

Upotreba goriva iz otpada u cementnoj industriji

=> Kvaliteta goriva – koprocesiranje – emisije – primjer Gospić

Assoc.Prof. Dipl.-Ing. Dr.mont. Renato Šarc



AKADEMIJA TEHNIČKIH ZNANOSTI HRVATSKE – Okrugli stol o energetskej uporabi (opasnog) otpada
Zagreb, 07.10.2026.

MOVE MOUNTAINS

Kvaliteta GIO-a počinje kvalitetom ulaznog otpada !

Miješane vrste industrijskog i komunalnog otpada



Möllnitz et al. (2020): <https://doi.org/10.1016/j.wasman.2019.12.037>

Proizvodnja Goriva iz Otpada

Ulazni otpad:

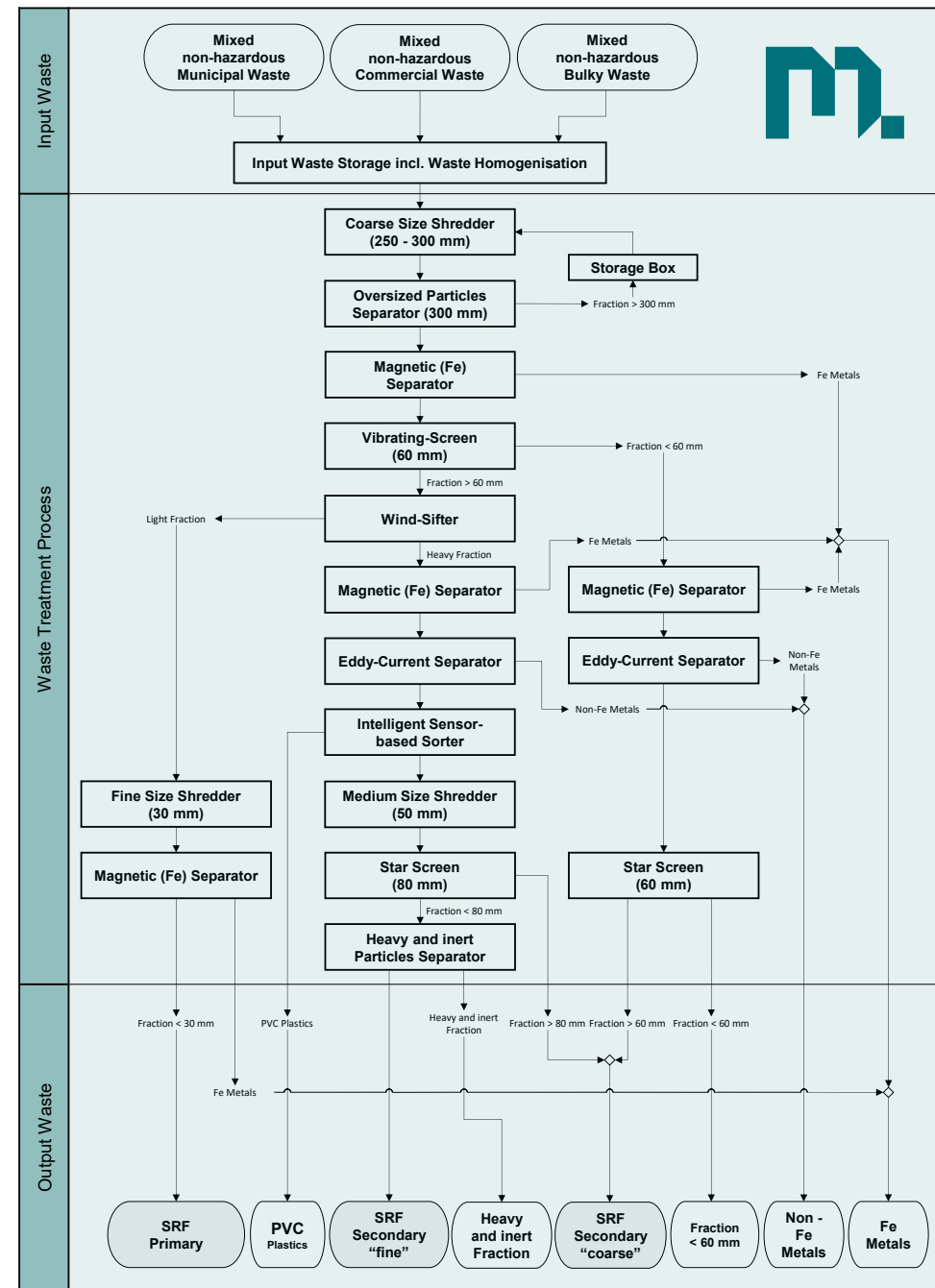
- Miješani komunalni i komercijalni otpad
- **HETEROGEN**, promjenjiv, određuje kvalitetu izlaznog proizvoda!

Proces obrade otpada:

- **Usitnjavanje** → veličina čestica i oslobađanje materijala
- **Klasiranje** → udio fine frakcije i odnos veličina čestica (relevantno za opremu)
- **Sortiranje** → vrijedne i neželjene komponente: Fe, obojeni metali, PVC, (PP, PE)
- **Naknadno usitnjavanje** → veličina čestica prema zahtjevima krajnjeg korisnika

Izlazni tokovi = otpad:

- GIO „primary“ za cementnu industriju
- GIO „secondary“ različitih granulometrijskih razreda, za cementnu industriju ili postrojenja za spaljivanje otpada (energane)



Kvaliteta GIO-a ovisi o mjestu doziranja

➤ GIO „primary“ / za primarni gorionik:

- LHV: 18–25 MJ/kg, ar
- veličina čestica: < 30 (35) mm
- primjena u primarnoj zoni izgaranja

➤ GIO “secondary“ / za sekundarne pozicije doziranja:

- LHV: 12–18 MJ/kg, ar
- veličina čestica: ovisno o tehnologiji < 80 do ca. 300 mm
- primjena u sekundarnoj zoni izgaranja, primjerice u kalcinatoru, ulazu u peć, predkomori peći



Viczek, S.A.; Aldrian, A.; Pomberger, R.; Sarc, R. Determination of the material-recyclable share of SRF during co-processing in the cement industry. *Resources, Conservation and Recycling* 2020, 156, 104696. <https://doi.org/10.1016/j.resconrec.2020.104696>.

