

Project Title: Torrefaction and Densification of Biomass Fuels for Generating Electricity

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MILESTONE 2 REPORT

Executive Summary:

This project will research torrefaction and densification of biomass feedstocks to develop a biomass supply chain that will be both efficient and as economical as possible. The approach is to develop and optimize a torrefaction regime that will improve storage capabilities, handling methods, and biomass feedstock uniformity. The project is designed to support the following goals:

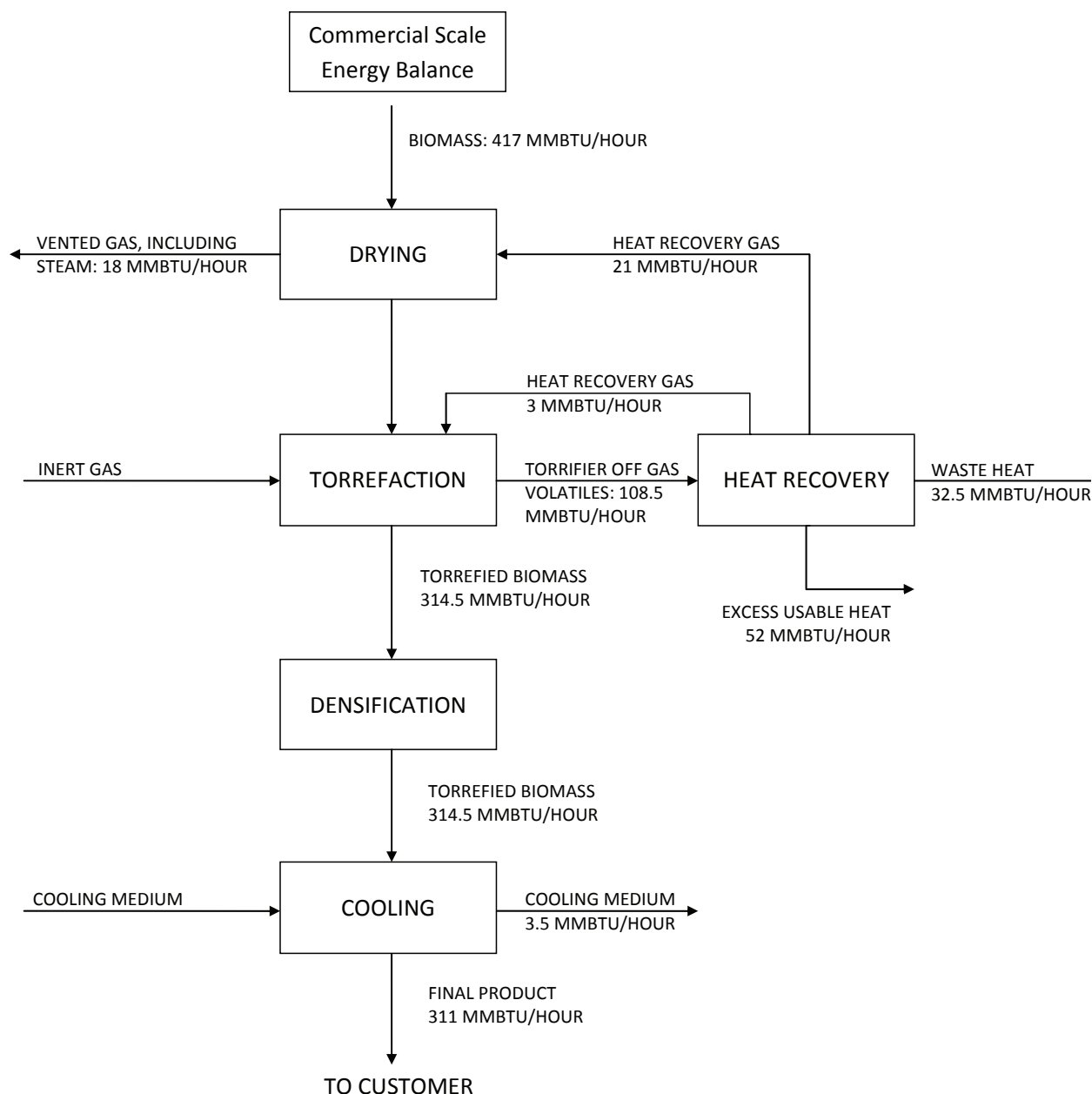
- Goal 1: Generate electricity, heat or syngas from renewable biomass energy sources that are readily available in Minnesota and approaching economic feasibility
- Goal 2: Strengthen the economy of rural Minnesota through value-added processes that capture renewable biomass energy production capability
- Goal 3: Increase accessibility to information that facilitates the adoption of biomass technologies to generate electricity and reduce fossil fuel use

