SECOND ANNUAL

ELECTRIC VEHICLE & INFRASTRUCTURE SUMMIT

Moving Forward with a Green Economy

Through the Development & Integration of Electric Vehicles

Ray Hoemsen, P. Eng.
Director, Applied Research & Commercialization
Red River College

Dale Friesen, P. Eng.
Division Manager, Industrial & Commercial Solutions Division
Manitoba Hydro

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Overview

- **Overview of College EV Engagement**
- **Manitoba EV Initiatives**
  - EV Road Map
  - EV Demonstrations
  - EV Advisory Committee
- **Electric Battery Transit Bus**
- **Impacts & Results**

CLEANTECH in Transportation

- **Fuel efficiency, renewable fuels, and cold weather operation for vehicle technology**
  - Bio-diesel, EVs and PHEVs, hydrogen, solar
  - Prototyping, testing and evaluation, demonstrations
- **Research infrastructure (ATEC and CARSI)**
- **Electric bus: battery, not trolley ($3M)**
- **Electric Vehicle Technology & Education Centre (EVTEC)**
- **Participation in numerous public advisory bodies**

Canada Manitoba Winnipeg

A123 SYSTEMS Kraus GLOBAL Manitoba Hydro MITSUBISHI HEAVY INDUSTRIES, LTD. NEW FLYER PERSENTECH

Past ATEC-Related Projects

- **2005: Hybrid Hydrogen Internal Combustion Engine (HHICE) transit bus cold-weather evaluation**
- **2005 and 2008: Red River Raycer solar car**
- **2006: Hydrogen Fuel Cell transit bus demonstration**
- **2007 and 2010: Integrated engine/transmission intercity MCI D4500 and J4500 bus prototypes**
- **2008-11: Plug-In Hybrid Vehicle cold-weather conversion/ modifications, demonstration and monitoring**
- **2009: Electric Vehicle Opportunities Report with EMC for IRAP**

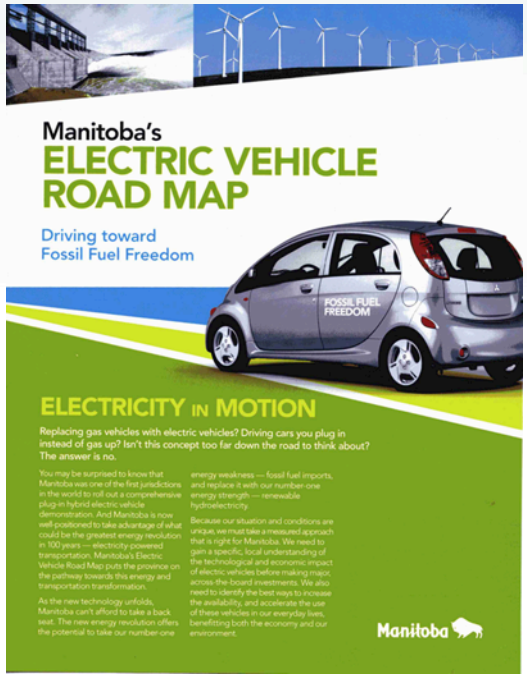
Manitoba Electric Vehicle Initiatives

- **EV Road Map (2011)**
- **PHEV/EV Demonstrations (since 2009)**
- **EV Advisory Committee (2011-12)**
- **EVTEC (established 2011)**
  - Manitoba Electric Transit Bus Project
  - New Flyer Industries - SDTC small fleet battery electric transit bus demonstration
    - MHI battery pack integration

http://www.manitoba.ca/iem/energy/transportation/index.html

Manitoba EV Road Map

- **Primary Actions**
  - Demonstration partnerships
  - Electric Vehicle Advisory Committee
  - EVTEC Electric Vehicle Technology & Education Centre @ Red River College



Manitoba EV Demonstrations

- **3-year PHEV Demonstration completed in 2012**
- **On-going demonstrations with Manitoba**
  - Chevrolet Volt
  - Mitsubishi iMiEV (two European versions)
    - One unit now at Red River College
  - Nissan LEAF
- **Centre for Emerging Renewable Energy**
  - Administrates demos on behalf of Manitoba
  - Final reports publicly available

MB EV Advisory Committee

- **Mandate to provide recommendations on the best ways to speed adoption of EVs**
- ***Realizing the Potential of Electric Vehicles in Manitoba* released June 2012**
  - Information and education
    - Must be accurate/comprehensive & address the value case
  - Infrastructure – good start, but need to
    - upgrade for code compliance & provide secondary charge points
  - Incentives - to address price differentials
- **Report Endorsed**
  - Some recommendations implemented
  - Low-cost electricity will offset some capital costs

EVTEC Electric Vehicle Technology & Education Centre

- **Demonstration and public education site for all-electric and plug-in hybrid-electric vehicles**
- **Provincial support based on RRC's track record of applied research and demonstrations in advanced transportation**
- **Mission:**
  - Support electric vehicle innovation in Manitoba's transportation sector
  - Enhance electric vehicle education at RRC and in the region
  - Increase public awareness of electric vehicle technology




Electric Vehicle Impacts

- **Infrastructure Overview**
  - 500,000+ Level 1 charge points in Manitoba
    - Winter is cold, all vehicles have block heaters
    - Private/public places will need to accommodate EVs
  - Bio-diesel for auxiliary power (winter heating)
  - Battery repurposing/end-of-life (still @ 80% capacity)
- **Education**
  - Operators and service personnel training

