



# Conversion of Char in CFB Gasifiers

**A. Gómez-Barea, M. Campoy**

Bioenergy Group, University of Seville (Spain)

**B. Leckner**

Chalmers University of Technology (Sweden)



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3. Conclusions



# Introduction-Motivation



1. Char conversion is decisive factor in FBG
  - Loss of thermal efficiency
  - High carbon content in the ash
2. Factor for char inefficiencies in FBG
  - Entrainment of fine/lighter material (char)
  - Bed removal
3. Modelling char conversion
  - Big effort on kinetic determination (TGA, FB, DFR, ...)
  - Huge effort in particle modelling
  - Poor implementation in reactor models

Conclusion: Need for appropriate models

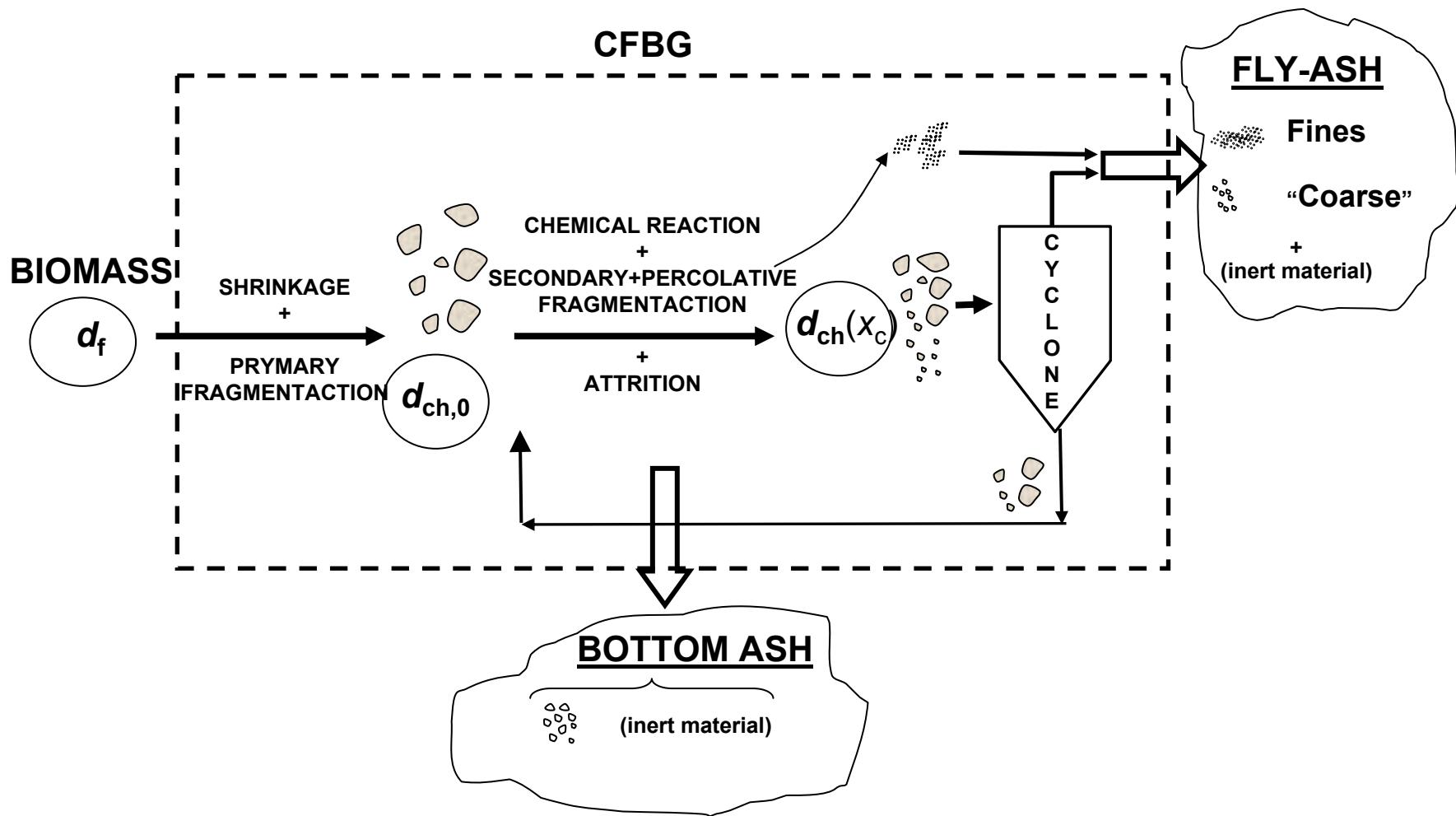


## Must:

- take into account the major phenomena
- be capable to give rapid estimations
- be properly implemented as submodel in (advanced) existing CFBGs
- establish clearly how to obtain the main inputs



