

Guidance Document for Measuring Employment Generated by the Nuclear Power Sector

**CONFÉRENCE SUR LES EFFETS SUR L'EMPLOI DES CHOIX
DANS LE SECTEUR ÉLECTRIQUE:
Smart Grids et transition énergétique
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(Retired Department of Economics, Stanford University, 1986-2013)

Guidance for Measuring Employment Generated by the Electricity Sector (1)

Although many macro-economic impact models are available, and while the **Input-Output (I-O) model** has its limitations, it is the most transparent with which to compare technologies. Analysts attempting to estimate the employment impacts of the existing or anticipated electric power industry should **identify the most transparent I-O model** of their country (region) and adapt the model by creating a separate electric power sector as described in this *Guidance Document*.

Guidance for Measuring Employment Generated by the Electricity Sector (2)

Direct employment in the commercial electric power sector consists of those employees working at power production facilities, including permanent subcontractors, such as security personnel and full-time equivalent outage/maintenance personnel.

Indirect employment includes full-time equivalent personnel in the supply chain (first-order indirect employees) and industries supplying products and services to this supply chain (nth-order indirect employees).

Induced employment is composed of all employment in the relevant economy.

Guidance for Measuring Employment Generated by the Electricity Sector (3)

For policy analysis, such as the calculation of employment impacts from new investment, **total gross employment** must be compared to the **total gross employment of the next-best alternative**.

The difference between the two yields the total net employment of investing in nuclear power. The next best alternative will vary from economy to economy and will usually be determined through the application of a multi-attribute analysis taking into account economics, energy security issues, and environmental impacts.

Foreword

Acknowledgements

Executive Summary

1. Introduction: Input-Output Models

2. Methodology: Input Flows to the Electric (Nuclear) Power Sector

3. Implementations: Estimating Electric (Nuclear) Sector Employment

4. Conclusions: Summary of Recommendations

Annex 1: Group of Expert Participants

Annex 2: UN Industrial Standard Industrial Classification Codes

Annex 3: Translating Industrial Classification Systems

Annex 4: GIF (Generation IV International Forum) Code of Accounts

Annex 5: Power Plant Overnight Construction Cost

Allocation to ISIC Industries

Annex 6: Interim Spent Nuclear Fuel Storage Facility Organizational Chart

References

UN International Standard Industrial Classification (ISIC, Revision 4)

<http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=27>

- A - Agriculture, forestry and fishing
- B - Mining and quarrying
- C - Manufacturing
- D - Electricity, gas, steam and air conditioning supply
- E - Water supply; sewerage, waste management, and remediation activities
- F - Construction
- G - Wholesale and retail trade; repair of motor vehicles and motorcycles
- H - Transportation and storage
- I - Accommodation and food service activities
- J - Information and communication
- K - Financial and insurance activities
- L - Real estate activities
- M - Professional, scientific and technical activities
- N - Administrative and support service activities
- O - Public administration and defence; compulsory social security
- P - Education
- Q - Human health and social work activities
- R - Arts, entertainment and recreation
- S - Other service activities
- T - Activities of households as employers and household production for own use
- U - Activities of extraterritorial organizations and bodies

21 “one-digit” sectors with 99 “two-digit” sectors

Table 3.1: 38 Sectors in the Korean Nuclear Power Sector and National Economy

	Sector name	No.	Sector name
1	Agriculture, forestry, and fisheries	20	Thermal power generation
2	Mining and Quarrying	21	Nuclear power generation
3	Food, beverage and tobacco	22	Other generation
4	Textile and apparel	23	Gas and water supply
5	Wood and paper products	24	Construction (except sector 25)
6	Printing and reproduction of recorded media	25	Electric power plant construction
7	Petroleum and coal products	26	Wholesale and retail trade
8	Chemicals, drugs and medicines	27	Accommodation and food services
9	Inorganic basic chemical products	28	Transportation
10	Non-metallic mineral products	29	Communications and broadcasting
11	Basic metal products (except 9 sector)	30	Finance and insurance
12	Primary metal products	31	Real estate agencies and rental
13	Fabricated metal products	32	Business services
14	General machinery and equipment	33	Public administration and defense
15	Electronic and electrical equipment	34	Research and Development
16	Precision instruments	35	Education
17	Transportation equipment	36	Health services and social welfare
18	Furniture and other manufactured products	37	Other services
19	Hydro power generation	38	Dummy sectors

38 “one-digit” sectors with 421 “three-digit” sectors

Decomposing the UN ISIC “Electricity, gas, steam and air conditioning supply” sector

D - Electricity, gas, steam and air conditioning supply

D.1 – Electricity

D.2 – Gas, steam, and air conditioning supply

D.1.1 – Electricity Generation

D.1.2 – Electricity Transmission and Distribution (T&D)

D.1.1.1 – Electricity Generation – Fossil (e.g., Natural Gas CCGT, Coal, Coal CCS, etc.)

D.1.1.2 – Electricity Generation – Nuclear (e.g., LWR, GCR, HTGR, etc.)

D.1.1.3 – Electricity Generation – Renewables (e.g., Hydro, Wind, Solar, Bio, etc.)

