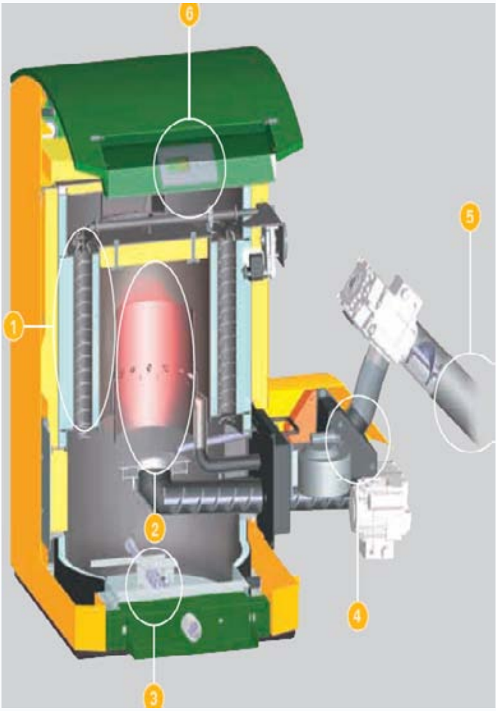
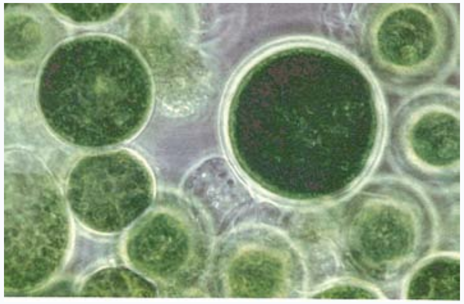


Emissions From Residential and Commercial Oil/Gas/Biomass-fired Heating Systems

Raymond J. Albrecht, P.E.
Technical Representative
National Biodiesel Board

rayalbrechtpe@gmail.com

www.biodiesel.org



Common Heating Fuels in New York State

Heating Oil
Propane
Natural Gas
Biomass

(Electricity not addressed in this presentation)

POLLUTANTS

Greenhouse Gas (CO_2 equivalent)

PM 2.5
Carbon Monoxide (CO)
Nitrogen Oxides (NO_x)
Sulfur Oxides (SO_2)

Assessment of New York City Natural Gas Market Fundamentals and Life Cycle Fuel Emissions

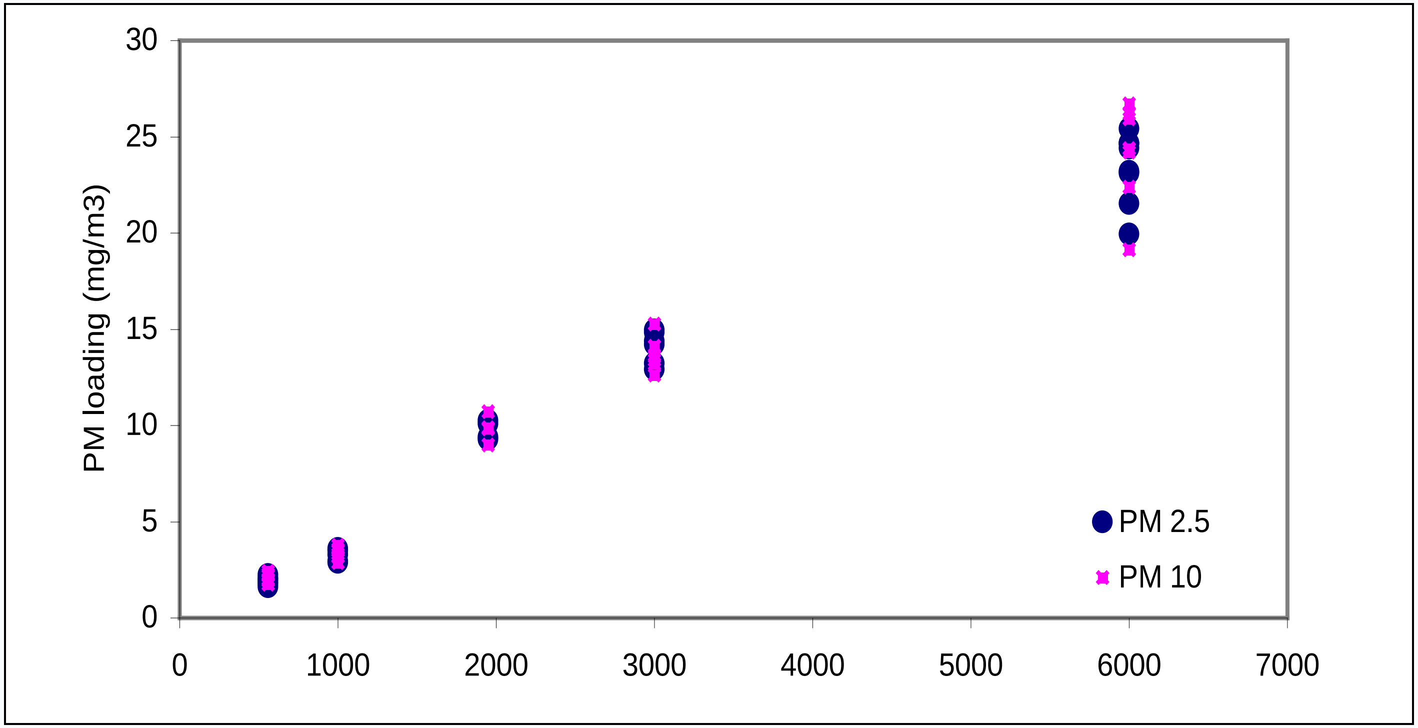
Prepared for:

New York City Mayor's Office of Long-Term Planning and Sustainability

Submitted by:
ICF International
9300 Lee Highway
Fairfax, VA 22031

Heating Oil

Effect of Fuel Sulfur on $PM_{2.5}$ and PM_{10} Emissions



Ultra-low (15 ppm) sulfur heating oil eliminates nearly all PM 2.5 emissions from oil-fired equipment

Exhibit 5-8: Life-Cycle GHG Emissions for Fuel Oil in New York City (kg CO_2e/MMBtu)

	ULS No. 2	LS No. 4	No. 6
Exploration and Production	5.5	5.5	5.5
Transportation and Storage	1.1	1.1	1.1
Refining	7.2	5.4	3.4
Bulk Shipment from Refinery	0.1	0.1	0.1
Retail Delivery	0.2	0.2	0.2
Total Upstream Emissions	**14.1**	**12.3**	**10.3**
Combustion emissions	74.0	75.0	75.1
Total Life-Cycle Emissions	**88.1**	**87.3**	**85.4**

Source: ICF Analysis.

Production and processing add approximately 19% to life-cycle greenhouse gas emissions

What is biodiesel?

Biodiesel is a renewable fuel, derived from natural oils, such as soybean oil, which meets the specifications of ASTM D 6751.

Biodiesel is <u>not</u> raw vegetable oil.

Biodiesel contains about 10 - 12 % oxygen in chemical structure.

Biodiesel has ultra-low sulfur and nitrogen contents.

Biodiesel can be blended with petroleum-based heating oil and used with little or no equipment modification.

