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75 th IEA-FBC meeting

Assessing CFB Combustors flexibility with respect to load changes and fuel type

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Introduction

- The development of **new** and **innovative** flexibility concepts for CFB technology, in terms of **fuel and operation**, is of high necessity

- A RFCS **European project, FLEX FLORES** introduces new concepts that are intended mainly for **low rank fuel** (e.g. lignite) co-combusting power plants **under high ramp-up rates**.

- The research activity will be supported by:
  i. Theoretical,
  ii. Experimental, and
  iii. Numerical studies (CFD and dynamic 1-D process modelling)

General perspective

Biomass co-firing

✓ Main advantage of co-firing: potential to **mitigate the CO_2 emissions** of coal sector at very low cost and short implementation time compared to other technologies.

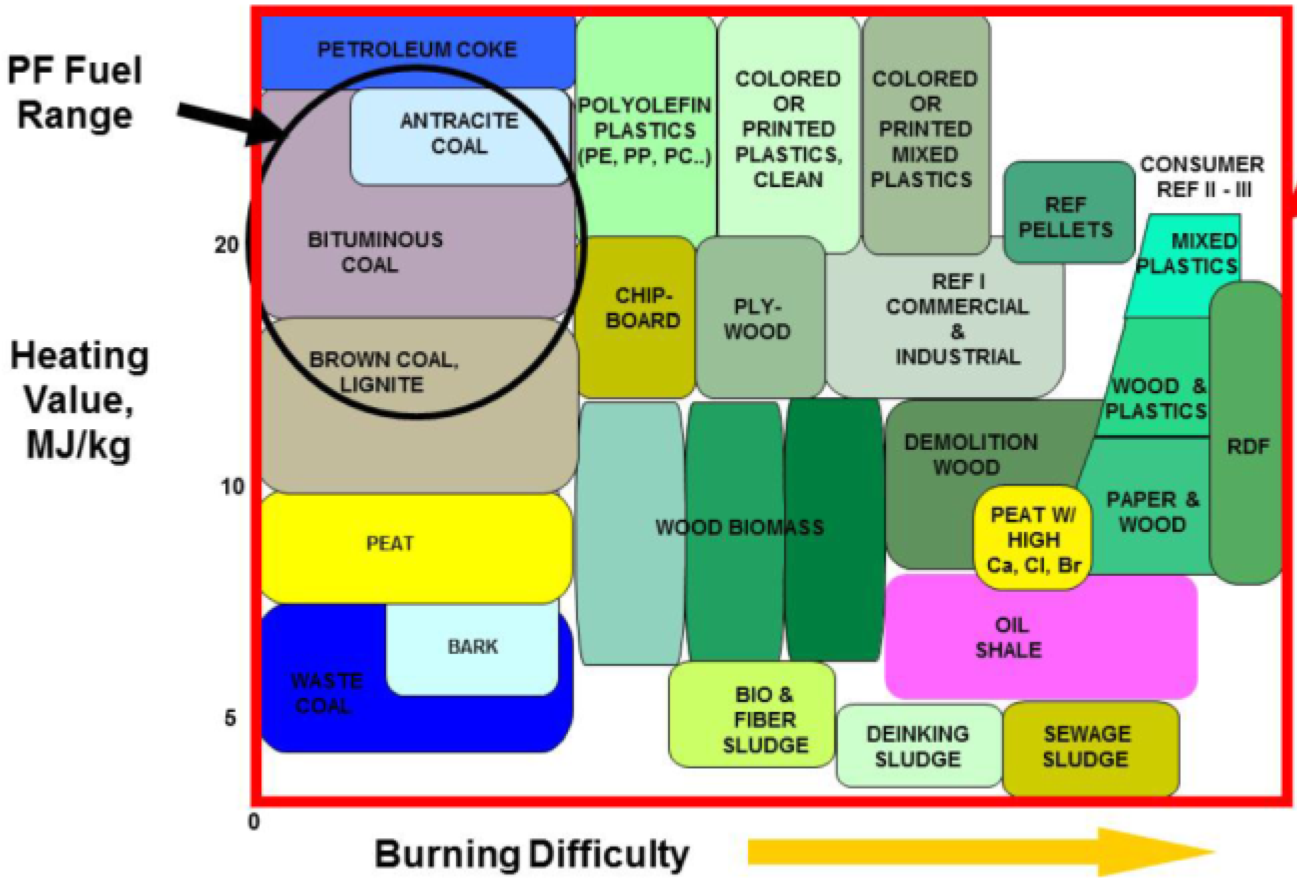
✓ Over **100 successful field demonstrations in 16 countries** that use every major type of biomass (herbaceous, woody, animal-wastes and wastes) combined with every rank of coal and combusted in every major type of boiler

Technical and environmental challenges

- Fuel handling
- Slagging/fouling/corrosion
- Emissions formation & gas cleaning equipment
- Ash utilization
- Biomass availability

Advantages

- Highest electrical efficiency (among biomass conversion technologies)
- Can produce power on demand
- Stability of electric grids
- Lower CO_2 at low cost

