Estimating Natural Resource and Energy Flows From New York State Economic Activity

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Abstract:
Estimates of direct and indirect waste, energy, and material input use resulting from New York State economic activity are derived from existing input-output and natural resource and energy data bases. The work provides both a generally applicable methodology and an empirical example using national level natural resource and energy use data. The primary contribution of the work is to demonstrate a methodology for estimating life-cycle impacts from regional level economic activity. The approach is demonstrated using indirect economic linkages in an empirical example for the state of New York.

A substantial body of work utilizes energy and material flow approaches to address the environmental impact of economic activity. This work recognizes that material inputs and wastes are used and generated at all levels of the economic supply chain and at final consumption. The insights of this work emphasize that regional economic activity generates not only its own environmental effects, but a range of upstream and downstream effects that spill over to broader geographical scales. Empirical work on natural resource and energy impacts has proceeded largely at the two extremes of national and international impacts of economic activity, and in work on the life cycle impact of specific industrial products and processes. The work reported here is positioned between these extremes, and provides both a generally applicable methodology and an empirical example for estimating natural resource and energy flows at the regional level.

The paper first provides a literature review, and then introduces the specific methodology used to estimate the regional natural resource and energy impacts. The data sources used here are then introduced, followed by a brief discussion of practical issues arising in using them with the economic input-output database. The resulting direct and indirect effects of New York State economic activity are then introduced and summarized.

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Literature Review

There is a substantial body of work which utilizes material flow approaches to address the environmental impact of economic activity. The early work of Kneese, Ayres, D'Arge (1970) recognizes that material inputs and wastes are used and generated at all levels of the economic supply chain, and at final consumption. The insights of this seminal work lead directly to the premise of industrial ecology, that industrial activity at any level generates not only its own environmental impacts, but a range of upstream and downstream impacts as well. Thus any specific economic activity or output inevitably generates indirect energy and natural resources impacts, and economic impacts across a broad range of economic sectors. This led to a key practical concern of conventional life cycle analysis, which sought to estimate physical impacts of a specific product by examining direct impacts of a small number of specific production practices: important indirect impacts would in many cases be excluded from the analysis. One solution was to apply input-output models (Leontief, 1936) to estimate the related economic activity. In a survey of the use of economic input-output models to estimate indirect environmental impacts, Forsund (1985) notes that it was Leontief (1970) who suggested extensions to basic input-output models to address environmental impacts. A useful example for the full United States was provided by Lave et al. (1995).

Similarly, input-output models have been applied directly to quantify economic linkages in life cycle analysis of specific products (see, for example Hendrickson et al., 1998, and Joshi, 1999). Lenzen (2000) demonstrates that using such a hybrid approach to eliminate the truncation error in conventional life cycle analysis is likely to produce superior impact estimates. A useful survey of current approaches to life cycle analysis is provided by Finnveden et al. (2009). Online calculators which provide impact estimates by economic sector using an underlying input output model are now widely available (e.g. Carnegie Mellon University Green Design Institute, 2011).

Integrating input-output models with energy and environmental impact estimates also provides a framework for conducting simulations to test policy impacts of, for example, efficiency mandates and energy taxes (Hawdon and Pearson, 1995). And because input-output models are available at a variety of spatial scales, environmental impacts of changes in consumption at scales from national to city to household levels can be estimated using this hybrid approach (Munksgaard et al. 2005). Policy analysis has also been demonstrated at the state level: Miernyk and Sears (1974), for example, worked directly with an input-output model for West Virginia to demonstrate impacts of emission standards.

State Level Environmental, Energy, and Natural Resource Flows

This paper focuses on the impact of state level economic activity on natural resource and energy flows both within and outside state boundaries. Waste and energy and material input use data from several alternative sources are integrated with a state input-output model to provide insight into the total environmental effects of state economic activity. The work follows the outlines of Tracey et al.

(2000), in which total energy inputs stemming from economic production in seven northeastern states were estimated separately for 15 industrial sectors. This work differs in focusing on New York State alone, but moves beyond industrial activity to include virtually all economic sectors. In addition to energy inputs, environmental and material inputs which stem from New York economic activity are estimated.

Methodology

A primary purpose of this work is to develop an understanding of the relationship between final demand in differing economic sectors and the resulting waste, energy, and material flows. First, an input-output model is used to estimate economic flows between sectors. This allows calculation of the economic inputs required to satisfy final demand in any given sector. Second, the natural resource and energy flows by sector are used to estimate the total environmental requirements which result from the final demand.