Reduced Emissions with Bioheat

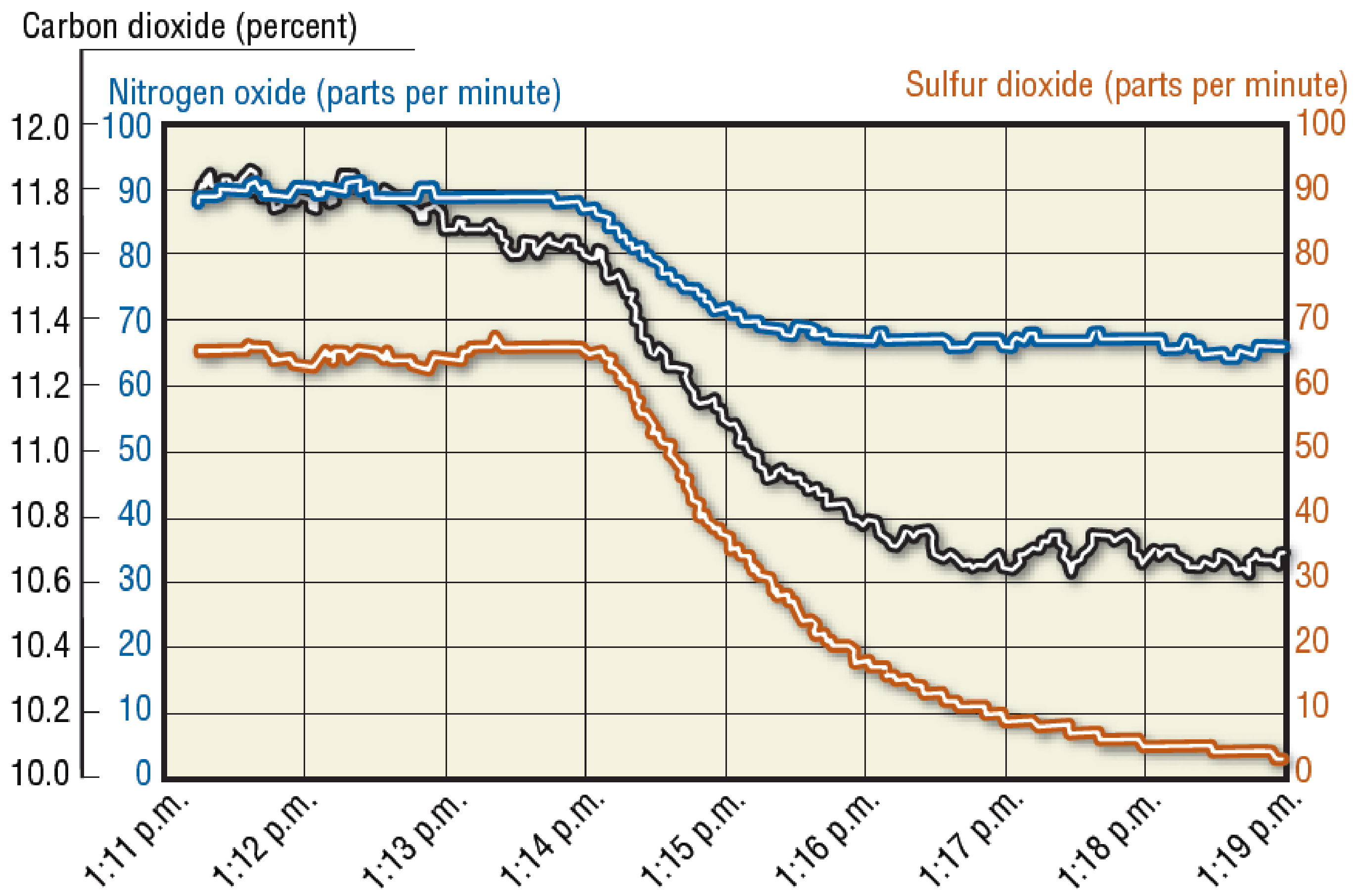


FIGURE 3. Emissions that occurred during the transition from No. 2 heating oil to B100.

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Performance and emissions of biodiesel in a boiler for residential heating

A. Macor*, P. Pavanello

Dipartimento di Tecnica e Gestione dei Sistemi Industriali, Università di Padova, Stradella San Nicola, 3-36100 Vicenza, Italy

BIODIESEL ACHIEVES SUBSTANTIAL REDUCTIONS IN PAH EMISSIONS

Table 6
PAH content in particulate matter.

PAH	Biodiesel 5/4		Biodiesel 13/4		Heating oil 7/4	
	ng/Nm^3	ng/g	ng/Nm^3	ng/g	ng/Nm^3	ng/g
Pyrene	1.7	500	3.8	2000	2154	259 518
Benzo(a)pyrene	0.2	59	0.2	105	13.6	1639
Benzo(*a*)anthracene	0.4	118	0.3	158	66	7952
Crysene	1.6	471	3.7	1947	16.5	1988
Benzo(*b*)fluoranthene	2.6	765	9.1	4789	16.5	1988
Benzo(*k*)fluoranthene	0.7	206	1.6	842	4	482
Dibenz(*a*,*h*)anthracen	0.2	59	0.2	105	0.8	96
Benzo(*g*,*h*,*i*)perilene	1.8	529	4.5	2368	28.7	3458
Indeno(1,2,3-*cd*)pyrene	1.2	353	3.8	2000	6.1	735
Total PAH	10.4	3060	27.2	14 314	2307	277 856

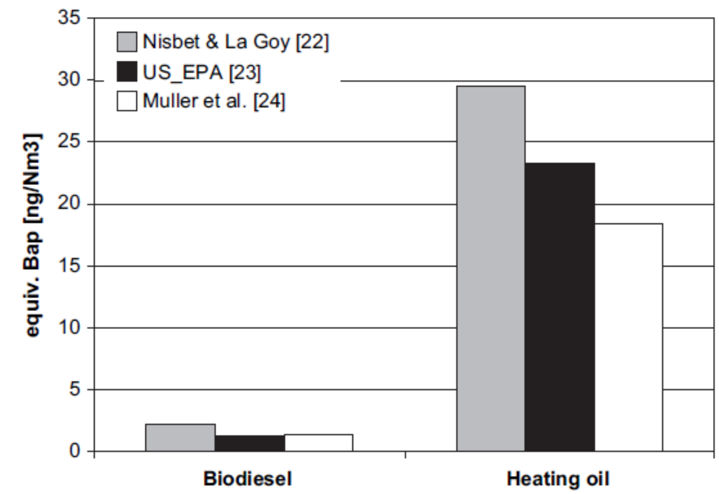
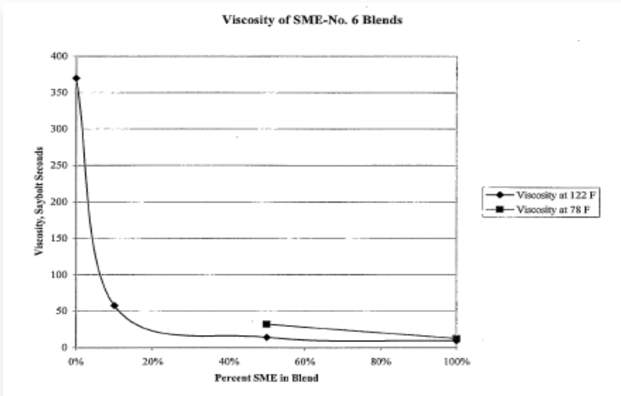


Fig. 6. PAH emissions in terms of equivalent BaP (per volume unit).

Department of Buildings and General Services
Vermont Biodiesel Pilot Project:
Emissions Testing of Biodiesel Blends With #6 Fuel Oil
At the
Waterbury State Office Complex

Biodiesel Blends with No. 6 Heating Oil



Viscosity vs. Biodiesel Concentration

Reduced fuel viscosity
Improved fuel atomization
Cleaner air swirl vanes and nozzles
Better air and fuel mixing
Cleaner combustion
Lower maintenance cost

<u>Air Shutter with Oil Deposits:</u>

Between the 2/3/06 cleaning and the 2/7/06 cleaning, the burner had operated 26.8 hours and burned 720 gallons of straight #6 fuel oil (B0).

Between the 2/17/06 cleaning and the 2/24/06 cleaning, the burner operated 121 hours and burned 5693 gallons of B20.

Notice as the concentration of biodiesel increases, the amount of deposits decreases even though more oil is burned, and the deposits become drier and less gummy, making it easier to clean them off.

Department of Buildings and General Services
Vermont Biodiesel Pilot Project:
Emissions Testing of Biodiesel Blends With #6 Fuel Oil
At the
Waterbury State Office Complex

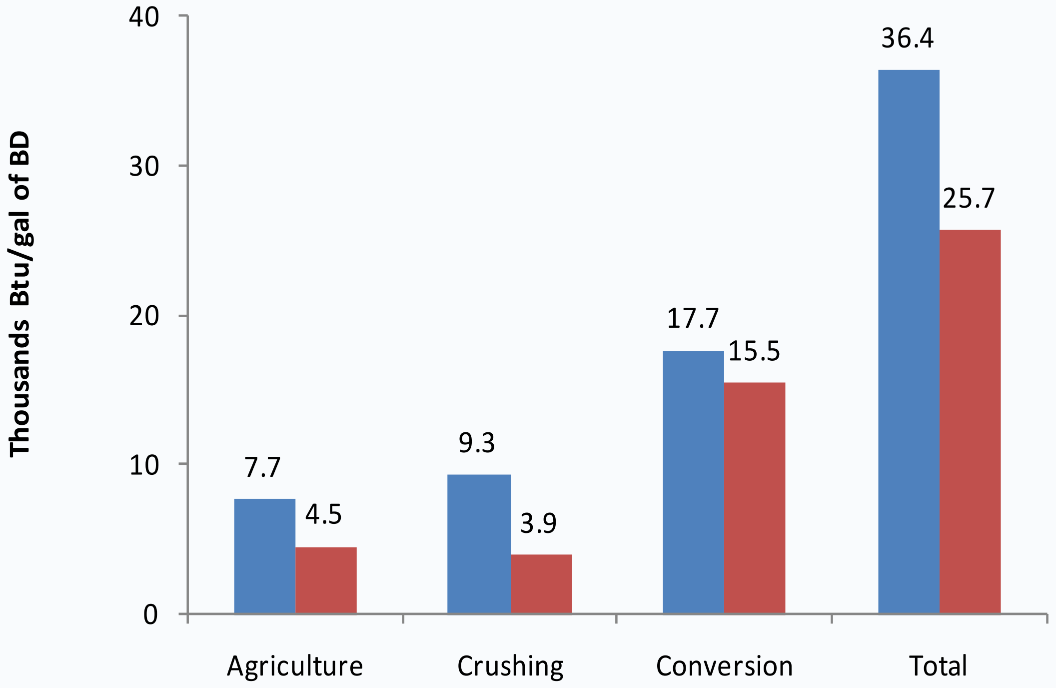
Biodiesel enables operation at lower excess air - lower emissions - higher efficiency

