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## Electric-Drive Vehicle Implementation Plan

Presented at  
*CEC-ARB Workshop on Developing a State  
Plan to Increase the Use of Alternative  
Transportation Fuels*  
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- 1**    **Methodology**
- 2**    **Overall Impact**
- 3**    **Cold-Ironing**
- 4**    **Truck Stop Electrification**
- 5**    **Transport Refrigeration Units**
- 6**    **Electric Forklifts**
- 7**    **Plug-In Hybrids**
- 8**    **Conclusions**

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- Goal: estimate and compare the cost effectiveness of five promising e-drive technologies
  - Cold-ironing, truck-stop electrification, transport refrigeration units, e-forklifts, and plug-in hybrid electric vehicles
  - CE calculated by considering all criteria pollutant, GHG, and petroleum dependence benefits



Source: <http://www.cashassociates.com/>

- Economic data gathered from widest possible survey of existing studies, combined with direct contact with manufacturers
- Emissions updated from Phase I study based upon all appropriate ARB and EPA rules (e.g. marine gas oil requirement, anti-idling restrictions)

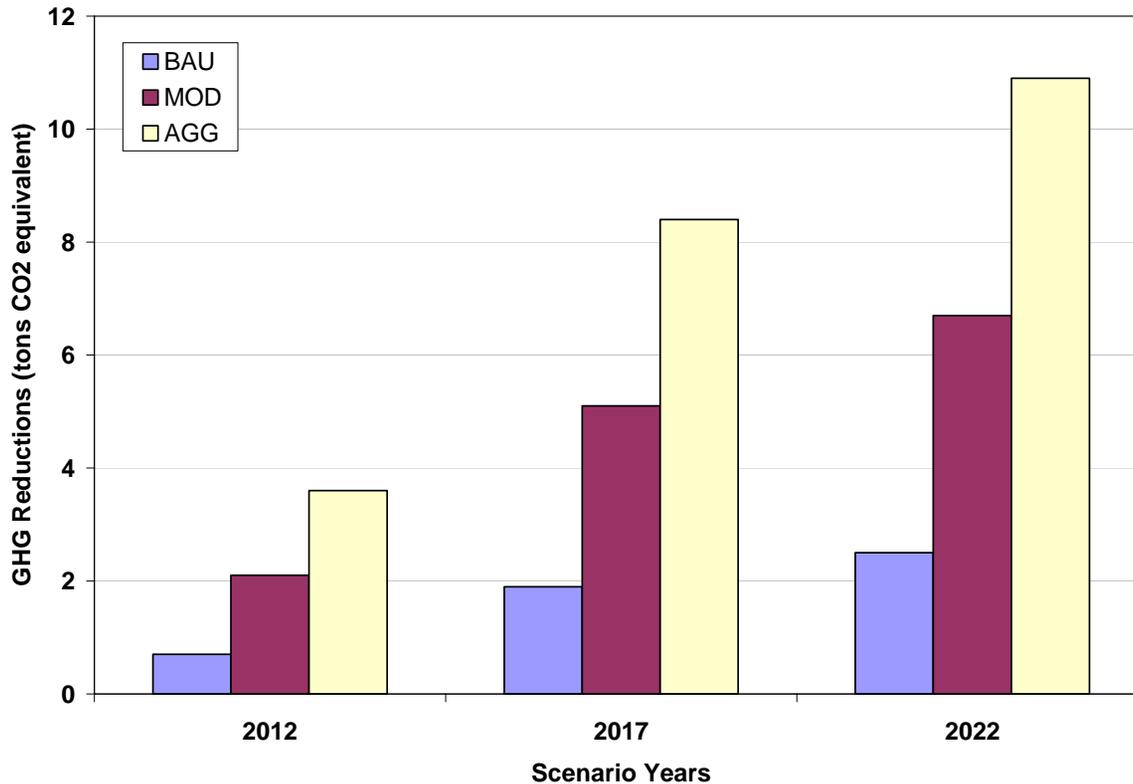
- Cost effectiveness estimated for:
  - Two scenarios: expected and achievable
  - Three years: 2010, 2015, and 2020
  - Two cases: low (good) and high (poor) cost effectiveness
- Selected two cost effectiveness metrics after surveying the field:
  - Moyer:  $\text{upfront capital costs} / (\text{NOx} + \text{ROG} + 20 \times \text{PM})$
  - Benefit/cost ratio:  $\text{monetized public and private benefit} / \text{annualized capital costs}$



Source: "Turn Idle Time Into Cash" *Fleet Owner* 2003.

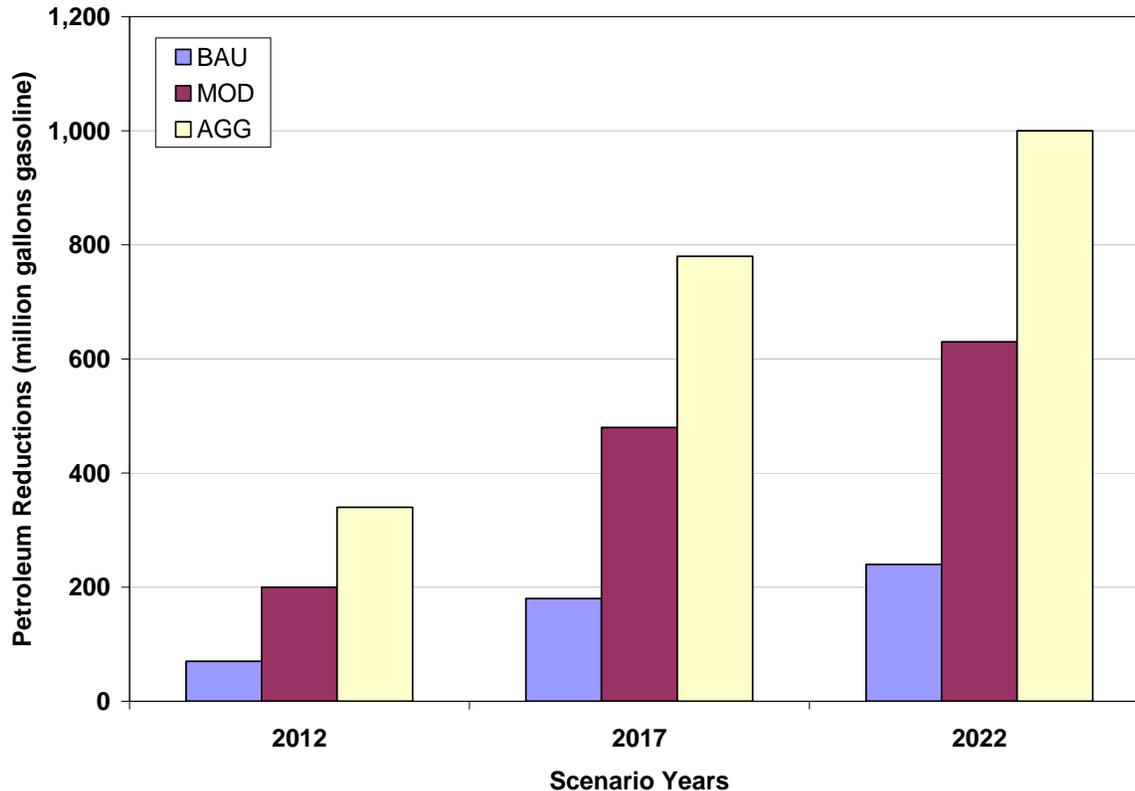
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**The adoption of electric drive technologies has the ability to provide GHG reductions up to 6.2% of reductions specified by AB 32**



**AB 32 requires 1990 GHG emission levels by 2020, necessitating a reduction of 175 tons of CO<sub>2</sub> equivalent in 2020**

## Petroleum reductions associated with adoption of electric drive technologies could reach 1 billion gallons of gasoline by 2022



**Approximately 80% of reductions in petroleum use and GHG emissions is attributable to e-forklifts and PHEVs in the 2017 and 2022 cases**

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## **Cold-ironing allows ocean-going vessels to reduce emissions by operating on grid power while in port and avoiding the operation of diesel engines**

- Cold-ironing can yield significant urban criteria pollutant reductions due to the offset of significant diesel loads in close proximity to densely populated areas
- Cold-ironing would have to be adopted by a range of vessels, including container ships, tankers, and refrigerated cargo ships
- Primary barrier to implementation is the need to retrofit existing vessels to operate on 6.6 kV power and investments in shoreside power supply
  - Many ships have long lifetimes and fall outside traditional local and national regulatory authority
  - Vessel retrofits: ~\$1.5 million
  - Berth retrofit: ~\$3-8 million