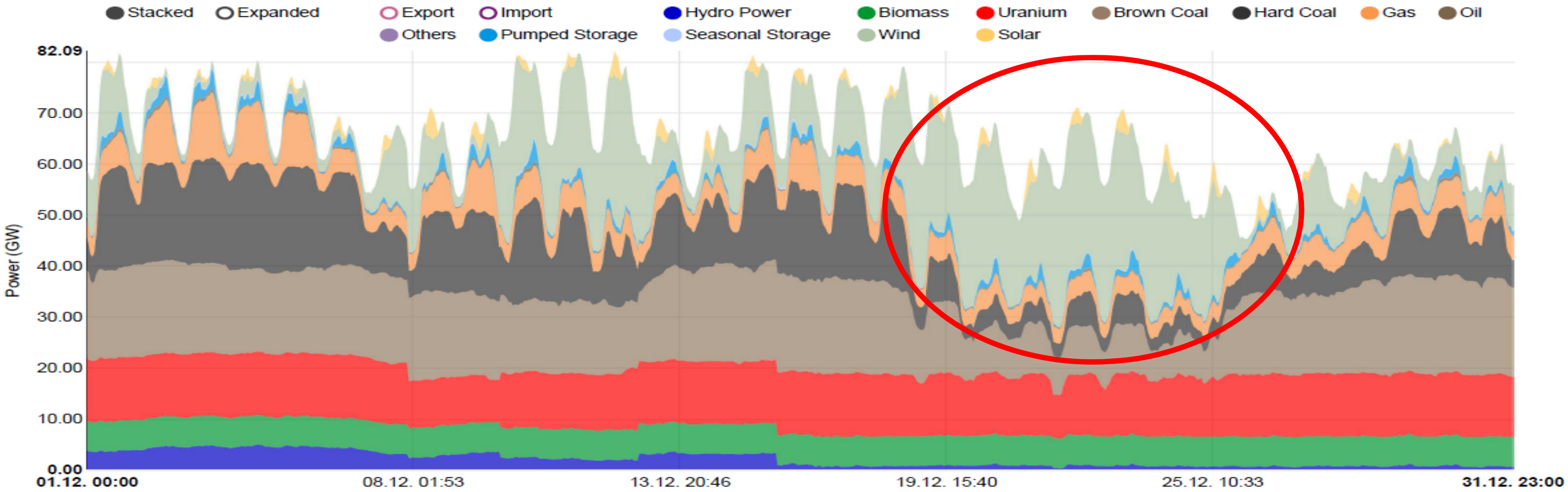


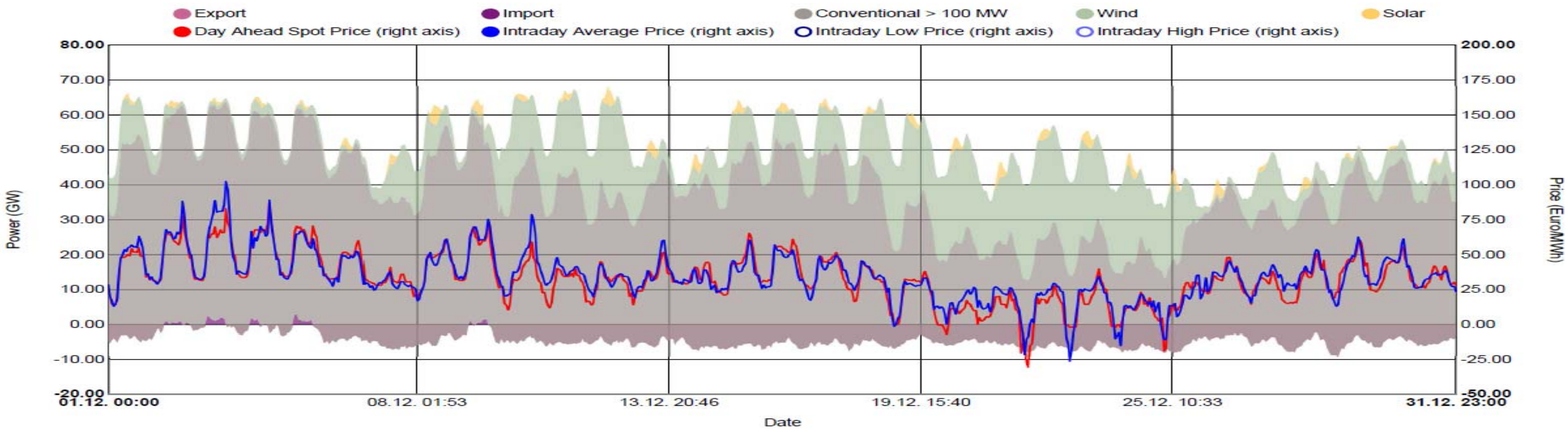
Technology gap:
A combined sophisticated research on the operational flexibility enhancement of CFB boilers for retrofitting cases that are fueled with Low Rank Coals and biomass/waste fuels blends, has not been conducted yet.

CFB outperforms PF technology with respect to fuel range.
Fuel flexibility is not the only Key indicator. Operation flexibility is also important

