SUBJECT
Intent to Plan: SDSMT MS in Green Chemistry

CONTROLLING STATUTE, RULE, OR POLICY
BOR Policy 2:23 – Program and Curriculum Approval

BACKGROUND / DISCUSSION
South Dakota School of Mines & Technology (SDSMT) requests permission to plan a Master of Science (MS) in Green Chemistry. This program would focus on development of new chemical processes and products to address pressing needs pertaining to the synthesis of green chemicals and polymers, efficient waste treatment, materials for green electric power generation and storage, environmentally benign processes, and green microbiology. This program would tie into the BS in Chemistry currently offered at SDSMT. Program graduates should be well positioned for green jobs (e.g., jobs related to energy conservation, alternative energy sources, pollution reduction, recycling, etc.), which are in high demand nationally. In addition, South Dakota ranks as a leading state in terms of green power generation and consumption.

IMPACT AND RECOMMENDATION
The proposed program is within SDSMT’s mission as presented in BOR Policy 1:10:3 and SDCL 13-60, including authorization for graduate programs emphasizing science and engineering. There are currently no programs in the public university system in Green Chemistry; however, traditional Chemistry master’s programs exist at USD and SDSU. SDSMT estimates graduating up to 10 students per year after full implementation.

Board office staff recommends approval of the intent to plan with the following conditions:

1. The university will research existing curricula, consult with experts concerning the curriculum, and provide assurance in the proposal that the program is consistent with current national standards and with the needs of employers.

DRAFT MOTION 20190626_7-B:
I move to authorize SDSMT to develop a program proposal for an MS in Green Chemistry, as presented.
2. The proposal will define the specific knowledge, skills, and competencies to be acquired through the program, will outline how each will be obtained in the curriculum and will identify the specific measures to be used to determine whether individual students have attained the expected knowledge, skills, and competencies.

3. The university will not request new state resources without Board permission, and the program proposal will identify the sources and amounts of all funds needed to operate the program and the impact of reallocations on existing programs.

ATTACHMENTS
Attachment I – Intent to Plan Form: SDSMT – MS in Green Chemistry
SOUTH DAKOTA BOARD OF REGENTS
ACADEMIC AFFAIRS FORMS

Intent to Plan for a New Program

Use this form to request authorization to plan a new baccalaureate major, associate degree program, or graduate program; formal approval or waiver of an Intent to Plan is required before a university may submit a related request for a new program. The Board of Regents, Executive Director, and/or their designees may request additional information. After the university President approves the Intent to Plan, submit a signed copy to the Executive Director through the system Chief Academic Officer. Only post the Intent to Plan to the university website for review by other universities after approval by the Executive Director and Chief Academic Officer.

<table>
<thead>
<tr>
<th>UNIVERSITY:</th>
<th>SDSM&amp;T</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEGREE(S) AND TITLE OF PROGRAM:</td>
<td>MS in Green Chemistry</td>
</tr>
<tr>
<td>INTENDED DATE OF IMPLEMENTATION:</td>
<td>Fall 2020</td>
</tr>
</tbody>
</table>

University Approval
To the Board of Regents and the Executive Director: I certify that I have read this intent to plan, that I believe it to be accurate, and that it has been evaluated and approved as provided by university policy.

__________________________
President of the University

Click here to enter a date.

Date

1. What is the general nature/purpose of the proposed program?

The proposed program in Green Chemistry (GC) will be an educational and research program in the broad new area of Green Chemistry. Green Chemistry research foci include development of new chemical processes and products to address pressing needs pertaining to the synthesis of green chemicals and polymers, efficient waste treatment, materials for green electric power generation and storage, environmentally benign processes, and green microbiology.

The proposed M.S. program rests on the American Chemical Society-certified BS program at SDSMT. The Department of Chemical and Applied Biological Sciences (CABS) already benefits from the expertise of and collaboration with faculty in civil engineering, chemical and biological engineering, materials engineering and science, and atmospheric sciences.

South Dakota is among the top US states in terms of green power generation and consumption based on green job market index[1]. South Dakota is among the states with the highest percentage of electricity generation from renewable resources, typically over 70%. In 2011, South Dakota became the first U.S. state to have at least 20% of its electricity generation come from wind power [2]. The proposed program will be the first of its kind in South Dakota and in Minnesota, North Dakota, Wyoming, and Montana. South Dakota has broad geographic capabilities to exploit sustainable energy sources while advancing economic development via green jobs, products, and
technologies. Agribusiness is a dominant economic sector of the state and ethanol producers, such as POET, could benefit from and support the proposed program.

The American Chemical Society (ACS) regards Green Chemistry [3] and Sustainable Energy [4] as inseparable aspects of green chemistry and considers green chemistry as a branch of science focused on major and fast growing concerns regarding anthropogenic impacts on sustainability of our planet. The ACS [5] strongly supports the efforts to minimize detrimental anthropogenic environmental impacts via eco-friendly chemical processes and sustainable energy solutions. This field is currently wide open for innovation, new ideas, and revolutionary progress.

The proposed program will retain top-level in-state students and attract regional, national and international students. Students will have a flexibility in choosing a thesis, non-thesis, or accelerated MS Green Chemistry option and have many collaborative research opportunities at SDSMT and within the SDBOR system.

2. What is the need for the proposed program (e.g., regental system need, institutional need, workforce need, etc.)? What is the expected demand for graduates nationally and in South Dakota (provide data and examples; data sources may include but are not limited to the South Dakota Department of Labor, the US Bureau of Labor Statistics, Regental system dashboards, etc.)?

