Expert survey on carbon cycle modelling

Dear participant,

Thank you for agreeing to participate in our expert survey about the representation of the carbon cycle in Earth System Models (ESMs) and Integrated Assessment Models (IAMs) and its role for analyzing Carbon Dioxide Removal (CDR).

The survey will take between 15 and 20 minutes to complete. You can interrupt the survey at any time, store your responses and resume later (see top right corner).

Your responses will be handled anonymously. The record of your survey responses does not contain any identifying information about you. Your access to this survey is personalized, but your individual link will not be stored together with your responses.

If you have any questions about the survey or any technical problems please do not hesitate to contact Christine Merk (Christine.Merk@ifw-kiel.de).

Please use only the 'Next' button at the bottom of the page to navigate, not the back button of your browser .

There are 52 questions in this survey.

What kind of model do you mainly use for your research on CDR?
Please refer to this model when you are asked about the `model that you use´ or `your model´ in the following questions.
*

❶ Choose one of the following answers
Please choose **only one** of the following:

◯ Detailed process Integrated Assessment Model
◯ Benefit-cost Integrated Assessment Model
◯ Earth System Model of full complexity
◯ Earth System Model of intermediate complexity
◯ Other type of Climate Model
◯ Other [   ]

How is the carbon cycle represented in the Integrated Assessment Model that you use? *

Only answer this question if the following conditions are met:
G1Q00001 (/admin/questions/sa/view/surveyid/874333/gid/41/qid/842) == 'A1' OR G1Q00001 (/admin/questions/sa/view/surveyid/874333/gid/41/qid/842) == 'A2'

❶ Choose one of the following answers
Please choose **only one** of the following:

◯ impulse-response representation
◯ linear box-type representation
◯ non-linear box-type representation
◯ combination of impulse-response and linear box-type representation
◯ combination of impulse-response and non-linear box-type representation
◯ There is no carbon cycle representation.
◯ don't know

Which component(s) of the Earth System do you mainly research? *

Only answer this question if the following conditions are met:
G1Q00001 (/admin/questions/sa/view/surveyid/874333/gid/41/qid/842) >= 'A3'

❶ Check all that apply
Please choose **all** that apply:

☐ atmospheric physics
☐ atmospheric chemistry
☐ ocean physics
☐ ocean biogeochemistry
☐ ocean sediments
☐ sea ice
☐ land ice
☐ terrestrial biosphere
☐ Other: [   ]

Which of the CDR methods listed below can be assessed with the Integrated Assessment Model that you use? *

Only answer this question if the following conditions are met:
G1Q00001 (/admin/questions/sa/view/surveyid/874333/gid/41/qid/842) == 'A1' OR G1Q00001 (/admin/questions/sa/view/surveyid/874333/gid/41/qid/842) == 'A2'

❶ Check all that apply
Please choose **all** that apply:

- [ ] Artificial Ocean Alkalinization (AOA)
- [ ] Afforestation (AF)
- [ ] Enhanced Weathering on Land (EW)
- [ ] Bioenergy with Carbon Capture and Storage (BECCS)
- [ ] Direct Air Capture of CO_2 with Storage (DACCS)
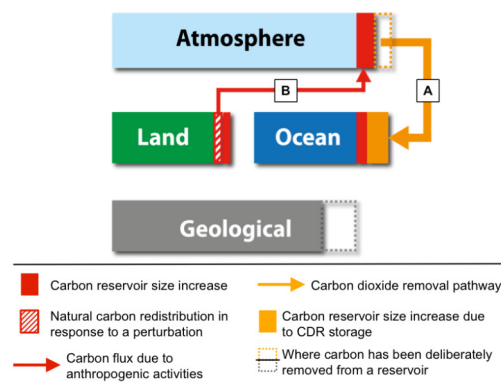- [ ] None of the above
- [ ] don't know

Figure: Global net negative emissions with **AOA**

When determining the net removal potential of <u>artificial ocean alkalinization</u> (AOA): Does your IAM account for the following carbon dioxide removal (CDR) pathway(s) and fluxes (**A** and **B**, respectively, see Fig. above) implicitly, explicitly or nor at all?

