BRIQUETTE QUALITY AND DURABILITY ACROSS MULTIPLE FEEDSTOCKS

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Anthony Eggink
Research Engineer
Schatz Energy Research Center

John Crouch
Director of Public Affairs
Pellet Fuels Institute

Schatz Energy Research Center SERC

RUF. BRIQUETTING SYSTEMS

Pellet Fuels Institute®

Biomass Conversion Technology (BCT): Densification via Briquetting

- Project Partners:
  - Pellet Fuels Institute (PFI)
  - RUF Briquetting Systems (manufacturer)
- Technology: Hydraulic Ram Densification
- Machine Specifics
  - Model: RUF 200
  - Specified Throughput: 200 kg/hr
- Lines of Inquiry:
  - Using Multiple Feedstocks and Moisture Content Levels
    - Briquette Durability
    - Briquette Quality
    - Machine Performance
- Conclusions

Briquetter Site Testing

- Testing at Green Diamond Resource Co. forest operations site in Big Lagoon CA, July and August 2015
- Multiple Feedstocks including:
  - Douglas Fir
  - Redwood
  - Tanoak
  - Forest Slash
  - Torrefied Biomass

GREEN DIAMOND RESOURCE COMPANY

Briquetter Testing

- Testing Matrix at forest operations site in Big Lagoon CA

Species	Comminution Method	Anatomical Distribution	Contamination	Moisture Content	Particle Size
Redwood	Chipped	Bole	None Added	Variable from <5% to 18%	0.75” minus, 0.75” – 1.5”, Overs up to 4”
Douglas Fir	Chipped	Bole & Tops			
	Ground	Bole			
Tan Oak	Chipped	Bole			
	Ground	Bole			
Forest Slash	Chipped	Bole & Tops			
Torrefied	Chipped	Bole		<3%	0.75” Minus

Briquetter Testing Outcomes

Initial Observations and Findings

- The RUF Briquetter is easy to operate and can run independently until the hopper is depleted
- The briquetter successfully processed a variety of chipped and ground raw woody biomass feedstocks. It also produced briquettes from torrefied biomass wood chips. No binders were needed.
- Briquettes produced are consistent in size and quality for each feedstock or moisture content

Briquetter Testing Outcomes

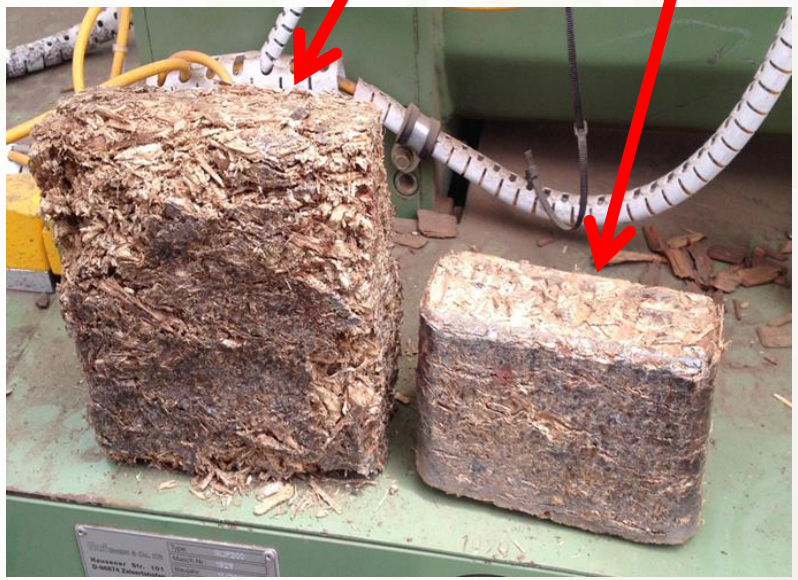
Initial Observations and Findings

- Accepts feedstocks over a range of particle sizes and is tolerant of modest contamination levels.
- Feedstocks with moisture content above 18% makes poor quality briquettes (below right)
- Chip sizes greater than 4 inches may jam the machine (below left)

Chip Size >4”

~18% Moisture Content

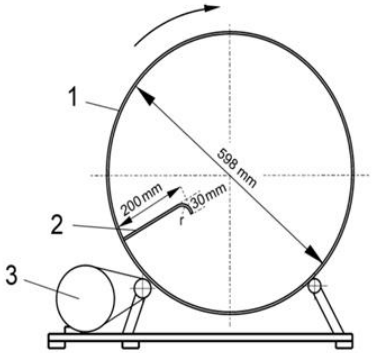
~8% Moisture Content



Durability Testing of Briquettes

Durability testing is used as a comparison to relate briquettes to the effects of transportation and handling

- Testing method: ISO/DIS 17831-2
- Briquettes were tumbled for 5 minutes
- After tumbling, briquette particles were sifted through a 2” screen
- Particles of a size larger than the screen were considered durable and counted as a mass % of the input weight