Impact of energy policy on electricity market

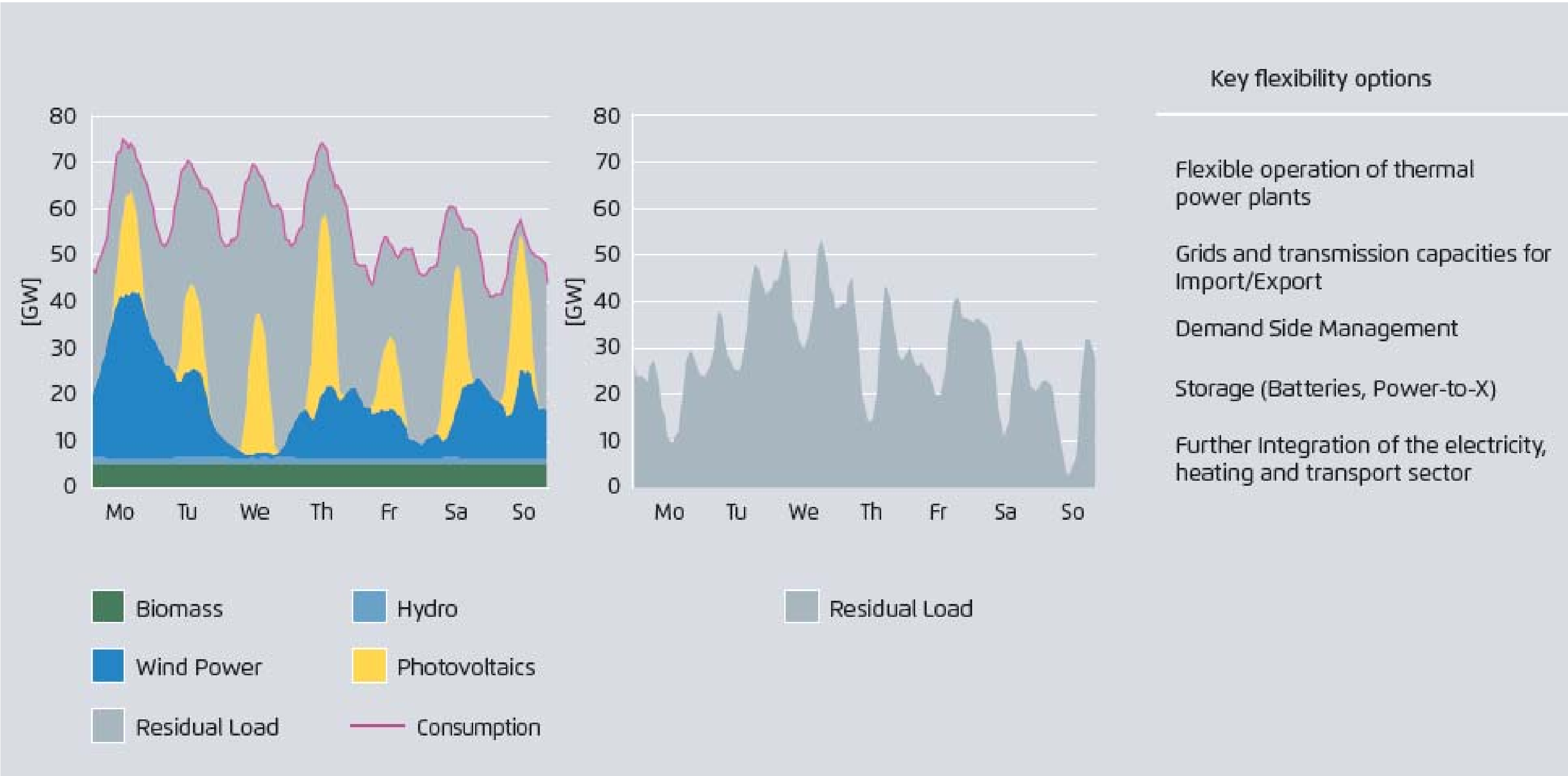
> The example of the German „Energiewende“ – energy mix and pricing December 2014





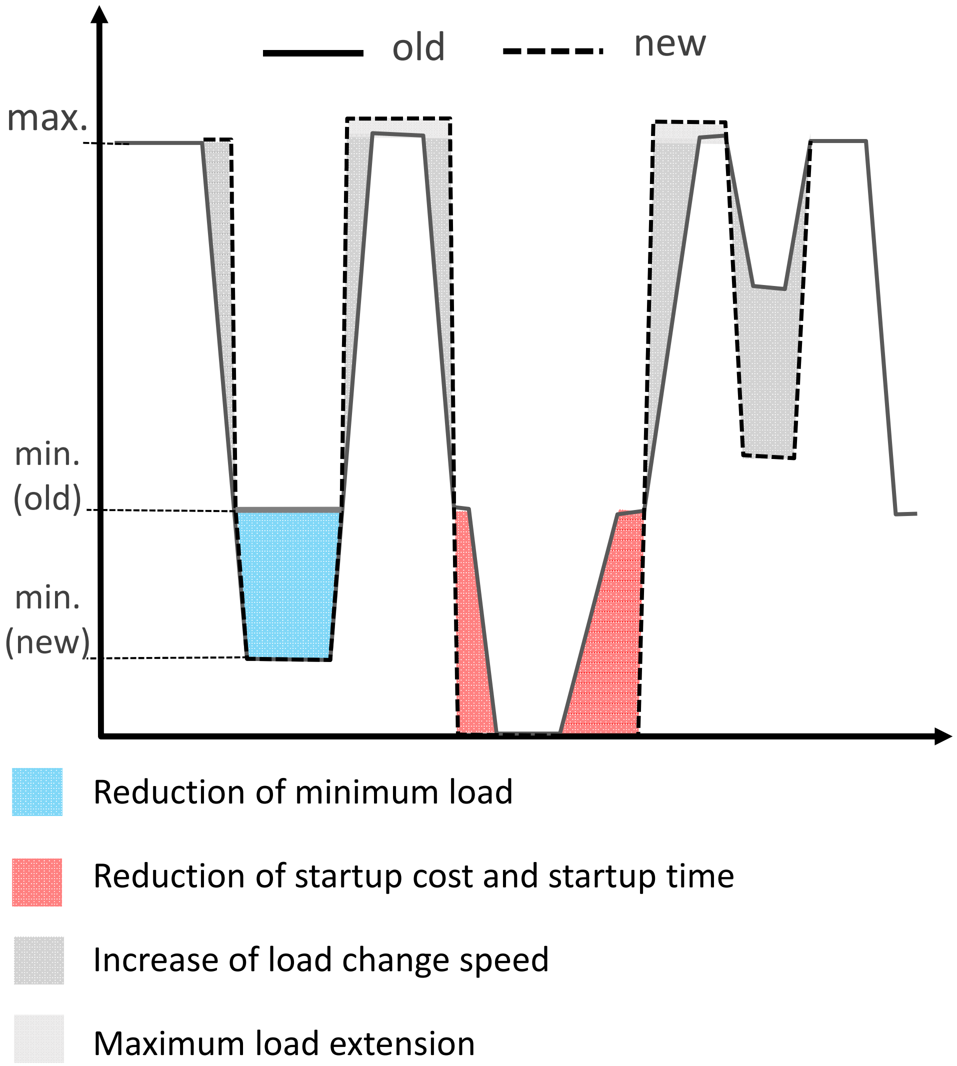
Source: Fraunhofer, ISE

Expected (2022) power production in Germany



Gross electricity generation and residual load in Germany in a sample week in April 2022 with 50% renewables

Flexibile operation of thermal plants. Which are the requirements?



