SOUTHERN CALIFORNIA ASSOCIATION of GOVERNMENTS

ICF International and Cambridge Systematics

Rail Emissions Reduction Strategies

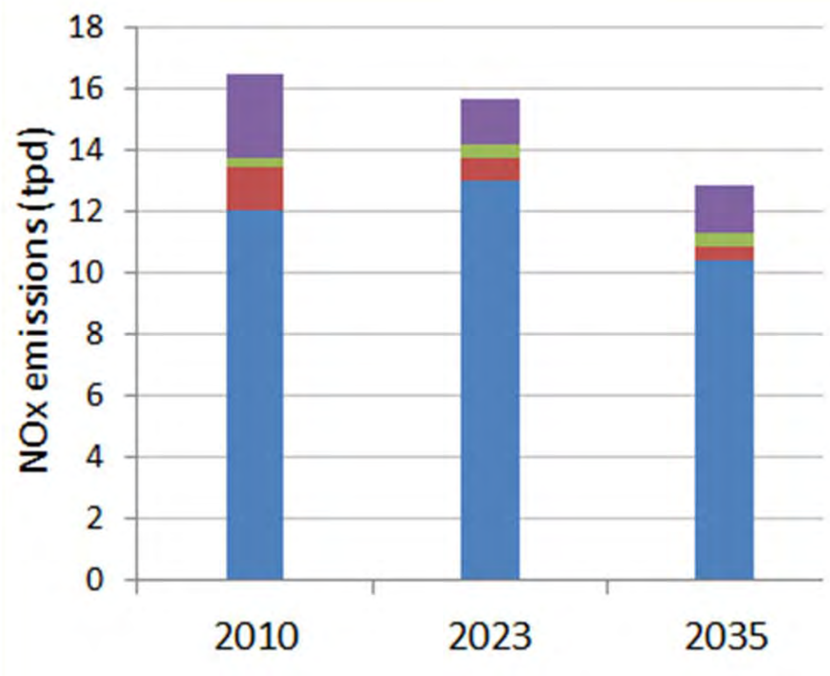
FREIGHTWORKS
SOUTHERN CALIFORNIA DELIVERS THE GOODS

Presentation Overview

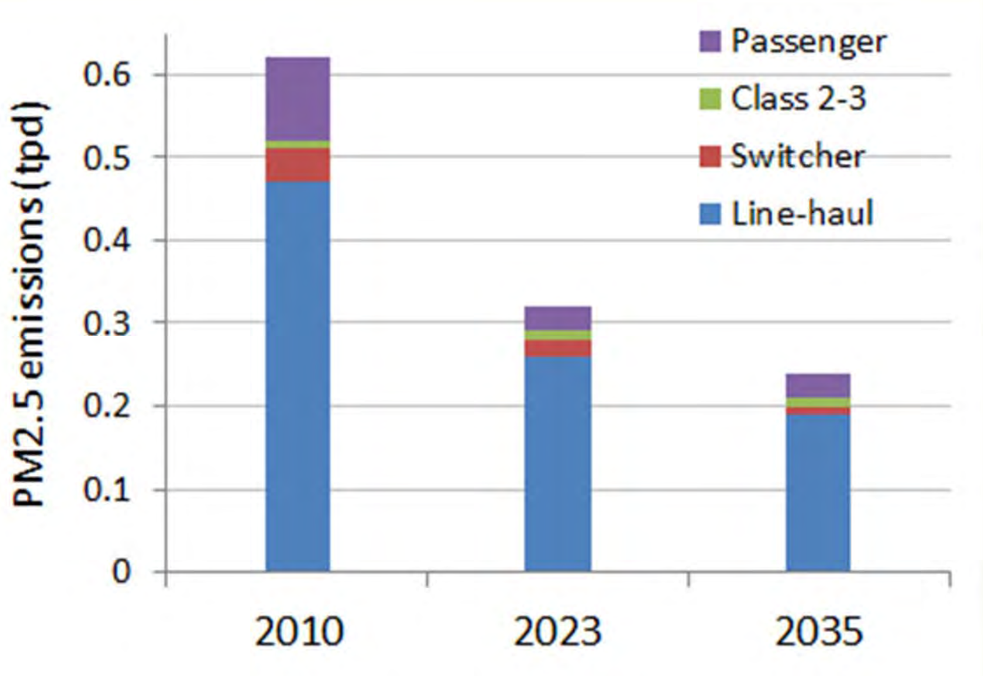
- Baseline emissions
- Accelerated Tier 4 deployment
- Switcher strategies
- Railroad mainline electrification
- Policy implications

