UNIVERSITÀ DEGLI STUDI DI PALERMO
Dipartimento di Ingegneria Chimica, Gestionale, Informatica, Meccanica (DICGIM)

COMSOL CONFERENCE ROTTERDAM 2013

Reverse Electrodialysis process with seawater and concentrated brines: a COMSOL model for equipment design

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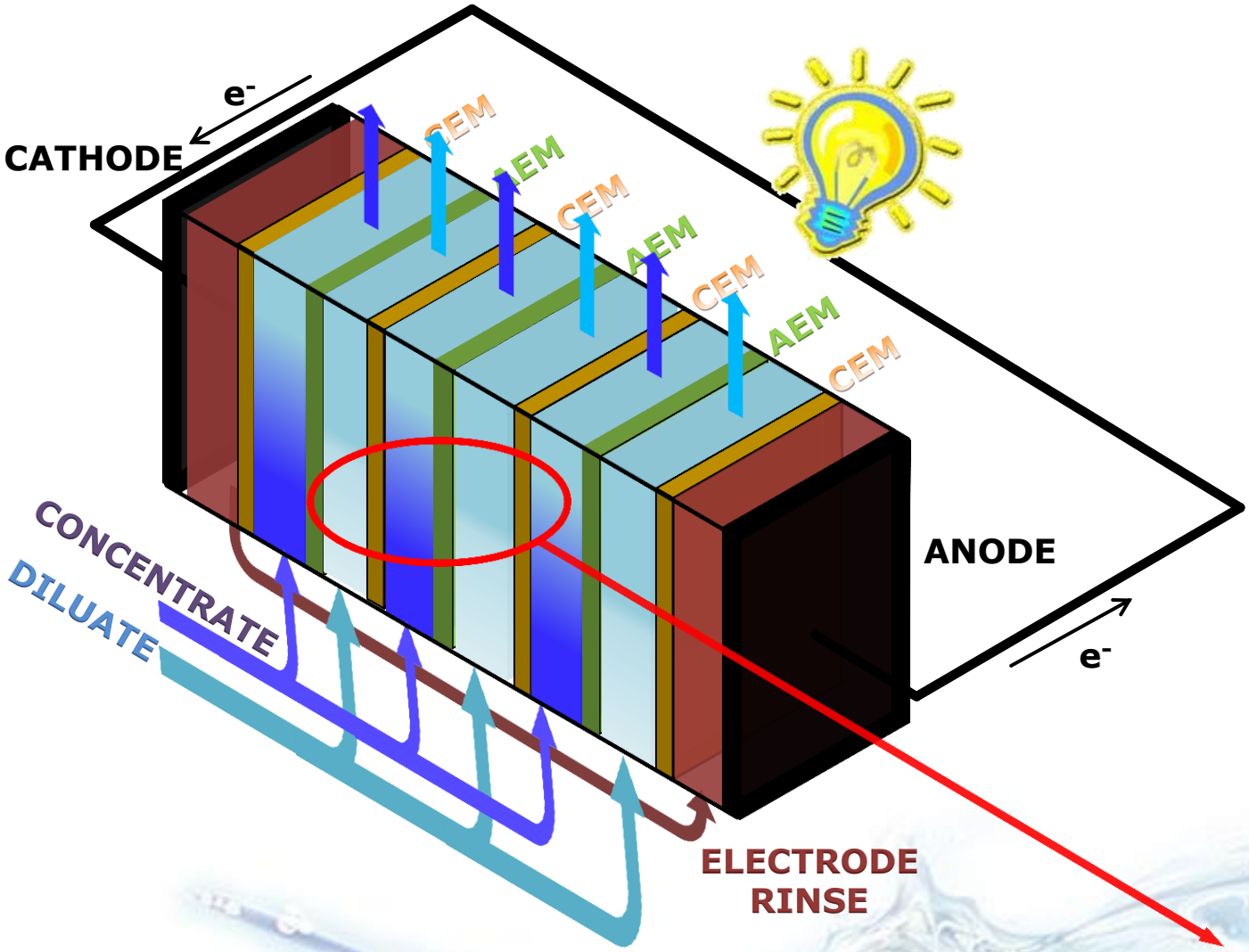
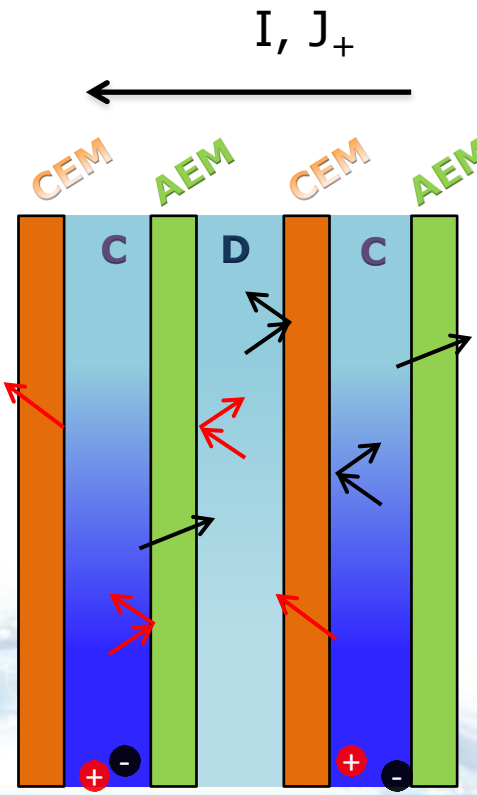
Outline