# Fuel conversion processes in CFBG



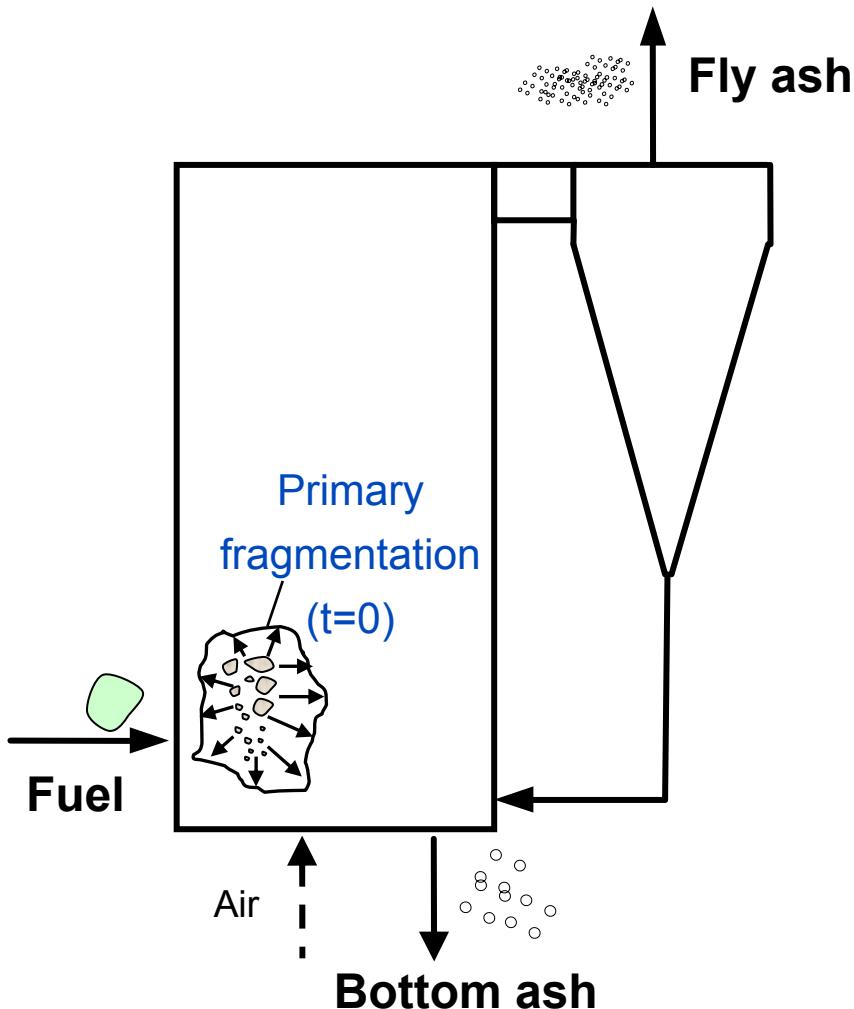


1. Introduction
- 2. Model development**

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# Model Approach

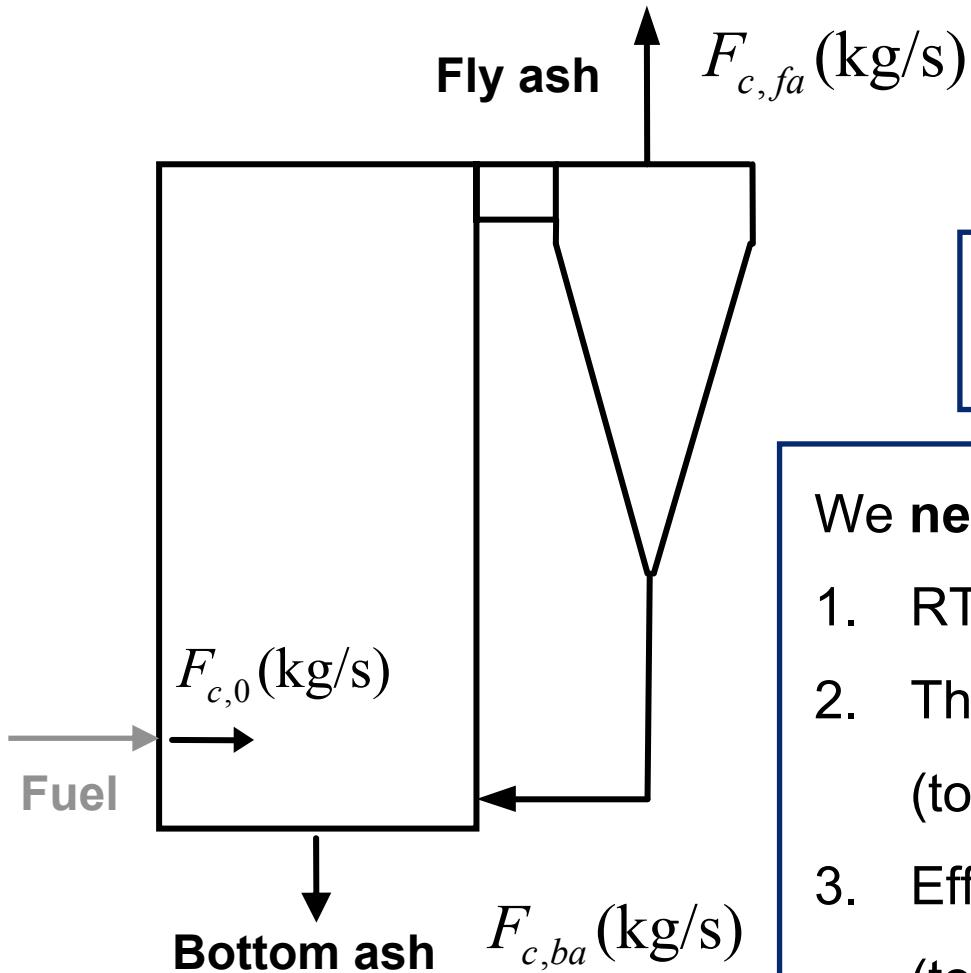


## Calculation of:

- distribution of the exiting char particles