Manitoba Electric Bus Project

- **Collaborative Effort of Industry and Public Sector Partners**
  - Project Partners - New Flyer Industries (manufacturer), Province of Manitoba (government), Mitsubishi Heavy Industries (batteries), Red River College (education) and Manitoba Hydro (electric utility)
  - Mandate to develop a commercial all-electric transit bus prototype
  - Initial phase - $3.0 Million in funding provided by project partners
- **Project Expanded to Include Multi-Year Demonstration**
  - Expanded scope to include four additional electric buses for four year demonstration in Winnipeg, including Government of Canada (SDTC) and Winnipeg Transit Authority as additional project partners
  - Demonstrate the feasibility of electric transit buses in cold weather climates and provide further validation of business case
  - Project funding expanded to $10.0 Million including SDTC funding a ons from rs

NEW FLYER

MITSUBISHI HEAVY INDUSTRIES, LTD.

Manitoba Hydro

Manitoba

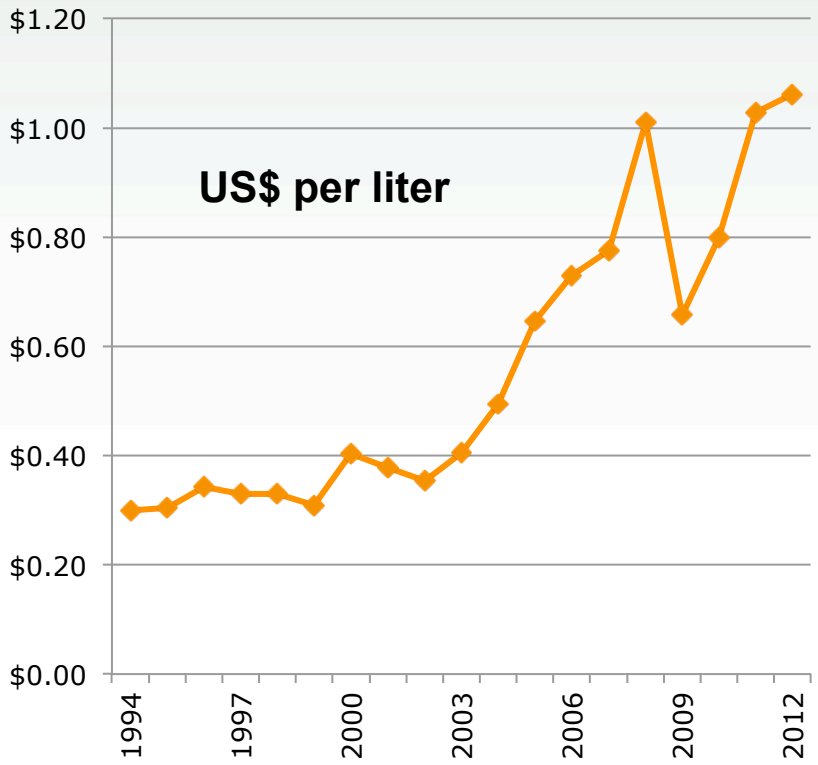
RED RIVER COLLEGE
OF APPLIED ARTS, SCIENCE AND TECHNOLOGY

Anticipated Project Benefits

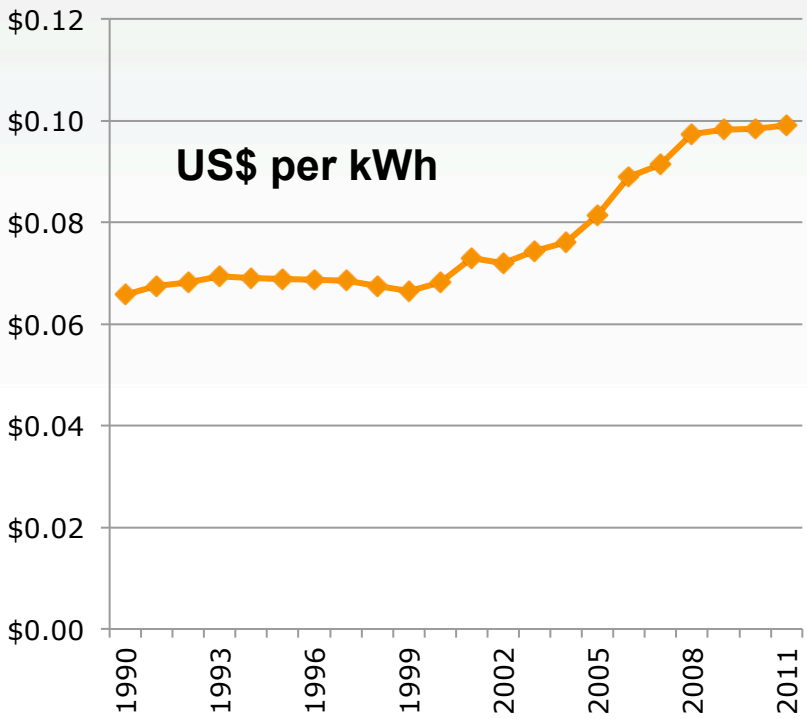
- **Near Zero Emissions from Electric Bus**
  - Typical greenhouse gas emissions
    - Battery-Based Electric 2 tonnes (renewable supply)
    - Diesel-Electric Hybrid 108 tonnes
    - Diesel 162 tonnes
- **Assurance of Long-Term Fuel Supply**
  - Eliminate dependency on finite domestic/foreign oil supply
  - Long term price stability and cost certainty
- **Overall Efficiency Improvements**
  - Electrification of ancillary vehicle accessories
  - Enhanced drive-train efficiency
- **Associated Benefits**
  - Enhanced reliability and longevity with lower maintenance costs

