DOE invites comment on appropriate standards-case voluntary magnetic T12 ballast retrofit rates for the 4-foot MBP and 8-foot SP slimline. (Issue #11)

DOE invites comment on the shipment scenarios analyzed and other scenarios DOE should analyze for GSFL. (Issue #12)

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National Impact Analysis

Incandescent Reflector Lamp Base-Case Shipment Methodology


```

    graph TD
        A[NEMA Historical Shipments (2001-2005)] --> B[Historical Shipments of Covered Lamps by Sector]
        B --> C[Extrapolated Shipments to 2011]
        C --> D[Lamps in the Inventory in 2011]
        E[Market Shares of the Lamp Inventory in 2011] --> D
        F[Rate of New Construction Emerging Technologies] --> G[# of Lamps in the Inventory in 2012-2042]
        D --> G
        H[Market Shares of the Lamp Inventory in 2012-2042] --> I[Lamp Replacement Shipments | New Construction Shipments]
        G --> I
        I --> J[Total Shipments]
    
```

Lamp Replacement Shipments	New Construction Shipments
Total Shipments	

- Product Mix of Shipments
- Product Mix of Inventory

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National Impact Analysis

Base-Case Shipments Forecasts: IRL 2011 Lamp Stock

- **NEMA data provides historical shipments for non-halogen and halogen IRL**
- **Assumptions:**
 - NEMA shipments represent 85% of total IRL shipments
 - DOE estimates that EISA 2007 exempts approximately 60% of non-halogen IRL
 - Non-halogen shipments: 33 percent serve the commercial sector, 67 percent serve the residential sector
 - Halogen shipments: 60 percent serve the commercial sector, 40 percent serve the residential sector
- **Installed stock of covered IRL in 2011**
 - Residential sector: 297 million lamps
 - Commercial sector: 77 million lamps

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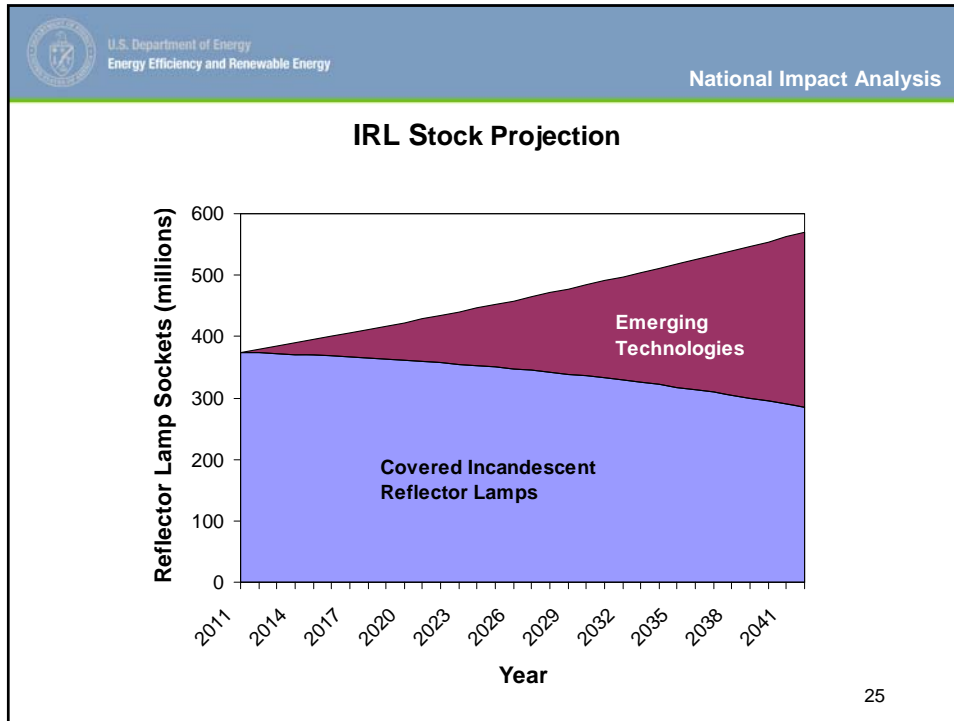
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National Impact Analysis

IRL Stock Projection Assumptions

- **New Construction: Exponential growth in IRL sockets**
 - Historical annual growth rate of IRL stock is estimated to be 8-10%. However, this growth may be unsustainable.
 - DOE uses building floor space growth to estimate new construction growth
 - 1.3% sockets/year in the residential sector (RECS building floor space)
 - 1.6% sockets/year in the commercial sector (CBECS building floor space)
- **DOE assumes other technologies like reflector CFL, ceramic metal halide, and solid state lighting will penetrate the IRL market: ~50% IRL sockets in 2042**