Locomotive baseline emissions

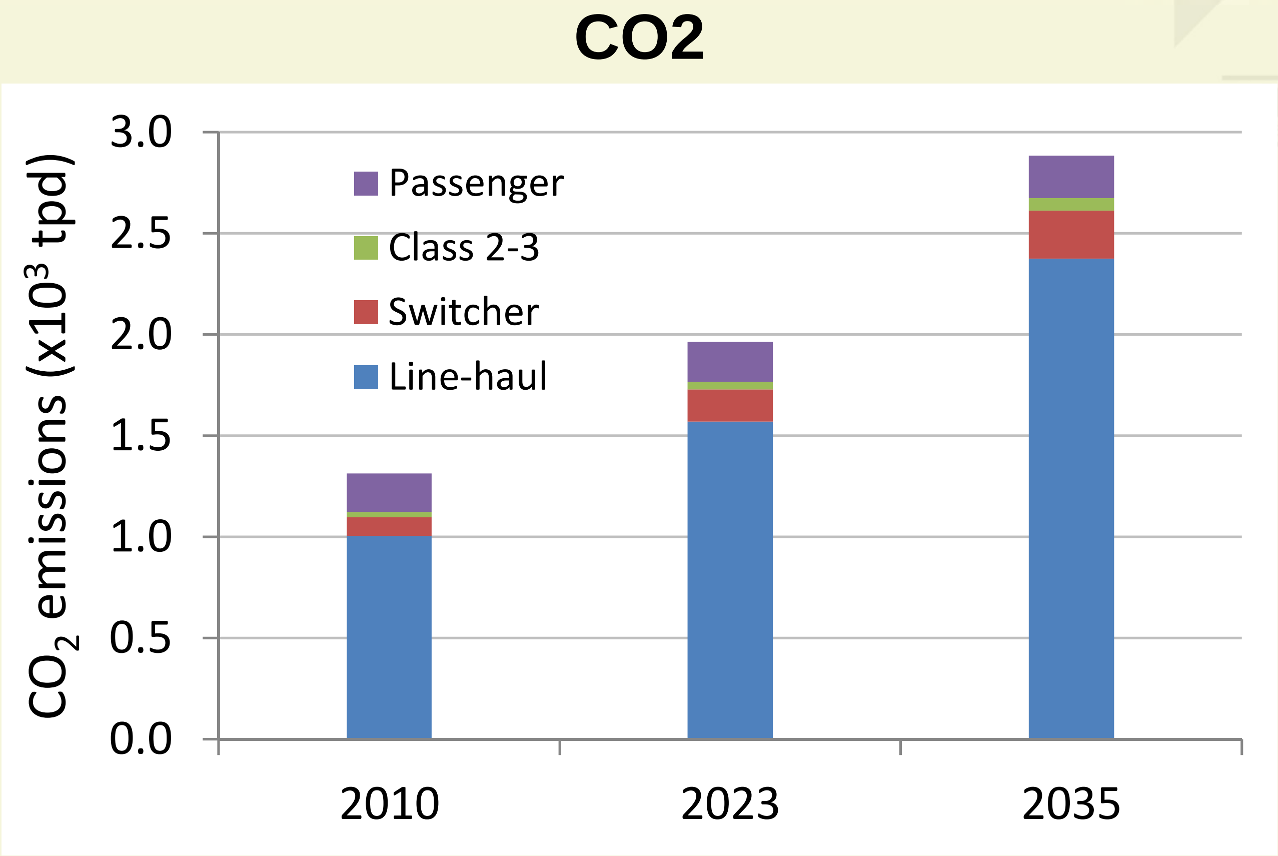
NOx



PM2.5



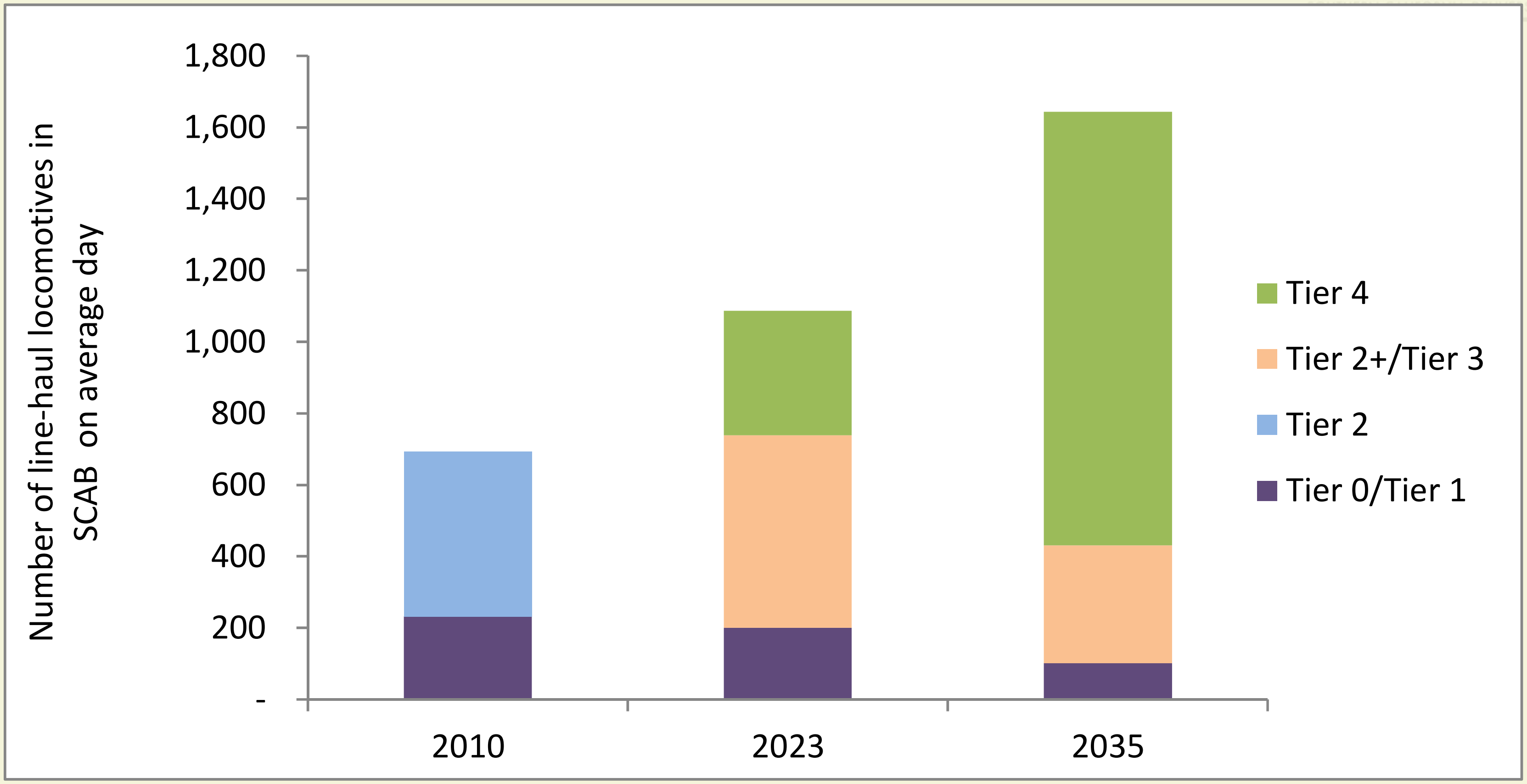
Locomotive baseline emissions



- Accelerated Tier 4 Locomotive Deployment -

Accelerated Tier 4 deployment

Projected baseline line-haul locomotive fleet



Analyzed implementation mechanisms

- Government incentives to subsidize the purchase of new Tier 4 locomotives
- New MOU by which railroads concentrate Tier 4 locomotives to Southern California interstate service
- Both of these

Emissions impacts

- Maximum emission benefits:

	NOx			PM		
Year	Line haul Baseline	With Strategy	% Change	Line haul Baseline	With Strategy	% Change
2010	12.1	12.1	0%	0.470	0.470	0%
2023	13.0	3.2	-75%	0.264	0.049	-82%
2035	10.4	4.9	-53%	0.191	0.074	-62%

- Incremental benefits: for every 100 Tier 4 line-haul units that replace Tier 2+ units
  - NOx reduction of 1.24 tpd (10% of baseline)
  - PM reduction of 0.02 tpd (8% of baseline)

Tier 4 acceleration: costs and other uncertainties

- New Tier 4 line haul locomotive
  - EPA estimated $3 million each
  - No units produced yet; cost could be higher
- Uncertain penetration in RR fleets
  - Concerns about performance in early years
- Ability to accelerate deployment
  - Uncertainty around RR ability to shift units and how many total Tier 4 would be needed in fleet
- No recommendation for Tier 4 acceleration program as part of RTP at this time