**Cold-ironing holds the potential for significant reductions in criteria pollutant emissions.**

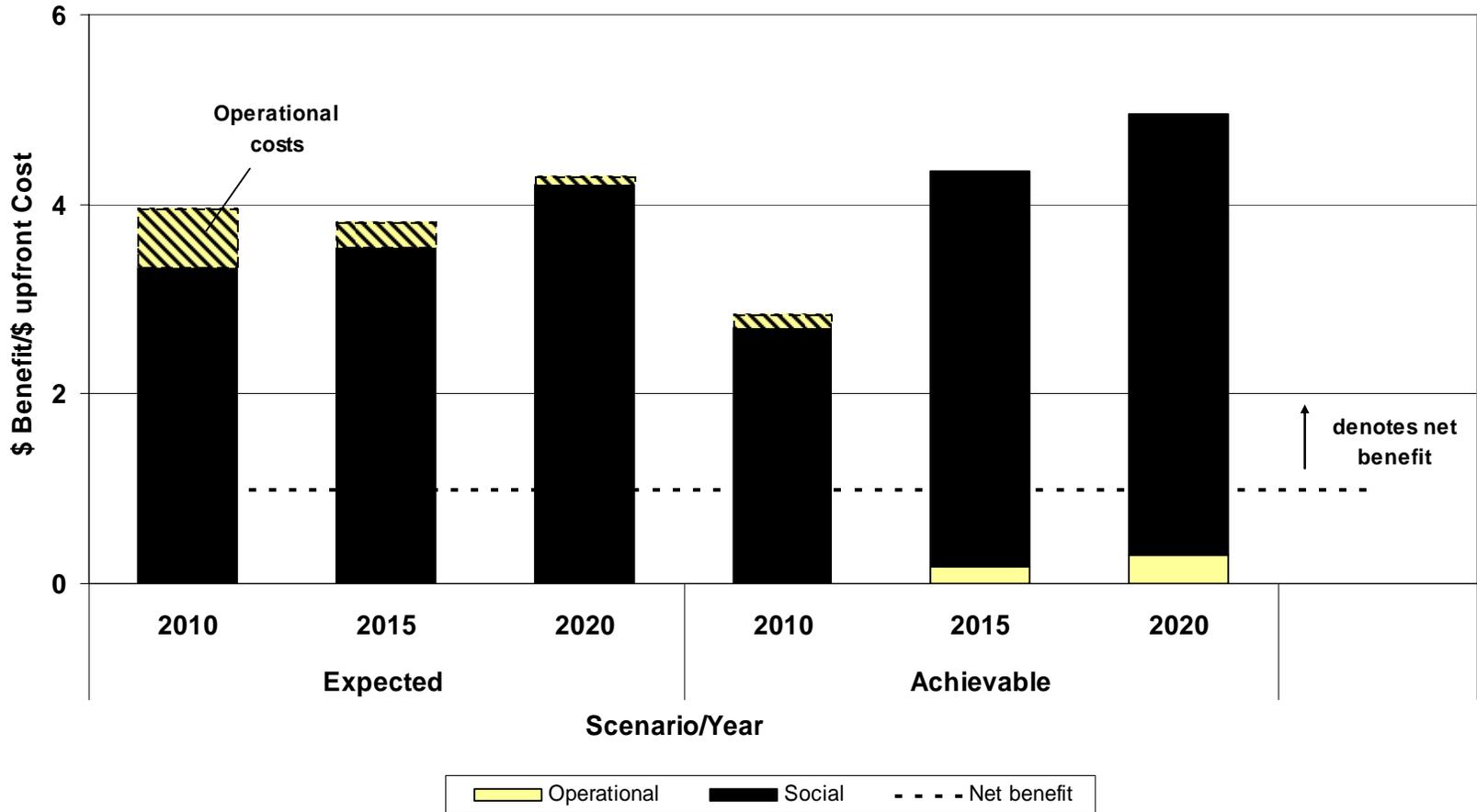
Pollutant	Scenario	Emissions Reduction by Year (tpd)		
		2010	2015	2020
NOx	Expected	2.5	5.9	9.0
	Achievable	5.1	29.7	47.2
NMOG	Expected	0.09	0.20	0.30
	Achievable	0.18	1.0	1.6
PM	Expected	0.04	0.10	0.16
	Achievable	0.09	0.50	0.80
SOx	Expected	0.04	0.09	0.14
	Achievable	0.08	0.45	0.71

**Cold-ironing holds the potential to significantly reduce GHG emissions and displace petroleum use.**

Species	Scenario	Annual Reductions		
		2010	2015	2020
GHG (tons CO <sub>2</sub> eq.)	Expected	37,725	101,764	160,092
	Achievable	104,136	530,982	854,484
Petroleum (million gge)	Expected	6.5	15.9	24.7
	Achievable	15.3	82.0	131.1

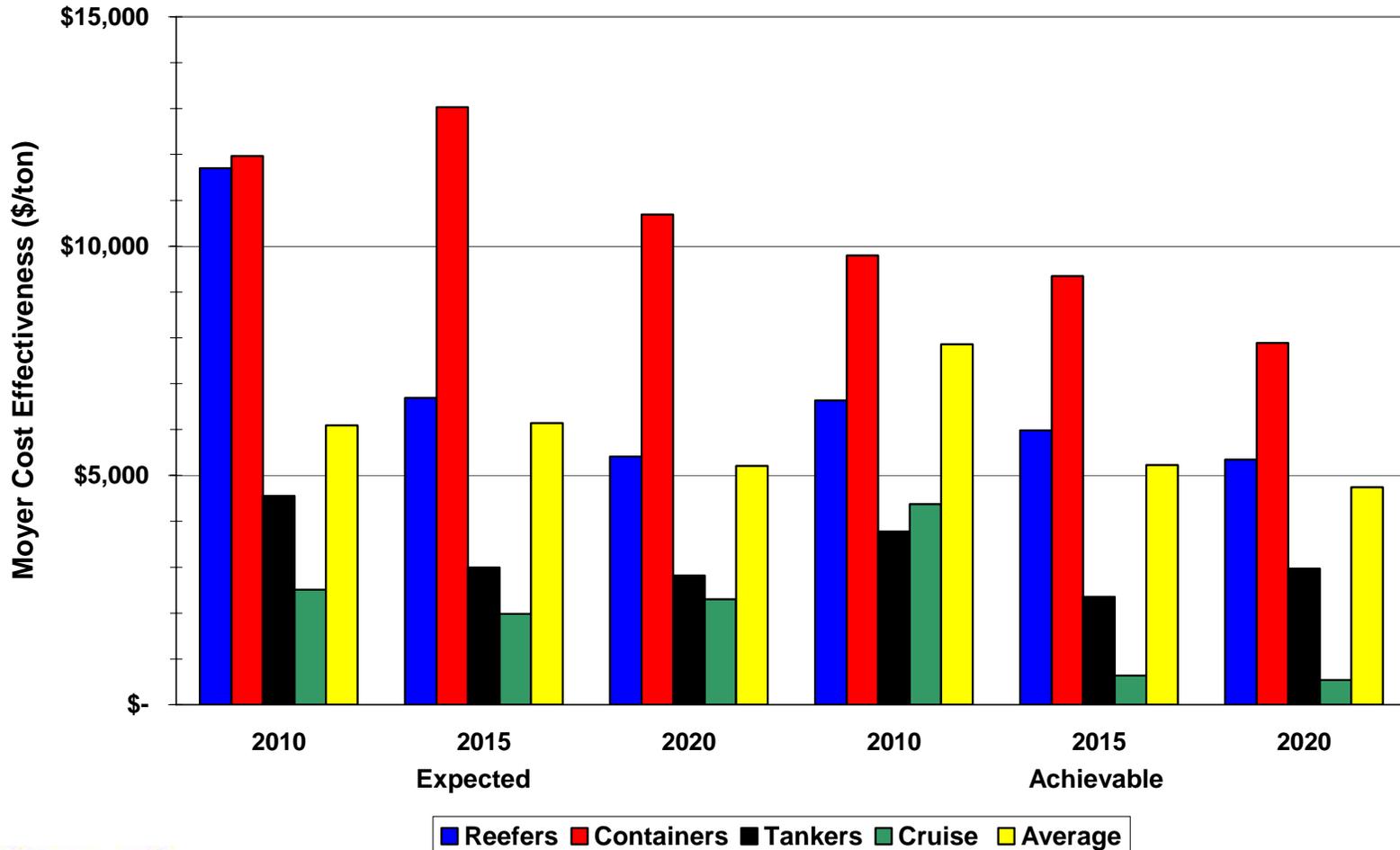
**Cold-ironing provides significant net social benefit.**