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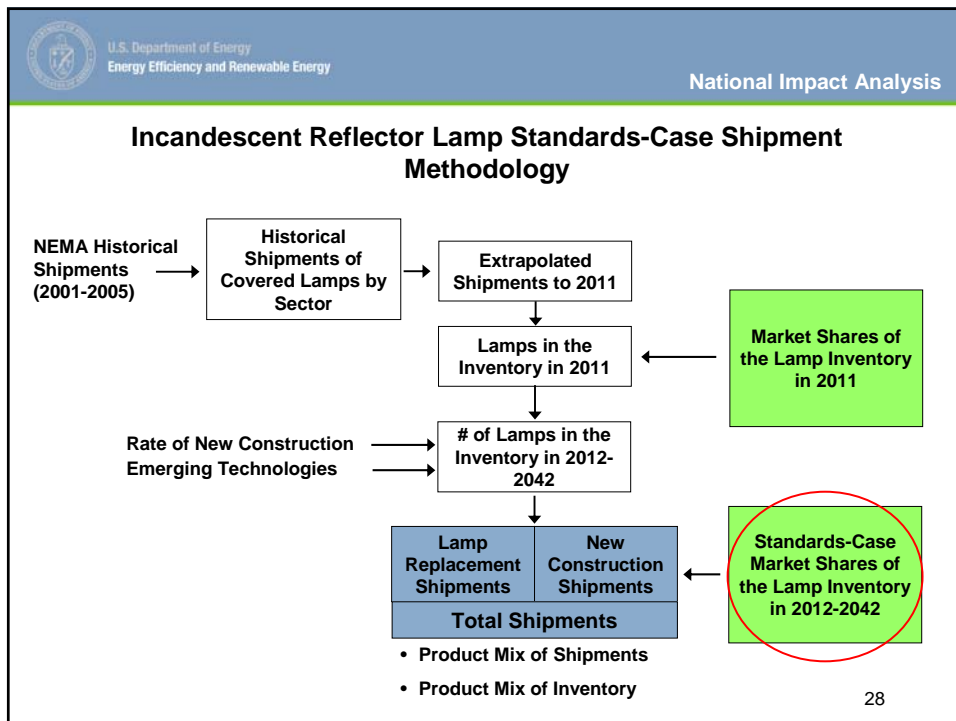
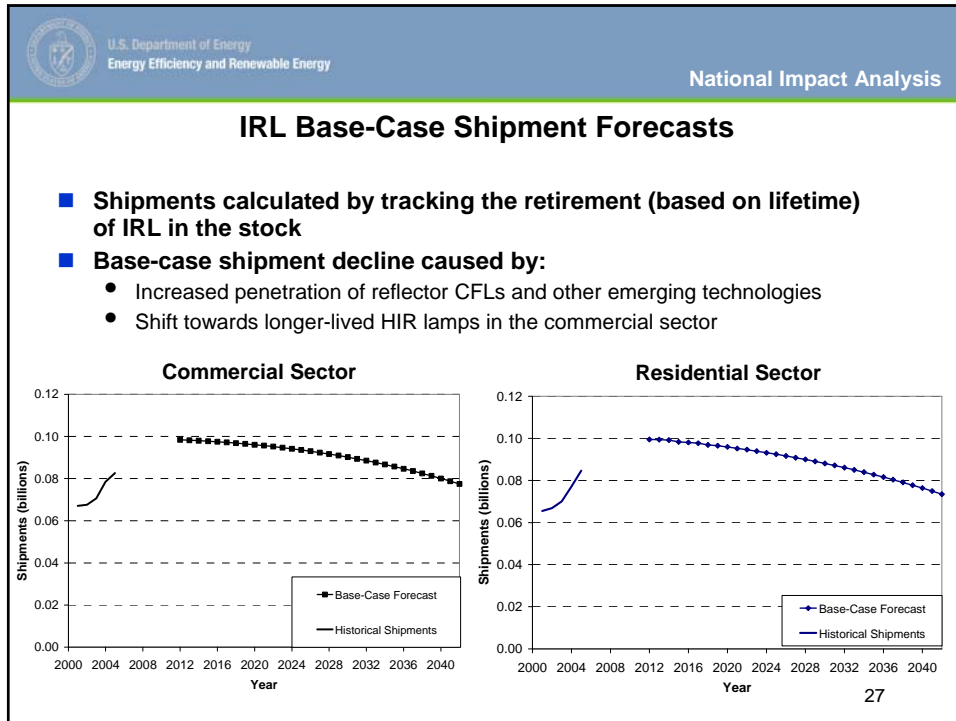
National Impact Analysis


