Acting on Climate Change:

Extending the Dialogue Among Canadians

A collection of texts in response to

Acting on Climate Change: Solutions from Canadian Scholars,

a consensus document released in March 2015

Sustainable Canada Dialogues

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ABOUT THE ORGANIZATION

HELIOS CENTRE

PHILIP RAPHALS AND RICK HENDRIKS

The Helios Centre is a non-profit research group based in Montreal that has provided independent expertise on a range of energy issues, including climate change policy, since 1997. Its clients have included environmental groups, consumer groups, First Nations, governments, and renewable energy producers.

The authors are Executive Director and Senior Analyst, respectively, at the Helios Centre. Mr. Raphals has appeared as an expert witness on various aspects of electricity policy before energy regulators and environmental assessment panels in four provinces. Mr. Hendriks provides management consulting services to Aboriginal communities and community-based organizations concerning the environmental, social and economic challenges and opportunities that accompany electricity generation and transmission developments, and he has testified in various fora across Canada in relation to these issues.

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THE MONTPARNASSE DERAILMENT (1895)

ON OCTOBER 22, 1895, THE GRANVILLE-PARIS EXPRESS ENTERED THE GARE DE L'OUEST TOO FAST, RAN THROUGH THE BUFFER STOP, CROSSED THE CONCOURSE, AND CRASHED THROUGH THE WALL, FALLING ON THE PLACE DE RENNES.

"THE BEST LAID SCHEMES O' MICE AN' MEN
GANG AFT A-GLEY, [OFTEN GO AWRY]
AN' LEA'E US NOUGHT BUT GRIEF AN' PAIN,
FOR PROMISED JOY."
SAID ROBERT BURNS

Contributed by

HELIOS CENTRE

Towards a Sustainable Low-carbon Electric System:

Challenges and Opportunities

Introduction

One of the key recommendations of *Acting on Climate Change: Solutions from Canadian Scholars* is the conversion of Canada's electricity system to 100% low-carbon resources within the next 20 years (p. 32).

> *Combining current hydroelectric production capacity with plentiful untapped renewable energy resources and east-west intelligent grid connections [57] between provinces… could allow Canada to adopt a target of 100 percent low-carbon electricity production by 2035.*
>
> ** Note 57. The Deep Decarbonization Canada chapter emphasizes the importance of an "enhanced transmission grid flexibility and energy storage technologies to allow more electricity generation from intermittent renewables" (p.14)*

This aspirational objective is commendable, but before adopting it as policy, some important and difficult questions need to be addressed. What existing high-carbon resources require replacement? What roles do these resources play in the electricity system? Can low-carbon resources fulfill those roles, and what economic, social and ecological impacts would they entail? How can we achieve a low-carbon electricity system while minimizing those impacts?

In this brief contribution we focus on the requirements and trade-offs inherent to meeting a goal of 100% low-carbon electricity.

Energy, capacity and load following: a multi-faceted problem

Currently, installed capacity of high-carbon electricity generation in Canada totals more than 33 000 MW, generating some 124 000 GWh of energy annually[1].

*(See **Table 1** on the next page)*

1 MW = megawatts = millions of watts; GWh = gigawatt-hours = millions of kilowatt-hours

Table 1. High-carbon electricity generation in Canada[2]

	Coal		Natural Gas		Other Fossils Fuels		TOTALS	
Region	MW	GWh / year	MW	Gwh / year	MW	GWh / year	MW	GWh / year
British Columbia	0	0	1464	3500	0	0	1464	3500
Alberta	6256	39 186	5812	29 028	12	40	12 082	68 254
Saskatchewan	1530	10 846	1567	6460	0	0	3097	17 306
Manitoba	105	811	412	3307	0	0	517	4118
Ontario	0	0	9920	14 800	0	0	9920	14 800
Quebec	0	0	411	211	0	0	411	211
New Brunswick[3]	467	818	378	662	1497	2623	2342	4103
Nova Scotia	1252	7098	500	1317	222	89	1974	8504
Prince-Edward-Island	0	0	0	0	134	876	134	876
Newfoundland	0	0	0	0	670	956	670	956
Territories and remote[4]	0	0	0	0	504	1104[5]	504	1104
TOTALS	**9612**	**58 759**	**20 464**	**59 285**	**3039**	**5688**	**33 115**	**123 732**

In comparison, wind and solar facilities in Canada generated just 7.4% of this amount: 9100 GWh[6]. Nonetheless, it may be possible to generate most of the *energy* required to achieve the 100% low-carbon objective from substantial increases in wind, solar and other renewables, combined with cost-effective energy-focused demand-side management[7]. However, the ecological and economic costs of this new infrastructure will not be trivial, and will be surprisingly large. Social acceptability cannot be presumed.