Minimum load reduction

(-) Lower efficiency = higher specific cost

(+) Continuous sales of grid services

(+) Savings in auxiliary fuels

(+) Avoiding start-up and additional thermal fatigue

Improvement of startup

(-) Loss of operational hours and income

(+) auxiliary fuel savings

(+) faster startup

FLEX FLORES FLEXible operation of FB plants co-Firing LOw rank coal with renewable fuels compensating vRES

Project Duration (months) 42, Total Budget € 2,863,691 EU Contribution € 1,718,215
Start Date 01/07/2017 End date 31/12/2020

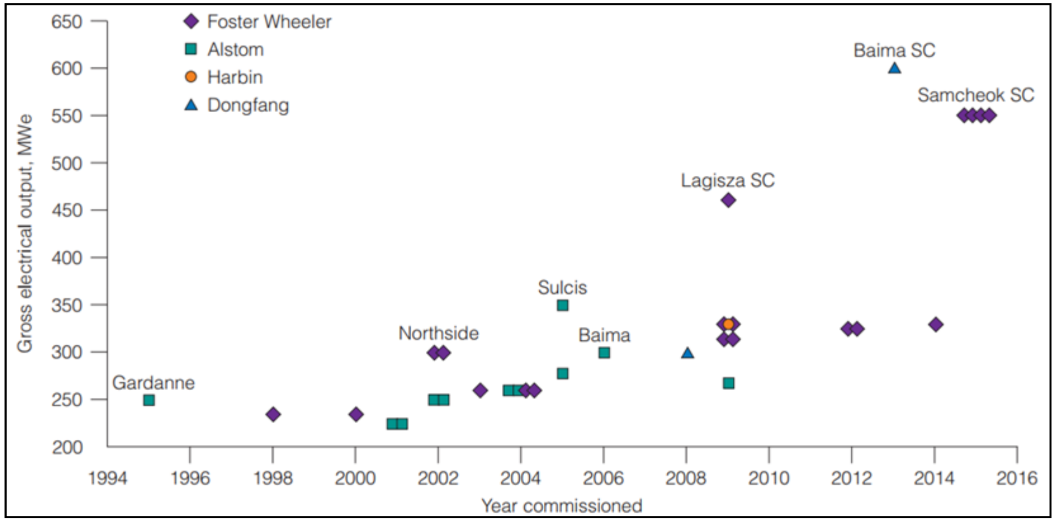
- RINA CONSULTING - Centro Sviluppo Materiali S.p.A.
- Foster Wheeler Energia Oy Finland
- CERTH
- TECHNISCHE UNIVERSITAT DARMSTADT Germany
- Teknologian tutkimuskeskus VTT Oy Finland
- PPC

General perspective

Need for more flexible CFB operation

- ✓ During the last two decades CFB technology has increased its installed capacity
- ✓ Construction of new fossil power plants in Europe does not seem promising
- ✓ **High necessity**: develop flexible operation concepts for existing CFBC plants and take advantage of FB fuel flexibility

Such concepts coupled with **energy storage solutions** can be extended to new built plans



The scale-up of CFB boiler capacity in the last twenty years, with significant plants labelled (*Source: IEA, 2013 "Techno-economic analysis of PC versus CFB combustion technology"*)

TES concepts in solid particle suspensions: have started gaining interest the last thirty years mainly in CSP plants

TES concepts have been introduced in coal-fired power plants with bypass of feed water heaters

Load Flexibility issues in CFBC plants

- ✓ Turbine and water/steam cycle issues similar to PCC plants

Current Minimum load to about **30 - 40 % of nominal load (no supplementary fuel)**

- ✓ Should go down to **20 % of nominal load**
- ✓ Load change rates should go up to **5 MCR (%/min*),** currently around 2%

Technical difficulties:

Damage in the combustor and in heat exchangers metal parts and in refractory materials, due to rapid temperature change during

- ✓ *Start-up*
- ✓ *Shut-down*
- ✓ *Load change*

Start-up times longer than PCC

Operating a CFBC at low loads can also have a negative effect on desulphurization efficiency due to reduced mixing in the furnace

**** Polish CFBC units at Lagisza, Turow, and Polaniec have successfully met grid requirements of 4%/min***

Foster Wheeler have implemented a reheat steam bypass system for reheat steam temperature control during start-up and shut-down

PF boilers:

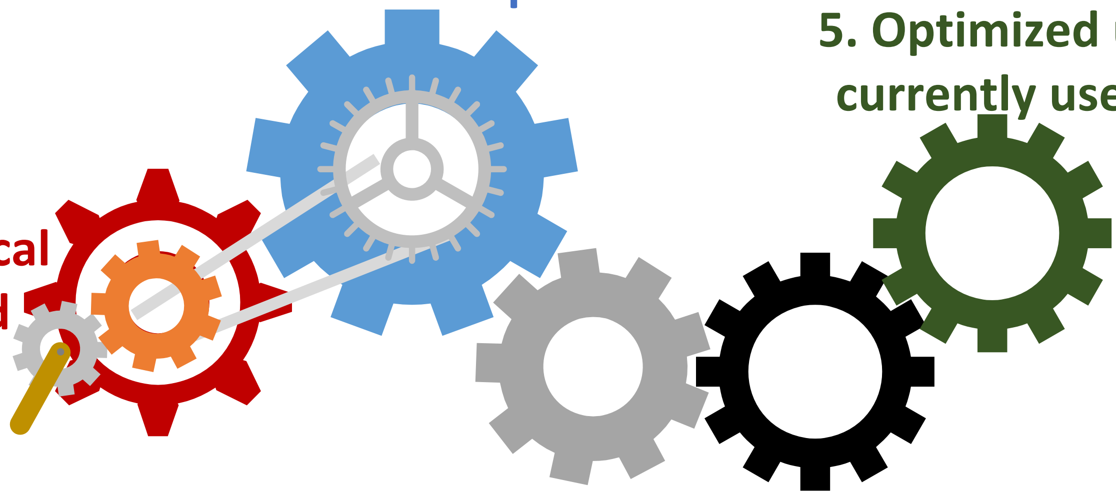
Parameters / characteristics	Currently operating PP fleet (PPs erected in the 20. century) [1)]	Current BAT (PPs erected in the 21 century) [1)]	Targets
Minimum load for continuous operation [%]	**15-20** for hard coal **>50** for lignite [4)]	**15-20** for hard coal [2)] **35-40** for lignite [3) 4)]	**~15** (considering alternative & low carbon solid support fuels and their blends)
Ramping rate [%/min]	**2-3**	**5**	**~10**
Frequent start-up and shut down ability (cold/warm/hot)	Specific nr. of start-ups /shut downs foreseen per year (limited to few cold start-ups)	Possible daily start-up for hard coal PP (usually hot/warm daily, cold over the weekend)	Possible daily variations between 15-100% to avoid daily start ups
Emissions and plant efficiency MUST BE KEPT DURING PART-LOAD	Optimum design for high efficiency and lowest emissions at full load	Optimum design for high efficiency and lowest emissions at full load and some low loads	Optimum design for high efficiency and lowest emissions (IED) for load following operation

[1)]Best possible known, and documented
[2)]Usual min load operation for recent new built plants still is only around 30-40% due to lowest marginal cost of all hard coal units
[3)]Oil/gas may be required as supporting fuel for lignite
[4)]Plants are existing in Germany or are being retrofitted with dry lignite firing to operate in the range of 20%-30% load

Source: MHPSE

FLEX FLORES

Beyond the state-of-the-art



KEY RESULTS

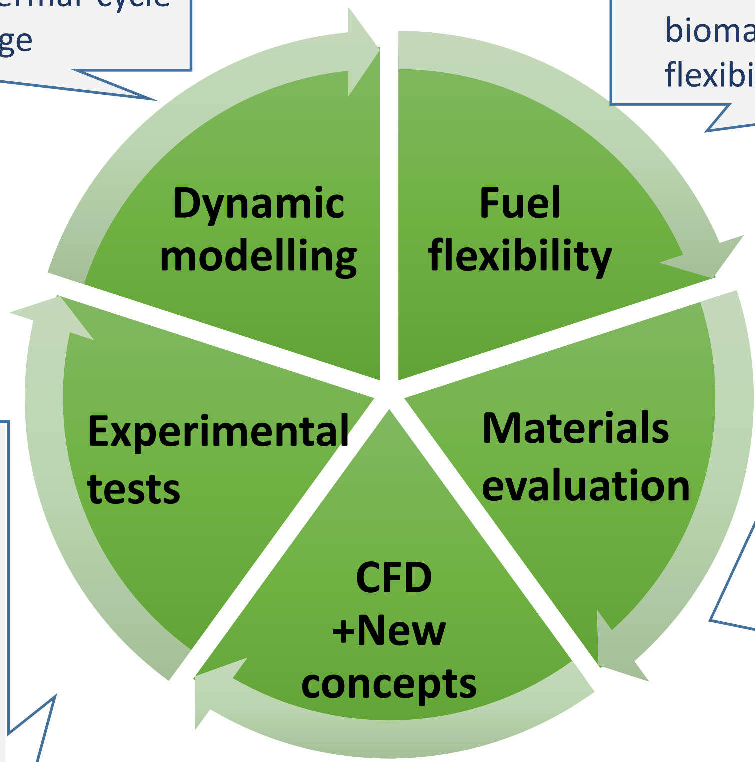
1. **Higher availability factor for the plant** (achieved with steady+ reliable operational mode parameters)
2. **High ramp-up rates (up to 5%MCR/min) and faster start-up procedures of the plant**
3. **The plant will operate under a wide range of different blends of LRC and biomass** (increase of biomass share, operational strategies for a wide range of LRC substitution)
4. **New operation strategies implementation+ new devices assessment**
5. **Increase of the components lifetime avoiding wastes of energy+ raw resources**

FLEX FLORES: **FLEX**ible operation of FB plants co-**F**iring **LO**w rank coal with renewable fuels compensating v**RES**

FlexFLores Strategy & Actions

- Pilot plant **dynamic modelling** (APROS software)
- **Full scale CFBC** transient thermal cycle simulations under load change

- **Multi-fuel** combustion optimization in terms of both **environmental & economic** (max possible share of cheap biomass) & **technical aspects** (fuel flexibility with corrosion minimization)



- **Currently** used and **innovative materials** under steady & cycling operation (pilot & commercial scale)
- **Refractory materials** performance under increased use of LRF& high ramp-up
- Laboratory **corrosion tests** & simulation of **thermal shocks**
- Identification **of steel alloys degradation**

Campaigns in TUDA 1 MWth **pilot plant** and Äänevoima commercial boiler

- Pilot furnace modifications for combustion stability, hot loop operation & low emissions **(multi-fuel environment)**
- **Multipollutant FGC optimization**
- Pilot & commercial tests for **heat extraction & corrosion evaluation** of steel materials