Air Quality Testing Services Emissions Tests Results:	No. 6	B5	B10	B20
O2	13.5	10.9	11.8	10.4%
CO2	5.8	7.7	7.0	8.0%
NOx	126.9	134.9	122.9	124.5ppm
Fd Emission Rate	0.403	0.314	0.313	0.274#/MMBtu
CO	329.6	139.1	160.9	122.8ppm
Bias Adjusted	304.7	114.2	135.8	97.9ppm
Fd Emission Rate	0.594	0.163	0.212	0.132#/MMBtu
SO2	383.1	484.2	472.9	509.4ppm
Fd Emission Rate	1.691	1.568	1.672	1.557#/MMBtu

Energy Characteristics of Biodiesel Production

Continuing Improvements in Biodiesel Production

Total Life-cycle Energy Requirements



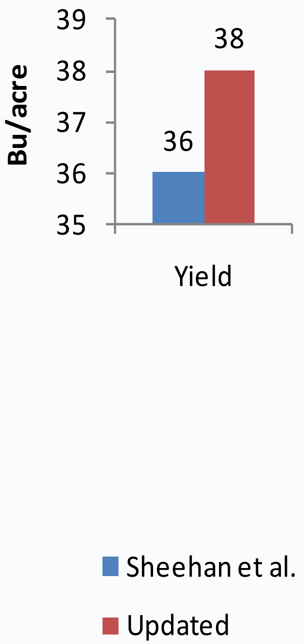


Exhibit 5-8: Life-Cycle GHG Emissions for Fuel Oil in New York City (kg CO_2e/MMBtu)

	ULS No. 2	LS No. 4	No. 6
Exploration and Production	5.5	5.5	5.5
Transportation and Storage	1.1	1.1	1.1
Refining	7.2	5.4	3.4
Bulk Shipment from Refinery	0.1	0.1	0.1
Retail Delivery	0.2	0.2	0.2
Total Upstream Emissions	**14.1**	**12.3**	**10.3**
Combustion emissions	74.0	75.0	75.1
Total Life-Cycle Emissions	**88.1**	**87.3**	**85.4**

Source: ICF Analysis.

Exhibit 5-9: Life-cycle Emissions for Biofuels (kg CO_2e/MMBtu)

	2006	2020	Average
Agriculture	2.9	2.4	2.6
Transport to Crusher	0.3	0.3	0.3
Crushing (Oil Extraction)	7.3	5.9	6.6
Intermediate Transport	0.5	0.5	0.5
Bio-Refining	10.5	8.4	9.4
Retail Transport	0.2	0.2	0.2
Total Upstream Emissions	**21.6**	**17.6**	**19.6**
BioFuel Combustion	0.0	0.0	0.0
Total Fuel Cycle Emissions	**21.6**	**17.6**	**19.6**

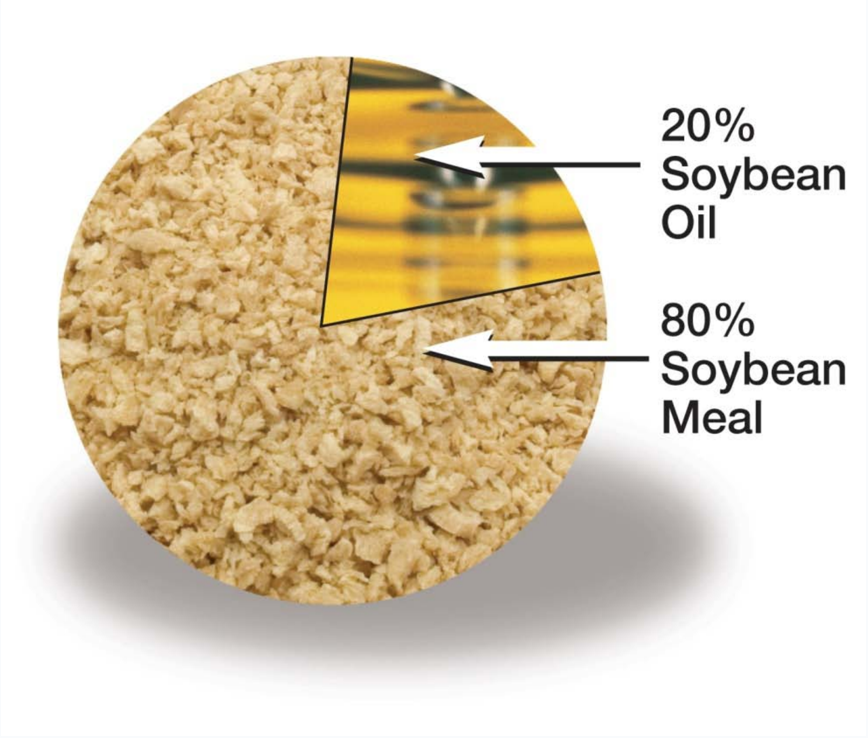
Source: ICF Analysis.

Biodiesel achieves greater than 80% reduction in life-cycle GHG emissions

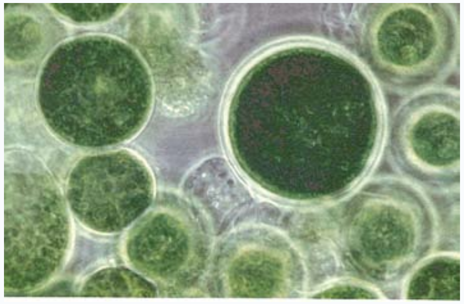
Co-products of Oilseed Production

Food plus Fuel

- **Co-production of oil and animal feed reduces energy and economic cost of biodiesel production**
- **Protein meal for livestock feed is the driver for soybean production**
- **Better utilization of the oil coproduct can reduce the price of the protein meal.**



