AB 1007 SCENARIOS

ELECTRIC DRIVE TECHNOLOGIES

ELECTRIC DRIVE TECHNOLOGIES STORYLINE

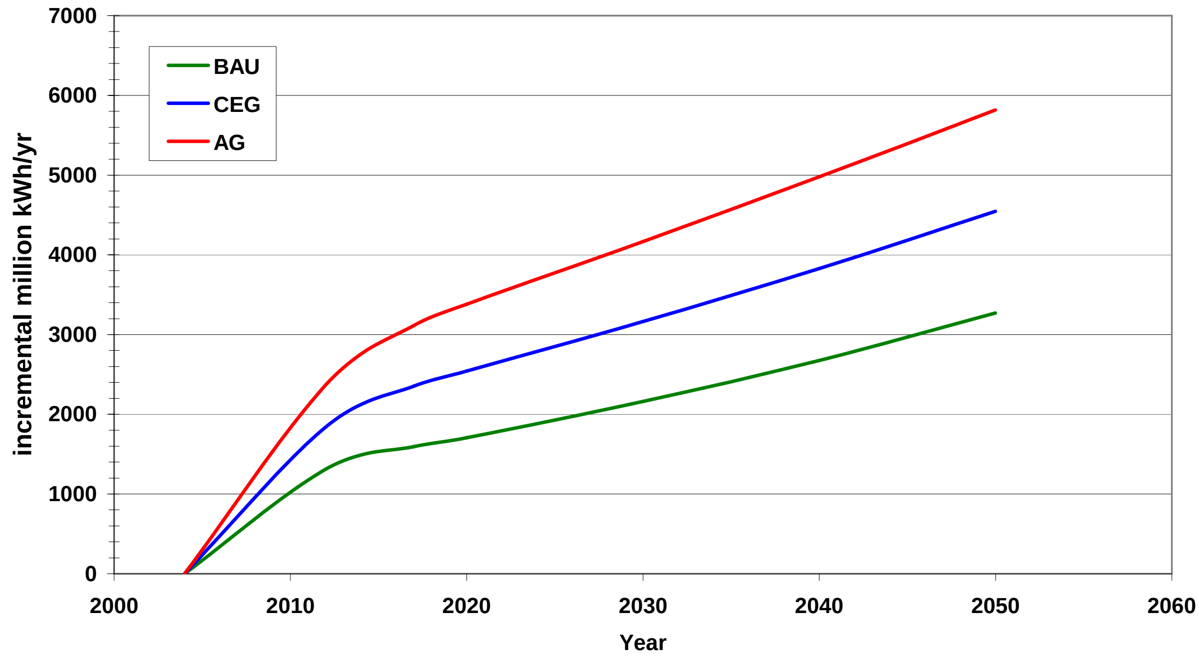
EXECUTIVE SUMMARY

This section outlines the methodology, assumptions, and results of efforts to estimate the social benefits and costs associated with the expanded use of electric drive technologies in California's transport sector. It includes information regarding incremental populations, greenhouse gas and petroleum reduction benefits, and costs, both upfront and lifecycle, associated with three scenarios for the adoption of electric drive technologies. Included in the analysis are five key applications – cold ironing, electric transport refrigeration units (e-TRUs), trucks stop electrification (TSE), electric forklifts (e-forklifts), and plug-in hybrid electric vehicles (PHEVs).

The Business As Usual (BAU) scenario, which estimates the level of e-drive penetration that can be expected given current market conditions and existing regulatory drivers, predicts incremental reductions in petroleum use of approximately 70, 180, and 240 million gallons of gasoline equivalent in 2012, 2017, and 2022. To this, the BAU scenario predicts GHG emissions reductions on the order of 0.7, 1.9, and 2.5 million tons of CO_2 equivalent in those three years. More than two-thirds of the benefit for both petroleum dependence and GHG emission reductions in 2012, and approximately 80% in 2017 and 2022, is attributable to the expanded use of e-forklifts and PHEVs.

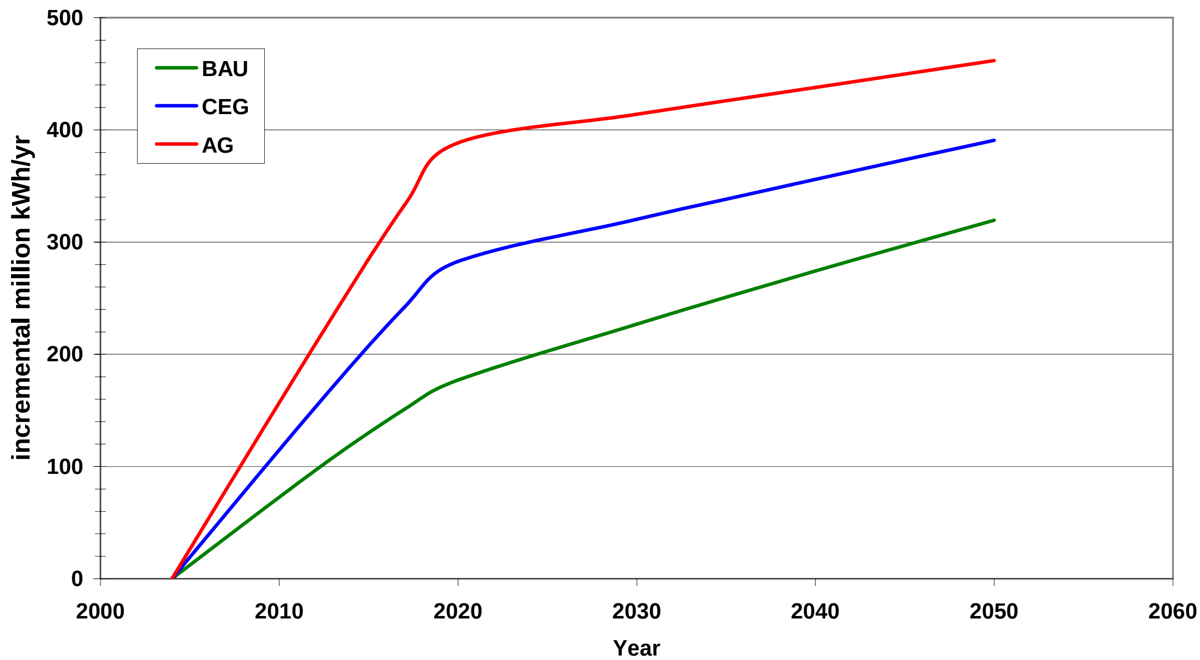
The Cost Effective Growth (CEG) scenario envisions reductions in petroleum consumption and GHGs more than twice that envisioned in the BAU scenario associated with the expanded use of e-drive technologies. The CEG scenario predicts significant reductions in petroleum consumption equal to approximately 200, 480, and 630 million gallons of gasoline equivalent in 2012, 2017, and 2022, respectively. These reductions translate to cuts in GHG emissions of 2.1, 5.1, and 6.7 million tons of CO_2 equivalent in 2012, 2017, and 2022, respectively. To place these numbers in perspective, the goal of reducing California's GHG emissions to 1990 by 2020 set out in the California Global Warming Solutions Act (AB32) would require reductions on the order of 175 million tons of CO_2 equivalent in 2020.

Finally, the Aggressive Growth (AG) scenario envisions reductions in petroleum consumption and GHGs between four and five times (depending on the particular scenario year) than in the BAU scenario. The AG scenario predicts reductions in petroleum consumption of 340, 780, and 1000 million gallons of gasoline equivalent in 2012, 2017, and 2022, respectively. These reductions in petroleum use translate to GHG emission reductions on the order of 3.6, 8.4, and 10.9 million tons of CO_2 equivalent in those three years. These reductions could results from concentrated regulatory efforts to support the use of electric drive, including the most aggressive cold-ironing rule possible from the California Air Resources Board, incorporating on- and off-road e-drive technologies into AB32 and California's proposed Low Carbon Fuel Standard, and the existence of, and U.S. participation in, an as yet unspecified post-Kyoto Protocol international regulatory regime for climate change.