Fuel Supply of the Future

Diesel fuel is trending to double in price over the next 12 years



Electricity is trending towards a 35 percent increase over the next 12 years



**http://www.eia.gov/oog/info/wohdp/diesel.asp

Life Cycle Fuel Costs (12 years)

Today's Economy

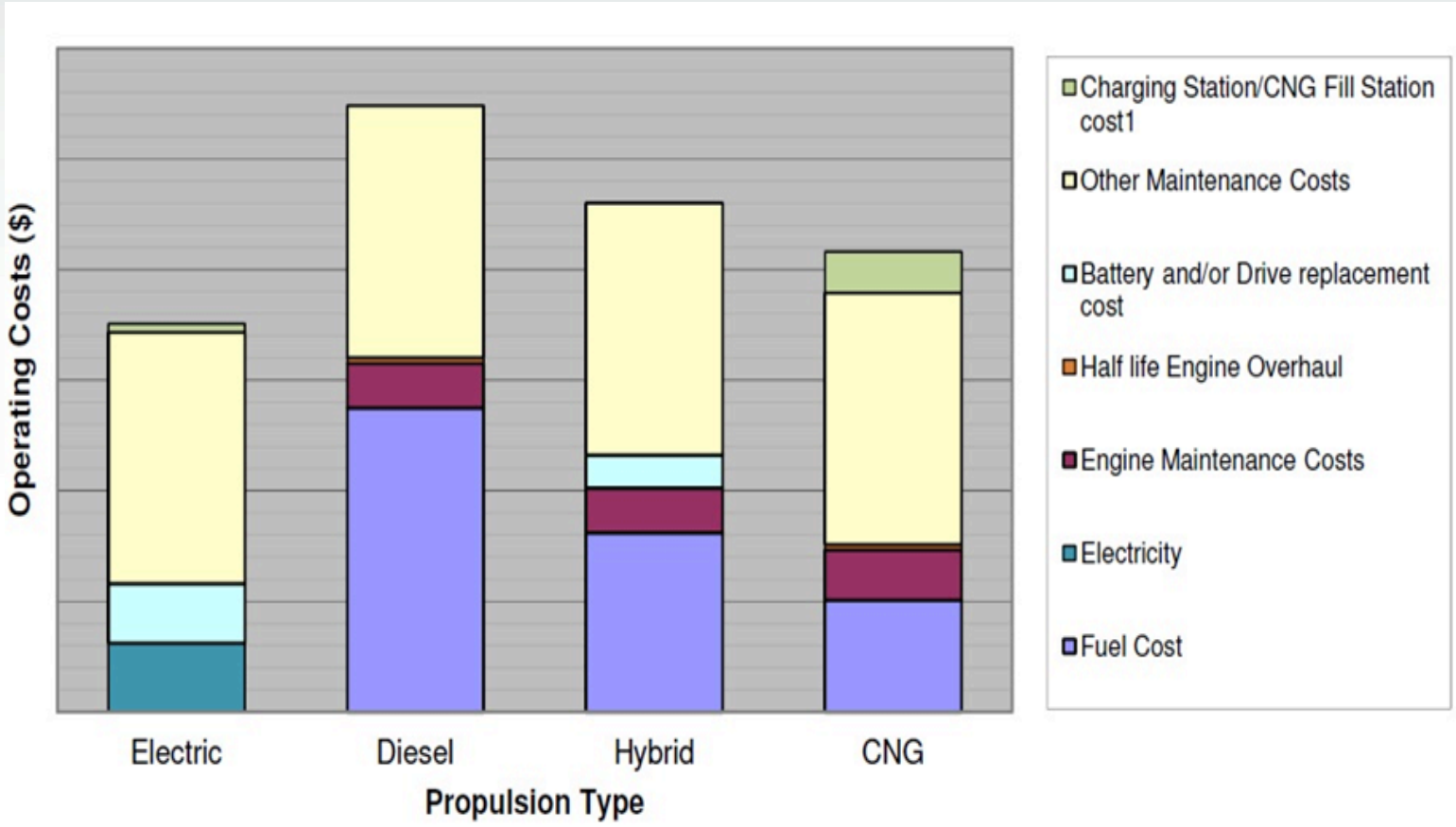
- Diesel Option
  - Consumption - 62 litres/100 km
  - Energy cost - $1.00 per litre
  - Life cycle cost - $485,000
- Electric Option
  - Consumption - 155 kWh/100 km
  - Energy Cost - $0.10 per kWh
  - Life cycle cost - $121,000
- Life Cycle Fuel Savings
  - $364,000 ($30,000 per year)

Tomorrow's Economy

- Diesel Fuel Option
  - Consumption - 62 litres/100 km
  - Fuel cost - $1.50 per litre
  - Life cycle cost - $725,000
- Electric Option
  - Consumption - 155 kWh/100 km
  - Energy cost - $0.12 per kWh
  - Life cycle cost - $145,000
- Life Cycle Fuel Savings
  - $580,000 ($48,000 per year)