The US Bureau of Labor Statistics (BLS) [6] defines green jobs as those related to preserving or restoring the environment. Climate change, rising energy costs, hazardous wastes, energy security, and ensuring human health are the most urgent challenges. Categories of “green jobs” include (1) producing energy from renewable sources, (2) improving energy efficiency, (3) preventing and cleaning up pollution and greenhouse gases, and (4) conserving natural resources. Green goods and services are classified by the industry sector [6].

Clean and sustainable energy [7] in the form of wind, solar, and hydroelectric power comprised 18% of all U.S. electricity production in 2017 (up from 15% the prior year). In 2017, the solar industry alone employed nearly 100,000 U.S. workers (up 20% from 2015), and today the wind and solar industries [8] employ more than 300,000 Americans. State and local governments are rapidly tapping into this growing industry to develop their economies. Wherever corn and wheat fields dominate the landscape, local governments are sponsoring programs to build wind and solar farms next door to the traditional ones, convert agricultural waste into high-value organic products, and produce green energy fuels.

The BLS [6] classifies additional green jobs as shown in the table below, where the number and percent distribution of establishments in industries with green goods and services are classified by an industry sector.
The BLS includes in green jobs workers who perform the following example activities:
- Developing processes to conserve energy or natural resources or to reduce pollution (e.g., a chemical engineer developing manufacturing processes to reduce harmful emissions);
- Planning, implementing, and monitoring processes related to renewable energy generation;
- Maintaining or installing equipment or infrastructure associated with renewable energy processes; and,
- Measuring and controlling outputs of energy-generation processes.

The ZipRecruiter Best Job Market Index [9] provides Metropolitan statistical areas (MSAs) to illustrate concentrations of renewable energy employment. Fig. 1 shows this index analysis of green-related employment opportunities combined with quality of life. One can observe a high concentration of green initiatives in bio-fuel and/or wind-energy rich areas. The Index also suggests opportunities to expand such activity across South Dakota.

<table>
<thead>
<tr>
<th>Industry sector</th>
<th>Number of establishments</th>
<th>Percent distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>820,700</td>
<td>38.1</td>
</tr>
<tr>
<td>Professional and business services</td>
<td>779,100</td>
<td>36.2</td>
</tr>
<tr>
<td>Other services (Repair and maintenance services, Professional organizations)</td>
<td>183,300</td>
<td>8.5</td>
</tr>
<tr>
<td>Natural resources and mining</td>
<td>88,700</td>
<td>4.1</td>
</tr>
<tr>
<td>Information</td>
<td>77,000</td>
<td>3.6</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>77,700</td>
<td>3.6</td>
</tr>
<tr>
<td>Trade, transportation, and utilities</td>
<td>49,300</td>
<td>2.3</td>
</tr>
<tr>
<td>Public administration</td>
<td>42,100</td>
<td>2.0</td>
</tr>
<tr>
<td>Education and health services</td>
<td>26,400</td>
<td>1.2</td>
</tr>
<tr>
<td>All other sectors</td>
<td>10,400</td>
<td>0.5</td>
</tr>
<tr>
<td>Total</td>
<td>2,154,700</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Renewable energy employment increased by nearly 18% between 2015 and 2016 according to the Department of Energy. Currently, 3.2 million Americans are employed in clean energy, 2.5 times
more than those employed in fossil fuel industry [10]. Solar jobs are growing 17 times faster than the U.S. economy. Wind capacity under construction or in advanced development grew 41% from 2016 to 2017 [11] according to the American Wind Energy Association (AWEA). Thirty percent of all in-state energy is produced largely by the thirteen wind energy projects underway in and around Sioux Falls [12]. Although South Dakota is a leader in wind energy production, it lags behind in large-scale solar production and green-energy research and development. As mentioned, the fields of green energy and green chemistry are currently wide open for innovation, new ideas, and revolutionary progress.

In this regard, a planning grant project at SDSMT “Center for Solid-State Green Electric Power Generation and Storage (CEPS)”, recently awarded by the NSF Industry University Cooperative Research Center (IUCRC) program, would have a synergistic effect in regard to the proposed GC program at SDSMT. Based on the long-term partnerships between four universities (SDSMT, SDSU, USD, and NEU), industry, national laboratories, and state and federal institutions, the IUCRC CEPS will bring new students to GC program, provide their financial support, professional expertise, and green energy jobs placement at the corresponding industrial sites of the CEPS members.

The proposed program will provide expertise in areas needed for SD industry to expand and for researchers to secure a portion of the significant grant funds available in this field. A Green Chemistry MS program has a high potential to benefit state economic development. To the best of our knowledge, no state or regional peers have a similar program.

3. How would the proposed program benefit students?

The proposed program will provide students with post-baccalaureate education, leading to an MS degree in green chemistry. Relative to students with BS degrees in this area, MS degree will: (1) Increase the students’ employment; (2) Increase the average salary at entry; and (3) Reduce the time to promotion.

At present, many undergraduate students indicate that they intend to pursue an equivalent MS degree out of state. The proposed green chemistry will be attractive to out-of-state students and international students as this field is growing rapidly and expertise in this area is in high demand.

The proposed program provides professional preparation for jobs in industry, national labs, and universities and/or careers in research and development and management.

Industry leaders as SAFT America, Dow Chemical, 3M, Tesla, and POET seek employees with the skills this program will impart. Most automotive companies, such as Ford, GM, Nissan, Toyota, and those developing solar energy systems will benefit from hiring MS GC graduates.
from SDSMT. It is important to emphasize, that most of these companies will be involved in the NSF IUCRC CEPS project.