Only answer this question if the following conditions are met:
((G2Q00001_SQ001.NAOK (/admin/questions/sa/view/surveyid/874333/gid/44/qid/851) == "Y"))

Please choose the appropriate response for each item:

	not at all	implicitly	explicitly	don't know
CDR pathway (A): atmosphere-to-ocean	○	○	○	○
terrestrial carbon cycle response (B)	○	○	○	○

What do you think, are the respective CDR pathway(s) or fluxes in your IAM sufficiently or insufficiently represented to assess the efficiency of **artificial ocean alkalinization**?

Please choose the appropriate response for each item:

|	insufficiently	somewhat sufficiently	sufficiently	don't know
CDR pathway (A): atmosphere-to-ocean	○	○	○	○
terrestrial carbon cycle response (B)	○	○	○	○

What general information or input from the Earth System Modelling community (e.g. parameterizations) would you need to improve the representation of **artificial ocean alkalinization** in your IAM? Please fill in keywords.

Only answer this question if the following conditions are met:
((G2Q00001_SQ001.NAOK (/admin/questions/sa/view/surveyid/874333/gid/44/qid/851) == "Y"))

Please write your answer here:

Afforestation (AF)
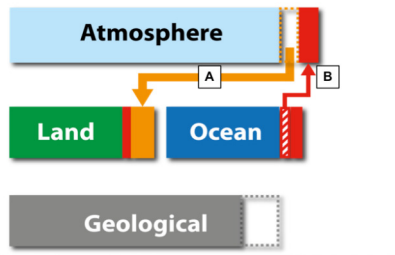
■ Carbon reservoir size increase	→ Carbon dioxide removal pathway
▨ Natural carbon redistribution in response to a perturbation	■ Carbon reservoir size increase due to CDR storage
→ Carbon flux due to anthropogenic activities	⌐ Where carbon has been deliberately removed from a reservoir

Figure: Global net negative emissions with **AF**

When determining the net removal potential of <u>afforestation</u> (AF): Does your IAM account for the carbon dioxide removal (CDR) pathway(s) and fluxes (**A** and **B**, respectively, see Fig. above) implicitly, explicitly or not at all?

Only answer this question if the following conditions are met:
((G2Q00001_SQ002.NAOK (/admin/questions/sa/view/surveyid/874333/gid/44/qid/851) == "Y"))

Please choose the appropriate response for each item:

	not at all	implicitly	explicitly	don't know
CDR pathway (A): atmosphere-to-terrestrial	○	○	○	○
ocean carbon cycle response (B)	○	○	○	○

What do you think, are the respective CDR pathway(s) or fluxes in your IAM sufficiently or insufficiently represented to assess the efficiency of **afforestation**?

Please choose the appropriate response for each item:

	insufficiently	somewhat sufficiently	sufficiently	don't know
CDR pathway (A): atmosphere-to-terrestrial	○	○	○	○
ocean carbon cycle response (B)	○	○	○	○

What general information or input from the Earth System Modelling community (e.g. parameterizations) would you need to improve the representation of **Afforestation** in your IAM? Please fill in keywords.

Only answer this question if the following conditions are met:
((G2Q00001_SQ002.NAOK (/admin/questions/sa/view/surveyid/874333/gid/44/qid/851) == "Y"))

Please write your answer here:

[ ]

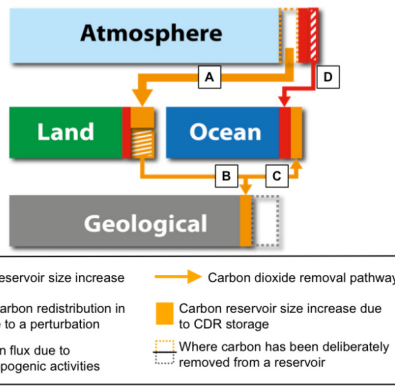**Enhanced weathering on land (EW)**

Figure: Global net negative emissions with **EW**

When determining the net removal potential of <u>enhanced weathering on land</u> (EW): Does your IAM account for the carbon dioxide removal (CDR) pathway(s) and fluxes **(A, B, C** and **D**, respectively, see Fig. above) implicitly, explicitly or not at all?

