



IEA Bioenergy
Technology Collaboration Programme



**International Institute for
Applied Systems Analysis**

IIASA



IEA Bioenergy TCP

IEA ETSAP TCP Workshop

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The IEA Bioenergy Technology Collaboration Programme (TCP) is organised under the auspices of the International Energy Agency (IEA) but is functionally and legally autonomous. Views, findings and publications of the IEA Bioenergy TCP do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

Technology Collaboration Programme

by **iea**

IIASA - Founded during the Cold War to build bridges based on international interdisciplinary science and cooperation



International Institute for Applied Systems Analysis

Today this mission is more relevant than ever ...

Member states (accession dates)

Austria (1973)	Ukraine (1994)	Iran (2016)	Room at the table for more
Finland (1976)	Norway (1996)	South Korea (2017)	
Germany (1972)	China (2002)		
Japan (1972)			
Russia (1972)			
Sweden (1976)		Sub-Saharan Africa (2022)	
USA (1972)		United Kingdom (2015)	
		India (2007)	

**Are you a PhD student?
Join our Young Scientists Summer Program!
<https://iiasa.ac.at/early-career/yssp>**

IEA Bioenergy TCP

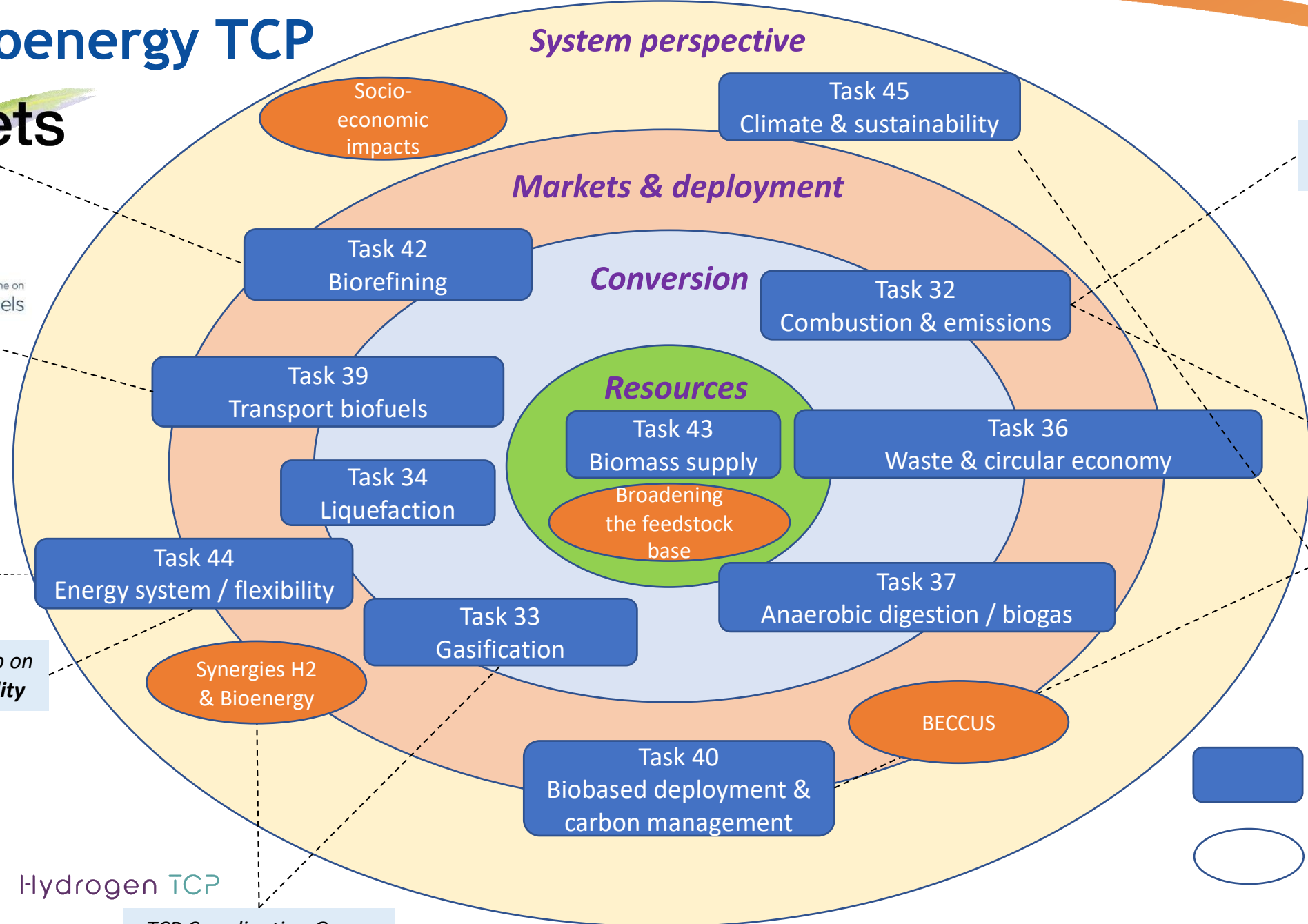
Industrial Energy-Related Technologies and Systems **ets**