Primjena otpadnih materijala u cementnoj industriji

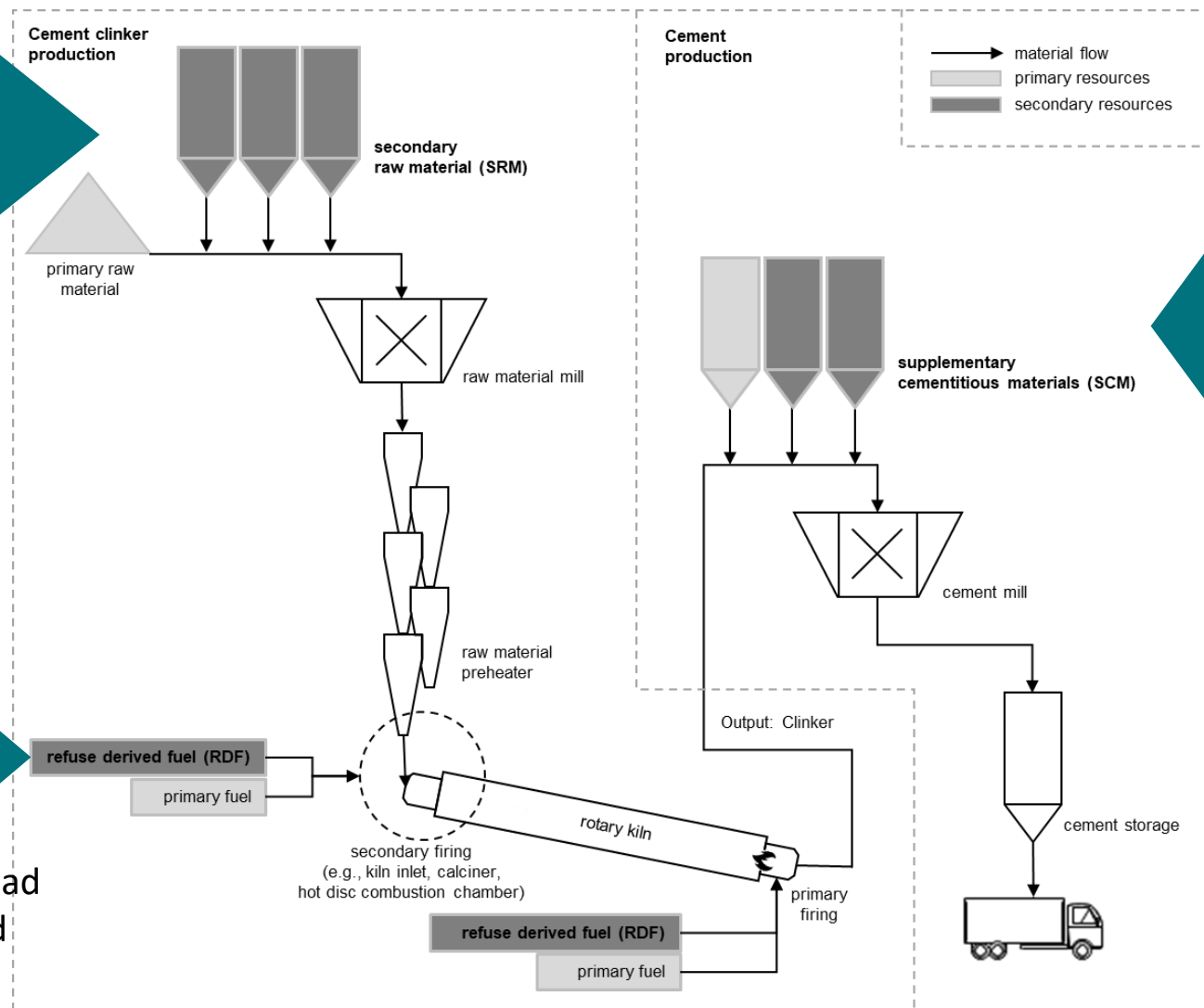


SEKUNDARNE SIROVINE (SRM – Secondary Raw Materials):

npr. vapneni muljevi,
ljevaonički pijesak,
dijelovi građevinskog
otpada

GORIVA IZ OTPADA

npr. otpadno ulje kao opasni otpad
i GIO iz MKO kao neopasni otpad



DODATNI CEMENTNI VEZIVNI MATERIJALI (SCM – Supplementary Cementitious Materials):

npr. granulirana troska
iz visokih peći, pepeo,
silicijska prašina

Uporaba GIO-a u CI = Koprocesiranje

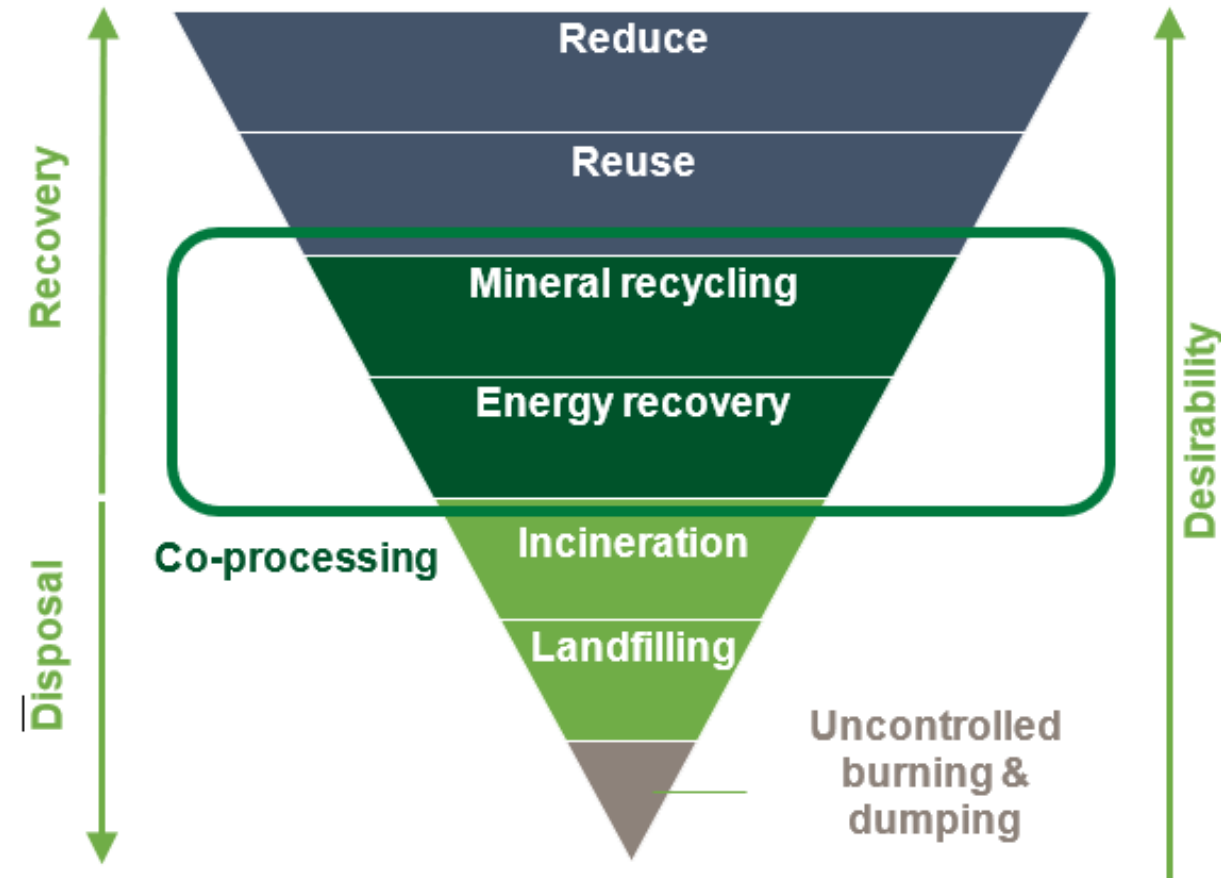
Koprocesiranje:

obuhvaća industrijske procese koji istodobno omogućuju::

- **ENERGETSKU OPORABU I**
- **MATERIJALNU OPORABU**
- MINERALNOG SADRŽAJA OTPADA**

čime se istodobno zamjenjuju fosilna goriva i primarni mineralni resursi.

Source: **Basel convention Technical guidelines 2012**, Lamas 2013.



Quelle: 16 GCCA Sustainability Guidelines for co-processing fuels and raw materials in cement manufacturing (2018):

https://gccassociation.org/wp-content/uploads/2019/03/GCCA_Guidelines_FuelsRawMaterials-v0.pdf (accessed Jan 15th 2024)

ISO 4349:2024 – Solid recovered fuels – Determination of the recycling index for co-processing





International
Standard

ISO 4349

First edition
2024-05

**Solid recovered fuels —
Determination of the recycling
index for co-processing**

*Combustibles solides de récupération — Détermination de
l'indice de recyclage pour le cotraitement*

Reference number
ISO 4349:2024(en)

© ISO 2024

HRVATSKI NORMATIVNI DOKUMENT

OZNAKA:	HRN EN ISO 4349:2024
Naslov (HR):	Kruta uporabljena goriva -- Određivanje indeksa recikliranja za koprosesiranje (ISO 4349:2024; EN ISO 4349:2024)
Naslov (EN):	Solid recovered fuels -- Determination of the Recycling Index for co-processing (ISO 4349:2024; EN ISO 4349:2024)
Područje primjene:	This document specifies the determination of the share of material recovery in the case of energy recovery (i.e. co-processing) of solid recovered fuels (SRFs), for example, in a cement kiln. This share, called the recycling index (R-index), is calculated on the basis of the ash content and the ash composition.
Izdanje:	1
ICS:	75.160.10
HZN TO/PO:	TO 572, Kruti uporabljani materijali uključujući kruta uporabljena goriva
Oznaka faze:	60.60
Glasilo - rasprava:	5/2023
Glasilo - objava:	6/2024
Način prihvatanja:	pr
Jezik:	en
Broj stranica:	27
Cjenovni razred:	G
Izvornik:	EN ISO 4349:2024 (CEN i ISO)