Decomposing Sector D into

(D1) Electricity T&D (distributed in Korean system)

(D2) Hydro Generation (Sector 19 in Korean system)

(D3) Fossil Generation (Sector 20 in Korean system)

(D4) Nuclear Generation (Sector 21 in Korean system)

(D5) Renewables Generation (Sector 22 in Korean system)

All generating sectors sell all output to T&D; T&D sells to the rest of the economy

		Producers		Final Demand		Import	Gross Output
		1 ... j ... n	Sum	C I E	Sum		
Producers	1 ⋮ i ⋮ n	$X_{11} \dots X_{1j} \dots X_{1n}$ ⋮ $X_{i1} \dots X_{ij} \dots X_{in}$ ⋮ $X_{n1} \dots X_{nj} \dots X_{nn}$	W_1 ⋮ W_i ⋮ W_n	$C_1 \dots I_1 \dots E_1$ ⋮ $C_i \dots I_i \dots E_i$ ⋮ $C_n \dots I_n \dots E_n$	F_1 ⋮ F_i ⋮ F_n	M_1 ⋮ M_i ⋮ M_n	X_1 ⋮ X_i ⋮ X_n
	Sum	$U_1 \dots U_j \dots U_n$	<p>From Lee (2014); see <i>Nuclear Technology and Economic Development in the Republic of Korea</i>, IAEA (2009) http://www.iaea.org/sites/default/files/rok0809.pdf</p>				
Value Added	Employees	$R_1 \dots R_j \dots R_n$					
	Business owners and Capital	$S_1 \dots S_j \dots S_n$					
	Depreciation	$D_1 \dots D_j \dots D_n$					
	Indirect taxes	$T_1 \dots T_j \dots T_n$					
	Sum	$V_1 \dots V_j \dots V_n$					
Gross Input		$X_1 \dots X_j \dots X_n$					

	x_{11}	x_{12}	...	x_{1n}
	x_{21}	x_{22}	...	x_{2n}

	x_{n1}	x_{n2}	...	x_{nn}

Insert Electricity Sector into
Input-Output Table in I-O Model

The I-O table is represented by the matrix of x_{ij} where the index i represents the intermediate input produced by industry i to produce *one unit* of commodity j .

				Electricity		
	x_{11}	x_{12}	...	$x_{1\eta}$	...	x_{1n}
	x_{21}	x_{22}	...	$x_{2\eta}$	...	x_{2n}

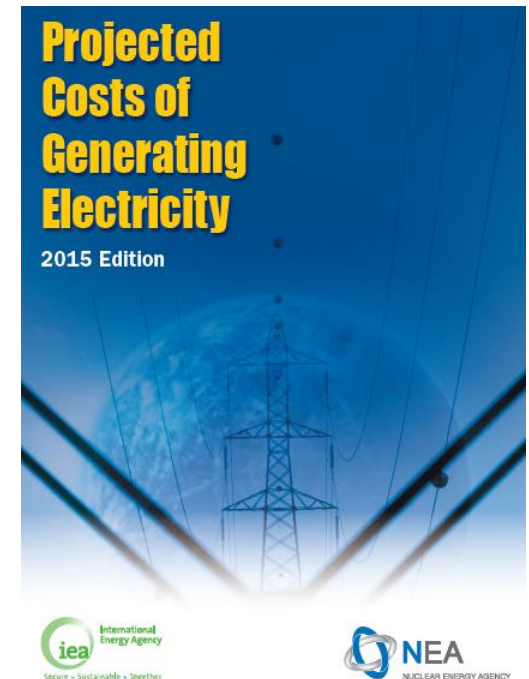
	x_{i1}	x_{i2}	...	$x_{i\eta}$	...	x_{in}

	x_{n1}	x_{n2}	...	$x_{n\eta}$	...	x_{nn}

			T&D	Hydro	Fossil	Nuclear	Renew		
x_{11}	x_{12}	...	$x_{1\eta}$	$x_{1\eta}$	$x_{1\eta}$	$x_{1\eta}$	$x_{1\eta}$	...	x_{1n}
x_{21}	x_{22}	...	$x_{2\eta}$	$x_{2\eta}$	$x_{2\eta}$	$x_{2\eta}$	$x_{2\eta}$	...	x_{2n}
...
x_{i1}	x_{i2}	...	$x_{i\eta}$	$x_{i\eta}$	$x_{i\eta}$	$x_{i\eta}$	$x_{i\eta}$	...	x_{in}
...
x_{n1}	x_{n2}	...	$x_{n\eta}$	$x_{n\eta}$	$x_{n\eta}$	$x_{n\eta}$	$x_{n\eta}$	...	x_{nn}

[https://www.iea.org/bookshop/711-
Projected Costs of Generating Electricity](https://www.iea.org/bookshop/711-Projected%20Costs%20of%20Generating%20Electricity)

- Focus on lifetime costs for broad set of generation technologies being built **between now and 2020 (projected costs in 2020!)**
- Joint study with the International Energy Agency (IEA)
- Levelised Cost of Electricity (LCOE)
- Does not include grid integration and issues covered by other NEA analyses
- Aims to maintain cross country and series comparability
- Study conducted under the Expert Group on Projected Costs of Generating Electricity(EGC) with advice from Prof. Dr. Jan Horst Keppler, co-author of “Project Costs, 2010 Update”



Type of Generation	Number of Data Points
D2: Hydro – small / large	12 / 16
D3: Coal	14
D3: Natural Gas – CCGT / OCGT	13 / 4
D4: Nuclear	11
D5: Solar PV – residential / commercial / large / CSP	12 / 14 / 12 / 4
D5: Wind – on-shore / off-shore	21 / 12
D5: CHP (all types)	19
D5: Biomass and biogas	11
D5: Geothermal	6
TOTAL (DOES NOT INCLUDE T&D, D1)	181

Report calculates the LCOE with discount rates of 3%, 7% and 10% equal to the present discounted value in all years for

$$\frac{\text{Capital Cost} + \text{O\&M Cost} + \text{Fuel Cycle Cost}}{\text{Energy Generated}}$$

The annual costs (in constant dollars) and revenues from energy (in MWh) are discounted to the start of plant operations using real discount rates.

