



# **Progress Report Wood Pellet Research**

## **Wood Pellet Association of Canada**

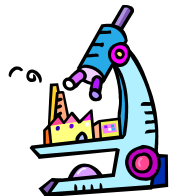
Biomass & Bioenergy Research Group  
Clean Energy Research Center  
University of British Columbia

May 11, 2011



# Update on Pellet storage

(Ms. Fahimeh Yazdanpanah, doctoral candidate)



# Experimental Set-up

## Instrumentation

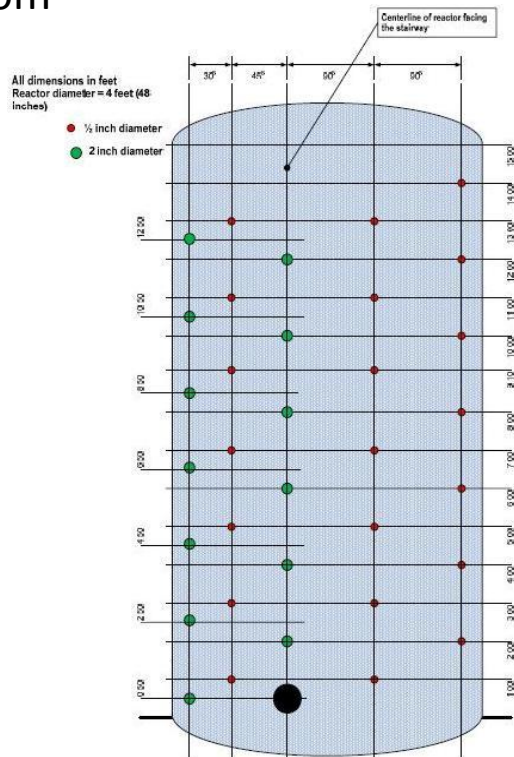
9 OPI T & RH cables each 29 sensors

7 pressure transducers

6 access ports (1/2") on each side for gas sampling

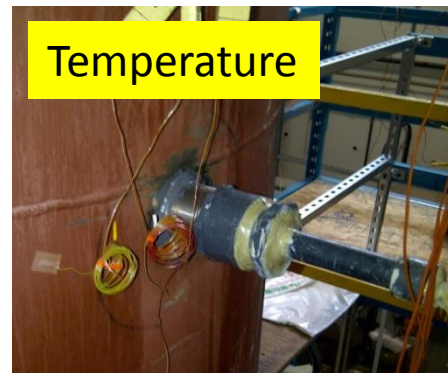
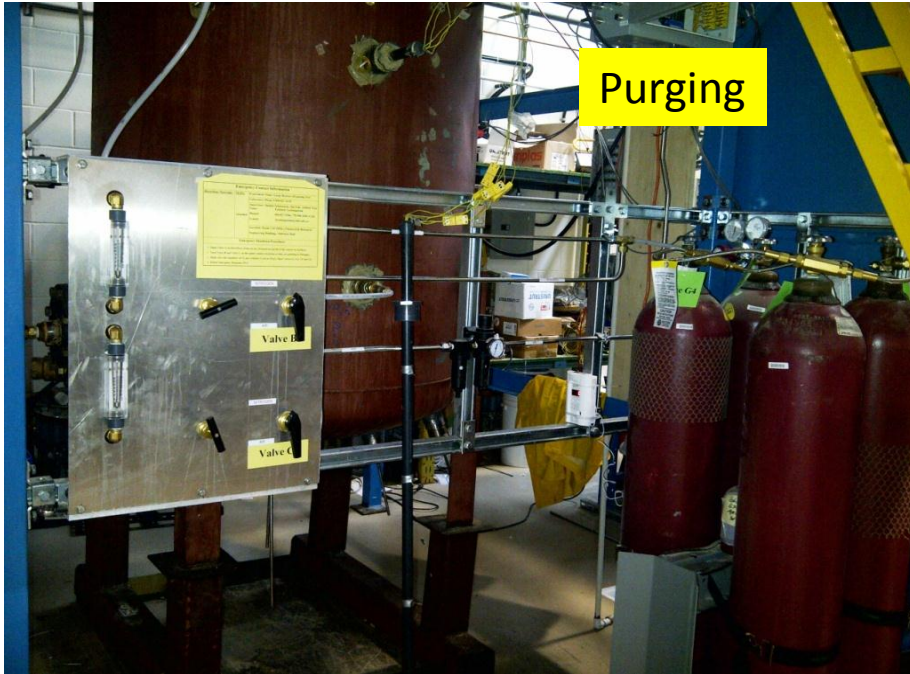
11 Ports for sampling pellets

