IEA Bioenergy
Technology Collaboration Programme

Bio-CCS and bioenergy flexibility - Finding the balance

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Intro: the starting point

How to implement climate mitigation scenarios or pathways and their respective measures in order to stay well below 2°C of global warming

Key pillars of decarbonisation of the global energy system

1. energy efficiency,
2. behavioural changes,
3. electrification,
4. renewables,
5. hydrogen and hydrogen-based fuels,
6. bioenergy and CCUS

Bioenergy perspective in this energy system transfromation

1. direct substitution of fossil fuels low-carbon energy supply
2. providing energy and climate system services

Intro: Focus of the research

- system perspective of bioenergy which is at the core of IEA Bioenergy Task 40 and IEA Bioenergy Task 44

- (bio)energy and climate system services of the bioenergy sector
  - Bio-CCS and
  - Flexible Bioenergy

- How to actually implement and bring Bio-CCS and Flexible Bioenergy into a (broader and faster) deployment, if required?

- still work in progress!!

Why is this important?

- Bio-CCS and flexibility - in the form of flexible bioenergy - are expected to be two of the more important characteristics for bioenergy systems of the future and services for a low-carbon energy system.

- It is important to see how these two aspects interact and find strategies for how these interactions can come in the form of synergies rather than trade-offs.

Background: The Role of Bio-CCS

- one of the main CDR technologies discussed ☞
- Bio-CCS can be implemented essentially anywhere there are biogenic CO_2 emissions
- Bio-CCS can be implemented in a broad range of sectors with sizeable quantities of biogenic emissions of CO_2

Table A.3: Electricity

	Electricity Generation (TWh)					Shares (%)			CAAGR (%)	
	2019	2020	2030	2040	2050	2020	2030	2050	2020-2030	2020-2050
Total generation	**26 922**	**26 778**	**37 316**	**56 553**	**71 164**	**100**	**100**	**100**	**3.4**	**3.3**
Renewables	7 153	7 660	22 817	47 521	62 333	29	61	88	12	7.2
Solar PV	665	821	6 970	17 031	23 469	3	19	33	24	12
Wind	1 423	1 592	8 008	18 787	24 785	6	21	35	18	9.6
Hydro	4 294	4 418	5 870	7 445	8 461	17	16	12	2.9	2.2
Bioenergy	665	718	1 407	2 676	3 279	3	4	5	7.0	5.2
of which BECCS	-	-	*129*	*673*	*842*	-	*0*	*1*	*n.a.*	*n.a.*
CSP	14	14	204	880	1 386	0	1	2	31	17
Geothermal	92	94	330	625	821	0	1	1	13	7.5
Marine	1	2	27	77	132	0	0	0	28	14
Nuclear	2 792	2 698	3 777	4 855	5 497	10	10	8	3.4	2.4
Hydrogen-based	-	-	875	1 857	1 713	-	2	2	n.a.	n.a.
Fossil fuels with CCUS	1	4	459	1 659	1 332	0	1	2	61	21
Coal with CCUS	1	4	289	966	663	0	1	1	54	19
Natural gas with CCUS	-	-	170	694	669	-	0	1	n.a.	n.a.
Unabated fossil fuels	16 941	16 382	9 358	632	259	61	25	0	-5.4	-13
Coal	9 832	9 426	2 947	0	0	35	8	0	-11	-40
Natural gas	6 314	6 200	6 222	626	253	23	17	0	0.0	-10
Oil	795	756	189	6	6	3	1	0	-13	-15

Source: IEA Roadmap Net Zero Emissions by 2050

Background: The Role of Flexible Bioenergy

- usually understood as providing flexibility from bioenergy a service for the electricity system
- the energy transition also requires flexibility measures in different and more sectors - including industrial and space heating but also e.g. provision of transportation services and in the broader bioeconomy
- Flexibility from bionergy also in terms of inputs, outputs and further energy system services
- IEA Bioenergy Task 44 definition Flexible Bioenergy: *"…a bioenergy system that can provide multiple services and benefits to the energy system under varying operating conditions and/or loads"* (source: IEA Bioenergy Task 44 – Flexible bioenergy and system integration)

The challenges of Bio-CCS & Flex

1. Bio-CCS and Flex are implemented at different speed
   - Bio-CCS actual implementation has become the subject of serious consideration only in the last five years
   - Flexible Bioenergy already in place for grid stability

2. The opportunities and challenges pertaining to taking Bio-CCS from pilots to full-scale projects (technological aspects, business models, regulations)

3. A key aspect of integration of Bio-CCS in already operating systems is how the addition of carbon capture and storage interacts with existing modi operandi, technologically, business models and value chain configurations.