If all costs are assumed (or calculated) to be equal in all years, LCOE can be determined from dividing annual total cost by annual energy generated.

FP&L estimate of Twin Unit ABWR in 2007 US\$ based on TVA (2005)							
p.248 in http://www.psc.state.fl.us/library/filings/07/09467-07/09467-07.pdf							
		MWe (gross) per unit x two units	2,742				
		MWe (net) per unit x two units	2,660				
Cost Category	ISIC	ISIC Code Description	NAICS	EMWG/GIF	2007\$*	Millions \$/kWe (net)	%
Reactor Plant Equipment	2513	Manu. of steam generators	332410	220	\$1,609	\$605	17.4%
Turbine Plant Equipment	2811	Manu. of engines and turbines	333611	230-233-234	\$1,074	\$404	11.6%
Electric Plant Equipment	2710	Manu. of electric ... generators, transformers, etc.	335310	240-241-242	\$475	\$179	5.1%
Misc. Plant Equipment	2810	Manu. of general-purpose machinery	333900	260	\$168	\$63	1.8%
Switch Yard	2710	Manu. of electric ... generators, transformers, etc.	423610	241+242	\$107	\$40	1.2%
Fuel	2011	Manu. of basic chemicals	325180	550	\$52	\$19	0.6%
Circ. Water Pumps & Pipe	2813	Manu. of other pumps ... and valves	333911	250-251	\$30	\$11	0.3%
Aux Boilers	2512	Manu. of tanks, reservoirs and containers	332410	234	\$18	\$7	0.2%
Owner Transition	3510	Electric power gen., trans. and distribution	221113	340	\$221	\$83	2.4%
Cooling Towers	3320	Installation of industrial machinery and equip.	238220	251	\$151	\$57	1.6%
Main Cond. Heat Reject Sys.	3320	Installation of industrial machinery and equip.	238220	233	\$97	\$36	1.0%
Other Owner Costs	3510	Electric power gen., trans. and distribution	221113	400	\$44	\$16	0.5%
Land Costs - Offsite	3510	Electric power gen., trans. and distribution	221113	110	\$0	\$0	0.0%
Land Costs - Site	3510	Electric power gen., trans. and distribution	221113	110	\$0	\$0	0.0%
Construction Labor, Manual	4220	Construction of utility projects	237130	Direct L	\$1,635	\$615	17.6%
Structure & Improvements	4220	Construction of utility projects	237130	210-211-214	\$911	\$342	9.8%
Site work	4220	Construction of utility projects	237130	211	\$296	\$111	3.2%
Security Infrastructure	4220	Construction of utility projects	237130	214	\$125	\$47	1.4%
Additional Required Scope	4220	Construction of utility projects	237130	500-550	\$113	\$42	1.2%
Engineers Home Office Services	7110	Architectural and engineering activities ...	541330	350+370	\$959	\$361	10.3%
Construction Services	7110	Architectural and engineering activities ...	541330	310+320	\$614	\$231	6.6%
Owner Project Management	7110	Architectural and engineering activities ...	541330	360+380	\$191	\$72	2.1%
EPC startup costs	7110	Architectural and engineering activities ...	541330	330	\$160	\$60	1.7%
Permits/Licensing	8413	Regulation... of businesses	926130	100-110	\$120	\$45	1.3%
Site Security	8010	Private security activities	561612	Indirect L	\$105	\$39	1.1%
Total Overnight		* Includes contingency			\$9,272	\$3,486	100%