Furthermore, a power system requires not only energy, but also *dependable capacity* and *load-following capability*[8]. Intermittent renewables are suitable for producing low-carbon energy, but much less effective at meeting capacity and load-following requirements[9]. Capacity-focused demand-side management can reduce peak demand requirements, but utility efforts in this area are nascent. In Ontario, targets for peak demand reduction from time-of-use rates have yet to be met[10], and overall peak capacity reduc-

2 Sources: BC Hydro, Atco Power, Capital Power, Alberta Energy, SaskPower, Manitoba Hydro, IESO, Québec Énergie et Ressources naturelles, NB Power, NS Power, Maritime Electric, Newfoundland and Labrador Hydro, Natural Resources Canada.

3 Total high-carbon energy of 4103 GWh/year allocated based on installed capacity.

4 Includes off-grid and remote high-carbon generation in all provinces and territories.

5 Assumes 25% load factor to determine GWh/year.

6 Statistics Canada. CAMSIM Table 127-0002. Data from 2014.

7 Demand-side management (DSM) includes measures and programs designed to reduce the energy requirements an electric utility must meet.

8 Capacity, usually measured in megawatts (MW) refers to the maximum electrical output of a generator, and dependable capacity refers to the maximum output the system can produce during hours of peak demand. Load-following capability refers to the system's ability to adapt to rapidly changing demand.

9 In Canada, the capacity contribution of solar power to the summer peak has been estimated at 30% to 55% of installed capacity; for wind power in winter-peaking regions, figures ranging from 14% to 35% have been cited. Dewees, D.N. (2013). The Economics of Renewable Electricity Policy in Ontario, Working Paper 478, U. of Toronto, Dept. of Economics, p. 13.

10 Office of the Auditor General of Ontario. (2014). 2014 Annual Report – Section 3.11 Smart Metering Initiative, p. 373.

tions have been limited[11]. There are promising demand response pilot projects in Ontario[12] and BC[13], but progress toward full-scale implementation remains halting.

Nuclear generation could be expanded to provide low-carbon dependable capacity to displace baseload high-carbon coal and natural gas[14]. However, this remains unlikely given recent closures[15], difficulties siting nuclear facilities[16,17], high capital costs[18], legislation barring nuclear development[19] and ongoing waste management issues[20].

Low-carbon geothermal resources could also contribute several hundred MW of dependable capacity by 2035, but these resources remain uncertain[21]. To date, not a single geothermal project has been developed in Canada. Biomass can provide dependable capacity, but large-scale deployment remains limited by feedstock sustainability[22]. Carbon capture and storage could allow high-carbon generation facilities to produce much lower emissions, but there is only a single facility in operation in Canada[23] and no additional facilities are planned.

Energy storage could provide dependable capacity and load-following capability, supporting intermittent renewables in a low-carbon electricity system. The Ontario Independent Electricity System Operator (IESO) is currently procuring up to 50 MW of energy storage, including solid state and flow batteries, thermal storage, hydrogen storage and flywheels[24]. Costs of these technologies are projected to decline substantially over time but, even so, will remain high[25]. More importantly, today's storage systems are limited to levelling daily power requirements, and cannot meet annual peaks without a substantial overbuild of energy capability[26].

Large-scale hydro currently provides most of the dependable capacity and load-following capability in BC, Manitoba, Quebec, and Newfoundland and Labrador, and a considerable portion in Ontario. Moving to a 100% low-carbon electricity system would still mean replacing 33 000 MW of high-carbon capacity, as well as adding new capacity to meet load growth.

The emphasis on east-west transmission lines in *Acting on Climate Change: Solutions from Canadian Scholars* suggests that hydro

11 The Brattle Group (2013). Impact Evaluation of Ontario's Time-of-Use Rates: First Year Analysis: A Report Prepared for Ontario Power Authority, pp. v-vii.