- effective time of reaction
- degree of conversion of char



# Char conversion in a CFBG



$$X_c = 1 - \left( \frac{F_{c,fa}}{F_{c,0}} + \frac{F_{c,ba}}{F_{c,0}} \right)$$

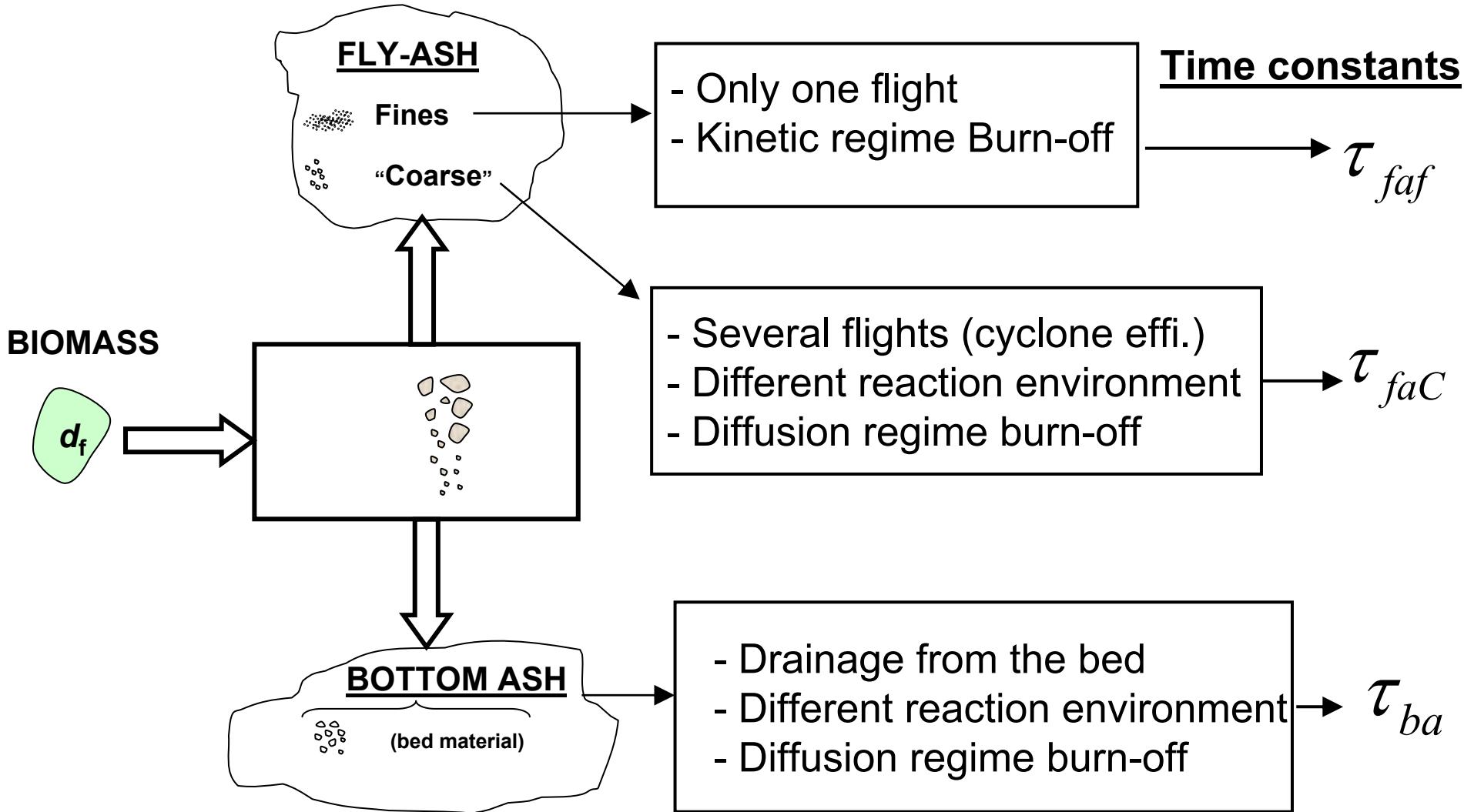
$$X_c = 1 - \sum_k \int_0^{\infty} E_k(t) (1 - x_{c,k}(t)) dt$$