Off-road includes cold-ironing/alternative marine power and electric forklifts.

Figure ES-1. Off-road E-Drive Penetration Scenarios



Truck-related includes truck-stop electrification and electric transport refrigeration units.

Figure ES-2. Truck-Related E-Drive Penetration Scenarios

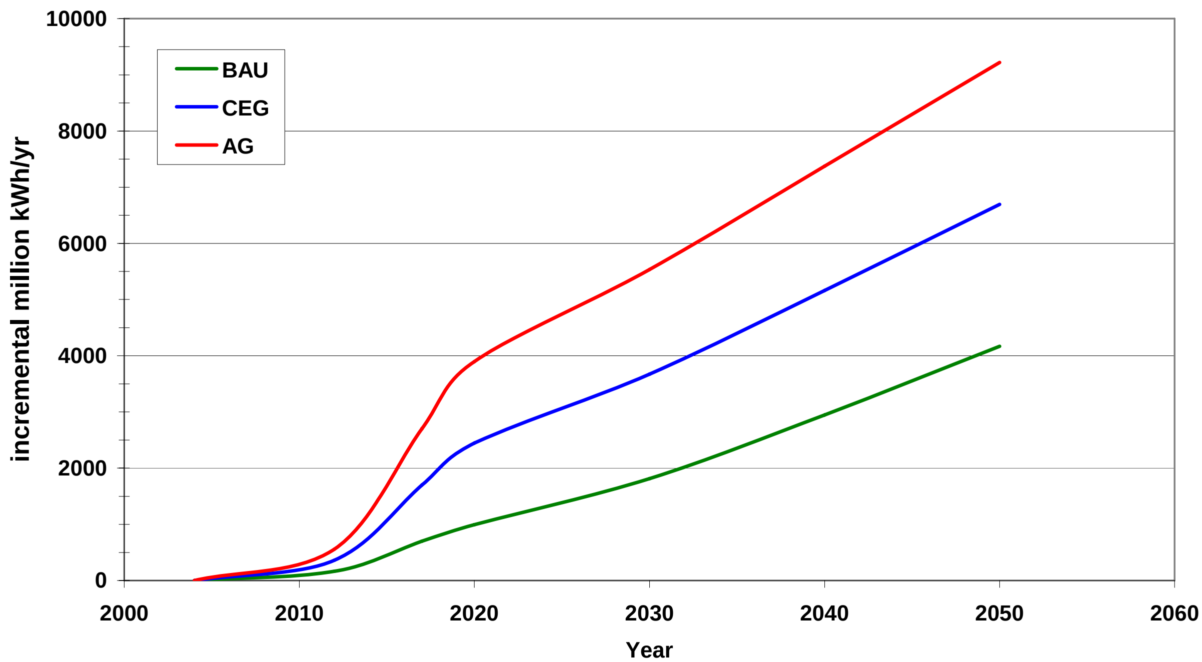


Figure ES-3. Light-duty PHEV Penetration Scenarios

Table ES-1. Performance Metrics

	Scenario*	2012			2017			2022		
		BAU	CEG	AG	BAU	CEG	AG	BAU	CEG	AG
Cold-ironing	Population (1,000s)	0.05	0.22	0.39	0.10	0.53	0.95	0.13	0.67	1.20
	Petroleum Displaced (10^6 gge/yr)	12	34	55	21	66	111	25	78	131
	GHG Reduction (10^6 tons/yr)	0.08	0.22	0.36	0.14	0.43	0.73	0.16	0.51	0.85
	Upfront Costs (10^6 \$/year)	\$14.7	\$36.2	\$57.7	\$23.7	\$62.0	\$100.3	\$26.2	\$70.2	\$114.2
	Operational Savings (10^6 \$/yr)	(\$3.3)	(\$0.2)	\$2.9	(\$2.8)	\$7.6	\$18.0	(\$2.0)	\$11.8	\$25.5
	Lifecycle Costs (10^6 \$/yr)	\$18.0	\$36.4	\$54.8	\$26.5	\$54.4	\$82.3	\$28.3	\$58.4	\$88.6
e-TRUs	Population (1,000s)	5	10	15	9	17	26	11	20	29
	Petroleum Displaced (10^6 gge/yr)	2	4	7	4	8	12	5	9	14
	GHG Reduction (10^6 tons/yr)	0.02	0.04	0.07	0.03	0.07	0.11	0.04	0.09	0.13
	Upfront Costs	\$2.9	\$7.8	\$12.7	\$6.4	\$14.4	\$22.3	\$8.3	\$17.1	\$25.8

	Scenario*	2012			2017			2022		
		BAU	CEG	AG	BAU	CEG	AG	BAU	CEG	AG
	(10^6 $/year)									
	Operational Savings (10^6 $/yr)	$3.2	$8.5	$13.7	$7.5	$16.2	$25.0	$9.8	$19.5	$29.3
	Lifecycle Costs (10^6 $/yr)	($0.3)	($0.6)	($1.0)	($1.1)	($1.8)	($2.6)	($1.5)	($2.5)	($3.5)
TSE	Population (1,000s)	11	17	22	15	23	31	17	26	35
	Petroleum Displaced (10^6 gge/yr)	13	19	26	19	30	40	23	35	47
	GHG Reduction (10^6 tons/yr)	0.14	0.20	0.27	0.21	0.31	0.42	0.24	0.37	0.50
	Upfront Costs (10^6 $/year)	$6.5	$9.6	$12.7	$8.9	$13.5	$18.0	$10.0	$15.2	$20.4
	Operational Savings (10^6 $/yr)	$31.7	$47.4	$63.0	$50.8	$77.6	$104.4	$59.6	$91.7	$123.8
	Lifecycle Costs (10^6 $/yr)	($25.2)	($37.8)	($50.3)	($41.9)	($64.1)	($86.4)	($49.6)	($76.5)	($103.4)
e-forklifts	Population (1,000s)	49	63	77	58	73	88	61	77	92
	Petroleum Displaced (10^6 gge/yr)	12	83	155	13	92	170	14	95	175
	GHG Reduction (10^6 tons/yr)	0.13	0.98	1.83	0.16	1.08	2.01	0.16	1.12	2.07
	Upfront Costs (10^6 $/year)	$7.6	$48.5	$89.4	$8.9	$52.6	$96.4	$9.4	$54.3	$99.2
	Operational Savings (10^6 $/yr)	$26.1	$166.2	$306.3	$30.5	$181.0	$331.4	$32.5	$188.1	$343.7
	Lifecycle Costs (10^6 $/yr)	($18.5)	($117.7)	($216.9)	($21.6)	($128.3)	($235.0)	($23.1)	($133.8)	($244.5)
PHEVs	Population (1,000s)	87	189	292	384	922	1,459	548	1,330	2,112
	Petroleum Displaced (10^6 gge/yr)	28	61	94	120	285	451	169	409	648
	GHG Reduction (10^6 tons/yr)	0.32	0.69	1.07	1.36	3.23	5.10	1.93	4.63	7.33
	Upfront Costs (10^6 $/year)	$102.2	$158.4	$214.6	$286.8	$640.8	$994.9	$369.6	$897.3	$1,425.0
	Operational Savings (10^6 $/yr)	$81.0	$176.9	$272.9	$353.8	$859.8	$1,365.9	$504.0	$1,240.8	$1,977.7
	Lifecycle Costs (10^6 $/yr)	$21.3	($18.5)	($58.3)	($67.0)	($219.0)	($371.0)	($134.4)	($343.6)	($552.7)
Total	Population (1,000s)	153	280	407	466	1,035	1,605	637	1,453	2,270
	Petroleum Displaced (10^6 gge/yr)	66	202	337	177	481	784	236	626	1,015
	GHG Reduction (10^6 tons/yr)	0.68	2.14	3.60	1.89	5.13	8.37	2.53	6.71	10.88
	Upfront Costs (10^6 $/year)	$134.0	$260.5	$387.1	$334.6	$783.3	$1,231.9	$423.5	$1,054.0	$1,684.6
	Operational Savings (10^6 $/yr)	$138.7	$398.8	$658.8	$439.7	$1,142.2	$1,844.7	$603.8	$1,551.9	$2,500.1
	Lifecycle Costs (10^6 $/yr)	($4.7)	($138.2)	($271.7)	($105.1)	($359.0)	($612.8)	($180.3)	($497.9)	($815.4)

