Redwood Coast Energy Authority

633 3rd Street, Eureka, CA 95501
Phone: (707) 269-1700 Toll-Free (800) 931-7323 Fax: (707) 269-1777
E-mail: info@redwoodenergy.org Web: www.redwoodenergy.org

Redwood Coast Energy Authority Office **July 10, 2018**
633 3rd St., Eureka, CA 95501 **Tuesday, 6 - 7:30 p.m.**

In compliance with the Americans with Disabilities Act, if you need assistance to participate in this meeting, please contact the Clerk of the Board at the phone number, email or physical address listed above at least 24 hours in advance.

Pursuant to Government Code section 54957.5, all writings or documents relating to any item on this agenda which have been provided to a majority of the Community Advisory Committee, including those received less than 72 hours prior to the Committee's meeting, will be made available to the public in the agenda binder located in the RCEA lobby during normal business hours, and at *www.redwoodenergy.org*.

PLEASE NOTE: Speakers wishing to distribute materials to the Committee at the meeting are asked to provide 17 copies to the Clerk.

COMMUNITY ADVISORY COMMITTEE REGULAR MEETING AGENDA

Agenda Item	What	When
1. Open	• Roll Call: Richard Johnson Norman Bell, Luna Latimer Jerome Carman, Dennis Leonardi Colin Fiske, Kit Mann Larry Goldberg, Craig Mitchell Pam Halstead, Kathy Srabian Tom Hofweber, Matty Tittman Michael Sweeney, Board Liaison • Review meeting agenda and goals	6 - 6:05 (5 min)
2. Approval of Minutes	**Action: Approve minutes of April 10, 2018 Special Meeting**	6:05 - 6:10 (5 min)
3. Oral Communications	This item is provided for people to address the Committee on matters not on the agenda. At the end of oral communications, the Committee will respond to statements. The Committee will set any requests requiring action to a future agenda or will refer the request to staff.	6:10 - 6:15 (5 min)
4. Community Advisory Committee Charter	**Action: Approve revised Community Advisory Committee Charter**	6:15 - 6:45 (30 min)
5. Community Choice Energy-Funded Customer Programs	**Action: Provide input to staff on the proposed CCE-funded customer programs**	6:45 - 7:15 (30 min)

6. Board Communication	**Action: List items to communicate to Board**	7:15 - 7:20 (5 min)
7. Close & Adjourn	Summarize actions, outcomes, next steps	7:20 - 7:30 (10 min)

NEXT REGULAR MEETING

Tuesday, October 9, 2018, 6-7:30 p.m.
RCEA Offices
633 3rd Street, Eureka, CA 95501

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Redwood Coast Energy Authority Office **April 10, 2018**
633 3rd St., Eureka, CA 95501 **Monday, 5:30 – 7:00 p.m.**

RCEA will accommodate those with special needs. Arrangements for people with disabilities who attend RCEA meetings can be made in advance by contacting Nancy Stephenson at 269-1700 by noon the day of the meeting.

COMMUNITY ADVISORY COMMITTEE SPECIAL MEETING MINUTES

1. Opening

Executive Director Matthew Marshall called the meeting to order at 5:33 p.m.

Committee members present: Jerome Carman, Pam Halstead, Dennis Leonardi, Larry Goldberg, Kathy Srabian, Craig Mitchell, Colin Fiske, Kit Mann, Norman Bell (arrived 5:43 p.m.) and Matty Tittman (arrived 5:47 p.m.).

Board liaison present: Director Michael Sweeney.

Staff present: Executive Director Matthew Marshall and Community Strategies Manager Nancy Stephenson.

The committee members, staff and Board Liaison introduced themselves. Executive Director Marshall and Board Liaison Sweeney thanked the group for their time and for providing a mix of perspectives.

2. RCEA Update

Executive Director Marshall provided a brief history of RCEA and described RCEA's current work:

- Demand Side Management (Energy Watch business and residential program, Proposition 39 school energy efficiency program);
- Alternative fuels and transportation (regional electric vehicle [EV] and hydrogen vehicle infrastructure planning, fleet owner and customer programs, EV rate electricity reduced rate program, public EV charging network), and
- Community Choice Energy (CCE), which delivered over $1 million in customer savings in 2017, and for which the Community Advisory Committee (CAC) was originally formed to help develop public messaging and facilitate public input on developing the goals for the program.

Other current projects include the 9-acre airport solar microgrid and battery system project in partnership with Schatz Energy Research Center, PG&E and the County; and the offshore wind project, a community-driven approach to developing a floating wind farm utilizing the best wind resource in the lower 48.

Board liaison Sweeney emphasized the airport microgrid's critical role in supplying ongoing back-up power to the airport and Coast Guard station in a major earthquake. ED Marshall pointed out that solar projects are common at airports since these flat lands are unusable for other purposes such as industry, agriculture or wildlife habitat. Solar panels are designed to absorb, not reflect, sunlight, and standardized panel positioning tools to minimize glare are used in project design. Committee member Carman confirmed that project construction will begin in 2019.

3. Committee Role & Process

Executive Director Marshall reviewed the September 2016 Board of Directors' Community Choice Energy program guidelines, and the objectives for CCE revenue funded customer programs.

Executive Director Marshall outlined the Community Advisory Committee's role:

- to support public engagement,
- provide the Board with input to inform decision-making, and
- assist with public messaging.

Committee membership is geographically diverse to encourage diverse opinions. The original CAC helped the Board establish CCE program goals through community meetings. After the CCE program launched, the Board asked that the CAC continue its work.

Examples of public engagement and decision-making support include:

- Input to staff on key messaging and how to best communicate it for specific RCEA projects.
- Clarifying confusion heard in the community about RCEA projects or referring questions to staff.
- Evaluating and recommending CCE-funded customer programs.

The Board will discuss the last item at its next meeting and the CAC's next agenda will include discussion on types of customer energy programs to fund through CCE revenues. Program analysis will be done by staff.

The Committee discussed how future CAC meetings should be run. Committee members agreed:

- A formal chair is not needed but a staff member facilitator is helpful to involve everyone, capture what is discussed, and move business along.
- Executive Director Marshall's presence helps to provide a big picture explanation of programs and issues.
- Future CAC agendas will include next steps/action items and what to report back to the Board as standing items.
- Executive Director Marshall or Board Liaison Sweeney will convey the gathered information at Board meetings.
- Community Strategies Manager Stephenson will communicate the CAC's suggestions to staff.
- The Committee will review and potentially revise the CAC Charter at the next meeting to clarify decision-making processes.

- The Committee will review the Brown Act's public meeting requirements at the next meeting.
- Agendas will be developed by ED Marshall. Committee members may request agenda items or study session topics.

Committee members asked questions about offshore wind leases, the possibility of combining the wind turbines with wave energy technology, transmission line upgrades, and financing for the airport microgrid project.

Executive Director described some RCEA key documents:

- Comprehensive Action Plan for Energy – A high level guiding document referenced in the County's General Plan and adopted by the RCEA Board in 2012 that outlines initial plans to look at local renewables and energy efficiency.
- Repower Humboldt – A more detailed study funded by the State and completed in partnership with the Schatz Energy Research Center and PG&E, investigating whether it was possible to meet local energy needs through local energy sources (wind, solar, biomass, small hydro, wave). Researchers deemed this was possible, which led to the Community Choice Energy program's launch.
- Guidelines for the RCEA Community Energy Program Launch-Period Strategy and Targets – A streamlined Board-level action plan for the first four to five years of the Community Choice Energy program.

4. Committee meeting schedule

The Committee decided to meet from 6:00 to 7:30 p.m. on the second Tuesday of the first month of each quarter, and that special meetings and study sessions may be scheduled by the Committee as needed. The next regular meeting will be on Tuesday, July 10.

Draft board meeting minutes and a post-Board meeting report on items concerning the Community Advisory Committee will be emailed to CAC members. Members will also receive the Board agenda packet and RCEA newsletter.

Community Strategies Manager Stephenson stated CAC input is very helpful when preparing outreach material. Committee members asked to have access to outreach materials prior to CAC meetings so they can prepare input. Executive Director Marshall also requested the Committee members let staff know of any mistakes they see in press coverage or social media. Nancy Stephenson or he can verify information, if needed. Committee members requested notification of RCEA stories in different media outlets and regular snapshots of RCEA's public relations efforts.

ED Marshall invited CAC members to the CEC Integrated Energy Policy Report meeting on state energy issues on April 20, and to an offshore wind stakeholder meeting on April 18.

Member Mann stated that correcting misinformation in the community is a CAC function; this includes responding to social media posts. Mann cited an example where he drafted a post as an individual, not as a CAC representative and asked Staff Manager Stephenson to review it for accuracy before posting. ED Marshall reminded members that he and Staff Manager Stephenson are also available to clarify community member misconceptions.

Member Leonardi suggested connecting with the Chambers of Commerce to promote RCEA's programs through their websites and other outreach efforts.

5. Close & adjourn

Executive Director Marshall summarized the group’s decisions and adjourned the meeting at 6:58 p.m.

Respectfully submitted,

Lori Taketa
Clerk of the Board

REDWOOD COAST
EnergyAuthority

COMMUNITY ADVISORY COMMITTEE
STAFF REPORT
Agenda Item # 4

AGENDA DATE:	July 10, 2018
TO:	RCEA Community Advisory Committee
PREPARED BY:	Matthew Marshall, Executive Director
SUBJECT:	Community Advisory Committee Revised Charter and Term Expiration Dates

SUMMARY

The RCEA Board of Directors created a nine-member Citizen's Advisory Committee (CAC) in June 2016. The Committee was established to facilitate public engagement and provide input to the Board. The initial charter outlined the group's 2016 community workshop assignments.