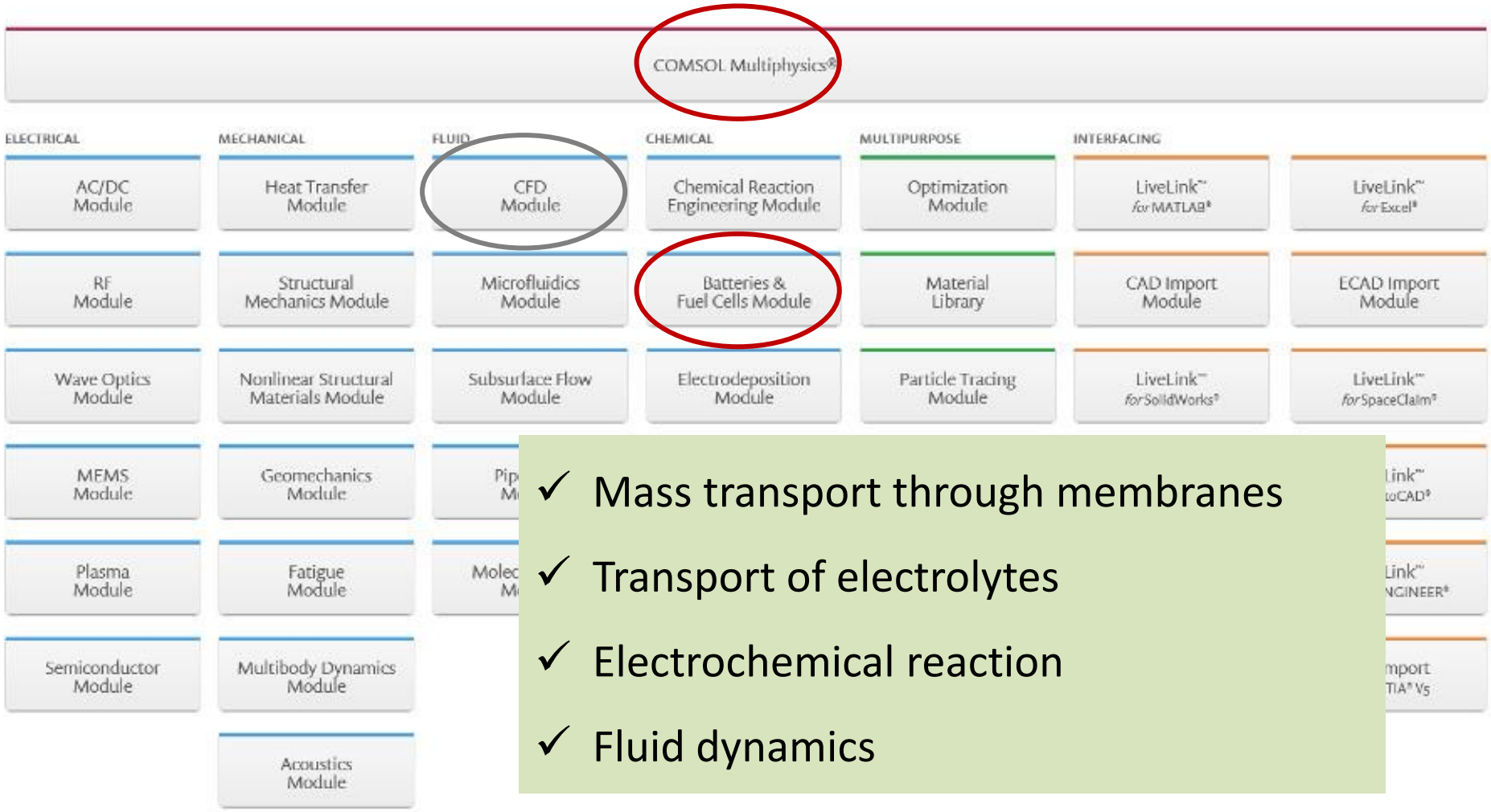
Reverse Electrodialysis Technology





Modelling goals

Investigated physics



- ✓ Mass transport through membranes
- ✓ Transport of electrolytes
- ✓ Electrochemical reaction
- ✓ Fluid dynamics

System definition and model assumptions

Model assumptions:

- **Empty channels**
- **NaCl** aqueous solutions
- **Negligible solvent flux** through membranes
- Adopting **Nernst-Planck** equation
- **Activity coefficients** equal to unity
- Adopting **Einstein** relation for ion diffusion coefficient

