Evaluation of Environmental Impact of Toll Collection System in Alberta by I-O Analysis

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Background

- Two major negative impacts of congestion:

1- *Impact on economy* :

- Annual delay time cost:
  - More than 90% of total congestion cost

- Annual wasted fuel volume cost:
  - 6070000 liter gasoline is wasted under congestion in Calgary.
  - About 7% of total congestion cost

2- *Impact on environment* :

- Contributes to 3% of total congestion cost in Calgary[1]

- 206 million $ in 2006

(Transport Canada)

Objective

- Determining the feasibility of implementing toll collection system in Alberta

(www.okroads.com)

Methodology

- Calculate total Alberta greenhouse gas (GHG) emission without toll collection system

- Calculate total Alberta GHG emission after implementing toll system
  - GHG emission from initial phase (operating phase)
  - GHG emission from secondary phase

- Compare the GHG emission before and after toll system deployment

Introduction to I-O Analysis

Transaction table:

- shows the financial flow between different industries in a regional economy in Dollar
- Money flows from upper right to lower left
- Manufacturing selling and mining purchasing

	Agriculture	Mining	Manufacturing	Total Output
Agriculture	500	100	200	800
Mining	200	200	400	800
Manufacturing	100	500	400	1000
Total Input	800	800	1000	

$

Introduction to I-O Analysis

Transaction table:

- Alberta symmetric Input-Output Table (Million $)[2]

	AFFH	Mi	U	C	Ma	WT	RT	TW	IC	FIRRL	PST	AWR	ES	HS	AER	AF	OP	P
AFFH	3584	56	13	109	5234	10	6	64	2	5	15	2	0.033	4	2	129	5	188
Mi	39	5879	763	4970	11325	191	100	73	15	194	34	13	5	12	2	15	15	254
U	189	989	17	64	1066	65	104	149	19	318	39	15	8	33	11	77	45	406
C	178	991	306	92	204	109	161	318	25	1563	72	44	4	18	17	147	33	1165
Ma	2887	7533	237	11884	15288	834	569	2227	536	1008	1050	666	20	424	241	1740	584	3196
WT	374	1868	70	1590	1850	340	242	237	87	248	345	146	5	97	52	286	119	842
RT	126	274	11	502	429	263	183	138	62	141	225	106	4	80	111	393	90	725
TW	348	1241	68	764	2496	857	360	2835	141	519	437	216	13	96	42	100	152	952
IC	102	479	48	174	233	405	373	211	1049	988	575	276	13	164	53	207	151	666
FIRRL	521	5604	198	1890	1723	1197	2087	1060	375	6846	1177	520	75	314	154	858	401	1177
PST	326	3697	105	2886	543	730	666	278	231	1835	2523	459	10	101	49	164	167	1925
AWR	46	1968	51	452	487	512	421	347	235	1754	714	311	19	95	81	192	240	1467
ES	0.092	12	1.5	16	1	5	6	2	3	14	10	10	1	38	1	8	8	131
HS	0.002	1	0.113	0	1	1.4	0.75	0.124	0.077	10	0.126	0.05	0.157	2.5	0.004	0.085	0.025	4176
AER	6	23	1.71	14	32	32	47	11	50	39	34	20	1.36	5	76	46	17	106
AF	22	121	4.34	44	135	79	120	185	64	190	304	128	7	62	55.33	79.3	97	400
OP	71	378	10	153	147	21	19	174	26	294	230	140	7	126	65	70	86	408
P	81	258	9	127	185	163	177	101	72	397	215	66	12	86	49	72	60	1665
Total	11347	82995	5865	47543	57291	17413	16337	18610	9041	52463	20857	8817	527	6677	2256	9788	6119	51999

(Statistics Canada,2009)

Introduction to I-O Analysis

Direct requirement table:

- Determines the amount of input that each industry needs from other industries to produce one unit of output.
- Usually called matrix A

	Agriculture	Mining	Manufacturing	Total Output
Agriculture	500	100	200	800
Mining	200	200	400	800
Manufacturing	100	500	400	1000
Total Input	800	800	1000	

	Agriculture	Mining	Manufacturing
Agriculture	0.625	0.125	0.2
Mining	0.250	0.250	0.4
Manufacturing	0.125	0.625	0.4
Total Input	1	1	1

Introduction to I-O Analysis

Direct requirement table:

- Alberta Direct Requirement Table

	AFFH	Mi	U	C	Ma	WT	RT	TW	IC	FIRRL	PST	AWR	ES	HS	AER	AF	OP	P
AFFH	0.3159	0.0007	0.0022	0.0023	0.0914	0.0006	0.0004	0.0034	0.0002	1E-04	0.00072	0.00023	6E-05	0.0006	0.0009	0.0132	0.0008	0.0036
Mi	0.0034	0.0708	0.1301	0.1045	0.1977	0.0110	0.0061	0.0039	0.0017	0.0037	0.00163	0.00147	0.0095	0.0018	0.0009	0.0015	0.0025	0.0049
U	0.0167	0.0119	0.0029	0.0013	0.0186	0.0037	0.0064	0.0080	0.0021	0.0061	0.00187	0.00170	0.0152	0.0049	0.0049	0.0079	0.0074	0.0078
C	0.0157	0.0119	0.0522	0.0019	0.0036	0.0063	0.0099	0.0171	0.0028	0.0298	0.00345	0.00499	0.0076	0.0027	0.0075	0.0150	0.0054	0.0224
Ma	0.2544	0.0908	0.0404	0.2500	0.2668	0.0479	0.0348	0.1197	0.0593	0.0192	0.05034	0.07554	0.0380	0.0635	0.1068	0.1778	0.0954	0.0615
WT	0.0330	0.0225	0.0119	0.0334	0.0323	0.0195	0.0148	0.0127	0.0096	0.0047	0.01654	0.01656	0.0095	0.0145	0.0230	0.0292	0.0194	0.0162
RT	0.0111	0.0033	0.0019	0.0106	0.0075	0.0151	0.0112	0.0074	0.0069	0.0027	0.01079	0.01202	0.0076	0.0120	0.0492	0.0402	0.0147	0.0139
TW	0.0307	0.0150	0.0116	0.0161	0.0436	0.0492	0.0220	0.1523	0.0156	0.0099	0.02095	0.02450	0.0247	0.0144	0.0186	0.0102	0.0248	0.0183
IC	0.0090	0.0058	0.0082	0.0037	0.0041	0.0233	0.0228	0.0113	0.1160	0.0188	0.02757	0.03130	0.0247	0.0246	0.0235	0.0211	0.0247	0.0128
FIRRL	0.0459	0.0675	0.0338	0.0398	0.0301	0.0687	0.1277	0.0570	0.0415	0.1305	0.05643	0.05898	0.1423	0.0470	0.0683	0.0877	0.0655	0.0226
PST	0.0287	0.0445	0.0179	0.0607	0.0095	0.0419	0.0408	0.0149	0.0256	0.0350	0.12097	0.05206	0.0190	0.0151	0.0217	0.0168	0.0273	0.0370
AWR	0.0041	0.0237	0.0087	0.0095	0.0085	0.0294	0.0258	0.0186	0.0260	0.0334	0.03423	0.03527	0.0361	0.0142	0.0359	0.0196	0.0392	0.0282
ES	8E-06	0.0001	0.0003	0.0003	2E-05	0.0003	0.0004	0.0001	0.0003	0.0003	0.00048	0.00113	0.0019	0.0057	0.0004	0.0008	0.0013	0.0025
HS	2E-07	1E-05	2E-05	0	2E-05	8E-05	5E-05	7E-06	9E-06	0.0002	6E-06	5.7E-06	0.0003	0.0004	2E-06	9E-06	4E-06	0.0803
AER	0.0005	0.0003	0.0003	0.0003	0.0006	0.0018	0.0029	0.0006	0.0055	0.0007	0.00163	0.00227	0.0026	0.0007	0.0337	0.0047	0.0028	0.0020
AF	0.0019	0.0015	0.0007	0.0009	0.0024	0.0045	0.0073	0.0099	0.0071	0.0036	0.01458	0.01452	0.0133	0.0093	0.0245	0.0081	0.0159	0.0077
OP	0.0063	0.0046	0.0017	0.0032	0.0026	0.0012	0.0012	0.0093	0.0029	0.0056	0.01103	0.01588	0.0133	0.0189	0.0288	0.0072	0.0141	0.0078
P	0.0071	0.0031	0.0015	0.0027	0.0032	0.0094	0.0108	0.0054	0.0080	0.0076	0.01031	0.00749	0.0228	0.0129	0.0217	0.0074	0.0098	0.0320

Introduction to I-O Analysis

Total requirement table:

- it shows the inputs that are required from other industries both directly and indirectly to produce a dollar of output.