Direct Energy and Natural Resource Flow Estimates

In order to utilize an input-output model to estimate direct natural resource and energy impacts, basic flow estimates by economic sector are needed. If region specific resource intensities are available by economic sector, then physical resource use and impacts $\boldsymbol{\rho}$ can be estimated directly from regional economic activity. But in most cases regional estimates of energy and natural resource use or intensity by economic sector are not known. In this case regional estimates can be developed from national physical impact estimates. Let **R** be a matrix of national material flow estimates, where r_{kj} is the total impact for material flow k in the economic sector j. For this paper, economic sectors j correspond closely to the 2-digit SIC level definitions. Then the direct material flows $\boldsymbol{\rho}$ for New York State can be estimated as

(1) $\boldsymbol{\rho} = (\boldsymbol{\alpha}\,\mathbf{I})\,\mathbf{R}$

where $\boldsymbol{\alpha}$ is the vector of New York State to national output ratios by economic sector, and **I** is the identity matrix.

Estimating Demand Driven Flows

With direct resource flows $\boldsymbol{\rho}$ estimated, indirect energy and natural resource impacts from New York State economic activity can be found following the basic input-output approach described by Joshi (1999) . Let **F** be a diagonal matrix of final demands for individual economic sectors j, and **I** is the identity matrix. Then the matrix of required inputs **X** to meet demand in sector j is given by

(2) $\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{F}$

where **A** is the matrix of intermediate demands by sector *j* for inputs from sector *i*. Then $(\mathbf{I} - \mathbf{A})^{-1}$ is the so-called Leontief inverse calculated from the input-output model. The vector of total material flows θ arising from final demands in sector *j* are then given by

$$\theta = \boldsymbol{\rho} \mathbf{X}$$

θ thus gives the material flows resulting from final demands in sector *j* by using the material flow database in conjunction with the input-output database to translate dollar flows to material flows.

Data

Making input-output analysis tractable are databases which characterize the economic activity induced by and stemming from economic output by any given sector of the national or regional economy. In this study we use 1999 state data from the Minnesota IMPLAN Group, Inc. (1999) to represent the structure of the New York State economy. In this formulation economic activity is disaggregated to the two digit SIC level, representing 67 distinct industries.

The direct natural resource and energy impacts are based upon state, regional, and national level estimates. In assigning impacts to a particular sector, the highest level sector to which the impact could be fully attributed was used. Thus carbon emissions from coal combustion were assigned to the utility sector, though the energy product (electricity) is in fact used throughout the economy. Less intuitively, emissions from refined oil products are assigned to petroleum and coal products rather than to service stations. While such fuels are sold by service stations, they also enter the economy through other channels (e.g. jet fuel for airplanes).

Four databases of environmental, energy, and natural resource impact are utilized. These include the Toxic Release Inventory (Environmental Protection Agency, 2002a), commonly abbreviated as TRI, AirData emissions (Environmental Protection Agency, 2002b), energy usage estimates from the Manufacturing Energy Consumption Survey (MECs) database (Energy Information Administration, 1998) and World Resources Institute estimates following from Adriaanse et al. (1997). An alternative approach would be to utilize a collected set of impact estimates such as the Comprehensive Datae Archive (CEDA) described by Suh and Kagawa (2005).

Toxic Releases Inventory

The Toxic Release Inventory (TRI) (Environmental Protection Agency, 2002a) covers air, land, and water discharges for a broad range of industries, with aggregate discharge quantities in each category reported annually at the facility level. For purposes of this paper, total discharges are aggregated by two-digit SIC code based on specific New York State facility discharges. TRI reported discharges are limited to specifically identified chemical compounds, and do not include many wastes of substantial concern. For example the regional pollutant sulfur dioxide (SO_2) is not reported (except when its product sulfuric acid is released as an aerosol), nor are globally important CO_2 emissions.

Air Emissions Database

An alternative emissions data source for air emissions is the AirData interface (Environmental Protection Agency, 2002b). AirData provides aggregated annual emissions data by state based on the Air Quality System and Nationl Emission Inventory databases. Emissions coverage includes sulfur dioxide (SO_2), nitrogen oxides (NOx), volatile organic compounds (VOC), particulates, and carbon monoxide (CO). Industry detail is provided to the four-digit SIC level, and aggregated for this paper to the two-digit level. While the emissions specificity is superior to TRI, industry coverage is limited. Emissions estimates based on AirData sources must therefore be interpreted as underestimates of total industry emissions.

Energy Database

Data for New York State industry level energy flows are derived from regional data reported by the Energy Information Administration in the Department of Energy's Manufacturing Energy Consumption Survey (1998). The regional data are reported for the states of New York, Pennsylvania, and New Jersey. The methodology outlined in equation (1) is used to estimate regional flows, with the vector $\boldsymbol{\alpha}$ used to represent, by economic sector, the ratio of New York State output to the three state total. While most important industrial and manufacturing sectors are included, data for electricity generation by public utilities (SIC 49) is not included.