- Develop **validated** 3D numerical tools
- **Concepts** for i) decreasing the hot-loop thermal inertia, ii) TES , iii) External heat exchanger

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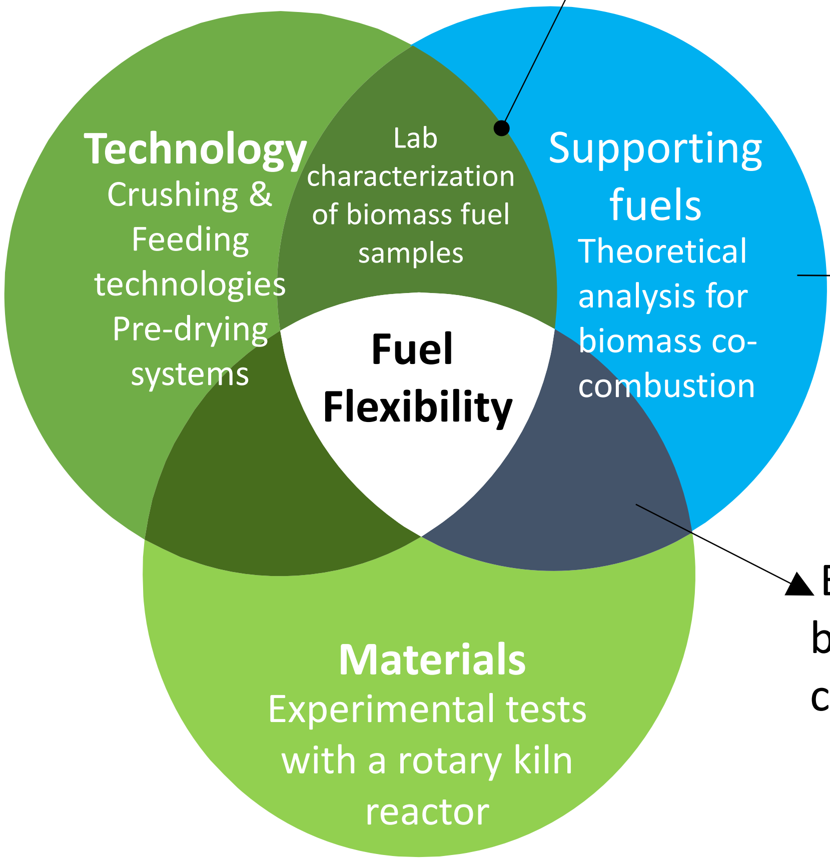
Fuel flexibility in CFBs

Main target:
Search of two of the most promising biogenic fuels to be experimentally tested for their co-combustion with low rank fuels (LRF) under **low thermal load conditions**

- ✓ Central and North Europe area
- ✓ South and South-East Europe area



“Difficult dirty opportunity” biomass fuels from agricultural, agro-industrial/waste treatment sectors

Evaluation of materials behavior under multi-fuels combustion conditions

Tool:
Use of the S2BIOM integrated tool set*

* This tool enables the user to make selections of biomass types for which data can be displayed in a map in relation to amount of biomass available per year and potential type combination.

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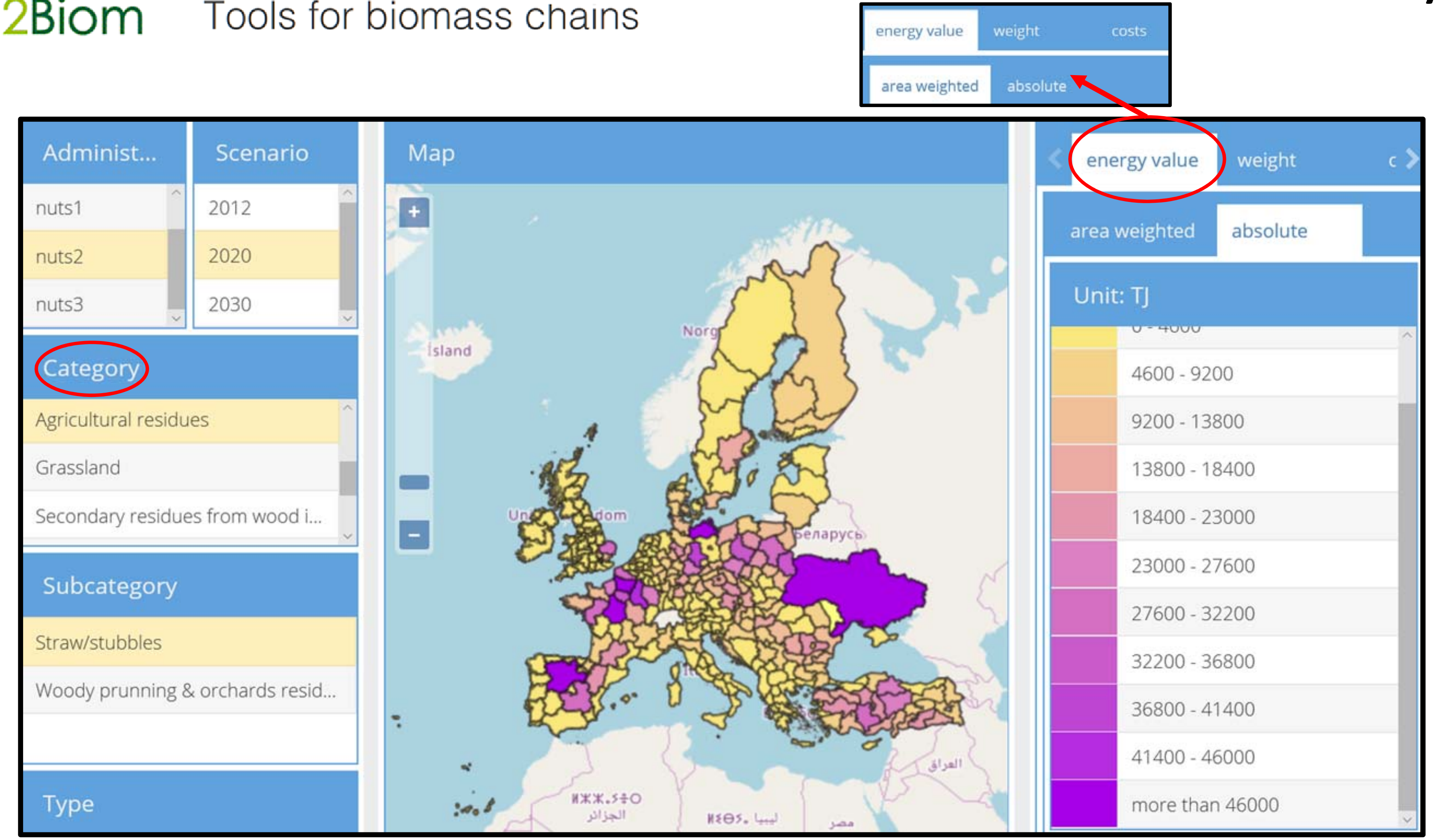
S2Biom Tools for biomass chains

