

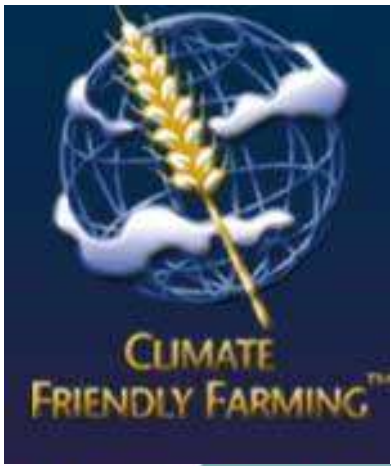
**Cow Power to Horsepower:
Using Dairy Cow Derived Biomethane
to Fuel Vehicles in Whatcom County**

**Western Washington University
Vehicle Research Institute
Eric Leonhardt**

Vehicle Research Institute Background
Why Use Biomethane for Transportation?
Challenges with Biogas
Experience with Viking 32 Hybrid
Pilot Project
Questions



Vehicle Research Institute



Thank you



THE PAUL G. ALLEN
FAMILY foundation

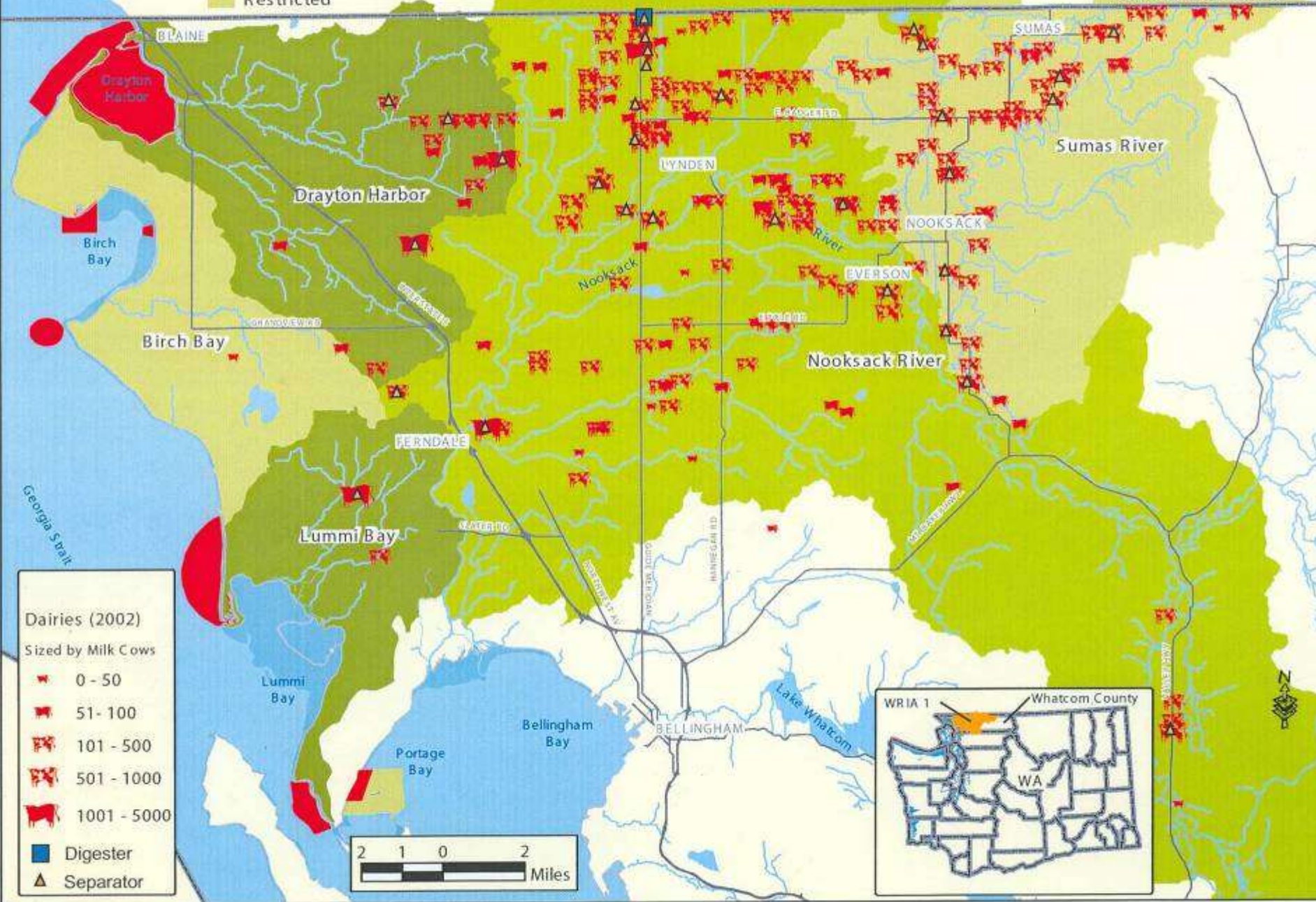


PUBLIC UTILITY DISTRICT No. 1
