



THE NORTHERNMOST UNIVERSITY
of Technology in Scandinavia

Minor Elements in Copper Converting

Andreas Lennartsson, Fredrik Engström,
Bo Björkman and Caisa Samuelsson
Luleå University of Technology



Background

- Increasing complexity of raw material
 - New mines with complex mineralization
 - Lower copper grade
 - Secondary material
- Waste Electric & Electronic Equipment (WEEE)
 - E-scrap for recycling
- Joint project together with Boliden Mineral AB
 - Dynamic model of Peirce-Smith Converter
 - Influence of treating WEEE



WEEE

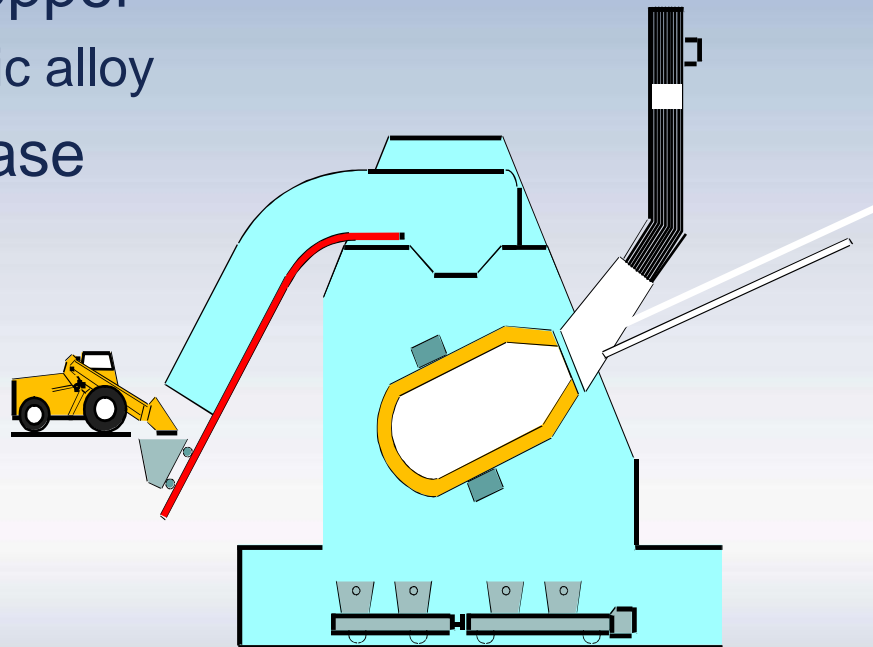


E-Scrap

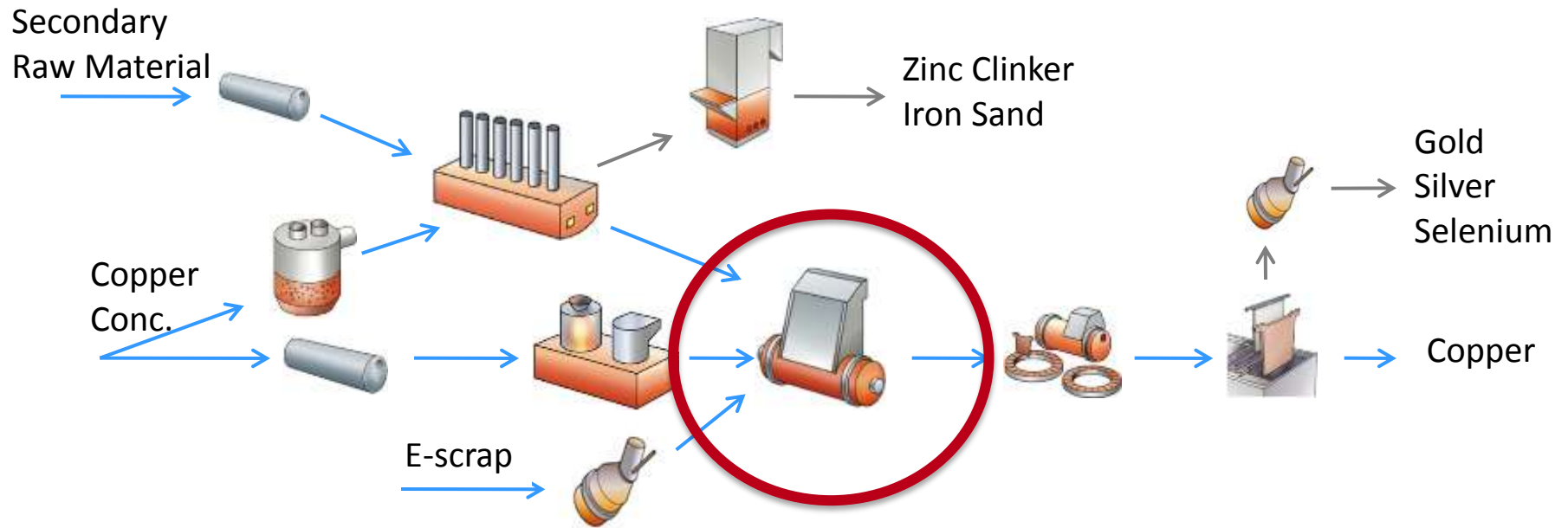


E-scrap smelting

- The KALDO
 - Black copper
 - Metallic alloy
 - Slag phase



Copper flow at Rönnskär Smelter



Element present at a copper smelter

hydrogen 1 H 1.0079																	helium 2 He 4.0026						
lithium 3 Li 6.941	beryllium 4 Be 9.0122																	boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305																	aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.096	