Material Use Database

World Resource Institute data (Adriaanse, 1997) provides estimates of material use in a number of manufacturing and industrial sectors for the United States. Matthews et al. (2000) provide a useful application of the database. In this paper New York State specific estimates are derived by scaling material usage to sector size as shown in equation (1). Specific material categories include biodegradable, geologic, processed materials, chemically active, and hazardous materials. As with the air emissions data, industry coverage is limited and resulting material input use estimates must be interpreted cautiously. Importantly, estimates of material use in primary agricultural sectors (e.g. SIC 01) are provided.

Direct material and energy impacts within New York State are estimated from the level of economic activity in each sector, multiplied by the estimated material or energy intensity in the sector. Second, the total direct plus indirect impact of economic activity in any one sector is estimated from economic input-output relationships between sectors. For example, these relationships (described by the 67x67 matrix of multipliers **X** in equation 2) provide an estimate of the total impacts or footprint of an activity such as purchases from food stores (SIC 54). While supermarkets themselves "produce" few impacts, they purchase from many sectors which do: from agriculture, transportation, and energy for example. This allows the impact estimate to capture effects of the many purchased inputs from both inside and outside New York State, including international purchases. These imports to the state thus represent material and energy impacts which result from economic activity within the state, but which occur elsewhere. Estimates of the dollar value of imports to the state are used to estimate material and energy impacts in the rest of the nation, and in the rest of the world resulting from state economic activity.

Results

Estimates of direct environmental and energy use intensities by economic sector are presented in Tables 1 and 2. The impact per million dollars of economic output (year 2000 US dollars) in the selected 2-digit SIC economic sectors is shown. Table 1 shows that toxic release intensities for air, water, and land emissions are greatest in the Leather and leather products (SIC 31), Lumber and wood products (SIC 24), and Metal mining (SIC 10) sectors respectively. Energy intensity (excluding the Electricity generation sector (SIC 49) is greatest in the Paper (SIC 26) and Chemicals (SIC 28) industries. Table 2 shows the intensity of material input use required in each sector. Notable among significant New York State industries are biodegradable and geologic materials used for agricultural crops (SIC 01), and chemically active materials used in Stone, clay, and glass products (SIC 32).

New York State direct impacts shown in Table 3 are estimated by scaling national or regional materials intensity data to the level of economic activity in the state following equation (1). Energy use, toxic releases, and specific air emissions are given for selected manufacturing and related sectors. Electricity generation (SIC 49) is the dominant source of New York State industry for air emissions. Food (SIC 20) and Lumber and wood products (SIC 24), together with Fabricated metal products (SIC 34) produce most water emissions. Land discharges are dominated by Metal mining (SIC 10); despite the industry’s limited presence within the state, waste discharges per unit of economic output are so significant that impacts are estimated to substantially exceed those in other state industries. But comparison of input intensities for Agricultural crops (SIC 01) and Stone, clay, and glass products (SIC 32) in Table 2 with land discharges for Metal mining (SIC 10) in Table 1 suggest that if commensurate emissions data were available for the crops and stone products, these would be identified as even larger producers of land discharges. Energy usage (again excluding Electricity generation (SIC 49)) is greatest in the Chemical (SIC 28) industry by a factor of three, with Paper (SIC 26) a greater energy consumer than the next four industries combined.

To fully capture the natural resource and energy impacts of regional economic activity, indirect impacts that occur as a result of that activity are now considered. Figure 1 shows the full direct plus indirect air, water, and land emissions of selected industries. To provide context for the economic importance of each industry, state output is also shown for each of the fourteen selected industries.

Table 1. New York State emission and energy intensity (direct) of selected resource intensive economic activities. No data are available for entries labeled "- " .