Only answer this question if the following conditions are met:
((G2Q00001_SQ003.NAOK (/admin/questions/sa/view/surveyid/874333/gid/44/qid/851) == "Y"))

Please choose the appropriate response for each item:

	not at all	implicitly	explicitly	don't know
CDR pathway (A): atmosphere-to-terrestrial	○	○	○	○
CDR pathway (B): terrestrial-to-geological	○	○	○	○
CDR pathway (C): terrestrial-to-ocean	○	○	○	○
ocean carbon cycle response (D)	○	○	○	○

What do you think, are the respective CDR pathway(s) or fluxes in your IAM sufficiently or insufficiently represented to assess the efficiency of **enhanced weathering on land**?

Please choose the appropriate response for each item:

	insufficiently	somewhat sufficiently	sufficiently	don't know
CDR pathway (A): atmosphere-to-terrestrial	○	○	○	○
CDR pathway (B): terrestrial-to-geological	○	○	○	○
CDR pathway (C): terrestrial-to-ocean	○	○	○	○
ocean carbon cycle response (D)	○	○	○	○

What general information or input from the Earth System Modelling community (e.g. parameterizations) would you need to improve the representation of **enhanced weathering on land** in your IAM? Please fill in keywords.

Only answer this question if the following conditions are met:
((G2Q00001_SQ003.NAOK (/admin/questions/sa/view/surveyid/874333/gid/44/qid/851) == "Y"))

Please write your answer here:
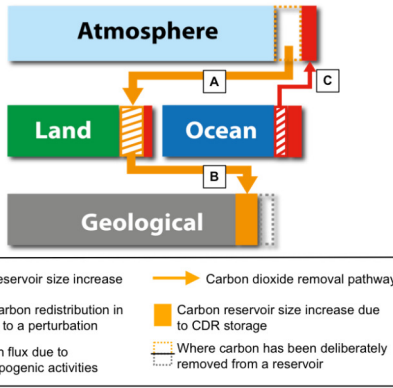
Bioenergy with carbon capture and storage (BECCS)

Figure: Global net negative emissions with **BECCS**

When determining the net removal potential of <u>bioenergy with carbon capture and storage</u> (BECCS): Does your IAM account for the carbon dioxide removal (CDR) pathway(s) and fluxes (**A**, **B** and **C**, respectively, see Fig. above) implicitly, explicitly or not at all?

Only answer this question if the following conditions are met:
((G2Q00001_SQ004.NAOK (/admin/questions/sa/view/surveyid/874333/gid/44/qid/851) == "Y"))

Please choose the appropriate response for each item:

	not at all	implicitly	explicitly	don't know
CDR pathway (A): atmosphere-to-terrestrial	○	○	○	○
CDR pathway (B): terrestrial-to-geological	○	○	○	○
ocean carbon cycle response (C)	○	○	○	○

What do you think, are the respective CDR pathway(s) or fluxes in your IAM sufficiently or insufficiently represented to assess the efficiency of **BECCS**?

Please choose the appropriate response for each item:

	insufficiently	somewhat sufficiently	sufficiently	don't know
CDR pathway (A): atmosphere-to-terrestrial	○	○	○	○
CDR pathway (B): terrestrial-to-geological	○	○	○	○
ocean carbon cycle response (C)	○	○	○	○

What general information or input from the Earth System Modelling community (e.g. parameterizations) would you need to improve the representation of **BECCS** in your IAM? Please fill in keywords.

Only answer this question if the following conditions are met:
((G2Q00001_SQ004.NAOK (/admin/questions/sa/view/surveyid/874333/gid/44/qid/851) == "Y"))

Please write your answer here:

Direct air capture of CO$_2$ with storage (DACCS)
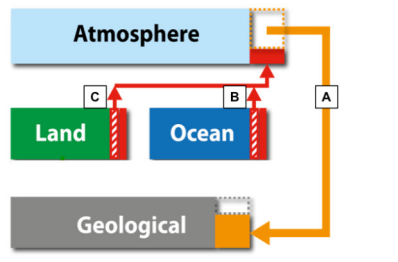
Figure: Global net negative emissions with **DACCS** perturbation

When determining the net removal potential of direct air capture of CO$_2$ with storage (DACCS): Does your IAM account for the carbon dioxide removal (CDR) pathway(s) and fluxes (**A**, **B** and **C**, respectively, see Fig. above) implicitly, explicitly or not at all?