* BAU = Business-As-Usual Growth; CEG = Cost-Effective Growth; AG = Aggressive Growth
Note: BAU = CalETC Expected Scenario; AG = Achievable Scenario; CEG = mean of BAU/AG
Numbers in parenthesis represent negative values. Negative operational savings represent net costs

SECTION 1. STATE OF TECHNOLOGY AND MARKETS

1.1 Cold-Ironing

Cold-ironing, also known as shorepower or alternative marine power, is the practice wherein ocean-going vessels plug into an electric grid while in port ("hotelling") rather than relying upon diesel auxiliary engines for power. Cold-ironing has been used extensively by the U.S. Navy during dry-docking, and has recently come into favor in as a means of reducing air emissions from cruise ships operating in Alaska. The technical barriers to the expanded use of cold-ironing in California are relatively minor, reflecting predominately the need to retrofit existing vessels, many of which have long operating lifetimes and fall outside traditional local and national regulatory authority, to operate off of 6.6 kV power, along with investments in berthside transmission at affected ports.

In order for cold-ironing to generate significant emissions reductions and petroleum dependence benefits, it would need to be adopted by range of vessels visiting California, including container ships, tankers, and refrigerated cargo ships. Since 2006 both state regulators, particularly the California Air Resources Board, and the San Pedro Bay Ports have shown increased interest in cold-ironing as a means of offsetting or reducing the emissions growth caused by the anticipated increase in goods movement through California's ports in the next two decades. ARB staff is preparing a possible cold-ironing rule for board consideration in late 2007, and the Ports of Los Angeles and Long Beach have outlined targets for cold-ironing investment and adoption in their recent Clean Air Action Plan.

Among the five electric drive applications surveyed here, cold-ironing is the most likely to require aggressive mandates and incentives to support its adoption. In contrast to the other four e-drive technologies, cold-ironing enjoys little or no operational savings associated with its use, potentially inhibiting its adoption in the private market. Second, significant upfront costs (on the order of $1.5 million per vessel and $3 to $8 million dollars per berth retrofit) are required to take advantage of cold-ironing, along with investments in new power generation and transmission infrastructure. Public policy is expected to play an important role in promoting and coordinating such investments. Finally, from a social benefit perspective the adoption of cold-ironing will result in substantial reductions in criteria pollutants in dense urban areas heavily impacted by port-related diesel pollution. Those benefits, which are not adequately accounted for in the free market, provide a strong basis for regulatory mandates for the adoption of cold-ironing, including that currently under consideration by the California Air Resources Board.

1.2 Electric Transport Refrigeration Units

Electric transport refrigeration units (e-TRUs) are used to keep perishable goods cold during transit, either on land or at sea. Two general types of e-TRU technologies are currently in widespread use in the US: diesel units with electric standby function attached to semi or bobtail trailers, and pure electrically driven ocean containers powered by ship generators at sea and by diesel generation sets while on land. One additional technology, common in Europe and now for sale in the US by dealers such as Carrier, is true hybrid diesel-electric TRUs with full electric pull-down capability. Hybrid e-TRUs, which provide substantial reductions in maintenance costs when operated in all-electric mode, are expected to be increasingly adopted in the future as their attractive lifecycle economics become more widely known.

The limited hours of electric operation for most TRUs mean that incremental capital costs are spread out over a more limited number of hours, degrading their lifecycle economics. As a result, incentives for the purchase of e-TRUs such as grants to subsidize their incremental capital costs, provide one possible method of promoting their adoption. In addition, tougher emission standards for diesel TRUs, either for new equipment on based upon a “fleet average” method, could also support the penetration of electric technologies by raising the cost of incumbent technologies or requiring the purchase of low-emitting electric versions for existing fleets. These regulations would be most likely adopted at the state level via tougher air toxic control measures under California’s Diesel Risk Reduction Plan.

1.3 Truck Stop Electrification

Concerns about particulate emissions from idling trucks, which often congregate close enough to one another to create local pollution “hotspots”, along the desire to reduce fuel costs associated with main engine idling (typically on the order of a gallon of fuel consumed per hour) have led to increasing interest on the part of both truck operators and state and local governments in truck stop electrification. Two general types of TSE technologies are currently available: those relying upon on-board HVAC systems, which typically provide electric power to support equipment already integrated into existing trucks, and off-board HVAC systems such as Idleaire packaging heating and cooling with ancillary services such as telephone, television, and Internet access. Both on-board and off-board HVAC technologies have the potential to reduce air emissions associated with main engine idling, while also reducing fuel and maintenance costs for truck operators.

Various efforts are underway to promote TSE, including EPA’s Smartway Transport program. The Smartway program provides grants for investments in technologies to improve fuel efficiency and reduce air emissions from goods movement nationwide. Another important driver for the adoption of truck stop electrification is an ARB rule, scheduled for enforcement from 2008, restricting main engine idling from sleeper trucks in California. That rule is expected to provide opportunities for companies providing TSE services by limiting the ability of truck operators to use their main engine to heat or cool their cabins, which is the primary reason given for truck idling.

Several specific incentives and mandates might reasonably be expected to effectively promote the truck stop electrification technologies. ARB’s anti-idling rule is expected to increase the incorporation of diesel auxiliary power units in new trucks, thus providing a cost effective opportunity to further promote TSE: a mandate requiring plug-in capability for new APUs sold in the state. Absent such a mandate, policies to internalize the GHG emissions and fuel benefits associated with diesel use might also be effective in hastening the spread of TSE.

1.4 E-Forklifts

Of the five technologies outlined here, electric forklifts currently enjoy the greatest market share, particularly for smaller capacity lifts used in indoor operations. The adoption of electric forklifts has been in large part a natural market response to their significant advantages relative to ICE forklifts, including fuel savings, reductions in maintenance costs, and suitability for narrow aisle operations. While the market for e-forklifts has been saturated in certain size ranges, potential exists for future growth in key market segments, including the downsizing of excessively large Class 4 and Class 5 forklifts and the replacement of heavy (e.g. 8,000 to 10,000 lb lift capacity) diesel forklifts typically used in outdoor operations. The increased use of electricity in these areas is expected to be driven by improvements in battery technology, shifts to more power AC drives, and the spread of fast-charging technologies, which offer the potential to minimize equipment downtime associated with the charging of larger capacity forklifts.

There have historically been efforts to promote the use of e-forklifts, some of which continued on to this day. Some electric utilities have offered incentives for the purchase of e-forklifts as a means to benefit through increases electricity sales.   Incentive programs such as California's Carl Moyer program typically distribute a fraction of their grant funds to cover the incremental capital costs of e-forklifts over SI models. Moyer funds have traditionally been focused on the purchase of Class 1 forklifts, which regulators believe represent real incremental replacement of SI forklifts.

While the private business case for e-forklifts, particularly the significant lifecycle savings in high fuel price scenarios, is strong, public policy may also be necessary support their increased use. The significant incremental upfront costs of e-forklifts create a high hurdle to their adoption in small and cash-strapped operations. Policy instruments likely to support the increased use of electricity in forklift applications fall into one of two categories: first, efforts to bridge the upfront/lifecycle cost gap, either by providing incentives to cover incremental equipment costs or through a combined fee/rebate system ("feebates") designed to convert lifecycle savings into upfront costs/savings; second, policies monetizing reductions in greenhouse gas emissions and petroleum use attributable to the use of e-forklifts. Two examples of such strategies, transport-sector offsets under AB32 and low carbon fuel credits under California's Low Carbon Fuel Standard, are described in further detail below.