Longer Term Biodiesel Feedstock Sources


Algae


Jatropha


Halophytes


Pennycress


Brown Grease


Low Ricin Castor

United Nations program to develop Jatropha in new country of South Sudan

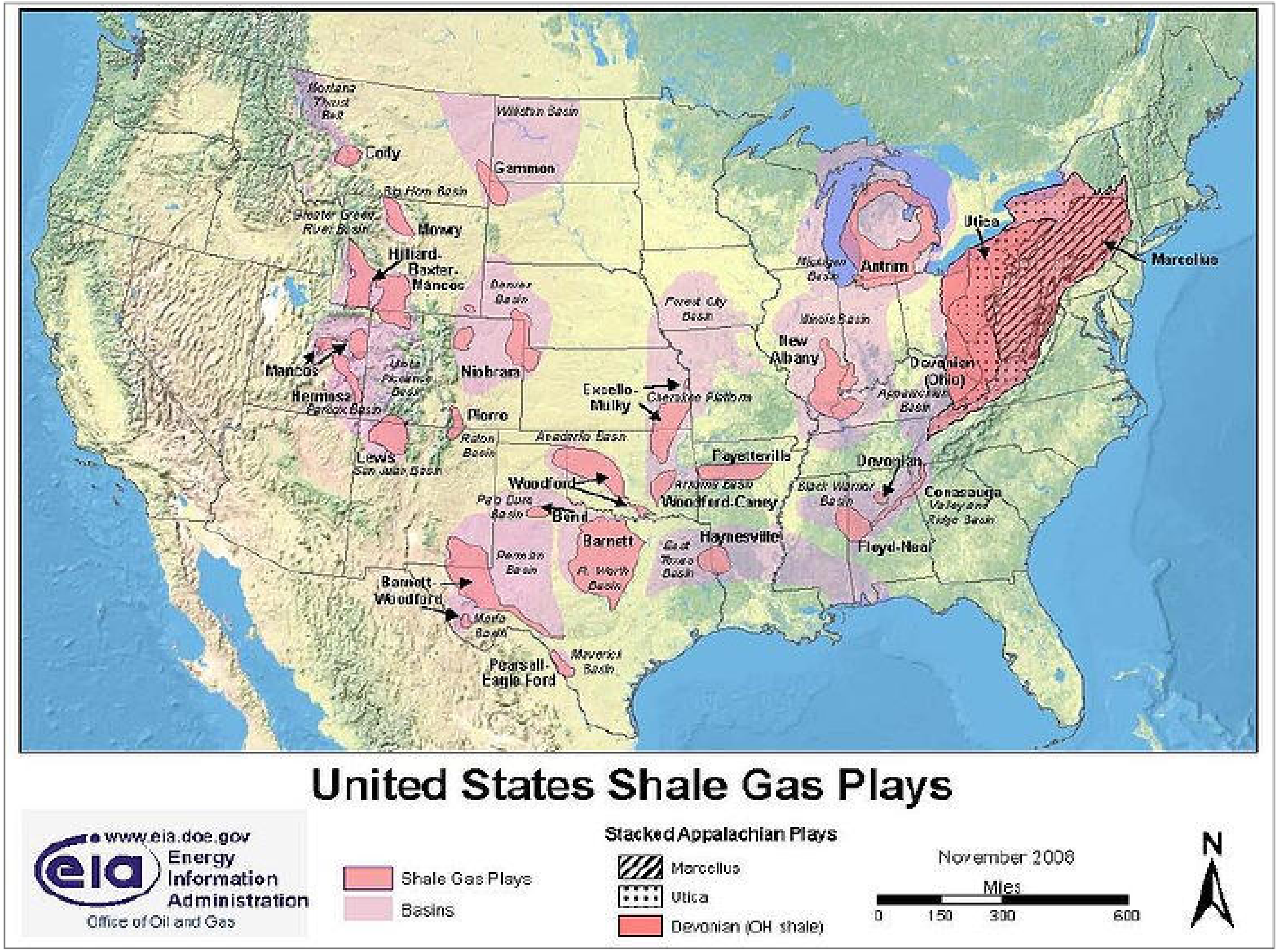
400 to 600 gallons per acre-year

Higher and more reliable agricultural income for subsistence farmer

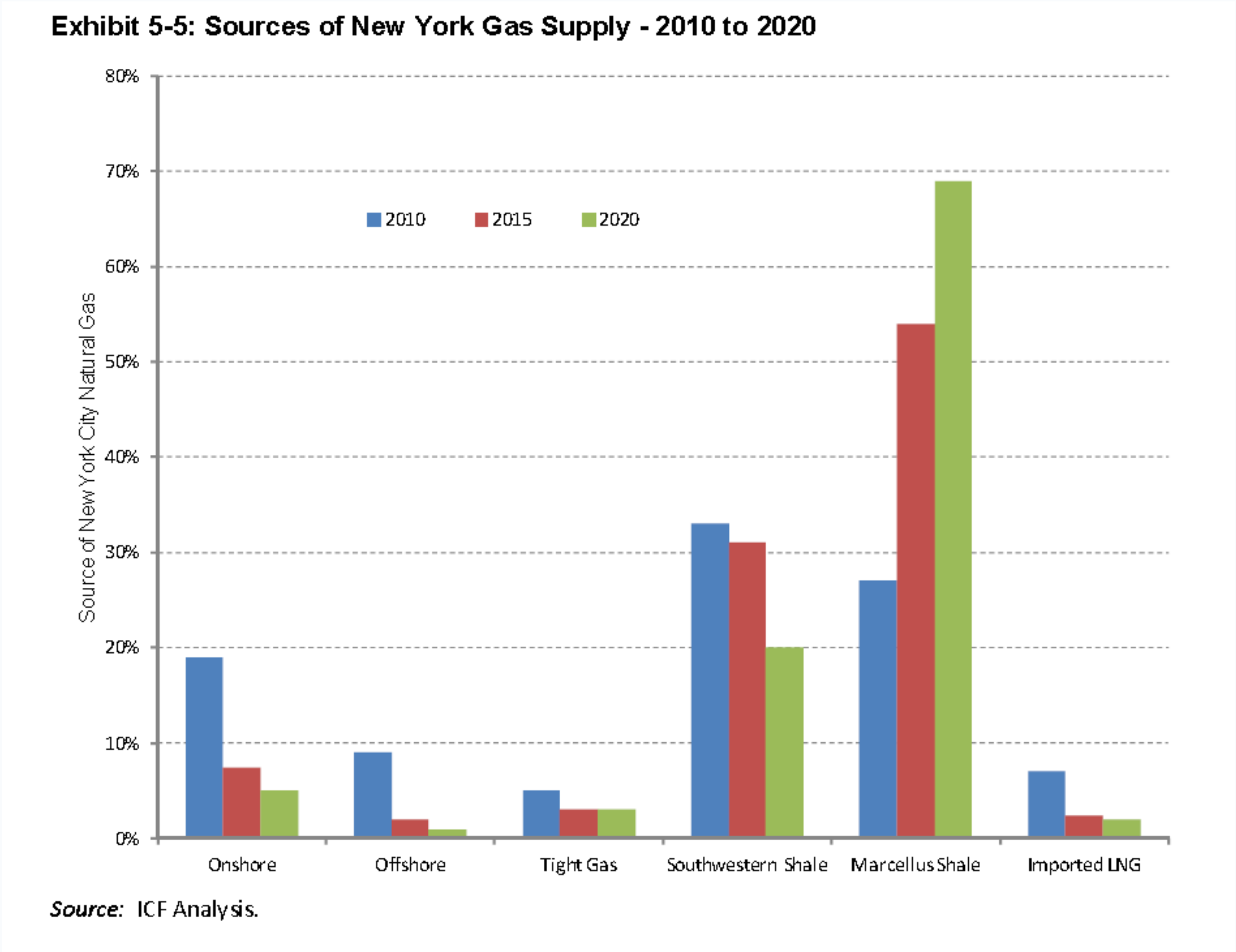
Suitable for arid climate and poor soils

Biomass residual also valuable for local energy needs

Exhibit 2-3: Shale Gas Resources in the United States



Source: EIA. Office of Oil and Gas. November 2008.



Increasing trend toward use of Marcellus shale gas in New York State

Sources of Greenhouse Gas Emissions

Production – Processing – Transmission - Distribution

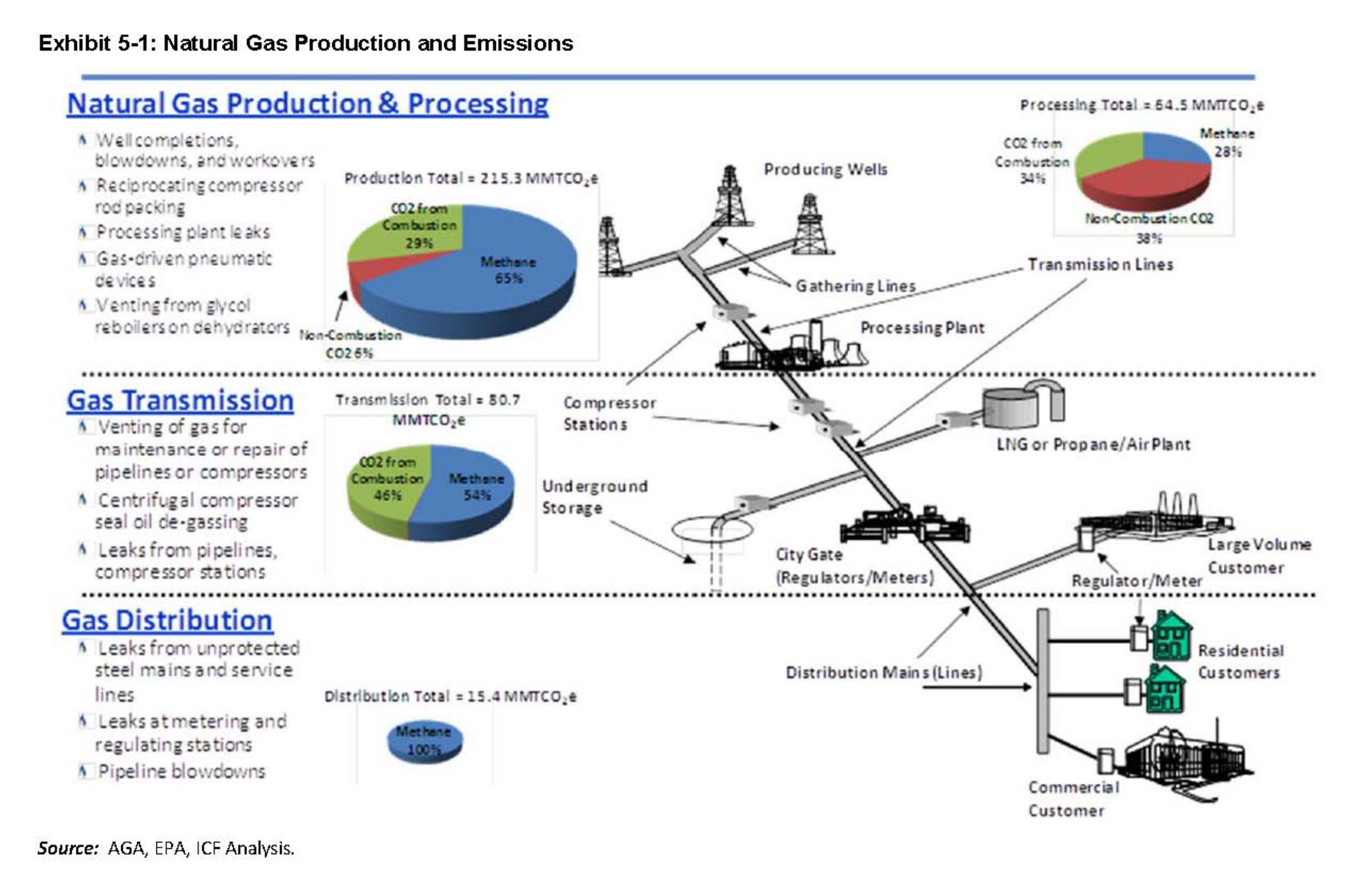
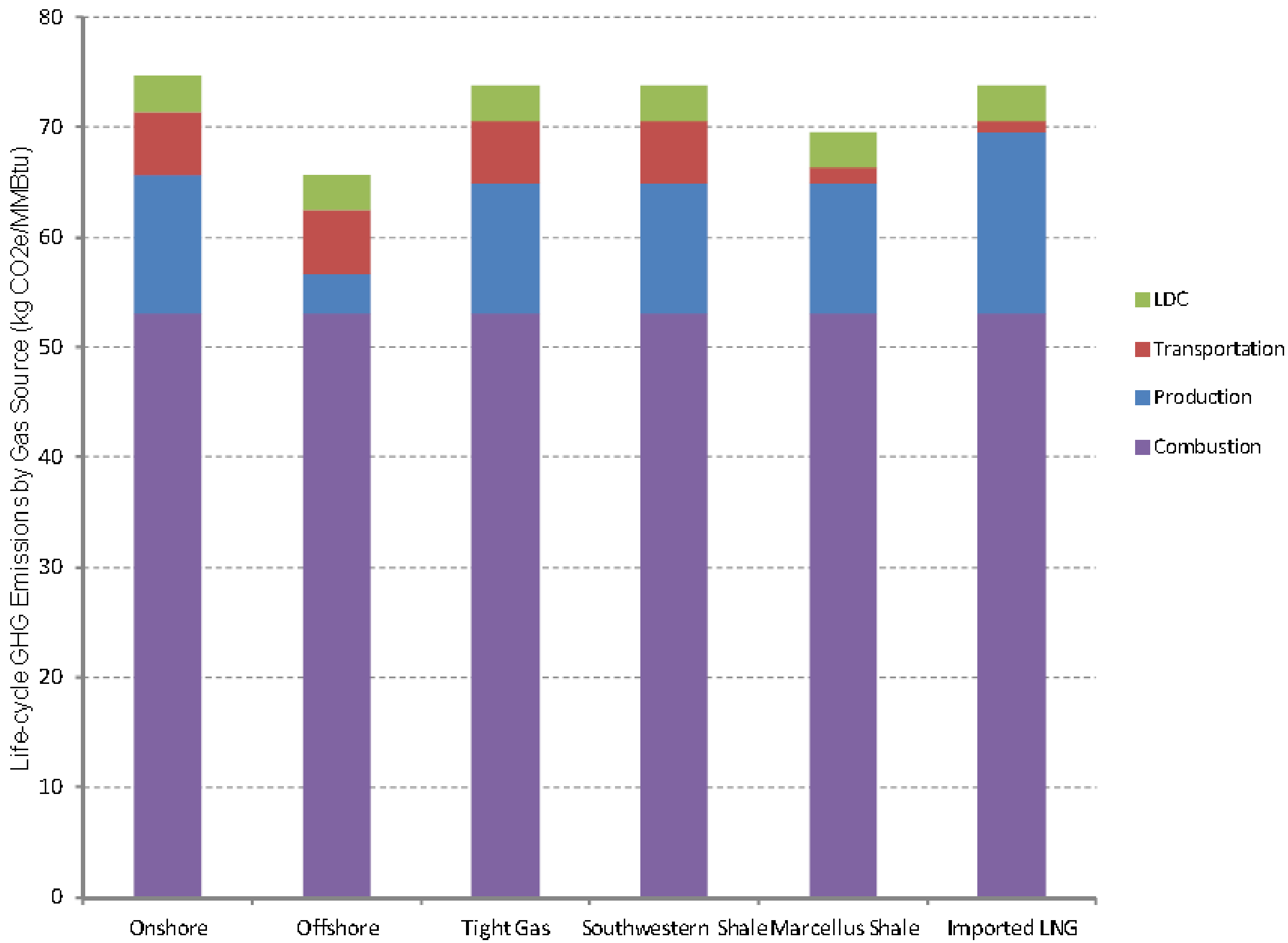


