Mill-Integrated CO_2-capture 2025-2027

Interim Project Results

25.8.2026

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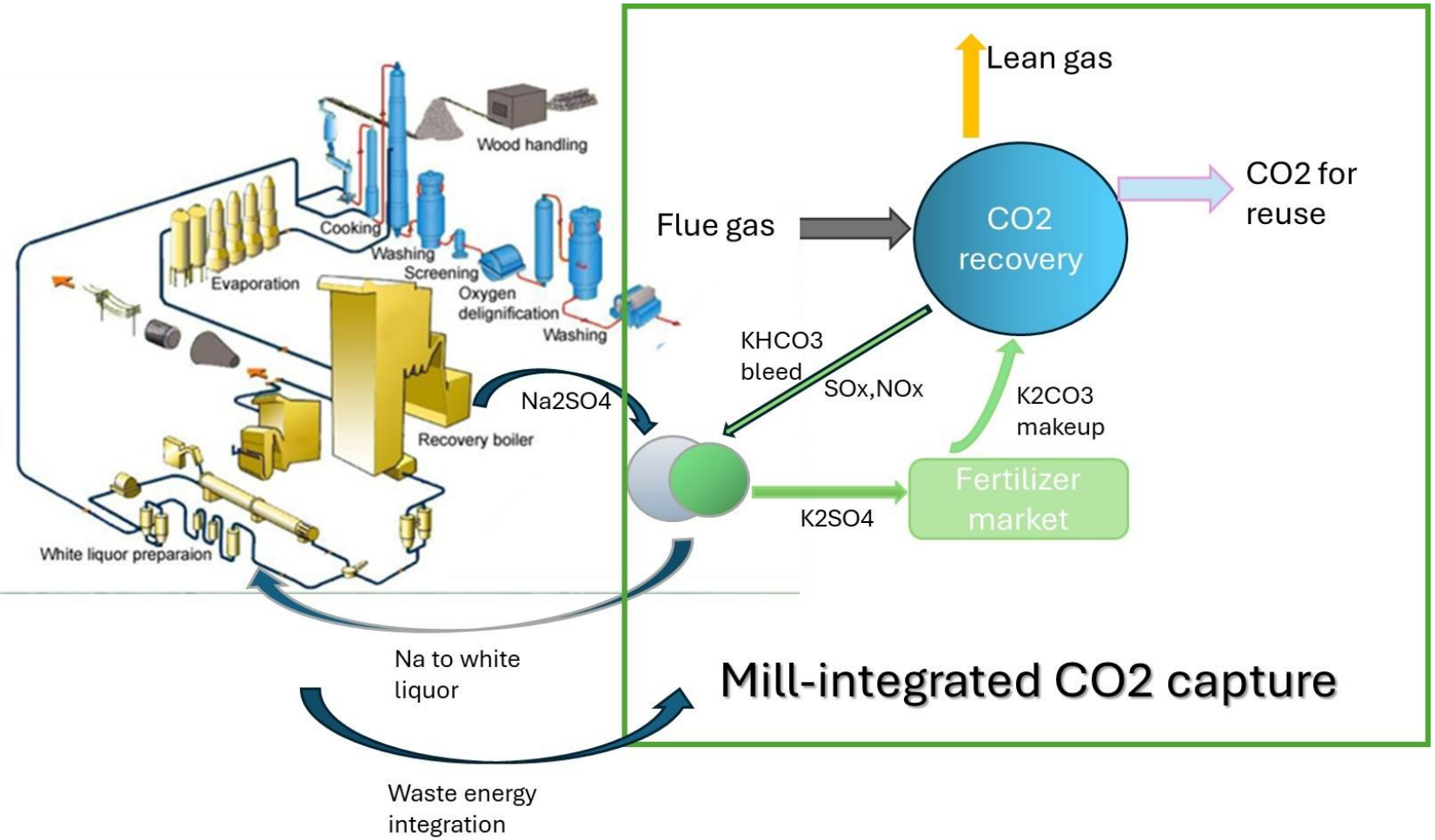
Mill-Integrated CO_2 Capture – Project Focus