of Whatcom County



■ Prohibited
■ Restricted

US/Canadian Border



Dairies (2002)
 Sized by Milk Cows
■ 0 - 50
■ 51 - 100
■ 101 - 500
■ 501 - 1000
■ 1001 - 5000
■ Digester
▲ Separator

2 1 0 2 Miles









Why Use Biomethane for Transportation?

Improve economics of the anaerobic digester

Alternate market for gas production

Provide low-cost fuel to consumers, public transportation, or farming equipment

Sufficient fuel quantity

Support low emission vehicles

Reduce equivalent carbon dioxide emissions

Reduce dependence on imported oil

Digester Economics

Relate electrical energy production to value of CH₄ gas

- 1) 1200 cows x 60 ft³/CH₄ per day = 72000 ft³ day or 3000 ft³/hour (actual value closer to 5040 ft³/hr)
- 2) Produce 350 kWh @ \$ 0.08 = \$28 per hour or \$672/day
- 3) Lower heating value of CH₄: ~904 BTU/ft³ with 90% CH₄
- 4) BTU per \$: (904 BTU/ft³ x 5040 ft³/hour) / (\$28/hour)

Result: 162,720 BTU/\$

Compare with Gasoline at \$3.06/gallon (West Coast 04/12/10):

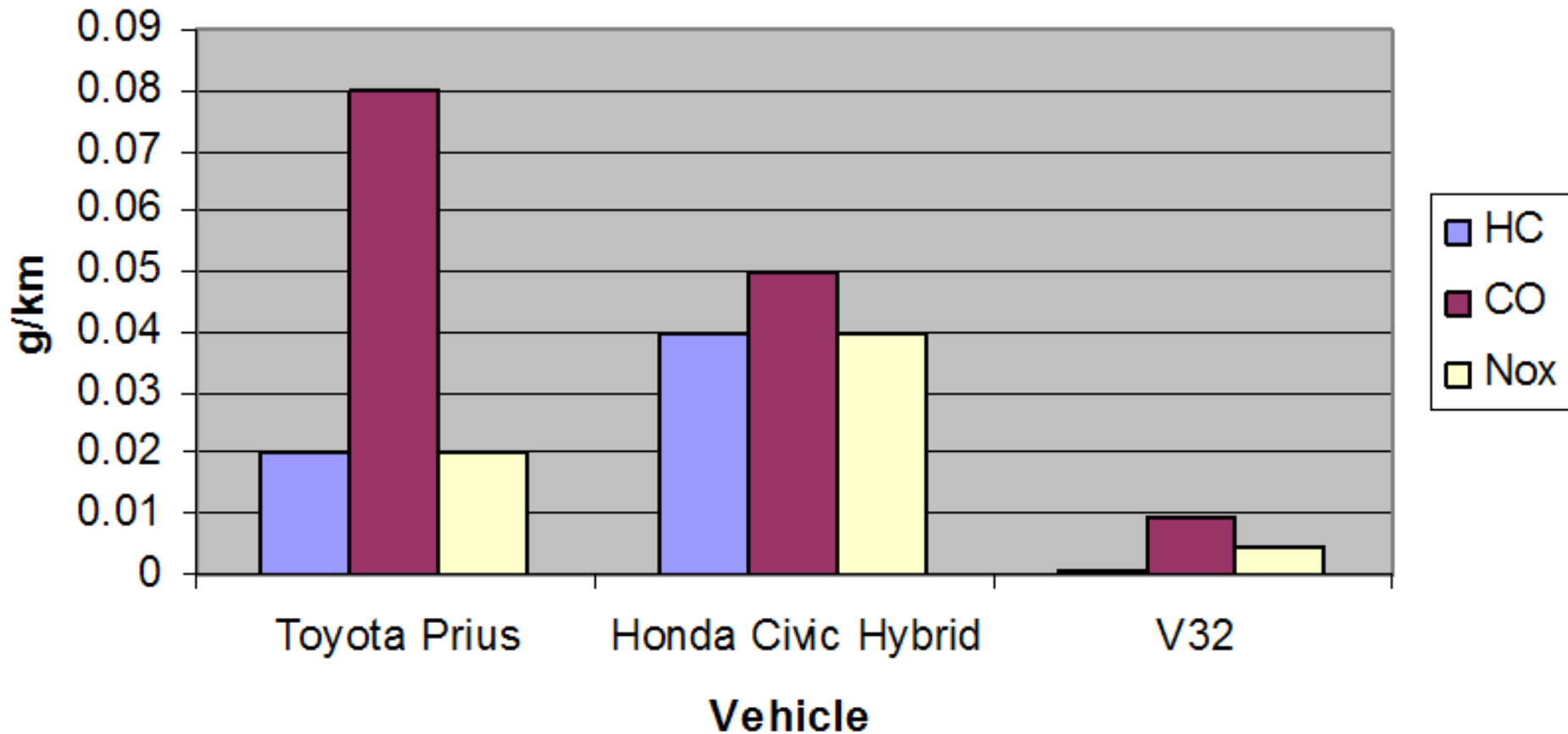
115,500 BTU/gallon * 1 gallon/\$3.06 = 37,745 BTU/\$