1.5 PHEVs

Plug-in hybrid electric vehicles capable of operating off of both gasoline or diesel fuel and electricity (or both in a blended strategy) hold the potential to significantly reduce transport sector petroleum use and associated greenhouse gas emissions. Since PHEV performance is independent of the state of charge of its battery and vehicles can operate on already widely available fuels, PHEVs are expected to require small infrastructure investments relative to other alternative fuel vehicles. The major technical challenge facing PHEVs is battery performance, as many vehicle architectures currently envision a significant amount of energy storage and battery durability to with stand large numbers of deep cycle discharges in operation.

In addition to their potential in light-duty applications, it is also possible that plug-in hybrids will be even more suitable for use in medium and heavy-duty vehicles. Plug-in hybrid capability in heavier vehicles classes may enjoy greater benefits due to heavier duty cycles, higher vehicle miles traveled, and longer idling times for some platforms, all of which translate into higher fuel use and emissions; as a medium and heavy-duty PHEV will have a better lifecycle cost in almost every case. In addition, original equipment manufacturers (OEMs) are more willing to build smaller lots (i.e. 20 to 200) of vehicles better tailored to their exact missions. Examples of this phenomenon include the PHEV school bus currently sold by International, the Daimler/Chrysler PHEV Sprinter van in phase II (prototype) production between summer 2007 and early 2008, and the EPRI/Eaton PHEV Ford F550 prototype anticipated to be built by early 2008.

Light-duty PHEVs, while not yet marketed by OEMs, are attracting significant attention from domestic policymakers, foreign policy experts, environmental groups, and influential right-wing intellectuals concerned about the costs of excessive dependence on foreign oil. Notable efforts to support the commercialization of PHEVs include “Plug-In Partners”, a national campaign in which consumers place “soft orders” by pledging to purchase plug-in hybrid vehicles once brought to market. Efforts have also been made to develop an aftermarket PHEV solution wherein existing charge sustaining HEVs such as the Toyota Prius are retrofit to provide plug-in capability; those efforts have met with limited success. There is also interest in better incorporating PHEVs in ARB’s Zero Emission Vehicle (ZEV) program and the proposed Low Carbon Fuel Standard, and moves to provide tax credits and incentives for PHEVs such as those currently provided to alternative fuel vehicles in the 2005 National Energy Policy Act.

Several incentives and mandates either currently in operation or planned for introduction could potentially provide strong incentives for the introduction and early adoption of PHEVs. Tighter fuel economy standards at either the state or local level could act as one possible driver. In addition, with their significant lifecycle savings and ability to reduce GHG emissions and petroleum use, the same set of policy options that could promote e-forklifts would likely boost PHEVs as well, including incentives to bridge the upfront/lifecycle cost gap and policies monetizing GHG and petroleum reduction benefits. Also, proactive action is likely needed on the part of state and federal regulators to establish the engine certification and testing protocols that will be necessary for OEMs to take advantage of the significant market opportunity provided by plug-in hybrid electric vehicles.

SECTION 2. SCENARIO I: BUSINESS AS USUAL

2.1 Societal Benefits

The Business as Usual scenario envisions significant reductions in petroleum consumption associated with predicted market penetrations of electric drive technologies, equal to approximately 70, 180, and 240 million gallons of gasoline equivalent in 2012, 2017, and 2022, respectively. The BAU scenario also envisions non-trivial GHG emission reduction benefits as well from those technologies on the order of 0.7, 1.9, and 2.5 million tons of CO_2 equivalent in 2012, 2017, and 2022, respectively. To place this number in perspective, the goal of reducing California's GHG emissions to 1990 by 2020 set out in the California Global Warming Solutions Act would require reductions on the order of 175 million tons of CO_2 equivalent in 2020.[1]

Regarding the specific applications responsible for these benefits, more than two-thirds of the benefit for both petroleum dependence and GHG emission reductions is attributable to e-forklifts and PHEVs in 2012, with the relative contribution of these technologies rising in the future. Approximately 80% of the benefit in 2017 and 2022 is expected to be contributed by plug-in hybrid electric vehicles and e-forklifts forklift applications. The GHG emission benefit of most technologies is proportional to their petroleum dependence benefits, with the exception of cold-ironing. Cold-ironing makes a larger relative contribution to petroleum reduction goals (around 18% of the total BAU reduction in 2012) than to GHG emission reductions (around 11%). This is attributable to differences in the inherent efficiencies of the incumbent ICE technologies with more efficient diesel-powered auxiliary generators (relative to IC engines used in transportation applications) leading to larger upstream electricity GHG emissions and therefore lower emissions offset due to the adoption of electric drive in cold-ironing applications.

2.2 Incentives/Mandates

Several existing incentives and mandates are assumed to continue in order to sustain the e-drive penetration numbers outlined above for the Business as Usual Scenario, including:

- Continued progress toward the goal adopted in California's 2000 Diesel Risk Reduction Plan to reduce the health risks posed by diesel particulate emissions by 85% by 2020.[2] This progress would be met primarily through increased use and tightening of Air Toxic Control Measures (ATCMs) to curb diesel particulate emissions, and would expect to promote the penetration of cold-ironing, e-TRUs, and TSE technologies.

[1] "AB 32 Overview", CAPCOA Planning Managers' Meeting, Charles M. Shulock, 5 October 2006.

[2] Source: ARB website; http://www.arb.ca.gov/diesel/documents/rrpapp.htm, accessed on 16 May 2007.

- Voluntary efforts on the part of California's ports, particularly the Ports of Los Angeles and Long Beach, to expand the use of cold-ironing as outlined in the San Pedro Bay Port's *Clean Air Action Plan*.

- ARB's ATCM to restrict idling for sleeper trucks, to be enforced from 2008. The anti-idling measure is expected to greatly expand the demand for TSE, either through the use of off-board HVAC systems such as Idleaire (especially for in-use trucks) or through the incorporation of diesel auxiliary power units into new vehicles by OEM. Those APUs could incorporate shorepower capability at a relatively low cost.

- Full implementation of the GHG emissions standards for light-duty vehicles incorporated in California Assembly Bill 1493 (Pavley), which would require that the greenhouse gas intensity of light duty vehicles sold in California to be reduced by approximately 30% once fully in force in 2016. Pavley could act as an important driver for the commercialization of plug-in hybrid electric vehicles.

- State and federal action to continue and expand current alternative fuel tax credits and cost sharing provisions in the 2005 Energy Policy Act. Those incentives may be especially important for the development of healthy market for plug-in hybrid electric vehicles.

SECTION 3. SCENARIO II: COST EFFECTIVE GROWTH

3.1 Societal Benefits

The Cost Effective Growth scenario envisions reductions in petroleum consumption and GHGs between double and 2.5 times (depending on the particular scenario year) that envisioned in the BAU scenario associated with the expanded use of e-drive technologies. The CEG scenario predicts significant reductions in petroleum consumption equal to approximately 200, 480, and 630 million gallons of gasoline equivalent in 2012, 2017, and 2022, respectively. These reductions in petroleum use translate to GHG emission reductions on the order of 2.1, 5.1, and 6.7 million tons of CO_2 equivalent in 2012, 2017, and 2022, respectively.