When the Board revised its Operating Guidelines in December 2017, it approved the renamed and expanded Community Advisory Committee's continuation. The CAC's revised status presents an opportunity to revise the body's original charter.

Term Expiration Dates

Each of the CAC's 15 members serves a 2-year term. Of the Committee's original nine members who began service in 2016, six agreed to continue. Earlier membership discussion indicated a desire to stagger terms to preserve knowledge of the Committee's work. This results in the following term expiration dates, with the recommendation that members be invited to reapply at the end of their terms if they so desire:

Terms ending 4/10/2019:	Norman Bell Richard Johnson Luna Latimer	Kit Mann Kathy Srabian Matty Tittman
Terms ending 4/10/2020:	Jerome Carman Colin Fiske Larry Goldberg Pam Halstead	Tom Hofweber Dennis Leonardi Craig Mitchell Member #14 Member #15

STAFF RECOMMENDATION

Approve revised Community Advisory Committee Charter.

ATTACHMENTS:

Draft Revised Community Advisory Committee Charter

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REDWOOD COAST ENERGY AUTHORITY

COMMUNITY ADVISORY COMMITTEE CHARTER

Adopted 6-20-16, Revised 7-10-18

Public Engagement Process

Purpose of Redwood Coast Energy Authority

The Redwood Coast Energy Authority (RCEA) is a Joint Powers Authority whose members include the County of Humboldt, the Cities of Arcata, Blue Lake, Eureka, Ferndale, Fortuna, Rio Dell, and Trinidad, and the Humboldt Bay Municipal Water District.

RCEA's purpose is to develop and implement sustainable energy initiatives that reduce energy demand, increase energy efficiency, and advance the use of clean, efficient and renewable resources available in the region.

Purpose of Public Engagement

- Provide clarity to the public and the Board on RCEA programs, particularly the Community Choice Aggregation Program (CCA)
- Provide education to increase understanding and awareness of RCEA programs
- Build trust and confidence in the programs with the public
- Create inclusion for members of the public so they are—and feel—heard and understood
- Build community support for RCEA programs
- Provide input to the Board and staff before decisions are made
- Engage a broad diversity of community stakeholders
- Ensure that RCEA decisions are made in alignment with explicitly stated criteria

Goals and Desired Outcomes of Public Engagement

- Community enthusiasm and support for RCEA decisions
- High participation in the public engagement process
- Establish and maintain high standards for public engagement strategies and processes
- High CCA customer participation rate (>90%)

RCEA Public Engagement Principles

Accountability and Transparency

RCEA will enable the public to participate in decision-making by providing clear information on the issues, the ways to participate, and how their participation contributes to the decision.

Fairness and Respect

RCEA will maintain a safe environment that cultivates and supports respectful public engagement.

Accessibility

RCEA will respect and encourage participation by providing ample public notice of opportunities, resources, and accommodations that enable all to participate.

Predictability and Consistency

RCEA will prepare the public to participate by providing meeting agendas, discussion guidelines, notes, and information on next steps.

Efficient Use of Resources

RCEA will balance its commitment to provide ample opportunities for public involvement with its commitment to delivering government services efficiently and using RCEA resources wisely to make effective forward progress on RCEA's goals.

Evaluation

RCEA will monitor and evaluate its public participation efforts to identify and act on opportunities to improve its processes.

Charter of the Community Advisory Committee

Role

- The role of the Community Advisory Committee to support RCEA public engagement efforts and to provide decision-making support and input to the RCEA Board.
- When the need arises, the Committee will help plan and conduct community meetings to educate and/or get input from the public on RCEA programs. This may include:
  - Helping develop the content and process for the meetings.
  - Participating in and assisting with facilitating the meetings
  - Understanding and summarizing the feedback from the meetings
  - Providing the RCEA Board with a synthesis of the feedback from the meetings
  - Making recommendations to the Board based on the feedback from the meetings.

Advisory Committee Decision-Making Process

Agree on the recommendations to the RCEA Board by consensus. In other words, every Advisory Committee member:

- Understands the decision
- Has had a chance to express his or her concerns
- States that he or she is willing to actively support the decision(s).

Every effort will be made to reach consensus. When consensus on any recommendation cannot be reached in a timely fashion and there is significant disagreement over direction, the decision will "fallback to" and be made by a super majority (two-thirds) of the full Committee. In the event of a "fallback decision," the Board will request that the broad range of thinking underlying the recommendations be reported. The RCEA Board will make the final decision.

Note: This Committee is advisory in nature and shall have no final decision-making authority. Any activity or recommendation from this Committee requiring policy direction or action shall be presented to the Executive Director and/or the RCEA Board Liaison who will refer the request to the Board.

RCEA Board Liaison Member(s) Role

- Contribute content knowledge and Board perspective
- Communicate Committee recommendations and perspectives to the Board
- Participate as a non-voting committee member

Committee Members Role

- Participate actively and fully in committee work to achieve the charter
- Surface issues and work to resolve them collaboratively
- Take responsibility for assignments between meetings and prepare for meetings
- Actively solicit and encourage participation in community meetings
- Actively challenge themselves to understand different perspectives on the committee and from the public
- Attend all agreed-upon meetings. If a committee member is unable to participate fully and has frequent absences, the Board will replace the member

Meeting Roles

- The Committee will have no formal chair. A staff member will facilitate meetings, helping the group stay focused on task to build agreements.
- The facilitator will remain neutral and make sure each committee member's thoughts and ideas are heard and that input and feedback from the public is fairly considered for each discussion item.
- A staff member or members will capture committee members' and the public's ideas during meetings and document meeting notes.
- Staff will provide guidance and content expertise, or request content advice and expertise from technical experts as needed

Proposed Ground Rules

- Listen carefully — try to understand, **first**
- Ask questions to increase your understanding of others' points of view
- Be open to divergent views
- Keep the "good of the whole" in mind at all times
- Help group stay on track

- Share the "air time."
- One speaker at a time (avoid interrupting each other)

REDWOOD COAST EnergyAuthority

COMMUNITY ADVISORY COMMITTEE
STAFF REPORT
Agenda Item # 5

AGENDA DATE:	July 10, 2018
TO:	RCEA Community Advisory Committee
PREPARED BY:	Lou Jacobson, Director of Demand Side Management
SUBJECT:	Community Choice Energy-Funded Customer Programs

SUMMARY

Current estimated funds from Community Choice Energy program revenues available for new or augmented customer programs are $400,000. $170,000 has been allocated to the Public Agency Solar Program leaving $230,000 to be allocated to new customer programs. Funding will carry most efforts through the end of the 2018-19 fiscal year.

During the Board’s February 2018 meeting, staff were directed to develop and present a process for selecting new customer programs to be supported with Community Choice Energy (CCE) revenues. The Board’s expressed intent was that the process includes public input while conforming to the CCE program’s guidelines. Attachment 5.2 page 4 presents current program guidelines. Staff proposed a program identification and approval process to the Board. That process was adopted during the April 16, 2018 meeting. The staff report presenting the adopted process is attached to this report as 5.1.

RCEA staff have completed the first two steps of the Phase 1 2018 program identification and approval process. These steps included developing a scoring matrix and rubric, soliciting program ideas from all RCEA staff and scoring those ideas with the developed rubric. The rubric measured proposals across the following categories:

- Ability to leverage existing programs and/or resources
- Proposal feasibility
- $/Metric ton CO2e abatement cost
- Demand response impact
- Alignment to local and state energy goals
- Innovation and creativity

Staff have identified and documented a number of lessons learned from this exercise and will be incorporating those lessons into an updated phase 2 process.

The following summary table presents staff recommendations for programs and funding levels. See attached proposal summaries for more information on each.

Summary Table of 2018 Customer Program Proposals

Program Name	Averaged Score	Proposed Funding
Residential Energy Services	77	$46,000
RCEA Rebate Catalog	73.75	$100,000
High-Volume PG&E EV Charging Cluster	73	$84,000
	Total Budget Request	$230,000

Several additional proposals were reviewed:

- Energy management support for large commercial and government customers
- On-Bill Financing Program bridge funding and micro-loans
- Generation-side CARE customer discounts
- An integrated customer product and services database

All noted proposals were validated and supported by the reviewers. The above noted proposals will be pursued through varying mechanisms not associated with customer program funding.

STAFF RECOMMENDATION

Provide input to staff on the proposed CCE-funded customer programs.

ATTACHMENTS:

5.1: Staff Report CCE Customer Programs Approval Process

5.2: Community Energy Program Guidelines Update

5.3: Residential Energy Services Summary

5.4: RCEA Rebate Catalog Summary

5.5: High-Volume PG&E EV Charging Cluster Summary

REDWOOD COAST EnergyAuthority

STAFF REPORT

Agenda Item # 8.2

AGENDA DATE:	April 16, 2018
TO:	Board of Directors
PREPARED BY:	Lou Jacobson, Director of Demand-Side Management Richard Engel, Director of Power Resources Lori Biondini, Director of Business Development and Planning Dana Boudreau, Director of Operations Steve Edmiston, Director of Finance and Human Resources
SUBJECT:	Adoption of CCE Customer Programs Approval Process

SUMMARY

In the Board's February 2018 meeting the Board directed staff to develop and present a proposed process for selecting new customer programs to be supported with Community Choice Energy (CCE) revenues. The Board's expressed intent was that the process includes public input while conforming to the CCE program's launch period guidelines, adopted in September 2016.