**Annualized Lifecycle and Social Benefit/Cost Ratio for Cold-Ironing  
Base Benefit Methodology**



**Cold-ironing Moyer cost effectiveness ranges between \$5000 and \$10,000/ton, generally decreasing over time.**

**Moyer Cost-Effectiveness by Scenario, Year, and Vessel Type**



**Due to low operational savings, cold-ironing is likely to require aggressive mandates and incentives in order to achieve large societal benefits**

- Business-as-Usual Growth Scenario
  - POLA/POLB outlined targets for voluntary adoption of cold-ironing in their *Clean Air Action Plan* to offset increased goods movement
  - Continued progress towards goals adopted in 2000 Diesel Risk Reduction Plan
- Moderate Growth Scenario
  - Vigorous incentives to overcome high upfront capital costs, perhaps by incorporating GHG and petroleum reduction into Moyer
- Aggressive Growth Scenario
  - ARB adopting the most aggressive rule possible, requiring 80% reduction of hotelling emissions
  - The existence of, and U.S. participation in, a post-Kyoto international regulatory regime for climate change

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## **Truck stop electrification aims to reduce emissions and fuel consumption associated with main engine idling at truck stops**

- TSE is of interest to both government agencies and operators as a way to reduce local pollution “hotspots” and reduce fuel costs
- Two types of TSE exist:
  - On-board TSE uses grid power supply to power on-board HVAC systems
  - Off-board TSE systems such as Idleaire utilize off-board HVAC to provide heating and cooling with other ancillary services
- The California ARB has passed a rule scheduled for enforcement in 2008 restricting main engine idling by sleeper trucks in California
- The U.S. EPA sponsored Smartway Transport program provides grants and technology investments to improve fuel efficiency and reduce airborne emissions from goods movements nationwide

**Truck stop electrification holds the potential for significant reductions in criteria pollutant emissions.**

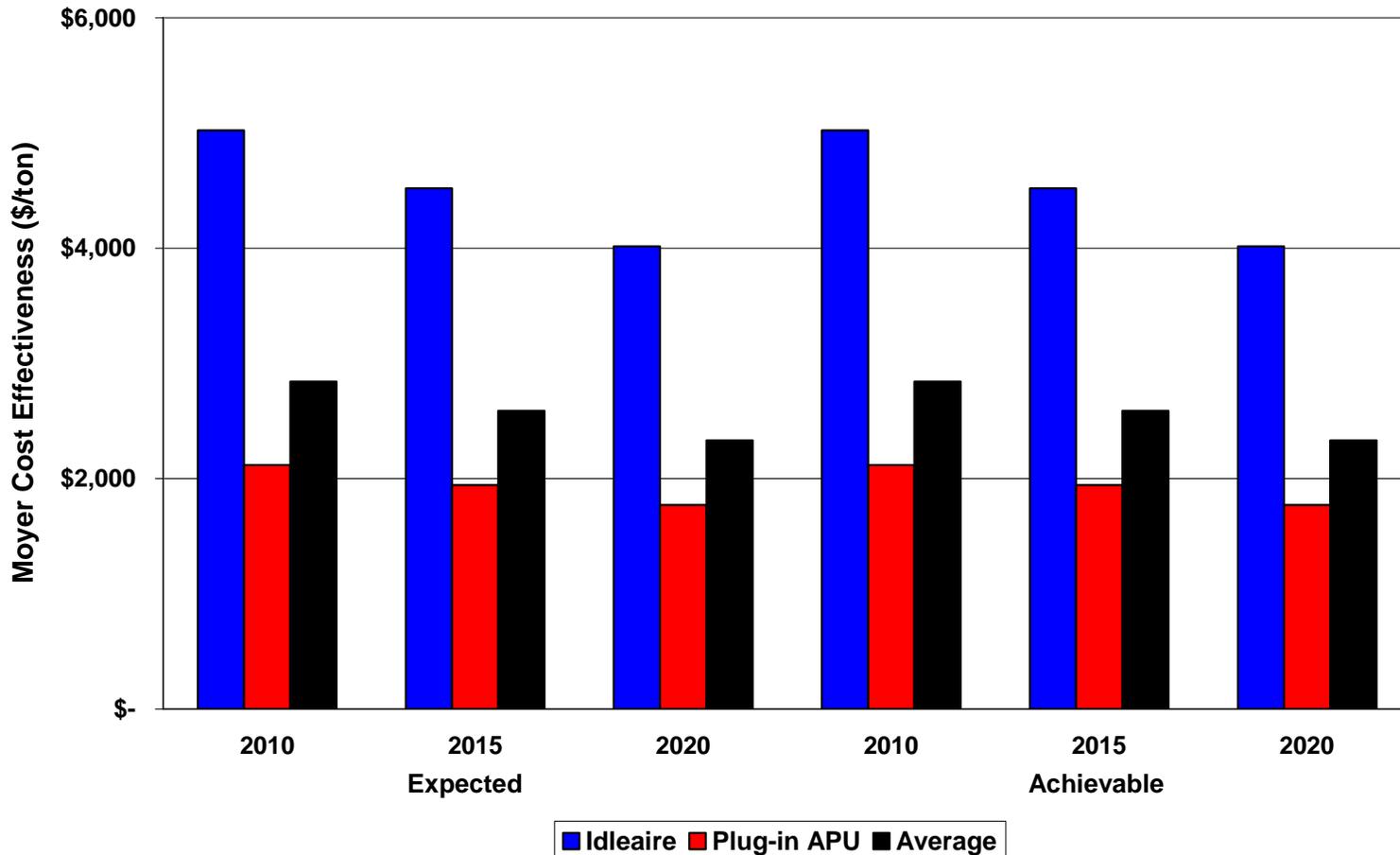
Pollutant	Scenario	Emissions Reduction by Year (tpd)		
		2010	2015	2020
NOx	Expected	4.2	6.3	9.5
	Achievable	8.1	12.6	19.8
NMOG	Expected	0.26	0.39	0.59
	Achievable	0.51	0.78	1.23
PM	Expected	0.03	0.04	0.06
	Achievable	0.05	0.08	0.12

**Truck-stop electrification holds the potential to significantly reduce GHG emissions and displace petroleum use.**

Species	Scenario	Annual Reductions		
		2010	2015	2020
GHG (tons CO <sub>2</sub> eq.)	Expected	105,072	157,144	238,890
	Achievable	203,929	314,909	496,327
Petroleum (million gge)	Expected	11.3	16.9	25.7
	Achievable	22.0	33.9	53.5