**Twin ABWR
TVA (2005)**

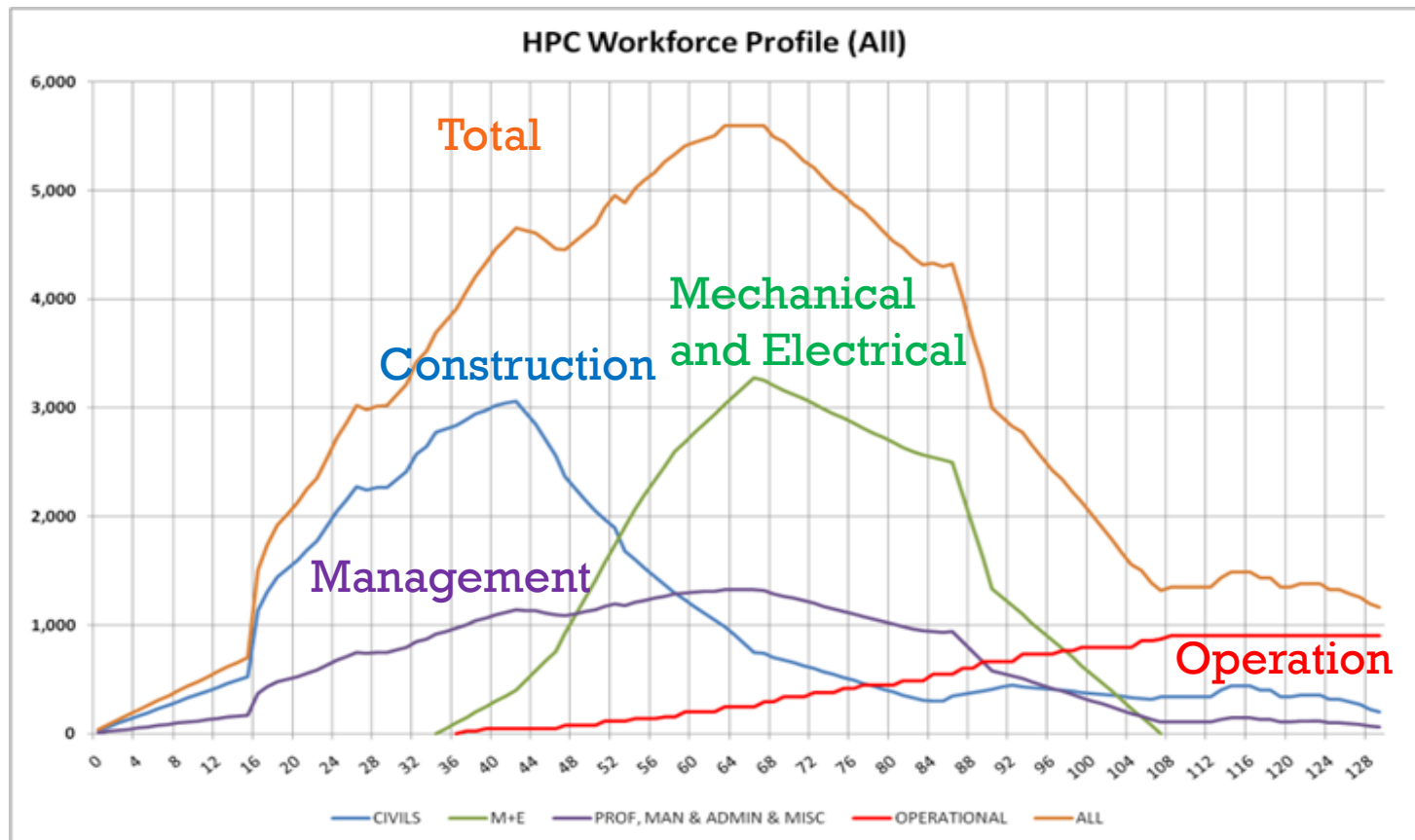
Here
“Direct” Labour
 and
“Indirect” Labour
 refer to construction
 accounts,
 not I-O model

← **“Direct” Labour**
\$1,635M (17.6%)

← **“Indirect” Labour**
\$959M (10.3%)

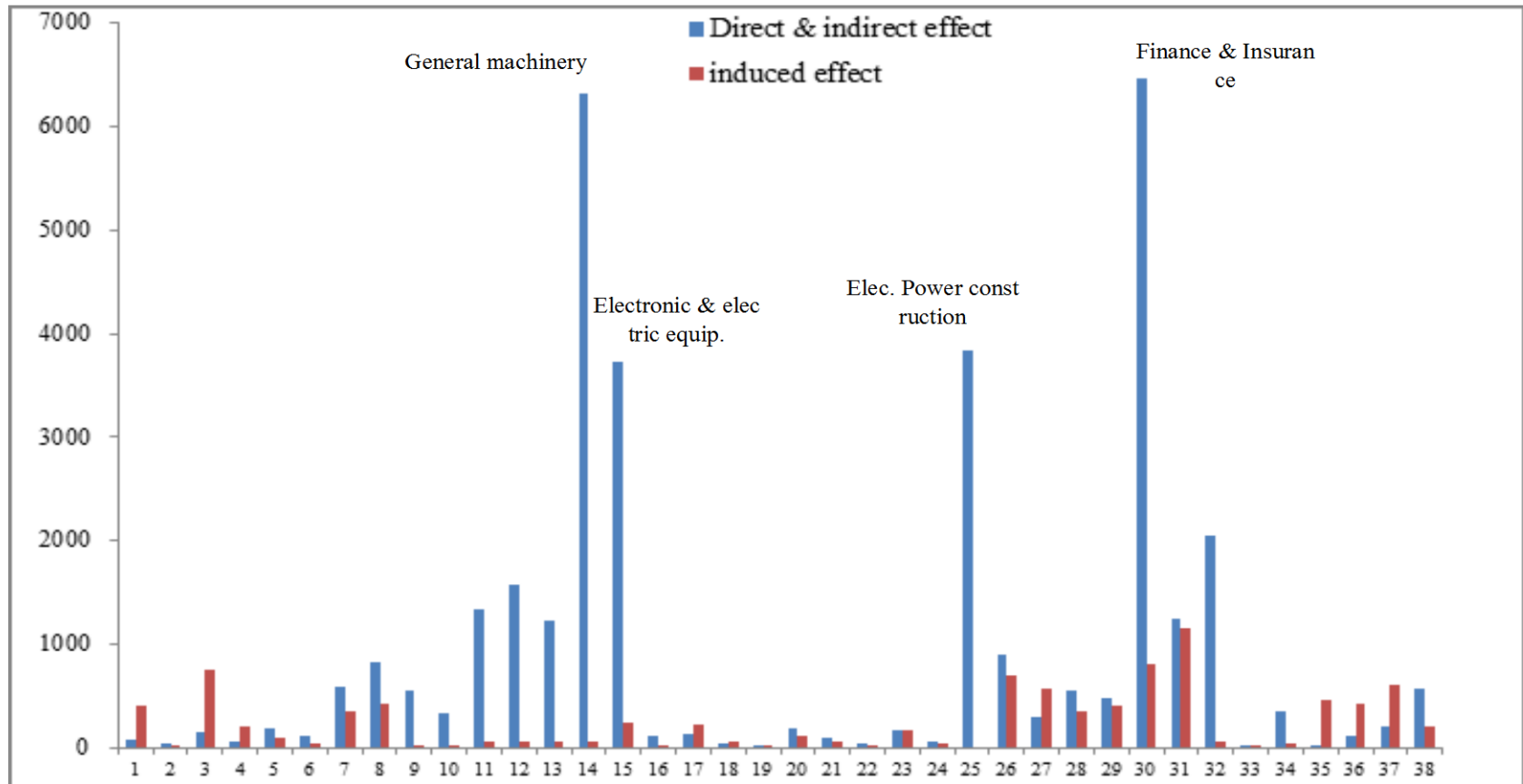
“Total” Labour
\$2,600M (28%)

