From: EnergyPlan2019@RedwoodEnergy.org
To: carilyn hammer; EnergyPlan2019@RedwoodEnergy.org
Cc: Paul Pitino; CityMgr@cityofarcata.org; Brett Watson; sornelas@cityofarcata.org; mwinkler@cityofarcata.org; Sofia Pereira
Subject: RE: Biomass is dirty
Date: Friday, September 20, 2019 5:14:29 PM

Thank you for your comment, Carilyn. We'll add this to our public comments which are available on our website.
https://redwoodenergy.org/services/planning/

Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: carilyn hammer [redacted]
Sent: Friday, September 20, 2019 4:10 PM
To: EnergyPlan2019@RedwoodEnergy.org
Cc: Paul Pitino <ppitino@cityofarcata.org>; CityMgr@cityofarcata.org; Brett Watson <bwatson@cityofarcata.org>; sornelas@cityofarcata.org; mwinkler@cityofarcata.org; Sofia Pereira <Spereira@cityofarcata.org>
Subject: Biomass is dirty

As a resident of Arcata, I am writing to ask that biomass not be eliminated completely from our energy plan by 2025 at the latest. Our aging biomass plants produce 400,000 tons of CO_2 each year which is the equivalent of doubling the number of cars in the county. As consumers we agreed to work with Redwood Coast Energy Authority to help reduce emissions, improve our environment, and do our part to help our planet. Biomass will accelerate climate change and thereby further endanger the lives of our children, grandchildren, all species, and our future.
Please, be sensible and plan to reduce biomass rather than have it be part of a plan for the next decade and years after.

Carilyn Goldammer
[redacted]
Arcata, CA [redacted]

From: EnergyPlan2019@RedwoodEnergy.org
To: Joyce King; EnergyPlan2019@RedwoodEnergy.org
Subject: RE: Comments
Date: Friday, September 20, 2019 5:13:25 PM

Thank you for your comment, Joyce. We'll add this to our public comments which are available on our website.
https://redwoodenergy.org/services/planning/

Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Joyce King [redacted]
Sent: Friday, September 20, 2019 5:01 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: Comments

Thanks to you at RCEA for the important work you do. Humboldt County is fortunate to have you.

My layperson's preferences with regard to your mission are as follows:

Actively investigate, publicly educate, and promote the most effective and feasible energy-conserving technologies and behaviors

Prioritize fossil fuel reduction in the transportation sector (60% of our greenhouse gas emissions)

Emphasize importance of cumulative environmental effects, especially from emerging energy-producing technologies, their yet-to-be-tested byproducts, and effects on already declining conditions

.

"impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertake such other actions. Cumulative impacts can result from individually minor, but collectively significant, actions taking place over a period of time". https://www.iaia.org/wiki-details.php?ID=9/Inform

Whilst all individual projects or actions affect their environment, the combined or cumulative effects of multiple actions can be greater than the sum of the individual parts (Canter and Kamath, 1995). Increasing numbers of proposed developments create greater pressures on the environment, making cumulative impacts a pressing issue. Such is the case for wind farms in the UK, where concerns have been raised over the negative impacts of increasing numbers of wind farms on bird populations (Stewart et al., 2007). Environmental Impact Assessment Review xxx (2009) xxx–xxx

Above all, avoid further harm to biodiversity and carbon-sequestering ecosystems. Humboldt County is blessed with many remnants of species and habitats which are rapidly being lost everywhere else. Our most important contribution to the global environmental catastrophe facing us may not be in alternative energy production, but in conserving biodiversity and the blueprints for future ecosystem revival.

In light of the above, I think it urgent to put your resources into the exploration and promotion of solar power instead of the present onshore wind-generation proposal. Or at least conduct a thorough point-by-point comparison of costs and benefits financially and environmentally, looking at the state of the art and foreseeable future advances of each.

It's hard to see how the benefits of the proposed wind project are enough to offset both the long-term losses of carbon sequestration and biodiversity at the proposed sites, and the short-term greenhouse gas emissions and other risks and impacts from construction, infrastructure, operation & maintenance, updating, refurbishing, and dismantling.

I am also dubious of mitigations and adaptive management which usually come with inadequate funding, oversight, enforcement, and few long-term, scientifically-documented records of success.

Thank you for the opportunity to comment.
Joyce King

From: EnergyPlan2019@RedwoodEnergy.org
To: Sue Y Lee; EnergyPlan2019@RedwoodEnergy.org
Subject: RE: CAPE input
Date: Friday, September 20, 2019 5:13:01 PM

Thank you for your comment, Sue. We'll add this to our public comments which are available on our website.
https://redwoodenergy.org/services/planning/

Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Sue Y Lee [redacted]
Sent: Friday, September 20, 2019 4:58 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: CAPE input

Dear RCEA staff,
We are very appreciative and thank you very much for your hard work attempting to meet our community's energy needs with clean renewable energy. We also applaud your current efforts to update your guiding strategy for the next 10 years via CAPE, and your efforts to obtain community input.

We ask for information and communication from RCEA as to how RCEA defines the term "clean" when referring to 'clean' energy. There seems to be a host of definitions for this term as understood and used by different entities in our community.

We wish to encourage RCEA to seek in the next 10 years as much renewable energy as possible from solar sources, and to scale back our dependence on wind and biomass energy to the extent possible.

In the meantime, while we are obtaining energy from biomass and wind, we ask RCEA to work with suppliers to mitigate the amount of pollutants and particulate matter released into the air and to find ways to mitigate the use of SF 6 in wind turbines.

So that the community can provide informed feedback to RCEA, we ask RCEA to seek more data that would provide everyone with information concerning:
1- the amount of carbon emissions resulting from burning biomass as compared to greenhouse emissions from composting biomass.

2- the amount of trees that are being cut to provide biomass fuel.

Finally, we ask that RCEA explore and find ways to promote the development of local grassroots, neighborhood energy production (solar panels on more individual homes and buildings; small neighborhood windmills) instead of focusing on creating large infrastructures to provide wind and solar energy to huge regions.

Thank you for your consideration.
Sincerely,
sue y. lee mossman
Archie S. Mossman

From:	EnergyPlan2019@RedwoodEnergy.org
To:	Lori Taketa
Subject:	FW: CAPE Comments
Date:	Friday, September 20, 2019 5:12:33 PM

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Barbara Kennedy [redacted]
Sent: Friday, September 20, 2019 4:57 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: CAPE Comments

To Whom it May Concern:

Regarding your request for comments., let me first comment on how disappointed I am that you are sponsoring the terrible Terra-Gen project - absolutely the worst possible and most destructive location anyone could have picked - I have commented on the project during the DEIR phase but I don't have any hopes that the FEIR will be any better.

You should be concentrating first, instead of this type of massive project, on distributed solar.

Copied here are suggested comments from Ken Miller. I heartily endorse these comments. The County should have solar panels on all County Buildings. County building codes should be changed to require solar panels on new home and commercial construction.

Distributed solar is far more efficient and less destructive than land-based wind energy with so much lost in transmission to substation. Rooftop solar feeds directly into the grid much more efficiently.

Also, more charging stations for electric vehicles - how about some down here in the south end of the County . The Parks should be installing charging stations at park campgrounds and parking areas for the tourists (and us.) I can't buy an electric vehicle until I can count on charging stations along the routes I travel.

All of this and more should be done before massive wasteful and destructive projects like Terra-Gen that will never return the amount of renewables we need in any order of magnitude to offset the environmental destruction and CO2 it creates.

Here are Ken's comments and I share his concerns and viewpoints as to how you should adjust your focus - forget massive destructive projects and concentrate on efficient and do-able solutions.

RCEA needs to focus on and dramatically expand

distributed solar, and abandon onshore wind power; and to stop minimizing the impacts from onshore wind and dismissing the feasibility of widespread solar.

•Fiduciary responsibility to explore, offer, and focus on the best, least impactful & least expensive energy option over time for Humboldt=Solar, it's really that simple.

•Hire a specialist to recruit the entire gamut of the solar and storage industries into our County

•Form a solar advisory committee representing all aspects instead of a poor stepchild to utility scale wind. Done right, solar can also feed the grid.

•Mobilize all resources to implement widespread solar, including door-to door outreach and accelerated solar mapping

•Focus on financing options that make solar electricity available to as many as possible, especially low income people

•Convert public offices and vehicles

•A massive active effort, as if this were an emergency

•Secure, resilient energy available during grid shutdowns and emergencies

•Reduce carbon footprint, increase energy awareness

•Electrify transportation and heating

•Share our energy wealth affordable for all, rather than concentrate it

•Reduce natural gas use

4 Components

Coordination

•Ensure building codes, maximize passive solar;

•Advise and promote solar training programs and education;

•Hospitals, shelters, Critical entities, HCAOG & Coalition for Responsible Transportation Priorities (CRTP), HSU;

•Entrepreneurs in EVs, charging, and EV2Grid, and micro-grids;

•The many companies and entrepreneurs specializing in solar financing,

Demand

•Efficiency

•Widespread distributed public and private rooftop and open space solar PV

•Solar electricity production fosters energy IQ

Transportation

•Electrify public and private transportation

•Best incentive for EVs is local solar production. It's the economics, with rapid payback, and low cost fuel, forever. EVs require little maintenance, no petroleum, and last a very long time, but their maximal benefit is when charged with locally produced solar. Many choices, ranges, prices for new and used EVs on the horizon.

Energy Generation and Environment

•We have arrived at both global heating and global extinction because we have ignored the impacts of

our industrial development on biodiversity. We should not succumb to the argument that climate change will kill all anyway, instead we should always choose energy options that protect biodiversity, for without biodiversity there can be no adaptation, so we must preserve what is left if we can. We must nourish our soils, forests, watersheds and vegetation that sequester carbon.

•Onshore wind divides our communities and fragments and degrades biodiversity, especially in the windiest sites, which are sacred to the local Native Americans, so utility scale onshore wind power should be abandoned in favor of offshore. Solar brings us together. The enormous construction of onshore emits many 1000s of tons of GHGs into our 10-year emergency window, while removing carbon sequestering trees, vegetation, grasslands and soils that would have eliminated 1000s of tons of GHGs annually.

•Local solar has no competition, so far, for our ideal energy source. Like all products, they contain embedded energy, but the lifecycle is containable, the elements abundant and recyclable, and used or recycled unused panels are widely available for as little as $65 for 270 W, and many are free for the hauling.

•Having a grid that continues to supply electricity from increasingly networked local solar has none of the impacts of wind, hydro, nuclear, or “solar farms,” and combined with local solar should define the future.

•Solar is 21 century technology that generates electricity by ionic transfers, like we do, with essentially no wasted heat. Solar is cool.

Wind turbines are based on 19 century technology, require constant surveillance and frequent maintenance to avoid potentially catastrophic accidents, and have ongoing adverse hydro-meteorological, socio-economic, biological, and psychological impacts.

•Solar just keeps getting less expensive and more rewarding over time with minimal if any adverse impacts.

•Solar requires no maintenance and minimal new infrastructure, including wildfire prone transmission lines, which lose up to 30% of transmitted electricity.

•Networked grid-tied micro-grids with EV stations

provide the ultimate in secure resilience, dynamic independence from the grid, intelligent supply-demand allocation, and mobile electricity storage and supply vehicles that can travel to shelters, hospitals, and other critical facilities.

•Solar creates jobs throughout the County, whereas utility scale generation yields very few.

•Solar engenders energy awareness and reduces reliance on the grid, PGE, and ever-increasing utility bills.

•Solar electricity plus EV and battery storage can be sold to the grid, earning public and private revenues while contributing to balanced grid loads.

•Solar is exciting because we own it, it supplies our homes, our neighborhoods, our public offices, our transportation, our bank accounts, our security, our resilience: that's what sharing our energy wealth looks and feels like.

•Solar can be installed in many very inexpensive ways by individuals, and systems can be portable.

Solar electricity and radiant energy can heat buildings. The grid can power induction electric cooking. That's having "both."

Respectfully submitted - Barbara Kennedy, [redacted] Weott, CA [redacted].

From:	EnergyPlan2019@RedwoodEnergy.org
To:	Lori Taketa
Subject:	FW: Comment re CAPE; the wind power failures and the radiative forcing of the various alternatives?
Date:	Friday, September 20, 2019 12:05:19 PM
Attachments:	Climate forcing 2015GL063514.pdf Agrophotovoltaics_harvesting_the_sun_for_power_and_potatoes.pdf image001.png image002.png

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Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Jesse Noell [redacted]
Sent: Friday, September 20, 2019 11:04 AM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: Fwd: Comment re CAPE; the wind power failures and the radiative forcing of the various alternatives?

Here is my comment:
with an addition, does RCEA consider the extent to which SF6 gas will is used in the power they contract for? If so, this should be revealed to those voting on or deciding alternatives--

https://www.bbc.com/news/science-environment-49567197
Exede Account Man... router admin Microsoft Word - A... thesaurus - Google Herbs celtic do...

It is widely used across the industry, from large power stations to wind turbines to electrical sub-stations in towns and cities. It prevents electrical accidents and fires.

Technicians display the importance of preventing electrical overloads

However, the significant downside to using the gas is that it has the highest global warming potential of any known substance. It is 23,500 times more warming than carbon dioxide (CO2).

---------- Forwarded message ---------
From: **Jesse Noell** [redacted]
Date: Fri, Sep 20, 2019 at 12:39 AM
Subject: Comment re CAPE; the wind power failures and the radiative forcing of the various alternatives?
To: <MMarshall@redwoodenergy.org>

Comments regarding the CAPE workshop

Hi Mathew,

One thing that I noticed at the CAPE was the lack of comparative safety and risk evaluations for solar, wind, natural gas, and transmission lines vs rootop microgrids with electric vehicles. Without these I don't see how the prioritization voting can be meaningful. See https://www.youtube.com/watch?v=nemy4TD4I3A

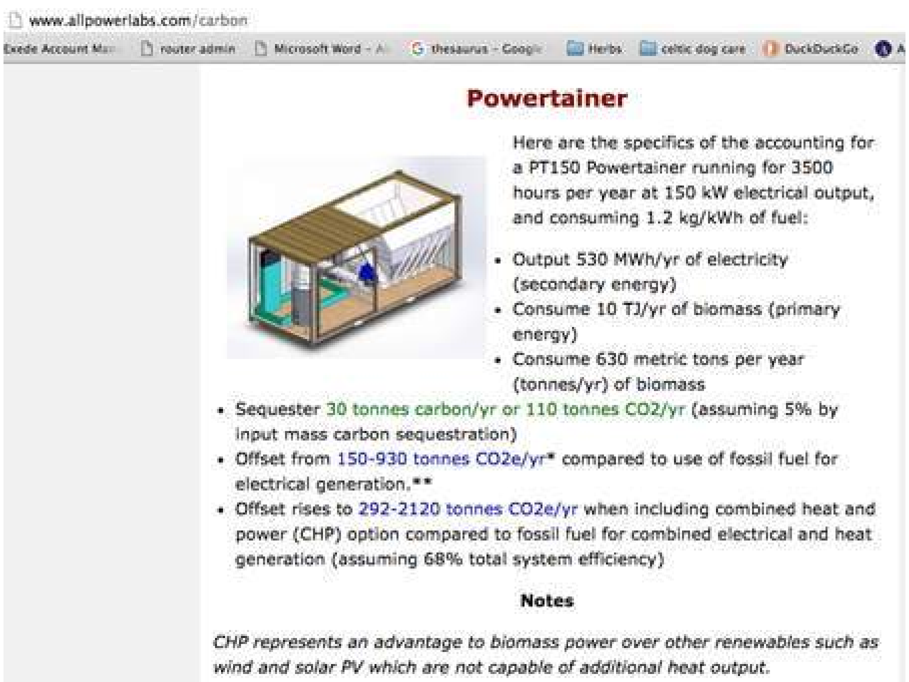
I also found that there was little or no analysis of greenhouse gas embedded emissions in combination with the project emissions and no quantification of how much additional radiative forcing heat will be retained in the atmosphere over the residence time of each GHG. This missing information is essential to an informed decision of altenatives. As stated in the abstract of the attached study, "the Earth warms both when fossil fuel carbon is oxidized to carbon dioxide and when greenhouse effect of carbon dioxide inhibits longwave radiation from escaping to space. Various important time scales and ratios comparing these two climate forcings have not previously been quantified. For example, the global and time-integrated radiative forcing from burning a fossil fuel exceeds the heat released upon combustion within 2 months. Over the long lifetime of CO2 in the atmosphere, the cumulative CO2-radiative forcing exceeds the amount of energy released upon combustion by a factor >100,000. For a new power plant, the radiative forcing from the accumulation of released CO2 exceeds the direct thermal emissions in less than half a year. Furthermore, we show that the energy released from the combustion of fossil fuels is now about 1.71% of the radiative forcing from CO2 that has accumulated in the atmosphere as a consequence of historical fossil fuel combustion." See attached.

It seems reasonable to break solar should into rooftop, dual usage agricultural voltaics, and megawatt generation.

Finally, since climate change consistently occurs much faster than predicted, and the science tells us that an arctic free of sea ice will double the rate of warming due to loss of albedo alone----any informed vote for an alternative will need to be made relative to the carbon footprint of the alternative in combination with the expected date of ice free Arctic. An alternative that might have been appropriate twenty years ago may not be appropriate today--this is why each alternative needs to identify the assumptions made and the decision pathway. In addition to Arctic sea ice loss, there are 70 or more other self reinforcing feedback loops that are being triggered----all of this information is critical to weeding out and discarding alternatives that are counter productive and that will accelerate climate change. Rationally, we must assure that we don't kill future generations. There is no need for power plants on a dead planet.

I find that placing recycled solar panels on existing grid tied rooftops with micro inverters is the most effective way to assure low income people participation in solving the problems we face, while minimizing carbon footprint. Recycled panels are plentiful and very low cost. Most structure have several unused circuit breakers that can be dedicated to microinverters. I have tested these systems; they are cheap and they work. The payback can come in a year or two. RCEA should prioritize these types of installation rather than spending most of its resources courting large projects.

Please investigate replacing biomass contracts with biochar power pallets or powertainers for peaker power at each greenwaste facility.



www.allpowerlabs.com/carbon

Powertainer

Here are the specifics of the accounting for a PT150 Powertainer running for 3500 hours per year at 150 kW electrical output, and consuming 1.2 kg/kWh of fuel:

- Output 530 MWh/yr of electricity (secondary energy)
- Consume 10 TJ/yr of biomass (primary energy)
- Consume 630 metric tons per year (tonnes/yr) of biomass
- Sequester 30 tonnes carbon/yr or 110 tonnes CO2/yr (assuming 5% by input mass carbon sequestration)
- Offset from 150-930 tonnes CO2e/yr* compared to use of fossil fuel for electrical generation.**
- Offset rises to 292-2120 tonnes CO2e/yr when including combined heat and power (CHP) option compared to fossil fuel for combined electrical and heat generation (assuming 68% total system efficiency)

Notes

CHP represents an advantage to biomass power over other renewables such as wind and solar PV which are not capable of additional heat output.

Sincerely,
Jesse Noell

AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2015GL063514

Key Points:
- The Earth is heated both by thermal energy and by CO_2 greenhouse effect
- Time scales and ratios of warming from thermal versus CO_2 are quantified
- Approximately 1% of net anthropogenic climate forcing from direct thermal emissions

Supporting Information:
- Texts S1–S4, Figure S1, and Table S1

Correspondence to:
X. Zhang,
xczhang@carnegiescience.edu

Citation:
Zhang, X., and K. Caldeira (2015), Time scales and ratios of climate forcing due to thermal versus carbon dioxide emissions from fossil fuels, *Geophys. Res. Lett.*, *42*, 4548–4555, doi:10.1002/2015GL063514.

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Published online 2 JUN 2015

Time scales and ratios of climate forcing due to thermal versus carbon dioxide emissions from fossil fuels

Xiaochun Zhang[1] and Ken Caldeira[1]

[1]Department of Global Ecology, Carnegie Institution for Science, Stanford, California, USA

Abstract The Earth warms both when fossil fuel carbon is oxidized to carbon dioxide and when greenhouse effect of carbon dioxide inhibits longwave radiation from escaping to space. Various important time scales and ratios comparing these two climate forcings have not previously been quantified. For example, the global and time-integrated radiative forcing from burning a fossil fuel exceeds the heat released upon combustion within 2 months. Over the long lifetime of CO_2 in the atmosphere, the cumulative CO_2-radiative forcing exceeds the amount of energy released upon combustion by a factor >100,000. For a new power plant, the radiative forcing from the accumulation of released CO_2 exceeds the direct thermal emissions in less than half a year. Furthermore, we show that the energy released from the combustion of fossil fuels is now about 1.71% of the radiative forcing from CO_2 that has accumulated in the atmosphere as a consequence of historical fossil fuel combustion.

1. Introduction

The Earth is heated both when reduced carbon is oxidized to carbon dioxide and when outgoing longwave radiation is trapped by carbon dioxide in the atmosphere (CO_2 greenhouse effect) [*Washington*, 1972; *Nordell*, 2003; *Block et al.*, 2004; *Chaisson*, 2008; *Flanner*, 2009; *Ma et al.*, 2011; *G. J. Zhang et al.*, 2013; *X. Zhang et al.*, 2013]. The purpose of this study is to improve our understanding of time scales and relative magnitudes of climate forcing increase over time from pulse, continuous, and historical CO_2 and thermal emissions. We aim to (1) improve our understanding of time scales and relative magnitudes of the forcing increase over time due to pulse fossil fuel combustion thermal and CO_2 emissions; (2) identify for a pulse emission the crossover time when warming from CO_2 exceeds warming from thermal; and (3) understand how this affects cumulative forcing from thermal and CO_2 emissions since the Industrial Revolution.

In converting energy from chemical/physical energy to thermal energy and from thermal energy to electrical energy, the electricity generation largely dissipates energy as thermal emission or heat [*United States Environmental Protection Agency* (*USEPA*), 1997; *Chen et al.*, 2009; *Zhan et al.*, 2009; *Zhang et al.*, 2009; *Ma et al.*, 2010, 2012; *Zhan et al.*, 2012; *Zhang et al.*, 2012a, 2012b]. Even the part that goes into useful energy is eventually dissipated as heat. Thermal emission from fossil fuel combustion is a forcing on the climate system [*Washington*, 1972; *Nordell*, 2003; *Block et al.*, 2004; *Chaisson*, 2008; *Flanner*, 2009; *Myhrvold and Caldeira*, 2012; *G. J. Zhang et al.*, 2013; *X. Zhang et al.*, 2013] (see also Text S1 in the supporting information). Thermal emissions are generally small compared with climate forcing due to CO_2 and other greenhouse gases [*Washington*, 1972] but could have important climate effects [*Nordell*, 2003; *Block et al.*, 2004; *Chaisson*, 2008; *Flanner*, 2009; *G. J. Zhang et al.*, 2013; *X. Zhang et al.*, 2013]. *G. J. Zhang et al.* [2013] and *X. Zhang et al.* [2013] points out that 42.2% of worldwide fossil fuel energy combustion occurs within 1.27% of the Earth surface, suggesting that thermal emissions may be more important to local and regional climates (and the urban heat island effect) than to global climate. For additional literature review, please see Text S1 in the supporting information.

2. Methods

To estimate the amount of global warming that would be produced by thermal and CO_2 emissions from fossil fuel combustion, we calculate thermal emissions with thermal contents of fossil fuels and estimate CO_2 emissions with emission factors from Intergovernmental Panel on Climate Change (IPCC) AR5 [*Intergovernmental Panel on Climate Change* (*IPCC*), 2013]. We then use a schematic climate model mimicking

Coupled Model Intercomparison Project Phase 5 [*Myhrvold and Caldeira*, 2012; *Caldeira and Myhrvold*, 2013; *G. J. Zhang et al.*, 2013; *X. Zhang et al.*, 2013, *Zhang et al.*, 2014a, 2014b, 2015] to investigate the climate forcing and the time-integrated climate forcing. Here we set three scenarios, i.e., pulse emission of CO_2 from fossil fuels at time zero, constant continuous emission scenario, and a historical/realistic scenario considering global fossil fuel emissions from 1751 to 2012.

2.1. Thermal Emission and CO_2 Emission

We estimate the climate impact of thermal emission and CO_2 emission from a pulse emission, continuous emissions, and historical emissions from fossil fuels (Table S1). All of the heat generated by combustion from coal, oil, and gas contributes to the heating of the environment [*Shiers and Marks*, 1973; *Färe et al.*, 1986; *USEPA*, 1997; *Myhrvold and Caldeira*, 2012]. To compare the climate effects of thermal emission and CO_2 emission (which is the major greenhouse gas emission from fossil fuel combustion), we estimate CO_2 emission ($\text{Emission}_{CO2(i)}$) with emission factors from IPCC [*IPCC*, 2014]. CO_2 emission factors for fossil fuels are shown in Table S1. For historical CO_2 emissions, we use coal, oil, and gas data from the Carbon Dioxide Information Analysis Center (CDIAC) fossil fuel CO_2 emissions data set [*Boden and Andres*, 2014] and then calculate energy combustion with equation (1).

$$\text{Thermal\_emission\_rate}_i(t) = \text{CO}_2\text{\_emission\_rate}_i(t)/\text{CO}_2\text{\_to\_heat\_ratio}_i, \tag{1}$$

where i is one of coal, oil, or gas and t is time in years; and $CO_2\_emission\_rate_i(t)$ is the CO_2 emission rate from fuel i in $MtCO_2$/yr (10^9 kg CO_2 per year) which is converted from CDIAC's reported MtC/yr (10^9 kg carbon per year) by multiplying the molar mass of CO_2 and dividing by the molar mass of carbon. The $CO_2\_to\_heat\_ratio_i$ is 94.6, 73.3, and 56.1 × 10^9 kg CO_2 per EJ for coal, oil, and gas, respectively.

2.2. Climate Forcing

The concentration of CO_2 decreases with time. In this study, we apply *Joos et al.*'s [2013] CO_2 impulse response function to estimate the atmospheric CO_2 concentration:

$$G_{CO_2}(t) = 0\ .2173 + 0.2240\, e^{(-t/394.4)} + 0.2824\, e^{(-t/36.54)} + 0.2763\, e^{(-t/4.304)}. \tag{2}$$

The atmospheric accumulation of CO_2 in ppmCO2 ($\text{AtmCO}_{2,i}$) for continuous emission from time t_0 to t is

$$\text{AtmCO}_{2,i}(t) = \alpha_{CO_2} \int_{t^*=t_0}^{t} [\text{CO}_2\text{\_emission\_rate}_i(t^*) \cdot G_{CO_2}(t - t^*)]dt^*, \tag{3}$$

where t is time and t_0 is the start time of emission; $CO_2\_emission\_rate_i(t)$ is CO_2 emission at time t; α_{CO2} is a parameter of mass to concentration (1.28742 × 10^{-4} $ppmCO_2/MtCO_2$).

The warming effect from increased atmospheric CO_2 content can be described using the concept of radiative forcing [*IPCC*, 2013]. The radiative forcing from CO_2 in the atmosphere increases approximately with the logarithm of atmospheric CO_2 content, with an increase of about 3.7 W m^{-2} for a doubling of atmospheric CO_2 [*Solomon et al.*, 2007]. Climate forcing from increased CO_2 concentrations is calculated more accurately using equations provided by the IPCC AR4 [*Solomon et al.*, 2007]:

$$\Delta F_{CO_2(i)}(t) = 3.35\left[g\left(C_{t_0.CO_2} + C_{CO_2(i)}(t)\right) - g\left(C_{t_0.CO_2}\right)\right], \tag{4}$$

where $g(p) = \ln(1 + 1.2p + 0.005p^2 + 1.4\ 10^{-6}\ p^3)$, $C_{t_0.CO_2}$ is the base concentration of CO_2 in the atmosphere and ln is the natural logarithm function.

The thermal climate forcing, $F_{\text{thermal},i}(t)$ in W/m^2 at time t is the thermal emission rate from fuel i at time t averaged over the surface of the Earth (A_{Earth}) is

$$F_{\text{thermal},i}(t) = \text{Thermal\_emission\_rate}_i(t)/A_{\text{Earth}}. \tag{5}$$

Climate forcing of thermal emission is

$$\Delta F_{\text{thermal},i}(t) = F_{\text{thermal},i}(t)/\Delta t. \tag{6}$$

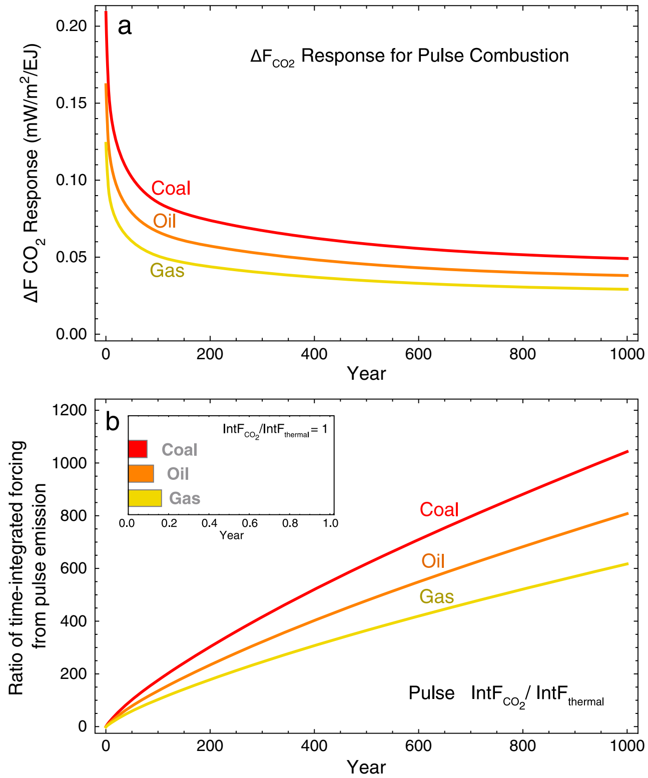

Figure 1. Results for instantaneous pulse emissions from burning coal, oil, and gas at time 0. (a) CO_2 forcing response for pulse combustion and (b) ratios of time-integrated CO_2 forcing ($IntF_{CO2}$) to time-integrated thermal forcing ($IntF_{thermal}$). $IntF_{thermal}$ is the heat of combustion. The inset in Figure 1b shows that it takes 0.093 years (~34 days), 0.122 years (~45 days), and 0.161 years (~59 days) for the integrated radiative forcing from CO_2 (i.e., the amount of energy that the CO_2 has prevented from escaping to space) to exceed the thermal forcing from the combustion that generated CO_2 for coal, oil, and gas, respectively.