12 IESO (2015). 18 Month Outlook: An Assessment of the Reliability and Operability of the Ontario Electricity System – From April 2015 to September 2016, p.8.

13 Enbala Power Networks (n.d). Capacity Focused Demand Side Management at BC Hydro: Industrial and Commercial Potential in the Kamloops Region.

14 GHG emissions lifecycle for nuclear energy is between 9 and 110 g CO_2e/kWh. Warner, E.S. and Heath, G.A. (2012). Life Cycle Greenhouse Gas Emissions of Nuclear Electricity Generation Systematic Review and Harmonization. Journal of Industrial Ecology, 16(S1): S73-S92.

15 http://nouvelles.hydroquebec.com/fr/communiques-de-presse/185/hydro-quebec-confirme-la-fermeture-de-la-centrale-de-gentilly-2-a-la-fin-2012/

16 Kuhn, R. G. (1998). Social political issues in siting a nuclear-fuel waste disposal facility in Ontario, Canada. The Canadian Geographer, 42(1): 14-28.

17 Price, L.L. and Rechard, R.P. (2014). Progress in Siting Nuclear Waste Facilities. Prepared for the U.S. Department of Energy.

18 United States EIA (2015). Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2015.

19 Clean Energy Act, SBC 2010 c22, s.2(o).

20 NWMO (2005). Choosing a Way Forward: The Future Management of Canada's Used Nuclear Fuel – Final Study.

21 BC Hydro (2013). BC Hydro Integrated Resource Plan: Chapter 3 Resource Options, p. 3-51.

22 IDDRI and SDSN (2014). Pathways to Deep Decarbonization: 2014 Report – Canada Chapter, p. 13.

23 SaskPower (n.d.). SaskPower CCS: Boundary Dam Carbon Capture Project.

24 IESO (2014). RFP for Energy Storage Service Backgrounder.

25 Viswanathan, V. et al. (2013). National Assessment of Energy Storage for Grid Balancing and Arbitrage, U.S. Dept. of Energy, Pacific Northwest National Laboratory.

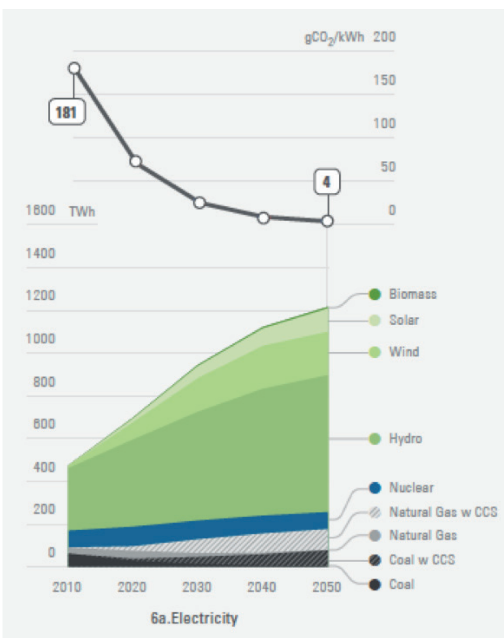
26 Because of their low contribution to peak per MW of installed capacity, a generation system based on wind and solar sufficiently large to meet capacity requirements would produce a great deal of surplus energy.

is expected to play an important role in replacing fossil-fuel capacity in neighbouring provinces[27]. Indeed, storage hydro and nuclear are the only low-carbon electricity resources available in meaningful quantities that, like thermal generation, are normally fully available at system peak. Of these, only storage hydro can be dispatched to follow rapidly changing loads.

Hydroelectric resources: limits to development

The 100% low-carbon electricity objective set out in *Acting on Climate Change: Solutions from Canadian Scholars* relies upon an important 2014 study, *Pathways to Deep Decarbonization*[29]. This influential study depicts the evolution of "energy supply pathways" for Canada from 2010 to 2050.

Figure 1. Energy Supply Pathways, by Resource[28]



As shown in Figure 1, hydroelectric resources are forecast to more than double over this 40-year period, increasing 80% by 2035, and comprising by far the largest block of new resources. The graph shows no expansion of nuclear generation.