After consideration of how best to efficiently identify and plan for new programs, staff recommends adopting multiple pathways for evaluating and approving new programs:

1. A competitive proposal and approval process, as outlined in the diagrams on the following page.

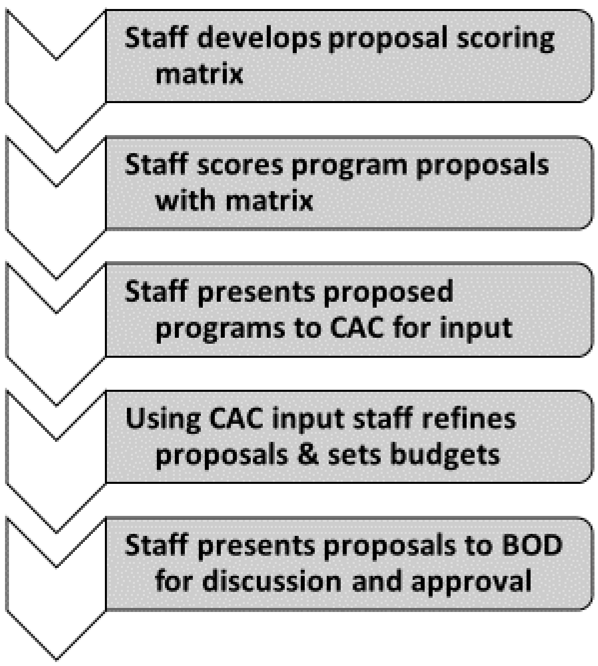
2. A non-competitive proposal and approval process for programs that are generally cost-neutral to RCEA. Examples could include a customer electricity-demand reduction incentive based on the associated wholesale power cost reductions, or a heat-pump water heater incentive based on the net-revenue increase from the associated additional electricity sales. Programs in this category would still be reviewed and discussed by the Community Advisory Committee (CAC) but would be exempt from competitive review alongside the non-cost-neutral proposals.

At the Board's discretion, program funding can be allocated outside of the above processes when there is a unique or urgent opportunity. This would include providing match funding for grant opportunities that bring additional resources into the community that would not otherwise be available.

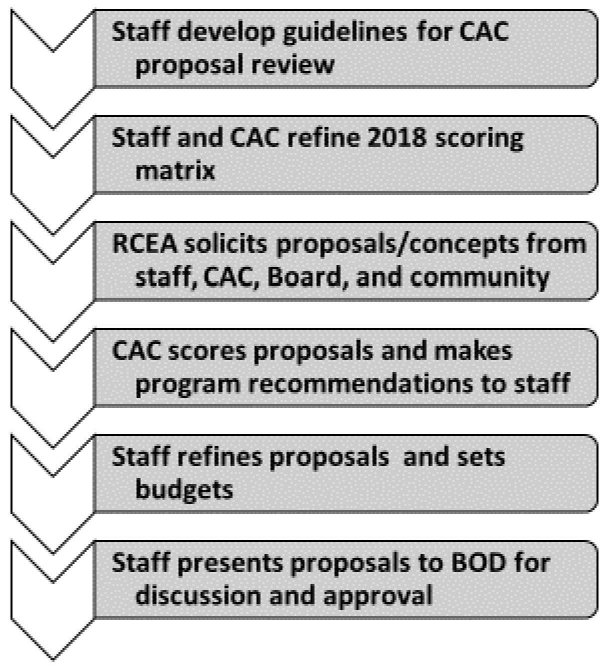
Staff have already begun to consider new program development options informed by the Board's guidelines adopted in 2016 and therefore recommends rolling out the proposed pathways in two phases. Phase 1 would remain mostly staff-driven and implemented right away; Phase 2 would begin in calendar year 2019 and would incorporate greater public participation and extensive involvement by the Community Advisory Committee.

Future processes in 2020 and beyond would be adapted to incorporate lessons learned in 2018 and in 2019.

Phase I: Program Identification and Approval Process through 2018



Phase 2: Program Identification and Approval Process for 2019



FINANCIAL IMPACTS

As reported by staff in the Board's February 2018 meeting, estimated funds available for customer programs through the end of calendar year 2018 are $400,000. Customer programs budget for future years is unknown and will depend on the CCE program's financial performance but is targeted to be larger than the current customer programs budget. Our current CCE program guidelines call for "up to $1,000,0000 per year" for customer programs.

RECOMMENDED ACTION

<u>Adopt the CCE-funded customer program evaluation and selection process for 2018 and 2019 as outlined in the staff report.</u>

GUIDELINES FOR
THE REDWOOD COAST ENERGY AUTHORITY
COMMUNITY ENERGY PROGRAM
LAUNCH-PERIOD STRATEGY AND TARGETS

Adopted September 19, 2016
Revised May 21, 2018, Resolution 2018-6

OVERVIEW & GOALS

The Redwood Coast Energy Authority (RCEA) is proceeding with the launch of a community choice energy program scheduled to commence service to customers in May of 2017. Based on the groundwork established by the RePower Humboldt strategic plan for developing local renewable energy, in June of 2015 the RCEA Board of Directors voted to proceed with developing a community choice energy program for Humboldt County with the following core goal:

Maximize the use of local renewable energy while providing competitive rates to customers.

In addition to this over-arching goal, the program will be designed to pursue the following aspirations and community benefits:

- Environmental Quality
- Local Control and the Ability to Pursue Local Priorities
- Economic Development
- Energy Independence
- Customer Rate-savings, Choice, and Community Programs

Implementing a community choice energy (CCE) program that furthers these goals will be an ongoing and evolving process. Outlined below are targets and objectives for the initial launch phase of the program during years 1-5 of operation. These targets and objectives will have to be adaptively managed based on market conditions and local considerations, but will be used as a guiding framework for the development of RCEA's CCE Program Implementation Plan, power procurement strategy, and the development of local generation projects and programs.

FINANCIAL TARGETS

- A target of approximately 5% of the available program annual budget will be allocated to customer rate savings (based on parity with PG&E generation rates and with PG&E PCIA fees factored in). This equates to a total customer rate savings that averages at least $2 million per year over the first 5 years, for a targeted total cumulative customer rate savings of at least $10 million over the first 5 years of operation.

- The program will target building a rate-stabilization/reserve/contingency fund of $35 million by the end of year five under projected market conditions. The program will be designed to target a minimum reserve of at least $10 million even under adverse market conditions.

- Over the first 5 years, the program will aim to retain and/or redirect $100 million dollars or more of rate-payer dollars back into Humboldt County when taking into consideration local power-procurement, customer rate-savings, local-program spending, and allocations toward building the reserve/contingency fund.

POWER OBJECTIVES

- At least 5% more renewable energy (as defined by state law) than PG&E's power mix.

- At least 5% lower greenhouse gas emission rate than PG&E mix.

- Maximize the use of local renewable energy to the extent technically and economically feasible and prudent.

- Strongly support energy efficiency and conservation as core strategies toward achieving the program's environmental, economic, and community goals.

GENERATION PORTFOLIO TARGETS

Existing Local Biomass

- Issue a Request for Offers targeting power purchase agreements with 1-2 existing facilities.
- Structure overall biomass procurement strategy around local waste-management and forest restoration priorities and needs.
- Include environmental, community, and economic considerations in selection process.
- Contingent on price and market conditions, contract for a target of around 20MW of local biomass energy (about 15% of the total RCEA power portfolio).

Existing Local Small Hydroelectric

- Pursue contracting with a target of 2MW of existing local small hydro.
- Ensure that any contracts are structured to support and prioritize the operators' water-management and environmental quality objectives.

New Local Solar Power

- ***Feed-in-tariff power procurement program for small generators***
    - o <1MW small/medium renewable generators (solar and other technologies)
    - o Eligible projects are designed primarily for wholesale power production (not focused on meeting on-site energy loads).
    - o Standardized, upfront purchase price, projected to be in the range of $80-100/MWh to facilitate project financing.
    - o Standardized, upfront, and straightforward contract terms and duration to facilitate project financing.
    - o Initial power portfolio allocation to the feed-in-tariff program will be targeted at 6MW.

- ***Utility-scale Solar***

  In parallel to the feed-in-tariff program RCEA will pursue the development of additional wholesale-generation solar projects, which could be developed by RCEA and/or third parties in pursuit of overall power portfolio solar content targets:
    - o Initial target of 5MW of new local wholesale solar online before the end of 2018.
    - o Launch-phase target of 15MW of utility-scale/wholesale solar online by the end of year 5 of operations.
    - o Focus project development on underutilized/idle public and industrial sites to limit impacts related to other beneficial uses such as agriculture, economic development, habitat, and open space.

Additional Power Resources

To meet and balance over-arching objectives for rates, renewable energy %, and greenhouse gas emissions as well as to match power generation availability to customer loads demands, the launch-period portfolio will incorporate the following additional power sources:

- Renewable generation projects--wind, solar, geothermal, etc--located outside the County.
- California and/or Pacific Northwest hydroelectric power (which is renewable and emissions-free, but cannot be counted toward CA state renewable portfolio standard requirements). This will not include any power from the Klamath River dams.
- Unspecified "system power" from the CAISO power market pool (while power from the pool is not traceable to any specific generator, in northern CA this power is predominantly generation from natural gas and large hydro power facilities).

Future/Long-term Generation

- ***New Local On-shore Wind Generation***
    - o Assess the possibility for up to 50MW of local on-shore wind energy generation.
        - ▪ The most viable site for local on-shore wind is Bear River Ridge west of Rio Dell and South of Ferndale.
        - ▪ While there are other possible sites in the area, Bear River Ridge has the best wind resource in the County (it is one of the top wind resource areas in the state), Bear River Ridge property owners are willing and interested in developing a wind project, and there was considerable environmental and technical study and evaluation previously conducted which, if utilized, would reduce the development costs and timelines of a potential project.

- ***New Local Small-scale Hydroelectric***
    - o Evaluate options for the development of new small-scale hydroelectric that would be compatible with environmental and cultural priorities.