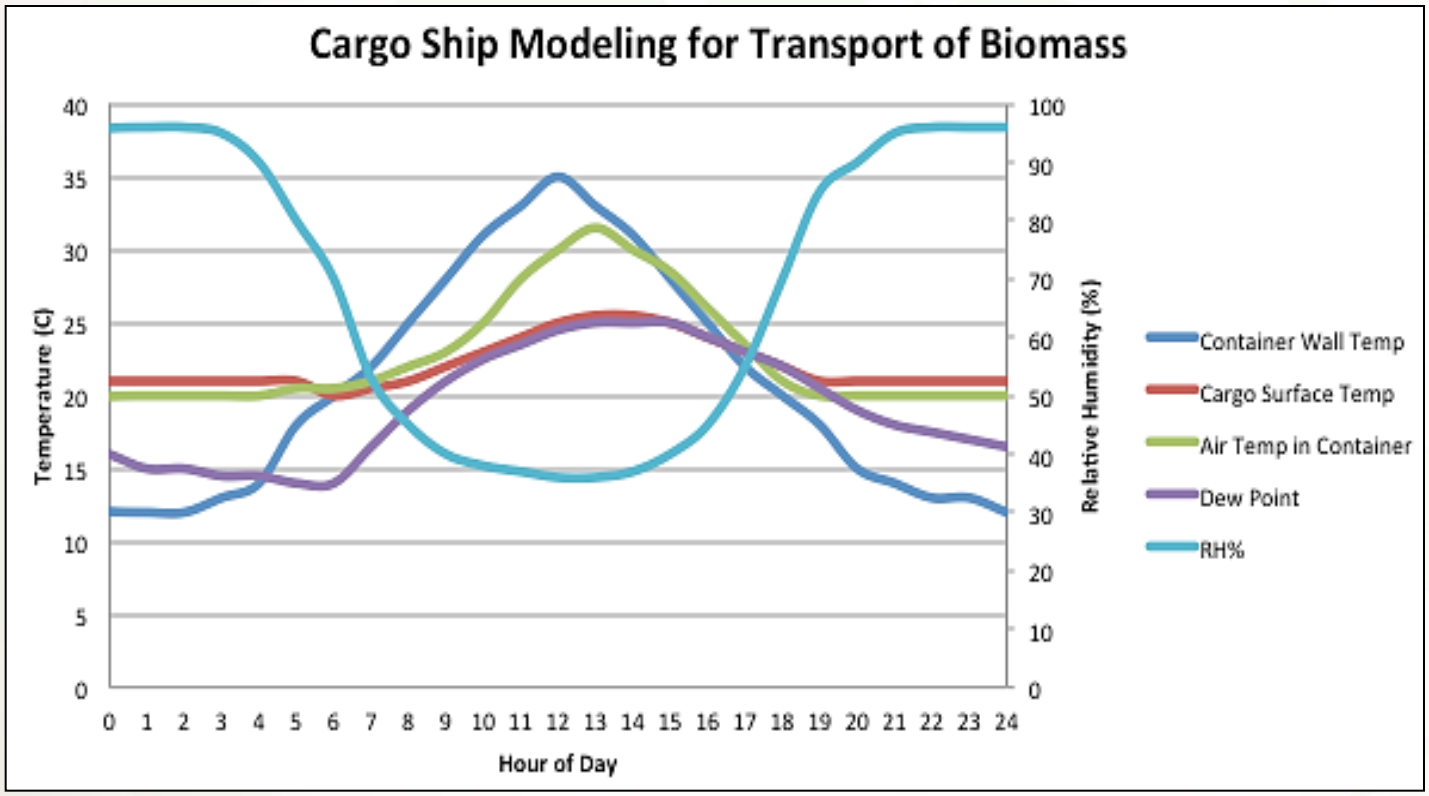
1 Drum
2 Baffle
3 Motor

Figure 1 - Principle of the durability drum

Transportation Testing of Briquettes

Briquettes were tested using the ESPEC EPL-3H environmental chamber.

- Shipping container transport was simulated from Wilsonville, Oregon to Japan (Leinberger, 2008)
- Simulation length was 194 hours, consistent with real time shipping



ESPEC Platinous EPL-3H Environmental Chamber

Absorption Testing of Briquettes

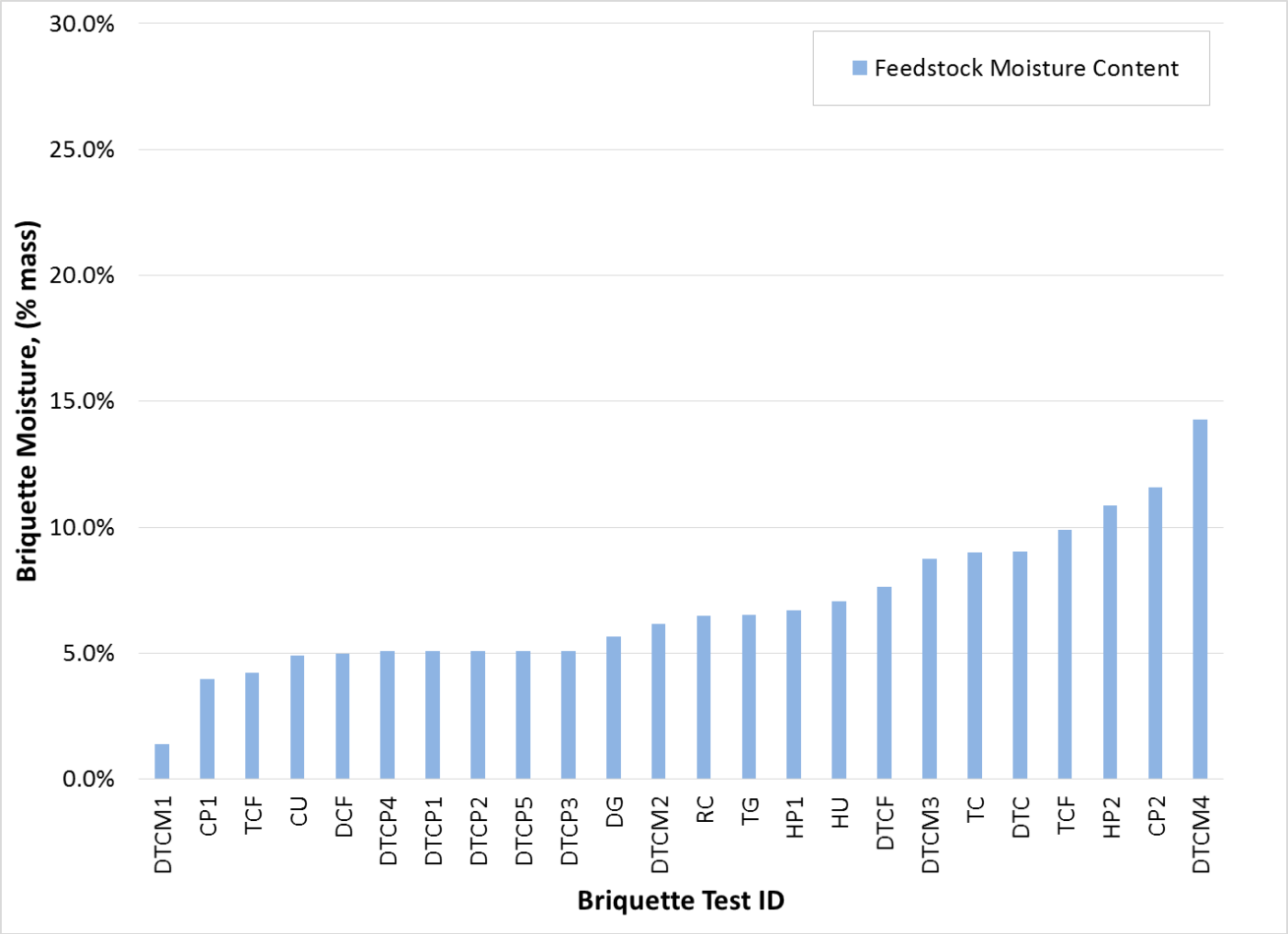
Briquettes were tested using the ESPEC EPL-3H environmental chamber.