SIC Industry		Toxic Release Inventory (TRI) categories			MECs reported	AirData reported air emissions			
	National Industry Output (million $)	1- Air emissions (lbs/million $)	2 - Water emissions (lbs/million $)	3 - Land emissions (lbs/million $)	4 - Total energy (billion BTU / million $)	6 - CO emissions (lbs/million $)	7 - NOX emissions (lbs/million $)	8 - SO2 emissions (lbss/million $)	9 - VOC emissions (lbs/million $)
10 - Metal mining	9,138	726	34	90,933	-	-	-	-	-
20 - Food and kindred products	488,217	12	173	2	2.3	-	-	-	-
21 - Tobacco products	45,321	6	-	-	0.6	-	-	-	-
22 - Textile mill products	75,939	125	0	-	4.1	-	-	-	-
23 - Apparel and other textile products	81,449	18	-	-	0.6	-	-	-	-
24 - Lumber and wood products	122,716	810	1,524	13	4.8	-	-	-	-
25 - Furniture and fixtures	70,963	178	-	-	1.1	-	-	-	-
26 - Paper and allied products	167,294	460	12	3	16.5	542	-	2,169	271
27 - Printing and publishing	218,672	0	0	-	0.8	-	-	-	146
28 - Chemicals and allied products	399,915	38	0	5	15.2	-	178	266	266
29 - Petroleum and coal products	167,693	7	-	-	-	-	-	-	-
30 - Rubber and misc plastic products	172,026	53	0	23	1.8	-	-	-	-
31 - Leather and leather products	8,832	3,254	163	7	1.0	-	-	-	-
32 - Stone, clay, and glass products	97,758	279	0	0	10.0	-	7,189	5,991	-
33 - Primary metal industries	178,943	55	1	0	-	6,771	752	1,128	-
34 - Fabricated metal products	245,863	42	212	0	1.7	-	-	-	-
35 - Industrial machinery and equipment	419,387	5	0	-	0.7	-	-	-	-
36 - Electronic and other electric equipment	378,986	267	36	0	0.7	1,346	-	-	-
37 - Transportation equipment	608,837	19	3	-	0.7	-	-	-	-
38 - Instruments and related products	162,191	-	-	-	0.7	199	994	-	1,491
39 - Miscellaneous mfg	52,926	-	-	-	0.9	-	-	-	401
49 - Electric, gas, and sanitary services (Pub Uti	347,119	892	17	63	-	1,760	13,614	32,878	185

Table 2. New York State material use intensity (direct) of selected manufacturing and related economic activities. No data are available for entries labeled "- " .

SIC Industry	Economic Output		Direct material input intensity (metric tons per million $ of output)				
	New York State Industry Output (million $)	National Industry Output (million $)	1 - Bio-degradable	2 - Geologic materials	3 -Processed materials	4 - Chemically active	5 - Hazardous materials
01 - Crops	4,457	161,722	4,300	15,920	-	-	-
02 - Livestock	2,041	95,590	1,559	-	-	-	-
10 - Metal mining	85	9,138	-	141,280	-	74,845	-
12 - Coal mining	0	23,678	-	286,776	2,042	2,119	-
13 - Oil and gas extraction	356	124,878	-	-	-	-	696
14 - Nonmetallic mineral except fuels mining	539	18,698	-	11,433	599	1,571	-
15-17 - Construction	54,787	1,209,633	-	2,947	-	-	-
20 - Food and kindred products	18,820	488,217	67	-	-	-	-
24 - Lumber and wood products	2,146	122,716	1,664	-	-	206	-
26 - Paper and allied products	7,376	167,294	276	-	-	-	-
28 - Chemicals and allied products	22,521	399,915	-	-	-	96	102
29 - Petroleum and coal products	2,709	167,693	-	-	455	4,110	614
32 - Stone, clay, and glass products	5,007	97,758	-	9,343	-	11,916	-
33 - Primary metal industries	5,317	178,943	-	-	-	259	-
49 - Electric, gas, and sanitary services (Pub Uti	21,595	347,119	-	-	-	3,170	-

Table 3. Direct emission and energy impacts of selected manufacturing and related economic activities for New York State. No data are available for entries labeled "- " .

SIC Industry		Toxic Release Inventory (TRI) categories			MECs reported	AirData reported air emissions			
	New York State Industry Output (million $)	1- Air emissions (thousand lbs)	2 - Water emissions (thousand lbs)	3 - Land emissions (thousand lbs)	4 - Total energy (trillion BTU)	6 - CO emissions (thousand lbs)	7 - NOX emissions (thousand lbs)	8 - SO2 emissions (thousand lbs)	9 - VOC emissions (thousand lbs)
10 - Metal mining	85	62	3	7,764	-	-	-	-	-
20 - Food and kindred products	18,820	217	3,264	30	43	-	-	-	-
21 - Tobacco products	3,974	24	-	-	2	-	-	-	-
22 - Textile mill products	1,870	234	0	-	8	-	-	-	-
23 - Apparel and other textile products	9,454	171	-	-	5	-	-	-	-
24 - Lumber and wood products	2,146	1,739	3,271	28	10	-	-	-	-
25 - Furniture and fixtures	2,225	396	-	-	2	-	-	-	-
26 - Paper and allied products	7,376	3,393	87	19	122	4,000	-	16,000	2,000
27 - Printing and publishing	27,325	0	0	-	21	-	-	-	4,000
28 - Chemicals and allied products	22,521	857	1	108	343	-	4,000	6,000	6,000
29 - Petroleum and coal products	2,709	18	-	-	-	-	-	-	-
30 - Rubber and misc plastic products	5,860	312	2	132	11	-	-	-	-
31 - Leather and leather products	597	1,943	97	4	1	-	-	-	-
32 - Stone, clay, and glass products	5,007	1,396	0	0	50	-	36,000	30,000	-
33 - Primary metal industries	5,317	294	3	0	-	36,000	4,000	6,000	-
34 - Fabricated metal products	8,837	374	1,875	1	15	-	-	-	-
35 - Industrial machinery and equipment	20,752	109	5	-	14	-	-	-	-
36 - Electronic and other electric equipment	17,835	4,770	634	1	13	24,000	-	-	-
37 - Transportation equipment	8,581	164	25	-	6	-	-	-	-
38 - Instruments and related products	20,121	-	-	-	14	4,000	20,000	-	30,000
39 - Miscellaneous mfg	4,994	-	-	-	5	-	-	-	2,000
49 - Electric, gas, and sanitary services (Pub Uti	21,595	19,266	364	1,362	-	38,000	294,000	710,000	4,000