Acting on Climate Change: Solutions from Canadian Scholars takes no explicit position regarding the expansion of large-scale hydroelectric (or nuclear) generation in Canada. That said, the hydropower future described in *Deep Decarbonization*, on which *Acting on Climate Change: Solutions from Canadian Scholars* relies, appears entirely unrealistic.

There are currently some 74 000 MW of hydroelectric capacity in Canada, producing about 350 000 GWh of energy annually[30]. Assuming comparable capacity factors, increasing capacity 80% by 2035 would require another **59 000 MW** of storage hydropower. This is far beyond the wildest dreams of even the hydro industry's most vigorous supporters.

For instance, the five largest hydroelectric projects likely to be commissioned in the upcoming decade together total 4600 MW[31]. The *Deep Decarbonization* scenario would reproduce this **13 times over** within the subsequent decade, 2025-2035. This level of hydroelectric development is, in our view, neither feasible – given the long lead times required for assessment, design and construction – nor desirable.

27 I.e., BC into Alberta; Manitoba into Saskatchewan; and Quebec/Labrador into the Maritimes and Ontario.

28 Source: IDDRI and SDSN (2014). Pathways to Deep Decarbonization: 2014 Report – Canada Chapter, Figure 6, p. 9.

29 IDDRI and SDSN (2014). Pathways to Deep Decarbonization: 2014 Report – Canada Chapter. See also note 57 in the quotation at the beginning of this contribution.

30 Canadian Hydropower Association – Association canadienne de l'hydroélectricité. (n.d.). Hydro in 5 Points: Five Things You Need to Know About Hydropower: Canada's Number One Electricity Source.

31 Composed of: Site C (BC Hydro), 1100 MW (under construction); Muskrat Falls (Nalcor Energy), 824 MW (under construction); La Romaine (Hydro-Québec), 1550 MW (partially completed); Keeyask (Manitoba Hydro), 695 MW (approved); Lower Mattagami (Ontario Power Generation), 438 MW (commissioned earlier this year).

Acting on Climate Change: Solutions from Canadian Scholars relies on a study by Global Forest Watch that describes Canada's hydro-power potential[32]. However, many of these projects either are legally prohibited in order to protect other values[33], have significant ecological and social consequences[34], or are located where First Nations could veto (and have vetoed) development[35].

Furthermore, the energy from large storage hydro does not arrive incrementally to meet load growth but in large blocks, resulting in sudden and large energy surpluses. Until recently, Canadian utilities could depend on export markets for profitable sales of these surpluses. Today, revenue streams from surplus sales are far below the annual costs of new hydroelectric facilities, producing multi-year losses that must be absorbed by ratepayers. This phenomenon is the result of dramatic declines in the price of natural gas, the primary price-setting fuel in U.S. electricity markets. Forecasters believe these low-price conditions will continue for decades, rising only 18% in real dollars over the next 25 years[36], compared to 54% over the previous 25-year period[37].

As an example, BC Hydro's Site C hydro project (1100 MW) will produce a substantial energy surplus, to be exported for many years at a price well below the cost of production, costing ratepayers hundreds of millions of dollars annually[38]. Consequently, BC Hydro will not require any other new utility-scale renewable resources until at least 2034[39], and has even signalled its intention not to renew contracts for lower-cost renewable facilities already operating[40], in order to soak up the energy surplus resulting from Site C.

BC Hydro is not alone. Newfoundland and Labrador Hydro has indicated that it will not renew its two existing wind contracts in order to absorb the much more expensive energy surplus from the Muskrat Falls project[41].

This makes no environmental or economic sense. To reduce economic impacts and maximize climate-change mitigation efforts, low-cost mitigation must take precedence over high-cost mitigation.

Beyond the economic realities, additional large-scale hydroelectric projects fail the environmental effectiveness criterion set out in *Acting on Climate Change: Solutions from Canadian Scholars*: to meet greenhouse gas (GHG) reduction targets without causing other significant environmental impacts (p. 27).

Recent environmental reviews of many of the available storage hydro projects (i.e. Site C, Lower Churchill, and Eastmain 1A/Rupert Diversion) raised serious ecological and social sustainability concerns. The Joint Review Panel for Site C concluded that the project, if developed, would have significant, extensive,

32 Global Forest Watch Canada (2012). Hydropower Developments in Canada: Number, Size and Jurisdictional and Ecological Distribution. See Figure 10. Boreal and temperate forest regions with existing, proposed and potential large hydropower developments.