- Maximum absorption testing was conducted at 95% relative humidity and 50 ˚C.
- Samples were weighed daily
- Absorption testing continued until mass % change was less than 0.1%.

ESPEC Platinous EPL-3H Environmental Chamber

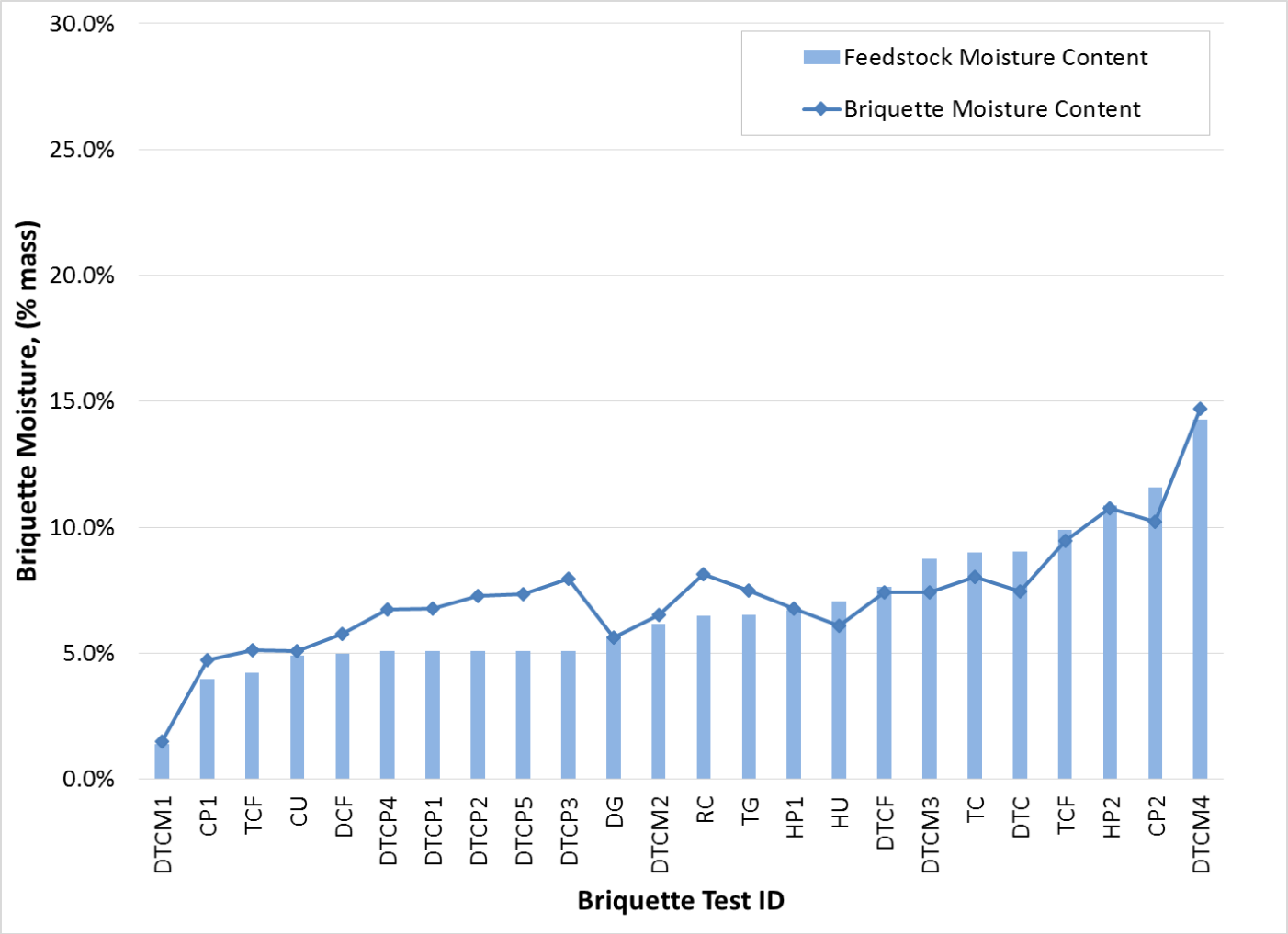