Life Cycle Value Proposition

- **Reduced Operating and Maintenance Costs**



New Flyer Industries Overview

- **Founded and Headquartered in Winnipeg, Manitoba**
  - Manufacturing plants in Manitoba and Minnesota
  - Fabrication plant in Indiana, Service center in Ontario
  - Parts distribution centers in Manitoba, Ontario, Kentucky and California
  - New product development center in Manitoba
  - Compliant with "Buy America" and "Canadian Content" mandates
- **Market Leader in Technology and Innovation**
  - Over 32,500 buses delivered, Over 24,000 are still in operation
  - Lengths ranging from 35 ft, 40 ft and 60 ft, articulating, low-floor buses
  - Diverse fuel and propulsion options, including clean diesel, electric-diesel hybrid, electric trolley and compressed natural gas, liquefied natural gas, hydrogen fuel cell, and all-electric prototype (delivered)
- **Focused on being an Employer of Choice**
  - Over 2,200 employees, Stable labor relations with CAW (MB) and CWA (MN)
  - Publically traded on TXS: FNI, NFI.BU.U

2010 Canada's Greenest Employers

2010 Top Employers for Canadians Over 40

Manitoba's Top Employers 2011

Canada's Top 100 Employers 2011

fp10 The Financial Post's Ten Best Companies to Work For

Leadership & Innovation

Compressed Natural Gas
1994

Diesel Electric-Hybrid
1998

Next Gen Electric Trolley
2001

Articulated Diesel-Electric
2002

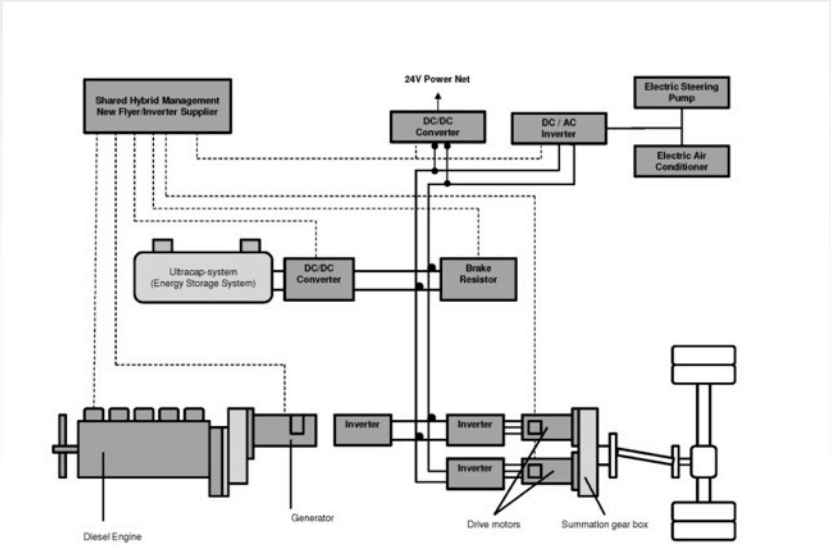
Hydrogen Fuel Cell Fleet
2010

Advanced Xcelsior Platform
2010

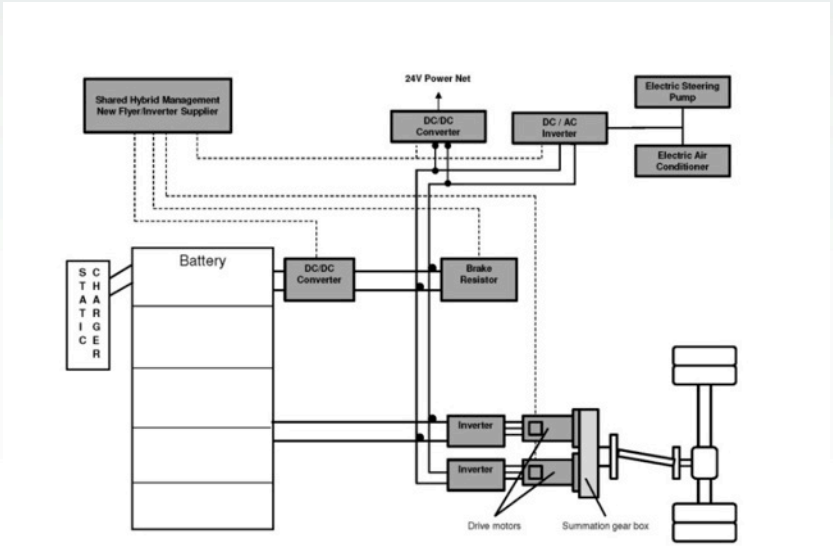
Transit Bus Industry's First Low Floor Buses in 1988

Path to an All-Electric Platform

Series-Hybrid Architecture



All-Electric Architecture



All-Electric Concept is Less Complex than Previous Series or Parallel Hybrid Designs