Only answer this question if the following conditions are met:
((G2Q00001_SQ005.NAOK (/admin/questions/sa/view/surveyid/874333/gid/44/qid/851) == "Y"))

Please choose the appropriate response for each item:

	not at all	implicitly	explicitly	don't know
CDR pathway (A): atmosphere-to-geological	○	○	○	○
ocean carbon cycle response (B)	○	○	○	○
terrestrial carbon cycle response (C)	○	○	○	○

What do you think, are the respective CDR pathway(s) or fluxes in your IAM sufficiently or insufficiently represented to assess the efficiency of **DACCS**?

Please choose the appropriate response for each item:

	insufficiently	somewhat sufficiently	sufficiently	don't know
CDR pathway (A): atmosphere-to-geological	○	○	○	○
ocean carbon cycle response (B)	○	○	○	○
terrestrial carbon cycle response (C)	○	○	○	○

What general information or input from the Earth System Modelling community (e.g. parameterizations) would you need to improve the representation of **DACCS** in your IAM? Please fill in keywords.

Only answer this question if the following conditions are met:
((G2Q00001_SQ005.NAOK (/admin/questions/sa/view/surveyid/874333/gid/44/qid/851) == "Y"))

Please write your answer here:

We will show you schematic representations of how the main carbon flows between atmospheric, terrestrial, ocean and geological reservoirs might change due to a substantial amount of net negative emissions via the prolonged deployment of various CDR methods. In the subsequent questions *"carbon dioxide removal pathways"* refers to the respective CDR technology's direct intervention.

We will ask you about the CDR methods artificial ocean alkalinization, enhanced weathering on land, afforestation, bioenergy with carbon capture and storage, and direct air capture of CO$_2$ with storage.

Please choose **only one** of the following:

○ Click here if you would like to see some additional information about these technologies. Otherwise just continue.

Artificial ocean alkalinization (AOA)

Increase the alkalinity of the upper ocean to chemically increase the carbon storage capacity of seawater and thus, also increase CO_2 uptake

Afforestation

Plant or restore forests to increase CO_2 uptake (via primary production) and storage in biomass and soils

Enhanced weathering on land

Spread alkaline minerals on land to chemically remove CO_2 from the atmosphere in reactions that form ions, which are eventually transported to the ocean or in some cases solid minerals (geological sequestration), may also enhance vegetation productivity and subsequently soil carbon storage

Bioenergy with carbon capture and storage (BECCS)

Grow terrestrial vegetation and use the biomass to create biofuels that can be burned in conjunction with carbon capture and storage technology

Direct air capture of CO_2 with storage (DACCS)

Technology that chemically or electro-chemically removes CO_2 from air and concentrates it for storage

Only answer this question if the following conditions are met:
TCDRhelp (/admin/questions/sa/view/surveyid/874333/gid/47/qid/2349) == 'A1'

Artificial ocean alkalinization (AOA)

Carbon reservoir size increase
Natural carbon redistribution in response to a perturbation
Carbon flux due to anthropogenic activities
Carbon dioxide removal pathway
Carbon reservoir size increase due to CDR storage
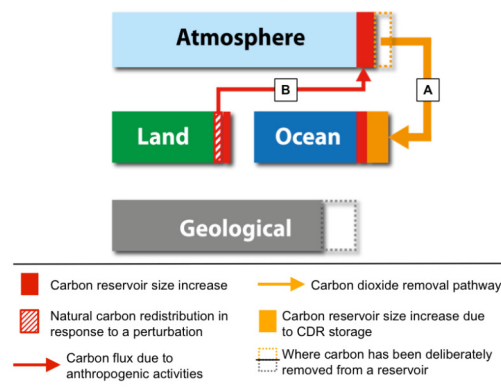Where carbon has been deliberately removed from a reservoir

Figure: Global net negative emissions with **AOA**

What do you think, does your model sufficiently or insufficiently represent the processes required to simulate the carbon dioxide removal pathway(s) (**A,** see Fig. above) of artificial ocean alkalinization (AOA)?