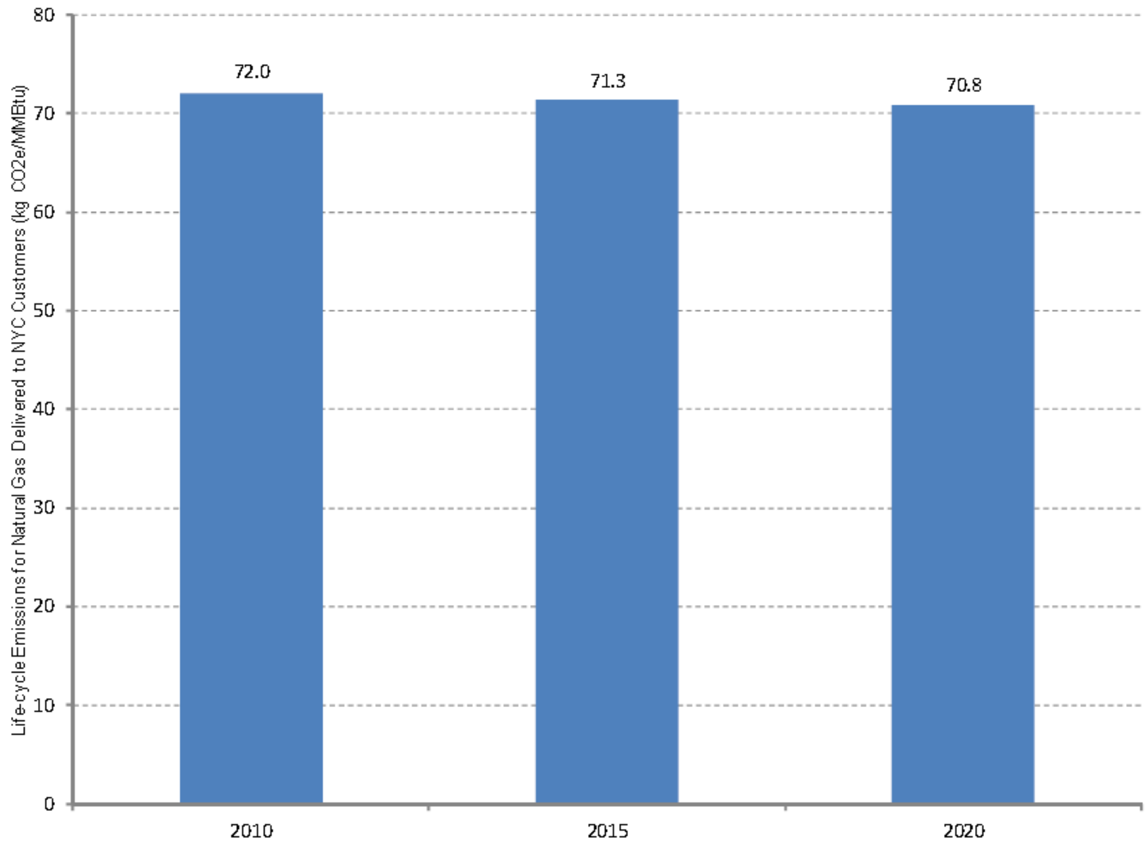
Exhibit 5-4: Life-cycle Emissions by Source of Gas (kg CO_2e/MMBtu)



Source: NETL and ICF Analysis.

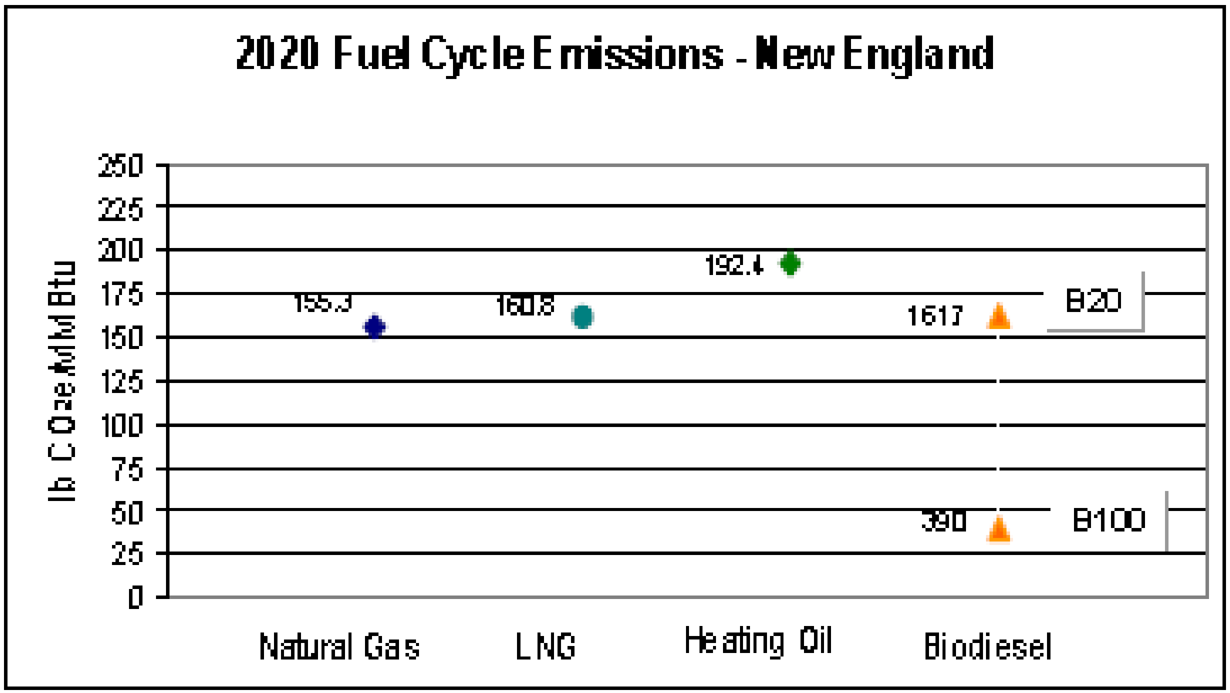
Forecast for Life-Cycle Emissions of Natural Gas in NYC

Exhibit 5-6: Average Life-cycle Emissions for Natural Gas Delivered to NYC Customers ($kg\ CO_2e/MMBtu$)



Source: NETL and ICF Analysis.