The significance of Metal mining (SIC 10) and Electricity generation (SIC 49) for land and air emissions respectively is immediately clear. One should be cautious in making direct comparisons of physical emissions (particularly across air, water, and land) as the environmental impact per unit of emissions varies widely. It is more useful to directly compare the scale of economic activity across sectors: while Electricity generation produced energy worth $22 billion, output in Metal mining was only $0.1 billion.

The upstream inputs used in industrial and manufacturing sectors are in many cases of limited importance in understanding natural resource and energy impacts. But in the service sectors in which the great majority of state economic output is focused, upstream inputs typically are the major determinant of environmental effects. In Tables 4 and 5 we present the direct plus indirect impact estimates for each of 67 sectors, treating New York State economic output in each sector as final demand in order to estimate the total impacts stemming from economic production in New York State. Electricity generation (SIC 49) again results in the largest air emissions, with over double the total emissions of Paper (SIC 26) and Electronic and other electric equipment (SIC 36) combined. Food (20) and Wood products (SIC 24) again are the largest water dischargers, with Metal mining (SIC 10) and Primary metals industries (SIC 33) the largest dischargers to land. Total energy use is greatest by almost a factor of three in the Chemicals (SIC 28) sector, recognizing that direct use in Electricity generation (SIC 49) is excluded.