Feedstock Moisture Content

Feedstock Moisture Content Ranged from ~2-14%



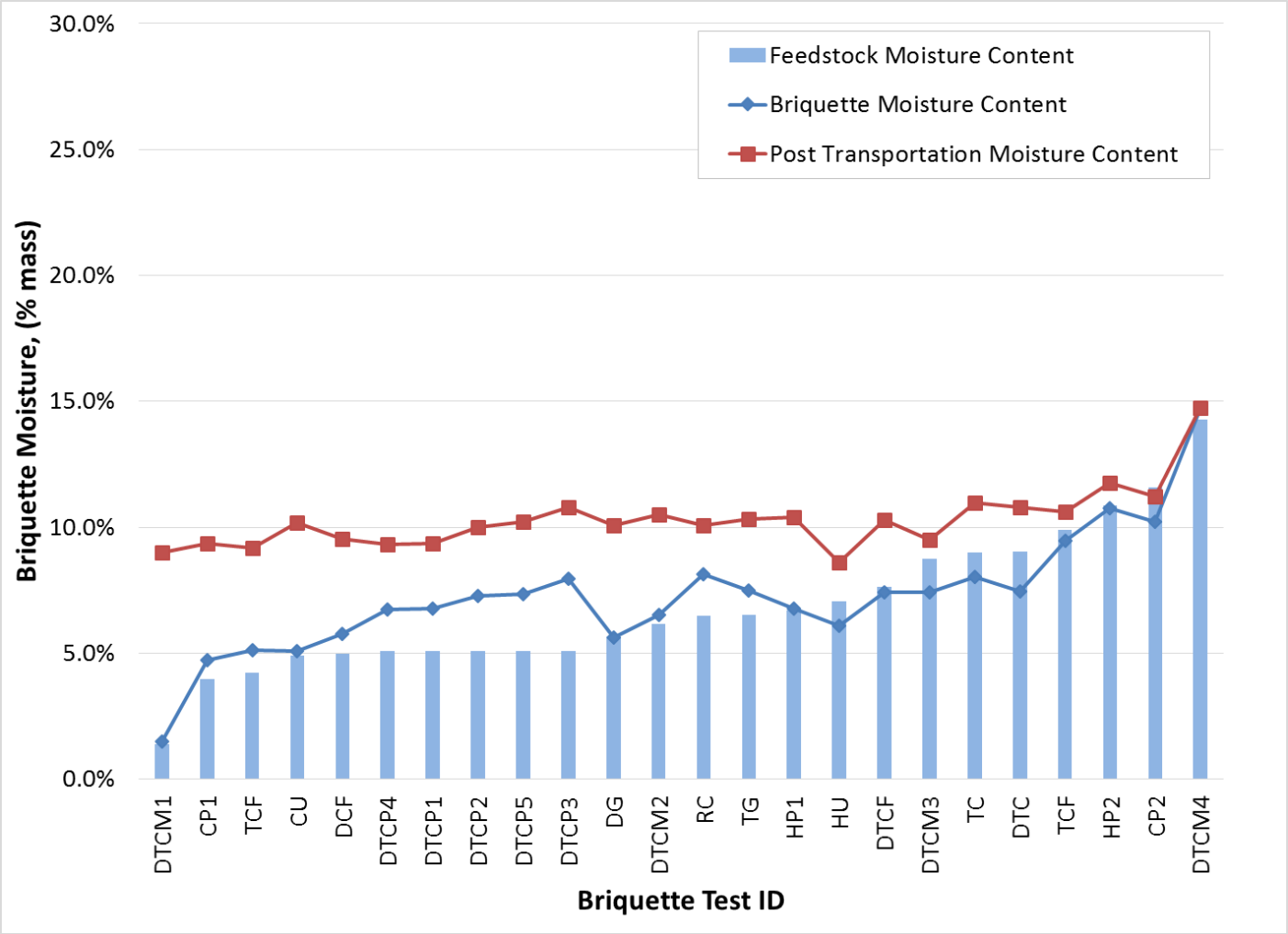
Briquette Moisture Content

Briquette Moisture Content Ranged from ~2-14%



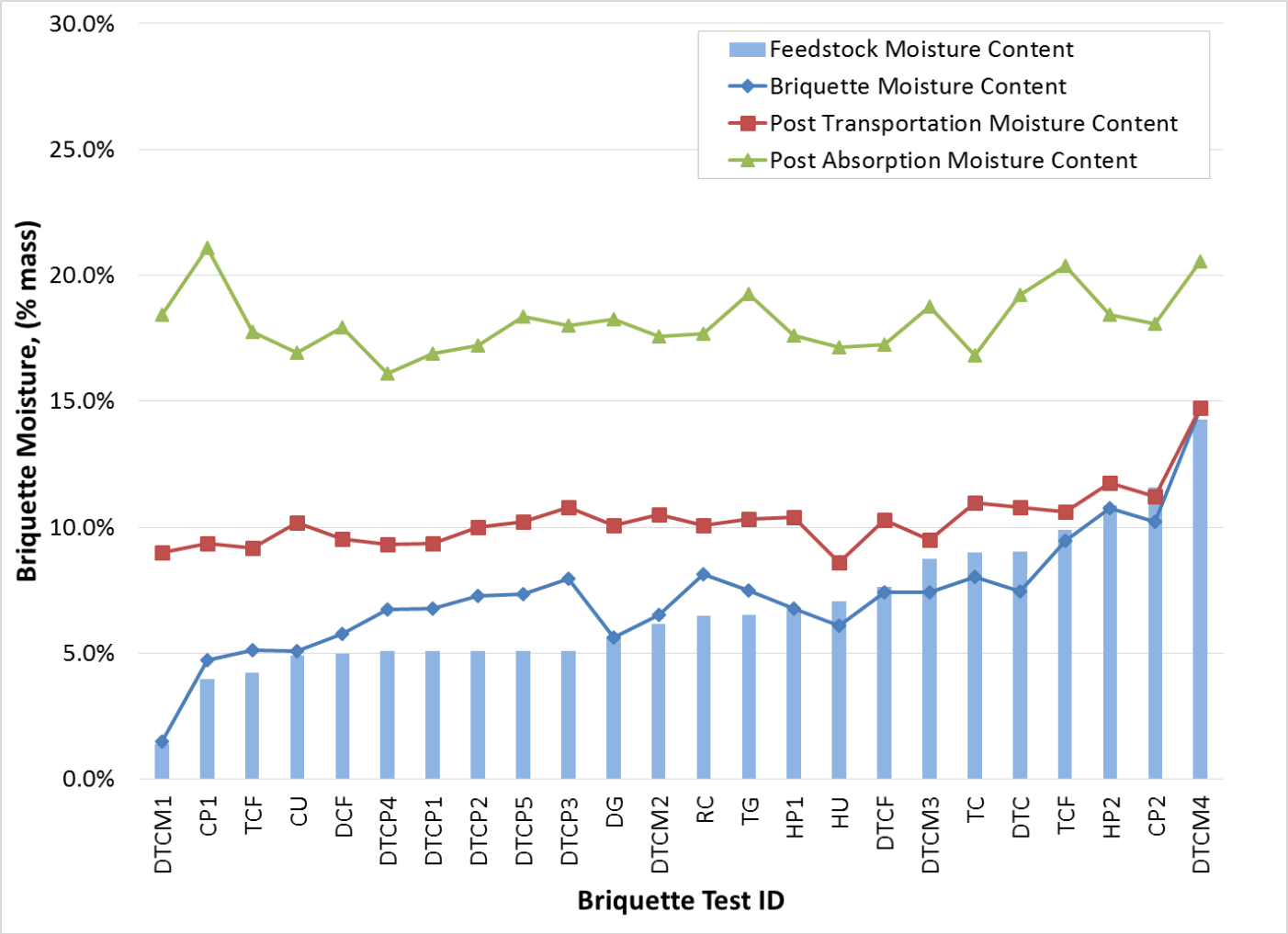
Post Transportation Briquette Moisture Content

