### TECHNICAL REVIEWERS' RATING SUMMARY

**R020-A**

**Commercial Application of Soybean Stalk as a New Alternative Fiber in Particle Boards**

North Dakota State University  
Principal Investigator: Dilpreet Bajwa  
Request for $200,400; Total Project Costs $400,800

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Average Weighted Score: 175 126 145 207 \( \text{Average: 169.33} \) 175.67

Maximum Weighted Score: 250.00

### OVERALL RECOMMENDATION

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R020-A
Commercial Application of Soybean Stalk as a New Alternative Fiber in Particle Boards
Submitted by North Dakota State University
Principal Investigators: Dilpreet Bajwa
Request for $200,400; Total Project Costs $400,800

1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Renewable Energy Council goals are: 1 – very unclear; 2 – unclear; 3 – clear; 4 – very clear; or 5 – exceptionally clear.

Reviewer 1A (Rating: 4)
The proposed objectives are clear and in line with North Dakota Industrial Commission/Renewable Energy Council goals. This proposed project will study the biomass feedstock supply logistics to provide alternative feedstocks to Masonite PrimeBoard, Inc - a North Dakota company manufactures particle board core materials for composite residential doors, which will benefit the economy, industry, and soybean farmers in ND.

Reviewer 2A (Rating: 3)
The author’s clearly identify the objectives of the proposal. These objectives are listed on page 4 of the proposal. These objectives are:
1. To understand the logistics of collection, baling, and transferring agricultural biomass (primarily soybean stalk) from the field to commercial processing plant.
2. To understand the factors affecting the efficiency of processing agricultural biomass.
3. Identifying changes in the equipment/machinery required to minimize the amount of fines generated during processing of the material.
4. To optimize the composition of the low density particle boards that uses a blend of soybean stalk and wheat straw to have similar or better physical and mechanical properties than the currently manufactured boards.

Reviewer 3A (Rating: 4)
The proposal does a very good job of clearly identifying objectives and how they are in line with the overall goals of the ND program. One issue to note is that this project does not have much to do directly with "renewable energy", per se. However, it very clearly has beneficial environmental and "green economy" benefits, as it would increase the use of agricultural waste for economic viable purposes (if successful).

2. With the approach suggested and time and budget available, the objectives are: 1 – not achievable; 2 – possibly achievable; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable.
Reviewer 1A (Rating: 4)
The proposed approaches and budget are most likely achievable. One suggestion is to study the thermal stability of the materials as temperature rise during process might cause degradation of materials.

Reviewer 2A (Rating: 3)
The objectives are relatively straightforward and likely achievable given the time and resources described in the proposal.

Reviewer 3A (Rating: 4)
Given the available resources and the deep backgrounds of the investigators, and particularly given that another group in Iowa appears to have been successful with a similar project, we can anticipate that the objectives are most likely achievable. In particular, the project team can point to some early indicative results that they can build upon. The facilities to be used seem very appropriate, and the collaboration brings together technical resources and business team.

3. The quality of the methodology displayed in the proposal is: 1 – well below average; 2 – below average; 3 – average; 4 – above average; or 5 – well above average.

Reviewer 1A (Rating: 3)
A general methodology was provided. Detail information such as the range of the parameters (moisture content, screen size …) will be helpful. Only one level was selected for density and resin for each feedstock in the Design of Experiments. It would be helpful to the reviewers if the methodology were provided based on the objectives.

Reviewer 2A (Rating: 23)
Overall, I felt the proposal was very weak in its scientific rigor and methodology. Essentially, the proposal topic is overly simplistic, and the authors merely propose to replace wheat straw with soybean (and corn) stalk in some proportions in the existing particle boards. The technology is not new (for example Agristrand Mankato already manufactures a similar Soy-straw particle board) or innovative.

PIs Comment – This proposal addresses the needs of a ND-based industry. The project will significantly contribute towards the economic development of ND and future growth of green/bio-products industry in ND. The methodology explained may appear simplistic but poses significant engineering challenges. The processing of wheat straw is significantly different from soy stalk. Soy stalks are stiffer, with low bulk density and minimal cutin, a waxy substance. Therefore dry processing (hammer milling, refining, drying and mat lay-up) with soy stalk is different from wheat straw. The two plant fibers interact differently with resins because of their biochemical make up. Wheat straw particles cannot be bonded with conventional adhesives due to high cutin content, therefore an expensive polymeric adhesives called MDI is used. Soy particles can be bonded with inexpensive resins such as urea formaldehyde therefore resin application and curing system will be different for soy straw boards. The long-term goal of the investigators for this project is to develop a 100% green fiber board that would use bio-based resin in place of MDI or urea formaldehyde, which would be an innovative product. This product
would allow the industry to take advantage of the LEED credit for this material used in building construction. We would also like to point out that this type of research falls under the priorities established by USDA and DOE, and the recent publications and patent activity (Appendix A) indicate the relevance and importance of such research.