Relative to the BAU case, e-forklifts lay claim to an increasingly large share of the environmental benefits associated with the use of electric drive. Approximately 80% of the benefit of both petroleum dependence and GHG emission reductions continues to be attributable to e-forklifts and PHEVs in the CEG case, although e-forklifts provide more than half of that benefit in 2012 as public policy begins to influence the purchasing decisions of forklift owners by converting lifecycle fuel savings to upfront capital savings (see below). The other major change in the relative contribution of technologies comes for truck stop electrification, whose share of the overall benefit decreases by a factor of two from the BAU to CEG case. This is consistent with the observation that the single most important driver of TSE adoption, ARB's anti-idling rule for sleeper cabs, is already incorporated into the BAU case and therefore incremental policy changes incorporated into the CEG case are unlikely to have much more of an influence on TSE adoption.

3.2 Incentives/Mandates Necessary

The penetration rates implicit in the Cost Effective Growth (CEG) scenario presume additional incentives and mandates above and beyond those outlined above for the BAU case. Possible policy measures to support the expanded use of electric drive consistent with the CEG scenario include:

- Vigorous set of incentives to overcome higher upfront capital costs, perhaps by incorporating GHG emissions reductions and petroleum dependence benefits into the Carl Moyer program.

- Significant public investments in battery technologies along the lines of that requested by U.S. automakers from the federal government in January 2007 (i.e. $500 million over five years).[3]

- The imposition of a comprehensive system of feebates, at either the state or federal level, providing incentives to consumers to fully value the fuel savings associated with e-drive technologies at the point of purchase.

- Increased action on fuel economy at the federal level. The level necessary for the aggressive growth scenario is likely in the range of a fleet average standard of 35 mpg CAFE, as passed by the Senate Commerce, Science, and Transportation Committee on May 8, 2007.

- Proactive action on the part of state and federal regulators regarding PHEV testing cycles.

- The cooperation of the Public Utilities Commission on establishing special residential rates for PHEV charging. Currently, the PUC does not allow for electric rate structure subsidies associated with societal benefits. A special rate is important because PHEV charging demand can push individual users into the utilities Tier 2/Tier 3 rates and therefore substantially increase the rate charged on a cents/kWh basis.

[3] (Source: Wall Street Journal, 9 January 2007, accessed at http://blogs.wsj.com/autoshow/2007/01/09/big-three-seek-battery-subsidies/ on 16 May 2007.)

SECTION 4. AGGRESSIVE GROWTH

4.1 Societal Benefits

The Aggressive Growth (AG)scenario envisions reductions in petroleum consumption and GHGs between four and five times (depending on the particular scenario year) that envisioned in the BAU scenario. The AG scenario predicts reductions in petroleum consumption equal to approximately 340, 780, and 1000 million gallons of gasoline equivalent in 2012, 2017, and 2022, respectively. These reductions in petroleum use translate to GHG emission reductions on the order of 3.6, 8.4, and 10.9 million tons of CO_2 equivalent in 2012, 2017, and 2022, respectively.

Relative to the CEG case, plug-in hybrid electric vehicles lay claim to an increasingly large share of the environmental benefits of electric drive, rising to 70% of the total petroleum reduction and GHG emissions benefit in 2022. This is perhaps not surprising given the very large share of fuel consumption and GHG emissions caused by on-road light-duty vehicles. Second to PHEVs in importance are e-forklifts, followed closely by cold-ironing promoted by a very aggressive ARB rule requiring the use of shorepower for most calls to California ports (see below). These benefits would be purchased at the cost of an estimated $1.6 billion dollars in annualized upfront capital costs, with approximately $1.50 in operational savings accruing to the technology adopter for every upfront dollar invested.

4.2 Incentives/Mandates Necessary

The penetration rates implicit in the Aggressive Growth (AG) scenario presumes additional incentives and mandates above and beyond those outlined above for the CEG case. Possible policy measures to support the expanded use of electric drive consistent with goals of the AG scenario include:

- The Air Resources Board adopting the most aggressive cold-ironing rule possible, requiring the offset of hotelling emissions from 80% of container, cruise, tanker, and refrigerated cargo ship calls in California by 2020.

- A new and comprehensive set of ATCMs to support even quicker reductions in diesel particulate exposure than those currently codified in the Diesel Risk Reduction Plan (e.g. 85% by 2015).

- Very aggressive public investments on the order of billions of dollars in battery technology in the time frame of 2007-2017.

- Incorporation of on and off-road e-drive technologies into California’s proposed Low Carbon Fuel Standard. Such a system would require action on the part of California Energy Commission and the Air Resources Board to generate protocols clarifying property rights to low carbon fuel credits for electricity used in transport applications, which might then be captured by utilities in return for providing consumers with a preferential charging rate for plug-in hybrid electric vehicles.

- Incorporation of transport sector offsets into the California Global Warming Solutions Act of 2006 (AB32). Without such offsets investments in expanding the use of electricity in transportation in the part of utilities could risk compliance with a load-based carbon emissions cap under AB32 compliance, which would act as a power disincentive for utilities.

- The existence of, and US participation in, an as yet unspecified post-Kyoto Protocol international regulatory regime for climate change.

SECTION 5. ASSUMPTIONS USED FOR STORYLINE

The following assumptions were used to estimate the populations, GHG and petroleum dependence benefits, and costs associated with e-drive technologies outlined above:

5.1 Population/Penetration

- Equipment populations in the three scenario years were estimated from the Phase I CalETC/TIAX study (2005). Populations in the intermediate AB1007 scenario years (2012, 2017) were linearly extrapolated between the CalETC scenario years of 2010, 2015, and 2020. 2022 populations were set equal to those in 2020.

- The CalETC "Expected scenario" was taken as the business as usual (BAU) scenario for this analysis. Equipment populations in the aggressive growth (AG) case were set equal to the CalETC "Achievable Scenario", which represents the upper bound for the adoption of electric drive. Cost effective growth (CEG) was estimated as the mean of BAU and AG scenarios.

- E-drive penetration rates after 2022 were estimated in the following manner: First, the total potential market (which includes both electric and ICE technologies) for TSE, TRUs, and e-forklifts was linearly extrapolated to 2050 from population growth between 2010 and 2020 in the CalETC study. For cold-ironing, where the very high growth rate of container traffic in the 2010-2020 time frame is unlikely to continue to 2050, the population of ship calls to California for which shorepower could be provided was estimated to increase 5% annually for the BAU (low-penetration) and 3% for the AG (high penetration) scenarios.

- A maximum e-drive penetration for each technology was then estimated via reference to the Phase I CalETC study. E-TRU's were assumed to have a maximum market share of 75%; maximum penetration rates were estimated to be 70 and 80% for truck stop electrification and e-forklifts, respectively. For alternative marine power (AMP), 80% of all ship calls were assumed to be capable of being cold-ironed, as consistent with the ARB's 2006 staff report. PHEV populations were estimated are detailed in the Table 5-1.

- E-drive electricity consumption was estimated from the above populations with the added assumption that any increases in per unit equipment activity after 2020 will be offset through increases in energy efficiency (i.e. electricity consumption per unit of equipment, measured in terms of kWh/yr, are assumed to remain constant at 2020 levels from 2030 to 2050.)

Table 5-1. E-Drive Equipment Populations

Technology	Scenario	Electric Population (thousands)					
		2012	2017	2022	2030	2040	2050
e-TRUs	BAU	11	15	17	24	30	36
	CEG	16	23	26	31	36	40
	AG	21	31	35	38	42	45
TSE	BAU	11	15	17	20	23	26
	CEG	17	23	26	28	30	32
	AG	22	31	35	36	37	38
AMP (calls)	BAU	1	2	2	4	6	10
	CEG	4	7	8	12	16	23
	AG	6	12	15	20	26	35
e-forklifts	BAU	49	58	61	76	93	111
	CEG	63	73	77	94	112	130
	AG	77	88	92	112	131	148
PHEVs	BAU	87	384	548	1000	1625	2300
	CEG	189	922	1330	2000	2813	3650
	AG	292	1459	2112	3000	4000	5000

This section outlines the various economic and emissions assumptions used in this analysis. It does so by first outlining those assumptions that are shared in common for all five applications, then by outlining those assumptions specific to a given application and its technologies. Tables 5-2 through 5-7 outline commonly shared assumptions: upstream emission factors, project lives, fuel and power consumption, estimated fuel prices, and two factors used to estimate the cost of grid power – the utility split, and assumption regarding the time of use of the electricity.