Labour Requirements and Costs can be levelised for 4 periods:
(1) Construction, (2) Operation, (3) Decommissioning & (4) Waste Management. Consider Hinkley Point C construction (2 EPRs):

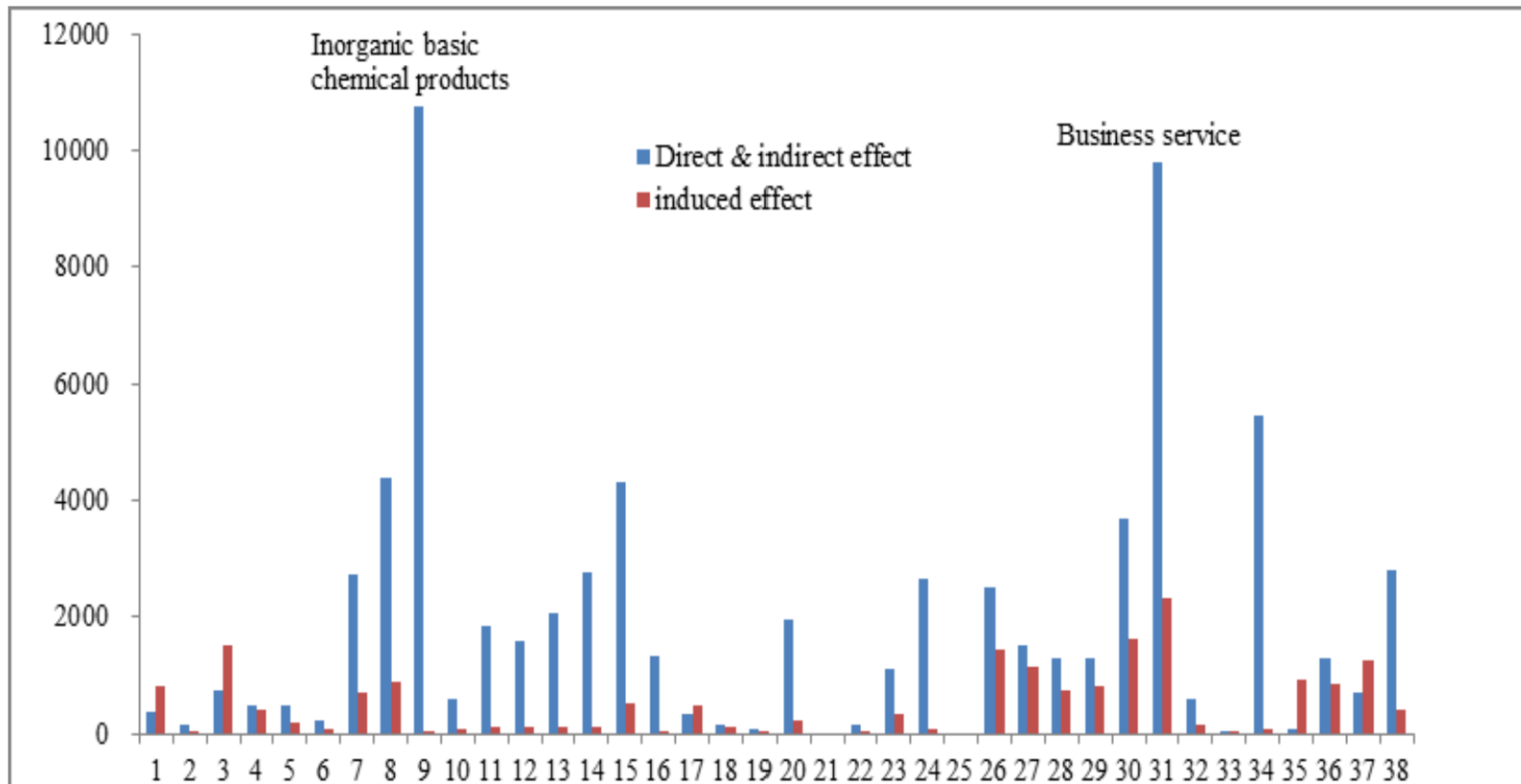


- 2. Input Flows to the Nuclear Power Sector
 - 2.1. **Nuclear Power Plant Construction (e.g., years 1-10)**
 - 2.1.1. Nuclear Power Plant Construction Expenditures
 - 2.1.2. Nuclear Power Plant Construction Labour
 - 2.2. **Nuclear Power Plant Operation (e.g., years 11-60)**
 - 2.2.1. Employment Expenditures during Nuclear Generation
 - 2.2.2 . O&M Expenditures during Nuclear Generation
 - 2.2.3. Fuel Expenditures during Nuclear Generation
 - 2.2.3.1. Uranium Mining and Milling
 - 2.2.3.2 . Uranium Conversion, Enrichment, and Fuel Fabrication
 - 2.3. **Nuclear Power Plant Decommissioning (e.g., years 60-70)**
 - 2.4. **Spent Nuclear Fuel and Waste Management (e.g., years 60-100)**