Base-Case Market-Share Matrices: IRL

- Analyzed three lumen packages:
 - 27% at 580 lumens (50W Halogen baseline)
 - 32% at 1,050 lumens (75W Halogen baseline)
 - 41% at 1,310 lumens (90W Halogen baseline)
- Residential stock: 100% halogen throughout the analysis period
- Commercial stock: 80% halogen and 20% HIR in 2012
50% halogen and 50% HIR in 2042

Commercial Sockets				Residential Sockets			
Lamp Design	Stock in 2011	Stock in 2042		Lamp Design	Stock in 2011	Stock in 2042	
90W, 14.6 lm/W, 2,500 hrs, Halogen	33%	21%		90W, 14.6 lm/W, 2,500 hrs, Halogen	41%	41%	
75W, 14.0 lm/W, 2,500 hrs, Halogen	26%	16%		75W, 14.0 lm/W, 2,500 hrs, Halogen	32%	32%	
50W, 11.6 lm/W, 3,000 hrs, Halogen	22%	14%		50W, 11.6 lm/W, 3,000 hrs, Halogen	27%	27%	
70W, 18.0 lm/W, 3,000 hrs, HIR	8%	21%					
60W, 17.5 lm/W, 3,000 hrs, HIR	6%	16%					
41.3W, 15 lm/W, 3,000 hrs, HIR	5%	14%					

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National Impact Analysis

Incandescent Reflector Lamp Standards Case Scenarios

- **Stock of IRL lamps in the standards-case is the same as the stock of IRL lamps in the base-case in all scenarios.**
- **Main Scenario – “upper bound of energy savings”**
 - Assumes all base-case IRL consumers continue to purchase regulated IRL products
 - All IRL consumers purchase lowest first cost, higher efficacy, reduced-wattage lamps in the standards case (light output of standards-compliant lamp is same as baseline lamp)
- **65W BR Lamp Substitution Sensitivity – “reduced energy savings”**
 - Accounts for standards case market migration to the exempted 65W BR30 and BR40 lamps
 - 65W BR lamp is a direct replacement for the 50W PAR baseline lamp.
- **10% Lumen Increase Sensitivity – “reduced energy savings”**
 - Residential consumers purchase same-wattage, higher-wattage, and reduced-wattage lamp designs
 - Results in an overall increase in lumens

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Energy Efficiency and Renewable Energy

National Impact Analysis

IRL Main Scenario: Commercial Standards-Case Market Share Matrices

CSL	Lamp Design	Stock in 2011*	Stock in 2013**	Stock in 2042
		%	%	%
Base Case	90W, 14.6 lm/W, 2,500 hrs, Halogen	33		21
	75W, 14.0 lm/W, 2,500 hrs, Halogen	26		16
	50W, 11.6 lm/W, 3000 hrs, Halogen	22		14
	70W, 18.0 lm/W, 3,000 hrs, HIR	8		21
	60W, 17.5 lm/W, 3,000 hrs, HIR	6		16
	41.3W, 15 lm/W, 3000 hrs, HIR	5		14
	Total		100	
CSL1	79W, 16.6 lm/W, 3000 hrs, Improved Halogen		32	21
	66W, 15.9 lm/W, 3000 hrs, Improved Halogen		25	16
	44.3W, 14 lm/W, 3000 hrs, Improved Halogen		21	14
	70W, 18 lm/W, 3000 hrs, HIR		9	21
	60W, 17.5 lm/W, 3000 hrs, HIR		7	16
	41.3W, 15 lm/W, 3000 hrs, HIR		6	14
	Total		100	
CSL2	70W, 18 lm/W, 3,000 hrs, HIR		41	41
	60W, 17.5 lm/W, 3,000 hrs, HIR		32	32
	41.3W, 15 lm/W, 3000 hrs, HIR		27	27
	Total			
CSL3	66W, 19.8 lm/W, 4,000 hrs, Improved HIR		41	41
	55W, 19.1 lm/W, 4,000 hrs, Improved HIR		32	32
	40W, 17 lm/W, 4,000 hrs, Improved HIR		27	27
	Total		100	


*Base-Case Input Only
**Standards-Case Input Only (2013 is the year when standards-compliant lamps are able to fill all sockets.