5.2 Shared Assumptions

- **Discount rate:** A discount rate of 5% was used in costing all technologies, equivalent to a societal rate typically used by government agencies in estimating project costs with significant societal benefits.

- **Population:** Unless specifically noted, equipment populations for the expected and achievable scenarios were derived from the 2005 TIAX CalETC study. The one exception to this rule, highlighted below, was for the population of ocean-going vessels retrofit for shorepower capability. Those numbers were revised upward substantially from the 2005 CalETC study reflecting recent policy documents expressing the desire of both California's ports (i.e. the Port of LA and Port of Long Beach, as expressed in the joint Clean Air Action Plan) and state agencies (i.e. the Air Resources Board)for the 2005 report.

- **Emission factors:** The electric pieces of equipment are also assumed to have emissions associated with their use. These upstream emissions are associated with the production of electricity at a power plant. The upstream emissions resulting from the use of electric-drive technologies were marginal in comparison to the emission reduction from replacement of an ICE version. The GHG emission factor for electricity was modified from the TIAX petroleum dependency report to include a 20% renewable in 2012 from the existing and rapidly expanding renewable electricity portfolio in California. A summary of the upstream emission factors are provided in Table 5-2.

  Final emissions benefit is calculated by subtracting the electric technology emissions from the displaced ICE emissions. The methodology description and assumptions made for each of the specific technologies considered in this study are provided below.

Table 5-2. Upstream Emission Factors by Fuel

Fuel and Unit	NOx (g/unit fuel)	ROG (g/unit fuel)	PM (g/unit fuel)	GHG (g/unit fuel)
RFG3, gallon	0.26	0.58	0.012	12,600
Diesel[1], gallon	0.28	0.66	0.024	12,200
MGO, gallon	0.28	0.66	0.024	12,200
Electricity, kwh	0.0001	0.005	0.018	390

[1] Also used for marine gas oil.

Source: TIAX AB1007 analysis.

- **Project lives:** Table 5-3 details the various projects lives used in this analysis.

Table 5-3. Project Lives by Application

Application	Capital Cost	Project Life (yrs)
Cold-ironing	Vessel	20
	Shoreside	20
Truck-stop electrification	Truck	7
	Truckstop	20
e-Transport Refrigeration Units	TRU	10
	Distribution Center	20
Electric forklifts	Forklift	7
	Battery	5.5
	Factory Infrastructure	14
Plug-in hybrid electric vehicles	Vehicle	10
	Charger (etc.)	10

- **Fuel Costs and Consumption:** Tables 5-4 to 5-7 provide detail regarding projected fuel costs, utility split and TOU assumptions by application and technology, and fuel and power consumption used to estimate the cost of the technologies included in this survey.

Power rates, including all customer and demand charges, were estimated for the five applications included in this study by researching representative tariff schedules from the fall of 2006 for California's four largest utilities. The utility split used for each of these five applications is shown in Table 5-4. Estimates were made from the regional port share of goods transported by a given application and technology type (e.g. containers for container ships, crude oil imports for tankers, etc.). LADWP rates were used as a proxy for other municipal rates throughout the state.

In addition to the utility split, in order to estimate that fraction of power cost associated with demand charges, further detail on time of use (TOU) was added by application and technology type. Table 5-6 summarizes assumptions made regarding the time of use of electricity in this study.

Table 5-7 details the primary ICE fuel consumption and electric power consumption for each application, technology, and operating regime applied in this analysis.

Table 5-4. Projected Fuel Costs

Fuel and Unit	Low Price ($/unit)			High Price ($/unit)		
	2010	2015	2020	2010	2015	2020
Diesel, gallon	$ 2.48	$ 2.11	$ 2.07	$ 3.14	$ 3.45	$ 3.68
RFG, gallon	$ 2.48	$ 2.10	$ 2.06	$ 3.02	$ 3.33	$ 3.56
Propane, gallon	$ 2.04	$ 1.94	$ 1.96	$ 2.14	$ 2.09	$ 2.09
Marine gas oil, metric ton	$ 508.09	$ 432.29	$ 424.09	$ 643.31	$ 706.82	$ 753.94

Source: EIA 2007 Annual Energy Outlook, CEC May 2007 IEPR workshop, and Bunkerworld.com, accessed on 27 November 2006. MGO costs were assumed to rise and fall in scenario years in proportion to the relative changes in the price of on-road diesel fuel. May need to be revised based upon TIAX methodology.

Table 5-5. Utility Split by Application and Technology

Application	Technology	PG&E	Public Utilities[1]	SCE	SDG&E	Source
Cold-ironing	Containers	16%	43%	41%	0%	GMAP
	Tankers	41%	30%	29%	0%	EIA
	Cruise	8%	43%	34%	16%	2006 ARB staff report
	Reefers	14%	22%	36%	28%	GMAP 2006 ARB staff report PoSD data
TSE	Plug-in APU	48%	5%	47%	0%	CA DoT Truck Stop Information
TRUs	All TRUs	35%	20%	35%	10%	California Energy Commission
e-Forklifts	All Forklifts	35%	20%	35%	10%	
PHEVs	All PHEVs	50%	50%	—	—	CalETC

[1] LADWP rates used for cold-ironing, TSE, TRUs, and e-forklifts. The Sacramento Municipal Utility District's EV charging rates were used for PHEVs.

Table 5-6. TOU Share of Power by Application and Technology

Application	Technology	Summer			Winter	
		On-peak	Mid-peak	Off peak	Mid-peak	Off-peak
Cold-ironing	Container	0.17	0.26	0.57	0.38	0.62
	Tanker	0.17	0.26	0.57	0.38	0.62
	Passenger	0.42	0.28	0.30	0.69	0.31
	Reefer	0.25	0.29	0.46	0.46	0.54
TSE	Plug-in APU	0.20	0.30	0.50	0.50	0.50
TRUs	All	0.10	0.40	0.50	0.50	0.50
E-forklifts	All	0	0.25	0.75	0.25	0.75
PHEVs	All	0.05	—	0.95	0.05	0.95

Source: TOU assumptions for cold-ironing come from the ARB 2006 Shorepower staff report (container, tanker, and passenger) and PoSD data (reefers). Tankers were assumed to have the same TOU profile as container vessels. TSE, TRUs, and e-forklifts TOU data are TIAX assumptions. PHEV TOU data provided by CalETC.