We **need** to calculate for “**k**” streams

1. RTD of the fly ashes
2. The conversion behaviour  $x_c(t)$   
(to obtain  $d_c(x_c)$  or  $d_c(t)$ )
3. Effective time  
(to relate  $t_{\text{inside the CFB}}$  and  $t_{\text{reaction}}$ )



# Type of particles in the ash streams





# Calculation of time constants



Coarse fly ash

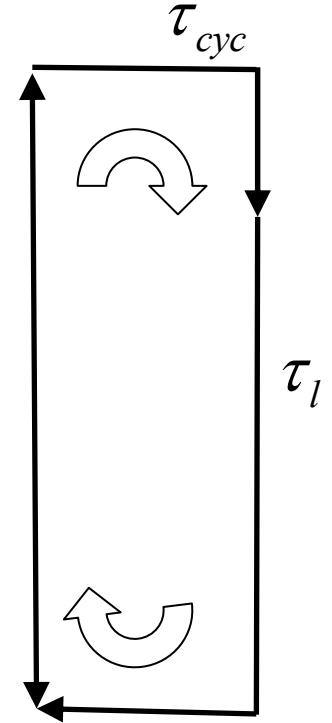
$$\tau_{fac} = \frac{\tau_{loop}(d_{ch})}{1 - \eta_{cyc}(d_{ch})}$$

Fine fly ash

$$\tau_{faf} = \frac{K_{att}(d_{ch})}{d_{ch}(u_0 - \psi u_t(d_{ch}))}$$

Bottom ash

$$\tau_{ba} = \frac{w_b}{\dot{m}_{ba}}$$



$$\tau_{loop} = \tau_R + \tau_{cyc} + \tau_L$$



# Comminution: Particle size $d_p(x_c)$



$$\frac{d_{ch,0}}{d_f} \approx \left( \frac{\varphi}{n_1} \right)^{\frac{1}{3}}$$

PRIMARY  
FRAGMENTACTION  
+  
SHRINKAGE

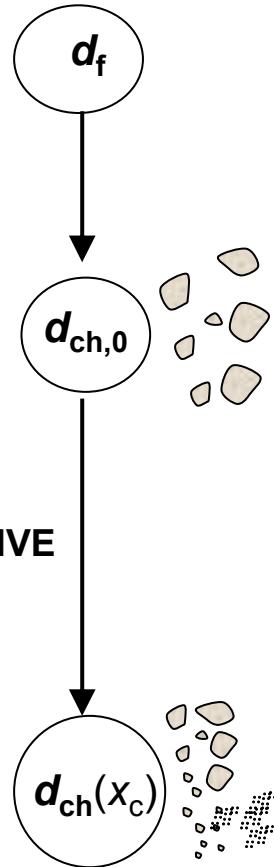
$$\frac{d_{ch}}{d_{ch,0}} \approx \sigma$$

CHEMICAL REACTION

$$\frac{d_{ch}}{d_{ch,0}} \approx \left( \frac{1}{n_{2m}} \right)^{\frac{1}{3}}$$