Please choose the appropriate response for each item:

	insufficiently	somewhat sufficiently	sufficiently	don't know
CDR pathway (A): atmosphere-to-ocean	○	○	○	○

What processes should be improved in your model in order to better simulate the **artificial ocean alkalinization** induced CDR pathway (**A**, see Fig. above)? Please limit your answer to the three most important processes.

Please write your answer here:

What do yo think, how important would it be to improve the factors listed below in your model to better simulate the terrestrial carbon cycle response (**B**, see Fig. above) to **artificial ocean alkalinization**?

Please choose the appropriate response for each item:

	not at all important	somewhat unimportant	somewhat important	very important	don't know
CO_2 fertilization parameterization	○	○	○	○	○
soil carbon cycling	○	○	○	○	○
hydrology and inland waters	○	○	○	○	○
vegetation representation	○	○	○	○	○
permafrost	○	○	○	○	○
representation of land-use change	○	○	○	○	○
disturbances (fires and pests)	○	○	○	○	○

Afforestation (AF)

Figure: Global net negative emissions with **AF**

What do you think, does your model sufficiently or insufficiently represent the processes required to simulate the carbon dioxide removal pathway (**A**, see Fig. above) of afforestation?

Please choose the appropriate response for each item:

	insufficiently	somewhat sufficiently	sufficiently	don't know
CDR pathway (A): atmosphere-to-terrestrial	○	○	○	○

What processes should be improved in your model in order to better simulate the **afforestation** induced carbon dioxide removal pathway (**A**, see Fig. above)? Please limit your answer to the three most important processes.

Please write your answer here:

What do you think, how important would it be to improve the factors listed below in your model to better simulate the ocean carbon cycle response (**B**, see Fig. above) to **afforestation**?

Please choose the appropriate response for each item:

	not at all important	somewhat unimportant	somewhat important	very important	don't know
air-sea gas exchange parameterization	○	○	○	○	○
ocean physical transport	○	○	○	○	○
carbonate chemistry	○	○	○	○	○
biology and biological pump	○	○	○	○	○
marine sediments	○	○	○	○	○
sea ice representation	○	○	○	○	○
biogeochemistry along the land-ocean continuum	○	○	○	○	○

Enhanced weathering on land (EW)

Figure: Global net negative emissions with **EW**

What do you think, does your model sufficiently or insufficiently represent the processes required to simulate the carbon dioxide removal pathways (**A**, **B** and **C**, respectively, see Fig. above) of <u>enhanced weathering on land (EW)</u>?

Please choose the appropriate response for each item:

	insufficiently	somewhat sufficiently	sufficiently	don't know
CDR pathway (A): atmosphere-to-terrestrial	○	○	○	○
CDR pathway (B): terrestrial-to-geological	○	○	○	○
CDR pathway (C): terrestrial-to-ocean	○	○	○	○

What processes should be improved in your model in order to better simulate the **enhanced weathering on land** induced carbon dioxide removal pathway (**A**, **B** and **C**, see Fig. above)? Please limit your answer to the three most important processes.
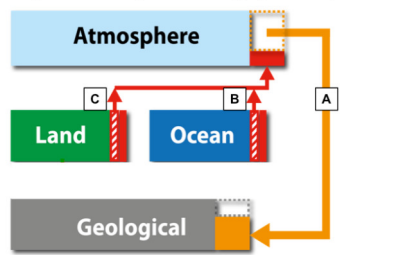
Please write your answer here:

What do you think, how important would it be to improve the factors listed below in your model to better simulate the ocean carbon cycle response (**D**, see Fig. above) to **enhanced weathering on land**?