ZAHTJEVI ZA PROIZVODNJU I OPORABU GIO-a

definicija: GIO (RDF i/ili SRF)



- **Austrija: WIO 2010: „goriva iz otpada“ odnosno „Refuse Derived Fuels (RDF = GIO)“**
„... **otpad** koji se u cijelosti ili u značajnom dijelu koristi u svrhu **proizvodnje energije** i koji zadovoljava **kriterije kvalitete** utvrđene ovom uredbom...”
- **GIO = RDF:** Europski katalog otpada: 19 12 12 – ostali otpad
različiti neopasni i/ili opasni otpad iz kućanstava, trgovine i industrije.
- **GIO “SRF”:** Europski katalog otpada: 19 12 10 – gorivi otpad
 - **Sukladno EN ISO 21640:2021: SRF – Specifications and Classes**
 - isključivo **kruti neopasni otpad**
 - podliježe normirano definiranom **sustavu osiguranja kvalitete**
 - koristi se za **energetsku uporabu**

GIO „SRF“ je podskupina GIO =RDF-a

Kvaliteta ulaznog GIO-a: Austrija – AVV / važeći kriteriji, Prilog 8

- Statistički definirane granične vrijednosti za EBS/SRF u cementnoj industriji
- Vrijednosti se iskazuju kao **medijan i 80. percentil** zbog heterogene raspodjele teških metala u gorivu iz otpada i posljedično velike varijabilnosti rezultata analiza.

Parametar	Granične vrijednosti [mg/MJ DM]	
	Median	80er Perzentil
Sb	7	10
As	2	3
Pb	20	36
Cd	0,23 ¹⁾	0,46 ¹⁾
Cr	25	37
Co	1,5	2,7
Ni	10	18
Hg	0,075	0,15

Teški metali prema hlapljivosti u cementnoj peći:

- **Hlapljivi (volatile):** talij (Tl), živa (Hg)
- **Poluhlapljivi (semi-volatile):** antimon (Sb), kadmij (Cd), olovo (Pb)
- **Niskohlapljivi / praktično nehlapljivi (non-volatile):** krom (Cr), arsen (As), nikal (Ni), kobalt (Co)

¹⁾ Goriva iz otpada osigurane kvalitete (KB 91108): Medijan ≤ 0,45 mg/MJ; 80. percentil ≤ 0,7 mg/MJ

Dodatne (ugovorne) specifikacije za GIO



⇒ Specifikacije GIO-a definiraju se UGOVOROM između dobavljača (postrojenja za proizvodnju GIO-a) i korisnika (postrojenja za energetske uporabu).

- Donja ogrjevna vrijednost (LHV): [MJ/kg ar]
- Veličina čestica (d_{95}): [mm]
- Nasipna gustoća: [kg/m³]
- Sadržaj klora (Cl): [% dm]
- Sadržaj vlage: [% ar]
- Sadržaj pepela: [% dm]
- Ostali odabrani „teški“ metali



I cementara u HR ima zahtjeve kvalitete za GIO



Investitor: Holcim (Hrvatska) d.o.o.
 Naziv projekta: Studija o utjecaju na okoliš – Rekonstrukcija postrojenja s ciljem smanjenja emisija ugljičnog dioksida kroz povećanje energetske uporabe otpada u tvornici cementa Koromačno, na području Općine Raša, Istarska županija
 Br. projekta: 2117-ST-EP-21034
 Voditelj izrade Studije: Morana Petrić, mag.oecol.et prot.nat. Datum: lipanj 2022. Rev. 2

Tablica 4. Sadržaj pojedinih elemenata u analiziranim uzorcima goriva (srednje vrijednosti)

GORIVO	Cl %	Hg mg/kg	Cr mg/kg	Cd mg/kg	Pb mg/kg	Ni mg/kg	V mg/kg	Ti mg/kg	As mg/kg	Co mg/kg	Cu mg/kg	Zn mg/kg	Sb mg/kg	Sn mg/kg
Petrol koks	0,003	0,038	9,00	0,06	3,50	10,00	16,00	0,00	2,20	4,00	6,60	0,00	0,00	0,60
Kameni ugljen	0,006	0,026	8,72	0,06	4,15	11,00	14,00	0,00	3,20	4,20	6,75	0,00	0,00	0,70
Gorivo iz otpada (GIO) visoke kalorijske vrijednosti	0,81	0,24	53,94	1,33	83,90	7,35	14,39	0,01	0,01	1,01	59,10	242	28,35	9,14
Gorivo iz otpada (GIO) niske kalorijske vrijednosti	0,46	0,26	97,10	0,43	151	13,20	25,90	0,54	0,04	1,82	106	436	51,03	16,45
Otpadna ulja	1,1	0,08	5,83	0,83	16,98	7,56	3,75	0,28	0,06	0,24	12,89	429	4,78	2,41
Emulzije	0,009	0,11	8,02	2,94	1,37	0,04	0,25	0,19	0,09	0,35	12,08	8,96	1,80	1,10
Mulj od obrade otpadnih voda	0,34	0,22	350	0,78	3,53	2,53	3,54	0,97	1,60	24,06	114	262	2,93	9,19
Mesno koštano brašno	1,57	0,08	5,83	0,83	1,20	0,08	1,21	0,28	0,06	0,24	12,89	80,57	4,78	2,41
Otpadne gume	0,3	0,02	3,10	3,14	83,00	3,10	15,00	0,06	1,00	5,00	20,00	8900	5,00	5,00

Tablica 5. Sadržaj pojedinih elemenata u analiziranim uzorcima goriva (maksimalne vrijednosti)

GORIVO	Cl %	Hg mg/kg	Cr mg/kg	Cd mg/kg	Pb mg/kg	Ni mg/kg	V mg/kg	Ti mg/kg	As mg/kg	Co mg/kg	Cu mg/kg	Zn mg/kg	Sb mg/kg	Sn mg/kg
Petrol koks	0,003	0,04	9,20	0,06	3,70	277	1327	0,00	2,40	4,10	6,70	0,00	0,00	0,70
Kameni ugljen	0,006	0,04	40,00	0,06	4,30	15,00	22,00	0,00	4,20	5,20	7,30	0,00	0,00	1,00
Gorivo iz otpada (GIO) visoke kalorijske vrijednosti	0,86	0,94	261	14,90	300	109	36,48	6,09	4,17	23,31	373	586	240	473
Gorivo iz otpada (GIO) niske kalorijske vrijednosti	0,86	0,85	59,33	14,90	92,30	97,81	32,83	6,09	3,75	20,98	335	528	216	425
Otpadna ulja	1,19	0,267	179	1,15	177	104	40,18	0,16	0,01	49,28	97,50	762	12,66	19,45
Emulzije	0,045	0,11	6,92	1,13	12,98	0,55	10,82	0,22	0,04	0,23	12,08	23,05	2,22	1,10
Mulj od obrade otpadnih voda	0,34	0,22	2354	0,50	3,69	3,08	4,46	0,21	1,60	24,06	45,20	224	1,06	0,82
Mesno koštano brašno	1,57	0,08	5,83	0,85	4,61	0,16	3,97	0,41	0,06	0,33	15,69	111	4,78	2,41
Otpadne gume	0,35	0,02	3,41	3,50	91,30	3,50	16,60	0,10	1,30	5,60	23,00	9000	5,50	5,60

I cementara u HR ima zahtjeve kvalitete za GIO



Tablica 7. Fizikalno - kemijska svojstva goriva iz otpada visoke kalorijske vrijednosti (GIO VKV)