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.38	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.907	selecnium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80						
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29						
caesium 55 Cs 132.91	barium 56 Ba 137.33	* 57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	mercury 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]					
francium 87 Fr [223]	radium 88 Ra [226]	* * 89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [269]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	unnilium 110 Uun [271]	ununium 111 Uuu [272]	ununbium 112 Uub [277]											

Major Elements

Minor Elements

* Lanthanide series

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
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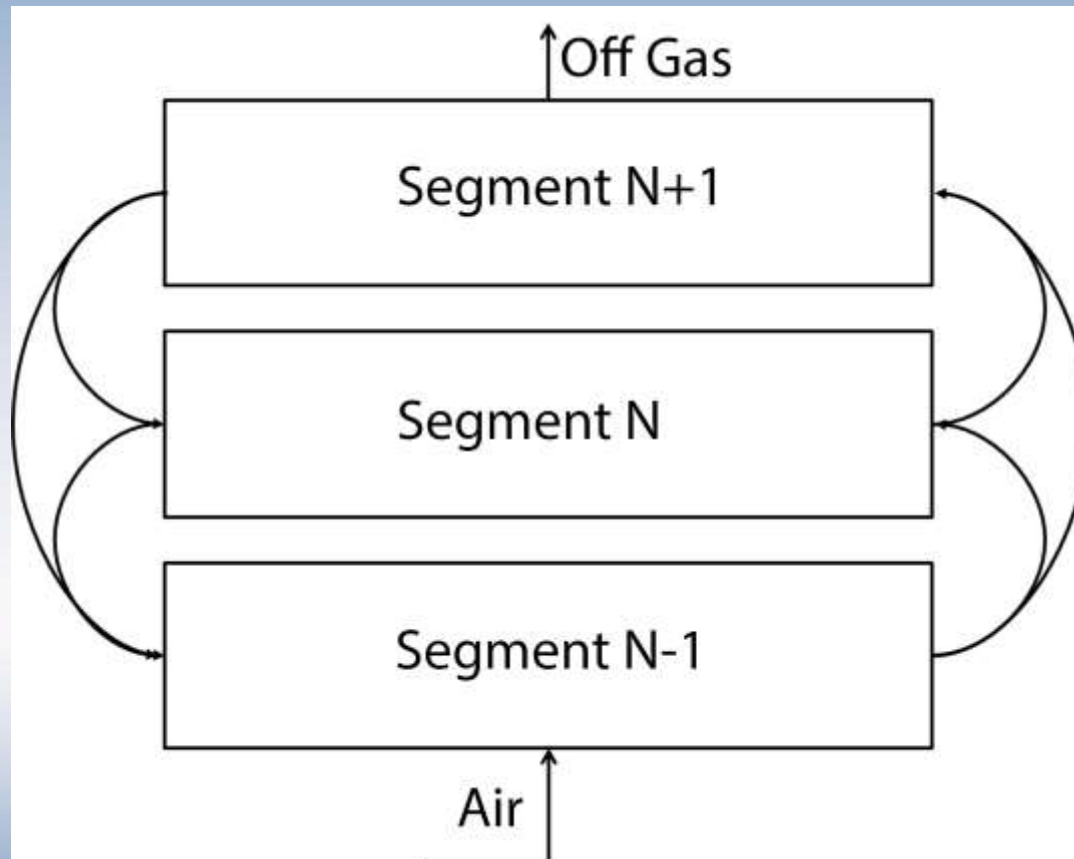
* * Actinide series

actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendeleevium 101 Md [258]	nobelium 102 No [259]
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Challenges in PS-Converter simulation