The success of comparable to GC programs in the US and around the world [14, 15] provides strong evidence that this program could be a game-changing opportunity for many prospective SDMS students and for the state economic development.

4. How does the proposed program relate to the university’s mission as provided in South Dakota Statute and Board of Regents Policy, and to the current Board of Regents Strategic Plan 2014-2020?1

The BOR Policy 1:10:3 provides the mission of South Dakota School of Mines and Technology as “that of a technological university specializing in undergraduate and graduate education emphasizing science and engineering” and SDCL 13-60-1 states the school “shall provide undergraduate and graduate programs of instruction in engineering and the natural sciences and other courses or programs as the Board of Regents may determine.” The proposed program will support all components of the SD Mines mission by preparing leaders in chemistry, engineering, and science. It will advance knowledge and its application through support of faculty-led and externally supported research. It will serve the region, the state, and the nation by providing well-trained graduates to drive economic development in green science and technology.

The program will support the SDBOR Strategic plan in the following ways:

- **Student Success** by increasing the number of graduate degrees awarded and by attracting / retaining more non-resident students in South Dakota
- **Academic Quality and Performance** by creating a new graduate program for the state
- **SD state workforce development** by providing workers to support the existing green technologies and initiate development of new technologies in SD
- **Research and Economic Development** by increasing grant and contract expenditures and the number of graduates from STEM programs.

The topic of economic development merits requires further extrapolation. The trend of large corporations ‘outsourcing’ their R&D to research universities can be seen in the enormous sums being invested in or made available to researchers. The following is a small representative sample of the types of funding initiatives for which researchers in the proposed program could be competitive:

- Top Renewable Energy Financiers Reveal Pathway to $1T (trillion) in U.S. Investment [16]
- Volkswagen invest $100M in California solid-state battery startup QuantumScape Stanford University spinoff [17]
- Toyota, Nissan, Honda, Panasonic partner to develop solid-state batteries [18]
- Tesla: Working on green energy storage with solid-state batteries since 2011 [19]
- Fisker Emotion: Green thin-film technology in partnership with Tesla to radically improve battery technology [20]
- Ford Motor Company [21]:

1 South Dakota statutes regarding university mission are located in SDCL 13-57 through 13-60; Board of Regents policies regarding university mission are located in Board Policies 1:10:1 through 1:10:6. The Strategic Plan 2014-2020 is available from https://www.sdbor.edu/the-board/agendaitems/Documents/2014/October/16_BOR1014.pdf.
GM and Honda are partnering for all-solid-state battery development [22]
Greentechmedia [23]
In 2018 California’s utility regulators approved a proposal from the Pacific Gas & Electric to build the two largest battery systems in the world in lieu of paying to keep existing gas plants online for grid reliability [24].

5. Do any related programs exist at other public universities in South Dakota? If a related program already exists, explain the key differences between the existing programs and the proposed program, as well as the perceived need for adding the proposed new program. Would approval of the proposed new program create opportunities to collaborate with other South Dakota public universities?

The state of South Dakota ranks among the top US states for green power generation and ethanol production that are the components of Green Chemistry, which overarching goals, namely, more resource-efficient and inherently safer design of molecules, materials, products, and processes—can be pursued in a wide range of contexts. Currently, there are no MS programs similar to the proposed GC program at SDSMT. However, a few programs at SDSU, USD, and BHSU in sustainability offer specific topics that will be incorporated into the GC program (Table 1).

As a new, important, and most attractive branch of science, Green Chemistry addresses the growing needs of environmental sustainability and has its own specific topics and requirements: [https://www.thoughtco.com/branches-of-chemistry-603910](https://www.thoughtco.com/branches-of-chemistry-603910).

The cohesiveness of the proposed Green Chemistry program is defined by its major R&D goal focused on the processes and products that eliminate or reduce the use or release of hazardous substances. The MS Chemistry programs at USD or SDSU do not specifically address this goal, but rather consider traditional branches of chemistry with addition of courses that have some relevance to the Green Chemistry.

The focus on the aspects of Green Chemistry in the proposed program defines its cohesiveness and distinguishes it from the programs at USD or SDSU. However, some courses offered at USD or SDSU will be included as electives that will bring broader students’ participation and awareness of the Green Chemistry challenges to both faculty and students within the state.

In the proposed Green Chemistry program, traditional classes such as inorganic, organic, or physical chemistry, will be modified to include the most recent aspects of Green Chemistry. There are no such classes proposed at SDSU or USD. This unique program builds on the broad, technical foundation acquired through the industry-university programs. One of such initiatives, the “Center for green solid-state electric power generation and storage” (Director Dr. Smirnova, SDSMT) has been approved by the NSF IUCRC program and will bring into the state $1.2 million or more per year starting later in 2019.

It is evident from the proposed curriculum, that Green Chemistry program includes a number of elective courses listed at USD or SDSU. Considering the interdisciplinary nature of Green Chemistry and its broad definition, this decision will support our vision of Green Chemistry as a state-wide program that will utilize the knowledge, capabilities, and resources at other universities. The elective courses from USD and SDSU included into the Green chemistry curriculum will
enhance students’ knowledge and capabilities in choosing diverse professional backgrounds relevant to both traditional Green Chemistry areas as well as the cutting-edge Green Chemistry interdisciplinary fields.

