

Supplementary Materials

Supporting Information for Discovering Energy Consumption Patterns with Unsupervised Machine Learning for Canadian In Situ Oil Sands Operations

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1.0 Data Selection

Table S1 presents the Battery facility ID and Injection facility ID used in this study to link the battery and injection facility together. The IDs were assigned by the Alberta government and included in the Petrinex report. The linked batteries and injections are called one scheme in this study.

Table S1: Battery and Injection Facility IDs for each scheme

Operation	BT ID	IF ID
AOCHS	132986	134766
AOCLM	105807	105806
CNOOCLK ¹	94109	94110
CNRLJF	94366	94395
	114300	130641
	130642	114303
CNRLKB	116017	116018
	136100	136101
CNRLWL	1330526	7653
		7970
		9037
		87025
		98706
CNULPR	7380030	7833
COGGD	112312	95645
	112313	109357
COPSM	111817	111818
CVEFC	66377	9473
CVECL	67303	9508
	121894	121895
HSESR	134400	126671

HSETL	89133	89451
IMOCL	111783	111784
	1330520	7678
	51211	8797
	51212	8798
	100902	100903
	119087	119086
JCOS	126134	126135
OSUM	95329	95664
PGFLB	135254	134729
SHAMR	142085	142086
SUFB¹	78417	78418
SUMR	67097	9498

1. The oil produced by the oil sands schemes was reported under the reporting facility subtype "In Situ Oil Sands" except for CNOOCLK and SUFB. The oil produced at the CNOOCLK and SUFB schemes were reported under "Sulphur Reporting at Oil Sands" reporting facility subtype under BT that is based on their operating permit.

Table S2 presents the number of monthly data used in this study.

Table S2: Number of monthly data used in the study

Operation	Operator	Scheme	Number of months used in the study
AOCHS	Athabasca Oil Corporation	Hangingstone	53
AOCLM	Athabasca Oil Corporation	Leismer	60
CNOOCLK	CNOOC Petroleum North	Long Lake	59
CNRLJF	Canadian Natural Resources Limited (CNRL)	Jackfish	60
CNRLKB	CNRL	Kirby	60
CNRLWL	CNRL	CNRL Wolf Lake, Primrose, and Burnt Lake	60
CNULPR	Canadian Natural Upgrading	Peace River	60

COGGD	Connacher Oil and Gas Limited	Great Divide	60
COPSM	ConocoPhillips Canada	Surmont	60
CVEFC	Cenovus Energy Inc.	Foster Creek	60
CVECL	Cenovus Energy Inc.	Christina Lake	60
HSESR	Husky Oil Operations Limited	Sunrise	57
HSETL	Husky Oil Operations Limited	Tucker Lake	59
IMOCL	Imperial Oil Resources	Cold Lake	60
JCOS	Japan Canada Oil Sands Limited	Hangingstone	29
OSUM	Osum Production Corp.	Orion	60
PGFLB	Pengrowth Energy Corporation	Lindbergh	59
SHAMR	Petrochina Canada Ltd.	Mackay River	31
SUFB	Suncor Energy Inc.	Firebag	60
SUMR	Suncor Energy Inc.	Mackay River	60

Table S3 presents the monthly data that were removed because of the production was less than 5000 m³

Table S3: Removed monthly data

Production Month	Oil (m³)	Operation	Scheme
2015-06	252	AOCHS	Hangingstone
2015-07	3,267	AOCHS	Hangingstone
2015-03	2,227	HSESR	Sunrise
2015-05	4,965	HSETL	Tucker Lake
2017-07	4,304	JCOS	Hangingstone
2016-06	1,471	CNOOCLK	Long Lake
2015-01	1,310	PGFLB	Lindbergh
2017-02	254	SHAMR	Mackay River
2017-03	258	SHAMR	Mackay River

2017-04	1,374	SHAMR	Mackay River
2017-05	4,445	SHAMR	Mackay River

AOCHS

June 2015 and July 2015 were the first two months of production reported in Petrinex. The production volumes were significantly low, compared to August 2015 at 11,054 m³

HSESR

March 2015 (2,227 m³ bitumen) was the first month of production reported in Petrinex for HSESR. April 2016, the production increased more than three times to 7.802 m³

HSETL

May 2015, the production of 4,965 m³ was suddenly dropped from production at 49,965 m³ in April 2015. In June 2015, the production was back up to 51,404 m³.