AFUELS Technology Collaboration Programme on Advanced Motor Fuels

tsap ENERGY SYSTEMS ANALYSIS PROGRAM

Coordination Group on Energy System Flexibility

IEA **H₂** Hydrogen TCP
Bioenergy



TCP Coordination Group on **Hydrogen**

TCP Coordination Group on **Thermal Networks**



INTERNATIONAL CENTRE FOR SUSTAINABLE CARBON

TCP Coordination Group on **Carbon Management**



- Tasks
- Strategic projects (more Tasks/TCPs involved)
- Link with other TCPs & TCP Coordination Groups

IEA Bioenergy ExCo96 - 17-18.Nov 2025

Research Council of Norway, Oslo



Bioenergy carriers & technology pathways - manifoldness

Provisioning systems:

Food

Materials

Energy

Other

(e.g., Infra-maintenance, landscape ...)



Bioenergy carriers:

Solid

Liquid

Gaseous

Hybrid

(mixed with other renewables)



Energy needs:

Cooking

Heat

Power

Propulsion

Solar
Carbon

Bioenergy carriers & technology pathways - manifoldness

Simplified examples:

Construction wood > shavings > pellets > via road > res. heating

Sugar cane > fermentation > ethanol > refinery blending > transport

Wheat farm > straw > gasification > heat & power grids > heat & light

Consumed food > waste-water > biogas > gas grid > industrial heat

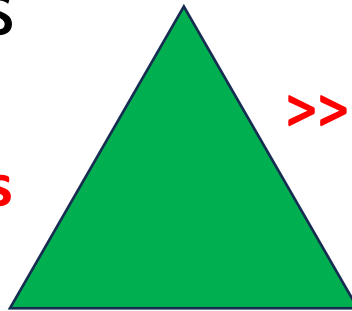
....

Societal contributions of these pathways

Food-materials-energy services:

Highly intertwined, the one needs the other, more synergies than trade-offs

IPBES Framework
Bioenergy processes



>>> Natures Contribution to People
>>> Extension to nature

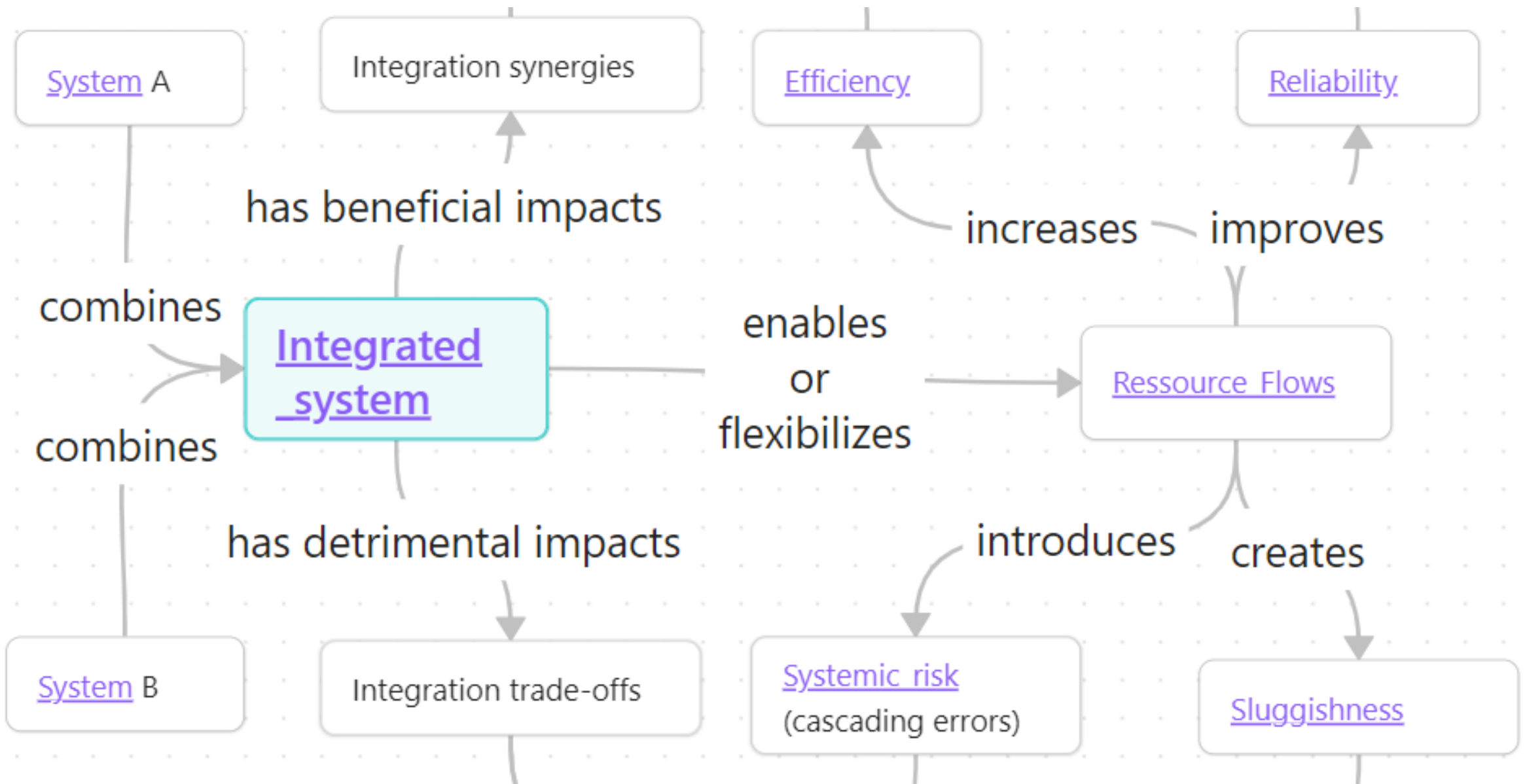
Non-tangible services:

Socio-economic, autonomous governance, education, connection to nature ...

Regulating services:

Recirculation of cleaned water, energy storage, short-, medium-, long term flexibility, carbon removal, ...

Regulating contributions - through system integration



System integration scopes

Scope 1

Process integration:

- On-site
- Process intensification
- Heat-network synthesis
- Hydrogen plus solar carbon
- ...

Scope 2

Industrial symbiosis:

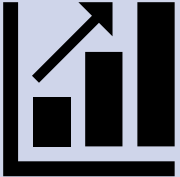


- Between-sites
- Residues from one resources for other
- Heat, CO₂, waste-water pipelines
- Cascading and circular paths
- ...

Scope 3

Networks of networks:

- Between SDGs
- Multi-sector coupling
- Multi-level governance coupling
- PV, wind + bioenergy
- Energy-food-water nexus
- ...

Regulating contributions for managing risks

	Uncertain trends	Uncertain variabilities	Uncertain extremes
Earth system <i>Considered uncertainties in ESMs</i>	<i>e.g. on global warming</i> 	<i>e.g. on weather seasonality and day-nighttime</i> 	<i>e.g. on climate extremes</i> 
Human system <i>Considered uncertainties in ESMs</i>	<i>e.g. on socio-economic trends</i>	<i>e.g. on costs and prices, on trade</i>	<i>e.g. on accidents, market crashes, wars, cyber-threats</i>

Decreasing Modelling Readiness Levels – potential evolution?