6. **Do related programs exist at public colleges and universities in Minnesota, North Dakota, Montana, and/or Wyoming?** *If a related program exists, enter the name of the institution and the title of the program; if no related program exists, enter “None” for that state. Add additional lines if there are more than two such programs in a state listed.*

To the best of our knowledge, the public universities and programs in MI, WY, ND, and MT do not have GC programs at the same MS degree level. The Associate Degree and BS educational programs, and the schools/departments where the relevant classes are listed in these states are provided below.

Table 1: Relevant programs in MI, ND, MT, and WY

<table>
<thead>
<tr>
<th>State</th>
<th>Institution</th>
<th>Program Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minnesota</td>
<td>Century college</td>
<td>Associate in Applied Science Degree in Solar and renewable energy</td>
</tr>
<tr>
<td>North Dakota</td>
<td>University of North Dakota</td>
<td>Sustainable Energy Concentration (B.S. in Chemical Engineering)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="https://engineering.und.edu/chemical/undergraduate-students/sustainable-energy-concentration.cfm">https://engineering.und.edu/chemical/undergraduate-students/sustainable-energy-concentration.cfm</a></td>
</tr>
<tr>
<td>Wyoming</td>
<td>University of Montana</td>
<td>Sustainable Energy Technology (Associate in applied science)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="http://mc.umt.edu/acet/Academic_Programs/NRGY/default.php">http://mc.umt.edu/acet/Academic_Programs/NRGY/default.php</a></td>
</tr>
<tr>
<td></td>
<td>University Wyoming School of Energy</td>
<td><a href="http://www.uwyo.edu/registrar/university_catalog/chem.html">http://www.uwyo.edu/registrar/university_catalog/chem.html</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="http://www.uwyo.edu/ser/">http://www.uwyo.edu/ser/</a></td>
</tr>
</tbody>
</table>

7. **Are students enrolling in this program expected to be new to the university or redirected from other existing programs at the university?**

Students that apply to this program could be new (e.g. in-state, out-of-state, and international), or they could be the former BS graduates from CABS or any other SDSMT department or program.

We expect that the Green Chemistry program will bring more students to SDSMT and the SD public university system that otherwise would not be attracted to the state programs. This expectation is based on the rapid growth of green chemistry programs nationally and worldwide. Supporting this assumption are the comments and requests coming from seniors in chemistry and applied biological sciences programs at SDSMT. Students are signaling their strong interest in this field of study and a willingness to continue education at SDSMT, if this program is approved.

Furthermore, our expectation is based on the knowledge of the fast growing research and development in this area and the corresponding market expansion (>17% Compound Annual Growth Rate).

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2 This question addresses opportunities available through Minnesota Reciprocity and WICHE programs such as the Western Undergraduate Exchange and Western Regional Graduate Program in adjacent states. List only programs at the same degree level as the proposed program. For example, if the proposed program is a baccalaureate major, then list only related baccalaureate majors in the other states and do not include associate or graduate programs.
As a Director of a new governmental and international NSF IUCRC “Center for green solid-state electric power generation and storage” (CEPS), Dr. Smirnova is currently talking to many in-state and out-of-state industry representatives who express their interest in hiring students with this degree.

The synergistic effect from combining the proposed Green Chemistry educational program with the CEPS R&D mission of developing industry-university collaboration in Green Chemistry involving sustainable energy will establish a new direction in the SD economic development.

8. What are the university’s expectations/estimates for enrollment in the program through the first five years? What are the university’s expectations/estimates for the annual number of graduates from the program after the first five years? Provide an explanation of the methodology the university used in developing these estimates.

The outreach program in Green Chemistry and the summer camps offered since 2013 at SDSMT grow yearly in popularity and attract students from across the US. [https://www.sdsmt.edu/Academics/Departments/Chemistry-and-Applied-Biological-Sciences/Outreach/Green-Chemistry-Outreach-Program/](https://www.sdsmt.edu/Academics/Departments/Chemistry-and-Applied-Biological-Sciences/Outreach/Green-Chemistry-Outreach-Program/).

The growing success of the outreach Green Chemistry program at SDSMT could be extrapolated to the MS in Green Chemistry. Success will be further ensured by the growing importance of green chemistry in high school curricula, as emphasized by the ACS [25]. Based on the importance of the Green Chemistry education and research at the state and national level, we envision that within the first 5 years the enrollment will grow to at least 20 students.

There is evidence that these numbers are realistic and can be provided in this GC program. For example, with growing SD greentech approach as a part of the NSF IUCRC Center program with involvement many in-state and out-of-state universities, agencies, and industries, these numbers will be easily achieved.

The program is designed to require 2 years for MS candidates to complete their education. Within the first 5 years, this will result in 2-3 to 10 students graduating from the program each year. With increased faculty size and research expenditures, the demand capacity for this degree could increase up to 50 students. However, this does not mean that additional faculty is needed to offer this program. The school has sufficient number of faculty that will be offering the required and elective courses listed in Appendix D.

We expect at least 5 students to enroll in Year 1. Thereafter, enrollment should increase steadily from the initial 5 to 20 after 3 to 4 years. As with other SDSMT programs, we anticipate at least 30% of enrollments to be international students.

The MS GC program (30 credits, Appendix C) will have a thesis and non-thesis option. The core courses (12 credits) will include four courses currently taught in CABS (Appendix D). They will be complemented by the new CABS courses or extra-departmental courses (Appendix D). The extra departmental courses will be chosen from the existing CEE and CBE courses and from the MES and AES programs.
Cross-listing of the required courses (Appendix D) will allow to avoid higher teaching load for the faculty in the CABS department.