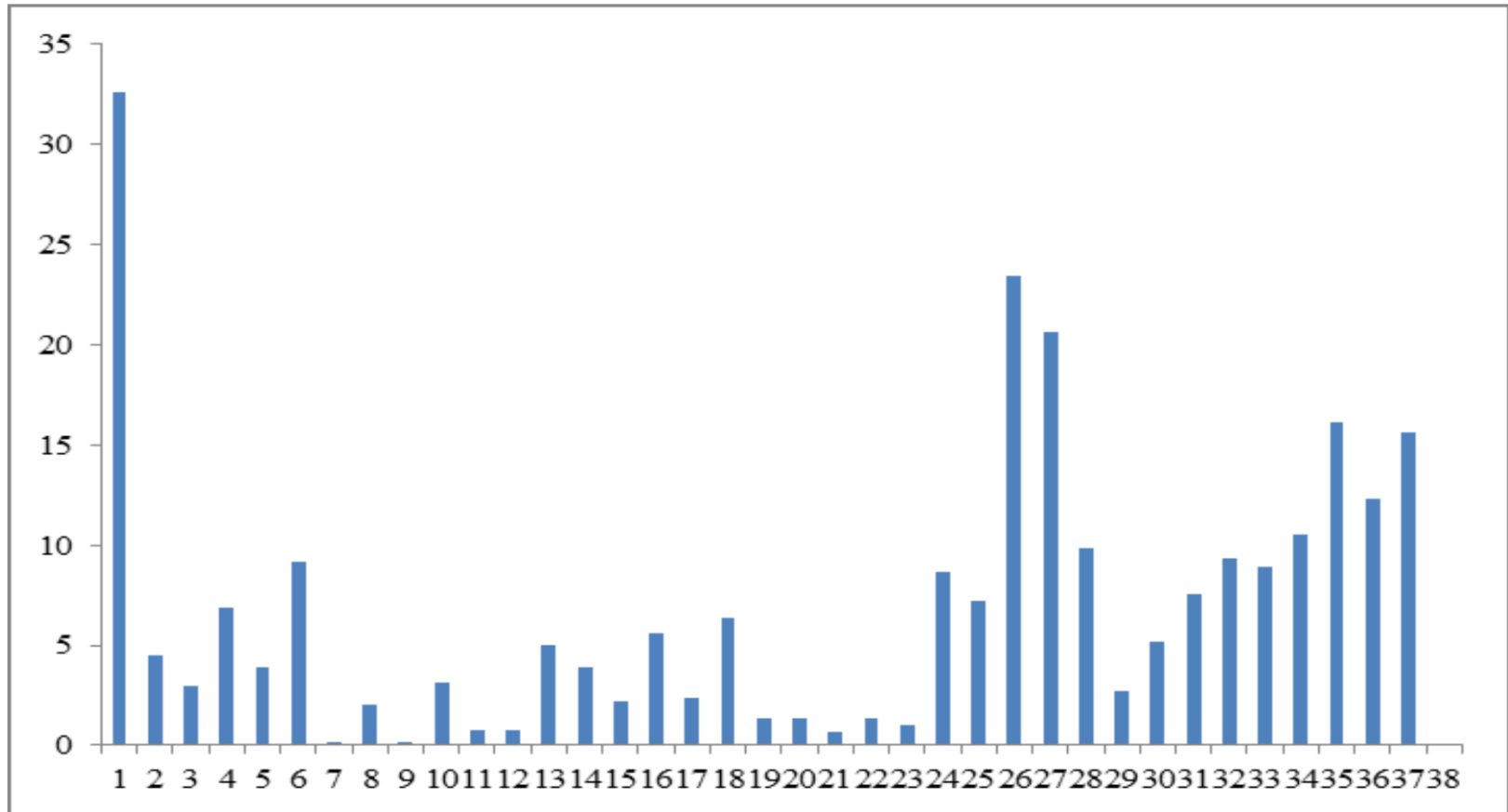
Sectorial Backward Linkages in NPP Construction (100 million won, 2009)