Post Transporation Briquette MC ~10%



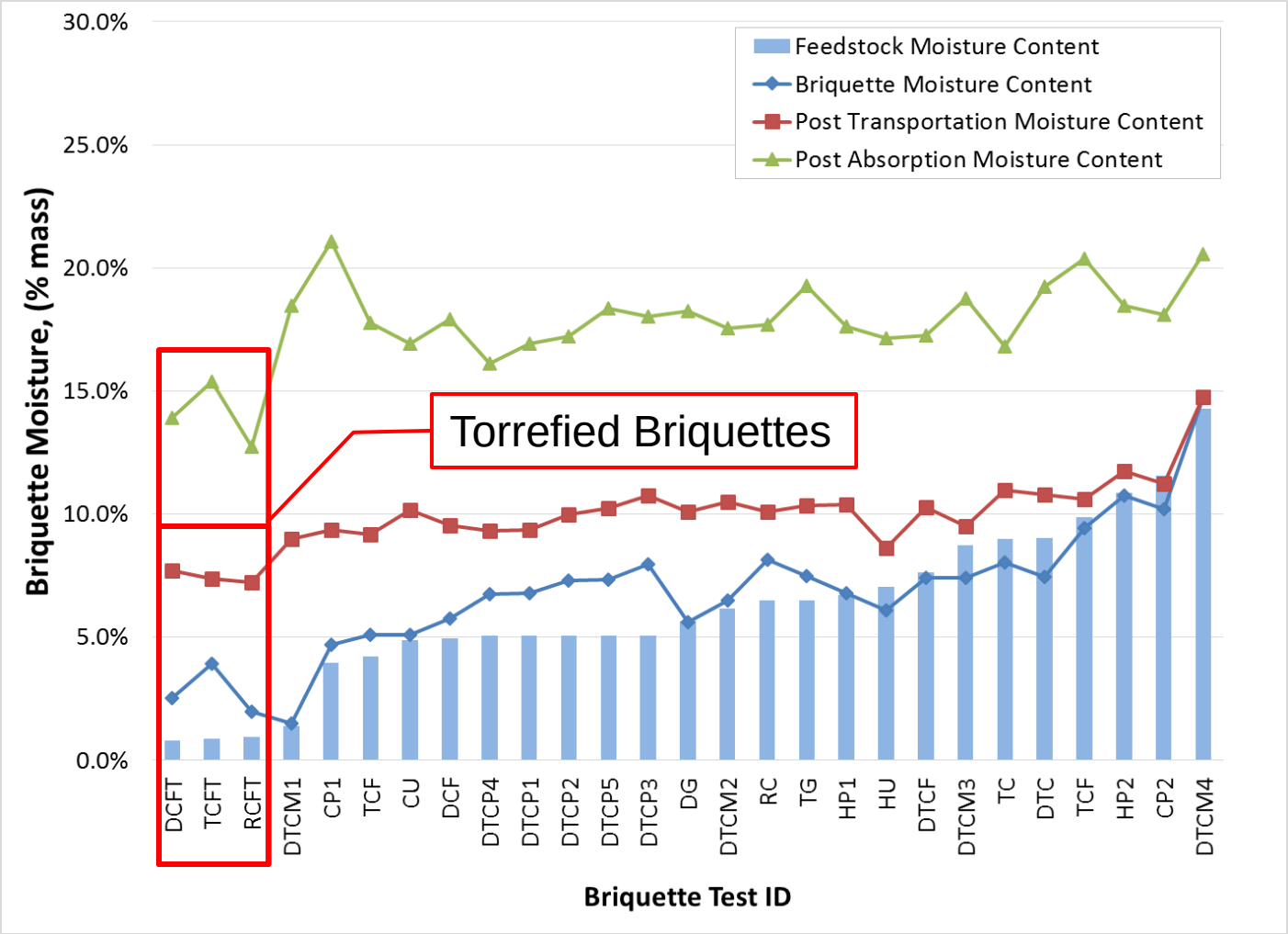
Maximum Absorptivity Briquette Moisture Content