Governing equations

- Laminar flow for Newtonian fluid:

$$\boldsymbol{\nabla u} = 0 \qquad \rho\frac{\partial \boldsymbol{u}}{\partial t} + \rho \boldsymbol{u}\boldsymbol{\nabla u} = -\boldsymbol{\nabla} P + \mu\nabla^2\boldsymbol{u} + \boldsymbol{F}$$

- Transport equation through solutions (*Nernst-Planck* model):

$$N_i = -D_i\nabla c_i - z_i u_{m,i} F c_i \nabla\Phi_l + u c_i$$

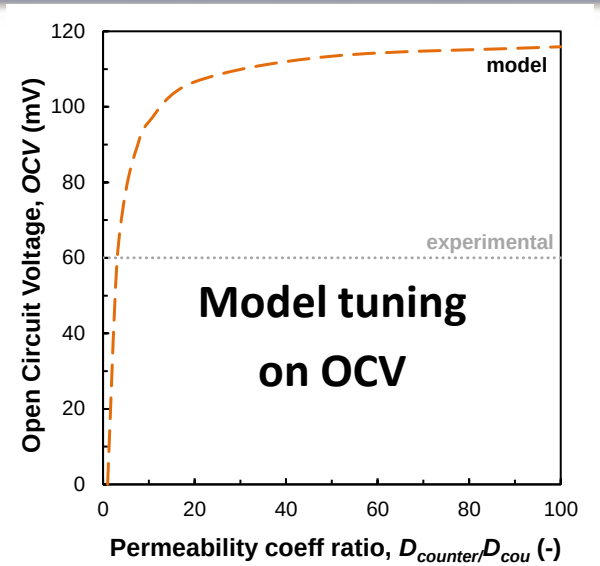
$$i_l = F\sum_i z_i\left(-D_i\nabla c_i - z_i u_{m,i} F c_i \nabla\Phi_l\right) \qquad \sum_i z_i c_i = 0$$