Table 5-7. Fuel/Power Consumption by Application and Technology

Application	Technology	ICE Equivalent			Mean Power	
		Fuel	Units	Value	Units	Value
Cold-ironing	All vessels (2010)	MGO	mtons/call	18.2 ~ 29.8	MW	1.6 ~ 3.1
	All vessels (2015)			20.5 ~ 32.9		2.1 ~ 2.5
	All vessels (2020)			20.2 ~ 34.2		2.0 ~ 2.6
TSE	Plug-in APU	Diesel	gal/hr	0.21	kW	1.4
TRUs	Semi-Truck (es)	Diesel	gal/hr	0.85	kW	4
	Semi-Truck (h)					15 (pd) 2 (sb)
	Bobtail Truck (es)			0.62		3
	Semi-Truck (h)					10 (pd) 1.5 (sb)
	Ocean-Going Container			0.21		4
E-forklifts	Class 4/5 – Class 1	Gasoline	gal/hr	1.30 ~ 1.88	kW	11
		Propane		1.88 ~ 2.72		
	Class 4/5 – Class 2	Gasoline		0.76 ~ 1.10		5
		Propane		1.10 ~ 1.59		
PHEVs	Baseline ICE	Gasoline	mi/gal	30.3	—	—
	PHEV20			47.9	mi/kWh	3.26
	PHEV40			49.7		

es = electric standby *h= hybrid* *pd = pull-down* *sb = standby*

Source: Cold-ironing – 2004 Environ PoLB report; 2006 ARB staff report. TSE – CalETC TSE analysis with 4% fuel penalty for DPF retrofit. TRUs – EPRI TRU report. E-forklifts – OFFROAD2007; SCE PHEVs – EPRI Report No. 1000349

5.3 Assumptions Specific to Cold-ironing

- **Population and utilization:** Annual visits per ship, net berthing times, anticipated growth in visits, and average power demand were all estimated from the 2006 ARB staff report. For the expected case, ship calls for containers and cruise ships were extracted from the Clean Air Action Plan and extrapolated to 2020 based upon expected patterns in goods movement/passenger ship traffic. Incremental growth in visits was met through by assuming that additional ships were visiting the port, rather than by increasing the number of calls made by vessels already visiting California. Additional ship calls were met first through retrofits and second through the purchase of new ships when the number of vessels visiting the state in 2015 and 2020 exceeding ARB's 2004 ship inventory due to growth in ship visits in the out years. Maximum berth occupancy was assumed to be 0.50. As a result, a new berth for each ship type was added once the total hours in port (cold-ironed hours per call x population x average calls per year)/(number of berths x 8760 hours/yr) exceeded 0.50. This value was estimated via the forthcoming Port of Long Beach's "Master Electrical Plan". We furthermore assumed that cold-ironing services infrastructure would be provided at a minimum of one berth at three ports for all scenario years irrespective of the berth occupancy factor. This assumption is necessary in order to make this analysis representative for the entire state.

- **Project costs:** Shoreside capital costs were estimated from current plans for cold-ironing as outlined under the "Clean Air Action Plan", with a low value of $3 million per berth and the high value of $8.7 million per berth corresponding to infrastructure costs for the Port of Los Angeles and the Port of Long Beach, respectively. Shipside retrofit costs were estimated to be $1.5 million per ship, as stated in the 2006 ARB staff report for vessels with a shipside transformer. The cost of installing shorepower capability in new vessels was assumed to be $250,000, or one-half the cost of retrofitting a ship operating off of 6.6 kV power in the 2004 Environ report. For shipside capital, we assumed that two-thirds of the capital costs are borne in-state, with the remaining one-third of the costs are assigned either to other states or foreign entities. Labor costs are estimated from the 2006 ARB staff report, capped at one shift per day per vessel type at each of three ports (a total of 4380 shifts in a year). The cost of marine gas oil was that for the Port of Los Angeles on www.bunkerworld.com, accessed on 27 November 2006. That value of $592.50 per metric ton was scaled according to the cost of petroleum fuels from the EIA Annual Energy Outlook 2007 for the three scenario years in 2010, 2015, and 2020.

- **Emissions:** Emissions factors for auxiliary engines were taken from the 2006 ARB staff report, which assumes the use of 1000 ppm sulfur marine gas oil in auxiliary engines from 2010. The equivalent emission factors used, expressed in terms of g/kWh diesel, were 13.9, 0.4, 0.25, and 0.4 for NOx, NMOG, PM, and SOx, respectively. Greenhouse gas emissions were estimated through the average fuel use per call and fuel cycle emissions for marine gas oil, assumed to be equivalent to that of diesel fuel (see Table 5-1. Petroleum consumption was provided by TIAX Petroleum Dependency report for California Energy Commission and ARB as 1 gallon of marine fuel equals 1.27 to 1.38 gasoline gallon equivalent (gge).

5.4 Assumptions Specific to Truck Stop Electrification

- **Population and utilization:** Population numbers for incremental semi-trucks, bobtails, and ocean containers at distribution centers were gathered from the prior TIAX CalETC report. Space utilization, measured in terms of hours per day, was taken from the same and was equivalent to 14.4, 16, and 18 hours per day in 2010, 2015, and 2020, respectively. These values were based upon conversations with SCE staff and outside consultants, as well as from Idle Aire. We assumed that the average numbers of spaces per electrified truck stop varied from technology to technology, with the average numbers of spaces being 20 per stop for plug-in APUs and 60 per stop for off-board HVAC systems such as Idleaire.

- **Technology split:** For this analysis, we assumed that three-quarters of the market for truck stop electrification for new sleeper trucks with APUs would be captured by the incorporation of shorepower capability into on-board APUs, with the remaining one-fourth of the market captured by off-board HVAC systems such as those pioneered by Idleaire.

- **Project costs:** Incremental truckside capital costs for plug-in APUs were assumed to vary from $300 (low case) to $1200 (high case) as based upon prior CalETC work on TSE. Idleaire was assumed to require no incremental truckside capital investments. Truck-stop side capital costs were estimated as varying from $2,600 (low case) to $6,000 (high case) per space, and between $10,000 (low case) and $15,000 (high case) for off-board HVAC systems. All of these values were taken from the CalETC technical brief on TSE prepared for EPRI. Auxiliary power units were assumed to require maintenance after 600 hours in operation, with the costs of that maintenance varying between $15 (low case) and $120 (high case). Labor costs associated with off-board HVAC system were taken from the NYSERDA report Idleaire report. TIAX assumes that those labor costs will decrease to 50% in 2015 and to 25% in 2010 as TSE becomes better integrated into existing truck stop concessions. Plug-in APUs were assumed to have zero labor costs associated with their use.

- **Emissions:** APU emission factors used were 29, 1.68, and 0.195 g/hr for NOx, ROG, and PM, respectively (Source: CalETC analysis, building upon 2005 ARB ISOR for anti-idling rules). Fuel consumption for diesel-powered APUs was assumed to be 0.21 gallons per hour, as described in previous CalETC TSE work along with an assumed 4% fuel penalty for a DPF retrofit.

5.5 Assumptions Specific to Electric Transport Refrigeration Units

- **Population and utilization:** Population, emissions, and usage values were taken from the 2005 TIAX/CalETC study, which themselves were taken from ARB e-TRU staff report dated October 2003 and conversations with Archana Agrawal at ARB and Andra Rogers at EPRI. Extrapolating from ARB's 2005 ISOR for low-emission TRUs, we assume that there are an average of 19 doors per facility within California. Of these, we assume that 60% are in use at any given time. (These two values are used to estimate demand charges associated with the use of a given facility.) 80% of TRU power was charged at the large commercial rate (peak demand in excess of 500 kW), with the remaining 20% of power charged at the small commercial rates. Reflecting the fact that most e-TRU demand at distribution centers is likely to occur outside of peak demand hours, we assessed time and facility demand charges to 20% of incremental attached load. Semi trucks and ocean containers are assumed to be used in short haul operations averaging 1800 hours of operation per year, with bobtail trailers in operation for 1038 hours annual, as assumed in the EPRI TRU Study entitled "Analysis of Economics and Emissions." The costs and benefits of e-TRUs were limited to the distribution center, where it was assumed that 30% of hours in operation were spent.

- **Technology split:** Incremental TRUs are assumed to be of one of two types: e-TRUs with electric standby option, or e-TRUs will full hybrid diesel-electric function, including the ability to "pull down" from ambient to operating temperatures within the industry mandated 30 minutes. This analysis assumes that half of incremental semi-truck and bobtail TRUs have e-standby capability, with the remaining half having hybrid diesel-electric capability. Pulldown requirements for e-standby TRUs were met through the assumption that e-standby could pulldown in twice the time of a standard diesel TRU or a full hybrid-electric TRU (e.g. 1 hour instead of 30 minutes).