33 E.g. Schedule 2 of the BC's Clean Energy Act prohibits development at eleven potential large-scale hydroelectric sites in the province.

34 E.g. Site C on the Peace River in BC, and developments on the Lower Albany River in Ontario.

35 E.g. the Slave River Hydro Development in Alberta, http://www.cbc.ca/news/canada/north/slave-river-hydro-project-nixed-1.962503

36 United States EIA (2015). Annual Energy Outlook 2015, p. ES-7.

37 United States EIA (n.d). 1990-2013 Average Price by State by Provider (EIA-861).

38 Raphals, P. (2014). Need for, Purpose of and Alternatives to the Site C Hydroelectric Project, Helios Centre, Fig. 10, p. 26.

39 BC Hydro. (2013). Response to Working Group and Public Comments on the Site C Clean Energy Project Environmental Impact Statement: Technical Memo — Alternatives to the Project, p. 18.

40 BC Hydro (2013). BC Hydro Integrated Resource Plan: Chapter 4 Resource Planning Analysis Framework, p. 4-15.

41 Nalcor Energy (2011). Nalcor's Submission to the Board of Commissioners of Public Utilities with respect to the Reference from the Lieutenant-Governor in Council on the Muskrat Falls Project, p. 40.

and comprehensive residual environmental effects, including on traditional activities of the affected First Nations[42]. These effects are among the most severe ever identified in a federal environmental assessment, and more extensive even than those for the Jackpine (Oilsands) Mine Expansion Project[43] and the Prosperity Gold-Copper Mine Project[44].

An influential paper recently published in *Science* describes several "planetary boundaries" necessary to maintaining a habitable Earth, noting that four have already been crossed. These include not only climate change, but also loss of biosphere integrity, altered phosphorus and nitrogen cycles, and the biogeophysical processes in land systems that directly regulate climate. If our energy choices are determined by a unidimensional focus on climate change, the threats to the other planetary boundaries, including loss of biodiversity in the boreal regions of Canada, will continue unabated[45].

Low-carbon, not no-carbon: judicious use of natural gas

Adopting a policy of 100% low-carbon electricity resources excludes the most widely used technology for meeting capacity. While relying on natural gas to meet baseload energy needs results in very substantial GHG emissions, simple cycle gas turbines[46] can add many megawatts of peak capacity at relatively low economic and environmental cost. When operated only during the system peak (1% or 2% of the time), a 100-MW facility would have annual emissions of only 5.9 to 11.74 kTonne CO_2e, just 2-3% of a baseload combined cycle natural gas turbine of the same capacity[47], or similar to the annualized life-cycle CO_2e emissions of a 370 MW wind farm[48]. When used only to meet reserve requirements, their emissions can be near zero[49].

With low capital costs and the capacity to meet peak and reserve requirements while facilitating the integration of complementary low-carbon intermittent resources, gas turbines can contribute to an electricity system with low GHG emissions. This is coherent with an important policy recommendation in *Acting on Climate Change: Solutions from Canadian Scholars*: policies should achieve the necessary GHG reductions at the least possible cost (p. 27). This need not require a conversion to 100% low-carbon electricity to the exclusion of all carbon-based resources, a strategy that is likely to be economically and ecologically unacceptable.

Policy in this area should acknowledge the marked superiority of natural gas over other fossil fuels. Almost half of Canada's high-carbon baseload generation relies on coal, with GHG emissions per kWh more than

42 Review Panel established by the Federal Minister of the Environment and the British Columbia Minister of Environment (2014). Report of the Joint Review Panel: Site C Clean Energy Project, pp. 310-325.

43 Joint Review Panel established by the Federal Minister of the Environment and the Energy Resources Conservation Board (2013). Report of the Joint Review Panel: Shell Canada Energy Jackpine Mine Expansion Project, pp. 4-9.

44 Review Panel established by the Federal Minister of Environment (2010). Report of the Federal Review Panel Established by the Minister of the Environment: Taseko Mines Limited's Prosperity Gold-Copper Mine Project, pp. 237-240.