Exemplary synergies Bioenergy <> Hydrogen

<https://task44.ieabioenergy.com/inter-task-project-on-hydrogen-and-bio-based-value-chains/>

Both technologies are metabolic, i.e. operationally rely on inputs (incl. water), creating outputs (incl. emissions) >>> need for infrastructures, conversion tech, storages, derivates, standards, emerging markets >>> complex integration opportunities

- knowledge and experience transfer
- joint use of infrastructures
- hydrogen improving bioenergy products (H₂ + Biogas)
- hydrogen produced from biomass



Exemplary synergies

Bioenergy <> Biogenic (solar) carbon removal

Starting into the
3rd triennium
phase

<https://task40.ieabioenergy.com/inter-task-beccus-2-0/>

Solid, liquid, gaseous bioenergy & CO₂ capture & more

- Biomass combustion for heat and electricity + CO₂
- Biomass gasification > CHP or CH₄ or fuels + CO₂
- Biomass liquefaction > crude biooil + CO₂
- Anaerobic digestion > waste-water treatment > CHP or CH₄ + CO₂
- CO₂ to store (BECCS, storage) or to use (BECCU, utilization)
- Biochar for carbon circulation and soil enhancement

Examples for the automation of flexibility

To provide the flexibility needed, **control strategies, able to handle strongly varying operating conditions** (fuel variations, load modulation, etc.) **automatically**, have to be developed

- **System level** - scheduling of controllable producers, storages and consumers
- **Technology level** - flexibilization of biomass conversion technologies by means of control

optimal operation

(efficiency, CO₂ emissions, ...)