9. Complete the following charts to indicate if the university intends to seek authorization to deliver the entire program on campus, at any off campus location (e.g., UC Sioux Falls, Capital University Center, Black Hills State University-Rapid City, etc.) or deliver the entire program through distance technology (e.g., as an on-line program)?

<table>
<thead>
<tr>
<th>On campus</th>
<th>Yes</th>
<th>Intended Start Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>Fall 2019</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Off campus</th>
<th>Yes/No</th>
<th>If Yes, list location(s)</th>
<th>Intended Start Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td></td>
<td>Choose an item.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distance Delivery (online/other distance delivery methods)</th>
<th>Yes/No</th>
<th>If Yes, identify delivery methods</th>
<th>Intended Start Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>SDSU, USD, and BHSU</td>
<td>Fall 2019</td>
</tr>
</tbody>
</table>

According to the AAC Guidelines 5.5 classification, for the proposed delivery method, we consider 025DDN Host/Send Site [26]. In this case, the instruction will be transmitted over the state’s two-way video and two-way audio system using Dakota Digital Network and will include those on-campus sections in which the instructor and some of the students are physically present in the same room. This method is currently used to teach the courses that will be included in the GC program, for example CHEM 462/562 “Green chemistry and processes” and MES711 “Materials for energy generation and storage” that will be modified to 500-600 level. Since the proposed program is not a collaborative one, special arrangements will be made between SDSMT, USD, SDSU, and BHU to ensure a proper use of the identified distance delivery method.

10. What are the university’s plans for obtaining the resources needed to implement the program? Indicate “yes” or “no” in the columns below.

<table>
<thead>
<tr>
<th>Development/Start-up</th>
<th>Long-term Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reallocate existing resources</td>
<td>Yes</td>
</tr>
<tr>
<td>Apply for external resources</td>
<td>No</td>
</tr>
<tr>
<td>Ask Board to seek new State resources</td>
<td>Yes</td>
</tr>
<tr>
<td>Ask Board to approve a new or increased student fee</td>
<td>No</td>
</tr>
</tbody>
</table>

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3 The Higher Learning Commission (HLC) and Board of Regents policy requires approval for a university to offer programs off-campus and through distance delivery.
4 Delivery methods are defined in AAC Guideline 5.5.
5 If checking this box, please provide examples of the external funding sites identified.
6 Note that requesting the Board to seek new State resources may require additional planning and is dependent upon the Board taking action to make the funding request part of their budget priorities. Universities intending to ask the Board for new State resources for a program should contact the Board office prior to submitting the intent to plan.
The examples of the kinds of external resources/sources that Mines would seek could include sponsoring professional exchange with other schools where similar programs are developed and scholarships for the students. We understand, that external funds would be looking at the 2020 legislative session and funding for 2021 (provided the Board is supportive). This aspect will involve some larger discussions, FYI.

11. Curriculum Example: Provide (as Appendix A) the curriculum of a similar program at another college or university. The Appendix should include required and elective courses in the program. Catalog pages or web materials are acceptable for inclusion. Identify the college or university and explain why the selected program is a model for the program under development.

The attached example and curriculum (Appendix A) provide information for the relevant PhD graduate program in Green Chemistry at Boston University. Appendix B provides an example of the related BS Minor program in Sustainable/Renewable Energy at SDSU.

We plan a flexible curriculum with both thesis and non-thesis options. Coursework will be primarily dictated by a student’s interests and the faculty committee overseeing the degree. This type of program will allow students to combine the 500 core courses (12 credits) currently taught in CABS with additional elective courses and required course work (0-6 for a non-thesis and 6-12 for a thesis option).

12. Additional Information: Additional information is optional. Use this space to provide information not specifically requested above. Delete this item if it is not used.

Collaborative opportunities within the SDBOR system are very promising and will be sought out by SDSMT in developing and offering the proposed program.

Students and faculty at USD [27] and SDSU [28] would benefit from the proposed MS in Green Chemistry program through cross-listing of the existing courses (see the Table below), development of the new courses relevant to the proposed MS GS program at SDSMT, students’ exchange, and broader funding opportunities.

For example, the Department of Chemistry & Biochemistry at SDSU offers Master of Science (MS) degrees in Chemistry, and an online Chemistry-Chemical Education specialization for high school teachers. SDSU also offers the PhD degree in either Chemistry (with a specialization in the Analytical Chemistry, Chemical Education, Environmental Chemistry, Organic Chemistry) or Biochemistry with a specialization in Biochemistry or Biophysical Chemistry [29]. Some of the courses can be cross-listed for MS GC program (Table SDSMT is committed to maximizing the benefits of the proposed program to the state through strong collaborations with SDBOR institutions. In this regard, the BHSU MS in Sustainability offered entirely online30 or the PhD at USD in Sustainability will have additional possibilities in terms of hands-on experience, higher students’ recruitment, and advanced professional knowledge while investigating a fast growing green job market. jobs placement.
Table 1: Programs and departments at SDSU [31], BHU, and USD that would benefit from the proposed MS Green Chemistry program through collaborative opportunities.