- Switcher Strategies -

Switcher strategies

- Replace Tier 0+ switchers with Tier 3 or Tier 4
- Repower GenSets with Tier 4 non-road engines
- Small regional impacts
- Help minimize railyard hotspot impacts
  - May be implemented through ARB 2010 railyard commitments

- Electrification of Freight Railroad Mainlines -

Electrification Analysis - Overview

- 3 Geographic Options Analyzed:
  - Alameda Corridor
  - Ports to West Colton/San Bernardino
  - Ports to Barstow/Indio/Chatsworth/San Fernando

- 3 Technologies Analyzed:
  - Straight-electric locomotives (Overhead Catenary)
  - Dual-mode locomotives (Overhead Catenary)
  - Linear synchronous motor (LSM) technology

Evaluation Criteria

- **Evaluation criteria used for comparing electrification options:**
  - Technology readiness
  - Railroad operations impacts
  - Total capital cost
  - O&M cost impacts (not calculated except energy costs)
  - Emissions impacts

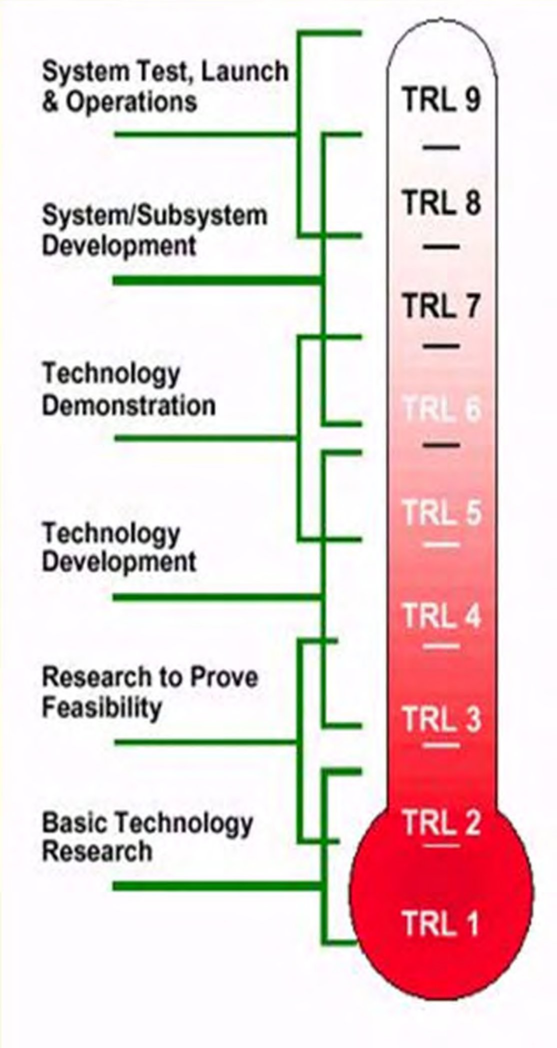
Assumptions were vetted through a small working group that included SCAQMD, ARB and California Environmental Associates (representing the railroads).

Technology overview and TRL

– Straight-Electric (Overhead Catenary)
  - Highest level of technology readiness of the three technology options (TRL 8-9)
  - Widespread use, locomotives may need some minor adjustments to operate in U.S. freight system, such as adjustments to increase tractive effort

– Dual-mode (Overhead Catenary)
  - TRL 6-7
  - Only in use for passenger operations in U.S.; high technology readiness for passenger rail
  - Would need significant adjustments for freight use, including substantial increase in starting tractive effort; design modifications to adapt for freight use

– Linear Synchronous Motor (LSM) Technology
  - Lowest TRL of the group (TRL 5-6)
  - No existing LSM system that moves heavy-haul, long distance freight
  - Port-led R&D efforts to further evaluate this option



RR Operations Impacts

- Used railroad, vendor, and expert input to identify potential operational impacts of each technology and geographic option, which may have impacts on railroad competitiveness. Discussed qualitatively in the paper.
  - Potential of increased travel times due to changing out locomotives at the edge of the electrified system (i.e. Barstow, Indio etc.)
  - Difficulty in switching out locomotives at high traffic areas, such as north of the Alameda Corridor
  - Impact on track maintenance workflows due to standardized equipment