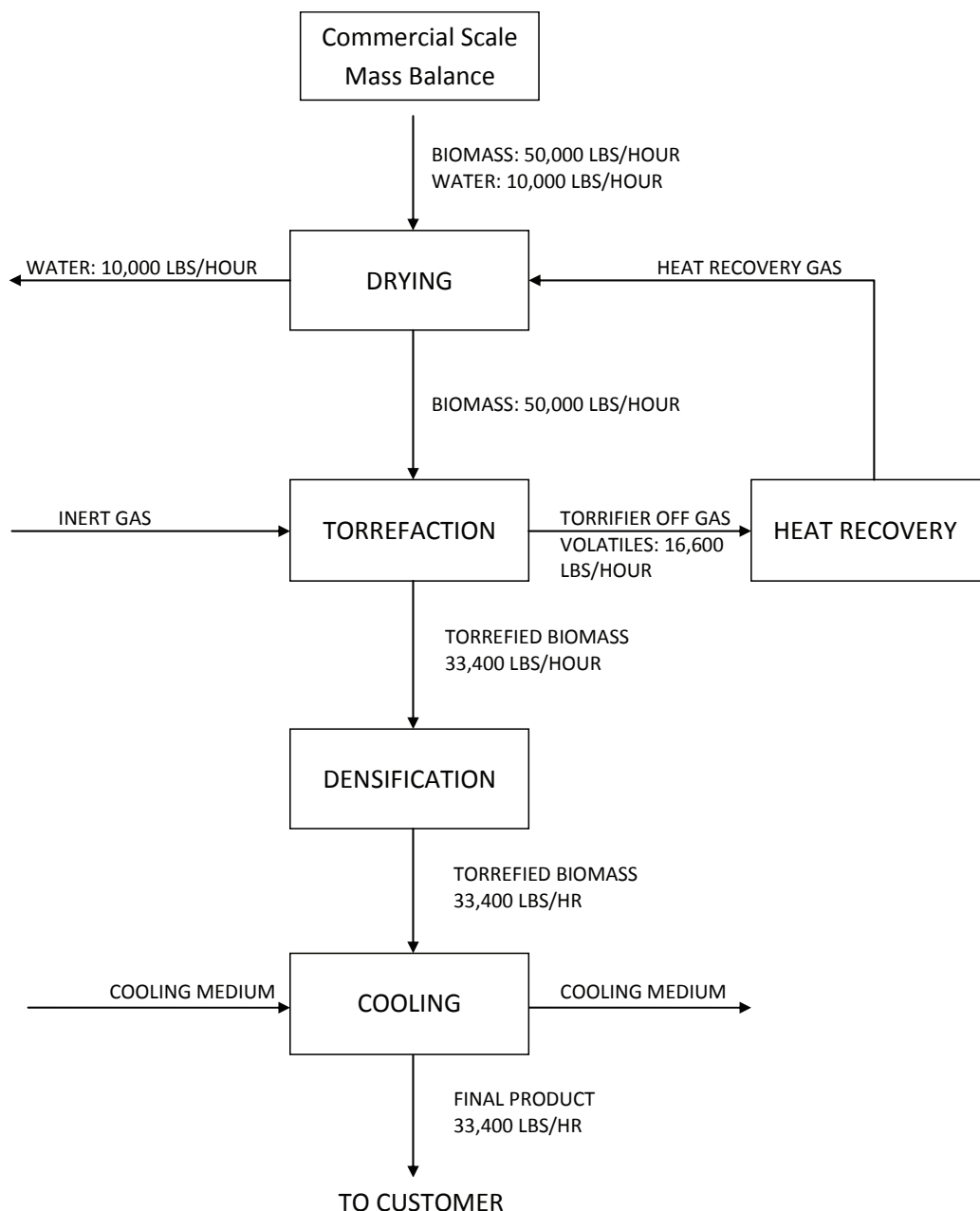
The project is continuing to march forward with work on Milestone 2, 3 & 4. The past five months (December '08 through April '09) have seen pilot scale process development testing in the Bepex central laboratory, preliminary process flow diagram with mass & energy balances, preliminary economic analyses, final design and fabrication of the custom equipment, biomass harvest logistical and economic modeling, and corn stover pre-processing (tub grinding) to affect the demonstration run to commence in June 2009.