Comparison of Life-Cycle Emissions



* CO_2 equivalent based on 100 year GHG warming potential

Figure 27 2020 Fuel Cycle Emissions Comparison for New England

Life Cycle Emissions Vs Fuel Vs Heating System Type

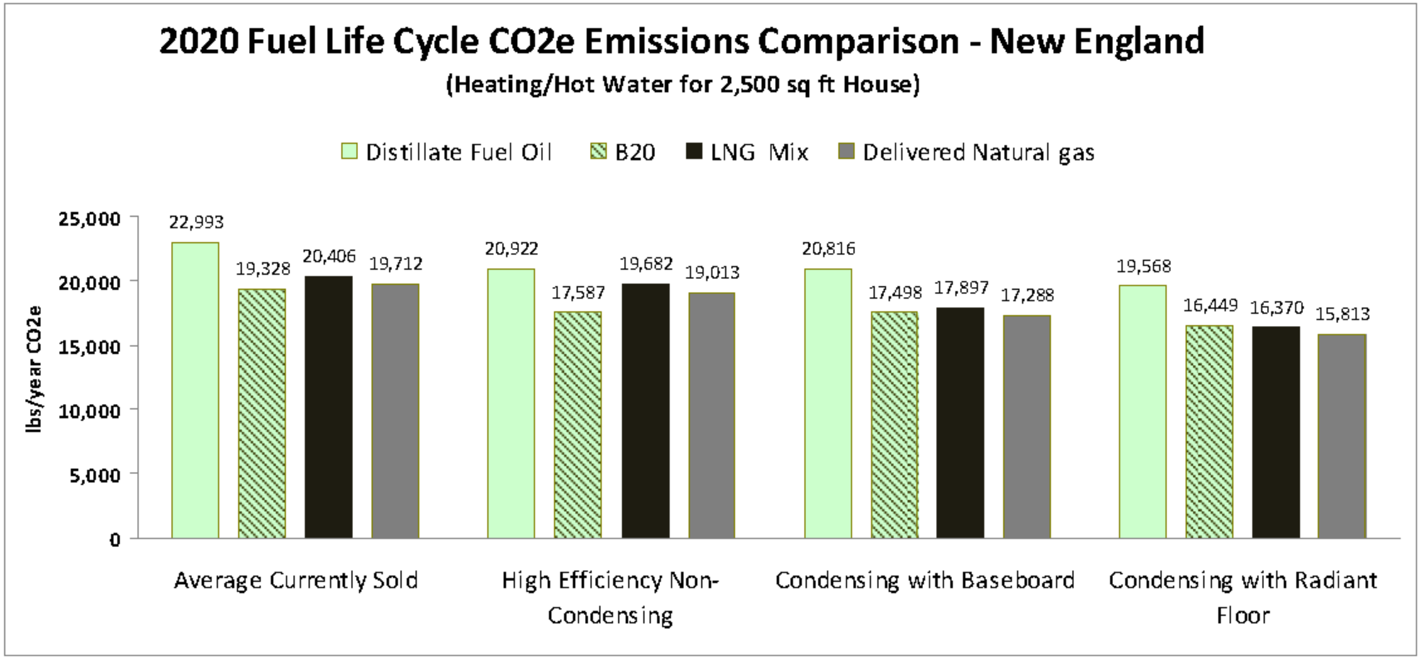
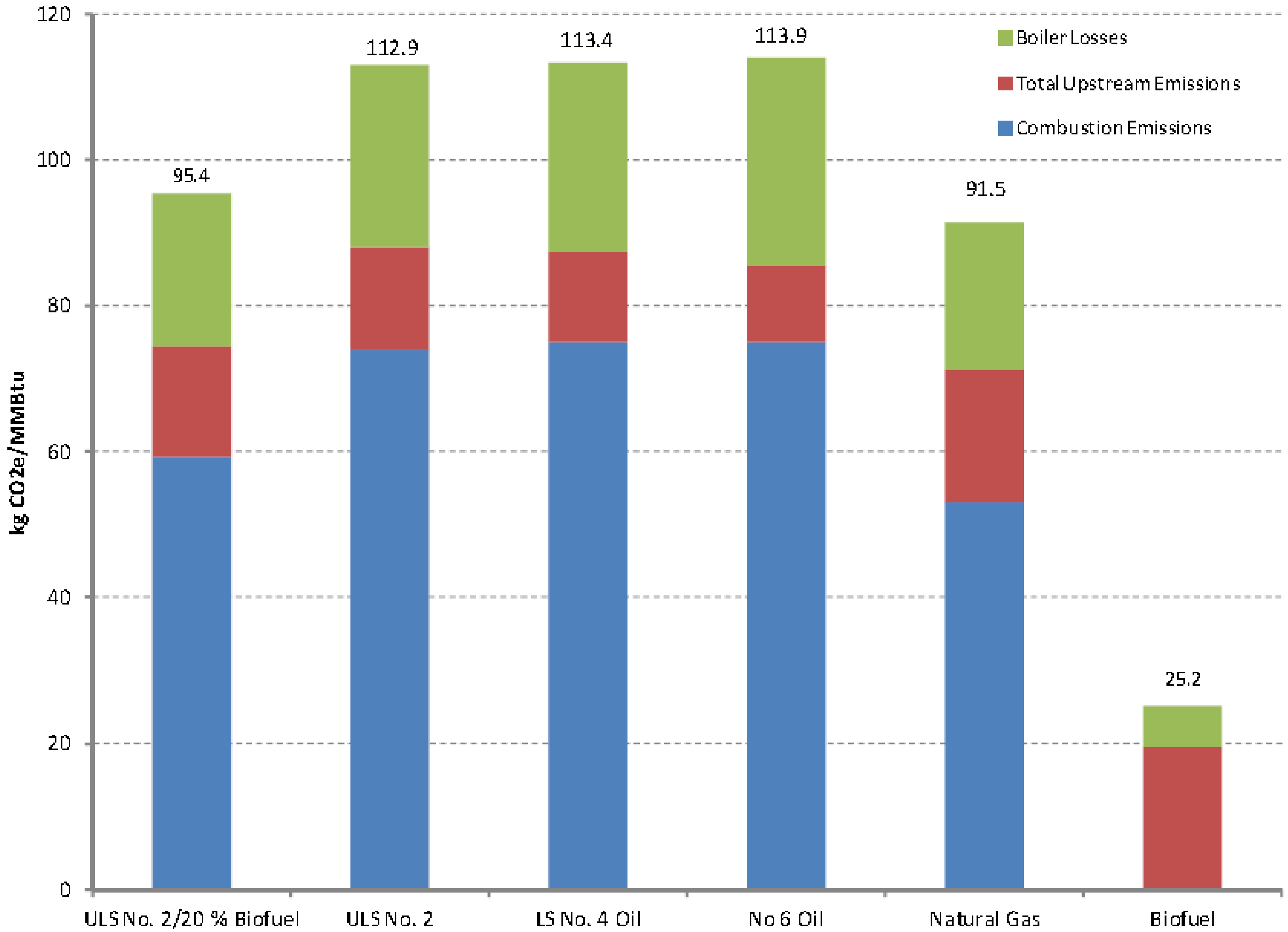


Figure ES-2 Heating System Emissions Comparison for New England in 2020

Heating system efficiency more important than choice of B20 vs. natural gas

Thermally-driven absorption heat pumps could push numbers even lower

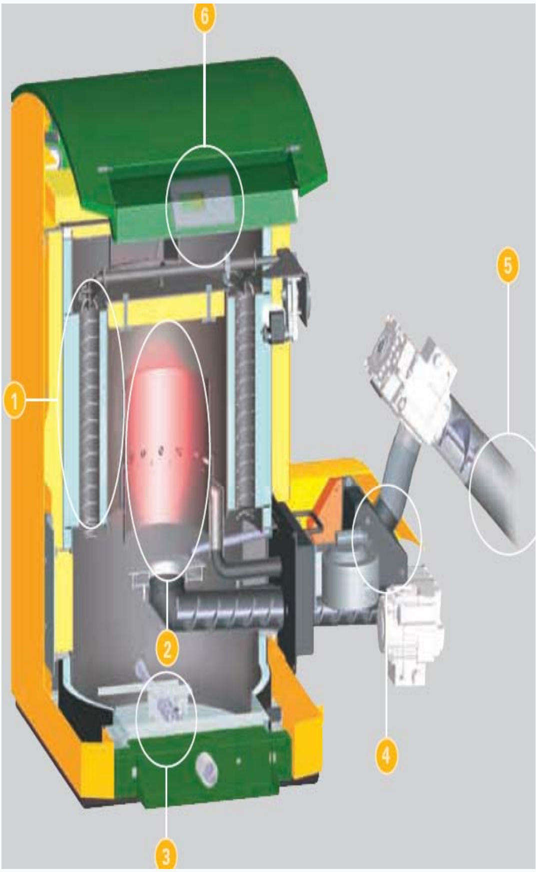
Exhibit 5-11: Summary Life-Cycle GHG Emissions Comparison for Residential and Commercial Boilers in New York City (kg CO_2e/MMBtu)



Source: ICF Analysis.