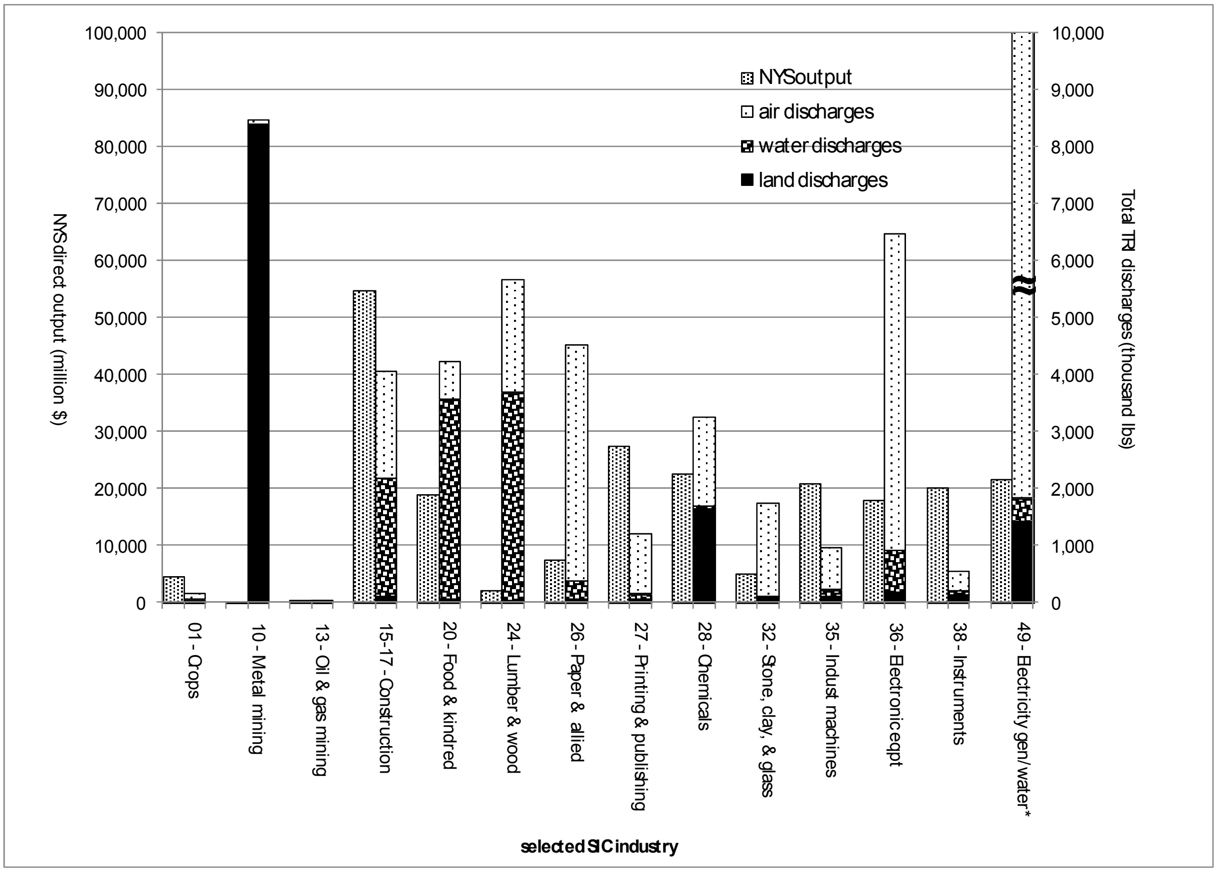

Figure 1. New York State total (direct plus indirect) Toxic Release Inventory (TRI) discharges in selected industries. Electricity generation (SIC 49) emissions are off-scale and total 22,000 thousand lbs.

Material inputs used directly plus indirectly in each sector are shown in Table 5. Notably, Construction (SIC 15-17) through its use of upstream industries is the largest users of geologic inputs, while Electricity generation (SIC 49) and Stone, clay, and glass (SIC 32) are the largest users of processed, chemically active, and hazardous inputs.

Discussion

This study shows that for New York State there is little correlation between regionally large economic sales and total energy and resource impacts. The tendency to generate particular natural resource and energy flows is highly industry specific and is based upon the characteristics of the products and/or services produced within that industry. Not surprisingly, it was found that the leading industries in economic sales are not the industries causing the largest energy and resource impacts. From Table 4, the three largest New York State economic sectors are Depository institutions (banking)

Table 4. Direct plus indirect emission and energy impacts by economic sector for New York State.