Hallinnoija: Xamk - LUT

Osatoteuttajat: Xamk – LUT rinnakkain

Muut kumppanit: CarbonREuse, JP-Set Oy, Ecopal Oy, Riitek Oy, Q-Power

Rahoittaja ja päärahoituslähde:

Kokonaisbudjetti: 550 000, Xamk Kuitu 275 000 €

BF:n osuus kokonaisbudjetista: 80 %

BUSINESS FINLAND

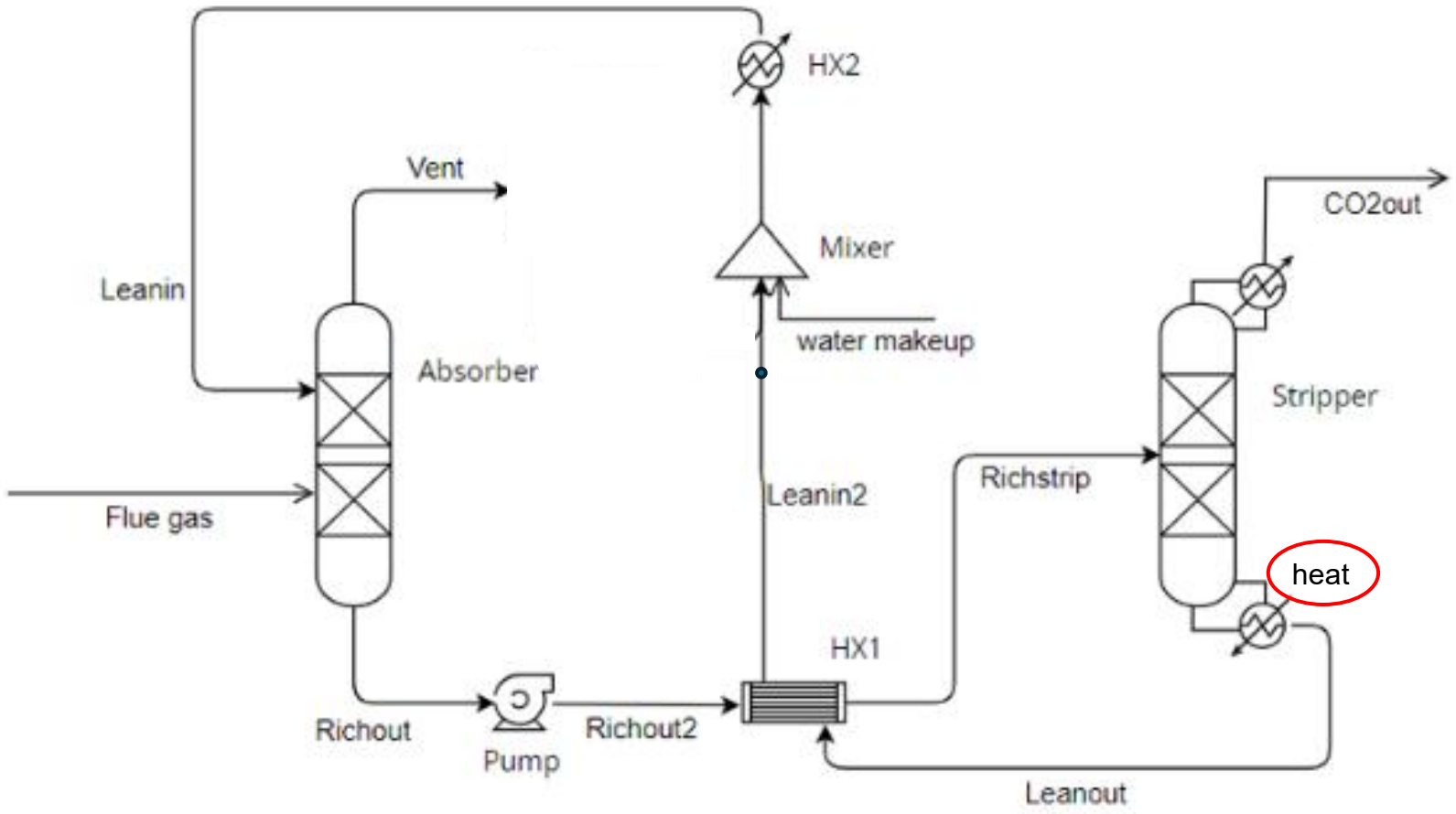
TARGET:

To integrate CO_2-capture by both chemical and energetic means for pulp mills

LUT University

XAMK

Flow scheme of CO_2 recovery with aqueous carbonates



Overall reactions:

$$CO_2 + K_2CO_3(aq) + H_2O$$

absorption ↓ ↑ desorption (by heat)

$$xKHCO_3\,(aq) + yKHCO_3(s) \quad (x+y=1)$$

- Well-known method (HPC) with hot aqueous potassium carbonate as absorbent
- HPC vs. amines: little or no make-up of absorbent, no toxic reaction products

Fradette & al. Energy Procedia 2017; Plakia & al *Energies 2025*

Absorption to potassium bicarbonate solids ($KHCO_3$)

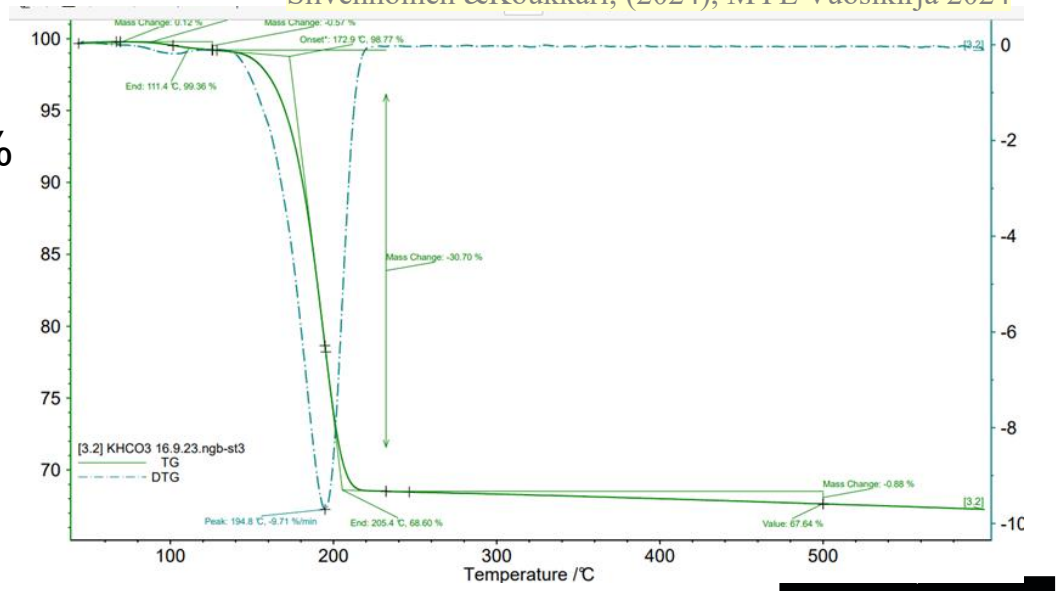
Conventional Hot Potassium Carbonate (HPC) method with aqueous carbonate solution (ca 25 w-% as K_2CO_3)

- Slow reaction rate (compared to amines)
- high L/G (liquid to gas) ratio in absorption
- operated over 100 C with elevated pressures

Bicarbonate method with high concentrations (up to 40 w-% K_2CO_3) to allow for bicarbonate precipitation*.