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IRL Main Scenario: Residential Standards Case Market Share Matrices				
CSL	Lamp Design	Stock in 2011*	Stock in 2015**	Stock in 2042
		%	%	%
Base Case	90W, 14.6 lm/W, 2,500 hrs, Halogen	41		41
	75W, 14.0 lm/W, 2,500 hrs, Halogen	32		32
	50W, 11.6 lm/W, 3,000 hrs, Halogen	27		27
	Total	100		100
CSL1	79W, 16.6 lm/W, 3,000 hrs, Improved Halogen		41	41
	66W, 15.9 lm/W, 3,000 hrs, Improved Halogen		32	32
	44.3W, 14 lm/W, 3,000 hrs, Improved Halogen		27	27
	Total		100	100
CSL2	70W, 18 lm/W, 3,000 hrs, HIR		41	41
	60W, 17.5 lm/W, 3,000 hrs, HIR		32	32
	41.3W, 15 lm/W, 3,000 hrs, HIR		27	27
	Total			
CSL3	66W, 19.8 lm/W, 4,000 hrs, Improved HIR		41	41
	55W, 19.1 lm/W, 4,000 hrs, Improved HIR		32	32
	40W, 17 lm/W, 4,000 hrs, Improved HIR		27	27
	Total		100	100

*Base-Case Input Only
**Standards-Case Input Only (2015 is the year when all standards-compliant lamps are able to fill all sockets.)

U.S. Department of Energy Energy Efficiency and Renewable Energy		National Impact Analysis	
IRL Shipment Forecasts			
<i>DOE invites comment on the methodology used to incorporate emerging technologies in the base-case IRL forecast. (Issue #11)</i>			
<i>DOE invites comment on the assumptions discussed including IRL operating sectors, market shares of incandescent and halogen IRL, and market shares of exempted IRL. (Issue #11)</i>			
<i>DOE invites comment on the population of IRL base-case and standards-case market share matrices. (Issue #10, Issue #12)</i>			
<i>DOE invites comment on the national lumen output projection in both the standards case and base case. Specifically DOE invites comment on whether any shipment or stock adjustments are necessary in response to over-lighting or under-lighting. (Issue #11)</i>			
<i>DOE invites comment on standards-case shipment scenarios analyzed for incandescent reflector lamps. (Issue #12)</i>			


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National Impact Analysis

National Energy Savings Inputs

- **Product Stock by Design**
 - Tracked by shipments, market-share matrices, and product retirements
- **Unit Annual Energy Consumption**
 - Per unit values for each lamp or lamp-and-ballast system as developed by the Energy-Use Characterization
- **Electricity Site-to-Source Conversion Factors**
 - Conversion factors forecast using *2007 Annual Energy Outlook (2030-2042 estimated using 2020-2030 forecast trends)*
 - Factors vary annually and account for generation, distribution, and transmission losses
- **HVAC Interaction**
 - Commercial and industrial sector: 6.25% (2000 Ballast rulemaking)
 - No HVAC modeled in the residential sector
- **Rebound Rate**
 - Accounts for increased lighting usage due to lower operating costs in the standards case
 - Commercial and Industrial sectors: 1%, Residential sector: 8.5%

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National Impact Analysis

National Energy Savings Inputs

DOE invites comment on the HVAC interaction implemented in the commercial and residential sectors.

DOE invites comment on the inclusion and the magnitude of the rebound effect for purposes analyzing the expected effects of this regulation.

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National Impact Analysis

Net Present Value Inputs

- **Shipments by Product Design**
 - Taken from shipments analysis
- **Per Unit Installed Cost**
 - Taken from LCC and Product Price Determination (prices and labor costs)
- **Electricity Prices**
 - Average prices taken from LCC analysis
 - Future energy prices adjusted according to trend forecasted by the *2007 Annual Energy Outlook*
- **Discount Rate**
 - 7% and 3% real from OMB's Regulatory Analysis Circular A-4
 - Future expenses discounted to 2007, reported in 2006\$
- **DOE also calculates a residual value in 2042 to account for remaining life of installed lamps in the base case and standards case.**

DOE invites comment on its usage of residual value to account for the remaining lifetime of lamps.