- Non-equilibrium process
- Minor elements not assessed for the system
 - Ftmisc-MAT2B (S-Cu-Fe-Ni)
 - Ftmisc-MATTE (S-Cu-Fe-Ni-Co-Pb-Zn-As)
 - What about Bi, Sb, Sn, In, etc
- Focus on Bi and Sb
 - Dilute components in matte, slag and metal phase

Non-equilibrium model





Simulation result

Charge No.860 Slag blow

	Liquid slag							
wt-%	Fe	Cu	Pb	Zn	S	SiO ₂	CaO	MgO
Plant data	31.2	6.1	6.5	6.6	-	29.9	0.6	0.3
Model	34.4	5.0	4.0	9.5	0.0	30.0	0.3	0.1
Equilibrium	36.1	2.1	3.2	9.8	0.1	32.7	0.3	0.1

	White metal				
wt-%	Fe	Cu	Pb	Zn	S
Plant data	0.4	75.9	0.5	0.1	17.8
Model	1.1	75.9	1.7	0.6	19.9
Equilibrium	1.0	75.9	1.7	0.5	20.0

Bismuth and Antimony in Charge 860

wt-%	Liquid slag		White metal	
	Bi	Sb	Bi	Sb
Plant data	0.006	0.11	0.02	0.10
Model prediction	0.006	0.04	0.03	0.11
Equilibrium	0.001	0.04	0.05	0.11

	L Matte/Slag	
	Bi	Sb
Plant data	3.3	0.9
Model prediction	3.9	3.1
Equilibrium	95.8	2.6