- Increase the reaction rate by solid partictle autocatalysis
- Reduce the L/G ratio
- Operation in atmospheric conditions

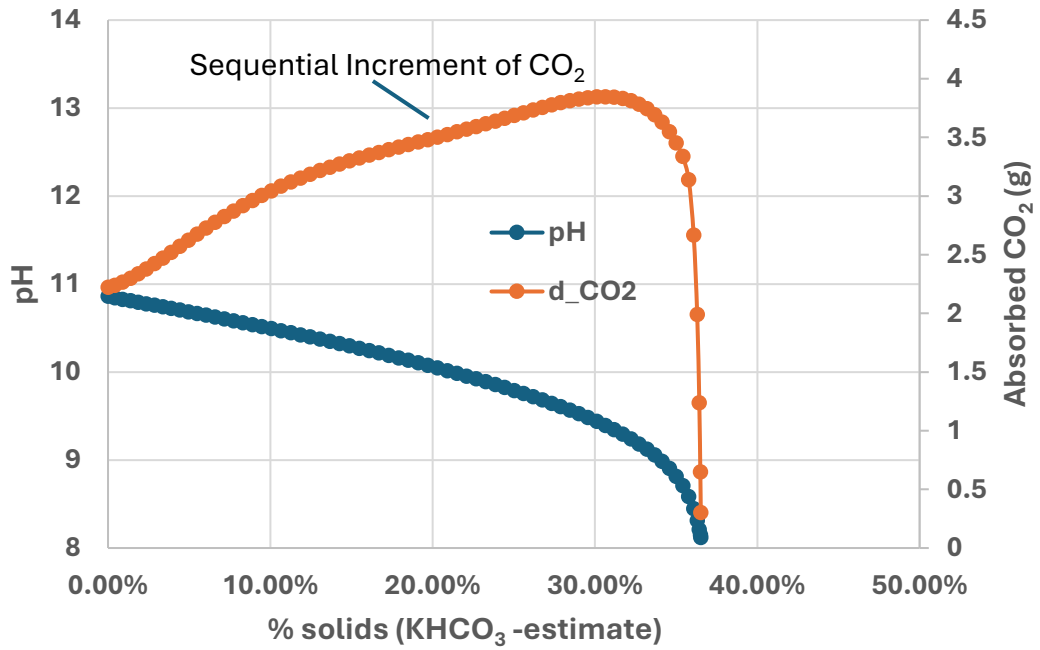
Silvennoinen &Koukkari, (2024), MYE Vuosikirja 2024



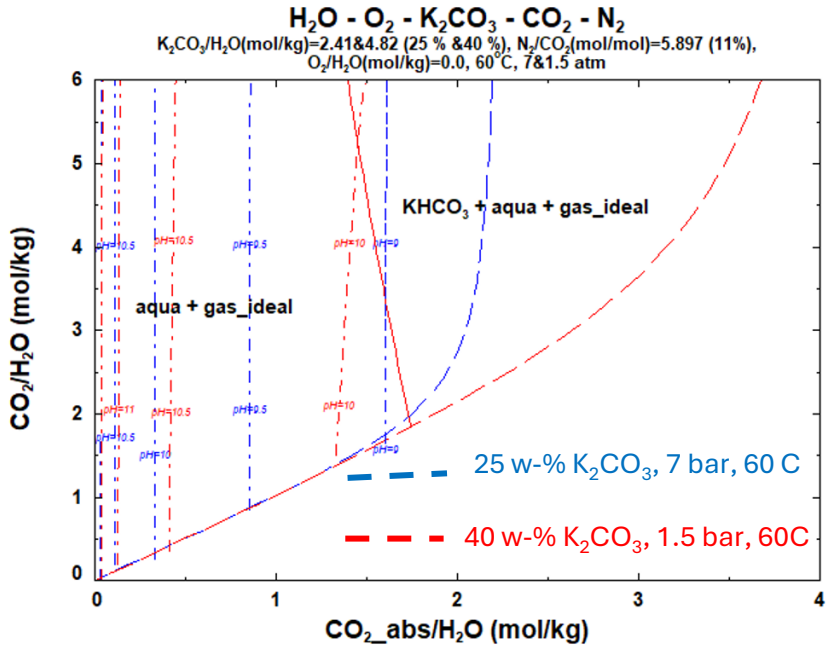
*Smith &al. Fuel Proc.Tech. 2014; Bhaduri, Ph.D.Thesis University of Newcastle 2018; Liu, Chem.Eng.J.2023