Another radiative forcing metric is integrated radiative forcing (IntF) which in time t is

$$\mathrm{IntF}(t) = \int_{\hat{t}=t_0}^{t} \Delta F(\hat{t}) \mathrm{d}\hat{t}, \tag{7}$$

where ΔF is the radiative forcing. For more details, please see *Zhang et al*. [2014a], and references therein.

3. Results and Discussion

3.1. Instantaneous Pulse Emissions From Fossil Fuel Combustion

First, we consider instantaneous pulse emissions from fossil fuel combustion, relevant to the combustion of a small mass of coal, oil, or gas. The warming from thermal energy production occurs when a fossil fuel undergoes combustion, whereas warming from the emitted CO_2 continues for the lifetime of CO_2 in the atmosphere and can last thousands of years [*Archer et al*., 2009]. There are three major types of fossil fuel: coal, oil, and natural gas. Each fuel differs in its thermal and CO_2 emissions per unit mass. To compare these fuels, we consider scenarios releasing the same amount of thermal energy but differing amounts of CO_2. We first consider the case of climate forcing from pulse combustion of fossil fuels (e.g., burning a single lump of coal). We consider thermal emissions and radiative forcing to have approximately equivalent effect on the climate system [*Hansen et al*., 1997] and refer to them collectively using the term “climate forcing,” We recognize that the geographic distribution of a forcing can have consequences for the resulting climate change [*G. J. Zhang et al*., 2013; *X. Zhang et al*., 2013] and that the effective radiative forcing can differ for different forcing factors with the same nominal climate forcing [*IPCC*, 2013], so results obtained here should be interpreted as approximate.

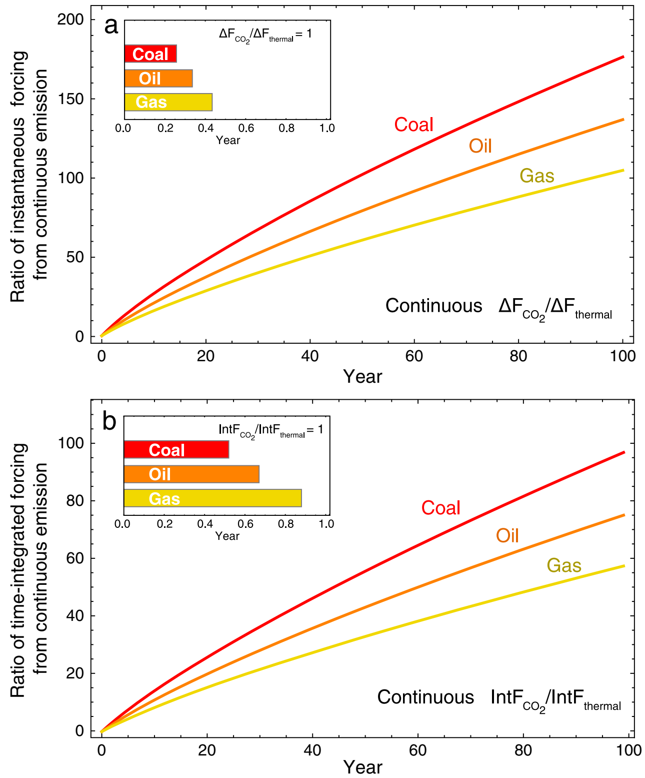

Figure 2. Results for constant continuous emissions from burning coal, oil, and gas. Ratios of (a) instantaneous CO_2 radiative forcing to instantaneous thermal forcing ($\Delta F_{CO2} / \Delta F_{thermal}$), and (b) time-integrated CO_2 radiative forcing to time-integrated thermal forcing ($IntF_{CO2} / IntF_{thermal}$). The inset in Figure 2a shows that it takes 0.26 years, 0.34 years, and 0.44 years for coal, oil, and gas, respectively, for the instantaneous forcing from accumulated CO_2 to exceed the instantaneous thermal forcing from combustion. The inset in Figure 2b shows that it takes 0.52 years, 0.67 years, and 0.88 years for coal, oil, and gas, respectively, for the time-integrated radiative forcing from the CO_2 released to exceed the cumulative thermal emissions from combustion.

Thermal emissions from fossil fuel combustion provide a pulse of warming, but the resulting CO_2-induced warming persists for many centuries or longer. Within a few months, the time-integrated CO_2-warming effect is greater than the direct thermal warming influence of an instantaneous pulse fossil fuel combustion. The time series of climate forcing (ΔF) resulting from the instantaneous pulse combustion of 1 EJ of coal, oil, or gas is shown in Figure 1a. This figure shows that radiative forcing from atmospheric CO_2 decreases as the CO_2 is absorbed by the oceans and land biosphere. At time 0, CO_2 forcings are 0.209, 0.162, and 0.124 mW/m^2 per EJ for coal, oil, and gas, respectively. Figure 1b shows, for instantaneous pulse combustion of fuel at time 0, the time-integrated global radiative forcing from the CO_2 released ($IntF_{CO2}$) divided by the amount of heat released upon combustion ($IntF_{thermal}$). The time-integrated radiative forcing from CO_2 released upon combustion exceeds the amount of heat released upon combustion after 0.093 years (~34 days), 0.122 years (~45 days), and 0.161 years (~59 days) for coal, oil, and gas, respectively. After 1 year, the integrated CO_2 radiative forcing ($IntF_{CO2}$) exceeds the thermal forcing by factors of 3.91, 3.03, and 2.32 for coal, oil, and gas, respectively; after 100 years, these values increase to 179, 139, and 106 years, respectively; and after 1000 years, they are 1047, 811, and 621, respectively (Figure 1b). As discussed below, ultimately, the warming induced by CO_2 over its lifetime in the atmosphere would exceed the warming from direct combustion by a factor of 100,000 or more.

The fossil fuel is burned in an instant, but some of the CO_2 remains in the atmosphere for many thousands of years. If we integrate the radiative forcing from a CO_2 emission over the surface of the Earth and over the lifetime of the CO_2 in the atmosphere, we can calculate the total amount of heating from that CO_2 in joules and compare it with the number of joules released from the oxidation of the carbon to CO_2. The lifetime of CO_2 in the atmosphere can be simulated by an ocean box model embedded within a representation of the carbonate-silicate cycle [*Caldeira and Rampino*, 1993; *Caldeira and Rau*, 2000] (See

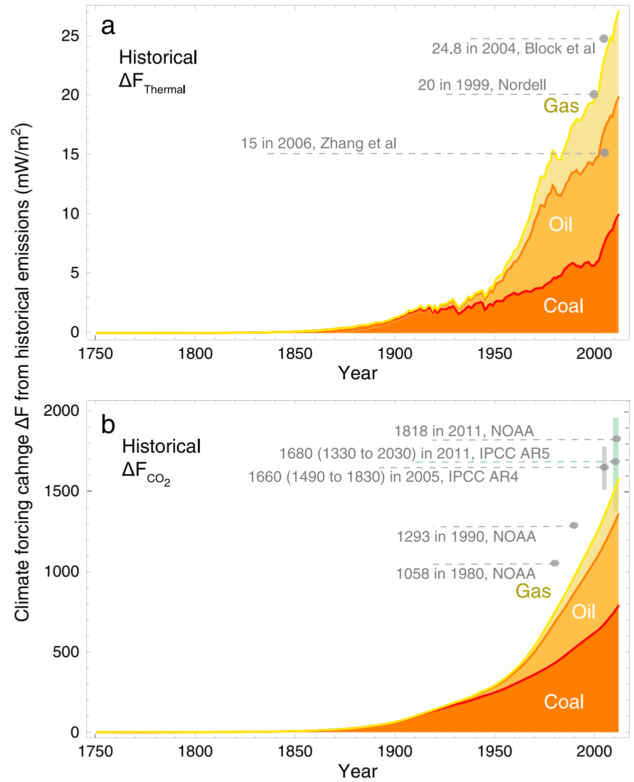

Figure 3. Instantaneous (a) $\Delta F_{thermal}$, thermal forcing and (b) ΔF_{CO2}, CO_2 radiative forcing from historical combustion of coal, oil, and gas between 1751 and 2012. At the end of 2012, the instantaneous total fossil fuel thermal forcing is 27.0 mW/m^2, and the instantaneous total fossil fuel CO_2 forcing is 1574.5 mW/m^2. We present other literature estimates for comparison [*Nordell*, 2003; *Block et al.*, 2004; *Solomon et al.*, 2007; *IPCC*, 2013; *G. J. Zhang et al.*, 2013; *X. Zhang et al.*, 2013; *NOAA*, 2014]. Grey dots in Figure 3a include heating from nonfossil fuels. Grey dots in Figure 3b include anthropogenic CO_2 forcing from land-use change.

Text S2 in the supporting information). The radiative forcing decays away on a range of time scales that can be associated with a variety of physical processes: time scales for carbon to mix into the oceanic mixed layer, thermocline, interior, and time scales for neutralization by carbonate and silicate mineral weathering [*Caldeira and Rampino*, 1993; *Caldeira and Rau*, 2000]. Calculations of radiative forcing from a CO_2 release are not very sensitive to background scenario, because at high CO_2 concentrations, the chemical effect of the increased ocean carbon buffer factor is largely offset by the lower sensitivity of radiative forcing to added CO_2 [*Caldeira and Kasting*, 1993]. Integrating the radiative forcing from zero to infinity yields about 4.5×10^{10} J of global warming per mol CO_2 released to the atmosphere. Combusting one mole of reduced carbon yields about 393.51 kJ/mol (standard enthalpies of formation) [*Oxtoby et al.*, 2011]. Therefore, on a molar basis, the time-integrated radiative forcing from CO_2 released from burning carbon, over its lifetime in the atmosphere, exceeds the thermal energy released by that burning by a factor of about 100,000. This ratio would be less for oil or gas than for coal, because less energy is released from the oxidation of carbon than from the oxidation of hydrogen when oil and gas are burned.

3.2. Steady Continuous Combustion of Fossil Fuels

Second, we consider the case of steady continuous combustion of fossil fuels, relevant to the case where a new power plant comes on line. With continuous fossil fuel combustion and atmospheric release of CO_2, the ratio of CO_2-induced warming to direct thermal warming increases over time because the instantaneous direct thermal effect depends only on the current rate of fossil fuel combustion, whereas instantaneous CO_2-induced radiative forcing depends on current CO_2 concentrations which include CO_2 that has accumulated in the atmosphere as a result of past combustion. For steady continuous combustion, it takes 0.26 years, 0.34 years, and 0.44 years for the instantaneous radiative forcing from the accumulated CO_2 to exceed the instantaneous thermal forcing from the combustion of coal, oil, and gas, respectively (Figure 2a). The time-integrated climate forcing from

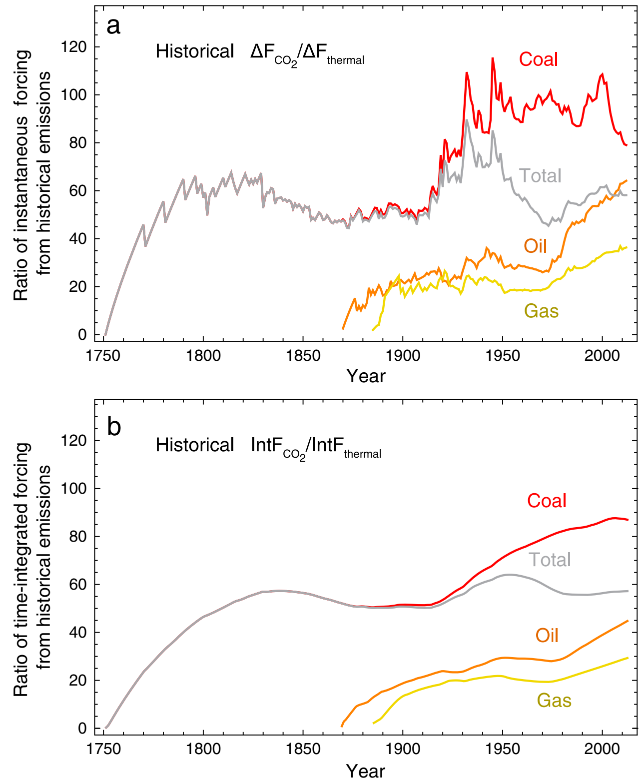

Figure 4. Ratios of (a) instantaneous ($\Delta F_{CO2}/\Delta F_{thermal}$) and (b) time-integrated ($IntF_{CO2}/IntF_{thermal}$) thermal to CO_2 radiative forcing from historical combustion of coal, oil, and gas from 1751 to 2012. At the end of 2012, the radiative forcing from CO_2 accumulated from the burning of coal, oil, and gas exceeded the instantaneous thermal forcing from the burning of coal, oil, and gas by factors of 79, 64, and 36, respectively. The overall ratio for total fossil fuel combustion was 58. If we consider the total amount of energy prevented from escaping to space by the excess CO_2 in the atmosphere divided by the total amount of energy released upon combustion ($IntF_{CO2}/IntF_{thermal}$), the ratios are 87, 45, and 29 for coal, oil, and gas, respectively and 57 for total fossil fuel consumption.

CO_2 emissions ($IntF_{CO2}$) exceeds the time-integrated thermal emissions ($IntF_{thermal}$) after 0.52 years, 0.67 years, and 0.88 years for coal, oil, and gas, respectively (Figure 2b).

3.3. Historical Emissions of Heat and Carbon Dioxide From Fossil Fuel Combustion

Third, we consider historical emissions of heat and carbon dioxide from fossil fuel combustion and how the thermal climate forcing from the combustion of coal, oil, and gas (Figure 2) compare with the climate forcing from carbon dioxide from the time economic development first relied heavily on fossil fuel. In the year 2012, the annual average atmospheric CO_2 concentration observed by National Oceanic and Atmospheric Administration was 393.82 ppm [*National Oceanic and Atmospheric Administration* (*NOAA*), 2014]. This compares with the preindustrial value of about 280 ppm [*IPCC*, 2013; *NOAA*, 2014]. The increase in atmospheric CO_2 concentration is a consequence of historical CO_2 emissions from fossil fuel burning and land cover change [*Prentice et al*., 2001; *IPCC*, 2013]. Since the preindustrial atmospheric CO_2 concentration was about 280 ppm, this implies that the radiative forcing of CO_2 from fossil fuel burning and land cover change was about 1.68 W/m^2. Using equation (3) and CO_2 emissions from CDIAC [*Boden and Andres*, 2014], we estimate the radiative forcing from fossil fuel CO_2 remaining in the atmosphere to be 1.57 W/m^2 in 2012. From 1751 to 2012, the world fossil fuel combustion increased from almost nothing to 480.5 EJ per year [*EIA*, 2014], an average of 0.023 W/m^2 over the area of the Earth (Figure 3). Thus, we can estimate that in the year 2012, the trapping of heat by CO_2 added to the atmosphere from human fossil fuel combustion activities warmed the Earth about 57 times more than the heat released directly to the environment by fossil fuel combustion (Figure 4). Thermal emission from fossil fuel combustion is approximately one quarter of the global mean geothermal flux of heat (~0.0916 W/m^2, i.e., 46.7 TW/510.1 million km^2) from Earth's interior to the surface [*Davies and Davies*, 2010].

4. Conclusions

Thermal emissions from fossil fuel combustion are not negligible, especially at local or regional scales [*G. J. Zhang et al.*, 2013; *X. Zhang et al.*, 2013]; however, CO_2 radiative forcing from fossil fuel combustion greatly exceeds thermal emissions from fossil fuel combustion. Considered globally, direct thermal forcing from fossil fuel combustion is about 1.71% the radiative forcing from CO_2 that has accumulated in the atmosphere from past fossil fuel combustion. When a new power plant comes on line, the radiative forcing from the accumulation of released CO_2 exceeds the thermal emissions from the power plant in less than half a year (and about 3 months for coal plants). Due to the long lifetime of CO_2 in the atmosphere, CO_2 radiative forcing greatly overwhelms direct thermal forcing on longer time scales. Ultimately, the cumulative radiative forcing from the CO_2 exceeds the direct thermal forcing by a factor of ~100,000.

Acknowledgments

The data used to calculate thermal emissions with thermal contents of fossil fuels and estimate CO_2 emissions are available from IPCC AR5 (https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter7.pdf). The historical CO_2 emissions data from the Carbon Dioxide Information Analysis Center (CDIAC) fossil fuel CO_2 emissions data set and can be accessed via http://cdiac.ornl.gov/ftp/ndp030/CSV-FILES/global.1751_2008.csv. Funding for this work was provided by the Fund for Innovative Climate and Energy Research (FICER) and the Carnegie Institution for Science endowment. We thank Dawn Ross and Chun Ma from Carnegie Institution for Science for help in preparing this document.

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Agrophotovoltaics: harvesting the sun for power and potatoes

Applications | The question of whether to use valuable land for farming or solar power generation has been a subject of fierce debate in the green energy transition. But, as Boris Farnung, Maximilian Trommsdorff and Stephan Schindele of Fraunhofer ISE write, the two activities need not be in conflict with each other and, with a new generation of solar technologies, can in fact be mutually beneficial

Credit: Fraunhofer ISE

The pilot agrophotovoltaic system uses bifacial glass-glass modules arranged in rows of two

Agrophotovoltaics: solving the food versus fuel conflict

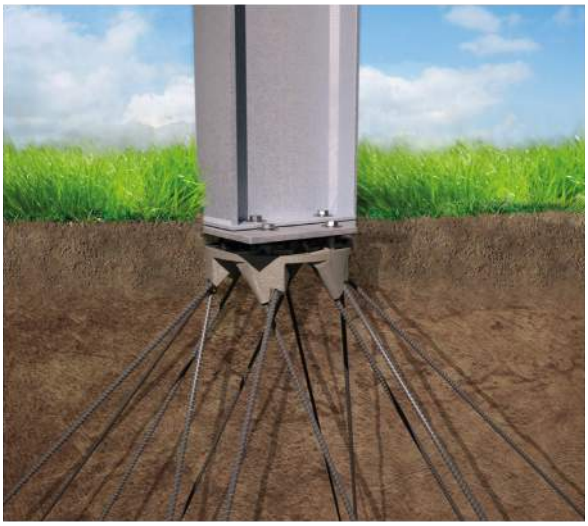
For farmers in Germany, energy harvesting is economically more beneficial than food production. Thus, for example about 18% of arable land in Germany is used for growing energy crops. And it is true that Germany must allocate new land for the production of solar electricity in order to meet the urgent expansion of renewables needed for the energy transformation. Studies show that photovoltaic installations in the range of 200GWp are required in order to meet the goal of reducing carbon emissions by 85% until 2050. This leads to a significant increase in the competition for land usage – "food versus fuel" – and at the same time presents an ethical dilemma: valuable, arable land is used to produce energy, while at the same time food is being imported from threshold and developing countries. As a result, these countries grow crops for export and less food is available for the indigenous population. But conflicts over land use are also arising in emerging and developing countries, as growing populations and rising living standards require more energy and food production.

Instead of being competitors, photovoltaics and photosynthesis can actually complement each other. So-called agrophotovoltaic (APV) systems make the efficient dual land usage possible: the farmer not only provides potatoes but also electricity – from the same piece of land – which dramatically increases the land use efficiency. The concept is not novel, quite the contrary: it was conceived by the founder of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Prof. Dr. Adolf Goetzberger, and his colleague Dr. Armin Zastrow in a paper published in 1981 [1]. Since then, numerous large agrophotovoltaic (APV) systems have been installed worldwide. Leading countries in the field are France, Japan, China, Korea and the United States, with support schemes for agrophotovoltaics established. The overall installed capacity is estimated to be 2.1GW, with approximately 1.9GW in China alone. Nevertheless, only a few research plants exist, and the full scope of applications is still to be investigated.

Pilot project "Agrophotovoltaics–Resource-Efficient Land Use"

In the project "Agrophotovoltaics: Resource-Efficient Land Use" (March 2015 to June 2019), the technical, societal, ecological and economical aspects of the technology were investigated in a pilot demonstration project. The seven partners of the model project, led by Fraunhofer ISE and financed by the German Federal Ministry of Education and Research and FONA (Research for Sustainable Development), also wanted to clarify the political and energy economical boundary conditions that are required to help the new technology break into the market.

The pilot APV system was installed at the organic Demeter farm in Heggelbach, near Lake Constance. On a test field covering one third of a hectare, 720 bifacial modules with a total power of 194.4 kWp were installed at a height of five meters above the ground. This clearance height makes sure that the use of versatile agricultural machinery is not restricted. The rows of semi-transparent glass-glass modules are placed at a slightly larger distance so that the crops growing underneath receive at least 60% of the total incoming irradiation. Modules are arranged in rows of two, with a gap between the rows to better distribute



The foundations were fixed by spinning anchor rods

rainwater. The modules' total surface measures 1206 square meters. The deviation from the south is 52 degrees, with an angle of inclination of 20 degrees.

Within the project, Fraunhofer ISE has developed accurate and validated calculation methods to design the system with a balanced ratio of light and shade. In addition, based on comprehensive light-management simulations, it is ensured that the irradiation is homogeneous over the designated area. Thus, Fraunhofer ISE is uniquely positioned to support project developers to define a system concept optimised for solar power and food production in the same area.

An important technical aspect was the possibility of deconstructing the plant without, for example, leaving foundations in the ground. The foundations were therefore laid using a spinning anchor system: up to eight-meter-long spinning anchor rods were turned down on a cast plate, in the center of which an Alpine anchor was drilled into the ground. In order to avoid damage to the facility by agricultural machineries, the posts were fitted with a ram protection, which was also fastened with anchor rods. In total, about 50 tons of steel were used.

One of the Demeter farmers' demands was that they could carry out their normal crop rotation under the plant: winter wheat, clover grass, celery and potatoes. The aim for the farmers was to achieve at least 80% of the usual yield. In order to be able to prove this, the same crops were cultivated on a reference area directly next to the test field. Over a period of three years, the experts for agricultural research of the University of Hohenheim accompanied the agricultural aspects of the project, from the measurement of the climatic conditions under the plant, through the yield and quality of the products to the effects on biodiversity.

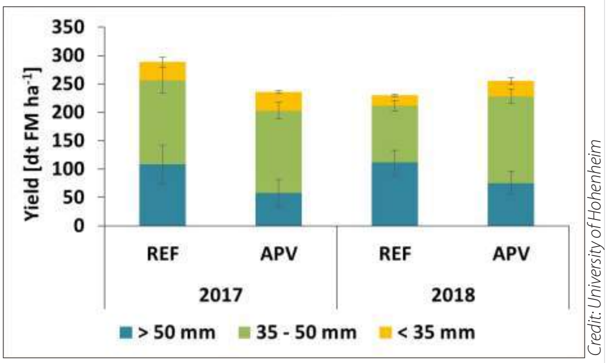
From September 2016 to June 2019, the solar power and the agricultural yield were assessed, accompanied by social science studies on the acceptance by the local population. Two full harvest cycles were completed during the project period.

Agricultural results: high yields in hot and dry summer

Over the first 12 months (October 2016 to October 2017), four crops (winter wheat, potatoes, clover and celery) were grown and harvested.

The University of Hohenheim investigated the response of the crops to the local changes in environmental conditions. Data on the microclimatic parameters such as photosynthetic active radiation (PAR), air and ground temperature as well as precipitation were collected. The analyses indicated that the PAR under the APV system is reduced by about 30%. In the first evaluated year, the local air temperatures under the APV system did not differ significantly to the reference plot. Washouts have been observed at single locations in the field, depending on the crop and its stage of development. In particular, the scientists observed a slightly less homogeneous distribution of rain water below the PV panels compared to the reference area.

While the clover yield was reduced only slightly (-5.3%) due to shading from the APV, the yield decrease for potatoes (-18.2%), wheat (-18.7%) and celery (-18.9%) was higher. The winter wheat and the potatoes growing under the PV array showed a slightly slower development than the same crops on the reference plot. At harvest, no mentionable difference in development was observable, so that the crops under the APV and on the reference field could be harvested at the same time. The results from the first year of practice showed that all four crops were qualitatively good and marketable. In comparison to the crops from the reference plot, a lower yield was observed, but it was still within the target horizon determined in advance by the farmers. It has to be noticed that the harvest was a bit too early for some of the plants under the APV array. Normally the potatoes and celery plants should have been given about two more weeks to ripen.



The marketable share (35-50 mm) of the potato harvest was higher under the APV system.

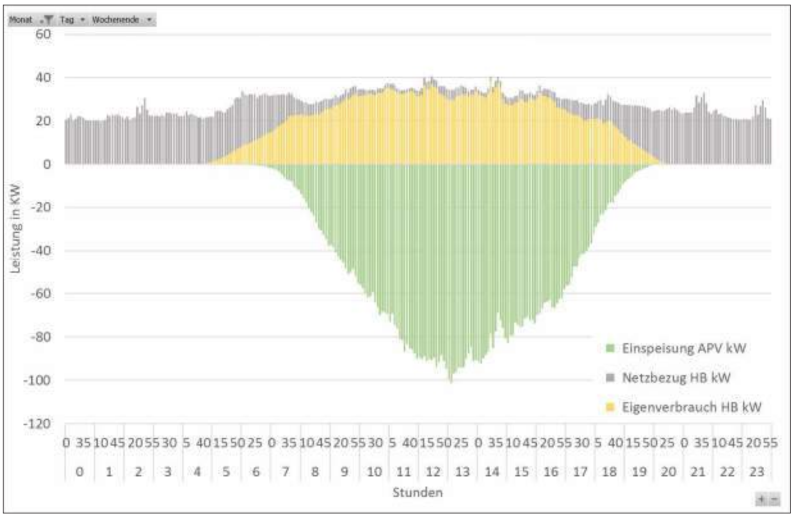
The second year, however, showed a different picture: In 2018, the yields from three of the four crops grown under the APV system were larger than the reference plot. The crop yields for celery profited the most by the system, with a gain of 12% compared to the reference. Winter wheat and potatoes produced a gain of 3 and 11% respectively, and clover a minus of 8%. In addition, in the case of potatoes, the marketable share (35-50 millimeters in size) was larger under the APV plant than under the reference area.

In spring and summer, the soil temperature under the APV system was less than on the reference field; while the air temperature was identical. In the hot, dry summer of 2018, the soil moisture in the wheat crop was higher than on the reference field, while in the winter months, it was less, as for the other crops. The agricultural scientists of the University of Hohenheim assume that the shade under the semi-transparent solar modules enabled the plants to better endure the hot and dry conditions of 2018. In their view, agrophotovoltaics could mitigate climate change effects on agriculture in many regions.

For the research project, no particularly shadow-tolerant or even shade-loving plants were selected, but varieties normally marketed by the Demeter farm. It can be assumed that shade-loving plants such as hops, leafy vegetables, legumes or certain wine and fruit varieties would have shown significantly better yields. Further follow-up research projects are needed to investigate this in more detail.

Solar energy harvest: yields exceed expectations

As for the solar yield, the project results of the first year already exceeded expectations, at least with respect to the initial specifications. In the first 12 months of operation, the PV plant produced 245,666kWh of electricity, or 1,266kWh



Credit: BayWa r.e.

During summer, the APV system covers the electricity load at the farm almost completely. The green area represents the feed-in of the solar power into the grid, the yellow area represents the own consumption, while the purchased power from the grid is plotted in grey

per kWp installed. The power output is mainly influenced by the use of bifacial module technology, but also by a larger distance from row to row which results in lower shading and temperature losses compared to conventional power plants. A detrimental factor with regard to the electrical yield is the orientation of the system, which is 52° off south.

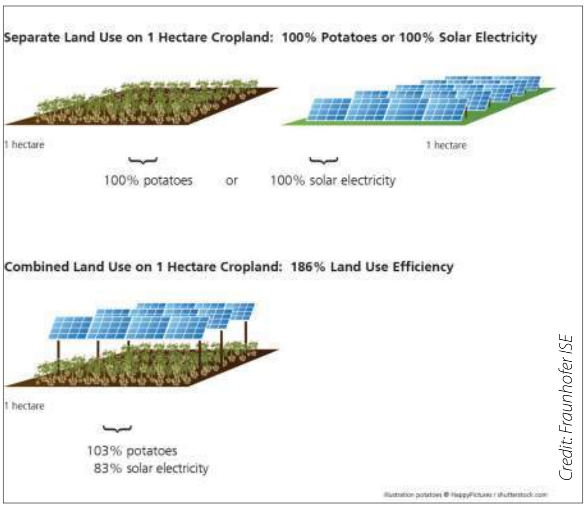
In the second year of operation, the solar irradiation totalled 1,319.7kWh/m^2, an increase of 8.4% compared to the previous year. The energy output of the APV system amounted to 249,857kWh, corresponding to an extraordinarily good specific yield value of 1285.3kWh/kWp.