- ***Offshore Wind Energy***
  - While not yet deployed in California, offshore wind energy generation is an established technology. The wind resource off of the Samoa Peninsula coastline is one of the best in North America, and the on-shore infrastructure on the peninsula appears well-suited to accommodate offshore wind development.
  - During the initial 5-year launch-phase of Program, RCEA will allocate resources to moving forward with community and stakeholder engagement, site selection, environmental review, and project scoping.

- ***Wave Energy***
  - Wave energy technology is in an early stage of development. During the program launch phase, RCEA will build on the previous WaveConnent and CalWave projects to explore and evaluate opportunities for local wave-energy research, development, and pilot-deployment.

PROGRAMS

Enhanced Solar Net-Energy-Metering (rate-based program)

- Self-generation power credited to customer's bill at retail rate plus $0.01/kWh (+5-10% above base retail generation rate).
- Excess generation credits roll-over from year to year and never expire.
- Excess generation credits can be cashed-out for full retail value.

100% Renewable Energy Option (rate-based program)

- Voluntary opt-up option for premium price (based on actual cost of service).
- Large hydro and system power components of base RCEA power mix replaced with renewable energy (non-local solar, wind, geothermal, etc).
- Evaluate 100% solar and/or 100% local renewable options in the near-term (in or after 2018, after launch and ramp-up of operations).

Programs budget target of an initial allocation of up to $1,000,000 per year for:

- ***Solar and Energy-storage Technical Assistance***
  Program emphasis will be on public-agency and community facilities, especially critical infrastructure such as water/wastewater treatment and emergency response.

- ***Electric Vehicles and Charging Infrastructure***
  Supporting the adoption of electric vehicles provides multiple benefits aligned with CCE Program goals: significant reductions in greenhouse gas emission compared to petroleum-powered vehicles; lower $/mile fuel costs compared to petroleum vehicles, increasing CCE customer-load base, and providing a flexible electricity demand load that has the future potential to be managed to support the integration of renewable energy.

- ***Energy Efficiency, Fuel Switching, and Conservation***
  New programs that support and enhance the existing programs offered by RCEA, PG&E, the Redwood Community Action Agency, and others.

- ***Match funding for State, Federal, and Foundation Energy Grants***
  The majority of grant funding opportunities require some level of local match funding, so tagging/reserving a flexible component of the CCE program budget to be available as-needed for use as energy-related grant match funding will support bringing resources into Humboldt County to pursue our community energy goals.

Attachment 5.3: Residential Energy Services Summary

This proposal is intended to fund Residential Energy Services (RES) through June of 2019. Staff recommends funding the RES program to minimize the likelihood of services gaps. An increased likelihood of service gaps exists because of PG&E's recent decision to defund RCEA's historic RES programs.

The program will:

- Sustain a primary point of contact for customers to learn about and select from all available local/state/federal services in an unbiased manner.
- Provide supplemental support to the home energy improvement market to address market barriers such as general knowledge, energy analysis, and upfront costs.
- Assist customers with strategies to combine various offerings including electrification measures.
- Educate customers on the current efficiency rating of their home and the whole-house approach to energy efficiency.
- Guide their plans for energy improvement projects using "no regrets" or "make ready" strategies.
- Support the local construction sector with affordable access to knowledge, tools, and analytical expertise on home energy efficiency.

Services will include the following programmatic pathways:

- **Home Energy Advisor**
  Staff will consult with customers over the phone or schedule in-office appointments for No-Cost. Customers will be directed to the Energy Advisor on staff that is best suited to answer their specific energy questions. A main component of the consultation is to recommend additional services to the customer. The customer will be directed to the program or resources (internal or external) that best meets their needs. Non-CCE customers will be encouraged to opt-in. Customers interested in further RCEA services will be transitioned to the appropriate staff member. Eligible participants will receive a customized efficiency kit valued at $75.00. Efficiency kits will include but will not be limited to items such as: LED light bulbs, smart strips, switch plate insulators and CO alarms.

- **Rater Pathway**
  Home Upgrade Rater services will meet the requirements of the Home Upgrade program for Participating Raters including Initial Assessments, Final Ratings, and Energy Modeling (see *homeupgrade.org* for program details). Participating homeowners will receive a report, consultation, and become eligible for up to $5500 in rebates from the Home Upgrade Program when completing a qualifying whole-house project. If approved, participating homeowners will also receive a local rebate match of $1500 through RCEA Core Products and Services Catalog. Owners of single family homes will be charged a $500 service fee to ensure the customer is reasonably committed to taking on a major investment. Pricing of services for 2-4 unit homes will be higher and will be based on the number of units tested and upgraded. A full refund of service fees will be offered for projects receiving a rebate from PG&E that complete within 1 calendar year

of the consultation. This is a continuation of the Home Upgrade Rater Services RCEA has offered for 4 years.

- **Home Energy Score**
  Homeowners enrolling in Home Upgrade Rater Services will also receive a No-Cost Home Energy Score (HES) Rating. The HES Rating assigns the home a score of 1-10 (10 being the highest) based on the results of the energy modeling (see *energy.gov* for more details). The score helps homeowners visualize how the efficiency of their home compares to other homes, much like a miles-per-gallon rating for a car. This pilot has the potential to scale in the future to assessments performed outside of Home Upgrade Rater Services. There is also the future potential to adopt HES Ratings onto the Multiple Listing Service.

RCEA expects to:

- Serve 250 or more residences through the Energy Advisor pathway
- Provide 250 or more efficiency kits
- Complete 25 or more Home Upgrade Assessments
- Refer and bridge services to:
  - Redwood Community Action Agency's Weatherization Assistance Program
  - PG&E's Energy Saving Assistance Program
  - Grid Alternatives' (Energy for All) low income solar energy program

The table below presents the proposed budget.

Staff time	$	38,000.00
Durable Equipment	$	2,200.00
Expendable materials/supplies	$	800.00
Travel & training costs	$	5,000.00
	$	46,000.00

Attachment 5.4: RCEA Rebate Catalog Summary

Redwood Coast Energy Authority (RCEA) will design, launch and implement a products and services rebate catalog. The phrase "products and services" defines items of economic value offered to Community Choice Energy ratepayers. The catalog concept is borrowed from PG&E's self-reporting rebate service channel. The objective of the proposed program is: to increase access to, and adoption of, varying energy efficiency and electrification measures; to leverage and bridge with existing programs; and to capitalize on existing administrative, marketing, and implementation structures. The catalog is envisioned as an ongoing activity that can be re-funded and grown over time.

RCEA's initial catalog launch will include a short-list of prioritized energy efficiency, electrification, storage and transportation related rebates. The following table presents the initial offerings and expected volume of disbursed rebates. The program will leverage and extend existing services to minimize resourcing requirements while maximizing community value. Staff development and launch costs are expected to be covered by existing resources. It is staff's intent to allocate all initial funding to rebates.

	Initial Catalog Measures		Fiscal Year 2018-2019 Estimates				
Unique Identifier	**Description**	**General Eligibility (Additional criteria to be defined post-approval)**	**Unit of Measure**	**Unit Quantity Rebated**	**Rebate /Unit**	**Total Initial Rebate Allocation**	**Est. Customers Served**
RCEA001	The rebate will buy down the cost of projects in business types with poor deemed hours of operation--a priority will be placed on public agencies participating in the public agency solar program.	Must be eligible for PG&E lighting rebates.	Per Lamp	4,875	$2	$9,750	100
RCEA002	Install air source heat pump water heater	Customer shows proof of installation and closed permit.	Per Water Heater	30	$500	$15,000	30
RCEA003	Install air source heat pump space heater	Customer shows proof of installation and closed permit.	Per Space Heater	25	$800	$20,000	25
RCEA004	Residential Efficiency Kit	Applies to residential ratepayers that have received a Home Energy Advisor Consultation.	Per Efficiency Kit	150	$75	$11,250	150
RCEA005	Electric Vehicle Level 2 Home Charger Rebate	Applies to any residential ratepayer who has proof of EV ownership.	Per household	15	$600	$9,000	15
RCEA006	Electric Vehicle Rebate Match	Applies to any battery or plug-in hybrid vehicle purchase that is eligible for the Clean Vehicle Rebate Project incentive.	Per vehicle	35	$1,000	$35,000	35
						$100,000	355

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Attachment 5.5: High-Volume PG&E EV Charging Cluster

This proposed project will provide match funds to the PG&E EV Charging Network program to install local electric vehicle charging stations. The goal is to collaborate with PG&E and one or more site hosts to create a bank of publicly-accessible charging ports at one or more high-value locations in Humboldt County to serve a growing population of EV drivers.

The main benefits will be to increase site host probability of success, secure commitment from a qualified site host, and ensure efficient allocation of local resources for EV charging infrastructure by leveraging PG&E's program for high-volume locations. The PG&E EV Charging Network provides funding for sites able to install 10 or more charging ports, and PG&E pays a large percent of electrical upgrade costs and provides access to volume discounts for EV charging equipment.

Based on January through April 2018 utilization of existing RCEA EV charging stations, 10 new stations would dispense 16.6 MWh in year 1. The expected first-year GHG emissions abated by the new stations once the program is implemented are 27.54 metric tons of CO2 equivalent.

The project will:

- Conduct a site evaluation and selection process, building on RCEA's previous regional EV charging infrastructure planning project.
- Facilitate engagement between potential site host and PG&E.
- Provide RCEA match funds to install one or more Level 2 EV charging clusters in conjunction with the Pacific Gas and Electric Company (PG&E) EV Charging Network program[1]. It is expected that installation costs, including site engineering, charging equipment purchase and construction will be split approximately 50/50 between PG&E and RCEA funding.
- Establish a relationship between the EV charging site host and RCEA to establish terms and conditions for successful long-term availability of the resource to local drivers.
- Operate and maintain the stations within the existing RCEA EV charging network.

The table below presents the proposed budget.