**Roughly 4.3 times more energy per \$ for Biomethane
(162,720 BTU/\$ / 37,745 BTU/\$)**

Whatcom County Fuel Quantity

- **66,000 cows * 60 ft³ = 3.96x10⁶ ft³/day CH₄**
- **3.96x10⁶ ft³ * 904 BTU/ ft³ =3.58x10⁹ BTU**
- **3.58x10⁹ BTU / 115,500 BTU/gal (gasoline)**
- **Result: 30,994 gallons of gasoline equivalent energy per day**
- **Over 11 million gallons of gasoline equivalent energy per year**

Natural Gas Emissions



Biogas Challenges for Transportation

1. **Digester biogas contains ~40% carbon dioxide**
2. **Biogas contains ~3000 ppm hydrogen sulfide**
3. **Cost of biogas upgrading**
4. **Biomethane must be compressed to 3600 psi to provide sufficient range in vehicle**
5. **Cost of compressed natural gas fueling station**
6. **Special fuel system and calibration required for biomethane or natural gas**
7. **Tank size is four times size of gasoline tank**
8. **Limited vehicle selection**

Clean Biogas Solutions

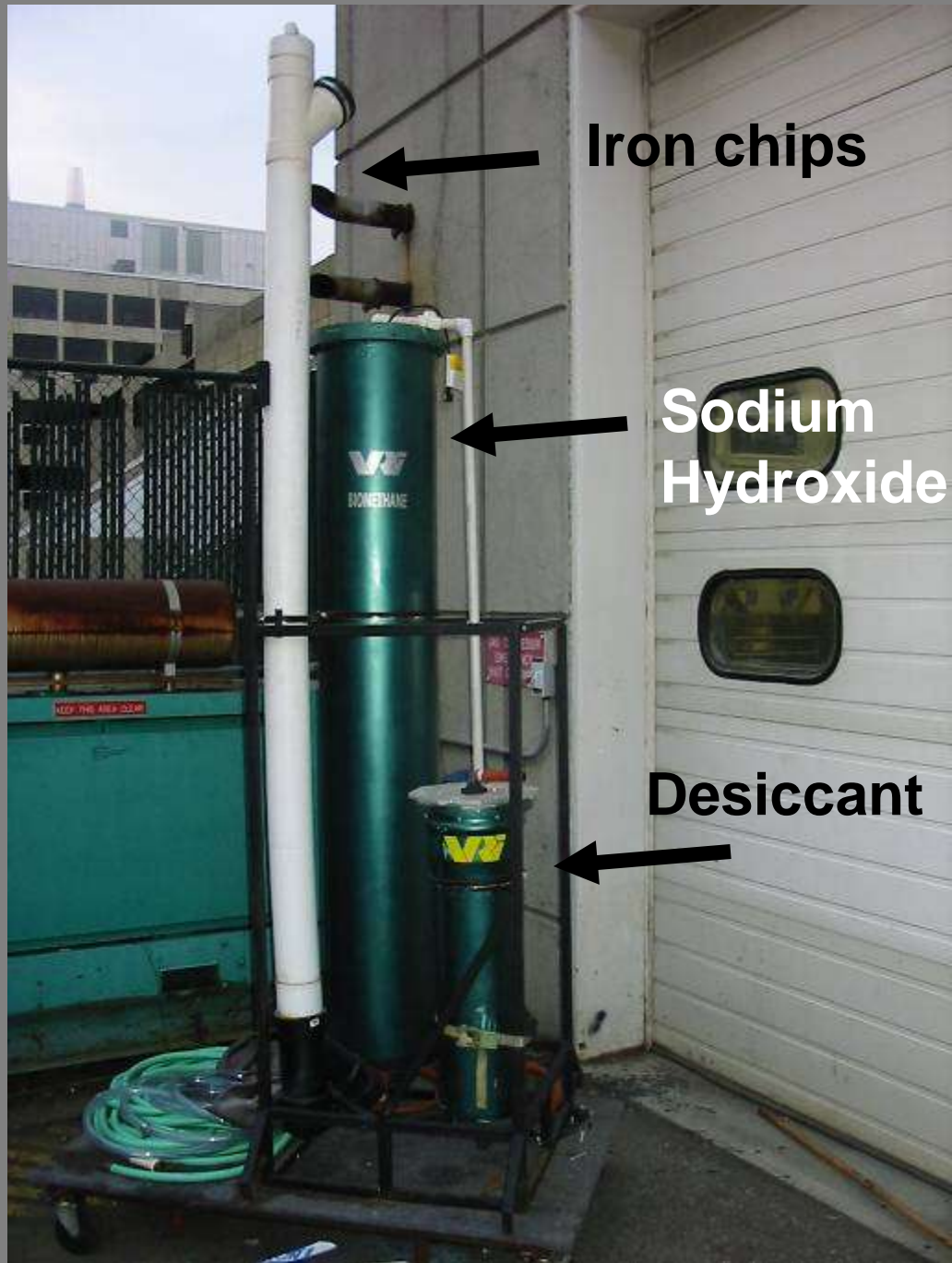
- **Petroleum Refining “Upgrading”**
- **Wastewater Treatment**
 - **South Seattle Waste Water Treatment Facility**
 - **Tacoma Waste Water Treatment Facility**
- **Iron Oxide (H₂S)**
- **Pressure Swing Absorber (CO₂)**
- **Membranes**
- **Polyethylene Glycol**
- **H₂O**
- **Amines**

Biogas Scrubber

Three stage process

- 1) Column of iron chips
- 2) Sodium Hydroxide
10% aqueous
solution
- 3) Desiccant