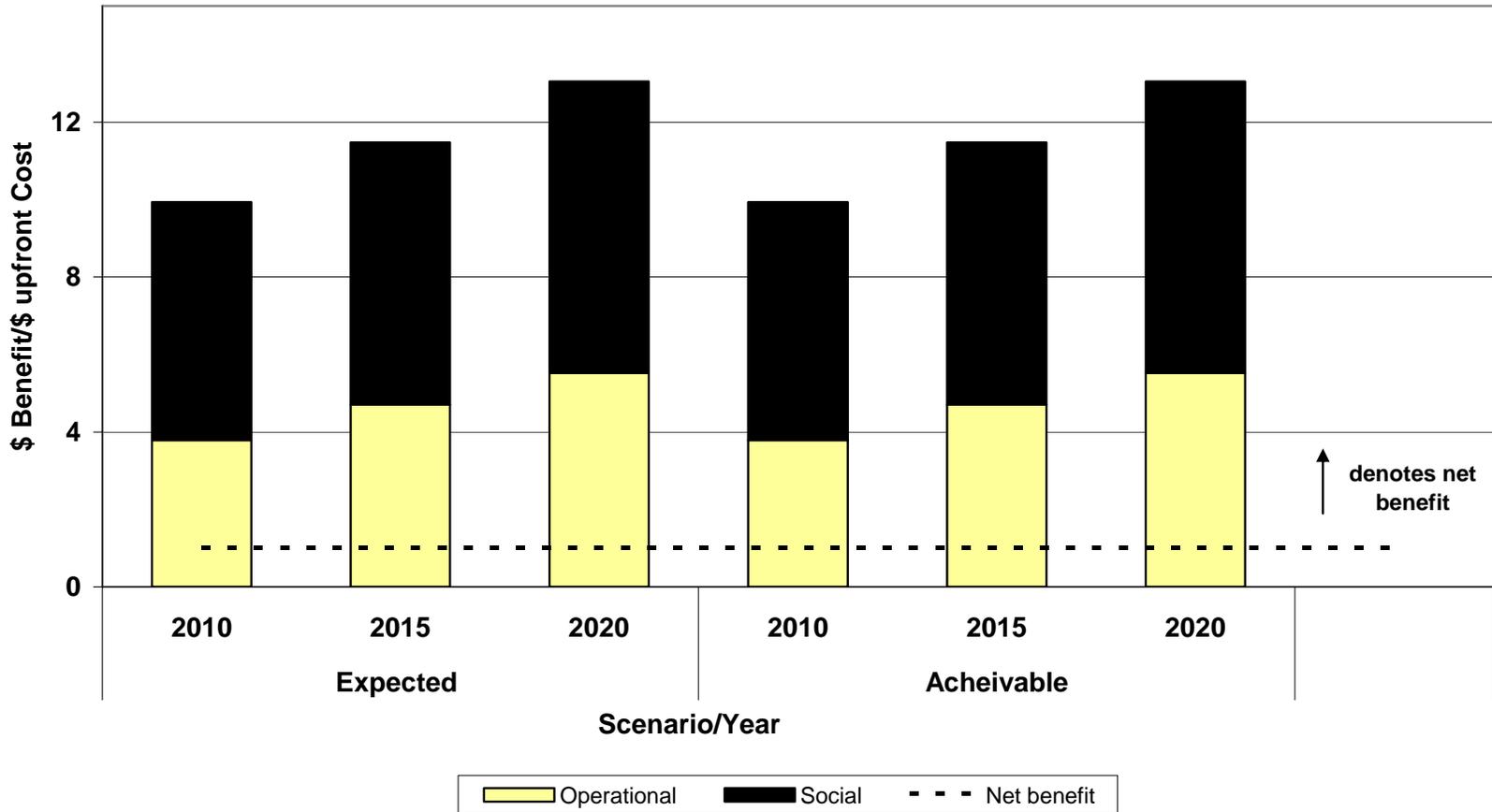
**TSE Moyer cost effectiveness ranges between \$2000 and \$5000/ton, decreasing over time.**

**Moyer Cost-Effectiveness by Technology, Scenario, and Year**



**TSE provides significant net private and social benefits.**

**Annualized Lifecycle and Social Benefit/Cost Ratio for TSE  
Base Benefit Methodology**



**ARB's 2008 anti-idling rule is the largest factor in reducing trucks stop emissions, making additional policies only marginally beneficial**

- Business-as-Usual Growth Scenario
  - ARB's anti-idling rule will significantly increase the adoption of diesel APUs in new trucks
  - Continued progress towards goals adopted in 2000 Diesel Risk Reduction Plan
- Moderate Growth Scenario
  - Vigorous incentives to overcome high upfront capital costs, perhaps by incorporating GHG and petroleum reduction into Moyer
  - Adopt comprehensive system of “feebates” to fully value fuel savings at the time of purchase
- Aggressive Growth Scenario
  - Incorporation of transport sector offsets into AB 32 so that expanded use of electricity will not risk utilities compliance with a load-based carbon cap

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## **The adoption of hybrid diesel-electric TRUs can reduce GHG and criteria pollutant emissions while yielding maintenance and fuel savings**

- Transport refrigeration units can reduce local pollution and fuel use by allowing trucks and trailers to plug in when not on the road
- Three types of TRU exist:
  - Diesel units with electric standby function can only perform pull-down when operating in diesel mode
  - Electrically driven ocean containers powered by ship power or diesel generator sets when on land
  - Hybrid diesel electrics have full electric pull-down capability and provide significant maintenance cost reductions
- Limited operational hours degrade lifecycle economics by spreading out the incremental capital cost over a longer period of time
- TRU adoption works best at central, fleet-based warehouses where a single owner is responsible for electricity and diesel purchase

**e-TRUs hold the potential for significant reductions in criteria pollutant emissions.**

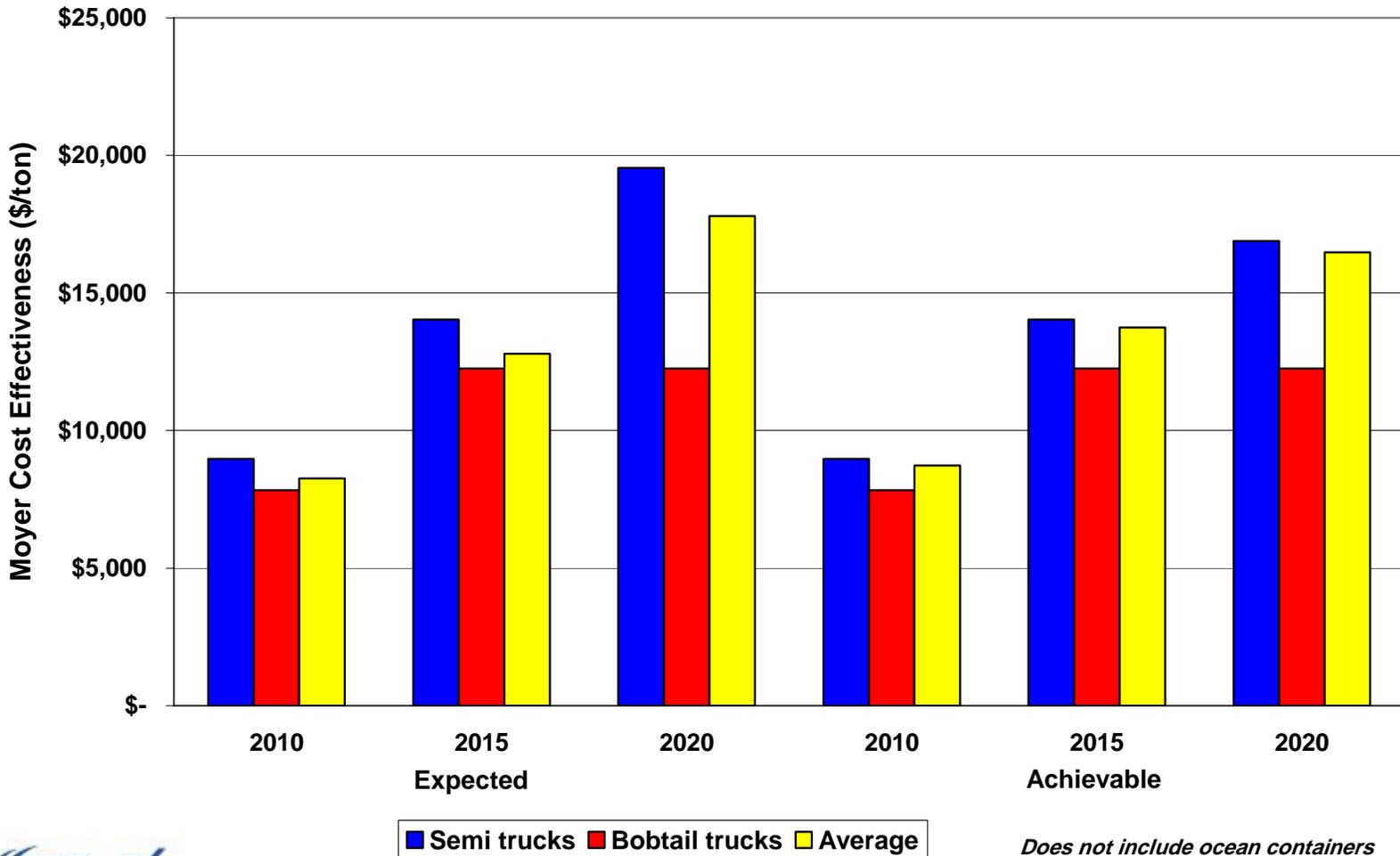
Pollutant	Scenario	Emissions Reduction by Year (tpd)		
		2010	2015	2020
NOx	Expected	0.36	0.52	1.00
	Achievable	1.08	2.27	3.14
NMOG	Expected	0.02	0.03	0.07
	Achievable	0.05	0.13	0.20
PM	Expected	0.01	0.01	0.01
	Achievable	0.04	0.05	0.05
SOx	Expected	—	—	—
	Achievable	—	—	—

**e-TRUs holds the potential to significantly reduce GHG emissions and displace petroleum use.**

Species	Scenario	Annual Reductions		
		2010	2015	2020
GHG (tons CO <sub>2</sub> eq.)	Expected	10,222	18,839	43,062
	Achievable	32,227	87,835	133,031
Petroleum (million gge)	Expected	1.12	2.05	4.62
	Achievable	3.43	9.28	14.03