Establishing the Goal Posts

- **Test Data and Industry Experience**
  - 125 kWh/100 km (no air conditioning) – spring / fall seasons
  - 185 kWh/100 km (full air conditioning) – summer season
  - 310 kWh/100 km (full heating) – winter season
- **Battery Storage Versus Range/Time and Life**
  - 100 kWh capacity (10 to 20 minute rapid charge)
    - 80% usage (90 - 10 SOC) 25 – 65 km, 1.0 – 3.0 hrs, 1000 – 2600 cycles
    - 50% usage (80 – 30 SOC) 15 – 40 km, 0.75 – 2.0 hrs, 1600 – 4300 cycles
  - 200 kWh capacity (20 to 40 minute rapid charge)
    - 80% usage (90 – 10 SOC) 50 – 125 km, 2.5 – 6.0 hrs, 500 – 1300 cycles
    - 50% usage (80 – 30 SOC) 20 – 80 km, 1.5 – 4.0 hrs, 800 – 3250 cycles
  - 300 kWh capacity (30 to 80 minute rapid charge)
    - 80% usage (90 – 10 SOC) 75 – 190 km, 3.5 – 9.5 hrs, 350 – 875 cycles
    - 50% usage (80 – 30 SOC) 50 – 120 km, 2.5 – 6.0 hrs, 550 – 1300 cycles
- **Desired Battery Life**
  - Six to eight years (80 percent of capacity)
  - One change-out over expected life of bus (12 years)

Performance Variables

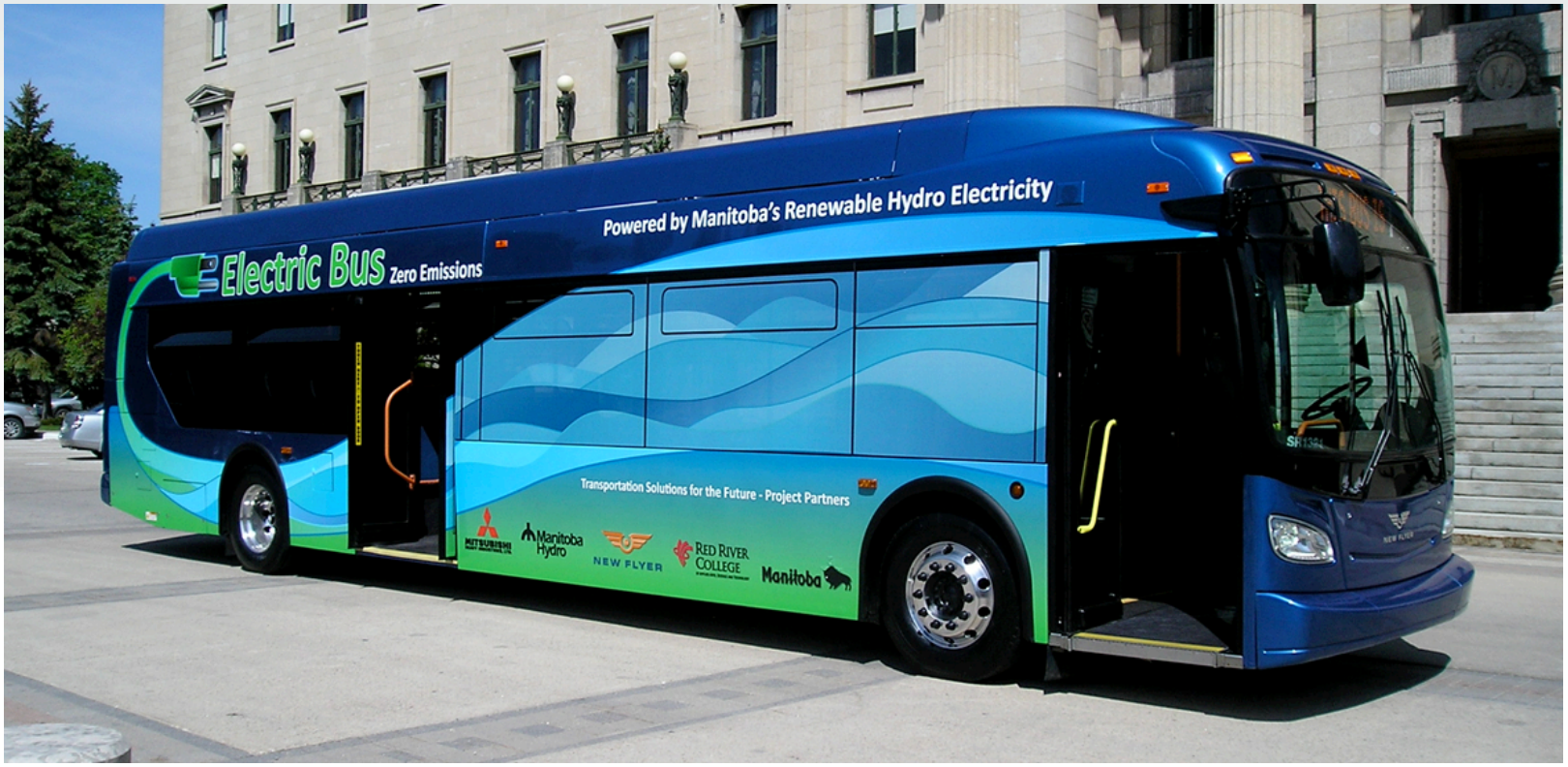
- **Useable On-Board Battery Storage Capacity**
  - Desired battery life (6 to 8 years), Thermal management
    - 90 – 10 percent SOC (maximum condition)
    - 80 – 30 percent SOC (more reasonable condition)
  - Emerging battery technologies (density, cost)
- **Energy Consumption**
  - Topography (hills, prairies, winding, straight)
  - Duty cycle (stop/start frequency, average speed, etc)
  - Climate (average temperatures, peak temperatures)
  - Traffic volatility (average speed, stop/start variance)
- **Charging System Characteristics**
  - Available charging capacity (volts, amps, kilowatts)
  - Battery characteristics (thermal degradation, cooling)
  - Acceptable charge rate (1C, 2C, 3C, ?C)
  - Opportunity charging (regenerative braking, intermittent charging)