Preliminary Process Flow Diagram (PFD), Mass & Energy Balances:

The team has successfully completed the mass and energy balances associated with the pilot scale and bench scale process research and development testing that has been completed to date. Additionally, a process flow diagram indicating one commercial scale plant option of which will be used as the basis for the preliminary economic analysis has been determined and is provided below. The plant scale provides for a final plant capacity of approximately 135 kTon/annum of final product. It should be noted that the system is self-sustaining in that the energy that is released from the raw biomass during torrefaction provides enough energy to drive the biomass drying and torrefaction process once commenced.





Preliminary Economic Analysis:

As a part of Milestone 2 we have generated a preliminary estimate on the installed cost and operating expenses of a commercial scale biomass torrefaction process plant designed to consume 30 tons/hour of raw feed (135 kTon/annum final product). Further refinement of the process and additional scales will be investigated later in the program. The goal of the work was to provide an estimate of the relative costs of operational expenses for the process, based on the major equipment and feedstocks included in the preliminary design of the process.



Common Size Income Statement
Commercial Biomass Torrefaction Plant

100%	Gross Revenue
85.5%	Product
14.5%	Excess Heat
 69.9%	 Cost of Sales
49.6%	Biomass Feedstock
20.3%	Utilities & Fuel
 2.4%	 Salaries & Benefits
3.0%	General Overhead
3.7%	Maintenance Expense
7.6%	Depreciation
6.4%	Interest (6.5% @ 15 Yrs)
2.4%	Income Tax Expense (35%)
 4.5%	 Net Income

We calculate that the commercial scale plant will liberate approximately 52 mmbtu/hour in excess of the plant's thermal demand to drive the process, resulting in an "over the fence" payment for the residual heating value estimated at 14.5% of the total gross revenue of the operating plant. Biomass feedstocks represent 49.6% of the cost of the gross revenue of the plant; the costs consist of harvesting costs (single pass harvester, semi-trucks, baling, nutrient replacement costs, interest carrying charges and farmer premiums). Utilities and fuel represent the utility costs to operate the plant (nitrogen, natural gas, water, electricity and diesel fuel). The Depreciation expenses were determined based on the approximate "economic life" of the individual assets and not the tax basis of the asset to ensure long term plant liquidity.

Using this scale processing plant and comparing our current final product specifications to that of Wyoming Sub-Bituminous coal we calculated the total potential impact to a 150 MW power plant if it were to co-fire the torrefied and densified final product at a 10% rate. Carbon dioxide emissions could be reduced by approximately 142,600 tons / year with sulfur emissions being reduced by 93 tons. Total increases in fuel costs on a per kw-h basis were estimated between \$0.008 and \$0.009 under this operational scenario assuming no monetization of a carbon cap and trade system. One commercial scale plant (135 kTon/year) would provide enough final product to supply this 150 MW power plant with material at the 10% co-fire rate.