Fuel flexibility in CFBs

Platform utilized for theoretical analysis



www.biomass-tools.eu

- The user can select regional level, year and different types of potentials. The level entities can be in absolute levels (Kton dm or TJ), area weighted (Kton dm/km^2 or GJ/km^2) and weighted average road side cost (€/ton dm)

Operating flexibility in CFBs

Flex Flores targets at a glance

Targets:

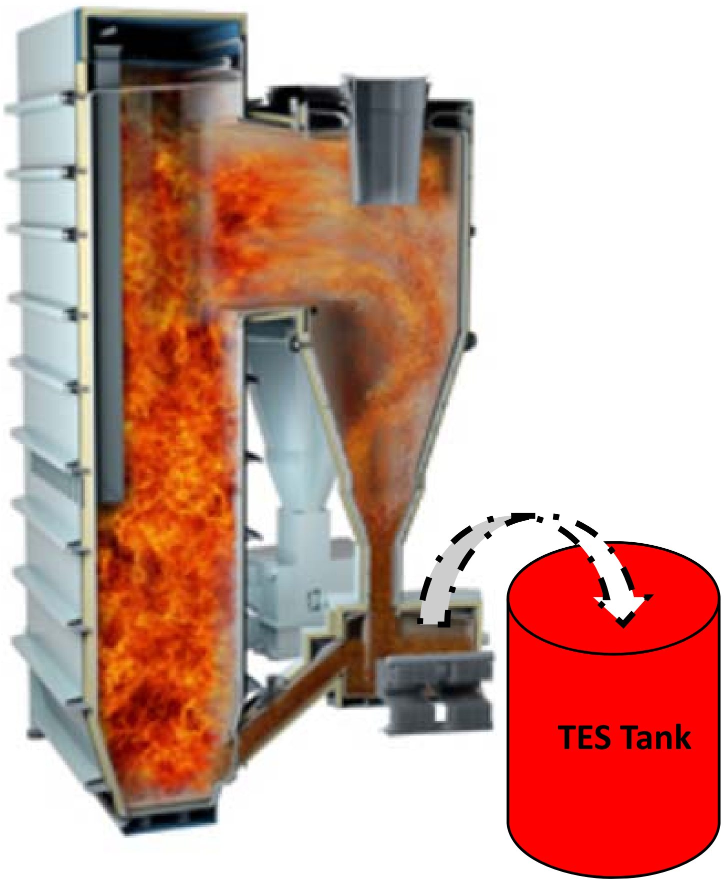
- ❑ Decrease the CFB start-up time
- ❑ Increase the ramp-up rate of a CFB unit from 2-3%MCR/min up to 5%MCR/min
- ❑ Decrease the technical minimum load down to 20-30% of nominal load

Technical challenges:

- ❑ Intermediate bed material thermal storage
- ❑ Develop an advanced CFB hot loop and water/steam side design
- ❑ Examination and optimization of the control strategy of heat exchangers (superheater, reheater)
- ❑ Thermal stresses
- ❑ Reducing the thermal inertia of a CFB boiler

Operating flexibility in CFBs

TES+ New concepts for improved operation



CFB hydrodynamics solutions for flexible operation

- Search of a new furnace flexible operating concept, aiming at optimizing hydrodynamics
- Aim: **1**. Increase furnace operability at low load level through **flue gas recirculation 2**. Increase the furnace capability to ramp up/down

Energy storage concepts

- Investigation of the bed material (inert material & fuel particles) intermediate storage during a rapid load ramp-down
- Aim: Enhance operation flexibility during start-up and quick load swings

CFD modelling

3D CFD analysis of the combustion system with multi-fuels (transient)

Simulation:

Flow hydrodynamics is a key factor for low load operation.