BayWa r.e. renewable energy GmbH, responsible for the construction and the load management of the APV system, also evaluated the self-consumption at the farm. Over the day, the power produced by the APV system was well matched to the power consumption on the Demeter farm. In the summer months, the load demand was covered almost fully by the APV system and in July close to 100%. The electricity generated could supply the annual demand of 62 four-person households. The Demeter farmers use it primarily for processing their products and charging their electrical vehicle. With the subsequent installation of a 150kWh battery in 2018, the farm community could increase the own consumption rate for the solar power to approximately 70%. This shows that if the electricity is stored and used on site, for example for the use of electric agricultural vehicles, additional sources of income arise due to synergy effects.

While the expected capex costs of an APV plant are about one-third higher than for a conventional open space plant, mostly due to the higher racking system and higher logistics costs, the OPEX costs tend to be about a quarter lower. This is due to synergy effects such as the avoided costs for mowing, surveillance or a fence. The electricity production costs of a typical APV system of 2MWp today are competitive with a small PV rooftop system (<10kWp). Further cost reductions due to economies of scale and learning effects are to be expected.

Land use efficiency dramatically increased

The results from 2017 already showed a land use efficiency of 160% compared to a single use of the land (i.e., either agriculture or PV). The performance of the APV system in the very hot and dry summer of 2018 greatly exceeded this value, as the partial shading underneath the photovoltaic modules improved the agricultural yield, and the sun-rich summer increased the solar electricity production. Based on the 2018 potato yield, the land use efficiency rose to 186% per hectare with the APV system.



Credit: Fraunhofer ISE

The land use efficiency was dramatically increased during the hot and dry summer of 2018

The APV-RESOLA project examined not only technological and agricultural aspects, but also the acceptance of this new technology by the local population, as this could become an obstacle to higher market penetration ("not in my backyard"). In two citizen workshops, social scientists from the Institute for Technology Assessment and System Analysis (ITAS) of the Karlsruhe Institute of Technology discussed which forms of energy production they would accept in their immediate living environment. One workshop was carried out before the construction of the plant, the second one afterwards, and there was also a survey. The results showed that the acceptance of APV systems increases if local citizens recognize clear advantages for themselves, for example if they are involved financially within the framework of a citizens' energy cooperative. The aesthetics of the plant was a point of criticism, especially with regard to the tourist attractiveness of the region. Still, the citizens surveyed prefer the APV system to a conventional PV plant. They also pointed out that uncontrolled growth and "pseudo-agriculture" must be avoided, i.e. clear standards must be established by the legislator with regard to the definition of an APV system. While in France, Japan, Korea and the USA there are already financial support schemes with corresponding definitions, this is lacking in Germany.

"While the expected capex costs of an APV plant are about one-third higher than for a conventional open space plant, mostly due to the higher racking system and higher logistics costs, the OPEX costs tend to be about a quarter lower"

Further research topics: horizontal and vertical technology development

Now that evidence of increased land use efficiency and economic viability has been provided, further horizontal and vertical technology development is needed to unlock the full potential of agrophotovoltaics. To provide the necessary proof-of-concept before market entry, other techno-economic APV applications must be compared and larger systems in the MW range need to be realised. Different possible applications shall be explored, such as the combination with fruits, berries, hops, wine crops and livestock farming. As far as vegetable cultivation is concerned, there is currently a trend towards closed cultivation. This serves on the one hand to adapt to climate change (protection against extreme weather conditions, improvement of the water balance) and to "green the deserts", but also helps to reduce the use of pesticides, as no pests can penetrate. To give an example, in France there are already large greenhouses with APV. In the future, a combination with organic photovoltaic modules or flexible photovoltaic foils would be conceivable: special absorber layers in the photovoltaic cells would allow certain parts of the sunlight, which are particularly conducive to plant growth, to pass through, while protecting the plants from excessive radiation.

Aquafarming is another possible application: in 2018, Fraunhofer ISE carried out a proof-of-concept study analysing the possibility of installing APV at shrimp farms located in the Vietnamese Mekong Delta. In this densely populated region with an energy consumption growing 10% annually, there is an increasing competition for land between aquaculture and renewable energy. The study showed that solar-aquaculture habitats

> "Solar-aquaculture habitats have the potential to promote the deployment of renewable energy as well as enact measures to counteract climate change, expand shrimp production yet protect water resources, decrease land use and reduce CO2 emissions at the same time"

have the potential to promote the deployment of renewable energy as well as enact measures to counteract climate change, expand shrimp production yet protect water resources, decrease land use and reduce CO2 emissions at the same time. Based on the first analyses, the pilot project in Bac Liêu can save about 15,000 tons of carbon dioxide emissions annually and reduce the water use by 75% compared to a conventional shrimp farm. The aquafarm operators appreciate other advantages from this technology, such as protection of shrimps and fish against predatory animals, improved working conditions due to shading and a stable or lower water temperature that helps to promote the shrimps' growth. The combination of aquaculture and photovoltaics is expected to significantly increase the land use rate.

In order to exploit the technology on the vertical level, further development work is required in the areas of organic PV film technologies, energy storage, water treatment, irrigation systems, agricultural robotics, electro-mobility, tracking systems, materials research and structural design. Another aspect to be considered is the rising use of electric vehicles in agriculture, which could increase the own consumption of solar power on farms.

Two years ago, the agricultural machinery manufacturers Fendt and John Deere introduced the first fully electric battery-operated tractors. A future vision is "swarm farming", with automated solar-powered electric farm machines working under the APV array and receiving their power directly from the APV system. Already today, machines exist that autonomously cut weeds or eliminate pests such as the Colorado potato beetle without using chemicals, polluting the ground water or the soil. Thus, farming would become more sustainable not only with environmentally friendly machines but also through intelligent technology.

High potential for arid regions

Another current research focus addresses the transfer of APV technology to other climate zones. The technology of dual use may prove to be especially advantageous in semi-arid threshold and developing countries. The results from the summer of 2018 demonstrate the enormous potential of agrophotovoltaics for arid climate zones. Crops and livestock can benefit from the shade given by the PV modules, while the electricity can be used for seawater desalination, water treatment or irrigation pumps. Fraunhofer ISE is already working on several projects to transfer the technology to threshold and developing countries as well as for new applications. A pilot study that Fraunhofer ISE carried out for the Indian state of Maharashtra showed that shading effects and less evaporation might result in up to 40% higher yields for tomatoes and cotton crops. In certain cases, the experts expect the land use efficiency to almost double for the region. In another project, carried out within the EU Horizon 2020 programme, the Fraunhofer ISE researchers are working together with partners from Algeria to test the effects of APV systems on the water balance. Besides

Credit: Hofgemeinschaft Heggelbach

Using agricultural vehicles under an APV system is not a problem. In the future, these could be e-vehicles

less evaporation and lower temperatures, harvesting the rain water with PV modules also plays a role.

Together with Fraunhofer Chile, Fraunhofer ISE is currently testing three 13kWp APV systems in the Chilean communities of El Monte, Curacavi and Lampa, which are the first of their kind in Latin America. Investigations involve adapting and optimising the APV technology according to the specific climatic and economic conditions in Chile. The results of both the crop and solar power production are very positive. In the arid and semi-arid regions in Northern and Central Chile, there is great potential for APV, since a large percentage of the people live from agriculture, which is impacted by the increasing amount of dry periods, desertification and water scarcity due to climate change. The projects show that the partial shading of crops planted underneath APV can reduce their need for water and also offer livestock shelter from the sun. Also, it is expected that various fruits which normally do not grow well in dry climates with high solar radiation would grow underneath an APV system.

The three pilot plants will be monitored for three additional years, operating them as on-field labs. A long-term plan involving different type of crops has been coordinated with the farmers, so it will be possible to test the concept with a large variety of products.

Apart from the higher land use efficiency, APV systems can help to improve the socio-economic situation of rural areas in threshold or developing countries. In those villages often situated far from the grid, the quality of life is increased immensely just with the electric output of a few solar modules providing improved access to information, education, clean water and also better medical care. For example, in sub-Saharan Africa, about 92% of the rural populations have no access to electricity. APV offers new sources of income to the local population and at the same time reduces the dependence on fossil fuels, needed for diesel generators. Besides this, solar power can be used for cooling, processing and preserving agricultural crops, making them more profitable as they can also be marketed outside the harvest period. ■

Authors

Boris Farnung joined the Fraunhofer Institute for Solar Energy Systems ISE in 2008. He is head of group PV Power Plants and over the years has gained extensive experience in quality assurance, bankability support, testing and characterisation on both the module and the system level from projects worldwide. He is also operating agent of the IEA PVPS Task 13 - Performance and Reliability of Photovoltaic Systems.

Stephan Schindele is working on his doctoral degree about the innovation processes of agrophotovoltaics and their political support. He is project manager of agrophotovoltaics at Fraunhofer ISE.

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September 20, 2019

Re: Blue Lake Rancheria Comments on Redwood Coast Energy Authority "Comprehensive Action Plan for Energy."

Submitted via email to: EnergyPlan2019@RedwoodEnergy.org

To All This May Concern,

The Blue Lake Rancheria is a federally recognized Native American tribal government and community ("Tribe") located approximately 5 miles east of Arcata, California, adjacent to CA Highway 299, with tribal lands spanning the Mad River. The Tribe respectfully submits these comments regarding the Redwood Coast Energy Authority (RCEA) "Comprehensive Action Plan for Energy" (CAPE) per RCEA's invitation.

Energy and transportation sectors are increasingly intertwined with growth of electrified transportation, and together comprise the largest contributor to the climate crisis. Reducing greenhouse gas (GHG) emissions from energy and transportation sectors – in the immediate 10-year term – is one of the most critical action items that governments and agencies can undertake, to improve human health and to control costs for the general public.[1] The science underlying the climate crisis is settled, and the vast majority of predicted global heating impacts and indicators are accelerating decades earlier than expected.[2] Geopolitics are worsening the climate crisis internationally, nationally, regionally, and locally we are already suffering from its impacts – drought, wildfires, sea level rise, and others.

Part of the acceleration of climate impacts is related to inaccurate carbon accounting – that is, we have not accurately accounted for the true amount of GHG emissions in our atmosphere, and many models are pointing to exponentially larger emissions than the most conservative estimates.[3]

With these climate and infrastructure considerations in mind, the Tribe urges RCEA to consider the following:

1) There are few mentions of climate change, or the climate crisis in RCEA's draft CAPE. Consider stating the climate crisis in the strongest terms possible, reflecting the latest international

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[1] https://www.sciencedaily.com/releases/2018/03/180328204126.htm Accessed online 8.27.2019
[2] https://unfccc.int/news/state-of-the-climate-in-2018-shows-accelerating-climate-change-impacts
[3] https://www.sciencedaily.com/releases/2019/08/190819110005.htm

consensus[4] (see enclosed report below) within RCEA's planning documents, including the CAPE. The current draft of the CAPE does not include any mention of climate in its 2030 Vision Statement, as an example.

2) Consider stating a goal of 100% zero-GHG-emission energy as the overarching goal, with a deadline of 2030 to achieve it. This aligns with California's goals, and with the IPCC and other international science.[5]
3) Define energy throughout the CAPE as "zero-GHG-emission energy" or "net-zero-energy" in all uses of the word "energy." This gives even a casual reader of the CAPE a reference to the goals for the energy portfolio.
4) Ensure the concept of "renewable" energy includes "zero-GHG emissions." Due to the acceleration of climate emergency, the concept of "renewable" energy is now firmly less important than ensuring energy (and transportation) are "zero-GHG-emission" within a timeframe that is meaningful for climate crisis mitigations: the next 10 years. All credible science points to a 2030 deadline for drastic climate mitigation.
5) Due to the climate crisis, the Tribe recommends sourcing price-competitive, zero-GHG-emission energy (e.g., solar, solar w/storage, wind, wind w/storage, etc.) where possible, and prioritizing the following resources in this order:
    a. local zero-GHG-emission resources
    b. non-local zero-GHG-emission resources
    c. local resources that have GHG emissions (black carbon, brown carbon, short lived climate pollutants, carbon dioxide, NOx, SOx, ozone, methane, others)
6) Due to the climate crisis and air pollution and other health hazards amplified by global heating, ensure that consistent regulatory compliance – especially air and water pollution and regulatory compliance – is a condition of holding any power purchase agreement with RCEA.
7) In bioenergy and biogas sections of the CAPE, include language that outlines expectations of operations that utilize best available control technologies (BACT) and/or best available retrofit control technologies (BARCT) in compliance with CA AB 617 and other regulation. RCEA's vision underscores human health as a priority. Human health will only be improved by ensuring communities adjacent to power plants, particularly disadvantaged communities, do not suffer disproportionate impacts, including toxic hot spots of air pollution and water pollution. Support for bioenergy is eroding (regionally, at the state level, and further) because of significant PM and other GHG emissions, fear about decimating forests to feed these plants, and the complicated and too-often inaccurate lifecycle calculations of actual, net GHG reductions and environmental benefits. Where bioenergy plants are operating in compliance with the Clean Air Act, Clean Water Act, individual Title V permits and all other permits and regulations, investing in best available control technology (above and beyond their mandates, ideally) to severely limit or eliminate air pollution – and where they have done a plant-level carbon lifecycle analysis to prove zero net GHGs (i.e., carbon neutral) bioenergy may be justifiable within a 20 year plan. However, we do not have 20 years to curb climate change, we have maybe 10. The Tribe suggests a bioenergy plant should not

[4] https://www.ipcc.ch/sr15/ Accessed online 9.20.19
[5] https://www.bbc.com/news/science-environment-48964736 Accessed online 8.27.2019

be a viable part of the RCEA portfolio if the plant is 1) creating a toxic hot spot in terms of air and water pollution for the surrounding community, and/or 2) if it is a net contributor to climate change. And the Tribe suggests it is RCEA's responsibility to investigate whether those two impacts are occurring and take action to remove that resource from the portfolio if so.

8) Consider conducting a thorough GHG inventory of the energy and transportation sectors in RCEA's jurisdiction.
9) Consider adding a 100% solar/wind rate option for the RCEA Community Choice Energy (Aggregation) customers (see PG&E's 100% solar "Solar Choice" program).

In conclusion, the time for relative justification for emissions is past. Governments and agencies must enact strong policy that drives down emissions at each source, regardless of how they compare to baseline emissions, wildfire emissions, or other sources of energy. The energy and transportation sector are at the epicenter of the success or failure of reaching a tipping point, past which the health and well-being of the North Coast will deteriorate significantly. We urge RCEA to consider these suggestions and act in concert with the Tribe and other regional leaders in treating the climate crisis as what it is: an emergency. The Tribe advocates for a just, predictable transition to zero emission energy and transportation, keeping in mind that there is a decade to work with, and that any emission reductions also have immediate health benefits for this region. The Tribe will submit further comments in the next comment period, which will include more specifics on electric transportation among other topics.

If there are questions on these comments, please contact Jana Ganion, Director of Sustainability and Government Affairs at 707.668.5101 x1044 or jganion@bluelakerancheria-nsn.gov

Sincerely,

/ s /

Arla Ramsey
Vice Chairperson

Enclosure

Summary for Policymakers

SPM

Summary for Policymakers

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SPM

Introduction

This Report responds to the invitation for IPCC '... to provide a Special Report in 2018 on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways' contained in the Decision of the 21st Conference of Parties of the United Nations Framework Convention on Climate Change to adopt the Paris Agreement.[1]

The IPCC accepted the invitation in April 2016, deciding to prepare this Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

This Summary for Policymakers (SPM) presents the key findings of the Special Report, based on the assessment of the available scientific, technical and socio-economic literature[2] relevant to global warming of 1.5°C and for the comparison between global warming of 1.5°C and 2°C above pre-industrial levels. The level of confidence associated with each key finding is reported using the IPCC calibrated language.[3] The underlying scientific basis of each key finding is indicated by references provided to chapter elements. In the SPM, knowledge gaps are identified associated with the underlying chapters of the Report.

A. Understanding Global Warming of 1.5°C[4]

A.1 Human activities are estimated to have caused approximately 1.0°C of global warming[5] above pre-industrial levels, with a *likely* range of 0.8°C to 1.2°C. Global warming is *likely* to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate. (*high confidence*) (Figure SPM.1) {1.2}

A.1.1 Reflecting the long-term warming trend since pre-industrial times, observed global mean surface temperature (GMST) for the decade 2006–2015 was 0.87°C (*likely* between 0.75°C and 0.99°C)[6] higher than the average over the 1850–1900 period (*very high confidence*). Estimated anthropogenic global warming matches the level of observed warming to within ±20% (*likely range*). Estimated anthropogenic global warming is currently increasing at 0.2°C (*likely* between 0.1°C and 0.3°C) per decade due to past and ongoing emissions (*high confidence*). {1.2.1, Table 1.1, 1.2.4}

A.1.2 Warming greater than the global annual average is being experienced in many land regions and seasons, including two to three times higher in the Arctic. Warming is generally higher over land than over the ocean. (*high confidence*) {1.2.1, 1.2.2, Figure 1.1, Figure 1.3, 3.3.1, 3.3.2}

A.1.3 Trends in intensity and frequency of some climate and weather extremes have been detected over time spans during which about 0.5°C of global warming occurred (*medium confidence*). This assessment is based on several lines of evidence, including attribution studies for changes in extremes since 1950. {3.3.1, 3.3.2, 3.3.3}

1 Decision 1/CP.21, paragraph 21.

2 The assessment covers literature accepted for publication by 15 May 2018.

3 Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, for example, *medium confidence*. The following terms have been used to indicate the assessed likelihood of an outcome or a result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%. Additional terms (extremely likely 95–100%, more likely than not >50–100%, more unlikely than likely 0–<50%, extremely unlikely 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics, for example, *very likely*. This is consistent with AR5.

4 See also Box SPM.1: Core Concepts Central to this Special Report.

5 Present level of global warming is defined as the average of a 30-year period centred on 2017 assuming the recent rate of warming continues.

6 This range spans the four available peer-reviewed estimates of the observed GMST change and also accounts for additional uncertainty due to possible short-term natural variability. {1.2.1, Table 1.1}

A.2 Warming from anthropogenic emissions from the pre-industrial period to the present will persist for centuries to millennia and will continue to cause further long-term changes in the climate system, such as sea level rise, with associated impacts (*high confidence*), but these emissions alone are *unlikely* to cause global warming of 1.5°C (*medium confidence*). (Figure SPM.1) {1.2, 3.3, Figure 1.5}

A.2.1 Anthropogenic emissions (including greenhouse gases, aerosols and their precursors) up to the present are *unlikely* to cause further warming of more than 0.5°C over the next two to three decades (*high confidence*) or on a century time scale (*medium confidence*). {1.2.4, Figure 1.5}

A.2.2 Reaching and sustaining net zero global anthropogenic CO_2 emissions and declining net non-CO_2 radiative forcing would halt anthropogenic global warming on multi-decadal time scales (*high confidence*). The maximum temperature reached is then determined by cumulative net global anthropogenic CO_2 emissions up to the time of net zero CO_2 emissions (*high confidence*) and the level of non-CO_2 radiative forcing in the decades prior to the time that maximum temperatures are reached (*medium confidence*). On longer time scales, sustained net negative global anthropogenic CO_2 emissions and/or further reductions in non-CO_2 radiative forcing may still be required to prevent further warming due to Earth system feedbacks and to reverse ocean acidification (*medium confidence*) and will be required to minimize sea level rise (*high confidence*). {Cross-Chapter Box 2 in Chapter 1, 1.2.3, 1.2.4, Figure 1.4, 2.2.1, 2.2.2, 3.4.4.8, 3.4.5.1, 3.6.3.2}

A.3 Climate-related risks for natural and human systems are higher for global warming of 1.5°C than at present, but lower than at 2°C (*high confidence*). These risks depend on the magnitude and rate of warming, geographic location, levels of development and vulnerability, and on the choices and implementation of adaptation and mitigation options (*high confidence*). (Figure SPM.2) {1.3, 3.3, 3.4, 5.6}

A.3.1 Impacts on natural and human systems from global warming have already been observed (*high confidence*). Many land and ocean ecosystems and some of the services they provide have already changed due to global warming (*high confidence*). (Figure SPM.2) {1.4, 3.4, 3.5}

A.3.2 Future climate-related risks depend on the rate, peak and duration of warming. In the aggregate, they are larger if global warming exceeds 1.5°C before returning to that level by 2100 than if global warming gradually stabilizes at 1.5°C, especially if the peak temperature is high (e.g., about 2°C) (*high confidence*). Some impacts may be long-lasting or irreversible, such as the loss of some ecosystems (*high confidence*). {3.2, 3.4.4, 3.6.3, Cross-Chapter Box 8 in Chapter 3}

A.3.3 Adaptation and mitigation are already occurring (*high confidence*). Future climate-related risks would be reduced by the upscaling and acceleration of far-reaching, multilevel and cross-sectoral climate mitigation and by both incremental and transformational adaptation (*high confidence*). {1.2, 1.3, Table 3.5, 4.2.2, Cross-Chapter Box 9 in Chapter 4, Box 4.2, Box 4.3, Box 4.6, 4.3.1, 4.3.2, 4.3.3, 4.3.4, 4.3.5, 4.4.1, 4.4.4, 4.4.5, 4.5.3}

SPM

Cumulative emissions of CO_2 and future non-CO_2 radiative forcing determine the probability of limiting warming to 1.5°C

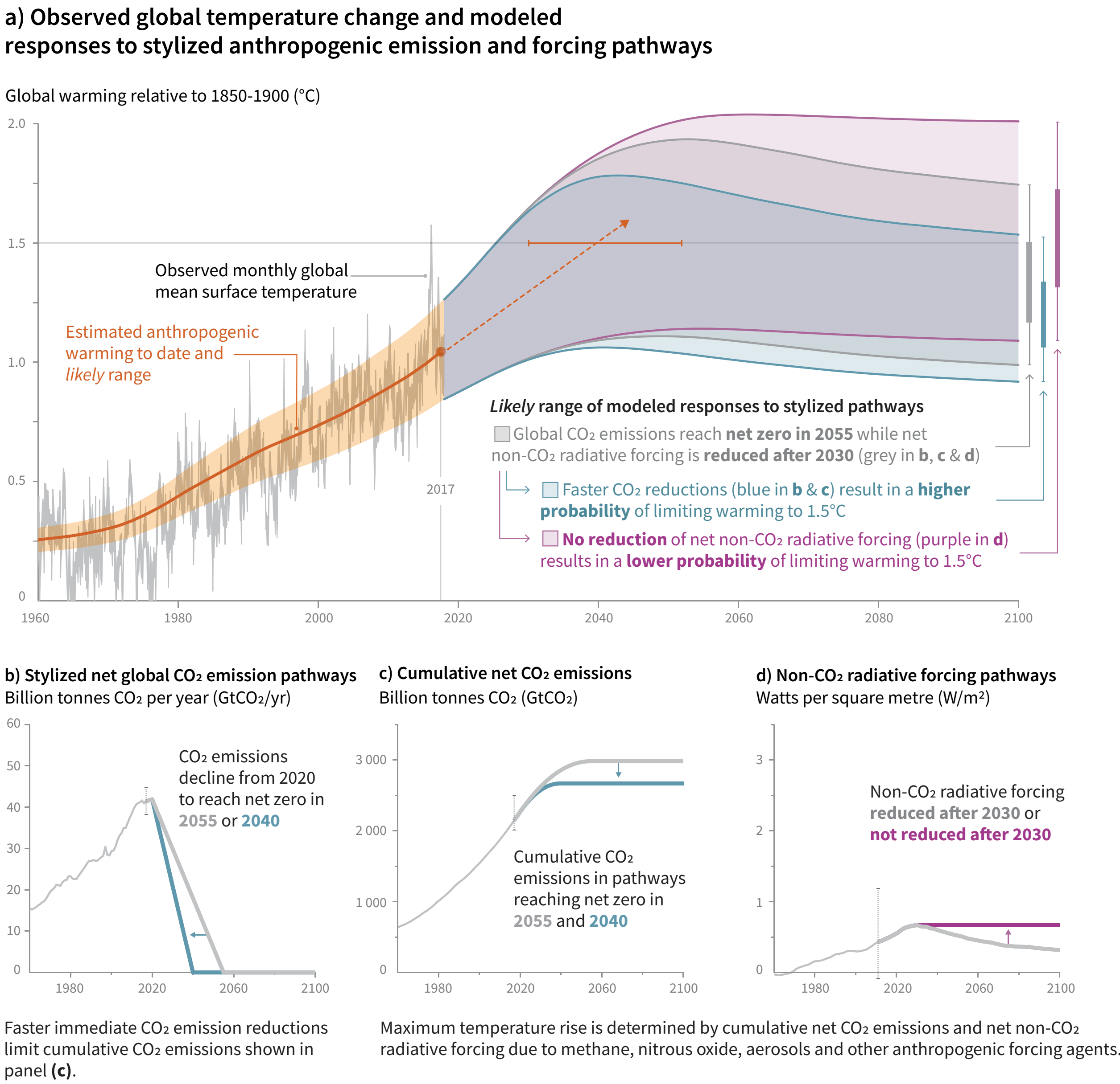

Figure SPM.1 | Panel a: Observed monthly global mean surface temperature (GMST, grey line up to 2017, from the HadCRUT4, GISTEMP, Cowtan–Way, and NOAA datasets) change and estimated anthropogenic global warming (solid orange line up to 2017, with orange shading indicating assessed *likely* range). Orange dashed arrow and horizontal orange error bar show respectively the central estimate and *likely* range of the time at which 1.5°C is reached if the current rate of warming continues. The grey plume on the right of panel a shows the *likely* range of warming responses, computed with a simple climate model, to a stylized pathway (hypothetical future) in which net CO_2 emissions (grey line in panels b and c) decline in a straight line from 2020 to reach net zero in 2055 and net non-CO_2 radiative forcing (grey line in panel d) increases to 2030 and then declines. The blue plume in panel a) shows the response to faster CO_2 emissions reductions (blue line in panel b), reaching net zero in 2040, reducing cumulative CO_2 emissions (panel c). The purple plume shows the response to net CO_2 emissions declining to zero in 2055, with net non-CO_2 forcing remaining constant after 2030. The vertical error bars on right of panel a) show the *likely* ranges (thin lines) and central terciles (33rd – 66th percentiles, thick lines) of the estimated distribution of warming in 2100 under these three stylized pathways. Vertical dotted error bars in panels b, c and d show the *likely* range of historical annual and cumulative global net CO_2 emissions in 2017 (data from the Global Carbon Project) and of net non-CO_2 radiative forcing in 2011 from AR5, respectively. Vertical axes in panels c and d are scaled to represent approximately equal effects on GMST. {1.2.1, 1.2.3, 1.2.4, 2.3, Figure 1.2 and Chapter 1 Supplementary Material, Cross-Chapter Box 2 in Chapter 1}

B. Projected Climate Change, Potential Impacts and Associated Risks

B.1 Climate models project robust[7] differences in regional climate characteristics between present-day and global warming of 1.5°C,[8] and between 1.5°C and 2°C.[8] These differences include increases in: mean temperature in most land and ocean regions (*high confidence*), hot extremes in most inhabited regions (*high confidence*), heavy precipitation in several regions (*medium confidence*), and the probability of drought and precipitation deficits in some regions (*medium confidence*). {3.3}

B.1.1 Evidence from attributed changes in some climate and weather extremes for a global warming of about 0.5°C supports the assessment that an additional 0.5°C of warming compared to present is associated with further detectable changes in these extremes (*medium confidence*). Several regional changes in climate are assessed to occur with global warming up to 1.5°C compared to pre-industrial levels, including warming of extreme temperatures in many regions (*high confidence*), increases in frequency, intensity, and/or amount of heavy precipitation in several regions (*high confidence*), and an increase in intensity or frequency of droughts in some regions (*medium confidence*). {3.2, 3.3.1, 3.3.2, 3.3.3, 3.3.4, Table 3.2}

B.1.2 Temperature extremes on land are projected to warm more than GMST (*high confidence*): extreme hot days in mid-latitudes warm by up to about 3°C at global warming of 1.5°C and about 4°C at 2°C, and extreme cold nights in high latitudes warm by up to about 4.5°C at 1.5°C and about 6°C at 2°C (*high confidence*). The number of hot days is projected to increase in most land regions, with highest increases in the tropics (*high confidence*). {3.3.1, 3.3.2, Cross-Chapter Box 8 in Chapter 3}

B.1.3 Risks from droughts and precipitation deficits are projected to be higher at 2°C compared to 1.5°C of global warming in some regions (*medium confidence*). Risks from heavy precipitation events are projected to be higher at 2°C compared to 1.5°C of global warming in several northern hemisphere high-latitude and/or high-elevation regions, eastern Asia and eastern North America (*medium confidence)*. Heavy precipitation associated with tropical cyclones is projected to be higher at 2°C compared to 1.5°C global warming (*medium confidence*). There is generally *low confidence* in projected changes in heavy precipitation at 2°C compared to 1.5°C in other regions. Heavy precipitation when aggregated at global scale is projected to be higher at 2°C than at 1.5°C of global warming (*medium confidence*). As a consequence of heavy precipitation, the fraction of the global land area affected by flood hazards is projected to be larger at 2°C compared to 1.5°C of global warming (*medium confidence*). {3.3.1, 3.3.3, 3.3.4, 3.3.5, 3.3.6}

B.2 By 2100, global mean sea level rise is projected to be around 0.1 metre lower with global warming of 1.5°C compared to 2°C (*medium confidence*). Sea level will continue to rise well beyond 2100 (*high confidence*), and the magnitude and rate of this rise depend on future emission pathways. A slower rate of sea level rise enables greater opportunities for adaptation in the human and ecological systems of small islands, low-lying coastal areas and deltas (*medium confidence*). {3.3, 3.4, 3.6}

B.2.1 Model-based projections of global mean sea level rise (relative to 1986–2005) suggest an indicative range of 0.26 to 0.77 m by 2100 for 1.5°C of global warming, 0.1 m (0.04–0.16 m) less than for a global warming of 2°C (*medium confidence*). A reduction of 0.1 m in global sea level rise implies that up to 10 million fewer people would be exposed to related risks, based on population in the year 2010 and assuming no adaptation (*medium confidence*). {3.4.4, 3.4.5, 4.3.2}

B.2.2 Sea level rise will continue beyond 2100 even if global warming is limited to 1.5°C in the 21st century (*high confidence*). Marine ice sheet instability in Antarctica and/or irreversible loss of the Greenland ice sheet could result in multi-metre rise in sea level over hundreds to thousands of years. These instabilities could be triggered at around 1.5°C to 2°C of global warming (*medium confidence*). (Figure SPM.2) {3.3.9, 3.4.5, 3.5.2, 3.6.3, Box 3.3}

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7 Robust is here used to mean that at least two thirds of climate models show the same sign of changes at the grid point scale, and that differences in large regions are statistically significant.