Parametar	Mjerna jedinica	Vrijednosti
Rasuto / balirano	-	Rasuto
Agregatno stanje	-	Kruto
Sumpor (S)	%	0,18
Donja ogrjevna vrijednost	kJ/kg	23,6 - 25
Sadržaj vode	%	max 20% prosjek 10,5%
Sadržaj pepela na 815°C	%	9,55
Kloridi	%	0,81 - 0,86
Živa (Hg)	mg/kg	0,24 - 0,94
Krom (Cr)	mg/kg	53,94 - 261
Kadmij (Cd)	mg/kg	1,33 - 14,90
Talij (Tl)	mg/kg	0,01 - 6,09
Nikal (Ni)	mg/kg	7,35 - 109
Vanadij (V)	mg/kg	14,39 - 36,48
Olovo (Pb)	mg/kg	83,90 - 300
Arsen (As)	mg/kg	0,01 - 4,17
Kobalt (Co)	mg/kg	1,01 - 23,31

Parametar	Mjerna jedinica	Vrijednosti
Bakar (Cu)	mg/kg	59,1 - 373
Cink (Zn)	mg/kg	242 - 586
Antimon (Sb)	mg/kg	28,35 - 240
Kositar (Sn)	mg/kg	9,14 - 473
Ugljik (C)	%	46
Vodik (H)	%	6,6 - 7
Dušik	%	0,5 - 0,8
Kisik	%	30,4 - 34,4
Nasipna gustoća	kg/m ³	100 - 400
Veličina čestica	mm	1-25 max 50
Debljina čestice	-	max 1mm

I cementara u HR ima zahtjeve kvalitete za GIO



Tablica 9. Fizikalno - kemijska svojstva goriva iz otpada niske kalorijske vrijednosti (GIO NKV)

Parametar	Mjerna jedinica	Vrijednosti
Rasuto / balirano	-	Rasuto
Agregatno stanje	-	Kruto
Sumpor (S)	%	0,31
Donja ogrjevna vrijednost	kJ/kg	14
Sadržaj vode	%	max 40% prosjek 30%
Sadržaj pepela	%	17
Kloridi	%	0,46 - 0,86
Živa (Hg)	mg/kg	0,26 - 0,85
Krom (Cr)	mg/kg	59,33 - 97,1
Kadmij (Cd)	mg/kg	0,43 - 14,90
Talij (Tl)	mg/kg	0,54 - 6,09
Nikal (Ni)	mg/kg	13,2 - 97,81
Vanadij (V)	mg/kg	25,9 - 32,83
Olovo (Pb)	mg/kg	92,3 - 151

Parametar	Mjerna jedinica	Vrijednosti
Arsen (As)	mg/kg	0,04 - 3,75
Kobalt (Co)	mg/kg	1,82 - 20,98
Bakar (Cu)	mg/kg	106 - 335
Cink (Zn)	mg/kg	436 - 528
Antimon (Sb)	mg/kg	51,03 - 216
Kositar (Sn)	mg/kg	16,45 - 425
Ugljik (C)	%	46
Vodik (H)	%	6,6 - 7
Dušik	%	0,5 - 0,8
Kisik	%	30,4 - 34,4
Nasipna gustoća	kg/m ³	100 - 250
Veličina čestica	mm	95%< 80 mm

Holcimov profil GIO-a potvrđuje visoke zahtjeve kvalitete usporedive s austrijskom pravnom praksom

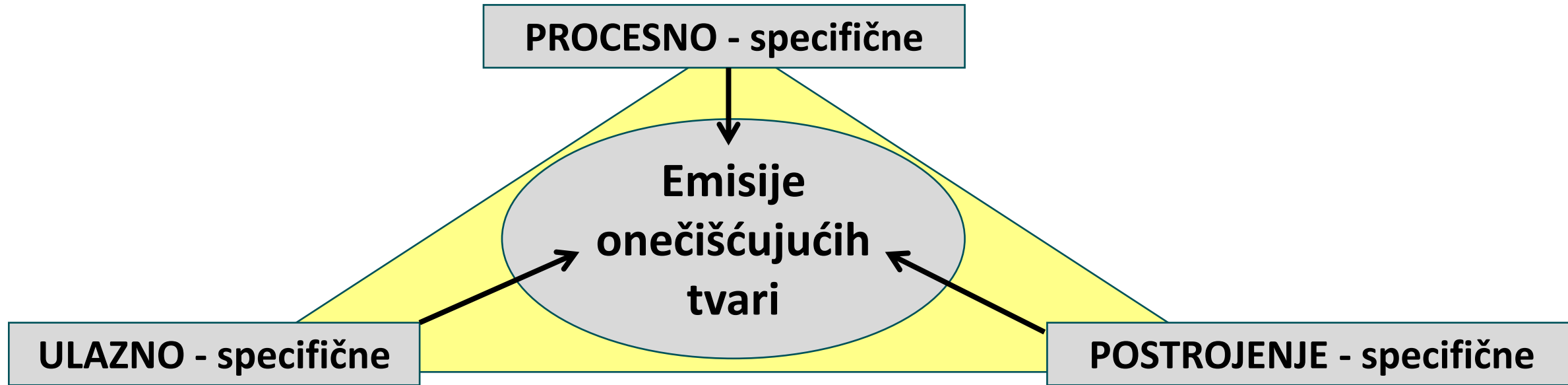


Parametar	Granične (statističke) vrijednosti [mg/MJ]		HOLCIM maksimalne vrijednosti [mg/MJ] sukl. SUO	
	Median	80er Perzentil	GIO VKV (Tablica 7.) SUO	GIO NKV (Tablica 9.) SUO
Sb	7	10	10,17	15,43
As	2	3	0,18	0,27
Pb	20	36	12,71	10,79
Cd	0,23 ¹⁾ 0,45	0,46 ¹⁾ 0,70	0,63	1,06
Cr	25	37	11,06	6,94
Co	1,5	2,7	0,99	1,50
Ni	10	18	4,62	6,99
Hg	0,075	0,15	0,04	0,06

¹⁾ Goriva iz otpada osigurane kvalitete (KB 91108): Medijan ≤ 0,45 mg/MJ; 80. percentil ≤ 0,7 mg/MJ

Emisije iz cementne industrije:

Emisije onečišćujućih tvari rezultat su kombinacije ulaznog materijala, procesnih uvjeta i specifičnosti postrojenja.



- **ULAZNO - specifične**

- Sadržaj hlapljivih metala, npr. živa (Hg) i talij (Tl)
- sadržaj **klora**
- ukupni unos **Cr** + procesni uvjeti → potencijal stvaranja Cr(VI)

- **PROCESNO - specifične:**

- **NO_x** – nastajanje pri visokim temperaturama
- **CO** – posljedica nepotpunog izgaranja

- **POSTROJENJE - specifične:**

- Mjesto doziranja je ključno za emisijsko ponašanje postrojenja (npr. VOC i dr. produkti nepotpunog izgaranja)
- **tehnologija i intenzitet pročišćavanja dimnih plinova**