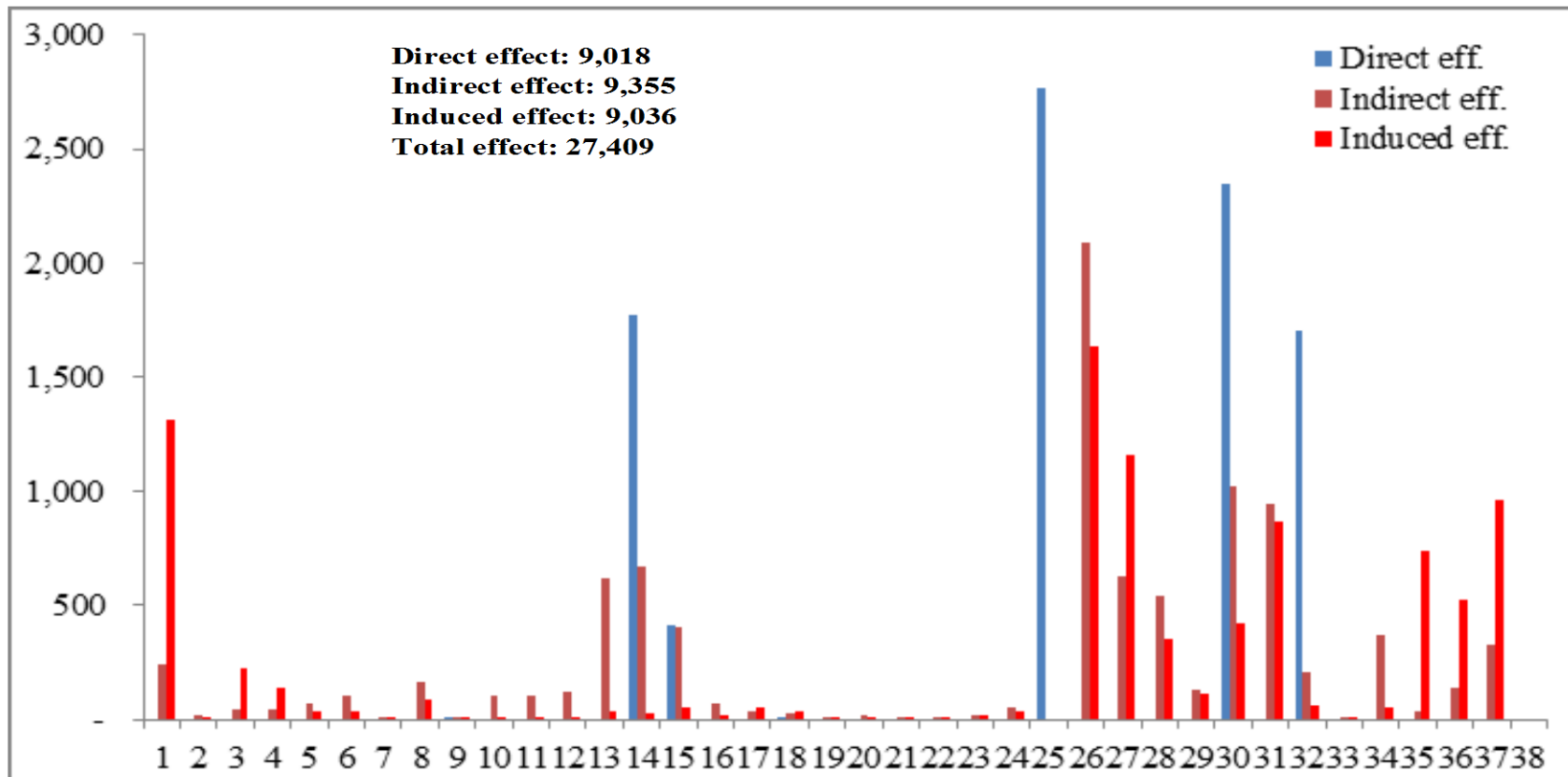
Sectorial Backward Linkages in NPP Operation (100 million Won, 2009)



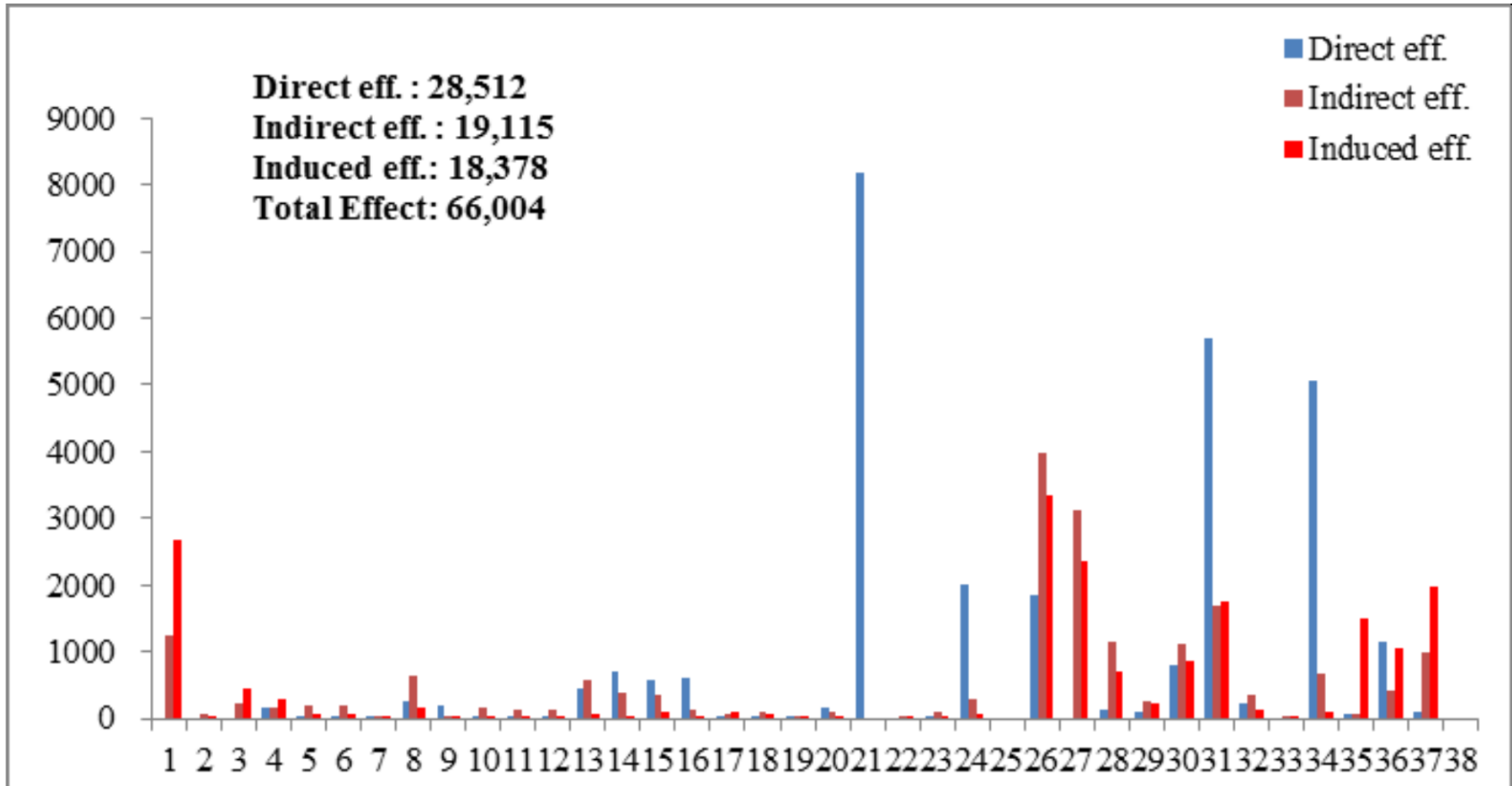
Labour Coefficients (employee/billion Won)