Custom Equipment Design & Fabrication

During the past several months, considerable effort has taken place to continue and finish the design of the custom equipment required to affect the Demonstration run. The work took longer than anticipated and resulted in the delayed completion of Milestone 2. The primary pieces of equipment that needed to be custom designed and fabricated, based off of our Process Research & Development included the



torrefaction reactor, a custom heated bag house, densification hopper, and a subsystem designed to utilize the torrefaction by-products to power the system in the future. Additionally, gas-tight modifications to the densification equipment and modifications to the feed handling equipment were designed and fabricated.

Biomass Harvest

During the week of October 27-31, 2008, 55 dry tons of corn stover was successfully harvested and transported from the field to a storage location 9 miles from the field, in Olivia MN.

Material and Methods

The corn stover was harvested from approximately 26 acres, providing 55 tons of dry stover, with an average moisture content of 35%. The estimated grain yield was 177 bu/acre and 19% grain moisture content. Prior to harvest, wind damage caused significant lodging of the corn stover which forced harvesting in a single direction, and a much lower harvest cut height than expected. The average stover yield was 2 tons/acre (dry basis).

A single-pass prototype harvesting systems, based on a John Deere 9750 STS combine was used for harvest. The system consists of a John Deere 9750 STS combine, with modifications including a modified chopper and forage blower for the collection of the stover from the rear of the combine. An 8 row, 863A row crop header was utilized to cut and feed the complete plant above a predetermined cut height, instead of a conventional corn head.

The stover harvested by the combine was directly blown into 42 ft walking floor trailer and semi-truck travelling alongside the combine at the same speed. The loading of the trucks was relatively routine. The use of walking floor trailer was successful. The median mass of stover collected per truck was 5480 lb (wet basis), resulting in a nominal bulk density of 1.8 lb/ft³ per truck load based on a nominal truck capacity of 3000 ft³.

Economic Analysis of Logistics

Based on the observed stover bulk density of 2 lb/ft³, the estimated total harvest and transportation costs (excluding timeliness costs) for grain and stover harvest on a commercial scale was determined to be \$112.89/acre assuming the biomass single pass harvester operates at 75% of field capacity. Of this \$112.89 \$45.65 represents the component from the grain harvest with the remaining \$67.24 being attributed to the corn stover (\$33.62/ton), not including nutrient replacement costs of which were determined to be approximately \$19/ dry ton. Therefore, the feedstock supply costs \$52.62/ton (with no premiums) at a harvest capacity of 75% (target capacity).

Technical Progress: Pilot Testing

Further pilot scale process development work was completed in the last two weeks of December with a drying/torrefying test. The primary goal of the test was to complete a side by side comparison of torrefying with wet feed versus pre-dried feed. The resulting process conditions and end product would be analyzed to determine if it is more beneficial to pre-dry or not. The secondary goals of the test were to improve on material and gas handling procedures and to optimize the compactor operation parameters.

During these tests the team learned a great deal about handling of the material and gas during processing. As a direct result, we have improved our process of feeding and discharging the raw and finished material from



the torrefaction and densification system. We have also developed a set of written start-up and shut-down procedures for our system which will augment the reliability and efficiency of the system for the Demonstration Run.

As a required step in the 5 Ton Demonstration run it is required to pre-process the feedstock to increase the feedstock's particle size uniformity, flow ability and bulk density. This is achieved by a rough size reduction step to reduce the particle size to 1/4" minus through the means of an industrial tub grinder. During the days of December 17 and 18 a Duratech Industries 1150 Haybuster ground up 55 dry tons of corn stover in Olivia, MN. The team encountered no issues during this feedstock pre-processing step. Several images from this activity are included in this report as an Appendix.