SECONDARY+PERCOLATIVE  
FRAGMENTACTION  
+  
ATTRITION

$$\frac{d_{ch}(x_c)}{d_f} \approx f(\varphi, n_1, n_{2,m}, \sigma)$$



Chemical Reaction rate

$$\frac{dx_c}{dt} = K_r F_i(x_c)$$

Experiments

$$\frac{dx_c}{dt} = K_r F_i(x_c)$$

$$\frac{d_{ch}(x_c)}{d_f} \approx f(x_c)$$



# Rate of gasification of a char particle



Rate of conversion (**intrinsic**)

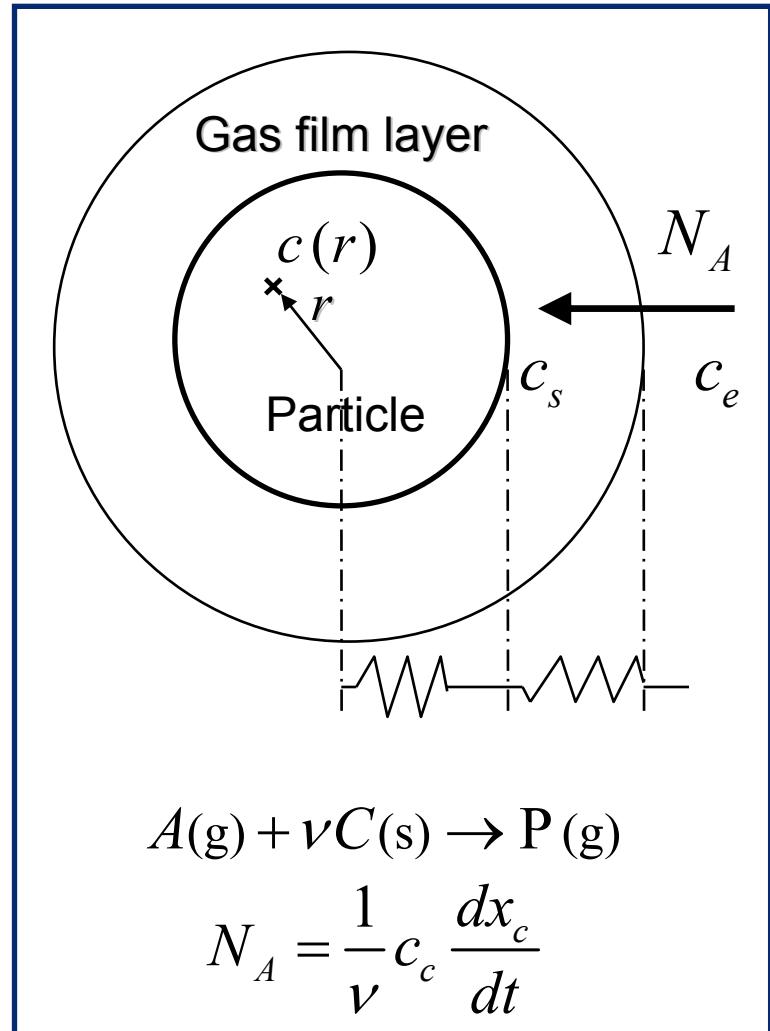
$$\frac{dx_c}{dt} = K_r F_i(x_c)$$

Rate of conversion (**actual**)