- It is shown as matrix B , $B = (I - A)^{-1}$
- Alberta Total Requirement Table

	AFFH	Mi	U	C	Ma	WT	RT	TW	IC	FIRRL	PST	AWR	ES	HS	AER	AF	OP	P
AFFH	1.5454	0.0260	0.0202	0.0611	0.2051	0.0172	0.0138	0.0401	0.0181	0.0103	0.01864	0.02221	0.0151	0.0183	0.0320	0.0625	0.0272	0.0259
Mi	0.1496	1.1213	0.1747	0.2086	0.3352	0.0408	0.0318	0.0652	0.0323	0.0262	0.03202	0.03896	0.0392	0.0322	0.0537	0.0768	0.0476	0.0434
U	0.0420	0.0189	1.0088	0.0147	0.0383	0.0087	0.0109	0.0172	0.0068	0.0098	0.00698	0.00747	0.0204	0.0096	0.0131	0.0181	0.014	0.0137
C	0.0387	0.0206	0.0589	1.0132	0.0214	0.0138	0.0186	0.0284	0.0087	0.0377	0.01073	0.01233	0.0181	0.0086	0.0178	0.0260	0.0137	0.0295
Ma	0.6161	0.1815	0.1215	0.4252	1.5253	0.1157	0.0937	0.2500	0.1282	0.0716	0.12391	0.15661	0.1049	0.1255	0.2194	0.3168	0.1868	0.1468
WT	0.0833	0.0372	0.0254	0.0600	0.0707	1.0305	0.0247	0.0312	0.0204	0.0135	0.02926	0.02948	0.0206	0.0242	0.0411	0.0500	0.0336	0.0301
RT	0.0280	0.0087	0.0062	0.0192	0.0194	0.0202	1.0161	0.0148	0.0121	0.0068	0.01739	0.01817	0.0132	0.0164	0.0590	0.0482	0.0211	0.0207
TW	0.1035	0.0382	0.0297	0.0566	0.1022	0.0735	0.0404	1.2028	0.0345	0.0240	0.04324	0.0476	0.0450	0.0312	0.0478	0.0425	0.0498	0.0408
IC	0.0323	0.0170	0.0166	0.0181	0.0216	0.0363	0.0363	0.0248	1.1390	0.0308	0.04413	0.04632	0.0394	0.0353	0.0411	0.0369	0.0389	0.0263
FIRRL	0.1477	0.1128	0.0716	0.1035	0.1165	0.1092	0.1727	0.1107	0.0769	1.1713	0.10083	0.10141	0.1922	0.0790	0.1270	0.1474	0.1105	0.0625
PST	0.0856	0.0723	0.0425	0.0994	0.0568	0.0653	0.0651	0.0408	0.0461	0.0579	1.15500	0.07769	0.0434	0.0315	0.0513	0.0465	0.0515	0.0618
AWR	0.0322	0.0394	0.0215	0.0311	0.0354	0.0437	0.0410	0.0363	0.0399	0.0472	0.05165	1.05076	0.0529	0.0254	0.0563	0.0385	0.0549	0.0428
ES	0.0003	0.0003	0.0004	0.0006	0.0003	0.0005	0.0006	0.0003	0.0005	0.0005	0.00077	0.00139	1.0022	0.0059	0.0008	0.0011	0.0016	0.0033
HS	0.0016	0.0006	0.0004	0.0008	0.0010	0.0012	0.0013	0.0009	0.0010	0.0011	0.00129	0.00101	0.0026	1.0017	0.0023	0.0011	0.0012	0.0834
AER	0.0022	0.0010	0.0009	0.0014	0.0019	0.0028	0.0038	0.0016	0.0070	0.0015	0.00281	0.00338	0.0036	0.0015	1.0362	0.0060	0.0039	0.0030
AF	0.0094	0.0052	0.0033	0.0061	0.0083	0.0085	0.0111	0.0152	0.0110	0.0070	0.01997	0.01899	0.0174	0.0123	0.0306	1.0127	0.0202	0.0123
OP	0.0161	0.0086	0.0049	0.0089	0.0102	0.0051	0.0050	0.0148	0.0063	0.0091	0.01594	0.02017	0.0177	0.0218	0.0348	0.0120	1.0184	0.0132
P	0.0187	0.0074	0.0048	0.0089	0.0115	0.0137	0.0153	0.0108	0.0123	0.0115	0.01568	0.01221	0.0280	0.0165	0.0287	0.0134	0.0146	1.0379