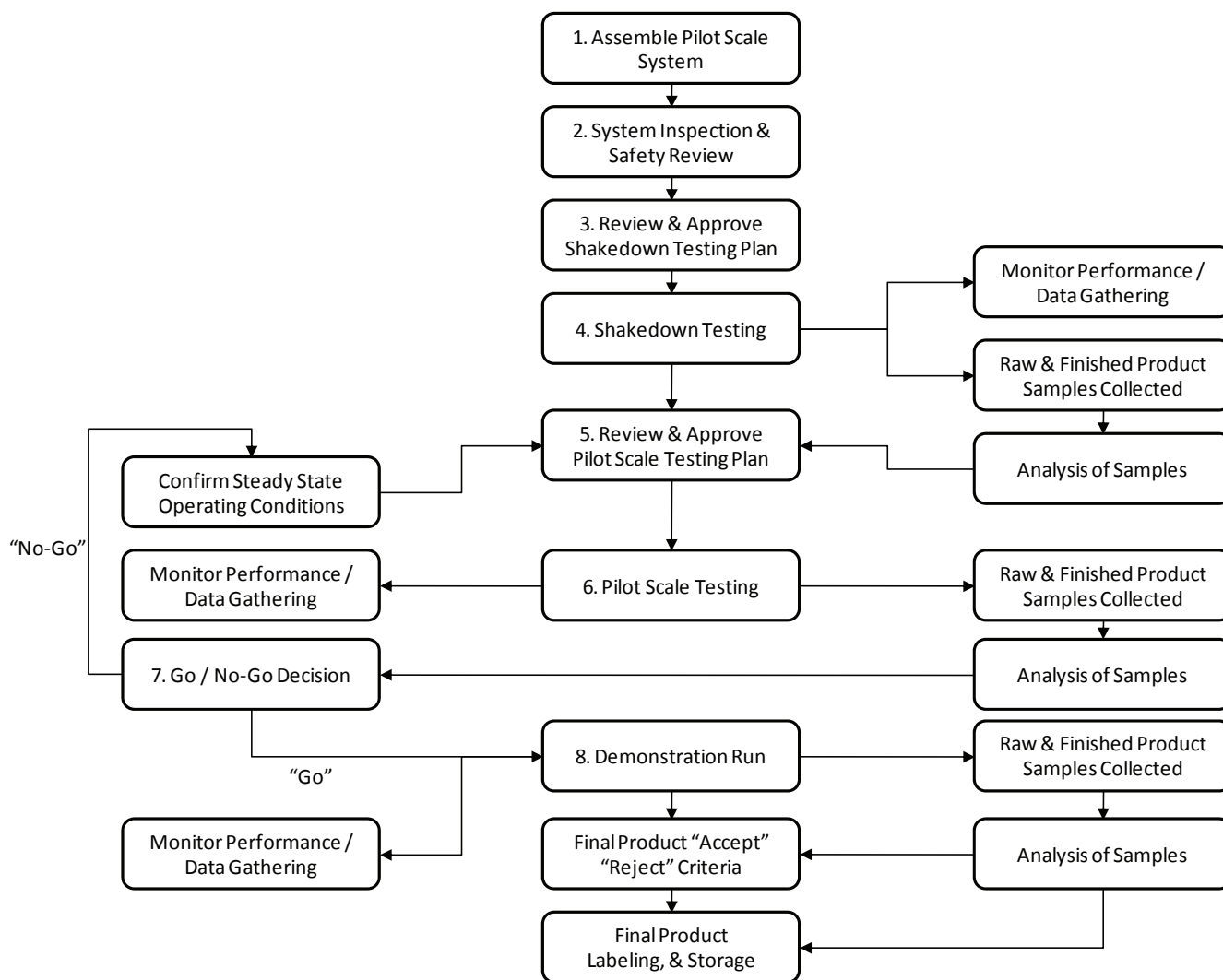
Technical Progress: Demonstration Run

The team continues to conduct detailed planning for the shakedown, pilot testing, and subsequent demonstration run. This includes detailed reviews of the drying, torrefaction, densification, and cooling processes to ensure necessary equipment, instrumentation, and quality control issues are discussed well ahead of the demonstration run to avoid any missing components.