$$\frac{dx_c}{dt} = \eta_p(x_c) (K_r F_i(x_c))$$

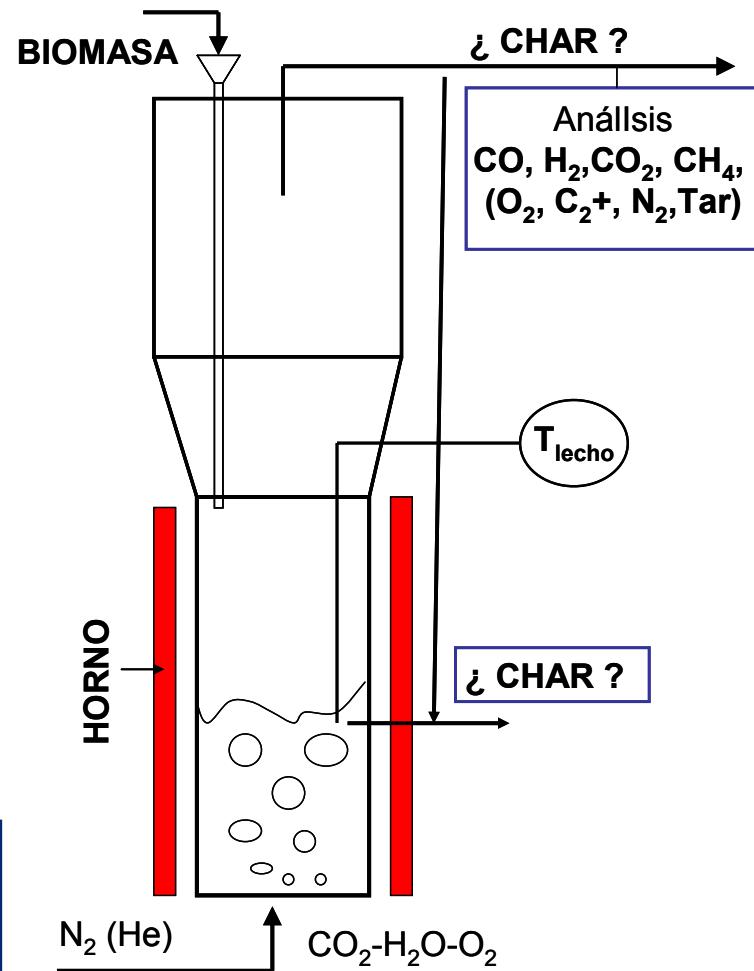
Particle effectiveness factor

$$\eta_p(x_c) = \frac{dx_c / dt}{dx_c / dt|_{FDE}} \begin{cases} \ll 1 & \text{Diffusional Reg} \\ \approx 1 & \text{Kinetic regime} \end{cases}$$





# Particle behaviour burn-off experiments (Chemical conversion and comminution)



Intrinsic Rate

$$\frac{dx_c}{dt} = K_r F_i(x_c)$$

Size variation

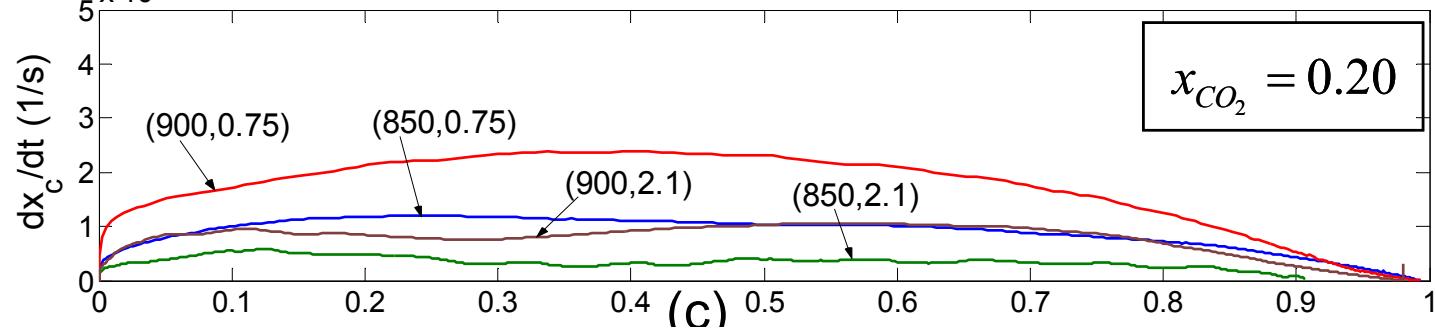
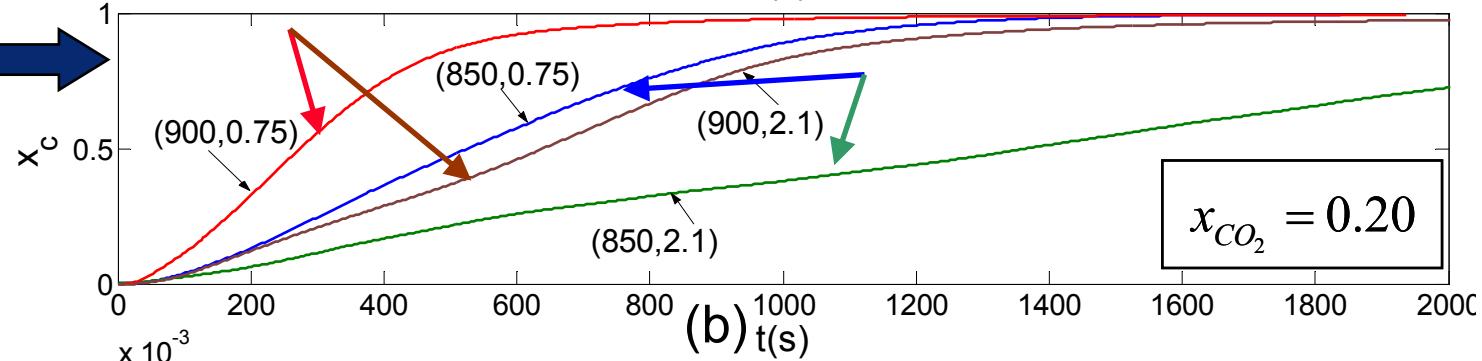
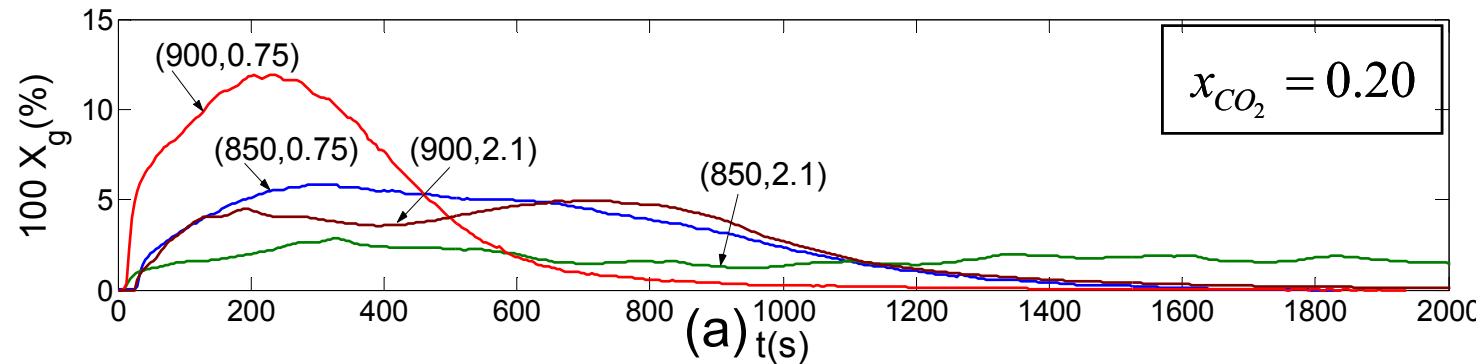
$$\frac{d_{ch}(x_c)}{d_f} \approx f(x_c)$$