<table>
<thead>
<tr>
<th>Program or department</th>
<th>USD</th>
<th>SDSU</th>
<th>BHSU</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological Sciences Program</td>
<td></td>
<td>X</td>
<td></td>
<td>The most relevant elective courses will be chosen for cross-listing from those taught in the departments and within the Biological Science Program at SDSU, USD, and BHU</td>
</tr>
<tr>
<td>Department of Biology &amp; Microbiology</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Department of Veterinary &amp; Biomedical Sciences</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Department of Health &amp; Nutritional Sciences</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
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<td>Department of Electrical Engineering &amp; Computer Science</td>
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<td>Department of Natural Resource Management</td>
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<td>Department of Chemistry and Biochemistry offers Bachelor of Science degrees in chemistry and biochemistry [32]</td>
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The following are examples of existing collaborations between SDSMT, USD, SDSU, and BHU:

- MES 711 Graduate course “Materials and sustainable energy generation and storage” taught at SDSMT since 2016 involved students from SDSMT and USD (025DDN Host/Send Site delivery method)
- Discussions of the role of the participants (SDSMT, USD, SDSU, and WDT) in establishing a Center for Green Power Generation and Storage. Based on recommendation from the SDBOR and GOED (the letters of commitment are attached), the planning grant proposal has been submitted to the NSF IUCRC program.
- NASA EPSCoR project (2014-2018) “Lithium-ion batteries for NASA Space exploration” involved three SD universities: SDSMT (Smirnova- Science PI), SDSU, and USD.
  - Based on the NASA EPSCoR results, two DOD SBIR Phase I (base and option) proposals have been funded by DOD NAVAIR and successfully completed in 2016-2017 (Smirnova –PI at SDSMT)
  - The first in SD Green Chemistry and Sustainable Energy summer institute for science teachers from middle and high school launched at SDSMT in 2015 was sponsored by the SD Space Grant Consortium (NASA) and involved BHSU faculty
- The results from the DOD SBIR Phase I (base and option) have been further supported by the DOD NAVAIR division in Phase II (S1M, 2018-2021, Smirnova- PI at SDSMT)
  - Based on the results of the NASA and DOD projects 2 patent applications have been submitted and 8 articles were published (2 under revision) by the faculty from SDSMT, USD, and SDSU.
Appendix A: University of Massachusetts (Boston); Chemistry department, PhD Green Track
https://www.umb.edu/academics/csm/chemistry/grad/phd_in_chemistry/cgc_phd

COURSEWORK (Complete 60 credits)

CORE COURSES (Both core courses are required)
CHEM 631 – Chemical Toxicology
CHEM 671 – Introduction to Green Chemistry

ELECTIVE COURSES (Choose four from list.)
CHEM 601 – Thermodynamics and Kinetics
CHEM 602 – Quantum Mechanics
CHEM 611 – Inorganic Synthesis and Analysis
CHEM 612 – Inorganic Structure and Reactivity
CHEM 621 – Synthetic Organic Chemistry
CHEM 622 – Physical Organic Chemistry
CHEM 631 – Chemical Toxicology
CHEM 641 – Chemistry and Biochemistry Education Research
CHEM 651 – Spectroscopic Identification of Organic Compounds
CHEM 654 – Biological Chemistry
CHEM 658 – Medicinal Chemistry
CHEM 661 – Analytical Instrumentation
CHEM 662 – Applied Chemometrics
CHEM 666 – Electrochemistry
CHEM 671 – Introduction to Green Chemistry
CHEM 680 – Physical Biochemistry
CHEM 681 – Medical Biochemistry
CHEM 687 – Topics in Chemistry
CHEM 688 – Topics in Physical Chemistry
CHEM 689 – Topics in Organic Chemistry
CHEM 690 – Topics in Inorganic Chemistry
CHEM 696 – Independent Study
CHEM 697 – Special Topics in Chemistry

EXTRA-DEPARTMENTAL ELECTIVES
Students may choose electives from external departments if they are relevant to their course of study and research. Students choose courses with the permission of the advisor and graduate program director.

Biology Department
BIOL 614 – Advanced Cell Chemistry
BIOL 678 – Protein Chemistry and Enzymology
BIOL 679 – Protein Chemistry and Enzymology Lecture
BIOL 685 – Biomedical Tracers

Physics Department
PHYSIC 601 – Electronic Instrumentation II: Digital
PHYSIC 612 – Electromagnetic Theory
PHYSIC 632 – Advanced Laser Optics (with lab)
PHYSIC 609 – Physics of Medical Imaging
PHYSIC 615 – Solid State Physics
PHYSIC 621 – Physics of Semiconductor Materials
Appendix B: SDSU BS program in sustainable energy (Minor)

Requirements for Sustainable Energy Systems BS Minor: 18 Credits

- ME 311 - Thermodynamics I Credits: 3
  or ME 314 - Thermodynamics Credits: 3
  or PHYS 341 - Thermodynamics (COM) Credits: 2
- ME 416-516 - Renewable Energy Systems Credits: 3
- ME 478 - Mechanical Systems Design I Credits: 2
  1
- ME 479-479L - Mechanical Systems Design II and Lab (COM) (AW) Credits: 2

Internship or Undergraduate Research/Scholarship Experience

The internship or Undergraduate Research/Scholarship experience must be a sustainable energy systems application approved by the Coordinator of the Minor. Credits: 2-3

- ABE 494 - Internship Credits: 1-6
- EE 494 - Internship Credits: 1-3
- ME 494 - Internship Credits: 1-3
- PHYS 494 - Internship Credits: 1-4
- ABE 498 - Undergraduate Research/Scholarship Credits: 1-3
- EE 498 - Undergraduate Research/Scholarship Credits: 1-3
- ME 498 - Undergraduate Scholarship/Research Credits: 1-3
- PHYS 498 - Undergraduate Research/Scholarship Credits: 1-12