- Electrode kinetics (*Butler-Volmer* theory):

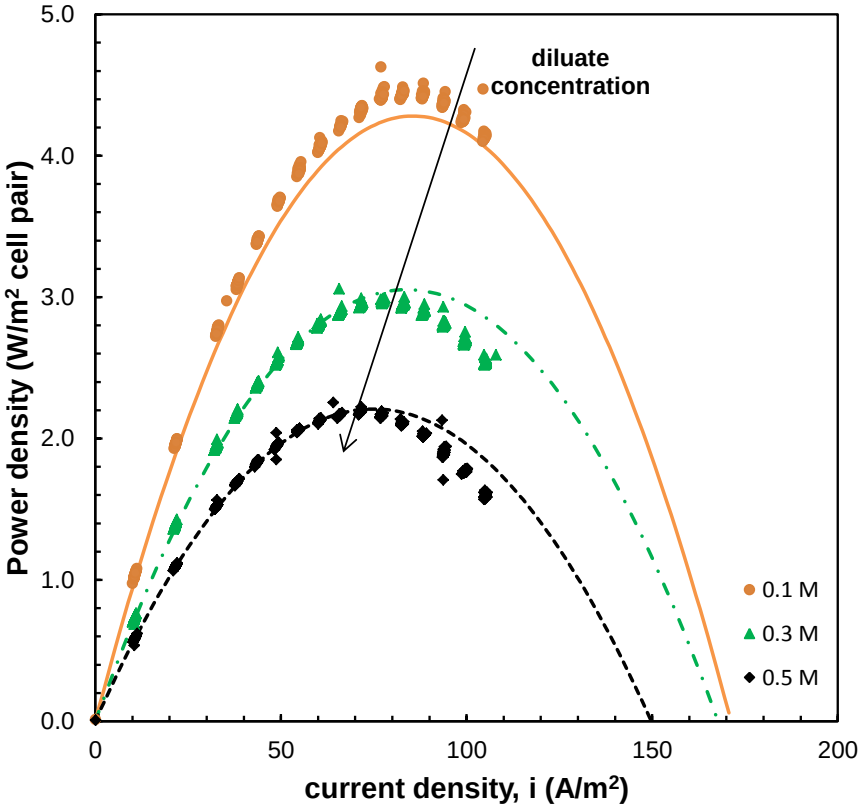
$$i = i_0\left[exp\left(\frac{\alpha_a F\eta}{RT}\right) - exp\left(\frac{-\alpha_c F\eta}{RT}\right)\right]$$