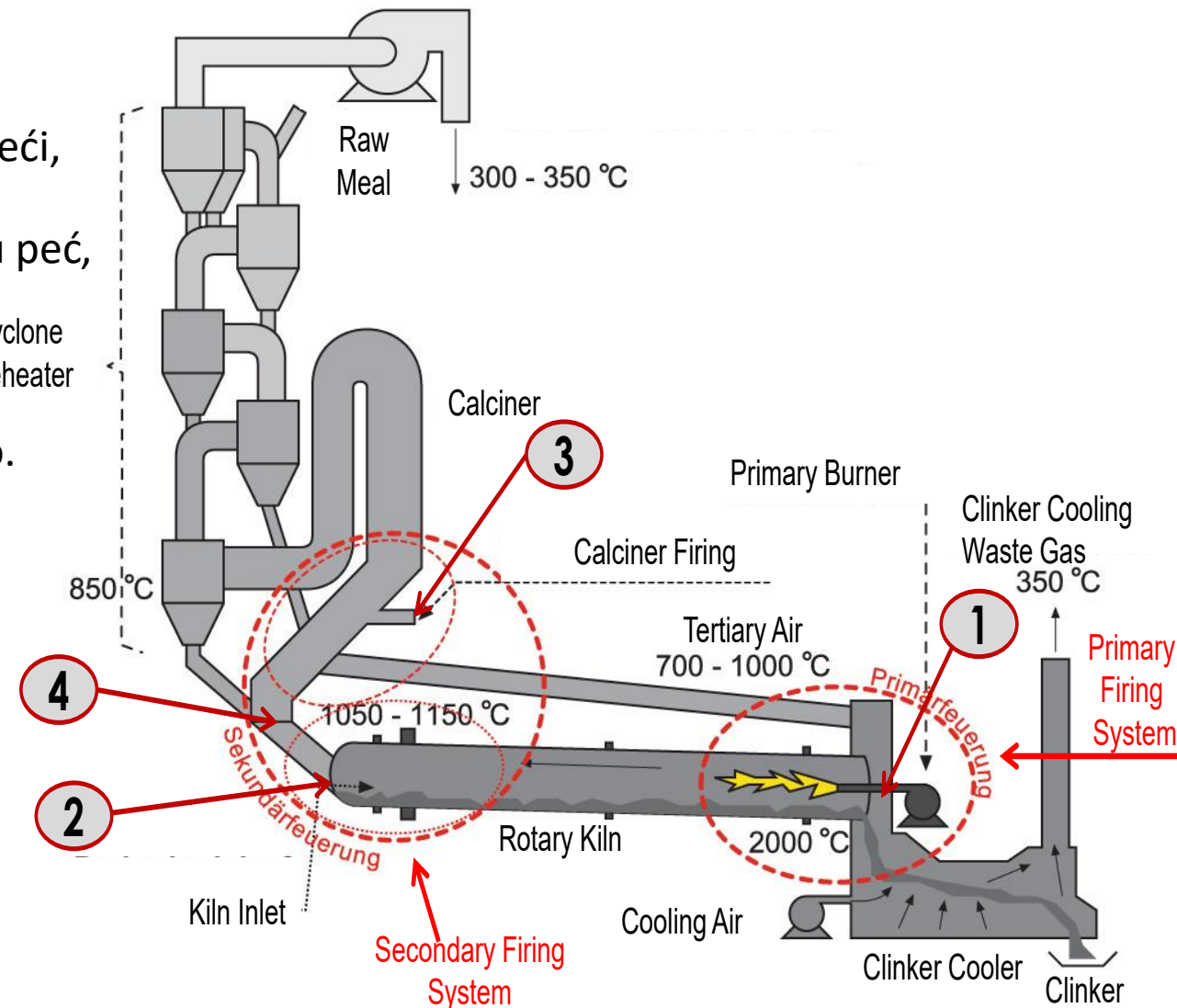
Mjesta doziranja goriva iz otpada u cementnoj peći i zahtjevi na kvalitetu goriva



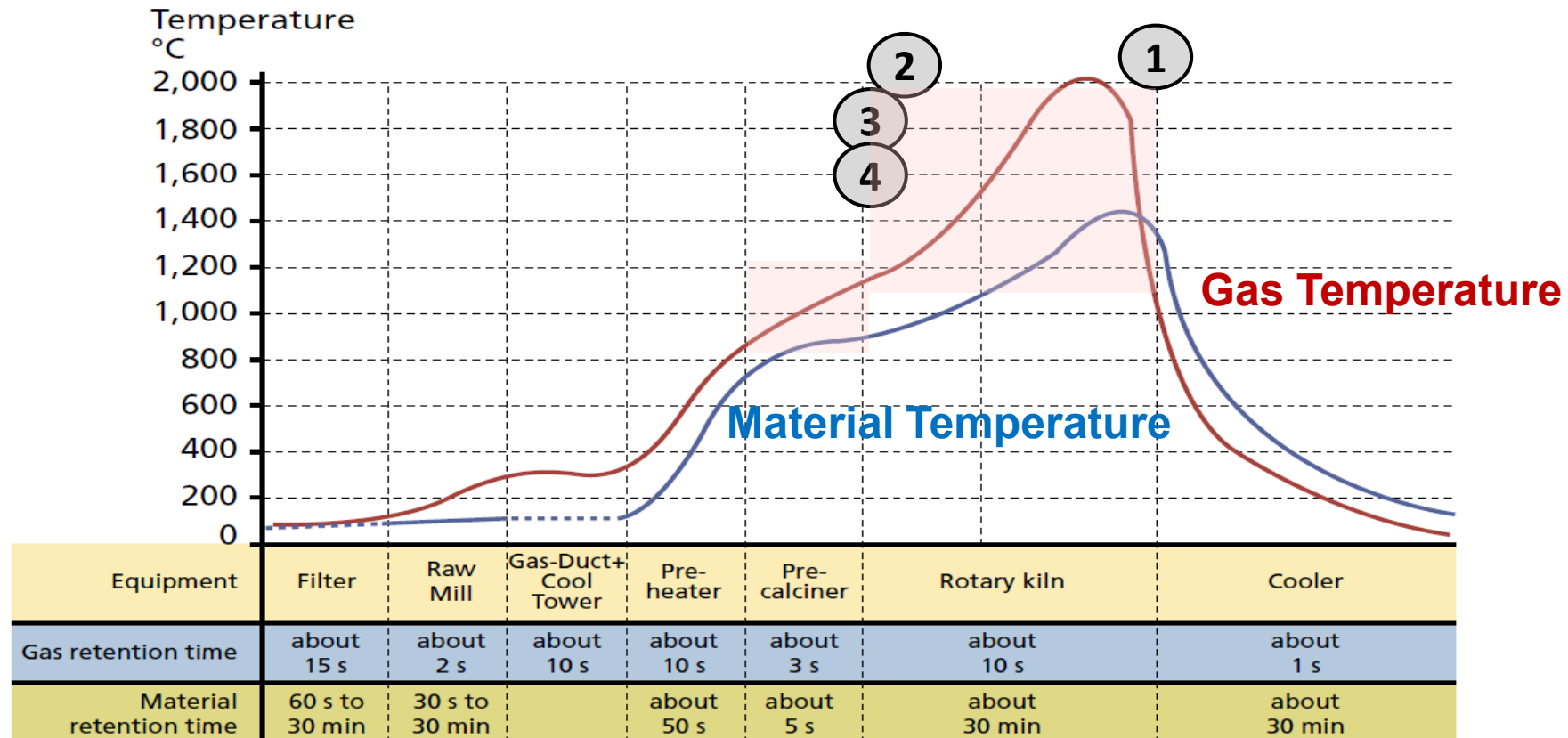
Mjesta doziranja u cementnoj peći:

- 1 preko glavnog plamenika na izlaznom kraju rotacijske peći,
- 2 preko sekundarnih plamenika u uzlazni kanal na ulazu u peć,
- 3 preko plamenika predkalcinatora u predkalcinator,
- 4 preko kosog dovoda u predkalcinator za krupnije gorivo.

- 1 GIO primary: $d_{95} < 35 \text{ mm}$, LHV: $> 18 \text{ MJ/kg}_{\text{OS}}$
- 2 GIO: otpadne gume
- 3 GIO secondary: $d_{95} < 80 \text{ mm}$, LHV: $12\text{-}18 \text{ MJ/kg}_{\text{O}}$
- 4 GIO secondary: $d_{95} \sim 300 \text{ mm}$, LHV: $12\text{-}18 \text{ MJ/kg}_{\text{C}}$



Pečenje klinkera: temperaturne zone i zahtjevi za kvalitetu goriva prema mjestu doziranja