8 Projected changes in impacts between different levels of global warming are determined with respect to changes in global mean surface air temperature.

B.2.3 Increasing warming amplifies the exposure of small islands, low-lying coastal areas and deltas to the risks associated with sea level rise for many human and ecological systems, including increased saltwater intrusion, flooding and damage to infrastructure (*high confidence*). Risks associated with sea level rise are higher at 2°C compared to 1.5°C. The slower rate of sea level rise at global warming of 1.5°C reduces these risks, enabling greater opportunities for adaptation including managing and restoring natural coastal ecosystems and infrastructure reinforcement (*medium confidence*). (Figure SPM.2) {3.4.5, Box 3.5}

B.3 On land, impacts on biodiversity and ecosystems, including species loss and extinction, are projected to be lower at 1.5°C of global warming compared to 2°C. Limiting global warming to 1.5°C compared to 2°C is projected to lower the impacts on terrestrial, freshwater and coastal ecosystems and to retain more of their services to humans (*high confidence*). (Figure SPM.2) {3.4, 3.5, Box 3.4, Box 4.2, Cross-Chapter Box 8 in Chapter 3}

B.3.1 Of 105,000 species studied,[9] 6% of insects, 8% of plants and 4% of vertebrates are projected to lose over half of their climatically determined geographic range for global warming of 1.5°C, compared with 18% of insects, 16% of plants and 8% of vertebrates for global warming of 2°C (*medium confidence*). Impacts associated with other biodiversity-related risks such as forest fires and the spread of invasive species are lower at 1.5°C compared to 2°C of global warming (*high confidence*). {3.4.3, 3.5.2}

B.3.2 Approximately 4% (interquartile range 2–7%) of the global terrestrial land area is projected to undergo a transformation of ecosystems from one type to another at 1°C of global warming, compared with 13% (interquartile range 8–20%) at 2°C (*medium confidence*). This indicates that the area at risk is projected to be approximately 50% lower at 1.5°C compared to 2°C (*medium confidence*). {3.4.3.1, 3.4.3.5}

B.3.3 High-latitude tundra and boreal forests are particularly at risk of climate change-induced degradation and loss, with woody shrubs already encroaching into the tundra (*high confidence*) and this will proceed with further warming. Limiting global warming to 1.5°C rather than 2°C is projected to prevent the thawing over centuries of a permafrost area in the range of 1.5 to 2.5 million km^2 (*medium confidence*). {3.3.2, 3.4.3, 3.5.5}

B.4 Limiting global warming to 1.5°C compared to 2°C is projected to reduce increases in ocean temperature as well as associated increases in ocean acidity and decreases in ocean oxygen levels (*high confidence*). Consequently, limiting global warming to 1.5°C is projected to reduce risks to marine biodiversity, fisheries, and ecosystems, and their functions and services to humans, as illustrated by recent changes to Arctic sea ice and warm-water coral reef ecosystems (*high confidence*). {3.3, 3.4, 3.5, Box 3.4, Box 3.5}

B.4.1 There is *high confidence* that the probability of a sea ice-free Arctic Ocean during summer is substantially lower at global warming of 1.5°C when compared to 2°C. With 1.5°C of global warming, one sea ice-free Arctic summer is projected per century. This likelihood is increased to at least one per decade with 2°C global warming. Effects of a temperature overshoot are reversible for Arctic sea ice cover on decadal time scales (*high confidence*). {3.3.8, 3.4.4.7}

B.4.2 Global warming of 1.5°C is projected to shift the ranges of many marine species to higher latitudes as well as increase the amount of damage to many ecosystems. It is also expected to drive the loss of coastal resources and reduce the productivity of fisheries and aquaculture (especially at low latitudes). The risks of climate-induced impacts are projected to be higher at 2°C than those at global warming of 1.5°C (*high confidence*). Coral reefs, for example, are projected to decline by a further 70–90% at 1.5°C (*high confidence*) with larger losses (>99%) at 2°C (*very high confidence*). The risk of irreversible loss of many marine and coastal ecosystems increases with global warming, especially at 2°C or more (*high confidence*). {3.4.4, Box 3.4}

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9 Consistent with earlier studies, illustrative numbers were adopted from one recent meta-study.

B.4.3 The level of ocean acidification due to increasing CO_2 concentrations associated with global warming of 1.5°C is projected to amplify the adverse effects of warming, and even further at 2°C, impacting the growth, development, calcification, survival, and thus abundance of a broad range of species, for example, from algae to fish (*high confidence*). {3.3.10, 3.4.4}

B.4.4 Impacts of climate change in the ocean are increasing risks to fisheries and aquaculture via impacts on the physiology, survivorship, habitat, reproduction, disease incidence, and risk of invasive species (*medium confidence*) but are projected to be less at 1.5°C of global warming than at 2°C. One global fishery model, for example, projected a decrease in global annual catch for marine fisheries of about 1.5 million tonnes for 1.5°C of global warming compared to a loss of more than 3 million tonnes for 2°C of global warming (*medium confidence*). {3.4.4, Box 3.4}

B.5 Climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5°C and increase further with 2°C. (Figure SPM.2) {3.4, 3.5, 5.2, Box 3.2, Box 3.3, Box 3.5, Box 3.6, Cross-Chapter Box 6 in Chapter 3, Cross-Chapter Box 9 in Chapter 4, Cross-Chapter Box 12 in Chapter 5, 5.2}

B.5.1 Populations at disproportionately higher risk of adverse consequences with global warming of 1.5°C and beyond include disadvantaged and vulnerable populations, some indigenous peoples, and local communities dependent on agricultural or coastal livelihoods (*high confidence*). Regions at disproportionately higher risk include Arctic ecosystems, dryland regions, small island developing states, and Least Developed Countries (*high confidence*). Poverty and disadvantage are expected to increase in some populations as global warming increases; limiting global warming to 1.5°C, compared with 2°C, could reduce the number of people both exposed to climate-related risks and susceptible to poverty by up to several hundred million by 2050 (*medium confidence*). {3.4.10, 3.4.11, Box 3.5, Cross-Chapter Box 6 in Chapter 3, Cross-Chapter Box 9 in Chapter 4, Cross-Chapter Box 12 in Chapter 5, 4.2.2.2, 5.2.1, 5.2.2, 5.2.3, 5.6.3}

B.5.2 Any increase in global warming is projected to affect human health, with primarily negative consequences (*high confidence*). Lower risks are projected at 1.5°C than at 2°C for heat-related morbidity and mortality (*very high confidence*) and for ozone-related mortality if emissions needed for ozone formation remain high (*high confidence*). Urban heat islands often amplify the impacts of heatwaves in cities (*high confidence*). Risks from some vector-borne diseases, such as malaria and dengue fever, are projected to increase with warming from 1.5°C to 2°C, including potential shifts in their geographic range (*high confidence*). {3.4.7, 3.4.8, 3.5.5.8}

B.5.3 Limiting warming to 1.5°C compared with 2°C is projected to result in smaller net reductions in yields of maize, rice, wheat, and potentially other cereal crops, particularly in sub-Saharan Africa, Southeast Asia, and Central and South America, and in the CO_2-dependent nutritional quality of rice and wheat (*high confidence*). Reductions in projected food availability are larger at 2°C than at 1.5°C of global warming in the Sahel, southern Africa, the Mediterranean, central Europe, and the Amazon (*medium confidence*). Livestock are projected to be adversely affected with rising temperatures, depending on the extent of changes in feed quality, spread of diseases, and water resource availability (*high confidence*). {3.4.6, 3.5.4, 3.5.5, Box 3.1, Cross-Chapter Box 6 in Chapter 3, Cross-Chapter Box 9 in Chapter 4}

B.5.4 Depending on future socio-economic conditions, limiting global warming to 1.5°C compared to 2°C may reduce the proportion of the world population exposed to a climate change-induced increase in water stress by up to 50%, although there is considerable variability between regions (*medium confidence*). Many small island developing states could experience lower water stress as a result of projected changes in aridity when global warming is limited to 1.5°C, as compared to 2°C (*medium confidence*). {3.3.5, 3.4.2, 3.4.8, 3.5.5, Box 3.2, Box 3.5, Cross-Chapter Box 9 in Chapter 4}

B.5.5 Risks to global aggregated economic growth due to climate change impacts are projected to be lower at 1.5°C than at 2°C by the end of this century[10] (*medium confidence*). This excludes the costs of mitigation, adaptation investments and the benefits of adaptation. Countries in the tropics and Southern Hemisphere subtropics are projected to experience the largest impacts on economic growth due to climate change should global warming increase from 1.5°C to 2°C (*medium confidence*). {3.5.2, 3.5.3}

10 Here, impacts on economic growth refer to changes in gross domestic product (GDP). Many impacts, such as loss of human lives, cultural heritage and ecosystem services, are difficult to value and monetize.

B.5.6 Exposure to multiple and compound climate-related risks increases between 1.5°C and 2°C of global warming, with greater proportions of people both so exposed and susceptible to poverty in Africa and Asia (*high confidence*). For global warming from 1.5°C to 2°C, risks across energy, food, and water sectors could overlap spatially and temporally, creating new and exacerbating current hazards, exposures, and vulnerabilities that could affect increasing numbers of people and regions (*medium confidence*). {Box 3.5, 3.3.1, 3.4.5.3, 3.4.5.6, 3.4.11, 3.5.4.9}

B.5.7 There are multiple lines of evidence that since AR5 the assessed levels of risk increased for four of the five Reasons for Concern (RFCs) for global warming to 2°C (*high confidence*). The risk transitions by degrees of global warming are now: from high to very high risk between 1.5°C and 2°C for RFC1 (Unique and threatened systems) (*high confidence*); from moderate to high risk between 1°C and 1.5°C for RFC2 (Extreme weather events) (*medium confidence*); from moderate to high risk between 1.5°C and 2°C for RFC3 (Distribution of impacts) (*high confidence*); from moderate to high risk between 1.5°C and 2.5°C for RFC4 (Global aggregate impacts) (*medium confidence*); and from moderate to high risk between 1°C and 2.5°C for RFC5 (Large-scale singular events) (*medium confidence*). (Figure SPM.2) {3.4.13; 3.5, 3.5.2}

B.6 Most adaptation needs will be lower for global warming of 1.5°C compared to 2°C (*high confidence*). There are a wide range of adaptation options that can reduce the risks of climate change (*high confidence*). There are limits to adaptation and adaptive capacity for some human and natural systems at global warming of 1.5°C, with associated losses (*medium confidence*). The number and availability of adaptation options vary by sector (*medium confidence*). {Table 3.5, 4.3, 4.5, Cross-Chapter Box 9 in Chapter 4, Cross-Chapter Box 12 in Chapter 5}

B.6.1 A wide range of adaptation options are available to reduce the risks to natural and managed ecosystems (e.g., ecosystem-based adaptation, ecosystem restoration and avoided degradation and deforestation, biodiversity management, sustainable aquaculture, and local knowledge and indigenous knowledge), the risks of sea level rise (e.g., coastal defence and hardening), and the risks to health, livelihoods, food, water, and economic growth, especially in rural landscapes (e.g., efficient irrigation, social safety nets, disaster risk management, risk spreading and sharing, and community-based adaptation) and urban areas (e.g., green infrastructure, sustainable land use and planning, and sustainable water management) (*medium confidence*). {4.3.1, 4.3.2, 4.3.3, 4.3.5, 4.5.3, 4.5.4, 5.3.2, Box 4.2, Box 4.3, Box 4.6, Cross-Chapter Box 9 in Chapter 4}.

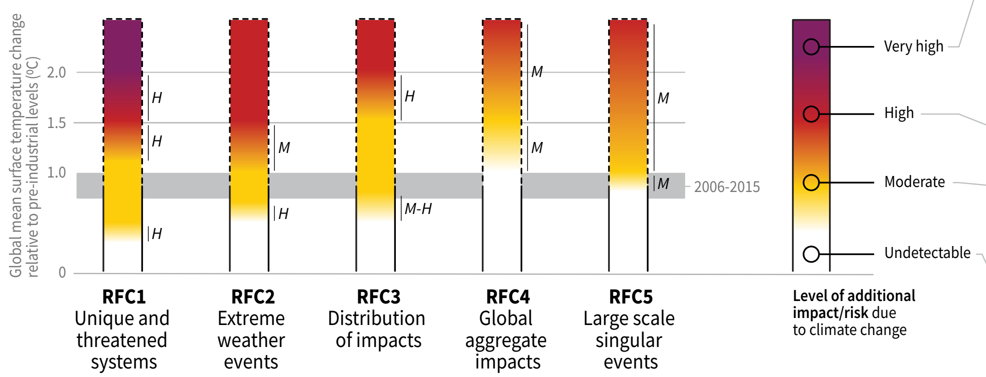
B.6.2 Adaptation is expected to be more challenging for ecosystems, food and health systems at 2°C of global warming than for 1.5°C (*medium confidence*). Some vulnerable regions, including small islands and Least Developed Countries, are projected to experience high multiple interrelated climate risks even at global warming of 1.5°C (*high confidence*). {3.3.1, 3.4.5, Box 3.5, Table 3.5, Cross-Chapter Box 9 in Chapter 4, 5.6, Cross-Chapter Box 12 in Chapter 5, Box 5.3}

B.6.3 Limits to adaptive capacity exist at 1.5°C of global warming, become more pronounced at higher levels of warming and vary by sector, with site-specific implications for vulnerable regions, ecosystems and human health (*medium confidence*). {Cross-Chapter Box 12 in Chapter 5, Box 3.5, Table 3.5}

How the level of global warming affects impacts and/or risks associated with the Reasons for Concern (RFCs) and selected natural, managed and human systems

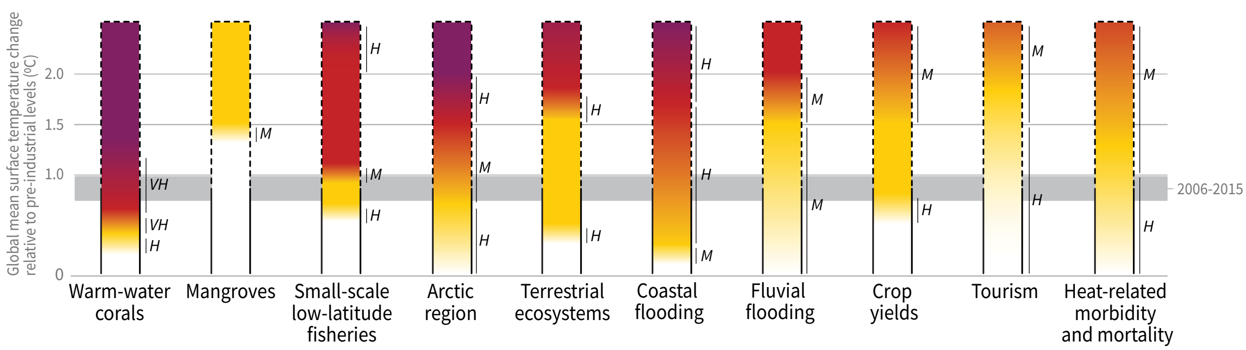
Five Reasons For Concern (RFCs) illustrate the impacts and risks of different levels of global warming for people, economies and ecosystems across sectors and regions.

Impacts and risks associated with the Reasons for Concern (RFCs)



Purple indicates very high risks of severe impacts/risks and the presence of significant irreversibility or the persistence of climate-related hazards, combined with limited ability to adapt due to the nature of the hazard or impacts/risks.
Red indicates severe and widespread impacts/risks.
Yellow indicates that impacts/risks are detectable and attributable to climate change with at least medium confidence.
White indicates that no impacts are detectable and attributable to climate change.

Impacts and risks for selected natural, managed and human systems



Confidence level for transition: *L*=Low, *M*=Medium, *H*=High and *VH*=Very high

Figure SPM.2 | Five integrative reasons for concern (RFCs) provide a framework for summarizing key impacts and risks across sectors and regions, and were introduced in the IPCC Third Assessment Report. RFCs illustrate the implications of global warming for people, economies and ecosystems. Impacts and/or risks for each RFC are based on assessment of the new literature that has appeared. As in AR5, this literature was used to make expert judgments to assess the levels of global warming at which levels of impact and/or risk are undetectable, moderate, high or very high. The selection of impacts and risks to natural, managed and human systems in the lower panel is illustrative and is not intended to be fully comprehensive. {3.4, 3.5, 3.5.2.1, 3.5.2.2, 3.5.2.3, 3.5.2.4, 3.5.2.5, 5.4.1, 5.5.3, 5.6.1, Box 3.4}
RFC1 Unique and threatened systems: ecological and human systems that have restricted geographic ranges constrained by climate-related conditions and have high endemism or other distinctive properties. Examples include coral reefs, the Arctic and its indigenous people, mountain glaciers and biodiversity hotspots.
RFC2 Extreme weather events: risks/impacts to human health, livelihoods, assets and ecosystems from extreme weather events such as heat waves, heavy rain, drought and associated wildfires, and coastal flooding.
RFC3 Distribution of impacts: risks/impacts that disproportionately affect particular groups due to uneven distribution of physical climate change hazards, exposure or vulnerability.
RFC4 Global aggregate impacts: global monetary damage, global-scale degradation and loss of ecosystems and biodiversity.
RFC5 Large-scale singular events: are relatively large, abrupt and sometimes irreversible changes in systems that are caused by global warming. Examples include disintegration of the Greenland and Antarctic ice sheets.

C. Emission Pathways and System Transitions Consistent with 1.5°C Global Warming

C.1 In model pathways with no or limited overshoot of 1.5°C, global net anthropogenic CO_2 emissions decline by about 45% from 2010 levels by 2030 (40–60% interquartile range), reaching net zero around 2050 (2045–2055 interquartile range). For limiting global warming to below 2°C[11] CO_2 emissions are projected to decline by about 25% by 2030 in most pathways (10–30% interquartile range) and reach net zero around 2070 (2065–2080 interquartile range). Non-CO_2 emissions in pathways that limit global warming to 1.5°C show deep reductions that are similar to those in pathways limiting warming to 2°C. (*high confidence*) (Figure SPM.3a) {2.1, 2.3, Table 2.4}

C.1.1 CO_2 emissions reductions that limit global warming to 1.5°C with no or limited overshoot can involve different portfolios of mitigation measures, striking different balances between lowering energy and resource intensity, rate of decarbonization, and the reliance on carbon dioxide removal. Different portfolios face different implementation challenges and potential synergies and trade-offs with sustainable development. (*high confidence*) (Figure SPM.3b) {2.3.2, 2.3.4, 2.4, 2.5.3}

C.1.2 Modelled pathways that limit global warming to 1.5°C with no or limited overshoot involve deep reductions in emissions of methane and black carbon (35% or more of both by 2050 relative to 2010). These pathways also reduce most of the cooling aerosols, which partially offsets mitigation effects for two to three decades. Non-CO_2 emissions[12] can be reduced as a result of broad mitigation measures in the energy sector. In addition, targeted non-CO_2 mitigation measures can reduce nitrous oxide and methane from agriculture, methane from the waste sector, some sources of black carbon, and hydrofluorocarbons. High bioenergy demand can increase emissions of nitrous oxide in some 1.5°C pathways, highlighting the importance of appropriate management approaches. Improved air quality resulting from projected reductions in many non-CO_2 emissions provide direct and immediate population health benefits in all 1.5°C model pathways. (*high confidence*) (Figure SPM.3a) {2.2.1, 2.3.3, 2.4.4, 2.5.3, 4.3.6, 5.4.2}

C.1.3 Limiting global warming requires limiting the total cumulative global anthropogenic emissions of CO_2 since the pre-industrial period, that is, staying within a total carbon budget (*high confidence*).[13] By the end of 2017, anthropogenic CO_2 emissions since the pre-industrial period are estimated to have reduced the total carbon budget for 1.5°C by approximately 2200 ± 320 $GtCO_2$ (*medium confidence*). The associated remaining budget is being depleted by current emissions of 42 ± 3 $GtCO_2$ per year (*high confidence*). The choice of the measure of global temperature affects the estimated remaining carbon budget. Using global mean surface air temperature, as in AR5, gives an estimate of the remaining carbon budget of 580 $GtCO_2$ for a 50% probability of limiting warming to 1.5°C, and 420 $GtCO_2$ for a 66% probability (*medium confidence*).[14] Alternatively, using GMST gives estimates of 770 and 570 $GtCO_2$, for 50% and 66% probabilities,[15] respectively (*medium confidence*). Uncertainties in the size of these estimated remaining carbon budgets are substantial and depend on several factors. Uncertainties in the climate response to CO_2 and non-CO_2 emissions contribute ±400 $GtCO_2$ and the level of historic warming contributes ±250 $GtCO_2$ (*medium confidence*). Potential additional carbon release from future permafrost thawing and methane release from wetlands would reduce budgets by up to 100 $GtCO_2$ over the course of this century and more thereafter (*medium confidence*). In addition, the level of non-CO_2 mitigation in the future could alter the remaining carbon budget by 250 $GtCO_2$ in either direction (*medium confidence*). {1.2.4, 2.2.2, 2.6.1, Table 2.2, Chapter 2 Supplementary Material}

C.1.4 Solar radiation modification (SRM) measures are not included in any of the available assessed pathways. Although some SRM measures may be theoretically effective in reducing an overshoot, they face large uncertainties and knowledge gaps

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11 References to pathways limiting global warming to 2°C are based on a 66% probability of staying below 2°C.

12 Non-CO_2 emissions included in this Report are all anthropogenic emissions other than CO_2 that result in radiative forcing. These include short-lived climate forcers, such as methane, some fluorinated gases, ozone precursors, aerosols or aerosol precursors, such as black carbon and sulphur dioxide, respectively, as well as long-lived greenhouse gases, such as nitrous oxide or some fluorinated gases. The radiative forcing associated with non-CO_2 emissions and changes in surface albedo is referred to as non-CO_2 radiative forcing. {2.2.1}

13 There is a clear scientific basis for a total carbon budget consistent with limiting global warming to 1.5°C. However, neither this total carbon budget nor the fraction of this budget taken up by past emissions were assessed in this Report.

14 Irrespective of the measure of global temperature used, updated understanding and further advances in methods have led to an increase in the estimated remaining carbon budget of about 300 $GtCO_2$ compared to AR5. (*medium confidence*) {2.2.2}

15 These estimates use observed GMST to 2006–2015 and estimate future temperature changes using near surface air temperatures.

as well as substantial risks and institutional and social constraints to deployment related to governance, ethics, and impacts on sustainable development. They also do not mitigate ocean acidification. (*medium confidence*) {4.3.8, Cross-Chapter Box 10 in Chapter 4}

Global emissions pathway characteristics

General characteristics of the evolution of anthropogenic net emissions of CO_2, and total emissions of methane, black carbon, and nitrous oxide in model pathways that limit global warming to 1.5°C with no or limited overshoot. Net emissions are defined as anthropogenic emissions reduced by anthropogenic removals. Reductions in net emissions can be achieved through different portfolios of mitigation measures illustrated in Figure SPM.3b.

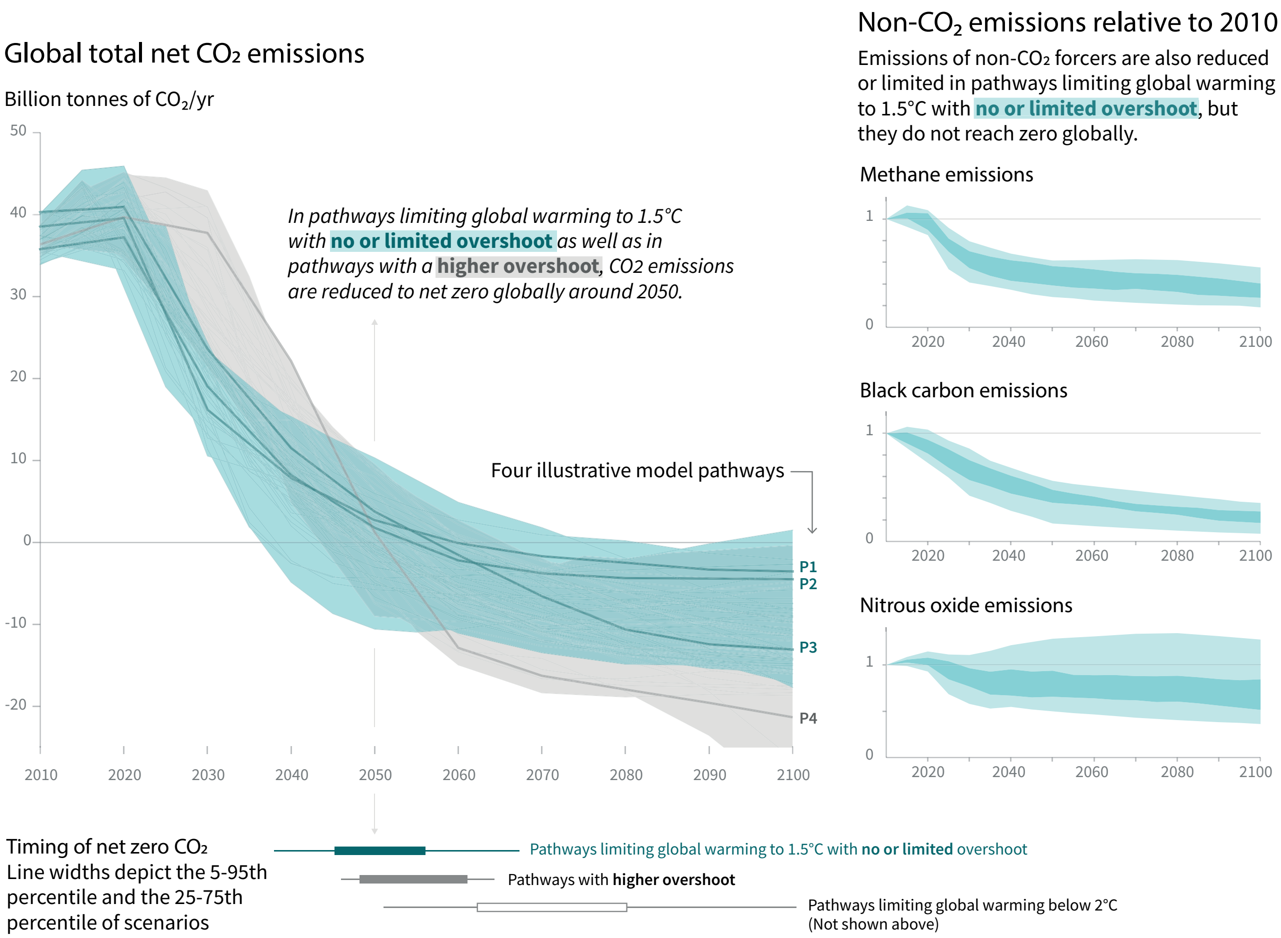
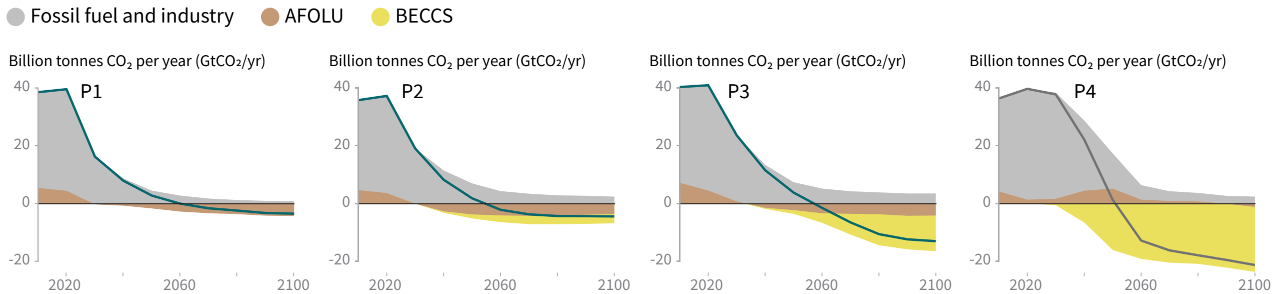


Figure SPM.3a | Global emissions pathway characteristics. The main panel shows global net anthropogenic CO_2 emissions in pathways limiting global warming to 1.5°C with no or limited (less than 0.1°C) overshoot and pathways with higher overshoot. The shaded area shows the full range for pathways analysed in this Report. The panels on the right show non-CO_2 emissions ranges for three compounds with large historical forcing and a substantial portion of emissions coming from sources distinct from those central to CO_2 mitigation. Shaded areas in these panels show the 5–95% (light shading) and interquartile (dark shading) ranges of pathways limiting global warming to 1.5°C with no or limited overshoot. Box and whiskers at the bottom of the figure show the timing of pathways reaching global net zero CO_2 emission levels, and a comparison with pathways limiting global warming to 2°C with at least 66% probability. Four illustrative model pathways are highlighted in the main panel and are labelled P1, P2, P3 and P4, corresponding to the LED, S1, S2, and S5 pathways assessed in Chapter 2. Descriptions and characteristics of these pathways are available in Figure SPM.3b. {2.1, 2.2, 2.3, Figure 2.5, Figure 2.10, Figure 2.11}

Characteristics of four illustrative model pathways

Different mitigation strategies can achieve the net emissions reductions that would be required to follow a pathway that limits global warming to 1.5°C with no or limited overshoot. All pathways use Carbon Dioxide Removal (CDR), but the amount varies across pathways, as do the relative contributions of Bioenergy with Carbon Capture and Storage (BECCS) and removals in the Agriculture, Forestry and Other Land Use (AFOLU) sector. This has implications for emissions and several other pathway characteristics.