While our research focus on low density fiber boards, Agristrand manufactures medium density boards using a set of entirely different processes [1]. Their process involves depithing, moisturizing (steaming), sizing, drying, and then applying resin (urea formaldehyde 5-12%). Our research is also aimed at identifying other OEM products and applications of soy stalks. (Note, all the references are in Appendix A)

Reviewer 3A (Rating: 5)
The methodology appears to be very well-grounded in pragmatism and upon validating data. They’ve identified a seemingly viable use for this agricultural waste, and even produced some preliminary results. They provide sufficient detail as to the process that it, along with the backgrounds of the investigators, provides comfort in the overall methodology.

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Renewable Energy Council goals will likely be: 1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant.

Reviewer 1A (Rating: 3)
Evaluation of the possibility to replace wheat straw with (partially with) soy stalks as a new alternative fiber in particle boards will be beneficial to Masonite Prime Board Inc. and soybean farmers, but the scientific contribution is limited.

Reviewer 2A (Rating: 12)
The scientific and technical contribution of the proposed work is minimal. No significant scientific breakthroughs are expected.

PIs Comment - This research ties with PIs and Masonite’s long term goals of producing fully biobased building and industrial products (Soy straw with Soy resin). The proposed project is aimed at meeting the increasing demand for sustainable bio-based and biodegradable materials. The PI is currently exploring, with the support of a Soybean Council grant, the properties of a soy-based resin and its suitability to be used in composite materials. The project we proposed will take us close to a completely biodegradable low density fiber board. Such a product will fall under the USDA’s Biopreferred program and Green Building Council’s LEED certification, which promote renewable products. Currently 30-50% of construction debris is recalcitrant in landfills [2]. It is expected that this process will be free of water use and discharge, and will produce minimal amount of fines that pose a fire hazard. The boards produced will have significantly lower resin content (2% - 3%), therefore meeting EPA guidelines for formaldehyde emissions.

Reviewer 3A (Rating: 4)
If successful, this project is likely to add wealth for landowners and agriculture producers to build and maintain a robust rural economy, as it could provide additional economic benefits to existing agricultural activities.

The presence of an existing relevant manufacturer in ND, and their involvement in the project, suggests a high potential for creating new renewable resource jobs, wealth, and tax revenues for North Dakota.

Soy is a major source of input for biodiesel production. If the proposed work results in additional revenue for soy farmers, it would help to maximize the market potential for renewable energy resources and the associated byproducts produced therewith.

5. The principal investigator’s awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 1A (Rating: 3)
The PIs know the needs of the industry very well, but lacking of a comprehensive discussion of the current research activity and published literature.

Reviewer 2A (Rating: 4)
The authors fail to reference ANY scientific literature related to the project. They describe some preliminary results in their own research which is listed in Appendix A, stating that boards made with various amounts of soy straw showed promise in terms of improved mechanical properties, but failed to list any values for these mechanical properties (other than to say they improved).

PIs comment: Due to page limitation, PIs didn’t include active literature review. The use of agricultural fibers for construction and automotive application is a widely researched area. Agriculture fibers are being used by several industries including construction and landscaping (deck boards, sidings, and furniture), automotive (composite panels, flooring) and by packaging industry [3, 4]. Several recent studies have highlighted the potential of soy fibers in the medium density boards, and polymer composites [5, 6, 7]. A recent study conducted a non-destructive performance prediction of soy stalk boards [8]. The “Billion-Ton Annual Biomass Study” by DOE and USDA highlights the potential of and importance of using agricultural biomass in making building products [9]. In summary this type of study is a priority for both USDA and DOE.

Reviewer 3A (Rating: 3)
The academic researchers as part of this team appear to have a background and current position that should enable them to be fairly aware of relevant current research activity.

It's unclear from the proposal how exhaustive their body of knowledge currently is regarding other efforts to produce particleboard using waste soy and corn material. They do point to the existence of a plant in Iowa, but this raises a concern about intellectual property. Namely, do
other parties hold intellectual property that would prevent the success of this project in terms of its ultimate commercial viability. This is not an insurmountable concern -- it's likely that IP is not an issue at all, or if it is that Masonite could license any relevant IP necessary. But it is a question that should be delved into deeper by the team.

6. **The background of the investigator(s) as related to the proposed work is:** 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

*Reviewer 1A (Rating: 4)*  
The PI has the background for the proposed work.

*Reviewer 2A (Rating: 4)*  
The investigators include two Ph.D. educated investigators with 28 years of combined experience in the field of bio-composites.

*Reviewer 3A (Rating: 5)*  
Dr. Dilpreet Bajwa has a very relevant background for pursuing this research, with multiple prior roles in R&D in the composites industry, and having authored several chapters in books on this very topic.