Transit Authority Considerations

- **Route Considerations**
  - Length of route, frequency of stops, charging opportunities
- **Charging Strategy Considerations**
  - Charging on route = smaller battery pack
    - Effectively enables indefinite stay on route
  - Charging at garage = larger battery pack
    - Multiple bus charging capacity required
    - Impacts servicing infrastructure requirements
  - Driver education/behavior impacts energy conservation
    - Behavior feedback related to energy performance
- **Effective Solutions**
  - Require balanced consideration of route requirements and charging strategy to provide cost-effective solutions

Manitoba Electric Bus Prototype

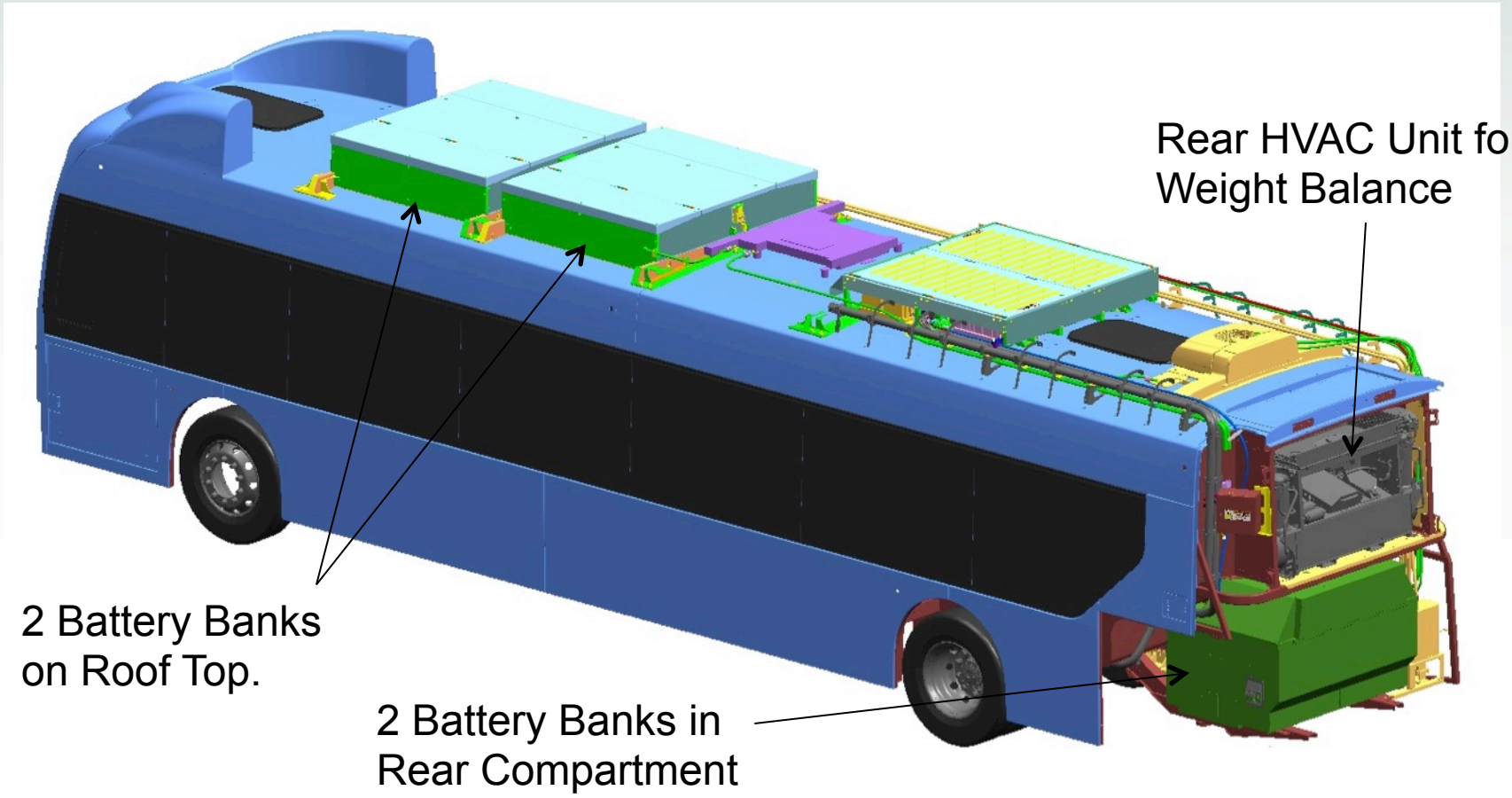
- **Functional Prototype Unveiled in June 2012**