Capital Costs

Table 4.3 Capital Cost Overview
In 2011 Dollars, Undiscounted

	Track Miles (Includes Sidings)	Cost of Rail Electrification (Undiscounted 2011 Dollars)[a]	Cost of Locomotives or LSM Helper Cars, Through 2035	Total Capital Cost (Undiscounted 2011 Dollars)
Alternative 1: Straight-Electric Locomotives (Electrified Catenary)		*($4.8 million per track mile)*	*($5 million per locomotive)*[b]	
Option I	51	$0.24 B	$1.0 B	$1.2 B
Option II	422	$2.0 B	$4.1 B	$6.1 B
Option III	863	$4.1 B	$11.4 B	$15.5 B
Alternative 2: Dual-Mode Locomotives (Electrified Catenary)		*($4.8 million per track mile)*	*($8 million per locomotive)*[c]	
Option I	51	$0.24 B	$1.6 B	$1.8 B
Option II	422	$2.0 B	$6.6 B	$8.6 B
Option III	863	$4.1 B	$18.2 B	$22.4 B
Alternative 3: LSM System*		*(Materials cost only: $5 million-$20 million per track mile)*[d]	Cost of retrofitting a railcar with magnets is $50k. An LSM helper car could be significantly more expensive.	
Option I	63**	$0.30 B – $1.2 B	$30 M – unknown	Cost Uncertainty*
Option II	422	$2.1 B – $8.4 B	$155 M – unknown	Cost Uncertainty*
Option III	863	$4.3 B – $17.3 B	$392 M – unknown	Cost Uncertainty*

Emissions Impacts

- Emissions impacts – Option III

	NOx (tpd)			PM2.5 (tpd)			CO2 (tpd)		
Year	Line haul baseline	With Strategy	% Change	Line haul baseline	With Strategy	% Change	Line haul baseline	With Strategy	% Change
2010	12.1	--	0%	0.47	--	0%	1,004	--	0%
2023	13.0	--	0%	0.26	--	0%	1,571	--	0%
2035	10.4	0.26	-98%	0.19	0.05	-74%	2,376	509	-79%

Energy Cost Impacts

Key Question: Does electrification have the potential to reduce cost related to fuel or energy use?

Six Scenarios were evaluated:

1. High Diesel Prices, Low Electric Prices
2. Low Diesel Prices, High Electric Prices
3. High Diesel Prices, High Electric Prices
4. Low Diesel Prices, Low Electric Prices
5. Low Diesel Prices, High Electric Prices, 30% higher electricity consumption, 30% lower diesel consumption
6. High Diesel Prices, Low Electric Prices, 30% lower electricity consumption, 30% higher diesel consumption

Energy Cost Impacts, cont'd

- Projected high future diesel prices and low electricity prices suggest significant energy cost savings for freight RRs are possible (~$9 billion in savings through 2050, undiscounted)
- However, in scenario where the reverse is true, RRs may pay more for energy costs than if they stick with diesel locomotives
- Further collaborative work is required with SCE, locomotive mfrs, and RRs to improve price assumptions
- Uncertainty related to fuel and electricity prices and relative efficiencies of each engine – affects estimates of future energy costs

Capital Costs vs. Energy Costs

- When looking at capital cost recovery, discounted energy cost savings as a result of electrification <u>could</u> recover significant percentage of discounted capital costs incurred through 2050
  - Potentially more through useful life of system
  - Potentially less under high electricity cost, low fuel cost scenarios

Electrification: General Conclusions

- Significant emissions benefits can be achieved
- Technologically ready options exist; but these have not been demonstrated in power ranges and applications that match all of the requirements of the western U.S. freight rail system
- Railroad operations may be impeded, the degree of which needs further study
- Energy cost scenarios suggest significant savings potential, but also a potential for no savings or additional costs as a result of electrification. Needs further study to solidify estimate.

Key Areas of Uncertainty – RD&D Required

- More information on the impacts of electrification on railroad operations
- Region-specific simulation of train movements necessary to improve analysis of energy costs, capital cost requirements, emissions
- Electricity and diesel price estimates – further effort needed to refine these to determine long term feasibility
- Further refinement of locomotive cost estimates through additional in depth discussions with the railroads
- LSM capital costs determination and additional testing of concept

- Policy Implications -

Rail strategies – Policy implications

- SCAG is working towards a regional vision of zero-emissions for rail, for which rail electrification is an applicable strategy
- Much uncertainty around the timing, technologies, operations, and cost impacts – needs to be resolved through further study and RD&D
- SCAG staff recommends a vision of cooperative RD&D to gain a comprehensive understanding of the costs and benefits of electrification; this should further focus on timing, technological and operations issues and mitigation of these issues