Purging system with air or Nitrogen at the bottom



Storage tank (1.2 m x 5 m)

# Experimental Set-up



# Properties of pellets in the storage reactor

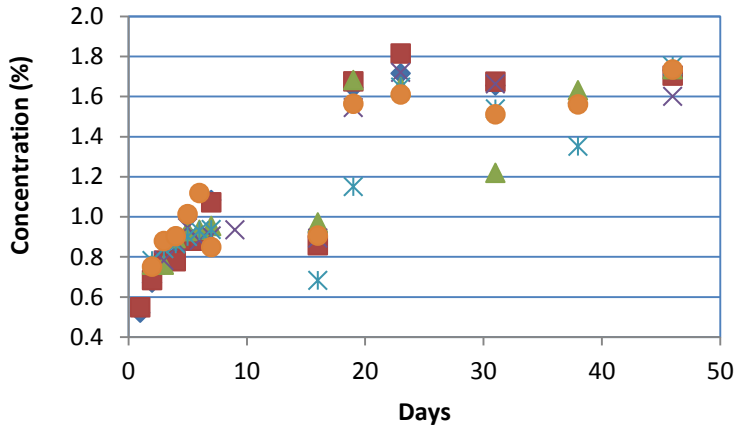
Statistics	Diameter (mm)	Length (mm)	Mass (g)	Density (kg/m <sup>3</sup> )	Moisture content (%)	Heat value (kJ/kg)
Mean	6.38	13.45	0.50	1.15	4.3	19,204
STD	0.08	4.27	0.17	0.74	0.2	n/a
CV, %	0.01	0.32	0.35	0.01	0.1	n/a
Min	6.26	5.38	0.18	0.95	4.0	19,064
Max	6.60	29.06	1.11	1.32	4.5	19,424

- White pellets
- Loading date February 12, 2011
- About 3 tons of pellets were loaded manually into the storage reactor
- A headspace of about 1 ft deep is left at the top
- Monitoring was initiated on February 13, 2011