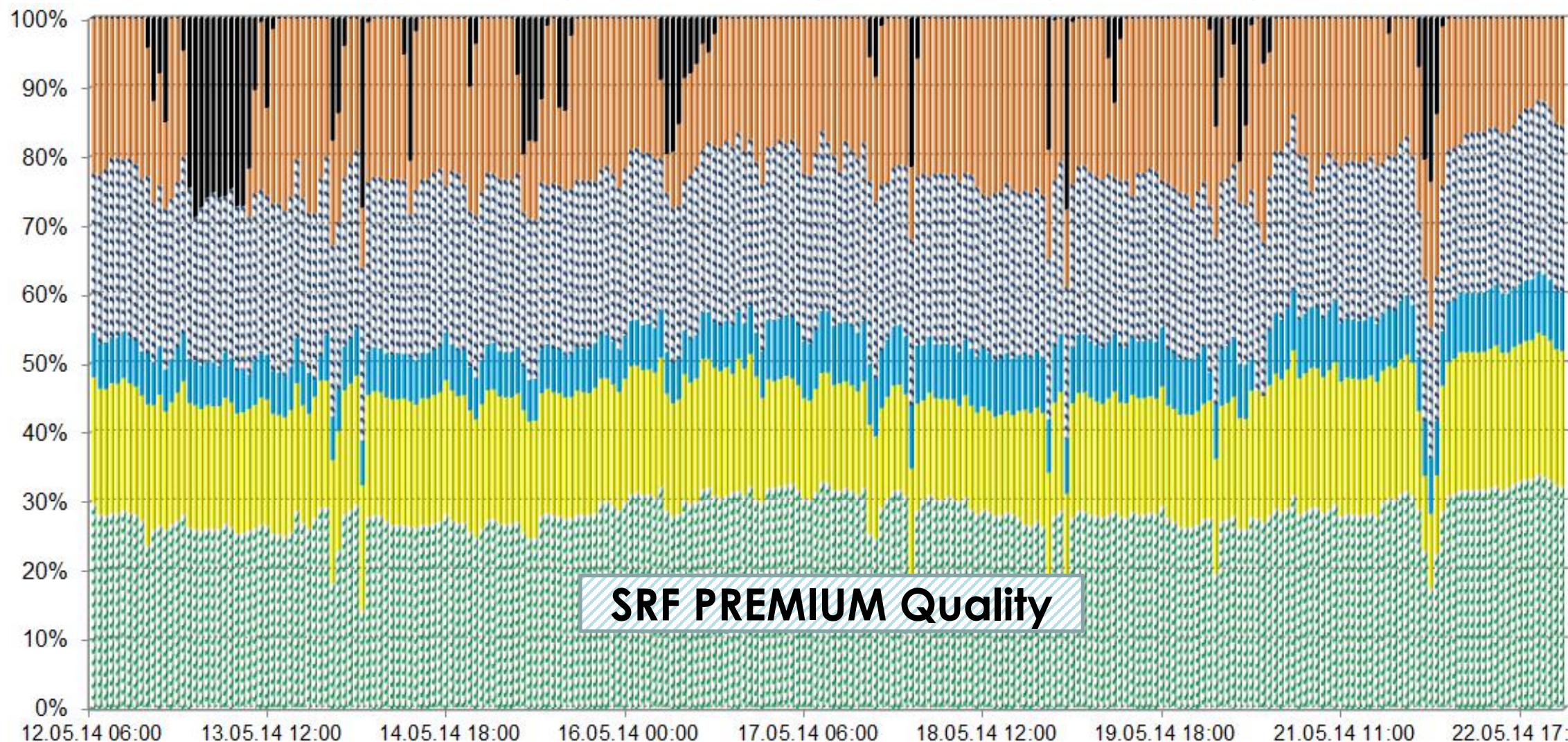


Odabir mjesta doziranja RDF/SRF-a je ključan:

- 1 preko **glavnog plamenika** na izlaznom kraju rotacijske peći: **GIO: $d_{95} < 35$ mm**, LHV: > 18 MJ/kg_{OS},
- 2 preko **sekundarnih plamenika** u uzlazni kanal na ulazu u peć: GIO – otpadni gume,
- 3 preko **plamenika predkalcinatora** u predkalcinator: **GIO: $d_{95} < 80$ mm**, LHV: 12-18 MJ/kg_{OS},
- 4 preko kosog dovoda u predkalcinator za krupnije gorivo: **GIO: $d_{95} < 300$ mm**, LHV: 12-18 MJ/kg_{OS}.

100 % termička supstitucija tehnički je demonstrirana i moguća uz odgovarajuću kvalitetu goriva i procesne uvjete

- rezultat vlastitog doktorskog istraživanja, 2015. godine



Sarc, R. (2015) PhD – Thesis. MUL, Leoben, Austria

Otpad iz big-bag vreća iz Gospića – stručna ocjena za cementnu industriju

Sažeta stručna ocjena tehničke prikladnosti neopasnog otpada iz big-bag vreća za korištenje kao goriva iz otpada u cementnoj industriji.



Ključna poruka: rezultati ne upućuju na gorivo osigurane i ujednačene kvalitete, nego na heterogene tokove otpada s jasno izraženim ograničavajućim parametrima.

Usporedba s pravilima struke (AT AVV / DE RAL-GZ 724)

#	Otpad / parametar	Izvješća o ispitivanju	Izmjerena vrijednost	Ocjena	Usporedba s referentnim vrijednostima
1	 KB 07 02 13 – Kobalt (Co)	Izvješća: 2026/30986 i 2026/30988	2,681 mg/MJ	 Prekoračenje	AT AVV medijan 1,5 mg/MJ → 1,79× više DE RAL medijan 0,38 mg/MJ → 7,1× više
2	 KB 19 12 04 – Antimon (Sb)	Izvješća: 2026/30991 i 2026/30989	20,896 mg/MJ	 Značajno prekoračenje	AT AVV medijan 7 mg/MJ → 2,99× više AT AVV 80. percentil 10 mg/MJ → 2,09× više DE RAL medijan 3,1 mg/MJ → 6,74× više
3	 KB 19 12 12 – Klor (Cl)	Izvješće: 2026/30992	1,06 %	 Ograničenje kvalitete	Tehnička praksa: ispod 1 %, ali u primjeni i strože vrijednosti od 0,8 %, pa čak i 0,6 %.

1. TEMELJ USPOREDBE – SUO HOLCIM



Naziv: Studija o utjecaju na okoliš „Rekonstrukcija postrojenja s ciljem smanjenja emisija ugljičnog dioksida kroz povećanje energetske uporabe otpada u tvornici cementa Koromačno, na području Općine Raša, Istarska županija“

Investitor: Holcim (Hrvatska) d.o.o. Koromačno 7b, 52222 Koromačno

Izvođač: IVICOM Consulting d.o.o. D.T. Gavrana 11, 10 020 Zagreb

Voditeljica izrade: Morana Petrić, mag. oecol. et prot. nat.

Odgovorna osoba: Dinko Čondić, dipl. ing. grad.

Oznaka projekta: 2117-ST-EP-21034, revizija 2, lipanj 2022.

Javno dostupna na: <https://www.rasa.hr/wp-content/uploads/2022/07/Studija-o-utjecaju-na-okolis-Holcim-Koromacno.pdf>

2. ŠTO SE NALAZI U TABLICAMA SUO-a?

Tablica 4 Srednje vrijednosti kemijsko-fizikalnih svojstava analiziranih goriva (uključujući GIO VKV i NKV).

Tablica 5 Maksimalne vrijednosti kemijsko-fizikalnih svojstava analiziranih goriva.

Tablica 7 Fizikalno-kemijski profil GIO visoke kalorijske vrijednosti (VKV) koji se razmatra za uporabu u postrojenju.

Tablica 9 Fizikalno-kemijski profil GIO niske kalorijske vrijednosti (NKV) koji se razmatra za uporabu u postrojenju.



“Gorivo iz otpada (GIO) dobiva se obradom, homogenizacijom i poboljšanjem kvalitete neopasnog otpada te se koristi kao zamjena za primarna goriva u cementnoj industriji.” (SUO Holcim, 2022.)

3. USPOREDBA KLJUČNIH PARAMETARA



U granicama uobičajenog GIO



Iznad uobičajenog GIO



Na donjoj granici / granično



KB 07 02 13

Parametar	Gospić (analize)	Holcim GIO VKV (srednje / max)	Holcim GIO NKV (srednje / max)	Ocjena
Co (mg/kg)	37,8	1,01 / 23,31	1,82 / 20,98	✗
Pepeo (%)	37,79	9,55	17	✗
Donja ogr. vrijednost (MJ/kg)	14,1	23,6 – 25	14	!

Ključni nalaz:

- Co je 62–80 % iznad maksimalnih vrijednosti.
- Pepeo je više nego dvostruko viši od tipične VKV vrijednosti (i također iznad NKV).
- Energetska vrijednost je značajno niža od VKV, na razini NKV.