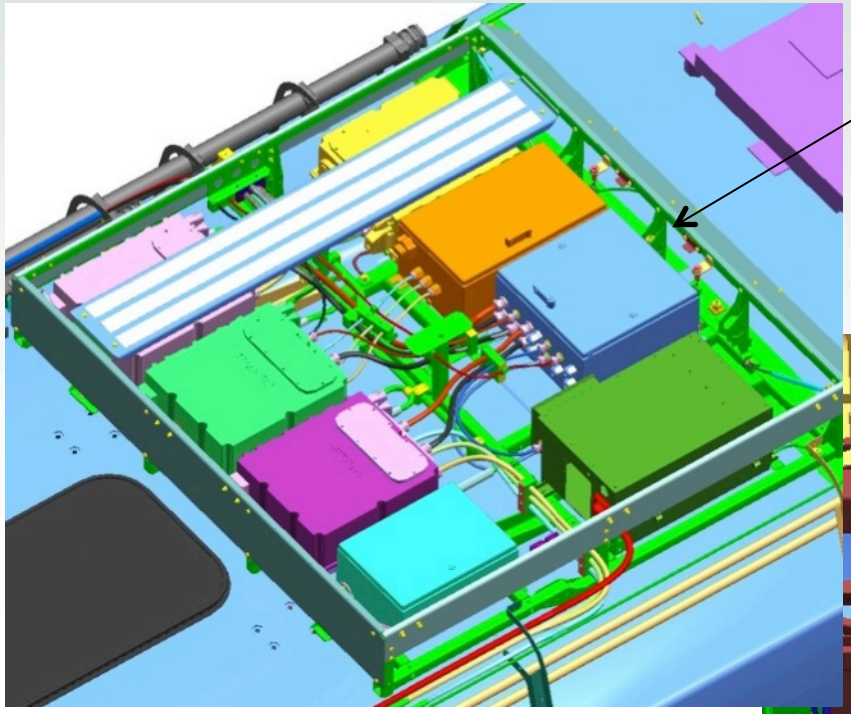
Xcelsior Electric XE40 Prototype

- **Electric Bus Platform**
  - Platform common to New Flyer diesel, diesel-hybrid, hydrogen and natural gas (compressed, liquefied)
  - Proven design, common parts, service and support training
  - Chassis already tested to standard industrial criteria for durability and life (6X Altoona Durability Test)
- **Advanced Performance**
  - Energy-efficient electric permanent magnet traction motor
  - Air-cooled lithium-ion batteries with 120 kWh on-board storage capacity
  - Optional bio-diesel heater for locations with cold winter climates
  - Comparable weight to comparable diesel-electric hybrid models

Xcelsior XE40 Overview

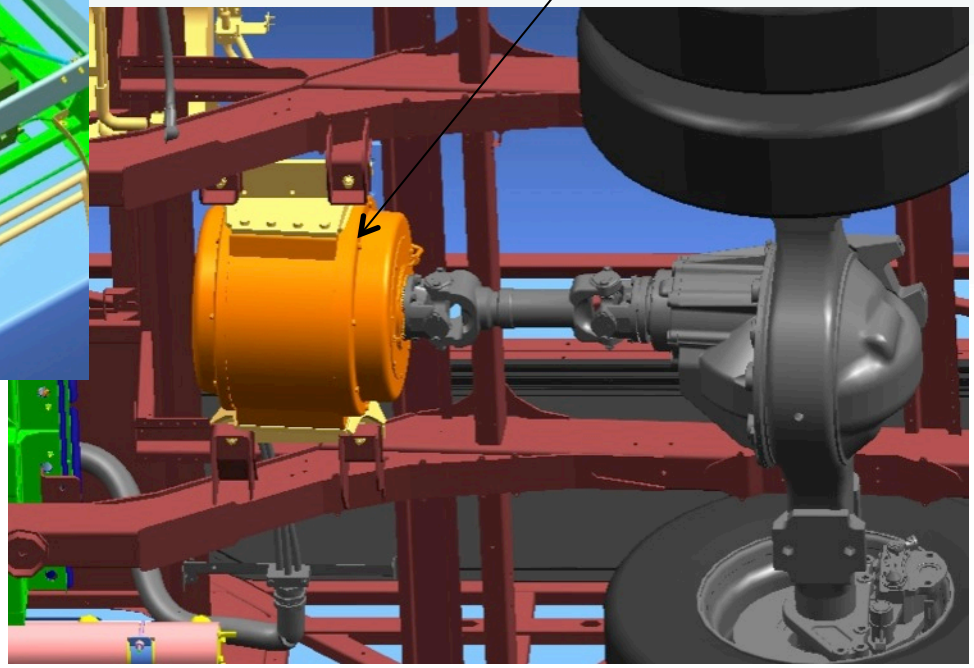


Siemens Drive System



Drive and auxiliary inverters, Siemens controller, high voltage contactor and fuse boxes, low voltage junction box, DC-DC converters

Permanent Magnet Traction Motor



Prototype Energy Performance

- **Phase One - Prototype Battery Configuration**
  - 120 kWh lithium-ion battery consisting of eight(8) 15 kWh modules
  - Air-cooled battery configuration in a controlled ambient temperature
- **In-Field Prototype Operating Performance**
  - Energy Consumption (operation only – no HVAC)
    - Average consumption of 133 kWh/100 km
  - HVAC Consumption (test chamber)
    - 32 – 45 kWh/100 km at 35 C ambient
    - 125 – 250 kWh/100 km at -30 C ambient
  - Sound (noise) output
    - Idle (all systems operating) – 50 dBA (background)
    - Idle (compressor operating) – 56 dBA
    - Full-throttle acceleration – 61 dBA