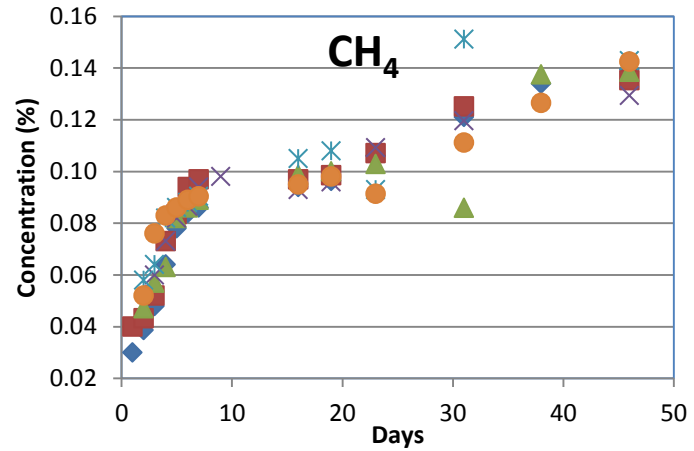


# Concentration of off gases during 50 days storage Feb 13 – March 31, 2011

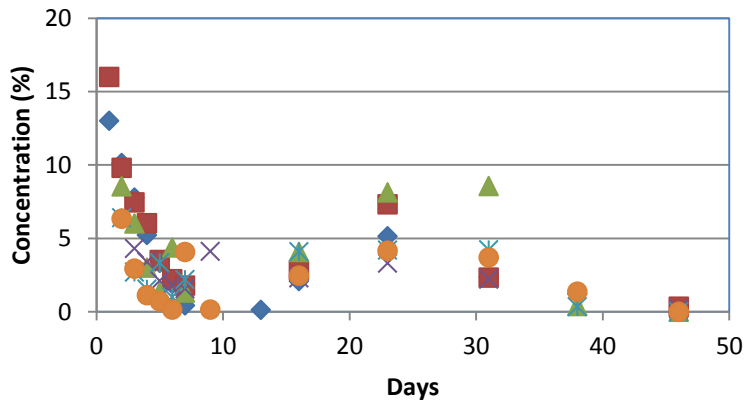
## CO



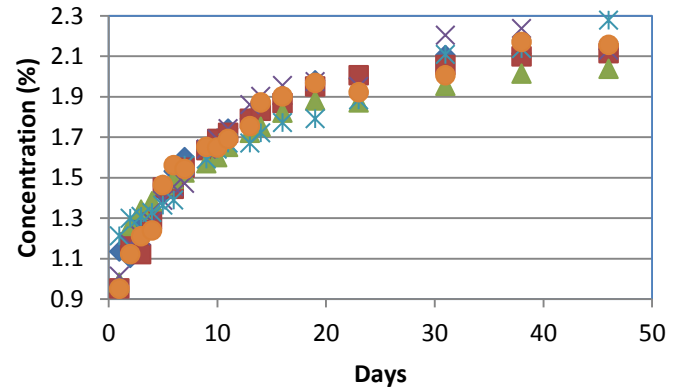
## CH<sub>4</sub>



## O<sub>2</sub>



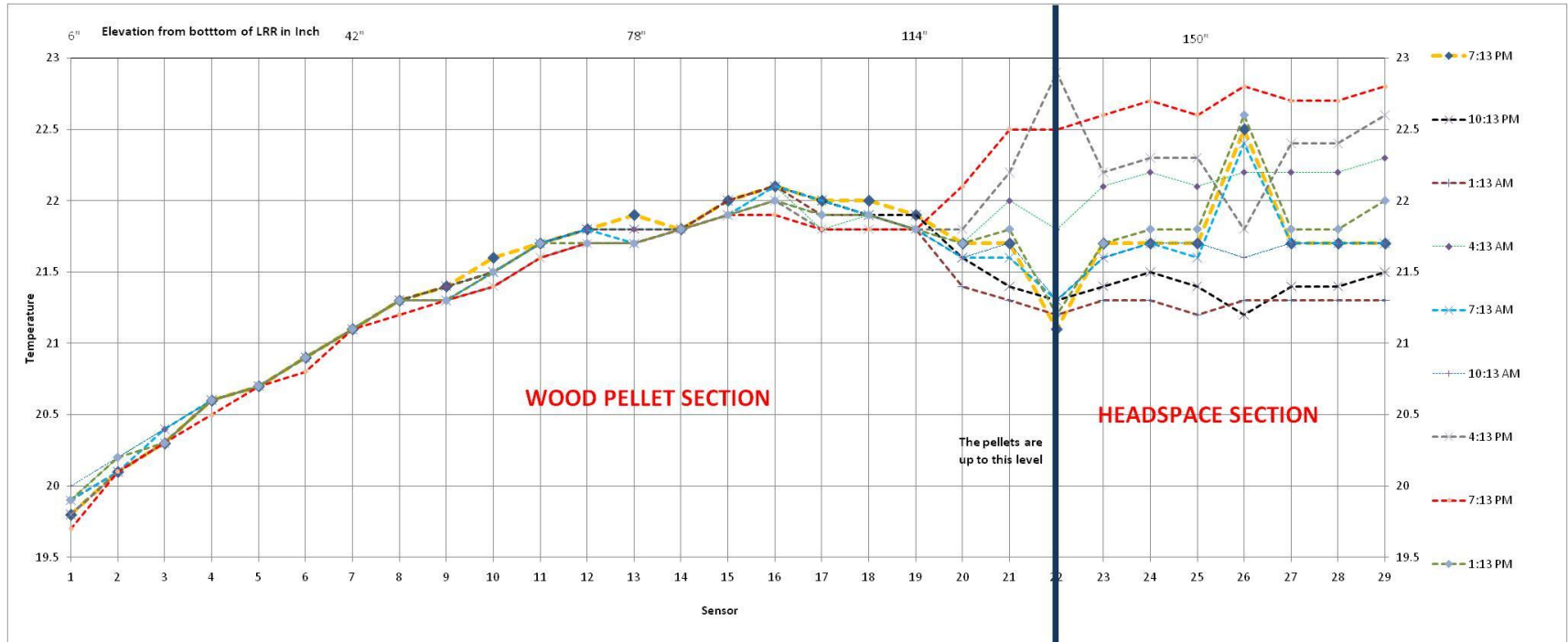