KB 19 12 04

Parametar	Gospić (analize)	Holcim GIO VKV (srednje / max)	Holcim GIO NKV (srednje / max)	Ocjena
Sb (mg/kg)	560	28,35 / 240	51,03 / 216	✗
Pepeo (%)	12,54	9,55	17	!
Donja ogr. vrijednost (MJ/kg)	26,8	23,6 – 25	14	✓

Ključni nalaz:

- Sb je 2,33 puta viši od maksimuma VKV i 2,59 puta viši od maksimuma NKV.
- Pepeo je iznad VKV, ali ispod NKV.
- Energetska vrijednost je povoljnija.



KB 19 12 12

Parametar	Gospić (analize)	Holcim GIO VKV (srednje / max)	Holcim GIO NKV (srednje / max)	Ocjena
Cl (%)	1,06	0,81 – 0,86	0,46 – 0,86	✗
Donja ogr. vrijednost (MJ/kg)	15,3	23,6 – 25	14	!

Ključni nalaz:

- Klor je oko 23 % iznad gornje vrijednosti (0,86 %) za VKV i NKV.
- Energetska vrijednost je ispod VKV, ali iznad NKV.

- **Neopasan otpad nije automatski GIO osigurane kvalitete** – pravna klasifikacija i tehnička prikladnost nisu isto.
- **Kvalitetno GIO zahtijeva višestupanjsku obradu i osiguranje kvalitete** – ulazni materijal i kemijsko-fizikalna svojstva presudno određuju izlaznu kvalitetu.
- **Kod otpada iz Gospića dostupne analize ukazuju na heterogenost i tehnička ograničenja kod korištenja u cementnoj industriji** – posebno za parametre Co, Sb i Cl.
- Primjena u cementnoj industriji zahtijeva **reprezentativne analize i prilagodbu konkretnom postrojenju i mjestu doziranja** – miješanje ne smije biti zamjena za obradu.
- Osnovni princip za Gospić: **prvo razumjeti sastav i svojstva otpada, zatim odabrati tehnologiju** – svaku tehnički definiranu frakciju usmjeriti u odgovarajući postupak prema stvarnim svojstvima.

Daljnja vlastita literatura...

Original Article

Design and qual recovered fuel

Karl E Lorber, Renato S

Abstract

This contribution describes the f wide range of co-incineration pla of two different specifications of multiple stage processing scheme removing of metals and sorting o matrix during several crushing a delivered to a cement plant by w two sampling procedures and sam assessment of heterogeneous wa cutting mills with attached cyclon from the laboratory sample prior

Keywords

Waste fuel, SRF processing, clas

Introduction

The European Union Directive 2 of waste (EC, 2000) limits emissi are burnt in co-incineration plant levels of pollutants in the fuels, come this shortage, the *GudeIn* (2008a) and the Waste Incineratio which define quality criteria for v tion plants, have been issued in A According to this legal frame that is used entirely or to a rele energy generation and which as down in the Waste Incineration D Thus, the composition of w/as ues (i.e. pollutant content per net Sh, As, Pb, Cd, Cr, Co, Ni, Hg an different types of plants, namely c other co-incineration plants. Befo that can be used in a co-inciner treatment by preparation and t waste fuels includes classifying, s and non-ferrous metals as well a Manufacturing, which includes crushing, drying and pelletizing, is the treatment of waste fuels to improve its feeding and incineration properties. Waste fuels having a low level of pollutants

Review Article

Design, quality, an solid recovered fue fossil feedstock in

R Sarc', KE Lorber', R Pom

Abstract

This paper describes the requirements increasingly used in the cement industry, on the quality of SRF used in the cement of input materials used at waste splitlin into two classes: a fine, high-calorific SI systems, such as precombustion chambe these two different waste fuel classes are plant in Roboňnik (Slovakia). The fine is fed to a FLS Houdisc combustion dev chemical compositions and other prop Europe. This approach allows to compa requirements on SRF that, at the momer

Keywords

Cement industry, quality assurance, sam

From waste to solid recover

In the last 20 years, Austrian waste ma from "uncontrolled waste disposal" to "resource management". Waste as resour on the separate collection of valuable al as (e.g. paper, plastics, glass, metals) fi biowaste (i.e. composting or fermenta (co-)incineration of (pretreated) residual

Before a waste becomes a waste fuel (e.g. cement industry), it has to underg manufacturing steps. Common treatm steps include multistage shredding, clas metals, non-Fe metals, and heavyweigh as sorting out of unwanted materials (PVC) plastics, by using modern nea technology (Kreindl, 2010; Lorber and Š 2012). In sum, the waste management through different developmental steps to for the co-incineration sector. These de can be generally divided into four cha material, plant, and economic) which a Individual developments and properi cussed in Pomberger and Sarc (2012

Karl E Lorber, Montanuniversität Leoben, Institute for Sust Waste Management and Technology (IAE), Franz Josef Straße 8700 Leoben, Austria
Email: iae@unileoben.ac.at

Original Article

Solid recovered fuels in the cement industry – semi-automated sample preparation unit as a means for facilitated practical application

Alexia Aldrian', Re Ernst-Michael Sipj

Abstract

One of the challenges for incineration plants – espo more importance in the su preparation do not cover ti shown in the present contri at a cement plant in Roboň sample preparation proces 'Houdisc SRF'. Therefore, values obtained through a l also showed that segregati that compliance with legal size alternative fuels. Inst gain a representative labor

Keywords

Alternative fuel, solid rec assurance

Introduction

A continued increase in p hand in hand with an incre recovered fuel, SRF) in ti alternative fuel in co-inci an adequate quality assum covers sampling, sample p

Relevant influencing quality of alternativ

The quality of alternativ cement industry is mainly The first factor is the type SRF production plant (e.g similar industrial waste) a sity of waste processing i Lorber et al., 2011, 2012; of high quality with strict

Downloaded from wem.sagepub.com by guest on July

WM&R

Waste Management & Research
2014, Vol. 34(3) 254–264
© The Author(s) 2014
Reprints and permissions:
sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/0734242X14262264
wem.sagepub.com
SAGE

detritus

Multidisciplinary Journal for Waste Resources & Residues

PRODUCTION AND C QUALITY FROM MUNI NON-HAZARDOUS WA AND SLOVAKIA

Renato Sarc*, Lisa Kandlbauer

Montanuniversität Leoben, Department of En and Waste Management, Franz-Josef-Straße 1

Article Info:
Received:
12 July 2019
Reviewed:
5 September 2019
Accepted:
24 October 2019
Available online:
6 December 2019

AE
Th
ro
en
de
MI
Wi
of
ve
fer
im
the
ica
(G
su
he
th
kie
res

Original Article

Design, quality and quality assurance of solid recovered fuels for the substitution of fossil feedstock in the cement industry – Update 2019

Renato Sarc[Ⓢ], IM Seidler, L. Kandlbauer, KE Lorber and R Pomberg

Abstract

Production, quality and quality assurance, as well as co-incineration of solid recovered fuels in of-the-art in the European cement industry. At the global level, average thermal substitution rate in Canada and in the USA 16%, while in the European Union 28 it is about 44% (i.e. 11,300,0 Austria, thermal substitution rate was ca. 80% in 2017, which was worldwide the highest one. the cement industry, two types are relevant, namely solid recovered fuels PREMIUM Quality i Quality. In the case study shown, solid recovered fuels PREMIUM Quality from 11 and solid from nine different solid recovered fuels production plants have been investigated. Investiga analyses (for PREMIUM), as well as physical–chemical analyses (for both solid recovered i national standards (i.e. Austrian 'ÖNORM', European 'EN' standards and CEN TC 343 guideli investigation were published in 2014 and here, results of further investigations are updated for legal and market relevant requirements. During the investigation, not enough parallel samples no adequate scientific statistical analyses could be elaborated but a more practical indicative inte can be confirmed, that all investigated solid recovered fuels fulfil the Austrian legal and intern incineration market requirements.

Keywords

Cement industry, quality assurance, solid recovered fuels (SRF), SRF production, SRF characte SRF MEDIUM Quality, thermal substitution rate

Received 27th March 2019, accepted 14th June 2019 by Associate Editor Nemanja Stanišević.