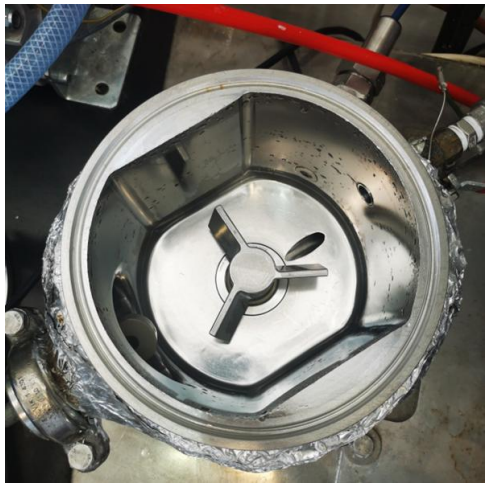
Absorption tests in the constant volume reactor

pH and CO_2-absorption vs solid bik-content (25 C, 3 bar, 23 % CO2)



Total CO_2-feed vs CO_2-absorption

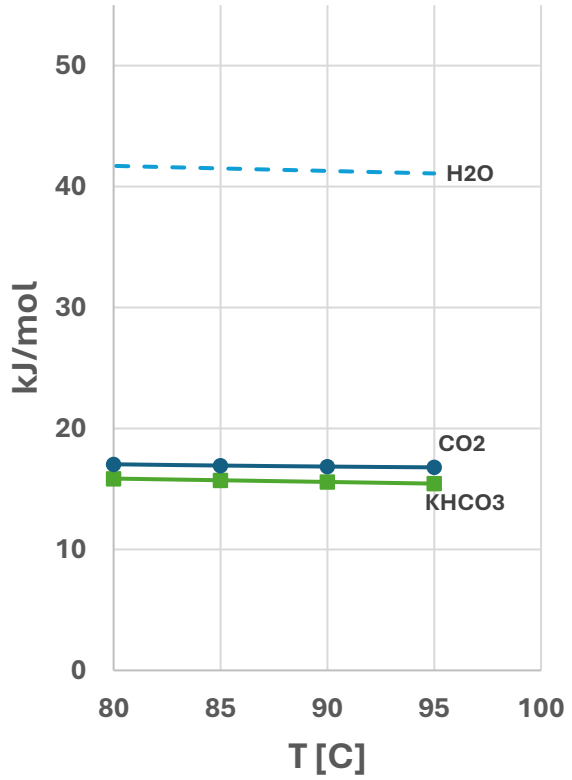




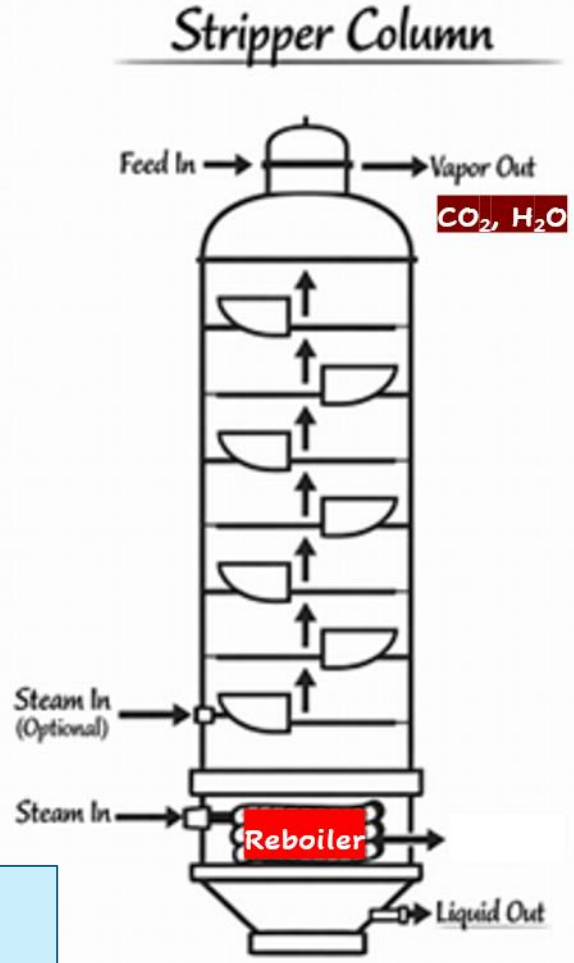
- Consecutive increments of CO_2 absorption measured in a constant volume reactor
- CO_2-absorption enhanced by a factor of 1.5-2 with increasing contents of $KHCO_3$-solids (measured CO_2 absorption vs. estimated $KHCO_3$ -content, up left)
- With added CO_2 feed the CO_2 -absorption increases until the absorbent becomes fully saturated (up right phase diagrams superimposed for the pressurised liquid and nearly atmospheric precipitating systems)
- Patented process concept (FI20236390)