predicting volatility

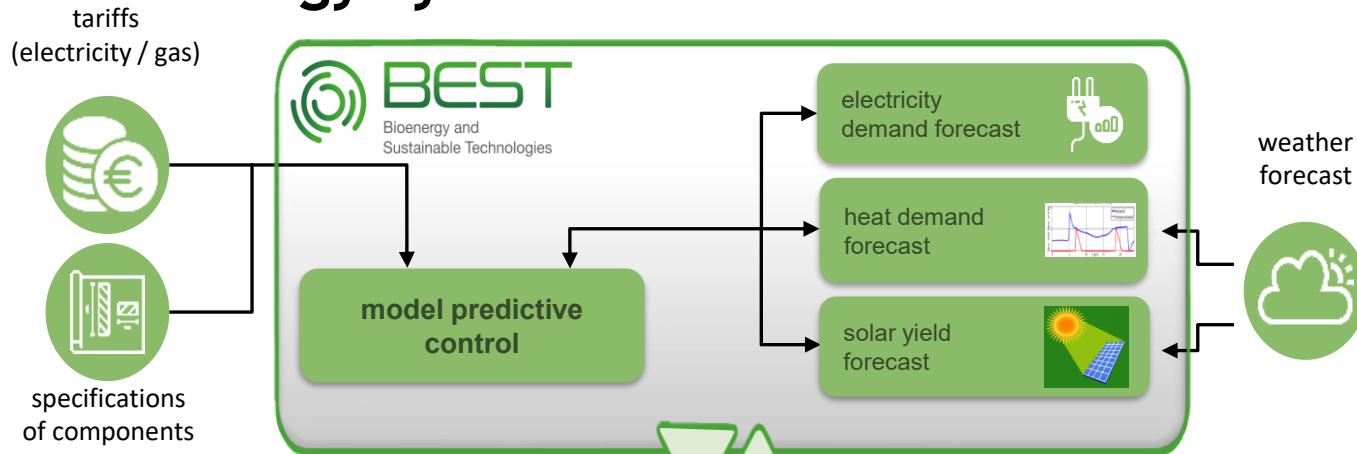
of production and consumption

modulating in variation range

of the configurations

Examples for the automation of flexibility

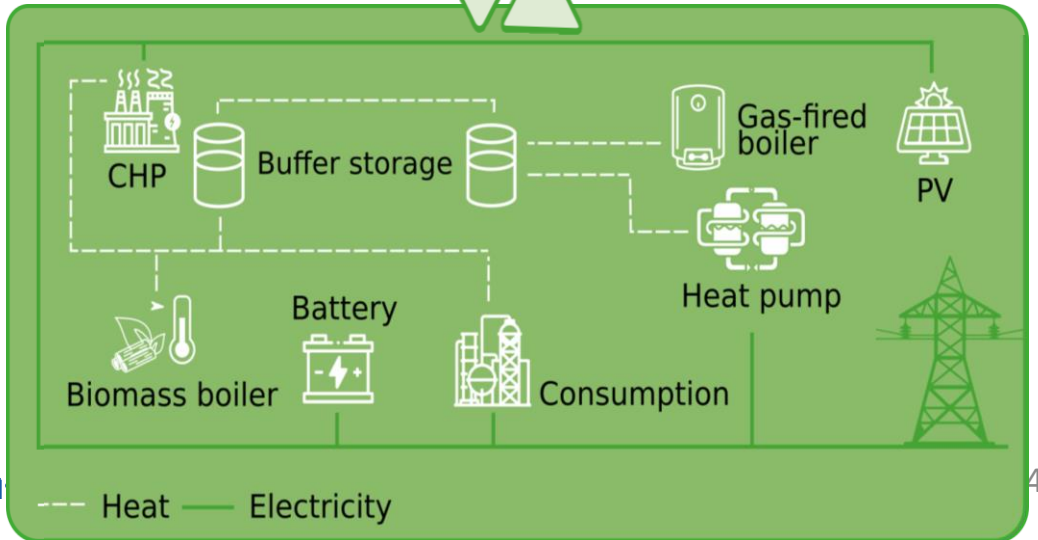
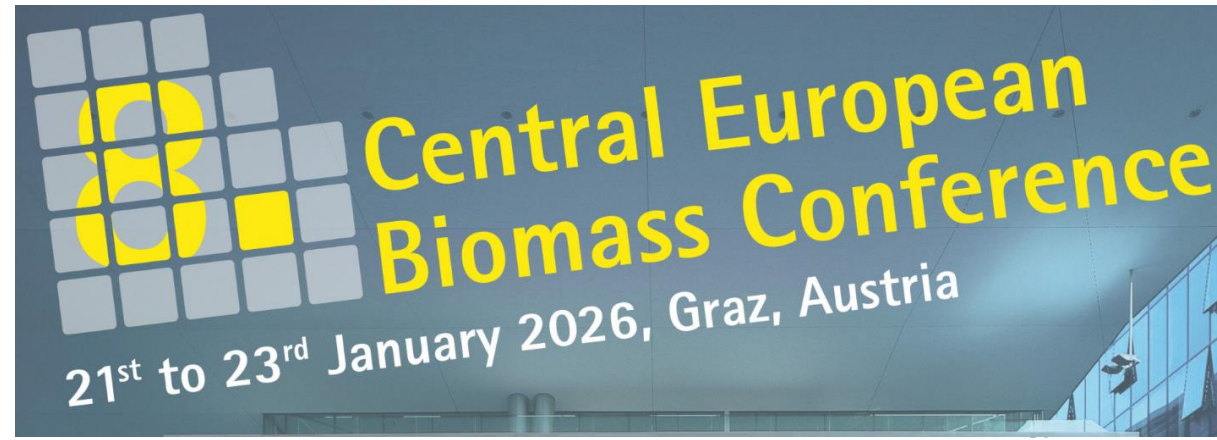
Modular, predictive, optimization-based supervisory control of multi-energy systems



Implementation & tests

- Coupled, cross-ownership district heating grid
- Biogas CHP plant connected to DH
- Fixed-bed biomass gasification CHP plants

Automation workshop at CEBC:



Call to action

Bioenergy paths are connectors

- ~~competitive advantage~~ synergistic advantage of bioenergy
- enables efficient risk management (e.g., portfolio effect)

Bioenergy domain experts
must reduce bioenergy
complexity without losing
the synergistic advantages
& tradeoff-risks



Modelling experts must
advance methodologies from
assessing uncertain trends, to
operations, to extremes
enabling models to anticipate
integration impacts

Elevating sustainable development toward reliable development

Including and beyond bioenergy: Hydrogen, BECCUS, Circular economy,
sustainability <> security, modelling for investor decision making

Thank you!

Bioenergy system integration and flexibilization: Technology guidebook, Case studies, Policy mapping, Value discussions, Automation insights (soon)

<https://task44.ieabioenergy.com/iea-publications/>

Synergies between bioenergy and hydrogen - all reports online

<https://task44.ieabioenergy.com/inter-task-project-on-hydrogen-and-bio-based-value-chains/>

Synergies between bioenergy and carbon removal (ongoing)

<https://task40.ieabioenergy.com/inter-task-beccus-2-0/>