1.4 scfm pump
compressed refined
gas to ~1700 psi

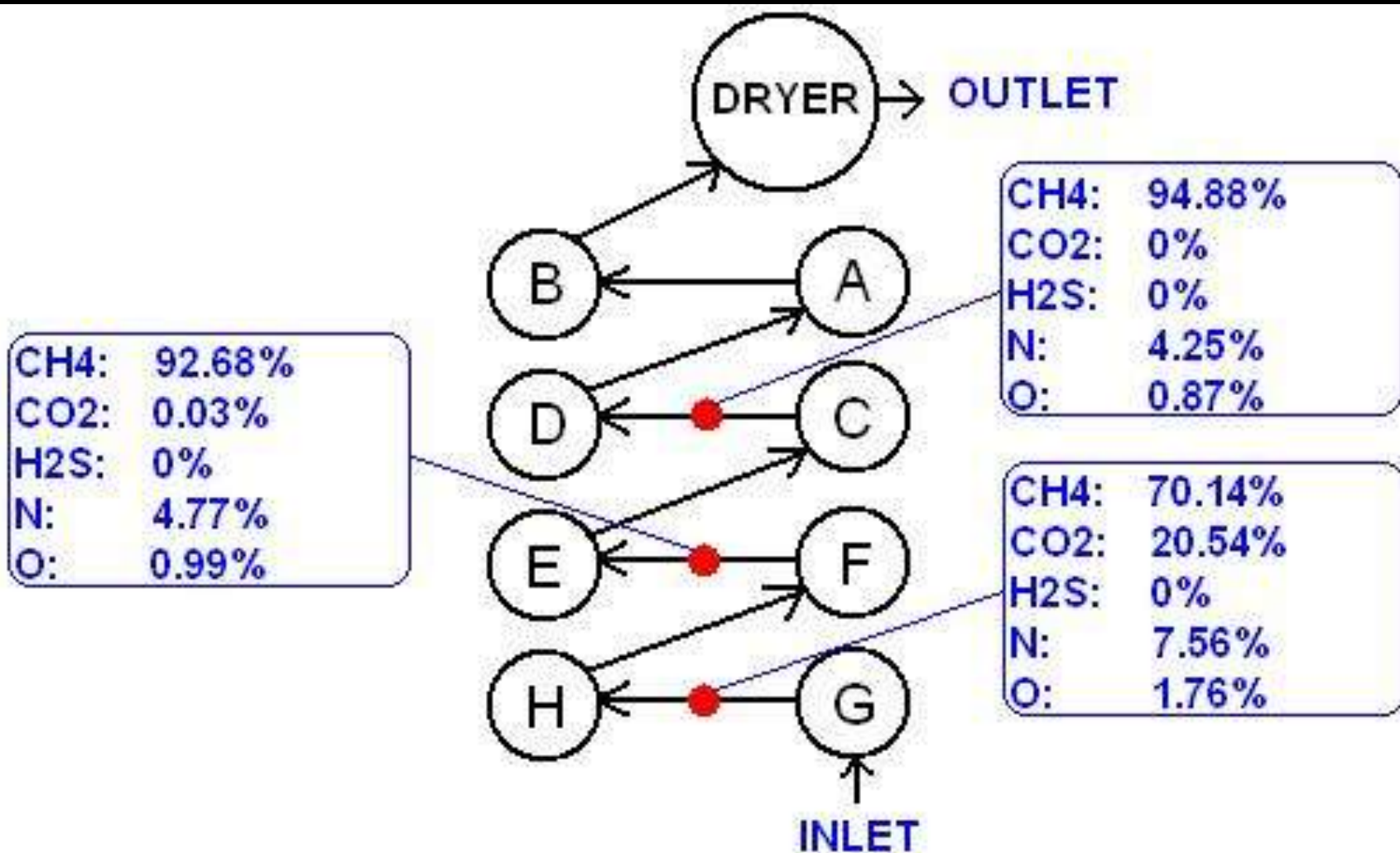


Tour de Sol





Results





**EPA People Prosperity Planet
Award Winner
April 2007**

Pilot Project

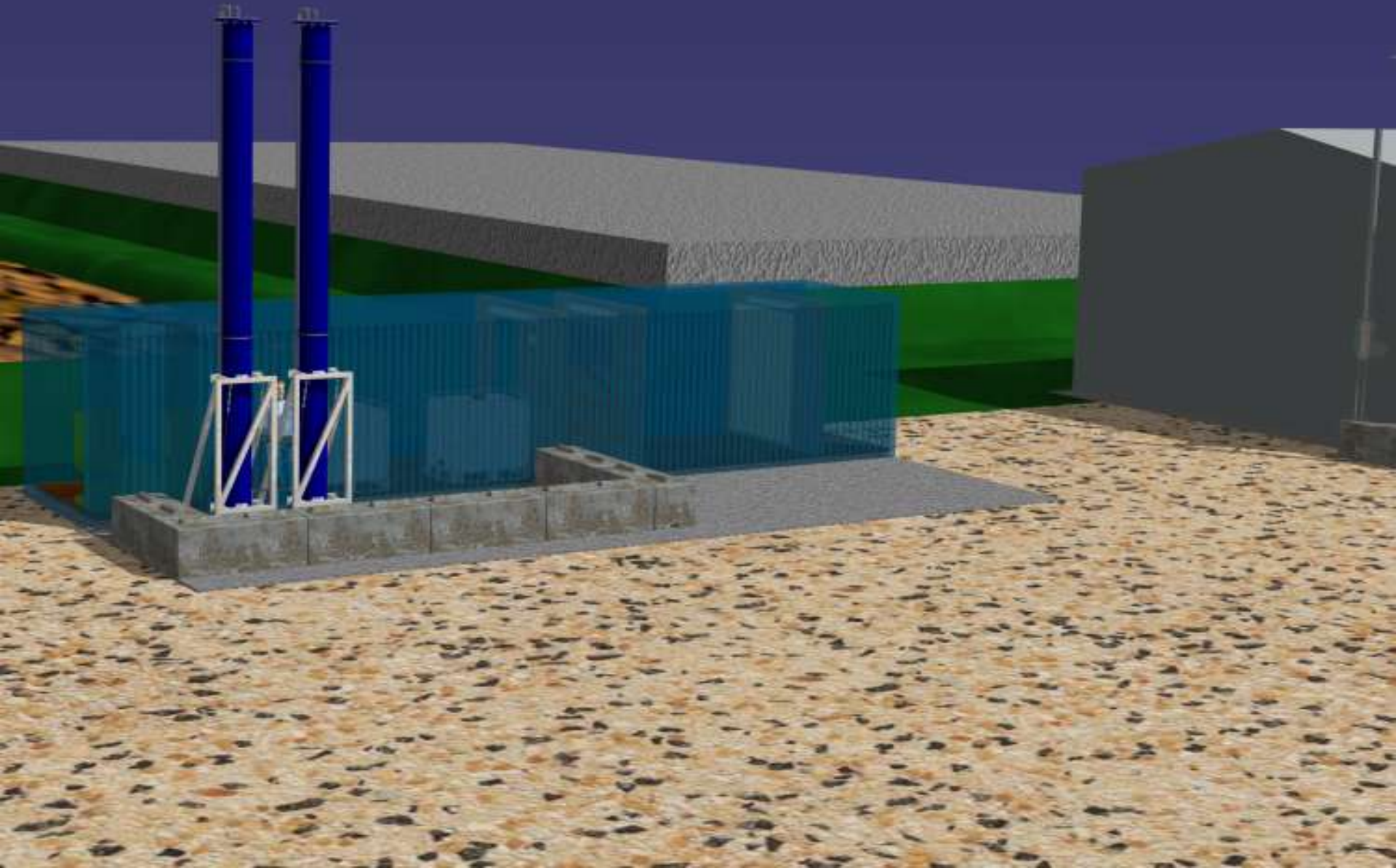
- Provide biomethane fuel for up to three MCI F coach buses or E450 Krystal Coaches with Airporter Shuttle/Bellair Charters
- Initially convert one bus
 - MCI F coach 36 passenger bus requires removing Cummins ISC 8.3 liter diesel and replace with Cummins Westport ISL G 8.9 liter natural gas engine
 - World CNG convert E450/E550 Ford V-10 platform
 - Meet 2010 EPA requirements
- Transport biomethane fuel from Vander Haak Dairy to Ferndale bus facility, ~34 miles round trip
- Operate pilot project within a five year window
- Create a roadmap for implementing biomethane in Whatcom County

Pilot Goals

- Power buses with biomethane in a pilot project with 100,000 Gasoline Gallon Equivalent annual production
- Less than 15 ppm Hydrogen Sulfide
- Produce 12 Gasoline gallon equivalents (GGE) per hour
- **Equivalent of 240 GGE in 20 hour of operation**
- **At 6 MPGe, 360,000 annual miles (6 MCI F coaches)**
- At 20 MPGe, 1,200,000 annual miles (60 cars served)
- At 30 MPGe, 1,800,000 annual miles (90 cars served)
- Based on 20k miles/year
- **At \$2.00/gasoline gallon equivalent, adds \$480/day or \$120,000 gross per year (5 days/wk, 50 wks/year)**