As part of the installation for the shakedown, pilot scale and demonstration run several smaller, sub-components such as interfaces between the major components, hoppers, and feeding screws are required. Many are currently being designed, and are in various stages of completion in regards to fabrication. We anticipate that the fabrication of these transitional pieces for the installation will be completed by early May 2009, such that the system can be assembled and shakedown testing can commence shortly thereafter.

The flowchart below lays the foundation to help ensure that the effort expended during the initial shakedown, pilot plant steady state operation, and demonstration run are properly aligned with the objectives of the Project. The flowchart clearly delineates the path that the effort will take, and how the Project will determine a "Go" or "No-Go" move forward decision based on initial product testing results prior to the start of the 5 ton demonstration run. To state in other words, a pre-steady state operating run will be required to produce representative product in a steady state phase that will be subject to extensive Final Product testing prior to a "Go" approval for the 5 Ton demonstration run using those same steady state operating conditions as the baseline for acceptable product.





During the shakedown, pilot scale steady state and demonstration run it will be important that key operating parameters and output sensors are monitored, and actively controlled to ensure the system maintains its preferred steady state operation. In addition, it is required for the Project that key operating parameters such as energy draws (amperage) and utility usage (nitrogen, electricity, air, natural gas & water) are collected so that commercial scale-up analysis can be reliably conducted for the process. Finally, data collection is required to determine overall torrefaction & densification performance to include a Raw Feedstock and Final Product sampling plan. All of these factors are being taken into consideration as we near the start of shakedown, pilot scale and the demonstration runs.

Additionally, per the above flowchart a Safety Inspection and Safety Review of the pilot plant system was conducted and, as a result of this review, a document detailing the specific safety policies and procedures specific to the pilot plant and supplementary to the existing policies and procedures in the Bepex Central laboratory was developed. All Bepex employees and contractors who will be operating the pilot plant will be trained to these procedures.



Milestones:

We have just completed Milestone 2 are currently working on Milestones 3, 4 & 5.

Milestone 2 primarily consists of furthering the development of the torrefaction process itself to include bench scale, pilot scale, mass & energy balances, custom equipment design and fabrication, biomass harvest and generally getting ready for the 5 ton demonstration run to take place in early 2009.

Milestone 3 primarily consists of the Demonstration Run producing torrefied corn stover briquettes at a specified quality utilizing the custom process equipment developed as a result of the Process Research & Development conducted within Milestones 1 & 2.

Milestone 4 primarily consists of developing benchmarks and testing our product and that of substitute products (biomass fuel pellets and coal) to compare and contrast their storage and bulk handling characteristics. Several analytical tests are currently ongoing with more planned. However, the bulk of this effort will occur during and after product has been produced during Milestone 3.

Milestone 5 consists of conducting the test gasification and combustion tests utilizing the product produced during Milestone 3. We are approximately 85% complete with sub-contract negotiations to perform these testing services on behalf of the project team.

Project Status:

The project has completed the Milestone 2 deliverables of process flow diagrams with mass and energy balances, preliminary economic analysis, custom equipment design and fabrication, and biomass harvesting. While the completion of Milestone 3 is currently anticipated to be delayed until late June 2009 due to the delay in the completion in Milestone 2 we do not currently anticipate any delays for Milestone 4 and 5 deliverables per the original contract.

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Appendix



Duratech Industries Haybuster 1150 & Front End Loader Grinding Corn Stover



Front End Loader Feeding Corn Stover Into Tub Grinder





Mound of 1/4" Minus Ground Corn Stover