Introduction

This article presents an update of the data and facts from the publication 'Design, quality and quality assurance of solid recovered fuels (SRF) for the substitution of fossil feedstock in the cement industry' (Sarc et al., 2014).

The volume of SRF industry

As concluded in Sarc et al. (2014), when dealing with waste as a resource for energy management, and considering the increasing amount of solid recovered fuels (SRF) that is utilised in the cement industry for heat and energy generation, it becomes clear that co-incineration of SRF has become an important tool in modern waste management. Additionally, according to the document on the best available techniques (BAT) in the cement, time and magnesium oxide manufacturing industries published by the European Commission (2013), utilisation of quality assured SRF has become state of the art in the European cement industry.

In Figure 1, the status o fossil fuels (e.g. coal and pe (RDF) in the cement indu Union (EU) 28 and worldi available official data for a wide). As shown at the glob whereby, only 13% in Cana EU 28 on average it is abou (e.g. Poland, Czech Repu reached even significantly h

Department of Environmental Montanuniversität Leoben, Li

Corresponding author:
Renato Sarc, Department of Environmental and Energy Process Engineering, Chair of Waste Processing Technology and Waste Management, Montanuniversität Leoben, Franz-Josef-Straße 18, Leoben 8700, Austria.
Email: renato.sarc@unileoben.ac.at



Method Article

Methods for identifying share of SRF during co-industry

Alexia Aldrian, Sandra A. Vicz

Chair of Waste Processing Technology and Waste A Leoben, Austria

ABSTRACT

Solid Recovered Fuels (SRF) include non-required as raw materials for producing i thermal recovery of SRF. This paper discuss that may be utilised as raw material (given of SRF was determined as the ash content methods.

- A fusion melt of the previously inciner well as a total digestion of the incinerator OES/ICP-MS were applied.
- The results showed a good agreement (Fe₂O₃, SiO₂, TiO₂, P₂O₅ and MgO (relativ Na₂O and SO₃ (14.2–06.0%).
- It was also shown that different inciner; result of the recycling index unless it is .

This is an open access article i

ARTICLE INFO
Method name: R-Index
Keywords: Solid recovered fuel, Recycling, Ash ce
Article history: Received 12 January 2020; Accepted

DOI of original article: 10.1016/j.wres.2020.100837
2025-01616/2020 The Authors. Published by Els
(http://creativecommons.org/licenses/by/4.0/)



Full length article

Determination of the material-rec in the cement industry

S.A. Viczek, A. Aldrian, R. Pomberger, R.

Chair of Waste Processing Technology and Waste Management, Montan

ARTICLE INFO

ABSTR

1. Introduction

The hydraulic binder cement is a crucial componen facturing of mortar and concrete (Gálvez-Martos and 2014), the latter being one of the world's most important materials (Huntzinger and Eatmon, 2009). For the p ment clinker, raw materials providing the four main ch dents of cement clinker or precursors thereof are re calcination oxide CaO, silicon dioxide SiO₂, aluminum ox iron(III) oxide Fe₂O₃ (cf. section 2.1). Besides raw materials, the man- ufacturing of cement also requires large amounts of energy (Gálvez-Martos and Schönbauer, 2014). In modern rotary kiln plants, the production of 1 metric ton of cement clinker requires between 3.0 and 3.8 GJ of thermal energy (under optimal conditions and depending on the technology used). Wet or shaft kilns, in contrast, may require up to 5.8 GJ of thermal energy per ton clinker (European Cement Research Academy (ECRA), 2016). To provide this energy, cement plant

Original Article

Co-processing of solid recovered fuels from mixed municipal and commercial waste in the cement industry – A pathway to a circular economy

Renato Sarc[Ⓢ] and Sandra A Viczek[Ⓢ]

Abstract

With global municipal solid waste generation increasing steadily, the importance of high-quality, environmentally friendly waste valorization methods is rising, too. Most countries have set themselves ambitious recycling goals and follow a waste hierarchy in which recycling is more preferable than energy recovery. This article focuses on a waste treatment option that already is an integral part of waste management in some countries and enables the simultaneous recovery of energy and mineral constituents: the production of solid recovered fuels (SRFs) from mixed municipal and commercial waste and their use in the cement industry is often referred to as co-processing. The state of the art of SRF production is described and the first comprehensive dataset for SRF samples including major constituents, heavy metal and metalloids contents, energy- and CO₂-emission-relevant parameters, ash contents and the material-recyclable share of SRF is presented. Additionally, a comparison with fossil fuels is given. It is concluded that SRF from state-of-the-art production plants complies with strict limit values for heavy metals, has an average biogenic carbon content of 60%, and its application in the cement industry can be considered as partial recycling (14.5%) and partial energy recovery (85.5%). Leaving no residues to be dealt with, co-processing of waste in the cement industry therefore offers many benefits and can support the shift from a linear to a circular economy.

Keywords

Co-processing, solid recovered fuel, waste management, waste valorization, recycling, energy recovery, ash composition, heavy metals

Received 12th December 2022, accepted 4th May 2023 by Editor in Chief Arne Ragnossig.

Introduction

While the globally generated amount of municipal solid waste (MSW) has reached 2 billion metric tonnes per year in 2016 and is expected to rise to 3.4 billion metric tonnes per year by 2050 (Kaza et al., 2018), the world is still struggling to utilize these resources appropriately in an environmentally benign manner. 33% of MSW is openly dumped, 37% is landfilled, 11% incinerated and only 19% is recovered through recycling or composting (Kaza et al., 2018). These numbers emphasize the importance of the principle that waste should be treated in a resource-efficient and sustainable way that minimizes its effect on the environment and enables the highest possible waste valorization. Consequently, numerous countries have published strategies for municipal waste management and have set ambitious recycling goals.

Examples include the US National Recycling Strategy (United States Environmental Protection Agency, 2021), the European Circular Economy Package (European Commission, 2019), the Canada-wide strategy on zero plastic waste (Canadian Council of Ministers of the Environment, 2018), the Australian National

1. Introduction
The hydraulic binder cement is a crucial componen facturing of mortar and concrete (Gálvez-Martos and 2014), the latter being one of the world's most important materials (Huntzinger and Eatmon, 2009). For the p ment clinker, raw materials providing the four main ch dents of cement clinker or precursors thereof are re calcination oxide CaO, silicon dioxide SiO₂, aluminum ox iron(III) oxide Fe₂O₃ (cf. section 2.1). Besides raw materials, the man- ufacturing of cement also requires large amounts of energy (Gálvez-Martos and Schönbauer, 2014). In modern rotary kiln plants, the production of 1 metric ton of cement clinker requires between 3.0 and 3.8 GJ of thermal energy (under optimal conditions and depending on the technology used). Wet or shaft kilns, in contrast, may require up to 5.8 GJ of thermal energy per ton clinker (European Cement Research Academy (ECRA), 2016). To provide this energy, cement plant

ement industry being covered by alternative fuel: 30 % are covered by RDF, e.g. old tires, used oil and solvents, etc. and 50 % are covered by SRF from plastic rich waste fractions of industrial, commercial, and municipal solid waste (MSW), corresponding to 350,500 tonnes of SRF (year 2018) (Mauschitzky, 2019). Sarc (2015) has demonstrated that even 100 % of thermal substitution is technically feasible when different types of RDF are used for energy generation in the clinker production process. International studies report that the use of SRF or RDF in the



Waste Management & Research
1–13
© The Author(s) 2023
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/0734242X231178217
journals.sagepub.com/home/wem
S Sage

Hvala na pažnji!

Assoc.Prof. Dipl.-Ing. Dr.mont. Renato Šarc

Tel.: +43 (0) 3842 / 402 - 5105
renato.sarc@unileoben.ac.at

**MONTANUNIVERSITÄT LEOBEN
LEHRSTUHL FÜR ABFALLVERWERTUNGSTECHNIK UND
ABFALLWIRTSCHAFT**

Franz-Josef-Straße 18
8700 Leoben, Austria
<http://avaw.unileoben.ac.at>