Winter Energy Performance

- **Energy Requirement for Winter Heating**
  - Electric heating can drive total energy consumption upwards to the range of 300 – 400 kWh/100 km
  - High winter consumption significantly limits available range and increases requirement for charging frequency
  - Greater on-board storage increases battery costs
  - Higher charging frequencies decrease battery life
- **Alternative Heating Options**
  - Evaluating the use of catalytic diesel or bio-diesel heaters with a thermal efficiency of 85 – 90 percent
  - Improved heating efficiency relative to electric heat using coal or natural gas-fired generation, converted through a battery-based on-board storage system
  - Regulator acceptance required to maintain zero-emission status

High Capacity Charging Systems

- **Evaluating a Dual Module Charger Configuration**
  - Two(2) module configuration with parallel output capability
  - Dual module output targets outputs in the range of 300 – 500 kW
  - Automated module isolation in case of failure (charge at half output)
  - Available with five(5) year warranty and 8 hour service response
- **Electric Utility Friendly Outdoor Enclosures**
  - Integrated utility termination and metering enclosure
  - Bottom entry for utility supply and output cables
  - Designed for curb-side installation in a single-footprint
  - Installation using standard utility methods and practices
  - Potential to integrate rapid charge capability for passenger vehicles
- **Enhanced Safety and Wireless Communication**
  - Integrated fault and isolation detection for enhanced safety
  - Seamless handshake and communication with Battery System Controller

Overhead Rapid Charging Dock

- **Overhead Charging Dock for Rapid Charging**
  - Automated rooftop interface engages charging dock
  - Quick and safe connect and disconnect capability
  - Easy drive-through ingress/egress for rapid charging
  - Facilitates rapid in-route high-rate charging

Low Capacity Charging System

- **Configured for Over-Night and In-Shop Charging**
  - Three-phase AC, 100 kW input via service plug
  - Fully isolated supply to AC charging station/on-board charger
- **Integrated Load Management System**
  - Modulated output allows for load management
  - Integrated charging controller manages multi-point charging
- **Monitoring and Safety Features**
  - Integrated consumption metering
  - Continuous fault and isolation monitoring
  - Easily accessible emergency stops
- **Ease of Configuration and Use**
  - Easy access, color touch screen monitors
  - Status indicators communicate charging status
  - Network capable with pre-programmed charging options

SDTC Project Considerations

- **Construction of Four(4) Additional Electric Buses**
  - Four year demonstration under regular transit operating conditions
  - Four season operation under full-route conditions
- **Enhanced Battery Performance**
  - Evaluate battery chemistry and the associated impacts/benefits
    - energy density, power density, cost, cycle life, temperature range
  - Examine battery cooling methodology
    - air-cooled versus liquid-cooled configurations and associated systems
  - Enhance capability to predict battery degradation
    - energy storage capability degrades 20 – 25 percent at end-of-life
    - explore opportunities for batter re-purposing including intermittent power storage, load balancing, backup power
- **Examine Opportunities for Transit Authorities**
  - Route planning to maximize electric bus efficiency and utilization
  - Optimize relationship between charging strategy and on-board storage
  - Optimize electric bus to charger ratios (reduce charging costs)
  - Additional passenger vehicle charging options

Battery Pack Integration

- **Role of Red River College (EVTEC)**
  - Assembly and preparation of batteries for prototypes
  - Develop charging infrastructure (with Manitoba Hydro)
  - Storage, minor maintenance and troubleshooting of prototype
  - Monitoring and evaluation of batteries during field tests
- **Battery Pack Integration into Prototypes**
  - RRC (with MHI guidance) assembled lithium ion battery packs for original Xcelsior electric battery bus prototype
  - Design, analysis, prototyping, testing, monitoring & troubleshooting of lithium ion battery packs
  - Multi-disciplinary approach with Mitsubishi Heavy Industries (battery) and New Flyer Industries (bus)

Summary

- **Real-World Cold Weather Experience**
  - Passenger and transit electric vehicle design and operation in extreme (especially cold) climatic conditions
- **Impact of Electric Vehicles**
  - Multi-partner approach examines infrastructure, education and implementation of electric vehicles
  - Evaluate the commercial model for an electric transit solution roll-out
- **Improving the Environment**
  - Electric vehicles operating on clean renewable electricity can help to improve our environment by reducing GHGs, while reducing costs and improving performance

Thank You

Dale Friesen, P. Eng.

Division Manager,
Industrial & Commercial Solutions
Customer Care & Marketing
Manitoba Hydro

Winnipeg, MB

Voice: (204) 360-4928

E-Mail: drfriesen@hydro.mb.ca

Web: www.hydro.mb.ca

Ray Hoemsen, M.Sc., FEC, P. Eng.

Director,
Applied Research & Commercialization

Red River College

Winnipeg, MB

Voice: (204) 632-2523
Mobile: (204) 799-6987
Fax: (204) 633-3079

E-mail: Rhoemsen@rrc.ca

Web: www.rrc.ca/appliedresearch
Blog: http://blogs.rrc.ca/ar/
Twitter: @RRCResearch

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