Please choose the appropriate response for each item:

	not at all important	somewhat unimportant	somewhat important	very important	don't know
air-sea gas exchange parameterization	○	○	○	○	○
ocean physical transport	○	○	○	○	○
carbonate chemistry	○	○	○	○	○
biology and biological pump	○	○	○	○	○
marine sediments	○	○	○	○	○
sea ice representation	○	○	○	○	○
biogeochemistry along the land-ocean continuum	○	○	○	○	○

Bioenergy with carbon capture and storage (BECCS)
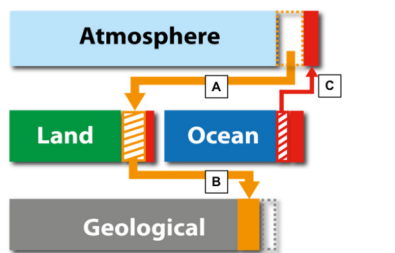
- ■ Carbon reservoir size increase
- ▨ Natural carbon redistribution in response to a perturbation
- → Carbon flux due to anthropogenic activities
- → Carbon dioxide removal pathway
- ■ Carbon reservoir size increase due to CDR storage
- ⋯ Where carbon has been deliberately removed from a reservoir

Figure: Global net negative emissions with **BECCS**

What do you think, does your model sufficiently or insufficiently represent the processes required to simulate the carbon dioxide removal pathways (**A** and **B**, respectively, see Fig. above) of <u>bioenergy with carbon capture and storage</u> (BECCS)?

Please choose the appropriate response for each item:

	insufficiently	somewhat sufficiently	sufficiently	don't know
CDR pathway (A): atmosphere-to-terrestrial	○	○	○	○
CDR pathway (B): terrestrial-to-geological	○	○	○	○

What processes should be improved in your model in order to better simulate the **BECCS** induced carbon dioxide removal pathways (**A** and **B**, respectively, see Fig. above)? Please limit your answer to the three most important processes.

Please write your answer here:

What do you think, how important would it be to improve the factors listed below in your model to better simulate the ocean carbon cycle response (**C**, see Fig. above) to **BECCS**?

Please choose the appropriate response for each item:

	not at all important	somewhat unimportant	somewhat important	very important	don't know
air-sea gas exchange parameterization	○	○	○	○	○
ocean physical transport	○	○	○	○	○
carbonate chemistry	○	○	○	○	○
biology and biological pump	○	○	○	○	○
marine sediments	○	○	○	○	○
sea ice representation	○	○	○	○	○
biogeochemistry along the land-ocean continuum	○	○	○	○	○

Figure: Global net negative emissions with **DACCS** perturbation

What do you think, does your model sufficiently or insufficiently represent the processes required to simulate the carbon dioxide removal pathway (**A**, see Fig. above) of direct air capture of CO_2 with storage (DACCS)?

Please choose the appropriate response for each item:

	insufficiently	somewhat sufficiently	sufficiently	don't know
CDR pathway (A): atmosphere-to-geological	○	○	○	○

What processes should be improved in your model in order to better simulate the **DACCS** induced carbon dioxide removal pathway (**A**, see Fig. above)? Please limit your answer to the three most important processes.

Please write your answer here:

What do you think, how important would it be to improve the factors listed below in your model to better simulate the <u>ocean carbon cycle response</u> (**B**, see Fig. above) to **DACCS**?

Please choose the appropriate response for each item:

	not at all important	somewhat unimportant	somewhat important	very important	don't know
air-sea gas exchange parameterization	○	○	○	○	○
ocean physical transport	○	○	○	○	○
carbonate chemistry	○	○	○	○	○
biology and biological pump	○	○	○	○	○
marine sediments	○	○	○	○	○
sea ice representation	○	○	○	○	○
biogeochemistry along the land-ocean continuum	○	○	○	○	○

What do you think, how important would it be to improve the factors listed below in your model to better simulate the <u>terrestrial carbon cycle response</u> (**C**, see Fig. above) to **DACCS**?

Please choose the appropriate response for each item:

	not at all important	somewhat unimportant	somewhat important	very important	don't know
CO_2 fertilization parameterization	○	○	○	○	○
soil carbon cycling	○	○	○	○	○
hydrology and inland waters	○	○	○	○	○
vegetation representation	○	○	○	○	○
permafrost	○	○	○	○	○
representation of land-use change	○	○	○	○	○
disturbances (e.g. fires and pests)	○	○	○	○	○

How likely do you consider greenhouse gas emission scenarios until the year 2100 without negative carbon emissions that are at the same time compatible with the 2° climate target?