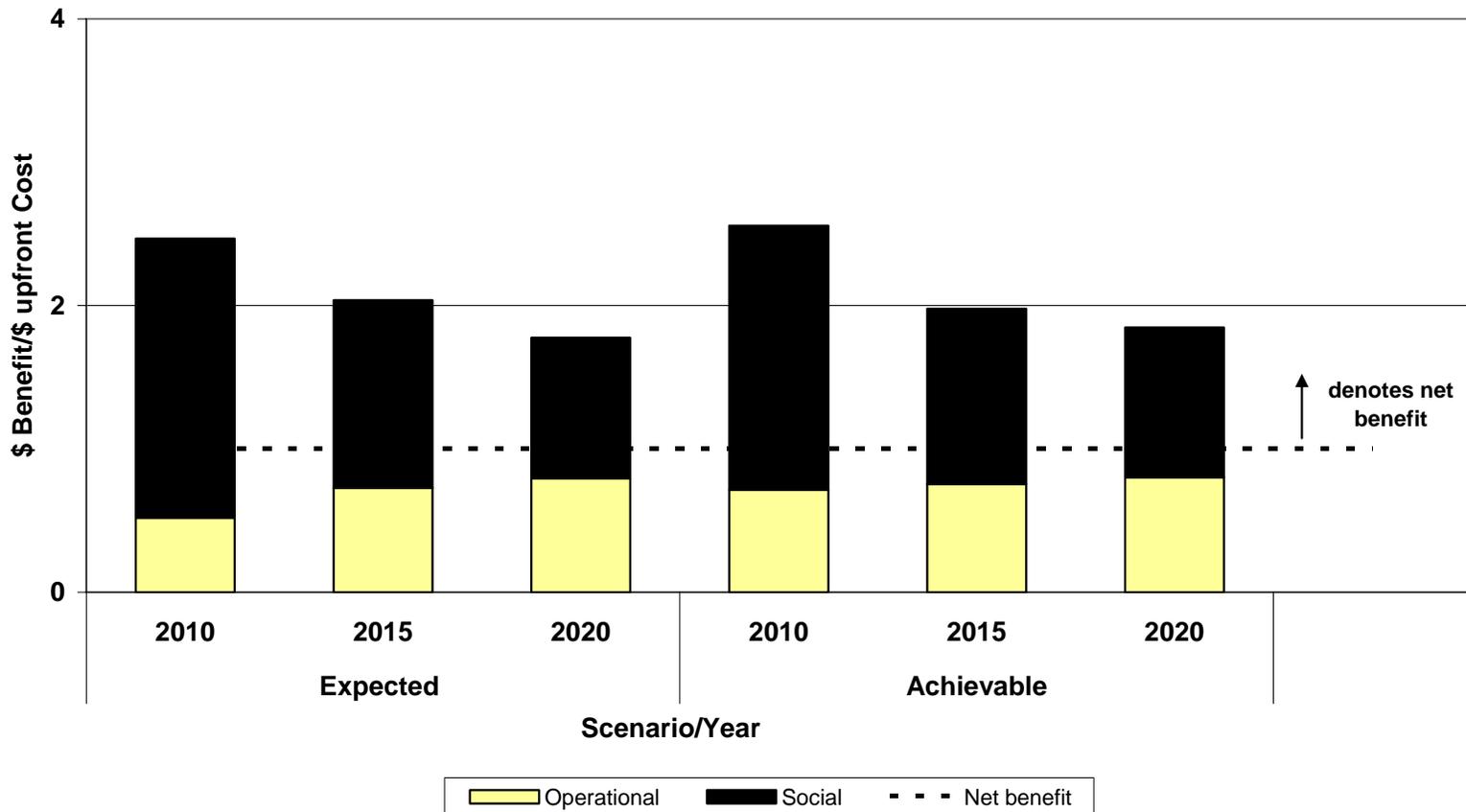
**e-TRU Moyer cost effectiveness ranges between \$4500 and \$20,000/ton, increasing over time.**

**Moyer Cost-Effectiveness by Technology, Scenario, and Year**



**e-TRUs provides significant net private and social benefits, decreasing over time as diesel TRUs become cleaner.**

**Annualized Lifecycle and Social Benefit/Cost Ratio for TRUs  
Base Benefit Methodology**



**The limited time of use of TRUs makes it more difficult to recover incremental costs, and reduces private and social cost-effectiveness**

- Business-as-Usual Growth Scenario
  - Continued progress towards goals adopted in 2000 Diesel Risk Reduction Plan
- Moderate Growth Scenario
  - Vigorous incentives to overcome high upfront capital costs, perhaps by incorporating GHG & petroleum reduction into Moyer
  - Adopt comprehensive system of “feebates” to fully value fuel savings at the time of purchase
- Aggressive Growth Scenario
  - Incorporation of transport sector offsets into AB 32 so that expanded use of electricity will not risk utilities compliance with a load-based carbon cap

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## **Electric forklifts already enjoy a large market share, but technology improvements will expand the potential uses and penetration for e-forklifts**

- E-forklifts have been widely adopted for indoor lift operations as they reduce fuel use, maintenance costs, and allow for narrow aisle operation
- Technology advancements in batteries, AC drive systems, and fast-charging systems will drive the expansion of e-forklift adoption
  - Many of these advancement will allow for replacement and downsizing of heavy-duty & outdoor forklifts with electric forklifts
- Of all the technologies analyzed, e-forklifts have the largest private benefit despite significant incremental costs
  - Despite favorable life-cycle costs the large incremental costs can serve as a barrier for small or cash-strapped businesses
- In all of the cases, e-forklifts provide a large fraction of the overall benefits for both GHG and petroleum reduction

**e-forklifts, which displace primarily gasoline and propane forklifts, provide relatively modest criteria pollution benefits.**

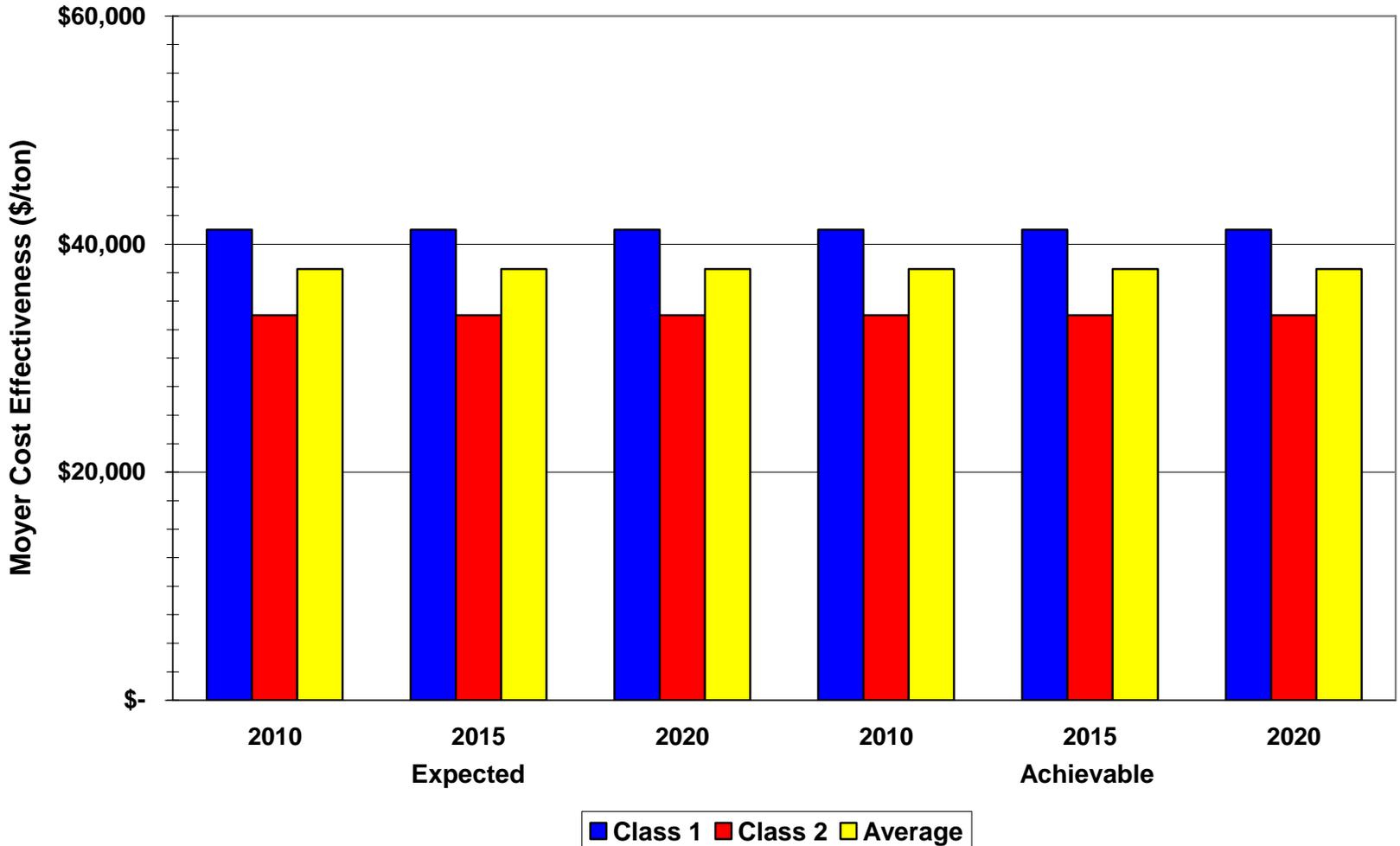
Pollutant	Scenario	Emissions Reduction by Year (tpd)		
		2010	2015	2020
NOx	Expected	0.24	0.28	0.33
	Achievable	2.96	3.21	3.46
NMOG	Expected	0.19	0.23	0.26
	Achievable	2.40	2.60	2.80
PM	Expected	0.00	0.00	0.00
	Achievable	0.04	0.04	0.04
SOx	Expected	—	—	—
	Achievable	—	—	—