## CO<sub>2</sub>



Top

- ◆ G3
- G5
- ▲ G7
- × G9
- ✱ G11
- G13

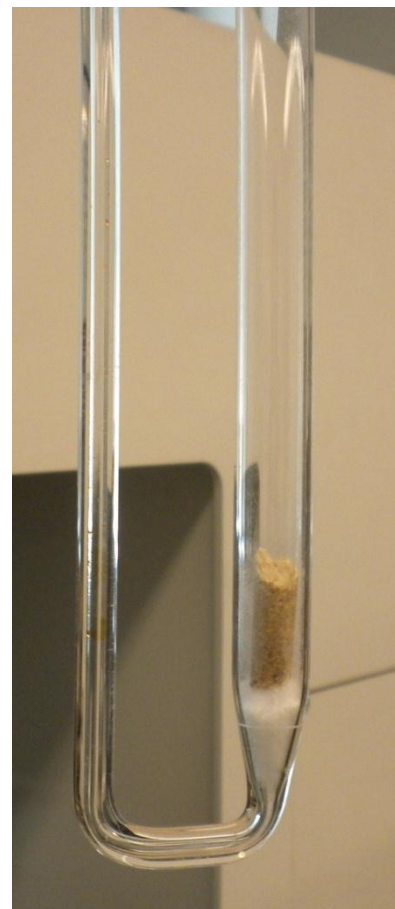
# Temperatures sensed by a single cable



# Gas adsorption – desorption by a single pellet

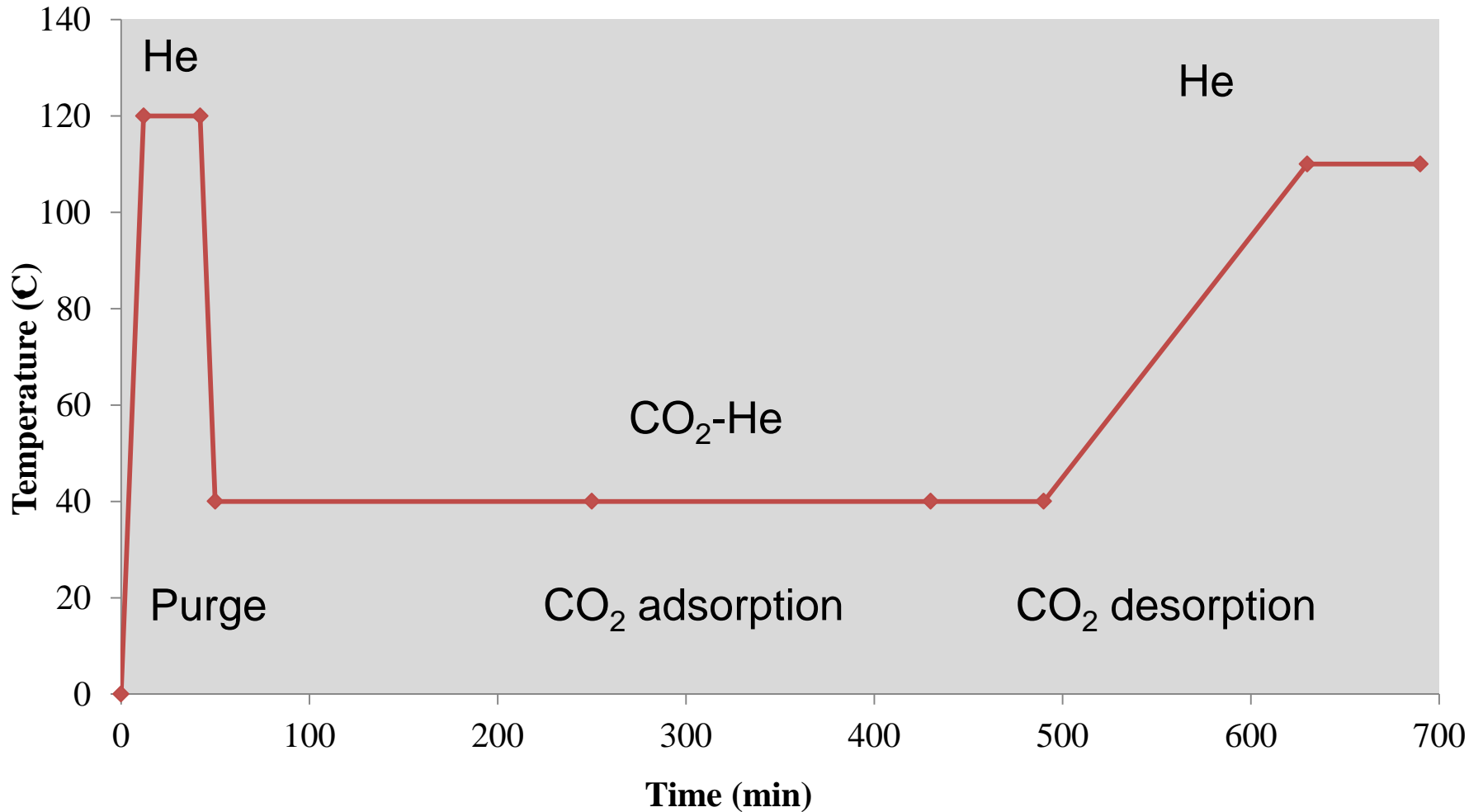