Staff time	$	6,320
Charging Station Installation	$	77,680
Total:	$	84,000

[1] https://www.pge.com/en_US/business/solar-and-vehicles/your-options/clean-vehicles/charging-stations/ev-charge-network.page

Materials Submitted to Board After Packet Publication

Summary Table of 2018 Customer Program Proposals – shown in descending order of score

Proposal UID	Program Name	Authors	Summary	Proposed Funding	Scoring Average	Proposed Adjustment/Recommendation
5	Residential Energy Services	Ben Mattio, Lena Means, Mike Bishop, Kevin Burks	Would provide incremental Residential Energy Services to encourage and support the transition of residential housing stock to meet local and state goals to achieve Zero Net Carbon.	$46,000	77	Yes, continue be mindful of how we present services across funding mechanisms.
3	Energy Management Program for Key Accounts	Patricia Terry, Patrick Owen, Marianne Bithell	Would provide support, including match funds for services, for key account management including energy audits and modeling; would also provide training for account managers	$0	76.5	Good idea, strongly supported: Training is funded, staffing for pushing to KAMs is available. Tech assistance to be considered in catalog.
1	RCEA Core Products Catalog	Lou Jacobson, Dana Boudreau, Aisha Cissna	Would create a catalog of new and existing energy services for which RCEA would provide matching rebates or direct subsidies	$100,000	73.75	Present simplified measures: storage, efficiency, heat pump installations and transportation. Next step is to dial in initial measures.
7	High-Volume PG&E EV Charging Cluster	Aisha Cissna, Dana Boudreau	Would award a selected site host with match funds to participate in the PG&E EV Charging Network program.	$84,000	73	Proposal team to combine phase 1 and phase 2 with a bigger ask; fully developed budget.
6	On-Bill Financing Bridge Payment and Micro-Loan Pilot Program	Patricia Terry, Patrick Owen, Kevin Burks, Lexie Fischer, Nicole Halvorsen and Steve Edmiston	Would create a revolving fund to provide short-term loans to customers or contractors for energy efficiency projects, including bridge loans in support of PG&E OBF, and micro-loans up to $5,000	$0	63.25	Revenue neutral, use reserve funds to tie $30k for mini-fund on the bridge payments. Micro-loans wil be placed on hold.
2	Generation-Side CARE Discount	Richard Engel, Mahayla Slackerelli, Jocelyn Gwynn	Would provide an additional monthly discount for CARE customers, applied on generation side of bill	$0	0	Good idea. Recommend exploring through rate setting.
4	RCEA Customer Products and Services Database 2.0	Patricia Terry, Dana Boudreau, Lou Jacobson	Would fund the first phase towards development of a new tracking and customer relationship managing database to consolidate/replace multiple tools currently in use	$0	0	Good idea. Not a program, fund through operations budget?
				$230,000		

Submitted by Community Advisory Committee Member Dr. Norman Bell.

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Bill (William) Moomaw

LETTER • OPEN ACCESS • FEATURED ARTICLE

Does replacing coal with wood lower CO_2 emissions? Dynamic lifecycle analysis of wood bioenergy

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Abstract

Bioenergy is booming as nations seek to cut their greenhouse gas emissions. The European Union declared biofuels to be carbon-neutral, triggering a surge in wood use. But do biofuels actually reduce emissions? A molecule of CO_2 emitted today has the same impact on radiative forcing whether it comes from coal or biomass. Biofuels can only reduce atmospheric CO_2 over time through post-harvest increases in net primary production (NPP). The climate impact of biofuels therefore depends on CO_2 emissions from combustion of biofuels versus fossil fuels, the fate of the harvested land and dynamics of NPP. Here we develop a model for dynamic bioenergy lifecycle analysis. The model tracks carbon stocks and fluxes among the atmosphere, biomass, and soils, is extensible to multiple land types and regions, and runs in ≈1s, enabling rapid, interactive policy design and sensitivity testing. We simulate substitution of wood for coal in power generation, estimating the parameters governing NPP and other fluxes using data for forests in the eastern US and using published estimates for supply chain emissions. Because combustion and processing efficiencies for wood are less than coal, the immediate impact of substituting wood for coal is an increase in atmospheric CO_2 relative to coal. The payback time for this carbon debt ranges from 44–104 years after clearcut, depending on forest type—assuming the land remains forest. Surprisingly, replanting hardwood forests with fast-growing pine plantations raises the CO_2 impact of wood because the equilibrium carbon density of plantations is lower than natural forests. Further, projected growth in wood harvest for bioenergy would increase atmospheric CO_2 for at least a century because new carbon debt continuously exceeds NPP. Assuming biofuels are carbon neutral may worsen irreversible impacts of climate change before benefits accrue. Instead, explicit dynamic models should be used to assess the climate impacts of biofuels.

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1. Introduction

Limiting global warming to no more than 2 °C requires large, rapid cuts in fossil fuel consumption by mid-century (Figueres *et al* 2017, IPCC 2014). In response, governments around the world are promoting biomass to reduce their greenhouse gas (GHG) emissions. The European Union declared biofuels to be carbon-neutral to help meet its goal of 20% renewable energy by 2020, triggering a surge in use of wood for heat and electricity (European Commission 2003, Leturcq 2014, Stupak *et al* 2007). The United Kingdom subsidizes wood pellets for electric power generation and has become the world's largest pellet importer (Thrän *et al* 2017). The US federal government and a number of US states are considering whether to declare wood fuels carbon-neutral or to promote their use (Cornwall 2017), while at COP23 in Bonn 'China and 18 other nations representing half the world's population said...they planned to increase the use of wood...to generate energy as part of efforts to limit climate change' (Biofuture Platform 2017, Doyle and Roche 2017).

But do biofuels actually reduce GHG emissions? The appeal is intuitive: fossil fuels inject carbon sequestered in geological reservoirs for millions of years into the atmosphere, where it accumulates and causes global warming (IPCC 2013). In contrast, biofuels recycle carbon from the atmosphere, helping to keep fossil carbon in the ground (IPCC 2013).

However, a molecule of CO_2 added to the atmosphere today has the same impact on radiative forcing and warming whether it came from coal millions of years old or biomass grown last year. Biofuels can only reduce atmospheric CO_2 over time by increasing net primary production (NPP) above what it otherwise would have been (DeCicco 2013). Assessing the climate impact of wood and other biofuels therefore depends on two critical questions: first, at the point of combustion, do biofuels generate more or less CO_2 per unit of end-use energy than fossil fuels? Second, what are the dynamics of biomass (re)growth and how do NPP and carbon fluxes from biomass and soils depend on the fate of the harvested land?

Confusion over these questions has caused the scientific debate over the climate impact of bioenergy and, especially wood, to remain 'contentious' (Creutzig *et al* 2015, Ter-Mikaelian *et al* 2015). The wood industry and many governments promote wood as a renewable, carbon-neutral fuel, while many environmental groups oppose wood bioenergy because it causes deforestation, harming natural carbon sinks, ecosystems, and biodiversity (Cornwall 2017). Advocates emphasize a long time horizon to evaluate the impact of biofuels, a century or more, by which time it is assumed forests will regrow, offsetting initial emissions. Opponents point to the potential for wood energy to increase CO_2 levels in the short run, incurring a 'carbon debt' that can only be paid off slowly, and worry that the resulting increase in atmospheric CO_2 will worsen global warming and lead to irreversible impacts before the benefits of new growth can occur (Brack 2017, Buchholz *et al* 2016, Cornwall 2017).

Life cycle analysis is commonly used to answer the first question. Results vary with the assumed system boundary and biofuel harvesting, processing and transport methods (e.g. Buchholz *et al* 2016). However, although wood has approximately the same carbon intensity as coal (0.027 vs. 0.025 tC GJ^{-1} of primary energy; see supplementary material), combustion efficiency of wood and wood pellets is lower (Netherlands Enterprise Agency; IEA 2016). Estimates also suggest higher processing losses in the wood supply chain (Röder *et al* 2015). Consequently, wood-fired power plants generate more CO_2 per kWh than coal (supplementary table S5 available at stacks.iop.org/ERL/13/015007/mmedia). Burning wood instead of coal therefore creates a carbon debt—an immediate increase in atmospheric CO_2 compared to fossil energy—that can be repaid over time only as—and if— NPP rises above the flux of carbon from biomass and soils to the atmosphere on the harvested lands.

Dynamic analysis is required to answer the second question (e.g. Helin *et al* 2013). The carbon cycle and climate impacts of bioenergy involve multiple stocks of carbon (e.g. in biomass, soils and dead organic matter, and the atmosphere) and the processes that control the flow of carbon among those stocks including NPP, transfer of carbon from biomass to soil, decomposition of organic matter, consumption and respiration of carbon in biomass and soils, etc. Tools are needed to assess the dynamic climate impact of bioenergy over policy-relevant time horizons. Because of the uncertainty and debate over the impacts of biofuels, such tools should allow users to examine alternative assumptions and scenarios easily and quickly, and would avoid the need to use static summary metrics such as global warming potentials (GWP) and contentious debate over the appropriate time horizon for these approximations, e.g. whether to use GWP20 or GWP100 (Ocko *et al* 2017).

To address this need we developed an interactive decision-support model that enables policymakers and other stakeholders to explore the dynamic impact of biofuels on carbon emissions and climate. The model is fully documented, freely available, runs in about a second on ordinary laptops and is extensible to any number of land use categories and spatial scales. Users receive immediate feedback on the impacts of their scenarios and assumptions. Here we describe the model and use it to explore the dynamics of substituting wood for coal in electric power production, using wood sourced from a range of forest types in the US to estimate model parameters governing NPP and carbon fluxes.