Diffusion effects

$$\eta_p(x_c)$$



# Char conversion experiments in an FB

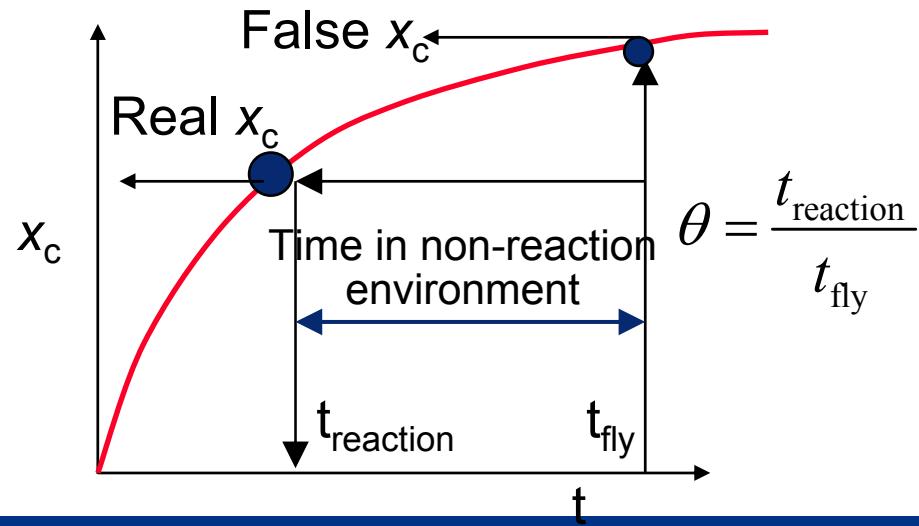




# Effective time of reaction



- The char particle is reacting depending of composition of gas (reaction conditions)
- The particle reacts only during part of the time in a CFB → **effective time of reaction**
- Mixing, entrainment, recirculation, determines the effective time of reaction