$$\nabla \cdot i_l = F\sum_i z_i R_{i,src} Q_l$$

Model tuning/validation

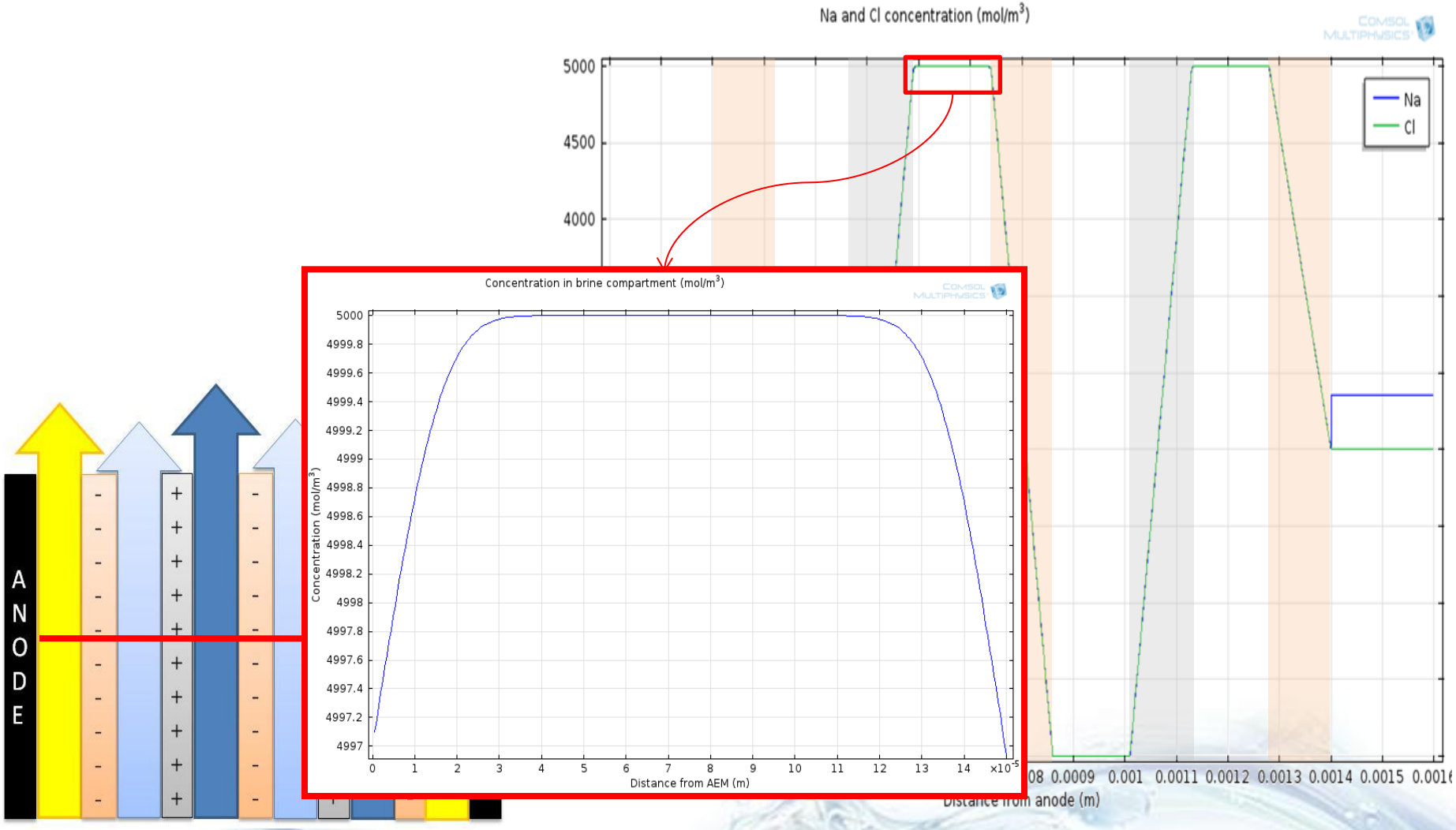


Model validation

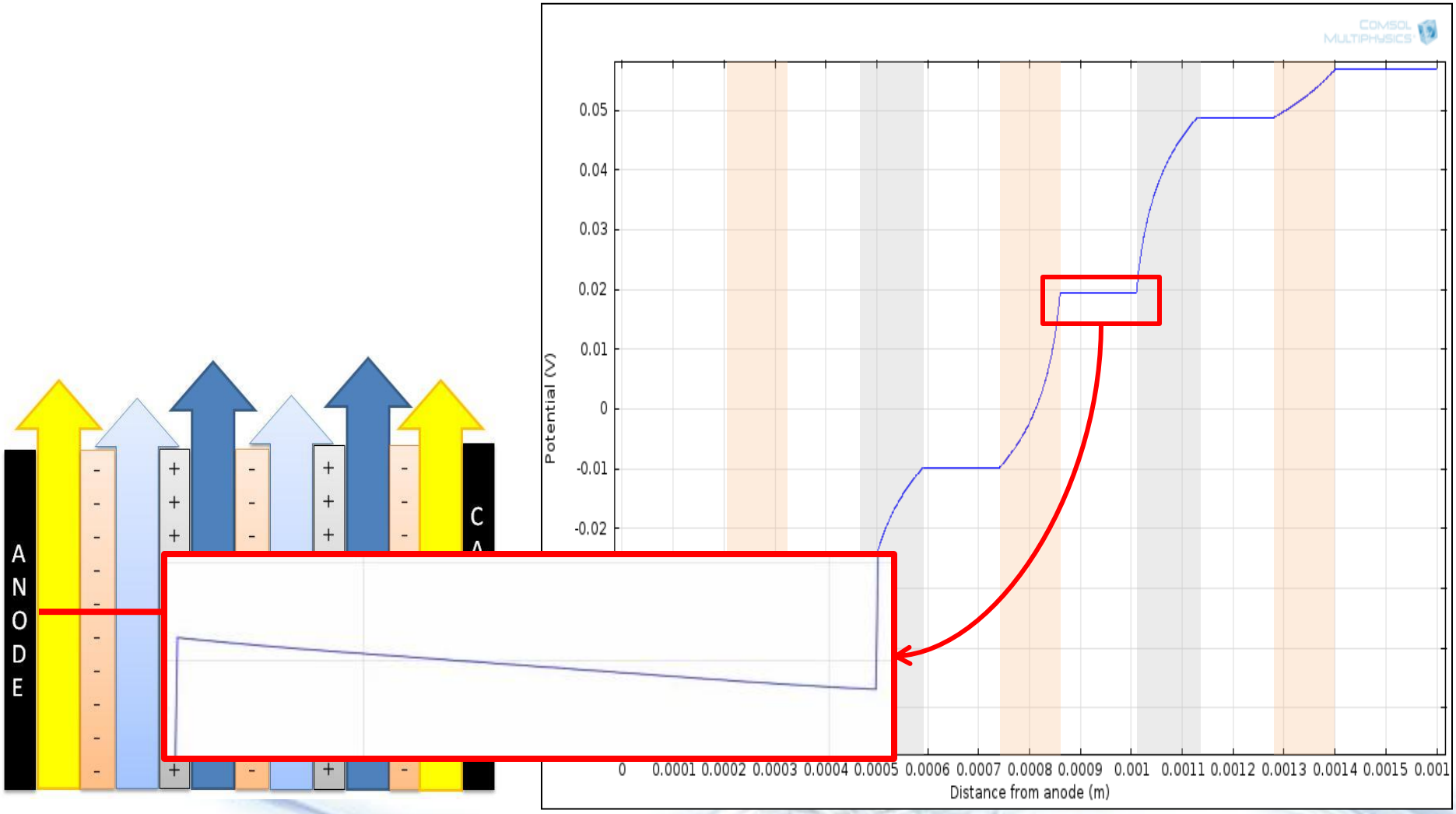


Experimental data collected with a 50 cell pairs stack, Fujifilm membranes, Deukum 270 µm spacers. Brine: 5 M NaCl. T=20° C. Fluid velocity: 1 cm/s.