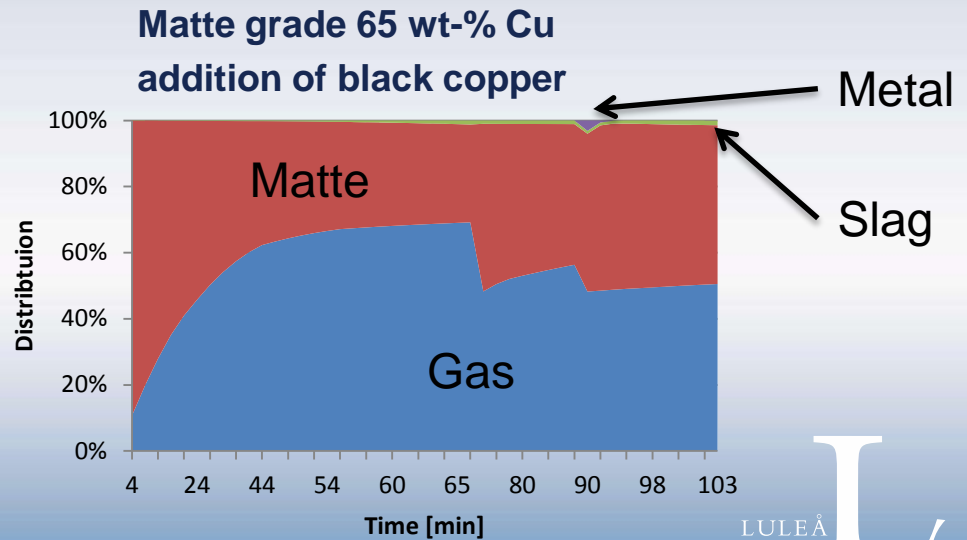
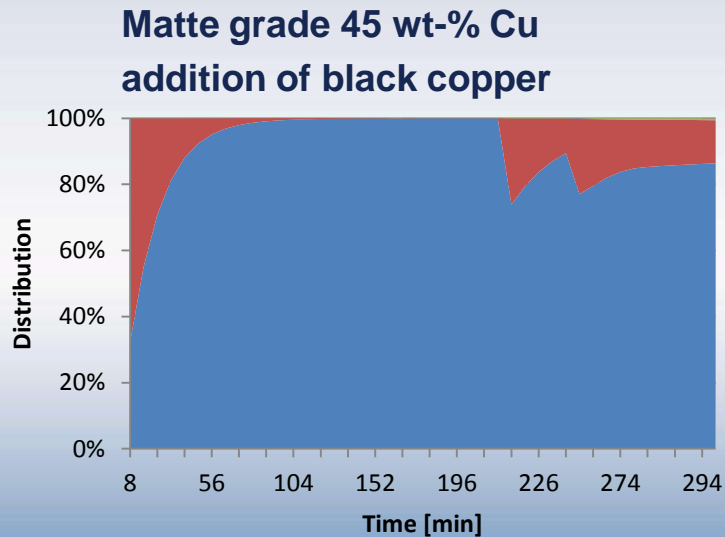
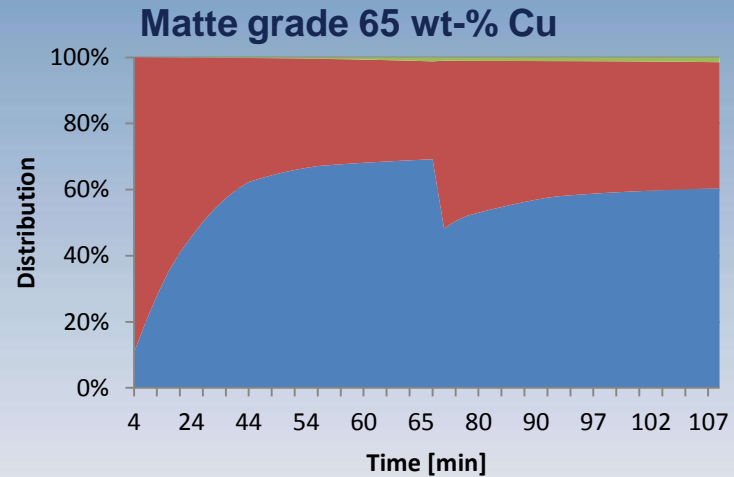
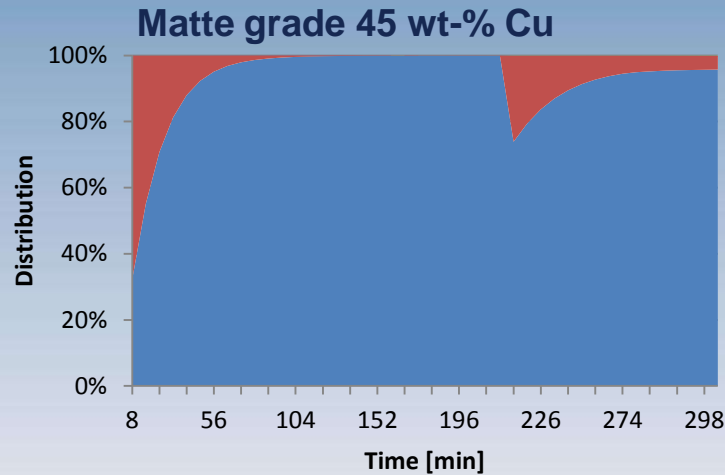


Case Study

- Addition of black copper during the slag blow
 - Matte grade
 - Point of addition
 - Isothermal
 - Constant Fe/SiO₂ ratio
- Focused on Bi and Sb