Introduction to Biomass-fired System Emissions

European biomass technology has favorable emission levels



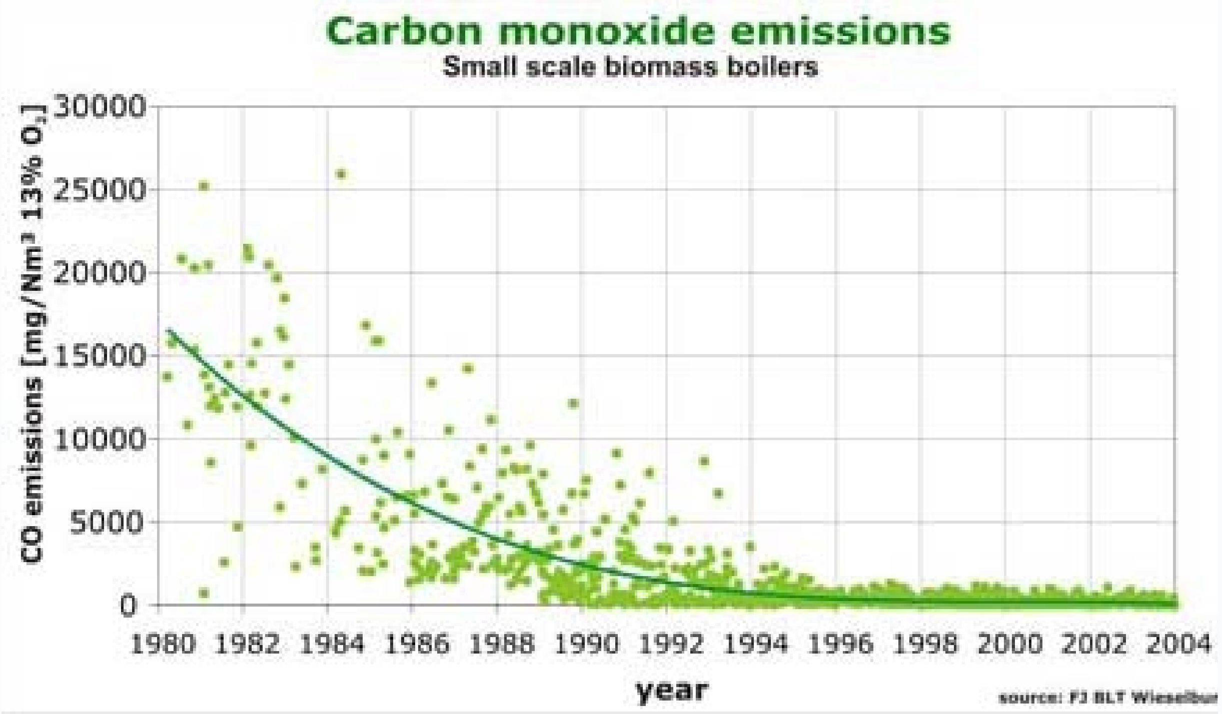
Pellet-fired Hydronic Boilers

	European	American	
NOx	0.14	0.15	lb/MMBtu
CO	10 to 25	300 +	ppm
PM	0.01 to 0.03	0.07 - 0.2	lb/MMBtu