SIC Industry		Toxic Release Inventory (TRI) categories			MECs energy	AirData air emissions categories			
	New York State Industry Output (million $)	1- Air emissions (thousand lbs)	2 - Water emissions (thousand lbs)	3 - Land emissions (thousand lbs)	4 - Total energy (trillion BTU)	6 - CO emissions (thousand lbs)	7 - NOX emissions (thousand lbs)	8 - SO2 emissions (thousand lbs)	9 - VOC emissions (thousand lbs)
01 - Crops	4,457	97	19	22	4,867	163	948	2,275	172
02 - Livestock	2,041	40	32	5	1,104	72	451	1,106	56
08 - Forestry (and hunting)	70	0	0	0	11	1	4	10	1
09 - Fishing (no hunting)	44	0	0	0	3	0	1	2	0
10 - Metal mining	85	70	3	8,379	29	6	41	98	2
12 - Coal mining	0	0	0	0	0	0	0	0	0
13 - Oil and gas extraction	356	4	0	1	62	9	63	147	3
14 - Nonmetallic mineral except fuels mining	539	18	1	2	133	38	247	596	11
15-17 - Construction	54,787	1,881	2,061	119	26,951	2,358	7,553	13,367	1,312
20 - Food and kindred products	18,820	671	3,489	66	56,874	701	3,553	9,197	631
21 - Tobacco products	3,974	75	5	4	4,217	78	259	738	89
22 - Textile mill products	1,870	306	3	21	13,083	84	636	1,483	122
23 - Apparel and other textile products	9,454	523	21	21	12,983	241	1,568	3,793	288
24 - Lumber and wood products	2,146	1,975	3,643	36	12,157	79	484	1,153	68
25 - Furniture and fixtures	2,225	511	115	7	4,102	84	364	895	76
26 - Paper and allied products	7,376	4,132	306	71	144,032	4,925	3,492	26,185	2,589
27 - Printing and publishing	27,325	1,047	85	52	56,386	1,419	3,558	12,049	5,149
28 - Chemicals and allied products	22,521	1,548	42	1,652	406,753	1,010	11,371	23,387	7,555
29 - Petroleum and coal products	2,709	129	4	15	666	214	1,636	3,931	57
30 - Rubber and misc plastic products	5,860	554	24	220	31,876	347	2,273	5,406	512
31 - Leather and leather products	597	2,033	103	7	1,131	17	123	298	17
32 - Stone, clay, and glass products	5,007	1,614	30	77	54,311	340	38,867	36,074	150
33 - Primary metal industries	5,317	533	28	4,042	1,839	36,664	6,771	12,577	196
34 - Fabricated metal products	8,837	536	1,899	105	17,491	640	1,910	4,592	221
35 - Industrial machinery and equipment	20,752	738	110	102	20,002	2,638	3,038	7,195	680
36 - Electronic and other electric equipment	17,835	5,539	738	175	20,127	27,327	2,342	5,274	513
37 - Transportation equipment	8,581	337	58	147	8,238	605	925	2,112	212
38 - Instruments and related products	20,121	929	128	149	26,960	7,565	23,620	7,871	31,247
39 - Miscellaneous mfg	4,994	105	41	19	7,902	217	535	1,367	2,169
40 - Railroads (and 4741)	1,802	11	5	1	169	24	87	202	14
41 - Local And Suburban Transit (incl IMPLAN 512)	6,990	337	56	25	2,086	816	3,598	8,588	262
42 - Trucking and warehousing (and part of 4789)	9,420	225	14	17	755	459	3,099	12,046	164
43 - Post office	5,390	78	4	6	386	151	1,041	2,568	40
44 - Water transportation	1,950	14	2	1	205	32	136	330	20
45 - Transportation by air	8,462	23	4	2	309	49	227	550	32
46 - Pipelines except natural gas	40	0	0	0	1	1	3	8	0
47 - Transportation services (except 4740)	2,695	15	6	1	193	26	117	293	16
48 - Communications	35,985	403	79	21	3,030	1,413	2,048	4,879	252
49 - Electric, gas, and sanitary services (Public Utilities)	21,595	19,914	414	1,415	1,440	39,270	303,324	732,441	4,211
50,51 - Wholesale trade	65,879	760	202	45	9,387	1,549	6,220	15,515	16,782
52 - Building materials and garden supplies	2,751	19	1	1	149	37	228	560	11
53 - General merchandise stores	5,059	52	4	3	402	100	617	1,511	29
54 - Food stores	8,569	35	3	2	268	66	410	1,005	19
55 - Automotive dealers and service stations	7,846	86	7	5	668	165	1,024	2,509	48
56 - Apparel and accessory stores	6,495	93	7	6	716	178	1,098	2,692	52
57 - Furniture and home finishing stores	3,407	30	2	2	229	57	350	859	16
58 - Eating and drinking stores	18,276	359	230	26	5,045	657	4,517	10,945	331
59 - Misc retail	14,907	133	10	8	1,029	255	1,577	3,865	74
60 - Depository institutions (banking)	84,567	547	46	35	5,544	1,097	6,095	15,174	494
61,67 - Non-depository and holding (exclude nonprofit)	13,466	19	2	1	309	39	171	433	25
62 - Security and commodity brokers	92,212	109	12	7	1,253	232	1,154	2,797	113
63 - Insurance carriers	23,093	27	4	2	394	58	253	627	33
64 - Insurance agents, brokers, service	7,739	36	5	2	504	76	335	833	43
65 - Real estate	129,584	1,233	431	88	9,160	2,177	17,780	32,084	642
70 - Hotels and lodging	7,622	169	11	12	765	324	2,324	5,569	72
72 - Personal services	6,506	113	8	8	884	218	1,350	3,284	82
73 - Business services	59,824	585	73	37	9,222	1,601	3,582	9,052	650
75 - Auto repair, services, and parking	7,052	66	8	6	661	157	685	1,606	77
76 - Miscellaneous repair services	2,662	72	9	5	632	218	378	887	67
78 - Motion pictures	8,681	69	14	4	651	169	645	1,558	92
79 - Amusement and recreation services	13,249	213	24	16	1,759	411	2,659	6,428	131
80 - Health services	63,333	722	85	171	38,449	1,358	7,898	17,687	1,785
81: Legal services	23,878	83	12	5	1,364	166	699	1,720	101
82 - Educational services	39,393	118	33	8	1,952	236	1,001	12,317	136
83 - Social services	16,268	281	77	19	3,371	515	3,030	7,396	259
84,86 Non-profit organizations (plus some 67 & 89)	13,826	291	59	19	2,459	525	3,338	7,900	197
87,89 - Professional services	34,157	278	35	21	4,755	767	1,949	4,752	301

Table 5. Direct plus indirect material use impacts by economic sector for New York State.