**e-forklifts holds the potential for large reductions in GHG emissions and petroleum use.**

Species	Scenario	Annual Reductions		
		2010	2015	2020
GHG (tons CO <sub>2</sub> eq.)	Expected	119,773	141,926	164,079
	Achievable	1,728,845	1,901,610	2,074,375
Petroleum (million gge)	Expected	10.41	12.34	14.26
	Achievable	146.69	160.98	175.26

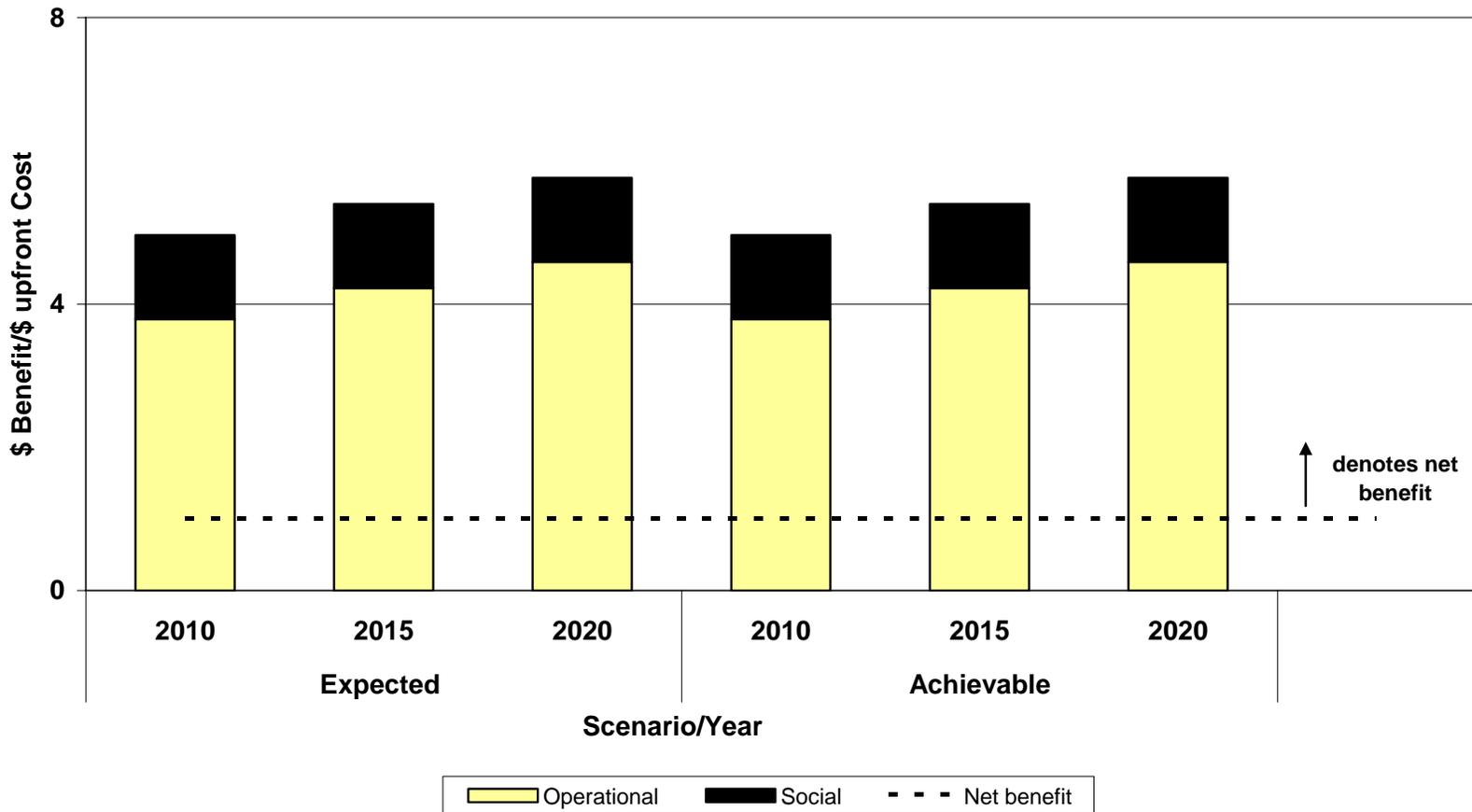
**Moyer cost effectiveness for e-forklifts relatively poor and stable over time.**

**Moyer Cost-Effectiveness by e-Forklift Class, Scenario, and Year**



**e-forklifts provides significant net private benefits, increasing over time as the cost of diesel fuel rises.**

**Annualized Lifecycle and Social Benefit/Cost Ratio for E-Forklifts  
Base Benefit Methodology**



**The significant life-cycle cost benefit of e-forklift use decrease the incentives that must be offered to increase overall e-forklift adoption**

- Business-as-Usual Growth Scenario
  - Under BAU growth, the lifecycle cost advantages of e-forklifts will sustain market growth
- Moderate Growth Scenario
  - Vigorous incentives to overcome high upfront capital costs, perhaps by incorporating GHG & petroleum reduction into Moyer
  - Adopt comprehensive system of “feebates” to fully value fuel savings at the time of purchase
- Aggressive Growth Scenario
  - Incorporation of transport sector offsets into AB 32 so that expanded use of electricity will not risk utilities compliance with a load-based carbon cap
  - The existence of, and U.S. participation in, a post-Kyoto international regulatory regime for climate change

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## **PHEVs hold the ability to significantly reduce transport sector petroleum use with little infrastructure investment relative to other alternative fuels**

- PHEVs have the ability to operate on electricity and gasoline allowing for home-charging without the range limitations of all-electric vehicles
- The major barrier to significant adoption of PHEVs is the current performance and cost of batteries
  - Batteries must have significant energy storage (with reasonable weight and volume), durability to withstand large numbers of deep discharge, and a cost that will not make vehicles prohibitively expensive
- PHEVs may be most suitable for the heavy-duty market as lifecycle costs are almost always more favorable
- Light-duty PHEVs are attracting significant attention from policy makers, environmental groups, right-wing intellectuals as a result of the large potential to reduce national GHG emissions, and significantly reduce petroleum dependency