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Global indicators	P1	P2	P3	P4	**Interquartile range**
Pathway classification	No or limited overshoot	No or limited overshoot	No or limited overshoot	Higher overshoot	No or limited overshoot
CO_2 emission change in 2030 (% rel to 2010)	-58	-47	-41	4	(-58,-40)
└ *in 2050 (% rel to 2010)*	-93	-95	-91	-97	(-107,-94)
Kyoto-GHG emissions in 2030 (% rel to 2010)*	-50	-49	-35	-2	(-51,-39)
└ *in 2050 (% rel to 2010)*	-82	-89	-78	-80	(-93,-81)
*Final energy demand** in 2030 (% rel to 2010)*	-15	-5	17	39	(-12,7)
└ *in 2050 (% rel to 2010)*	-32	2	21	44	(-11,22)
Renewable share in electricity in 2030 (%)	60	58	48	25	(47,65)
└ *in 2050 (%)*	77	81	63	70	(69,86)
Primary energy from coal in 2030 (% rel to 2010)	-78	-61	-75	-59	(-78, -59)
└ *in 2050 (% rel to 2010)*	-97	-77	-73	-97	(-95, -74)
from oil in 2030 (% rel to 2010)	-37	-13	-3	86	(-34,3)
└ *in 2050 (% rel to 2010)*	-87	-50	-81	-32	(-78,-31)
from gas in 2030 (% rel to 2010)	-25	-20	33	37	(-26,21)
└ *in 2050 (% rel to 2010)*	-74	-53	21	-48	(-56,6)
from nuclear in 2030 (% rel to 2010)	59	83	98	106	(44,102)
└ *in 2050 (% rel to 2010)*	150	98	501	468	(91,190)
from biomass in 2030 (% rel to 2010)	-11	0	36	-1	(29,80)
└ *in 2050 (% rel to 2010)*	-16	49	121	418	(123,261)
from non-biomass renewables in 2030 (% rel to 2010)	430	470	315	110	(245,436)
└ *in 2050 (% rel to 2010)*	833	1327	878	1137	(576,1299)
Cumulative CCS until 2100 ($GtCO_2$)	0	348	687	1218	(550,1017)
└ *of which BECCS ($GtCO_2$)*	0	151	414	1191	(364,662)
Land area of bioenergy crops in 2050 (million km²)	0.2	0.9	2.8	7.2	(1.5,3.2)
Agricultural CH_4 emissions in 2030 (% rel to 2010)	-24	-48	1	14	(-30,-11)
in 2050 (% rel to 2010)	-33	-69	-23	2	(-47,-24)
Agricultural N_2O emissions in 2030 (% rel to 2010)	5	-26	15	3	(-21,3)
in 2050 (% rel to 2010)	6	-26	0	39	(-26,1)

NOTE: Indicators have been selected to show global trends identified by the Chapter 2 assessment. National and sectoral characteristics can differ substantially from the global trends shown above.

** Kyoto-gas emissions are based on IPCC Second Assessment Report GWP-100*
*** Changes in energy demand are associated with improvements in energy efficiency and behaviour change*

Figure SPM.3b | Characteristics of four illustrative model pathways in relation to global warming of 1.5°C introduced in Figure SPM.3a. These pathways were selected to show a range of potential mitigation approaches and vary widely in their projected energy and land use, as well as their assumptions about future socio-economic developments, including economic and population growth, equity and sustainability. A breakdown of the global net anthropogenic CO_2 emissions into the contributions in terms of CO_2 emissions from fossil fuel and industry; agriculture, forestry and other land use (AFOLU); and bioenergy with carbon capture and storage (BECCS) is shown. AFOLU estimates reported here are not necessarily comparable with countries' estimates. Further characteristics for each of these pathways are listed below each pathway. These pathways illustrate relative global differences in mitigation strategies, but do not represent central estimates, national strategies, and do not indicate requirements. For comparison, the right-most column shows the interquartile ranges across pathways with no or limited overshoot of 1.5°C. Pathways P1, P2, P3 and P4 correspond to the LED, S1, S2 and S5 pathways assessed in Chapter 2 (Figure SPM.3a). {2.2.1, 2.3.1, 2.3.2, 2.3.3, 2.3.4, 2.4.1, 2.4.2, 2.4.4, 2.5.3, Figure 2.5, Figure 2.6, Figure 2.9, Figure 2.10, Figure 2.11, Figure 2.14, Figure 2.15, Figure 2.16, Figure 2.17, Figure 2.24, Figure 2.25, Table 2.4, Table 2.6, Table 2.7, Table 2.9, Table 4.1}

C.2 Pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems (*high confidence*). These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options (*medium confidence*). {2.3, 2.4, 2.5, 4.2, 4.3, 4.4, 4.5}

C.2.1 Pathways that limit global warming to 1.5°C with no or limited overshoot show system changes that are more rapid and pronounced over the next two decades than in 2°C pathways (*high confidence*). The rates of system changes associated with limiting global warming to 1.5°C with no or limited overshoot have occurred in the past within specific sectors, technologies and spatial contexts, but there is no documented historic precedent for their scale (*medium confidence*). {2.3.3, 2.3.4, 2.4, 2.5, 4.2.1, 4.2.2, Cross-Chapter Box 11 in Chapter 4}

C.2.2 In energy systems, modelled global pathways (considered in the literature) limiting global warming to 1.5°C with no or limited overshoot (for more details see Figure SPM.3b) generally meet energy service demand with lower energy use, including through enhanced energy efficiency, and show faster electrification of energy end use compared to 2°C (*high confidence*). In 1.5°C pathways with no or limited overshoot, low-emission energy sources are projected to have a higher share, compared with 2°C pathways, particularly before 2050 (*high confidence*). In 1.5°C pathways with no or limited overshoot, renewables are projected to supply 70–85% (interquartile range) of electricity in 2050 (*high confidence*). In electricity generation, shares of nuclear and fossil fuels with carbon dioxide capture and storage (CCS) are modelled to increase in most 1.5°C pathways with no or limited overshoot. In modelled 1.5°C pathways with limited or no overshoot, the use of CCS would allow the electricity generation share of gas to be approximately 8% (3–11% interquartile range) of global electricity in 2050, while the use of coal shows a steep reduction in all pathways and would be reduced to close to 0% (0–2% interquartile range) of electricity (*high confidence*). While acknowledging the challenges, and differences between the options and national circumstances, political, economic, social and technical feasibility of solar energy, wind energy and electricity storage technologies have substantially improved over the past few years (*high confidence*). These improvements signal a potential system transition in electricity generation. (Figure SPM.3b) {2.4.1, 2.4.2, Figure 2.1, Table 2.6, Table 2.7, Cross-Chapter Box 6 in Chapter 3, 4.2.1, 4.3.1, 4.3.3, 4.5.2}

C.2.3 CO_2 emissions from industry in pathways limiting global warming to 1.5°C with no or limited overshoot are projected to be about 65–90% (interquartile range) lower in 2050 relative to 2010, as compared to 50–80% for global warming of 2°C (*medium confidence*). Such reductions can be achieved through combinations of new and existing technologies and practices, including electrification, hydrogen, sustainable bio-based feedstocks, product substitution, and carbon capture, utilization and storage (CCUS). These options are technically proven at various scales but their large-scale deployment may be limited by economic, financial, human capacity and institutional constraints in specific contexts, and specific characteristics of large-scale industrial installations. In industry, emissions reductions by energy and process efficiency by themselves are insufficient for limiting warming to 1.5°C with no or limited overshoot (*high confidence*). {2.4.3, 4.2.1, Table 4.1, Table 4.3, 4.3.3, 4.3.4, 4.5.2}

C.2.4 The urban and infrastructure system transition consistent with limiting global warming to 1.5°C with no or limited overshoot would imply, for example, changes in land and urban planning practices, as well as deeper emissions reductions in transport and buildings compared to pathways that limit global warming below 2°C (*medium confidence*). Technical measures and practices enabling deep emissions reductions include various energy efficiency options. In pathways limiting global warming to 1.5°C with no or limited overshoot, the electricity share of energy demand in buildings would be about 55–75% in 2050 compared to 50–70% in 2050 for 2°C global warming (*medium confidence*). In the transport sector, the share of low-emission final energy would rise from less than 5% in 2020 to about 35–65% in 2050 compared to 25–45% for 2°C of global warming (*medium confidence*). Economic, institutional and socio-cultural barriers may inhibit these urban and infrastructure system transitions, depending on national, regional and local circumstances, capabilities and the availability of capital (*high confidence*). {2.3.4, 2.4.3, 4.2.1, Table 4.1, 4.3.3, 4.5.2}

C.2.5 Transitions in global and regional land use are found in all pathways limiting global warming to 1.5°C with no or limited overshoot, but their scale depends on the pursued mitigation portfolio. Model pathways that limit global warming to 1.5°C with no or limited overshoot project a 4 million km^2 reduction to a 2.5 million km^2 increase of non-pasture agricultural land for food and feed crops and a 0.5–11 million km^2 reduction of pasture land, to be converted into a 0–6 million km^2 increase of agricultural land for energy crops and a 2 million km^2 reduction to 9.5 million km^2 increase in forests by 2050 relative to 2010 (*medium confidence*).[16] Land-use transitions of similar magnitude can be observed in modelled 2°C pathways (*medium confidence*). Such large transitions pose profound challenges for sustainable management of the various demands on land for human settlements, food, livestock feed, fibre, bioenergy, carbon storage, biodiversity and other ecosystem services (*high confidence*). Mitigation options limiting the demand for land include sustainable intensification of land-use practices, ecosystem restoration and changes towards less resource-intensive diets (*high confidence*). The implementation of land-based mitigation options would require overcoming socio-economic, institutional, technological, financing and environmental barriers that differ across regions (*high confidence*). {2.4.4, Figure 2.24, 4.3.2, 4.3.7, 4.5.2, Cross-Chapter Box 7 in Chapter 3}

C.2.6 Additional annual average energy-related investments for the period 2016 to 2050 in pathways limiting warming to 1.5°C compared to pathways without new climate policies beyond those in place today are estimated to be around 830 billion USD2010 (range of 150 billion to 1700 billion USD2010 across six models[17]). This compares to total annual average energy supply investments in 1.5°C pathways of 1460 to 3510 billion USD2010 and total annual average energy demand investments of 640 to 910 billion USD2010 for the period 2016 to 2050. Total energy-related investments increase by about 12% (range of 3% to 24%) in 1.5°C pathways relative to 2°C pathways. Annual investments in low-carbon energy technologies and energy efficiency are upscaled by roughly a factor of six (range of factor of 4 to 10) by 2050 compared to 2015 (*medium confidence*). {2.5.2, Box 4.8, Figure 2.27}

C.2.7 Modelled pathways limiting global warming to 1.5°C with no or limited overshoot project a wide range of global average discounted marginal abatement costs over the 21st century. They are roughly 3-4 times higher than in pathways limiting global warming to below 2°C (*high confidence*). The economic literature distinguishes marginal abatement costs from total mitigation costs in the economy. The literature on total mitigation costs of 1.5°C mitigation pathways is limited and was not assessed in this Report. Knowledge gaps remain in the integrated assessment of the economy-wide costs and benefits of mitigation in line with pathways limiting warming to 1.5°C. {2.5.2; 2.6; Figure 2.26}

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16 The projected land-use changes presented are not deployed to their upper limits simultaneously in a single pathway.

17 Including two pathways limiting warming to 1.5°C with no or limited overshoot and four pathways with higher overshoot.

C.3 All pathways that limit global warming to 1.5°C with limited or no overshoot project the use of carbon dioxide removal (CDR) on the order of 100–1000 $GtCO_2$ over the 21st century. CDR would be used to compensate for residual emissions and, in most cases, achieve net negative emissions to return global warming to 1.5°C following a peak (*high confidence*). CDR deployment of several hundreds of $GtCO_2$ is subject to multiple feasibility and sustainability constraints (*high confidence*). Significant near-term emissions reductions and measures to lower energy and land demand can limit CDR deployment to a few hundred $GtCO_2$ without reliance on bioenergy with carbon capture and storage (BECCS) (*high confidence*). {2.3, 2.4, 3.6.2, 4.3, 5.4}

C.3.1 Existing and potential CDR measures include afforestation and reforestation, land restoration and soil carbon sequestration, BECCS, direct air carbon capture and storage (DACCS), enhanced weathering and ocean alkalinization. These differ widely in terms of maturity, potentials, costs, risks, co-benefits and trade-offs (*high confidence*). To date, only a few published pathways include CDR measures other than afforestation and BECCS. {2.3.4, 3.6.2, 4.3.2, 4.3.7}

C.3.2 In pathways limiting global warming to 1.5°C with limited or no overshoot, BECCS deployment is projected to range from 0–1, 0–8, and 0–16 $GtCO_2\ yr^{-1}$ in 2030, 2050, and 2100, respectively, while agriculture, forestry and land-use (AFOLU) related CDR measures are projected to remove 0–5, 1–11, and 1–5 $GtCO_2\ yr^{-1}$ in these years (*medium confidence*). The upper end of these deployment ranges by mid-century exceeds the BECCS potential of up to 5 $GtCO_2\ yr^{-1}$ and afforestation potential of up to 3.6 $GtCO_2\ yr^{-1}$ assessed based on recent literature (*medium confidence*). Some pathways avoid BECCS deployment completely through demand-side measures and greater reliance on AFOLU-related CDR measures (*medium confidence*). The use of bioenergy can be as high or even higher when BECCS is excluded compared to when it is included due to its potential for replacing fossil fuels across sectors (*high confidence*). (Figure SPM.3b) {2.3.3, 2.3.4, 2.4.2, 3.6.2, 4.3.1, 4.2.3, 4.3.2, 4.3.7, 4.4.3, Table 2.4}

C.3.3 Pathways that overshoot 1.5°C of global warming rely on CDR exceeding residual CO_2 emissions later in the century to return to below 1.5°C by 2100, with larger overshoots requiring greater amounts of CDR (Figure SPM.3b) (*high confidence*). Limitations on the speed, scale, and societal acceptability of CDR deployment hence determine the ability to return global warming to below 1.5°C following an overshoot. Carbon cycle and climate system understanding is still limited about the effectiveness of net negative emissions to reduce temperatures after they peak (*high confidence*). {2.2, 2.3.4, 2.3.5, 2.6, 4.3.7, 4.5.2, Table 4.11}

C.3.4 Most current and potential CDR measures could have significant impacts on land, energy, water or nutrients if deployed at large scale (*high confidence*). Afforestation and bioenergy may compete with other land uses and may have significant impacts on agricultural and food systems, biodiversity, and other ecosystem functions and services (*high confidence*). Effective governance is needed to limit such trade-offs and ensure permanence of carbon removal in terrestrial, geological and ocean reservoirs (*high confidence*). Feasibility and sustainability of CDR use could be enhanced by a portfolio of options deployed at substantial, but lesser scales, rather than a single option at very large scale (*high confidence*). (Figure SPM.3b) {2.3.4, 2.4.4, 2.5.3, 2.6, 3.6.2, 4.3.2, 4.3.7, 4.5.2, 5.4.1, 5.4.2; Cross-Chapter Boxes 7 and 8 in Chapter 3, Table 4.11, Table 5.3, Figure 5.3}

C.3.5 Some AFOLU-related CDR measures such as restoration of natural ecosystems and soil carbon sequestration could provide co-benefits such as improved biodiversity, soil quality, and local food security. If deployed at large scale, they would require governance systems enabling sustainable land management to conserve and protect land carbon stocks and other ecosystem functions and services (*medium confidence*). (Figure SPM.4) {2.3.3, 2.3.4, 2.4.2, 2.4.4, 3.6.2, 5.4.1, Cross-Chapter Boxes 3 in Chapter 1 and 7 in Chapter 3, 4.3.2, 4.3.7, 4.4.1, 4.5.2, Table 2.4}

D. Strengthening the Global Response in the Context of Sustainable Development and Efforts to Eradicate Poverty

D.1 Estimates of the global emissions outcome of current nationally stated mitigation ambitions as submitted under the Paris Agreement would lead to global greenhouse gas emissions[18] in 2030 of 52–58 $GtCO_2eq\ yr^{-1}$ (*medium confidence*). Pathways reflecting these ambitions would not limit global warming to 1.5°C, even if supplemented by very challenging increases in the scale and ambition of emissions reductions after 2030 (*high confidence*). Avoiding overshoot and reliance on future large-scale deployment of carbon dioxide removal (CDR) can only be achieved if global CO_2 emissions start to decline well before 2030 (*high confidence*). {1.2, 2.3, 3.3, 3.4, 4.2, 4.4, Cross-Chapter Box 11 in Chapter 4}

D.1.1 Pathways that limit global warming to 1.5°C with no or limited overshoot show clear emission reductions by 2030 (*high confidence*). All but one show a decline in global greenhouse gas emissions to below 35 $GtCO_2eq\ yr^{-1}$ in 2030, and half of available pathways fall within the 25–30 $GtCO_2eq\ yr^{-1}$ range (interquartile range), a 40–50% reduction from 2010 levels (*high confidence*). Pathways reflecting current nationally stated mitigation ambition until 2030 are broadly consistent with cost-effective pathways that result in a global warming of about 3°C by 2100, with warming continuing afterwards (*medium confidence*). {2.3.3, 2.3.5, Cross-Chapter Box 11 in Chapter 4, 5.5.3.2}

D.1.2 Overshoot trajectories result in higher impacts and associated challenges compared to pathways that limit global warming to 1.5°C with no or limited overshoot (*high confidence*). Reversing warming after an overshoot of 0.2°C or larger during this century would require upscaling and deployment of CDR at rates and volumes that might not be achievable given considerable implementation challenges (*medium confidence*). {1.3.3, 2.3.4, 2.3.5, 2.5.1, 3.3, 4.3.7, Cross-Chapter Box 8 in Chapter 3, Cross-Chapter Box 11 in Chapter 4}

D.1.3 The lower the emissions in 2030, the lower the challenge in limiting global warming to 1.5°C after 2030 with no or limited overshoot (*high confidence*). The challenges from delayed actions to reduce greenhouse gas emissions include the risk of cost escalation, lock-in in carbon-emitting infrastructure, stranded assets, and reduced flexibility in future response options in the medium to long term (*high confidence*). These may increase uneven distributional impacts between countries at different stages of development (*medium confidence*). {2.3.5, 4.4.5, 5.4.2}

D.2 The avoided climate change impacts on sustainable development, eradication of poverty and reducing inequalities would be greater if global warming were limited to 1.5°C rather than 2°C, if mitigation and adaptation synergies are maximized while trade-offs are minimized (*high confidence*). {1.1, 1.4, 2.5, 3.3, 3.4, 5.2, Table 5.1}

D.2.1 Climate change impacts and responses are closely linked to sustainable development which balances social well-being, economic prosperity and environmental protection. The United Nations Sustainable Development Goals (SDGs), adopted in 2015, provide an established framework for assessing the links between global warming of 1.5°C or 2°C and development goals that include poverty eradication, reducing inequalities, and climate action. (*high confidence*) {Cross-Chapter Box 4 in Chapter 1, 1.4, 5.1}

D.2.2 The consideration of ethics and equity can help address the uneven distribution of adverse impacts associated with 1.5°C and higher levels of global warming, as well as those from mitigation and adaptation, particularly for poor and disadvantaged populations, in all societies (*high confidence*). {1.1.1, 1.1.2, 1.4.3, 2.5.3, 3.4.10, 5.1, 5.2, 5.3. 5.4, Cross-Chapter Box 4 in Chapter 1, Cross-Chapter Boxes 6 and 8 in Chapter 3, and Cross-Chapter Box 12 in Chapter 5}

D.2.3 Mitigation and adaptation consistent with limiting global warming to 1.5°C are underpinned by enabling conditions, assessed in this Report across the geophysical, environmental-ecological, technological, economic, socio-cultural and institutional

18 GHG emissions have been aggregated with 100-year GWP values as introduced in the IPCC Second Assessment Report.

dimensions of feasibility. Strengthened multilevel governance, institutional capacity, policy instruments, technological innovation and transfer and mobilization of finance, and changes in human behaviour and lifestyles are enabling conditions that enhance the feasibility of mitigation and adaptation options for 1.5°C-consistent systems transitions. (*high confidence*) {1.4, Cross-Chapter Box 3 in Chapter 1, 2.5.1, 4.4, 4.5, 5.6}

D.3 Adaptation options specific to national contexts, if carefully selected together with enabling conditions, will have benefits for sustainable development and poverty reduction with global warming of 1.5°C, although trade-offs are possible (*high confidence*). {1.4, 4.3, 4.5}

D.3.1 Adaptation options that reduce the vulnerability of human and natural systems have many synergies with sustainable development, if well managed, such as ensuring food and water security, reducing disaster risks, improving health conditions, maintaining ecosystem services and reducing poverty and inequality (*high confidence*). Increasing investment in physical and social infrastructure is a key enabling condition to enhance the resilience and the adaptive capacities of societies. These benefits can occur in most regions with adaptation to 1.5°C of global warming (*high confidence*). {1.4.3, 4.2.2, 4.3.1, 4.3.2, 4.3.3, 4.3.5, 4.4.1, 4.4.3, 4.5.3, 5.3.1, 5.3.2}

D.3.2 Adaptation to 1.5°C global warming can also result in trade-offs or maladaptations with adverse impacts for sustainable development. For example, if poorly designed or implemented, adaptation projects in a range of sectors can increase greenhouse gas emissions and water use, increase gender and social inequality, undermine health conditions, and encroach on natural ecosystems (*high confidence*). These trade-offs can be reduced by adaptations that include attention to poverty and sustainable development (*high confidence*). {4.3.2, 4.3.3, 4.5.4, 5.3.2; Cross-Chapter Boxes 6 and 7 in Chapter 3}

D.3.3 A mix of adaptation and mitigation options to limit global warming to 1.5°C, implemented in a participatory and integrated manner, can enable rapid, systemic transitions in urban and rural areas (*high confidence*). These are most effective when aligned with economic and sustainable development, and when local and regional governments and decision makers are supported by national governments (*medium confidence*). {4.3.2, 4.3.3, 4.4.1, 4.4.2}

D.3.4 Adaptation options that also mitigate emissions can provide synergies and cost savings in most sectors and system transitions, such as when land management reduces emissions and disaster risk, or when low-carbon buildings are also designed for efficient cooling. Trade-offs between mitigation and adaptation, when limiting global warming to 1.5°C, such as when bioenergy crops, reforestation or afforestation encroach on land needed for agricultural adaptation, can undermine food security, livelihoods, ecosystem functions and services and other aspects of sustainable development. (*high confidence*) {3.4.3, 4.3.2, 4.3.4, 4.4.1, 4.5.2, 4.5.3, 4.5.4}

D.4 Mitigation options consistent with 1.5°C pathways are associated with multiple synergies and trade-offs across the Sustainable Development Goals (SDGs). While the total number of possible synergies exceeds the number of trade-offs, their net effect will depend on the pace and magnitude of changes, the composition of the mitigation portfolio and the management of the transition. (*high confidence*) (Figure SPM.4) {2.5, 4.5, 5.4}

D.4.1 1.5°C pathways have robust synergies particularly for the SDGs 3 (health), 7 (clean energy), 11 (cities and communities), 12 (responsible consumption and production) and 14 (oceans) (*very high confidence*). Some 1.5°C pathways show potential trade-offs with mitigation for SDGs 1 (poverty), 2 (hunger), 6 (water) and 7 (energy access), if not managed carefully (*high confidence*). (Figure SPM.4) {5.4.2; Figure 5.4, Cross-Chapter Boxes 7 and 8 in Chapter 3}

D.4.2 1.5°C pathways that include low energy demand (e.g., see P1 in Figure SPM.3a and SPM.3b), low material consumption, and low GHG-intensive food consumption have the most pronounced synergies and the lowest number of trade-offs with respect to sustainable development and the SDGs (*high confidence*). Such pathways would reduce dependence on CDR. In modelled pathways, sustainable development, eradicating poverty and reducing inequality can support limiting warming to 1.5°C (*high confidence*). (Figure SPM.3b, Figure SPM.4) {2.4.3, 2.5.1, 2.5.3, Figure 2.4, Figure 2.28, 5.4.1, 5.4.2, Figure 5.4}

SPM

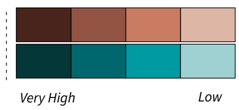
Indicative linkages between mitigation options and sustainable development using SDGs (The linkages do not show costs and benefits)

Mitigation options deployed in each sector can be associated with potential positive effects (synergies) or negative effects (trade-offs) with the Sustainable Development Goals (SDGs). The degree to which this potential is realized will depend on the selected portfolio of mitigation options, mitigation policy design, and local circumstances and context. Particularly in the energy-demand sector, the potential for synergies is larger than for trade-offs. The bars group individually assessed options by level of confidence and take into account the relative strength of the assessed mitigation-SDG connections.

Length shows strength of connection

The overall **size of the coloured bars** depict **the relative potential** for synergies and trade-offs between the sectoral mitigation options and the SDGs.

Shades show level of confidence



The shades depict **the level of confidence** of the assessed potential for **Trade-offs**/**Synergies**.

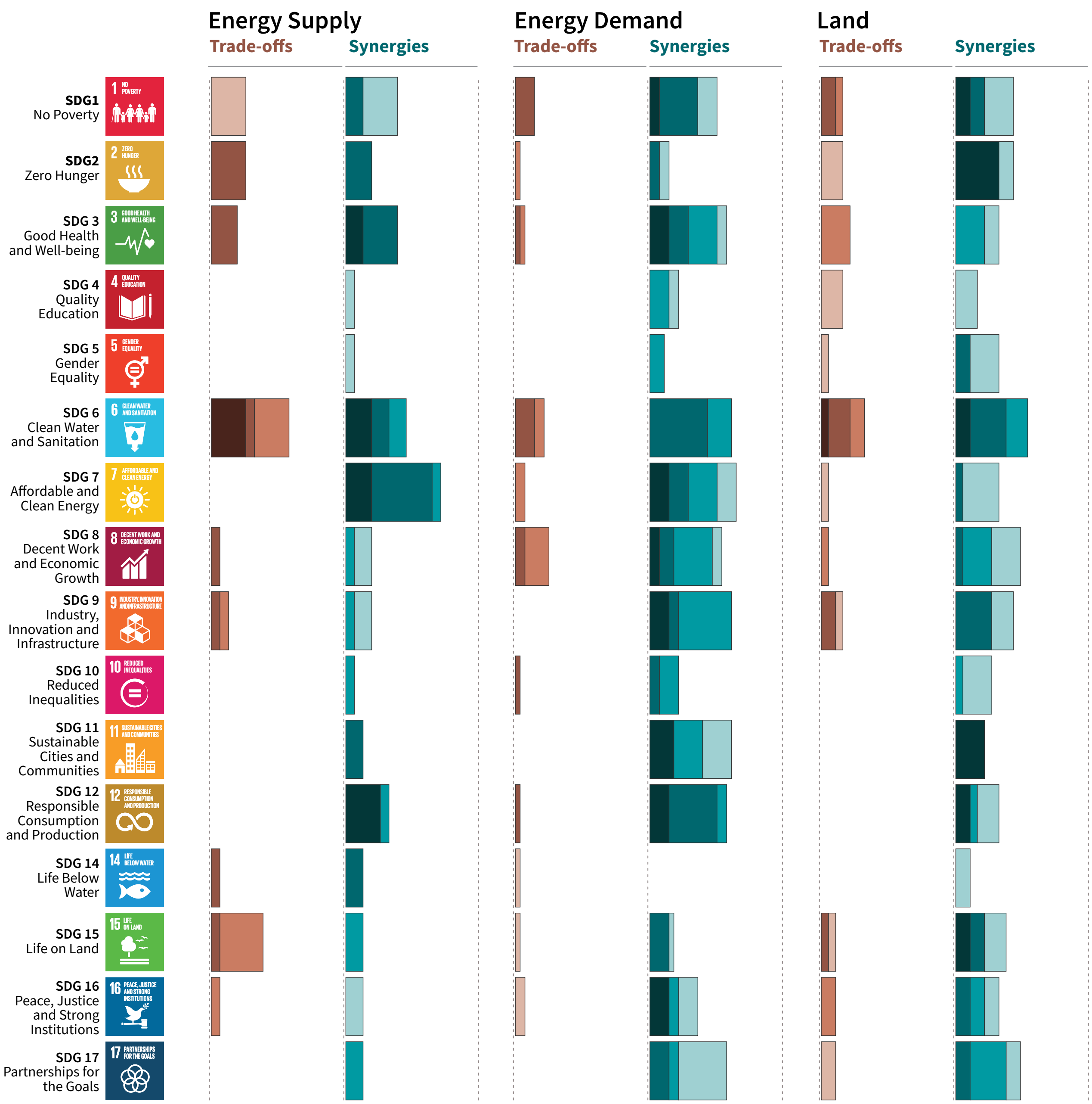


Figure SPM.4 | Potential synergies and trade-offs between the sectoral portfolio of climate change mitigation options and the Sustainable Development Goals (SDGs). The SDGs serve as an analytical framework for the assessment of the different sustainable development dimensions, which extend beyond the time frame of the 2030 SDG targets. The assessment is based on literature on mitigation options that are considered relevant for 1.5°C. The assessed strength of the SDG interactions is based on the qualitative and quantitative assessment of individual mitigation options listed in Table 5.2. For each mitigation option, the strength of the SDG-connection as well as the associated confidence of the underlying literature (shades of green and red) was assessed. The strength of positive connections (synergies) and negative connections (trade-offs) across all individual options within a sector (see Table 5.2) are aggregated into sectoral potentials for the whole mitigation portfolio. The (white) areas outside the bars, which indicate no interactions, have *low confidence* due to the uncertainty and limited number of studies exploring indirect effects. The strength of the connection considers only the effect of mitigation and does not include benefits of avoided impacts. SDG 13 (climate action) is not listed because mitigation is being considered in terms of interactions with SDGs and not vice versa. The bars denote the strength of the connection, and do not consider the strength of the impact on the SDGs. The energy demand sector comprises behavioural responses, fuel switching and efficiency options in the transport, industry and building sector as well as carbon capture options in the industry sector. Options assessed in the energy supply sector comprise biomass and non-biomass renewables, nuclear, carbon capture and storage (CCS) with bioenergy, and CCS with fossil fuels. Options in the land sector comprise agricultural and forest options, sustainable diets and reduced food waste, soil sequestration, livestock and manure management, reduced deforestation, afforestation and reforestation, and responsible sourcing. In addition to this figure, options in the ocean sector are discussed in the underlying report. {5.4, Table 5.2, Figure 5.2}

Information about the net impacts of mitigation on sustainable development in 1.5°C pathways is available only for a limited number of SDGs and mitigation options. Only a limited number of studies have assessed the benefits of avoided climate change impacts of 1.5°C pathways for the SDGs, and the co-effects of adaptation for mitigation and the SDGs. The assessment of the indicative mitigation potentials in Figure SPM.4 is a step further from AR5 towards a more comprehensive and integrated assessment in the future.