Maximum Absorptivity Briquette MC ~16-21%



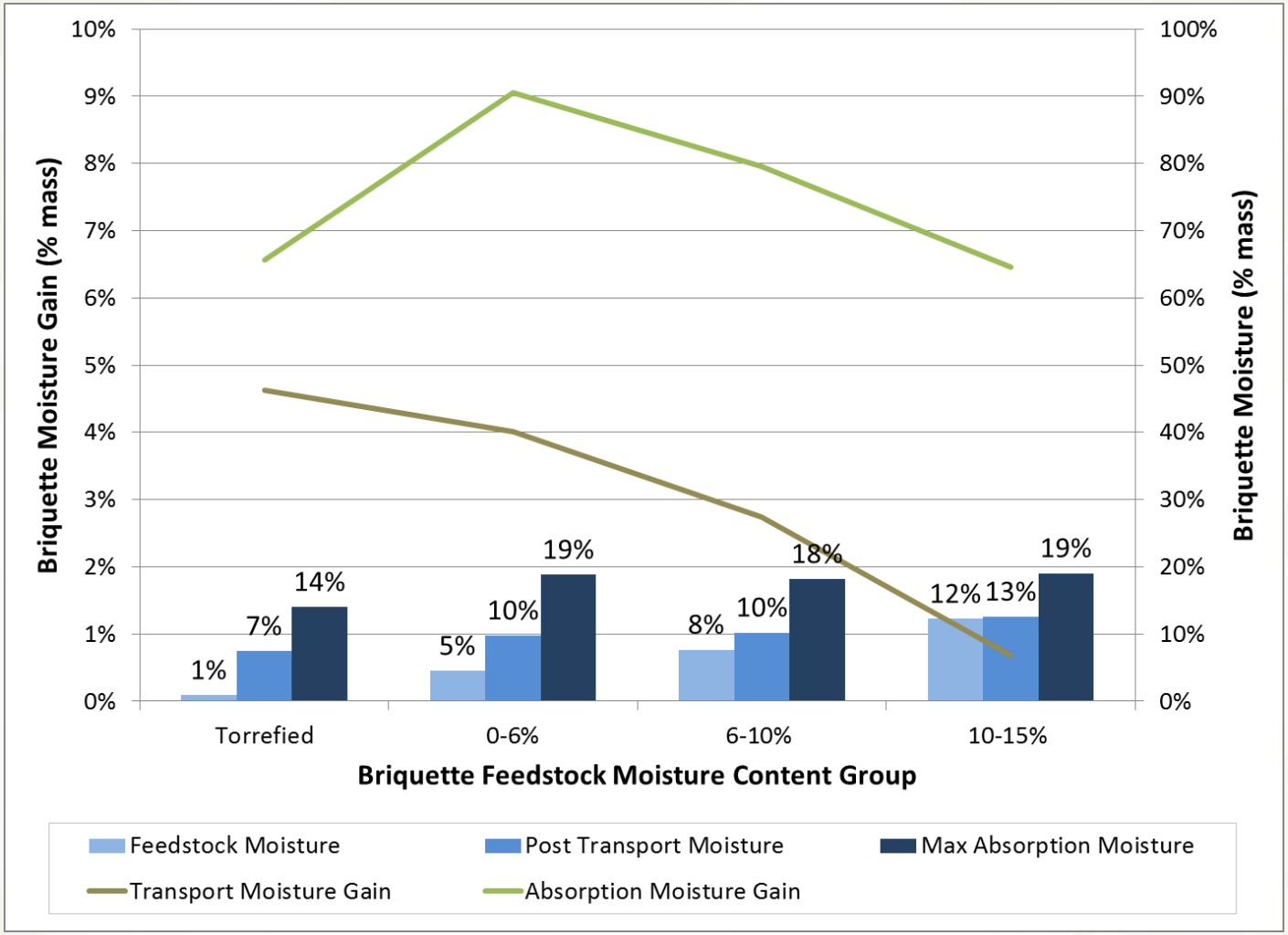
Torrefied Briquettes Moisture Content

Torrefied Briquettes have Lower MC Compared with Raw Briquettes



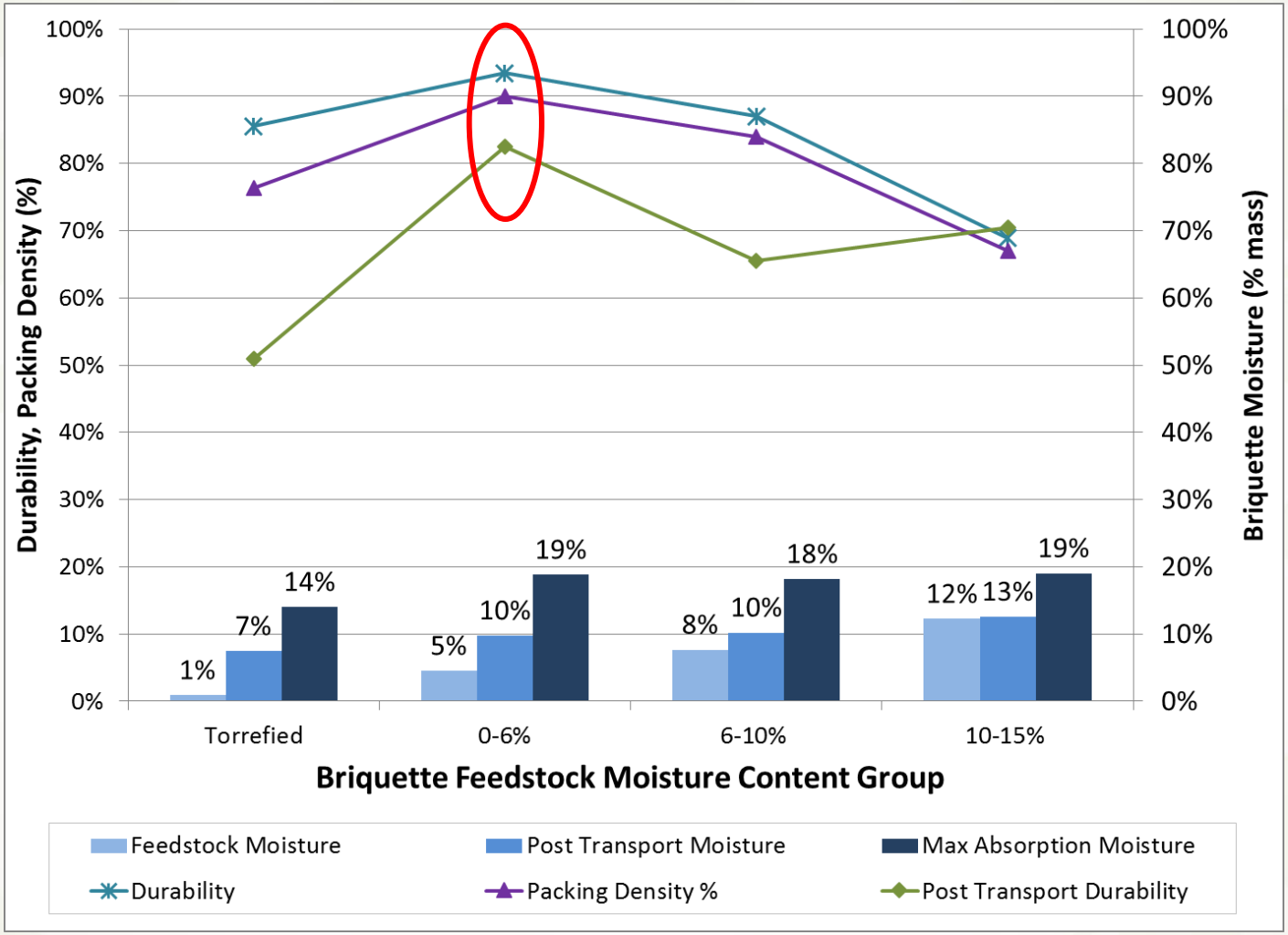