2. Methods

2.1. Model structure

We build on the widely-used C-ROADS climate policy model (Sterman *et al* 2012, Sterman *et al* 2013), developing a more detailed representation of land use, the carbon stocks associated with different types of land and the fluxes arising from them. C-ROADS is a member of the family of simple climate models, consisting of a system of differential equations representing the carbon cycle, budgets and stocks of GHGs, radiative forcing and the heat balance of the Earth. C-ROADS closely replicates GHG concentrations, global mean surface temperature, and other climate metrics from 1850, and matches CMIP5 model projections through 2100 across a wide range of Representative Concentration Pathways (RCPs) (Knutti and Sedlacek 2013, Vuuren *et al* 2011). C-ROADS has been used by policymakers (Sterman *et al* 2012) and is freely available (www.climateinteractive.org).

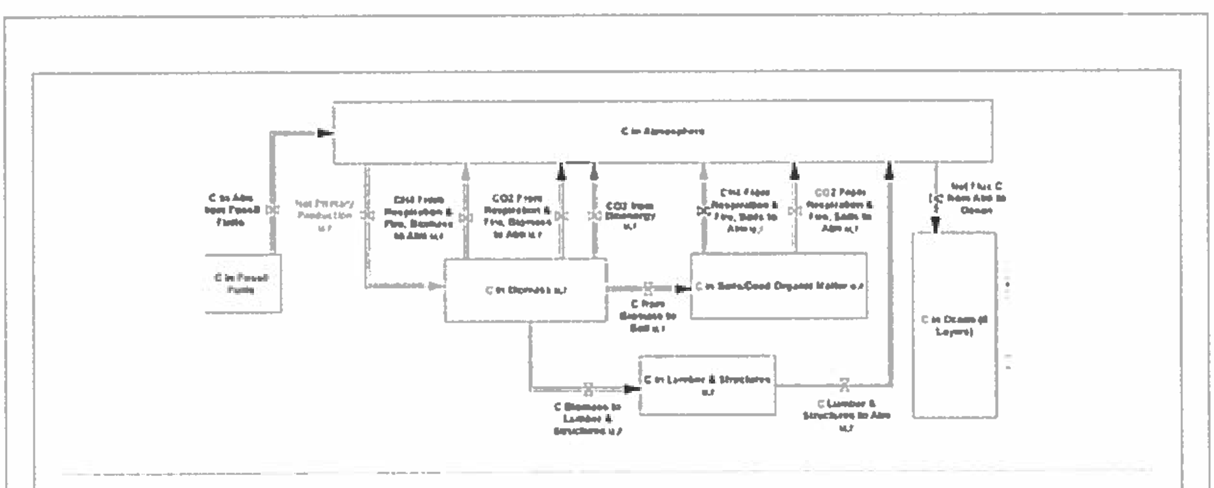

Figure 1. Modified carbon cycle in extended C-ROADS model. Carbon in biomass, soils, and structures (e.g. lumber in buildings), and fluxes among these compartments, are disaggregated by land type, *u*, and region, *r*. Carbon can flow from biomass and soils from each patch, *u*, *r*, to the atmosphere as CO_2 or CH_4. In addition, bioenergy harvest and combustion generate CO_2. CO_2 and CH_4 fluxes associated with changes in land use, e.g. from forest to pasture, cropland or developed land are included in the model but not shown here. On the policy-relevant time scale (e.g. through 2100), creation of new fossil fuels from terrestrial or oceanic carbon sources assumed to be negligible. Note: as described in the text and supplementary material, CH_4 fluxes from biomass and soils are set to zero for forest scenarios considered here to isolate the impact of bioenergy in the scenarios tested.

The carbon cycle in the original C-ROADS model includes globally aggregated stocks of carbon in fossil fuels, the atmosphere, terrestrial biomass and soils, and a four-layer ocean. Here we disaggregate the treatment of terrestrial carbon stocks both geographically and by land type (e.g. forest, pasture, cropland, developed land, etc.). For each region, the model represents the area of each type of land and changes in land use resulting from natural processes and human activity, along with the carbon stocks and fluxes associated with each. The model is extensible to any number of land/land use categories and geographic areas. For example, one could configure the model to represent different types of forests, with similar disaggregation for other land types, and at geographic scales from regions to nations to, if data are available, even smaller areas.

Figure 1 shows an overview of the carbon cycle in the extended model. As in the original model, combustion of fossil fuels injects carbon into the atmosphere. Unlike the original model, carbon stocks in biomass and soil are now represented for each category of land and geographical area. The model also includes a compartment for carbon stored in lumber and structures. Consistent with reporting approaches for the IPCC, FAO, and US Forest Service (FAO 2016, Penman *et al* 2003, Smith *et al* 2006), biomass in forest land includes living trees, including stems, branches, foliage, and coarse roots in both mature and understory trees; the stock denoted 'soil carbon' includes soil organic matter, dead roots, litter (dead foliage, dead branches, etc), downed and standing dead trees, and living fine roots (Woodall *et al* 2015). Biomass is increased by net primary production. Carbon in biomass can return to the atmosphere as CO_2 or CH_4 and is transferred to the soil stock via litterfall and tree mortality. Carbon is also lost from both biomass and dead organic matter by fire. Carbon in the soil stock is transferred to the atmosphere through the activity of decomposers and other heterotrophs (Fahey *et al* 2005). The supplementary material provides full documentation.

Although the model can be configured for any number of land types and uses, here we focus on wood harvested for electricity generation. For simplicity, we configure the model to represent one region with three categories of land: unmanaged forest, recently harvested forest, and 'other,' which includes all other land use categories (cropland, pasture, developed land, etc.).

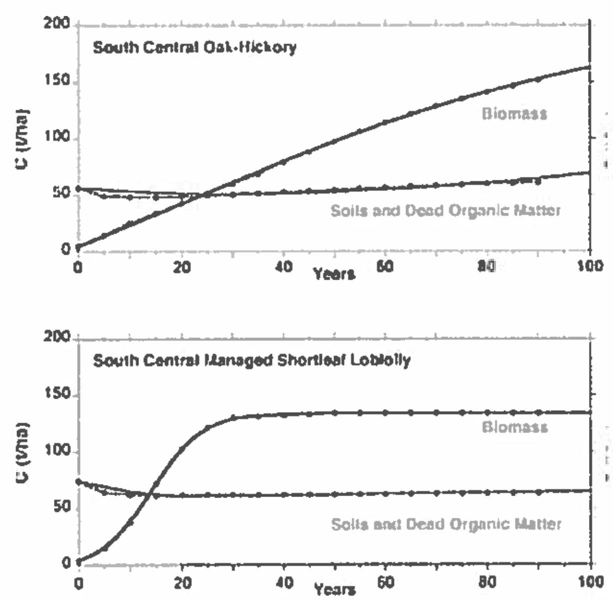

Figure 2. Growth curves showing carbon density (tC ha^{-1}) for oak–hickory (top) and managed shortleaf loblolly pine plantations (bottom) in the south-central US, comparing Smith *et al* (2006) growth curves (dashed lines

with data points) to the model (solid lines), with best-fit parameters. Supplementary figure S2 and tables S2–S3 show results for all forest types estimated.

2.2. Parameter estimation

Each unit of end-use bioenergy displaces the same end-use energy generated from fossil fuels, so net CO_2 emissions from biomass at the point of combustion depend on which energy source is more efficient overall, given fuel carbon intensity, combustion efficiency, processing losses, and emissions from their supply chains. Typical combustion efficiencies for wood are approximately 25%, compared to 35% for coal (Netherlands Enterprise Agency 2011, IEA 2016). Published estimates vary with the process examined and the system boundary considered, but processing losses (in energy content) for the wood pellet supply chain are on the order of approximately 27% if biomass is used in the drying process (Röder *et al* 2015), compared to losses of approximately 11% for coal (IEA 2016). Differences in supply chain emissions from extraction/harvest, and transportation are uncertain but relatively small compared to the large differences in combustion and processing efficiencies (e.g. Odeh and Cockerill 2008, Röder *et al* 2015). Consequently, wood pellets emit approximately 0.071 tC more CO_2 per GJ of end-use energy than coal (see supplementary material).

The determinants of NPP and carbon fluxes from biomass and soil to the atmosphere are therefore critical to assessing the dynamic impact of bioenergy including the carbon debt payback period and long-run reduction in atmospheric CO_2. To estimate the parameters governing NPP and these fluxes we use the post-harvest growth curves in Smith *et al* (2006), which span many regions and species in US forests. To illustrate, figure 2 shows the Smith *et al* growth curves for south-central US oak–hickory forest and managed shortleaf loblolly pine plantations. The growth patterns differ markedly in both their shape and time required to reach maximum biomass. After harvest, the managed loblolly plantation regrows quickly, following a classic S-shaped curve and reaching maximum biomass after about three decades, while the hardwood forest grows roughly linearly for about 50 years and is still growing after a century. Note that in both cases, soil carbon declines for several decades after harvest because the C flux from biomass to soils is cut while heterotrophic respiration continues to release C from soils and dead organic matter to the atmosphere.

To model NPP we specify a variant of the Richards (1959) growth model, widely used in forest growth modeling. The US wood pellet industry is growing rapidly, and much of the production is exported to the EU and UK. We therefore estimate the carbon cycle parameters from growth curves for temperate US forests reported by Smith *et al* (2006). We estimate the parameters of NPP jointly with those governing fluxes of CO_2 from biomass to soil and from each compartment to the atmosphere using nonlinear least squares and Markov Chain Monte Carlo methods (supplementary material). The model fits the Smith *et al* growth curves closely: the mean absolute error relative to the mean ranges from 0.008%–0.065% for biomass and from 0.006%–0.074% for soils (figure 2, table S2).