D.4.3 1.5°C and 2°C modelled pathways often rely on the deployment of large-scale land-related measures like afforestation and bioenergy supply, which, if poorly managed, can compete with food production and hence raise food security concerns (*high confidence*). The impacts of carbon dioxide removal (CDR) options on SDGs depend on the type of options and the scale of deployment (*high confidence*). If poorly implemented, CDR options such as BECCS and AFOLU options would lead to trade-offs. Context-relevant design and implementation requires considering people's needs, biodiversity, and other sustainable development dimensions (*very high confidence*). (Figure SPM.4) {5.4.1.3, Cross-Chapter Box 7 in Chapter 3}

D.4.4 Mitigation consistent with 1.5°C pathways creates risks for sustainable development in regions with high dependency on fossil fuels for revenue and employment generation (*high confidence*). Policies that promote diversification of the economy and the energy sector can address the associated challenges (*high confidence*). {5.4.1.2, Box 5.2}

D.4.5 Redistributive policies across sectors and populations that shield the poor and vulnerable can resolve trade-offs for a range of SDGs, particularly hunger, poverty and energy access. Investment needs for such complementary policies are only a small fraction of the overall mitigation investments in 1.5°C pathways. (*high confidence*) {2.4.3, 5.4.2, Figure 5.5}

D.5 Limiting the risks from global warming of 1.5°C in the context of sustainable development and poverty eradication implies system transitions that can be enabled by an increase of adaptation and mitigation investments, policy instruments, the acceleration of technological innovation and behaviour changes (*high confidence*). {2.3, 2.4, 2.5, 3.2, 4.2, 4.4, 4.5, 5.2, 5.5, 5.6}

D.5.1 Directing finance towards investment in infrastructure for mitigation and adaptation could provide additional resources. This could involve the mobilization of private funds by institutional investors, asset managers and development or investment banks, as well as the provision of public funds. Government policies that lower the risk of low-emission and adaptation investments can facilitate the mobilization of private funds and enhance the effectiveness of other public policies. Studies indicate a number of challenges, including access to finance and mobilization of funds. (*high confidence*) {2.5.1, 2.5.2, 4.4.5}

D.5.2 Adaptation finance consistent with global warming of 1.5°C is difficult to quantify and compare with 2°C. Knowledge gaps include insufficient data to calculate specific climate resilience-enhancing investments from the provision of currently underinvested basic infrastructure. Estimates of the costs of adaptation might be lower at global warming of 1.5°C than for 2°C. Adaptation needs have typically been supported by public sector sources such as national and subnational government budgets, and in developing countries together with support from development assistance, multilateral development banks, and United Nations Framework Convention on Climate Change channels (*medium confidence*). More recently there is a growing understanding of the scale and increase in non-governmental organizations and private funding in some regions (*medium confidence*). Barriers include the scale of adaptation financing, limited capacity and access to adaptation finance (*medium confidence*). {4.4.5, 4.6}

D.5.3 Global model pathways limiting global warming to 1.5°C are projected to involve the annual average investment needs in the energy system of around 2.4 trillion USD2010 between 2016 and 2035, representing about 2.5% of the world GDP (*medium confidence*). {4.4.5, Box 4.8}

D.5.4 Policy tools can help mobilize incremental resources, including through shifting global investments and savings and through market and non-market based instruments as well as accompanying measures to secure the equity of the transition, acknowledging the challenges related with implementation, including those of energy costs, depreciation of assets and impacts on international competition, and utilizing the opportunities to maximize co-benefits (*high confidence*). {1.3.3, 2.3.4, 2.3.5, 2.5.1, 2.5.2, Cross-Chapter Box 8 in Chapter 3, Cross-Chapter Box 11 in Chapter 4, 4.4.5, 5.5.2}

D.5.5 The systems transitions consistent with adapting to and limiting global warming to 1.5°C include the widespread adoption of new and possibly disruptive technologies and practices and enhanced climate-driven innovation. These imply enhanced technological innovation capabilities, including in industry and finance. Both national innovation policies and international cooperation can contribute to the development, commercialization and widespread adoption of mitigation and adaptation technologies. Innovation policies may be more effective when they combine public support for research and development with policy mixes that provide incentives for technology diffusion. (*high confidence*) {4.4.4, 4.4.5}.

D.5.6 Education, information, and community approaches, including those that are informed by indigenous knowledge and local knowledge, can accelerate the wide-scale behaviour changes consistent with adapting to and limiting global warming to 1.5°C. These approaches are more effective when combined with other policies and tailored to the motivations, capabilities and resources of specific actors and contexts (*high confidence*). Public acceptability can enable or inhibit the implementation of policies and measures to limit global warming to 1.5°C and to adapt to the consequences. Public acceptability depends on the individual's evaluation of expected policy consequences, the perceived fairness of the distribution of these consequences, and perceived fairness of decision procedures (*high confidence*). {1.1, 1.5, 4.3.5, 4.4.1, 4.4.3, Box 4.3, 5.5.3, 5.6.5}

D.6 Sustainable development supports, and often enables, the fundamental societal and systems transitions and transformations that help limit global warming to 1.5°C. Such changes facilitate the pursuit of climate-resilient development pathways that achieve ambitious mitigation and adaptation in conjunction with poverty eradication and efforts to reduce inequalities (*high confidence*). {Box 1.1, 1.4.3, Figure 5.1, 5.5.3, Box 5.3}

D.6.1 Social justice and equity are core aspects of climate-resilient development pathways that aim to limit global warming to 1.5°C as they address challenges and inevitable trade-offs, widen opportunities, and ensure that options, visions, and values are deliberated, between and within countries and communities, without making the poor and disadvantaged worse off (*high confidence*). {5.5.2, 5.5.3, Box 5.3, Figure 5.1, Figure 5.6, Cross-Chapter Boxes 12 and 13 in Chapter 5}

D.6.2 The potential for climate-resilient development pathways differs between and within regions and nations, due to different development contexts and systemic vulnerabilities (*very high confidence*). Efforts along such pathways to date have been limited (*medium confidence*) and enhanced efforts would involve strengthened and timely action from all countries and non-state actors (*high confidence*). {5.5.1, 5.5.3, Figure 5.1}

D.6.3 Pathways that are consistent with sustainable development show fewer mitigation and adaptation challenges and are associated with lower mitigation costs. The large majority of modelling studies could not construct pathways characterized by lack of international cooperation, inequality and poverty that were able to limit global warming to 1.5°C. (*high confidence*) {2.3.1, 2.5.1, 2.5.3, 5.5.2}

D.7 Strengthening the capacities for climate action of national and sub-national authorities, civil society, the private sector, indigenous peoples and local communities can support the implementation of ambitious actions implied by limiting global warming to 1.5°C (*high confidence*). International cooperation can provide an enabling environment for this to be achieved in all countries and for all people, in the context of sustainable development. International cooperation is a critical enabler for developing countries and vulnerable regions (*high confidence*). {1.4, 2.3, 2.5, 4.2, 4.4, 4.5, 5.3, 5.4, 5.5, 5.6, 5, Box 4.1, Box 4.2, Box 4.7, Box 5.3, Cross-Chapter Box 9 in Chapter 4, Cross-Chapter Box 13 in Chapter 5}

D.7.1 Partnerships involving non-state public and private actors, institutional investors, the banking system, civil society and scientific institutions would facilitate actions and responses consistent with limiting global warming to 1.5°C (*very high confidence*). {1.4, 4.4.1, 4.2.2, 4.4.3, 4.4.5, 4.5.3, 5.4.1, 5.6.2, Box 5.3}.

D.7.2 Cooperation on strengthened accountable multilevel governance that includes non-state actors such as industry, civil society and scientific institutions, coordinated sectoral and cross-sectoral policies at various governance levels, gender-sensitive policies, finance including innovative financing, and cooperation on technology development and transfer can ensure participation, transparency, capacity building and learning among different players (*high confidence*). {2.5.1, 2.5.2, 4.2.2, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.5.3, Cross-Chapter Box 9 in Chapter 4, 5.3.1, 5.5.3, Cross-Chapter Box 13 in Chapter 5, 5.6.1, 5.6.3}

D.7.3 International cooperation is a critical enabler for developing countries and vulnerable regions to strengthen their action for the implementation of 1.5°C-consistent climate responses, including through enhancing access to finance and technology and enhancing domestic capacities, taking into account national and local circumstances and needs (*high confidence*). {2.3.1, 2.5.1, 4.4.1, 4.4.2, 4.4.4, 4.4.5, 5.4.1 5.5.3, 5.6.1, Box 4.1, Box 4.2, Box 4.7}.

D.7.4 Collective efforts at all levels, in ways that reflect different circumstances and capabilities, in the pursuit of limiting global warming to 1.5°C, taking into account equity as well as effectiveness, can facilitate strengthening the global response to climate change, achieving sustainable development and eradicating poverty (*high confidence*). {1.4.2, 2.3.1, 2.5.1, 2.5.2, 2.5.3, 4.2.2, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.5.3, 5.3.1, 5.4.1, 5.5.3, 5.6.1, 5.6.2, 5.6.3}

Box SPM.1: Core Concepts Central to this Special Report

Global mean surface temperature (GMST): Estimated global average of near-surface air temperatures over land and sea ice, and sea surface temperatures over ice-free ocean regions, with changes normally expressed as departures from a value over a specified reference period. When estimating changes in GMST, near-surface air temperature over both land and oceans are also used.[19] {1.2.1.1}

Pre-industrial: The multi-century period prior to the onset of large-scale industrial activity around 1750. The reference period 1850–1900 is used to approximate pre-industrial GMST. {1.2.1.2}

Global warming: The estimated increase in GMST averaged over a 30-year period, or the 30-year period centred on a particular year or decade, expressed relative to pre-industrial levels unless otherwise specified. For 30-year periods that span past and future years, the current multi-decadal warming trend is assumed to continue. {1.2.1}

Net zero CO_2 emissions: Net zero carbon dioxide (CO_2) emissions are achieved when anthropogenic CO_2 emissions are balanced globally by anthropogenic CO_2 removals over a specified period.

Carbon dioxide removal (CDR): Anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage, but excludes natural CO_2 uptake not directly caused by human activities.

Total carbon budget: Estimated cumulative net global anthropogenic CO_2 emissions from the pre-industrial period to the time that anthropogenic CO_2 emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions. {2.2.2}

Remaining carbon budget: Estimated cumulative net global anthropogenic CO_2 emissions from a given start date to the time that anthropogenic CO_2 emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions. {2.2.2}

Temperature overshoot: The temporary exceedance of a specified level of global warming.

Emission pathways: In this Summary for Policymakers, the modelled trajectories of global anthropogenic emissions over the 21st century are termed emission pathways. Emission pathways are classified by their temperature trajectory over the 21st century: pathways giving at least 50% probability based on current knowledge of limiting global warming to below 1.5°C are classified as 'no overshoot'; those limiting warming to below 1.6°C and returning to 1.5°C by 2100 are classified as '1.5°C limited-overshoot'; while those exceeding 1.6°C but still returning to 1.5°C by 2100 are classified as 'higher-overshoot'.

Impacts: Effects of climate change on human and natural systems. Impacts can have beneficial or adverse outcomes for livelihoods, health and well-being, ecosystems and species, services, infrastructure, and economic, social and cultural assets.

Risk: The potential for adverse consequences from a climate-related hazard for human and natural systems, resulting from the interactions between the hazard and the vulnerability and exposure of the affected system. Risk integrates the likelihood of exposure to a hazard and the magnitude of its impact. Risk also can describe the potential for adverse consequences of adaptation or mitigation responses to climate change.

Climate-resilient development pathways (CRDPs): Trajectories that strengthen sustainable development at multiple scales and efforts to eradicate poverty through equitable societal and systems transitions and transformations while reducing the threat of climate change through ambitious mitigation, adaptation and climate resilience.

19 Past IPCC reports, reflecting the literature, have used a variety of approximately equivalent metrics of GMST change.

From:	EnergyPlan2019@RedwoodEnergy.org
To:	Kate McClain; EnergyPlan2019@RedwoodEnergy.org
Subject:	RE: Please consider widespread use of solar instead of wind and biomass for Humboldt County
Date:	Friday, September 20, 2019 3:28:29 PM

Thank you for your comment, Kate. We'll add it to our public comments which are available on our website.
https://redwoodenergy.org/services/planning/

Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Kate McClain [redacted]
Sent: Friday, September 20, 2019 2:46 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: Please consider widespread use of solar instead of wind and biomass for Humboldt County

To RCEA:
Please slow down. Please stop and consider all aspects of new and positive energy generation possibilities for Humboldt County. Please don't rely on a quick fix from outside investors who do not live here and will not be concerned about the consequences of their actions years later when they've made their money and have vanished. We need to think locally. Decolonize our economics. Operate from community grassroots. We need to decentralize our energy production and take the responsibility for the waste produced for all alternative systems.

Wind: I agree with Ken Miller's paper on the benefits of local microgrids. We need to focus on widespread use of solar for Humboldt County and abandon you consideration of onshore wind power. All the negative environmental impacts addressed by our local environmental groups and objection from the Wyiott tribe as their sacred lands should be enough for RCEA to stop rushing into the Wind power project. There are probably many more specifics. I understand that there are terrible chemicals needed for wind power as well as questions about what to do with "spent" blades. Huge poly/resin fiberglass blades will go to whose landfill? And at whose expense?

Biomass: Burning biomass is a short sighted solution also. It is dirty and will not get us to clean air, less carbon in the atmosphere. Please consider the potential economic benefits of returning mill waste back to the soil and the potential jobs that can be created with a commitment to recycling wood products.

Think like Mother Earth. You are Her - water, fire, earth and air. Start thinking and acting for rejuvenating systems.

Thank you very much for considering my letter.

Kate McClain
[redacted] McKinleyville, CA [redacted]
[redacted]

"Renewable energy microgrids pair onsite resilience with global sustainability. Microgrid storage can help smooth the effects of intermittent power generation (e.g. from solar and wind) and increase overall grid stability."
(http://schatzcenter.org/microgrids/)

These microgrids must be powered by onsite generation.

RCEA needs to focus on and dramatically expand distributed solar, and abandon onshore wind power; and to stop minimizing the impacts from onshore wind and dismissing the feasibility of widespread solar.

•Fiduciary responsibility to explore, offer, and focus on the best, least impactful & least expensive energy option over time for Humboldt=Solar, it's really that simple.
•Hire a specialist to recruit the entire gamut of the solar and storage industries into our County
•Form a solar advisory committee representing all aspects instead of a poor stepchild to utility scale wind. Done right, solar can also feed the grid.
•Mobilize all resources to implement widespread solar, including door-to door outreach and

accelerated solar mapping
•Focus on financing options that make solar electricity available to as many as possible, especially low income people
•Convert public offices and vehicles
•A massive active effort, as if this were an emergency

•Secure, resilient energy available during grid shutdowns and emergencies
•Reduce carbon footprint, increase energy awareness
•Electrify transportation and heating
•Share our energy wealth affordable for all, rather than concentrate it
•Reduce natural gas use

4 Components

Coordination

•Ensure building codes, maximize passive solar;
•Advise and promote solar training programs and education;
•Hospitals, shelters, Critical entities, HCAOG & Coalition for Responsible Transportation Priorities (CRTP), HSU;
•Entrepreneurs in EVs, charging, and EV2Grid, and micro-grids;
•The many companies and entrepreneurs

specializing in solar financing,

Demand

•Efficiency
•Widespread distributed public and private rooftop and open space solar PV
•Solar electricity production fosters energy IQ

Transportation

•Electrify public and private transportation

•Best incentive for EVs is local solar production. It's the economics, with rapid payback, and low cost fuel, forever. EVs require little maintenance, no petroleum, and last a very long time, but their maximal benefit is when charged with locally produced solar. Many choices, ranges, prices for new and used EVs on the horizon.

Energy Generation and Environment

•We have arrived at both global heating and global extinction because we have ignored the impacts of our industrial development on biodiversity. We should not succumb to the argument that climate change will kill all anyway, instead we should always choose energy options that protect biodiversity, for without biodiversity there can be no adaptation, so

we must preserve what is left if we can. We must nourish our soils, forests, watersheds and vegetation that sequester carbon.

•Onshore wind divides our communities and fragments and degrades biodiversity, especially in the windiest sites, which are sacred to the local Native Americans, so utility scale onshore wind power should be abandoned in favor of offshore. Solar brings us together. The enormous construction of onshore emits many 1000s of tons of GHGs into our 10-year emergency window, while removing carbon sequestering trees, vegetation, grasslands and soils that would have eliminated 1000s of tons of GHGs annually.

•Local solar has no competition, so far, for our ideal energy source. Like all products, they contain embedded energy, but the lifecycle is containable, the elements abundant and recyclable, and used or recycled unused panels are widely available for as little as $65 for 270 W, and many are free for the hauling.

•Having a grid that continues to supply electricity from increasingly networked local solar has none of the impacts of wind, hydro, nuclear, or “solar farms,” and combined with local solar should define the future.

•Solar is 21 century technology that generates electricity by ionic transfers, like we do, with essentially no wasted heat. Solar is cool.
Wind turbines are based on 19 century technology, require constant surveillance and frequent maintenance to avoid potentially catastrophic accidents, and have ongoing adverse hydro-meteorological, socio-economic, biological, and psychological impacts.

•Solar just keeps getting less expensive and more rewarding over time with minimal if any adverse impacts.

•Solar requires no maintenance and minimal new infrastructure, including wildfire prone transmission lines, which lose up to 30% of transmitted electricity.
•Networked grid-tied micro-grids with EV stations provide the ultimate in secure resilience, dynamic independence from the grid, intelligent supply-demand allocation, and mobile electricity storage and supply vehicles that can travel to shelters, hospitals, and other critical facilities.
•Solar creates jobs throughout the County, whereas utility scale generation yields very few.
•Solar engenders energy awareness and reduces reliance on the grid, PGE, and ever-increasing utility bills.
•Solar electricity plus EV and battery storage can be

sold to the grid, earning public and private revenues while contributing to balanced grid loads.

•Solar is exciting because we own it, it supplies our homes, our neighborhoods, our public offices, our transportation, our bank accounts, our security, our resilience: that's what sharing our energy wealth looks and feels like.

•Solar can be installed in many very inexpensive ways by individuals, and systems can be portable. Solar electricity and radiant energy can heat buildings. The grid can power induction electric cooking. That's having "both."

From:	EnergyPlan2019@RedwoodEnergy.org
To:	Harriet Hill; EnergyPlan2019@RedwoodEnergy.org
Subject:	RE: CAPE comments
Date:	Friday, September 20, 2019 2:36:29 PM

Thank you for your comment, Harriet. We will add it to our public comments that will appear on our website.
https://redwoodenergy.org/services/planning/

Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Harriet Hill [redacted]
Sent: Friday, September 20, 2019 2:34 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: CAPE comments

Dear RCEA staff:

My comments pertain to the plan component of "Energy generation – what local energy resources should be developed? How should we balance energy cost with environmental quality?"

I recommend that every effort be made to develop local solar resources and promote electric vehicles, etc., rather than focusing on new wind farm construction in Humboldt County. I believe that such a strategy will better protect our natural resources and also perhaps address the Wiyot Tribe's concerns.

The wind farm project proposed by Terra-Gen in the Draft Environmental Impact Report (DEIR) would have 900 acres of permanent or temporary impacts as per the California Department of Fish and Wildlife (CDFW) letter of June 14, 2019 to the Humboldt County Planning and Building Department. The project was found to "likely to result in considerable take over the 30 year Project period via collision with turbines for numerous special status species that are State and Federally listed, Fully Protected, locally rare and State Species of Special Concern."

The gold standard for wind farm development is correct siting and design (Audubon Society Magazine, *How New Technology Is Making Wind Farms Safer for Birds,* Spring 2018). I don't believe that placing a wind farm in the midst of the concentrations of bats, raptors, endangered Marbled Murrelets, a unique Horned

Lark population, and rare plants found in the Monument and Bear Ridge areas could be considered appropriate and careful siting. Indeed, the CDFW letter concluded that "all or or portions of the Project site fall into Category 4, Project Sites Inappropriate for Wind Development." Category 4 is contained in the "Guidelines for Reducing Impacts to Birds and Bats from Wind Energy Development" created by CDFW and the California Energy Commission and indicates an unacceptable risk of bird or bat fatalities.

Terra-Gen submitted such a flawed and incomplete DEIR that CDFW determined that most of their chosen site is inappropriate for wind development based on state guidelines. Many other environmental agencies and non-profit environmental groups had major problems with the document. The DEIR was so hastily prepared (so that Terra-Gen could meet a tax break deadline) that it did not even rely on the industry standard for two year wildlife surveys to assess potential impacts. Even if the turbines were to be relocated or eliminated such that there is less damage, I fear that this company would not properly carry out promised mitigation measures (for the turbines these would be completely or relatively untested high tech operational measures and thus require constant vigilance and maintenance), mortality surveys, make needed changes to the operation as requested by the agencies, etc.

Bird losses in North America are already catastrophic as indicated in a study that was just released. A news story reported by National Public Radio yesterday states: *"We saw this tremendous net loss across the entire bird community," says Ken Rosenberg, an applied conservation scientist at the Cornell Lab of Ornithology in Ithaca, N.Y. "By our estimates, it's a 30% loss in the total number of breeding birds." That's according to a new estimate published in the journal* Science *by researchers who brought together a variety of information that has been collected on 529 bird species since 1970.* The study found the main culprit to be habitat loss from urbanization and agriculture, and determined that grassland birds (including Horned Larks) have suffered a 53% decrease in their numbers.

Climate change is expected to cause massive loss of habitat. But does that mean we should tacitly accept the major impacts of this 'green' project on our local flora and fauna, which includes a quantity of endangered, rare and unique species?

Wind farms are fully appropriate for some areas with relatively few natural resources. But it seems like instead of taking the time to consider the issues in a planned, cautious, scientific way, we are rushing full speed ahead to site this wind farm here to ameliorate our concerns about impending climate change. Yes, climate change is an emergency that cannot be ignored. But so would be the large scale destruction of many unique natural resources residing in our very midst.

I recommend that the RCEA not only look more carefully at solar and other alternatives to meet the goal of maximizing local energy production, but also consider not restricting the solution to include only locally produced power. We presently import 1/3 of our power from established wind farms. I think this should be allowed to continue if it would save Bear and Monument Ridges from such development.

"…nothing will do more to harm to the [wind] industry than excusing or tolerating wildlife-stupid projects that give it a bad name." - Ted Williams, *Green Energy: Can We Save the Planet and Save Birds?* Audubon Magazine, March 8, 2014

Thanks very much for the opportunity to comment on this document. I greatly appreciate your prodigious efforts to obtain public feedback.

Harriet Hill, [redacted] Eureka, CA [redacted]

DEPARTMENT OF FORESTRY AND FIRE PROTECTION
118 S. Fortuna Blvd.
Fortuna, CA 95540
(707) 725-4413
Website: www.fire.ca.gov

September 20, 2019

Redwood Coast Energy Authority
633 3rd Street
Eureka, CA 95501

Dear Board of Directors,

This letter is submitted to you to provide comment regarding your agency's 2019 Comprehensive Action Plan for Energy. The Humboldt-Del Norte Unit of the California Department of Forestry and Fire Protection (CAL FIRE) is the administrative unit that is responsible for all local CAL FIRE programs and operations in Humboldt, Del Norte, and western Trinity Counties. It is the Unit's responsibility to locally fulfill the CAL FIRE Mission that states, "The Department of Forestry and Fire Protection serves and safeguards the people and protects the property and resources of California." Often under our Mission, the tasks associated with protecting people, property, and resources overlap. The increased duration of fire seasons in recent history coupled with more frequent large and destructive wildfires has increased the need to manage forest health and fuel loading to minimize adverse effects of wildfires as well as enhance the benefits forest provide to public. As a result, it is the expectation from our State Government and the citizens of California to further engage forest health and forest fuel reduction projects. Most often, the largest financial costs and logistical challenges associated with these types of projects is directly related to the treatment of forest fuels. While prescribed burning is the most cost effective and efficient forest management tool available, there are many geographical areas or site conditions that do not allow the use of prescribed fire. Biomass energy production facilities provide a feasible and often essential option to manage the by-product of forest fuels treatments where other fuel treatments are not feasible. Therefore, I would like to offer the following points for your consideration in maintaining or enhancing the utilization of local biomass energy in your Comprehensive Action Plan for Energy:

1) Biomass Energy Utilization – The California Forest Carbon Plan released in May of 2018 provides goals and actions to improve overall forest health, enhance carbon storage resilience, increase carbon sequestration, and reduce greenhouse gas (GHG) emissions. One of the stated goals of the Carbon Plan is to provide innovative solutions for wood products and biomass utilization to support ongoing forest management activities. This goal includes maintaining existing bioenergy capacity at a level necessary to utilize materials removed as part of forest restoration. ***Your agency has the ability and opportunity by helping California meet this goal by acquiring energy produced from existing local biomass facilities. Furthermore, the commitment to utilizing local biomass energy provides an incentive for those energy producers or potential large as well as***

small scale biomass energy producers to invest in local biomass energy production infrastructure.

2) Vegetative Carbon Stocks – With the aggressive suppression of wildfires in California during the past seven decades, there is now a higher level of carbon stored in forest fuels when compared to natural California fire regime conditions. Due this condition, there is now a large amount of carbon available for immediate release due to wildfires. This carbon is positioned in a relatively unstable manner as many of our forests and wildlands are overgrown with vegetation leading to large destructive fires emitting staggering amounts of carbon. Forest fuel treatments are a solution to stabilizing carbon in more fire resilient landscape and forest conditions. While some people may argue prescribed fires or other treatments of fuel such as biomass utilization release carbon, the amounts through such means is considerably less and allows remaining carbon across our landscapes to be positioned in a much more stable condition with resiliency to wildfire. ***The utilization of biomass energy by your agency will enhance the ability to remove local stocks of unstable carbon and create fire resilient forests that will increase stable carbon stocks.***

3) Human Health – The impacts from wildfire on air quality are very impactive and adverse toward human health. Adverse impacts on air quality in our local region as well as urban areas far away from wildfires have experienced increasing frequency and severity of poor air quality over the past twenty years. The resiliency of forests through fuels reduction and fire prevention projects will help minimize adverse impacts to air quality. For a portion of these projects, biomass energy provides a means of managing project by-product and although the by-product is burned in biomass facilities, the resulting air quality is much less impactive than emissions produced by wildfires. ***Your agency's utilization of biomass energy will provide improved air quality when compared with the air quality impacts resulting from the combustion of forest fuels during wildfires.***

It is my belief that the Department of Forestry and Fire Protection and the Redwood Coast Energy Authority share common goals related to the health of our natural resources; resiliency to wildfires; secure forest carbon storage; and quality of life for the public we serve. The continued inclusion and enhancement of biomass in your agency's renewable energy portfolio benefits goals of both of our agencies and the well-being of the public we serve.

Thank you for your consideration of the items in my letter.