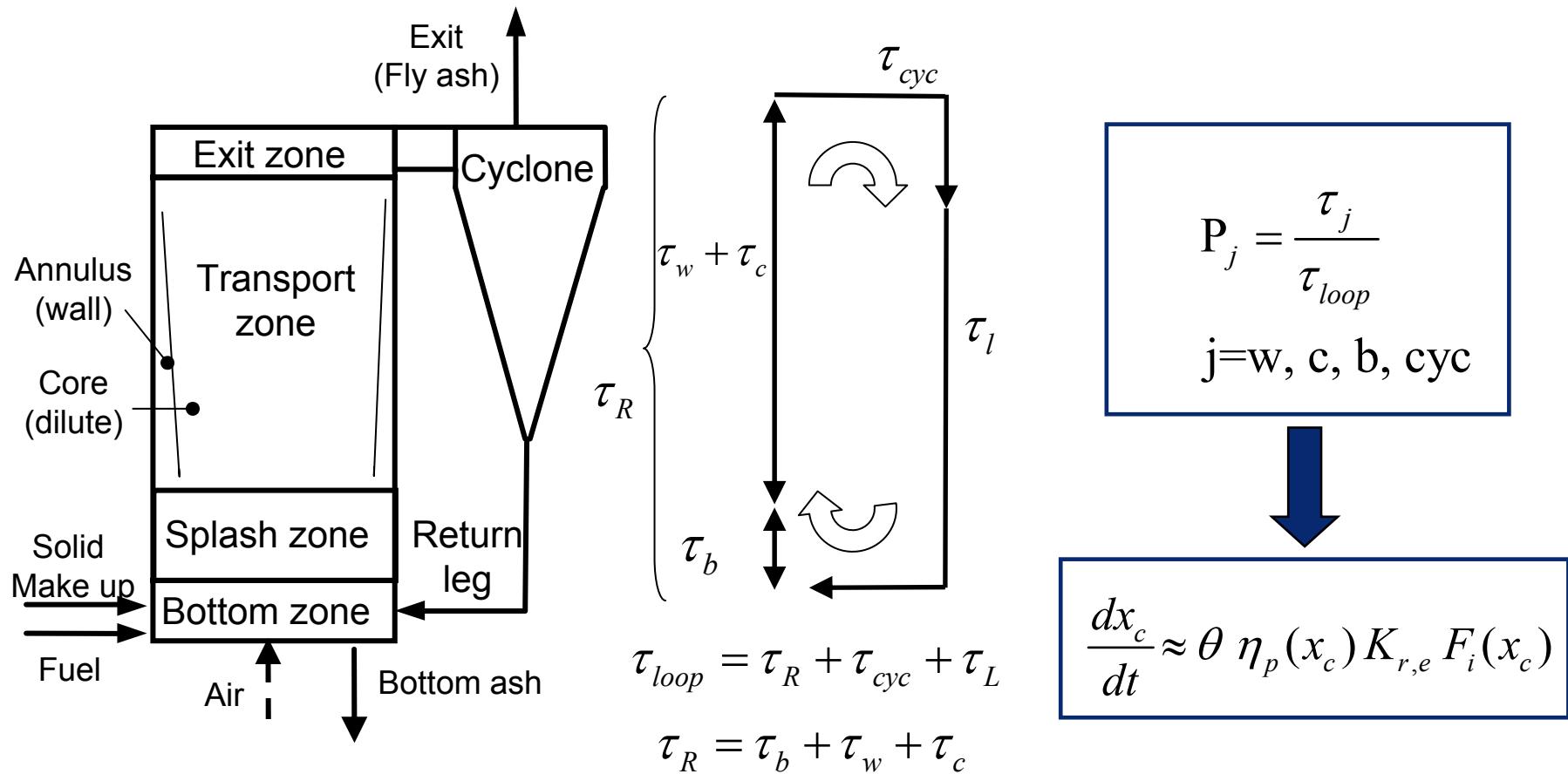




# Estimation of the effective time of reaction



- Development of a probabilistic model to obtain the time in the reacting zones (**fluid-dynamics** submodel)





# Evaluation of carbon conversion



$$X_c = 1 - \sum_k \frac{1}{\theta_k} \int_0^1 \frac{G(x_c)(1-x_c)}{\tau_k(d_{ch}(x_c)) \eta_{p,k}(x_c; d_{ch}) F_i(x_c) K_{r,e}} dx_c$$

## Main inputs:

$\theta_k$  : Effective time in different zones ("c", "b", "wl", ...)

$\tau_k$  : Time constants ("faf", "fac" and "ba")

$d_{ch}(x_c)$  : Changes of char particle size with conversion

$F_i(x_c) K_{r,e}$  : Intrinsic reactivity (with respect gas and solid)

$\eta_{p,k}(x_c; d_{ch})$  : Diffusion effects



# Summary and Conclusions



1. Char conversion is a decisive factor in CFBG
2. Precise modelling of the process is too difficult
3. Need for better implementation (as a submodel) in existing CFBG:
  - Simplifications
  - Laboratory tests (properly designed)
4. Comparison with data from CFBG in progress



# Contact /further information



Thank you for your kind attention  
(More details in our paper)

web:

<http://www.grupobioenergia.com>

Contact:

[agomezbarra@esi.us.es](mailto:agomezbarra@esi.us.es)

[ble@chalmers.se](mailto:ble@chalmers.se)