The AutoChem II 2920 is a fully automated chemisorption analyzer that can provide comprehensive studies of chemical adsorption desorption and temperature-programmed reactions.



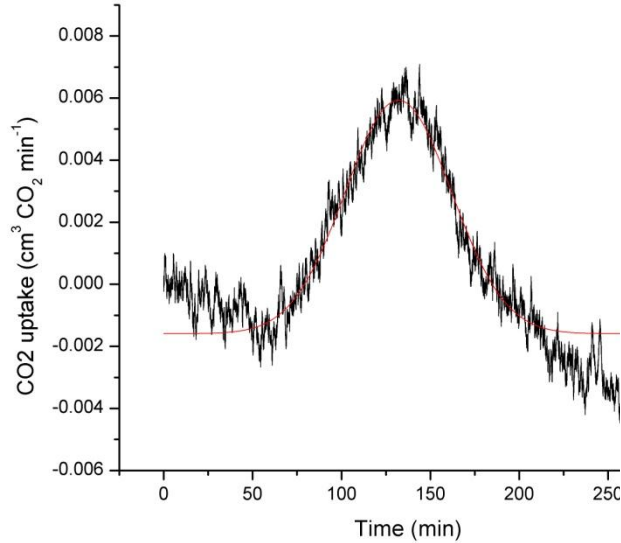
Pellet sample in the tube before the test