4. Identifying and implementing approaches for how Bio-CCS systems can be deployed and integrated in ways that maximize benefits in terms of climate change mitigation - as well as in terms of energy system integration and sustainability ambitions more broadly - is highly important.

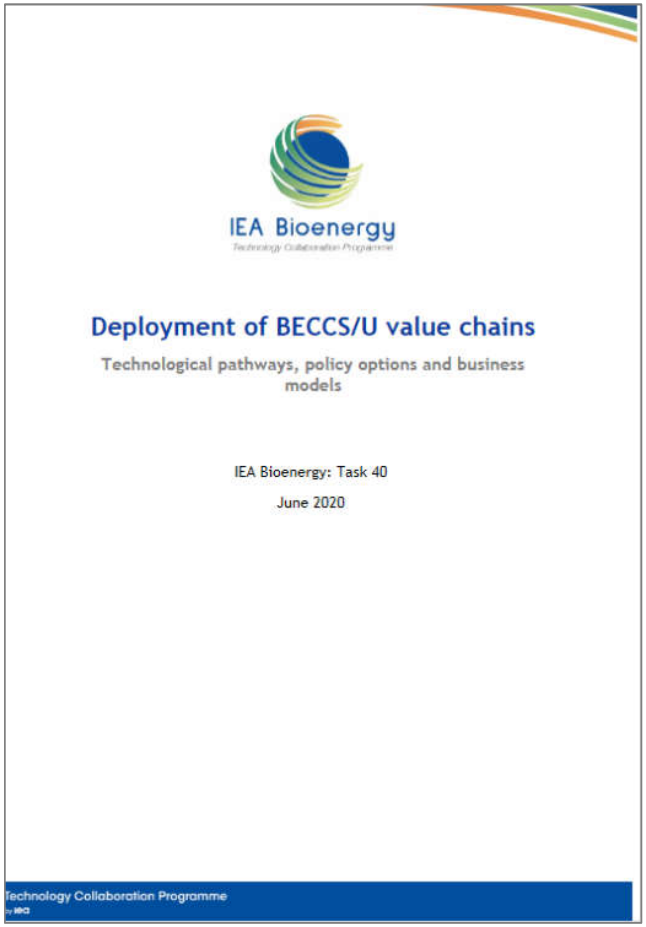
Questions to be addressed

- Where and how do Bio-CCS and flexibility interact in biobased value chains and what are the implications for the (bio)energy system?

- How can the implementation of Bio-CCS solutions in different sectors can be combined with different forms of bioenergy flexibility (in terms of inputs, shifting between different outputs and varying outputs over time)?

Approach

- Sample case studies of different sectors with Bio-CCS applications
  - biomass based combined heat and power
  - waste-to-energy
  - bioelectricity
  - bioethanol
  - cement
- Case studies from publication „Deployment of bio-CCS case studies“ ☞
- How could a more flexible operation (provided by bioenergy) of the production chains of the various sectors in combination with CCS look like?



Preliminary understanding & findings #1

- combining CCS and a flexible operation is possible from a technological point of view
- a more flexible operation in current mode of operandi may lead to a lower level of CO_2 captured per installation due to ramping up and down
- first research on combining flexibility and CCS

Preliminary understanding & findings #2

- status quo: decision for the type of operation guided by electricity market prices or other incentive schemes for providing flexibility services and by the potential revenue generated from carbon dioxide removal

- Bio-CCS is important for the climate system to generate negative emissions and may add problems for the energy system in the absence of a mechanism that rewards CO_2 removal

- considering CCU (carbon capture & utilization) a constant CO_2 capture rate could be required CO_2-utilization concepts and business models

Preliminary understanding & findings #3

- Assessment matrix: example electricity sector (work in progress!!)

Sector	Techno-economic issues	Negative emissions possible?	Bio-CCS or Bio-CCU?	Business model	Importance of Bio-CCUS?	Main other decarb options	Key flexibility aspects (input, output, grid stability)	Synergies, trade-offs and/or challenges applying flexibility and Bio-CCS/U
Electricity	Optimize on CO_2 capture or electricity value?	Yes	Both possible	Policy incentives for negative emissions	Nice to have	Solar, wind,…	Flexibility both grid stability (ramping up and down) and in output, i.e., maximize CDR or electricity generation?	Bio-CCU: When operated flexibly a constant CO_2 capture rate can not be assured

Outlook

- decision makers need to be aware of implications for the deployment of Flexible Bioenergy and Bio-CCS when implementing pathway(s) for staying well below 2°C
- current support measures (premium, ETS etc.) need revision
- a key question is the exact policy design of CDR rewards

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