Moisture Gain of Briquettes Varies

Briquette MC Gain Varies by Feedstock Moisture and Torrefaction



Packing Density Impacts Durability

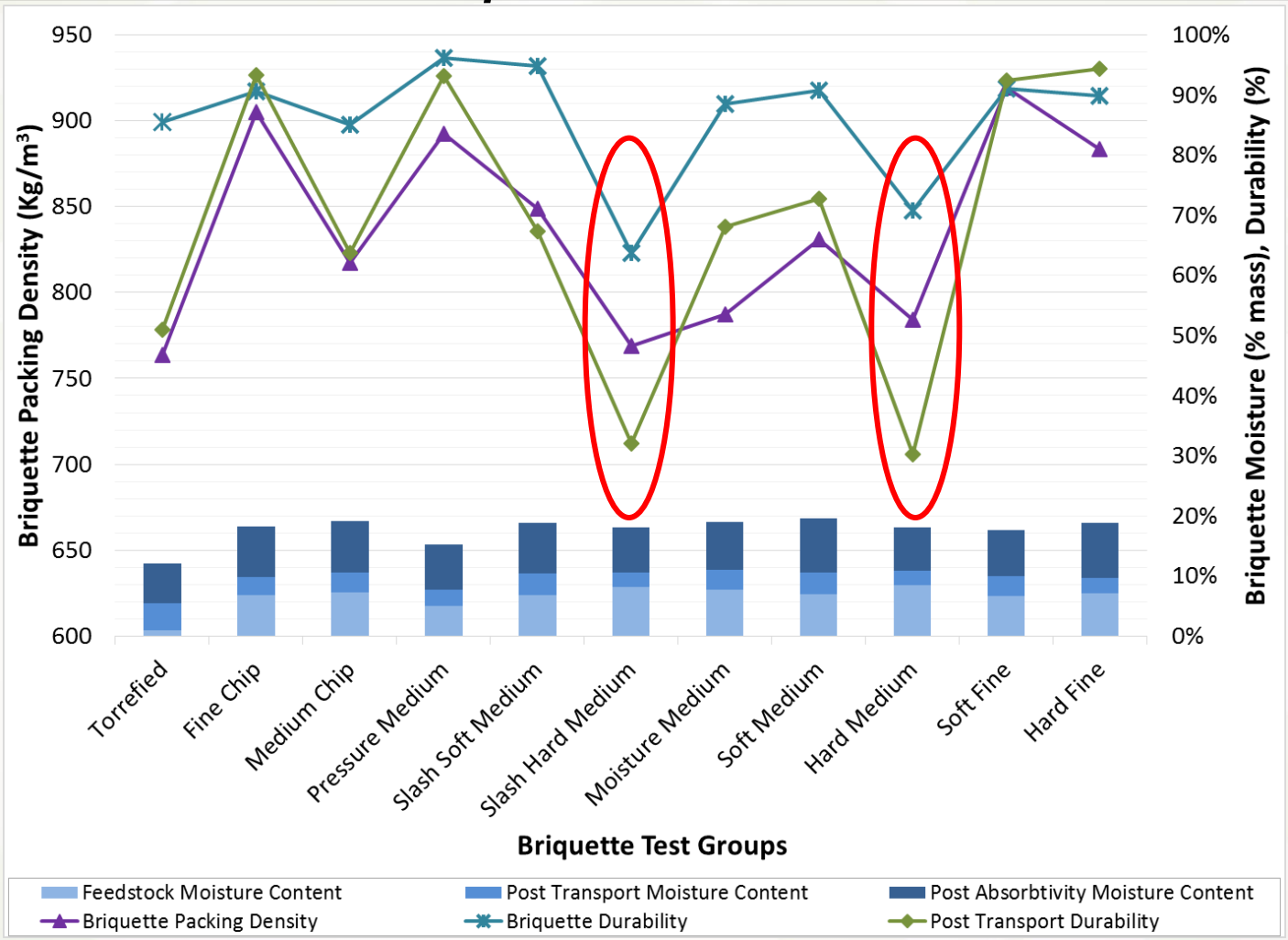
Durability Follows Packing Density for Feedstock Moisture Groups