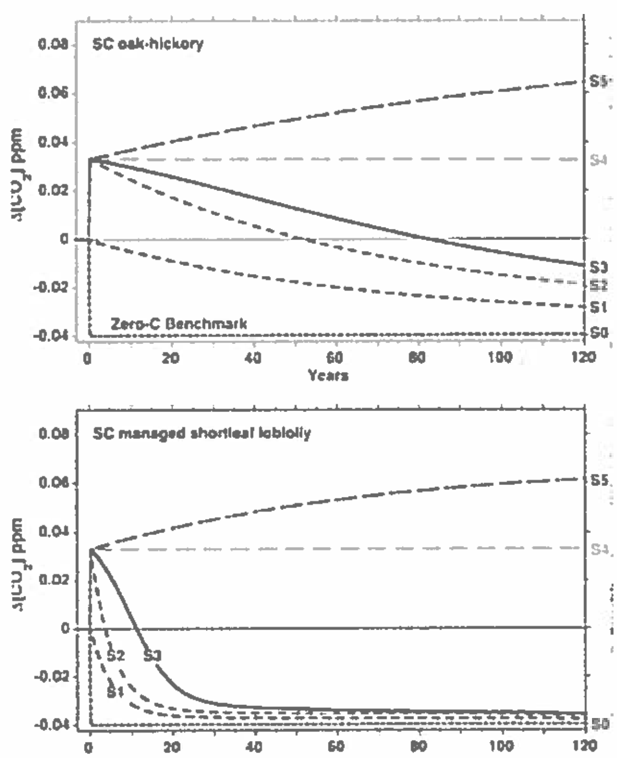

Figure 3. Change in atmospheric CO_2 concentration resulting from displacement of coal by wood. $\Delta[CO_2]$ is relative to continued coal use. All scenarios show the change in atmospheric CO_2 (ppmv) resulting from a single 1 EJ pulse of end-use energy from biomass used to displace coal in year 0. Top: south-central (SC) oak–hickory forest; bottom: SC managed shortleaf loblolly plantation. The bioenergy pulse causes an immediate increase in CO_2 concentration (the initial carbon debt) in scenarios 2–5 due to lower combustion and processing efficiencies for wood compared to coal. The year in which $\Delta[CO_2]$ falls below zero is the carbon debt payback time. Supplement figure S3 shows the results for all eight forest types examined. S0: Benchmark showing impact of 1 EJ pulse of zero carbon energy. S1: Bioenergy assumed to have the same combustion and processing efficiency as coal, and the same supply chain emissions; with 25% of biomass removed from the land harvested through thinning. S2: Actual efficiencies and supply chain emissions for wood pellets; 25% of biomass harvested through thinning. S3: S2 with 95% of biomass harvested (clear cut). S4: S3 with clear cut and no regrowth of harvested land and no C released from soil stocks. S5: S4 with C released from soil stocks at the estimated fractional rate.

3. Results

In the scenarios below, we adopt assumptions that favor bioenergy. Specifically, we assume bioenergy from wood pellets is used to offset coal, the most carbon intensive fossil fuel; if wood offsets power generated from natural gas its carbon debt would be much larger. Estimates of net CH_4 fluxes from forest biomass and soils are poorly constrained and considered to be insignificant in most global methane budgets (e.g. Ito and Inatomi 2012, Saunois *et al* 2016, Shoemaker *et al* 2014); we therefore assume them to be zero. We assume all land harvested for bioenergy is allowed to regrow without any fire (Buchholz *et al* 2016), erosion, disease, unplanned logging, or other ecological disturbances, including climate change impacts, that could limit regrowth or inject GHGs into the atmosphere beyond the direct impact of the bioenergy harvest. We further assume that the decline in coal use resulting from wood does not lower coal prices, increasing coal demand elsewhere, an effect estimated to be large (e.g. York 2012).

To isolate the dynamic impact of bioenergy on CO_2 emissions we run the model from an initial equilibrium in which the carbon fluxes from biomass and soils to the atmosphere are balanced by NPP, and in which net CO_2 flux to the ocean is zero throughout, identifying the impacts of bioenergy separate from other sources of disequilibrium, e.g. prior logging and marine uptake of CO_2. Including ocean CO_2 uptake would moderate increases in atmospheric CO_2 from bioenergy but worsen ocean acidification and other impacts. These effects are left for future work.

Figure 3 shows the results for a set of scenarios using parameters estimated for oak –hickory forest in the south-central US (supplementary figure S3, table S7 provide results for all eight forest types we estimated). All scenarios examine a 1 exajoule (EJ) pulse of end-use electric energy generated from wood pellets in year 0, offsetting 1 EJ of end-use electricity generated from coal (total world energy use exceeds 550 EJ yr^{-1}, US EIA 2016).

Scenario 0 provides a benchmark showing how atmospheric CO_2 would change if 1 EJ of end-use energy from coal were offset by a zero-carbon energy source, such as solar or wind (and assuming zero emissions from the supply chain). Displacing 1 EJ of end-use energy from coal with a zero C alternative keeps 0.07 GtC of fossil carbon in the ground, immediately and permanently lowering atmospheric CO_2 by approximately 0.04 ppm relative to continued coal use.

Scenario 1 simulates the counterfactual case in which bioenergy is assumed to have the same carbon emissions per EJ of end-use energy as coal, including the same combustion and processing efficiency and supply chain emissions. We assume that 25% of the biomass is removed from each hectare of the harvested forest by thinning, not clear cutting, that the forest is allowed to regrow with no subsequent harvest, fire, disease, or other disturbances. Because emissions are counterfactually assumed to be the same as coal, there is no immediate change in atmospheric CO_2.

However, as the forest grows back, carbon is gradually removed from the atmosphere to biomass and soils. After 100 years, the forest has recovered enough to lower atmospheric CO_2 by 0.026 ppm, still 34% above the zero C case.

Scenario 2 shows the realistic case with the combustion efficiency and supply chain emissions estimated for wood pellets (supplementary table S5), again assuming 25% of the biomass is harvested by thinning. Because production and combustion of wood generate more CO_2 than coal, the first impact of bioenergy use is an increase in atmospheric CO_2. Regrowth gradually transfers C from the atmosphere to biomass and soil C stocks, leading to a carbon debt payback time of 52 years; after 100 years CO_2 remains 62% above the zero C case.

Scenario 3 is the same as S2 except we now assume the land is clear cut instead of thinned, with 95% of the biomass removed. Near-complete biomass removal reflects the growing practice of harvesting whole trees and residues (branches, litter, etc) (Achat *et al* 2015). A 95% clear cut requires only 26% as much land as in S2, but the carbon debt payback time increases to 82 years; after 100 years CO_2 remains 86% above the zero C case.

Scenario 4 shows the impact of assuming that the harvested area is clear cut as in S3 but never allowed to regrow, for example, because it is developed, with the additional assumption that the flux of C from soils and dead organic matter to the atmosphere is set to zero. Without regrowth, the carbon debt is never repaid and atmospheric CO_2 remains permanently higher.

Scenario 5 is the same as S4 except the flux of C to the atmosphere from soils and dead organic matter continues at the original fractional rate. Without regrowth, there is no flux of CO_2 from the atmosphere to terrestrial biomass or soils, but continued C flux from soils to atmosphere, causing CO_2 concentrations to rise beyond the immediate impact of the bioenergy. After a century atmospheric CO_2 has risen by 0.076 ppm, 2.3 times more than the initial impact. The actual impact of converting harvested forests to other uses will likely lie between the results of Scenarios 4 and 5, but could rise further if conversion of forest to other uses increases C fluxes from soils above the values estimated from the Smith *et al* (2006) data. Such an outcome could result from disturbances to soils from, e.g. plowing, development, fire or increasing methanogenesis, all of which we assume to be zero.

In Scenario 6 (figure 4) oak–hickory forest is clear cut and replanted as a shortleaf loblolly pine managed plantation. Loblolly pine grows faster than hardwoods (figure 2), so intuitively the conversion from unmanaged hardwood forest to managed pine plantation should speed the repayment of the carbon debt. As expected, atmospheric CO_2 initially falls faster in the plantation case compared to regrowth of the oak–hickory forest. However, the concentration bottoms out after approximately 20 years and then starts to rise, exceeding the CO_2 level when the forest is allowed to regrow. The explanation lies in the different maximum carbon densities of the two forest types: loblolly plantation grows faster but reaches a lower equilibrium carbon density compared to the unmanaged forest (figure 4), with estimated equilibrium values of 130 tC ha^{-1} for loblolly plantation vs. 211 tC ha^{-1} for oak–hickory. Consequently, although plantations grow faster, they do not remove as much C from the atmosphere as was lost when the hardwood forest was harvested, even if allowed to grow to their maximum biomass and remain unharvested. In reality, plantations are thinned every few years and harvested about every decade (US Forest Service 2000), further lowering their average C density and increasing atmospheric CO_2. Furthermore, repeated harvests can degrade the productivity of the soils, lowering NPP. To compensate, managed plantations are typically fertilized several times per rotation, increasing N_2O emissions that would further worsen the climate impact of Scenario 6 (Schulze *et al* 2012).