- **Project costs:** Incremental capital costs for e-TRUs were derived from EPRI and NYSERDA TRU studies, along with appropriate simplifying assumptions where necessary. Incremental costs for semi-trucks ranged from $2000 (low case) to $2500 (high case) for TRUs with e-standby capability, and $3500 to $4000 for full hybrid TRUs. Bobtail e-standby varied from $1000 (low) and $1500 (high), with a $1500 premium for hybrid technologies. Ocean containers were assumed to have no incremental equipment costs as they currently operate under electric power prior to arriving in California. Infrastructure capital costs were taken from the EPRI TRU study, and varied from $3000 (low) to $5800 (high) for semi-trucks and $500 to $1500 for bobtail trailers. Ocean containers were assumed to be able to use infrastructure prepared for semi-trucks (TIAX assumption).

- **Emissions:** Emission factors for diesel TRUs (for semi trucks and bobtails) were taken from EPA off-road equipment standards and the EPRI e-TRU report (Emissions and Economics of TRUs) for baseline (2004), low emission (2008), and ultra-low emission (2013) TRUs. The appropriate emission factors, measured in terms of g/kWh diesel, were 7.5, 7.5, and 4.7 for NOx, 0.4 for ROG/NMOG (for all emission years), and 0.6, 0.3, and 0.03 for PM, for baseline, low-emission, and ultra-low emission TRUs, respectively. Emission factors for diesel generation sets used on ocean containers in transit on land were 29, 1.68, and 0.195 g/hr for NOx, NMOG, and PM, respectively, as cited in CalETC's TSE analysis.

5.6 Assumptions Specific to e-forklifts

- **Population and utilization:** Incremental population numbers was as those used in the Phase I study. We assumed that 54% of incremental e-forklifts were of Class 1, and the remaining 46% being of Class 2. Based upon conversations with AeroVironment, we assume that 50% of e-forklifts are used in single-shift operations, with 25% being used in two- and three-shift operations alike. Based upon this finding and ARB's OFFROAD2007 model, we the average activity of e-forklifts to be 3150 hours per year. The average number of forklifts at facility charged at large commercial rates was assumed to be 15, with only five forklifts assumed to be in operation at facilities charged at the commercial rate for small operations.

- **Technology split:** Based upon the ARB OFFROAD2007 model, we assume that 65% of ICE forklifts replaced by incremental e-forklifts are powered by propane, with the remaining 35% powered by gasoline. Conventional charging was assumed to be used in 100% of single-shift operations, 60% of two-shift operations, and 30% of three-shift operations. The balance of forklifts are assumed to be charging using new and emerging fast-charge technologies. Power consumption of fast chargers was assumed to be 35 kW for large Class 1 forklifts and 25 kW for downsized Class 2 forklifts. One charger was assumed to be capable of charging between one and two fast charged forklifts.

- **Project costs:** Based upon numerous conversations with manufacturers such as Toyota Handling and Mitsubishi as well as with SCE staff, incremental costs of Class 1 forklifts replacing Class 4/5 forklifts with lift capacities in the 8,000-10,000 lb range varied from as low $2,000 to as high as $18,000 for large forklifts with pneumatic tires. Class 2 forklifts downsized from Class 4/5 were assumed to have no incremental capital costs associated with them. Labor associated with charging and/or maintaining forklifts was charged at a loaded rate of $26/hr. On average, we assumed that conventionally charged e-forklifts required two batteries: one for use, the other for charging/cool-down. Battery costs varied from $3000 to $5000/battery for conventional charging, with a $500 to $600 premium for batteries capable of fast-charging. Conventional chargers were assumed to cost between $1881 and $3000, and fast chargers between $10,000 and $12,000. Conventional ICE forklifts were assumed to require 40 hours of maintenance a year, with only 22 hrs/yr for e-forklifts (Source: EPRI "Increasing Profits.") Parts required for maintenance were estimated to be approximately $1400 for ICE forklifts and $974 for e-forklifts based upon conversations with Toyota Handling, Starcam, and Tincy In estimating power rates, we assumed that 50% of electricity sold is charged at the large commercial rate (i.e. peak demand in excess of 500 kW), with the balance sold at the small commercial rate (i.e. peak demand less than 500 kW). Reflecting the fact that not all charging demand will occur at peak periods, we assume that only 25% of charging demand is assessed time demand charges, while 100% is assessed facility demand charges.

- **Emissions:** Consistent with the methodology adopted in TIAX's Phase I study for CalETC, the following emission factors for gasoline-powered forklifts were used to estimate the emissions benefit associated with electric replacement: 0.6, 0.3, and 0.015 g/bhp-hr r for NOx, ROG, and PM, respectively (Source: EPRI: "SIP 2003 Seven Possible Mobile Source Control Measures"; 2005 ARB ISOR for anti-idling rules). An evaporative emissions factor of 0.05 lbs/day was also assigned to ICE forklifts.

5.7 Assumptions Specific to Plug-in Hybrid Electric Vehicles

- **Population and utilization:** It was assumed that the PHEV operates 149,322 miles over the 10 year project lifetime, from a high of 16,700 miles during its first year of operation down to 13,300 miles in its tenth year (Source: EPRI – Report ID 1009299). Of those miles, it was assumed that 36% (PHEV20) and 64% (PHEV40) were operated in all electric mode (or, for a blended PHEV strategy, the equivalent); the sources of this data were EPRI reports #1000349 and 1009299. Neither benefits associated with operation beyond that time frame, nor values attributable to, for example, the residual value of the PHEV battery in secondary applications were included in this study's cost analysis.

- **Technology split:** This study furthermore assumes that 90% of PHEVs in all scenario years have an all electric range of 20 miles, with the remaining 10% having an all electric range of 40 miles. In a similar fashion, this study assumes that 90% of vehicles are owned by individuals and charged at residences, with the remaining 10% owned in fleets and charged at commercial/industrial sites.

- **Project costs:** Table 4-8 provides the ranges of incremental capital costs associated with PHEV20 and PHEV40 applications. Incremental capital costs for the expected case are based upon annual worldwide production volumes of 30,000 vehicles annually for the expected scenario and 100,000 vehicles for the achievable scenarios. These costs also assume "piggybacking" wherein components shared with pure charge sustaining hybrid electric vehicles are produced in higher volumes (100,000 vehicles for the expected case and 300,000 vehicles for the achievable case).

  The costs of charging infrastructure was assumed to range from $0 to $100 for residential applications and $200 to $500 for commercial/industrial applications for the low and high case, respectively. Regularly schedule maintenance costs were estimated to be 4.8 cents per mile for a baseline ICE and 0.036 cents per mile for both configurations of PHEVs. (Source: EPRI – Cost Study presented at ZEV Technology Symposium). Unscheduled maintenance costs were considered to be outside of the scope of this study and were therefore not included in the analysis.

Table 5-8. PHEV Incremental Capital Costs by Case, Technology, Level, and Year

Case	Technology	Level	Incremental Cost by Year		
			2010	2015	2020
Expected	PHEV20	Low	$7,963	$7,963	$4,604
		High	$9,396	$9,396	$5,319
	PHEV40	Low	$10,433	$10,433	$5,925
		High	$13,293	$13,293	$7,366
Achievable	PHEV20	Low	$7,963	$4,910	$4,604
		High	$9,396	$5,812	$5,319
	PHEV40	Low	$10,433	$6,380	$5,925
		High	$13,293	$8,098	$7,366

Source: EPRI – Cost Study presented at ZEV Technology Symposium and modified for this study.

- **Emissions:** Emissions factors for upstream emissions came from the ARB 2000 ZEV Program Biennial Review (which provided overall numbers in terms of g/mi for criteria pollutants) as modified under TIAX's 2007 AB1007 fuel cycle analysis. The relevant values were 0.034, 0.051, and 0.009 g/mi for NOx, ROG, and PM, respectively. Power plant emissions were calculated using appropriate EERs for plug-in hybrids, or a value of 3.6 for a PHEV operating in all electric mode, respectively (Source: TIAX Tank to Wheels report).