**PHEVs, which displace relatively clean gasoline engines, provide modest criteria pollution benefits.**

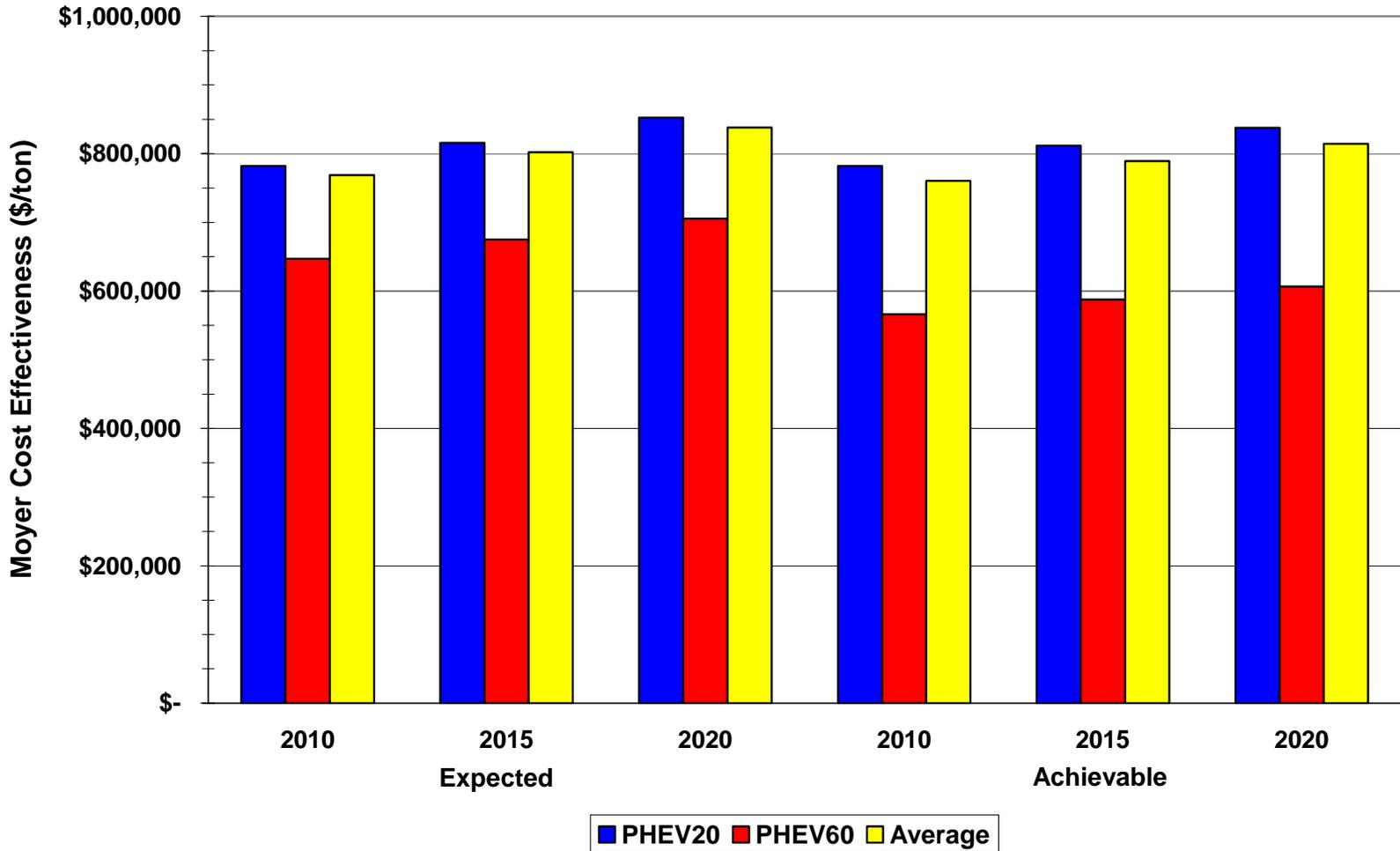
Pollutant	Scenario	Emissions Reduction by Year (tpd)		
		2010	2015	2020
NOx	Expected	0.01	0.14	0.52
	Achievable	0.01	0.48	2.04
NMOG	Expected	0.02	0.24	0.90
	Achievable	0.02	0.83	3.54
PM	Expected	0.00	0.01	0.04
	Achievable	0.00	0.03	0.14
SOx	Expected	—	—	—
	Achievable	—	—	—

**PHEVs holds the potential for large reductions in GHG emissions and petroleum use.**

Species	Scenario	Annual Reductions		
		2010	2015	2020
GHG (tons CO <sub>2</sub> eq.)	Expected	56,594	750,040	2,844,363
	Achievable	56,594	2,593,484	10,822,828
Petroleum (million gge)	Expected	5	64	242
	Achievable	5	221	926

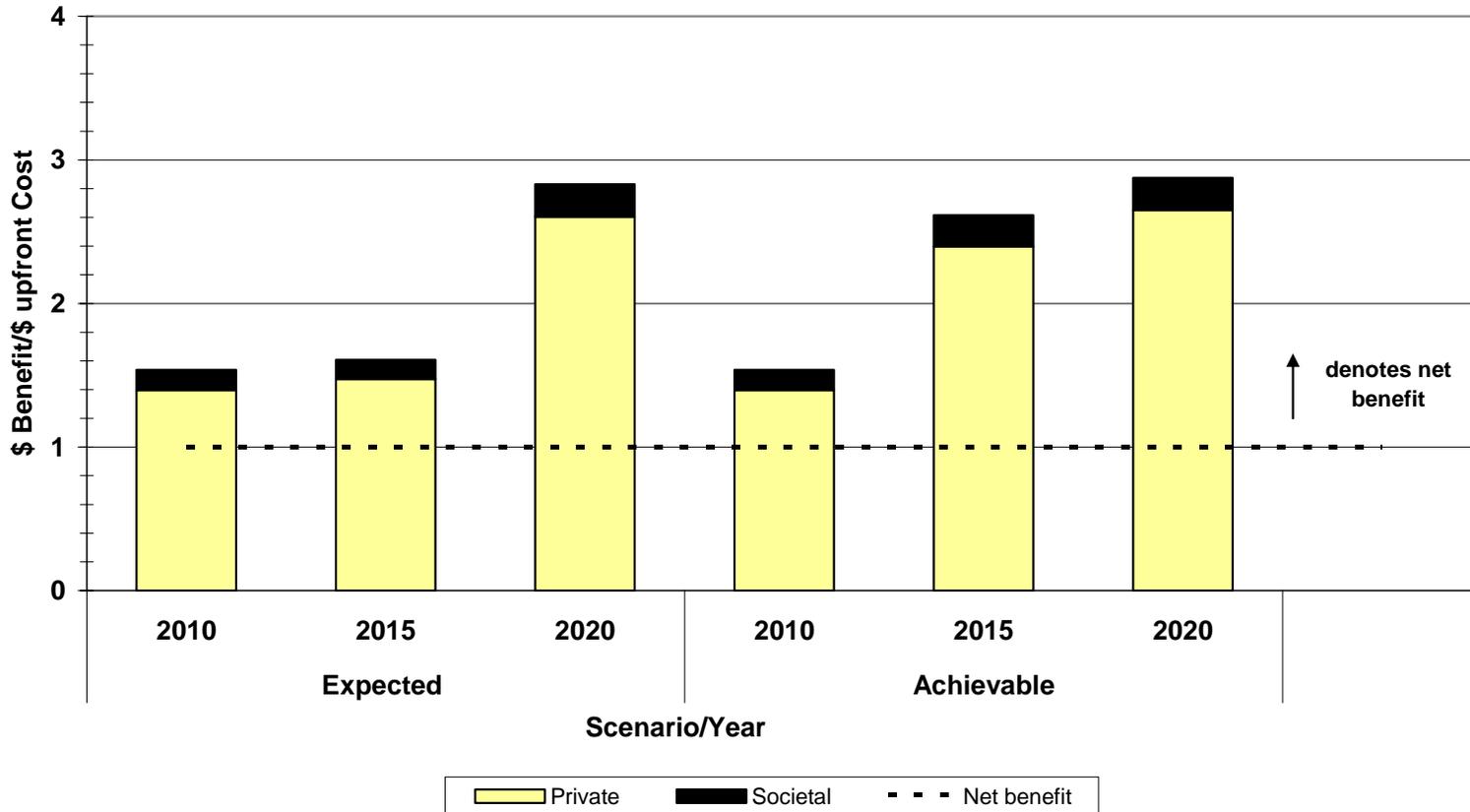
**Moyer cost effectiveness for PHEVs poor and relatively stable over time.**

**Moyer Cost-Effectiveness by Scenario, Year, and All Electric Range**



**PHEVs provides significant net private benefits, increasing over time as fuel prices increases and upfront capital costs fall.**

**Annualized Lifecycle and Social Benefit/Cost Ratio for PHEVs**



**The adoption of PHEVs will require significant investment in technology development as well as the commitment to improving LDV fuel economy**

- Business-as-Usual Growth Scenario
  - Full implementation of GHG standards incorporated in AB 1493
  - Maintain alt. fuel tax credits and cost sharing in 2005 EPACT
- Moderate Growth Scenario
  - Significant public investments in battery technology as requested by U.S. automakers (\$500 million over 5 years)
  - Increased action on fuel economy at the federal level, such as adoption of a 35 mpg CAFÉ standard passed by Senate Commerce, Science, and Transportation committee on May 8, 2007
  - Proactive action on the part of regulators regarding PHEV testing
  - Cooperation of PUC on establishing residential rates for home charging
- Aggressive Growth Scenarios
  - Very aggressive public investment in battery technology over the next decade (on the order of billions of dollars)