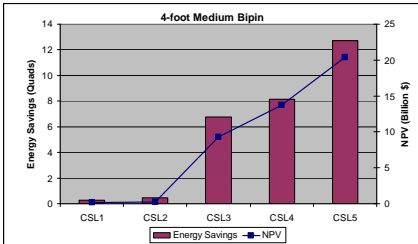
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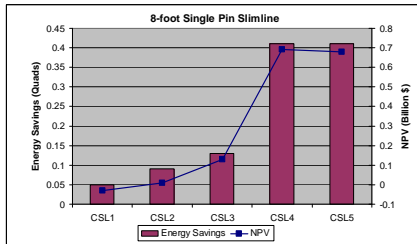
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National Impact Analysis

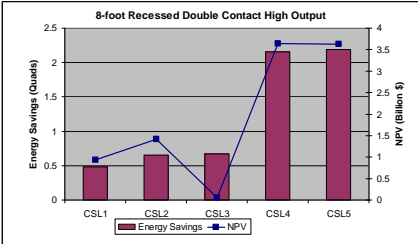
General Service Fluorescent Lamps NES and NPV Results (Shift Scenario, 7% Discount Rate)



Scenario	Energy Savings (Quads)	NPV (Billion \$)
CSL1	0.2	0.2
CSL2	0.5	0.5
CSL3	6.5	10.0
CSL4	7.5	15.0
CSL5	12.5	22.0

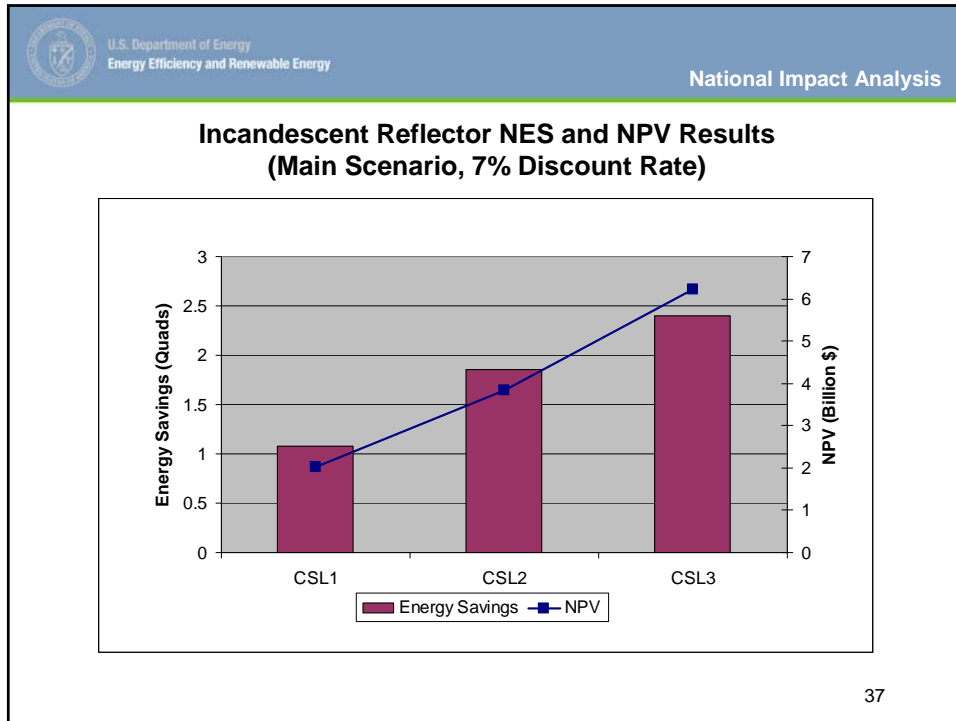


Scenario	Energy Savings (Quads)	NPV (Billion \$)
CSL1	0.05	0.05
CSL2	0.1	0.1
CSL3	0.15	0.2
CSL4	0.4	0.7
CSL5	0.4	0.7



Scenario	Energy Savings (Quads)	NPV (Billion \$)
CSL1	0.5	1.0
CSL2	0.7	1.5
CSL3	0.7	1.0
CSL4	2.2	3.5
CSL5	2.2	3.5

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- National Impact Analysis
- ### ANOPR Issues for Public Comment
- Base-Case and Standards-Case Market Share Matrices (Issue #10)
 - Shipment Forecasts (Issue #11)
 - Base-Case and Standards-Case Forecasted Efficiencies (Issue #12)
 - NES and NPV Calculation Inputs
- 38