JCOS

June 2017 was the first month of production reported in Petrinex for JCOS. In August 2017, the production increased to 10,809 m³.

CNOOCLK

The production dropped from 11,062 m³ in May 2016 to 1,471 m³ in June 2016, then increased to 97,981 m³ in July 2016

PGFLB

January 2015 was the first month of production reported in Petrinex for PGFLB. The production increased by over five times in February 2015 to 5,331 m³.

SHAMR

February to May 2017 were the first few months of production reported in Petrinex for SHAMR the production increased to 9116 m³ in June 2017.

Table S4 presents which columns were removed from the original Petrinex dataset.

Table S4: Removed Columns

	Column Name	Removed	Kept
1	Activity ID	Y	
2	CCI Code		Y
3	Energy	Y	
4	Facility Legal Subdivision		Y
5	Facility Meridian		Y
6	Facility Range		Y
7	Facility Section		Y
8	Facility Township		Y
9	From To ID	Y	
10	From To ID Identifier	Y	
11	From To ID Province State		Y
12	From To ID Type	Y	
13	Hours		Y
14	Operator BAID	Y	
15	Operator Name	Y	
16	Product ID	Y	
17	Production Month	Y	
18	Proration Factor		Y
19	Proration Product		Y
20	Reporting Facility ID	Y	
21	Reporting Facility Identifier	Y	
22	Reporting Facility Location		Y
23	Reporting Facility Name	Y	
24	Reporting Facility Province State		Y
25	Reporting Facility Sub Type	Y	
26	Reporting Facility Sub Type Desc	Y	
27	Reporting Facility Type	Y	
28	Submission Date		Y
29	Volume	Y	

2.0 Criteria used for Association Rule

Table S5 presents the criteria used for association rule analysis. The value below the median value of 3.31 was considered as Low SOR. The months with volumes above the median values were considered the months with solvent co-injection with steam.

Table S5: Criteria used for Association Rule

	Median
SOR	3.31 (m ³ steam /m ³ oil)
Gas Injected	1456 (10 ³ m ³)
Condensate Injected	1096 (m ³)
C3 Injected	2603 (m ³ /m ³)
Solution Gas Oil Ratio (SGOR)	0.1444 (m ³ solution gas/m ³ oil)

Table S6 presents a summary of the co-injection classification for each scheme.

Table S6: Summary of Gas Co-injection

Operation	Gas injection (average per month 103 m3)	Meet the gas co-injection criteria?	Number of months for Co-injection	Number of production Month	Average SOR
AOCHS		N		53	5.2
AOCLM	204	N	43	60	3.3
CNOOCLK	292	N	6	59	3.7
CNRLJF	2,723	Y	46	60	2.4
CNRLKB	181	N	14	60	2.9
CNRLWL		N		60	5.8
CNULPR		N		60	6.8
COGGD	298	N	31	60	4.6

COPSM	2,079	Y	38	60	3.2
CVECL	15,380	Y	60	60	1.9
CVEFC	13,033	Y	60	60	2.7
HSESR		N		57	5.2
HSETL		N		59	4.2
IMOCL		N		60	4.2
JCOS	183	N	29	29	3.1
OSUM	323	N	8	60	3.8
PGFLB	1,003	N	5	59	3.1
SHAMR	2,675	Y	16	31	7.2
SUFB	3,805	Y	60	60	2.7
SUMR	874	N	36	60	3.0