45 W. Steffen et al. (2015). Planetary boundaries: Guiding human development on a changing planet. Science, 347(6223).

46 The word "gas" refers here to exhaust gases, not to fuel. A gas turbine can be fueled by many different hydrocarbons, including natural gas (methane).

47 O'Donoughue, P.R. et al. (2014). Life Cycle Greenhouse Gas Emissions of Electricity Generated from Conventionally Produced Natural Gas. Journal of Industrial Ecology. 18(1): 125-144.

48 Dolan, S.L. and Heath, G.A. (2012). Life Cycle Greenhouse Gas Emissions of Utility-Scale Wind Power. Journal of Industrial Ecology, 16(S1): S136-S154. Based on a 30% capacity factor.

49 Reserve requirements describe the amount of supply resources in excess of demand required to maintain reliability in the event of equipment failure. They vary depending on the nature of the system, and are often 15-20% of annual peak demand. IESO. (2014). Ontario Reserve Margin Requirements, 2015-2019.

twice[50] that of gas[51]. The potential emissions reductions from substituting coal with a combination of renewables and natural gas are therefore enormous. Judicious use of simple-cycle gas turbines to meet reserve and peaking requirements can displace the need for resources with much greater financial costs and ecological impacts.

Conclusion

Converting Canada's electricity system to 100% low-carbon resources is an admirable goal. However, barring major and rapid technological breakthroughs or a large-scale move to nuclear generation, meeting this goal would require an inadvisable and unrealistic expansion of hydropower. This would constitute a high-cost path in economic, ecological, and social terms, initiating and perpetuating conflicts with Aboriginal peoples, while driving out investment in other low-carbon renewables that are modular, incremental and declining in cost. Canadian ratepayers would find themselves unable to take advantage of these increasingly affordable alternatives, being locked into paying down the high-cost capital legacy of large-scale hydroelectric projects.

Policy efforts need to be directed at ensuring that the most cost-effective and environmentally benign measures for reducing GHG emissions from the electricity sector receive priority implementation. The considerable opportunities to displace high-carbon *energy* with low-carbon supply-side and demand-side alternatives constitute the "low-hanging fruit".

Displacing the *capacity* and *load-following* roles currently played by high-carbon resources will prove more difficult. While geothermal power, energy storage, carbon capture and storage, and even some additional storage hydro will play a role in supporting a transition to a low-carbon future, they will not be sufficient.

Difficult choices lie ahead. Trade-offs must be informed by thorough and transparent analysis. The scale of the challenge should not be underestimated.

50 O'Donoughue, P.R. et al. (2014). Life Cycle Greenhouse Gas Emissions of Electricity Generated from Conventionally Produced Natural Gas. Journal of Industrial Ecology, 18(1): 125-144, p.141. The harmonized median for combined cycle natural gas is 450 g CO_2e/kWh.

51 Whitaker, M. et al. (2012). Life-cycle Greenhouse Gas Emissions of Coal-Fired Electricity Generation: Systematic Review and Harmonization. Journal of Industrial Ecology, 16(S1): S53-S72, p. S62. The harmonized median for all coal technologies is 980 g CO_2e/kWh.

ABOUT THE INITIATIVE

SUSTAINABLE CANADA DIALOGUES

This contribution is part of a collection of texts, *Acting on Climate Change: Extending the Dialogue Among Canadians*, stemming from interactions between Sustainable Canada Dialogues, an initiative of the UNESCO-McGill Chair for Dialogues on Sustainability, and business associations, First Nations, non-governmental organizations, labour groups, institutions, organizations and private citizens.

Sustainable Canada Dialogues is a voluntary initiative that mobilizes over 60 researchers from every province in Canada, representing disciplines across engineering, sciences and social sciences. We are motivated by a shared view that putting options on the table will stimulate action and is long overdue in Canada.

Together, the contributions enrich the scope of possible solutions and show that Canada is brimming with ideas, possibilities and the will to act. The views expressed in *Acting on Climate Change: Extending the Dialogue Among Canadians* are those of the contributors, and are not necessarily endorsed by Sustainable Canada Dialogues.

We thank all contributors for engaging in this dialogue with us to help reach a collective vision of desired pathways to our futures.

FOR MORE INFORMATION, VISIT OUR WEBSITE

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