Electives

- ABE 444-444L/544-544L - Unit Operations of Biological Materials Processing and Lab Credits: 4
- ABE 555-555L - Principles of Biological Separation Processing and Lab Credits: 3
- EE 430-430L - Electromechanical Systems and Lab Credits: 4
- EE 434-434L - Power Systems and Lab Credits: 3, 1
- EE 436-436L/536-536L - Photovoltaic Systems Engineering and Lab Credits: 3, 1
- ME 410-510 - Principles of HVAC Engineering Credits: 3
- ME 412-512 - Internal Combustion Engines Credits: 3
- ME 413-513 - Turbomachinery Credits: 3
- ME 414-514 - Air Pollution Control Credits: 3
- ME 415 - Heat Transfer Credits: 3
- ME 418-518 - Design of Thermal Systems Credits: 3
- ME 431-531 - Aerodynamics Credits: 3
- ME 439-439L/539-539L - HVAC System Design and Lab Credits: 3
- NE 435 - Introduction to Nuclear Engineering Credits: 3
- PHYS 331 - Introduction to Modern Physics (COM) Credits: 3
Appendix C: Requirements for the MS Degree in Green Chemistry at SDSMT (30 credits)

1. Master’s Program Requirements:
http://ecatalog.sdsmt.edu/content.php?catoid=17&navoid=3659

2. Thesis Option Requirements
   a) At least 30 combined credit hours of coursework and research;
   b) At least 15 credit hours of graduate coursework approved by the program (500 level courses and above);
   c) At least 6 credit hours of thesis research and no more than 12 credit hours of thesis research;
   d) A thesis that conforms to standard American English style and usage;
   e) Successfully defending the thesis;
   f) Meeting or exceeding academic standards prescribed elsewhere in this catalog, including maintaining at least a 3.0 cumulative GPA, and
   g) Satisfaction of all departmental- or program-specific requirements.

3. Non-thesis Option Requirements
   The minimum requirements for the non-thesis Master’s degree option are:
   a) At least 30 credit hours of coursework,
   b) At least 20 credit hours of graduate level coursework approved by the program (500 and above),
   c) A maximum of 6 credits of non-thesis research project,
   d) Maintaining at least a 3.0 cumulative GPA.
   e) Satisfaction of all departmental- or program-specific requirements.

4. Accelerated MS Option Requirements

The accelerated master’s program enables a student to complete both the BS and MS degrees in as little as 5 years. Up to 12 credits applied toward the BS program may be used to satisfy graduate credit requirements. See individual programs for the number of credits allowed by the program. Additional restrictions apply; please see section GEP IV.2. Accelerated Master’s Programs for further information.
Appendix D: Master of Science in Green Chemistry (MS GC) Degree Program
(CABS Department)- 30 credits

http://ecatalog.sdsmt.edu/content.php?catoid=17&navoid=3795

Core MS GC courses (12 credits)
1. CHEM 462/562 Green Chemistry and Processes. (Filipova) 3 credits; Prerequisites: CHEM 326 Organic Chemistry I and Calculus II CALC 125 MATH 125, CHEM 326
2. CHEM 582 Environmental Chemistry (Heglund), 3 credits; CHEM 316 or CHEM 328
3. CHEM 552 Inorganic Chemistry (Smirnova)- 3 credits Prerequisites: CHEM 352 and CHEM 328
4. CHEM 5XX/6XX Physical Chemistry (Zhu, to be developed, agreed) 3 credits Prerequisites: Calculus II CALC 125.
5. CHEM XXX TEACHING EXPERIENCE: All students must acquire at least one semester of teaching experience (1 credit/semester) in one of the advanced chemistry 300-400 labs (Organic CHEM 326L, CHEM 328L, Inorganic CHEM 452L, Analytical CHEM 332L, and Biochemistry I CHEM 464L) subject to approval by the graduate program director -1 credit

Elective MS GC courses in CABS (optional, to be developed)
1. CHE 5XX/6XX Topics in Green chemistry: Energy generation and storage, 3 credits (Smirnova, based on current MES 711)
2. CHE 5XX/6XX Organic Chemistry (TBD, new faculty) 3 credits
3. CHE 5XX/6XX Analytical Chemistry (Heglund to be developed) 3 credits
4. CHE 5XX/6XX Topics in Green chemistry: Biomass and lignin reforming (Smirnova) 3 credits
5. CHE 5XX/6XX Topics in Green chemistry: Biodegradable polymers (Filipova) 3 credits
6. CHE 5XX/6XX Topics in Green chemistry: Green microbiology based on Molecular cell biology
7. BIOL 446-546 Green Microbiology/Molecular Cell Biology (Gilley, to be developed) 3 credits

Extra-departmental elective MS GC courses

Civil and Environmental Engineering
1. CEE 525 Sustainable engineering (Benning) 3 credits; Prerequisites: Junior standing
2. CEE 492/692 Topics: Solid and hazardous waste management (Gadhamshetty) 3 credits Prerequisites: None

Chemical and Biological Engineering
1. CBE 741 Microbial and enzymatic processing (Sani, 3 credits) Prerequisites: BIOL 341, BIOL 331 or permission of instructor.
2. CBE 585 Renewable and sustainable energy (Shende, 3 credits) Prerequisites: Junior standing or permission of instructor.
Biology
1. BIOL 580 Bioinformatics (Sani) 3 credits Prerequisites: BIOL 331, BIOL 341, or BIOL 371; CHEM 564; or permission of instructor.
2. BIOL 506 Global Environmental Change Prerequisites: CHEM 112, PHYS 111 or PHYS 113 or PHYS 211/211A or PHYS 213/213-A and BIOL 311, or permission of instructor.