Packing Density Impacts Durability

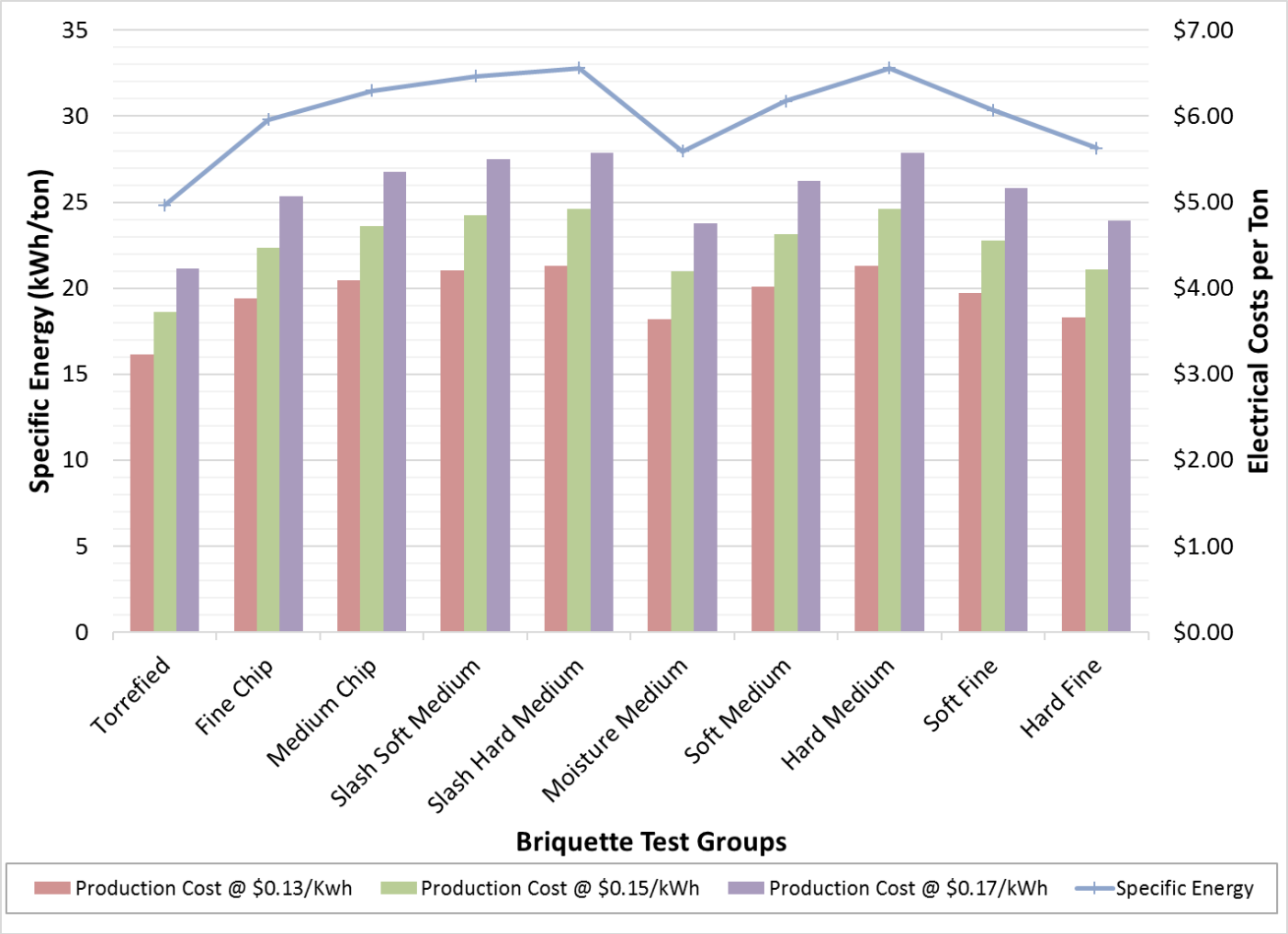
Hardwood Medium Chip (~2") are Less Durable

Moisture Increase via Transportation Simulation Reduces Durability



Cost to Produce

Electrical cost to produce is from ~$3/ton to ~$5.50/ton



Conclusions

- The RUF 200 is a robust and mature BCT requiring minimal operator effort
- Feedstock moisture should be kept at or below 15% and particle sizes should be less than 4”
- Briquettes are of consistent size and quality for each feedstock/moisture level

Conclusions

- Briquette moisture content stabilizes at ~10% post transportation simulation
- Torrefied briquettes have a lower moisture content
- Durability follows packing density of briquettes
- Briquettes made from fine chip are more durable
- Cost to produce is as little as ~$3 per ton

Thank You

Appendix A – Feedstock Descriptions

Test Information		
Test ID	Feedstock Description	Size
DCFT	Doug Fir, Chip, Torrefied, 0.75" & under	Fine Chip
TCFT	Tanoak, Chip, Torrefied, 0.75" & under	Fine Chip
RCFT	Redwood, Chip, Torrefied, 0.75" & under	Fine Chip
DTCM1	Doug Fir Tops, Chip, 2" - 0.75"	Medium Chip
DC	Doug Fir, Chip, 2" - 0.75"	Medium Chip
CP1	Conifer Slash Processed, Chip, 2" - 0.75"	Medium Chip
TCF	Tanoak, Chip, 0.75" & under	Fine Chip
CU	Conifer Slash Unprocessed, Chip, 2" - 0.75"	Medium Chip
DCF	Doug Fir, Chip, 0.75" & under	Fine Chip
DTCP4	Doug Fir Tops, Chip, 2" - 0.75"	Medium Chip
DTCP1	Doug Fir Tops, Chip, 2" - 0.75"	Medium Chip
DTCP2	Doug Fir Tops, Chip, 2" - 0.75"	Medium Chip
DTCP5	Doug Fir Tops, Chip, 2" - 0.75"	Medium Chip
DTCP3	Doug Fir Tops, Chip, 2" - 0.75"	Medium Chip
DG	Doug Fir, Ground, 2" - 0.75"	Medium Chip
DTCM2	Doug Fir Tops, Chip, 2" - 0.75"	Medium Chip
RC	Redwood, Chip, 2" - 0.75"	Medium Chip
TG	Tanoak, Ground, 2" - 0.75"	Medium Chip
HP1	Hardwood Slash Processed, Chip, 2" - 0.75"	Medium Chip
HU	Hardwood Slash Unprocessed, Chip, 2" - 0.75"	Medium Chip
RCN	Redwood, Chip, Not Sorted	Unsorted Chip
RCF	Redwood, Chip, 0.75" & under	Fine Chip
DTCF	Doug Fir, Tops Chip, 0.75" & under	Fine Chip
DTCM3	Doug Fir Tops, Chip, 2" - 0.75"	Medium Chip
TC	Tanoak, Chip, 2" - 0.75"	Medium Chip
DTC	Doug Fir, Tops Chip, 2" - 0.75"	Medium Chip
TCF	Tanoak, Chip, 0.75" & under	Fine Chip
HP2	Hardwood Slash Processed, Chip, 2" - 0.75"	Medium Chip
CP2	Conifer Slash Processed, Chip, 2" - 0.75"	Medium Chip
DTCM4	Doug Fir Tops, Chip, 2" - 0.75"	Medium Chip