# Temperature program to measure CO<sub>2</sub> desorption by a single pellet

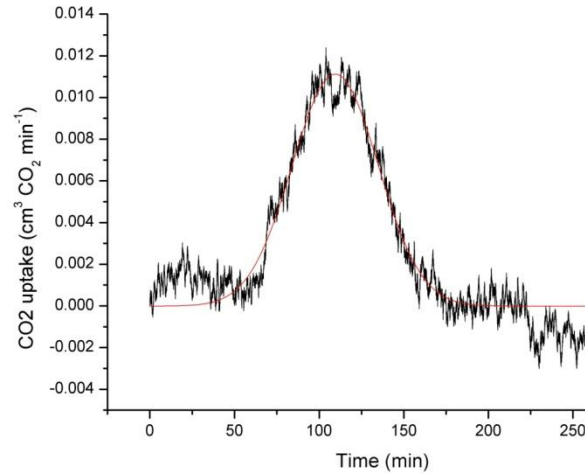


# Results - CO<sub>2</sub> adsorption

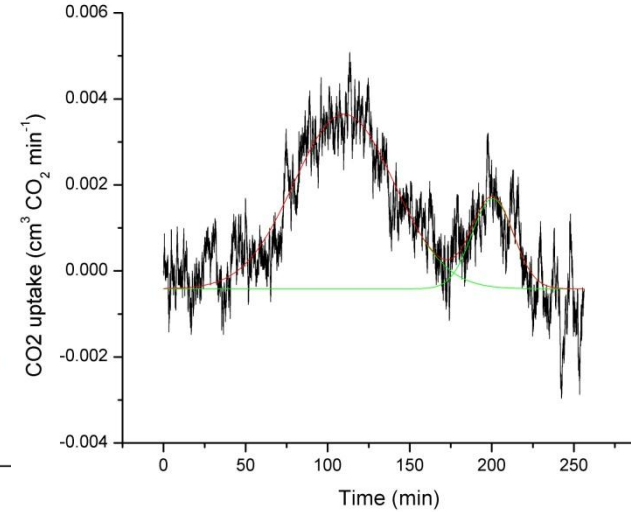
### Regular Pellets



### Torrefied Pellets



### Steam treated Pellets



Sample	Weight (g)			CO <sub>2</sub> Uptake (cm <sup>3</sup> )			CO <sub>2</sub> Uptake (Average) (cm <sup>3</sup> /g)
	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3	
<b>Torrefied</b>	0.792	0.601	0.763	0.77	0.56	0.70	0.946
<b>Steam Exploded</b>	0.752	0.759	0.750	0.17	0.10	0.18	0.205
<b>Regular</b>	0.748	0.746	0.745	0.56	0.56	0.58	0.764



# Conclusions (to date) from pellet storage research

- Oxygen depletion was immediate at all levels.
- Gas concentrations progressively diverged, tended to reach a single concentration value with storage time.
- Methane ( $\text{CH}_4$ ) has not reached a plateau pointing to possible anaerobic reactions
- Variability in CO concentrations was much larger than variability in  $\text{CO}_2$  or  $\text{O}_2$ .
- Increase in temperature within the pellet storage was not significant
- The temperatures sensed in the headspace show a high variability
- Torrefied pellets had the highest gas adsorption, followed by regular pellets and then by pellets made from steam explosion.
- The large reactor with its instrumentation is well suited to conduct storage management of pellets.
- AutoChem equipment used for catalyst studies can be used to study gas adsorption desorption by wood pellets.



# To conclude storage studies

- Develop design and management models for ventilating and purging pellet storage enclosures; subject to the following empirical observations:
- Excessive temperature rise due to self heating is controlled by injecting an inert non-combustible gas such as  $N_2$ ;
- When combustion is not an imminent concern, atmospheric air is used to purge stored pellets from toxic gases;
- A programmed frequent ventilation strategy using atmospheric air would minimize the potential for self heating.
- *Would it be feasible to purge fresh pellets to minimize off gassing?*
- *Would it be feasible to combine steam explosion with torrefaction conditions to minimize off gassing?*



# Overview



## **Accomplishments: The following research is accomplished either with WPAC – NSERC funding or with leveraged funding**

- Determined optimum temperature, time, and particle size to torrefy wood and optimum conditions to make durable torrefied pellets
- Completed a sequence of steam explosion process followed by pelletization of exploded material to maximize density, durability, and hydrophobicity of pellets.
- Completed comparing the durability of wood pellets on free fall and compared European round hole sieve (3.15 mm) with the 1/8” mesh sieve (ASTM, E-11)
- Completed life cycle analysis of wood pellet compared to wood chips and natural gas.
- Completed the techno-economic assessment of wood pellets for district heating.



## **Accomplishments: The following high quality graduates (HQP) have been trained with WPAC – NSERC funding or with leveraged funding**

1. Ann Pa defended her M.Sc. thesis on life cycle analysis of wood pellets.
2. Ehsan Oveisi defended his M.Sc Thesis on durability of wood pellets.
3. Asa Parker defended his M.Eng. Project on spectro-analysis of fractionating bark and stemwood
4. Saeed Ghafghazi defended his Ph.D. thesis on wood pellets for district heating. Saeed is working with Ausenco – Sandwell.
5. Wilson Lam defended his Ph.D. thesis on steam explosion of wood pellets. He is employed by OPG.
6. Dr. Jaya Shankar Tumuluru completed 2-years of post doctoral on storage of wood pellets. Jaya serves as a bioenergy scientist by INL.
7. Dr. Igathi completed one year of post doctoral on image analysis of wood particles. Igathi serves as bioenergy professor at the North Dakota State University.
8. Dr. Sylvia Larson completed 9 months of post doctoral on characterization of wood pellets. Sylvia is a faculty at Umea University, Sweden.
9. Dr. Congwei Wang completed one year of post doctoral on torrefaction analysis
10. At least 4 undergraduate students during summer months.