*Advanced drag model **(EMMS model)***

Fuel related data

Evolution of combustion products as a function of temperature & time with different blends

Particle loading in the riser

Optimize hydrodynamics especially for low load cases

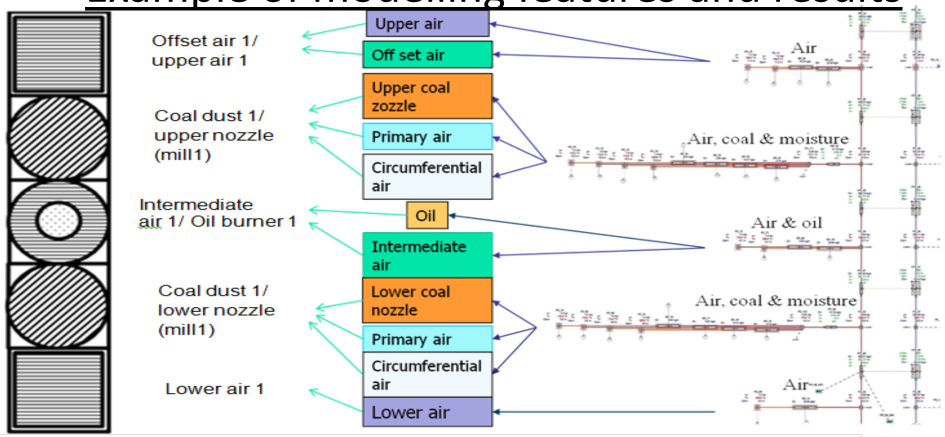
Investigate the flue gas recirculation idea for lowering the min load idea

Dynamic process modelling

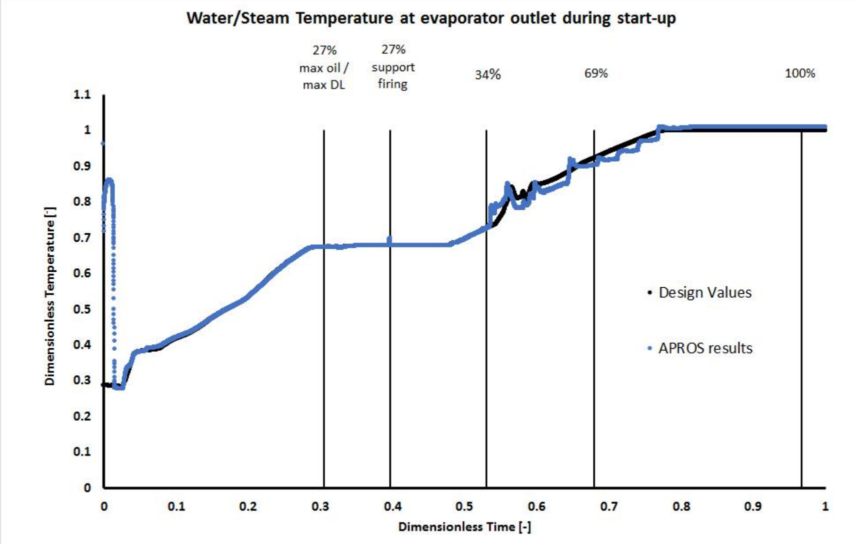
Transient thermal cycle simulations of a full scale CFB boiler. **Model Validation** against experimental data. 1D dynamic modelling of TUDA 1 MW_{th} pilot plant and Äänevoima commercial boiler (APROS software).

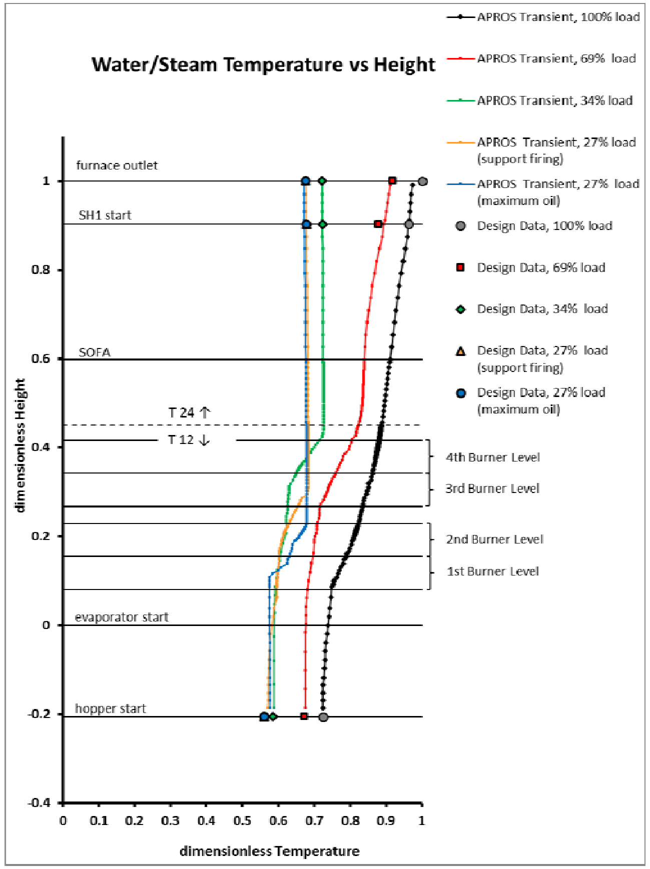
Example of modelling features and results

Modeling of both flue gas and water/steam sides of hard coal fired GKM boiler, with full respect of burners set-up through separate inlets for every nozzle (coal, air, oil) (**APROS**)



Water/steam temperature time series throughout start-up





Water/steam temperature distribution along height at various loads

Concluding Remarks

- **Flex Flores project** aims at **flexible** and **environmental friendly** CFB technologies under **high ramp-up rates (up to 5% MCR/min)** and the adoption of LRFs co-combustion with biogenic fuels as a retrofitting option in FB power plants

- Different research activities will be undertaken including **CFD modelling, dynamic process modelling, lab/pilot/commercial scale experimental campaigns**

- **Technical achievements** beyond **the state of the art** will include:
  1. **Lower technical minimum load**
  2. **Flexible operation:** high ramp-up rates and faster start-up procedures
  3. **Flexible fuel utilization**
  4. **New operation concepts:** TES, External heat exchanger
  5. **Optimized utilization of currently used materials**

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Thank you for your attention!!!!.

Questions ????

ACKNOWLEDGEMENTS

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