Alberta GHG Emission without Toll

Total GHG emission for each sector:

$$T = E(I - A)^{-1}D$$

$E_{n\times n}$: GHG emission for each sector to produce one unit of output.

$D_{n\times n}$: Final demand for each sector

$T_{n\times 1}$: Total GHG emission for each sector

Total GHG emission of the economy:

Total Emission $= T_{11} + T_{21} + \cdots + T_{n\times 1} =$ 206.82 Megatons of CO_2 equivalent

Alberta GHG Emission with toll

Step 1 – Evaluating the economic impact of ITS by Paramics

- 20% reduction in congestion cost
- 20% reduction in GHG emission in transportation sector(5.34 MT CO_2 equivalent)

Step 2 – Adopting 20% reduction in congestion cost in transportation sector in transaction table

Step 3 – Calculating Growth Correlation (GC) for other economic sectors

$$\mathrm{GC_{Ma}} = 0.069316 \approx 6.93\%$$

Alberta GHG Emission with toll

Step 4 – Updating transaction table incorporating the changes in economic sectors

- Updated Alberta symmetric Input-Output Table (Million $)

	AFFH	Mi	U	C	Ma	WT	RT	TW	IC	FIRRL	PST	AWR	ES	HS	AER	AF	OP	P
AFFH	3584	56	13	109	5234	10	6	51.2	2	5	15	2	0.033	4	2	129	5	188
Mi	39	5879	763	4970	11325	191	100	58.4	15	194	34	13	5	12	2	15	15	254
U	189	989	17	64	1066	65	104	119.2	19	318	39	15	8	33	11	77	45	406
C	178	991	306	92	204	109	161	254.4	25	1563	72	44	4	18	17	147	33	1165
Ma	2766.91	7219.63	227.14	11389.63	15288	799.31	545.33	1707.49	513.70	966.07	1006.32	638.29	19.17	406.36	230.97	1667.61	559.71	3063.05
WT	374	1868	70	1590	1850	340	242	189.6	87	248	345	146	5	97	52	286	119	842
RT	126	274	11	502	429	263	183	110.4	62	141	225	106	4	80	111	393	90	725
TW	348	1241	68	764	2496	857	360	2835	141	519	437	216	13	96	42	100	152	952
IC	102	479	48	174	233	405	373	168.8	1049	988	575	276	13	164	53	207	151	666
FIRRL	521	5604	198	1890	1723	1197	2087	848	375	6846	1177	520	75	314	154	858	401	1177
PST	326	3697	105	2886	543	730	666	222.4	231	1835	2523	459	10	101	49	164	167	1925
AWR	46	1968	51	452	487	512	421	277.6	235	1754	714	311	19	95	81	192	240	1467
ES	0.092	12	1.5	16	1	5	6	1.6	3	14	10	10	1	38	1	8	8	131
HS	0.002	1	0.113	0	1	1.4	0.75	0.0992	0.077	10	0.126	0.05	0.157	2.5	0.004	0.085	0.025	4176
AER	6	23	1.71	14	32	32	47	8.8	50	39	34	20	1.36	5	76	46	17	106
AF	22	121	4.34	44	135	79	120	148	64	190	304	128	7	62	55.33	79.3	97	400
OP	71	378	10	153	147	21	19	139.2	26	294	230	140	7	126	65	70	86	408
P	81	258	9	127	185	163	177	80.8	72	397	215	66	12	86	49	72	60	1665
Total	11226.91	82681.63	5855.14	47048.63	57291	17378.31	16313.33	17420.86	9018.70	52421.07	20813.32	8789.29	526.17	6659.36	2245.97	9715.62	6094.71	51866.05