Kurt McCray, Unit Chief
CAL FIRE
Humboldt-Del Norte Unit

From:	EnergyPlan2019@RedwoodEnergy.org
To:	Lori Taketa
Subject:	FW: 100% Carbon free
Date:	Friday, September 20, 2019 2:33:29 PM

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

-----Original Message-----
From: Brian Merrill [redacted]
Sent: Friday, September 20, 2019 2:17 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: 100% Carbon free

I was a customer for many years until I decided to seek out 100% carbon free energy for my home supply. Sadly, the RCEA did not have a carbon free package to choose from. In the future please add a 100% carbon free electric package to your menu of power supply sources.
Thank you,
Brian R. Merrill

From: Information
To: Isaac West; Information
Subject: RE: Concerns about Biomass as part of the power mix
Date: Friday, September 20, 2019 12:09:32 PM

Thank you for your comment, Isaac. We will add it to the public record which can be seen on our website. https://redwoodenergy.org/services/planning/

Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Isaac West [redacted]
Sent: Friday, September 20, 2019 11:29 AM
To: Information <info@redwoodenergy.org>
Subject: Concerns about Biomass as part of the power mix

Please consider removing biomass from the mix or modernize the biomass power plants to operate as air friendly as possible.

I am asking you all to be mindful of using biomass as part of the mix for a 100% renewable powered future. Biomass does make sense locally, as long as were only using waste, not cutting down trees to make power, that would be a huge step backwards.

Additionally, our facilities are very old and spew out lots of particles, not just co2. If were going to use biomass in the power mix, we need to modernize our biomass power plants, otherwise were just taking one step forward and five backwards. Whats the point of getting all these gas powered cars off the road and reducing emissions if the biomass plant is more polluting to the air than anything else around?

Don't ruin what could be a good thing.

Thanks for taking the time to read this, -Isaac West

From: EnergyPlan2019@RedwoodEnergy.org
To: [redacted] EnergyPlan2019@RedwoodEnergy.org
Subject: RE: Industrial wind
Date: Friday, September 20, 2019 12:08:13 PM

Thank you for your comment, Howard. We will add it to the public record which can be seen on our website. https://redwoodenergy.org/services/planning/

Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

-----Original Message-----
From: [redacted]
Sent: Friday, September 20, 2019 12:02 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: Industrial wind

Why allow another mega corporation to use more of Humboldt County's precious habitat when solar powered micro grids are more efficient, resilient, and dependable? We have a drastically changing environment. PG&E just told me to invest in a gas powered generator for when they cut power due to increased fire hazards. Terra Gen's planned addition of more power lines and destruction of more forests, pastures, and wildlife is not compensated by their plan to cash in and export electricity. Please think outside the box of increasingly vulnerable centralized power and encourage new technologies that provide safe, harmless utilities for our homes, businesses, transportation, and wildlife.
Thanks, Howard Russell
[redacted] Eureka.
Sent from my iPad

Sent from my iPad

From: EnergyPlan2019@RedwoodEnergy.org
To: Lynne Martinez; EnergyPlan2019@RedwoodEnergy.org
Subject: RE: Please get biomass out of our energy mix
Date: Friday, September 20, 2019 12:07:19 PM

Thank you for your comment, Lynne. We will add it to the public record which can be seen on our website.
https://redwoodenergy.org/services/planning/

Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

-----Original Message-----
From: Lynne Martinez [redacted]
Sent: Thursday, September 19, 2019 1:13 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: Please get biomass out of our energy mix

Thank you for taking my comment on RCEA's CAPE. I'm concerned about the biomass component of the plan because our biomass is not clean energy. The plants are over 30 years old and emit way too many emissions. I hope RCEA will update the plan to get the country off biomass by 2025. Thank you.

Lynne Martinez
[redacted]
Arcata, CA [redacted]

From: EnergyPlan2019@RedwoodEnergy.org
To: Carol Woods; EnergyPlan2019@RedwoodEnergy.org
Subject: RE: CAPE input on Biomass energy
Date: Friday, September 20, 2019 12:06:57 PM

Thank you for your comment, Carol. We will add it to the public record which can be seen on our website.
https://redwoodenergy.org/services/planning/

Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

-----Original Message-----
From: Carol Woods [redacted]
Sent: Friday, September 20, 2019 11:30 AM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: CAPE input on Biomass energy

My comment is that RCEA should place mitigating climate change as first priority in deciding where to buy electricity.?? Using biomass in the current local sources, where the plants have not worked to clean their emissions, is not acceptable.?? Please work with the local sources to encourage or demand that they upgrade the plants to reduce emissions, which are currently close to 400,000 tons of CO_2 per year.

Thank you, Carol Woods, [redacted] Arcata

September 19th, 2019

Dear North Coast Energy Authority,

Thank you for the opportunity to provide input on the future of biomass utilization in Humboldt County.

The Buckeye strives to promote sound resource management practices and policies that contribute to the ecological and economic health of our region's wildlands and open spaces. We work to maintain the economically viable working landscapes of rangelands and forestlands, most of which are owned by multigenerational families.

On any given family ranch ownership in Humboldt County you will find a somewhat varied mixture of agriculture production, but predominately our landowners graze cattle on rangelands and participate in some scale in forest management. The sustainable harvesting of wood products is a significant part of a landowners purpose for owning and managing land. It is also used as a method of meeting other land management goals, including the creation of wildlife habitats, maintenance of biodiversity, promotion of recreational opportunities, and protection of clean water.

Many of these ranches span multiple generations, so it's common to find grandparents working alongside their grandchildren. We tend the soil, forests and fields in hopes of supporting our families now and into the future. This is our lens when looking at the future of biomass utilization in Humboldt County, and here is a summary of our comments.

- **Biomass provides clean continuous energy:** The conservative use of biomass for both "clean energy" and a forest and range land management tool is practiced through-out the world. In Humboldt County biomass operations turn wood waste into electricity while maintain cultural and habitat values and providing jobs. It provides a source of "clean or carbon neutral". This county has an abundance of biomass. Unlike wind and solar it is available 24/7 "rain or shine".
- **Biomass can help reduce emissions from wildfires**: The forests and rangelands of Humboldt county have, through lack of management have been allowed to develop a landscape of dead, dying trees, as well as dense vegetation of "understory" trees and brush that is highly flammable. A prevailing philosophy has endured for the past 30 years in which a "hands off", "let nature take its course" approach has been made to forest and range management. Rather than letting these fuels burn on the landscape we can use our Biomass plants with effective air quality technologies. The emissions from biomass facilities are substantially less than wildfires.
- **Biomass can be part of the solution:** Today, there is a great emphasis to control the massive forest fires of the past 10 years. The removal of ladder fuels (excess small trees and understory brush) is vital to "fire proofing" and restoring our forests and

rangelands. There are number of ways which these conservation practices can be done. One is through controlled burns but in areas where biomass is purchased for electricity or fuel, removal of this fire prone material is very effective. Costs are reduced and may even be turned into profit.

- **Biomass utilizes a local product:** In Humboldt County we have two biomass facilities that are utilizing the waste from making products at our sawmills. This work supports families in our county, as well as our foresters, loggers, truckers, mill workers, biologists, ecologists, and forest landowners. There is an economic incentive for landowners and governmental land managers to steward and conserve land through sale of what would otherwise by wood waste. All while energy is produced locally.
- **Biomass continues to advance and innovate:** Just as agricultural and forestry best management practices have advanced, so has the technology in our sawmills and biomass facilities. The NCEA contract will help keep our local biomass facilities advancing, by providing income for their efficiency and technology upgrades. A viable biomass market supports forest restoration, our small-scale forest management, the enhancement of wildlife habitat and can reduce risk of wildfire. We hope we can keep our existing facilities which compliment new developing technologies and infrastructure. Humboldt County has the option to continue moving forward in supplying energy into a local grid. Energy that supports family land operations, wildlife habitat, and restoration projects in addition to a product we know and love, wood.

Biomass utilization is integral to stewarding our forests and protecting California from wildfire. We think Biomass is an important part of a diverse energy portfolio. We urge NCEA to carry forth that vision, via biomass as a growing proportion of its energy portfolio.

Thank you for the opportunity to provide input on this matter that we feel is critical to our land and people.

Sincerely,

The Buckeye

Sarah Mora, Chair Jim Able, Past Chair Valerie Elder, Executive Director

PO BOX 5607 | Eureka, CA 95502
buckeyeconservancy.org | info@thebuckeye.org | 707-725-8847

mad river
LUMBER
Redwood Fencing Experts
P.O. Box 1134 • Arcata, CA 95518
Tel.: 707-822-4384 • Fax: 707-826-1838

September 20, 2019

Redwood Coast Energy Authority
633 3rd Street
Eureka, CA 95501

RE: Energy Plan 2019

To Whom It May Concern:

Thank you for the opportunity to comment on the role of biomass energy in Humboldt County. We have reviewed the detailed letter from Humboldt Redwood Company regarding the Comprehensive Action Plan for Energy Update and completely concur with all of their conclusions.

Mad River Lumber has been in business in Arcata, CA for more than 25 years. We currently employ 30 people and account for more than 150 jobs indirectly throughout the community. We have consistently been very strong supporters of community service organizations and youth sports.

Not only is biomass energy environmentally sound and sustainable, if there was no local facility available to serve as an outlet for biomass, it is possible that Mad River Lumber would have to shut down operations as hauling the material out of the area would be cost-prohibitive.

We strongly urge the RCEA to maintain biomass as a significant portion of your renewable energy portfolio.

Sincerely,

Travis Campbell, Owner
Mad River Lumber

From:	EnergyPlan2019@RedwoodEnergy.org
To:	Judy Haggard; EnergyPlan2019@RedwoodEnergy.org
Subject:	RE: Terra-Gen wind turbine project
Date:	Friday, September 20, 2019 12:03:20 PM

Thank you for your comment, Judy. We will add it to the public record which can be seen on our website. https://redwoodenergy.org/services/planning/

Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Judy Haggard [redacted]
Sent: Friday, September 20, 2019 9:43 AM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: Terra-Gen wind turbine project

Sirs/Ms:

Among the several concerns I have regarding the proposed Terra-Get wind turbine project (bird [especially marbled murrelet] and bat mortality, loss of wildlife habitat, lack of adequate biological surveys done for the draft EIR to address these and other issues, etc), a new concern has cropped up. I recently came across an article from the BBC (https://www.bbc.com/news/science-environment-49567197) regarding the rapid increase in sulphur hexafluoride (SF6) in the electrical industry, particularly in relation to wind turbines in Europe. SF6 is used to prevent accidents in switchgear. Unfortunately, the downside to the use of this gas is that it has the "highest global warming potential of any know substance."

Does Terra-Gen use SF6 in their switchgear? If so, do they include SF6 emissions in their calculations in reducing gas emission outputs?

I assume that rooftop solar installations do not have this same problem. In fact, Humboldt County should be investing in "rooftop solar" instead of these huge projects that have the potential of huge adverse impacts.

Thank you.

Judy Haggard
[redacted]
Fieldbrook, CA [redacted]

From:	EnergyPlan2019@RedwoodEnergy.org
To:	Fania Franklin; EnergyPlan2019@RedwoodEnergy.org
Subject:	RE: Wind turbines
Date:	Friday, September 20, 2019 12:02:41 PM

Thank you for your comment, Fania. We will add it to the public record which can be seen on our website.
https://redwoodenergy.org/services/planning/

Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

-----Original Message-----
From: Fania Franklin [redacted]
Sent: Friday, September 20, 2019 8:02 AM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: Wind turbines

To Whom It May Concern,
I am aware of a major wind turbine instillation being considered in Humboldt County. While it is exciting to think of our area as a leader in the alternative energy field, I do have some concerns about this project.
I am concerned about;
1. Cutting down many trees in order to clear the site.
2. I have read that there will be a need for major infrastructure such as a large network of roads.
3. There doesn't seem to be a way to deter certain bird migrations from flying by this site causing obvious harm to bird populations.

Please take the time to compare this energy source to Solar Power. I know there is time pressure to get this instillation in place due to the end of tax incentives in 2020 but this is not a good enough reason to rush into a project that might not necessarily be right for our area.
I thank this committee for all your hard work.
Fania Franklin
[redacted]
Eureka, Ca. [redacted]
Sent from my iPad

From: EnergyPlan2019@RedwoodEnergy.org
To: Nancy Ihara; EnergyPlan2019@RedwoodEnergy.org
Subject: RE: CAPE
Date: Friday, September 20, 2019 12:01:40 PM

Thank you for your comment, Nancy. We will add it to the public record which can be seen on our website. https://redwoodenergy.org/services/planning/

Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Nancy Ihara [redacted]
Sent: Friday, September 20, 2019 7:33 AM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: CAPE

I believe that RCEA should move away from the use of biomass energy production. The plants are old, not clean and opposed by numerous health organizations, and produce more carbon dioxide than natural gas. I do not believe that the operators of the Fairhaven and Scotia plants will develop more environmentally friendly means of dealing with mill waste unless they are forced to do so. A commitment on the part of RCEA to phase out reliance on biomass energy would be useful in promoting this transition.
Nancy Ihara

GREEN DIAMOND
Resource Company

California Timberlands Division
P.O. Box 68
Korbel, California
95550-0068
T (707) 668-4400
F (707) 668-4402
greendiamond.com

Redwood Coast Energy Authority
633 3rd Street
Eureka, CA 95501

Submitted via email to: EnergyPlan2019@RedwoodEnergy.org.

RE: Comments on Energy Plan 2019

Energy Authority Board Members:

Thank you for the opportunity to provide input to the RCEA planning process. Green Diamond is keenly interested in the energy future of the region and appreciates you taking a long-term approach to our local energy needs.

Green Diamond is a family owned company which manages 375,000 acres of timberland in Humboldt/Del Norte Counties and operates a wood chip export facility at the Port of Humboldt (Fairhaven) and a whole-log chipping facility at Samoa. Green Diamond locally employs 170 full time employees along with many contractors and subcontractors. Our employees are members of local school boards, fire district boards, they coach youth sports teams, are members of local chambers, and volunteer for non-profits like CASA and Hospice of Humboldt. Green Diamond supports reliable and reasonably priced local power generation with preference for locally sourced renewable fuels.

Green Diamond respectfully suggests the mission and vision of RCEA looking forward should be to ensure reliable and reasonably priced power with preference to local producers utilizing locally sourced renewable fuels. Local power generation should be a mix of baseload and intermittent generation from multiple providers with preference to local, renewable sources.

There are exciting local wind energy projects in the planning stages that could help supply our energy needs. It is not clear when or if these projects will come to fruition. However, there are two operational biomass plants that can produce the needed baseload to supplement wind-generation and solar. While some challenge biomass as being "clean" energy, these plants must meet all air emission standards set by CARB and the local AQMD. Biomass plants do emit CO_2 back into the atmosphere, but this is "short lived" carbon that was sequestered by the trees within the last 30 to 70 years and will be recaptured by our growing forests. The power generated from biomass also offsets the need to pump, dig or fracture fossil fuels that have been stored underground for millions of years.

Local biomass generation is primarily fueled from sawmill waste- bark, sawdust, chips, and shavings. Without local utilization, these waste products must be transported 150 miles one way to a landfill or another biomass plant. A single sawmill operating at two shifts can produce 30 truckloads per day. That equates to 190,000 tons of waste material per year. It would take 7,500 trips for a single truck to move that volume over the course of a year. That corresponds to 2,250,000 on highway miles and roughly 281,000 gallons of diesel fuel just to move the material generated by a single sawmill. This will not only challenge the economic viability of local sawmills, but result in additional CO_2 emissions associated with transportation.

From 2011 to 2014 Green Diamond had an in woods slash grinding program. This took an average of 40,000 tons annually of limbs, tops, and hardwood material off the landscape which fueled the biomass plant in Scotia. The Placer County Air Pollution Control District sponsored a study that found that when compared to open pile burning, emissions from biomass plants have a 98% to 99% reduction to $PM_{2.5}$, carbon monoxide, nonmethane organic compounds, methane, and black carbon. The study also found that biomass plants had a 20% reduction in nitrous oxides and CO_2 equivalent greenhouse gases. This was a case study to quantify the air quality and GHG benefits of using biomass for renewable energy versus open pile burning[1]. This program became unfeasible once the power purchase agreement for the receiving plant expired. This material is now piled and burned or left in the woods to decay.

Green Diamond believes your consideration for future energy needs should include a comprehensive review of the co-benefits associated with biomass energy. This is consistent with your question: "How should we balance energy cost with environmental quality?" Biomass energy generation can be a critical tool to help restore health and resilience to our forests. Forest health treatments include thinning of the smaller, understory trees while retaining the larger overstory trees. The result is fewer trees per acre and more natural density. While some of the smaller trees are large enough to produce lumber, many are too small and are only suitable for biomass.

Protecting our rural communities from wildfire, reducing smoke emissions and fire severity, moving toward energy independence with locally source power, and supporting local living wage jobs all must be considered as part of the analysis of RCEA's energy plan. Ideally power generated from biomass would enjoy a price structure that would support necessary forest health projects on public and private forests thereby creating a more fire resilient landscape.

Thank you for the opportunity to provide comments. We wish you the best in the development of the path forward for our region's energy future.

Sincerely,

Jason Carlson, Vice President and General Manager
Green Diamond Resource Company

[1] Forest biomass diversion in the Sierra Nevada: Energy, economics and emissions, by Bruce Springsteen, Thomas Christofk, Robert A. York, Tad Mason, Stephan Baker, Emily Lincoln, Bruce Hartsough and Takuyuki Yoshioka, 2015

Humboldt County Association of Governments
611 I Street, Suite B
Eureka, CA 95501
(707) 444-8208

Date: September 17, 2019
To: Matthew Marshall, Executive Director, Redwood Coast Energy Authority
From: Oona Smith, Senior Planner, HCAOG
Re: CAPE preliminary draft #1

Thanks to all those who have been updating RCEA's guiding strategic document, and working on the draft "Comprehensive Action Plan for Energy" (CAPE).

As a first and non-substantive comment, I would like to remark that I think the previous name was cool, ,
and that the revised title doesn't improve on it. If there were a vote, I would vote for RePower Humboldt.

As perhaps my most substantive comment, I appeal to RCEA to include explicit strategies to also work directly on reducing the number of miles that people drive internal-combustion vehicles. I was reminded of this critical need by Transportation For America. Their goal "*is to raise reducing vehicle miles traveled to the same level of importance of electric vehicles and fuel efficiency*." In a recent post, they remind us:

> The conversation on climate change tends to focus on a few big things—electric vehicles, renewable energy, putting a price on carbon. But no matter how much progress we make on those fronts,…With vehicle miles traveled increasing every year, we'll never achieve ambitious climate targets if we don't reduce driving.
>
> (Transportation) (e)missions have risen despite increases in fuel efficiency standards and the adoption of electric vehicles. Despite an admirable 35 percent increase in the overall fuel efficiency of our vehicle fleet from 1990-2016, emissions still rose by 21 percent. Why was that? Because the total amount of miles traveled increased by 50 percent in that same period.
>
> California, Hawaii, and Minnesota have all found that even with a fleet of electric vehicles, they will still fail to reach their aggressive climate targets without an accompanying effort to reduce driving.[1]

In the CAPE (or RePower Humboldt :)), RCEA's purpose should convey RCEA's intent to reduce fossil fuel use and CO_2 emissions, if not VMT. Additionally, there's no good reason to not be explicit about working towards averting global climate catastrophe.

> **Redwood Coast Energy Authority Mission and Purpose**
> The purpose of the Redwood Coast Energy Authority 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 for the benefit of the Member agencies and their constituents.

---

[1] T4America BLOG, September 16, 2019, posted by Emily Mangan.
http://t4america.org/2019/09/16/federal-transportation-policy-is-undermining-any-progress-on-climate/

The changes below end up leaving out mention of strategies for coordinating sustainable land use and transportation. Is there, also, room for strategies for *carbon-neutral* transportation?

> ...The CAPE is intended to support achieving these goals through strategies that specifically address: Regional Energy Planning & Coordination,
>
> and Energy Generation & Utility Services.

On another note, I don't know what "Integrated Demand Side Management" means. I don't really know what "Distributed Generation and Storage" means, either. "Increased Advanced Fuel Vehicle Adoption & Fuel Efficiency" also takes some time to comprehend.

I recommend that RCEA's Vision Statement be more aspirational. Do not limit it to what seems realistically achievable by 2030. *Go for vision.* For example:

> **VISION STATEMENT**
> In 2030...
> Humboldt County is no longer a net importer of energy. We achieve ~~a high degree of~~ energy independence and self-sufficiency through high levels of energy conservation and efficiency combined with locally-produced and -managed energy generation. ~~Most of o~~Our energy comes from renewable sources. ~~Significantly less m~~Money spent on energy ~~leaves~~ stays in the county.
>
> Individual communities have developed ~~greater~~ energy self-sufficiency and independence as has the county overall. Citizens have a diversity of choices for how to meet their energy needs. We have ~~much more~~ local control over energy prices. We ~~have been able to~~ readily adapt to any major external changes in energy supply or technology.
>
> Our rate of energy consumption is ~~level~~ *("level"! Come on!)* has reduced 50% or at least 40% below 1990 levels , due to increasing conservation and efficiency to offset increases in growth-related demand.
>
> Our overall quality of life is ~~as good as or~~ better than it was in 2005. ...
>
> The County is energy efficient through neighborhood design. Good community planning has reduced sprawl. For travel, people depend more on transit, bikes, scooters, walking, and shared-use automobiles than they depend on private automobiles. There are fewer automobiles ~~and there is less automobile dependence~~....
>
> All buildings are energy efficient. .... *Nice vision.*

Please see my other comments and recommended edits in the attached printout.

Thank you for this opportunity to comment and be part of the strategic development.

RCEA Preliminary draft #1 CAPE (iRePower Humb!)

SECTION TO BE UPDATED

In Humboldt County, as in all parts of the United States, we depend on energy 24 hours a day, and we continuously benefit from direct and indirect use of energy resources. Energy is so pervasive in our daily lives that it can sometimes be taken for granted. From the sun we draw heat, light, and solar power; we depend on it to grow our food, forests, flowers, etc. We depend on fossil fuels to get us to work, school, the local shops, and the hospital; to transport our food, commodities, mail, and even garbage; we depend on it to visit exotic places by plane (and to get to the airport), or to visit a friend by car. Electricity enables us to work after the sun goes down; we depend on it to light our offices, classrooms, and streets; to keep our food cold and our ice cream frozen; to pump water through pipes; and to transmit information during this electronic age. Energy in a diversity of forms fuels our industries and business ventures: from powering lumber mills to dairy farms; from firing ceramics to pizzas, and from brewing beer to baking bread. Energy generation and transmission is also an industry in and of itself. Clearly, reliance on energy resources characterizes a large part of our everyday lives.

The production and consumption of energy also affects our daily lives in more indirect ways, particularly with regard to the environment. The burning of fossil fuels has led to damaging environmental effects such as acid rain, smog, water pollution, and global warming. Exploratory drilling and extraction of non-renewable energy sources (such as coal, petroleum, and natural gas), and their attendant infrastructure, has resulted in the degradation of other natural resources, for example forests, coastal communities, and rainforests. Although these areas may be far away, the environmental impacts can reach Humboldt County.

~~estimates that, in 2010, to meet local energy demands, Hum. Co. spent $460M, the majority of which...~~

In Humboldt County, energy is used as a transportation fuel and as electrical and heat energy in homes, businesses, industries, and agriculture. In 2010 it is estimated that Humboldt County spent $460 million to meet local energy demands, the majority of which left the county. Approximately half of the energy was used as a transportation fuel (gasoline and diesel), with large amounts also used to meet end-use electrical demands and end-use natural gas heating demands. Primary energy sources were comprised mainly of natural gas, gasoline, diesel, and biomass (wood waste and firewood). (ignore)

~~misplaced modifier~~

REDWOOD COAST ENERGY AUTHORITY MISSION AND PURPOSE

nothing about reducing CO_2, carbon neutral, or global climate crisis/catastrophe.

The purpose of the Redwood Coast Energy Authority 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 for the benefit of the Member agencies and their constituents. To further that purpose, the Redwood Coast Energy Authority will work toward the following goals:

A. To lead, coordinate and integrate regional efforts that advance secure, sustainable, clean and affordable energy resources. implicit

B. To develop a long-term sustainable energy strategy and implementation plan.

C. To increase awareness of, and enhance access to, energy conservation, energy efficiency, and renewable energy opportunities available to the region.

D. To add value to, but not duplicate, energy services offered by utilities and others serving the region in a manner that does not conflict with acting as a community choice aggregator.

E. To keep key decision makers and stakeholders informed of policy, regulatory, and market changes that are likely to impact the region.

F. To support research, development, demonstration, innovation, and commercialization of sustainable energy technologies by public and private entities operating in Humboldt County.

Comments from Oona Smith, Sr. Planner HCAOG (444-8208)

Attachment, 9/17/19.

G. To develop regional capabilities to respond to energy emergencies and short-term disruptions in energy supply, infrastructure, or markets that could adversely affect Humboldt residents and businesses.

The CAPE is intended to support achieving these goals through strategies that specifically address: Regional Energy Planning & Coordination, Integrated Demand Side Management, Low Carbon Transportation, ~~Energy Reliability & Security, Economic Development, Built Environment Efficiency, Education, Water & Waste, Transportation,~~ and Energy Generation & Utility Services.

VISION STATEMENT

The below vision statement was developed through the public comment process for the original draft of the Energy Element prepared by RCEA. It expresses the community qualities and characteristics that the CAPE aspires to achieve, expressed as how Humboldt County could be described in 2030.

In 2030...

Humboldt County is no longer a net importer of energy. We achieve a high degree of energy independence and self-sufficiency through high levels of energy conservation and efficiency combined with locally-produced and -managed energy generation. Most of our energy comes from renewable sources. Significantly less money spent on energy leaves the county.

Individual communities have developed greater energy self-sufficiency and independence as has the county overall. Citizens have a diversity of choices for how to meet their energy needs. We have much more local control over energy prices. We have been able to readily adapt to any major external changes in energy supply or technology.

Our rate of energy consumption is level, due to increasing conservation and efficiency to offset increases in growth-related demand.

Our overall quality of life is as good as or better than it was in 2005. The population is healthier as a result of leading energy-conserving lifestyles. It is safe, pleasant, economically favorable, and typical to have a lifestyle that doesn't consume much energy.

Energy conservation education has reached, and continues to reach, effectively, everyone in the county.

Energy considerations and decisions are integrated with all other decision-making arenas.

The County is energy-efficient through neighborhood design. Good community planning has reduced sprawl. There are fewer automobiles and there is less automobile dependence. Public transportation is conveniently available and well utilized and walking, bicycling and other non-automobile forms of transportation are commonly used. There is much less consumption of energy from non-renewable sources for transportation.

All buildings are energy efficient. All new construction is done in the most energy efficient manner, starting with building design. All existing buildings have been upgraded to be more efficient. Energy efficiency is integral to building standards, which have flexibility and include meaningful incentives. Many homes and businesses produce more energy than they consume.

The County is a thriving research and development center and incubator for energy technology and related manufacturing, which is a stable source of local jobs.

DRAFT 2019 STRATEGIES UPDATE

Regional Energy Planning & Coordination

RCEA will take a leadership role to develop and advance strategic regional energy goals through economic development, funding, planning efforts, and education. This work will be done in coordination with RCEA's member governments, other local public agencies, local tribes, and other public and private stakeholders.

ECONOMIC DEVELOPMENT

Attract Energy-related Business. Collaborate with local economic development entities to attract technology developers, manufacturers, and energy service providers to locate operations in the County when appropriate.

HCD?

Support Proactive Energy-related Business Development. Collaborate with local jurisdictions to identify and pre-assess locations and facilities for energy-related business ventures.

training thing Sec 3 fed "reqmt" (meets)

Support Energy-sector Workforce Development. Work with other local entities to provide training and continuing education that develops and maintains a qualified local workforce available to implement energy efficiency upgrades, renewable energy projects, and advanced-vehicle technology deployment.

FUNDING

Develop Regional Energy Funding Mechanisms. Offer support and act as the fiscal agent and funding clearinghouse for countywide energy programs.

Pursue Cap and Trade Auction Proceeds. Work regionally to access Cap and Trade auction proceeds and other State funding mechanisms to ensure effective, efficient, coordinated, and equitable resource allocation in the North Coast Region.

Develop Job Development Incentives? Collaborate with local economic development entities to identify opportunities for developing jobs in the field of energy conservation, efficiency, and renewable sources. funding? If not funding, then move this to E.D.

Implement Energy Project Financing. Work with local economic development entities and/or financial institutions to develop and implement financing programs that enable residents and businesses to implement energy efficiency and renewable energy projects.

Facilitate Financing Mechanisms. Facilitate Property Assessed Clean Energy (PACE) and other financing programs that access the needed capital to deploy regional energy independence strategies.

Develop Local Energy Investment Programs. Work with local economic development entities and financial institutions to develop programs and resources that facilitate local community investment in and/or ownership of energy efficiency and renewable energy projects.

PLANNING

planning

Support Carbon Sequestration. Support the development and deployment of mechanisms for retaining carbon in the region's abundant natural areas and working lands.

Assist with Climate Action Planning. Work with local jurisdictions to complete greenhouse gas inventories, set greenhouse gas reduction targets, and develop climate action plans.

Support Climate Change Adaptation. Work with other local entities to conduct a climate change risk assessment and develop an adaptation plan consistent with the best-practices guidance provided by the California Natural Resources Agency and California Emergency Management Agency.

Support Countywide Strategic Energy Planning. Coordinate an effective energy strategy based on self-sufficiency, development of renewable energy resources and energy conservation that is actively implemented countywide through Climate Action Plans, General Plans and the Redwood Coast Energy Authority's Comprehensive Energy Action Plan.