Employment from NPP Construction in 2009



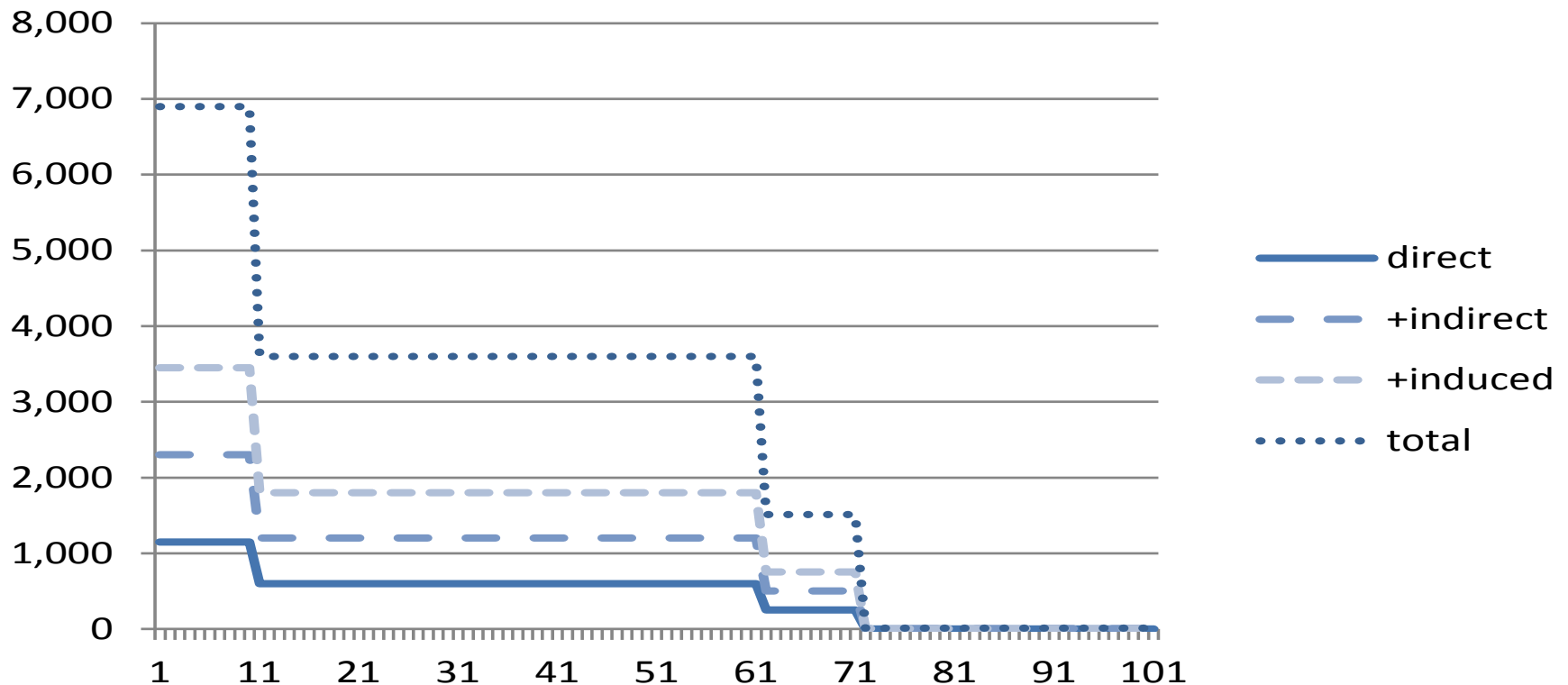
Employment from NPP Operation



Total Korean Direct, Indirect, and Induced Employment in the Korean Nuclear Power Sector (2007)

	Direct Employment	Indirect Employment	Induced Employment	Total Employment
Construction	9,020	9,350	9,030	27,400
<u>Operation</u>	<u>20,350</u>	<u>27,280</u>	<u>18,380</u>	<u>66,010</u>
Total	29,370	36,630	27,410	93,410

Employment per 1,000 MW (levelized) following Korean Multipliers



Sub-activities to achieve the overall goal of CRP:

- (1) Assemble a group of experts to provide the input on the quantitative macroeconomic analysis of nuclear projects**
- (2) Support efforts of participating Member States in developing appropriate tools and methods**
- (3) Review, test and apply prototype methodologies (quantitative models) to analyse economic and social impacts of nuclear programmes at the national and region level; if needed, agree on common harmonization of analytical elements**
- (4) Provide assistance in application of the IAEA's tools for quantitative macroeconomic analysis to selected case studies; arrange training in tools and methods for capacity building (if needed)**
- (5) Compile the current knowledge in a report together with areas of future research and development to cover the modelling techniques, data restrictions and ways to manage the data gaps**