Alberta GHG Emission with toll

Step 5

- **Updating direct requirement table.**

Updated Alberta Direct Requirement Table

	AFFH	Mi	U	C	Ma	WT	RT	TW	IC	FIRRL	PST	AWR	ES	HS	AER	AF	OP	P
AFFH	0.3192	0.0007	0.0022	0.0023	0.0914	0.0006	0.0004	0.0029	0.0002	1E-04	0.0007	0.0002	6E-05	0.0006	0.0009	0.0133	0.0008	0.0036
Mi	0.0035	0.0711	0.1303	0.1056	0.1977	0.0110	0.0061	0.0034	0.0017	0.0037	0.0016	0.0015	0.0095	0.0018	0.0009	0.0015	0.0025	0.0049
U	0.0168	0.0120	0.0029	0.0014	0.0186	0.0037	0.0064	0.0068	0.0021	0.0061	0.0019	0.0017	0.0152	0.0050	0.0049	0.0079	0.0074	0.0078
C	0.0159	0.0120	0.0523	0.0020	0.0036	0.0063	0.0099	0.0146	0.0028	0.0298	0.0035	0.0050	0.0076	0.0027	0.0076	0.0151	0.0054	0.0225
Ma	0.2465	0.0873	0.0388	0.2421	0.2668	0.046	0.0334	0.0980	0.0570	0.0184	0.0483	0.0726	0.0364	0.0610	0.1028	0.1716	0.0918	0.0591
WT	0.0333	0.0226	0.0120	0.0338	0.0323	0.0196	0.0148	0.0109	0.0096	0.0047	0.0166	0.0166	0.0095	0.0146	0.0232	0.0294	0.0195	0.0162
RT	0.0112	0.0033	0.0019	0.0107	0.0075	0.0151	0.0112	0.0063	0.0069	0.0027	0.0108	0.0121	0.0076	0.0120	0.0494	0.0405	0.0148	0.0140
TW	0.0310	0.0150	0.0116	0.0162	0.0436	0.0493	0.0221	0.1627	0.0156	0.0099	0.0210	0.0246	0.0247	0.0144	0.0187	0.0103	0.0249	0.0184
IC	0.0091	0.0058	0.0082	0.0037	0.0041	0.0233	0.0229	0.0097	0.1163	0.0188	0.0276	0.0314	0.0247	0.0246	0.0236	0.0213	0.0248	0.0128
FIRRL	0.0464	0.0678	0.0338	0.0402	0.0301	0.0689	0.1279	0.0487	0.0416	0.1306	0.0566	0.0592	0.1425	0.0472	0.0686	0.0883	0.0658	0.0227
PST	0.0290	0.0447	0.0179	0.0613	0.0095	0.0420	0.0408	0.0128	0.0256	0.035	0.1212	0.0522	0.0190	0.0152	0.0218	0.0169	0.0274	0.0371
AWR	0.0041	0.0238	0.0087	0.0096	0.0085	0.0295	0.0258	0.0159	0.0261	0.0335	0.0343	0.0354	0.0361	0.0143	0.0361	0.0198	0.0394	0.0283
ES	8E-06	0.0001	0.0003	0.0003	2E-05	0.0003	0.0004	9E-05	0.0003	0.0003	0.0005	0.0011	0.0019	0.0057	0.0004	0.0008	0.0013	0.0025
HS	2E-07	1E-05	2E-05	0	2E-05	8E-05	5E-05	6E-06	9E-06	0.0002	6E-06	6E-06	0.0003	0.0004	2E-06	9E-06	4E-06	0.0805
AER	0.0005	0.0003	0.0003	0.0003	0.0006	0.0018	0.0029	0.0005	0.0055	0.0007	0.0016	0.0023	0.0026	0.0008	0.0338	0.0047	0.0028	0.0020
AF	0.0020	0.0015	0.0007	0.0009	0.0024	0.0045	0.0074	0.0085	0.0071	0.0036	0.0146	0.0146	0.0133	0.0093	0.0246	0.0082	0.0159	0.0077
OP	0.0063	0.0046	0.0017	0.0033	0.0026	0.0012	0.0012	0.0080	0.0029	0.0056	0.0111	0.0159	0.0133	0.0189	0.0289	0.0072	0.0141	0.0079
P	0.0072	0.0031	0.0015	0.0027	0.0032	0.0094	0.0109	0.0046	0.0080	0.0076	0.0103	0.0075	0.0228	0.0129	0.0218	0.0074	0.0098	0.0321

Alberta GHG Emission with toll

Step 5

- **Updating direct requirement table.**
- **Updating total requirement table**

Updated Alberta Total Requirement Table

	AFFH	Mi	U	C	Ma	WT	RT	TW	IC	FIRRL	PST	AWR	ES	HS	AER	AF	OP	P
AFFH	1.5501	0.0249	0.0195	0.0592	0.2049	0.0163	0.0132	0.0335	0.0174	0.0099	0.0179	0.0212	0.0144	0.0176	0.0308	0.0612	0.0261	0.0251
Mi	0.1452	1.1198	0.1738	0.2062	0.3334	0.0393	0.0307	0.0542	0.0310	0.0254	0.0306	0.0373	0.0380	0.0309	0.0516	0.074	0.0456	0.0419
U	0.0418	0.0187	1.0086	0.0143	0.0380	0.0085	0.0107	0.0146	0.0066	0.0097	0.0068	0.0072	0.0203	0.0094	0.0128	0.0178	0.0137	0.0135
C	0.0386	0.0205	0.0589	1.0129	0.0211	0.0136	0.0185	0.0244	0.0085	0.0376	0.0106	0.0121	0.0179	0.0085	0.0176	0.0259	0.0135	0.0293
Ma	0.5949	0.1732	0.1158	0.4089	1.5168	0.1088	0.0886	0.2062	0.1220	0.0680	0.1176	0.1489	0.0993	0.1194	0.2094	0.3039	0.1779	0.1397
WT	0.0830	0.0369	0.0251	0.0597	0.0702	1.0301	0.0244	0.0265	0.0201	0.0133	0.0290	0.0291	0.0203	0.0240	0.0408	0.0496	0.0333	0.0298
RT	0.0280	0.0086	0.0062	0.0191	0.0192	0.0201	1.0160	0.0127	0.0121	0.0068	0.0173	0.0181	0.0131	0.0163	0.0591	0.0483	0.0211	0.0207
TW	0.1044	0.0382	0.0298	0.0566	0.1030	0.0741	0.0407	1.2140	0.0346	0.0241	0.0434	0.0478	0.0452	0.0313	0.0479	0.0424	0.0500	0.0409
IC	0.0322	0.0168	0.0166	0.0179	0.0214	0.0361	0.0362	0.0213	1.1392	0.0307	0.0441	0.0463	0.0393	0.0353	0.0411	0.0369	0.0389	0.0262
FIRRL	0.1468	0.1123	0.0711	0.1026	0.1152	0.1082	0.1723	0.0949	0.0763	1.1710	0.1002	0.1007	0.1917	0.0785	0.1264	0.1471	0.1098	0.0618
PST	0.0856	0.0722	0.0424	0.0997	0.0564	0.0650	0.0649	0.0349	0.0460	0.0578	1.1550	0.0776	0.0432	0.0313	0.0510	0.0463	0.0513	0.0616
AWR	0.0317	0.0393	0.0214	0.0308	0.0350	0.0434	0.0408	0.0311	0.0398	0.0472	0.0515	1.0506	0.0528	0.0253	0.0562	0.0383	0.0548	0.0427
ES	0.0003	0.0003	0.0004	0.0006	0.0003	0.0005	0.0006	0.0003	0.0005	0.0005	0.0008	0.0014	1.0022	0.0059	0.0008	0.0011	0.0016	0.0033
HS	0.0016	0.0006	0.0004	0.0007	0.001	0.0012	0.0013	0.0008	0.0010	0.0011	0.0013	0.0010	0.0026	1.0017	0.0024	0.0011	0.0012	0.0836
AER	0.0022	0.0010	0.0008	0.0013	0.0018	0.0027	0.0038	0.0013	0.0071	0.0015	0.0028	0.0034	0.0036	0.0015	1.0363	0.0060	0.0039	0.0030
AF	0.0092	0.0051	0.0033	0.0059	0.0081	0.0084	0.0111	0.0131	0.0109	0.0069	0.0199	0.0189	0.0174	0.0122	0.0306	1.0127	0.0201	0.0123
OP	0.0161	0.0085	0.0048	0.0087	0.0100	0.0049	0.0049	0.0127	0.0063	0.0091	0.0159	0.0201	0.0176	0.0218	0.0348	0.0119	1.0183	0.0131
P	0.0187	0.0074	0.0047	0.0088	0.0113	0.0136	0.0153	0.0092	0.0123	0.0114	0.0156	0.0122	0.0279	0.0165	0.0288	0.0133	0.0146	1.0380