CAPE?

* I like the name "Repower Humboldt". Why change from that? I vote to keep name.

Encourage Adoption of Energy Elements. Encourage the adoption of energy elements in other local and regional jurisdictions. Periodically review local Energy Elements and recommend updates, as necessary, to reflect changing technologies for the generation, transmission, and efficient use of energy.

Assist with Energy Emergency Response Procedures. Assist the Humboldt County Office of Emergency Services in the preparation of energy emergency response procedures for the Humboldt County Emergency Response Plan.

Encourage Energy Policies and Plans. Encourage other jurisdictions and entities, including the cities in Humboldt County, to adopt and implement sound energy plans and policies, to include energy elements and/or energy policies in their general plans and ordinances. Advocate and disseminate energy planning strategies, policies, and other information.

EDUCATION

Maintain an Energy Resource Center. Operate an energy resource center open to the public and provide energy conservation, energy planning, renewable energy, and energy-efficient building design and retrofit information.

Hold Regional Energy Forums. Serve as a forum for addressing countywide energy issues.
Develop Public Displays. Encourage and assist development of educational displays for exemplary renewable energy and distributed energy systems installed throughout Humboldt County. Displays should provide county residents and businesses with information on how the systems work and how well they perform, and should inform county residents about the importance, benefits, and associated impacts of developing local energy resources.

Provide Energy Efficiency Education and Training. Provide community education on energy issues, including the benefits of reduced energy consumption, and increased energy efficiency. Collaborate with schools and colleges for energy-related research, education, and conservation practices.

Integrated Demand-Side Management

RCEA will use an Integrated Demand Side Management (IDSM) approach to match and enhance customer energy use with intermittent clean and renewable energy supplies. An additional priority will be placed on energy resiliency and independence.

INTEGRATED DEMAND-SIDE MANAGEMENT STRATEGIES

Support Member Agency and Local Government Energy Management. Support member agencies in managing their energy consumption. RCEA will support varying activities that reduce and align energy use with available clean and renewable supplies to reduce costs while aligning to performance-based action plans and Greenhouse Gas Emission Reduction goals. Additional activities will be prioritized where they support energy resiliency and independence.

Support Implementation of Codes and Standards. Support the local implementation of Title 24 building energy codes, Title 20 appliance efficiency standards and individual projects that strive to achieve energy efficiencies that exceed state or local requirements. Support the consideration and adoption of above code energy ordinances.

Promote No-Regrets Energy Efficiency, Solar and Storage Permitting. Support local ordinances that streamline permitting processes for energy efficiency, solar and storage technologies.

---------------- Page 8 --------------------

Assist with Facility Benchmarking. Assist local governments with facility benchmarking to evaluate and track the energy performance of non-residential buildings.

Support Zero-Net–Energy Standards. Support the State's goals related to residential and commercial net-zero-energy standards along with other green building standards that align with RCEA's IDSM strategies.

Conduct Community Engagement. Provide community facing information and resources that will support informed decision-making as relating to customer energy use.

Support Energy Assessments. Support and encourage full knowledge of the costs and benefits (including product stewardship) of energy efficiency, conservation, generation and storage activities through assessments.

Integrate Distributed Energy Resources. Support, promote and integrate distribution-connected generation, energy storage, energy efficiency, electric vehicle and demand response technologies into new and existing customer-facing programs.

Integrate a Distributed Energy Resource Management System. Integrate distributed energy resources into a unified system that can aggregate or automate demand response activities.

Support and Deploy Microgrids. Support and deploy energy microgrids, focusing on critical infrastructure and community facilities that through onsite generation, energy storage, and advanced control systems provide energy resiliency and emergency-response capabilities as well as ongoing economic and environmental benefits.

Use Advanced Metering Infrastructure. Use advanced metering infrastructure to make informed, data-driven program decisions.

ENERGY EFFICIENCY & CONSERVATION

RCEA will support energy efficiency and conservation as core strategies toward achieving the program's environmental, economic, and community goals. Where feasible, energy efficiency technologies will be controllable and integrated as a distributed resource. RCEA will:

Support electrification. Prioritize new programs and alterations to existing services that promote the use of air-source heat pump domestic hot water and space heaters, induction stoves and clothes dryers.

Encourage Energy-Efficient Equipment. Encourage the use of the most energy-efficient equipment for space and water heating, ventilation, lighting, refrigeration, and air conditioning in all buildings and developments, including residential and commercial facilities.

Promote Performance Contracting. Promote residential and commercial performance contracting that is consistent with current best practices for energy efficiency and environmentally sound construction techniques.

Develop and Support Behavioral, Commissioning and Operations (BROs). Develop, promote and support programs that promote conservation, building system commissioning and operational changes that reduce or change the time of energy use.

Replace Plug Loads. Replace existing plug load devices and install line-signaling smart technologies that save energy and provide an integrated solution that aligns with demand-response and storage measures. Examples include internet-of-things enabled lighting, water and space conditioning, dish and clothes washing and refrigeration.

DEMAND RESPONSE

RCEA will support and prioritize demand-response programs that give ratepayers an opportunity to play a role in balancing energy load with renewable energy supply. Demand-response programs and offerings will, where possible, integrate with distribution-connected efficiency, solar and storage measures.

Support Time of Use. Notify, support and enable action from customers who express an interest in load shifting or shaving to reduce evening hour coincident demand.

Provide and Support Peak-Day Pricing. Notify and support customer energy-use changes during summer peak day events.

Enable Automated Demand-Response. Install electrification, efficiency, and storage technologies that automatically reduce energy use during demand-response events.

Implement Grid-Connected Buildings. Implement grid-connected buildings that allow for the curtailment of loads in descending order of priority.

DISTRIBUTED GENERATION & STORAGE

RCEA will support the deployment of distribution-connected solar and storage technologies as core strategies toward achieving the program's environmental, economic, and community goals.

Administer and Implement the Public Agency Solar Program. Continue to implement the solar and energy-storage technical assistance program for public agencies; integrate grid-connected resources and microgrids as feasible.

Administer and Implement the Community Solar and Storage Program. Evaluate, design and launch community solar and storage program services that support the increased adoption of grid-connected solar and storage technologies.

Integrate Vehicle-to-Grid Storage. Integrate vehicle-to-grid storage solutions with transportation and IDSM goals and objectives.

10

Low-carbon Transportation

RCEA will decarbonize regional transportation through efforts to reduce vehicle miles travelled, increase advanced fuel vehicles adoption and fuel efficiency, and expand advanced fuel infrastructure.

REDUCE VEHICLE MILES TRAVELED

Strengthen Broadband Infrastructure. Support efforts to strengthen rural regional broadband infrastructure to facilitate remote access to educational and business opportunities, and deploy advanced, resilient grid management technology and integrated energy efficiency and demand response solutions.

Encourage Transportation-efficient Land Use Planning. Encourage infill, transit-oriented development, and walkable and bikeable communities through thoughtful zoning and land-use planning process.

Facilitate Multi-modal Transportation Infrastructure. Support improving multi-modal transportation options through regional trail networks, transit infrastructure, and complete streets infrastructure strategies that support walking, biking, and the use of public transportation.

INCREASE ADVANCED FUEL VEHICLE ADOPTION & FUEL EFFICIENCY

Electrify Transportation. Encourage local government and private fleets to maximize the use of low-carbon vehicles. Provide local incentives for electric vehicles.

Promote Advanced Fuels. Encourage the use of non-fossil sources of advanced fuels that reduce greenhouse gas emissions, which may include hydrogen, biodiesel, ethanol, and renewable diesel.

Promote PEV Adoption. Conduct public outreach campaigns to promote EV driving, fleet analysis. Provide web and in-person decision support. Conduct leadership by example among government agencies. Support low-carbon transportation initiatives at other agencies.

Promote Efficient Driving Practices. Promote the use of energy-efficient driving practices that improve fuel efficiency, such as moderate speed changes and legal speeds, anti-idling, and traffic-calming features.

Support Shipping Efficiency. Support the implementation of trucking efficiency technologies and best-practices, including idle-reduction technologies, aerodynamic retrofits, and low rolling resistance tires. Support the analysis of other potential transportation modes that could provide efficient shipping alternatives, such as barge and rail.

Support technologies (internet-of-things) that will bundle deliveries ∴ reduce trips offer more options for time of delivery, e.g. non rush, not next day, etc.

EXPAND FUELING INFRASTRUCTURE

Develop Transportation Electrification Infrastructure. Develop and implement Electric Vehicle (EV) charging stations. Provide local incentives for EV charging infrastructure.

Develop Biofuels. Promote using waste oils and other biomass sources for biofuels production. Focus on waste oils and other biomass that are not already being used for other purposes, and explore potential opportunities and issues of new technologies for biofuels production from local resources.

¿for prod'n... process?

Streamline Permitting for PEV Charging Infrastructure. List PEV charging as a permitted use across a broad range of zoning classifications. If a zoning review is triggered, consider the EVSE as an accessory use to another permitted use whenever possible. Develop a standard EVSE permitting process that can be used across the North Coast Region, etc. ?

Promote Vehicle-to-Grid Connection. Promote integration of motor vehicles with the electric grid, including battery electric vehicles, fuel-cell vehicles, plug-in hybrid electric vehicles, and solar electric vehicles. Evaluate development status of vehicle-to-grid interconnect standards and the use of grid-connected vehicles for short-term energy storage.

Energy Generation& Utility Services

RCEA will address supply-side energy needs ~~for~~ Humboldt County's through its existing Community Choice Aggregation program, and developing ~~of~~ new programs and initiatives as appropriate. by

POWER RESOURCES (CCA)

Maximize the Use of Local Renewable Energy to the Extent Technically and Economically Feasible and Prudent. Use the CCA program with its renewable energy targets, and programs supporting distributed energy resources, to achieve this aim.

Minimize Greenhouse Gas Emissions Associated with RCEA's CCA Program. CCA power mix has, at least, a 5% lower greenhouse gas emission rate than PG&E mix. Page 13

fact or goal?

Reduce Regulatory Barriers. Support efforts to increase the efficiency of the energy systems permitting process and reduce any excessive regulatory barriers to renewable energy and distributed generation projects. Work to develop proactive strategies to reduce and mitigate the environmental and community impacts of potential energy projects.

Maximize Renewable Energy Content of RCEA's CCA Program. CCA power mix is at least 5% more renewable energy (as defined by state law) than PG&E's power mix and reaches 100% clean and renewable content by 2025.

ditto

Ensure Diversity in Local Sources. Pursue development of a diverse, locally-produced energy supply, with an emphasis on renewable resources, that is price-competitive in the California market and that can be generated in a way that minimizes adverse environmental impacts.

Promote Energy Feasibility Studies. Encourage and support feasibility studies of local wind, solar, hydro-power, and ocean energy resources. Make recommendations on preferred alternatives that are consistent with the County's goals for energy security and sustainability.

whose goals? County of Hum. adopted goals? Broaden/fix.

Power Resources: Distributed Generation

Designate "Renewable Energy Parks." Work with County and City planning departments to designate areas of the county preferred for renewable energy development.

Develop Distributed Generation. Encourage studies to identify key facilities throughout the county that would benefit from distributed generation and cogeneration energy systems. Encourage development of responsive, environmentally-preferable distributed generation and cogeneration energy systems where appropriate. Encourage and publicize demonstration sites.

Provide Education on Renewable Energy and Distributed Generation. Provide educational and promotional programs that encourage and demonstrate the use of renewable energy and environmentally-preferable distributed energy generation and cogeneration systems.

Provide Feed-In-Tariff Power Procurement Program for Small Generators. Offer long-term contracts at a set rate for Renewable Portfolio Standard-eligible renewable energy generators of 1MW or smaller.

Power Resources: Solar

Support Solar Energy Development. Support local efforts to develop solar electric systems and solar hot water systems in the county. Support development of local training programs for solar contractors and installers. Educate the public about the benefits of solar energy systems. Develop programs that facilitate an increase in the number of solar energy systems in the County.

Power Resources: Offshore Wind

Pursue Offshore Wind Energy. Work with public and private entities to develop offshore wind energy off of Humboldt County's coastline, and support establishing Humboldt Bay as a west-coast hub for the offshore wind industry.

Power Resources: Onshore Wind

Promote Large-Scale Wind Energy. Provide information about the potential for cost-effective commercial-scale wind farms in the county. Educate the public about the benefits and impacts of wind energy systems. Work with utilities, local government, and private companies to develop onshore wind energy projects.

Power Resources: Bioenergy

Support Biomass Fuels Reduction and Utilization. Develop strategies and technologies for improved biomass utilization in ways that effectively support restoration objectives and fire management priorities. Coordinate with local agencies, communities, and landowners to develop biomass energy plans that are consistent with sustainable forest management, hazardous fuels reduction, fire safety, and restoration needs.

Contract for 20MW Local Biomass Energy. Contingent on price and market conditions, contract for a target of around 20MW of local biomass energy.

Promote Small-scale Biomass Generation Sites. Monitor feasibility of smaller and/or mobile biomass electric generators fed with wood waste and very small diameter logs (e.g., from thinning for fire safety and timber harvest slash in National Forest areas). If/when technology proves feasible and cost effective, promote its use in county areas near National Forests where existing electric transmission lines are available.

Pursue Biogas Development. Support HWMA and others in ~~the development the~~ development of a food waste digester. Develop and publicize dairy biogas demonstration sites and work with local farm organizations to promote dairy biogas energy systems where appropriate. Publicize the use of biogas at existing local wastewater treatment facilities and encourage its use at additional facilities where appropriate.

Power Resources: Wave and Tidal

We are residents of Westhaven, and as opt up customers and members of HUUE which has also opted up, we encourage your efforts. In your plans for the future I'm sure you will modify your actions as new info suggests is logical. Thanks again for your efforts! Our immident concern is the proposed use of biomass.

[signature]

HI MICHAEL - 9/22/19

I HOPE YOU'LL CONSIDER SLOWING DOWN THE CADE PROCESS. NEED MORE INPUT FROM COMMUNITY ABOUT POSSIBLE RISKS.

THANKS - Jamie

JAMIE FLOWER

Sept. 22, 2019

Dear Dwight,

Please slow down the Biomass Planning Process.

Source more energy from solar and err conservatively on Biomass and Windpower. I support a more balanced Planning Process. The Ten year plan needs [illegible] solar energy.

Lynthia Cheron
McKinleyville

[redacted] McKinleyville

9/22/19

The Climate Action Campaign of the Unitarian wants Redwood Coast Energy authority wants to slow down CAPE so more Community input Can be ma[de] regarding biomass + wind, I WANT CONSERVATION as #1.

Thanks, Michael
Joanne Mc[illegible] [redacted]

Dear Austin Allison,

I am writing to ask you use your influence and voice on the Board to slow down movement on CAPE. Please take the time to hear from the community via an open and public discussion.

Thank you, Rebekah Paez

[redacted] Eureka [redacted]

Sept. 22, 2019

Dear Shari,

Please slow down the Biomass Planning Process

Source more energy from Solar and move more slowly on Biomass and Wind Power. I support a more balanced Planning Process. The Ten year plan needs to focus on Solar energy.

Cynthia Chason

[redacted]

McKinleyville, CA

Dear Michael,

I hope you will delay adopting the CAPE until the public offers its opinion. Particularly I am concerned about biomass

John Schaefer

Dear Dwight,

As a resident of Westhaven and an Opt Up customer, and a member of the Humboldt U.U. Fellowship which is also an Opt Up customer, I ask you to use your influence and voice on the Board to slow down movement on CAPE. Please hear the community voices via open and public discussion, re risks of biomass + wind power energy in the next 10 years. Thank you for your efforts to provide "clean" renewable energy sources for our community. Sue Lee Mossman

From:	BYRD LOCHTIE
To:	EnergyPlan2019@RedwoodEnergy.org
Subject:	Comments on CAPE
Date:	Monday, September 23, 2019 10:18:48 AM

I would like to comment on CAPE. I am a person who has chosen to get clean energy through RCEA, and I was dismayed to learn that at least 12% of my energy comes from biomass. I am concerned because I do not consider biomass clean energy. It pollutes the air with micro particles that are dangerous to our health.

I understand that the timber industry is PAID for the energy and therefore does not want to find and implement other solutions for the disposal of their wood wastes. These solutions already exist and would be better for the planet and our health.

Please consider these points in your plan:

- Reduce the use of biomass from local dirty plants; eliminate biomass by 2025.
- Encourage timber industry to find more environmentally friendly uses for waste wood.
- Do not pay timber industry for dirty energy.
- Consider climate change—emergency—in all areas of your plan.
- Do not give preferential pricing to dirty biomass energy.
- PUT THE PLANET AND PERPLE'S HEALTH BEFORE PROFITS.

Thank you for allowing me to comment.
Byrd Lochtie
[redacted]
Eureka, CA [redacted]

From: [redacted]
To: EnergyPlan2019@RedwoodEnergy.org
Subject: Biomass burning
Date: Sunday, September 22, 2019 7:22:13 PM

It has come to my attention that RCEA considers the burning of biomass to be a "clean" source of energy. I have to disagree with this assessment. It's my understanding that the burning of biomass at one plant contributes 235,524 metric tons of CO_2/year, along with 5 tons of benzene, 6 tons of formaldehyde, along with other dangerous pollutants. Such a single source of pollution would not be condoned in the middle of a large city, so how can it be allowed to remain in Humboldt County? We have to do our part to lower the carbon footprint in our county. We cannot say that it's someone else's problem. Scientists estimate that we have only 11 years to drastically lower our carbon emissions before a mass extinction event becomes inevitable and irreversible. Why isn't solar along with battery storage a larger portion of our clean energy plan? Germany, one of the cloudiest nations in Europe, generates a large portion of their electricity needs through solar panels. I've heard that they have occasional days where 100% of their electricity needs are met through solar.

I've heard that the biomass in Humboldt County, specifically the waste product of harvesting and milling trees, can be put to better use by combining it with bio solids from waste water treatment plants. The end product would be compost.

I urge you to stop the use of biomass burning as an energy source. The cost of clean renewable power has been going down and will continue to go down as new technology is developed. We should not be locking in a 10-year commitment to biomass when there are much cleaner sources of renewable energy.

Sincerely,
Suzanne Cook
[redacted]
McKinleyville, CA [redacted]

From: carilyn hammer
To: Wendy Ring
Cc: Paul Pitino; mark/margaret shaffer; CityMgr@cityofarcata.org; EnergyPlan2019@RedwoodEnergy.org; Elizabeth Conner
Subject: Auto edit and biomass
Date: Saturday, September 21, 2019 9:38:13 AM

I don't know if it was auto edit or my brain working too fast (or not at all) forming sentences, but the first sentence in my letter concerning biomass read that I did *not* want biomass eliminated. But, I humbly and with a bit of blush, need to clarify that I meant to write that I am concerned that RCEA wants it as part of the plan til 2030. Dr Wendy Ring has cited concerns about emissions from the use of biomass. Brett and Michael Winkler (MW *at length*) responded applauding the use of biomass. But I do hope that Wendy's concern about health and CO2 risks are considered. I guess I should proof read as well as not combine writing a letter with an RCEA looming "deadline of 5oclock" with roasting and skinning Anaheim chili.
Oh well.
Wishing you well,
Carilyn Goldammer

From:	Nancy Stephenson
To:	Lori Taketa
Subject:	FW: [NorCAN] RCEA Public energy workshops
Date:	Thursday, September 26, 2019 11:58:47 AM

CAPE public comment:

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Ann Anderson [redacted]
Sent: Wednesday, September 25, 2019 9:43 AM
To: Nancy Stephenson <NStephenson@redwoodenergy.org>
Subject: RE: [NorCAN] RCEA Public energy workshops

How do we register opposition to Wind Mills near Ferndale. The environmental destruction is too high compared to the benefits. Solar Micro Grids would be less destructive, less expensive and more effective!

Ann Anderson
[redacted]

From: NorCAN [mailto:norcan-bounces@humguide.com] **On Behalf Of** Nancy Stephenson
Sent: Thursday, September 19, 2019 12:04 PM
To: norcan@humguide.com
Subject: [NorCAN] RCEA Public energy workshops

The Redwood Coast Energy Authority (RCEA) is updating its guiding strategic document, the Comprehensive Action Plan for Energy (CAPE), and is seeking public input and support in the process. Workshops began in August and will continue through October, including the meetings below:

Offshore Wind Energy Stakeholder Meeting

Wednesday, September 25, from 5:30-7:00 pm at the Wharfinger Building in Eureka.
There will be an update on RCEA's proposed Redwood Coast Offshore Wind Project and the status of engagement with the fishing community and other stakeholders, updates on Humboldt State University's research on local offshore wind, and time for public input and discussion. Sandwich wraps and refreshments will be served.

Draft 2 CAPE Public Workshop

Thursday, October 17, 5:30-7:30 p.m. at the Aquatic Center in Eureka, 921 Waterfront Drive
This is an opportunity to learn about and discuss the Complete Draft CAPE, which incorporates public input received in August and September on the Preliminary CAPE update. The updated plan includes RCEA's goal of 100% clean and renewable electricity by 2025 and proposed quantitative targets for RCEA's power mix makeup for the next ten years. Sandwich wraps and refreshments will be served.

Forestry, Energy and the Environment

Friday, October 18, 1:00-4:00 p.m. at the Aquatic Center in Eureka, 921 Waterfront Drive
Biomass power derived from mill residuals and other wood waste has been a significant source of local-generated electric power in Humboldt County since the 1980s and has been an element of the renewable energy power mix of RCEA's community choice energy program since 2017. At this workshop a diverse panel of

experts will share information, discuss, and answer questions about the role of biomass power in meeting our local electricity needs as well as its role in the management of local forest lands and the forest products sector of our economy.

The community is also encouraged to submit written comments to **EnergyPlan2019@RedwoodEnergy.org**. Meeting agendas, schedule updates, and additional meeting details can be found on RCEA's website, **RedwoodEnergy.org**. Please contact the RCEA at **(707) 269-1700** for more information.

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From:	EnergyPlan2019@RedwoodEnergy.org
To:	Lori Taketa
Subject:	FW: No Biomass Burning-Solar and Wind instead
Date:	Thursday, September 26, 2019 12:01:17 PM

Public comment:

From: Sue Parsons [redacted]
Sent: Thursday, September 26, 2019 8:09 AM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: No Biomass Burning-Solar and Wind instead

Dear Redwood Coast Energy:

Please do NOT pursue biomass burning to provide energy for Humboldt County.

Why? Because we have just 11 years to cut climate pollution in half.

Because local biomass burning plants are Humboldt's biggest climate polluters, emitting more CO_2 than all the cars in the county combined!

While we wait for our saplings-both child and tree-to grow, CO_2 from burning biomass warms the planet, causing wildfires, melted permafrost, and more greenhouse gas emissions.

We cannot pursue such self-inflicting harm.

Redwood Coast Energy Authority promised clean energy. Do not call biomass clean. Do not lock it into our power mix until 2030.

Why? Because it's harmful.
The American Lung Association, the American Academy of Pediatrics, the American Public Health Association, and the National Association of County and City Health Officials oppose biomass because it is unhealthy.

Local biomass emits over a ton of fine particulates each week. These enter our lungs and bloodstreams, increasing our risk of asthma and heart attacks, cancer, and early death.

And, it is expensive.
Our biomass plants are old and inefficient. Their product costs more than clean energy.

Choose solar, wind, and battery storage for power, instead.

While biomass prices will stay the same or rise, the costs of solar, wind, and battery storage keep dropping. Locking in a ten year commitment to biomass means less investment in new local clean energy. We need to send carbon DOWN, not up.

Mill waste can do that. It returns carbon to the soil and blunts climate impacts. Composting with high nitrogen waste, like food, sequesters carbon and avoids emissions from synthetic fertilizer and landfills. Wood chip mulch prevents storm runoff and erosion. Recycled wood products save trees.

Do not support timber industry's insistence on biomass power. Lead the industry to these other alternatives.

Monetary profit won't matter to future generations when the planet is unfit for life due to climate change.

You have the power to act now to help future generations manage climate change.

Please do the right thing: reject biomass burning in favor of solar, wind, and battery storage.

Susan B. Parsons
Arcata

--
"A book, too, can be a star, explosive material capable of stirring up fresh life endlessly, a living fire to brighten the darkness, leading out into the expanding universe." - Madeleine L'Engle

From:	EnergyPlan2019@RedwoodEnergy.org
To:	Lori Taketa
Subject:	FW: BIOMASS IS NOT CLEAN ENERGY
Date:	Thursday, September 26, 2019 12:02:01 PM

Public comment:

From: Margaret Emerson [redacted]
Sent: Wednesday, September 25, 2019 3:39 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: BIOMASS IS NOT CLEAN ENERGY

RCEA,

I don't want any part of the energy coming into my home to come from biomass.

It's dirty: The American Lung Assn., the Academy of Pediatrics, the American Public Health Assn., and the National Association of County and City Health Officials oppose its use because it's unhealthy.

It's expensive: Biomass plants are old and inefficient. The costs of solar, wind, and battery storage keep decreasing while biomass prices will stay the same or rise.

The timber industry won't return carbon to the soil unless we stop paying for biomass.

Local biomass plants are our county's biggest polluters, emitting more CO2 than all the cars in the county combined.

Leave biomass out of the mix. Go with 100% solar and wind.

Sincerely,

Margaret Emerson

Arcata

From: Matthew Marshall
To: Lori Taketa
Subject: FW: Nancy FYI- Arcata Forest Mgmt Committee action at their 9-12-19 meeting Pertaining to Local Biomass energy production - They are advisory to the City Council fyi
Date: Friday, September 27, 2019 10:56:16 AM

See below from Mark Andre for public comments

From: Mark Andre [redacted]
Sent: Monday, September 23, 2019 11:52 AM
To: Nancy Stephenson <NStephenson@redwoodenergy.org>
Subject: Nancy FYI- Arcata Forest Mgmt Committee action at their 9-12-19 meeting Pertaining to Local Biomass energy production - They are advisory to the City Council fyi

Motion Russ Forsburg
Second Dennis Halligan
Approved by committee 6-0

Reaffirm the Forest Management Committee's previous recommendation to the Arcata City Council that the existing co-generation and biomass energy facilities in Humboldt County are an important part of the energy generation mix; are constant with the State Forest Carbon Plan and are important components to the City's Community based forest management program by:

1. ***Helping the city sell logs at a higher price than would be the case if mill waste was not able to be utilized locally for energy production.***
2. ***Helping the City do periodic forest restorative treatments by accepting material locally instead of pile burning or broadcast burning in the woods.***

Mark Andre
Environmental Services Director
City of Arcata
736 F Street
Arcata, CA. 95521
707 822-8184 office
[redacted]

From: EnergyPlan2019@RedwoodEnergy.org
To: Lynda McDevitt; EnergyPlan2019@RedwoodEnergy.org
Subject: RE: CAPE comment
Date: Thursday, September 19, 2019 1:56:31 PM

Thank you for your comment; we'll add it to our comments that will be made public.
Sincerely,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Lynda McDevitt [redacted]
Sent: Thursday, September 19, 2019 12:51 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: CAPE comment

Thank you for taking my comment on RCEA's CAPE . Biomass is NOT clean energy. The CAPE update should include a plan to get off biomass by 2025. Dirty local energy should not get preference or non competitive pricing compared to clean energy. The older plants in Humboldt produce excess emissions and CO2. Biomass is the wrong source of energy considering the urgency of climate change.
Thank you,
Lynda McDevitt
Trinidad, Ca

From: Information
To: Matthew Marshall
Cc: Lori Taketa
Subject: FW: Stop Biomass usage locally
Date: Friday, September 27, 2019 2:57:15 PM

From: Terri Bonow [redacted]
Sent: Friday, September 27, 2019 2:55 PM
To: Information <info@redwoodenergy.org>
Subject: Stop Biomass usage locally

Dear Redwood Coast Energy:

Please do NOT pursue biomass burning to provide energy for Humboldt County.

Why? Because we have just 11 years to cut climate pollution in half.

Because local biomass burning plants are Humboldt's biggest climate polluters, emitting more CO_2 than all the cars in the county combined!

While we wait for our saplings-both child and tree-to grow, CO_2 from burning biomass warms the planet, causing wildfires, melted permafrost, and more greenhouse gas emissions.

We cannot pursue such self-inflicting harm.

Redwood Coast Energy Authority promised clean energy. Do not call biomass clean. Do not lock it into our power mix until 2030.

Why? Because it's harmful.

The American Lung Association, the American Academy of Pediatrics, the American Public Health Association, and the National Association of County and City Health Officials oppose biomass because it is unhealthy.

Local biomass emits over a ton of fine particulates each week. These enter our lungs and bloodstreams, increasing our risk of asthma and heart attacks, cancer, and early death.

And, it is expensive.

Our biomass plants are old and inefficient. Their product costs more than clean energy.

Choose solar, wind, and battery storage for power, instead.

While biomass prices will stay the same or rise, the costs of solar, wind, and battery storage keep dropping. Locking in a ten year commitment to biomass means less investment in new local clean energy. We need to send carbon DOWN, not up.

Mill waste can do that. It returns carbon to the soil and blunts climate impacts. Composting with high nitrogen waste, like food, sequesters carbon and avoids emissions from synthetic fertilizer and landfills. Wood chip mulch prevents storm runoff and erosion. Recycled wood products save trees.

Do not support timber industry's insistence on biomass power. Lead the industry to these other alternatives.

Monetary profit won't matter to future generations when the planet is unfit for life due to climate change.

You have the power to act now to help future generations manage climate change.

Please do the right thing: reject biomass burning in favor of solar, wind, and battery storage.

Terri Bonow MLIS