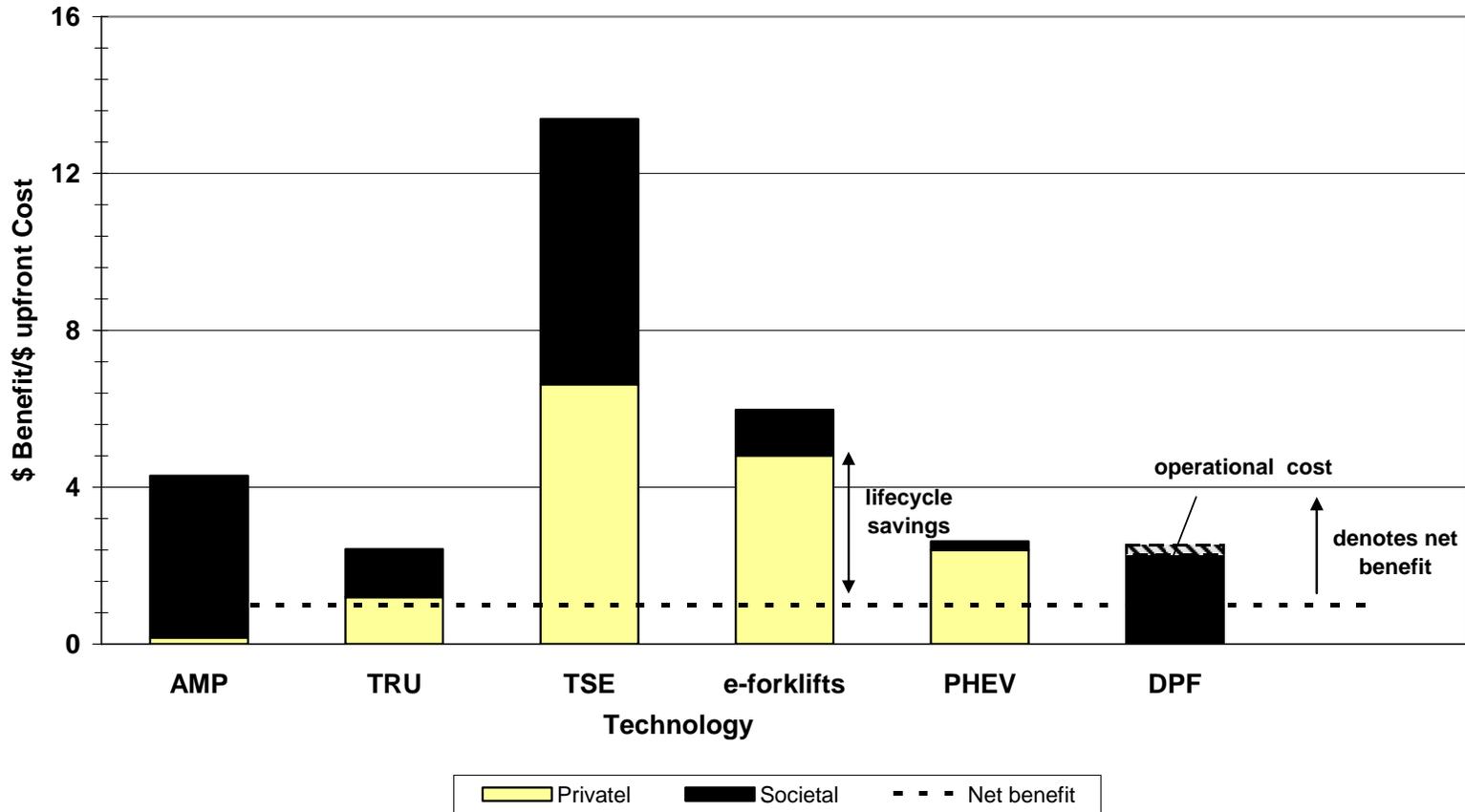
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## **A number of policies and incentives will benefit all of the various electric drive technologies**

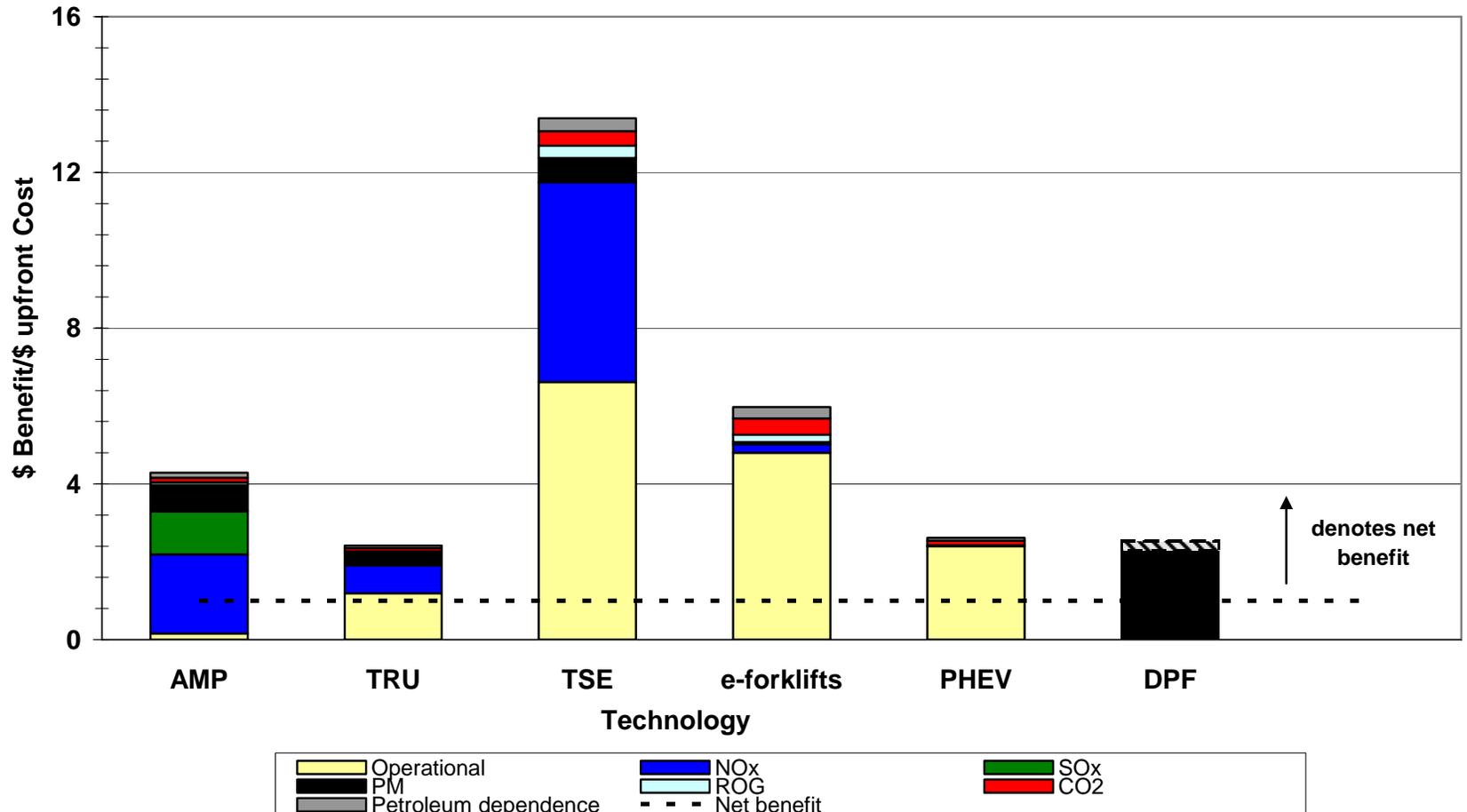
- Incorporation of on and off-road e-drive technologies into California's LCFS in order to generate protocols regarding property rights to the low carbon fuel credits for electricity used in the transportation sector
- Incorporation of transport sector offsets into AB 32 to reduce the risk that investments in electric drive technologies jeopardize the compliance of utilities in load-based carbon cap regime
- The existence of, and participation in, a post-Kyoto international regulatory regime for climate change

Relative to other electric-drive technologies, PHEVs enjoy modest, although positive, public and private benefits.

Six Technology Annualized Lifecycle and Social Benefit/Cost Ratio



### Six Technology Annualized Lifecycle and Social Benefit/Cost Ratio Base Benefit Methodology, 2015 Achievable Case



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