Dr. Sreekala Bajwa, as chair of the Department of Ag & Biosystems Engineering at NDSU, is similarly well-positioned, and also should be able to help attract the student resources necessary for this project's operations.

The team from Masonite International Wahpeton provide the real-world operations expertise to help ensure that the results are relevant, replicable, and economic outside of an academic research setting.

7. **The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is:** 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – very good; or 5 – exceptionally good.

*Reviewer 1A (Rating: 3)*  
The proposal has a detailed schedule. On suggestion is to conduct the economic analysis (Task 2) after experimental study for determining the optimal processing conditions.

*Reviewer 2A (Rating: 3)*  
The management plan is typical and adequate. The lab experiments to identify formulations starts rather late in the project, and it is not clear what the team will be doing during the first 3 tasks of the timetable (consisting of data collection on soybean stalk data and economic analysis).

*Reviewer 3A (Rating: 4)*
The plan seems feasible and realistic.

8. The proposed purchase of equipment is: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.)

Reviewer 1A (Rating: 3)
The equipment name were mentioned, but without quote from manufactures.

Reviewer 2A (Rating: 3)
The investigators propose to spend $45,000 for a hot press ($5,000) and an instron testing machine ($40,000). This equipment is necessary to complete the proposed work, but are not particularly specialized pieces of equipment and would already be available at most university research laboratories related to characterizing material properties.

Reviewer 3A (Rating: 2)
Justification is lacking for the small portion of the requested budget that is dedicated for equipment purchases. At this small amount it's not concerning, but this could be a follow-up question to ask the team, just for program clarity.

9. The facilities and equipment available and to be purchased for the proposed research are: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good.

Reviewer 1A (Rating: 4)
The facilities and equipment are adequate for the proposed project.

Reviewer 2A (Rating: 3)
The listed facilities and equipment seem adequate to complete the proposed research.

Reviewer 3A (Rating: 5)
It would be difficult to picture a more appropriate setting for this work than the actual manufacturing facility where the products would eventually be produced.

10. The proposed budget “value” relative to the outlined work and the financial commitment from other sources is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value. (See below)

Reviewer 1A (Rating: 3)
The proposed project is valuable and the budget request is reasonable. Only for equipment, it may be more economical to test mechanical properties in other labs or in Masonite other than purchasing an instron ($40,000).

Reviewer 2A (Rating: 4)
Apart from the $45,000 for relatively standard equipment the value seems above average. There is a significant in-kind support from the partner company (Masonite Co.), although all cash match would have been even more effective in showing a strong value.

**Reviewer 3A (Rating: 5)**
In a larger corporate R&D setting, the budget for a program like this would likely be much higher. Much of the salary-driven cost would be born, whereas here it is defrayed by project partners.

1 “Value” – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.

10a. **Financial commitment from other sources** – A minimum of 50% of the total project must come from other sources to meet the program guidelines. Higher priority is to be given if the application has private industry investment equal to or at least 50% or more of total cost.

The minimum 50% cash match is demonstrated.

**Section C. Overall Comments and Recommendations:**

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

**Reviewer 1A (Fund)**
Overall this project will be beneficial to the industry and economy of ND although the proposal can be further improved technically in some aspects. The collaboration and commitment from Masonite will be critical to this project. Although CO-PIs from Masonite are included, but there is no commitment letter from the company.

**Reviewer 2A (Do-Not-Fund  Funding May Be Considered)**
The topic of the proposal is rather low-tech and not very innovative. I don’t anticipate any significant scientific innovations coming out of the proposed research. The proposed economic impact of the proposed work is completely unsubstantiated in the proposal. For example, the investigators contend that the economic impact is estimated to be $6 million/year, but give no justification for how that estimate was calculated.

PIs comment: The economic impact is based on several factors such as new raw material purchase, increased payroll, growth forecast, energy use, material handling and transportation cost, business lost due to lack of adequate amount of suitable quality raw material (wheat straw), the cost of business opportunity lost with the increase in raw material cost, and the increase in production possible with the recovery of building industry if adequate raw material is available. With the increase in raw material cost and decrease in availability, there is possibility of plant reducing its capacity or moving out to another region. Currently the plant is paying over 3
million for buying wheat straw, 2 million in payrolls, 1 million for energy and 0.5 million in material collection and transportation. With soy straw as an alternate raw material, the industry will be able to expand their business, reduce processing loss of materials (reducing environmental burden), and capture new markets for green materials. All these cost centers are generating revenue for the state. Including a growth projection of 20% to account for the growth in building materials sector, the economic impact of this project will be over $6 million.

Reviewer 3A (Fund)
This seems like a very pragmatic effort to develop new economic value from a local renewable resource. The team seems very well-positioned for the project. If it's successful (and they have early results to indicate a high likelihood of success) a local commercial partner is already involved. This seems like a generally low-risk project that is very much in line with the objectives of the ND state program.

Appendix A (References)