Stripper column model to recover CO_2 from bicarbonate slurries

Endotherms of the desorption reactions



- Desorption reactions are endothermic
- To avoid column fouling $KHCO_3$ must be dissolved (by heat) before CO_2 -stripping



- CO_2 -stripping by heating or by added steam in a tray column
- Steam &a CO_2 move upwards on successive equilibrium trays
- Iteration model with constant heat/steam input from the bottom
- column pressure & tray temperatures given as inputs
- LP-steam (110-120 C, 1.5-2 bar)
- CO_2 -recovery given from the column top
- Solution gives compositions & heat load
- Heat load average 2.91 MJ/kg_ CO_2 (1.5 bar 110-100C; cf. Fradette & al 2017 3.6-4.0 MJ/kg; Plakia & al 2017 3.5-6 MJ/kg for atmospheric HPC)

Mahdollisia lämmönlähteitä CO_2-talteenottoon

Lämmönlähde	Energiamäärä (MJ/kg_ADt)	Lämpötila-alue
Soodakattilan savukaasupesuri	3–4,5 MJ/kg_ADt	40–65°C (tyypillinen)
Meesauunin savukaasupesuri	0,8 MJ/kg_ADt	60–65°C
Haihduttamon pintalauhdutin	3,5–4,55 MJ/kg_ADt	40–50°C
Haihduttamon sekundäärilauhteet	1,2–1,6 MJ/kg_ADt	60–70°C
Kuitulinjan kuumat suodosvedet	1,5–2,5 MJ/kg_ADt	40–50°C
Kuivatuskoneen poistoilma	2–3 MJ/kg_ADt	40–70°C
Keittämö (pusku- ja kaasuhöngät, paisuntahöngät)	0,8–1,3 MJ/kg_ADt	100–150°C
Keittämön hönkähöyryt (KnowPulp)	0,8–1,0 MJ/kg_ADt	60–65°C

KnowPulp 2026 / XAMK Aino Pesonen

- **Korkean lämpötilatason lähteet** (≥120°C):
  – Soodakattilan savukaasut – Keittämön 100–150°C höngät
- **Keskitason lähteet** (60–100°C):
  – Savukaasupesurit – Sekundäärilauhteet – Kuivatuskoneen poistoilma (yläosa).
- **Matalan ja erittäin matalan tason lähteet** (40–60°C): -Pintalauhduttimet – Suodosvedet – Kuivatuskoneen poistoilma (alapää)

*** CO_2-talteenottopotentiaali**

Tehdas	Sellu (Mt/a)	Biogeeninen CO_2 (Mt/a)
Äänekoski	**1,3**	**~1,0**
Kemi	**1,5**	**~1,1**
Rauma	**0,75**	**~0,55**

- * CO_2-talteenottopotentiaali ≈ ADt per vuosi
- CO_2:n talteenoton kannalta hukkalämpömäärä jopa yksittäisistä lähteistä on merkittävä
- Mahdollisuus lämpöpumppusovelluksiin ($KHCO_3$-liuotus)

Mill-Integrated CO_2 -capture: Interim conclusions

- Formation of solid $KHCO_3$ in absorption reduces L/G ratio and increases the reaction rate
- Allows for operation in atmospheric conditions and relatively low temperatures (below 120 C)

- No toxic side products and less (zero ?) need of gasout washing
- Little makeup of absorbent, recovery of SOx and NOx impurities as potassium salts

- Heat/steam integration needed for industrial operation

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Tunne huominen - All for the future.