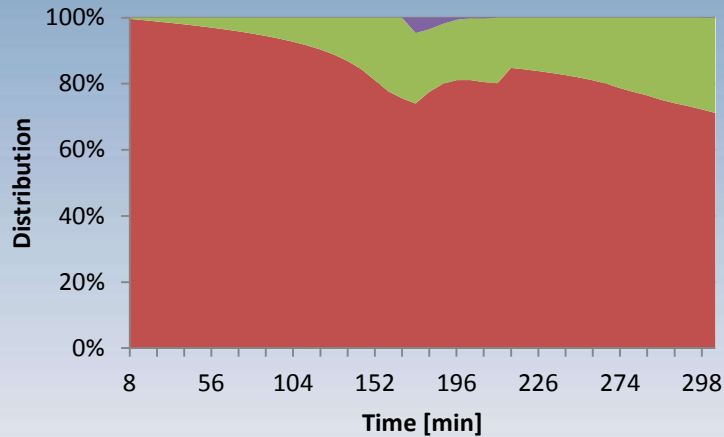
Bismuth distribution



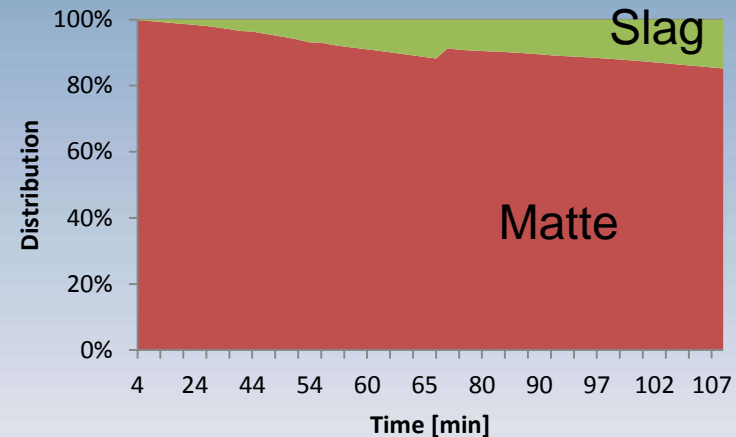


Antimony distribution

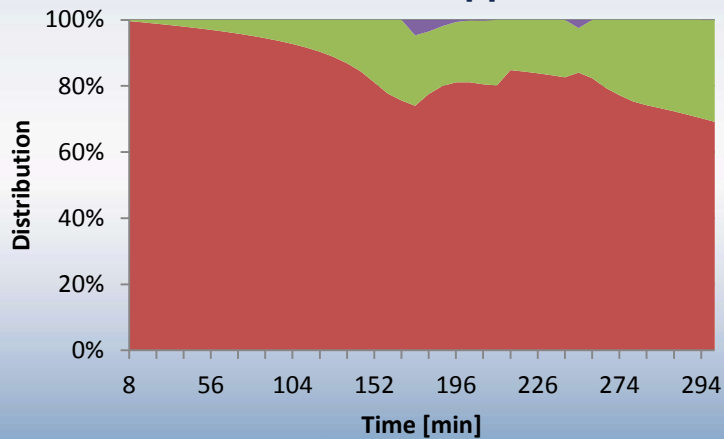
Matte grade 45 wt-% Cu



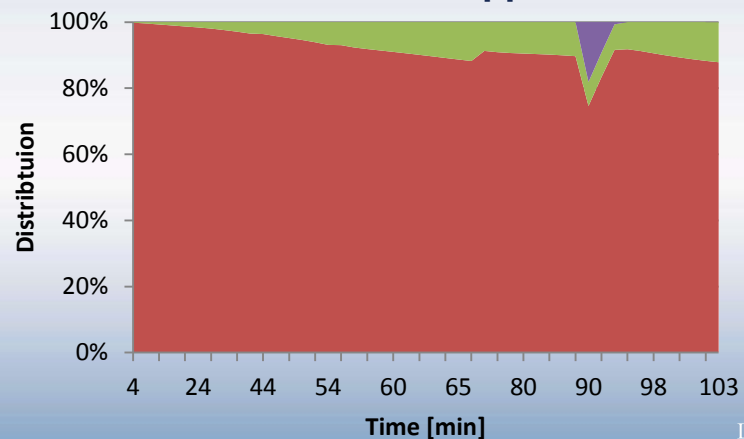
Matte grade 65 wt-% Cu



**Matte grade 45 wt-% Cu
addition of black copper**



**Matte grade 65 wt-% Cu
addition of black copper**



Conclusions

- A non-equilibrium model based on segments has been realized with SimuSage
- Adding Bi and Sb as dilute components works
- The vaporization of Bi and slagging of Sb is influenced by matte grade
- Addition of black copper
 - negative influence on the vaporization of bismuth
 - Slightly positive influence on slagging of Sb when low grade matte
 - Slightly negative influence on slagging of Sb when high grade matte

Thank you for the attention

Questions

Non-equilibrium model