Please choose the appropriate response for each item:

very unlikely	somewhat unlikely	somewhat likely	very likely	don't know
○	○	○	○	○

Do you agree or disagree that the model development of your model family should also be guided by the requirements for assessing negative emissions via CDR methods?

Please choose the appropriate response for each item:

disagree	somewhat disagree	somewhat agree	agree	don't know
○	○	○	○	○

Assume there is a future climate policy portfolio including various CDR methods. In your view, which of the following terrestrial and marine CDR methods would you include in this portfolio?

❶ Check all that apply
Please choose **all** that apply:

- [ ] Direct air capture of CO_2 with storage
- [ ] Bioenergy with carbon capture and storage (BECCS)
- [ ] Soil carbon sequestration (e.g., no-till farming)
- [ ] Afforestation
- [ ] Biochar
- [ ] Enhanced weathering on land
- [ ] Ocean alkalinization
- [ ] Ocean iron fertilization
- [ ] Artificial ocean upwelling
- [ ] Blue carbon (i.e., enhancing natural ocean carbon sinks by mangroves, seagrasses or salt marshes)
- [ ] None of them
- [ ] Don't know

How well can the current version of your model simulate the portfolio of CDR methods you have just put together?

Only answer this question if the following conditions are met:
(is_empty(G6Q00002_SQ011.NAOK (/admin/questions/sa/view/surveyid/874333/gid/42/qid/847))) and (is_empty(G6Q00002_SQ012.NAOK (/admin/questions/sa/view/surveyid /874333/gid/42/qid/847)))

Please choose the appropriate response for each item:

not at all	poorly	decently	very well	don't know
○	○	○	○	○

What do you think, are the following factors a weak, a strong or no constraint on the feasibility of the terrestrial CDR methods listed below?

If you want to know more about the technologies you can open an infomation box below this question.

Please insert the numbers, which represent the strength of the constraint for every factor and every CDR method:
-1 for 'don't know'
0 for 'no constraint'
1 for 'weak constraint'
2 for 'medium constraint'
3 for 'strong constraint'

❶ Only numbers may be entered in these fields.
❶ Each answer must be between -1 and 3

	Enhanced weathering on land	BECCS	Soil carbon sequestration	Afforestation	Biochar
carbon cycle responses/feedbacks (e.g. ocean carbon outgassing due to deliberate terrestrial carbon uptake)	☐	☐	☐	☐	☐
climate feedbacks (e.g. change in albedo)	☐	☐	☐	☐	☐
non-CO_2 forcing (e.g. methane)	☐	☐	☐	☐	☐
physical CO_2 removal capacity	☐	☐	☐	☐	☐
resource competition (e.g. land availability)	☐	☐	☐	☐	☐
environmental and human health side effects	☐	☐	☐	☐	☐
cost effectiveness	☐	☐	☐	☐	☐
political feasibility (incl. public acceptance)	☐	☐	☐	☐	☐

Please choose **only one** of the following:

○ Click here to open the info box about the terrestrial CDR methods listed above.

Info box: Terrestrial CDR methods

Enhanced weathering on land

Spread alkaline minerals on land to chemically remove CO_2 from the atmosphere in reactions that form ions, which are eventually transported to the ocean or in some cases solid minerals (geological sequestration), may also enhance vegetation productivity and subsequently soil carbon storage

Bioenergy with carbon capture and storage (BECCS)

Grow terrestrial vegetation and use the biomass to create biofuels that can be burned in conjunction with carbon capture and storage technology

Soil and land carbon management

Employ management practices, such as no-till agriculture, irrigation, cover crops, compost amendments, wetland restoration, and fire management, to increase C retention and storage in agricultural soils or managed natural lands

Afforestation

Plant or restore forests to increase CO_2 uptake (via primary production) and storage in biomass and soils

Biochar

Pyrolyze terrestrial biomass to form biochar and add it to soils where the C can remain sequestered (biochar is recalcitrant); biochar amendments may also enhance vegetation productivity and soil carbon storage

Only answer this question if the following conditions are met:
MCDRhelpchoose2 (/admin/questions/sa/view/surveyid/874333/gid/42/qid/2353) == 'A1'

Just as you did in the previous question.
Please insert the numbers, which represent the strength of the constraint for each factor on the feasibility of each CDR method.