WWU Prototype Upgrading Facility







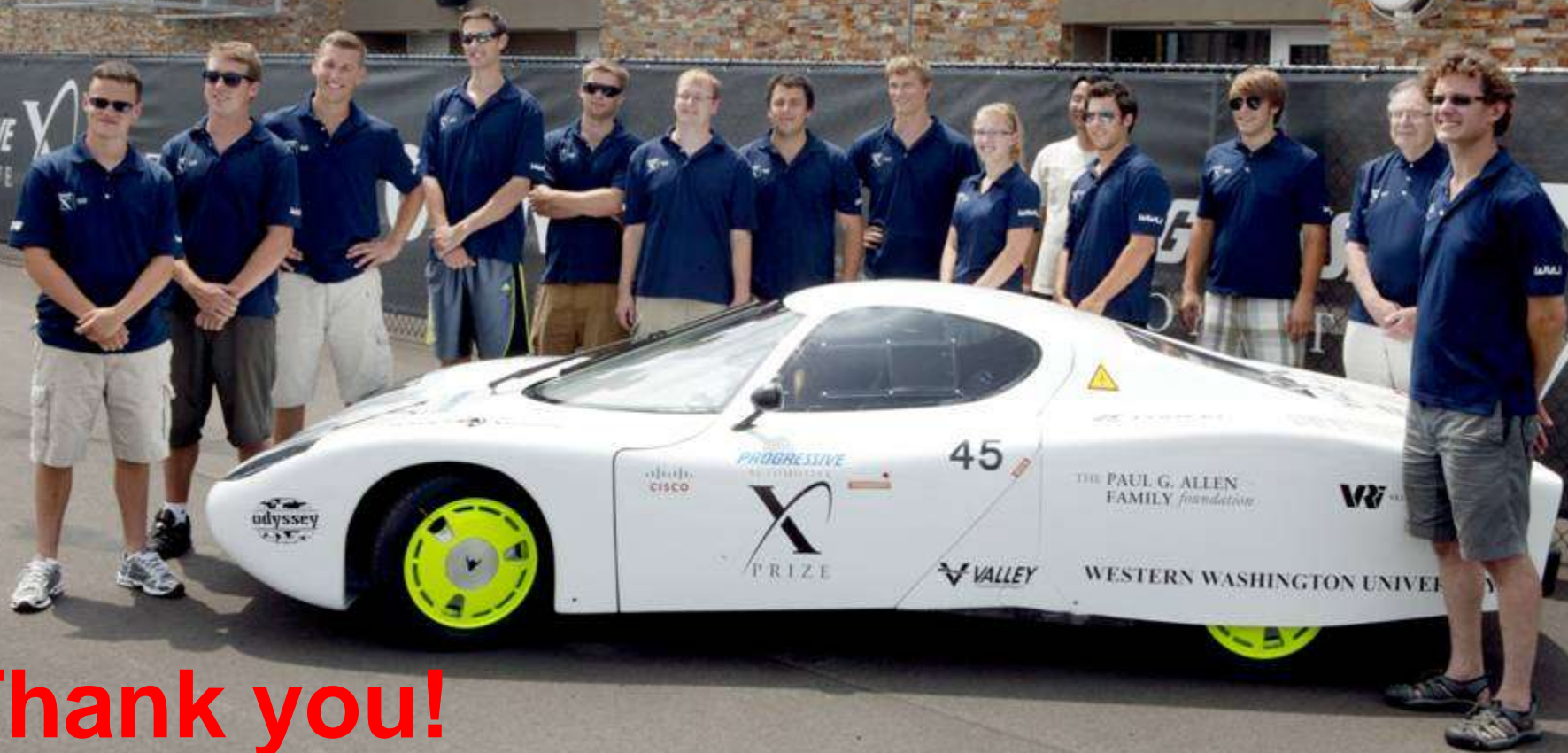


42G1
MCKU4000

System Cost

Biogas Blower	\$	10,000.00	
Upgrading Facility	\$	50,000.00	
Gas Dryer, 50 scfm to 75 scfm	\$	50,000.00	\$75,000.00
Compressor 60-80 scfm	\$	100,000.00	
Priority Fill Panel	\$	10,000.00	\$20,000.00
Storage Tank Array ~\$30,000 per 10,000 scf/80 GGE	\$	150,000.00	
Dispenser -- Fast Fill 2 post	\$	37,000.00	
Dispenser Time Fill ~\$3,000 per Post	\$	15,000.00	
Card Reader	\$	4,000.00	
Facility--pad, container, power	\$	50,000.00	
Plumbing	\$	10,000.00	
	\$	486,000.00	

Viking 45



Thank you!

Progressive Automotive X Prize