Alberta GHG Emission with toll

Step 6 – Calculating updated total GHG emission of economy

Total GHG emission for each sector:

$$T = E(I - A)^{-1}D$$

$E_{n\times n}$: GHG emission for each sector to produce one unit of output

$D_{n\times n}$: Final demand for each sector

$T_{n\times 1}$: Total GHG emission for each

Total GHG emission of the economy:

Total Emission $= T_{11} + T_{21} + \cdots + T_{n\times 1} =$ 211.53 Megatons of CO_2 equivalent

GHG emission due to secondary phase:

$211.53 - 206.82 = +\mathbf{4.71}$ Megatons of CO_2 equivalent

Total Alberta GHG Emission Saving

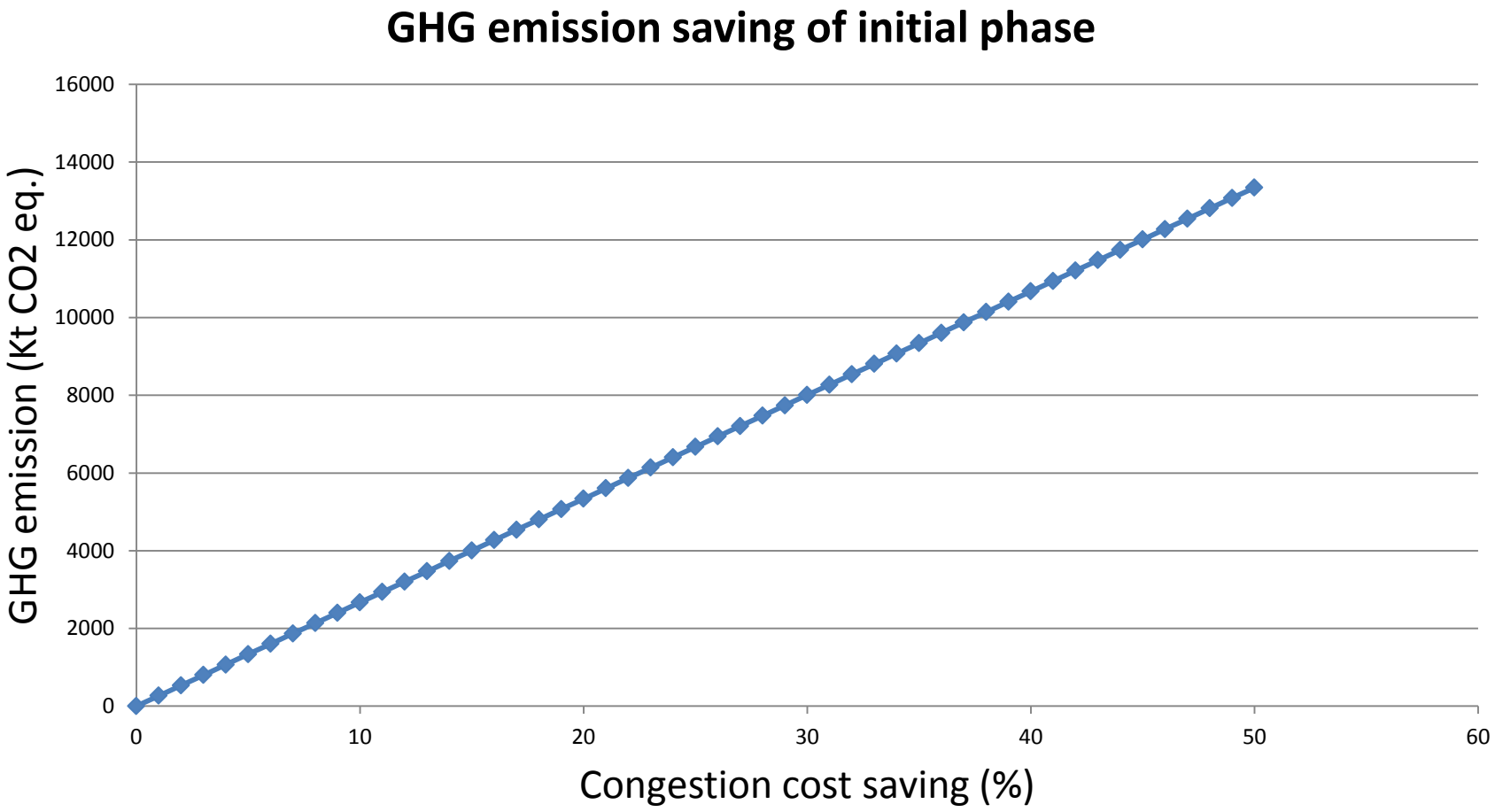
Total Change in Alberta GHG emission =

Saving from initial phase + Extra emission due to secondary phase =

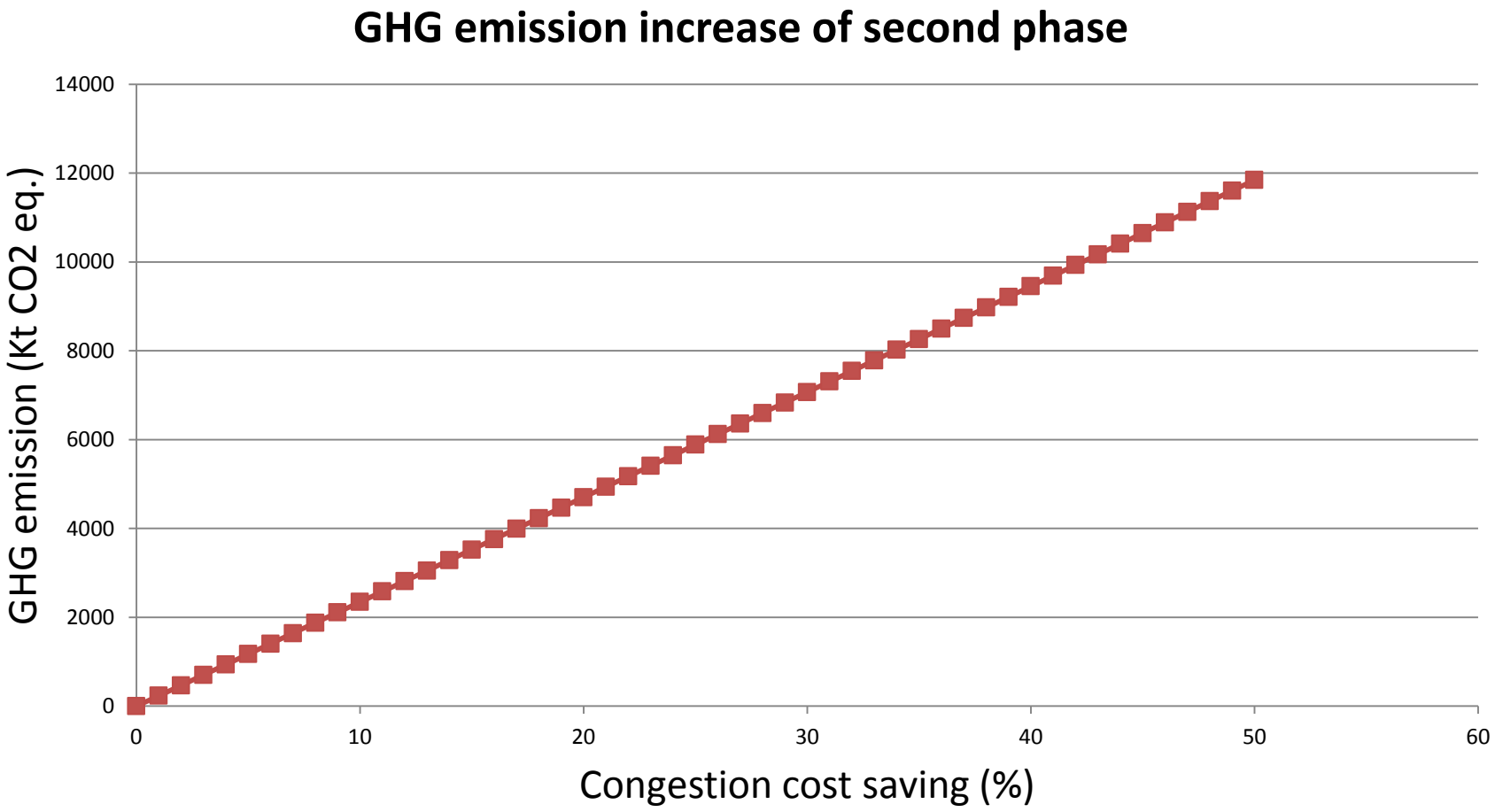
$-5.34 + 4.71 = -\mathbf{0.63}$ megatonnes of CO_2 equivalent

(www.businessinsider.com)