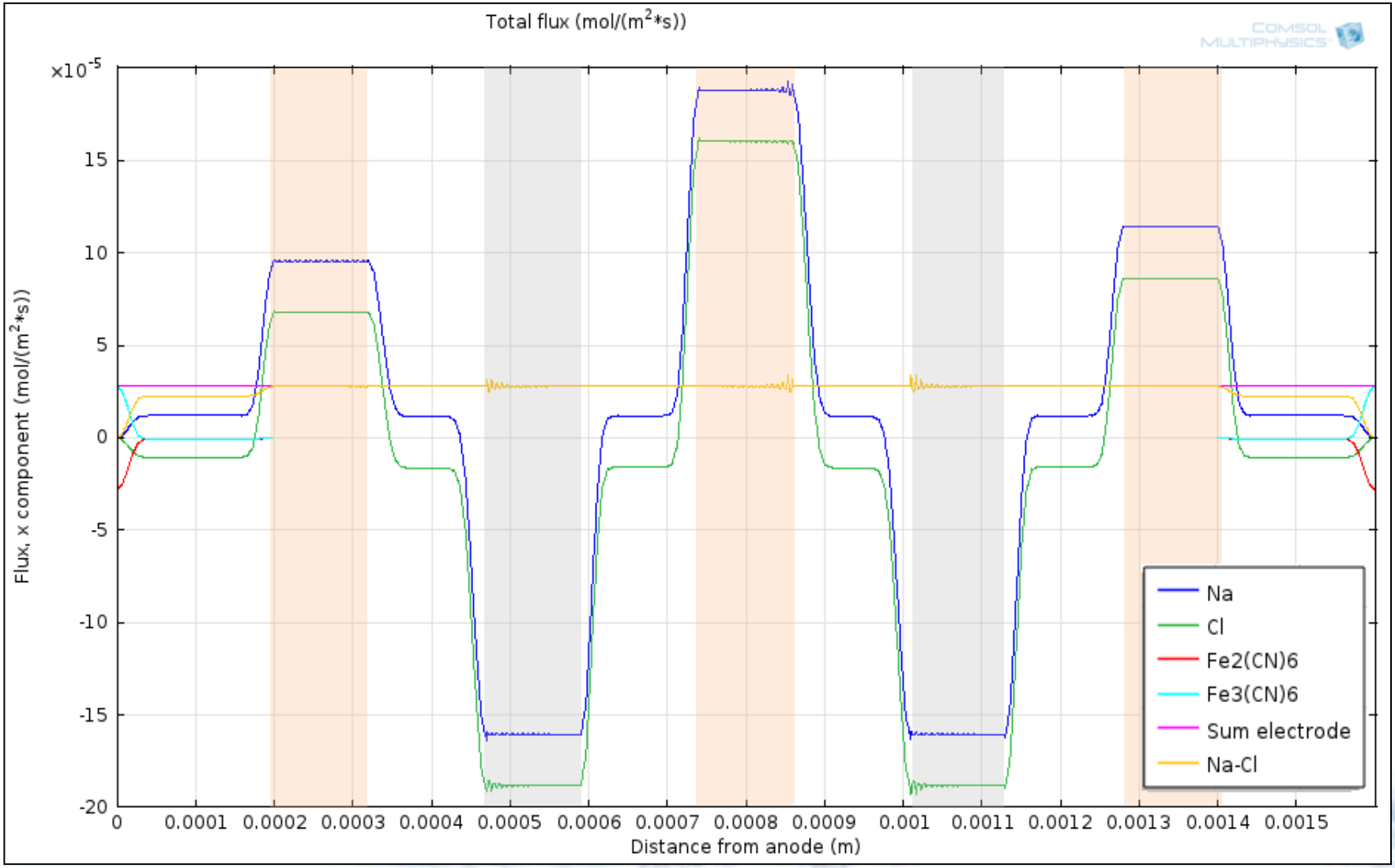
Concentration profiles along channels



Electric potential through the stack



Salt fluxes through membranes



Conclusions

✓ **Model validated** on experimental data under different conditions

✓ Simplified approach to simulate both **fluid dynamics/electrochemical phenomena**

Next steps

- **Activity coefficients** evaluation
- **Mechanical analysis** on membranes
- Description of **Donnan Potentials** across membranes

Acknowledgments

www.reapower.eu

Project title: *Reverse Electrodialysis Alternative Power Production*

Call identifier: FP7-ENERGY-2010-FET

(Future Emerging Technologies for Energy Applications)

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Thank you for your attention

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