## In progress or planned

- Integrate dry/wet torrefaction treatments with pelletization.
- Minimize size reduction operations and costs.
- Develop reproducible energy balances for each of unit operations (drying, size reduction, pelletization) for making pellets.
- Develop alternate pelletization process (non-frictional pressing, granulation) to minimize energy and power input in making pellets.
- Optimize the selection of raw feedstock to produce pellets with specific grade (quality) target.
- Assess the benefit of pelletization for pyrolysis and gasifications.
- Assess the benefit of pelletization for biochemical conversion.
- Assess the logistics and cost of integrating regular and torrefied pellets
- Develop methods for evaluating the physical and chemical properties of pellets.



## Other funding sources

- US DOE on torrefaction of wood residues (2010 - );
- Agricultural Canada's Agricultural Bioenergy Innovation Network (ABIN) program on biomass microwave pyrolysis and life cycle analysis of wood pellets (2009-2011); and on pellet supply logistics;
- NSERC Discovery grant on pelletization (Sokhansanj) on fluidized bed torrefaction of biomass (Bi);
- BC Natural Resource and Applied Science (NRAS) grant on steam treated wood pellets for bioethanol production (2010-2013);
- Nanyang University of Technology on torrefaction of palm residues (2009);
- BC Ministry of Forest & Range on utilization of forest resources;
- Agriculture & Agri-Food Canada on integration of Resource Analysis Model (BIMAT) with the UBC logistics model (IBSAL).



## Current high quality graduate students (HQP) supported by WPAC – NSERC funding or with leveraged funding

Fahimeh Yazdanpanah*	Pellet storage management
Marius Wohler	Pelletization for a targeted grade
Zahra Tooyserkani	Steam treated pellets for bioethanol
Jianghong Peng	Torrefaction and pelletization of woody biomass
Ehsan Oveisi	Logistics of supply to UBC Bioenergy CHP (nexterra)
Ladan Naimi	Minimizing energy and power in size reduction
Mahdi Mobini	Logistic of pellet production
Xiao He	Biodrying and storage of woody biomass
Wendi Guo	Self heating of pellets in storage
Bahman Ghiasi	Special short term (industry) projects
Mahmoud Ebadian	Logistics of agricultural biomass supply
* Fahimeh is the Webmaster and coordinator for the BBRG	



# Current Full Time Faculty & Members BBRG

- Dr. Taraneh Sowlati, Wood Science, Faculty of Forest Sciences
- Dr. Tony Bi, Chemical & Biological Engineering
- Dr. Anthony Lau, Chemical & Biological Engineering
- Dr. Jim Lim, Chemical & Biological Engineering
- Dr. Shahab Sokhansanj, Chemical & Biological Engineering (Adjunct), Oak Ridge National Laboratory (Tennessee)
- Mr. Staffan Melin, Chemical & Biological Engineering (honorary), DRC and WPAC
- Mr. Bijan Shams, Cogent\*
  - \* BBRG adviser

Biomass Pelletization Workshop  
May 17-18, 2011  
University of British Columbia



[www.biomass.ubc.ca](http://www.biomass.ubc.ca)

# Funding situation

## Project: Modeling of Off-Gassing for Wood Pellets NSERC-Collaborative Research and Development Grant

Year		Awarded amount				Delta Research Corporation
		NSERC	Wood Pellet Association of Canada		In-Kind	
			Cash received	Cash committed		
1	2007	\$111,900	\$50,000	\$50,000	Equipment and Large Storage Reactor OPI Instrumentation	Research Advice Industry liaison
2	2008	\$108,400	\$50,000	\$50,000		
3	2009	\$123,900	\$50,000	\$50,000		
4	2010	\$104,900	\$50,000	\$25,000		
5	2011	\$50,400	\$50,000	\$0		
	<b>Total</b>	<b>\$499,500</b>	<b>\$250,000</b>	<b>\$175,000</b>		