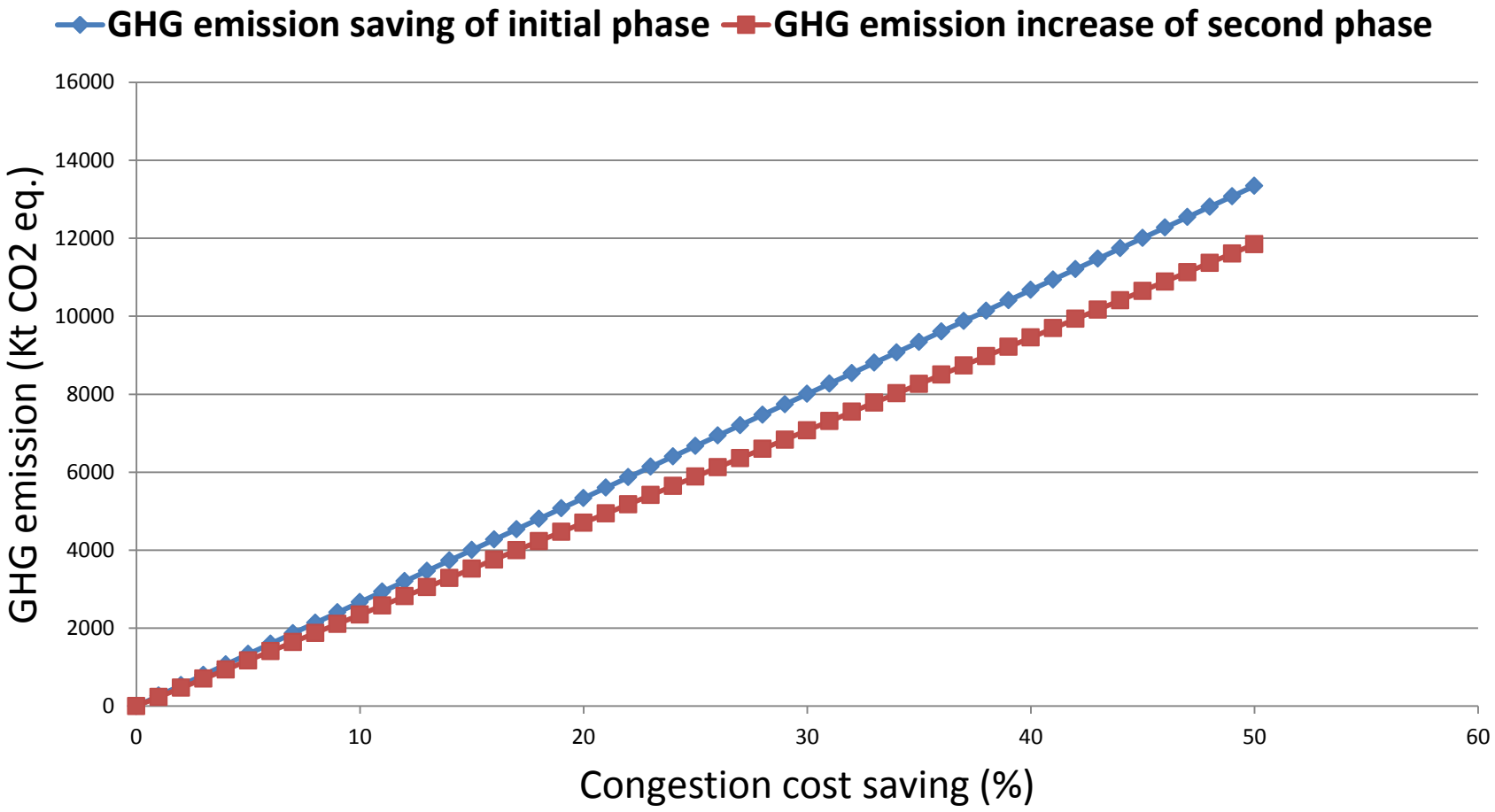
Sensitivity Analysis



Sensitivity Analysis



Sensitivity Analysis



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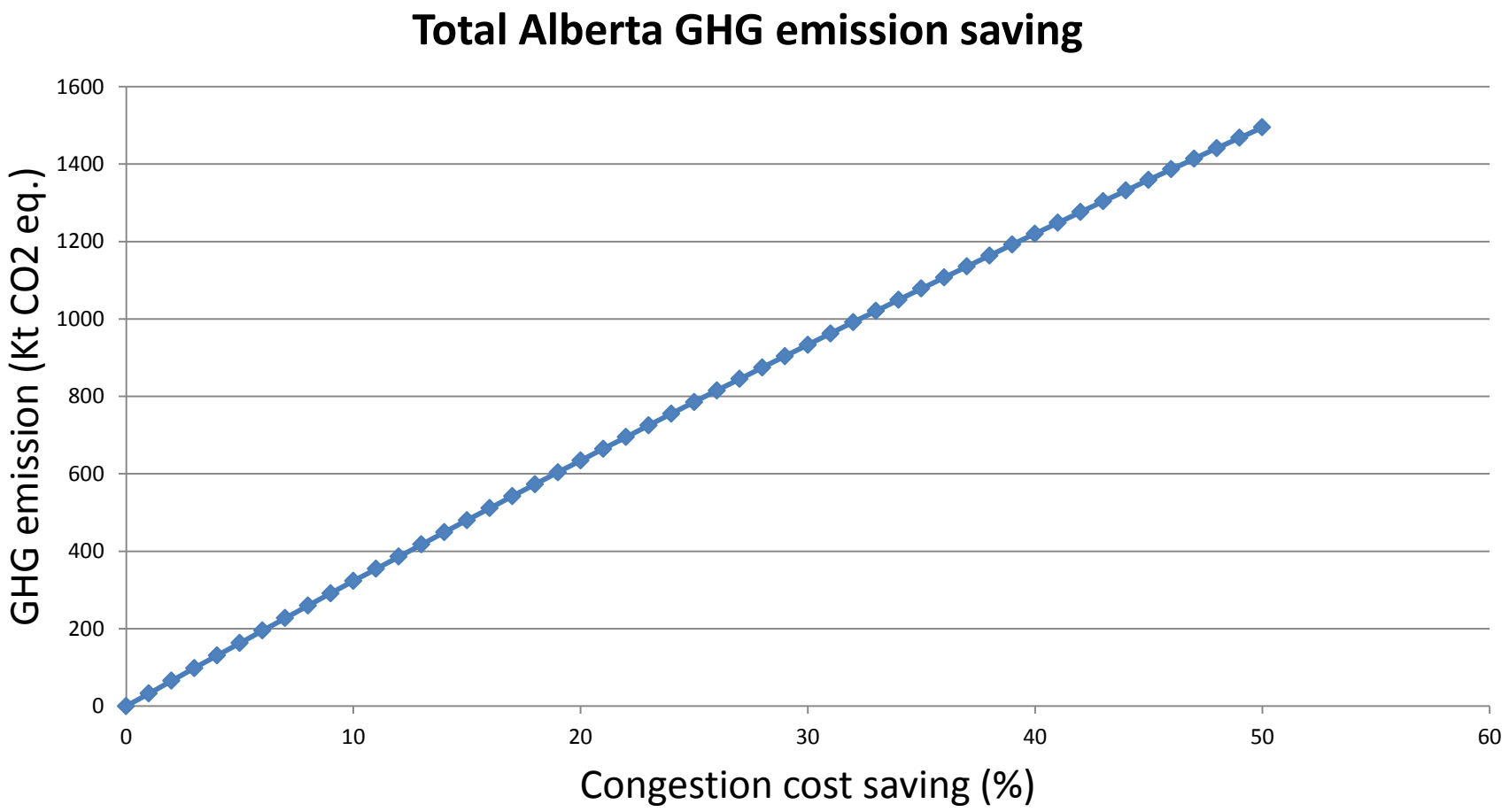
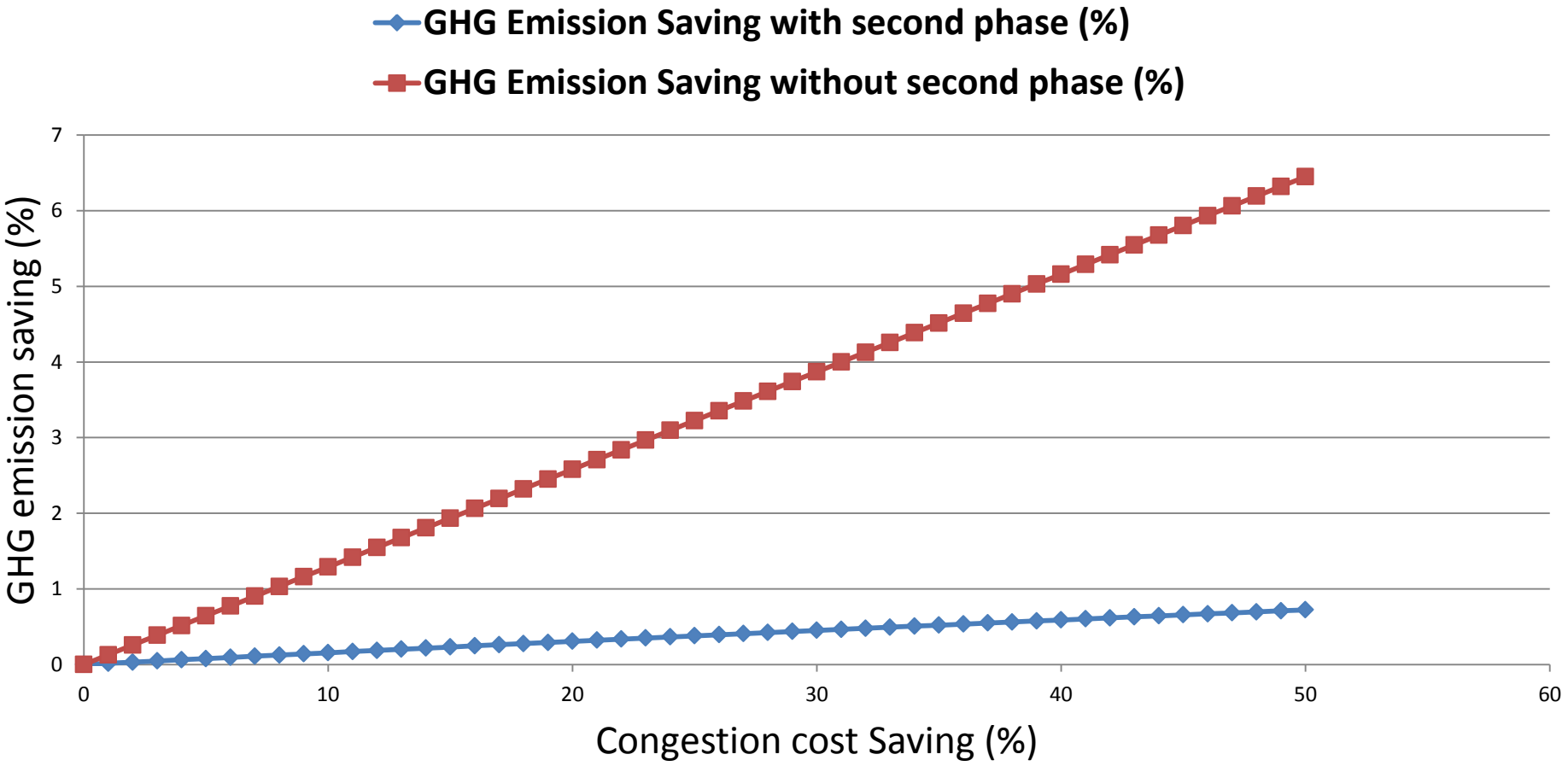


Sensitivity Analysis



Thank you

Appendix

Calculating Growth Correlation (GC) for other economic sectors

$$\mathrm{VC} = \frac{\text{National total transportation output}}{\text{National total manufacuring input}} \times \frac{\text{LQ of transportation}}{\text{LQ of manufacturing}} \times \%\text{Effect}$$

While

$$\mathrm{LQ_{TW}} = \frac{\text{TW Alberta Salary}}{\text{Total Alberta Salary}} \div \frac{\text{TW National Salary}}{\text{Total National Salary}}$$

Then

$$\mathrm{VC} = \frac{119912.658 \text{ million } \$}{527726.526 \text{ million } \$} \times \frac{1.00149}{0.656593} \times 0.2 = 0.069316 \approx 6.93\%$$

Appendix

Two digits NAICS industrial sectors and related codes

Agriculture, forestry, fishing and hunting	AFFH
Mining, quarrying, and oil and gas extraction	Mi
Utilities	U
Construction	C
Manufacturing	Ma
Wholesale trade	WT
Retail trade	RT
Transportation and warehousing	TW
Information and cultural industries	IC
Finance and insurance, real estate and rental and leasing	FIRRL
Professional, scientific and technical services	PST
Administrative and support, waste management and remediation services	AWR
Educational services	ES
Health care and social assistance	HS
Arts, entertainment and recreation	AER
Accommodation and food services	AF
Other services (except public administration)	OP
Public administration	P