SoCalGas and AQMD

Webinar

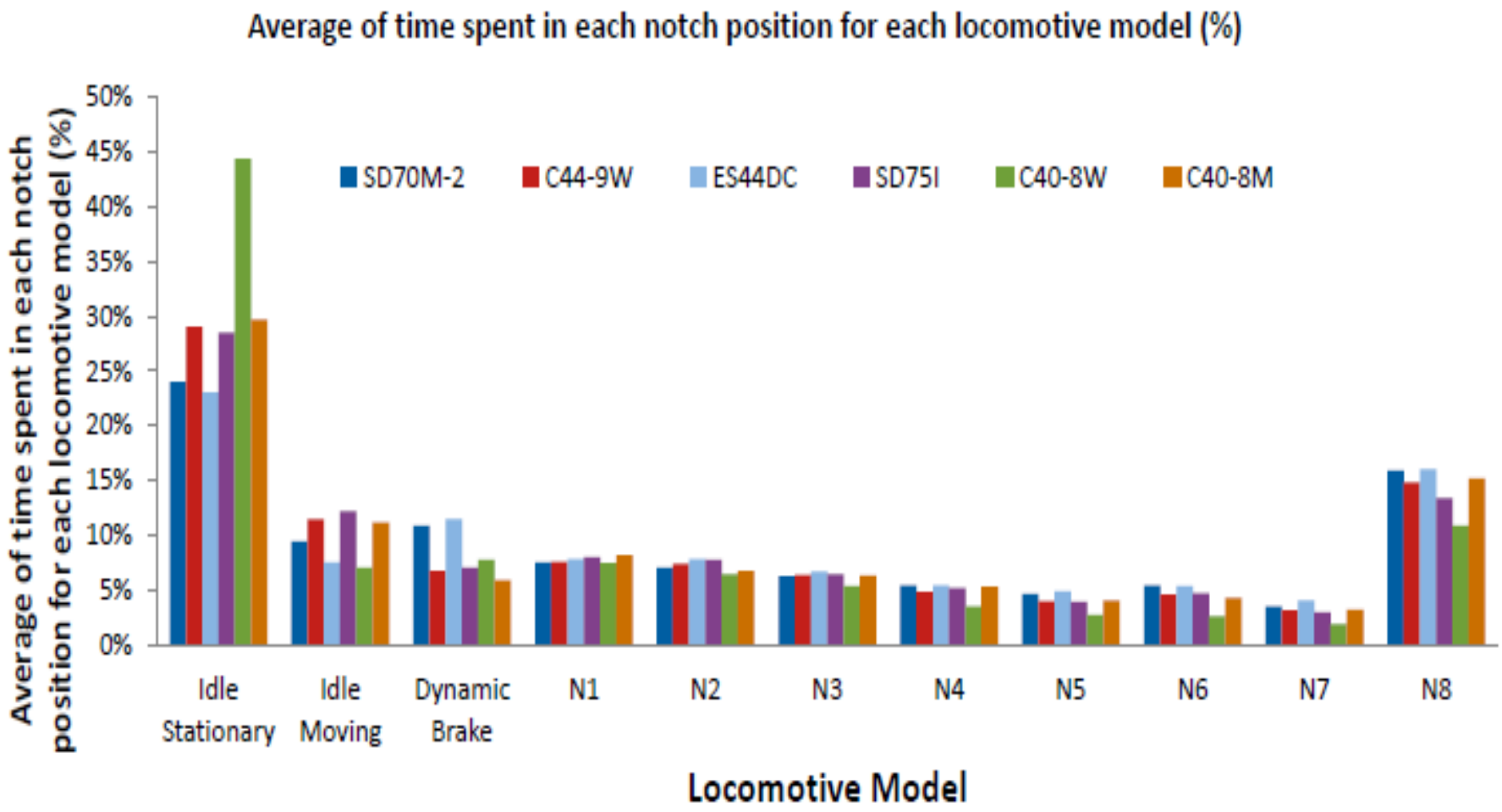
Natural Gas for High Horsepower Engine

Normand Pellerin
Canadian National Railway

LNG consist

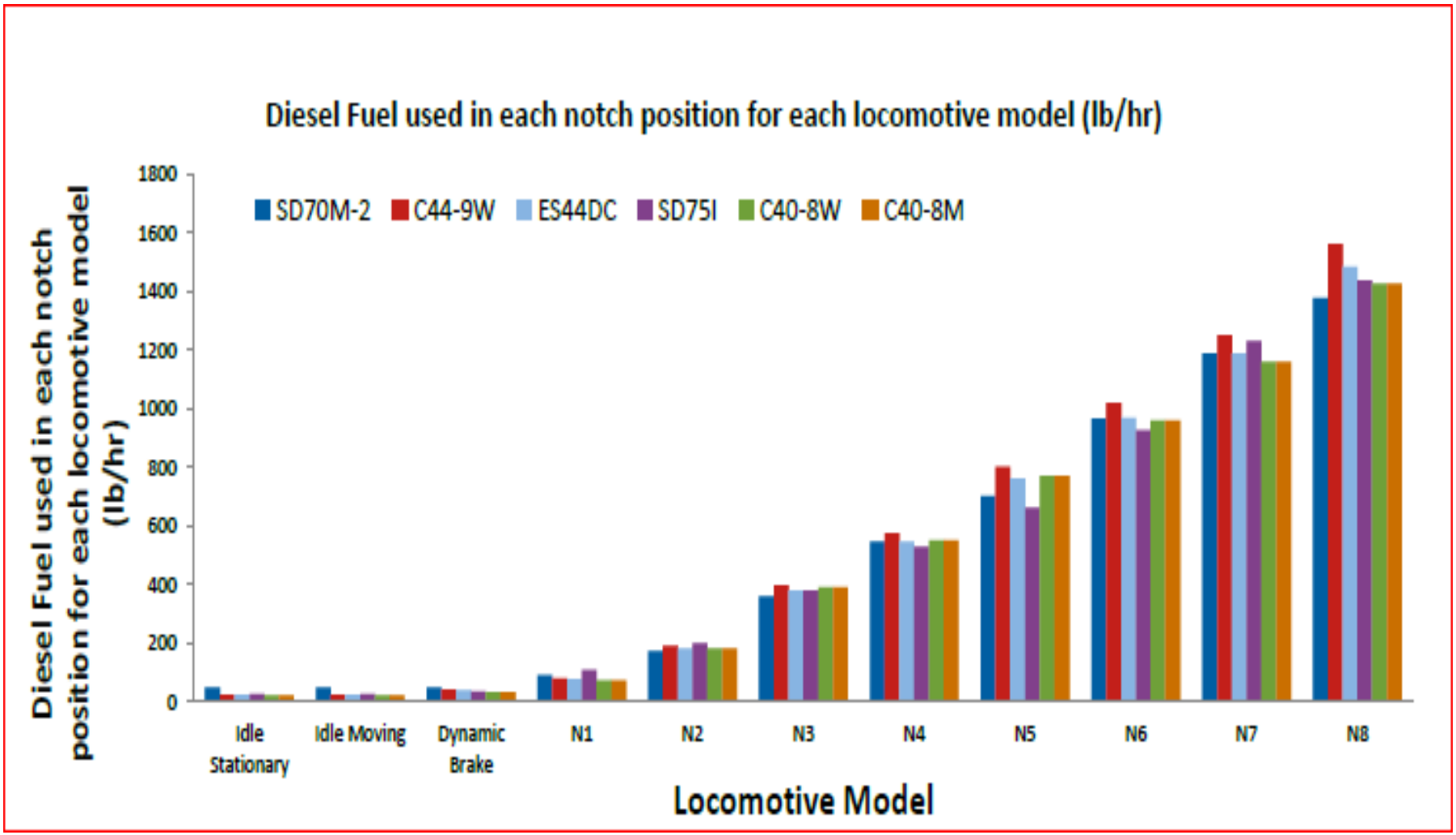
Trial test on main line

Locomotive Usage



Fuel usage

Main line



Engine

- Locomotive fleet is a mix (different HP and manufacturers)
- Average fuel consumption on main line

Engine

- What are the technologies
- Key effects and performance
- Performance profile
  - Power, fuel consumption, emissions, cleanliness of the gas, substitution rate
- Ability to operate at high power rating
- Gas conversion via retro-fit
- Gas quality consideration (methane, propane, butane)

Engine substitution

- Two technical approaches:
  - High Pressure Direct Injection
  - Low Pressure (port or direct injection)
- Various type of injections
  - Existing system, modified injectors, pilot injectors, etc.