	Economic Output	Direct plus indirect material input use (thousand metric tons)		
SIC Industry	New York State Industry Output (million $)	1 - Bio-degradable	2 - Geologic materials	3 - 5 Processed, chemically active, and hazardous materials
01 - Crops	4,457	19,652	72,970	424
02 - Livestock	2,041	3,851	2,238	152
08 - Forestry (and hunting)	70	15	54	1
09 - Fishing (no hunting)	44	0	5	2
10 - Metal mining	85	0	13,023	6,908
12 - Coal mining	0	0	3	0
13 - Oil and gas extraction	356	0	13	274
14 - Nonmetallic mineral except fuels mining	539	1	6,188	1,248
15-17 - Construction	54,787	2,635	168,242	7,707
20 - Food and kindred products	18,820	4,038	5,252	1,300
21 - Tobacco products	3,974	147	565	94
22 - Textile mill products	1,870	86	410	259
23 - Apparel and other textile products	9,454	63	451	503
24 - Lumber and wood products	2,146	3,990	139	684
25 - Furniture and fixtures	2,225	135	117	164
26 - Paper and allied products	7,376	2,502	570	1,101
27 - Printing and publishing	27,325	544	1,095	1,132
28 - Chemicals and allied products	22,521	147	3,610	8,598
29 - Petroleum and coal products	2,709	4	111	14,706
30 - Rubber and misc plastic products	5,860	56	572	1,005
31 - Leather and leather products	597	3	24	41
32 - Stone, clay, and glass products	5,007	49	48,005	61,436
33 - Primary metal industries	5,317	27	6,589	5,532
34 - Fabricated metal products	8,837	29	465	655
35 - Industrial machinery and equipment	20,752	81	996	1,046
36 - Electronic and other electric equipment	17,835	58	1,189	1,088
37 - Transportation equipment	8,581	25	537	467
38 - Instruments and related products	20,121	138	1,497	1,416
39 - Miscellaneous mfg	4,994	65	188	221
40 - Railroads (and 4741)	1,802	6	334	113
41 - Local And Suburban Transit (incl IMPLAN 512)	6,990	61	3,268	2,557
42 - Trucking and warehousing (and part of 4789)	9,420	17	313	1,250
43 - Post office	5,390	7	146	277
44 - Water transportation	1,950	3	37	75
45 - Transportation by air	8,462	5	63	329
46 - Pipelines except natural gas	40	0	3	1
47 - Transportation services (except 4740)	2,695	9	27	39
48 - Communications	35,985	94	3,312	676
49 - Electric, gas, and sanitary services (Public Utilities)	21,595	52	2,605	71,038

Table 5. Direct plus indirect material use impacts by economic sector for New York State (continued).

50,51 - Wholesale trade	65,879	334	1,596	1,959
52 - Building materials and garden supplies	2,751	5	55	61
53 - General merchandise stores	5,059	13	148	165
54 - Food stores	8,569	8	98	110
55 - Automotive dealers and service stations	7,846	21	245	275
56 - Apparel and accessory stores	6,495	22	263	295
57 - Furniture and home finishing stores	3,407	7	84	94
58 - Eating and drinking stores	18,276	360	1,258	1,241
59 - Misc retail	14,907	32	377	423
60 - Depository institutions (banking)	84,567	125	1,241	1,620
61,67 - Non-depository and holding (exclude nonprofit)	13,466	7	73	52
62 - Security and commodity brokers	92,212	31	484	323
63 - Insurance carriers	23,093	9	119	75
64 - Insurance agents, brokers, service	7,739	11	134	99
65 - Real estate	129,584	1,753	37,358	4,575
70 - Hotels and lodging	7,622	43	596	633
72 - Personal services	6,506	19	251	356
73 - Business services	59,824	162	1,276	1,248
75 - Auto repair, services, and parking	7,052	10	187	290
76 - Miscellaneous repair services	2,662	8	107	134
78 - Motion pictures	8,681	24	259	181
79 - Amusement and recreation services	13,249	116	941	709
80 - Health services	63,333	255	2,723	2,732
81: Legal services	23,878	36	369	214
82 - Educational services	39,393	81	2,308	432
83 - Social services	16,268	145	1,070	873
84,86 Non-profit organizations (plus some 67 & 89)	13,826	181	4,091	961
87,89 - Professional services	34,157	74	768	667

(SIC 60; $84 billion), Security and commodity brokers (SIC 62; $92 billion), and Real estate (SIC 65; $129 billion), while the largest air emissions were from Paper and allied products (SIC 26; 4 million lbs), Electronic and other electric equipment (SIC 36; 6 million lbs.), and Electricity generation (SIC 49; 20 million lbs.). Across the various energy and natural resource impact measures, only Real estate caused leading impacts (fourth in use of geologic inputs, through its economic linkage to the Construction sector). For the three largest air emitters, Electronic equipment and Electricity generation each produced of about $20 billion, while Paper output was only $7 billion.

More generally, levels of total energy and resource intensity vary by up to five orders of magnitude. Comparing industries at the 5 and 95 percentile ranking for energy intensity, total TRI air emissions per unit of economic output vary by a factor of about 250. Specifically, Educational services (SIC 82) has air emissions at the 5 percent level of 3 lbs/million $, while Metal mining at the 95 percent level has TRI air emissions of 818 lbs/million $.

The study makes three primary contributions. First, a generally applicable methodology is developed for estimating regional energy and natural resource flows. Additional work would be desirable to correct for missing energy and emissions data. Most significantly, direct energy use in Electricity generation is not captured by the energy data set. Also significant is the exclusion of primary agriculture from Toxic Release Inventory data. Recognizing the data limitations, the second contribution is an empirical example demonstrating the use of estimates of indirect economic activity in order to capture hidden natural resource and energy flows. Third, alternative measures of natural resource use are considered in developing a life-cycle impact estimate for output from each New York State economic sector.

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