If you want to know more about the technologies you can open an infomation box below this question.

-1 for 'don't know'
0 for 'no constraint'
1 for 'weak constraint'
2 for 'medium constraint'
3 for 'strong constraint'

❶ Only numbers may be entered in these fields.
❶ Each answer must be between -1 and 3

	Ocean alkalinization	Ocean iron fertilization	Artificial ocean upwelling	Blue carbon	Direct air capture of CO_2 with storage
carbon cycle responses/feedbacks (e.g. ocean carbon outgassing due to deliberate terrestrial carbon uptake)	☐	☐	☐	☐	☐
climate feedbacks (e.g. change in albedo)	☐	☐	☐	☐	☐
non-CO_2 forcing (e.g. methane)	☐	☐	☐	☐	☐
physical CO_2 removal capacity	☐	☐	☐	☐	☐
resource competition (e.g. land availability)	☐	☐	☐	☐	☐
environmental and human health side effects	☐	☐	☐	☐	☐
cost effectiveness	☐	☐	☐	☐	☐
political feasibility (incl. public acceptance)	☐	☐	☐	☐	☐

Please choose **only one** of the following:

◯ Click here to open the info box about the marine CDR methods listed above.

> *Info box:* **Marine CDR methods and DACCS**
>
> **Artificial ocean alkalinization (AOA)**
>
> Increase the alkalinity of the upper ocean to chemically increase the carbon storage capacity of seawater and thus, also increase CO_2 uptake
>
> **Ocean iron fertilization**
>
> Add micronutrients like iron to increase phytoplankton growth (CO_2 fixation) and ocean carbon storage via the biological pump (the transport of this fixed carbon into the deep ocean)
>
> **Artificial ocean upwelling**
>
> Use pipes or other methods to pump nutrient rich deep ocean water to the surface where it has a fertilizing effect; see ocean fertilization above
>
> **Blue carbon**
>
> Enhancing natural ocean carbon sinks by mangroves, seagrasses or salt marshes
>
> **Direct air capture of CO_2 with storage (DACCS)**
>
> Technology that chemically or electro-chemically removes CO_2 from air and concentrates it for storage
>
> Only answer this question if the following conditions are met:
> **MCDRhelp3 (/admin/questions/sa/view/surveyid/874333/gid/42/qid/2355) == 'A1'**

For how many years have you already been working in research?

❶ Choose one of the following answers
Please choose **only one** of the following:

◯ <3 years
◯ 3-5 years
◯ 6-10 years
◯ 11-15 years
◯ >15 years

For how many years have you already been researching CDR?

❶ Choose one of the following answers
Please choose **only one** of the following:

◯ <1 year
◯ 1-2 years
◯ 3-5 years
◯ 6-10 years
◯ >10 years
◯ I do not research CDR.

What are your main research interests with respect to CDR?

Please fill in keywords.

Only answer this question if the following conditions are met:
G6Q00007 (/admin/questions/sa/view/surveyid/874333/gid/42/qid/840) >= 'A2'

Please write your answer here:

What are your current research topics? Please fill in keywords.

Only answer this question if the following conditions are met:
G6Q00007 (/admin/questions/sa/view/surveyid/874333/gid/42/qid/840) == 'A1'

Please write your answer here:

Do you have any comments or suggestions about the survey?

Please write your answer here:

Thank you for taking the time to complete the survey! We truly value the information you have provided.

If you want to be informed about the results of the survey or can recommend any postdoc(s) from your group who should also participate in this survey, please send an email to Fabian Reith (freith@geomar.de).

Have a good day!

05.01.2019 – 12:45

Submit your survey.
Thank you for completing this survey.