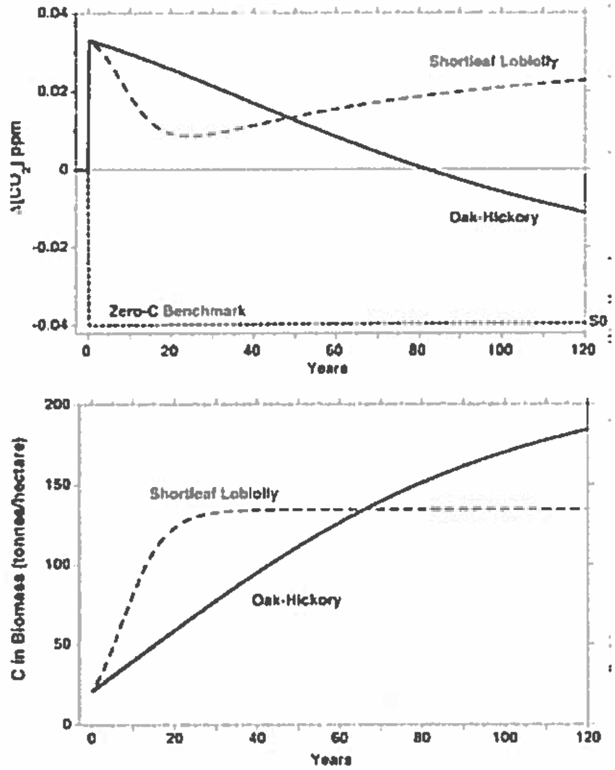

Figure 4. Scenario 6: replanting harvested oak–hickory forest after clear cut with managed plantation of shortleaf loblolly pine (south-central US), compared to allowing the oak–hickory forest to regrow (Scenario 3 in figure 2). Top: change in atmospheric CO_2 (ppmv) resulting from a single 1 EJ pulse of end-use energy from biomass used to displace coal in year. $\Delta[CO_2]$ is relative to continued coal use. Bottom: carbon in biomass (tC ha^{-1}). For the first 20 years, faster-growing loblolly pine lowers atmospheric CO_2 compared to regrowth of the oak–hickory forest, but the estimated maximum carbon density of oak–hickory forest is larger than the managed loblolly plantation (211 vs. 131 tC ha^{-1}, respectively; supplementary table S3). Consequently, the carbon debt is never repaid even if the loblolly plantation is never harvested. Due to CO_2 flux from soils, atmospheric CO_2 rises after approximately 20 years, exceeding the level from regrowth of oak –hickory after approximately 50 years.

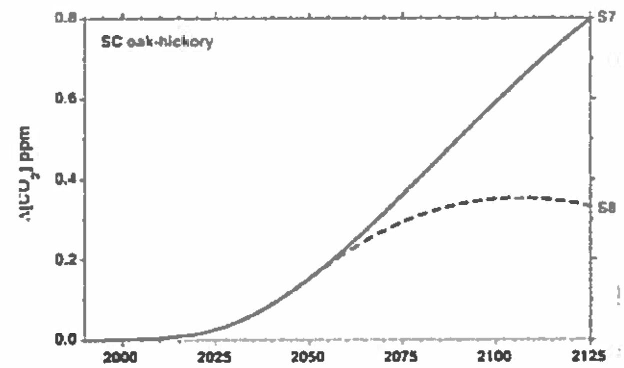

Figure 5. Change in atmospheric CO_2 concentration resulting from growth in end-use energy supplied by wood, displacing coal. $\Delta[CO_2]$ is relative to continued coal use. Scenario 7 (solid line): linear growth in end-use energy supplied by US wood pellet production, from the 2016 value of 0.028 EJ to 0.28 EJ yr^{-1} by 2050 and continuing linearly thereafter. Parameters estimated for south-central US oak–hickory forest, with harvest by clearcut. Scenario 8 (dashed line): the same as S7 except growth in end-use energy supplied by wood ceases in 2050. Supplementary figure S4 reports results for all forest types considered.

The supplementary material reports the 95% confidence intervals (CIs) for the estimated parameters (table S4), and sensitivity analysis across the eight forest types arising from parameter uncertainty, computed by Markov Chain Monte Carlo (table S8). The 95% CIs for the carbon debt payback times vary from 74–110 years for the hardwood species under clear cut (Scenario 3) and 11.25–12 years for the managed plantations. The supplementary material also reports the long-run CO_2 reductions for Scenarios 1–5 (table S7). For Scenario 3, after 100 years CO_2 falls an average of 51% of the maximum possible reduction (the difference between the initial carbon debt and the zero-C level in Scenario 0) for the forests and 92% for the plantations.

The supplementary material also reports sensitivity analysis of combustion efficiencies and supply chain emissions. Clearly, innovation that improves the combustion and processing efficiencies of wood *relative to coal* reduces the initial carbon debt of wood and reduces the carbon debt payback time and climate impacts of wood. However, innovations that improve the efficiencies of *both* fuels yield smaller benefits. For example, combined heat and power systems offer substantially higher combustion efficiency than conventional boilers, but would still cause an initial carbon debt since the combustion and processing efficiencies of wood remain lower than coal in such systems (supplementary figures S5–6).

The wood pellet industry is expanding rapidly and many projections call for substantial growth through 2030 or beyond (IEA 2012, IRENA 2015). Scenario 7 (figure 5) shows the impact of linear growth in end-use bioenergy; Scenario 8 is the same except growth ceases in 2050. Growth in wood supply causes steady growth in atmospheric CO_2 because more CO_2 is added to the atmosphere every year in initial carbon debt than is paid back by regrowth, worsening global warming and climate change. The qualitative result that growth in bioenergy raises atmospheric CO_2 does not depend on the parameters: as long as bioenergy generates an initial carbon debt, increasing harvests mean more is 'borrowed' every year than is paid back. More precisely, atmospheric CO_2 rises as long as NPP remains below the initial carbon debt incurred each year plus the fluxes of carbon from biomass and soils to the atmosphere. Note further that in Scenario 8, CO_2 continues to rise for 56 years after bioenergy production growth stops and only falls below initial levels 144 years after growth stops. Results for the other forest types are similar (supplementary figure S4).

4. Discussion and conclusion

We extended the carbon cycle model in the C-ROADS climate policy model to account for different land and land use types, by region. The model explicitly treats stocks of carbon in fossil fuels, biomass, soils and dead organic matter, the atmosphere, and the fluxes among them including combustion, supply chain emissions, and regrowth of harvested lands. The model is extensible to any number of land types and uses, and geographic scales. To demonstrate the approach, we analyzed the dynamic impact of displacing coal with wood in electricity production, finding:

First, yet contrary to the policies of the EU and other nations, biomass used to displace fossil fuels injects CO_2 into the atmosphere at the point of combustion and during harvest, processing and transport. Reductions in atmospheric CO_2 come only later, and only if the harvested land is allowed to regrow.

Second, the combustion and processing efficiencies of wood in electricity generation are lower than for coal (supplementary material). Consequently, the first impact of displacing coal with wood is an increase in atmospheric CO_2 relative to continued coal use, creating an initial carbon debt.

Third, after the carbon debt is repaid, atmospheric CO_2 is lower, showing the potential long-run benefits of bioenergy. However, before breakeven, atmospheric CO_2 is higher than it would have been without the use of bioenergy, increasing radiative forcing and global average temperatures, worsening climate change, including potentially irreversible impacts that may arise before the long-run benefits are realized.

Fourth, biofuels are only beneficial in the long run if the harvested land is allowed to regrow to its pre-harvest biomass and maintained there. Natural forests have high carbon density compared to pasture, cropland, developed land and managed tree plantations. The carbon debt incurred when wood displaces coal may never be repaid if development, unplanned logging, erosion or increases in extreme temperatures, fire, and disease (all worsened by global warming) limit regrowth or accelerate the flux of carbon from soils to the atmosphere. Further, lower coal prices caused by the drop in power sector demand may stimulate coal use elsewhere, offsetting even the potential long-run benefits of bioenergy (e.g. York 2012).

Fifth, counter to intuition, harvesting existing forests and replanting with fast-growing species in managed plantations can worsen the climate impact of wood biofuel. Although managed loblolly pine grows faster than hardwood, speeding the initial recovery of forest biomass, the equilibrium carbon density of managed plantations is lower than unmanaged forest, so carbon sequestered in plantations never offsets the carbon taken from the original forest. This is true even if the managed plantation is never reharvested, and worse if the plantation is periodically reharvested. Further, typical plantations require periodic fertilization, increasing N_2O emissions and worsening their climate impact beyond what we report here (Schulze *et al* 2012).

Sixth, growth in wood harvest for bioenergy causes a steady increase in atmospheric CO_2 because the initial carbon debt incurred each year exceeds what is repaid. With the US forest parameters used here, growth in the wood pellet industry to displace coal aggravates global warming at least through the end of this century, even if the industry stops growing by 2050.

Seventh, using wood in electricity generation worsens climate change for decades or more even though many of our assumptions favor wood, including: wood displaces coal (the most carbon intensive fossil fuel); all harvested land is allowed to regrow as forest with no subsequent conversion to pasture, cropland, development or other uses; no subsequent harvest, fire or disease; no increase in coal demand resulting from lower prices induced by the decline in coal use for electric power; no increase in N_2O from fertilization of managed plantations; and no increase in CO_2 emissions or methanogenesis from disturbed land. Relaxing any of these assumptions worsens the climate impact of wood bioenergy.

In sum, although bioenergy from wood can lower long-run CO_2 concentrations compared to fossil fuels, its first impact is an increase in CO_2, worsening global warming over the critical period through 2100 even if the wood offsets coal, the most carbon-intensive fossil fuel. Declaring that biofuels are carbon neutral as the EU and others have done, erroneously assumes forest regrowth quickly and fully offsets the emissions from biofuel production and combustion. The neutrality assumption is not valid because it ignores the transient, but decades to centuries long, increase in CO_2 caused by biofuels.

Methodologically, we demonstrate the feasibility of integrating static life cycle considerations around the efficiencies of and emissions from biofuels with explicit modeling of biomass dynamics in a model that runs fast enough to enable policymakers and other stakeholders to design and test their own scenarios. Future work will integrate the model into full climate models such as C-ROADS, creating a fast, interactive simulator that can model the impacts of different biofuel technologies and scenarios on CO_2 concentrations, radiative forcing, warming, ocean acidification, sea level rise and other impacts.

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