Locomotive substitution

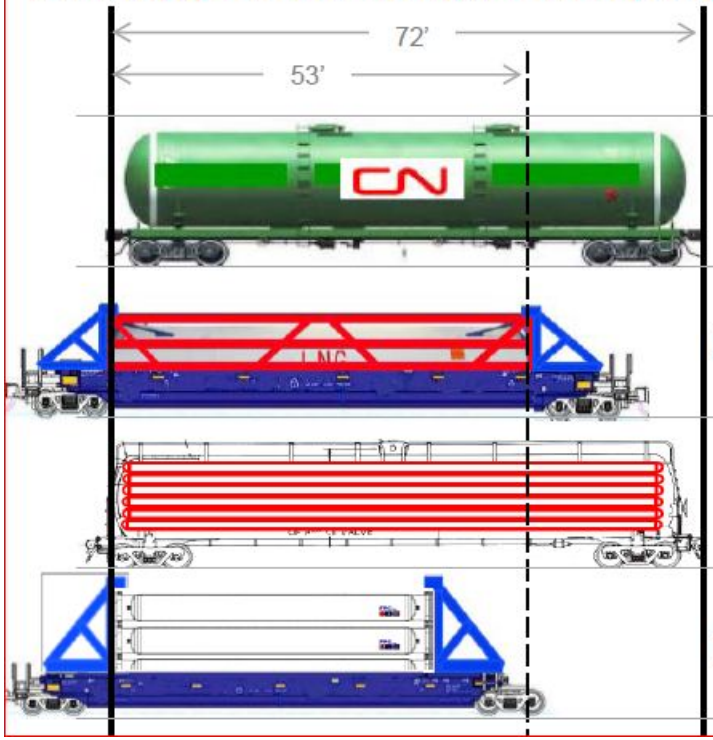
- Target of 85 % rate of substitution, have to look at a 95 % of diesel substitution at higher notch
- Substitution is linked to load profile; therefore impact on the conversion of the fleet, higher load usage more cost effective conversion
- Identify technology that will deliver a > 95 % fuel substitution rate
- Retrofit locomotives with high load operating profile

Tender

LNG tank car tender provides highest range even when shared between two locomotives

CNG requires one tender per locomotive

Summary of Tender Car Concepts (Selection)



Concept Name	Specs[1]	Range[2] Gas 85/15	Est. cost per unit	Time to Fuel	Locos Powered
LNG Tank Car	25.5k gal 0-150 psi -263° F	2,200 mi	$0.9 M	35 min @ 700 gpm	2 locos per tender
LNG Intermodal 53'	12.5k gal 0-150 psi -263° F	2,200 mi	$0.6 M	18 min @ 700 gpm	1 loco per tender
CNG Tank Car	24.0k gal 3,600 psi 60° F	1,600 mi	$1.0 M	144 min @ 5,000 scfm 60 min @ 12,000 scfm	1 loco per tender
CNG Intermodal (FPC)	16.4k gal 3,600 psi 60° F	1,100 mi	$1.0 M	96 min @ 5,000 scfm 40 min @ 12,000 scfm	1 loco per tender

Tender

- Method of transferring
- Type, size, location of compressors pumps
- Location and size of heat exchanger, pressure regulator
- Cooling components
- Complexity of systems

Tender consideration

- Range (volume of tank)
- Output power
- System mass
- Costs development / conversion , operational (fuel)
- Plant and Infrastructure, maintenance and breakdown
- Emissions and waste
- Controllability ,fuel flow and distribution on-board
- Fuel safety collision/rupture safety, exhaust fire / explosion
- Fuel storage self pressurization
- Gas / cryo link between loco and tender
- Contamination of fuel at refuel
- Gradient effects on fuel flow (fuel slosh) use baffles & have gasification on loco, rather than tender , Icing up of fuel lines
- Use of Commercial Off-The-Shelf (COTS) components
- Readiness levels of technology / manufacturing /
- Failure of tender coupling, thermal cycling / fatigue life, vibration (at cold)
- Adequate grounding; static build-up

Refuelling efficiency

- Time to fill (less than 30 minutes)
- Sizing of the fuel system
- Gas supply pressure available
- Number of nozzles
- Cost of the systems

Safety

- Compressed gas at a minimum distance from locomotive
- Safety of the tank
- Safety at the refuelling

Business Case

Key factors to consider

- Engine hardware and performance requirements
- Tender and options
- Refuelling and safety impacts
- Cost of capital to replace the fleet
- Implementation

Key challenges

Finding the proper trade-offs