Biomedical Engineering
1. BME 601 Biomaterials No Prerequisites; This course is cross listed with MET 601.

Atmospheric and Environmental Sciences
1. Air quality Prerequisites: MATH 125, and CHEM 106 or CHEM 112.
2. AES 406/506 Global Environmental Change; Prerequisites: CHEM 112, PHYS 111 or PHYS 113 or PHYS 211/211A or PHYS 213/213-A and BIOL 311 or permission of instructor.
3. AES 612 Atmospheric Chemistry Prerequisites: Graduate standing
4. AES 612 Atmospheric Chemistry Prerequisites: Graduate standing

Electrical and Computer Engineering
1. Electrical system design Prerequisites: Graduate standing
Appendix E: Definition of Green Chemistry and mainstream Green Chemistry technologies

Green Chemistry is an area of chemistry focused on designing products and processes that minimize the use and generation of hazardous substances. GC approaches chemistry from a perspective of environmental protection and eco-friendly environment. GC strategies shift our dependence on fossil fuels to alternative energy sources presenting safer and cleaner sustainable energy capabilities.

The principles of GC concepts:
- Design of processes to maximize the amount of raw material that ends up in the product
- Use of renewable material feedstocks and renewable energy sources
- Use of safe, environmentally benign substances, including solvents, whenever possible
- Design of energy efficient processes
- Minimization of waste, which is viewed as the ideal form of waste management.

Sustainable energy, as a part of Green Chemistry concept, is defined as energy that is consumed at insignificant rates compared to its supply and with manageable collateral effects, especially environmental effects.

A common definition of sustainable energy, as a part of Green Chemistry, is related to energy systems that serve the needs of the present without compromising the ability of future generations to meet their energy needs and keep sustainability of the environment.

Based on REN21’s 2017 report, renewables contributed 19.3% to humans' global energy consumption and 24.5% to their generation of electricity in 2015 and 2016, respectively. This energy consumption is divided as 8.9% coming from traditional biomass, 4.2% as heat energy (modern biomass, geothermal and solar heat), 3.9% hydroelectricity and 2.2% is electricity from wind, solar, geothermal, and biomass.

Worldwide investments in renewable technologies amounted to more than US$286 billion in 2015, with countries such as China and the United States heavily investing in wind, hydro, solar and biofuels. Globally, there are an estimated 7.7 million jobs associated with the renewable energy industries, with solar photovoltaics being the largest renewable employer. As of 2015 worldwide, more than half of all new electricity capacity installed was renewable. This number steadily increases each year.

Appendix F: SD companies that will be involved to support MS GC students

a) POET https://poet.com/
b) DARCEO: http://darceo.com/
c) VRC Metals: https://vrcmetalsystems.com/
d) Endlas: https://www.endlas.com/
e) Raven: https://ravenind.com/
f) NanoCoatings Inc.: https://americannanocoatings.com/nci-testing/
g) Black Hills Energy: http://www.blackhillsenergy.com/
References

1 https://www.eia.gov/energyexplained/?page=us_energy_home
2 https://en.wikipedia.org/wiki/Renewable_energy_in_South_Dakota
3 ACS Green Chemistry Institute®: https://www.acs.org/content/acs/en/greenchemistry.html
4 2018 ACS Summer School on Green Chemistry and Sustainable Energy: https://www.acs.org/content/acs/en/greenchemistry/students-educators/summerschool.html?_ga=2.203738128.1680235069.1539469669-557364927.1539469669
5 https://www.acs.org/content/acs/en/membership-and-networks/td/divisions-by-class.html
6 https://www.bls.gov/green/
7 http://fortune.com/2018/02/18/renewable-energy-us-power-mix/
9 https://www.ziprecruiter.com/blog/where-the-most-green-energy-jobs-are-cropping-up-in-2018/
10 https://www.greenbiz.com/article/green-jobs-are-still-mostly-promising
12 http://puc.sd.gov/energy/Wind/project.aspx
13 https://www.wikipedia.org/wiki/Renewable_energy_in_South_Dakota
14 Center for Green Chemistry and Green Engineering at Yale: https://greenchemistry.yale.edu/about
15 PhD in Sustainable Chemistry at the Universidade de Aveiro, Portugal: http://phdsusche.itqb.unl.pt/
17 https://www.greentechmedia.com/articles/read/wv-quantumscape-investment
22 https://electrek.co/2018/06/07/qm-honda-partner-next-gen-batteries-electric-vehicles/
23 https://www.greentechmedia.com/
24 https://www.greentechmedia.com/articles/read/pges-recording-breaking-battery-proposal-wins-loses#gs.zyLep0sD
25 https://www.acs.org/content/dam/acsorg/greenchemistry/education/resources/cccew-green-chemistry-discussion-questions.pdf
26 https://www.acs.org/content/dam/acsorg/greenchemistry/education/resources/cccew-green-chemistry-discussion-questions.pdf
27 Academic affairs guidelines: AAC Guideline 5.5
28 https://www.usd.edu/-/media/files/graduate-school/student-handbooks/chemistry.ashx?la=en
30 https://www.usd.edu/-/media/files/graduate-school/student-handbooks/chemistry.ashx?la=en
31 https://www.bhsu.edu/Academics/Graduate-Programs/Sustainability
32 http://catalog.sdstate.edu/index.php?catoid=31
33 https://www.sdstate.edu/chemistry-biochemistry/request-information-chemistry-and-biochemistry-programs