Improved Energy and Environmental Performance

Wood and Biomass-fired Heating Systems

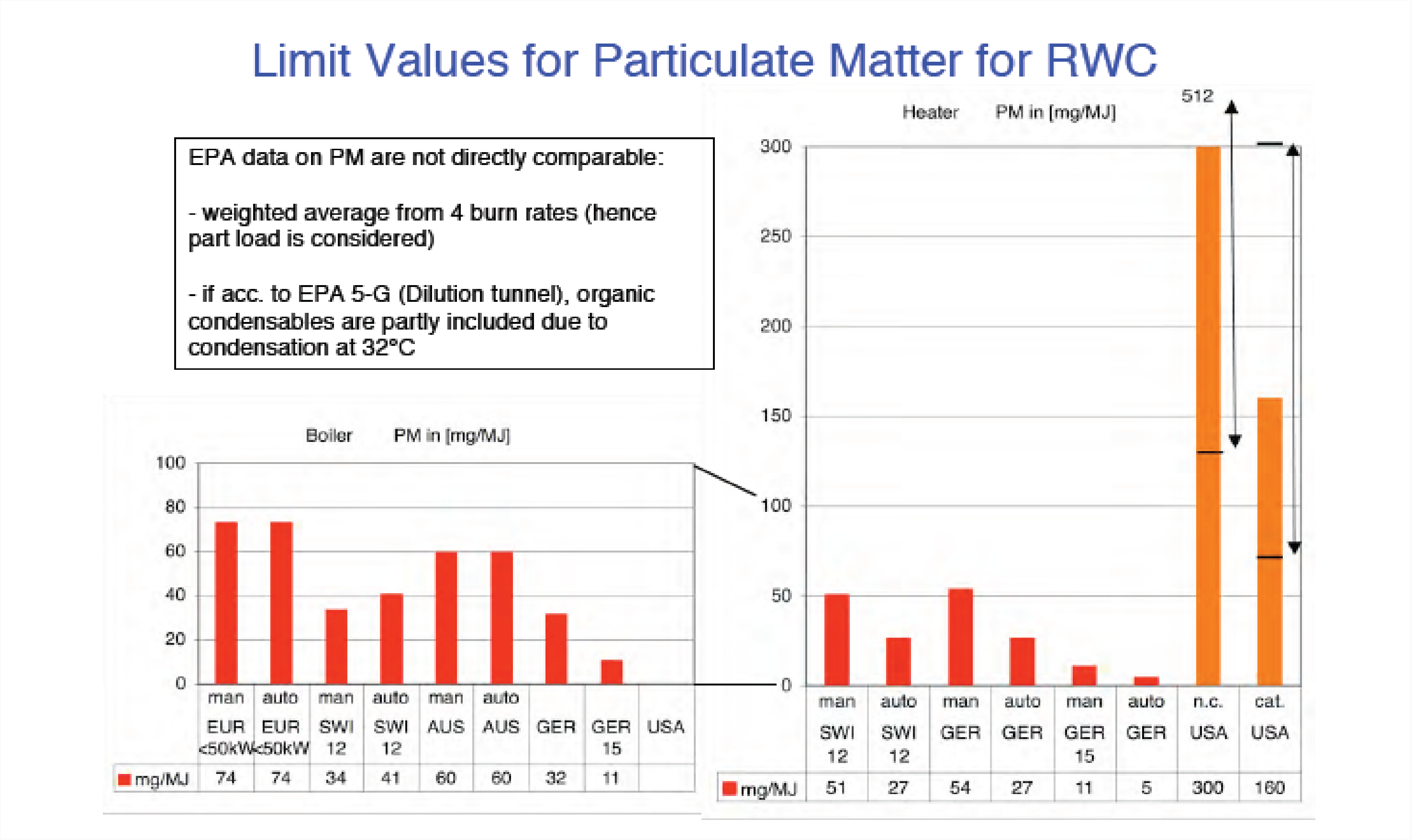
in Austria



Emissions standards introduced during early 1990s

US and European PM 2.5 Standards

Wood-fired Boilers

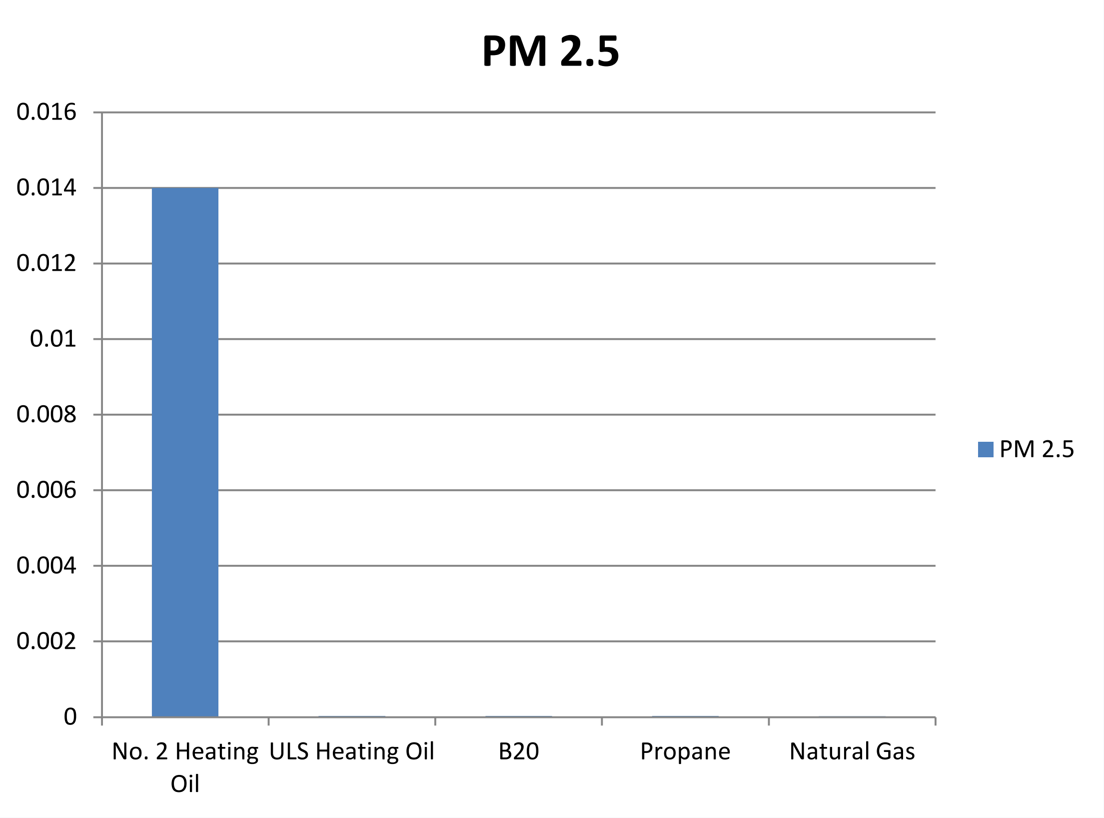


PM Emissions (lb/MMBtu) and Efficiency vs Fuel Type

OWB standard - Phase I	0.44 input	30 - 40 % ?
OWB standard - Phase II	0.32 output	
EPA certified woodstove (non-catalytic)	0.78 approx.	70 %
EPA certified woodstove (catalytic)	0.42 approx.	
American pellet stoves	0.07 - 0.2	60 - 80 %
Austrian pellet stoves/boilers	0.01 - 0.02	80 - 85 %
Austrian wood-fired boilers	0.01 - 0.04	80 - 85 %
No. 2 oil-fired boilers	0.005	80 - 88 %
500 ppm S oil-fired boilers	0.001	
500 ppm S - B20 oil-fired boilers	0.0008	
15 ppm ULS oil-fired boilers	0.00002 - 0. 00004	80 – 90 %
Natural gas-fired boilers	0.00002	80 - 90 %

PM 2.5 Emissions for Heating Oil – Propane – Natural Gas

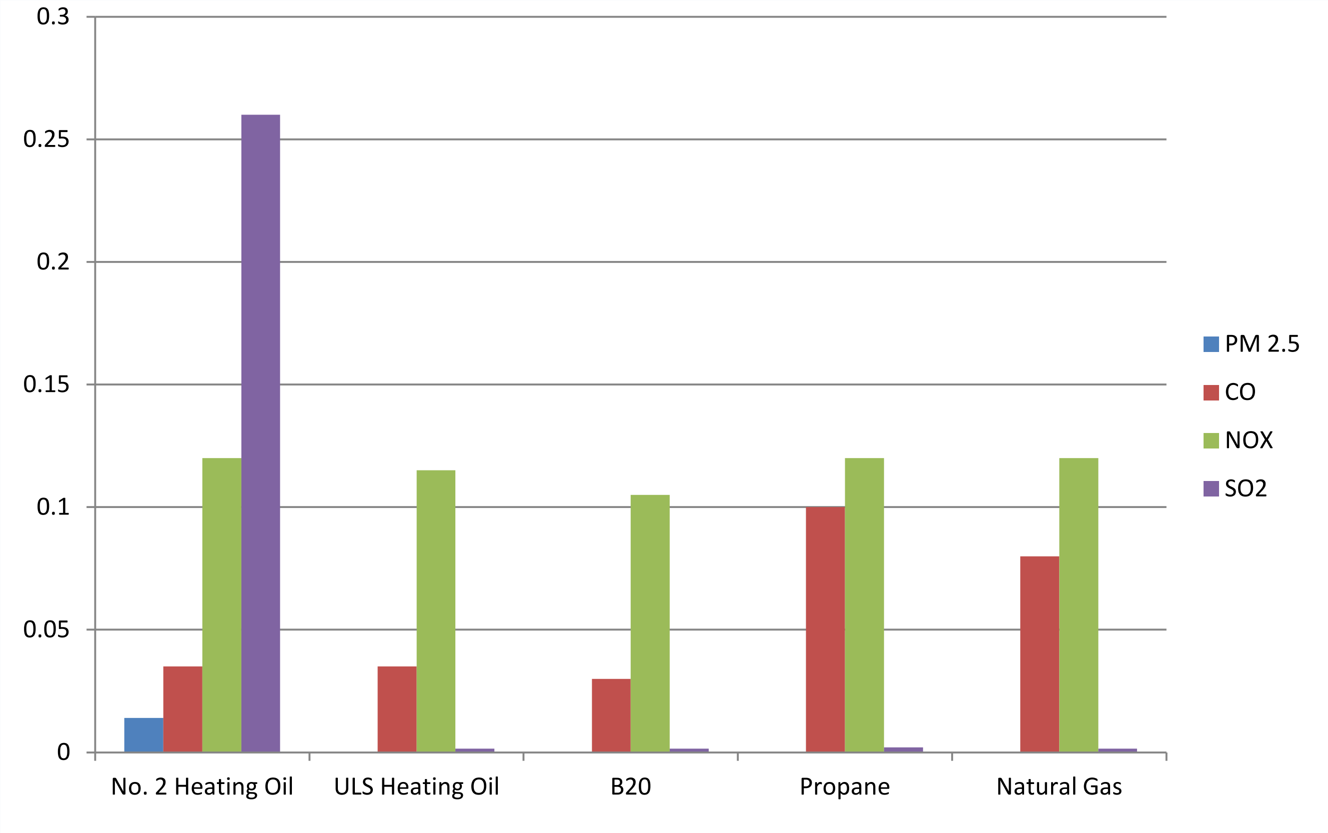
LBS/MMBTU



Transition to ULS heating oil achieves parity in PM 2.5 emissions

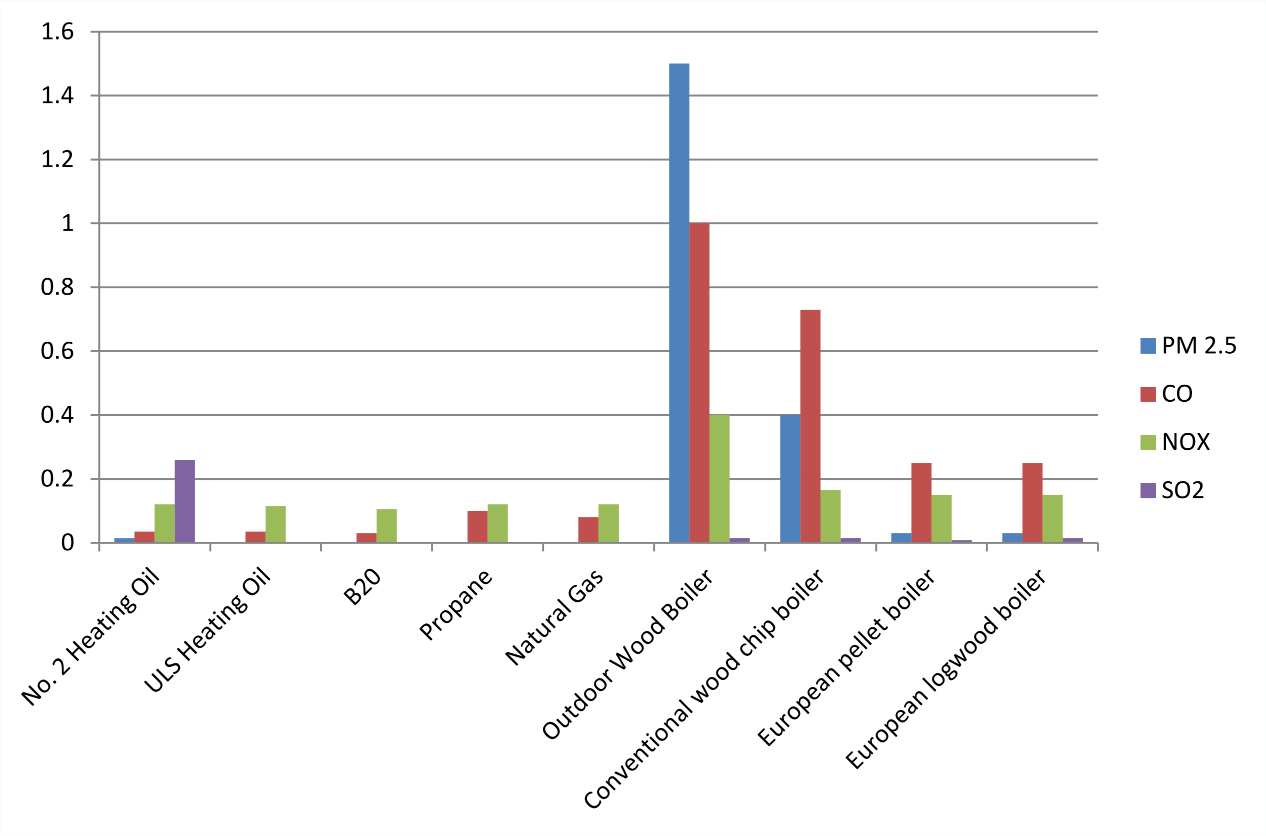
Comparison of Criteria Pollutants

Residential and Small Commercial Heating Systems



Only small differences in CO and NOX remain

Comparison of Criteria Pollutants Including Biomass-fired Systems



European technology much cleaner – but still a long way to go

Thank You!

www.biodiesel.org

NATIONAL BIODIESEL™ BOARD